SCIENCE

Standard X

Revised Based on the Recommendation of the Hard Portion Deletion Committee

Untouchability is a sin
Untouchability is a crime
Untouchability is inhuman

TAMILNADU TEXTBOOK CORPORATION
College Road, Chennai - 600 006.

REVISED BASED ON THE RECOMMENDATION OF THE HARD PORTION DELETION COMMITTEE

© Government of Tamilnadu
First Edition - 2004
Revised Edition - 2009

Chairperson

Dr. A. SUBBIAH PANDI

Reader in Physics

Presidency College (Autonomous)
Chennai - 600 005

PHYSICS

Reviewer

Dr. K. Sakthi Murugesan
Senior Lecturer in Physics,
Dr. Ambedkar Govt. Arts College,
Vyasarpadi, Chennai - 600 039

Authors

Dr. S. Pandi
Reader in Physics
Presidency College, Chennai - 600 005

G. Anbalagan
Lecturer in Physics
A.A. Govt. Arts College,
Vilupuram

N.A. Masilamani
Headmaster,
Govt. (Hindu) High School,
Rasathupuram, Vellore District - 632 509

CHEMISTRY

Reviewer

Dr. R. Nanthini
Reader in Chemistry,
Pachaiyappa's College, Chennai - 600 030

Authors

I. Rose Kumari
Selection Grade Lecturer in Chemistry
Queen Mary's College, Chennai - 600 004

R.C. Saraswathi
PG Asst. in Chemistry,
Govt. Girls Hr. Sec. School,
Ashok Nagar, Chennai - 600 083

BOTANY

Reviewer

Dr. K. Ajithadoss
Reader in Botany
Presidency College, Chennai - 600 005

Authors

S.S. Rathina Kumar
Selection Grade Lecturer in Botany,
Presidency College, Chennai - 600 005

Dr. Renu Edwin
Lecturer in Botany,
Presidency College, Chennai - 600 005.

A. Parimmala Devi
Asst. Headmistress,
Govt. Girls Hr. Sec. School,
Ashok Nagar, Chennai - 600 083.

ZOOLOGY

Reviewer

Dr. K. Valivittan
Reader in Zoology,
Presidency College, Chennai - 600 005.

Authors

Dr. Susan Edward
Headmistress,
Dr. Ambedkar Govt. Hr. Sec. School,
Egmore, Chennai - 600 008.

V. Srinivasa Venkatanathan,
Lecturer in Zoology,
Presidency College, Chennai - 600 005.

Indira Vincent
Lecturer in Zoology,
Presidency College, Chennai - 600 005.

Price : Rs.

This book has been prepared by The Directorate of School Education on behalf of the Government of Tamilnadu.

This book has been printed on 60 G.S.M. Paper.

PREFACE

Science dictates almost every field of our activities. Science is responsible for bringing out the vast social changes that we witness today. The impact of science and technology on society has led man from stone age to information age. Science has entirely transformed our standard of living with new dimensions.

The students have to be prepared to face the challenges of fast developing world, based on science and technology. The present text-book of science is an effort in making the children to be the future scientists in various disciplines. This text-book has been prepared strictly according to the revised syllabus (2003). We have attempted to present the basic concepts and their applications in day-to-day life.

This book consists of 15 chapters in different branches of science viz., physics, chemistry and biology. Every chapter starts with an introduction highlighting the importance and applications of the concepts in that chapter. A number of activities have been given. These activities may be modified and performed using the low cost, easily available and discarded materials. Science is the process of discovering the natural world. Science is not just memorising facts. It is a method of thinking process. It is about asking questions like what, how and why. Learning to ask questions and learning to question the answers are the two invaluable skills that the young children have to develop. It is our hope that the teachers encourage the students to do such activities. There is a Chinese proverb saying "I hear, I forget; I read, I remember; I do, I understand". So, the demonstrations and activities should be an integral part of the teaching-learning process in the classroom.

A large number of clearly drawn and neatly labelled diagrams have been included wherever necessary. This will definitely help the students to understand the concepts and experiments effectively. Additional information have been summarised in the form of tables. Feynman, Nobel laureate in physics, once said "you do not know anything until you have practised". In keeping with this statement, the most important skill the students should develop is the ability to solve problems. So, adequate number of solved problems and exercises have been provided in this book.

To evaluate the knowledge and skills gained by the students, questions of different varieties, problems and activities have been designed and given at the end of each chapter.

While preparing for the examination, students should not restrict themselves, only to the questions / problems given in the self evaluation. They must be prepared to answer the questions and problems from the entire text.

Kothari Education commission report says, "If science is poorly taught and badly learnt, it is little more than burdening the young mind with dead information, and it could degenerate even into a new superstition". Science education in addition to providing the students a sound knowledge, cultivate scientific skills and inculcate a scientific temper.

I, as the Chairperson, thank the authors, reviewers and those who have been associated with the development of this book.

We welcome feedback from students, teachers and parents for the improvement of the book. Your comments and suggestions will be greatly appreciated.

Dr. A. Subbiah Pandi
Chairperson

CONTENTS

Preface iii

Cover Illustration iv

Syllabus v

PHYSICS

1. **Mechanics and Properties of Matter** 1
2. **Heat** 19
3. **Light** 34
4. **Electricity and its effects** 60
5. **Atomic and Nuclear Physics** 82

CHEMISTRY

6. **Chemical Reactions** 95
7. **Chemical Compounds** 110
8. **Metals and Non-metals** 120
9. **Carbon Compounds** 149

BIOLOGY

10. **Levels of Organisation** 163
11. **Cell Biology** 188
12. **Reproductive Biology** 202
13. **Diseases and Immunology** 222
14. **Our Environment** 235
15. **Applied Biology** 253

COVER ILLUSTRATION

TOP : Cut-away view inside a human eye. The image is upside down because of the refraction of light through eye lens.

BOTTOM LEFT : Dolly the sheep, born in 1997, was the first large animal to be cloned from an adult. A cell from a sheep (Dolly's mother) was injected into an unfertilized sheep's egg that had its nucleus removed. The two cells were fused using a spark of electricity. The new cell was placed in the womb of a third sheep where it grew into Dolly. Dolly has exactly the same genetic characters as her mother.

BOTTOM RIGHT : Thulasi (*Ocimum sanctum*) is a traditional medicinal plant effectively used for common cold.

CENTRE : A glass blower uses a long tube to blow through, so the heat from the glass won't burn him.

CENTRE RIGHT : Genes are made from a chemical called DNA. Each gene is one section of an enormously long DNA molecule. DNA is like a long ladder, twisted into a spiral. The rungs of the ladder carry coded information that body cells can use to make proteins.

BACKGROUND : Light beams emerge from the end of a cable of optical fibres. The fibres are made from flexible glass. Telephone conversations travel along optical fibre cables as pulses of laser light. A thin optical - fibre cable can carry 40,000 digitized telephone cells at the same time.

SYLLABUS

PHYSICS

Unit - I. Mechanics and Properties of Matter [6 periods]

1.1 Free fall and projectile motion with initial horizontal velocity.

1.2 Uniform circular motion, applications of centrifugal force.

1.3 Gravitation - Kepler's laws of planetary motion - Newton's laws of gravitation.

1.4 Surface Tension - Capillary rise

1.5 Viscosity - flow of liquid through a pipe - importance of viscosity.

1.6 Bernoulli's theorem and its applications.

Unit - 2. Heat [12 periods]

2.1 Heat - specific heat capacity.

2.2 Compute heat lost or gained by method of mixtures.

2.3 Mechanical equivalent of heat

2.4 Thermal expansion - co-efficient of linear and volume expansion.

2.5 Change of state - latent heat - cooling due to evaporation - principle of refrigerators.

2.6 Latent heats of fusion and vaporization.

2.7 Variation of boiling and melting points with pressure and impurities.

2.8 Humidity and relative humidity.

Unit - 3. Light [12 periods]

3.1 Refraction of light - laws of refraction, refraction through a glass slab and a prism determination of Refractive Index - Raising effect of refraction.
Critical angle and total internal refraction - totally reflecting prism.

3.2 Refraction of light - image formation by convex and concave lenses, lens formula, sign convention, power of a lens, - twinkling of stars, mirage.

3.3 Vision & Optical instruments - construction and working of a compound microscope and astronomical telescope.

3.4 Dispersion of light - dispersion of white light by glass prism - composition of white light - colours of objects - primary colours of - light and pigments, super position of light of primary colours.

3.5 Photography - Camera - Persistence of Vision - Projector

Unit - 4. Electricity and its effects [14 periods]

4.1 Electric field - potential and potential difference electric current.

4.2 Ohm's law - combination of resistances.

4.3 Heating effects - Heating effects of current-applications.
Power - Commercial unit of electrical energy.

4.4 Chemical effects - Electrolysis - Faraday's laws - electroplating - electro chemical cells - dry cells.

4.5 Magnetic effects - Magnetic field due to current carrying conductors - straight, coil and solenoid.

4.6 Electromagnets - Microphone, loud speaker.

4.7 Mechanical force on a current carrying conductor placed in a magnetic field - Fleming's left hand rule - moving - coil galvanometer.

4.8 Electromagnetic induction - Faraday's laws - Lenz's law - Fleming right hand rule.

4.9 AC Generator - DC Generator - transformer.

4.10 Domestic electric circuits - safety measures in handling electricity - fuse and earthing - electrocution.

Unit - 5. Atomic and Nuclear Physics [10 periods]

5.1 Electromagnetic radiation - Electromagnetic spectrum.
X rays - production, properties and uses.
Applications of infra red, microwaves and radiowaves.

5.2 Radioactivity - α, β, γ rays - properties - radioisotopes and their applications.

5.3 Nuclear fission and fusion - Chain reaction
Nuclear reactors

5.4 Advantages and hazards of nuclear energy - safety measures.

CHEMISTRY

Unit - 6. Chemical Reactions [12 periods]

6.1 Rate of chemical reaction

6.2 Types of reactions

Slow and fast reactions

Reaction with measurable rates

6.3 Reversible and irreversible reactions

6.4 Chemical equilibrium - Dynamic equilibrium

6.5 Energy changes during chemical reaction - Exothermic and endothermic reactions

6.6 pH scale - acidic and basic nature

Unit - 7. Chemical Compounds [11 periods]

7.1 Washing soda, preparation, Properties, Uses

7.2 Baking soda preparation, Properties, Uses

7.3 Bleaching powder - Manufacture, Properties, Uses

7.4 Plaster of Paris - preparation, Properties, Uses

7.5 Cement manufacture, Uses of cement

7.6 Glass manufacture - raw materials required (outline), cooling of glass, annealing, Uses

7.7 Steel

Alloy steel stainless steel - composition and uses, tungsten steel - composition uses.

Unit - 8. Metals and Non metals [14 periods]

8.1 Characteristic properties of metals and non metals

8.2 Minerals and Ores

8.3 Metallurgy

8.4 Metallurgy of iron - Properties of iron, uses

8.5 Metallurgy of Aluminium

Properties of Aluminium, uses

8.6 Alloys

8.7 Alloying of gold

1. Activity series

2. Displacement of one metal from another metal

8.8 Corrosion of metals

8.9 Introduction about hydrogen - Preparation of Hydrogen

Properties - Uses

8.10 Ammonia - Preparation - Properties of NH_3 - Uses

8.11 Occurrence of sulphur - Allotropy of sulphur - Extraction of sulphur - Properties - Uses

8.12 Preparation of sulphur dioxide - Properties - Uses

8.13 Manufacturing of sulphuric acid - Properties - Uses of sulphuric acid

Unit - 9. Carbon Compounds [8 periods]

9.1 Alcohol - types, fermentation and its importance, Ethanol, properties - Uses.

9.2 Carbonyl compounds - Aldeyde - methanol

Preparation - Properties of formaldehyde - Uses

9.3 Ketones - Acetone - Preparation - Properties - Uses

9.4 Carboxylic acid - Preparation of acetic acid - Properties - Uses

9.5 Soap and Detergents - Preparation

BIOLOGY

Unit - 10. Levels of Organisation [16 periods]

10.1 Viruses - Definition - T.M.V. (Tobacco Mosaic Viruses)

Differences between plant and Animal viruses. - Common viral diseases in plants and animals including human beings.

10.2 Bacteria - Introduction - prokaryotic nature - Types based on shape - Cell structure - Reproduction - Primary fission

Beneficial and harmful role of bacteria with examples.

10.3 Penicillium - Introduction to fungi - - Structure - Reproduction (Asexual only) - Economic importance - (Antibiotics industry, cheese industry) - Discovery of penicillin - Alexander Flemming's work

10.4 Medical Entomology - Insect vectors - Anopheles culex, Aides - Pheleobotomus, bed bug, head louse - Vector borne diseases - Malaria (parasite plasmodium) - Life history of Filarial worm - Dengue fever - Brain fever - Cholera - Vector control - Research centre - (VCRC) NMEP

10.5 Multicelllar level organisation (Frog) - Frog - systematic position - External morphology and sexual dimorphism - Digestive system - Buccal activity and Alimentary canal and physiology of digestive system - Respiratory system - Circulatory system - Nervous system - Sense organs- Urinogenetal system

10.6 Plant physiology - Introduction

Different areas of plant physiology (Absorption, Transpiration, Mineral - Nutrition, Photosynthesis, Respiration, Nitrogen, Metabolism, Flowering, Growth - List and brief explanation)

Absorption of water - osmosis - Thistle funnel experiment - Entry of water through root - hair - Root pressure.

Photosynthesis - Definition - Light reaction and dark reaction - a brief account.

Respiration - aerobic and anaerobic mechanism of aerobic respiration - a brief account. Fermentation of milk.

Growth - Definition - Growth harmones including synthetic hormones.

10.7 Human Physiology

Physiology of following - Digestion, Respiration, Circulation, Nervous system, Excretion and Sense organs (eye and ear) - related diseases - brief account.

Unit - 11. Cell biology [8 periods]

11.1 Chromosomes and Genes - Introduction - A typical chromosome - structure - Types of chromosomes - Number of chromosomes - Karyotypes - Genes - sites - structures and Role - Genomes

11.2 Genes and Nucleic acids - Gene - DNA nucleotide nucleoside bases -DNA model with strips and beads

Double helix Watson and Crick's model. - DNA Replication - Structure of RNA and functions - Genetic code and its significance

11.3 Gene expression - Protein synthesis

Genetic expression through genetic code DNA, RNA

Expression of genetic characters.

11.4 Mutation - Mutation - gene, chromosome definition

Gene reaction - Hugo devries, Dobzhansky and works of TH Morgan - Molecular Basis of gene mutation

Induced mutation - Chromosomal aberrations - Evolutionary significance of mutation - Applied mutation

11.5 Genetic Engineering

Genetic Engineering - Manipulaton of genes.

Tools used in genetic engineering Host-Vector DNA enzymes. - Mechanism of genetic engineering - Isolation - Integration and cloning of NiF gene - Application of Genetic Engineering

11.6 Biotechnology - Scientific art of using micro organisms. - Application of Bio technology in production industries. - Products of Biotechnology - Future of Biotechnology

Unit - 12. Reproductive Biology [14 periods]

12.1 Pollinaton and Fertilisation - Definition - pollination - Types of pollinations - Contrivances for cross pollinaton - Definition of fertilisation - Process of fertilisation - Double fertilisation - Post fertilisation changes in a flower

12.2 Dispersal of fruits and seeds - Agents of dispersal - Adaptations of fruits and seeds for dispersal - Advantages of dispersal - Germination - Parts of a seed - Germination types

12.3 Gametogenesis - Testis - Spermatogenesis - Phases multiplication - Growth - Maturation, spermiogenesis, structure of sperm - Ovary - Oogenesis menstrual cycle

12.4 Types of Vertebrate eggs - Egg cell - definition - Sizes and shapes - Types of animal eggs - Egg membranes - Amphioxus egg - Hen's egg - Typical structure -

12.5 Fertilization - Introduction - External fertilisation - Internal fertilisation - Mechanism of fertilisation - The meeting of gametes penetration of the sperm into the egg, activation of the egg, fusion of male and female pronuclei. - Significance of fertilization

12.6 Cleavage - Microlecithal egg - Planes - patterns cleavage - Cleavage of upto 64 cell stage. - Blastula - Begining of multi cellular organisation

12.7 Applied Embroyology - Introduction

Tissue culture - Technique - Application

Cloning Technique - Cloned animals

Stem cells - Maintenance of cell lineages - application - organ repair

Unit - 13. Diseases and Immunology [10 periods]

13.1 Medicinal plants - Improtance of plants as a source of drug for various kinds of ailments.

13.2 Medical practices - Types of Indian Medicine

(Siddha, Naturopathy, Homeopathy, Unani and Ayurvedic) - Study of a few common medicinal plants and their uses. -(Azadizhata Indica (Neem) Catharanthus roseus) (Vinca rosea) - Zingibar officinale (Ginger) - Ocimum santum (Thulsi)

13.3 Non-Communicable diseases - Definition - Non-Communicable diseases - A study of following diseases.

Diabeties, CHD, RHD, Anorexia, nervosa, Renal failure, obesity - protein deficiency diseases.

13.4 Addictions - Definition - Alchoholism and ill effects

Abuse of Tobacco - various forms of usage - Cancer

Drugs - Narcotic - Drugs - Types - severe addictions - Dependence

De addiction methods - Govt. and Non-Govt. organisations. - Social aspects

13.5 Health - Immunisation - Artificial immunity - Types - Development of vaccines - history - vaccines available -Immunisation schedule

14. Our Environment [8 periods]

14.1 Social Forestry - Definition - Deforestation and afforestation - Advantages of social forestry

Plants employed in social forestry

14.2 Global issues - Global environmental issues - introduction - Global warming - A crisis - Gases - Effect of global warming - Ozone layer depletion - causes - effects - control. - Earth summits

14.3 Fresh water crisis and management

Role of water in animal system

Availability of fresh water - Depletion - Conservation - Rain water harvesting (RWH)

14.4 Effluent Treatment - Industrial effluents

Heavy metals and their effects on organisms

Common effluent treatment plants and their importance

14.5 Air pollution

Air pollution - pollutants - Carbon monoxide, sulphur dioxide, Nitrous oxide - effects - Control of Air pollution

Noise pollution - Decibel levels

14.6 Wild life protection - Wild life - Need for protection - conservation - Indian wild life-fauna and flora - Sanctuaries - other protection methods - Extinct and endangered species - Governmental and NGO agencies

Unit - 15. Applied Biology [10 periods]

15.1 Sustainable Agriculture - Definition - Mixed cropping - Crop rotation - Green revolution - Plant breeding - Eco - friendly agriculture (use of biofertilisers and biopesticides) - (avoiding chemical fertilizers and pesticides)

15.2 Natural Resources - Types of natural resources - Air - Water - Soil - Minerals - Energy - Flora and Fauna - Management of Natural resources

15.3 Crop Production - Importance of crops for man - Cultivation of crops (cash and food crops) - Nutrients required for the crops (organic and inorganic) - Water requirements - Crop protection -

15.4 Aquaculture and Vermiculture - Aquaculture - Cultivable organisms - Fish varieties - Fish culture - Prawns - Crabs - Algae - Pearl oyster - Mussels - Vermi culture - Need - Species of Earthworms - Vermitech products and uses

15.5 Bio-medical - Instrumentation - Introduction to instrumentation techniques - ECG - equipment usage and operation - sphygmomonometer - CT scan application - Audiogram - application - Dialysis - various techniques - need - Laproscopy and Endoscopy - applications - Eye lens implantation - Organ transplantations - precaution and care - Blood transfusion - Blood groups - Blood Banks - Techniques - Scope for further studies institutes

REFERENCE BOOKS

1. Practical Physics - Jerry. D. Wilson - Saunders College Publishing.
2. Science Experiments - H.J. Press - Scholastic.
3. Advanced Level Physics - Nelkon and Parker, C.B.S. Publishers.
4. Engineering Physics - R.K. Gaur & S.L. Gupta, Dhanpat Rai & Sons - New Delhi.
5. University Physics - Young & Freedom, Addison - Wesley.
6. Principles of Physics - Bueche and Jerde, McGran Hill.
7. Essential Science - Free Mantle Tidy, Oxford University Press.
8. Chemistry Matters - Richard Hart, Oxford University Press.
9. Introductory Chemistry - M. Katyal, Oxford University Press.
10. Chemistry - Facts, Patterns and Principles. Kneen, Rogers and Simpson - (ELBS), The English Language Book Society.
11. Physical Chemistry - P.L. Soni.
12. Advanced Organic Chemistry - Bahl and Arun Bhal.
13. Introductory Mycology - Alexopoulos & Mins.
14. Introductory, Microbiology - Pelizer.
15. Plant Physiology - Devlin & Witham CBS Publishers, Delhi.
16. A text book of Bio technology - R.C. Dubey, S.Chand Publications.
17. Ecology - H.D. Kumar
18. Plant Breeding - Choudhury - IBH.
19. Longman's medical embryology - T.W. Sadler.
20. Cell and Molecular Biology - De Robertis & Robertis - B.I. Publications - New Delhi.
21. A text book of fishery science & Indian fisheries - C.B.L. Srivastava. Kitab Mahal Publishers
22. Chordate Embryology - Developmental biology. Verma & Agarwal, S.Chand and Company.
23. Manual of Zoology - Ekambaranatha Iyer, Viswanathan Publishers.
24. Human Physiology - Guyton.

COVER ILLUSTRATION

TOP : Cut-away view inside a human eye. The image is upside down because of the refraction of light through eye lens.

BOTTOM LEFT : Dolly the sheep, born in 1997, was the first large animal to be cloned from an adult. A cell from a sheep (Dolly's mother) was injected into an unfertilized sheep's egg that had its nucleus removed. The two cells were fused using a spark of electricity. The new cell was placed in the womb of a third sheep where it grew into Dolly. Dolly has exactly the same genetic characters as her mother.

BOTTOM RIGHT : Thulasi (*Ocimum sanctum*) is a traditional medicinal plant effectively used for common cold.

CENTRE : A glass blower uses a long tube to blow through, so the heat from the glass won't burn him.

CENTRE RIGHT : Genes are made from a chemical called DNA. Each gene is one section of an enormously long DNA molecule. DNA is like a long ladder, twisted into a spiral. The rungs of the ladder carry coded information that body cells can use to make proteins.

BACKGROUND : Light beams emerge from the end of a cable of optical fibres. The fibres are made from flexible glass. Telephone conversations travel along optical fibre cables as pulses of laser light. A thin optical - fibre cable can carry 40,000 digitized telephone cells at the same time.

PHYSICS

1. MECHANICS AND PROPERTIES OF MATTER

The branch of Physics dealing with the behaviour of matter under the action of forces is called **Mechanics. Dynamics** and **Statics** are the two branches of mechanics. The mathematical and physical study of the behaviour of bodies under the action of forces that produce changes of motion in them is known as dynamics. Statics deals with the cases where no motion is produced in the bodies under the action of forces. Objects have translational motion, rotational motion and vibrational motion. The motion of wheels, blades of fan, planets around sun and electrons around the nucleus of atoms are some examples of rotational motion. Elasticity, surface tension and viscosity are a few important physical properties of matter. These properties can be explained on the basis of forces between molecules of matter. A thorough knowledge of properties of matter is essential in identifying different materials available with us. This is useful in choosing proper materials for different applications. This study is made use in the branch of physics called **Properties of matter.**

In this chapter we shall study the basic concepts of projectile motion, circular motion, gravitation, planetary motion, surface tension, viscosity, Bernoulli's theorem and their applications.

1.1 Motion of freely falling bodies and projectile motion

1. Freely falling bodies

When an object falls towards the earth under gravity in the absence of air resistance, it is called a freely falling body. All objects in free fall near the earth have the same acceleration called the acceleration due to gravity (g). The gravitational force acting on an object of mass (m) near the earth is its weight $W = mg$. The acceleration of an object in free fall is independent of its mass.

As air resistance normally acts on a falling body and opposes its motion, the object falls at a slower rate than in free fall.

Coin and feather experiment : Drop a coin and a feather simultaneously in a tube. Evacuate air from the tube and repeat the same dropping. Observe that in the first case the coin which is heavier than the feather reaches the bottom of the tube more rapidly while the feather flutters down slowly. But in the second case the coin and the feather to fall together. From this experiment we understand that air resistance affects the motion of a falling body.

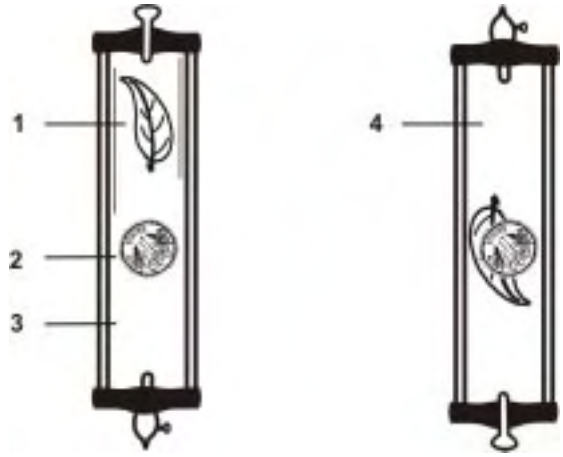


Fig. 1.1 Coin and feather experiment

1. falling feather 2. falling coin 3. air 4. partial vacuumm 5. vaccum device

The air resistance on a falling body depends on its shape, size and speed.

Examples

(1) A skydiver with an unopened parachute falls quite rapidly and when the chute opens due to the shape and size of the body the air resistance increases and the descent is slowed. This is how the skydiving gives pleasure.

(2) Automobiles are now streamlined in shape to reduce air resistance and improve fuel consumption.

(3) When a body falls, it accelerates due to gravity and the retarding force of air resistance increases with speed. This continues till the force of air resistance equals the weight of the object. Now the object no longer accelerates but falls with a constant speed called the **terminal velocity.** The terminal velocity is about 200 km/hr for a skydiver with an unopened parachute.

(4) While falling the skydivers use a "spread-eagle" position to increase the air resistance and prolong the time of fall. When the parachute is opened, the fall is slowed by the additional resistive force.

Fig. 1.2 Air resistance in action
Spread-Eagle position

2. Projectile motion

Any object which follows a path determined by the gravitational force and air resistance when an initial velocity is given, is called a projectile. A bullet shot from a rifle, a rocket after its fuel is exhausted, a javelin thrown by an athelate and a thrown cricket ball are examples of projectile. The path followed by a projectile is called its trajectory.

1) Vertical projection

We often throw or toss things directly upward and this is a vertical projection. The initial velocity of the object is upward but the acceleration due to gravity is downward. Hence a vertically projected object at its maximum height stops instantaneously and changes its direction. Now it becomes a dropped object in free fall.

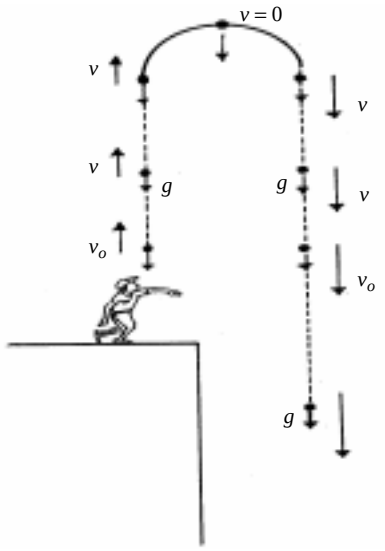


Fig. 1.3 Vertical projection

Acceleration remains constant and velocity varies.

(1) Equations of motion for bodies projected upwards

If a body is projected vertically upwards its velocity gradually decreases and when the body reaches the maximum height its velocity becomes zero.

The general equations of motion which are useful in discussing the projectile motion are,

$$v = u + at$$

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

When the body is projected vertically upwards the equations of motion become,

$$v = u - gt \quad \text{..... (1)}$$

$$s = ut - \frac{1}{2}gt^2 \quad \text{..... (2)}$$

$$v^2 = u^2 - 2gs \quad \text{..... (3)}$$

(2) Maximum height attained (h)

Let a body be projected vertically upwards with an initial velocity u. As it moves upwards its acceleration is taken as $-g$. As the body goes up its velocity decreases and finally becomes zero ($v = 0$) when it reaches maximum height. Now the equation (3) becomes

$$\therefore \quad -u^2 = -2gh$$

$$\therefore \quad h = \frac{u^2}{2g} \qquad \text{... (4)}$$

Hence the maximum height attained by a body is directly proportional to the square of its initial velocity ***u***.

(3) Time of ascent (t_1)

The time taken by a body thrown up to reach maximum height is called its time of ascent.

Let t_1 be the time of ascent. At the maximum height its velocity $v = 0$.

Equation (1) becomes

$$\therefore \quad 0 = u - gt_1$$

$$t_1 = \frac{u}{g} \qquad \text{..... (5)}$$

(4) Time of descent (t_2)

After reaching the maximum height, the body begins to travel downwards like a freely falling body.

The time taken by a freely falling body to reach the ground is called the time of descent (t_2). In this case $u = 0$ and g is positive.

$\therefore$ Equation (2) becomes

$$h = 0 + \frac{1}{2} g t_2^2$$

$$t_2^2 = \frac{2h}{g}$$

$$t_2 = \sqrt{\frac{2h}{g}}$$

By equation (4)

$$h = \frac{u^2}{2g}$$

$$\therefore \quad t_2 = \sqrt{\frac{2}{g} \times \frac{u^2}{2g}}$$

$$= \sqrt{\frac{u^2}{g^2}}$$

$$t_2 = \frac{u}{g} \qquad \text{..... (6)}$$

Comparing equations (5) and (6)

$$t_1 = t_2$$

It is an interesting fact that the time of ascent is equal to the time of descent in the case of bodies moving under gravity.

(5) Time of flight

The time of flight is the time taken by a body to remain in air and is given by the sum of the time of ascent (t_1) and the time of descent (t_2).

Here $t_f = t_1 + t_2$

$$= \frac{u}{g} + \frac{u}{g}$$

$$t_f = \frac{2u}{g} \qquad \text{..... (7)}$$

(6) Velocity on reaching the ground

When a body is dropped from a height h its initial velocity u is zero. Let the final velocity on reaching the ground be v.

Equation (3) becomes

$$v^2 = 2gh$$

$$\therefore \quad v = \sqrt{2gh} \qquad \text{..... (8)}$$

from equation (4)

$$u = \sqrt{2gh} \qquad \text{..... (9)}$$

From equations (8) and (9) we conclude that the velocity of the body falling from a height h on reaching the ground is equal to the velocity with which it is projected vertically upwards to reach the same height h.

Hence the upward velocity at any point in its flight is the same as its downward velocity at that point. The value of g at a place can be determined by noting the time taken (t) to cover a vertical height (h) in free fall ; $g = \frac{2h}{t^2}$

Problem : A body is thrown vertically upwards and rises to a length of 10 metre. Calculate (i) the velocity with which the body

was thrown upwards and (ii) the time taken by the body to reach the highest point.

Here $h = 10$ m, $v = 0$, $u = ?$,

$g = -9.8\ ms^{-2}$

(i) $v^2 - u^2 = 2gh$

$0 - u^2 = -2 \times 9.8 \times 10$

$u^2 = 196$

$u = 14\ ms^{-1}$

(ii) $v = u - gt$

$0 = 14 - 9.8 \times t$

$t = 1.43$ second

Problem : A body is thrown up vertically with a velocity of 14.7 ms^{-1} from a tower of height 49 metre. Find the time required by the body to reach ground.

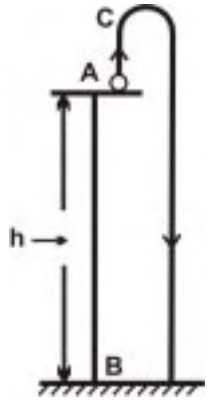


Fig. 1.4 Vertically thrown body from the top of a tower

Let AB be the tower of height h.

A body projected from the point 'A' vertically upwards reaches the maximum height at C, from where it falls freely.

Let AC $= x$

Displacement of the body $= s = x - (x + h)$

$= -h = -49$ m

$u = 14.7\ ms^{-1}$, $g = -9.8\ ms^{-2}$

Time required to reach the ground $= t$

Using the equation of motion

$$s = ut + \frac{1}{2}gt^2$$

$$-49 = 14.7\,t - \frac{1}{2} \times 9.8 \times t^2$$

Dividing by 4.9 on both sides,

$$-10 = 3t - t^2$$

$$t^2 - 3t - 10 = 0$$

$$(t - 5)\,(t + 2) = 0$$

$t = 5\ s$ or $t = -2\ s$

t cannot be negative.

$\therefore\ t = 5$ seconds.

2) Horizontal projection

A horizontally thrown ball and a bullet fired from a rifle held horizontally are the projectiles in the horizontal direction. For this type of projection there is an initial velocity u only in the horizontal or x-direction. But

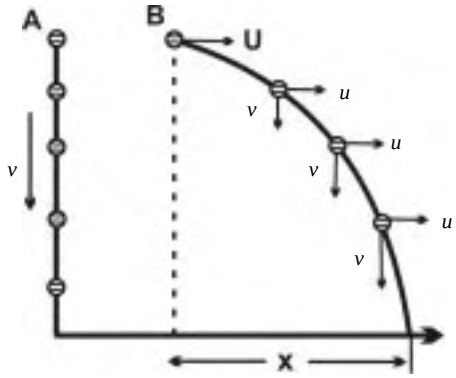


Fig. 1.5 Path of a projectile

A. Freely falling body B. Horizontally projected body

there is no initial velocity in the vertical or y-direction. However, there is an acceleration in the downward direction due to gravity. Since there is no acceleration or force in the x-direction after it is projected, the projectile moves in this direction with a constant speed (u). As the object moves horizontally, it also falls in the downward direction due to gravity. In the downward direction, the motion is the same as that of a dropped object.

Let us consider a body A which is allowed to fall freely and another body B projected horizontally with a velocity u from the same height and at the same time. The

body B possesses simultaneously (i) uniform horizontal velocity u and (ii) a non-uniform vertical velocity v. As the body B travels down its vertical velocity (v) increases due to acceleration due to gravity. But the horizontal velocity u remains constant. Hence the body A which is freely falling and the body B projected horizontally from the same height at the same time will strike the ground simultaneously at different points.

But the two bodies at any instant will be at the same vertical height above the ground. Thus the motion of a freely falling body is same as that of a horizontally thrown projectile.

A stone released from a moving train behaves like the horizontal projectile B (Fig.1.5). As the path of B is a parabola, a stone released from a moving train also follows a parabolic path.

3) Projection at an angle (Oblique projection)

Consider a body which is projected at an angle with the horizontal. Let u be the initial velocity of the projectile and θ be the angle of projection. Initial velocity can be resolved into two components viz. (i) the horizontal component $u\cos\theta$ and (ii) the vertical component $u\sin\theta$. The path of the

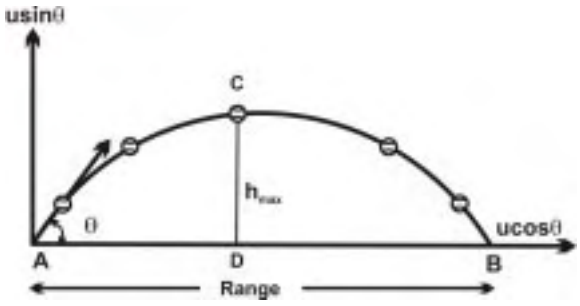


Fig. 1.6 Projection at an angle

projectile ACB is a parabola and CD (h) is the maximum height reached by it.

The time (t) taken by the projectile to reach the maximum height is given by

$$t = \frac{u \sin\theta}{g} \qquad \ldots (1)$$

The maximum height reached is given by

$$h = \frac{u^2 \sin^2\theta}{2g} \qquad \ldots (2)$$

The time of flight (t_f) of a projectile is defined as the time taken by it to reach the horizontal plane after its projection. It is given by

$$t_f = \frac{2u \sin\theta}{g} \qquad \ldots (3)$$

The distance between the point of projection A and the point B where the projectile strikes the horizontal plane again is called its range (R). It is given by

$$R = \frac{u^2 \sin 2\theta}{g} \qquad \ldots (4)$$

Equation (4) shows that the range is maximum when $\theta = 45^o$

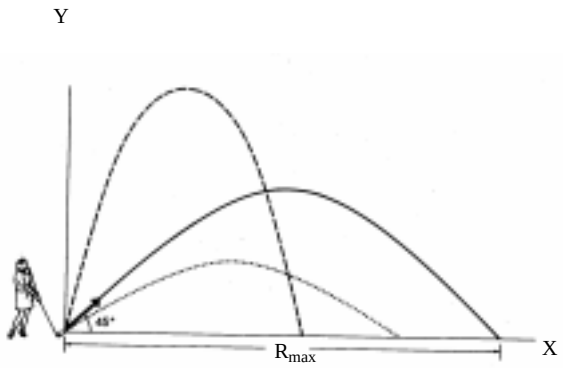


Fig. 1.7 The projection angle is 45^o for maximum range

This is a consideration in several sports events such as shotput, javelin and golf where maximum ranges are desired.

1.2 Circular motion

Relation between Linear velocity and angular velocity

When a particle moves in a circle with a constant speed then the motion is known as uniform circular motion.

Consider an object moving in a circle with a uniform speed a round a fixed point O as centre.

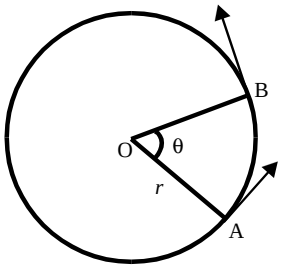


Fig. 1.8 Circular motion

If the object moves from A to B so that the radius OA moves through an angle θ, its ***angular velocity (ω) about O is defined as the rate at which the radius vector sweeps.*** If t is the time taken by the object to move from A to B then,

$$\omega = \frac{\theta}{t} \qquad \ldots (1)$$

The unit of the angular velocity is rad s^{-1}. The time taken T by the object to describe the circle once is called the period of circular motion. It is given by

$$T = \frac{2\pi}{\omega} \qquad \ldots (2)$$

If s is the length of the arc AB, then

$$s = r\theta$$

$$\frac{s}{t} = r\frac{\theta}{t} \qquad \ldots (3)$$

The linear velocity v of the rotating object is given by

$$v = \frac{s}{t} \qquad \ldots (4)$$

Substituting equation (1) and (4) in (3)

$$v = r\omega \qquad \ldots (5)$$

This is the relation connecting the linear velocity and the angular velocity of the object in circular motion.

1. Centripetal force

Activity : Swing a stone tied to a string and observe that the stone follows a circular path. Let the string slip through your fingers

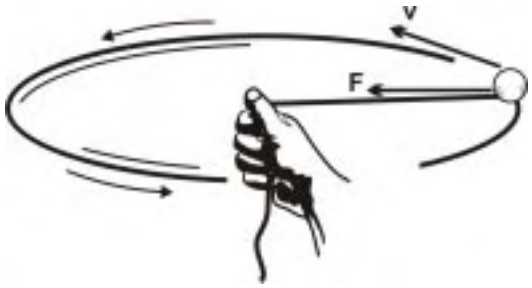


Fig. 1.9 Centripetal force

1. String 2. Stone 3. Tangential velocity

and observe that the stone no longer follows a circular path but flies off in the direction of the instantaneous velocity. This direction is tangential to the circular path.

From this activity we understand that a force acting on the stone pulls it towards the centre of the circle. This force is called the **centripetal force.** Centripetal force is the force needed to make an object travel in the circular path.

The centripetal force causes an acceleration towards the centre of the circle and this acceleration is called the centripetal acceleration. The centripetal acceleration (a_c) of an object in uniform circular motion is given by

$$a_c = \frac{v^2}{r} \qquad \ldots (6)$$

If m is the mass of the object then the centripetal force (F) is given by

$$F = \frac{mv^2}{r} \qquad \ldots (7)$$

In terms of angular velocity (ω) of the object, equation (7) becomes

$$F = m r \omega^2 \qquad \ldots (8)$$

Centripetal force finds many practical applications

(1) In washing machine's spin cycle, water is separated from the clothes. The tub

of the washer rotates rapidly. The force exerted on the water present in the clothes is not much enough to make the water

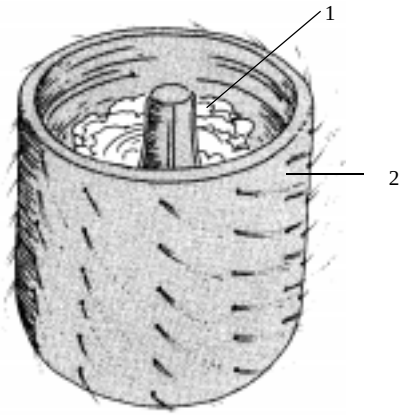


Fig. 1.10 Washing machine

1. Clothes 2. Tub of washer

travel in a circle with the clothes. The water flies off, leaving the clothes less wet due to lack of centripetal force.

(2) The less desirable case of lack of centripetal force is when the rear wheel of an automobile spins in mud. The adhesion of the mud to the wheel which is the centripetal force in this case is not enough to hold the mud on the tyre. So it comes off tangentially to the tyre's circular motion.

(3) Gravitational force between a satellite and the earth acts as a centripetal force, keeping the satellite in orbit.

2. Centrifugal force

We feel a force pushing us outward or away from the centre of curvature when we travel in a fast moving car rounding a sharp curve or in a rotating ride in an amusement park. This force is known as **centrifugal force**. It acts in the opposite direction to that of centripetal force. The centrifugal force is also given by

$$F = \frac{mv^2}{r}$$

When earth rotates about its own axis, the velocity of bodies near the equator is more than that at the poles. On earth the centrifugal force is minimum at the poles and maximum at the equator. This is the reason why the poles of the earth are found to be nearly flat and the diameters of earth along the equator and poles are different by 48 km.

The centripetal force required for a car or a bicycle to go round a circular curve depends on its speed and the radius of curvature of the curve.

3. Applications of centrifugal force

(1) The principle of centrifugal force is applied to the machines called **centrifuges.** They are used to separate materials of different weights or densities by spinning action. The liquid is rotated in a cylindrical vessel at a high speed with the help of an electric motor. The heavier particles move away from the axis of rotation and lighter particles move nearer to the axis of rotation.

The spinning drum in a washing machine to separate water from clothes is a centrifuge. Centrifuges are used in separating blood cells from plasma and cream from milk in dairy separators. Ultra centrifuges with speeds of the order of 5×10^5 rpm are used to concentrate viruses in solution.

The holder of a centrifuge container is pivoted, so that the container will be in the horizontal position, when the centrifuge spins rapidly. The heavier materials migrate towards the outer end of the container. For example when blood samples are centrifuged, the red cells reach the bottom and lighter white cells go to the top of the tube. Sugar crystals are separated from molasses with the help of a centrifuge. Honey is also separated from bees wax with the help of a centrifuge.

(2) If a vehicle moves at very high speed over a curved path, the centrifugal force $\left(\frac{mv^2}{r}\right)$ makes it topple. This is because the centrifugal force overcomes the frictional force between the road and the tyres of the vehicle. To prevent this, the curved tracks are always banked. It means that the outer edge of the road

is slightly elevated at an angle θ. This angle of elevation is given by

$$\theta = \tan^{-1}\left(\frac{v^2}{rg}\right)$$

where g is the acceleration due to gravity. Due to banking of curves the centrifugal force balances with frictional force and equilibrium is reached. Thus toppling of vehicles is prevented on curved roads. This is known as banking of tracks. The racing track is designed like a concave disc for the same reason.

(3) **Watt governor** makes use of the centrifugal force for regulating the speed of an engine or machine.

It consists of two heavy balls B_1 and B_2 joined to the ends of the rods R_1 and R_2 hinged at H, the end of the spindle **S**. These rods are connected through the link rods

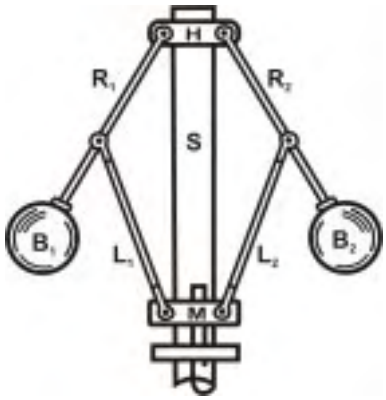


Fig. 1.11 Watt governor

B_1 , B_2 - Heavy balls R_1 , R_2 - rods H - Hinged position, S - Spindle L_1 , L_2 - Link rods.

L_1 and L_2 to a sleave m which can slide up and down on the spindle. As the speed of the engine increases, the speed of rotation of the spindle also increases and consquently the centrifugal force on the balls B_1 and B_2 increases. Now the balls and the sleave move up due to the increase in speed of rotation of the balls. This partially closes a valve which controls the entry of steam to the engine and the speed of the engine is checked. Thus the speed of the engine is regulated by regulating the supply of steam.

(4) In circus there is an event known as the **cage of death**. In this event, a motor cyclist drives a motor cycle at a high speed on the inner walls of a spherical cage of iron. But he does not fall off the motor cycle even when he is upside down. The centrifugal force keeps the motor cyclist glued to his seat while driving his motor cycle inside the cage.

1.3 Gravitation

Planetary motion is one of the important periodic motions. According to **Ptolemy's** (2nd century A.D.) **geocentric theory**, the earth was assumed to be at the centre of the universe and the sun, the moon, the planets and even the stars were thought to move around in complicated paths. Later **Copernicus** proposed a new theory called **heliocentric theory** (15 century A.D.) In this theory the sun was considered to be at the centre and the earth and other planets revolve around the sun in circular orbits of different radii. Copernicus also believed that the earth rotates on its axis once every day. The famous Indian mathematician and astronomer **Aryabhatta** who lived in the fifth century A.D. perceived the earth's rotation on its axis.

Later in 16th century **Tycho Brahe** made very careful and accurate measurements of the motion of the planets and the sun. Based on the study of Tycho Brahe, another astronomer **Kepler** laid the foundation of modern astronomy. Kepler deduced three laws which accurately described the motions of planets about the sun. These laws formed the basis of the famous Newton's law of universal gravitation.

1. Kepler's laws

First law (Law of orbits)

Each planet moves around the sun in an elliptical orbit with the sun at one of its foci.

An ellipse is a closed curve such that the sum of the distances from any point P on the curve to two fixed points (F_1 , F_2) remains constant. That is (F_1 P + F_2P) is the same for all **points P** on the curve. In fig. F_1 is the position of the sun at one of the foci of the ellipse. P is the position of the planet revolving round the sun. The position A of the planet

where it is close to the sun is known as **perigee** (A) and the position of the planet L

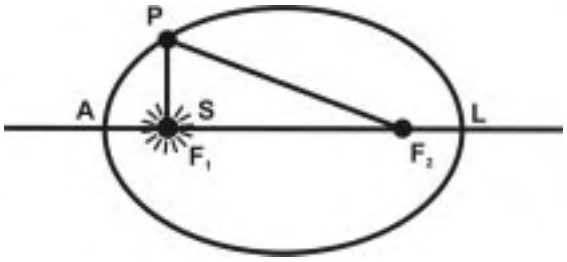


Fig. 1.12 Kepler's first law

P - Planet, F_1 - Sun, A - Perigee, L - Apogee

where it is farthest (L) from the sun is known as **apogee.**

Second law (Law of areas)

As the planet moves in its orbit, a line drawn from the sun to the planet sweeps out equal areas in equal intervals of time.

Let PQS and RST be the areas swept by the line joining the planet and the sun in equal intervals of time. Kepler found that these areas are equal. Hence the speed of the planet

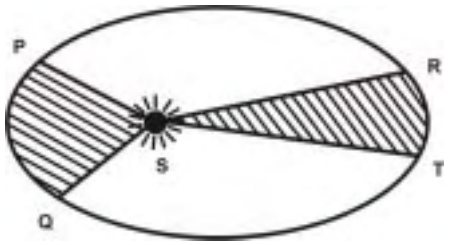


Fig. 1.13 Kepler's Second law

S - Position of sun P - Position of planet

must be maximum at the perigee position and minimum at the apogee position.

Third law (Law of periods)

The squares of the periods of revolution of the planets are proportional to the cubes of their mean distances from the sun.

If R is the mean distance of the planet from the sun and T is the period of its revolution the third law states that

$$T^2 \propto R^3$$

$$\frac{T^2}{R^3} = \text{a constant}$$

The planets with the mean distances from the sun, their orbital periods and velocities are listed in the table.

Table 1.1. Law of periods

Name of Planet	Time Period T (years)	Mean distance from the sun R ($\times 10^9$ m)	Mean velocity ($\times 10^3$ m/s^{-1})	$\frac{T^2}{R^3}$ ($\times 10^{-25}$) $\frac{\text{years}^2}{\text{km}^3}$
Mercury	0.241	57.91	47.875	2.991
Venus	0.615	108.21	35.056	2.985
Earth	1.000	149.60	29.806	2.987
Mars	1.881	227.94	24.144	2.988
Jupiter	11.862	778.30	13.072	2.985
Saturn	29.458	1427.00	9.651	2.986
Uranus	84.015	2869.00	6.804	2.990
Neptune	164.788	4498.00	5.438	2.984
Pluto	248.400	5900.00	4.732	3.004

About 100 years later, Newton demonstrated that Kepler's laws were the consequence of a simple force that exists between any two masses. Newton's law of gravitation and laws of motion, provide the basis for the motion of planets and satellites.

2.Newton's universal law of gravitation

Everybody in the universe attracts every other body with a force which is directly proportional to the product of the masses of the two bodies and inversely proportional to the square of the distance between them.

If m_1 and m_2 are the masses of two bodies separated by a distance r, the force of attraction F between them is given by

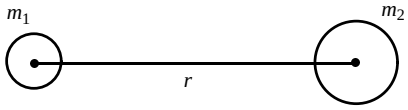


Fig. 1.14 Newton's law of gravitation

$$F = \frac{G\, m_1\, m_2}{r^2}$$

where G is the universal constant of gravitation.

The value of $G = 6.67 \times 10^{-11}$ N m^2 Kg^{-2}

The force of gravitation is directed along the line joining the two bodies.

If $m_1 = m_2 = 1$ kg and $r = 1$ m

then F = G

Thus the gravitational constant is equal to the force of attraction between two bodies each of mass 1 kg separated by a distance of 1 metre.

1.4 Surface Tension

Have you seen insects like ants, water-spider walking on the surface of water ? You have seen mosquitoes sit and move freely on the surface of stagnant water. When we sprinkle water at the roots of trees and shrubs, the sprinkled water gradually rises to their branches upwards. All these observations can be explained on the basis of a property of liquids.

Activity : Take a clean glass plate. Place very small amount of mercury on the plane surface. Observe that mercury assumes the

Fig. 1.15 Shape of a small and big drop of mercury

form of a spherical drop. Place large amount of mercury on the plane surface observe that now mercury assumes ellipsoidal shape.

Activity : Place a greased sewing needle carefully on a water surface. The sewing needle makes a small depression in the surface.

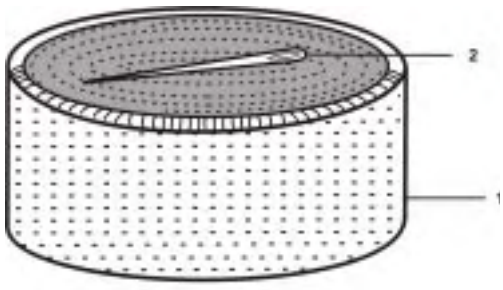


Fig. 1.16 Needle Floating on water

1. Tub 2. Water 3. Needle

Observe that the needle floats on the surface of water even though the density of the needle is very much greater than that of water.

From the above activities we understand that there exists a tension on the surface of a liquid which tends to contract the surface to a minimum area. This property of the liquids is known as surface tension.

Surface tension of a liquid is defined as the tangential force per unit length acting at right angles on an imaginary line drawn on the surface of the liquid. It's unit is $N\ m^{-1}$.

1. Molecular Forces :

Surface Tension is essentially a molecular phenomenon. There are two types of molecular forces of attraction (1) adhesive force and (2) cohesive force.

Forces between molecules of different substances are called **adhesive forces.** The adhesive force is different for different pairs of substances. Gum or glue is an adhesive. The force of attraction between gum and paper is an adhesive force.

Forces between molecules of the same substances are called **cohesive forces.** The cohesive forces are short range forces and therefore they are effective only up to a very small distance.

The adhesion of water to glass is stronger than the cohesion of water. On the other hand, the cohesion of mercury is greater than its adhesion to glass. The maximum distance at which the molecules can attract each other is called molecular range. The molecular range is of the order of 10^{-8} cm.

2. Explanation of surface tension on the basis of molecular theory :

A sphere drawn with the molecule as centre and radius equal to the molecular range is called the sphere of molecular influence.

The molecular forces are effective within this sphere of molecular influence. Therefore all the molecules lying within this sphere of

molecular influence exert a force of attraction on the molecule at the centre. These molecular forces are responsible for surface tension.

Laplace gave an explanation of the surface tension on the basis of molecular theory.

PQ represents the free surface of a liquid in a container.

Let A, B and C represent molecules with their spheres of influence drawn around them. The sphere of influence around the molecule A is well within the free surface

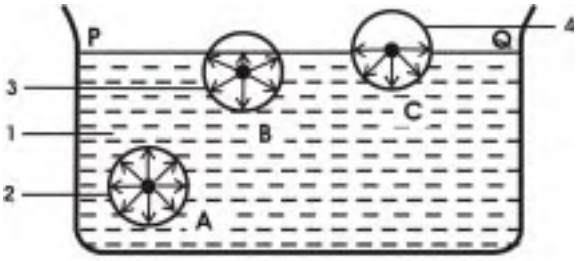


Fig. 1.17 Inter Molecular forces

1. water 2. molecule-A 3. molecule-B, 4. molecule-C

PQ. Hence it is equally attracted in all directions by the molecules in the sphere of influence. Therefore the resultant force acting on the molecule A is zero.

In the case of molecule B the sphere of influence is partly outside the liquid surface PQ. The number of molecules in the upper half is less than that in the lower half. Thus the resultant force on B acts in the downward direction.

The molecule C is exactly on the free surface PQ. The sphere of influence around the molecule C is exactly half outside and half inside the liquid. Hence this molecule C is attracted in the downward direction with maximum force.

Thus we conclude that the molecules in the surface PQ are pulled downwards due to the resultant cohesive force. This makes the free surface of the liquid at rest behave like a stretched elastic membrane. This force gives rise to the surface tension of the liquid.

3. Illustrations of Surface Tension

The following activities illustrate surface tension of liquids.

Activity : A wire ring is made as shown in the figure and a loop of thread is attached across the ring. The wire and thread are dipped in a soap solution and taken out gently. Now

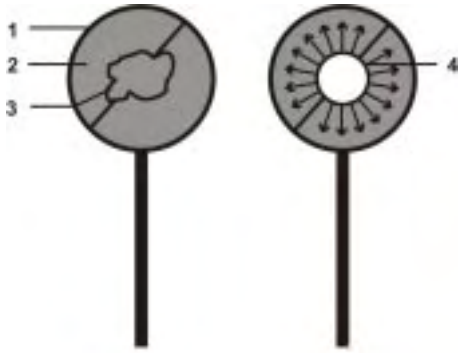


Fig. 1.18 Illustrations of Surface Tension

1. Wire ring 2. Soap film 3. Loop of thread before puncturing 4. loop of thread after puncturing

a film of the soap solution is formed across the ring. The zig-zag loop of the thread lies on the film.

If the film inside the loop of thread is punctured with a needle, then the loop takes the shape of a circle due to surface tension.

The surface of the liquid film pulls the thread radially outward as shown by the arrows.

Activity : A tumbler is filled to the brim with water. Some nails are put inside the water so that water is displaced upwards. A few more nails are added carefully. It is found that water surface rises well above the edge of the tumbler but water does not overflow. This is because the water surface stretches as water is displaced upwards.

Activity : If a brush is dipped in water its bristles spread out. If it is taken out the bristles come closer and cling together.

The above three activities show that the surface of a liquid acts like a stretched

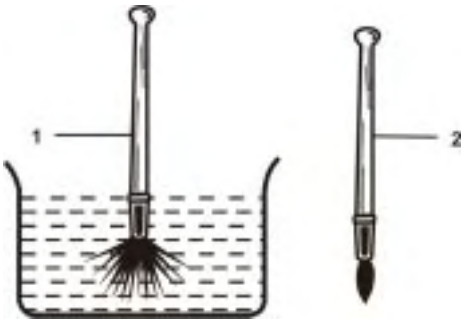


Fig. 1.19 Illustrations of Surface Tension

1. Brush in water 2. Brush takenout from water

membrane and surface tension always tends to minimise the surface area of a liquid.

4. Capillary rise :

A glass tube with a very fine uniform bore is called a capillary tube. When a capillary tube is dipped vertically into a liquid contained in beaker, the liquid immediately rises or falls in the tube.

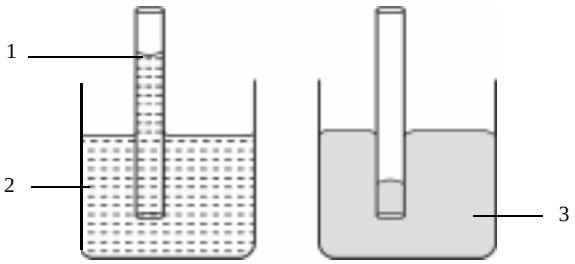


Fig. 1.20 Capillary rise

1. Capillary tube 2. Water 3. Mercury

The rise or fall of a liquid in a very narrow capillary tube is given by

$$h = \frac{2T \cos \theta}{r \rho g}$$

where T is the surface tension of the given liquid.

r is the radius of the capillary tube

ρ is the density of the liquid

g is acceleration due to gravity

θ is the angle of contact for the given pair of solid and liquid. The angle of contact is defined as the angle between the tangent to the liquid surface at the point of contact and the solid surface inside the liquid.

If the angle of contact is acute, the level of liquid inside the capillary tube is higher than that in the beaker. This capillary rise is observed in the case of water. If the angle of contact is obtuse, the level of liquid inside the tube is lower than that in the beaker. This capillary fall is observed in mercury ($\theta \approx 140^o$). For water in silver tube, $\theta = 90^o$ and $h = 0$. The level of liquid remains the same. For pure water and clear glass $\theta = 0^o$.

This phenomenon of rise or fall of liquid in a capillary tube is called capillarity and this capillarity is due to the property of surface tension of liquids.

Examples of capillary action

(1) The rise of sap in trees and plants.

(2) The rise of kerosene or oil in the wick of an oil lamp or stove

(3) The absorption of ink in a blotting paper.

(4) Sandy soil is drier than clay : The interspaces between the particles of the clay form finer capillaries and water rises to the surface quickly.

5. Applications of Surface Tension

(1) Capillary rise is responsible for rising of water in plants. In an oil lamp or stove the oil rises up the wick due to capillarity.

(2) The purpose of applying soap to clothes is to spread it over large area. When soap is dissolved in water the surface tension of water is lowered. Surface tension always opposes the spreading of a liquid. By reducing surface tension we facilitate the liquid to spread over larger surfaces. This is why soap is used for washing. For the same reason The paste spreads more freely in the mouth and facilitates cleaning of the mouth.

(3) When we pour oil on the surface of water it lowers the surface tension of water. Hence the mosquito breed sinks down and perishes.

(4) In voyage at the high seas, when there are violent waves the sailors pour tins of oil around their boats or ships. Due to oil the surface tension of sea water is reduced thereby the height of water waves is also reduced.

(5) A pen nib is split at the tip to provide the narrow capillary and the ink is drawn upto the tip continuously.

(6) When molten lead is allowed to fall through the end of a narrow tube, lead drops assume spherical shape due to surface tension. In factories lead shots are manufactured in this way. Rain drops assume spherical shape due to surface tension of water.

1.5 Viscosity

Activity : Take three beakers one containing water, the other honey and the third glycerine. When all are poured in a funnel water immediately starts flowing while honey

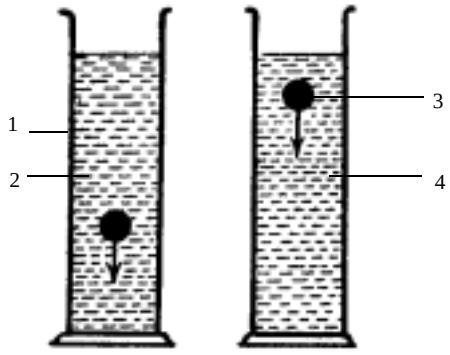


Fig. 1.21 Demonstration for Viscous force

1. Long cylinder 2. Water 3. Leadshot 4. Glycerine

and glycerine take more time to flow down. This shows that glycerine is more viscous than honey and honey is more viscous than water. A less viscous liquid is more mobile.

If we move our fingers through any liquid we experience a resistance. This shows that the liquid offers a frictional force. The resistance offered by fluids (liquids and gases) to relative motion between its different layers is called viscos force. This property is called viscosity.

The viscous forces are similar to frictional forces which resist relative motion between two bodies in contact.

Activity : Take two long cylinders, one filled with water while the other filled with glycerine. Take two identical lead shots and drop one in water and the other in glycerine at the same time. Observe that the lead shot dropped in water comes down more quickly and the leadshot in glycerine descends slowly.

This activity shows that the viscous force is more in the case of glycerine than that in the case of water.

1. Flow of liquid through a pipe :

Let us consider a liquid flowing through a pipe. There are two types of flow namely streamlined flow and tubulent flow. If all the particles of the liquid pass across a point with

Fig. 1.22 Flow of liquid through a pipe

1. Tube 2. Liquid

the same velocity, the flow is said to be stream lined. In this flow, a particle follows the same path throughout its motion. If the particles pass across a point with different velocities, the flow is turbulent. In this flow, a particle does not follow the same path throughout its motion.

When a liquid flows slowly and steadily through a pipe, the velocity of the layer of the liquid in contact with the walls of the pipe is zero. As we move towards the axis of the tube, the velocity of the layers gradually increases and reaches a maximum value along the axis of the tube. In the case of streamlined flow of a river, the velocity is maximum for water on the upper layer (surface) of river.

The velocity is minimum for water in the bottom most layer.

When two parallel layers of a liquid are moving with different velocities, they experience tangential forces which tend to retard the faster layer and accelerate the slower layer. These forces are (F) called viscous forces. Newton found that the viscous force is

(i) directly proportional to the common area (A) of the liquid layers in contact.

(ii) directly proportional to their relative velocity $(v_1 - v_2)$

(iii) inversely proportional to the distance (x) between them.

$$\text{(or) } F = \eta A \frac{(v_1 - v_2)}{x}$$

where η is a constant known as coefficient of viscosity of the liquid and $\frac{(v_1 - v_2)}{x}$ is called the velocity gradient.

The unit of coefficient of viscosity is **N s m^{-2} or Poise.** The values of coefficient of viscosity are different for different liquids.

Table 1.2. Coefficient of viscosity of some fluids

Fluid	η (poise)
Glycerine	13.4
Castor oil	9.86
Olive oil	0.84
Turpentine	0.015
Water	0.018
Mercury	0.0015
Honey	0.2
Blood	0.0027
Air	0.019×10^{-3}

2. Applications of viscous fluids in daily life

(1) The motion of falling raindrops is opposed by the viscous force offered by air. Hence the rain drops falls slowly.

(2) The viscosity of sea water makes the waves subside during a storm.

(3) The motion of objects in fluids depends upon the viscosity of the fluids. The viscous force of water or air opposes the motion of ships, cars, aeroplane etc., Hence their shapes are streamlined in order to minimise the viscous drag on them.

(4) Friction reduces the efficiency of a machine by converting mechanical energy into heat energy and causes much wear and tear of the moving parts. Friction is reduced by using lubricants. A lubricant is a substance used to reduce friction. The lubricant forms a thin layer between the two surfaces in contact. It also fills the depressions present in the surfaces of contact and reduces friction considerably. In light machinery, thin oils (e.g., clock oil) with low viscosity are used. In heavy and fast moving machinery solids or thick highly viscous oils (e.g., grease) are used. By adding long chain polymers with lubricating oil, its coefficient of viscosity is kept constant even at high temperatures.

A **good lubricant** should have the following **properties.**

(i) It should be able to spread and fill up the minute depressions in the surfaces.

(ii) It should be chemically inert and should not undergo any decomposition at high temperature.

(iii) It should be capable of conducting away the heat produced by friction.

(5) If the arteries and veins of human body contract and become hard, their diameters decrease. Hence the flow of blood is affected due to the viscosity of blood and the blood pressure increases. This affects the functioning of heart. When the temperature of human body increases during fever, the coefficient of viscosity of blood decreases. This increases the blood circulation and the normal heart functioning is maintained.

1.6 Bernoulli's theorem and its applications

Activity : When air is blown over the top of a sheet of paper, the paper rises in the

air stream. This happens because the pressure falls above the paper where the air is moving faster.

Activity : Place a table tennis ball in a funnel and hold it with the mouth sloping upwards. Blow as hard as you can through

Fig. 1.23 Activity for Bernoulli's principle

1. Funel 2. Ping pong ball

the spout. Observe that you cannot blow the ball out.

Activity : When two balloons are suspended side by side and air is blown up through the space between them. As the air flows through the narrow space between the balloons, the pressure falls. The atmospheric pressure from the sides brings the balls together.

From these activities it is observed that there is a relation between pressure and velocity of air.

Bernoulli's equation is a fundamental relation in fluid mechanics. It can be derived from the work-energy theorem. The

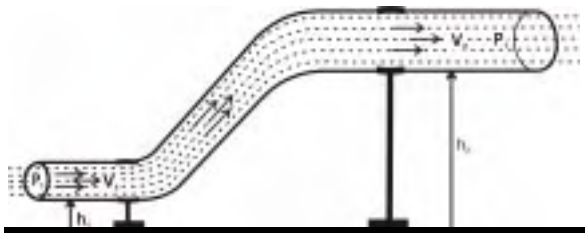


Fig. 1.24 Bernoulli's Theorem

A - Narrow bore B - Broad bore

work-energy theorem states that the work done by the resultant force acting on a system is equal to the change in kinetic energy of the system.

A liquid possesses kinetic energy by virtue of its motion. It has potential energy due to its position. Since a liquid is subjected to pressure it also possesses pressure energy.

Kinetic energy of the liquid

Let m be mass of the liquid and v be its velocity in motion. Then its kinetic energy $= \frac{1}{2}mv^2$

$\therefore$ kinetic energy per unit mass $= \frac{1}{2}v^2$

Potential energy of the liquid

Let h be the height of the liquid above the earth's surface. Then its potential energy $= mgh$

$\therefore$ potential energy per unit mass $= gh$

Pressure energy of the liquid

Let p be the hydrostatic pressure excerted by a liquid, ρ be its density and V be its volume. Then its pressure energy = PV

$$= P\left(\frac{m}{\rho}\right)$$

Pressure energy per unit mass $= \frac{P}{\rho}$

These three types of energies possessed by a liquid under flow are mutually convertible one into another.

1. Bernoulli's Theorem

The sum of the energies possessed by a flowing, non-viscous, incompressible liquid at any point throughout its flow is constant when the flow is streamlined. This is called Bernoulli's theorem.

$$\left.\begin{matrix}\text{Pressure}\\ \text{energy}\end{matrix}\right\} + \left.\begin{matrix}\text{Kinetic}\\ \text{energy}\end{matrix}\right\} + \left.\begin{matrix}\text{potential}\\ \text{energy}\end{matrix}\right\} = \text{a constant.}$$

For unit mass of a liquid flowing

$$\frac{p}{\rho} + \frac{1}{2}v^2 + gh = \text{constant}$$

This is called Bernoulli's equation.

In the case of a horizontal pipe h is constant,

$$\therefore \frac{P}{\rho} + \frac{v^2}{2} = \text{constant.}$$

The above equation shows that when the velocity of the fluid increases, the pressure of the fluid decreases and vice versa. This principle can be illustrated by the following demonstrations.

2. Demonstration of Bernoulli's principle

(1) **Magic ball :** A small ping pong ball is placed in a vertically upward stream of liquid. It is observed that the ball rises to a certain height above the nozzle and stays there against gravity. The ball continues to spin. The velocity of the liquid along the axis of the nozzle is high and hence the pressure is low. As

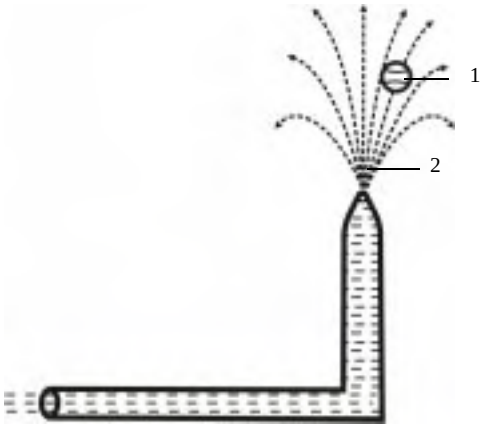


Fig. 1.25 Magic Ball

1. Ping-pong ball 2. Jet of water

the atmospheric pressure is greater than this pressure, it pushes the ball against the stream without falling down.

(2) A monometer is a U-tube containing a liquid. When both arms of a manometer are open to the atmosphere, the liquid level is the same in both arms.

When air is blown over one end of the manometer tube the pressure of air decreases and liquid level rises in that arm of the tube.

3. Applications of Bernoulli's theorem

(1) Bernoulli's principle is used in venturimeter to find the rate of flow of a liquid.

(2) It is used in pitot tube to find the velocity of a fluid in motion.

(3) It is used in a carburettor to mix air and petrol vapour in an internal combustion engine.

(4) Bernoulli's principle is used in an atomiser and filter pump.

(5) Wings of an aeroplane are made tapering as shown in fig. The upper surface is made convex and the lower surface is made concave. Due to this shape of the wing, the air currents at the top have a large velocity than at the bottom. Consequently the pressure above the surface of the wing is less as compared to the lower surface of the wing. This difference of pressure is helpful in giving a vertical lift to the plane.

4. Effects of Bernoulli's principle

(1) Due to strong wind, storm or cyclone, the roofs are blown off. When a strong wind blows over the roof, there is lowering of pressure on the roof. As the

Fig. 1.26 Blowing of roofs

pressure on the bottom side of the roof is higher, roofs are easily blown off without damaging the walls of the building.

(2) A suction effect is experienced by a person standing close to the platform at railway station when a fast train passes the person. This is because the fast moving air between the person and train produces a decrease in pressure and the excess air pressure on the other side pushes the person towards the train.

SOLVED PROBLEMS

(1) A truck of mass 1000 kg takes a round turn of radius 50 metre with a velocity of 15 ms^{-1}. Calculate the centripetal force required by the truck.

Mass of the truck, m = 1000 kg

Radius of circular path, r = 50 m

Velocity of the truck, v = 15 ms^{-1}

Centripetal force required, F = ?

Centripetal force required, $F = \frac{mv^2}{r}$

$$F = \frac{1000 \times 15 \times 15}{50}$$

$$= 100 \times 3 \times 15$$

$$F = 4500 \text{ N}$$

(2) A cyclist is running at a speed of 10 ms^{-1}. If the radius of each wheel of the bicycle be 45 cm, Calculate the angular velocity of the wheels.

Speed of the cyclist, v = 10 ms^{-1}

Radius of the wheel of the bicycle, r = 45 cm

$$= 45 \times 10^{-2} \text{ m}$$

Angular velocity, ω = ?

$$v = r\omega$$

$$\therefore \omega = \frac{v}{r}$$

$$= \frac{10}{45 \times 10^{-2}}$$

$$= \frac{1000}{45}$$

$$= 22.2 \text{ radian/second}$$

(3) A bullet fired from a gun with a velocity of 140 ms^{-1} strikes the ground at the same level as the gun. If the angle of inclination with the horizontal at which the bullet is fired is 15^o. Find the horizontal range.

Velocity of the bullet, v = 140 ms^{-1}

Angle of projection, $\theta = 15^o$

Horizontal range, R = ?

$$R = \frac{u^2 \sin 2\theta}{g}$$

$$= \frac{140 \times 140 \times \sin (2 \times 15)^o}{9.8}$$

$$= \frac{140 \times 140 \times \sin 30^o}{9.8}$$

$$= \frac{140 \times 140}{9.8} \times \frac{1}{2}$$

$$= 1000 \text{ m} = 1 \text{ Km}$$

SELF EVALUATION

Choose the correct answer

1. The relation between time of ascent and time of descent in the case of bodies moving under gravity is
   (1) time of ascent is more than the time of descent.
   (2) time of ascent is less than the time of descent.
   (3) time of ascent is equal to the time of descent.
   (4) time of ascent and time of descent will never be equal.

2. The force between a satellite and the earth which acts as a centripetal force keeping the satellite in orbit is
   (1) gravitational force (2) molecular force
   (3) cohesive force (4) adesive force

3. The centripetal force required for a car or a bicycle to go round a circular curve depends on
   (1) the angle of elevation of the curved track
   (2) speed of the vehicle only
   (3) the radius of curvature of the path only
   (4) speed and the radius of curvature of the curve

4. Kepler's first law of planetary motion is also called
   (1) law of periods (2) law of areas
   (3) law of orbits (4) law of distances

5. Rain drops assume sperical shape due to
   (1) surface tension (2) gravitational force
   (3) centripetal force (4) centrifugal force

Fill in the blanks

6. Automobiles are now streamlined in shape to ..... air resistance and improve fuel consumption.
7. ..... makes use of the centrifugal force for regulating the speed of an engine or machine.
8. Forces between molecules of different substances are called ..... forces.
9. Surface tension always tends to ..... the surface area of a liquid.

Answer briefly

10. On which factors does the air resistance on a falling body depend? Explain this with an example.
11. Why does a stone released from a moving train follow a parabolic path ?
12. What is time of flight of a projectile ?
13. Define the range of a projectile.
14. At what angle the range of the projectile is maximum ? Give examples where maximum ranges are considered.
15. What is uniform circular motion ?
16. Define angular velocity. Give its unit.
17. What is called the period of circular motion ?
18. Define centripetal force and centripetal acceleration.
19. Give any one of the practical applications of centripetal force.
20. What are called centrifuges ? Mention ay two of its uses.
21. State Kepler's laws of planetary motion.
22. Give the Newton's universal law of gravitation.
23. Define surface tension of a liquid.
24. What is called adhesive forces and cohesive forces ?
25. Give any two applications of surface tension in everyday life.
26. State any two applications of viscosity of fluids in daily life.
27. State any two properties of a good lubricant.
28. State Bernoulli's theorem and write Bernoulli's equation.
29. Mention any two applications of Bernoilli's theorem.
30. Is it safe for a person standing very close to the platform in a railway station when a fast train passes ? Explain.

Answer in detail

31. Derive equations for (i) time of flight and (ii) velocity on reaching the ground in the case of vertical projection.
32. Compare the motion of a freely falling body with that of a horizontally thrown projectile.
33. Derive the relation between linear velocity and angular velocity.
34. Write a note on (i) centripetal force and (ii) centrifugal force.
35. State and explain Kepler's laws of planetary motion.
36. Explain surface tension of a liquid on the basis of molecular theory.
37. Explain the applications of surface tension of liquids in everyday life.
38. Give the applications of viscous fluids in daily life.
39. What are lubricants ? Give examples. Mention the properties of a good lubricant.
40. Write a note on the energy possessed by a flowing liquid and explain Bernoulli's theorem.

Problems

41. If the tyre of a car has a diameter of 0.7 m and if the wheel has an angular velocity of 10 radians per second, what is the speed of the car ? [**Ans.** 3.5 ms^{-1}]
42. A scooter is running at a speed of 4 ms^{-1}. If the diameter of the scooter wheel be 40 cm. Calculate the angular velocity of the wheels. [**Ans.** 20 radians/second]
43. Calculate the centripetal force required by a car of mass 500 kg which takes a round turn of radius 50 metre with a velocity of 20 ms^{-1}. [**Ans.** 4,000 N]

2. HEAT

Heat is the most common form of energy. Heat can be transferred from one place to another by means of conduction, convection and radiation. It can be converted into other forms of energy. Sun is the main source of heat energy. Fuels such as wood, petrol, coal and gas are other sources of heat energy. For the survival of all living things, heat energy is essential. The temperature of a body is a measure of its hotness or coldness. It is a measure of the kinetic energy of the particles of the body. Change in temperature, change of state and thermal expansion in a body are some of the main observable physical effects of heat energy. Heat energy plays a major role in determining the climatic and weather conditions.

In this chapter, we shall study specific heat capacities of substances, the relation between mechanical and heat energies, thermal expansion, change of state, humidity of atmosphere and their applications in everyday life.

2.1 Specific heat capacity

Activity : Take three identical glass beakers and fill them with equal mass of water, kerosene and coconut oil. Note their initial temperatures. Using the same spirit lamp heat the three beakers one by one for five minutes. Observe that the rise in temperature is different for different liquids.

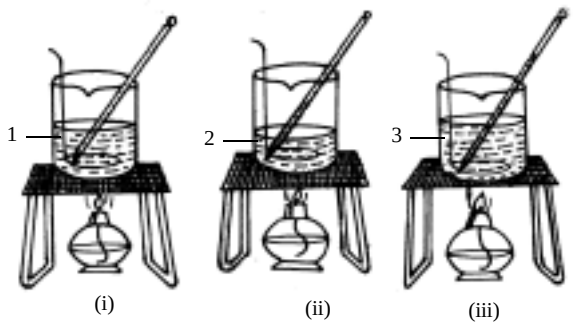


Fig. 2.1 Specific heat capacity of liquids.

1. Coconut oil 2. Water 3. Kerosene

Activity : Take four cylindrical blocks of aluminium, lead, copper and iron of equal mass having the same area of cross section. Suspend the cylindrical blocks fully inside boiling water. After few minutes, take out the blocks simultaneously and place them on a thick paraffin cake side by side. Observe that depths of sink is different for different materials.

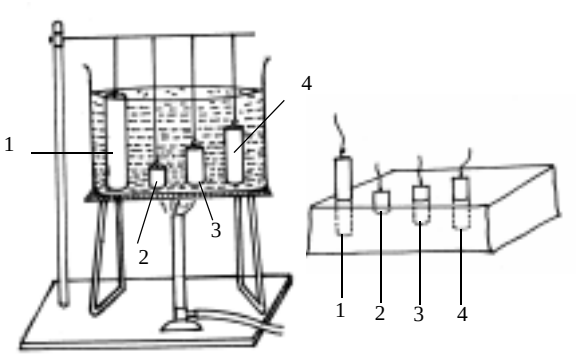


Fig. 2.2 Specific heat capacity of solids

1. Aluminium 2. Lead 3. Copper 4. Iron

Activity : Take a stone and water of same mass. Place them in the hot sun for about half an hour. Now touch the stone with one hand and water with the other hand. Observe that the stone is hotter than water.

From the above three activities, we can understand that heat capacities are different for different substances.

When a substance is heated, it absorbs heat energy and its temperature rises. The amount of heat energy absorbed by the substance (Q) is directly proportional to (i) mass of the substance (m) (ii) change in temperature (Δt)

$$Q = m s \Delta t$$

Where s is a constant called specific heat capacity of the substance and its value depends on the nature of the substance.

If m = 1 kg and Δt = 1 **K** then Q = s

The specific heat capacity of a substance is the amount of heat energy required to raise the temperature of 1 kg mass of the substance by 1 K. Its unit is J kg^{-1} K^{-1}. It is a measure of thermal inertia of a substance.

The heat capacity of a substance is defined as the amount of heat required to raise the temperature of the substance through 1 K.

Heat capacity = mass × specific heat capacity.

Its unit is J/K

Table 2.1 Specific heat capacities of some common substances.

Sl. No.	Substance	Specific heat capacity J kg^{-1} K^{-1}
1.	Lead	128
2.	Mercury	138
3.	Copper	386
4.	Aluminium	899
5.	Wood	1755
6.	Kerosene	2090
7.	Ice	2130
8.	Water	4180
9.	Paraffin Wax	2900

Among the liquids, the specific heat capacity is maximum for water and minimum for mercury. Hence water is used as a coolant in radiators of automobile engines and mercury is used as a thermometric liquid.

Problem : Calculate the amount of heat energy required to raise the temperature of 0.150 kg of iron from 283K to 533K. Specific heat capacity of iron is 480 J kg^{-1} K^{-1}.

Mass m = 0.150 kg

Specific heat capacity = 480 J kg^{-1} K^{-1}

Initial temperature = 283K

Final temperature = 533K

Change in temperature = 533 – 283

Δt = 250K

Heat absorbed Q = ?

$$Q = m\, s\, \Delta t$$

$$= 0.150 \times 480 \times 250$$

$$= 18{,}000 \text{ J}$$

Problem : How much heat must be added to raise the temperature of 100 g of water from 278K to 368K ? Specific heat capacity of water = 4180 J kg^{-1} K^{-1}.

Mass of water m = 100 g = 0.1 kg

Specific heat capacity s = 4180 J kg^{-1} K^{-1}

Initial temperature = 278K

Final temperature = 368K

Change in temperature Δt = 368–278 = 90K

Heat required Q = ?

$$Q = m\, s\, \Delta t$$

$$= 0.1 \times 4180 \times 90$$

$$= 37620 \text{ J}$$

Problem : 52 kJ of heat energy raises the temperature of 0.50 kg of gold through 800K. Calculate the specific heat capacity of gold.

Heat energy supplied Q = 52 kJ = 52,000 J

Mass of gold m = 0.50 kg

Change in temperature Δt = 800K

Specific heat capacity s = ?

$$Q = m\, s\, \Delta t$$

$$52{,}000 = 0.50 \times s \times 800$$

$$s = \frac{52{,}000}{0.5 \times 800}$$

$$= 130 \text{ J kg}^{-1} \text{ K}^{-1}$$

2.2 Method of mixtures

When two substances at different temperatures are mixed, heat flows from hot substance to cold substance, till both attain the same temperature. If no heat is received from or given to the surroundings and also if there

is no chemical action in the mixture. Then heat lost by the hot substance is equal to heat gained by the cold substance.

1. Determination of specific heat capacity of a solid

The mass of an empty copper calorimeter with stirrer of the same material is found out (m_1). Half of the calorimeter is filled with a liquid of known specific heat capacity (s_2) and the mass of the calorimeter with liquid is found out (m_2).

The calorimeter with its contents is placed in a wooden box filled by cotton and wool. The solid of unknown specific heat capacity (s_3) is heated in a sinclair heater till it reaches a steady state temperature (θ_2). The initial temperature of the liquid in the calorimeter is noted (θ_1). The hot solid is dropped into the calorimeter with simultaneous stirring. The final temperature of the mixture is noted (θ_3).

Calculation :

Mass of calorimeter = m_1

Mass of the liquid = $m_2 - m_1$

Mass of the solid = $m_3 - m_2$

Raise in temperature of calorimeter and liquid = $\theta_3 - \theta_1$

Specific heat capacity of calorimeter = s_1

Specific heat capacity of liquid = s_2

Specific heat capacity of solid = s_3

Fall in temperature of the solid = $\theta_2 - \theta_3$

Heat gained by the calorimeter = $m_1 s_1 (\theta_3 - \theta_1)$

Heat gained by the liquid = $(m_2 - m_1) s_2 (\theta_3 - \theta_1)$

Total heat gained
$= m_1 s_1 (\theta_3 - \theta_1) + (m_2 - m_1) s_2 (\theta_3 - \theta_1)$

Heat lost by the solid
$= (m_3 - m_2) s_3 (\theta_2 - \theta_3)$

According to the principle of method of mixtures Heat lost = Heat gained

$$(m_3 - m_2) s_3 (\theta_2 - \theta_3) = m_1 s_1 (\theta_3 - \theta_1) + (m_2 - m_1) s_2 (\theta_3 - \theta_1) \quad \ldots (1)$$

Rearranging,

$$s_3 = \frac{[m_1 s_1 + (m_2 - m_1) s_2] (\theta_3 - \theta_1)}{(m_3 - m_2) (\theta_2 - \theta_3)} \quad \ldots (2)$$

Using this formula the specific heat capacity of a given solid s_3 can be determined.

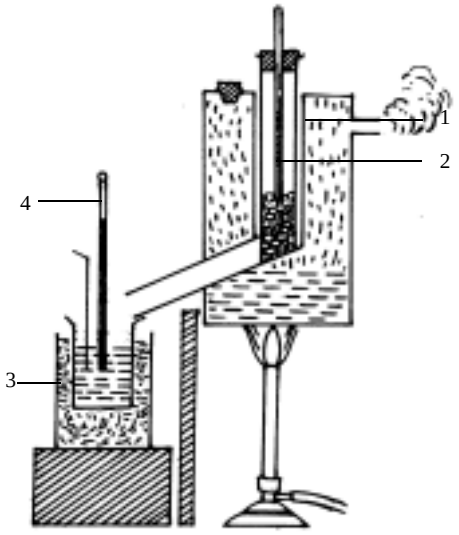


Fig. 2.3 Specific heat capacity of solids - method of mixtures.

1. Steam boiler 2. Solids 3. Calorimeter with liquid
4. Thermometer

The method of mixture can be used to determine the specific heat capacity of the given liquid, if the specific heat capacity of the solid (s_3) is known.

Rearranging equation (1)

The specific heat capacity of the given liquid can be determined

$$s_2 = \frac{(m_3 - m_2) s_3 (\theta_2 - \theta_3) - m_1 s_1 (\theta_3 - \theta_1)}{(m_2 - m_1) (\theta_3 - \theta_1)} \quad \ldots (3)$$

2. Precautions in calorimeter experiments :

(1) The calorimeter should be nickel coated and well polished in order to reduce heat loss by radiation.

(2) The calorimeter should be placed in a wooden box throughout the experiment to minimize the heat exchange with the surroundings through conduction and convection.

(3) The solid should be in the form of fine powder or of small bits so that its temperature is uniform.

(4) There should be no chemical action between the liquid taken in the calorimeter and hot solid added.

(5) A half degree thermometer should be used for better accuracy.

(6) The initial temperature of the liquid should be noted just before the hot solid is transferred to the calorimeter.

Problem : A brass rod of 0.4 kg mass at 373K is dropped into 0.7 kg of water at 293K. The final temperature is 296K. Calculate the specific heat of brass. Specific heat of water = 4180 $J\,kg^{-1}\,K^{-1}$

Mass of brass rod m_1 = 0.4 kg

Mass of water m_2 = 0.7 kg

Initial temperature = 293K

Final temperature = 296K

Specific heat capacity of water
= 4180 $J\,kg^{-1}\,K^{-1}$

Specific heat capacity of brass = ?

According to the principle of method of mixtures Heat lost = Heat gained

$$0.4 \times s_1 \times 77 = 0.7 \times 4180 \times 3$$

$$s_1 = \frac{0.7 \times 4180 \times 3}{0.4 \times 77}$$

$$= 285\ J\,kg^{-1}\,K^{-1}$$

2.3 Mechanical equivalent of heat

James Prescott Joule, a British physicist performed a series of experiments and concluded that there is an exact equivalence between the mechanical energy spent and heat produced.

If W is the amount of work done and H is the quantity of heat produced, then

$$W = JH\ ; \quad J = \frac{W}{H}$$

where J is a constant known as Joule's constant or mechanical equivalent of heat. The mechanical equivalent of heat (J) is defined as the amount of work done to produce a unit quantity of heat. The value of J is 4.186 Joule/cal. In S.I units W = H and therefore J = 1.

2.4 Thermal Expansion

The thermal expansion takes place in all states of matter. The gas expand more than liquids and liquids expand more than solids for the same amount of heat. Thermal expansion plays an important role in many engineering applications.

Activity : The bar B exactly fits into a gauge G at room temperature. Heat the bar and try to fit the bar into the gauge. Observe

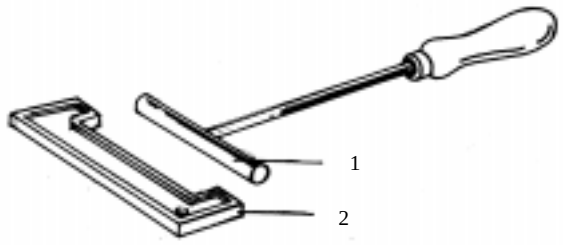


Fig. 2.4 Bar and gauge experiment

1. Bar 2. Gauge

that it no longer fits into the gauge. On cooling, the bar again fits into the gauge.

Activity : A metal ball can just pass through the ring at room temperature. Heat

the ball and place it on the ring. Observe that the ball does not pass through the ring.

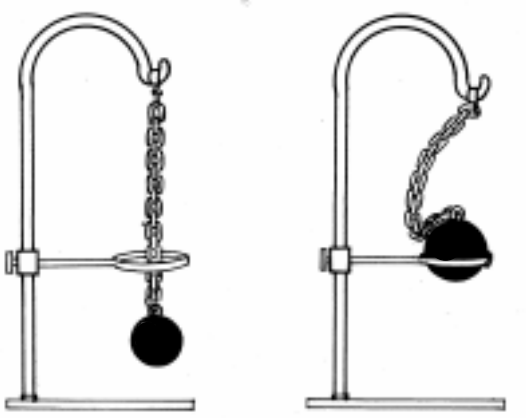


Fig. 2.5 Ball and ring experiment

From the above two activities we can understand that substances expand on heating and contract on cooling.

When an object is heated its molecules vibrate more violently because they have more kinetic energy. They also need more space around them. This causes the material to expand. Increase in length due to heating is called linear expansion. Increase in area as superficial expansion and that of volume as volume expansion or cubical expansion. The thermal expansion is different for different substances.

1. Linear expansion

Let a metal rod of length L_1 at a temperature t_1K be heated. Its length becomes L_2 at the temperature t_2K

then Linear expansion = $L_2 - L_1$

This linear expansion depend upon

(i) original length of the rod (L_1)

(ii) raise in temperature ($\Delta t = t_2 - t_1$)

$$L_2 - L_1 = \alpha\, L_1\, \Delta t$$

where α is constant of proportionality called the coefficient of linear expansion of material of the rod.

$$\alpha = \frac{L_2 - L_1}{L_1\, \Delta t}$$

$$\alpha = \frac{\text{increase in length}}{\text{original length} \times \text{rise in temperature}}$$

The coefficient of linear expansion of the material of the rod is defined as the ratio of its increase in length per degree rise in temperature to its initial length. In solids metals have high values of coefficient of linear expansion.

Table 2.2 Coefficient of Linear expansion of some common solids

S.No.	Substance	Coefficient of linear expansion $10^{-6}\ K^{-1}$
1.	Pyrex glass	3
2.	Soft glass	9
3.	Concrete	11
4.	Steel	11
5.	Iron	12
6.	Gold	14
7.	Copper	17
8.	Brass	19
9.	Silver	19
10.	Aluminium	26

2. Volume expansion

Suppose a body of volume V_1 at a temperature t_1K is heated and its volume becomes V_2 at the temperature t_2K.

The volume expansion = $V_2 - V_1$ and this volume expansion depends upon (i) original volume (V_1) (ii) rise in temperature ($\Delta t = t_2 - t_1$)

$$\therefore\ V_2 - V_1 = \gamma\, V_1\, \Delta t$$

where γ is constant of proportionality called coefficient of volume expansion whose value depends upon the material of the body.

$$\gamma = \frac{V_2 - V_1}{V_1 \times \Delta t}$$

$$\gamma = \frac{\text{increase in volume}}{\text{original volume} \times \text{rise in temperature}}$$

The coefficient of volume expansion of a solid is defined as the ratio of increase in volume per degree rise of temperature to its initial volume.

The coefficient of volume expansion of a solid is three times its coefficient of linear expansion, $\gamma = 3\alpha$

3. Advantages of thermal expansion of solids.

(1) If we find difficult to remove the stopper from a glass bottle, we can heat the neck of the bottle. Now the neck of the bottle expands and the stopper comes out easily.

(2) The principle of thermal expansion is used in fixing iron rim with the wooden wheel firmly.

(3) Rivets are used to hold steel plates together very tightly. A very hot rivet is pushed through the two plates and its end is hammered over. When the rivets cools down it pulls the two plates together very tightly.

(4) **The bimetallic strip :** A bimetallic strip consists of two different metals such as brass and iron joined together. At normal temperature the bimetallic strip is straight. As it is heated the brass expands more than the iron. So the brass forms the outside of a curve with the iron on the inside.

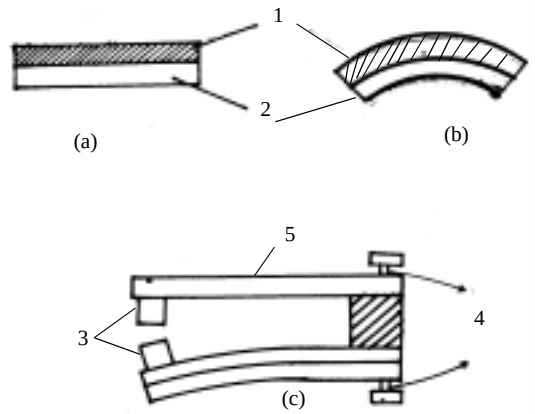


Fig. 2.6 Bimetallic strip (a) Cold (b) Hot (c) Bimetallic strip switch

1. brass 2. iron 3. switch contacts 4. to heater 5. copper strip

A bimetallic strip can be used in a thermostat to break an electrical circuit. A thermostat is used to maintain a steady temperature in a system. As the temperature increases the strip bends and breaks electrical contact in the heater circuit. When the temperature decreases, the bimetallic strip returns to its original position and shape. Thus contact is restored.

4. Disadvantages of thermal expansion

(1) Changing of shape and dimensions of objects such as doors, (2) Wall collapsing due to bulging, (3) Cracking of glass tumbler due to heating and (4) Bursting of metal pipes carrying hot water or steam are some of the disadvantages of thermal expansion of matter.

Effects of thermal expansion in daily life

(1) **Railway lines :** Rails are made of steel which expands on heating and contracts on cooling. A gap is left between two ends of the rails at the joint. If no gaps are left, due to expansion in summer the rails get distorted causing derailment.

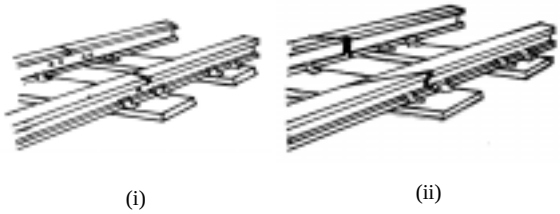


Fig. 2.7. Railway lines

1. Gap 2. Wedge - shaped gap

For the same reason, gaps are left in the concrete slabs of bridges and Highways.

(2) The period of oscillation of a pendulum in a clock depends on its length. When the temperature changes, the length also

changes. Hence the clock loses time in summer and gains it in winter. This can be compensated by using a bimetallic pendulum against the effect of thermal expansion.

(3) To avoid bursting of soft drink bottles containing gas, due to thermal expansion, their walls are made very thick.

Problem : A brass rod measures 52.2 cm at 289.6K and 52.28 cm at 368.5K. Calculate the coefficient of linear expansion of brass.

Initial length of rod L_1 = 52.2 cm

Final length of rod L_2 = 52.28 cm

Initial temperature t_1 = 289.6 K

Final temperature t_2 = 368.5 K

The coefficient of linear expansion α = ?

$$\alpha = \frac{L_2 - L_1}{L_1 \times \Delta t}$$

$$= \frac{52.28 - 52.20}{52.2 \times (368.5 - 289.6)}$$

$$= \frac{0.08}{52.2 \times 78.9}$$

$$= 1.94 \times 10^{-5}\ K^{-1}$$

2.5 Change of state

Matter exists in three states viz., solid, liquid and gas. The change from one state to another can be brought about by the application

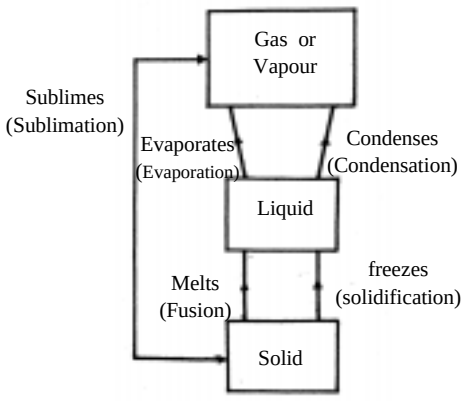


Fig. 2.8 Change of states

or withdrawal of heat. The water can be in the form of solid ice or liquid water or gaseous steam. The process in which a solid changes into liquid on heating is called melting. For example, ice changes into water. The change of a liquid into a solid on cooling is known as freezing. The process in which a liquid changes into vapour on heating is called vapourisation. e.g., water changes into water vapour or steam.

Some materials may change directly from a solid to a gas. This is called sublimation. Solid carbon dioxide changes to carbon dioxide gas as it warms up. Another substance which sublimes is Iodine. When vapour condenses to form a liquid the change of state is called condensation. Steam changes to water as it condenses.

1. Latent heat

The latent heat of a substance is defined as the amount of heat absorbed by a unit mass of the substance to change its state without change of temperature.

The heat absorbed during the change of state of a substance is used to overcome the force of attraction between the molecules of a substance. The kinetic energy of the molecules does not increase and hence there is no raise in temperature during the change of state of the substance.

2. Cooling due to evaporation

Activity : Put a little ether or petrol at the back of your hand and wave it around. The spirit evaporates rapidly and your hand feels very cold. The sprit takes the heat of vapourisation from our hand. The hand loses heat and gets cooled. Similarly, water vapourising from the leaves of the trees cools the surrounding air.

A liquid evaporates when it changes into gas. Evaporation occurs at the surface of a liquid. During evaporation, only high energy molecules overcome the attraction of their neighbouring molecules and leave the liquid. In this way, the liquid loses its most energetic molecules, while the less energetic molecules are left behind. The average kinetic energy of

the remaining molecules is therefore, reduced. This results in a fall of temperature of the liquid which gets cooled. The rate of evaporation of a liquid depends on its surface area, temperature and the amount of vapour already present in the surrounding air.

On a rainy day, wet clothes take longer time to dry, because large amount of vapour already present in the air, slows down the evaporation. Similarly, during high fever, a cloth soaked in cold water is kept on the forehead the water evaporates rapidly and takes heat from the head and the body.

3. Cooling effects of evaporation

(1) Dogs keep their tongue usually out in summer. Water evaporates from the tongue and keeps it cool.

(2) Water in an earthen pot remains cool in summer. Water comes out of the pores of the vessel and evaporates. Therefore water remains cool in an earthen vessel by evaporation.

(3) Evaporation of sweat or perspiration from our skin causes a cooling effect.

4. Change of state - ice

A test tube is taken with clean water and a thermometer is placed in the test tube. The test tube is placd in a freezing mixture bath. The water level in the test tube is well below the level of the freezing mixture. While stirring water slightly and carefully, the thermometer readings for every 30 seconds are recorded till the temperature falls a few degrees below 0^{o} C. A graph is drawn by taking time along the X-axis and temperature long the Y axis.

The portion AB represents the liquid state. At B the change of state takes place from liquid to ice at 0^{o} C. At C entire liquid is changed to ice. Here during the change of state the temperature remains constant. Below C it is in the solid state (ice). The flat portion of the graph represents the time during which the water solidifies.

Here both solid and liquid states exist together. This is the melting or freezing point. During this time heat continues to be lost from

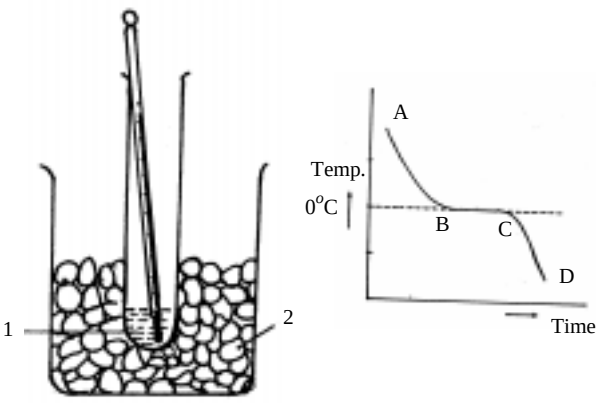


Fig. 2.9 Fusion of ice

1. Water 2. freezing mixture

the substance as it changes from liquid to solid but there is no fall in temperature. When water changes into solid, its volume increases. When a substance melts, heat is gained. When it freezes, heat is lost.

5. Change of state - wax

A test tube with sufficient quantity of wax is taken and thermometer is placed in the test tube through a cork. It is then placed in a beaker containing water. Water is heated

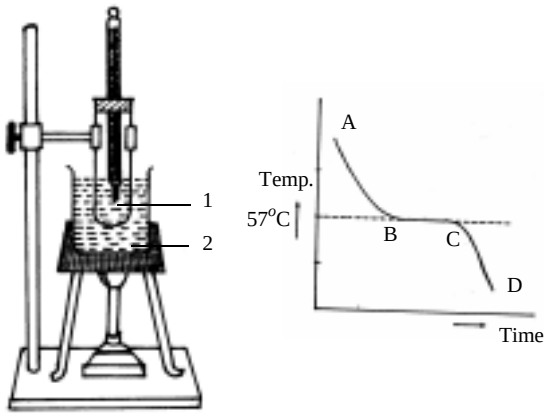


Fig. 2.10 Fusion of wax

1. Wax 2. Water

till the wax in the test tube melts and gets converted completely into the liquid state. Heating is stopped and wax is allowed to cool. The temperature of wax is noted for every

one minute till the temperature of wax is about 30^{o} C.

A graph is plotted between time along the X-axis and temperature along the Y axis. In the graph the portion AB shows the wax in the liquid state and below C it is in solid state.

The temperature corresponding to the horizontal line in the graph gives the melting point of wax. At this temperature the liquid wax is converted into solid without change of temperature. The melting point of wax is 57^{o} C. When the liquid wax changes into a solid, its volume decreases.

6. The refrigerator

When a liquid evaporates it takes in heat energy and cools its surroundings. When the gas condenses back to a liquid, the latent heat is released. This is used to take heat from inside a fridge, and release it outside.

A liquid which evaporates easily is called volatile liquid. Freon is a volatile liquid used in most fridges. The liquid evaporates in the coils around the ice box or cold plate inside the fridge. This causes cooling. The freon gas

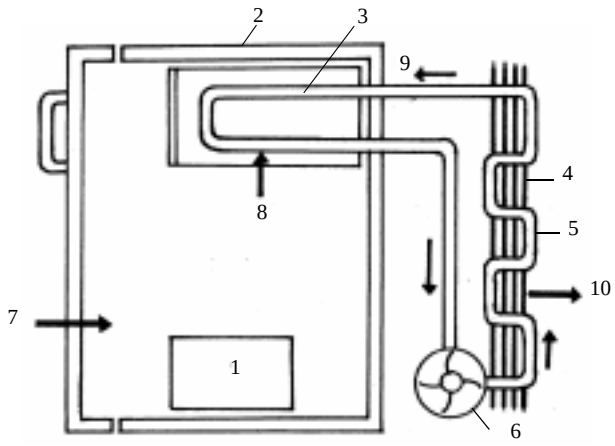


Fig. 2.11 Refrigerator

1. food 2. insulation 3. evaporator pipes 4. metal cooling fins 5. condenser pipes 6. compressor pump 7. heat in 8. heat 9. liquid 10. heat out

formed is pumped away and pressurised in the condenser on the back of the fridge. Here the freon gas condenses back into liquid. As it condenses it releases the heat energy it has taken in. So heat energy has been taken from food and other things inside the fridge and released outside it. If we leave the fridge door open, the pump has to work hard and more heat will be released into the kitchen which will eventually become hotter.

7. Freezing mixtures

A mixture of compounds that produces a low temperature is called freezing mixture. A freezing mixture consists of powdered ice, common salt and ammonium nitrate. Temperature lower than 0^{o} C can be produced by mixing certain salts with ice. When salt is mixed with ice, some ice melts taking heat from the salt. The temperature of the mixture decreases. Now salt gets dissolved in the water formed. The necessary heat for this is extracted from the mixture itself and consequently the temperature of mixture falls below zero. With the freezing mixture of salt and ice in the ratio 1 : 3, temperatures as low as -13^{o} C can be obtained.

Table 2.3 The temperatures of some freezing mixtures.

S. No.	Salt	Amount of salt in 100 g of mixture	Lowest temperature (^{o}C)
1.	$MgSO_4$	19	–3.9
2.	KCl	19.7	–11.1
3.	NH_4Cl	18.6	–15.8
4.	NaCl	22.4	–21.2
5.	$CaCl_2$	29.8	–55
6.	KOH	31.5	–65

2.6 Latent heat of fusion

The latent heat of fusion of a substance is the quantity of heat required to convert unit mass of the solid at its melting point to the liquid state at the same temperature. The S.I unit of Latent heat is J kg^{-1}.

Table 2.4 Latent heat of fusion and melting point of some common substances

No.	Substance	Latent heat fusion $\times 10^5$(J kg^{-1})	Melting point (^{o} C)
1.	Ice	3.34	0
2.	Napthalene	1.46	80
3.	Lead	0.25	327
4.	Silver	0.92	961
5.	Zinc	1.13	420
6.	Copper	1.8	1083
7.	Aluminium	3.21	658
8.	Paraffin wax	1.8	57
9.	Bismuth	0.5	269

Ice at 0^o C is more effective in cooling a substance than water at 0^o C. This is due to the fact that for melting at 0^o C each kilogram of ice takes its latent heat of 3.34×10^5 J from the substance and hence cools the substance more effectively. On the other hand water at 0^o C cannot take latent heat from the substance. This concept is valid for most of the liquids and their solids.

1. Determination of the Latent heat of fusion of ice.

A clean, dry and empty calorimeter with stirrer is weighed (m_1). Some water in a beaker is heated to a temperature of about 10^o C above the room temperature and half of the calorimeter is filled with this hot water. The calorimeter with hot water and stirrer is weighed (m_2). The calorimeter with its contents is placed in a wooden box and the temperature of water is noted (t_1). Dry pieces of ice are added gradually into the calorimeter till the temperature of water is about 4 to 5^o C lower than the room temperature. The final temperature is noted (t_2) and the final mass of the calorimeter with is contents is found out (m_3).

Let s_1 and s_2 be the specific heat capacity of the material of calorimeter and water respectively. The temperature of ice = 0^o C. Let the Latent heat of ice be L.

$\therefore$ Total heat lost by calorimeter and water
$= m_1 s_1 (t_1 - t_2) + (m_2 - m_1)s_2 \ (t_1 - t_2)$ ... (1)

Total heat gained by the
ice $= (m_3 - m_2)$ L + $(m_3 - m_2)\ s_2\ t_2$ ... (2)

According to the principle of method of mixtures Heat gained = Heat lost

$\therefore \ (m_3 - m_2)$ L + $(m_3 - m_2)\ (s_2)\ t_2$

$= m_1 s_1 \ (t_1 - t_2) + (m_2 - m_1) \ (t_1 - t_2)$

the latent heat of fusion of ice can be determined using the formula

$$L = \frac{[m_1 s_1 + (m_2 - m_1)s_2](t_1 - t_2) - (m_3 - m_2)\ s_2 t_2}{(m_3 - m_2)}$$

Problem : Calculate the amount of heat required to convert 500 g of ice into water without change of temperature. Latent heat of ice = 3.34×10^5 J/kg

Mass of ice = 500 g = 0.5 kg

Latent heat of ice L = 3.34×10^5 J/kg
Amount of heat energy required Q = ?

$Q = m \times L$
$Q = 0.5 \times 3.34 \times 10^5$
$= 1.67 \times 10^5$ J

2. Latent heat of vapourisation :

Latent heat of vapourisation of a liquid is the amount of heat required to convert unit mass of a liquid at its normal boiling point into vapour at the same temperature.

Table 2.5 Latent heat of vapourisation and boiling point of some common substances

S.No.	Substance	Latent heat of vapourisation (J kg^{-1})	Boiling point (^{o} C)
1.	Water	2.26×10^6	100
2.	Alcohol	8.5×10^5	78.5
3.	Ether	3.9×10^5	34.5
4.	Mercury	2.96×10^5	357
5.	Turpentine	2.93×10^5	159
6.	Chloroform	2.45×10^5	61.2

The burns caused by steam are much more severe than those caused by boiling water though both of them are at the same temperature of 100^o C. This is due to the fact that steam contains more heat in the form of latent heat (2.26×10^6 J/kg) than boiling water.

From tables 2.4 and 2.5 we find that the latent heats of fusion is maximum for ice and latent heat is maximum for steam. Hence steam and ice can be considered to be the best source and sink of heat respectively in a heat engine.

3. Determination of Latent heat of vapourisation of water

A clean, dry calorimeter is weighed with stirrer (m_1). Half of the calorimeter is filled with water and weighed again (m_2). The initial temperature of the water is noted (t_1). Now steam is passed through the delivery tube into the calorimeter and water is stirred continuously. When the temperature of water raises to about 10^o C, the delivery tube is taken out carefully. The final temperature of the mixture is noted (t_2). Now the calorimeter with its contents is weighed (m_3).

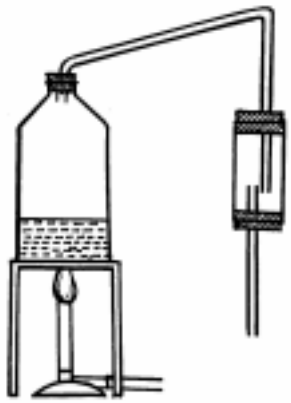


Fig. 2.12 Latent heat of Vapourisation

The temperature of steam = 100^o C

Specific heat capacity of the calorimeter and stirrer = s_1

Specific heat capacity of water = s_2

Latent heat of vapourisation of water = L

Total heat gained by calorimeter and water

$$= [m_1 s_1 + (m_2 - m_1) s_2] (t_2 - t_1) \ldots (1)$$

Heat lost by the steam in condensing to water at 100^o C = $(m_3 - m_2)$ L

Heat lost by condensed steam in lowering its temperature by t_2^o C

$$= (m_3 - m_2) s_2 (100 - t_2)$$

Total heat lost

$$= (m_3 - m_2)\text{L} + (m_3 - m_2) s_2 (100 - t_2) \ldots (2)$$

According to the principle of method of mixtures, Heat lost = Heat gained

$$(m_3 - m_2)\ \text{L} + (m_3 - m_2) s_2 (100 - t_2) = m_1 s_1 (t_2 - t_1) + (m_2 - m_1) s_2 (t_2 - t_1)$$

The latent heat of vapourisation of water can be determined using the formula

$$\text{L} = \frac{[m_1 s_1 + (m_2 - m_1) s_2](t_2 - t_1) - (m_3 - m_2) s_2 (100 - t_2)}{(m_3 - m_2)}$$

Problem : 0.40 kg of water at 373K changes into steam at the same temperature. Calculate the amount of heat energy required to do so. Latent heat of steam = 2.26×10^6 J/kg

Mass of water = 0.40 kg

Temperature = 373K

Latent heat of steam = 2.26×10^6 J/kg

Heat energy required, $Q = m \times \text{L}$

$= 0.4 \times 2.26 \times 10^6$

$= 0.904 \times 10^6$

$Q = 904$ kJ

2.7 Variation of melting point and boiling point with pressure and impurities

Activity : Take two pieces of ice. Apply pressure and release them. Observe that the two pieces freeze together.

The melting point of a substance can be lowered by applying pressure.

1. Effect of pressure on melting point of ice : Regelation experiment.

A slab of ice is taken and a metal wire is put over it. Two equal weights (5 kg) are fixed to its ends. The wire passes through ice slab due to the load applied to it. Just below the wire, ice melts at a lower temperature due

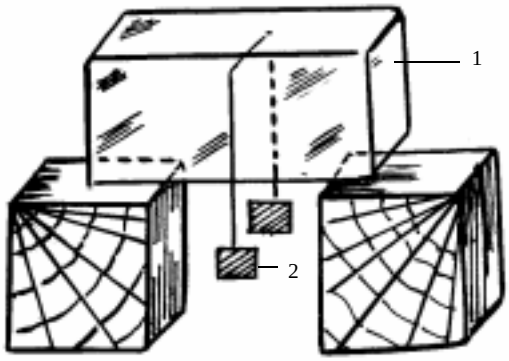


Fig. 2.13 Regelation experiment

1. Ice bar 2. Weight

to increase in pressure. When the wire has passed, the water above the wire freezes again. Thus the wire passes through the slab and the slab doesnot split. This phenomenon of refreezing is called regelation.

If a substance contracts on melting, as in the case of ice., its melting point is lowered by an increase of pressure. If a substance expands on melting, as in the case of a paraffin wax, its melting point is raised by an increase of pressure.

2. Ice - Skating

As the edges of the skates are fine, the pressure applied on ice is sufficient to melt it. Water thus formed due to melting acts as a lubricant and enables the skates to move freely over ice. Due to regelation the water formed is again converted into ice. Thus free motion of skates with good grip is achieved. The same explanation holds good for sledges and snow balls.

3. Variation of boiling point and melting point with impurities

Activity : Put some salt or other impurity into a beaker of water and heat it untill it boils. Measure the boiling point and observe that it is above 100^o C. It shows that the boiling point of liquid is raised by adding impurities.

Activity : Take some pieces of ice in a beaker and sprinkle some salt on the ice. Stir until the ice melts and measure its temperature. Observe that it is less than 0^o C. The presence of impurity lowers the melting point.

4. Effect of pressure on boiling point

Experiment : A round bottomed flask is filled with water. The water is boiled for 2 to 3 minutes. The steam produced will drive out the air from the flask. Heating is stopped and the mouth of the flask is tightly closed with a rubber cork. Invert the flask and pour cold water over it. The pressure inside the flask decreases due to condensation of steam. Observe that water continues to boil. This experiment shows that the boiling point of water is lowered under reduced pressure. Hence the boiling point of a liquid increases with increase of pressure.

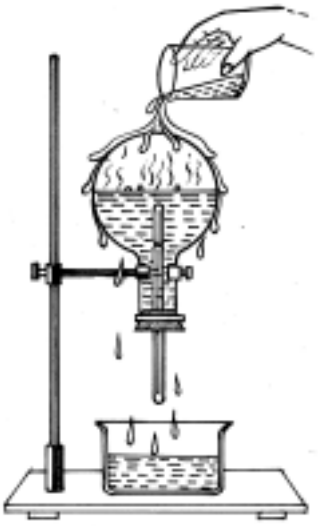


Fig. 2.14. Effect of pressure on boiling point

The atmospheric pressure is less on the top of a mountain and therefore water boils at a lower temperature. This temperature is too low to cook food properly. It means that a longer time is required for cooking in hill stations. The time required for cooking vegetables and other foods can be greatly

reduced if the boiling point of water is raised. This can be done by the use of a pressure cooker.

5. Pressure cooker

Pressure cookers are based on the principle that the boiling point of liquid increases with increase in pressure. A pressure cooker consists of a strong vessel of an aluminium alloy or stainless steel sealed so tightly that steam can be confined inside it with a pressure of about 2 atmospheres. The boiling point of water at this pressure will be

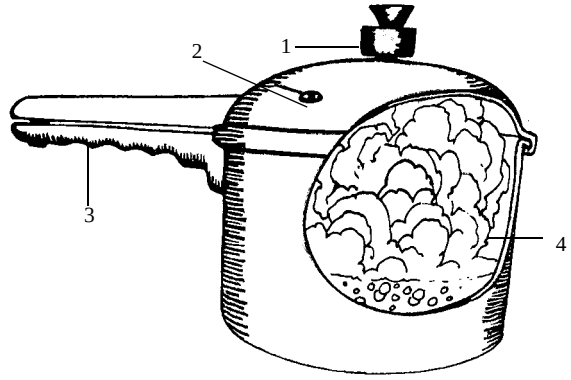


Fig. 2.15. Pressure cooker

1. Pressure valve 2. Safety valve 3. Handle 4. Steam

about 120^{o} C. When foods are cooked under these conditions there is a considerable saving of fuel and time. Since the cooking time is reduced the food value (vitamins and minerals) is retained better. Any possible oxidation of food material is also prevented because cooking takes place in an atmosphere of steam instead of air. The pressure cooker solves cooking problems at high altitudes also.

2.8 Humidity and Relative humidity

Humidity is the amount of water vapour present in atmosphere. The amount of water vapour in atmosphere changes with time and weather. The air containing water vapour is called humid air. The amount of vapour present per unit volume of air is called the humidity of air. Humidity is generally measured in kg/m^3. The knowledge of humidity helps us to predict weather.

When the amount of water vapour in the air is small, the air appears to be dry and the humidity is low. When the amount of water vapour in the air is large, the air appears to be wet and the humidity is high. The degree of wetness of air is expressed in terms of its relative humidity.

The ratio of the mass of water vapour actually present in certain volume of air (m) to the mass of water vapour (M) required to saturate the same volume of air at the same temperature is called relative humidity (R.H)

$$\text{Relative humidity} = \frac{m}{\text{M}} \times 100\%$$

If the air contains the maximum amount of water vapour its R.H is 100%. In such a case, water on earth cannot evaporate at all. If the relative humidity is less than 100% but still high, the rate of evaporation will be slow and the clothes do not dry up easily in such weather.

Table 2.6 Variation of amount of water vapour in air with temperature

S.No.	Temperature of air (^{o}C)	Mass of water vapour [cubic metre of air]
1.	10	9.3
2.	15	12.7
3.	20	17.1
4.	25	22.8
5.	30	30.9
6.	35	39.2
7.	40	51.0
8.	50	60.0

The relative humidity varies from season to season. During rainy season, as the amount of water vapours in air increases, the relative humidity becomes more (R.H = 100%) More R.H is a permanent feature of coastal areas. Due to more R.H perspiration from our body does not evaporate and we feel sultry.

SELF EVALUATION

Choose the correct answer

1. The unit of specific heat capacity is .....

   (1) $J\,kg^{-1}\,K^{-1}$ (2) $kg^{-1}\,K^{-1}$
   (3) JK^{-1} (4) $J\,kg^{-1}$

2. As compared to boiling evaporation is a

   (1) slow and calm process
   (2) slow and noisy process
   (3) rapid and calm process
   (4) rapid and noisy process

3. Latent heat of ice has value .....

   (1) 80 J/kg (2) 3.34×10^5 J/kg
   (3) 22.57×10^5 J/kg (4) 540 J/kg

4. When a liquid evaporates, its temperature .....

   (1) rises (2) falls
   (3) does not change
   (4) may rise or fall depending upon the situation

5. When water solidifies to ice

   (1) heat is absorbed
   (2) heat is released
   (3) temperature increases
   (4) temperature decreases

6. Evaporation occurs at .....

   (1) the surface of the liquid
   (2) the bottom of the liquid
   (3) the middle of the liquid
   (4) both at surface and bottom of a liquid

7. In a rainy day, the relative humidity is

   (1) 70% (2) 0%
   (3) 50% (4) 100%

8. The boiling point of water inside the pressure cooker is .....

   (1) 100^o C (2) 0^o C
   (3) 120^o C (4) -120^o C

9. The volatile liquid used in refrigerator is

   (1) freon (2) water
   (3) helium (4) acetone

10. Total amount of heat required to melt the solid .....

    (1) $H = ms\,\theta$ (2) $H = ms$
    (3) $H = m\,L$ (4) $H = m\,\theta$

Fill in the blanks

11. The specific heat capacity of water is .....

12. When an impurity is added to ice, the melting point of ice .....

13. In the case of wax, the application of pressure ..... the melting point.

14. Among the solids ..... have high values of coefficient of linear expansion.

15. The pressure of steam inside the pressure cooker is about .....

16. The process of changing a solid into gas directly is called .....

Answer Briefly

17. Define specific heat capacity of a substance.

18. Define heat capacity of a substance.

19. Mercury is used as a thermometric liquid. Why ?

20. Water is preferred as a coolant. Why ?

21. State the principle of method of mixtures.

22. Mention any two precautions in calorimeter experiments.

23. Define mechanical equivalent of heat.

24. What is the relation between mechanical energy and heat energy ?

25. Why do substances expand on heating ?

26. Define coefficient of linear expansion of a material rod.

27. On what factors does the linear expansion depend ?

28. Define coefficient of volume expansion of a solid.

29. Why gaps are left in bridges, railway lines and concrete highways ?

30. What is a bimetallic strip ?

31. The soft drink bottles are made of thick walls. Why ?

32. Define Latent heat of fusion.

33. Which produces severe burns - boiling water or steam ? Explain.

34. Why is ice at 0^{o} C more effective in cooling than water at 0^{o} C ?

35. Define Latent heat of vapourisation.

36. Explain the principle of ice skating.

37. Why cooking takes longer time in hill stations?

38. Define humidity and give its unit.

39. Define Relative humidity.

40. Why do we feel sultry in rainy days and in coastal areas ?

41. Define melting and freezing.

42. Define vapourisation and condensation.

43. Define sublimation.

44. On what factors does the evaporation of a liquid depend ?

45. On a rainy day, wet clothes take longer time to dry. Why ?

46. During high fever a wet cloth soaked in water is kept on the forehead. Why ?

47. State the principle of a refrigerator.

48. What is a freezing mixture. Give example.

Answer in detail

49. Explain the method of determination of specific heat capacity of a solid.

50. Explain the method of determination of specific heat capacity of a liquid.

51. Explain linear expansion and volume expansion of solids.

52. Describe a method to determine the latent heat of fusion of ice.

53. Explain the method of determination of latent heat of steam.

54. Explain variation of melting point with pressure and impurities.

55. Explain variation of boiling point with pressure and impurities.

56. Explain the change of states of ice and wax using time-temperature graph. Comment on the results.

Problems

57. How much heat is required to raise the temperature of 150 g of copper from 293K to 295K. [**Ans.** 115.5 J]

58. The coefficient of linear expansion of copper is 16×10^{-6} K^{-1}. Calculate the increase in length of a copper wire 5 cm long, when heated through 274K. [**Ans.** 2.19 cm]

59. How much heat is required to convert 1 kg of ice at 0^{o} C to water at 0^{o} C ?

[**Ans.** 3.34×10^{5} J]

60. Calculate the amount of heat energy required to convert 0.175 kg of ice at 273K to steam at 373K [**Ans.** 527.2 kJ]

3. LIGHT

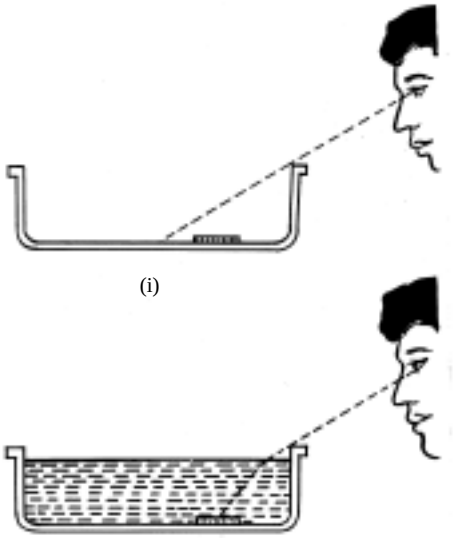
Without light from the sun, all life on earth would come to an end. Green plants use sunlight to make food through photosynthesis and store the food with themselves. Men and all animals depend on plants for food. Hence sun is the primary source of energy. Light is a form of an energy that causes the sensation of vision. It is an important tool by which we can explore the colourful beauty of nature. Many fascinating and wonderful phenomena in nature such as the blue of the sky, the rainbow, the twinkling of stars and the sparkling of diamonds etc., can be studied through light. In this chapter we shall study refraction of light through prisms and lenses. The principles and working of some optical instruments like camera, microscope, and telescope are also discussed.

3.1 Refraction of light

Activity : Place a pencil in a beaker containing water. Observe that the pencil appears to be bent at the point where it just enters water.

Fig. 3.1 A pencil placed in a beaker

Activity : Put a coin in the bottom of an empty cup and position your head so that the coin is just off sight. How can you bring it into view without moving your head or the cup ? Pour water in the cup and observe that the coin appears raised.



(i)

(ii)

Fig. 3.2 Coin appears raised
(i) Coin invisible (ii) Coin visible

1. Refraction of light through glass slab

Fix a sheet of white paper on a drawing board and place a rectangular glass slab on it. Mark its boundary ABCD. Draw a normal NM on AB at O. Draw OX and fix two pins P and Q on OX. Viewing through the opposite side of the slab locate the images of the pins P and Q. Fix two pins R and S such that these pins are exactly in a straight line with the images of P and Q. Mark the positions of the pins. Remove the pins and slab. Join R and S and extend this line to meet CD at O′. Draw normal N′M′ to CD at O′. Join OO′. Observe that the path of the ray XOO′Y bends at O towards NM and at O′ away from N′M′. The ray of light bends at the boundaries of air and glass medium.

The phenomenon of bending of light as it passes from one medium to another is known as the refraction of light. (Refraction is a latin word which means fracture or broken).

The angle between incident ray and the normal is the angle of incidence. $i_1 = \angle XON$.

The angle between the refracted ray and the normal is the angle of refraction.

$r_1 = \angle MOO'$, $r_2 = \angle N'O'O$

The angle of emergence, $i_2 = \angle M'O'Y$.

Extend XO to E, which is the direction of original ray. Observe that the incident ray (XOE) is parallel to the emergent ray (O′Y).

Although the direction of the light is

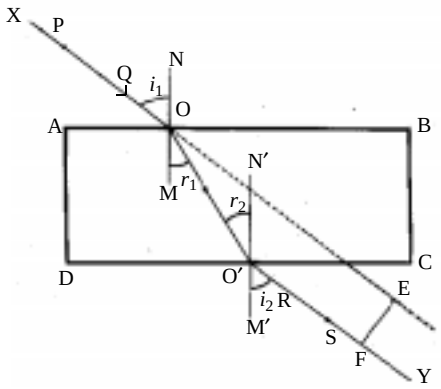


Fig. 3.3 Refraction of light through glass slab

not altered when it pasess through a parallel sided block, it is displaced side ways. This displacement is known as lateral displacement (EF). Measure the angles i_1, r_1, i_2 and r_2. It is found that $i_1 = i_2$ and $r_1 = r_2$. Repeat the experiment for different angles of incidences and tabulate the corresponding angles of refraction and emergence. It is found that the ratio $\frac{\sin i}{\sin r}$ is a constant.

Table 3.1 : Refractive index of material of the slab.

S. No.	i_1	r_1	i_2	r_2	$_1\mu_2 = \frac{\sin i_1}{\sin r_1}$	$_1\mu_2 = \frac{\sin i_2}{\sin r_2}$

Laws refraction

(i) The incident ray, refracted ray, and the normal to the surfaces of separation at the point of incidence, all lie in the same plane.

(ii) In 1612 Snell established a relation that the ratio of the sine of angle of incidence to the sine of angle of refraction is a constant for any two given media. This law is known as Snell's law of refraction.

$$\sin i \propto \sin r$$
$$\sin i = {}_1\mu_2 \sin r$$
$$\frac{\sin i}{\sin r} = {}_1\mu_2 = \text{a constant}$$

The constant ${}_1\mu_2$ is called the refractive index of the second medium with respect to first medium. It is a dimensionless quantity. The refractive index of the medium does not depend on the angle of incidence. It depends upon the nature of the material of the medium. For a ray of light moving from medium 1 to medium 2,

$$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}$$

(i.e.,) $\mu_1 \sin i = \mu_2 \sin r$

An easy way to remember Snell's law is that

$$\left(\begin{matrix}\textbf{refractive index}\\ \textbf{of the medium}\end{matrix}\right) \times \left(\begin{matrix}\textbf{sine of the angle}\\ \textbf{in the medium}\end{matrix}\right) = \textbf{constant}$$

The refractive index of the medium with respect to air (or vacuum) is called the absolute refractive index of the material. The refractive index for light going from first medium to second is equal to the reciprocal of the refractive index for light going from second to first medium.

$$_1\mu_2 = \frac{1}{{}_2\mu_1}$$

The refractive index of glass with respect to water is equal to the ratio of refractive index of glass and refractive index of water with respect to air.

$$_{\text{water}}\mu_{\text{glass}} = \frac{{}_{\text{air}}\mu_{\text{glass}}}{{}_{\text{air}}\mu_{\text{water}}}$$

Similarly, the refractive index of water with respect to glass is

$$_{glass}\mu_{water} = \frac{_{air}\mu_{water}}{_{air}\mu_{glass}}$$

The refractive index of the medium gives the light bending ability of that medium. Glass has higher refractive index than air. So more bending of light rays take place in glass. Glass is said to be optically denser medium and air is an optically rarer medium.

Activity : Try to catch a fish in a fish tank. The fish is not in a place where it

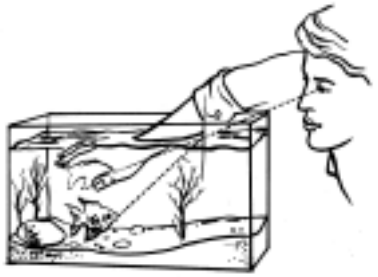


Fig. 3.4 A fish in tank

appears. Because of refraction, the fish is actually at a lower depth than we think it to be.

Table 3.2 Refractive index of some common materials with respect to air or vacuum.

Material	Refractive index	Material	Refractive index
Air	1.0029	Sugar solution (80%)	1.49
Ice	1.30	Benzene	1.50
Water	1.33	Crown glass	1.52
Ethanol	1.35	Flint glass	1.65
Sulphuric acid	1.43	Canadian balsm	1.53
Kerosene	1.44	Sodium chloride	1.54
Quartz	1.46	Carbon di sulphide	1.63
Turpentine oil		Ruby	1.71
Glycerine	1.48	Diamond	2.42
Sugar solution (30%)	1.38		

Problem : Calculate the refractive index of a material when the angle of incidence in air is 50^o and the angle of refraction in the material is 36^o.

$$i = 50^o,\ r = 36^o,\ \mu_2 = ?$$

From Snell's law,

$$\mu_1 \sin i = \mu_2 \sin r$$

$$1 \times \sin 50^o = \mu_2 \sin 36^o \quad (\because \mu_{air} = 1)$$

$$\mu_2 = \frac{\sin 50^o}{\sin 36^o} = 1.303$$

$\therefore$ The refractive index of the material = 1.303.

Problem : A ray of light enters the water from air at an angle of incidence of 53^o. The refractive index of water is 1.33. Find the angle of refraction in water.

$$i = 53^o,\ \mu_w = 1.33,\ r = ?$$

From Snell's law,

$$\mu_1 \sin i = \mu_2 \sin r$$

$$1 \times \sin 53^o = 1.33 \sin r$$

$$\sin r = \frac{\sin 53^o}{1.33}; \qquad r = 36.9^o$$

$\therefore$ The angle of refraction in water = 36.9^o.

Problem : The refractive index of glass and water with respect to air are $\frac{3}{2}$ and $\frac{4}{3}$ respectively. What is the refractive index of glass with respect to water.

$$_{air}\mu_{glass} = \frac{3}{2}$$

$$_{air}\mu_{water} = \frac{4}{3}$$

$$_{water}\mu_{glass} = ?$$

The refractive index of glass with respect to water is,

$$_{water}\mu_{glass} = \frac{_{air}\mu_{glass}}{_{air}\mu_{water}}$$

$$= \frac{\left(\frac{3}{2}\right)}{\left(\frac{4}{3}\right)} = \frac{3}{2}\times\frac{3}{4} = \frac{9}{8} = 1.125$$

2. Refraction of light through a prism

A prism is a transparent medium bounded by three plane surfaces. One of them is grounded and the other two are polished. The polished surfaces are called the refracting surfaces and the grounded one is called the base of the prism. The angle between the two refracting surfaces is called the angle of prism. A prism need not always be equilateral.

Experiment : Fix a sheet of chart paper on the drawing board and place a prism on it. Draw the boundary of the prism ABC. Remove the prism and draw a normal NM at

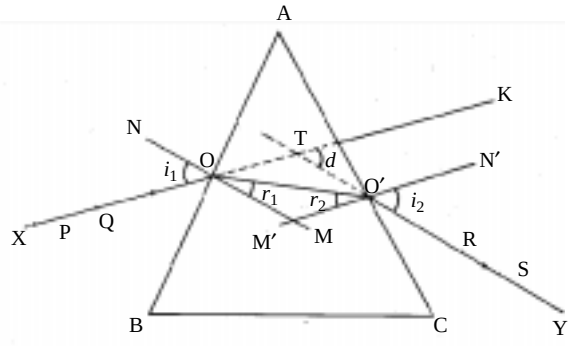


Fig. 3.5 Refraction of light through prism

O. Draw a line XO and fix two pins P and Q on this line. Place the prism in position and look the images of the pins P and Q from the opposite refracting face AC. Fix two pins R and S such that these pins are in straight line with the images of P and Q. Mark the positions of the pins. Remove the prism and pins. Join R and S and extend it to meet the prism at O′. Draw normal N′M′ at O′ and join O and O′.

Let angle of incidence $i_1 = \angle XON$,

angle of refractions $r_1 = \angle MOO'$

$r_2 = \angle M'O'O$

and angle of emergence $i_2 = \angle YO'N'$

Measure the angles of incidence i_1, i_2 and angles of refraction (r_1, r_2). Repeat the experiment for different angles of incidence and emergence. Record the observations in a table. From the table, it is found that sine of the angle of incidence is proportional to the sine of the angle of refraction. The refractive index of the material of the prism can be determined using,

$$_1\mu_2 = \frac{\sin i_1}{\sin r_1} = \frac{\sin i_2}{\sin r_2}$$

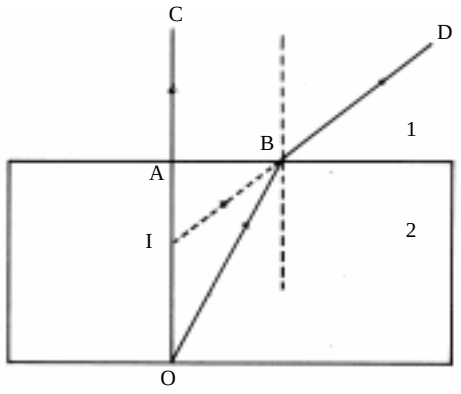
Table 3.3 Refractive index of the material of prism

S. No.	i_1	r_1	i_2	r_2	$_1\mu_2=\frac{\sin i_1}{\sin r_1}$	$_1\mu_2=\frac{\sin i_2}{\sin r_2}$

3. Raising effect of refraction

When an object placed in one medium is viewed from another medium, the object appears to be in a position other than its true position.

Suppose an object O kept in a medium like glass slab, is viewed from air, a ray OA



1. Air medium 2. Glass medium

Fig. 3.6 Raising effect of an object due to refraction

from O falls normally on the surface and passes straight as AC into air. Another ray OB strikes the surface of separation at some angle and bends away from the normal along BD. An eye intercepting these rays will feel as if they are coming from I. An object placed in a denser medium when viewed from a rarer medium will be seen nearer.

From Snell's law,

$$_1\mu_2 = \frac{OA}{IA} = \frac{\text{real depth}}{\text{apparent depth}}$$

Experiment : The simplest way to measure the refractive index of a liquid is to measure its apparent depth and its real depth. Place a scale inside a glass beaker containing liquid. Take another scale and hold it outside

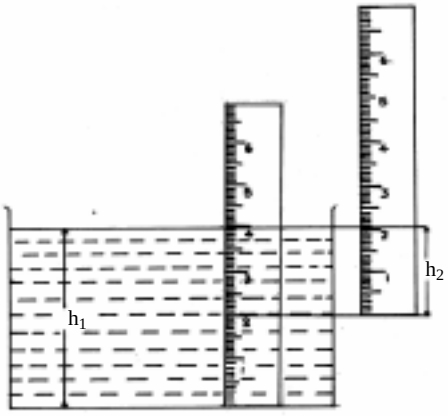


Fig. 3.7 Determination of refractive index of a liquid

of the beaker by stand. View the scale from the top and adjust the outside scale until the bottom ends of both scales appear to be at the same level. Measure the heights h_1 and h_2 of the level of water surface on both scales. h_1 and h_2 are the real and apparent depth respectively. The refractive index of the liquid with respect to air.

$$_{air}\mu_{water} = \frac{\text{real depth}}{\text{apparent depth}} = \frac{h_1}{h_2}$$

Using this formula the refractive index of the liquid can be determined.

Problem : The apparent depth of an object seen through a glass slab of refractive index 1.5 is 4 cm. Calculate the actual depth.

Refractive index of glass, $\mu = 1.5$

Apparent depth = 4 cm

Actual depth = ?

$$\mu = \frac{\text{Actual depth}}{\text{Apparent depth}}$$

$$1.5 = \frac{\text{Actual depth}}{4}$$

$\therefore$ Actual depth $= 1.5 \times 4 = 6$ cm.

Problem : A swimming pool appears to be 12 m deep. Find the refractive index of water if the real depth of water in the pool is 16 m.

Real depth = 16 m

Apparent depth = 12 m

Refractive index μ = ?

$$\mu = \frac{\text{Real depth}}{\text{Apparent depth}}$$

$$= \frac{16}{12} = \frac{4}{3} = 1.33$$

$\therefore$ The refractive index of water = 1.33

4. Total internal reflection :

Activity : Place a coin at the bottom of a glass tumbler containing water. Hold it in a slanting position and look at the surface of separation of water and air from the side.

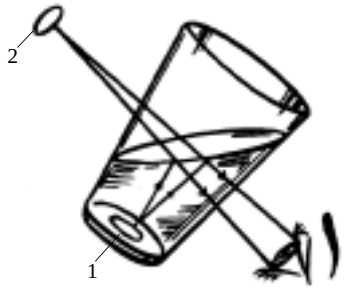


Fig. 3.8 Water surface acts as plane mirror

1. Coin 2. Image of coin

The surface appears to shine like a plane mirror. Objects above the surface cannot be seen by the eye but a bright image of the coin is seen due to total internal reflection.

Activity : Take a fish tank half filled with water. Make the room dark. Place the head of the torch light below the bottom surface of the fish tank. Tilt the torch light gradually and observe that the light rays get reflected within the water medium.

When a ray of light passes from an optically denser medium into a rarer medium, the refracted ray is bent away from the normal. A ray of light incident normal to the surface, passes without any deviation. As the angle of incidence increases, the angle of refraction also increases and at a certain angle of incidence,

the refracted ray just grazes surface of water. This angle of incidence within a denser medium for which angle of refraction becomes 90^o is called the critical angle. If the angle of incidence is increased beyond the critical angle, the ray bends inside the denser medium.

When a ray of light travelling from a denser medium into a rarer medium, incident at an angle greater than the critical angle, the ray is totally reflected back in the same medium. This is called total internal reflection.

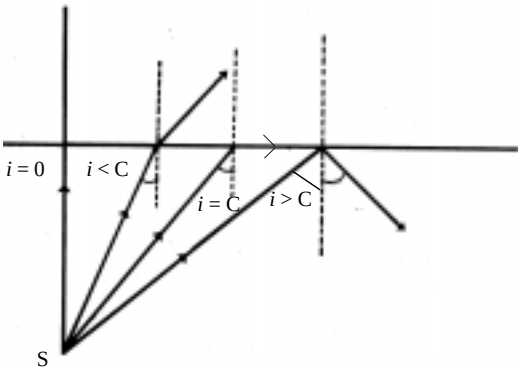


Fig. 3.9 Total internal reflection

Relation between critical angle and refractive index

We know that $_w\mu_a = \frac{1}{_a\mu_w}$

$$\frac{\sin C}{\sin 90^o} = \frac{1}{_a\mu_w}$$

$$\sin C = \frac{1}{_a\mu_w} \quad (\because \sin 90^o = 1)$$

$$_a\mu_w = \frac{1}{\sin C}$$

The refractive index of any medium with respect to air is the reciprocal of the sine of the critical angle.

Necessary conditions for Total Internal Reflection

(i) The light must proceed from denser medium to a rarer medium.

(ii) The angle of incidence in the denser medium must be greater than the critical angle.

Problem : The critical angle of diamond is 24.4^o. Calculate its refractive index.

$$C = 24.4^o \; ; \; \mu = ?$$

$$_{air}\mu_{diamond} = \frac{1}{\sin C}$$

$$= \frac{1}{\sin 24.4^o} = 2.42$$

The refractive index of diamond = 2.42

5. Totally reflecting prisms

A prism having an angle of 90^o between its two refracting surfaces and the other two angles each equal to 45^o is called a totally reflecting prism.

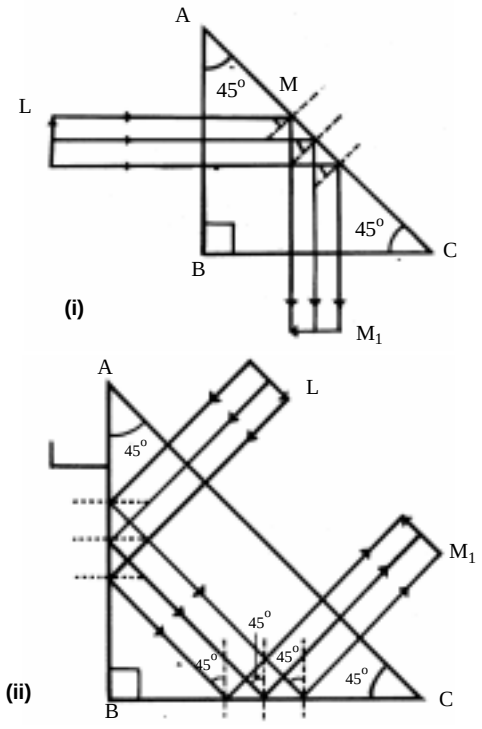


Fig. 3.10 Totally internally reflecting prisms (i) 90^o reflecting prism (ii) 180^o reflecting prism

ABC represents a right-angled glass prism. A ray LM is incident normally on the face AB. It enters the prism undeviated and then falls on the face AC at an angle of 45^o which is greater than the critical angle

for glass (42^o). Consequently, it is totally reflected along MM_1 and emerges out of the face BC normally. Thus the ray LM is deviated through 90^o without any loss of intensity. Such a prism is called totally reflecting prisms and is often used instead of mirror for reflecting a ray through 90^o. The same prism can also be used to turn the rays through 180^o.

Totally reflecting prisms are used in the construction of periscope. Periscope is used in the submarines to see objects above the surface of water.

6. Optical fibre :

An optical fibre is a device based on total internal reflection by which a light signal can be transmitted from one place to other with negligible loss of energy.

An optical fibre is a long glass rod of only a few millimeter thick and it is quite flexible. The fibre glass consists of a cylindrical inner core that carries light and an outer

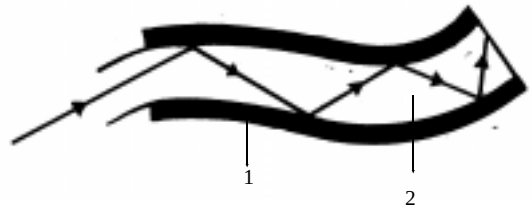


Fig. 3.11 Light passing through optical fibre

1. Cladding 2. Core

concentric shell called cladding. The refractive index of inner core (μ = 1.7) is relatively greater than that of cladding (μ = 1.5). The rays of light travelling along the fibre cannot escape because they are totally reflected from the core-cladding interface. So the fibre of solid glass can be used as a light pipe.

Applications :

(1) Optical fibres can carry light round bents. This allows doctor to see inside our body. (endoscope)

(2) Optical fibres can also carry information in the form of a digital code of light pulses with minimum loss. They carry telephone messages and computer data.

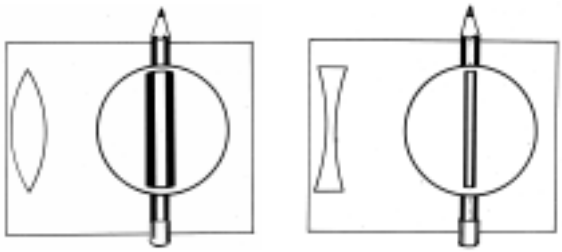
(3) Fibre optics technique is used to destroy tumours in solid organ like liver.

3.2 Refraction of light through lenses

Lens plays an important role in our everyday life. A palmist uses a lens for seeing the details of the lines of a person's palm. A watch maker also uses a lens to see the extremely small parts of a watch clearly. Lenses are used in making spectacles, cameras, microscopes and many other optical instruments.

Activity : You are given with different types of lenses. Observe the shapes of them by touching and identify the lens as convex or concave. You can find that the convex lenses are thicker in the middle and thinner at the edges. Concave lenses are thinner in the middle and thicker at the edges.

Activity : Hold a lens above a pencil. Adjust it to see the clear image of the pencil.



(i) **(ii)**

Fig. 3.12 Action of (i) convex and (ii) concave lens

If the pencil looks bigger, the lens in your hand is convex. If the pencil appears smaller, the lens is concave.

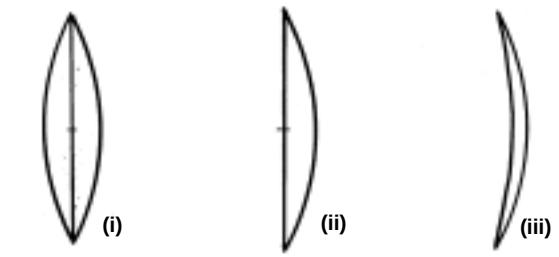
1. Lenses

A lens is a thin piece of a transparent material bounded by two spherical surfaces or by one spherical and other plane surface. The different types of lenses are shown in the figure 3.13.

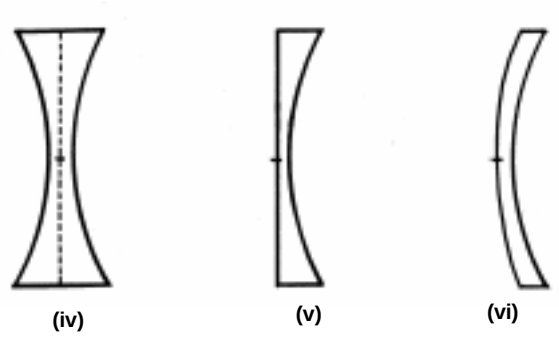
2. Lens - Definitions

(1) The width or diameter of a lens is called the **aperture of the lens.**

(2) The geometric centre of a lens is known as its **optic centre (O).**



(i) Biconvex (ii) Plano-convex lens (iii) Concavo-convex lens



(iv) Biconcave (v) Plano-concave (vi) Convexo-concave lens

Fig. 3.13 Different types of lenses

(3) **The centre of curvature (C)** is the centre of the sphere of which its surface forms a part.

(4) **The radius of curvature (R)** of a surface is the radius of the sphere of which the surface forms a part.

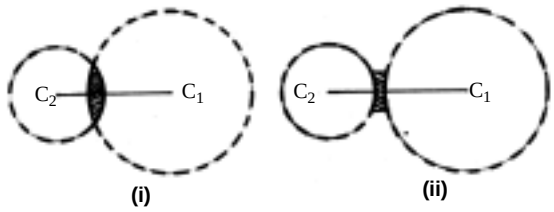
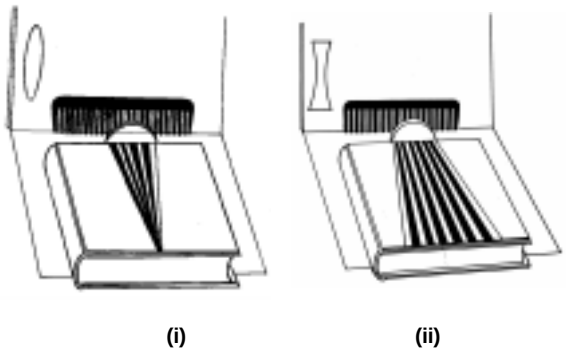


Fig. 3.14 Radius and Centres of curvature of lenses

(i) Convex lens (ii) Concave lens

(5) The line passing through the centres of curvature of the two surfaces and optic centre of a lens is called the **principal axis.**

Activity : Place a comb in between the torch light and the convex lens. Adjust the lens and observe that the light rays converge at a point. In the case of concave lens, the rays appear to diverge from a point.



(i) Convex lens (ii) Concave lens

Fig. 3.15 Converging and diverging action of lenses

(6) A beam of rays parallel to the principal axis after refraction through the lens actually converges at a point on the principal axis. This point is called **principal focus of a convex lens.**

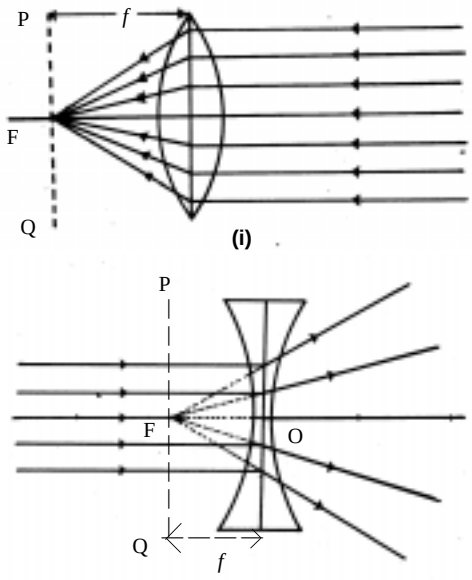


Fig. 3.16 Principal focus of lenses
(i) Convex lens (ii) Concave lens

A beam of rays parallel to the principal axis after refraction through a concave lens appear to diverge from a point on the principal axis. This point is called **principal focus of a concave lens.**

(7) **The focal length of a lens** is the distance between optic centre and principal focus of the lens

3. Lens is made up of prisms :

A lens may be regarded as made up of a large number of tiny prisms. The prisms are

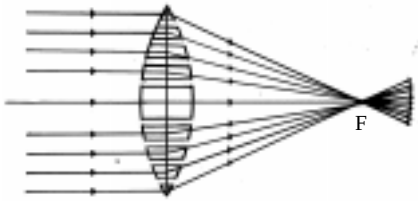


Fig. 3.17(i) Lens is made up of prisms convex lens

arranged in such a way that the light is deviated more at the edges of a lens than at the centre. This will explain how a beam of light parallel to the principal axis of a lens is either brought to a real focus in the case of converging lens or appear to diverge from a virtual focus in the case of diverging lens.

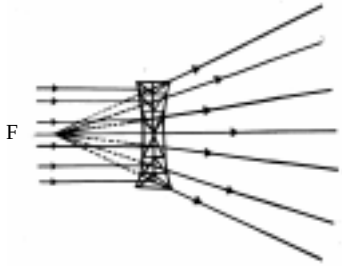
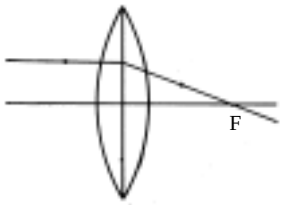
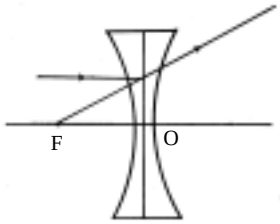
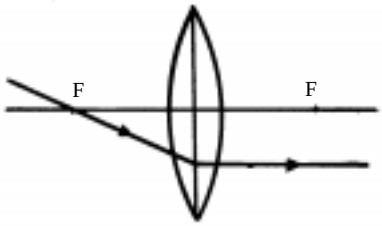
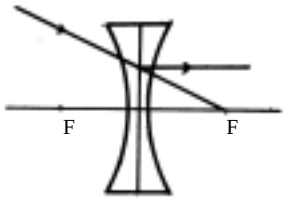
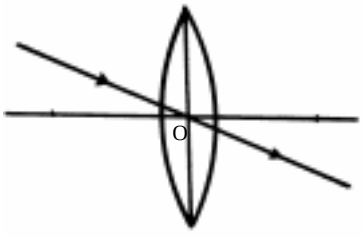
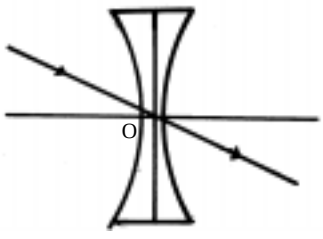


Fig. 3.17 (ii) Lens is made up of prisms Concave lens

Table 3.4 Images formed by convex and concave lens - Rules

	Convex Lens	Concave Lens
1.	An incident ray which is parallel to the principal axis, after refraction, passes through the principal focus on the other side of the lens. 	An incident ray which is parallel to the principal axis, after refraction, appears to diverge from the principal focus on the same side of the lens as the incident light. 
2.	An incident ray which passes through the principal focus, after refraction, emerges parallel to the principal axis. 	An incident ray which proceeds towards the principal focus, after refraction, emerges parallel to the principal axis. 
3.	An incident ray which passes through the optic centre goes straight without deflection. 	An incident ray which passes through the optic centre goes straight without deflection. 

4. Real and virtual images in lens

The image formed by the actual intersection of refracted rays through a lens is called the real image. The real images can be caught on the screen and they are inverted.

The images that appear without actual intersection of the refracted rays are called virtual images.

5. Images formed by a convex lens

AB is an object placed on the principal axis of a convex lens beyond 2F. A ray of light starts from B, parallel to principal axis after refraction through the lens actually passes through F. Another ray from the same point B after passing through the optic centre O goes straight along its path. These two refracted rays meet at B′ thereby forming real, diminished and inverted image A′B′ between F and 2F.

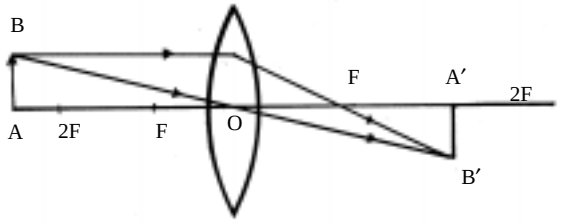


Fig. 3.18 Image formation in convex lens

Similarly, we can locate and find the nature of images formed by convex lens for various positions of an object using the ray diagram. (Table 3.5)

6. Relationship between (1) The object distance and image distance (2) Object size and image size in convex lens.

As the object is moved closer to the lens, the image distance increases and the image size increases. At 2F, the object distance equals the image distance. As the object distance approaches one focal length, the image distance and size approach infinity. When the object distance is one focal length, there is no image. When the object distance is less than one focal length, the images are virtual erect and located on the same side of the object. Finally, if the object distance approaches zero, the image distance also becomes zero. The image size ultimately becomes equal to the

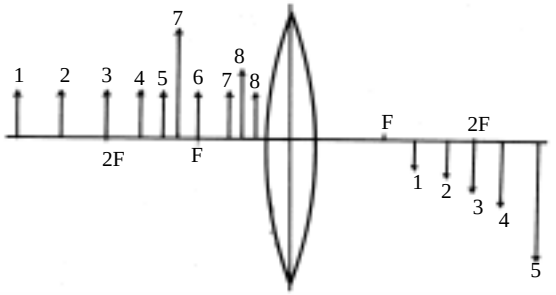


Fig. 3.19. Variation of image distance and size with object distance and size

object size. Eight different object locations and the corresponding image locations are marked with the identical numbers.

Activity : Mount a convex lens on a stand and place a lighted candle such that the flame lies on the principal axis of the lens. Place a screen infront of the lens and adjust it to get a well defined real, inverted image on the screen. Observe the location, nature and size of the image for different object distances and compare your results with those given in the table. 3.5

7. Images formed by a concave lens

Consider an object placed beyond F on the principal axis. A ray of light starts from B and parallel to the principal axis after

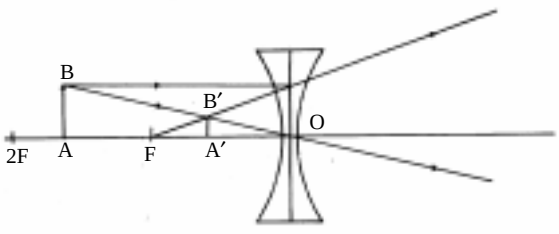


Fig. 3.20 Image formation in concave lens

refraction through the lens diverges outward. On producing it backward appears to pass

through F. Another ray from B, on passing through optic centre passes undeviated. When these diverging rays enter the eye, they appear to come from B′, forming a small erect image A′B′ between optic centre and F.

Table 3.5 Position and nature of images at various positions of object

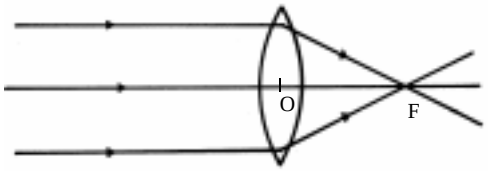
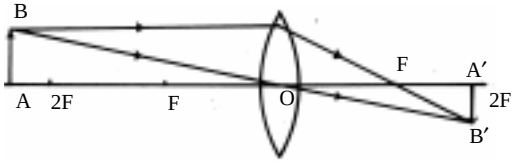
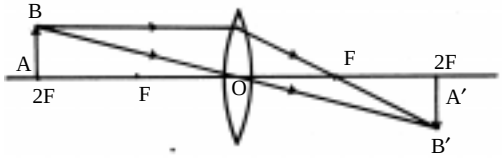
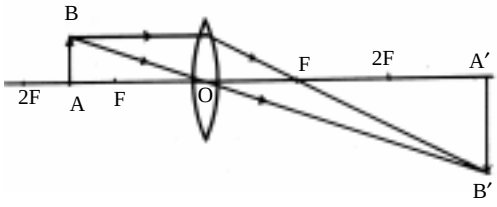
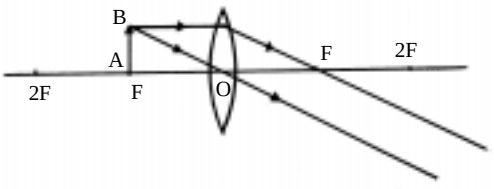
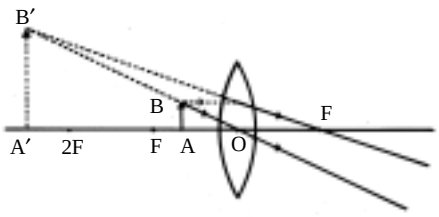
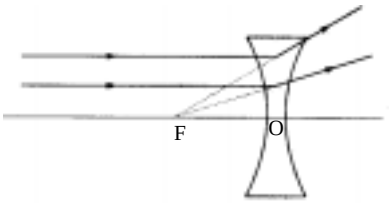
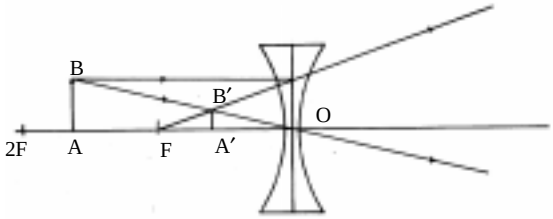
		Position of the object	Position of the image	Nature and size	Practical application
(i)		at infinity	at F	real, point-sized	Telescope objective lens
(ii)		beyond 2F	between F and 2F	real, diminished inverted	camera
(iii)		at 2F	at 2F	real, same sized, inverted	Terrestial telescope invert the image so that it is upright.
(iv)		between 2F and F	beyond 2F	real, enlarged inverted	projector
(v)		at F	at infinity	real, infinitely large, inverted	spotlights
(vi)		between F and O	on the side of the object	virtual, enlarged, erect	magnifying glass

Table 3.6 Position and nature of image for different positions of the object for a concave lens.

Ray diagram	Position of the object	Position of the image	Nature and size
	at infinity	at F	virtual, point-sized
	between infinity and O	between F and O	virtual, erect and diminished

8. Relationship between (1) The object distance and image distance (2) object size and image size in concave lens.

When an object is moved closer to the concave lens, the image distance decreases and the image size increases with respect to that of previous image. As the object approaches

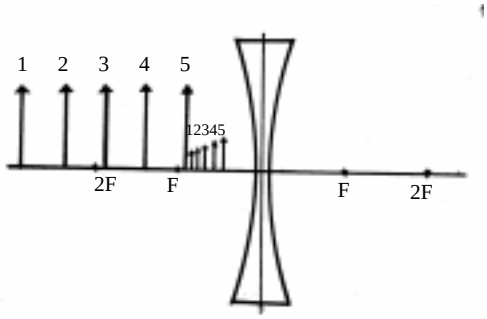


Fig. 3.21 Variation of image distance with object distance

the lens, its virtual image on the same side of the lens also approaches the lens and image size increases. If the object is placed at the optic centre, the virtual erect image of same size will be formed at the optic centre itself. Five different object locations and the corresponding image locations are marked with identical numbers.

9. Cartesian sign convention

The following sign conventions are used.

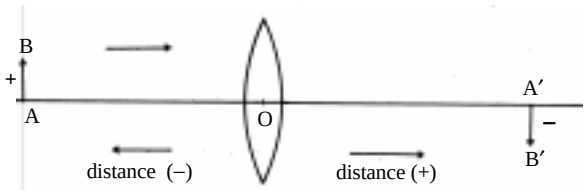


Fig. 3.22 Cartesian sign convention

(1) The object is always placed on the left side of the lens, so that the direction of incident light is always from left to right.

(2) All distances are measured from the optic centre of the lens.

(3) The distances measured from optic centre in the direction of incident light are taken as positive.

(4) The distances measured from optic centre against the direction of incident light are negative.

(5) The heights measured upward and perpendicular to the principal axis are taken as positive.

(6) The heights measured downward and perpendicular to the principal axis are taken as negative.

10. Lens formula

The relationship between the object distance **(*u*),** the image distance **(*v*)** and the focal length **(*f*)** of the lens is called lens formula.

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

Consider a thin convex lens of focal length *f*. Let the optic centre be O. An object AB is placed perpendicular to the principal axis of the convex lens. The ray BD parallel to the principal axis strikes the lens at D and is refracted by the lens. It passes through the focus F on the other side of the lens. A ray BO passes undeviated through the optic centre. The two refracted rays meet at B′. Draw A′B′ perpendicular to the principal axis. A′B′ is the real, inverted image of AB.

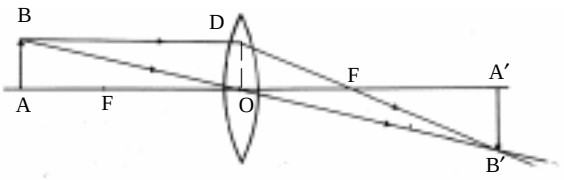


Fig. 3.23 Relation between u, v and f

Using sign convention,

Let the distance of the object from the lens = OA = $-u$

Distance of the image from the lens = OA′ = + v

Focal length of the lens = OF = f

Triangles ABO and A′B′O are similar.

$$\therefore \frac{AB}{A'B'} = \frac{OA}{OA'} \quad \text{... (1)}$$

Also triangles DOF and B′A′F are similar.

$$\therefore \frac{DO}{A'B'} = \frac{OF}{FA'}$$

But AB = DO

$$\therefore \frac{AB}{A'B'} = \frac{OF}{FA'} \quad \text{... (2)}$$

From equations (1) and (2)

$$\frac{OA}{OA'} = \frac{OF}{FA'} \quad \text{... (3)}$$

From fig.3.23 FA′ = OA′ – OF

Substituting in equation (3) we get,

$$\frac{-u}{v} = \frac{f}{v-f}$$

$$-u(v-f) = vf$$

$$-uv + uf = vf$$

$$-uv = vf - uf$$

$$uv = uf - vf$$

$$uv = f(u-v)$$

Rearranging the above equation we can get,

$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ which is the lens formula. This formula can be obtained for concave lens using the figure 3.20.

11. Experimental determination of focal length of a convex lens - $u - v$ method.

Mount the given convex lens on a stand and place an illuminated wire gauze in front

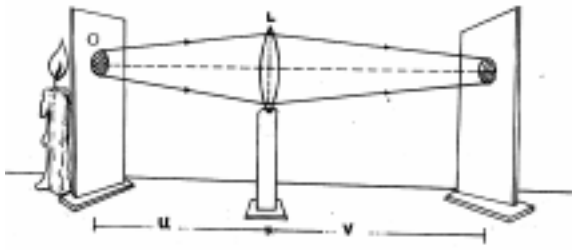


Fig. 3.24 $u - v$ method

of it. Adjust the position of the screen to get a clear image of the object. The distance between the object and lens (u) and the distance between the lens and screen (v) are measured. The experiment is repeated for different positions of the object, obtaining both magnified and diminished images and the corresponding image distances are measured. The observations are tabulated. The focal length f is found from the formula,

$$f = \frac{uv}{u+v}$$

Table 3.7 u-v method the focal length of a convex lens

S.No.	u **m**	v **m**	$f = \frac{uv}{u+v}$ **m**
1			
2			
3			
4			
5			

Graphical Method :

A graph is drawn taking u on the X-axis and v on the Y-axis, the scale for both axes and their values at the origin are the same.

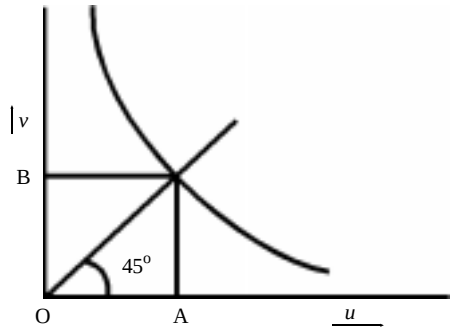


Fig. 3.25 *u–v* graph

The graph is symmetrical about the bisector of the two axes. At the point where the bisector cuts the graph, u and v are evidently equal. Now in a convex lens u and v are equal only when the object is at 2F from the lens. Hence this equal value of u and v gives $2f$.

$$f = \frac{u}{2} = \frac{v}{2}$$

$$f = \frac{OA}{2} = \frac{OB}{2}$$

12. Power of a lens

The power of a lens is the measure of its ability to produce convergence or divergence of a parallel beam of light. The power of a lens depends on its focal length. **The power of a lens is defined as the reciprocal of its focal length in metres.** The unit of power of a lens is dioptre (D).

If two lenses of focal length f_1 and f_2 are in contact, $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$ and $P = P_1 + P_2$

Here P_1 and P_2 are the power of the two lenses and P is the equivalent power.

Problem : A thin lens has a focal length 40 cm. What is its power ?

$$f = 40 \text{ cm} = 40 \times 10^{-2} m$$

$$p = ?$$

$$\text{Power, } P = \frac{1}{f \text{ (in metres)}}$$

$$P = \frac{1}{40 \times 10^{-2}}$$

$$= \frac{100}{40}$$

$$P = 2.5 \text{ D}$$

$\therefore$ The power of a lens = 2.5 D

13. Magnification in lenses

The size of an object or image as measured perpendicular to the principal axis is called the object or image height. Let h be the height of the object and h' be the height of the image then,

$$\text{Lateral magnification } |m| = \frac{h'}{h}$$

Magnification includes a plus sign when the image orients in the direction as that of the object and a minus sign when the image orientation is opposite to that of the object.

$$\text{Also lateral magnification } m = -\left(\frac{v}{u}\right)$$

Table : 3.8 Nature of images formed by convex and concave lenses

Lens type	Object location	Image				Sign			
		Location	Type	Orientation	Size	f	u	v	$m = -\left(\frac{v}{u}\right)$
Convex	within F	beyond F on the object side	virtual	erect	enlarged	+	–	–	–
	beyond F	other side of the lens.	real	inverted	diminished, same size, enlarged	+	–	+	+
Concave	Any where	same side of object	virtual	erect	diminished	–	–	–	–

14. Applications of lenses

(i) Convex lens

(1) The convex lenses are used as magnifying lenses. A watch maker uses a lens to see the small parts of a watch and a palmist sees the details of the lines of a person's palm using magnifying lens.

(2) The vision defect long-sightedness, can be corrected by a suitable convex lens.

(3) In an optical projector (slide projector), the enlarged image of a small slide can be formed on the screen using convex lens.

(4) The inverted image formed by the objective in terrestial telescope can be erected by convex lens.

(5) The convex lenses are used as objective lens of the telescope to form small inverted image of the far off objects in the focal plane.

(ii) Concave lens

(1) The vision defect short-sightedness can be corrected by using a concave lens.

(2) Concave lenses are used as the eyelenses in Galilean telescope.

Problem : A convex lens of focal length 10 cm is placed at a distance of 60 cm from a screen. How far from the lens should be placed an object to obtain a real image on the screen? Calculate the magnification of the image and its characteristics.

(i) f = + 10 cm (convex lens)

v = + 60 cm (image is real)

Applying the lens formula,

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{60} - \frac{1}{u} = \frac{1}{10}$$

$$\frac{-1}{u} = +\frac{1}{10} - \frac{1}{60}$$

$$\frac{-1}{u} = \frac{5}{60}$$

$$u = -12$$

Thus the object should be placed at a distance of 12 cm from the convex lens.

(ii) Magnification $m = -\left(\frac{v}{u}\right)$

$$= -\left(\frac{60}{-12}\right)$$

$$m = + 5$$

(iii) the image is real, inverted and enlarged.

15. Twinkling of stars

Heat energy radiated by the earth changes the density of the atmospheric layers

continuously. This changing density of the air layers near the ground affects its refractive index. Due to the refraction of light rays from the star, path of these rays goes on varying. Hence the eye some times receives more light with the result that the star appears brighter and sometimes it receives only a few rays or no rays which makes the star appear fainter.

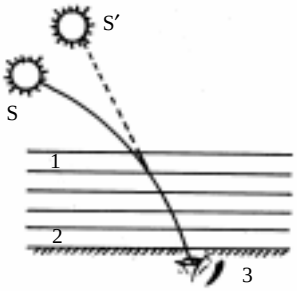


Fig. 3.26 Twinkling of stars

1. Rarer layer 2. Denser layer 3. Earth

The brighter and fainter appearance of the star with varying time is called the twinkling of the stars.

16. Mirage

A mirage is an optical illusion observed in deserts or over hot extended surfaces like a coal tarred road. During hot days the lower layers of air near the earth's surface are hotter and lighter than the upper layers away from

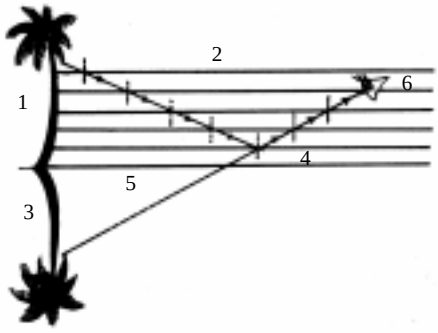


Fig. 3.27 Mirage in hot deserts

1. Tree 2. Cold and most denser layer of air 3. image of tree 4. Hot and least denser layer of air 5. Ground 6. eye

the earth's surface. Hence light from an object (say the top of a tree) undergoes a series of total internal reflections and bends upwards. This produces an inverted virtual image of the object below it. Due to this a traveller sees shimmering pond of water some distance ahead of him. This optical illusion is called mirage.

A similar phenomenon takes place in very cold regions or over the sea during cold winters is called Looming. The image in the

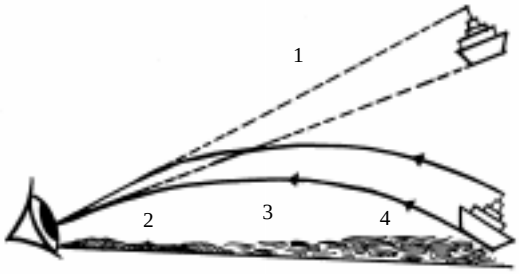


Fig. 3.28 Looming in cold regions

1. Warm air (Rarer) 2. Land 3. Cold air (denser) 4. Sea

looming is erected and it appears above the object.

3.3 Vision and Optical Instruments

The eye is the unique sensitive sense organ. It is useful to see the wonderful world of light and colour.

1. The human eye

The eyeball is nearly spherical with white outer layer called the **sclera.** The light enters the eye through a curved transparent tissue called Cornea. Behind the cornea, is a circular diaphragm called iris which has a central hole called pupil. The size of the pupil aperture is adjusted by muscle action and controls the amount of light entering the eye. The converging crystalline lens composed of glassy fibres is situated behind the iris. The shape and curvature of the crystalline lens is controlled by ciliary muscles. The images are formed on the retina by adjusting and changing the curvature of the lens. This is called **accomadation of the eye**. The eye ball contains a fluid infront of the lens and a jellatinous material in the space behind it. The retina of the eye consists of two types of photo sensitive rods and cones. The more numerous rods have a greater sensitivity to light, but do not respond to colour. Rods work well when the light is dim. The cones are sensitive to bright light

and colour. They are helpful to us to see things in colour. Special optical nerves carry the messages from retina to the brain which interprets the images as erect images. The functioning of the eye is similar in many ways

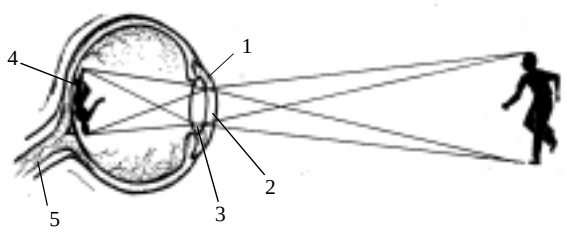


Fig. 3.29 The human eye

1. Iris 2. Pupil 3. Lens 4. Retina 5. Optical nerve

to that of a camera. Both have a lens but curvature of the camera lens cannot be changed.

Activity : Make a small hole in the middle of the black card-board. Place it on one side of round bottomed flask containing water. Place a lamp infront of the black

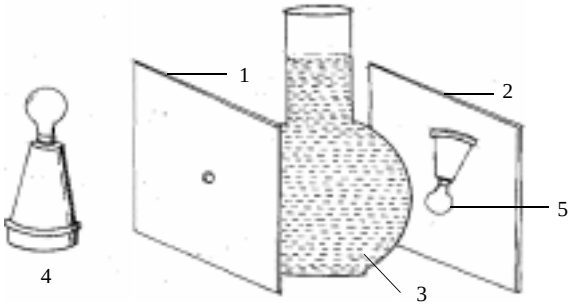


Fig. 3.30 Working of the eye

1. Black card 2. White card 3. Water in a flask 4. Object 5. Image

cardboard. Adjust a screen on the other side of the flask to get a clear image of the lamp. Observe that the image is small and inverted.

The points between which the eye can see distinctly are called far point and near point. The far point is normally without limit (infinity) and near point depends on the accomadation of the crystalline lens.

Activity : Move a pencil slowly towards your nose. At some points observe that the pencil appears blurred. The point at which the pencil appeares blurred is called near point.

The normal eye produces sharp images on the retina for objects between near and far points. A person may be near sighted or long sighted with blurred images. This results from images not being focussed on the retina. The eye defects generally occur because the eye is abnormal for some reasons. This can be due to disease, injury and ageing.

The closest distance at which one can see a clear image of an object is called the near point or the least distance of distinct vision. For a normal human eye, the near point is 25 cm from the eye.

Table 3.9 Approximate near points of the normal eye

Age (yr)	Near point (cm)
10	10
20	12
30	15
40	25
50	40
60	100

2. Defects of the eye

(1) Short-sightedness or Myopia

The inability to see the distant objects clearly and distinctly is called short sightedness. This defect arises when the image

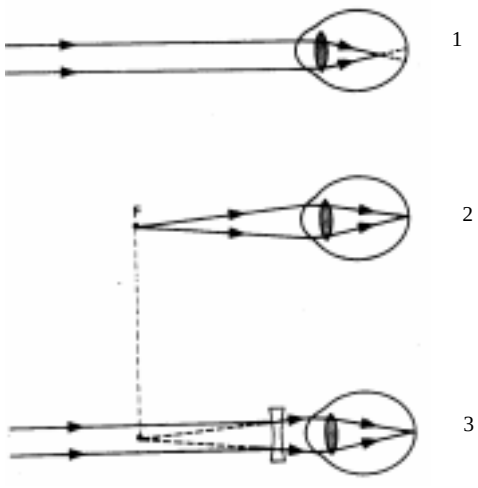


Fig. 3.31 Short sightedness and its correction

1. Defective eye 2. Normal eye 3. Corrected eye

is formed infront of the retina. A short sighted person can see near objects clearly. This may

arise due to either excessive curvature of the cornea or elongation of the eyeball. This defect is corrected by wearing glasses with a concave lens.

(2) Long sightedness (or) Hyper metropia

The inability to see near objects clearly and distinctly is called long sightedness. This defect arises when the image is formed behind the retina. This defect may arise due to shortening of eye ball.

A long sighted person can see the distant objects clearly. This defect is corrected by wearing spectacles with convex lens (converging) of appropriate focal length. A converging lens will correct this defect by converging the incoming rays so that the image is formed on the retina.

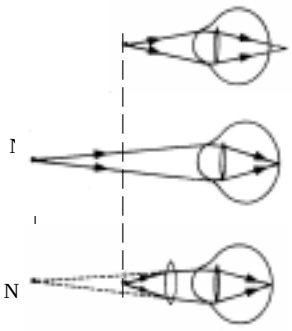


Fig. 3.32 Longsightedness and its correction

1. Defective eye 2. Normal eye 3. Corrected eye

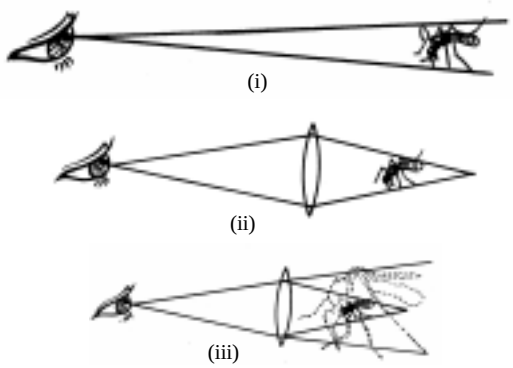
Longsightedness occurs naturally with age. An older person without glasses holds newspaper away from him or herself. As a person grows older, the ciliary muscles weaken, and the crystalline lens looses its elasticity or hardens which limits the eye's accomadation.

Some persons may have both longsightedness and short sightedness defects. They should wear glasses consisting of both converging and diverging lenses on the same piece of glass. This is called bifocal glass. The bifocal lens was invented by Benjamin Franklin. He glued two lenses together in the same frame. For example, a small lower lens can correct for longsightedness (for reading), and the upper lens is used to correct for near-sightedness.

3. Optical Instruments

It is too difficult to see things at far away distance like stars, planets, sun etc. and very small things such as cells, bacteria and viruses with the help of naked eye. We cannot explore these things. So it is necessary to devise some instruments to view clearly and distinctly. A telescope enables us to see things at vastly greater distances. Microscope, as its name suggests is an instrument for magnifying and observing very small objects.

Activity : View a housefly through a magnifying lens. Observe that housefly looks



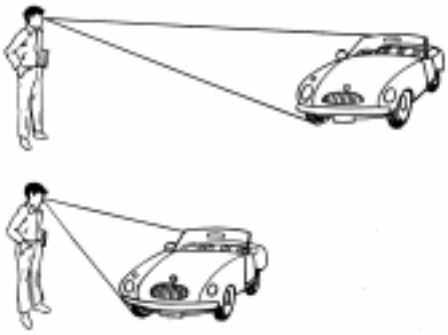
3.33 Convex lens act as magnifying lens

(i) Narrow angle (ii) Wider angle
(iii) Observed size of house fly

much bigger. The magnifying glass bends the light from an object to an angle at which the eye is used to receive light from a much larger object. It means that magnifying lens itself is a simple microscope.

A car in the distance appears quite small as compared with when it is near. The difference is the angle of view. When the car is very near it looks much bigger because it is viewed through a much wider angle. A lens can make an object appears larger than it is because the refraction of light increases the angle of view. But the eye sees the light as if it had been travelling in a straight line. So the object appears much larger than that it really is. To obtain greater magnification than

that given by a single lens or simple microscope, compound microscopes are greatly used.



3.34 The angle of view determines how large an object appears

4. Simple microscope

A convex lens produces an enlarged virtual image of an object when the object is placed within F. In this position, the lens behaves like a simple microscope.

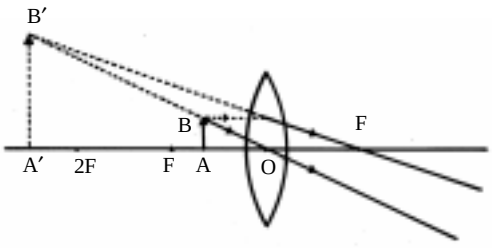


Fig. 3.35 A Simple microscope

Let f be the focal length of the lens. The image is formed at comfortale distance for viewing, v = 25 cm.

Using the lens formula and applying sign convention,

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{(-v)} - \frac{1}{u} = \frac{1}{f}$$

$$\frac{-v}{v} - \frac{v}{u} = \frac{v}{f}$$

$$-1 - m = \frac{v}{f} \qquad \left(\because \quad m = \frac{v}{u}\right)$$

$$m = -1 - \frac{v}{f}$$

$$m = -\left(1 + \frac{v}{f}\right)$$

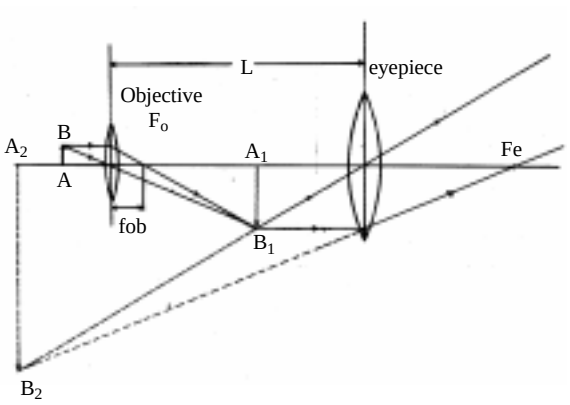
$$= -\left(\frac{25}{f} + 1\right)$$

Thus smaller values of 'f' larger is the magnification produced by the lens.

5. Compound microscope

Construction : The common microscope is a compound microscope because it uses more than one lens. A compound microscope consists of two convex lenses of short focal length fitted at the outer ends of the two tubes. These tubes can slide into one another to adjust the distance between the two lenses. The lens towards the object is called objective and lens which is towards our eye is called eye piece. The focal length and aperture of the objective is a little shorter than that of the eye piece.

Working : A well illuminated tiny object AB is placed in between F and 2F of the objective. A magnified real inverted image



3.36 Compound microscope

$A_1 B_1$ is formed beyond 2F of the objective. This image acts as the object placed within F of the eye piece. The eye piece forms a magnified virtual erect image $A_2 B_2$ on the same side of the object. Final image $A_2 B_2$ is errect and magnified with respect to the first image $A_1 B_1$ and is inverted and magnified with respect to the object AB.

The distance between the objective and the eye piece is called the tube length (L).

Let, D - the least distance of distinct vision

fo - focal length of the objective

fe - focal length of the eye piece

The magnification of a compound microscope is the ratio of the angular size of the final image to that of the angular size of object AB. Then the magnification is given by, $m = \frac{A_2 B_2}{AB}$

$$m = \left(\frac{25}{fe} + 1\right) \times \left(\frac{v}{u}\right)$$

We can increase the magnification by placing objects close to principal focus of the objective.

Activity : Choose two cylindrical tubes (plastic or cardboard) such that one slides over the other. Fix two convex lenses of different focal length at both the ends. Viewing the object through the lens of longer focal length,

Fig. 3.37 Simplified Telescope

adjust the tubes one over other to get a clear image of the distant object. Observe that the distant object appears very close to the eye.

6. Astronomical Telescope

It is an optical device used for seeing heavenly bodies such as the stars, and the planets. It may be of refracting type in which a large convex lens is used as the objective or reflecting type in which a large concave mirror is used as the objective.

Refracting astronomical telescope

Construction : The optics of an astronomical telescope are similar to those of a microscope. It consists of two convex lenses, an objective lens of very large focal length and an eye lens of very small focal length. These two lenses are mounted on separate tubes which can easily slide in one another. The tubes are blackened from inside so as to

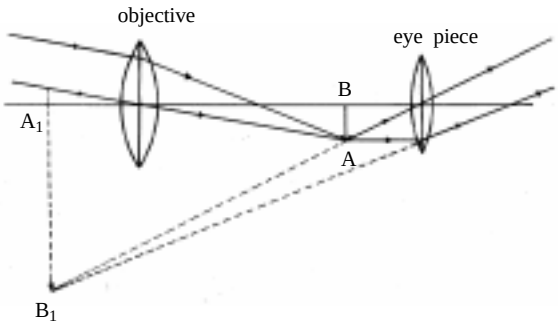


Fig. 3.38 Refracting Astronomical Telescope

prevent the reflection of light from their inner sides.

Working : The rays from a distant object form a parallel beam of light. This parallel beam of light is incident on the objective lens. After refraction through this objective lens, a sharp, real and inverted image AB is formed at the focus of the objective. The eye piece is now so adjusted that the image AB lies at the focus of the eye piece. Thus final image is formed at infinity. The telescope is then set to be in normal adjustment. At normal adjustment distance between objective and eyepiece is equal to sum of the focal length of objective (*fo*) and focal length of eyepiece (*fe*)

(i.e.) $L = fo + fe$

For normal adjustment the magnifying power of an Astronomical Telescope

$$= \frac{\text{focal length of the objective}}{\text{focal length of the eyepiece}}$$

$$m = \frac{fo}{fe}$$

For least distance of distinct vision adjustment, $m = \frac{fo}{fe}\left(1 + \frac{fe}{D}\right)$

where D is the least distance of distinct vision, (25 cm).

For the astronomical purposes, it does not matter that the final image is inverted.

3.4 Dispersion of Light

Activity : Take a cardboard in the form of circular disc. Divide its surface into seven equal parts. Colour these parts with different water colours. Make the disc move around the pencil point and rotate fast. Observe that the disc appears white.

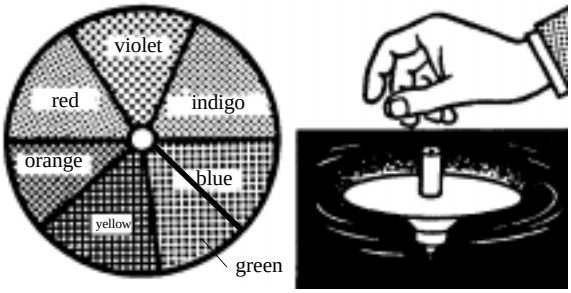


Fig. 3.39 White colour is a combination of seven colours

Activity : Place a plane reflecting mirror obliquely in a beaker filled with water and keep it in a dark room. Allow the narrow beam of sun light to fall on the plane mirror.

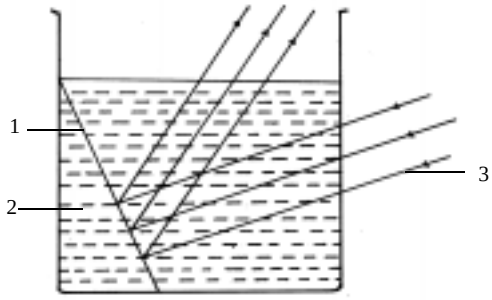


Fig. 3.40 Formation of spectrum

1. Plane mirror 2. Water 3. Sunlight

Observe the band of colours formed on the wall of the room.

1. Dispersion of white light by a prism

When a beam of white light is passed through a prism, white light splits up into different colours. Consequently a coloured pattern is obtained on the screen. This splitting of white light into its constituent colours is called dispersion of light. The coloured pattern obtained on the screen is called a spectrum. The colours are not in strips but change gradually through many different shades of

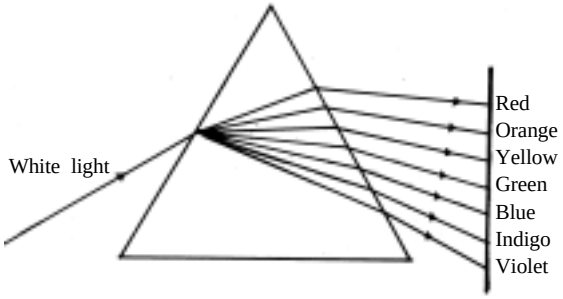


Fig. 3.41 Dispersion of light

colour. The colours of the spectrum of white light are violet, indigo, blue, green, yellow, orange and red (VIBGYOR).

The white light is a mixture of different colours. Each colour is associated with light of a particular wavelength. Red light has a longer wavelengths than the blue light. The angle of deviation by a prism is not the same for all the wavelength (colours) of light. Hence

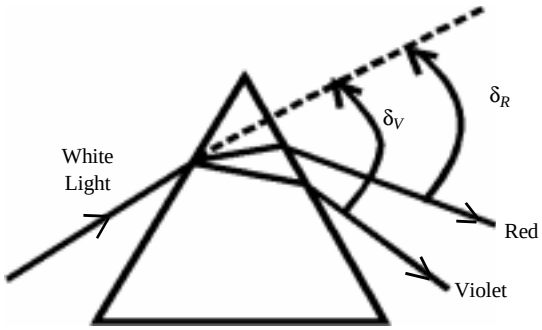


Fig. 3.42 The angle of deviation of different colours

the prism disperses white light into its constituent colours. The red is deviated least and the violet most.

Table 3.10 Wavelength of different colours.

Colour	Wavelength (nm)
Violet	400 - 440
Indigo	440 - 460
Blue	460 - 500
Green	500 - 570
Yellow	570 - 590
Orange	590 - 620
Red	620 - 720

2. Colour of objects

The colour of an object depends upon the colour of light it reflects. If all colours are reflected the object appears white. If some colours are reflected, the object appears

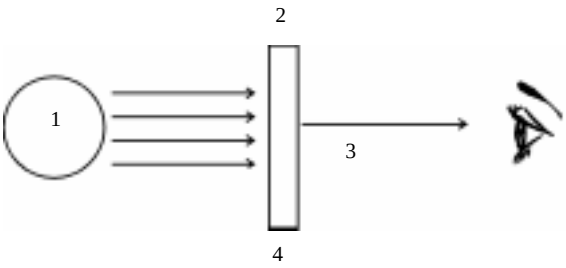


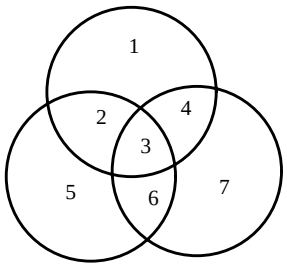
Fig. 3.43 Appearance of a ball in red glass

1. Ball 2. Red glass 3. red light passes through glass 4. OYGBIV absorbed

coloured. The colour seen by the eye is the colour of the reflected light. A ball appears red when it is seen through a piece of red glass. White objects reflect all colour and black objects absorb all colours. Red objects reflect red only and absorb other colours.

3. Colour formation

It has been shown that by combining red, green, and blue colours in right proportions practically all colours can be produced. But whatever combination one may choose it is not possible to produce a red, green or blue colour by mixing other colours. It is because



1. Red
2. Magenta
3. White
4. Yellow
5. Blue
6. Cyan
7. Green

Fig. 3.44 Mixing of colours

of the reason that red, green and blue colours are called primary colours. The colours obtained by mixing of any two primary colours are called secondary colours. Two colours which when mixed in correct proportion give white light are known as complimentary colours.

red + green $\longrightarrow$ yellow
red + blue $\longrightarrow$ magenta } secondary colours
blue + green $\longrightarrow$ cyan

red + green + blue $\longrightarrow$ white

yellow + blue $\longrightarrow$ white

magenta + green $\longrightarrow$ white

cyan + red $\longrightarrow$ white

Complimentary colours + primary colours $\longrightarrow$ white

4. Colour filter

It is a coloured transparent material which allows only light of certain colour to pass through and absorbs all other colours of white light. For example a red filter transmits red light and absorbs other colours. If a filter absorbs green and blue components of white

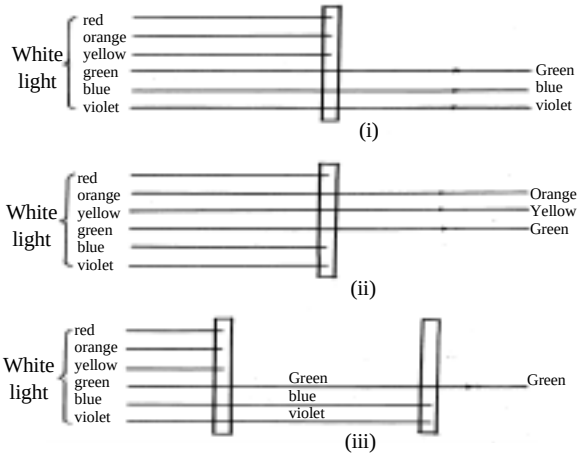


Fig. 3.45 Colour filters
(i) Blue filter (ii) Yellow filter
(iii) Blue filter + Yellow filter

light, the transmitted light will be red. Thus filter produces light by subtractive process.

5. Pigments

Coloured pigments are opaque substances which absorb all components of white light except some components which are reflected. Examples : **Chlorophyll** in plants, paints, dyes.

The eye only sees the results of what a pigment reflects. An object becomes coloured when a pigment is applied to it. Sometimes

artists need to mix pigments to obtain the requied shade. A red dress appears red because the dress absorbs all other colours and reflect only red. Yellow paints absorb blue light and reflect red, yellow and green light. Blue paints absorbs red and yellow but reflect blue and green light. Mixing of yellow and blue paints produces green paint because together the yellow and blue, absorbs red, yellow and blue. This is not the same as mixing yellow and blue light.

6. Rainbow

Rainbow is nature's most spectacular display of the spectrum of sunlight produced by several raindrops. It is observed when the sun shines on the raindrops, during or immediately after a shower. An observer standing with his back towards the sun observes it in the form of concentric circular arcs of different colours in the sky. Normally a part of bow alone is visible. A complete circular rainbow can be seen in an aeroplane with sun overhead.

Primary rainbow : The common rainbow is known as primary rainbow. It is

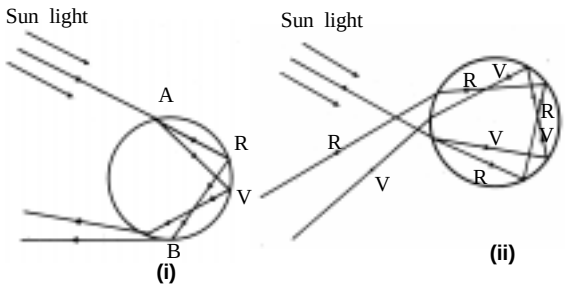


Fig. 3.46 Rainbows
(i) Primary Rainbow (ii) Secondary Rainbow

formed by light from the sun undergoing one internal reflection and two refractions and emerging out at minimum deviation. The band of primary rainbow has red on the outside and violet on the inner side. The other spectral colours lie in between violet and red in their order. The inner violet edge subtends an angle of 40.8^o and outer red edge subtends an angle of 42.8^o. An observer on the ground cannot see a primary bow when the sun's altitude is greater than 42^o, angle above the horizon.

Secondary rainbow : The main or primary rainbow is sometimes accompanied by

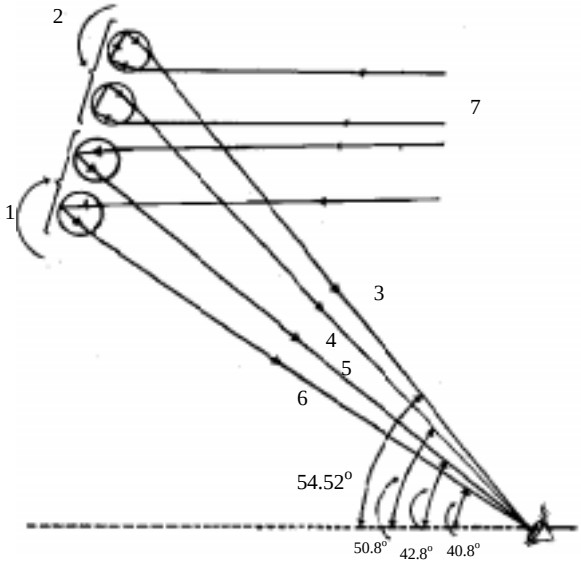


Fig. 3.47 The angle of inclination of various colours in rainbows

1. Primary 2. Secondary 3. Violet 4. Red 5. Red 6. Violet 7. Sunlight

a fainter secondary rainbow arc. Secondary rainbow is formed due to two internal reflections and two refractions of the sun light falling on the raindrops. The double total internal reflections give rise to an inversion of sequence of colours in the secondary rainbow from that in the primary rainbow. The band of secondary rainbow has violet on the outerside and red on the innerside. The inner red edge subtends on angle of 50.8^o and outer edge subtends an angle of 54.42^o. When the sun's altitude is greater than 54^o then the observer on the ground cannot see a secondary rainbow.

The space between the two bows appears dark because the angle of deviation of the raindrops in between them should be less than the minimum. Sometimes other bows are observed near the inner edge of the primary bow or near the outer edge of secondary bow. These are known as **super numerarary** bows and these bows depend upon the size of the raindrops.

3.5 Photography

Photography is the process of forming image of an object directly or indirectly by the action of light on sensitive surfaces. It is based on reaction of chemicals with light.

1. Camera :

A camera consists of a light tight box with a convex lens at one end and the film at the other end. The lens produces a real image on the film by camera. The image formed is real, inverted and diminished [refer table 3.5(b)]

(i) Focusing

A camera is focussed by varying the distance between the lens and film. To keep the image in focus on the film, the lens must be moved back and forth.

(ii) The shutter

The amount of light entering the camera can be controlled by the length of time that the shutter is open. The exposure time is called shutter speed. Typical shutter speeds are $\frac{1}{30}$, $\frac{1}{60}$, $\frac{1}{125}$ and $\frac{1}{250}$ seconds. For a stationary object, the shutter speed is $\frac{1}{60}$ s and for fast moving objects it is $\frac{1}{500}$th second.

(iii) The aperture stop or diaphragm

The amount of light entering the camera can also be controlled by varying the size of the hole in the diaphragm. It is just behind the lens. To take a photograph in dim light, the size of the aperture must be large. The shutter speeds and aperture settings are worked together to obtain a correct exposure for any given light conditions. The depth of field is an expression used to describe the distances infront of the camera within which a sharp well focussed picture can be obtained.

(iv) The *f*-numbers :

The ratio of the focal length of the lens (f) to the diameter of the aperture (D) is called the *f*-number.

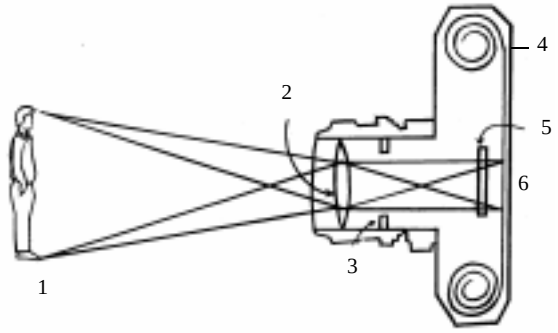


Fig. 3.48 Camera

1. Object 2. Lens 3. Aperture 4. film (and focal plane) 5. Shutter 6. Image

$$f\text{-number} = \frac{f}{D}$$

The intensity of light incident on the film

$$I \propto \frac{1}{(f - \text{number})^2}$$

(v) Film speed :

It is a measure of the rate of reaction of chemicals on the film with light. For fast film, the exposure time required is short. A long exposure time is required for slow film. While taking a good photograph the film speed, the *f*-number and the shutter speed must always be taken into account.

2. Persistence of vision

The ability of an eye to continue to see the image of an object for a very short duration even after the removal of the object is called persistence of vision. The visual sensation of a particular object or scene persists for about $\frac{1}{16}s$ after it disappears. When the movie is screened, the frames are displayed one after another at the rate of 24 frames per second. The time $\frac{1}{24}$ second for which a frame is displayed is less than the time of persistence of vision. The visual sensation of the previous frame remains when that of the current frame starts. This gives us a sense of continuity.

SELF EVALUATION

Choose the correct answer

1. A ray of light travelling in air falls obliquely on the surface of a calm pond. It will
   (1) go into the water without deviating from its path
   (2) deviate away from the normal
   (3) deviate towards the normal
   (4) turn back on its original path

2. Where should an object be placed so that a real and inverted image of the same size is obtained using a convex lens ?
   (1) between the lens and its focus
   (2) at the focus
   (3) at twice the focal length
   (4) at infinity

3. A ray of light travels from water to air, if the angle of incidence is 40^o, then the angle of refraction is
   (1) 40^o
   (2) less than 40^o but not zero.
   (3) greater than 40^o
   (4) equal to zero

4. The critical angle of diamond is
   (1) 24.4^o (2) 42.4^o
   (3) 34.4^o (4) 24.8^o

5. The refractive index of glass depends on
   (1) the angle of incidence
   (2) the colour of the incident light
   (3) the size of the glass slab
   (4) intensity of the incident light

6. The colour which deviates the least during dispersion is
   (1) green (2) violet
   (3) blue (4) red

7. If an object absorbs all colours it appears
   (1) black (2) shiny
   (3) multi coloured (4) white

8. When magenta, yellow and cyan are added, the colour obtained is
   (1) green (2) blue
   (3) red (4) white

9. The SI unit of power of a lens is
   (1) metre (2) dioptre
   (3) watt (4) calories

10. Which of the following are primary colours ?
    (1) red, green and blue
    (2) red, cyan and blue
    (3) blue, cyan and magenta
    (4) violet, red and green

Fill in the blanks

11. The refractive index of air medium is .....

12. The stick within the water appears to be bent due to .....

13. The long sightedness defect can be corrected using a suitable ..... lens.

14. A lens may be regarded as made up of .....

15. The image formed in a cinema projector is .....

16. The power of a lens can be measured directly using .....

17. A blue object reflects only .....

18. The optical phenomenon which causes mirage is .....

19. In a telescope, the focal length of the objective is ..... than that of the eye piece.

20. Greater the refractive index ..... is the deviation.

Answer briefly

21. How will you distinguish convex and concave lens ?

22. Define : Principal focus and focal length of a convex lens ?

23. Distinguish between real and virtual images.

24. State Snell's law of refraction of light.

25. Define refractive index of medium.

26. State the relationship between refractive index and real depth.

27. Define critical angle of a medium.

28. State conditions for total internal reflection.

29. What is core and cladding in optical fibres?

30. Mention the applications of optical fibres.

31. What are the rules followed in the image formed by a convex lens ?

32. What are the rules used for obtaining the images by concave lens ?

33. What are the sign conventions for lenses ?

34. Define power of a lens.

35. If two lenses are in contact, what is the power of combination ?

36. Define the magnification of a lens.

37. Define dispersion of light.

38. What are the differences between Primary and Secondary rainbows ?

Answer in detail

39. Draw the path of light ray inside a glass slab and describe the method of determining the refractive index of glass.

40. Explain the refraction of light through a prism.

41. Draw the path of a ray of light through a glass prism and explain to determine the refractive index of the material of the prism.

42. Explain the raising effect of refraction with an example.

43. Write a note on optical fibers.

44. Derive the relation between u, v and f of a thin lens.

45. Explain the twinkling of stars and mirage.

46. Describe the construction and working of a compound microscope.

47. Describe the construction and working of a astronomical telescope.

48. What are primary and secondary colours and explain the superposition of colours.

49. Explain the principle and working of a camera.

Problems

50. A ray of light incident on the surface of sea water at an angle of 50^o making an angle of refraction of 17^o. Calculate the refractive index of sea water. [**Ans.** 2.62]

51. The critical angle of glass is 41.8^o. Calculate its refractive index. [**Ans.** 1.501]

52. An object and a screen are fixed 80 cm apart. For a particular position of convex lens, a real image is formed on the screen with a magnification of 2/3. Find the focal length of the lens. [**Ans.** 19.2 cm]

53. A compound microscope has an objective of focal length 0.5 cm and a tube of length 15 cm. If it produces angular magnification of 225 in normal adjustment, find the focal length of the eyepiece. [**Ans.** 3.33 cm]

Extend your knowledge

54. Why does the sun look a little oval when it is at the horizon ?

55. How does the refraction affects the length of the day ?

56. Why does upper surface of water contained in a beaker and held above eye level appear silvery ?

57. Why do not planets twinkle ?

58. A fish swims in a fish tank. A person whose eye is above the level of water, sees two fishes. Draw a ray diagram to illustrate this.

59. By means of graphical construction, determine the positions, size and nature of image of an object of 1 cm in height, at a distance of 80 cm from the lens. The focal length of a convex lens is 20 cm.

4. ELECTRICITY AND ITS EFFECTS

We are living in the age of information technology. Electricity plays a major role in modern society. Electricity paved the way for scientific, industrial and technological developments. The advancement in computers, information technology and communication systems is possible only with the help of electricity. We can easily realise the importance of electricity, when the power supply breaks down and the standby electric generator units maintained in hospitals, shops and houses start operating instantly. Electricity has developed into one of the most convenient and widely used forms of energy in the world. Moreover, it can be easily transmitted over long distances with very little energy loss.

In this chapter, we shall study the basic concepts of electricity and its various effects such as heating and magnetic effects.

4.1 Electric field and potential

We are familiar with the fact that when we put off our clothes made of terylene or nylon, a crackling sound is produced. When a body is rubbed with a different body, electric

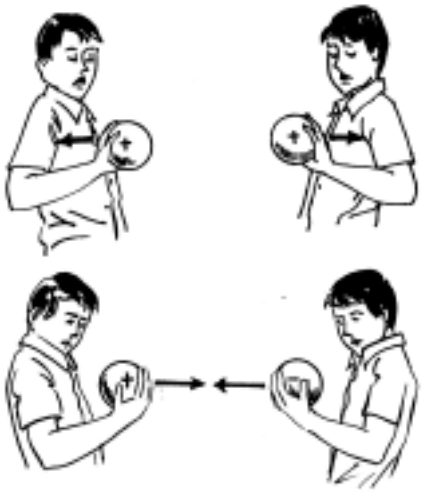


Fig. 4.1 The law of charger

charge is produced. If a glassrod is rubbed with silk, positive charge is produced. If a hard rubber rod is rubbed with fur, negative charge is produced.

The electric force can be either attractive or respulsive. This is expressed in the law of charges. Like charges repel; unlike charges attract.

Coulomb's law : The magnitude of electric force between two charges is directly proportional to the product of charges and inversely proportional to the square of the distance between them.

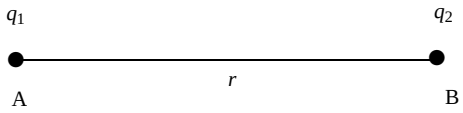


Fig. 4.2 Coulomb's law

$$F = \frac{1}{4\pi\in_o} \cdot \frac{q_1 q_2}{r^2}$$

where q_1 , q_2 are charges, and r is the distance between the charges.

$\in_o$ is the permittivity of free space

$\in_o = 8.85 \times 10^{-12}\ C^2\ N^{-1}\ m^{-2}$.

1. Electric field due to point charge

The region in which a charged body can experience a force is called the **electric field.** Let P be a point in vacuum at a distance r from a point charge q kept at O. Let a unit positive charge be placed at P. The force between the two charges is given by

$$F = \frac{1}{4\pi\varepsilon_0} \times \frac{q \times 1}{r^2}$$

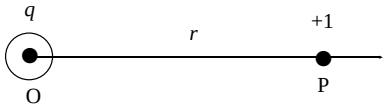


Fig. 4.3 Electric field

Electric field (E) at a point due to a point charge is defined as the force experienced by a unit positive charge placed at the point.

$$E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2}$$

The direction of E is along the line joining the points O and P pointing outward. Electric field is a vector quantity. If charge $-q$ is placed at O, then the direction of E is inward. The unit of electric field is newton per coulomb (NC^{-1}).

2. Electric lines of force

If we place a small positive charge in an electric field it will experience a force and tend to move in a fixed direction. Electric line of force is defined as the path along which a unit positive charge would tend to move in an electric field.

The lines of force due to different systems of charge are illustrated in figure.

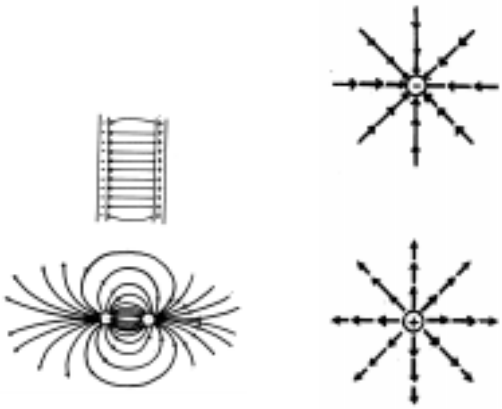


Fig. 4.4 Electric lines of force

Properties of electric lines of force.

(1) They originate from a positive charge and terminate on a negative charge.

(2) The tangent to the line of force at any point gives the direction of the electric field E at that point.

(3) Lines of force never intersect.

(4) The number of lines of force per unit area at right angles to the lines is proportional to the field strength.

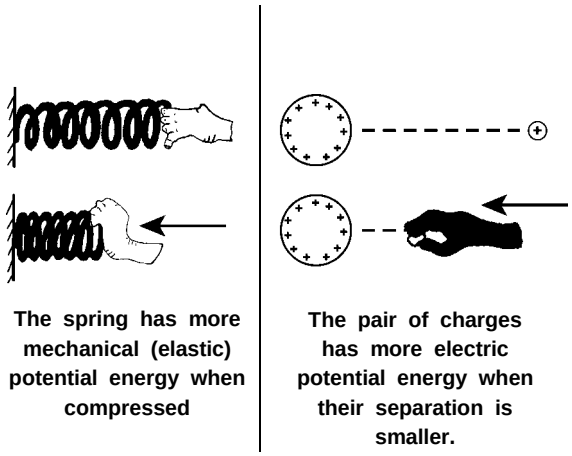
(5) A line of force is always normal to the surface of the conductor.

(6) The lines of force do not pass into a closed conductor.

3. Electric potential

We use electrical energy in our daily life to do work. If this energy is stored as potential energy, it can be used whenever it is required.

When a charge is moved toward a like charge or away from an unlike charge, work is required against the electric forces. This is like doing work in compressing and stretching



The spring has more mechanical (elastic) potential energy when compressed

The pair of charges has more electric potential energy when their separation is smaller.

Fig. 4.5 Work is done aganist the electric force, which is stored as electric potential energy.

electrical "springs". As a result the electrical charges have potential energy. The unit of electric potential is volt (V). We commonly speak of electric potentials in terms of voltages. The volt is named in honour of Alessandro Volta (1745 - 1897) an Italian scientist who invented one of the first batteries.

Electric potential at a point is defined as the amount of work done in moving a unit positive charge from infinity to that point against the electric field.

The electric potential at a distance r from a point charge q is given by

$$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r}$$

The potential at a point is one volt if the amount of work done in bringing one coulomb positive charge from infinity to that point is one joule.

The potential difference between two points in an electric field is equal to the amount of work done in moving a unit positive charge from one point to the other against the field.

Electric potential is measured at a point but potential difference is difference of potentials at two points. Potential and potential difference are expressed in the same unit, volt.

4. Relation between electric potential and electric field

Consider two points separated by a distance *d*. Let the potential difference between the two points be V, then the electric field (E) between the two points is given by

$$E = \frac{V}{d}$$

The electric field can be expressed in Vm^{-1}. Electric field is a vector whereas potential is a scalar.

5. Electric current

In a metallic conductor there are a number of free electrons which are in random motion. If the ends of a metallic wire are subjected to a potential difference by connecting the wire to a battery, there will be a net flow of electrons through the wire. An electric current is defined as the flow of charge from higher potential to a lower potential.

The temperature difference is responsible for flow of heat. The difference in levels between two vessels is the deciding factor for flow of water. Similarly the potential difference determines the flow of electrons. The current flowing through a conductor is the rate of flow of charge through any cross section of it. If a charge *q* passes through any cross section of the wire in a time '*t*' the current flowing through the wire I is given by the relation

$$I = \frac{q}{t}$$

The unit of current is ampere (A).

One ampere is defined as the current which flows through a conductor when one coulomb of charge flows through the conductor in one second.

4.2. Ohm's law

George Simon Ohm a German physicist established an important relation between current and potential difference known as Ohm's law. According to this law the steady current flowing through a conductor is directly proportional to the potential difference between its ends, provided the temperature remains constant.

If I is the current passing through conductor and V is the potential difference between the ends of the conductor

$$V \propto I \quad \text{(or)} \quad V = IR$$

where R is a constant known as the electrical resistance of the conductor. The unit of resistance is ohm. The symbol for ohm is Ω.

One ohm is defined as the resistance of a conductor through which one ampere current flows when a potential difference of one volt is maintained between its two ends.

1. Verification of ohm's law

A fixed resistance, a key, a battery, an ammeter and a variable resistance are joined in series as shown in Fig. A voltmeter is

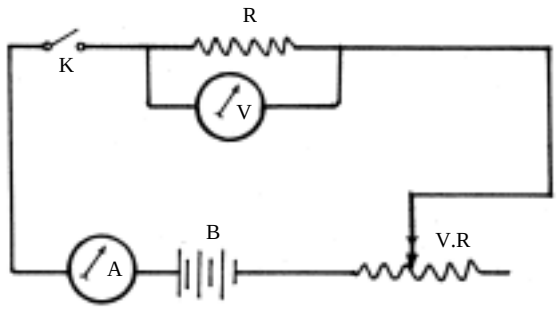


Fig. 4.6 Verification of ohm's law

K-Key V-Voltmeter R-Fixed resistance
A-Ammeter B-Battery V.R. - Variable resistance

connected in parallel with the fixed resistance. Ammeter is used to measure the current in the circuit and the voltmeter is used to measure the potential difference between the two ends of the fixed resistance.

After making the connections the key is pressed and the current flows in the circuit. A set of voltmeter and ammeter readings is taken. The experiment is repeated by changing the current in the circuit and the readings are tabulated.

Table 4.1 Verification of Ohm's law

S.No.	Voltmeter reading (V)	Ammeter reading (I)	$R = \frac{V}{I}$
1.			
2.			
3.			

The ratio of potential difference to current in each case is found to be the same.

$$\text{i.e., } \frac{V}{I} = R = \text{constant}$$

This verifies Ohm's law.

Ohm's law is obeyed by many conductors over a wide range of V and I. The plot of

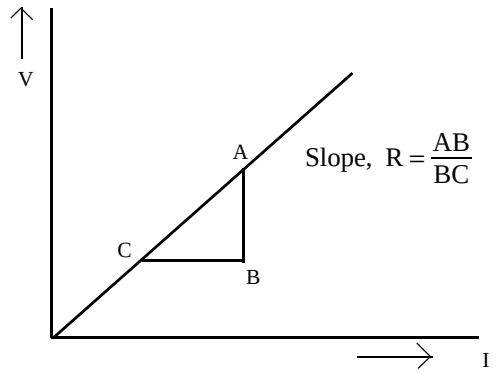


Fig. 4.7 Ohm's law

V against I is a straight line. The slope of the line gives the resistance of the conductor.

Limitations of Ohm's law

(i) Only small current should be allowed to flow through the circuit so that the temperature remains constant.

(ii) The conductor should not be subjected to any kind of stress, strain or tension.

2. Resistance

Motion is generally accompanied by frictional resistance between objects. Similarly, when there is a flow of charge, there is electrical resistance. This opposition to flow of charge arises from collisions between electrons and ions of a material.

The resistance (R) of a metal wire is directly proportional to the length (L) and inversely proportional to the cross-sectional area A.

$$R = \rho \frac{L}{A}$$

where ρ is a constant called the specific resistance which depends on the material used. The unit of specific resistance is ohm-metre. The above relation shows that the resistance of thick wire is less than that of a thin wire and the resistance is greater if the length is greater.

3. Combination of resistances

We know that, a sustained flow of current requires a complete path and a voltage source. When there is a break in the path, it is called an open circuit. Switches are used to open or close a circuit. There are two basic types of connections, namely series and parallel connections. Each has different voltage and current characteristics and different applications.

(i) Series circuit :

When conductors having resistances R_1, R_2 and R_3 are connected end to end they are said to be connected in series. In this case, the current flowing through all the resistances is the same.

Let the potential difference between the points A and B be V_1, the potential difference between B and C be V_2 and that between C and D be V_3. If V is the total potential difference between the points A and D and I is the current flowing in the circuit, by ohm's law, we have

$$V = IR \qquad \ldots (1)$$

where R is the equivalent resistance of the combination

$$V_1 = IR_1 \; ; \quad V_2 = IR_2 \; ; \quad V_3 = IR_3$$

But $V = V_1 + V_2 + V_3$ ... (2)

i.e., $IR = IR_1 + IR_2 + IR_3$

(or) $R = R_1 + R_2 + R_3$ ... (3)

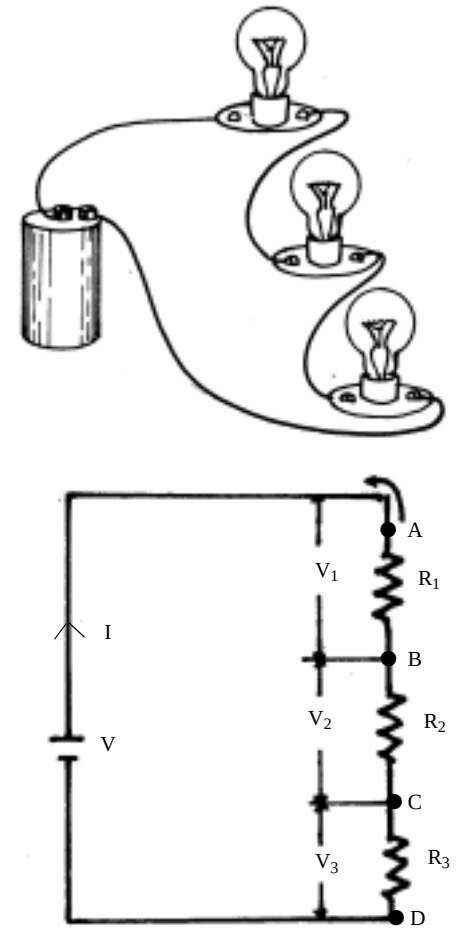


Fig. 4.8(a)

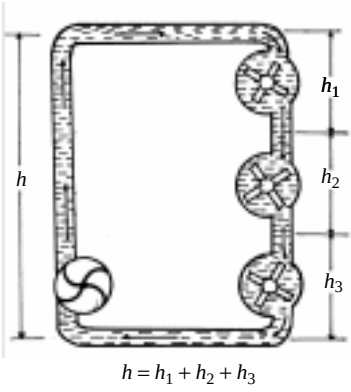


Fig. 4.8 (b) A liquid circuit with paddle wheels (resistances) in series. Compare with the electrical circuit 4.8(a)

Hence the effective resistance of a number of resistances in series is equal to the sum of the individual resistances.

(ii) Parallel circuit

If a number of resistances are joined such that one end of each resistance is connected to one common point while other ends of the resistances to another common

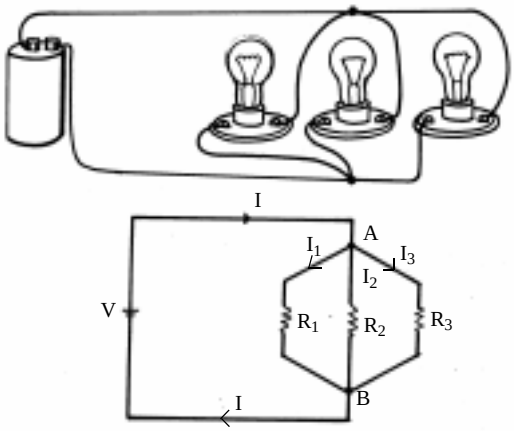


Fig. 4.9 (a)

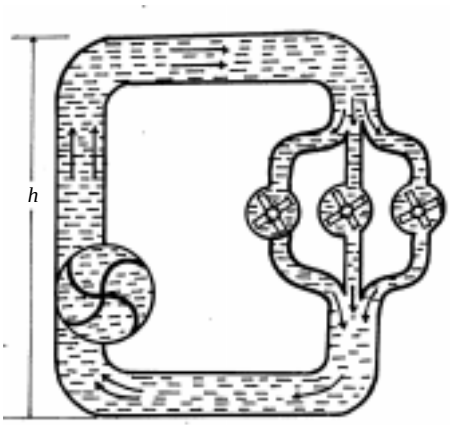


Fig. 4.9 (b) A liquid circuit with paddle wheels (resistances) in parallel. Compare with the electrical circuit 4.9(a)

point, the resistances are said to be connected in parallel. In this circuit current is different in each resistance while the potential difference across all resistances is the same. Three resistance R_1, R_2 and R_3 connected in parallel are shown.

The total current (I) flowing in the circuit is the sum of the individual currents I_1, I_2 and I_3 in each resistance. If V is the potential difference between A and B, by ohm's law, we have

$$I = \frac{V}{R} \quad \text{... (4)}$$

where R is the effective resistance of the combination

$$I_1 = \frac{V}{R_1}; \quad I_2 = \frac{V}{R_2}; \quad I_3 = \frac{V}{R_3}$$

$$I = I_1 + I_2 + I_3, \qquad \text{... (5)}$$

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

(or) $$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \qquad \text{... (6)}$$

Hence, in a parallel circuit, the reciprocal of the effective resistance is equal to the sum of the reciprocals of the individual resistances.

Problem : Calculate the effective resistance of three resistors 1Ω, 2Ω and 3Ω connected in series.

$$R = R_1 + R_2 + R_3$$
$$= 1 + 2 + 3$$
$$R = 6\ \Omega$$

The effective resistance (6 Ω) is greater than the highest value of resistance (3 Ω) in the circuit.

Problem : Calculate the effective resistance of three resistors 2 Ω, 4 Ω and 6 Ω connected in parallel.

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R} = \frac{1}{2} + \frac{1}{4} + \frac{1}{6}$$

$$= \frac{6+3+2}{12} = \frac{11}{12}$$

$$\therefore R = \frac{12}{11}\Omega$$

The effective resistance $\left(\frac{12}{11}\Omega\right)$ is less than the least value (2 Ω) of resistance in the circuit.

4.3. Heating effect of current

A conductor is heated up when an electric current flows through it. When a steady flow of current is maintained through a conductor, the energy liberated is converted into heat. The heat produced per second by a current in a wire is a measure of the energy which it liberates in one second. As the free electrons move through the metal, they collide frequently with atoms on their way and the kinetic energy of vibration of the metal atoms is converted into heat energy. This heating effect is desirable in some cases such as electric heater and electric iron. This effect is undesirable in many other cases such as generators and transformers.

1. Joule's law of heating

Joule found that the heat (H) developed in a conductor carrying current is directly proportional to the square of the current (I^2) passing through the conductor, the resistance (R) of the conductor and the time of flow (*t*) of current

$$H = I^2\ Rt$$

This relation is called Joule's law of heating.

2. Applications of heating effect of current

(i) Electric heaters

The electric kettle, the electric iron and the electric oven are some of the household appliances which utilise the heating effect of electric current. In all these devices, the heating coils are made up of the strips of a special alloy of nickel and chromium called nichrome. This alloy has a high specific resistance and can be heated to very high temperatures without oxidation of the element. The resistance coils are wound on refractory materials like asbestos, fireclay, porcelain or mica to prevent heat flowing out of the devices.

(ii) Electric filament lamp

The electric filament lamp consists of a fine filament of **platinum** or **carbon** placed inside a glass bulb and heated to incandescence by an electric current. On account of the low melting point and the brittle nature, the platinum filament was later replaced by filaments of carbon. The carbon filament lamp was invented almost at the sametime by Edison in America and Swan in England. To prevent the filament

from burning away it was enclosed in an evacuated glass bulb. As carbon tends to melt and evaporate at temperatures above 1800^{o} C and the power consumption of the lamp is high, carbon filaments are replaced by filaments of osmium, tantalum and tungsten. In the vacuum type lamp, the tungsten filament is arranged in a zig zag manner inside an evacuated glass bulb.

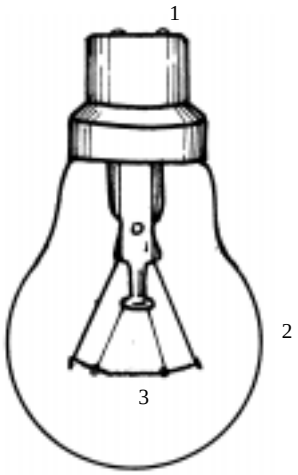


Fig. 4.10 Electric filament lamp

1. Leads 2. Glass bulb 3. Filament

The leads of the filament lamp are made of an alloy of iron and nickel which has the same coefficient of expansion as glass. This is used to prevent breakage of the bulb at high temperature. In all electric filament lamps only about 5% of the electrical energy is converted into light and the rest is wasted as heat.

The presence of inert gases like argon, neon or nitrogen inside the bulb retards the evaporation of the filament and makes it possible to operate it at higher temperatures than in vacuum. As the intensity of light from gas filled lamps is very high, they are in use for street lighting. The life of an electric lamp is about 1000 hours. Any variation in the thickness of the filament reduces the life of the bulb considerably.

3. Electric power

The power of an electric circuit is the rate at which electrical energy is expended in the circuit. When an electric current I flows for a time *t* through a conductor having a potential difference V, then the work done (W) is given by

$$W = VIt \qquad \ldots (1)$$

Electric power is the rate of doing work and hence the power

$$P = \frac{\text{work done}}{\text{time}} = \frac{W}{t}$$

$$\therefore \; P = \frac{VIt}{t}$$

$$\text{or} \quad P = VI \qquad \ldots (2)$$

The unit of electric power is watt (W)

$$\text{watt} = \frac{\text{joule}}{\text{second}}.$$

The practical unit of power is 1 kilowatt (kW) which is equal to 1000 W.

4. Electric energy

The practical unit of work or energy is joule (J).

If an electric circuit of power 1 watt consumes electricity for an hour, the total energy consumed is known as 1 watt-hour.

$$1 \text{ watt-hour} = 1 \text{ watt} \times 1 \text{ hour}$$

$$= 1 \text{ joule/sec.} \times 3600 \text{ sec.}$$

$$= 3600 \text{ joules}$$

$$= 3.6 \times 10^{3} \text{ J}$$

The amount of energy consumed in 1 hour by an electric circuit of power 1 kilowatt is known as 1 kilowatt - hour (kWh).

$$1 \text{ kWh} = 1000 \text{ watt} \times 1 \text{ hour}$$

$$= 3.6 \times 10^{6} \text{ J}$$

Sometimes Horse Power is also used as the unit of electric power.

1 horse power (H.P.) = 746 watts.

1 kilowatt = 1.341 H.P.

The commercial unit of electric energy is kilowatt hour.

The common house-hold appliances and the electric power consumed by them are shown in the table 4.2 :

Table 4.2 Electric power of some appliances.

Device	Normal power consumed (Watts)
Filament lamp	40 - 100
Electric iron	1000
Electric heater	1500
Wet grinder	1000
Mixie	800
Refrigerator	500
Television	100
Electric Oven	600
Electric Motor	700
Air Conditioner	1500

Problem : An electric installation consists of five 60 watt lamps. Find the cost of working the installation for a month at 5 hours a day, if the cost of energy is Rs. 2.00 per unit.

Energy consumed by each lamp in 1 hour = 60 W

Energy consumed by each lamp in 30 days at 5 hours / day $= 60 \times 5 \times 30$

$= 9000$ Watt-hours

Total energy consumed by 5 lamps

$= 9000 \times 5$ Watt-hours

$= \frac{9000 \times 5}{1000}$ K.W.h.

$= 45$ k.W.h.

$= 45$ unit

Total cost of energy $= 45 \times 2.00$

$= 90$

$=$ Rs. 90.00

Problem : Calculate the cost of using a 1000 W heater for a month at the rate of 1 hour per day. The cost of one unit is Rs. 4.

Electrical energy consumed per day

$= 1000 \times 1$ watt-hour

$= 1$ kilowatt hour $= 1$ unit

$\therefore$ Energy spent in one month

$= 1 \times 30$

$= 30$ units

$\therefore$ Cost of the energy $= 30 \times 4$

$=$ Rs. 120

4.4. Chemical effect of electric current

1. Electrolysis

When an electric current is passed through a metal wire, there will be no visible change except a slight heating of the wire. But, when the current is passed through aqueous or molten solutions of inorganic acids, bases and salts, the conduction of electricity is always accompanied by chemical decomposition of the substances. Such substances are called electrolytes and the phenomenon of the conduction of electricity through electrolytes is called electrolysis.

In electrolytic conduction, the conductors by which the current enters and leaves the electrolyte are called electrodes. That electrode by which the current enters the electrolyte is called the anode and that by which it leaves the electrolyte is called the cathode. The products obtained by the decomposition of the electrolyte by the electric current appear at the electrodes. All substances that appear at the cathode are said to be electropositive and all those which appear at the anode are said to be electronegative. The chemical actions that occur in the electrolyte during the conduction of electricity depend on the nature of the electrolyte.

2. Faraday's laws of electrolysis

The factors affecting the quantities of matter liberated or dissolved in electrolysis were investigated by Faraday and can be summarized in the following laws.

First law : *When an electric current causes electrolysis, the mass of any substance liberated or dissolved is proportional to the total electric charge that passes.*

If M is the mass liberated or dissolved, Q is the total charge passing and I is the current passed for *t* seconds,

$$M = ZI\ t \qquad \ldots (1)$$

where Z is constant for any given substance and is called as its electrochemical equivalent (E.C.E.)

The **electrochemical equivalent** of a substance may be defined as the mass of the substance deposited at the electrode, when one ampere of current is passed through the electrolyte for one second.

Second law : *The masses of different substances liberated or dissolved by the passage of the same electric charge are in the ratio of their electrochemical equivalents.*

If M_1 and M_2 are the masses and Z_1 and Z_2 are the electrochemical equivalents, then

$$\frac{M_1}{M_2} = \frac{Z_1}{Z_2} \qquad \ldots (2)$$

3. Applications of electrolysis

(1) Extraction of metals

In metallurgy, the most important application of electrolysis is the extraction of metals like aluminium and magnesium. Aluminium is now cheaply obtained by electrolysing bauxite (Al_2O_3) dissolved in a molten cryolite. Magnesium is prepared by the electrolysis of fused potassium and magnesium chlorides. Other metals extracted by the electrolytic process include copper, sodium, potassium and calcium.

(2) Production of Chemicals

Many valuable chemicals of commercial importance are nowadays prepared by the electrolytic method. Caustic soda, potassium chlorate and sodium hypochlorite are few examples.

(3) Refining of metals

Copper, used for electrical work, should be as pure as possible and even a small percentage of impurity produces a large increase in its resistance. Copper is purified electrolytically by making the crude metal as the anode and using a thin sheet of pure copper as the cathode. The electrolyte is copper sulphate solution. Electrolytic copper is claimed to be 99.99% pure. Gold, zinc, nickel and lead are other metals refined by electrolytic method.

(4) Electroplating

Electroplating is the process by which a thin coating of any desired metal can be deposited on another metallic object.

Some metals like iron rust very quickly under the influence of air and water and they

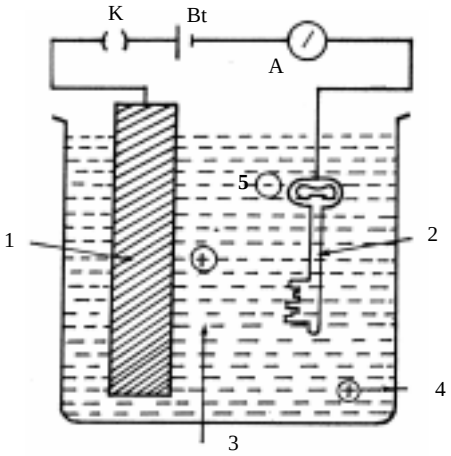


Fig. 4.11 Electroplating

1. Copper anode 2. Cathode (object) 3. $CuSO_4$ solution
4. Copper ion 5. Sulphate ion
A-Ammeter, K - Key, Bt - Battery

can be protected by coating them with a fine layer of a metal like tin, zinc, cadmium, nickel or chromium. This protective coating invariably improves the appearance also. The article to be electroplated is carefully cleaned to remove all traces of grease and rust. It is then suspended in a suitable electrolyte to act as the cathode. Cheap ornaments or metals are gold-plated or silver-plated to make them attractive.

Consider the copper plating of an object. Copper sulphate solution is taken as electrolyte and the object to be copper plated is taken as the cathode. The anode is a pure copper rod. When electric current is allowed to pass through the electrolyte, copper ions (+) are transported to the cathode and the metallic object is copper plated.

$$CuSO_4 \longrightarrow Cu^{+} + SO_4^{-}$$

Table 4.3 The details of some common electroplating baths.

Purpose	Anode	Electrolyte
Silver plating	Silver	Silver cyanide dissolved in excess of potassium cyanide.
Gold plating	Gold	Gold cyanide dissolved in excess of potassium cyanide.
Nickel plating	Nickel	Solution of nickel ammonium sulphate and ammonium sulphate.
Chromium plating	Chromium or lead	Solution of chromic acid, chromic sulphate and chromic carbonate.

The so called **Ever silver** articles are made by electroplating the iron articles first with nickel and then with silver. So, they are also known as electroplated nickel silver (E.P.N.S.) articles.

4. Electrochemical cells

The cells in which the electrical energy is derived from the chemical action are called electrochemical cells.

(i) Dry cell

This is a modified form of the Lachlanche cell. It consists of a cylinder of thin zinc sheet

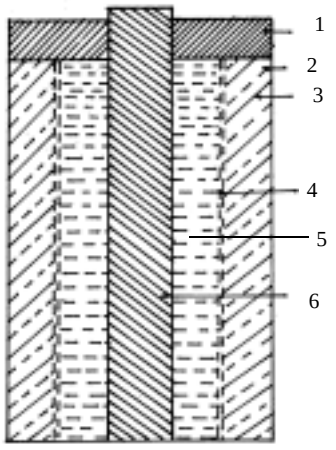


Fig. 4.12 Dry Cell

1. Pitch 2. Zinc 3. Ammonium chloride paste 4. Porrus sheet 5. Carbon-MnO_2 paste 6. Carbon rod

covered all round by card board casing and sealed with pitch. This serves as the negative electrode. The carbon rod through the centre is the positive electrode. The electrolyte is in the form of a paste of ammonium chloride and zinc chloride. A hard paste of carbon, manganese dioxide, zinc chloride, ammonium chloride and water surrounds the carbon rod.

The contents are kept intact by a layer of hardened pitch which is provided with a hole for the escape of the gases produced. The e.m.f. of the cell is the same as that of the Lechlanche cell but its internal resistance is much smaller.

(ii) Advantages of dry cell

(1) Its internal resistance is very low.

(2) It is easily portable. It can be easily handled and used in any place and time.

(3) It is available in different sizes.

(4) It is available with different voltages.

(5) It is widely used in torches, telephone, transistor sets etc.

(iii) Types of cells

Primary Cells : The electrochemical cells which make use of irreversible chemical reactions are called primary cells. Drycell, Lechlanche cell and Daniel cell are some examples.

Secondary Cells : The electro- chemical cells which make use of reversible reactions are called secondary cells. Lead acid accumulator and Nickel-cadium cell are some examples.

Table 4.4 Some important cells and their features

Cell	Anode	Cathode	Electrolyte	e.m.f.
Daniel	Copper	Zinc	dil. H_2SO_4	1.1 V
Lechlanche	Carbon	Zinc	NH_4Cl	1.5 V
Drycell	Carbon	Zinc	$NH_4Cl + ZnCl_2$	1.5 V
Mercury Cell	Zinc	Mercuric Oxide + graphite	KOH	1.4 V
Lead acid accumulator	PbO_2	Pb	dil. H_2SO_4	2.1 V
H–O fuel cell	Porous nickel	Porous nickel	KOH	1.0 V

4.5 Magnetic effect of electric current

In 1820 Oersted discovered that a pivoted magnetic needle placed under a current carrying conductor was deflected from its usual north-south setting. This result indicates that an electric current is capable of producing magnetic field. The experiment is of historic importance since it revealed the ultimate connection between magnetism and electricity. Reversing the direction of current reverses the direction of deflection of the magnetic needle.

1. Direction of magnetic field

The direction of the magnetic field due to a current carrying conductor is given by two important rules.

(i) Ampere's swimming rule

If a man swims in the direction of the current with his face towards the magnetic needle, then the north pole of the needle will be deflected towards his left hand.

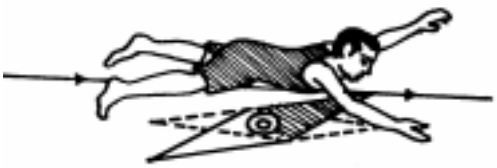


Fig. 4.13 Ampere's swimming rule

(ii) Maxwell's corkscrew rule

If a right handed cork screw is rotated so as to advance in the direction of the current,

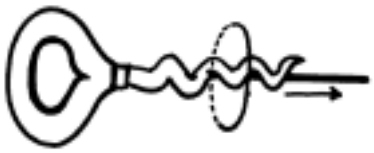


Fig. 4.14 Maxwell's corkscrew rule

then the direction of rotation of the screw gives the direction of the magnetic lines of force.

2. Magnetic field due to a straight conductor carrying current :

Activity : A thick straight insulated copper wire is passed vertically through a smooth cardboard held horizontally. Fine iron filings are sprinkled uniformly on the cardboard. A strong current is passed through the wire and the cardboard is tapped gently. Observe that the iron filings are arranged themselves in concentric circles around the wire.

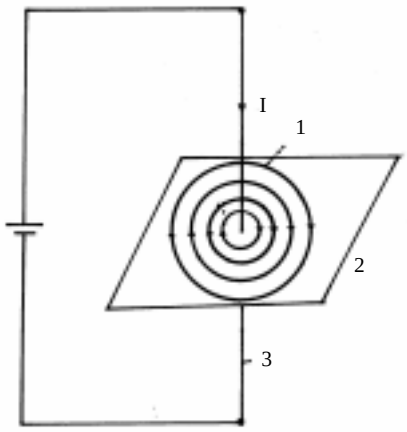


Fig. 4.15 Magnetic field due to a straight conductor carrying current

1. Iron filings 2. Cardboard 3. Conductor

These circles represent the magnetic lines of force due to the current carrying conductor. The direction of the lines of force shown in the fig. is in accordance with Maxwell's corkscrew rule.

3. Magnetic field due to a circular coil carrying current

A thick long wire is bent and its two ends are passed through a thin cardboard and

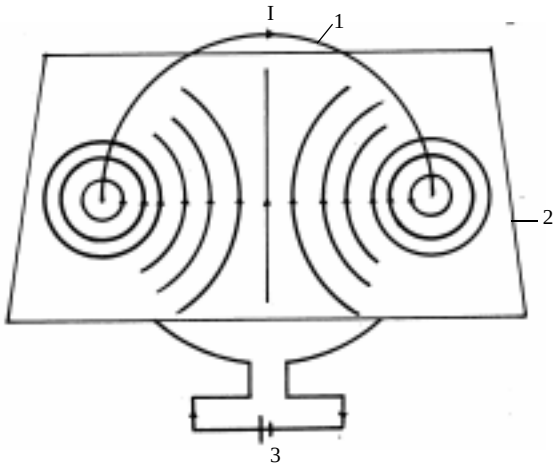


Fig. 4.16 Magnetic field due to a circular coil carrying current

1. Wire 2. Cardboard 3. Battery

a circular coil is formed. The coil is connected to a battery. Iron filings are sprinkled on the cardboard. The current is switched on and the cardboard is tapped gently. It is found that the iron filings arrange themselves in a pattern as shown in fig. The following observations are made in this experiment.

(1) There are concentric circles near the wire. The circles straighten themselves as their distance from the wire increases.

(2) The line is straight at the centre of the coil.

(3) The lines are perpendicular to the plane of the coil.

4. Magnetic field due to a solenoid carrying current

A solenoid is a cylindrical coil of wire. When a current flows in it, the solenoid behaves like a bar magnet. One end of the solenoid acts as north pole and the other as the south pole.

The magnetic flux pattern of the solenoid is the same as that of a bar magnet. The magnetic field is different at different points along the axis of the solenoid.

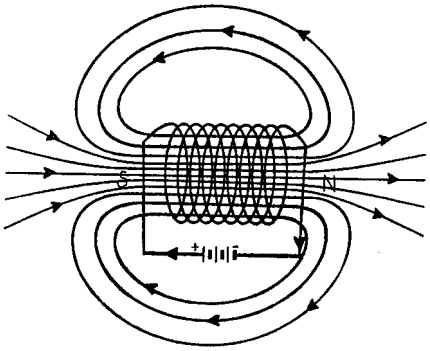


Fig. 4.17 Magnetic field lines through and around a solenoid carrying current

4.6 Applications of magnetic effects of current

The magnetic effect of electric current is applied to **many devices** such as electromagnets, microphone.

1. Electromagnets :

Electromagnets possess many special properties.

(1) The strength of the electromagnets can be increased by increasing the current in the coil.

(2) The strength of the electromagnets can be increased by introducing a soft iron core inside the coil.

(3) They are very strong temporary magnets.

(4) As soon as the current is switched off, the electromagnets become demagnetised.

(5) Electromagnets can be made in different shapes and sizes according to the requirements.

Due to their remarkable properties electromagnets find wide applications.

(1) They are used in motors.

(2) Electric bells make use of electromagnets.

(3) Telegraph and telephones make use of them.

(4) Electromagnets are used for separating iron and steel from other materials.

(5) For lifting and carrying heavy steel and cast iron articles, electromagnets are used.

2. Microphone :

Microphone is a device which converts sound energy into electrical energy. A microphone consists of a diaphragm with a light coil of wire attached to it. The coil is placed in a strong magnetic field due to a cylindrical pot magnet. The input to a microphone is a sound wave which causes the diaphragm to vibrate.

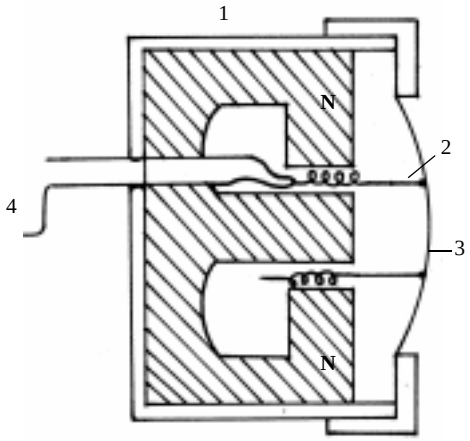


Fig. 4.18 Microphone

1. Potmagnet 2. Coil 3. Diaphragm 4. Amplifier

As the coil vibrates in the magnetic field, a varying e.m.f. is induced in it due to electromagnetic induction. This varying e.m.f. is the output of a microphone. Thus sound energy is converted into electrical energy.

3. Loudspeaker

This is a device used to convert electrical energy into sound energy. The working of the loudspeaker is based on the principle that when a coil carrying current is kept in a magnetic field, it experiences a mechanical force and moves.

A loudspeaker consists of a short cylindrical voice coil which is free to move in the radial magnetic field of a permanent pot magnet. The coil is attached to a cone which is made of a specially treated paper.

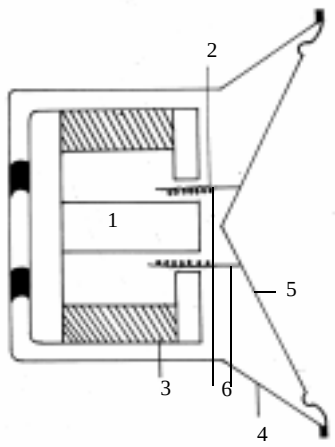


Fig. 4.19 Loudspeaker

1. Softiron core 2. Voice coil 3. Permanent magnet
4. casing 5. Paper cone 6. Amplifier

The output of a microphone is amplified and that is fed into the voice coil of the loudspeaker as the input. As current passes through the coil which is kept in a magnetic field, it experiences a mechanical force and moves. The direction of motion of the coil is given by Fleming's left hand rule.

As the current in the coil varies due to the varying e.m.f., it moves to and fro. As the paper cone is attached to the voice coil, the cone also moves along with the coil and sets the surrounding air into vibration. Thus sound is reproduced by the loudspeaker.

4.7. Mechanical effect of electric current

1. Mechanical force experienced by a current carrying conductor in a magnetic field.

It is found that when a current carrying conductor is placed in a magnetic field, it expereinces a force. This force tends to move the conductor at right angles to the direction of the field and the current. The magnitude of this force (F) depends upon the strength of the current (I), the length of the conductor (l) and the flux density of the magnetic field (B).

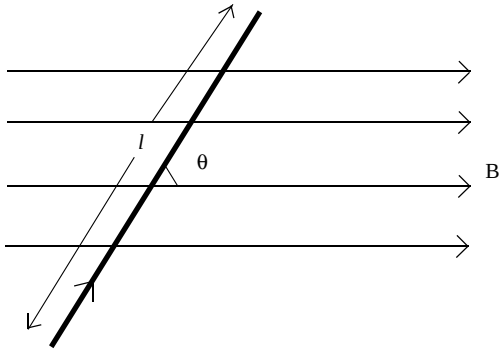


Fig. 4.20 Mechanical effect of electric current

The force experienced (F) by the conductor is given by

$$\therefore \ F = BIl \sin\theta$$

The force experienced by a current carrying conductor in a magnetic field is maximum, when it is placed perpendicular to the field and becomes zero, if it is kept parallel to the field.

2. Fleming's left hand rule :

This rule is used to find the direction of the mechanical force experienced by a current carrying conductor in a magnetic field.

The thumb, forefinger and the middle finger of the left hand are held at right angles to each other. If the forefinger points in the direction of the field and the middle finger in the direction of the current, then the thumb

will point in the direction of motion (the force) of the conductor.

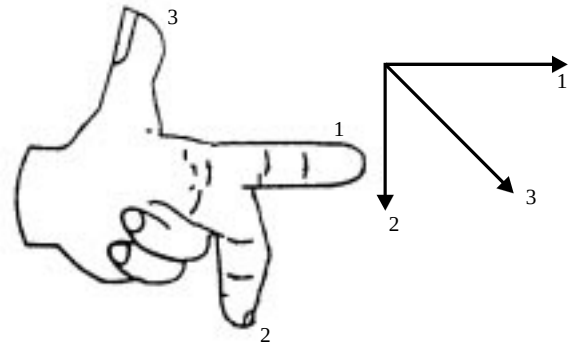


Fig. 4.21 Fleming's left hand rule

1. Forefinger (Field) 2. Middle finger (current) 3. Thumb (motion)

4.8. Electromagnetic Induction

Faraday in 1831 discovered that an e.m.f. is produced in a circuit whenever the magnetic flux linked with it changes. He showed that e.m.f. is generated in a conductor whenever there is relative motion between the conductor and a magnetic field. The e.m.f. produced in this way is called an induced e.m.f. and the phenomenon is known as electromagnetic induction. The induced e.m.f. will cause a current to flow through the conductor. Such a current is known as induced current. The discovery of the electromagnetic induction heralded a new era in the history of electrical engineering.

1. Production of induced e.m.f.

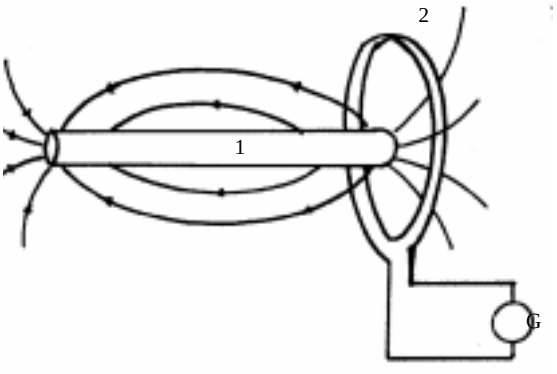


Fig. 4.22 Self induction

1. Bar magnet 2. Coil G - Galvanometer

Activity : A flat circular coil consisting of a large number of turns of thick insulated copper wire is connected to the terminals of a sensitive moving coil galvanometer (G). A long bar magnet is suddenly moved towards the coil. A momentary deflection will be observed in the galvanometer. Again on withdrawing the north pole of the magnet from the coil, there is again momentary deflection in the galvanometer, but in the opposite direction. If the experiment is repeated by reversing the magnet pole to pole, then the deflection is produced in opposite direction.

Also by moving the magnet rapidly towards or away from the coil, it will be seen that the deflection becomes greater. This shows that the induced e.m.f. and current produced in the coil depend on the rate of motion of the magnet relative to the coil. Thus e.m.f. and current can be induced in a coil using a magnetic field.

Faraday also observed that current is induced in a coil, when an electric current is switched on or off in a neighboring coil. Two coil P and S are mounted coaxially close to each other. The coil P having a few turns of

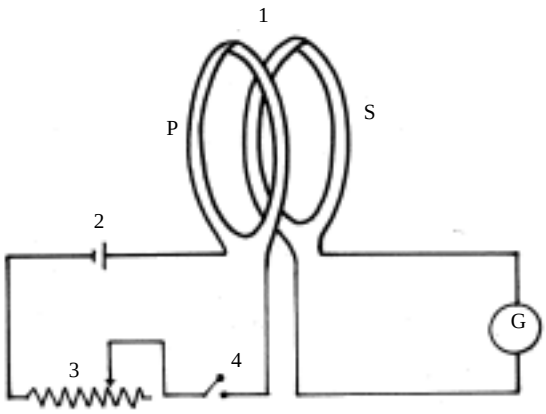


Fig. 4.23 Mutual induction

1. Pair of coils 2. Battery 3. Rhaostat 4. Key G-Galvanometer

insulated copper wire is joined with a battery, a rheostat and a key. This coil is called the primary coil. The second coil S is connected to the terminals of a sensitive moving coil galvanometer. It is called secondary coil. In establishing a current in P by closing the key a momentary deflection will be observed in the galvanometer showing the presence of an

induced current in S in a direction opposite to that of the primary current. The induced current in S exists only until the current in P has attained its steady value.

2. Laws of electromagnetic induction

The results of the simple experiments described above can be summed up into three laws which are known as the laws of electromagnetic induction.

Faraday's laws

(1) Whenever the magnetic flux linked with a closed circuit is changed, an induced e.m.f. and current are set up in the circuit. The induced e.m.f. and current last only so long as the flux change is taking place. This is known as Faraday's first law.

(2) The magnitudes of the induced e.m.f. and current are directly proportional to the rate at which the magnetic flux linked with the closed circuit is changed. This is known as Faraday's second law.

Lenz's law

(3) The directions of the induced e.m.f. and the current set up in the circuit are such as to oppose the very cause or motion which has produced them.

3. Fleming's right hand rule

The direction of the current induced in a conductor when it is moved across the lines of force in a magnetic field is given by Fleming's right hand rule.

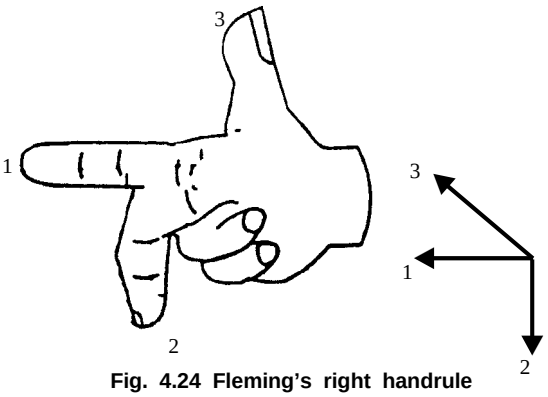


Fig. 4.24 Fleming's right handrule

1. Magnetic field (Forefinger)
2. Current induced in conductor (Middle finger)
3. Movement of conductor (Thumb)

The forefinger, middle finger and the thumb of the right hand are at right angles to each other. If the forefinger gives the direction of the magnetic field, the thumb indicates the direction of motion of the conductor, then the middle finger indicates the direction of the current.

4.9. Applications of electro-magnetic induction

The working of many devices such as generator and transformer is based on electromagnetic induction.

1. A.C. generator

A dynamo or an electric generator is a device which converts mechanical energy into electrical energy. An e.m.f. is induced in a coil of wire when it is rotated with a constant angular velocity in a magnetic field. A machine which sets up an alternating current in an external circuit is called an A.C. generator or A.C. dynamo.

An A.C. generator consists of (1) the armature, (2) the field magnet, (3) slip rings, and (4) brushes.

The armature consists of a coil of wire wound over a soft iron core built up of laminated sheets of soft iron. It is mounted on a shaft and is rotated with a constant speed in between the pole pieces of an electromagnet.

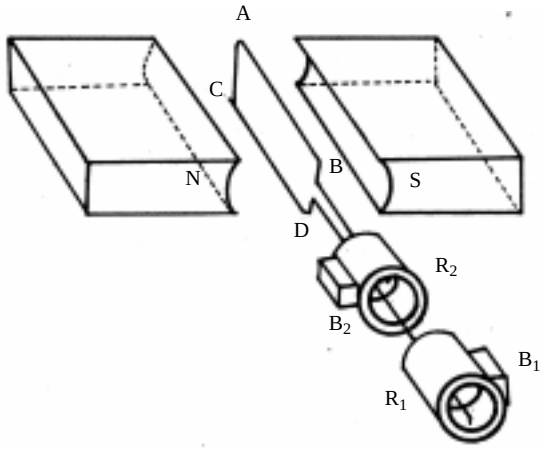


Fig. 4.25 A.C. Generator

The ends of the armature coil are connected to two copper rings R_1 and R_2 known as slip rings. When the armature is rotated the slip

rings also rotate. Two metal or carbon brushes B_1 and B_2 are arranged to press gently on the rings R_1 and R_2 and they are connected through an external circuit.

Let us assume that the plane of the armature ABCD is perpendicular to the magnetic field initially and AB is above CD. In the first half rotation of the coil AB moves downwards and CD upwards. By Fleming's right hand rule the current flows through the coil in the direction ABDC. In the external circuit B_1 is negative and B_2 is positive. In the next half rotation B_1 is positive and B_2 is negative. Thus in one complete rotation of the coil, the e.m.f. and current change the direction twice and their magnitudes vary sinusoidally. The same series of changes get repeated during successive revolutions of the coil. The variation of e.m.f. with time is shown in fig.

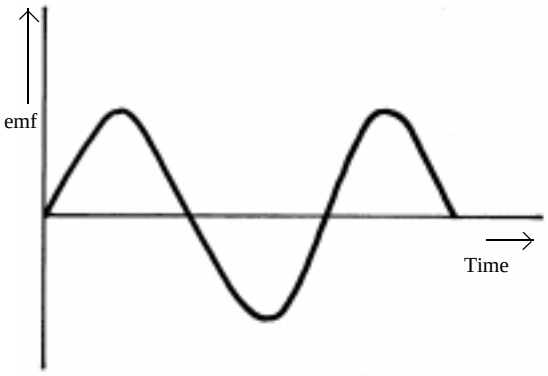


Fig. 4.26 A.C. Waveform

2. Transformer

A transformer is a device by which a low voltage in a circuit can be converted into a high voltage in a neighboring circuit or vice versa. The device is based on the principle of mutual induction between a pair of coils. It is suitable only for changing alternating voltages.

A transformer consists of two coils P and S wound separately upon a common laminated iron core CC. The coil P which is connected to the voltage to be changed is called the primary and the other coil S which delivers the altered voltage is called the secondary.

The alternating voltage V_p when applied between the ends of the primary produces an

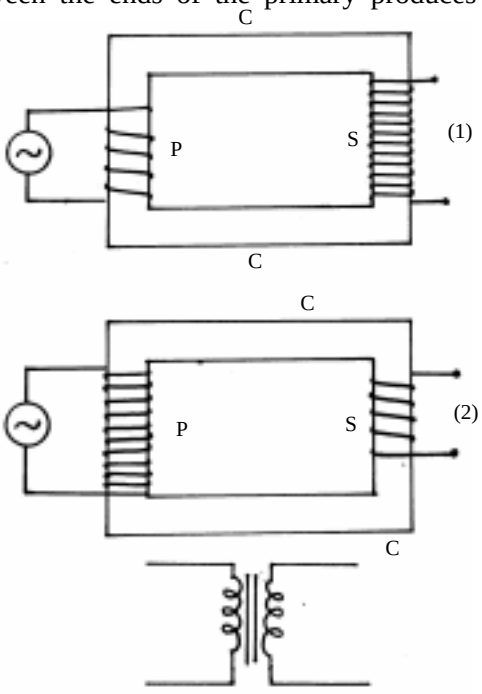


Fig. 4.27 Transformer

1. Step up transformer 2. Step down transformer

alternating current in it. This causes a varying magnetic flux in the core. Hence an A.C. voltage of the same frequency is induced in the secondary. Let it be V_s. Let the number of turns in the primary and secondary coils be n_p and n_s respectively.

$$V_p \propto n_p \; ; \quad V_s \propto n_s$$

$$\therefore \frac{V_s}{V_p} = \frac{n_s}{n_p} \qquad \ldots (1)$$

(i) In the case of the step up transformer, $V_s > V_p$ and hence $n_s > n_p$. The primary contains a few turns of thick insulated copper wire, while the secondary consists of a large number of turns of thin insulated copper wire.

(ii) In a step down transformer, $V_s < V_p$ and therefore $n_s < n_p$. The secondary has few turns of thick wire while the primary has many turns of thin wire.

If i_p and i_s are the currents in the primary and secondary of an ideal transformer, then the input power and output power are equal

$$V_s\ i_s = V_p\ i_p$$

or $$\frac{V_s}{V_p} = \frac{i_p}{i_s} = \frac{n_s}{n_p} \quad \ldots (2)$$

In practical transformers, the output power is always less than the input power due to energy losses which occur on account of the imperfection in the design.

Step up transformers are used in transmitting electric power to distant places, to operate loudspeakers in radios, to supply energy to X-ray tubes and to light neon lamps. Step down transformers are used to reduce the main voltage to ring door bells. They are used to stepdown the transmitted power voltage to 230 V. Transformers with several secondaries are used in T.V. receivers where different voltages are required.

4.10 Domestic electric circuits

We receive electric power supply in our homes through underground cables or overhead electric poles. The current produced by an A.C. generator consisting of a single coil is called a single phase A.C. The current produced by an A.C. generator consisting of three coils inclined at 120^o to one another is called a three phase A.C. Both single phase and three phase supplies are available. One of the wires in this supply, usually with red insulation cover, is called live wire. Another wire, with black insulation, is called neutral wire. Potential difference between them is 220 V in our country.

These wires pass into a watt-hour meter through a main fuse at the meter-board in the house. They are connected to the line wires through the main switch. These wires supply electricity to separate circuits within the house. 15 A high power circuit and 5A low power circuit are used separately in our houses. The earth wire, with green insulation is usually connected to a metal plate which is placed deep in the earth near the house. This is used as a safety measure, especially for those appliances with metallic body. This body is connected to the earth wire which provides a low resistance path for current. It avoids any electric shock due to leakage of current to the metallic body.

A schematic diagram of one of the common domestic circuits is given in fig. 4.28

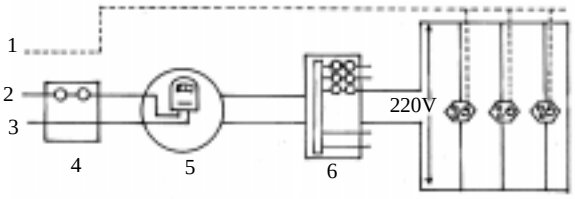


Fig. 4.28 Common Domestic circuit

1. Earth 2. Live line 3. Neutral line 4. E.B. fuse
5. Electricity metre 6. Distribution box

Different appliances can be connected across the live and neutral wires in each separate circuit. Each appliance has a separate switch. They are connected parallel to each other so that each appliance has the same voltage. It also ensures that if one switch is 'on' or 'off', others are not affected.

When too much current flows in a circuit it becomes hot and perhaps melts the insulation and starts a fire. An overload may also burn out and damage appliances. Short circuits which occur in improperly operating circuits also damage electrical appliances. Many equipments protect electrical devices and components from over currents and short circuits. **Fuses, circuit breakers,** and **safety switches** have been designed to shut-off electrical flow when a device, system or individual is **threatened** due to overload.

1. Fuses for electrical safety

A fuse is a short piece or strip of metal with a low melting point. When the current in a fused circuit exceeds the predetermined magnitude, say 15 or 20 amps, the joule heat melts the fuse strip. The fuse blows and the circuit is opened.

In some cases the insulation on wires may become worn and the bare wires touch

each other. Sometimes a high voltage wire called hot wire may touch ground. Since the path of the circuit is shortened in these two cases, they are called short circuits. Such a circuit provides a low resistance path and a large current flows in the circuit. It blows the protecting fuse and all the appliances are safeguarded.

For domestic purposes, a short lead wire of melting point 230^{o} C is commonly used. This wire fuses when the current exceeds 5 amps. For heavier currents a piece of copper wire may be used. It melts when the current exceeds 35 A.

Many useful designs of fuse have been now developed whose uses depend upon the nature of work. Three types of fuses are (i) Semi-enclosed fuse, (ii) Totally enclosed or cartridge fuse and (iii) Edison-base fuse.

In the first type of fuses the fuse element is neither kept in free air nor it is totally enclosed. For household installations mostly such fuses are used. A very short fuse wire is used in this fuse. The shorter length increases the minimum fusing current.

In the second type of fuses, the fuse element is placed in an insulating container called the cartridge. The cartridge is, in the form of a tube and its ends are enclosed with metallic caps. This type of fuse is used in all electronic instruments.

The third type in older homes is the Edison-base fuse. Its base is same as that of an ordinary light bulb. They are interchangeable in the fuse socket; for example, a 30A fuse can be placed in a 15A circuit.

The important terms in fuses are as follows.

(i) **Minimum fusing** current is defined as the minimum value of current at which the fuse wire melts.

(ii) **Current rating** of fuse wire is defined as the current which the fuse wire can normally carry without overheating or melting. It is less than the minimum fusing current.

(iii) **Fusing factor** is defined as the ratio of minimum fusing current to the current rating (safe limit) of fuse wire. It is always greater than one.

Under normal load conditions, the current flowing through the fuse wire does not produce excessive heat and hence the fuse does not

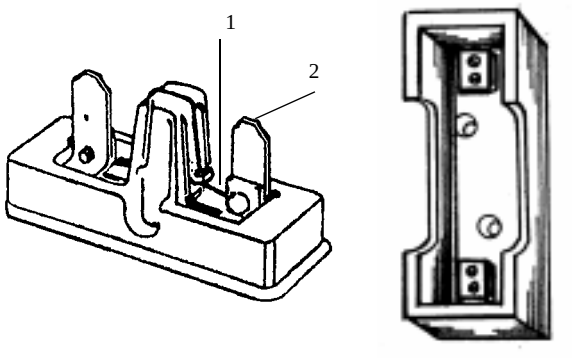


Fig. 4.29(a) Semi enclosed fuse

1. Fuse wire 2. Contact

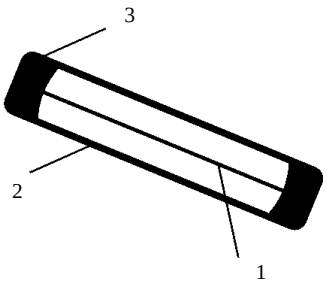


Fig. 4.29. (b) Totally enclosed fuse

1. Fuse wire 2. Glass tube 3. Contacts

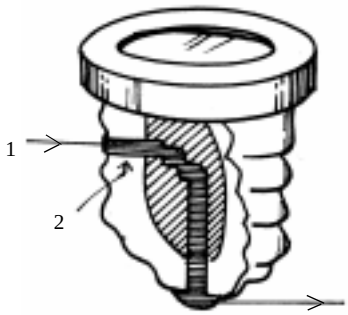


Fig. 4.29. (c) Edison-base fuse

1. Wire Carrying Current 2. Fuse ribbon

blow. If the current goes above the safe limit, the fuse wire blows.

2. Circuit breakers

Circuit breakers are used as control devices in industrial and domestic applications.

A circuit breaker carrys a rated current and opens the circuit automatically at overload. To protect electronic devices short time delayed breakers are used. Longer time delayed breakers are used to protect motors and heating devices.

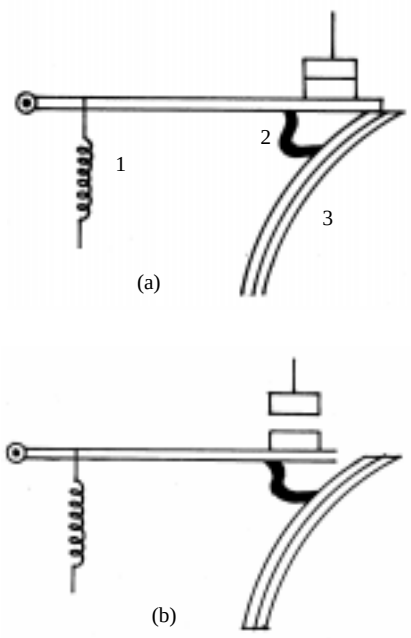


Fig. 4.30 Thermal circuit breaker

1. Spring 2. flexible conductor 3. bimetal element

There are different types of circuit breaker.

(1) Thermal circuit breaker

(2) Thermal - magnetic circuit breaker

(3) Hydraulic - magnetic circuit breaker

In a thermal circuit breaker, in the normal conditions the current flows through the switch contacts and the bimetal element. The bimetal element does not expand to switch off the circuit, when the current is below the rated value. If the current goes above the rated value, the bimetal element expands due to rise in temperature. Then it bends and the circuit gets opened. The bending of the bimetal element and the circuit breaking take place quickly for very high currents.

3. Grounding

The safety devices, switches, fuses and circuit breakers may not always protect us from electrical shock. A hot wire inside a tool or appliance may come into contact with the metal frame or housing. The wire from the winding of a motor touching the metal housing is an example for this case. If we touch the frame there can be serious results depending on the amount of current flow.

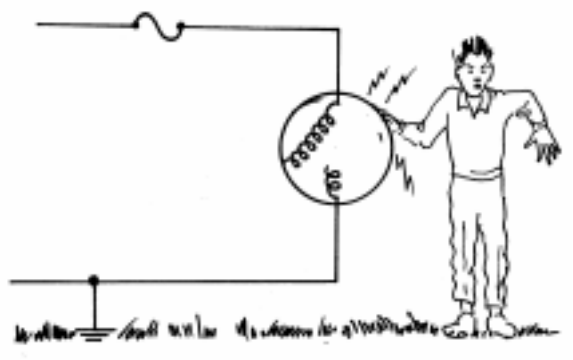


Fig. 4.31 (a) A hot wire in contact with the metal casing of a motor which is connected to ground, gives shock.

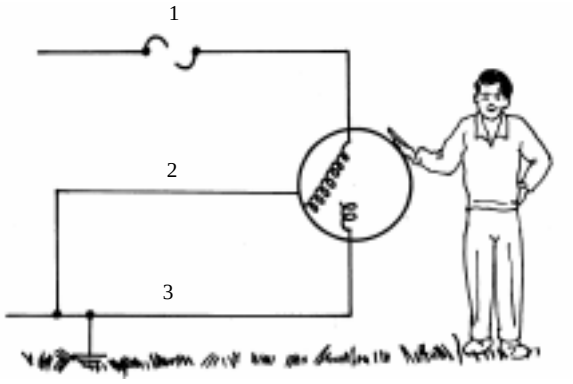


Fig. 4.31 (b) If the casing is grounded, the circuit would be completed to ground and the fuse blown there is no shock. This is the purpose of earthing prong of a three pin plug.

1. Fuse 2. Grounding wire 3. Grounded wire

To prevent this, an earthing wire is required. The circuit is then shorted to ground and the fuse in the circuit is blown. This is why many electrical appliances have three-pin plugs. The grounding pin connection runs to ground. This pin is bigger than the others. Such a three pin plug is called a polarized plug. Polarizing means a method or identification to make proper connections. The intent of this plug is as a safety feature. The small slit in the wall receptacle is the hot side and the large slit the neutral or ground side.

The housing of an electrical appliance could then be connected to the ground side always by means of the polarized plug.

If a condition such as in fig. 4.35(a) occurs, it gives a dangerous situation. If the metal casing of the motor is grounded then the circuit would be completed to ground and the fuse blown.

4. Electrocution

Personal safety in working with electricity involves common sense and a basic knowledge of electricity. We must remember mainly that we should not become part of a circuit. The current drawn by the human body depends on its resistance and the voltage source. By ohm's law, $I = \frac{V}{R_b}$, where R_b is the body resistance. A dry skin has a high resistance and current will be less in this case. An electrical shock here is only mild. If the skin is wet, the resistance may be very low and injurious and fatal current will be allowed to flow.

If we come into contact with a hot wire and if the circuit is closed through our hand a shock and burn can result. But, if the circuit is closed through the body, one may lose muscle control and find difficult to walk. This is because muscles are controlled by nerves, which are activated by electrical impulses. If the current is large, it may cause breathing difficulties and uncontrolled contraction of the heart. Death can result for currents greater than 100 mA.

Table 4.5 : The effects of electric currents on human body

Current (mA)	Effect
1	Barely perceptible
5 - 10	Mild shock
10 - 15	difficult to let go
15 - 25	Loss of muscle control
25 - 50	Breathing difficulty
50 - 100	Uncontrolled contraction of heart; breathing may stop.
> 100	death

We have to keep the following in mind : "*It is the current that kills, not the high voltage itself*".

SOLVED PROBLEMS

(1) Calculate the potential at a point due to a charge of 100 micro coulomb at a distance of 9 metres.

$q = 100\mu C = 100 \times 10^{-6} C = 10^{-4} C$

$r = 9$ m and $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ Nm}^2 \text{ C}^{-2}$

$$\text{Potential (V)} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r}$$

$$= 9 \times 10^9 \times \frac{10^{-4}}{9} = 10^5 \text{ V}$$

(2) Find the resistance of a conductor carrying a current 3 A which has a potential difference of 15 V between its two ends.

V = 15 V and I = 3A

$$\text{Resistance, } R = \frac{V}{I} = \frac{15}{3} = 5 \text{ ohm}$$

(3) Find the heat developed in a conductor of resistance 5 Ω, when a current 1 A flows through it for 30 minutes.

I = 1A, R = 5 Ω and
t = 30 min = 1800 sec.

$$\text{Heat developed (H)} = I^2Rt$$
$$= 1 \times 5 \times 1800$$
$$= 9000 \text{ joule}$$
$$H = 9\text{kJ}$$

(4) If the current flowing through a filament lamp of power 60 W is 1A, find its filament resistance.

$$P = VI = I^2R$$

$$\therefore \quad R = \frac{P}{I^2} = \frac{60}{1} = 60 \ \Omega$$

(5) In a step-up transformer the turns ratio is 5. If the input voltage is 200 V, what is its output voltage ?

$\frac{n_s}{n_p} = 5$ and $V_p = 200$ V.

$$\frac{V_s}{V_p} = \frac{n_s}{n_p} = 5$$

$$\therefore \quad V_s = 5 \times V_p = 5 \times 200 \text{ V} = 1000 \text{ V}$$

(6) A voltage of 0.10 V is applied to a copper wire whose resistance is $4.383 \times 10^{-2}\ \Omega$. Calculate the current in the wire.

$$I = \frac{V}{R} = \frac{0.1}{4.383 \times 10^{-2}} = 2.28\ A$$

(7) 2 kW stove is switched on for 6 hours. Calculate the electrical energy consumed.

$$E = P.t$$
$$= 2\ kW \times 6\ hours$$
$$E = 12\ KWh = 12\ units$$

SELF - EVALUATION

Choose the correct answer

1. The number of electric lines of force per unit area at right angles to the lines is proportional to
   (1) electric field strength
   (2) square of electric potential
   (3) permittivity of the medium
   (4) density of the medium
2. Resistance of a conductor depends on
   (1) length of the conductor only
   (2) thickness of the conductor only
   (3) material of the conductor only
   (4) both the material and the dimensions of the conductor
3. Heat developed in a conductor is
   (1) directly proportional to the current
   (2) inversely proportional to the current
   (3) directly proportional to the cubic value of current
   (4) directly proportional to the square of current
4. 1 H.P. equals
   (1) 1000 watts (2) 500 watts
   (3) 746 watts (4) 647 watts
5. Electrolytes are usually in the form of
   (1) solids (2) liquids
   (3) gases (4) plasma
6. The article to be electroplated is placed as
   (1) cathode (2) anode
   (3) cathode or anode (4) electrolyte
7. The primary cell widely used is
   (1) Lechlanche cell
   (2) Daniel cell
   (3) dry cell
   (4) lead acid accumulator
8. The direction of magnetic field due to a current element is given by
   (1) Fleming's left hand rule
   (2) Fleming's right hand rule
   (3) Faraday's first law
   (4) Ampere's swimming rule
9. Electromagnets are based on the principle of
   (1) heating effect of current
   (2) mechanical effect of current
   (3) magnetic effect of current
   (4) chemical effect of current
10. Mechanical energy is converted into electrical energy in a
    (1) loud speaker (2) microphone
    (3) generator (4) motor
11. The e.m.f. induced in a circuit is
    (1) directly proportional to the change in magnetic flux
    (2) directly proportional to the rate of change of flux
    (3) inversely proportional to the flux change
    (4) inversely proportional to the rate of flux change
12. Fleming's right and rule is used to find the direction of
    (1) mechanical force (2) induced e.m.f.
    (3) magnetic field (4) electric field
13. Slip rings are placed in a
    (1) DC generator (2) AC generator
    (3) galvanometer (4) transformer

Fill in the blanks

14. Electric field is a ..... quantity and the potential is a ..... quantity.
15. If many resistors are connected in parallel, the effective resistance of the combination is ..... than the ..... value of the resistance.
16. The alloy of nickel and chromium is called ..... .
17. A galvanometer is converted into an ammeter by connecting a ..... resistance in .....
18. The direction of the induced current is ..... to the ..... producing it.
19. ..... transformers are used along with doorbells.
20. The input power is .... the output power in an ideal transformer.

21. To get a higher value of resistance, ... connection is used.
22. Circuit breakers are used for ....., ...

Answer briefly

23. Define intensity of electric field.
24. Define electric potential.
25. What are electric lines of force ?
26. Define electric current.
27. Define specific resistance of a material
28. Define one kilo watt - hour.
29. What are electrolytes ?
30. State Maxwell's corkscrew rule.
31. State Fleming's left hand rule.
32. What is meant by electromagnetic induction ?

Answer in detail

33. Mention the properties of electric lines of force.
34. State ohm's law and explain how it can be verified.
35. Obtain expressions for the effective resistance of a combination of resistances in (i) series and (ii) parallel.
36. State and explain Joule's law of heating.
37. Explain the applications of heating effect of current.
38. Describe the electrolysis process with an example.
39. Explain how electroplating is done.
40. Explain the working of a drycell with a diagram.
41. Explain the properties and uses of electromagnets.
42. Describe the construction and working of (i) microphone (ii) loudspeaker
43. Describe Faraday's experiments on electromagnetic induction.
44. State and explain Faraday's laws and Lenz's law of electromagnetic induction.
45. Describe the construction and working of an A.C. generator.
46. Describe the construction and working of a transformer.
47. Explain the role of fuses in electrical safety.
48. Explain the role of circuit breakers in electrical safety.
49. Explain why earthing is required for electrical safety.
50. Write short notes on electrocution.

Problems

51. The potential difference across two parallel plates separated by a distance 10 cm is 10 V. Find the intensity of electric field between them. (**Ans.** 100 Vm^{-1})
52. The current passing through a resistance 2 Ω is 0.5 A. Find the potential difference between the ends of the resistance (**Ans.** 1V)
53. A conductor of length 25 cm carrying 2A current is placed in a magnetic field 3T at an angle 30^o with the field. Calculate the force acting on it. (**Ans.** 0.75 N)
54. Find the current required to develop a heat 80 J in a conductor of resistance 0.1 Ω, if it has to pass through it for 200 seconds. (**Ans.** 2A)
55. A 3 kW stove is switched on for 5 hours. Calculate the cost of using it, if the cost of energy is 3 Rs. per unit. (**Ans.** Rs. 45)
56. The primary voltage and current in an ideal transformer are 220 V and 1A. Calculate the electric power available across the secondary of it. (**Ans.** 220 W)
57. The turns ratio of a step down transformer is 1/2. If the primary current is 1A, what is its secondary current ? (**Ans.** 2A)

Activities

58. Rub a plastic spoon with a woollen cloth. Turn a water tap on gently and hold the spoon near the fine stream. What do you observe ? Explain.
59. Wind about 15 cms of thin insulated wire around an iron bolt and connect the bare ends of the wire to a battery. Bring many metal objects close to the bolt. What do you observe ? Explain.
60. Insert pieces of copper and zinc strips, into a raw potato. Hold an earphone on the wires connected to metal strips. What do you observe?

5. ATOMIC AND NUCLEAR PHYSICS

Atomic Physics is a branch of Physics which deals with the structure and the properties of atoms of elements. An atom consists of negatively charged electron revolving round the positively charged nucleus. The atomic nucleus is a cluster of charged protons and uncharged neutrons occupying a small region at the centre of the atom with a diameter of the order of 10^{-14} m. Protons and neutrons in the nucleus are called nucleons. Nuclear physics is the study of structure of nucleus and nuclear processes such as radioactivity and nuclear reactions.

In this chapter we shall study the electromagnetic waves, the radio activity and the production of nuclear energy.

5.1 Electromagnetic Radiation

Ordinary waves like ocean waves and the waves created by the wind in a flag are visible mechanical waves. Sound waves is another mechanical wave which cannot be seen. All these mechanical waves need a material medium to propagate. There are other kinds of waves known as electromagnetic waves which do not need material medium to propagate.

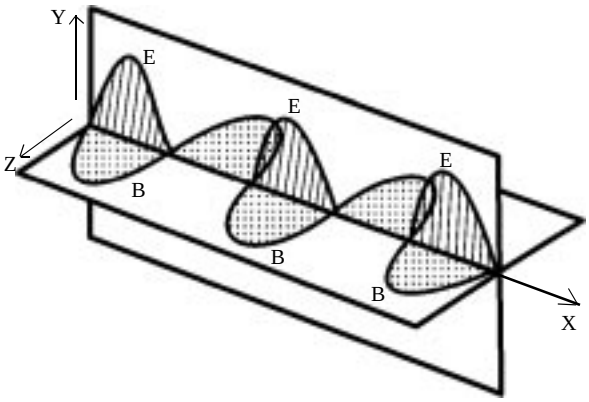


Fig. 5.1 Electromagnetic waves

E - Electric field B - Magnetic field

Electromagnetic waves consist of a magnetic field and an electric field vibrating at right angles to each other. Energy changes in atoms or electrons produce electromagnetic waves.

1. Classification of electromagnetic waves

Electromagnetic waves cover a wide range of frequencies or wave lengths. The behaviour of an electromagnetic wave is determined by its wavelength and hence it is useful to group electromagnetic waves according to their wave lengths.

Electromagnetic waves are classified into seven types, viz.,

1. Gamma rays
2. X-rays
3. Ultra violet rays
4. Visible rays
5. Infra red rays
6. Micro waves
7. Radio waves

All the electromagnetic waves have the following common properties.

(1) All electromagnetic waves travel at the same speed (3×10^8 ms^{-1}) in vacuum or through space. The speed of electromagnetic waves is given by $c = \gamma \lambda$

where γ is the frequency and λ is the wave length of electromagnetic waves.

(2) They do not need any material medium to propagate.

(3) All are transverse waves.

(4) All exhibit the basic wave properties, reflection, refraction, interference and diffraction etc.,

(5) They carry no electric charge.

(6) They transfer energy from one place to another.

(7) They can be emitted and absorbed by matter.

2. X-rays

X-rays were discovered first by W. Roentgen in the year 1895. As the nature of radiation was unknown at that time he called them X-rays. These rays are also called as Roentgen rays.

1) Production of X-rays

Principle : When fast moving electrons fall on a target of high atomic weight X-rays are produced.

A modern type of X-ray tube had been designed by Coolidge. It consists of highly evacuated (~0.0001 mm of Hg pressure) hard

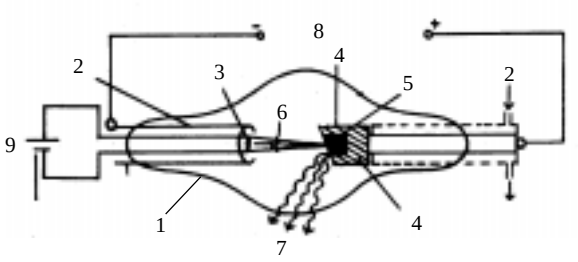


Fig. 5.2 X-ray tube

1. Highly evacuvated hard glass tube. 2. Molybdenum metallic cylinder 3. Tungsten filament (Cathode) 4. Anode 5. target 6. electrons 7. X-rays 8. High voltage device 9. Low voltage battery

glass tube containing a cathode and an anode. Molybdenum metallic cylinder (M) and tungsten filament (F) together act as cathode. The anode is a block of copper in which the target tungsten is embedded. Tungsten has high atomic weight and high melting point as well as very good electrical and thermal conductivities.

The tungsten filament F is heated by a low voltage battery (4 V) to emit electrons. These electrons are highly accelerated and focussed by Molybdenum metallic cylinder on to the anode by applying a high potential difference of about 1,00,000 V between the cathode and the anode. As the fast moving electrons strike the solid tungsten in the anode X-rays are emitted.

In order to save the target from melting it is constantly cooled by running water.

The intensity of X-rays depends on the number of electrons striking the target per second. By adjusting the filament current the intensity of X-rays can be controlled. The quality of X-rays depends on the energy of electrons. Hence the quality of X-rays can be controlled by adjusting the voltage between the cathode and anode.

2) Properties of X-rays

(1) X-rays are electromagnetic waves having a wavelength range from 10^{-9} m to 6×10^{-12} m

(2) X-rays travel with the velocity of light.

(3) X-rays are not deflected by electric and magnetic fields since they are not charged.

(4) They produce fluorescence in certain materials like Zinc Sulphide and Barium Platino-cyanide.

(5) They affect photographic plates strongly.

(6) They ionise the gases through which they pass.

(7) They can pass through substances like glass, flesh, wood etc. But they cannot pass through bones and heavy elements such as gold and lead. Bones contain large amount of calcium which is a heavy element and hence they are good absorbers of X-rays. But soft tissues of flesh contain lighter elements like hydrogen, carbon, nitrogen, oxygen and hence they are poor absorbers of X-rays. Hence X-rays can pass through flesh.

An exposure to a large dose of X-rays may cause enough destruction to produce sickness or death.

3) Applications of X-rays

X-rays play an important role in medicine, industry, scientific research and forensic Sciences.

(i) Medical Applications

(1) **Radiography :** X-ray photographs are used to detect fracture and dislocation of bones. They are used to locate the foreign body in digestive track or lungs and the bullet embedded in a limb.

(2) **Radiotheraphy :** They are used to destroy malignant tumours and cure some skin diseases.

(ii) Industrial and Scientific applications

(1) They are used to find whether a given gem is genuine or artificial.

(2) X-rays are used to detect the defects in tennis balls, rubber tyres, etc.

(3) They are used for the detection of cracks and flaws in metal castings and welded joints in machinery parts etc.

(4) The X-rays are used to study the effect of heat treatment and the formation of alloys.

(5) X-rays are used to study the structure of crystals, organic and biological molecules.

(iv) Applications in Forensic Science

X-ray examination, screening and radiographs can be used in crime detection.

(1) If a person is suspected to have swallowed jewel, the object would be revealed in a X-ray radiograph.

(2) The hidden gold, opium and explosive in a luggage can be identified using X-rays with a fluorescent screen.

(3) Very soft X-rays are used for the detection of counterfeit currency and forgery in documents.

3. Infrared Rays (IR rays)

Electromagnetic radiation with wavelengths a little longer than that of red light is called infrared radiations. This covers wavelengths from 10^{-3} m to 7.8×10^{-7} m. These waves are produced by molecules of hot bodies. Sun is the natural sources of infra red rays. Electric lamp, fire, molecules of hot bodies are the artificial sources of infra red radiations. Human body gives off IR radiation with a wavelength of 1/10 mm to 1/100 mm. The human eye cannot detect IR radiation but we can feel it on our skin as warmth.

Some snakes have specially designed sense organs which make good use of this ability. They are situated in pit on either side of their head, and they use them to 'see' a warm object, such as a mouse in the dark.

Uses of IR rays

(1) Infra-red radiations are not absorbed by air or thick fog. Hence infra-red rays are used to take photographs where visible light cannot penetrate.

(2) Infra red can penetrate deep into the human body than visible light. These IR rays enlarge blood vessels which increase the blood circulation.

(3) In physio-theraphy IR is used to releive pain from muscles and joints.

(4) They are used in the determination of molecular structure.

(5) They are used to dry newly painted and enamelled surfaces within a short time.

(6) During second world war infra-red lamps were fitted to military vehicles for night driving.

(7) As water absorbs IR radiation, satellite pictures of lakes and rivers would appear black. Hence IR radiation can be used to identify the water sources on the earth.

(8) Infra red satellite pictures of the earth are used in weather forecasting.

(9) IR satellite photos reveal diseased crops.

4. Microwaves

Shorter wave length radio waves with wavelengths from 1 mm to 10 cm are known as microwaves. Microwaves are generated by special electronic devices such as, magnetron, klystron and travelling wave tube.

Applications

(1) Telephone links between cities are achieved by microwaves.

(2) Microwaves are used in satellite communication and radar.

(3) Microwaves are used for cooking. A microwave oven produces electromagnetic waves with a wave length of about 12 cm. These waves transmit energy to cook the food.

(4) Microwaves can be used to kill insects in grain stores and also used to kill bacteria in food without heating the food so much.

(5) Microwaves are used in the field of radio astronomy..

(6) They are used to study atomic and molecular structures.

5. Radio waves

Electromagnetic waves with longest wavelengths are called radio waves. They have a wavelength range from 0.3 m to a few kilometer. Radio waves are produced by stars and galaxies. They are also produced by vibrating electrons using electronic circuits. They are used in Radio and Television communication systems.

5.2 Radioactivity

Radioactivity was discovered by Henry Becquerel in the year 1896. He found that uranium and some of its salts emit spontaneously some invisible penetrating radiations which affected the photographic plate. This phenomenon of spontaneous emission of highly penetrating radiations by heavy elements is called radio activity. The elements which emit radioactive radiations are called radioactive elements or radioelements. These radiations are called Becquerel rays or radioactive rays.

Later investigations by Madame Curie, and her husband Piere Curie, Rutherford and others showed that the phenomenon was exhibited by heavy elements of atomic weights greater than 206 like Uranium, Polonium, Radium, Thorium etc., The radio activity is not affected by physical or chemical conditions like variations of temperature or pressure.

1. Experimental study of Radioactivity

A small quantity of some radioactive material is placed at the bottom of a small hole drilled in a lead block. Lead is the best absorber of all kinds of radiations. Hence radiations in all other directions will be absorbed by lead. A photographic plate is placed at a short distance above the lead block. The whole arrangement is enclosed inside an evacuated chamber and placed in a dark room. A strong magnetic field is applied at right angles to the plane of the diagram. After a long exposure, the photographic plate is developed. Three distinct spots are found on the photographic plate.

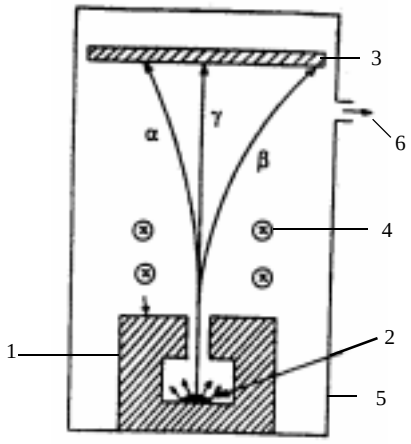


Fig. 5.3 Effect of magnetic field on radioactive rays

1. Lead block 2. Radioactive material 3. Photographic plate
4. ⊗ mark - magnetic field 5. Evacuted champer
6. To vacuum pump 7. Electric field

It is observed that the beam of radiations coming out of the hole splits into three parts. The first part which bends towards the left end is called α- particles, the second part which bends towards the right end is called β particles, while the third part which goes straight without bending is called γ-rays. By applying Fleming's left hand rule it may be seen that α- particles are positively charged, β particles are negatively charged while γ-rays are uncharged or neutral.

Distinction between γ rays and X-rays.

γ rays and X-rays are both electromagnetic radiations which differ from each other as given in table 5.2.

Table 5.2. Comparision of γ rays with X-rays.

S.No.	γ rays	X-rays
1.	γ rays are produced due to the spontaneous emission of radiation from the nucleus. (nuclear origin)	X-rays are produced due to the transition of electrons from higher to lower energy orbits of atoms (atomic origin).
2.	The wavelength of γ rays is much shorter than that of X-rays.	Shorter wavelength

Radioactive decay :

When a radioactive nucleus disintegrates by emitting α or β particles a new element is formed.

α - decay : When a radioactive nucleus disintegrates by emitting an α - particle its atomic number decreases by two and its mass number decreases by four.

$$_{z}X^{A} \xrightarrow{\alpha} {}_{z-2}Y^{A-4} + {}_{2}He^{4}$$

where Z-atomic number, A-mass number
X-parent element, Y-daughter element

$_2He^4$ – α particle.

Example : Uranium decays to thorium by α emission.

$$_{92}U^{238} \longrightarrow {}_{90}Th^{234} + {}_{2}He^{4}$$

β - decay : When a radioactive substance disintegrates by emitting a β - particle there is no change in its mass number but its atomic number increases by one.

$$_{z}X^{A} \xrightarrow{\beta} {}_{Z+1}Y^{A} + {}_{-1}e^{0}$$

Example : Radium decays to actinium by β emission.

$$_{88}Ra^{228} \longrightarrow {}_{89}Ac^{228} + {}_{-1}e^{0}$$

γ emission : When a radio active substance emits a γ-ray there is no change in both atomic number and mass number. Only the energy level of the nucleus undergoes a change.

5.3 Nuclear Fission and Nuclear fusion :

1. Nuclear fission

In 1939 Otto Hahn and Strassman in Germany bombarded uranium by neutrons. It exploded into two nearly equal fragments of lighter elements such as Barium and Krypton and enormous amount of energy. Since this process somewhat resembles fission of cells in biology this phenomenon of nuclear disintegration is called *nuclear fission.*

The process of breaking up of the nucleus of a heavy atom into two nearly equal fragments with the release of a large amount of energy is known as nuclear fission.

When uranium is bombarded with slow neutrons, the uranium nucleus becomes unstable. This unstable uranium nucleus splits into two nearly equal fragments. Two or three free neutrons are also released in this process.

$$_{92}U^{235} + {}_{0}n^{1} \longrightarrow {}_{92}U^{236}$$
$$\longrightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3\,{}_{0}n^{1} + Q$$

Here Q is the amount of energy released.

2. Energy released in Nuclear Fission

During nuclear fission enormous amount of energy is released. This energy is produced because the original mass of the nucleus is greater than the sum of the masses of the end products. The excess mass appears as energy in accordance with the Einstein's mass energy relation $E = mc^2$.

In order to calculate the energy released let us consider the above fission reaction.

Mass of $_{92}U^{235}$ nucleus = 235.045733 a.m.u.
(a.m.u means atomic mass unit)
Mass of neutron ($_0n^1$) = 1.008665 a.m.u

Total mass before fission = 236.044398 a.m.u.

Mass of barium = 140.9177 a.m.u.

Mass of krypton = 91.8854 a.m.u.

Mass of 3 neutrons (3×1.008665) = 3.025995 a.m.u.

Total mass after fission = 235.829095 a.m.u

Difference in mass = 0.2153 a.m.u

1 a.m.u. = 931 MeV

So the energy released per fission = difference in mass $\times$ 931

$= 0.2153 \times 931$

= 200.5 MeV

(MeV = Million electron volt)

Thus when one nucleus of uranium undergoes fission 200 MeV energy is released.

The energy released by the fission of one gram of uranium is 5.128×10^{23} MeV, which is equivalent to 2.26×10^4 kilowatt hour. Since large amount of energy is released in fission the nuclear energy is being used for the generation of electricity.

3. Chain Reaction :

The chain reaction is a process in which the nuclear fission of an atom induces nuclear fission in another atom which again induces fission in another atom and so on. During fission process neutrons are emitted which attack other atoms causing fission. The number of neutrons goes on multiplying rapidly during fission process till the whole of the fissionable material is disintegrated.

Let us consider the chain reaction in uranium (U^{235}). When uranium nucleus is bombarded by slow neutrons the nucleus is broken into two parts viz. Barium and Krypton. The process is accompanied by the emission of three neutrons. Nearly 200 MeV energy is released per fission. The neutrons thus produced in this process further attack other uranium

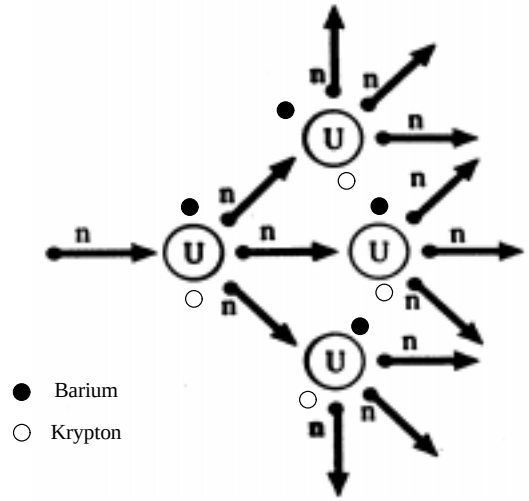


Fig. 5.7 Chain reaction

U - Uranium n - Neutron

nuclei and produce further fission. Now more number of neutrons are released and an enormous amount of energy is produced. This process continues and the series of fission reaction is called a chain reaction.

If the number of neutrons produced in a nuclear fission is not controlled a large amount of energy is released in a violent explosion within a very short interval of time. This is called uncontrolled chain reaction, which is the basic principle of atom bomb.

4. Nuclear Reactor

A nuclear reactor is a device in which nuclear fission is produced under a self sustaining controlled nuclear chain reaction.

The following are the essential components of a nuclear reactor.

(1) Fuel : The material containing fissile isotope is called reactor fuel. U^{235}, Pu^{239} and U^{233} are used as fuel in the reactor. The fuel is sealed in aluminium cylinder and kept in the form of rods. Natural uranium contains 99.28% of U^{238} and only 0.72% of fissile

U^{235}. The fissile U^{235} fuel is called enriched uranium.

(2) Moderator : The moderator is a material which is used to slow down the neutrons produced by nuclear fission. Graphite, heavy water (D_2O), Berillium and its oxides

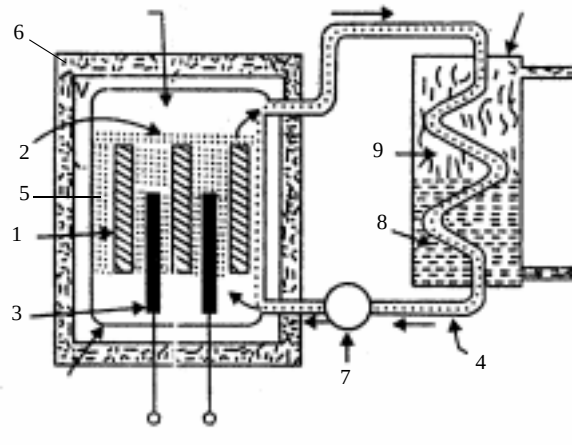


Fig. 5.8 Nuclear Reactor

1. Fuel 2. Moderator 3. Control rods 4. Coolant
5. Neutron reflector 6. Shielding 7. Pump 8. Water
9. Steam

are used as moderators. A good moderator should have high boiling point and low atomic number.

(3) Control Rods : In order to control the chain reaction, control rods are used. These rods are made up of neutron absorbing materials. Cadmium, boron or Hafnium rods are used as control rods. When the control rod is completely pushed into the fuel, the neutrons are absorbed and hence the chain reaction stops. If the rods are withdrawn stronger will be the chain reaction.

(4) Coolant : A material used to absorb the heat generated in chain reaction is called coolant. The heat carried by coolant is used to convert water into steam which in turn runs the turbines to produce electricity. Ordinary water, heavy water, air, carbon-dioxide, helium gas and liquid sodium and are used as coolants. Heavy water serves both as moderator and as coolant. A pump is provided to pump the coolant into the reactor. The coolant should have high boiling point and high specific heat

(5) Neutron reflector : Neutron reflector is a mateial surrounding the fuel and moderator. It is used to reflect the escaping neutrons back into the reactor. This minimises the leakage of neutrons.

(6) Shielding : The radiations emitted during nuclear fission reactions are very dangerous and harmful to living beings. To protect the people operating the reactor it is surrounded by thick lead lining and concrete wall of thickness about 2 to 2.5 metre.

5. Nuclear Fusion

The process of combining two or more lighter nuclei to form a heavier and stable nucleus with the release of a large amount of energy is known as nuclear fusion.

The mass of the single nucleus formed in fusion is always less than the sum of the mass of the individual light nuclei. The difference in mass is converted into energy according to Einstein's mass energy relation

$E = mc^2$.

For example when two deuterium nuclei fuse together a helium nucleus is formed.

$$_1H^2 + {}_1H^2 \longrightarrow {}_2He^4$$

Mass of $_1H^2$ = 2.014102 a.m.u.

Mass of $_2He^4$ = 4.002604 a.m.u.

Difference in mass = 2 (2.014102) – 4.002604

= 0.025600 a.m.u.

1 a.m.u. = 931 MeV

$\therefore$ Energy released in this fusion = difference in mass $\times$ 931

= 0.0256×931 MeV

= 23.84 MeV

Since the process of nuclear fusion requires a very high temperature, the nuclear fusion reactions are called the thermonuclear reactions and the energy released is termed as the thermonuclear energy. Bethe has given a detailed theory of nuclear reactions in the sun and stars. He proposed a carbon-nitrogen cycle as one of the most important nuclear reactions for the release of energy from the sun. In this cycle four protons fuse together to give a helium nucleus two positrons and energy equal to 24.7 MeV.

$$4\ {}_1H^1 \longrightarrow\ {}_2He^4 + 2\ {}_{+1}e^0 + \text{energy}$$

Stars which are hotter than the sun get their energy from the carbon-nitrogen cycle. Stars which are cooler than the sun get their energy through another cycle called proton-proton cycle. In the proton-proton cycle also four protons fuse together to give a helium nucleus. Carbon acts as a catalyst in the carbon-nitrogen cycle and there is no catalyst in the proton-proton cycle. Fusion is the process which powers the sun and stars where temperatures are very high.

Advantages of using nuclear fusion : (i) The required fuels like hydrogen, deuterium and lithium nuclei are in plentiful supply in the sea. (ii) There are no nuclear waste materials left in fusion.

Table 5.3. Differences between nuclear fission and fusion :

S.No.	Nuclear Fission	Nuclear Fusion
1.	A heavy nucleus is split up into two fragments	Two lighter nuclei fuse together.
2.	It produces harmful radiations. Hence nuclear fission energy is not a clean energy.	It does not produce any harmful radiations. Hence fusion energy is called a clean energy.
3.	This process is possible even at room temperature	This process is only possible at very high temperature ($\sim 10^7$ K)
4.	The links of this process are neutrons	The links of this process are protons.
5.	The energy produced per nucleon is 0.85 MeV.	The energy produced per nucleon is 6.75 MeV.
6.	This principle is used in the explosion of Atom Bomb	This principle is used in the explosion of Hydrogen Bomb.

5.4 Advantages and hazards of nuclear energy and safety measures

1. Advantages of nuclear energy

Nuclear power stations have many advantages over thermal power stations.

(1) Nuclear power stations do not produce gases like carbon dioxide and sulphur oxides. So they do not pollute the atmosphere.

(2) Their fuel uranium will not run out even after the available fossil fuels are used up completely.

(3) Some reactors called breeder reactors actually produce nuclear fuel while they are in operation.

(4) The nuclear reactors generate power for the propulsion of ships and submarines.

(5) They produce radio isotopes and neutron beam for medical and nuclear research applications.

2. Hazards of nuclear energy

Inspite of all these advantages there are many disadvantages also. People all over the world are always exposed to radiation.

α, β and γ radiations are all ionising radiations. They knock electrons away from atoms when they pass through them. This causes a change in the structure and behaviour of molecules in cells. If an organism receives a large dose of radiation, then many molecules may get damaged. This affects all the processes

taking place in the body and the person feels ill. This is known as radiation sickness.

If a nuclear reactor runs out of control large amounts of radiation may be released into air. This happened at the nuclear station in Chernobyl, Russia, in 1986. Hence the radiation spreaded into air and blown by winds into the Central Europe thousands of kilometres away. Some farmers in Britain were not able to sell their lambs for meat because of radioactive contamination of the soil from the Chernobyl accident even after five years.

The unit of radiation exposure is roentgen. One roentgen (R) is a quantity of radiation which produces 1.61×10^{15} ion pairs in one kilogram of air.

Table 5.4 Effects of radiation

Dose in roentgen	Effect
0 - 25	no observable effect
25 - 50	slight blood changes
50 - 100	vomitting and fatigue
100 - 200	hemorrhage
200 - 400	permanent damage in the body
400	50% chances of death
600	100% chances of death

Workers in nuclear power stations, mines and X-ray laboratories wear photographic film badges. If the wearer is exposed to radiation, it will affect the film. The badges are collected regularly and the film is developed to check if the wearer is being exposed to radiation.

3. Safety measures

The following precautions are taken in radiation laboratories :

(1) Radioactive materials are kept in thick walled lead containers.

(2) Lead aprons and gloves are used while working in hazardous places.

(3) A small micro-film badge is always worn by the person and it is checked periodically for the safety limit of radiation.

4. Indian Nuclear Energy Programme

Energy plays an important role in determining the development of a country. Electricity can be produced by different methods such as hydroelectric, thermal and nuclear generations. Even though there are many disadvantages of electric power generation from nuclear energy, a large amount of electricity can be generated even with a small amount of nuclear fuel.

Industrialised countries like Belgium, Germany, Japan, Taiwan and Spain generate more than 30% of their total electric power by using many nuclear reactors. There is a major programme for the production of nuclear power in India. However, it is still about 4% of the total power being generated in our country. A number of nuclear reactors are in operation at present in India. Some of them are research reactors and the others are power reactors. Dr. Homi Bhabha, the pioneer of nuclear power programme in India took efforts to start the first and major nuclear reactor in India. This nuclear research centre located at Trombay in Mumbai is called Bhabha Atomic Research Centre (BARC). Apsara, Cirus, Zerlina, Purnima and Dhruva are the research reactors located at BARC.

Nuclear Power Corporation of India Ltd. (NPCIL) is the public sector company which owns, constructs and operates nuclear power plants in India. NPCIL has a plan to put up a total installed nuclear power capacity of 20,000 MWe (Megawatt energy) by the year 2020. India's nuclear power programme has 14 reactors in operation and eight power reactors under construction.

Some important operating nuclear power reactors and power reactors which are under construction are shown in the tables 5.5 and 5.6 respectively.

Table 5.5. Operating Nuclear Power Reactors

Location	Type	Capacity (in MWe)
Tarapur	Boiling Water Reactor	2×160
Rajasthan	Pressurised Heavy water reactor	1×100, 1×200 and 2×220
Kalpakkam	Pressurised Heavy water	2×170
Narora	Pressurised Heavy water	2×220
Kakrapar	Pressurised Heavy water	2×220

Table 5.6. Nuclear Power Reactors under construction

Location	Type	Capacity (in MWe)	Expected date of operation
Tarapur (3 and 4)	Pressurised Heavy water reactor	2×540	unit - 3 : July 2006 unit 4 : October 2005
Kaiga (3 and 4)	Pressurised Heavy water reactor	2×220	unit 3 : December 2006 unit 4 : June 2007
Rajasthan (5 and 6)	Pressurised Heavy water reactor	2×220	unit 5 : May 2007 unit 6 : November 2007
Kudankulam (Tamil Nadu)	---	2×1000	unit 1 : 2007 unit 2 : 2008

SELF EVALUATION

Choose the correct answer

1. The wave length range of the visible rays in the electromagnetic spectrum is of the order of .....

   (1) ~ 10^{-9} m to 6×10^{-12} m
   (2) ~ 3.8×10^{-7} m to 6×10^{-10} m
   (3) ~ 7.8×10^{-7} m to 3.8×10^{-7} m
   (4) ~ 10^{-3} m to 7.8×10^{-7} m

2. X-rays cannot pass through .....

   (1) glass (2) wood
   (3) flesh (4) bone

3. When a radioactive nucleus disintegrates by emitting a β-particle its atomic number

   (1) increases by two (2) decreases by one
   (3) increases by one (4) decreases by two

4. Which of the following is not electro magnetic in nature

   (1) alpha rays (2) gamma rays
   (3) infra-red rays (4) UV-rays

Fill in the blanks

5. The wave length range of the X-rays in the electromagnetic spectrum is .....

6. Human body gives off infra red radiation with a wavelength of ..... to .....

7. The two rays which cannot be deflected by both electric and magnetic fields are ..... and .....

Answer briefly

8. State any four common properties of all the electromagnetic waves.

9. Give the principle of the production of X-rays.

10. Write any four properties of X-rays.

11. Give the medical applications of X-rays.

12. State any four uses of infra red rays.

13. Name the devices that could generate microwaves.

14. State any four uses of microwaves.

15. Give the applications of radio waves.

16. What is radio activity ?

17. What are radio active elements ? Give examples.

18. Distinguish between γ - rays and X-rays.

19. What happens when a radio active element emit γ-rays ?

20. In the nuclear reaction given below, a nucleus X-changes into another nucleus Y.

$$_{88}X^{226} \longrightarrow Y + {}_{2}He^{4}$$

What are the atomic number and mass number of Y ?

21. What is nuclear fission ?

22. Write the nuclear reaction for the phenomenon of nuclear fission.

23. What is chain reaction in nuclear fission ?

24. What is a nuclear reactor ?

25. What is a moderator ?

26. What is a coolant ? Give examples.

27. What is nuclear fusion ?

28. What are the advantages of using nuclear fusion as the source of energy ?

29. Give any four differences between Nuclear fission and nuclear fusion.

30. What are the main sources of radiation which affect the people ? Give their sources.

31. Define the unit of radiation exposure.

32. Tabulate the dose of radiation and the effect on human body.

33. Name the research reactors located at BARC.

34. Give the places of locations of operating nuclear power reactors in India.

Answer in detail

35. Give with the principle, the production of X-rays.

36. State the properties of X-rays.

37. Give the uses of X-rays.

38. Write a note on (i) Infra-red rays (ii) Microwaves and (iii) Radio waves.

39. Describe the experimental study of radio activity.

40. Write a note on radio active decay and radio active materials.

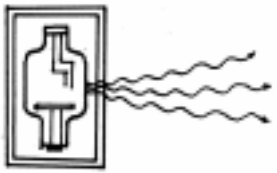
41. Give in detail (i) Nuclear fission (ii) Energy released in Nuclear fission and (iii) Chain reaction.

42. What is a nuclear reactor ? Explain the essential components of a nuclear reactor.

43. Write a note on nuclear fusion. Compare nuclear fission with nuclear fusion.

44. Give the advantages and disadvantages of nuclear energy and safety measures.

Table 5.1 Important features of electromagnetic spectrum.

S.No.	Type of Wave	Source	Wavelength Range in metre ~	Frequency range in hertz ~	Energy range in (electron volts) ~	Uses	Detection
1.	Gamma rays	Nuclei of radio active atoms, (Cobalt 60^{*})	Nearly 10^{-10} to 10^{-14}	3×10^{16} to 3×10^{22}	~10^{4} to 10^{7}	1. Treatment of cancer 2. To find flaws in metal. 3. Sterilises equipment in hospitals and food industry	1. By photographic films 2. Geiger-Muller tube
2.	X-rays	X-ray tube 	10^{-9} to 6×10^{-12}	3×10^{17} to 3×10^{19}	~10^{3} to 10^{5}	1. Treatment of skin diseases 2. Detection of broken bones	1. Photographic film 2. Flourescent screen
3.	Ultra Violet rays	UV lamp 1. The sun 2. Very hot objects 3. Mercury lamps Mercury lamp	3.8×10^{-7} to 6×10^{-10}	8×10^{14} to 3×10^{17}	~10 to 10^{3}ü ç10ç ª ØBÇ3é	1. Treatment of skin disorders 2. Makes clothes washed with powders look whiter 3. With certain inks helps to detect fake currency	1. Photographic film 2. Photo cells 3. Flourescent Chemicals

4.	Visible light	The sun, various lamps, and various flames. The sun	7.8×10^{-7} to 3.8×10^{-7}	4×10^{14} to 8×10^{14}	~1 to 10	1. To help us to see 2. Photography 3. Photosynthesis and plant growth	1. Eye 2. Photographic film 3. Photocells
5.	Infra red light	The sun, warm and hot objects	10^{-3} to 7.8×10^{-7}	3×10^{11} to 4×10^{14}	~10^{-2} to 1	1. I R photographs 2. To increase the flow of blood	1. Special photo film 2. Skin 3. Semiconductor devices : 4. Light dependent resistance (LDR)
6.	Microwaves	Microwave communication dish	0.3 to 10^{-3}	10^9 to 3×10^{11}	~10^{-5} to 10^{-3}	1. Microwave cooking 2. Microwave Communication Links	Microwave Receiving Aerials
7.	Radio waves	Radio Transmitter, Stars, Galaxies	A few km. to 0.3 metre	A few to 10^9	~10^{-11} to 10^{-6}	1. Radio Broadcasting 2. T.V. and Satellite communication 3. Radar detection of ships and aircraft. 4. Radio astronomy	Metal aerials and tuned circuits.

CHMISTRY

6. CHEMICAL REACTIONS

Chemical reactions are happening around us all the time and even in our body. Respiration and digestion in all living organisms, rusting of iron, cooking of food, formation of brown colour on a cut piece of apple etc., are some of the important and common chemical reactions taking place in our daily life.

In our daily life, we see burning of camphor and coal. Camphor burns quickly whereas coal burns slowly. When a piece of sodium metal is dropped in water, sodium reacts very fast with water to an extent that it explodes with a huge sound. When a little of yellow phosphorous is thrown on a heap of waste papers, it catches fire immediately. These reactions are fast reactions. Every one of us would have noticed that setting of cement and rusting of iron take atleast a few days or weeks time. These are very slow reactions. In this chapter, let us discuss about the type of reactions and different examples for each one of them.

In all chemical reactions, reactants combine to form new substances called products. A change is considered to be chemical reaction only if chemical bonds are broken in reactants and new bonds are formed in products. In other words, chemical reaction is a bond breaking and bond making process. In some cases, the products of a reaction recombine to form the reactants back. These are called reversible reactions.

For example, when blue coloured hydrated copper sulphate salt is heated in a test tube, white coloured anhydrous copper sulphate is formed. This white substance again combines with water to give back blue coloured hydrated copper sulphate. So this is a reversible reaction. It can be represented as

$$\underset{\text{Blue}}{CuSO_4 . 5H_2O} \overset{\Delta}{\rightleftharpoons} \underset{\text{White}}{CuSO_4 + 5H_2O}$$

In many cases, the products cannot recombine to form the reactants. These are called irreversible reactions. These reactions are discussed in detail in this chapter.

When washing soda is dissolved in water to wash clothes, heat is given out. When baking soda is touched with wet hand, the chillness is felt. During these processes, heat is either given out or absorbed from the surroundings. In the same way, in most of the chemical reactions, energy is either taken up or given out.

Most of the enzyme catalysed reactions taking place in our body depend on the pH of the medium. In this chapter, we shall try to understand these facts which are very important to know in order to carry out any chemical reaction. We shall now discuss the speed or rate of reactions and how they change with different factors like concentration, temperature, light and catalyst.

6.1 Rate of a Chemical Reaction

At the beginning of a chemical reaction, there are only reactants and no products. As the reaction proceeds, the concentration of reactants goes on decreasing but the concentration of products increases. The change in the concentration of reactants or products with time gives us an idea of the rate at which the reaction proceeds. *Thus, the rate of a chemical reaction is defined as the change in the concentration of the reactant or product per unit time.* The rate of a reaction is positive, when expressed in terms of change in concentration of products but negative in terms of change in concentration of reactants. The rate of a chemical reaction is given in terms of the change in concentration either of a reactant or of a product.

As the reaction proceeds, the reactant concentration decreases with time.

In terms of the change in concentration of a reactant, the rate is negative.

$$\text{Rate of reaction} = -\frac{\text{Change in concentration of a reactant}}{\text{Time taken}}$$

Since the concentration of product increases with time during the reaction, the rate is positive.

In terms of the change in concentration of a product,

$$\text{Rate of reaction} = \frac{\text{Change in concentration of a product}}{\text{Time taken}}$$

For all reactions,

$$\text{Rate of reaction} = \frac{\text{Change in concentration of reactant or product}}{\text{Time taken}}$$

$$\text{Unit of rate of reaction} = \frac{\text{mol/litre}}{\text{second}}$$

$$= \text{mol/litre/second}$$

$$= \text{mol } L^{-1} s^{-1}$$

The rate of a reaction can be expressed in terms of any of the reactants or products. For example, the following reaction is considered.

$$NO_{2(g)} + CO_{(g)} \longrightarrow CO_{2(g)} + NO_{(g)}$$

In the reaction, the stoichiometric coefficient of each species is one and therefore the rate of disappearance of any of the reactants is the same as the rate of appearance of any of the products.

Thus, rate of reaction =

$$\frac{-d[NO_2]}{dt} = \frac{-d[CO]}{dt} = \frac{d[CO_2]}{dt} = \frac{d[NO]}{dt}$$

'd' represents a small change and $[NO_2]$ molar concentration of nitrogen dioxide.

Let us now study an example, in which the stoichiometric coefficients are not same,

Consider the reaction,

$$2HI_{(g)} \longrightarrow H_{2(g)} + I_{2(g)}$$

In this case, the rate of disappearance of hydrogen iodide is twice the rate of appearance of hydrogen or iodine. This can be given as,

(Rate of disappearance of HI)
= 2 (Rate of appearance of H_2)
= 2 (Rate of appearance of I_2)

Thus, the rate of reaction

$$= -\frac{1}{2}\frac{d[HI]}{dt}$$

$$= \frac{d[H_2]}{dt} = \frac{d[I_2]}{dt}$$

For expressing the rate of such reactions, the rate of disappearance or the rate of appearance of the species is divided by its stoichiometric coefficient, which is the number preceeding the formula of the compound in the balanced equation.

Problem : The concentration of I_2 in the reaction $2HI \longrightarrow H_2 + I_2$ increases by 0.2×10^{-4} mol L^{-1} in 20 seconds. What is the rate of reaction ?

Since, I_2 is the product in the reaction,

$$\text{Rate} = \frac{\text{Change in concentration of } I_2}{\text{Time taken}}$$

$$= \frac{d[I_2]}{dt} = \frac{0.2 \times 10^{-4}}{20}$$

$$= 1.00 \times 10^{-6} \text{ mol } L^{-1} s^{-1}$$

Problem : The concentration of a reactant A, in a reaction, $A \longrightarrow B$, decreases from 0.8mol L^{-1} to 0.6 mol L^{-1} in 10 seconds. What is the rate of reaction ?

$$\text{Rate of reaction} = -\frac{\text{Change in concentration of a reactant}}{\text{Time taken}}$$

$$= \frac{-(0.6 - 0.8)\ \text{mol/litre}}{10\ \text{seconds}} = \frac{-(-0.2)\ \text{mol/litre}}{10\ \text{seconds}}$$

$$= 0.02\ \text{mol}\ L^{-1}\ s^{-1}$$

Reaction rate curves

A typical graph showing the change in the concentration of a reactant or product of a reaction with time is given here.

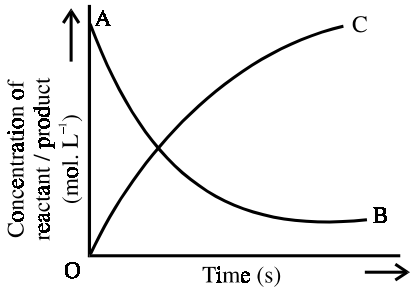


Fig. 6.1 Change of concentration of Reactant / Product with time

Initially at zero time, the concentration of the reactant is the maximum as represented by point A in the graph. As the time passes and reaction proceeds, the concentration of reactant decreases along the curve AB. At the end of the reaction, which may take infinite time the concentration of the reactant becomes minimum.

A typical curve showing the change in concentration of a product of a reaction with time is given by the curve OC.

In the above curve, it is evident that as the time passes, the concentration of the product goes on increasing. Initially at zero time, the concentration of the product is zero as represented by point O in the graph. As the time passes and reaction proceeds, the concentration of the product increases along the curve OC. At the end of the reaction, the concentration of the product becomes maximum as shown by point C.

The rate of reaction at any time can be found from the reaction rate curves by measuring the slope of either of the two curves at that time, thus the rate varies as the reaction proceeds.

Activity : Put a piece of magnesium ribbon into each of two test tubes A and B. Add hydrochloric acid to test tube A and ethanoic acid to the test tube B. We observe that evolution of hydrogen gas is very fast in the test tube A containing hydrochloric acid and it is very slow in test tube B containing ethanoic acid. This shows that the reaction rate is greater in the former than in the later.

Factors affecting the rate of reaction

1) Effect of concentration on the rate of reaction

The rate of reaction generally increases with increase in concentration of the reactants. We can demonstrate the effect of concentration of the reactant on the rate of reaction by performing the following experiment. 3 g of granulated zinc is taken in a flask. A graduated syringe is attached to the mouth of the flask.

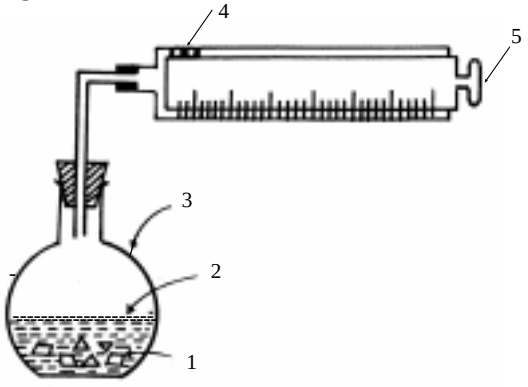


Fig. 6.2 Experiment to show the effect of concentration of reactant on the rate of reaction

1. Zinc granules 2. HCl 3. Flask 4. Graduated syringe
5. The plunger which can move out

5 ml of 1M hydrochloric acid is added. Hydrogen gas is produced during this reaction and this goes into syringe which exerts a pressure on the plunger. Therefore, the plunger starts moving out. The volume of hydrogen

gas formed can be noted from the markings along the length of the syringe which will vary according to the volume of hydrogen gas. The volume of hydrogen gas formed at the intervals of 10 seconds is measured using a stop watch.

In the same way, the experiment is repeated with 5 ml of 2M hydrochloric acid. The volume of hydrogen gas formed at the intervals of 10 seconds is measured using a stop watch.

We plot the graph between the time readings and the corresponding volume readings of hydrogen gas evolved for both the experiments on the same graph paper. We get two curves showing the rate of reaction at two different concentrations as shown below.

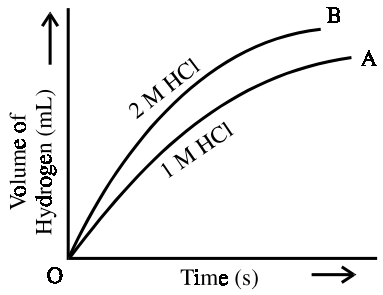


Fig. 6.3 Effect of concentration on the rate of reaction

The curve OA is for the reaction between zinc and 1M hydrochloric acid whereas curve OB is for the reaction between same amount of zinc and 2M hydrochloric acid. We can see from the above graph that the curve OB is steeper than curve OA. From this, we conclude that when the concentration of hydrochloric acid is increased from 1M to 2M, the rate of formation of hydrogen gas increases. In otherwords, the rate of reaction increases with increase in reactant concentration.

2) Effect of temperature on the rate of reaction

Cooked food gets spoilt quickly during summer than winter. Souring of milk is faster in summer. These are all due to the fact that the chemical reactions responsible for these changes take place faster at higher temperatures.

Generally increase in temperature increases the rate of reaction. When the temperature increases, the reactant molecules acquire higher energy and can easily form the products.

The effect of temperature on the rate of reaction is studied by performing a similar experiment as in the case of change of rate of reaction with concentration.

The experiment is repeated by taking 3 g of zinc granules and 5 mL of 1 M HCl at two different temperatures 298 K and 308 K. The volume of Hydrogen gas formed at definite time intervals are measured for two different temperatures and plotted. The graph shows that the volume of hydrogen gas formed during the same time is more at 308 K than at 298 K.

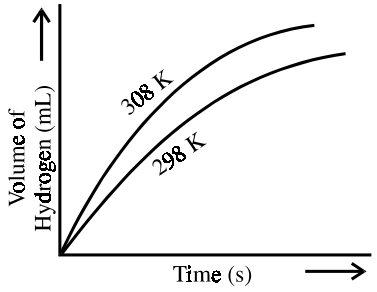


Fig. 6.4 Effect of temperature on the rate of a reaction

Activity : Take marble chips in a test tube and add hydrochloric acid to it. You observe that the effervescence is very slow. Heat the test tube and observe. The effervescence is fast. This is because, calcium carbonate present in marble chips reacts slowly with hydrochloric acid at low temperature and evolves less carbon dioxide. Whereas on heating, the rate of reaction increases giving more of carbon dioxide.

3) Effect of light

There are certain reactions which take place or are accelerated by the absorption of

light by the reactants. Such reactions are known as photochemical reactions. These reactions do not occur if the reactants are shielded from light.

The combination of hydrogen and chlorine to produce hydrogen chloride does not take place at measureable rate in the dark. The combination, however, occurs as soon as the mixture is exposed to sunlight.

$$H_{2(g)} + Cl_{2(g)} \xrightarrow{\text{sunlight}} 2HCl_{(g)}$$

The plants prepare starch from carbon dioxide and water in the presence of sunlight by the process of photosynthesis. This reaction is slow in dim sunlight but it is much faster in bright sunlight. The reaction which takes place on a photographic film also depends on the varying intensity of light falling on different parts of the film.

4) Effect of catalyst

A catalyst is a substance which is added to a reaction mixture to alter the rate of chemical reaction where the mass and the chemical composition of the catalyst remain unchanged at the end of the reaction.

Many industrially important reactions such as manufacture of ammonia, sulphuric acid, nitric acid and polythene are carried out using suitable catalysts.

In the laboratory preparation of oxygen if potassium chlorate alone is heated, then oxygen is evolved very slowly. If, however, when manganese dioxide is added as a catalyst to the reaction mixture oxygen is liberated very fast at a comparatively lower temperature. Thus, the catalyst increases the rate of this reaction.

$$2KClO_{3(s)} \xrightarrow[\Delta]{MnO_2} 2KCl_{(s)} + 3O_{2(g)}$$

Iron is used as a catalyst in the manufacture of ammonia by Haber process.

6.2 Types of Reactions

1. Fast reactions

Those reactions which take place at once when the reactants come in contact with each other are called fast reactions.

Example : If we add barium chloride solution to dilute sulphuric acid, a thick white precipitate of barium sulphate is obtained at once. This reaction is fast because it takes place between the ions of the reactants.

$$\underset{\text{barium chloride}}{BaCl_{2(aq)}} + \underset{\text{sulphuric acid}}{H_2SO_{4(aq)}} \longrightarrow \underset{\text{barium sulphate}}{BaSO_4} \downarrow + \underset{\text{hydrochloric acid}}{2HCl_{(aq)}}$$

In general, the reaction between ionic compounds are fast or instantaneous.

2. Moderate reactions

Chemical reactions which are neither fast nor slow, but occur at measurable rates are called moderate reactions.

Examples

(1) The reaction between hydrochloric acid and zinc granules to form hydrogen gas takes place at a moderate rate.

$$Zn_{(s)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H_{2(g)}$$

(2) The combination of hydrogen and iodine to produce hydrogen iodide also takes place at a moderate rate.

$$H_{2(g)} + I_{2(g)} \longrightarrow 2HI_{(g)}$$

3. Slow reactions

Those reactions which occur in a few hours are called slow reactions. For example, when ethyl alcohol and acetic acid are mixed in the presence of a little concentrated sulphuric acid (catalyst), the reaction takes place in few hours and an ester called ethyl acetate is formed.

$$CH_3COOH_{(aq)} + C_2H_5OH_{(l)} \xrightarrow{\text{con. } H_2SO_4} CH_3\,COO\,C_2H_{5(aq)} + H_2O_{(l)}$$

This reaction is slow because it takes place between covalent compounds. *In general, the reactions between covalent compounds are slow.*

4. Very slow reactions

Those reactions which take days, weeks or even months to occur are called very slow reactions. For example, rusting of iron occurs over a period of weeks. When iron is exposed to humid air (which contains oxygen and water), a brown flaky coating of hydrated iron (III) oxide is formed on the surface of iron. This is called rusting of iron.

$$4Fe_{(s)} + 3O_{2(g)} + x\,.\,H_2O_{(g)} \longrightarrow 2Fe_2O_3\,.\,x\,H_2O_{(s)}$$

Thus, Rusting of iron is a very slow oxidation reaction.

6.3 Reversible and Irreversible reactions

1. Reversible reactions

Those chemical reactions in which the products can recombine to give back the reactants are known as reversible reactions.

In other words, a reaction which takes place in both ways (i.e.,) in the forward as well as in the backward direction is known as reversible reaction.

Example : The reaction between hydrogen and iodine to form hydrogen iodide is discussed.

$$\underset{\text{hydrogen}}{H_{2(g)}} + \underset{\text{iodine}}{I_{2(g)}} \longrightarrow \underset{\text{hydrogen iodide}}{2HI_{(g)}}$$

In the above reaction, it is observed that when hydrogen and iodine gases are taken in stoichiometric ratio (ratio of masses of constituents in the balanced chemical equation) in a closed container, they do not fully react to form hydrogen iodide. For example, if we take 2 grams of hydrogen and 254 grams of iodine, we will not get 256 grams of hydrogen iodide. This is because, the hydrogen iodide formed starts breaking down into hydrogen and iodine which shows that the above reaction is possible in both the directions. Therefore, this reaction will never go to completion. Since the reaction is possible in both the directions, the reaction between hydrogen and iodine is reversible and the equation is given as,

$$H_2 + I_2 \rightleftharpoons 2HI$$

A double half-headed arrow ($\rightleftharpoons$) is a sign of reversibility and indicate that the reaction can take place in either directions.

Few other examples for reversible reactions are given below :

$$N_{2(g)} + 3H_{2(g)} \underset{\text{backward reaction}}{\overset{\text{forward reaction}}{\rightleftharpoons}} 2NH_{3(g)}$$

$$N_{2(g)} + O_{2(g)} \underset{\text{backward reaction}}{\overset{\text{forward reaction}}{\rightleftharpoons}} 2NO_{(g)}$$

$$CaCO_{3(s)} \underset{\text{backward reaction}}{\overset{\text{forward reaction}}{\rightleftharpoons}} CaO_{(s)} + CO_{2(g)}$$

2. Irreversible Reactions

Those chemical reactions in which the products obtained cannot recombine to give back the reactants are called irreversible reactions.

Let us consider the reaction between hydrogen and oxygen to form water

$$2H_{2(g)} + O_{2(g)} \xrightarrow[\text{arc}]{\text{electric}} 2H_2O_{(l)}$$

This reaction proceeds in the forward direction only which is indicated by using a single arrow (⟶). The product obtained in the above reaction does not recombine to form the reactants. Thus, this reaction is an irreversible reaction.

Few more examples for irreversible reactions are given below :

$$2KClO_{3(s)} \xrightarrow{\Delta} 2KCl_{(s)} + 3O_{2(g)}$$

$$2Na_{(s)} + 2H_2O_{(l)} \longrightarrow 2NaOH_{(aq)} + H_{2(g)}$$

$$Zn_{(s)} + H_2SO_{4(aq)} \longrightarrow ZnSO_{4(aq)} + H_{2(g)}$$

$$2Pb(NO_3)_{2(s)} \longrightarrow 2PbO_{(s)} + 4NO_{2(g)} + O_{2(g)}$$

6.4 Dynamic nature of chemical equilibrium

Children playing on the seesaw in the park is a good example of static equilibrium.

Let us discuss about chemical equilibrium using the following chemical reaction.

When hydrogen and iodine are taken in a closed vessel maintained at 717 K, hydrogen molecule combines with iodine molecule to form hydrogen iodide.

$$H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$$

Since the reaction is reversible in nature, the molecules of hydrogen iodide formed begin to dissociate to form hydrogen and iodine.

As the reaction progresses, the concentration of hydrogen and iodine decreases and hence, the rate of forward reaction slows down. On the other hand, concentration of hydrogen iodide increases and therefore the rate of backward reaction increases. A stage is reached when the rate of forward reaction becomes equal to the rate of backward reaction and the system attains equilibrium. Such an equilibrium is therefore called Dynamic equilibrium.

In this case, attainment of equilibrium has been recognised by observing constancy of intensity of colour of the reaction mixture. The colour of the reaction mixture is deep violet at the beginning of the reaction due to the presence of iodine. As the reaction progresses, the intensity of colour decreases due to the decrease in the iodine concentration resulting in the formation of colourless hydrogen iodide. After some time, it is observed that the intensity of colour becomes constant indicating that the system acquires a state of equilibrium.

The variation of rates of forward and backward reaction is shown below.

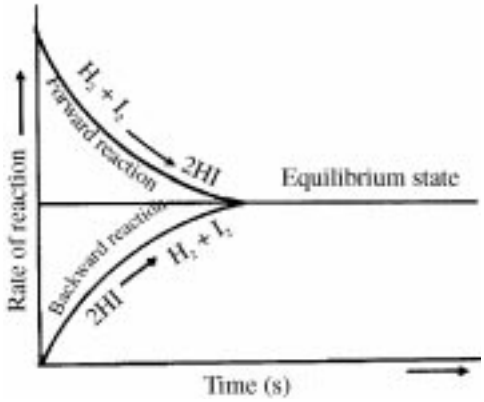


Fig. 6.5 Attainment of equilibrium state

After the attainment of equilibrium, there is no change in concentration. *This is not a static but a dynamic equilibrium in which the forward and backward reactions proceed simultaneously at the same rate.* It is noted that the reaction goes on and on and never comes to a completion.

Equilibrium constant

At equilibrium, the ratio between concentration of reactants and products become constant.

$$H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$$

$$\text{At equilibrium} = \frac{[HI]^2}{[H_2][I_2]} = K_c$$

Here, concentration of product (hydrogen iodide) occurs in numerator and those of reactants (hydrogen and iodine) occur in denominator. Each concentration term [HI], $[H_2]$, or $[I_2]$ is raised to the power equal to stoichiometric coefficient in the balanced equation. K_c is called equilibrium constant.

For a general reaction,

$$aA + bB \rightleftharpoons cC + dD$$

at equilibrium, equilibrium constant can be written as

$$K_c = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

The above expression is known as **law of chemical equilibrium.**

In the above expression, square bracket denotes molar concentration (i.e.,) concentration in mol./L. At a particular temperature, equilibrium constant has a definite value. When we express concentrations in mol. L^{-1}, equilibrium constant is denoted by K_c. Larger the value of K_c , higher will be the concentration of the products at equilibrium. Smaller value of K_c indicates the lower concentration of the products at equilibrium.

Another important example of a reversible reaction which attains equilibrium is the reaction between nitrogen and hydrogen to form Ammonia.

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

Problem : For the reaction,

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$$

at equilibrium at 1000 K, the molar concentration of SO_2, O_2 and SO_3 are 1.44, 1.98 and 0.41 mol L^{-1} respectively. Calculate the equilibrium constant K_c for this reaction.

$[SO_3] = 0.41 \text{ mol } L^{-1}$

$[SO_2] = 1.44 \text{ mol } L^{-1}$

$[O_2] = 1.98 \text{ mol } L^{-1}$

$$K_c = \frac{[SO_3]^2}{[SO_2]^2 [O_2]}$$

$$= \frac{(0.41)^2}{(1.44)^2 \times 1.98}$$

$$K_c = \frac{0.1681}{2.0736 \times 1.98}$$

$$= \frac{0.1681}{4.1057}$$

$$= 0.0409$$

$$= 4.09 \times 10^{-2}$$

Problem : Equilibrium constants for the following reactions at 298 K are given below :

$$N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)} \qquad K_c = 4.66 \times 10^{-3}$$

$$2NH_{3(g)} \rightleftharpoons N_{2(g)} + 3H_{2(g)} \quad K_c = 3.0 \times 10^{-9}$$

In which case, formation of the products will be more favoured ?

The formation of products will be more favoured in that reaction for which the equilibrium constant (K_c) has a greater value. Now, out of the two given values of the equilibrium constants, the value of the first reaction 4.66×10^{-3} is greater than that for the second reaction which is 3.0×10^{-9}. So, the formation of product will be more favoured in the case of the first reaction, which is

$$N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$$

6.5 Energy changes during chemical reaction

Activity : Dissolve a spoon of glucose in a glass of water. When you touch the glass observe that the glass is chill. Add water to the lime in a glass. Observe by touching the glass that the glass is warm.

Let us now discuss the reason for the above heat changes. You know that most of the chemical reactions are usually accompanied by energy changes.

To understand how energy change occurs in a chemical reaction, we should know about internal (intrinsic) energy. It is a kind of energy that is stored within the structural units of every substance.

Consider the following hypothetical reaction,

$$\underset{E_A}{A} + \underset{E_B}{B} \longrightarrow \underset{E_C}{C} + \underset{E_D}{D}$$

where A and B are the reactants and C and D are the products. Suppose the internal energies of A, B, C and D are E_A, E_B, E_C and E_D respectively. If $(E_A + E_B) > (E_C + E_D)$, then the excess energy will be released. But if $(E_A + E_B) < (E_C + E_D)$, then the deficit energy will be absorbed from the surroundings.

1. Exothermic reactions

The chemical reactions which proceed with the evolution of heat energy are called exothermic reactions.

In general, exothermic reactions may be represented as,

$$A + B \longrightarrow C + D + q$$

where q is the heat evolved. The heat evolved is expressed in Joules (J) or kilo Joules (kJ).

All combustion reactions are exothermic. These reactions proceed with the evolution of heat energy. An important exothermic reaction occurs in our body cells which is nothing but respiration.

During respiration, glucose in food burns in oxygen and gives out heat energy. Some amount of this heat energy is used up to maintain our body temperature at 310 K even when the temperature of our environment is much less. The remaining energy is used for other muscular activities.

A chemical reaction involves the rearrangement of atoms. During the reaction, certain bonds are broken while certain new bonds are formed between the atoms. If the energy released during the formation of bonds is more than the energy absorbed for breaking the bonds, then there is net release of energy and the reaction is exothermic.

Examples

1) Let us consider the following reaction.

$$CH_4 + 2O_2 \longrightarrow 2H_2O + CO_2$$

In this reaction energy is required to break C–H and O–O bonds and energy is released during the formation of O–H and C–O bonds.

Since, the energy released during the formation of bonds is greater than the energy absorbed during the breaking of bonds, the reaction is exothermic.

2) When nitrogen combines with hydrogen in the presence of iron catalyst to form ammonia, a lot of heat is produced. Thus, the formation of ammonia is an exothermic reaction

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)} + \text{Heat}$$

There are many other exothermic reactions which you are familiar with. They are neutralisation of an acid by an alkali, the burning of petrol etc.

Activity : In villages, there will be compost heap in the backyard of every house. Go and stand near the heap. When they dig the heap to take away for manuring, you feel the warmth. This is because the vegetable and plant matters in the heap rot and decay. During

this decay, heat is given out. Because of this exothermic reaction, you feel the warmth.

2. Endothermic reactions

The chemical reactions which proceed with the absorption of heat energy are called endothermic reactions. In general,

$$A + B + q \longrightarrow C + D$$

It is otherwise written as,

$$A + B \longrightarrow C + D - q$$

where q is the heat absorbed.

A chemical reaction involves the rearrangement of atoms. During the reaction, certain bonds are broken while certain new bonds are formed between the atoms. If the energy required to break the bonds is more than the energy released during the formation of bonds, then there is net absorption of energy and the reaction is endothermic.

Examples : 1) Let us consider the following reaction.

$$2NH_{3(g)} \longrightarrow N_{2(g)} + 3H_{2(g)} - q$$

In this reaction, energy is required to break N–H bonds and energy is released during the formation of N–N and H–H bonds. Since the energy released during the formation of bonds is lesser than the energy absorbed during the breaking of bonds, the reaction is endothermic.

2) When nitrogen and oxygen are heated to a very high temperature, they combine to form nitrogen monoxide and a lot of heat is absorbed in this reaction. Thus, the formation of nitrogen monoxide is an endothermic reaction. This can be written as,

$$N_{2(g)} + O_{2(g)} + \text{Heat} \longrightarrow \underset{\text{nitrogen monoxide}}{2NO_{(g)}}$$

Let us remember that *increase in temperature favours endothermic reactions and decrease in temperature favours the exothermic reactions.*

6.6 The importance of pH

The maintenance of pH is very essential in biological systems where life processes can take place only within a limited range of pH. The functioning of enzymes is sharply pH dependent. The pH of blood and intra cellular fluids in our body also has to be maintained to a particular range for proper functioning of the different systems. In industries, many chemical reactions take place only at a specified pH. Hence, it is necessary to understand the term pH and the related facts.

1. Acids

The term acid is derived from the Latin word **acidus** meaning sour. Acids can be defined in many ways but generally their aqueous solutions have the following properties.

1) They are sour in taste.
2) They turn blue litmus red.
3) They react with certain metals and liberate hydrogen gas.
4) They react with oxides and hydroxides of metals forming salt and water.
5) Their aqueous solutions conduct electricity.

2. Bases

Bases are defined in various ways but generally substances having the following characteristics are called bases.

1) They have a bitter taste.
2) Their aqueous solutions have a soapy touch.
3) They turn red litmus blue.
4) They react with acids to form salt and water.
5) Their aqueous solutions conduct electricity.

Some naturally occuring acids and their sources are given in table 6.1.

Table 6.1 Acids and their sources

Acid	Source
Citric acid	Lemon juice
Ethanoic acid (acetic acid)	Vinegar
Tannic acid	Tea
Lactic acid	Sour milk
Tartaric acid	Grapes
Hydrochloric acid	Stomach juices

3. Arrhenius concept

According to Arrhenius, *an acid is a substance which give hydrogen ions in its aqueous solution. A base is a substance which give hydroxyl ions in its aqueous solution.*

For example, substances such as Nitric acid, Hydrochloric acid, acetic acid are acids whereas substances such as sodium hydroxide, potassium hydroxide and ammonium hydroxide are bases according to this concept.

$HNO_{3(aq)} \longrightarrow H^+_{(aq)} + NO^-_{3(aq)}$

nitric acid

$HCl_{(aq)} \longrightarrow H^+_{(aq)} + Cl^-_{(aq)}$

hydrochloric acid

$CH_3COOH_{(aq)} \longrightarrow H^+_{(aq)} + CH_3COO^-_{(aq)}$

acetic acid

$NaOH_{(aq)} \longrightarrow Na^+_{(aq)} + OH^-_{(aq)}$

sodium hydroxide

$KOH_{(aq)} \longrightarrow K^+_{(aq)} + OH^-_{(aq)}$

potassium hydroxide

$NH_4OH_{(aq)} \longrightarrow NH^+_{4(aq)} + OH^-_{(aq)}$

ammonium hydroxide

Acids such as HCl, H_2SO_4 and HNO_3 which are almost completely ionised in aqueous solution are termed as strong acids. CH_3COOH is partially ionised and is called a weak acid.

Similarly, bases like NaOH and KOH are almost completely ionised in aqueous solution and are therefore called strong bases. Ammonium Hydroxide is partially ionised and is called a weak base. The Arrhenius theory of acids and bases has proved to be very useful in the study of chemical reactions. But the theory has certain limitations. To overcome these limitations, in 1923, a Danish chemist, J.N. Bronsted and a British chemist T.M. Lowry proposed a more logical concept of acids and bases.

4. Bronsted and Lowry theory

According to this theory, *an acid is a substance that has the tendency to lose a proton and a base is a substance that has the tendency to accept a proton.* This theory will be discussed in detail in higher classes.

5. pH scale

The acidity or basicity of a solution is usually expressed in terms of function of the hydrogen ion concentration. This function is called pH of a solution. *pH of a solution may be defined as the negative logarithm (to the base 10) of hydrogen ion concentration expressed in moles per litre.*

$$pH = -\log_{10} [H^+]$$

For pure water and neutral solutions, at 298 K, concentration of hydrogen ions is 1×10^{-7} mol L^{-1}. These hydrogen ions are formed by ionisation of some of the water molecules.

$$H_2O_{(l)} \rightleftharpoons H^+_{(aq)} + OH^-_{(aq)}$$

Thus, for pure water at 298 K,

$[H^+] = [OH^-] = 1 \times 10^{-7}$ mol L^{-1}

pH of pure water

at 298 K $= -\log [H^+]$

$= -\log (1 \times 10^{-7}) = 7$

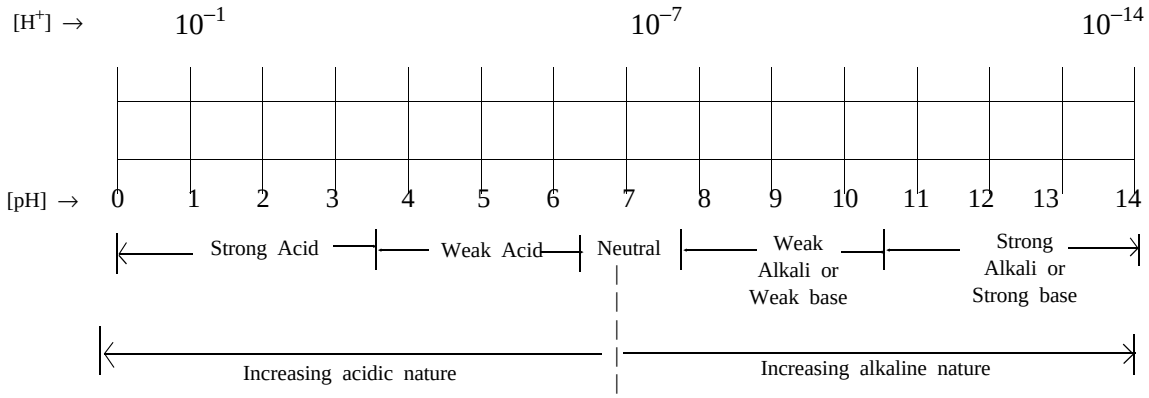


Fig. 6.6 pH scale

The product of $[H^+]$ and $[OH^-]$ is known as ionic product of water.

$$[H^+][OH^-] = (10^{-7} \text{mol L}^{-1})\ (10^{-7} \text{mol L}^{-1})$$

$$= 10^{-14}\ \text{mol}^2\ \text{L}^{-2}$$

The value of ionic product of water is $1 \times 10^{-14}\ \text{mol}^2\ \text{L}^{-2}$ at 298 K

Thus, for all aqueous solutions,

$$[H^+]\ [OH^-] = 1 \times 10^{-14} \text{mol}^2\ \text{L}^{-2} \text{ at } 298\text{K}$$

$$[H^+] = \frac{1 \times 10^{-14}}{[OH^-]}\ \text{mol L}^{-1}$$

$$[OH^-] = \frac{1 \times 10^{-14}}{[H^+]}\ \text{mol L}^{-1}$$

Problems

(1) What is the pH of 0.1 M solution of HCl ?

HCl is a strong acid. It is completely ionised in aqueous solution.

$$\text{HCl + water} \longrightarrow H^+_{(aq)} + Cl^-_{(aq)}$$

$$[H^+] = [\text{HCl}] = 0.1 \text{ M (or) } 0.1 \text{ mol L}^{-1}$$

$$\text{pH} = -\log [H^+]$$

$$= -\log (0.1)$$

$$\text{pH} = -\log (10^{-1})$$

$$\text{pH} = 1$$

(2) What is the concentration of OH^- ions in a solution containing 0.001 mol L^{-1} of H^+ ions ?

$$[H^+] = 0.001 \text{ mol L}^{-1}$$

$$= 1 \times 10^{-3} \text{ mol L}^{-1}$$

$$[OH^-] = \frac{1 \times 10^{-14}}{[H^+]}$$

$$= \frac{1 \times 10^{-14} \text{mol}^2 \text{L}^{-2}}{1 \times 10^{-3} \text{mol L}^{-1}}$$

$$[OH^-] = 1 \times 10^{-11} \text{ mol L}^{-1}$$

(3) pH of a solution changes from 2 to 3. What is the change in concentration of H^+ ions in the solution.

$$\text{pH} = -\log [H^+]$$

when $\text{pH} = 2$,

$$\log [H^+] = -2$$

$$[H^+] = 1 \times 10^{-2} \text{ mol L}^{-1}$$

when $\text{pH} = 3$

$$\log [H^+] = -3$$

$$[H^+] = 1 \times 10^{-3} \text{ mol } L^{-1}$$

Thus, with increase in pH of the solution from 2 to 3, the concentration of H^+ ion decreases from 1×10^{-2} mol L^{-1} to 1×10^{-3} mol L^{-1}.

$$\frac{[H^+]_{pH=3}}{[H^+]_{pH=2}} = \frac{1 \times 10^{-3} \text{ mol } L^{-1}}{1 \times 10^{-2} \text{ mol } L^{-1}}$$

$$= \frac{1}{10}$$

Thus, when pH of a solution increases by 1 unit, concentration of H^+ ions becomes one-tenth of the original concentration.

The strength of an acid or a base is measured on the pH scale.

The pH scale ranges from 0 to 14. A solution with a pH value of 7 is neutral which means that it is neither acidic nor basic.

Water is the best known example of a neutral liquid. It is neither acidic nor basic and has a pH value of 7. If a solution has a pH value less than 7, it is acidic. If a solution has a pH value greater than 7, it is basic. Acidic solutions which are very strong have a very low pH value. Lower the pH value, stronger is the acid. Similarly higher the pH value, the stronger is the base.

Basic solution which are very strong have a very high pH value.

pH of a solution can be measured using a pH meter. But pH meters are expensive. A more common method of measuring pH in a school laboratory is by using **universal indicator.** This is a mixture of indicators, which gives different colours across the entire pH range. You can use it as a solution or strip of paper.

Activity : Prepare your own indicator : Take a jar with cabbage leaves and pour boiling water to it. Allow it to cool to room temperature and filter it. This cabbage juice is used to find whether the given solution is acidic or basic. This juice produces a red colour when mixed with an acid and a green colour with a base.

Table 6.2 Approximate values of pH for some familiar solutions.

Solutions	pH
Blood	7.3 - 7.5
Saliva	6.5 - 7.5
Urine	5.5 - 7.5
Coffee	4.5 - 5.5
Tomato juice	4.0 - 4.4
Vinegar	2.4 - 3.4
Lemon juice	2.2 - 2.4
Gastric juice	1.0 - 3.0
Soft drinks	3.0
Milk	6.5
Sea water	8.5

Activity : Take any tooth paste. Add cabbage juice to it. It changes to green which shows that tooth paste is basic in nature. The tooth paste should be basic due to the reason, that some acids are formed by the bacteria in our mouth and these are neutralised by the bases present in the tooth paste.

SELF EVALUATION

Choose the correct answer

1. The unit of the rate of the reaction is
   (1) mol L^{-1} (2) mol L^{-1} S^{-1}
   (3) mol LS^{-1} (4) L mol^{-1} S^{-1}

2. Which of the following is a weak acid ?
   (1) HNO_3 (2) H_2SO_4
   (3) HCl (4) CH_3COOH

3. The value of ionic product of water at 298 K is,

(1) 1×10^{-7} $mol^2 L^{-2}$

(2) 1×10^{-14} $mol^2 L^{-2}$

(3) 1×10^{14} $mol^2 L^{-2}$

(4) 1×10^{7} $mol^2 L^{-2}$

4. In a neutral solution,

(1) $[H^+] = 0$

(2) $[OH^-] = 0$

(3) $[H^+] = [OH^-]$

(4) $[H^+] = [OH^-] = 0$

5. pH of 0.1 M HCl would be,

(1) 1 (2) 0

(3) 13 (4) −1

6. pH of 0.1 M NaOH would be

(1) 2 (2) 13

(3) 1 (4) 6

7. For a reversible reaction at equilibrium,

(1) there is no change in volume

(2) the reaction is stopped completely

(3) the rate of forward reactin is equal to the rate of reverse reaction

(4) the forward reaction is faster than the reverse reaction

8. The rate of chemical reaction generally,

(1) increases with increase in temperature

(2) increases with decrease in temperature

(3) decreases with increase in temperature

(4) does not change with temperature

9. According to Arrhenius, NaOH is a base because it gives

(1) OH^- ions in aqueous solution

(2) Na^+ ions in aqueous solution

(3) both Na^+ and OH^- ions in aqueous solution

(4) no ions in aqueous solution

Fill in the blanks

10. The equilibrium constant is independent of the ..... of the reactants.

11. The pH of an acidic solutin is ..... than 7 and the pH of an alkaline solution is ..... than 7.

12. According to Arrhenius an acid gives ..... ions and a base gives ..... ions when dissolved in water.

13. pH of a solution is found to be 4.0. The solution will turn ..... litmus .....

14. Reaction between covalent compounds are usually ..... and reaction between ionic compounds are very .....

15. Complete the following :

$N_2 + 3H_2 \rightleftharpoons$ .....

16. Marble chips + HCl $\longrightarrow$ .....

17. pH of blood is .....

18. ..... is the catalyst used in the Haber process.

Answer briefly

19. Define the rate of chemical reaction.

20. Name two strong acids and two strong bases.

21. Define pH of a solution and write an expression for it.

22. What are exothermic reactions ? Give two examples.

23. What are endothermic reactions ? Give two examples.

24. Give the expression for the ionic product of water. What is the value of ionic product of water ?

25. Write an expression for the rate of reaction.

(a) in terms of the change in concentration of a reactant.

(b) in terms of the change in concentration of a product.

26. What is called rusting of iron ?

27. Write the equilibrium constant for the following reactions.

(i) $CO_{(g)} + 3H_{2(g)} \rightleftharpoons CH_4(g) + H_2O_{(g)}$

(ii) $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

Answer in detail

28. What are reaction rate curves. Explain with diagram.

29. Explain fast, slow and very slow reactions with examples.

30. Discuss that chemical equilibrium is called dynamic equilibrium.

31. Explain the effect of concentration of reactants on the rate of reaction.

32. Explain that formation of HI is a reversible reaction. Give two more examples.

33. The formation of ammonia is an exothermic reaction while that of formation of Nitric oxide is an endothermic reaction. Explain.

Problems

34. The hydrogen ion concentration of a solution is 1×10^{-4} mol L^{-1}. Find the hydroxide ion concentration of the solution ?

[**Ans.** 1×10^{-10} mol L^{-1}]

35. The pH of a solution is 6. What is the concentration of OH^- ions in the solution ?

[**Ans.** 1×10^{-8} mol L^{-1}]

36. The pH values of 1 M aqueous solutions of these acids X, Y and Z are 2.0, 1.0 and 3.0 respectively. Arrange these acids in the increasing order of acid strength.

37. For the reaction $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$, at 373 K if $[N_2O_4] = 1.4 \times 10^{-3}$ molL^{-1} and $[NO_2] = 1.7 \times 10^{-2}$ mol L^{-1} at equilibrium, calculate the value of equilibrium at 373 K.

[**Ans.** $2.1 \times 10^{-1} = 0.21$]

38. At 298 K, equilibrium concentration of the reactants and products for the reaction,

$$H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$$

are given as

$[H_2] = 0.04$ M
$[I_2] = 0.03$ M
$[HI] = 0.25$ M

Calculate the equilibrium constant for this reaction at the given temperature.

[**Ans.** 52.08]

39. What is the pH of an aqueous solution of sodium hydroxide having a concentration, 0.01 mol L^{-1} ?

[**Ans.** 12]

Activities

40. Place a mixture of NO_2 and N_2O_4 in each of the three separate density bottles. Place one bottle in H_2O at 298 K, the other in H_2O at 323 K and third one in H_2O at 373 K. Compare the intensity of the colour in three bottles and explain.

41. Use cabbage juice as indicator and find out whether the solution of baking soda and washing soda are acidic or basic.

42. Take a bowl of plaster of pairs and add water to it. Touch the paste and observe. How do you feel and why ?

43. Take each 200 ml of warm milk and cold milk in two different bowls. Add a few drops of butter milk to both. What do you observe after about few hours ? explain.

7. CHEMICAL COMPOUNDS

Chemical compounds play an important role in our daily life. For example, washing soda is used to clean our clothes, baking soda is used as baking powder and in antacids. Bleaching powder makes water disinfected. Plaster of Paris is used in hospitals for setting fractured bones. Cement and steel are inevitable wonderful building materials which are widely used in the construction of buildings, bridges, dams etc. There are different types of glass which are used as mirrors, lenses, windows, decorative articles etc. All these substances are the precious gifts of chemical industry. In this chapter, we shall restrict our discussion to some of the chemical compounds without which our modern-day life would be very difficult.

7.1 Washing soda

Washing soda is sodium carbonate decahydrate, $Na_2CO_3.10H_2O$. Formerly, sodium carbonate was made from the ash of sea weeds. It was also found to occur as an efflorescent deposit (Trona, $Na_2CO_3.\ NaHCO_3\ .\ 2H_2O$) in Egypt. In India, an efflorescent soil called Sajimati, which is a mixture of sodium carbonate, sodium bicarbonate, sodium sulphate and clay is found in places such as Dehradun, Mathura, Varanasi and Jaunpur.

Sodium carbonate is one of the most important industrial chemicals. First, anhydrous sodium carbonate is manufactured by the **Solvay process** (ammonia-soda process) and then it is converted into sodium carbonate decahydrate which is called washing soda**.**

1. Manufacture

This is the modern method used for the manufacture of sodium carbonate. The basic raw materials required for this process are saturated (concentrated) solution of sodium chloride (brine), ammonia and limestone (to furnish carbon dioxide). The various steps involved in the process are described below.

1) Ammonia absorber

In ammonia absorber, ammonia gas and traces of carbon dioxide are passed through brine solution. The ammoniated brine is filtered to remove precipitated calcium and magnesium carbonate.

2) Carbonating Tower

It is a high tower fitted with perforated plates. Ammoniated brine solution is made to trickle down from the top of the tower while carbon dioxide gas from the limekiln is introduced from the base of the tower. Carbon dioxide rises through the small perforations and reacts with ammoniated brine forming insoluble sodium hydrogencarbonate.

$$NH_3 + H_2O + CO_2 \longrightarrow \underset{\substack{\text{ammonium}\\ \text{hydrogen carbonate}}}{NH_4HCO_3}$$

$$NaCl + NH_4HCO_3 \longrightarrow \underset{\text{Sodium bicarbonate}}{NaHCO_3} + NH_4Cl$$

The solution containing crystals of sodium hydrogencarbonate is drawn off from the base of the carbonating tower and filtered to get sodium hydrogencarbonate.

3) Calcination

Sodium hydrogencarbonate obtained from the above step is heated strongly in a kiln to convert it into sodium carbonate.

$$2NaHCO_3 \longrightarrow Na_2CO_3 + CO_2 + H_2O$$

Carbon dioxide evolved here is sent to carbonating tower.

Sodium carbonate is then recrystallised by dissolving in water to get washing soda, sodium carbonate decahydrate.

$$Na_2CO_3 + 10H_2O \longrightarrow Na_2CO_3 . 10H_2O$$

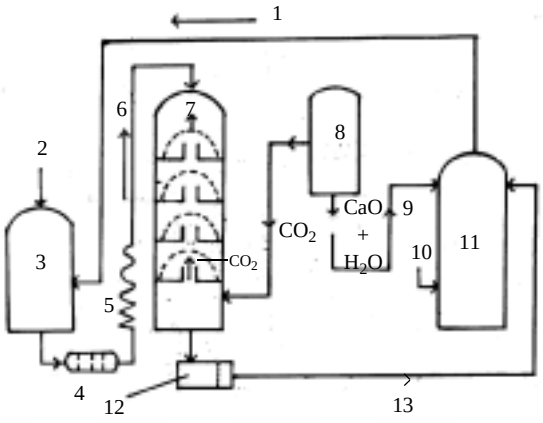


Fig. 7.1 Solvay Process

1. $NH_3 + CO_2$ (traces) 2. Brine 3. Saturating tank
4. Filter 5. Cooling pipes 6. Ammoniacal brine
7. Carbonating tower 8. Lime kiln 9. Slaked lime
10. Steam 11. Ammonia recovery tower
12. $NaHCO_3$ (for ignition) 13. NH_4Cl + a little NH_4HCO_3

4) Ammonia Recovery Tower

The filtrate, after the removal of sodium hydrogencarbonate, contains ammonium salts such as ammonium hydrogencarbonate and ammonium chloride. The filtrate is mixed with slaked lime and is heated in ammonia recovery tower.

$$NH_4HCO_3 \longrightarrow NH_3 + H_2O + CO_2$$

$$2NH_4Cl + Ca(OH)_2 \longrightarrow 2NH_3 + 2H_2O + CaCl_2$$

ammonium chloride — slaked lime

The mixture of ammonia and carbon dioxide obtained is used for saturation of brine while calcium chloride is obtained as a by-product.

5) Lime kiln

Lime stone is heated at about 1373K to obtain carbon dioxide.

$$CaCO_3 \longrightarrow CaO + CO_2 \uparrow$$

The carbon dioxide gas goes to the carbonating tower while lime is mixed with water to form slaked lime which is utilised for the reaction with ammonium chloride to get back ammonia.

Since most of the ammonia can be recovered, brine and lime stone are the only raw materials required for this process.

2. Properties

1) Washing soda is a transparent, crystalline solid, soluble in water and the solution is found to be alkaline as it turns red litmus blue.

2) Washing soda, the decahydrate of sodium carbonate effloresces in air forming sodium carbonate monohydrate. **Efflorescence** is the process of losing water of crystallisation from a hydrated salt when kept exposed to air for a long time.

$$Na_2CO_3 . 10H_2O \longrightarrow Na_2CO_3 . H_2O + 9H_2O$$

The monohydrate, $Na_2CO_3 . H_2O$ is a white amorphous solid, which is stable in air.

3) On heating, washing soda gives anhydrous sodium carbonate called **soda ash.**

$$Na_2CO_3 . 10H_2O \longrightarrow \underset{\text{soda ash}}{Na_2CO_3} + 10H_2O$$

4) Sodium carbonate reacts with dilute acids and gives carbon dioxide.

$$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2$$

$$Na_2CO_3 + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O + CO_2$$

5) It precipitates insoluble carbonates from some metallic salt solutions.

$$BaCl_2 + Na_2CO_3 \longrightarrow BaCO_3\downarrow + 2NaCl$$

$$ZnSO_4 + Na_2CO_3 \longrightarrow ZnCO_3\downarrow + Na_2SO_4$$

3. Uses

Sodium carbonate is used

1) in the manufacture of paper, soap, textiles, paints, etc.

2) in laundry as washing soda and as a cleaning agent for domestic purposes.

3) as an important laboratory reagent both in qualitative and quantitative analysis.

4) in softening of hard water.

Softening of hard water

Hardness of water is due to the presence of soluble salts of calcium and magnesium.

When washing soda is dissolved in hard water, calcium and magnesium salts which cause hardness, react with washing soda and gets precipitated as insoluble solids, thus leaving the water soft.

$$Na_2CO_3 + MgSO_4 \longrightarrow Na_2SO_4 + MgCO_3\downarrow$$

Activity : Take washing soda in a test tube and add dilute hydrochloric acid to it. You observe a brisk effervescence due to the evolution of a gas. Pass the gas into the test tube containing lime water and the lime water turns milky. This is because, washing soda reacts with dilute hydrochloric acid and liberates carbon dioxide. This carbon dioxide gas turns lime water milky due to the formation of calcium carbonate, a white precipitate.

7.2 Baking soda

Sodium hydrogencarbonate, $NaHCO_3$ *(sodium bicarbonate) is known as baking soda.*

1. Manufacture

Sodium bicarbonate is manufactured by Solvay process which has already been described in section 7.1.

It is prepared in the laboratory, by saturating aqueous solution of sodium carbonate with carbon dioxide.

$$Na_2CO_3 + CO_2 + H_2O \longrightarrow 2NaHCO_3$$

2. Properties

1) Baking soda is a white solid. It is sparingly soluble in water and the solution is slightly alkaline which turns red litmus blue.

2) When it is heated, it decomposes with the evolution of carbon dioxide gas. Hence, it is used as a constituent of baking powder to soften the dough and to aerate the drinks.

$$2NaHCO_3 \xrightarrow{\Delta} Na_2CO_3 + CO_2\uparrow + H_2O$$

3) It gives brisk effervescence with acids due to the liberation of carbon dioxide.

$$NaHCO_3 + HCl \longrightarrow NaCl + CO_2\uparrow + H_2O$$

3. Uses

1) Baking soda is used in the preparation of baking powder. Baking powder is a mixture of sodium bicarbonate and tartaric acid. Baking powder is used in aerated drinks and as an additive in food stuff to make it soft.

2) Baking soda is used in fire extinguishers.

3) It is an important ingredient of antacids to reduce the acidity of stomach, as its solution is alkaline in nature.

4) Baking soda is used as an important reagent in the laboratory.

5) It is also used as an important chemical in the textile, tanning, paper and ceramic industries.

Activity : Take required quantity of cake dough in each of two bowls A and B. To bowl A add baking powder and bowl B add baking soda. Bake the dough and taste the cake in bowl A and B. You observe that cake in bowl A tastes sweet and bowl B bitter. The

cakes are soft and swollen in both. This is because, carbon dioxide is evolved on heating which has given softness to the cakes in bowls both A and B. But, sodium carbonate produced during baking is neutralised by tartaric acid present in baking powder in bowl A and therefore cake bowl A tastes good. Bowl B with baking soda does not contain tartaric acid and sodium carbonate produced during baking remains as such and gives the bitter taste.

Activity : Carbon dioxide the enemy of fire : Take little vinegar and baking soda in two separate wide mouth bottles and add half a cup of water in to each of them. Bring a burning match stick at the mouth of two bottles. You observe that the match sticks continue burning. Then, pour vinegar into baking soda solution and observe the effervescence. Bring a burning match stick at the mouth of the bottle containing the mixture. You observe that the burning match stick is extinguished. This is because carbon dioxide is produced during the reaction which puts off the burning match stick.

7.3 Bleaching powder

Bleaching powder is chemically, calcium oxychloride.

1. Manufacture

Bleaching powder is manufactured using Backmann's plant. It consists of a vertical tower made of cast iron, provided with inlets slightly above the base, for chlorine and hot air, a hopper and an exit for the unused chlorine at the top. Inside the tower, are a number of horizontal shelves at regular heights. Each shelf is provided with rotating rakes.

The dry slaked lime is fed into the chlorinating tower through the hopper at the top. Slaked lime thus added moves downwards with the help of the rotating rakes. During its downward movement, it meets the upcoming current of chlorine. By the time, it reaches the bottom, it gets thoroughly saturated with chlorine gas, and is converted into bleaching

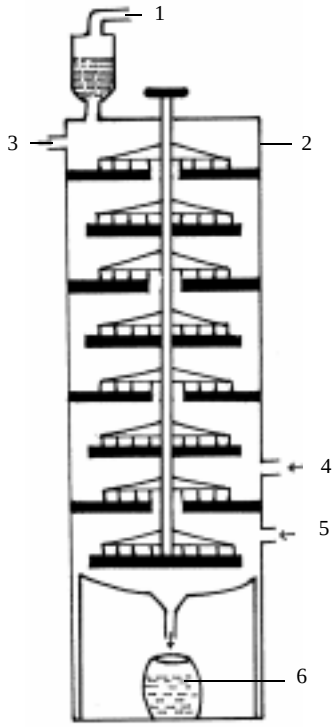


Fig. 7.2 Bachmann's plant

1. Slaked lime + compressed air 2. chlorinating tower
3. Exit for unused chlorine 4. Chlorine 5. Hot air
6. Bleaching powder

powder which gets collected in the container at the bottom. A current of hot air drives away the unreacted chlorine.

$$\underset{\text{slaked lime}}{Ca(OH)_2} + Cl_2 \longrightarrow \underset{\text{bleaching powder}}{CaOCl_2} + H_2O$$

2. Properties

1) Bleaching powder is a yellowish white powder with a strong smell of chlorine.

2) When exposed to air, bleaching powder gives a smell of chlorine. This is because bleaching powder reacts with carbon dioxide from the atmosphere to produce calcium carbonate and chlorine.

$$CaOCl_2 + CO_2 \longrightarrow CaCO_3 + Cl_2$$

3) In the presence of a very small amount of dilute acid, it gives nascent oxygen.

$$2CaOCl_2 + H_2SO_4 \longrightarrow CaCl_2 + CaSO_4 + 2HOCl$$

(hypo chlorous acid)

$$2HOCl \longrightarrow 2\ HCl + 2\ [O]$$

(nascent oxygen)

Due to the evolution of nascent oxygen, it acts as an oxidising and a bleaching agent.

4) When it is treated with excess of dilute acids, chlorine is evolved.

$$CaOCl_2 + H_2SO_4 \longrightarrow CaSO_4 + H_2O + Cl_2$$

$$CaOCl_2 + 2HCl \longrightarrow CaCl_2 + H_2O + Cl_2$$

Chlorine gas produced in this way is known as, "available chlorine" which is responsible for the bleaching action of bleaching power. Available chlorine in bleaching powder is usually 35 - 38% by weight. The strength of bleaching powder is estimated on the basis of available chlorine content. Commercially prepared bleaching powder is seldom pure as it contains a small amount of unreacted slaked lime.

3. Uses

1) Bleaching powder is used to bleach cotton and linen in textile industry and wood pulp in paper industry. It is also used to bleach washed clothes in laundry.

2) It is used as a disinfectant and germicide, since it liberates chlorine on exposure to the atmosphere which destroys the germs. It is also used for disinfecting water for the same reason.

3) It is also used as an oxidising agent in many chemical industries.

Activity : Take about 50 g of bleaching powder, apply it on the wet floor of the bath room and allow it for some time. Then wash the floor. You observe that the floor is very clean which is due to the bleaching action of bleaching powder.

Activity : Take a glass of water supplied by your Panchayat / Municipality / Corporation and smell it. You get the smell of chlorine in it. This is due to the reason that a required quantity of bleaching powder is treated with water. This liberates chlorine which acts as a disinfectant and keeps the water free of germs.

7.4 Plaster of Paris

Plaster of Paris is calcium sulphate hemihydrate. The formula is given as, $CaSO_4 . 1/2H_2O$ or $(2\ CaSO_4) . H_2O$.

About 5000 years ago, Egyptians obtained a powder by heating gypsum ($CaSO_4 . 2H_2O$) in open air fires. This powder was used for cementing blocks of their monuments. The powder is called plaster of Paris, because the gypsum which was used to get the powder was mainly found in Paris. Initially, plaster of Paris was used only in construction industry, but now it is found to be of great use in medical field and manufacture of toys.

1. Preparation

It is prepared by heating gypsum at 373K in rotary kilns, where it gets partially dehydrated.

$$\underset{\text{gypsum}}{CaSO_4 . 2H_2O} \xrightarrow{373K} \underset{\text{plaster of Paris}}{CaSO_4 . \tfrac{1}{2}H_2O} + 1\tfrac{1}{2}\ H_2O$$

$$2(CaSO_4 . 2H_2O) \xrightarrow{373K} (2CaSO_4) . H_2O + 3H_2O$$

If the temperature is not maintained carefully, further dehydration will take place at higher temperature and setting property of the plaster will be partially reduced.

$$CaSO_4 . 2H_2O \longrightarrow CaSO_4 + 2H_2O$$

2. Properties

Plaster of Paris is a white powder. When it is mixed with water (1/3rd of its mass), gypsum is obtained back. It initially forms a

plastic mass with the evolution of heat and then sets to a hard solid mass within 5 to 15 minutes.

$$\underset{\text{plaster of Paris}}{CaSO_4 . \tfrac{1}{2}H_2O} + 1\tfrac{1}{2}\, H_2O \longrightarrow \underset{\text{gypsum}}{CaSO_4 . 2H_2O}$$

$$(2\, CaSO_4)\, . H_2O + 3\, H_2O \longrightarrow 2\, (CaSO_4 . 2H_2O)$$

Setting of plaster of Paris is accompanied by a slight expansion (about 1%) in volume which makes it suitable for making casts for statues, toys, etc. The setting of plaster of Paris can be catalysed by adding sodium chloride to it.

3. Uses

Plaster of Paris is used

1) to make black board chalks, toys and decorative materials.
2) for making smooth surfaces and ornate designs on walls and false ceilings.
3) to make casts for statues.
4) in hospitals for setting broken or fractured bones and in dentistry.
5) in laboratories, for sealing air gaps in apparatus to make it air tight.

Activity : ***Home - made plaster of Paris :*** Take few pieces of chalk, grind it into a fine powder and put it in a clean beaker. Then, pour the same volume of dilute hydrochloric acid into it. A turbulent reaction takes place with effervescence. When the effervescence ceases, add sulphuric acid drop by drop. Continue till the precipitation is complete and filter. The white substance left on the filter paper is plaster of Paris.

7.5 Cement

Cement is one of the most important building materials used worldwide. The first people known to have used cement were the Egyptians who used it to build their pyramids. Egyptians, Greeks and Romans used volcanic stuff as cement. These natural cements consist of a mixture of burnt silicates and lime.

Cement was first discovered by an English brick layer named Joseph Aspdin in 1824. He called it Portland cement for the reason that the cement he discovered, resembled the limestone found in Portland. Note that whether we call it cement or Portland cement, it means the same.

1. Manufacture

The approximate composition of Portland cement is given below :

Lime (CaO)	-	60 - 70%
Silica (SiO_2)	-	20 - 25%
Alumina (Al_2O_3)	-	5 - 10%
Ferric oxide (Fe_2O_3)	-	2 - 3 %

The raw materials used for the manufacture of Portland cement are limestone (provides CaO) and clay (provides SiO_2, Al_2O_3 and Fe_2O_3) which are finely powdered and then mixed in the ratio 3 : 1 by mass. The mixture is again ground to a fine powder and water is added. The finely

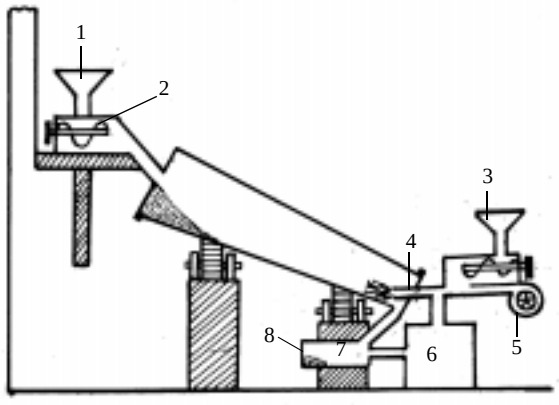


Fig. 7.3 Manufacture of Portland Cement

1. Hopper for raw materials 2. Screw conveyer
3. Hopper for coal dust 4. Hot air 5. Air blower
6. Dust chamber 7. Cooler 8. Cement clinker

ground powder called slurry is heated to 1773 K in a rotary kiln. On heating, lime, silica, alumina and ferric oxide react together and produces a mixure of dicalcium silicate, tricalcium silicate and tricalcium aluminate called **clinker**.

The clinker is cooled and a small amount of gypsum (2 - 5%) is added to it, to delay the setting time of cement. The mixture of clinker and gypsum is then ground to a fine powder which is called cement. It is stored in tall structures called silos. The cement is then packed in water-proof bags and sent to the market for sale.

2. Setting of cement

When cement is mixed with water, it becomes hard over a period of time. This is called setting of cement.

3. Uses of cement

Cement is used in various forms such as mortar, concrete and Reinforced concrete cement.

1) Mortar

A mixture of cement and sand in the ratio 3 : 1 with required amount of water is called mortar. The cement mortar sets to a hard mass after sometime and binds the building materials like bricks and stones very firmly.

2) Concrete

A mixture of cement, sand, gravel (crushed stones) and water is called concrete. On setting, concrete becomes extremely hard and strong. It is used in the construction of buildings, roads, dams, bridges etc.

3) Reinforced Cement Concrete (RCC)

Reinforced cement concrete is obtained by embedding iron rod or steel mesh in the body of the concrete. On setting, it becomes extremely hard and strong. RCC is used for building dams, bridges, roofs and pillars. Other materials used for RCC are wire mesh, asbestos, bamboo etc. The RCC set around circular wire mesh is used to make pipes used for water supply and in sewage system.

7.6 Glass

Glass is one of the earliest manufactured materials. It is believed that the first glass objects were made by the Egyptians. They used glass jars and pots for storing and preserving perfumes, ointments, and oils. Later, a method of blowing glass into bottles from molten glass was developed. In fact, now, glass is used in one form or the other in almost every sphere of life.

Window panes of buildings and auto mobiles, artificial gems in jewellery, mirrors on our dressing tables, electric bulbs, ovenware and laboratory glassware like test tubes, funnels beakers, are all made of glass. The lenses of cameras, microscopes and telescopes and our spectacles are also made of glass. In India, different varieties of glass is being manufactured at Bangalore, Mumbai, Kolkata, Ferozabad and Delhi, etc.

1. Manufacture of glass

The approximate composition of ordinary glass is given by the formula, Na_2O. CaO $6SiO_2$.

The raw materials required for the manufacture of ordinary glass are sodium carbonate, calcium carbonate and silica. The raw materials are ground separately to a fine powder, weighed accurately and mixed in a definite proportion. The mixture is called **batch.** A specific amount of cullet (broken pieces of glass) is added to increase the fusibility of the glass produced.

The mixture is heated in fire clay pots or in a tank furnace. The pots (or tanks) are heated by using producer gas. The burning of gases produce a high temperature of about 1673 K in the furnace. The raw materials present in the batch melt at this high temperature and react with one another to form glass. Carbon dioxide is evolved during the reaction.

After a few hours, when the evolution of carbon dioxide ceased the mass has melted to a clear liquid and it is allowed to cool down.

Annealing

The glass articles are made by pouring molten glass into moulds and then cooling. If the glass is cooled rapidly, it becomes very

brittle and cracks easily and if it is cooled very slowly, it becomes opaque. Therefore, it should be cooled neither very slowly nor very quickly. In the annealing process, the hot glass articles are placed on a slow moving belt which passes through a long narrow chamber in which the temperature is regulated carefully so that it is hot at the starting point and at room temperature at the other end. This process of slow and uniform cooling is called annealing and it takes several days for completion.

2. Properties

Glass

1) is considered to be a super cooled liquid.
2) is hard and brittle.
3) has no fixed melting point.
4) is practically insoluble in water.
5) is not attacked by air and any other oxidising agents.
6) is also resistant to chemical reagents except hydrofluoric acid and alkalis. Alkalis have a slow corroding action on glass.

Activity : *Etching of glass :* Cover the surface of glass to be etched with paraffin wax by coating molten wax when yet hot with a brush. You write anything or make a floral design on the glass surface coated with wax with a sharp pointed instrument so that the wax is scratched off. Apply hydrofluoric acid on the scratched portion and leave it for 15 minutes. Then, wash it with running water (Don't touch hydroflouric acid). Remove wax either by scratching off or by keeping the article in hot water. You observe that the design or the writing which you did by scratching the wax was seen etched on the glass. This is due to the reason that the exposed glass surface alone has reacted with hydrofluoric acid and has created a beautiful design or letters on the glass. Thus, you can etch the glass surfaces with your own designs.

7.7 Steel

Steel is the most important commercial form of iron. Steel was employed for the manufacture of swords in pre-historic times. In India, the metallurgical marvels of the past ages can be witnessed at various historical sites. One such marvel is the Chandraraja iron pillar at Delhi, which was built during Gupta age and the pillar is still free of rust. The massive beams in the Sun temple at Konark shows the efficiency of the ancient Indian metallurgists.

Iron and steel are being manufactured in India by Tata Iron and Steel company at Jamshedpur. The other steel plants are located at Rourkela, Bilai, Durgapur, Bokaro, Salem and Vishakapatnam.

The properties of steel depend on the amount of carbon present in it. There are mainly two types of steel.

1. Mild steel

Iron containing 0.1 - 0.4% carbon is called mild steel. It is quite malleable, ductile and very tough. Mild steel is used for making sheets, wires, car parts, springs, axles, screws, railway lines, wheels, ships, bridges, pipes, cables, and in building construction.

2. Hard steel

Iron containing 0.5 - 1.5% carbon is called hard steel. It is very hard and can be further hardened by the process of quenching. (Unit 8) It is used for making razor blades, knives, drill bits and cutting tools.

Both mild and hard steel have one major disadvantage that they tend to rust unless they are protected. To overcome such problems and to give certain desirable properties to steel so that they can be used for distinct purposes, some special types of steel called alloy steels are made.

3. Alloy steels

The alloy steels are formed by alloying steel with some other metal or metals in different proportions. The addition of metals

has a remarkable effect on the properties of steel. Some of the alloy steels made are stainless steel, tungsten steel, nickel steel, manganese steel, etc.

1) Stainless steel

It contains 8% nickel and 18% chromium. It is resistant to corrosion and has high tensile strength. Therefore it is used for making utensils, cutlery, automobile parts, surgical instruments, etc.

2) Tungsten steel

It contains 20% tungsten, 5% chromium and a little of vanadium. It acquires hardness on alloying with tungsten. It is used in making drilling tools and cutting tools.

3) Nickel steel

It contains 2% nickel. It is hard, resistant to corrosion and elastic. It has higher tensile strength than iron. It is used for making bicycle parts, automobile parts and aeroplane parts. If the percentage of nickel is 36, then the alloy is used for making scientific instruments. If the alloy contains 46% nickel, it is used in making radio valves.

4) Manganese steel

It contains 7-20% manganese. It is very hard and tough and resistant to wear and tear. It is used for making steel helmets, rock-crushing machinery, burglar proof safety lockers and rail road tracks.

5) Silicon steel

Silicon steel containing about 15% silicon is extremely hard and resistant to acids. It is used to make pipes for carrying acids. Silicon steel, containing 35% silicon is used for making transformers and electromagnets.

6) Cobalt steel

Steel containing upto 35% cobalt possesses exceptionally good magnetic properties. Hence, cobalt steel is used for making permanent magnets.

SELF EVALUATION

Choose the correct answer

1. Concentrated solution of sodium chloride is called

   (1) saline water (2) Sterilized water
   (3) brine (4) mineral water

2. In Solvay process, the salt that separates out in carbonating tower is,

   (1) NH_4HCO_3 (2) $NaHCO_3$
   (3) Na_2CO_3 (4) $CaCl_2$

3. The chemical formula of baking soda is

   (1) CaO (2) SiO_2
   (3) $NaHCO_3$ (4) Na_2CO_3

4. Bleaching powder is prepared by passing chlorine through

   (1) quick lime (2) milk of lime
   (3) dry slaked lime (4) limestone

5. Bleaching powder is represented by the formula

   (1) $CaO . CaCl_2$ (2) $CaOCl_2$
   (3) $CaCl_2$ (4) $CaCl_2 . CaCO_3$

6. Chemical formula of plaster of Paris is

   (1) $(2CaSO_4) . H_2O$
   (2) $CaSO_4 . H_2O$
   (3) $CaSO_4 . 2H_2O$
   (4) $(CaSO_4)_2 . 2H_2O$

7. The setting of plaster of Paris takes place due to

   (1) oxidation (2) reduction
   (3) dehydration (4) hydration

8. The oxide that is present in maximum portion in cement is

   (1) SiO_2 (2) Fe_2O_3
   (3) Al_2O_3 (4) CaO

9. Glass is attacked by

   (1) HCl (2) H_2SO_4
   (3) HF (4) HNO_3

Fill in the blanks

10. $NH_4HCO_3 \xrightarrow{\Delta}$ .....+ ..... + H_2O.
11. The formula of washing soda is .....
12. ..... is evolved when bleaching powder is treated with excess of dilute acids.
13. The basic raw materials required for the manufacture of cement are ..... and .....
14. ..... effloresces in air.
15. Sodium hydrogencarbonate is ..... soda whereas sodium carbonate is ..... soda.
16. ..... is used for bleaching wood pulp in paper industry.
17. ..... is used to join the broken bones.
18. Wet concrete is allowed to set around steel bars and it forms .....
19. ..... is considered to be a super-cooled liquid.
20. ..... is used in softening of hard water.

Answer briefly

21. What happens when washing soda is left exposed to air for a long time ?
22. A baker found that the cake prepared by him is hard and flat. Which ingredient has he forgotten to add that makes the cake fluffy? Explain your answer.
23. How does bleaching powder react with excess of dilute sulphuric acid ? Give the equation for the reaction involved.
24. Why is bleaching powder packed in air-tight containers ?
25. Give important uses of plaster of Paris .
26. What will happen if heating is not controlled while preparing plaster of Paris ?
27. Give an approximate composition of Portland cement.
28. Why is gypsum added to cement ?
29. When lime stone is strongly heated with a substance X, it forms cement. Another substance Y is then added to retard the initial setting of cement? What are X and Y?
30. Explain the terms, concrete and mortar.
31. What is RCC and give its uses.
32. What is annealing of glass ?
33. How does the percentage of carbon in mild steel and hard steel differ ?
34. Write the composition and uses of tungsten steel.

Answer in detail

35. Describe Solvay process with diagram for the manufacture of washing soda. Give equations for the reactions involved.
36. Which compound is used in antacids in medicine ? How is it obtained from sodium chloride ? Write equations for the reactions involved.
37. How will you obtain bleaching powder from slaked lime ? Explain it with diagram.
38. Explain the preparation, properties and uses of plaster of Paris.
39. Describe a method with neat labelled diagram for the manufacture of cement.
40. Give the composition of ordinary glass. How is glass manufactured ?

Activity

41. What happens when you dip the red litmus paper in the solution of either washing soda or baking soda ? Why ?
42. For an insect bite, your teacher asks you to apply sodium bicarbonate. Why ?
43. Dip a few wet rose petals in the solution of bleaching powder. What happens ? Why ?
44. Take a container of bleaching powder and smell it. Do you get any smell ? What is the smell due to ? Why ?
45. Keep a burette filled with dilute caustic soda solution for a day or two. What happens to the stopper ? Why ?
46. Take any bottle containing an antacid. Notice the composition of the ingredients given on the label. Sodium bicarbonate is one of the important ingredients present in them. Why?
47. Take a glass jar, fill with water, add about 2 tablespoon of sodium bicarbonate, and then 10 ml of hydrochloric acid and a few naphthalene balls. Can you see the balls dancing in the glass jar ? Reason out.

8. METALS AND NON-METALS

In ancient History, the progress of civilization has been marked by man's discovery and usage of metals in the earth's crust. This is understood by the fact that the great epochs of prehistory are still called "Bronze Age" and "Iron Age". The modern chemists have discovered ways and means of extracting metals from the ores with exception of gold and platinum which occur in the native state.

Metals are widely used in our daily life. Utensils made of copper, aluminim, brass and stainless steel are being used in our homes. Metals like zirconium, titanium, etc. are used in atomic energy projects, space science project, etc.

Many metals are used in the construction of buildings, bridges, automobile, aeroplanes, ships, trains, etc. Copper, iron, gold, etc. have been in use since ancient times.

Metals in trace are useful to our body, but their presence in excess has poisonous effects.

For example, deficiency of iron in our body leads to anemia; but its presence in excess leads to a disease called siderosis. The advancement of metal technology have led to the development of the miniature silicon chip which are used in computers.

There are about 115 chemical elements known at present. On the basis of their properties, the elements are broadly classified into metals and non-metals. The metals have been placed on the left hand side and in the centre of the periodic table, whereas non-metals have been placed on the right hand side. The element hydrogen has been placed on the left hand side of the periodic table. There are certain elements which show the properties of both metals and non-metals and these are called metalloids. The metals and non-metals in the periodic table are separated by a zig-zag line of metalloids. The metalloids are bismuth, silicon, germanium, arsenic, antimony, tellurium and polonium.

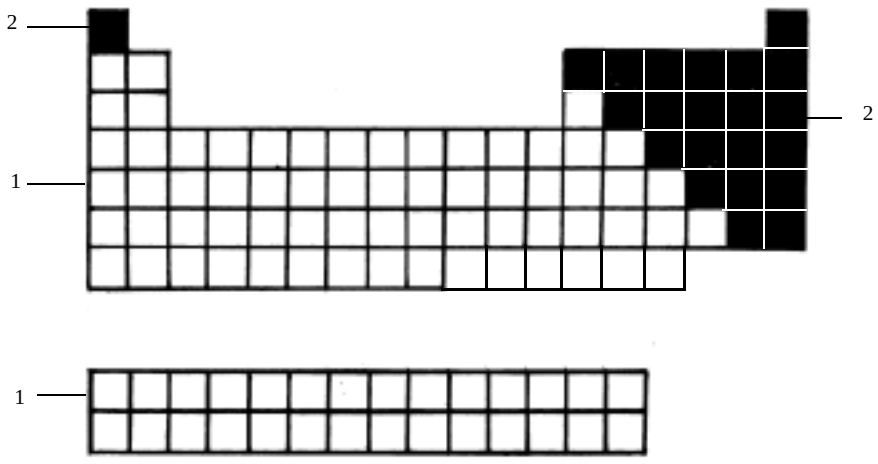


Fig. 8.1 Periodic Table

1. Metals 2. Non-metals

8.1 Characteristic properties of Metals and Non-Metals

Table 8.1 Comparison of metals and non-metals

	Metals	Non-metals
1.	They are all solids at room temperature (except mercury which is a liquid)	They can be solids or gases (except bromine which is a liquid)
2.	They are hard and malleable and can be beaten into thin sheets.	They are not malleable and cannot be beaten into sheets. They are brittle.
3.	They are lustrous (shiny) and corroded on the outside.	They are not lustrous (except Iodine, graphite and diamond)
4.	They are ductile and can be stretched into wires. (Gold and silver are the best ductile metals).	They are non-ductile. (except carbon fibre)
5.	They are sonorous and clang if they are hit.	They are non-sonorous.
6.	They are good conductors of heat and electricity. Copper and aluminium are very good conductors of heat and electricity.	They are bad conductors of heat and electricity, (except graphite).
7.	They are hard (except sodium and potassium) and have high tensile strength	They are soft (except diamond which is extremely hard) and have low tensile strength.
8.	Metals have high density.	They have low density.
9.	They have high melting and boiling points. (except sodium and potassium)	They have low melting and low boiling points (except graphite).
10.	Metals react with oxygen and forms metal oxides. which are mostly basic in nature. $4Na + O_2 \longrightarrow 2\ Na_2O$ $2\ Mg + O_2 \longrightarrow 2\ MgO$ $Na_2O + H_2O \longrightarrow 2\ NaOH$ (base) Aluminium and zinc oxides exhibit acidic as well as basic properties. Such metal oxides are known as amphoteric oxides.	Non-metals react with oxygen and form acidic or neutral oxides. Carbon and sulphur form acidic oxides. Hydrogen forms a neutral oxide. $C + O_2 \longrightarrow CO_2$ $CO_2 + H_2O \longrightarrow H_2CO_3$ (acid) $S + O_2 \longrightarrow SO_2$ $SO_2 + H_2O \longrightarrow H_2SO_3$ (acid) $2\ H_2 + O_2 \longrightarrow 2\ H_2O$ Neutral oxide.
11.	Metals react with water and form the corresponding metal hydroxides with the evolution of hydrogen. Sodium and potassium react voilently with cold water to an extent that the hydrogen evolved catches fire immediately. $2\ Na + 2H_2O \longrightarrow 2\ NaOH + H_2 \uparrow$ $Ca + 2\ H_2O \longrightarrow Ca(OH)_2 + H_2 \uparrow$ Magnesium does not react with the cold water, but it reacts with hot water. $Mg + 2H_2O \longrightarrow Mg(OH)_2 + H_2 \uparrow$ Metals like aluminium, zinc and iron reacts with steam only.	Non-metals do not react with water or steam.

	$2\ Al + 3H_2O \longrightarrow Al_2O_3 + 3H_2\uparrow$ $Zn + H_2O \longrightarrow ZnO + H_2\uparrow$	
12.	Metals displace hydrogen from dilute acids which depends upon its chemical reactivity. Sodium reacts faster with dilute acids. $2Na + 2HCl \longrightarrow 2NaCl + H_2\uparrow$ Iron reacts slowly with dilute hydrochloric acid. $Fe + 2HCl \longrightarrow FeCl_2 + H_2\uparrow$ Copper, silver and gold do not react with dilute acids.	Non-metals do not displace hydrogen from dilute acids. Non-metals, being themselves, the acceptor of electrons, cannot give electrons to the hydrogen ions of the acid to reduce them to hydrogen gas.
13.	A more reactive metal displaces a less reactive metal from its salt solution. $CuSO_4 + Zn \longrightarrow ZnSO_4 + Cu\downarrow$ $ZnSO_4 + Cu \longrightarrow$ No reaction. Copper is less reactive than zinc but more reactive than silver. $2AgNO_3 + Cu \longrightarrow Cu(NO_3)_2 + 2Ag\downarrow$	A more reactive non-metal displaces a less reactive non-metal from its salt solution. $2\ NaBr + Cl_2 \longrightarrow 2NaCl + Br_2$
14.	Metals react with chlorine to form electrovalent chlorides. $2Na + Cl_2 \longrightarrow 2NaCl$ $Ca + Cl_2 \longrightarrow CaCl_2$	Non-metals react with chlorine to form covalent chlorides. $H_2 + Cl_2 \longrightarrow 2HCl$ $P_4 + 6Cl_2 \longrightarrow 4PCl_3$
15.	Generally, metals do not react with hydrogen. But few metals like sodium, potassium, calcium and magnesium react with hydrogen to form metal hydrides which are electrovalent in nature. $2\ Na + H_2 \longrightarrow 2NaH$ $Ca + H_2 \longrightarrow CaH_2$	Non-metals react with hydrogen to form covalent hydrides. $H_2 + S \longrightarrow H_2S$ $N_2 + 3H_2 \longrightarrow 2NH_3$
16.	Metals are electropositive (donate electrons easily) in nature.	Non-metals are electronegative (accept electrons easily) in nature.
17.	Metals are good reducing agents.	Non-metals are good oxidising agents.

8.2 Minerals and Ores

It is believed that the ores in the earth's crust have come from the underground magma. During volcanic eruptions the lava brought out the metals to the earth's crust. The lava which came to the surface got cooled rapidly and seldom provided ores. However, the magma which remained under the earth's crust cooled slowly and is found to be a rich source of

minerals. It is because of the slow cooling that different ores got separated.

1. Importance of minerals and ores in day today life

Minerals like limestone and marble are found to be important building materials. Gypsum and clay are useful to manufacture cement. The precious gems used in jewellery are also some type of minerals. Rubies are aluminium oxide with impurities of chromium compounds and sapphires are aluminium oxide with impurities of cobalt and titanium compounds. Probably, the most valuable of all minerals is diamond.

2. Minerals and ores

The Inorganic elements or compounds of various metals found in nature, associated with their earthly impurities are called Minerals. For example, sodium chloride - NaCl, potassium chloride - KCl, calcium carbonate, - $CaCO_3$, magnesium carbonate - $MgCO_3$, zinc sulphide - ZnS, cuprous sulphide - Cu_2S etc., which are found in nature are minerals.

Some minerals may contain a large percentage of metals whereas others may contain only a small percentage. All the minerals cannot be used to extract metals. Those minerals from which metals can be extracted profitably and conveniently are called **Ores.**

Example : Bauxite ($Al_2O_3 . 2H_2O$) and Clay ($Al_2O_3 . 2SiO_2 . 2H_2O$)

3. Types of ores

Oxide ores : Bauxite $Al_2O_3 . 2H_2O$, Cuprite Cu_2O, Zincite ZnO, Haematite Fe_2O_3, Pyrolusite MnO_2

Sulphide ores : Copper pyrites $CuFeS_2$, Argentite Ag_2S, Zinc blende ZnS, Cinnabar HgS, Galena PbS and Copper glance Cu_2S.

Carbonate ores : Limestone $CaCO_3$, Calamine $ZnCO_3$.

Halide ores : Rock salt NaCl, Fluorspar CaF_2.

8.3 Metallurgy

The process of extracting metals from their ores followed by refining is known as metallurgy. The four steps usually employed in metallurgy are :

1. Concentration of ore (or enrichment of ore)
2. Conversion of concentrated ore into metal oxide.
3. Reduction of metal oxide to metal
4. Refining of impure metal.

1. Concentration of ores

Ores are usually associated with unwanted earthly matter called gangue (sand, clay etc.,) and the removal of this unwanted impurity is called concentration. Concentration of ores is generally carried out by any one of the following processes.

1) Gravity separation

The method is generally used for the concentration of oxide ores. The ore is thoroughly crushed, sieved and levigated in a

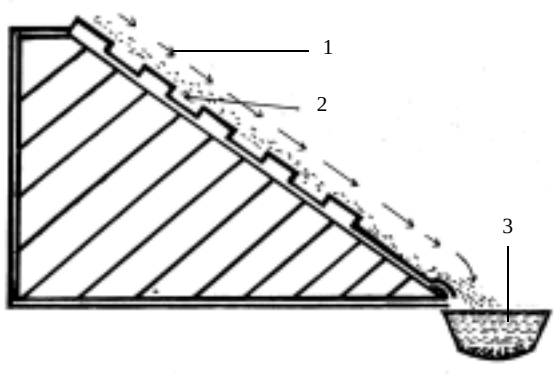


Fig. 8.2 Gravity separation

1. Flow of water 2. Dense ore particles 3. Lighter gangue

stream of water. The heavier ore particles stays back while the lighter earthly impurities are washed away.

2) Froth floatation process

The process is commonly employed for the concentration of sulphide ores, which are preferentially wetted by oils. The well powdered ore is added to a mixture of pine or eucalyptus

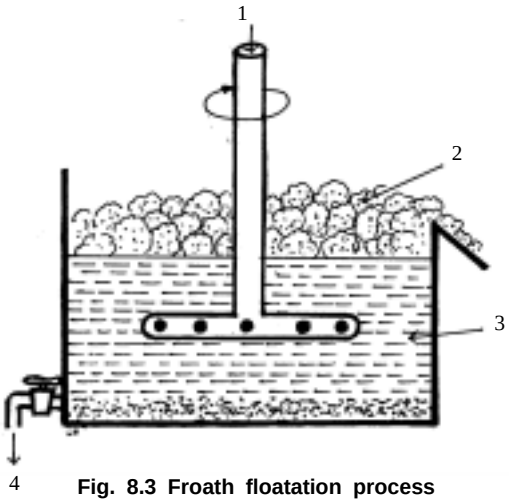


Fig. 8.3 Froath floatation process

1. Air 2. Froth containing sulphide ore
3. Ore + Water + Pine oil 4. gangue

oil and water and agitated by flowing air into the mixture. The ore which is wetted by oil comes to the surface with the froth while the impurities go to the water layer below. For example, Zinc sulphide and Galena are concentrated by this method.

3) Electromagnetic separation

If one of the impurities present is magnetic in nature, it can be removed by this method. Thus, tinstone, an ore of tin, contains Wolframite as an impurity, which is paramagnetic (i.e., attracted by a magnet). To remove wolframite the powdered tinstone ore is dropped over a travelling belt passing over electromagnetic rollers. Worlframite being paramagnetic is attracted and collected in a heap near the magnets while tinstone is dropped away from the roller and forms another separate heap.

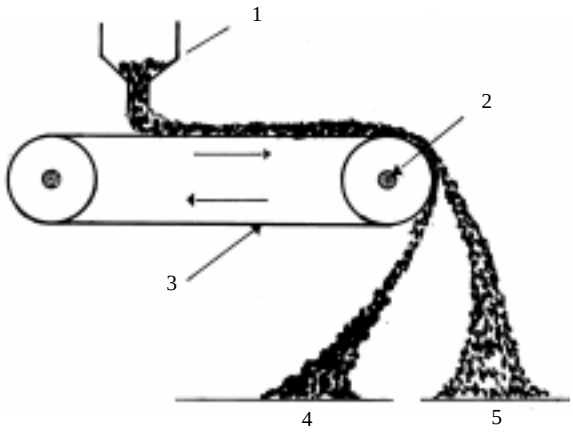


Fig. 8.4 Magnetic separation

1. Powdered ore 2. Magnetic roller 3. Moving belt
4. Magnetic impurities 5. Non-magnetic ore particles

2. Conversion of concentrated ore into metal oxide

1) Calcination

It is the process of heating the concentrated ore in the controlled supply of air at a temperature sufficient to melt the ore.

$$FeCO_3 \xrightarrow{\Delta} FeO + CO_2 \uparrow$$

$$ZnCO_3 \xrightarrow{\Delta} ZnO + CO_2 \uparrow$$

During calcination process, the moisture and volatile impurities are removed from the concentrated ore and the mass becomes porous. Decomposition of the ores may also take place. Thus, in the case of oxide ores water is lost from the ores and Carbonate ores undergo decomposition with the evolution of carbon dioxide leaving behind a porous oxide ore.

2) Roasting

Process of heating the concentrated ore strongly in the presence of excess air is called roasting. Usually, sulphide ores are subjected to roasting. For example, zinc sulphide gives zinc oxide on roasting.

$$2\ ZnS + 3O_2 \xrightarrow{\Delta} 2\ ZnO + 2SO_2 \uparrow$$

3. Reduction of metallic oxide to the metal.

Reduction is carried out either by electrolysis or by smelting.

1) Electrolysis

Electrolysis is the process employed for highly electropositive metals which cannot be reduced by reducing agents such as carbon, carbon monoxide, hydrogen etc., Electrolysis is carried out on fused metallic salts (halides or oxides) resulting in deposition of metal ions at cathode.

Oxides of potassium, sodium, calcium, magnesium and aluminium are reduced to metals by electrolysis of their fused metallic salts.

2) Smelting

The calcined or roasted ore is reduced to the metallic form. The high temperature reduction process in which the metal is usually obtained in a molten state is called smelting. The smelting operations are usually carried out in the presence of a flux.

Metallic oxides are reduced to metals by coke, carbon monoxide or hydrogen. Zinc oxide is reduced by coke. Oxides of Iron, lead and copper are reduced by carbon, carbon monoxide or hydrogen. Oxides of Mercury and silver are reduced by thermal decomposition.

4. Refining of metals

The metals obtained by any of the methods described above need further purification as they may contain other metals, dissolved oxides, carbon, phosphorous etc. The following methods are employed for refining.

1) Distillation

This is employed for purifying volatile metals like zinc and mercury. On heating, pure metal is vapourised, condensed and gets collected and non-volatile impurities remain behind.

2) Liquation

It is used for refining easily fusible metals having low melting point like tin. Impure metal is placed on the inclined bed of a furnace and heated. When the metal melts, it flows down leaving the non-fusible impurities behind.

3) Oxidation

If the impurities present in a metal can be easily oxidised, then the metal is refined by stirring the molten mass thoroughly in the presence of air. During this process, the impurities come to the surface in the form of a scum and can be skimmed off.

4) Electrolytic refining

The impure metal to be refined is made as anode and the cathode consists of a piece of pure metal in an electrolyte which is a suitable salt of the impure metal. Pure metal gradually passes from the anode to the cathode while the impurities settle to the bottom. Copper, tin, lead, aluminium etc., are purified by this method.

Explanation for some important terms

Gangue or matrix : The ore mined from the earth's crust contains some unwanted substances or impurities such as sand, rocky or clay materials. These substances are called gangue or matrix. The gangue has to be removed before the extraction of metals.

Flux : A flux is a substance that is added to the furnace charge (roasted or calcined ore and coke) during the process of smelting to remove the non-fusible impurities present in the ore.

Slag : Flux combines with non-fusible impurities to convert them into fusible substances known as slag. It is being light, floats over the molten metal and is removed from there. Impurities present in metal oxides may be acidic or basic. For acidic impurities, such as silica or phosporus pentoxide (SiO_2 or P_2O_5), calcium oxide is added as a flux to the mixture during smelting. If basic impurities such as manganese oxide are present, silica is added as a flux.

$$\underset{\text{acidic impurity}}{SiO_2} + \underset{\text{base flux}}{CaO} \longrightarrow \underset{\text{slag}}{CaSiO_3}$$

$$P_2O_5 + 3CaO \longrightarrow Ca_3(PO_4)_2$$

$$\underset{\text{basic impurity}}{MnO} + \underset{\text{acidic flux}}{SiO_2} \longrightarrow \underset{\text{slag}}{MnSiO_3}$$

8.4 Iron

Iron is known from the prehistoric times. Primitive man made use of iron for tools and weapons. The Egyptians were the first people to make considerable use of iron. The earth's

crust consists of about 5% iron. Iron is called the king of metals since it is being used extensively in almost all fields. Iron in trace is essential to all living matters and present in red corpuscles of blood.

There are three commercial forms of iron which differ from each other in their carbon content. Cast iron contains about 2 to 5% carbon along with impurities such as silicon, phosphorus, manganese etc. It is the least pure form of iron. Steel contains 0.1 to 1.5% carbon. Wrought iron is the purest form of iron and contains carbon and other impurities less than 0.2%.

Ores of iron : (1) Haematite (Fe_2O_3)
(2) Magnetite (Fe_3O_4)
(3) Iron pyrites (FeS_2)

1. Extraction of Iron

Cast iron is generally extracted from Haematite which is the most important ore of iron.

1) Concentration

Haematite being an oxide ore, is concentrated by gravity separation.

2) Roasting

The concentrated ore is calcined to remove the moisture and make the ore porous. It is roasted to make the ore easily reducible and also to oxidise impurities like carbon, sulphur and arsenic.

3) Reduction of the roasted ore to molten iron in the blast furnace

The iron ore is reduced in a blast furnace at high temperature to yield iron. The principal reducing agent is carbon monoxide.

$$Fe_2O_3 + 3CO \xrightarrow{875K} 2\,Fe + 3CO_2\uparrow$$

The yield of iron is increased by using excess of carbon monoxide.

Carbon monoxide is produced in the blast furnace from coke and air. First, coke burns in hot compressed air. The reaction is exothermic and high temperature is produced.

$$C + O_2 \xrightarrow{1775K} CO_2\uparrow \quad q = 406 \text{ kJ/mol.}$$

Carbon dioxide, then reacts with more carbon to produce carbon monoxide.

$$CO_2 + C \longrightarrow 2CO\uparrow$$

It is necessary to remove the impurities then and there; otherwise the blast furnace would become clogged. Impurities are removed from the furnace as liquid slag. Limestone ($CaCO_3$) is added for this purpose. When heated, limestone decomposes forming calcium oxide and carbon dioxide.

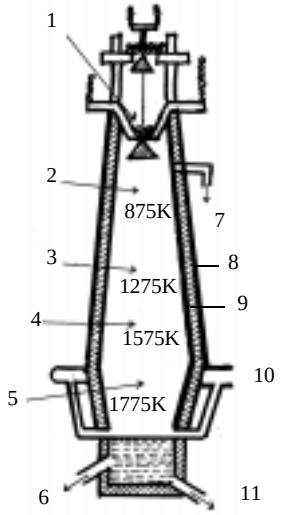


Fig. 8.5 Blast furnace for smelting

1. Ore + Coke + limestone 2. Iron oxide reduced by CO 3. Lime reacts with silica to form slag 4. Iron melts and dissolves C, Si, P. 5. Carbon burns to give CO_2 6. Slag 7. Waste gases (CO, CO_2, N_2 8. Steel sheet 9. Fire bricks 10. Hot air blast main 11. Molten iron.

$$CaCO_3 \xrightarrow{\Delta} CaO + CO_2\uparrow$$

Calcium oxide acts as a flux and combines with earthly impurities (sand) to form liquid slag.

$$CaO + SiO_2 \xrightarrow{1275K} CaSiO_3$$

The blast furnace works continuously and the molten iron and slag are tapped off from time to time. Iron produced by the blast furnace is cast iron.

2. Types and composition of iron

Table 8.2 Types, Properties and uses of Iron

	Types of Iron	% composition of carbon	Properties	Uses
1.	Cast iron or pig iron	2 to 5	Brittle, non-malleable and non-ductile, cannot be tempered or welded, resistant to corrosion.	Sewage pipes, Gutter covers, weights, rails, etc.
2.	Wrought iron	0.1 - 0.25	Not brittle, soft but tough, malleable, ductile can be welded and tempered.	Can withstand strain and hence used in chains, anchors, horse shoes, electro magnets, etc.
3.	Steel	0.25 - 2	Malleable, ductile, can be welded and tempered.	Has high tensile strength and hence used in automobiles, machines, ships, etc.

Steel can be classified as mild steel and hard steel based on the content of carbon.

Physical properties of mild and hard steel can be altered by proper heat treatment.

The hardness and malleability of steel can be controlled by heat treatment.

3. Heat Treatment of steel

Quenching : Mild steel is heated to red hot temperature and then cooled suddenly by plunging into oil or cold water. This process is called quenching. This makes steel very hard and brittle.

Tempering : The quenched steel is reheated to a temperature below red hot and cooled slowly. This process is called tempering. The tempered steel is much less brittle and not so hard. Steel of any desired hardness can be obtained by adjusting the temperature of tempering.

Annealing : Hard steel is heated to redness and then allowed to cool slowly. This process is called annealing. Annealing makes the steel soft.

4. Physical properties of iron

Pure iron is grey in colour and becomes reddish brown on rusting, It's boiling point is 2808 K, and melting point is 2648 K.

5. Chemical properties

1) Air : Iron is unaffected by dry air. In moist air, iron is oxidised to form rust.

$$4Fe + 3O_2 + XH_2O \longrightarrow 2Fe_2O_3\,XH_2O$$

On heating in air, it burns with a brilliant flame and forms Fe_3O_4.

$$3Fe + 2O_2 \longrightarrow Fe_3O_4$$

2) Water : Iron is unaffected by pure cold water. Hydrogen is liberated when steam is passed over red hot iron.

$$3\ Fe + 4H_2O \longrightarrow Fe_3O_4 + 4H_2\uparrow$$

3) Non-metals : (1) Chlorine : It forms ferric chloride when heated with chlorine.

$$2\ Fe + 3Cl_2 \xrightarrow{\Delta} 2FeCl_3$$

(2) Sulphur : It forms ferrous sulphide when heated with sulphur.

$$Fe + S \xrightarrow{\Delta} FeS$$

4) Acids : (1) HCl : Iron liberates hydrogen on reaction with dilute or concentrated hydrochloric acid.

$$Fe + 2HCl \longrightarrow FeCl_2 + H_2 \uparrow$$

(2) H_2SO_4 : Hydrogen is liberated on reaction with dilute sulphuric acid and sulphur dioxide is formed with hot concentrated sulphuric acid.

$$Fe + \underset{(dil)}{H_2SO_4} \longrightarrow FeSO_4 + H_2 \uparrow$$

$$Fe + \underset{(conc.)}{2H_2SO_4} \xrightarrow{\Delta} FeSO_4 + 2H_2O + SO_2 \uparrow$$

(3) HNO_3 : Nitric oxide is liberated with hot dilute nitric acid.

$$3Fe + \underset{(dil)}{8HNO_3} \xrightarrow{\Delta} 3Fe(NO_3)_2 + 4H_2O + 2NO\uparrow$$

Concentrated nitric acid renders iron passive due to the formation of a thin layer of ferric oxide. Passivity can be removed by strongly heating the metal.

5) Displacement reaction : Iron displaces metals like copper and silver from their metallic salt solutions due to its higher position in the activity series.

$$CuSO_4 + Fe \longrightarrow FeSO_4 + Cu \downarrow$$

$$2AgNO_3 + Fe \longrightarrow Fe(NO_3)_2 + 2Ag$$

6. Uses of iron

1. Wrought iron and cast iron are largely used in the manufacture of locomotives, railway lines, springs, tubes, etc.
2. Iron finds wide application in building construction. For example, in the reinforcement of roofs and other parts of buildings.
3. Iron is used in making household utensils and equipments.

8.5 Aluminium

Aluminium is the silvery white metal known for its strength and light weight. It is the most abundant metal found in the surface of the earth. Aluminium is found only in combination with other elements. It is easily rolled or stretched into sheets or wires. It is found most frequently in clays and other minerals. Aluminium was first extracted in 1827 from aluminium chloride.

$$AlCl_3 + 3Na \longrightarrow Al + 3NaCl.$$

But the process was very expensive. Scientists were impressed by the properties of aluminium like high electrical conductivity, resistance to corrosion and great lightness. So, scientists all over the world attempted to develop a process for the commercial production of aluminium, but it remained a costly metal till 1886. Heroult in France and Hall in U.S.A succeeded in developing independently a process for the extraction of aluminium. Since then, large scale production of aluminium began in several parts of the world.

1. Ores of Aluminium

1. Bauxite $Al_2O_3 . 2H_2O$
2. Cryolite Na_3AlF_6
3. Corundum Al_2O_3

2. Extraction

Aluminium is usually extracted from bauxite by electrolysis. Since it is difficult to remove impurities from aluminium, the raw materials from which it is obtained must be pure. Bauxite is usually associated with iron oxide as the impurity. It is first roasted in air to convert iron oxide to the ferric state and then digested at 423 K with a 10% solution of caustic soda in autoclaves. The aluminium oxide present in bauxite alone goes into solution, forming sodium aluminate.

$$Al_2O_3 . 2H_2O + 2NaOH \xrightarrow{423K} 2\,NaAlO_2 + 3H_2O$$

The solution of sodium aluminate is agitated with a large excess of water. Then the whole of aluminium present in the solution precipitates out as aluminium hydroxide.

$$NaAlO_2 + 2H_2O \longrightarrow Al(OH)_3\downarrow + NaOH$$

Aluminium hydroxide is then filtered, pressed, dried and ignited to obtain pure anhydrous aluminium oxide (alumina). The regenerated sodium hydroxide solution is concentrated by evaporation and used again.

Electrolysis of fused alumina

The pure alumina is dissolved in fused cryolite Na_3AlF_6 and electrolysed in a steel tank lined inside with carbon, which serves as cathode. A number of carbon rods dipped in

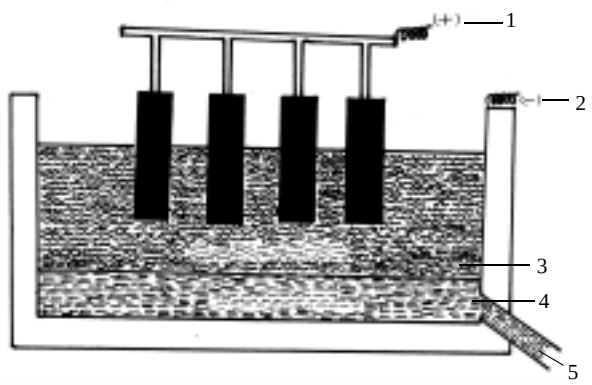


Fig. 8.6 Electrolytic cell for the production of aluminium

1. Graphite anode 2. Carbon lining (Cathode) 3. Molten $Al_2O_3 + Na_3AlF_6$ 4. Molten aluminium 5. Al (99.5%)

molten electrolyte serve as anode. The electrolysis is carried out at about 1173 K - 1223 K temperature and aluminium produced sinks to the bottom of the tank while oxygen evolved burns away the carbon anodes necessitating their replacement from time to time.

$$2Al_2O_3 \longrightarrow 4\ Al + 3O_2$$

Refining of Aluminium : Aluminium thus obtained is not very pure. It contains small amounts of iron, silicon etc. It is purified in Hope's cell.

3. Physical Properties

1) It is a light metal and is silvery white in colour.

2) It is hard, malleable and ductile.

3) Its melting point is 933 K and boiling point is 2323 K.

4) It is one of the best conductors of heat and electricity.

5) It can be easily welded or cast but can be soldered using a special solder with difficulty.

4. Chemical properties

1) Air : Aluminium is unaffected by dry air but tarnished in moist air. It forms a thin surface film of aluminium oxide which guards itself against corrosion. On heating in air, it, forms aluminium oxide and nitride.

$$4\ Al + 3O_2 \xrightarrow{\Delta} 2Al_2O_3$$

$$2\ Al + N_2 \xrightarrow{\Delta} 2AlN$$

2) Water : It is unaffected by pure water. When steam is passed over red hot aluminium, hydrogen is liberated.

$$2\ Al + 3H_2O \longrightarrow Al_2O_3 + 3H_2\uparrow$$

3) Non-metals

(1) Chlorine : Aluminium forms aluminium chloride when heated with chlorine.

$$2\ Al + 3Cl_2 \xrightarrow{\Delta} 2AlCl_3$$

(2) Sulphur : It forms aluminium sulphide when heated with sulphur.

$$2\ Al + 3S \xrightarrow{\Delta} Al_2S_3$$

4) Alkalis :

Aluminium forms aluminates and liberates hydrogen on reaction with boiling concentrated sodium hydroxide and potassium hydroxide.

$$2Al+2NaOH + 2H_2O \xrightarrow{\Delta} \underset{\text{sodium aluminate}}{2NaAlO_2} + 3H_2\uparrow$$

$$2Al+2KOH + 2H_2O \xrightarrow{\Delta} \underset{\text{potassium aluminate}}{2KAlO_2} + 3H_2\uparrow$$

5) Acids

(1) HCl : It liberates hydrogen on reaction with dilute or concentrated acid.

$$2\ Al + 6\ HCl \longrightarrow 2AlCl_3 + 3H_2\uparrow$$

(2) H_2SO_4 : Dilute sulphuric acid liberates hydrogen and conc. sulphuric acid liberates sulphur dioxide with aluminium.

$$2Al + 3\underset{\text{(dil)}}{H_2SO_4} \longrightarrow Al_2(SO_4)_3 + 3H_2\uparrow$$

$$2Al+6\underset{\text{(conc.)}}{H_2SO_4} \longrightarrow Al_2(SO_4)_3 + 6H_2O + 3SO_2\uparrow$$

(3) HNO_3 : Aluminium is rendered passive with both concentrated and dilute nitric acid due to the formation of a thin aluminium oxide layer.

6) Reducing property

It reduces heated metallic oxides of iron, chromium, manganese, etc., to metals.

$$Fe_2O_3 + 2Al \xrightarrow{\Delta} Al_2O_3 + 2Fe$$

5. Uses of Aluminium

1. Aluminium is a good conductor of heat and it does not get corroded. Hence, it is used to make domestic utensils like pans, kettles, etc.
2. Aluminium is used in making electrical wires because it is a good conductor of electricity.
3. Aluminium foils are used for packing and wrapping foodstuff and drugs.
4. Aluminium is a light metal. Hence, it is used in making the body and other parts of aircraft, buses, cars, furniture etc; Since pure aluminium is not very strong, alloys of aluminium are used for these purposes.
5. Aluminium powder is used in making anti-corrosion paints and explosives.
6. Bright aluminium surface is used in reflecting telescopes.

Activity : Take a piece of aluminium wire and note the appearance. Rub the surface with sand paper and observe. On rubbing, aluminium appears bright. This is because, when metals are exposed to air for a long time, they lose their brightness due to the formation of a thin layer of oxide on its surface and this layer is rubbed off by sand paper to give back its original colour.

8.6 Alloys

An Alloy is a mixture of two or more metals fused together in the molten state in a fixed proportion. Pure metals are often soft

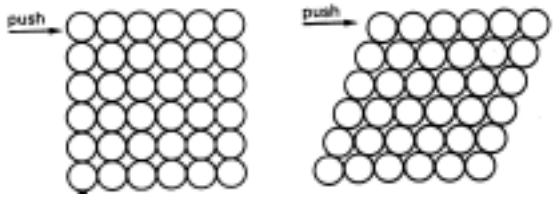


Fig. 8.7. Layers of atoms can slide over each other

and easily bent or distorted. This is because the regular arrangement of atoms in a metal can allow the layer of atoms to slide over each other.

1. Special characteristics of Alloys

Sometimes, Alloying becomes a useful phenomenon. For example, alloying of gold with few other metals enables gold to be used

in jewellery which is not possible with pure gold. Another example is that aluminium is a light metal and it is not very strong. But duralumin, an alloy of aluminium is light and very strong and it is used to make body of aircrafts. The colour of an alloy is different from the metals from which it is formed. For example, both silver and zinc are almost white but the alloys formed from them are pink in colour. Alloys are resistant to corrosion.

Alloys of mercury with other metals are called amalgams. Silver and tin amalgams are formed directly by rubbing the metal with mercury. Iron amalgam is formed by placing sodium or magnesium amalgam in ferrous sulphate solution.

There are many examples of alloys in everyday use. Sometimes, an alloy has a much lower melting point than any of its component. e.g., solder. Another amazing example is wood metal. This is made of bismuth, lead, tin and cadmium. It has a melting point of 344 K, that it melts in hot water. It is used in the newspaper industry as a type metal.

New alloys are often made for specific purposes. A new alloy which would be light and could withstand very high temperature was made while designing the supersonic aeroplane, "concorde". Recently in 1976, a Russian pilot landed his MIG Fighter in Japan. This was a new aeroplane that had never been closely studied by Western countries and the first thing that Western Scientists did was to examine the alloys from which it was made.

Table 8.3 Some of the commonly used alloys, their composition, and uses

	Name of the alloy	Composition	Uses
	Alloys of Aluminium		
1.	Duralumin	Aluminium, copper and traces of magnesium and manganese	Aircraft parts, rails, car, pressure cooker, boat machinery space satellites, bodies of ship.
2.	Aluminium bronze	Copper, aluminium and traces of tin.	Cheap ornaments, photoframes, coinage, golden paint.
3.	Magnalium	Aluminium, magnesium and calcium	Scientific instruments.
	Alloys of Iron		
4.	Steel	Iron, carbon	nails, screws
5.	Stainless steel	Iron, chromium and nickel	Cooking utensils, knives, scissors, tools. It is used for making surgical instruments.
	Some other alloys		
6.	Type metal	Lead, antimony and tin	Casting type
7.	Solder	Equal amounts of lead and tin.	used for welding electrical wires together (soldering wires)
8.	Brass	Copper and zinc	Electrical connections and machine bearings, making utensils.
9.	Bronze	Copper and tin	Machine parts, making statues, medals, coins.
10.	Sodium amalgam	Sodium and mercury	Used as mild reducing agent.

8.7. Alloying of gold

Gold is a soft metal which is hardened by alloying with copper, silver, etc., Alloy of gold with copper is reddish yellow in colour and is used for coinage and jewellery. The gold content of an alloy is commonly stated in carats. Pure gold is 24 carats fine and an alloy that has 75% gold by weight is 18 carats fine. The most commonly used gold alloys are 22 and 18 carats. 22 carat gold contains 91.6% gold.

The colour of the alloy depends on the metals with which gold is mixed. In coloured golds, red shades are achieved by increasing the copper content at the expense of silver and zinc. Pale yellow and green shades are achieved by increasing silver and / or zinc content at the expense of copper. Copper-rich alloys are harder than silver rich alloys of the same gold content. White golds are achieved by alloying pure gold with nickel or palladium.

Table 8.4 Alloys of gold and their percentage composition

Type	Gold % wt	Ag	Cu	Colour
22 ct	91.6	8.4	-	yellow
		5.6	2.8	yellow
		3.3	5.1	deep yellow
		-	8.4	pink/rose
18 ct	75	25	-	green-yellow
		16	9	pale yellow
		9	16	pink
		4.5	20.5	red

1) Activity Series

Some metals are very reactive chemically, example, sodium and potassium. Some metals are unreactive, example, silver and mercury. Metals can be arranged in increasing or decreasing order of their reactivity. This is called the reactivity series of metals. The reactivity series is also known as activity series.

Table 8.5 Activity series

Activity series of metals

more reactive

Potassium	K		These metals are more reactive than hydrogen.
Sodium	Na		
Calcium	Ca		
Magnesium	Mg		
Aluminium	Al		
Zinc	Zn		
Iron	Fe		
Tin	Sn		
Lead	Pb		
Hydrogen	**H**		
Copper	Cu		These metals are less reactive than hydrogen
Mercury	Hg		
Silver	Ag		
Gold	Au	*less reactive*	

Metals at the top of the series lose electrons more easily and form ions readily. They are said to be more electropositive. Metals at the bottom of the series lose electrons with difficulty and do not readily form ions. They are said to be less electropositive.

2) Displacement reactions

Metals from solution : A more reactive metal, top in the series displacing a less electropositive metal down in the series from a solution of one of its salts is called displacement reaction.

(1) When iron filings are put in copper sulphate solution, a brown precipitate of copper

is formed. The solution changes from blue to green as blue coloured copper ions are used up and green coloured iron (II) ions are formed.

$$Fe + CuSO_4 \longrightarrow FeSO_4 + Cu\downarrow$$

Iron is higher in the series than copper, Iron, thus loses electrons more easily than copper. Electrons are transferred from iron to copper ions.

$$Fe + Cu^{2+} \longrightarrow Fe^{2+} + Cu\downarrow$$

Few other examples showing displacement reaction are given below.

(2) When granulated zinc is put in lead nitrate solution, formation of lead metal is observed.

$$Zn + Pb(NO_3)_2 \longrightarrow Zn(NO_3)_2 + Pb\downarrow$$

The ionic equation is,

$$Zn + Pb^{2+} \longrightarrow Zn^{2+} + Pb\downarrow$$

(3) When a coil of copper wire is suspended in silvernitrate solution, shiny silver metal is formed.

$$Cu + 2AgNO_3 \longrightarrow Cu(NO_3)_2 + 2Ag\downarrow$$

The ionic equation is,

$$Cu + 2Ag^{+} \longrightarrow Cu^{2+} + 2Ag\downarrow$$

(4) When magnesium ribbon is placed in a solution of copper sulphate, blue colour of the solution fades, as magnesium displaces copper.

$$Mg + CuSO_4 \longrightarrow MgSO_4 + Cu\downarrow$$

The ionic equation is,

$$Mg + Cu^{2+} \longrightarrow Mg^{2+} + Cu\downarrow$$

Activity : Take small pieces of Mg, Al, Zn, Fe and Cu metals. Clean their surfaces by rubbing with a sand paper. Place these metals in separate test tubes. Add about 10 ml of dilute hydrochloric acid to each of these test tubes. Observe carefully the rate of formation of bubbles. We observe that the rate of formation of bubbles was the fastest in the case of magnesium. It decreases in the order, Mg > Al > Zn > Fe. In the case of Cu, no bubbles were evolved. This shows that Cu does not react with dilute hydrochloric acid. Since Cu is below hydrogen in the activity series whereas Mg, Al, Zinc and Iron are above hydrogen in the series.

8.8 Corrosion of metals

Some metals react with oxygen, moisture and pollutants present in the atmosphere and form compounds like oxides, carbonates, etc., and the surfaces of the metals lose their shine. This process is known as corrosion. Noble metals are low in the reactivity series of metals and therefore they are not easily corroded, example : gold, silver and platinum. Some metals form a layer of oxide on the surface when exposed to the atmosphere, example aluminium and zinc. This oxide layer, prevents them from further attack of the atmosphere.

Lithium, sodium and potassium have to be stored in oil to protect them from air and moisture.

Magnesium and calcium are usually get covered with a thin coating of oxide. Fresh and new pink coloured pure copper forms a thin surface coating of black copper oxide (CuO). In the open air, copper covered roofs (which got already coated with CuO) turn green because of the formation of Verdigris which is a mixture of copper carbonate and copper sulphate. In the above metals, corrosion is an advantage, because it protects the underneath layers once it has been formed. However, corrosion of iron called rusting is never beneficial.

1. Rusting

The corrosion of iron is known as rusting. The rust is hydrated iron (III) oxide. $Fe_2O_3 . XH_2O$ (X is variable). Rusting is a complex process which involves the oxidation of iron.

Rust is a mixture of ferric hydroxide $Fe(OH)_3$ and ferric oxide Fe_2O_3 and is

produced by the action of **water** on **iron** in the **presence of dissolved** oxygen.

Rust does not adhere to the surface and therefore there is no protection for the metal. Rusting breaks up the surface of the metal and gradually "eats" into the metal which then looses it strength.

2. Prevention of Rusting

1) By painting : Corrosion can be prevented by applying paint on the metal surface.

2) By galvanisation : The process of depositing a thin layer of zinc metal on iron objects is called galvanisation. This prevents iron from rusting.

Activity : Take four test tubes and place a clean iron nail in each of them. Label these test tubes A, B, C and D. Pour some water

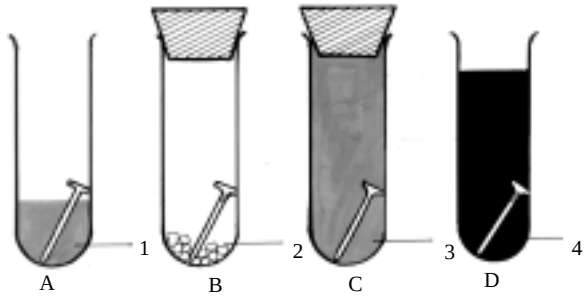


Fig. 8.8 Need of air and water for rusting

1. Water 2. Calcium Chloride 3. Boiled water 4. Oil

into test tube A. Put some anhydrous calcium chloride into test tube B. Pour boiled distilled water into test tube C. Pour oil into test tube D. Close test tubes B and C with rubber stopper to prevent the entry of air into them. Leave the test tubes for a few days and then observe.

We observe that the nail in test tube A alone rusted whereas the nails in test tubes B, C and D are not rusted. This is because, both air and water are necessary for rusting which are available only in test tube A.

In B, there is no water, in C, there is no air and in D, there is neither air nor water. So, the nails in them did not get rusted.

8.9 Hydrogen

Hydrogen is the most common element in the Universe but it is less common on Earth. The amount of hydrogen in the atmosphere and in the earth's crust is very small. But, hydrogen is the main element present in the Sun. Hydrogen undergoes fusion reaction to form helium with the release of tremendous energy which we get as light and heat from the Sun. But, hydrogen in water is three-fourth of the earth's surface. Hydrogen is also present in oil, natural gas and all organic compounds and living things. It does not occur naturally as a free element except in negligible quantities.

Hydrogen has always been a very important chemical industrially. Hydrogen is the first element in the periodic table of elements.

1. Preparation of hydrogen

Hydrogen gas can be prepared by the reaction of metals with either water or dilute acids. More reactive metals react violently with cold water to produce hydrogen. For example,

$$2K + 2H_2O \longrightarrow 2KOH + H_2 \uparrow$$

Less reactive metals react with steam and liberate hydrogen gas. For example,

$$3\ Fe + \underset{\text{steam}}{4H_2O} \longrightarrow Fe_3O_4 + 4H_2 \uparrow$$

1) Laboratory preparation

In the laboratory, hydrogen gas is prepared by adding dilute hydrochloric acid to granulated zinc. A little copper sulphate solution is usually added to speed up the reaction.

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2 \uparrow$$

The gas is collected over water and it is collected in an inverted gas jar by the downward displacement of water.

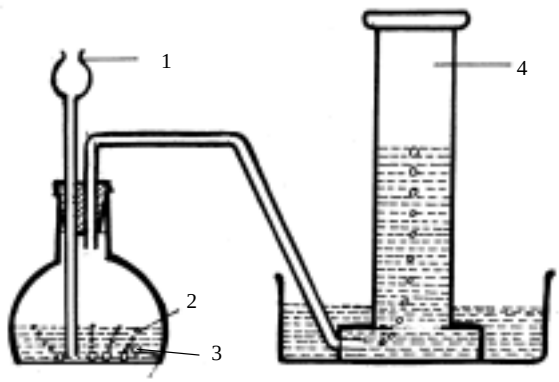


Fig. 8.9 The preparation of Hydrogen

1. Thistle funnel 2. Dilute Hydrochloric acid 3. Zinc 4. Hydogen

If dry hydrogen gas is required, the gas can be passed through concentrated sulphuric acid and then collected in an inverted gas jar by the downward displacement of air.

2) Industrial preparation

Hydrogen is manufactured by the **steam reforming** of **natural gas.** In this process, the natural gas, methane and steam are passed over a nickel catalyst at a temperature of 1073^{o} K and a pressure of 50 atmospheres.

$$CH_4 + H_2O \xrightarrow[1073\,K,\ 50atm]{Ni} CO\uparrow + 3H_2\uparrow$$

Carbon monoxide then reacts with more steam and gives carbon dioxide and hydrogen. The mixture of carbon dioxide and hydrogen is passed through water under 30 atm. pressure.

$$CO + H_2O \longrightarrow CO_2\uparrow + H_2\uparrow$$

Carbon dioxide gets dissolved in water and hydrogen is collected.

3) As a by-product

A lot of hydrogen gas is obtained as a by-product from other industrial processes. For example, when sodium hydroxide is made by the electrolysis of brine, hydrogen is evolved as a by-product.

Caution : Since a mixture of hydrogen and air are explosive, there should be no flame near the apparatus.

2. Physical Properties

1) Hydrogen is a colourless, odourless and tasteless gas.

2) It is lightest of all gases and thus diffuses very rapidly.

3) It is virtually insoluble in water.

4) Hydrogen is neither acidic nor basic.

3. Chemical properties

1) Combustion : If a lighted splint is introduced into a gas jar containing hydrogen gas, it gets extinguished but the gas burns explosively wtih a 'pop' sound. This shows that hydrogen does not support combustion but is combustible.

$$2H_2 + O_2 \longrightarrow 2H_2O$$

Hydrogen gas forms an explosive mixture with oxygen. When the mixture is ignited, it explodes violently. The explosion produces such a huge amount of energy that it is utilised to feed space rockets.

2) Reducing Agent : Hydrogen reduces the oxides of certain metals to metals depending on the position of that metal in the activity series.

Hydrogen reduces copper oxide to copper.

$$CuO + H_2 \longrightarrow Cu + H_2O$$

3) Reaction with metals : Hydrogen combines with some reactive metals forming hydrides.

$$2\ Na + H_2 \longrightarrow 2NaH$$

$$2\ Li + H_2 \longrightarrow 2\ LiH$$

4) Reaction with non-metals

(1) Chlorine : Hydrogen has a great affinity for chlorine. A mixture of equal volumes of hydrogen and chlorine will explode, if exposed to sunlight. In the absence of sunlight, hydrogen burns in chlorine forming white fumes of hydrogen chloride gas.

$$H_2 + Cl_2 \longrightarrow 2HCl$$

(2) Nitrogen : Hydrogen combines with nitrogen in the presence of iron catalyst to form ammonia.

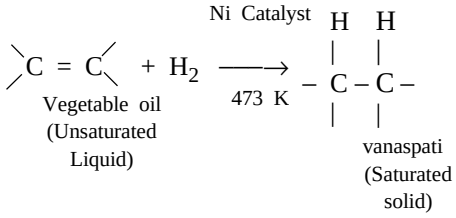
$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

(3) Sulphur : Hydrogen combines with sulphur to form hydrogen sulphide.

$$H_2 + S \longrightarrow H_2S$$

5) Reaction with vegetable oils

Vegetable oils are unsaturated compounds which contain double bonds. When hydrogen is added, they become saturated and get converted into Vanaspati. This is called hydrogenation of oils.



4. Uses

1) Hydrogen is used in the manufacture of many industrial chemical compounds. It is used in the synthesis of ammonia, which in turn is used in the manufacture of fertilizers, nitric acid and explosives. Hydrogen is also used in the manufacture of methanol.

2) Liquid hydrogen is used as a fuel in the rockets of the American space programmes.

3) Hydrogen has the highest calorific value. When hydrogen burns, it produces more energy when compared to any other fuel. So, it can be used as a fuel in future. It does not cause pollution because its reaction with oxygen produces only water. Cars have been manufactured that use hydrogen as a fuel, rather than petrol.

4) Hydrogen is used in welding. When hydrogen gas is passed through an electric arc, its molecules split into atoms. When these atoms combine again to form a molecule, an enormous amount of heat is released. This heat is used to melt and fuse the metal surfaces together.

5) Hydrogen is used for hydrogenation of vegetable oils.

Activity : Take a balloon and fill it with hydrogen. Tie its neck with a thread and release it in a room. We observe that it floats upto the ceiling. This shows that hydrogen is lighter than air.

Activity : Take a lighted splint at the mouth of a test tube or gas jar containing hydrogen. We observe that the splint got extinguished, but hydrogen gas burns with a

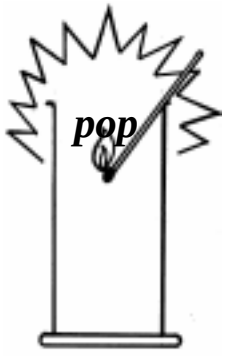


Fig. 8.10 The gas jar trick

'pop' sound and forms water. This is because, hydrogen does not support combustion that it mixes quickly with air and that the mixture explodes when lit giving the sound.

8.10 Ammonia

There are several possible accounts of how the gas ammonia got its name. The most likely seems to be that it might have come from the Greek word 'sal ammoniac', which was the name given to ammonium chloride, a naturally occuring substance that would yield ammonia. Joseph Priestley first prepared

ammonia in 1774 by heating slaked lime with 'sal ammoniac'.

Ammonia is an important chemical as it is used to manufacture fertilizers such as ammonium sulphate, and ammonium phosphate. It is also used in the preparation of plastics, nylon, etc.

1. Manufacture of Ammonia - Haber process

Principle : Ammonia is synthesised by the reaction of nitrogen and hydrogen under suitable conditions. The reaction is represented by the following equation.

$$\underset{1\text{vol}}{N_2} + \underset{3\text{vol}}{3H_2} \rightleftharpoons \underset{2\text{vol}}{2NH_3} \qquad q = 92.6 \text{ kJ}$$

The process is named after Fritz Haber a German Scientist, who devised the process during the First World War. It is still being used today

The reaction is reversible and exothermic. It is accompanied by decrease in volume.

Since the reaction takes place with decrease in volume and evolution of heat, larger yield of ammonia can be obtained at higher pressure and lower temperature. But at lower temperature, the rate of the reaction is slowed down. Hence, the reaction is carried out at moderate temperature, called optimum temperature, and under high pressure. The reaction is carried out at the temperature range from 723 K to 773 K and under a pressure of 250 atmospheres. The rate of the reaction is increased by using iron as a catalyst and molybdenum as a promotor. A promotor is one which can increase the efficiency of a catalyst.

The reverse reaction is prevented by removing ammonia from the reaction mixture as soon as it is formed.

Procedure : One part of nitrogen and three parts of hydrogen are mixed and the mixture is compressed to 250 atmospheres. The mixture is then carried into the catalyst chamber in which it is passed over a series of catalyst beds. The catalyst consists of finely divided iron. The temperature of the catalyst chamber is maintained at 723 K. Since the reaction between nitrogen and hydrogen is reversible, the reaction does not go to completion. The gaseous mixture coming out of the catalyst chamber consists of nitrogen, hydrogen and ammonia. The proportion of ammonia in the mixture is about 15% only. The mixture is then passed through a cooling chamber in which ammonia having higher boiling point is condensed first. The unreacted nitrogen and hydrogen are recirculated over the catalyst. This increases the yield of ammonia to 98%.

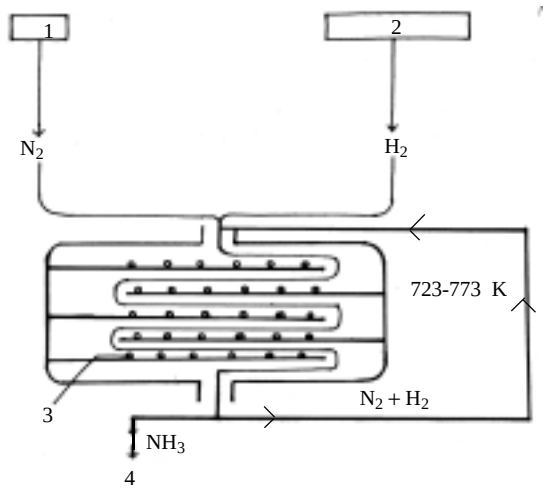


Fig. 8.11 The Haber process for the manufacture of ammonia

1. Air 2. Natural gas 3. Catalyst
4. Condensed ammonia liquid

2. Physical Properties

1) Ammonia is a colourless gas with a characteristic pungent smell.

2) It is lighter than water.

3) It is alkaline in nature and bring tears in eyes.

4) It is extremely soluble in water. A saturated solution of ammonia in water is known as liquor ammonia.

The high solubility of ammonia gas in water can be demonstrated by the fountain experiment.

Activity : Fountain experiment : Take a dry round bottom flask filled with ammonia gas. The mouth of the flask has a rubber stopper with two holes, one for a jet tube and the other for a dropper containing water Place red litmus solution in the trough and set up the apparatus as shown below.

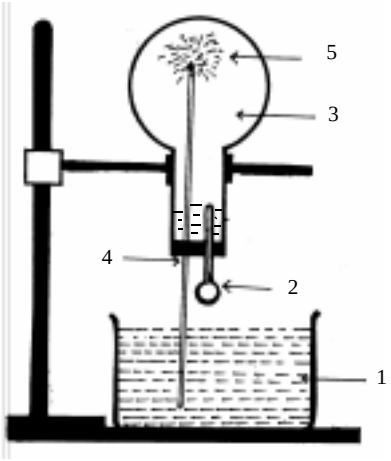


Fig. 8.12 Fountain Experiment

1. Red litmus solution 2. Dropper 3. Dry ammonia gas
4. Jet tube 5. Blue fountain

Squeeze the dropper containing water. You observe a blue fountain at the end of the jet tube. This is because as soon as you squeeze the dropper, water enters the flask. Ammonia gas present in the flask dissolves in water due to its high solubility, thereby creating a partial vacuum in the flask. The outside pressure being higher, pushes the red litmus solution up the jet tube which emerges at the end of the tube as a blue fountains.

3. Chemical properties

1) Combustibility : Ammonia is neither combustible nor a supporter of combustion. However, it burns with a yellow flame accompanied by a feeble explosion.

$$4NH_3 + 3O_2 \longrightarrow 6H_2O + 2N_2 \uparrow$$

When ammonia is mixed with air and passed over a catalyst such as platinum at 1073 K, nitric oxide is produced.

$$4NH_3 + 5O_2 \xrightarrow[1073K]{Pt} 4\,NO + 6H_2O$$

This reaction is made use of in the manufacture of nitric acid.

2) Basic nature : It dissolves in water forming ammonium hydroxide. The aqueous solution of ammonia turns red litmus blue. Perfectly dry ammonia gas is neutral to dry litmus.

$$NH_3 + H_2O \longrightarrow NH_4OH$$

3) Reaction with acids : It reacts with acids to produce the corresponding salts.

$$NH_3 + HCl \longrightarrow NH_4Cl$$

Ammonium chloride

$$2NH_3 + H_2SO_4 \longrightarrow (NH_4)_2\,SO_4$$

Ammonium sulphate

$$NH_3 + HNO_3 \longrightarrow NH_4NO_3$$

Ammonium nitrate

4) Reaction with salts of metals

On treatment with soluble salts of metals in their solution state, ammonium hydroxide gives insoluble precipitate of the respective metallic hydroxides which vary in colour.

For example, a dirty green precipitate is formed with Fe^{2+} ions.

$$FeSO_4 + 2NH_4OH \longrightarrow (NH_4)_2\,SO_4 + Fe\,(OH)_2 \downarrow$$

Ferrous hydroxide

green

A white precipitate is formed with Pb^{2+} ions.

:

$$Pb\,(NO_3)_2 + 2NH_4OH \longrightarrow 2NH_4NO_3 + Pb\,(OH)_2 \downarrow$$

white

Lead hydroxide

With copper sulphate solution, ammonium hydroxide gives initially a pale blue precipitate of copper II hydroxide and with the addition of excess of ammonium hydroxide, it gives a deep blue solution due to the formation of a complex.

$$CuSO_4 + 2NH_4OH \longrightarrow (NH_4)_2SO_4 + \underset{\text{pale blue}}{Cu(OH)_2}$$

5) Reaction of ammonia with metal oxides : Ammonia gas is a strong reducing agent and reduces metallic oxides to the corresponding metals.

$$3CuO + 2NH_3 \longrightarrow 3Cu + 3H_2O + N_2 \uparrow$$

$$3PbO + 2NH_3 \longrightarrow 3Pb + 3H_2O + N_2 \uparrow$$

6) Reaction with carbon dioxide : When carbon dioxide gas is passed into an aqueous solution of ammonia, ammonium carbonate is formed.

$$2NH_3 + H_2O + CO_2 \longrightarrow (NH_4)_2 CO_3$$

This reaction is used in the manufacture of washing soda by Solvay process.

7) Reaction with Nessler's reagent : Nessler's reagent is a solution of mercuric iodide (HgI_2) in excess of potassium iodide. When ammonia gas is passed in to Nessler's reagent, a reddish brown precipitate is formed. This reaction is used to detect the presence of ammonia.

4. Uses of ammonia

1) Industrial uses : Ammonia is used

(1) in the manufacture of nitric acid by Ostwald's process.

(2) in the manufacture of washing soda and baking soda by Solvay process.

(3) in the manufacture of fertilizers like ammonium sulphate, ammonium phosphate and urea.

(4) in the manufacture of plastics

(5) in the manufacture of dyes and drugs.

2) Aqueous ammonia can dissolve grease and oil. Because of this, most of the kitchen cleaning agents contain ammonia.

3) Ammonium chloride is used in the dry cell.

4) Liquid ammonia is used as a refrigerant in the ice making plant.

5) Ammonium salts are used in medicine, Example ammonium carbonate is used as "smelling salt".

8.11 Sulphur

Sulphur has been known from Biblical days under the name brimstone, which produces unpleasant and suffocating gases on burning. Ancient Indians and Egyptians had used sulphur as disinfectant. The largest amount of sulphur is extracted from underground deposits in Texas, U.S.A.

Sulphur is present in certain proteins which are the important constituent of living matter. It is also an important constituent of natural organic compounds such as insulin and certain antibiotics. Sulphur is present in eggs, onions, garlic etc.

Sulphur occurs in nature both in free state and in combined state. In combined state, it is widely distributed as metal sulphides, example : galena PbS, zinc blende ZnS, cinnabar HgS Iron pyrites, proteins., gypsum ($CaSO_4 . 2H_2O$) etc.

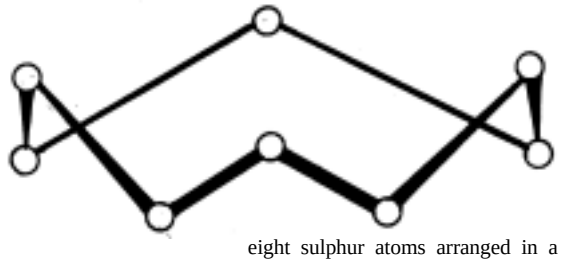
Sulphur is in the second period and 16th (XVI) group of the periodic table. Its atomic number is 16. Its electronic configuration is 2, 8, 6. It contains 6 electrons in the valency shell. Sulphur can form both ionic and covalent compounds. It exhibits a variable valency of 2, 4 and 6. It also shows the property of catenation.

1. Allotropy of sulphur

Sulphur exists in different crystalline solid forms namely, rhombic sulphur and monoclinic sulphur. These different forms are known as allotropes. Carbon and phosphorus also exhibit this property.

Allotropy is a typical non-metallic property. Tin is the only metal which exhibits allotropy. Allotropy is due to the difference in the arrangement of atoms or molecules in the element.

Thus Allotropy is the existence of an element in two or more different forms in the same physical state having the same chemical properties but different physical properties and these forms are known as allotropes.



eight sulphur atoms arranged in a ring alternating up and down

Fig. 8.13 The shape of a sulphur molecule

Allotropes of sulphur contain S_8 rings (exhibit the property of catenation). On heating, it is found that rhombic form is stable upto 369 K and crystals seem to be octahedral in shape. Above 369 K, the monoclinic form of sulphur is found to be stable which forms fine needle shaped crystals. On cooling, when the temperature goes below 369 K, octahedral crystals of rhombic sulphur is formed. Thus, 369 K is described as the transition temperature of the two allotropes.

Rhombic sulphur $\rightleftharpoons$ Monoclinic sulphur

This is because arrangement of the S_8 molecules in sulphur have been found to be different in rhombic and monoclinic forms.

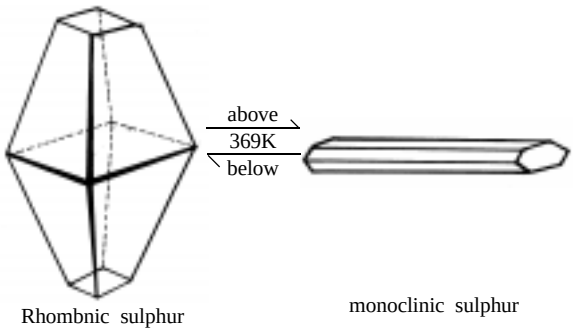


Fig. 8.14 The shapes of rhombic and monoclinic sulphur

The allotropes are identical chemically but have different crystal shapes and hence different physical properties.

In rhombic crystals, the S_8 rings fit singly into each other

In monoclinic crystals the S_8 rings are stacked on top of each other

Fig. 8.15 The arrangement of molecules in rhombic and monoclinic sulphur

2. Extraction of sulphur

Most of the world supply of sulphur is obtained from native deposits. Sulphur is chiefly extracted by melting it out of the rocks in which it is present in the elementary state. It is extracted by Frasch process.

Frasch process

Large deposits of sulphur exists in the Gulf of Mexico in U.S. The deposits usually occur below the surface of the earth at about 1000 - 1500 feet deep. Mining of sulphur has become easy due to a process invented by Herman Frasch in 1894 and is hence called Frasch process.

The process consists of digging three concentric pipes into the surface of the earth till they reach the sulphur deposits. The outer most pipe is about eight to nine inches in diameter and the innermost has about one inch diameter. The outermost pipe carries down super heated water (water heated to about 443 K under pressure). At the bottom of the holes, sulphur and water meet each other. Sulphur melts in its natural deposits and a sort of cavity is formed just below the pipes into which molten sulphur from the surroundings goes on collecting. The innermost pipe carries hot compressed air to the sulphur beds which

helps the molten sulphur to rise upwards through the middle pipe. As it reaches the

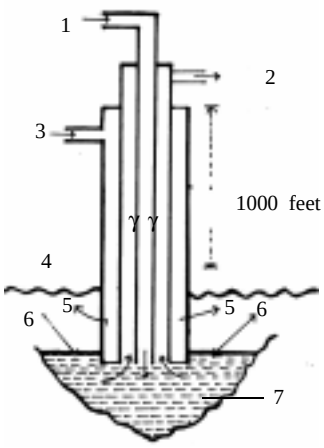


Fig. 8.16

1. Hot compressed air 2. Sulphur foam 3. Hot water 4. Sulphur bearing Rock 5. Water 6. Sulphur 7. Molten sulphur

surface of the earth, it is collected in larger tanks where it solidifies. The essential feature of this process is a large water supply. Cooled water is again used after heating to the required temperature. This Sulphur is almost pure and does not need further purification.

3. Physical properties

(1) It is a yellow crystalline solid at room temperature.

(2) Sulphur has a relatively low melting point, 388 K.

(3) It is a poor conductor of electricity, even in molten state.

(4) Sulphur exhibits allotropy.

(5) It is insoluble in water but soluble in organic solvents such as carbon disulphide and toluene.

(6) Sulphur is poisonous to bacteria and fungi and is used as an antiseptic and a fungicide.

(7) Sulphur exhibit catenation forming S_8 molecules.

4. Chemical properties

Sulphur is fairly inert when cold but on heating it becomes extremely active. It combines with almost all elements except gold, platinum and inert gases.

1) Burning of sulphur : When strongly heated, sulphur burns in air with a blue flame.

$$S + O_2 \xrightarrow{\Delta} SO_2 \uparrow$$

2) Reaction with metals : Sulphur vapours reacts with metals forming the corresponding metal sulphides.

$$Fe + S \xrightarrow{\Delta} \underset{\text{ferrous sulphide}}{FeS}$$

$$Cu + S \xrightarrow{673K} \underset{\text{cupric sulphide}}{CuS}$$

$$Zn + S \xrightarrow{\Delta} ZnS$$

3) Reaction with non-metals : Sulphur reacts with non-metals to form covalent sulphides. On passing hydrogen gas into boiling sulphur, hydrogen sulphide is formed. It has a smell of rotten eggs.

$$H_2 + S \xrightarrow{\Delta} H_2S \uparrow$$

Sulphur reacts with carbon and forms carbon disulphide

$$C + 2S \xrightarrow{\Delta} \underset{\substack{\text{carbon}\\ \text{disulphide}}}{CS_2}$$

4) Reaction with halogens : Sulphur in molten state reacts with halogens to form the corresponding halides.

$$2S + Cl_2 \longrightarrow \underset{\text{sulphur monochloride}}{S_2Cl_2}$$

$$2S + Br_2 \longrightarrow \underset{\text{sulphur monobromide}}{S_2Br_2}$$

$$S + 3F_2 \longrightarrow \underset{\text{sulphur hexafluoride}}{SF_6}$$

Iodine does not combine usually.

5) Reaction with acids : Sulphur does not react with dilute acids. It reacts only with concentrated sulphuric acid and nitric acid because these acids are strong oxidising agents. Sulphur acts as a reducing agent.

$$S + 2H_2SO_4 \longrightarrow 3SO_2 \uparrow + 2H_2O$$

$$S + 6HNO_3 \longrightarrow H_2SO_4 + 6NO_2 \uparrow + 2H_2O$$

6) Reaction with alkalis : It reacts with sodium hydroxide and forms sodium thiosulphate.

$$4S+6NaOH \longrightarrow Na_2S_2O_3 + 2Na_2S + 3H_2O$$

5. Uses of sulphur

1) Industrial uses : Sulphur is used in

(1) Explosive industry

(2) Paper industry

(3) Photographic industry

(4) the manufacture of sulphuric acid

2) Medicinal use

(i) Sulphur is used as a disinfectant, fungicide and germicide for destroying bacteria and fungi in plants.

(ii) It is used as an antiseptic in making skin oinments.

(iii) It is also used in the preparation of sulpha drugs such as sulphonamide.

2) Sulphur is also nowadays used in beauty parlours to give specific shapes to our hair.

3) Sulphur is used in vulcanisation of rubber.

Vulcanisation :

Heating natural rubber with sulphur to a definite temperature for a known period of time is known as vulcanisation of rubber.

Sulphur atoms act as bridges between rubber molecules, initiate cross-linking and convert the soft sticky rubber into a hard, elastic mass which can be put to an extensive use.

The hardness and elasticity varies depending on the percentage of sulphur added during the process.

Rubber bands have only little amount of sulphur, so that it can be stretched. Other rubber articles like eraser, balls, etc., have varying amounts of sulphur.

8.12 Sulphur dioxide

J. Priestly prepared sulphur dioxide gas in the year 1770, by the action of concentrated sulphuric acid on mercury and called it sulphurous acid. Sulphur dioxide occurs in the free state in fumes from volcanic vents and effluent industrial gases. Traces of sulphur dioxide are present in air, especially in industrial areas and where there are a large number of automobiles. This is because fuels like coal, petrol, diesel etc., containing sulphur gives sulphur dioxide gas when burnt in air. This sulphur dioxide dissolves in rain water and forms acid rain which damages metal works, buildings, bridges and crops.

1. Preparation of sulphur dioxide

1) In the laboratory, sulphur dioxide gas is prepared by heating copper turnings with concentrated sulphuric acid.

$$Cu + 2H_2SO_4 \xrightarrow{\Delta} CuSO_4 + SO_2 \uparrow + 2H_2O$$

2) It can also be prepared by burning sulphur in oxygen.

$$S + O_2 \xrightarrow{\Delta} SO_2 \uparrow$$

3) The most convenient method for the preparation in the laboratory is shown below. Dilute hydrochloric acid is added to solid sodium sulphite.

$$Na_2SO_3 + 2HCl \longrightarrow 2NaCl + H_2O + SO_2 \uparrow$$

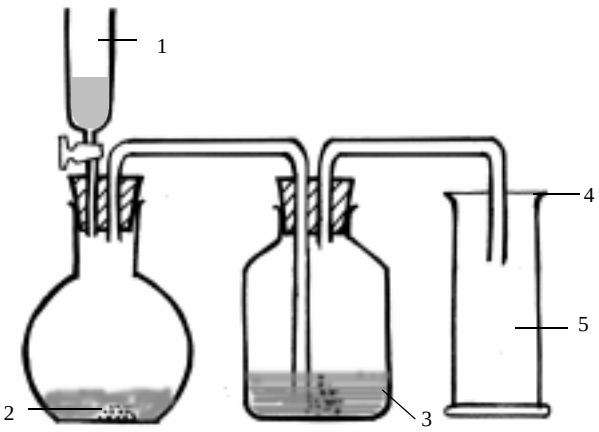


Fig. 8.17 Laboratory preparation of sulphur dioxide

1. Dilute Hydrochloric acid 2. Sodium Sulphite 3. Conc. Sulphuric acid 4. Cover 5. Suphur dioxide

The gas is purified and dried by passing it through concentrated sulphuric acid and collected by the upward displacement of air.

2. Physical properties

1) Sulphur dioxide is a poisonous, colourless gas. It has a characteristic suffocating smell.

2) It is denser than air.

3) Sulphur dioxide is neither combustible nor supporter of combustion.

4) Sulphur dioxide is readily soluble in water and forms acidic solution.

3. Chemical properties

1) Reaction with water : Sulphur dioxide dissolves in water to form sulphurous acid. It is a weak acid and decomposes readily into sulphur dioxide and water, therefore it is not kept in the laboratory as an acid.

$$SO_2 + H_2O \rightleftharpoons H_2SO_3$$

Being an acidic oxide, the solution is acidic and turns blue litmus red.

2) Reaction with base : The solution of sulphur dioxide is dibasic and forms two kinds of salts with alkalis.

It gives sodium bisulphite first and then sodium sulphite with excess of NaOH.

$$SO_2 + NaOH \longrightarrow NaHSO_3$$

$$SO_2 + 2NaOH \longrightarrow Na_2SO_3 + H_2O$$

3) Reaction with oxygen : Sulphur dioxide combines with oxygen in the presence of Vanadium (V) oxide catalyst at 723 K to form sulphur trioxide.

$$2SO_2 + O_2 \xrightarrow[723K]{V_2O_5} 2SO_3$$

4) Sulphur dioxide as an oxidising agent : Sulphur dioxide oxidises hydrogen sulphide to sulphur.

$$SO_2 + 2H_2S \longrightarrow 3S + 2H_2O$$

It oxidises certain metals like magnesium, potassium, etc.

$$2Mg + SO_2 \longrightarrow 2MgO + S$$

5) Sulphur dioxide as a reducing agent : Sulphur dioxide acts as a reducing agent only in the presence of moisture. This is because nascent hydrogen is liberated when sulphur dioxide reacts with water.

$$SO_2 + 2H_2O \longrightarrow H_2SO_4 + \underset{\text{nascent hydrogen}}{2[H]}$$

(1) When sulphur dioxide gas is passed into the solution of orange coloured bromine water, it is decolourised due to the reduction of bromine to bromide.

$$SO_2 + 2H_2O \longrightarrow H_2SO_4 + 2\,[H]$$

$$Br_2 + 2[H] \longrightarrow 2HBr$$

$$Br_2 + SO_2 + 2H_2O \longrightarrow 2HBr + H_2SO_4$$

(2) Ferric chloride is reduced to ferrous chloride.

$$2FeCl_3 + SO_2 + 2H_2O \longrightarrow 2FeCl_2 + H_2SO_4 + 2HCl$$

(3) When sulpur dioxide gas is passed through pink coloured potassium permanganate solution, it turns colourless. This is because, sulphur dioxide reduces permanganate and gets itself oxidised to sulphuric acid.

$$2KMnO_4 + 2H_2O + 5SO_2 \longrightarrow K_2SO_4 + 2MnSO_4 + 2H_2SO_4$$

(4) Nitric acid is reduced to nitrogen dioxide.

$$2HNO_3 + SO_2 \longrightarrow H_2SO_4 + NO_2 \uparrow$$

The last reaction is due to the removal of oxygen which is also a reduction reaction.

6. Sulphur dioxide as a bleaching agent : The bleaching action of sulphur dioxide is due to its reducing property.

In the presence of moisture, it forms nascent hydrogen and removes oxygen from the coloured substances and decolourise them. Sulphur dioxide is a mild bleaching agent, and hence sulphur dioxide is used to bleach delicate things like wool, silk, straw, blue flowers such as blue bells and paper.

The bleaching action of sulphur dioxide is not permanent, because the bleached substance is slowly oxidised by the atmospheric oxygen to give back the original coloured substance after a certain period of time.

Coloured matter + [H] $\longrightarrow$ colourless product

4. Uses of Sulphur dioxide

1) Industrial uses : Sulphur dioxide is used in the

(i) the manufacture of sulphuric acid by contact process.

(ii) sugar industry for refining sugar.

(iii) manufacture of paper.

2) It is used as a germicide and insecticide.

3) It is used to bleach delicate objects like wool, silk, etc.

4) It is used as a refrigerant in place of freons.

5) It is used as a preservative in orange and lemon squashes, jams and in drying fruits as it prevents the growth of bacteria.

6) It is used as an antichlor as it removes excess chlorine from bleached articles by reducing it to chloride.

Activity : Dip blue litmus paper into the solution of sulphur dioxide. We observe that, blue litmus paper turns red. This indicates that the solution of sulphur dioxide is acidic.

Activity : Take acidified potassium dichromate solution in a test tube and pass sulphur dioxide gas. You observe that orange coloured solution of potassium dichromate solution turns green. This is because sulphur dioxide reduces potassium dichromate to chromium sulphate which is green in colour.

8.13 Sulphuric acid

Sulphuric acid is the most important chemical and hence it is called the "king of chemicals". It is used in the manufacture of large number of substances. In the past, chemists made sulphuric acid by heating crystals of zinc sulphate, which they called white vitriol and the oily liquid they obtained was called oil of vitriol.

Farmers use fertilisers and many of them are prepared from sulphuric acid. In everyday life, we use, thousands of tonnes of detergents just for washing. The Detergents are made by reacting chemicals from crude oil with sulphuric acid. Steel objects that are going to be electroplated with nickel and chromium to make them shiny (such as electric kettles and kitchen taps) have to be throughly cleaned first with dilute sulphuric acid. (The process is called pickling). Thus, sulphuric acid is used in innumerable ways either directly or indirectly. Dilute sulphuric acid is used in car batteries.

1. Manufacture of sulphuric acid by contact process

The raw materials for this process are sulphur or sulphide ore, oxygen from the air and water. There are three essential stages in the manufacture of sulphuric acid by the Contact process.

1. Preparation of sulphur dioxide : Sulphur dioxide is made by burning sulphur in air. Sulphur reacts with oxygen in air.

$$S + O_2 \xrightarrow{\Delta} SO_2 \uparrow$$

2. Preparation of sulphur trioxide : Sulphur dioxide reacts with more oxygen forming a gas called sulphur trioxide.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3 \uparrow$$

$\rightleftharpoons$ indicates that this reaction is reversible, and an equilibrium reaction. To get more sulphur trioxide, the gases are heated to 723 K in the presence of Vanadium (V) oxide at a pressure of 200 atmospheres.

3. Preparation of sulphuric acid : The sulphur trioxide gas is passed into concentrated sulphuric acid, instead of water to form a thick

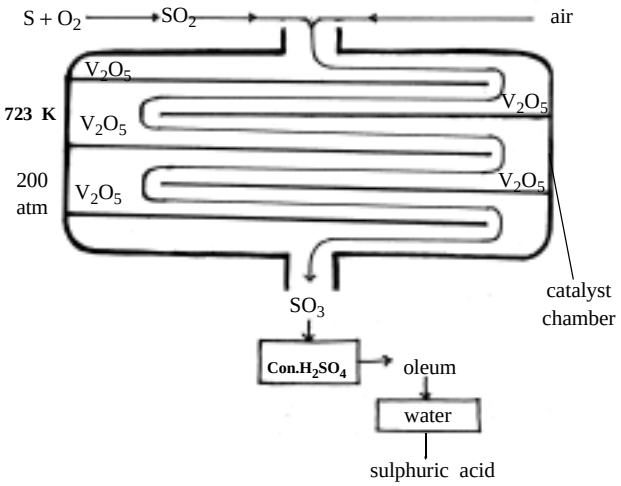


Fig. 8.18 The contact process for making sulphuric acid

fuming liquid called oleum ($H_2S_2O_7$). [If sulphur trioxide is dissolved in water, a highly corrosive mist of sulphuric acid will be formed]. The oleum is then diluted carefully to give concentrated sulphuric acid which is 98% acid and 2% water.

$$SO_3 + H_2SO_4 \longrightarrow \underset{\text{oleum}}{H_2S_2O_7}$$

$$H_2S_2O_7 + H_2O \longrightarrow 2H_2SO_4$$

2. Properties

Sulphuric acid is used in two forms concentrated sulphuric acid and dilute sulphuric acid

Concentrated sulphuric acid : It is colourless, odourless dense, hygroscopic (absorbs moisture from the atmosphere) and oily liquid. It is highly corrosive and chars the skin black due to the dehydration of flesh. It is about 98% sulphuric acid and 2% water.

Chemical properties

1) As a dehydrating agent : Concentrated sulphuric acid is a powerful dehydrating agent. It can remove water from many substances such as sugar, formic acid, ethyl alcohol and copper sulphate and cellulose (wood, paper)

$$\underset{\text{glucose}}{C_6H_{12}O_6} \xrightarrow{\text{conc . } H_2SO_4} 6C + 6H_2O$$

$$\underset{\text{formic acid}}{HCOOH} \xrightarrow{\text{conc . } H_2SO_4} CO\uparrow + H_2O$$

$$\underset{\text{ethanol}}{C_2H_5OH} \xrightarrow{\text{conc . } H_2SO_4} \underset{\text{ethene}}{C_2H_4} + H_2O$$

$$CuSO_4 . 5H_2O \xrightarrow{\text{conc. } H_2SO_4} CuSO_4 + 5H_2O$$

$$\underset{\text{starch}}{[\ C_6H_{10}O_5\ ]_n} \xrightarrow{conc.H_2SO_4} 6[\ C\ ]_n + 5[\ H_2O\ ]_n$$

2) As an oxidising agent : Concentrated sulphuric acid acts as a strong oxidising agent. It oxidises carbon, sulphur, phosphorus.

$$C + 2H_2SO_4 \longrightarrow CO_2\uparrow + 2H_2O + 2SO_2\uparrow$$

$$S + 2H_2SO_4 \longrightarrow 3SO_2\uparrow + 2H_2O$$

$$2P + 5H_2SO_4 \longrightarrow \underset{\text{phosphoric acid}}{2H_3PO_4} + 2H_2O + 5SO_2\uparrow$$

Dilute sulphuric acid : It is about 10% sulphuric acid and 90% water. It must be prepared by adding concentrated sulphuric acid to water. Water should never be added to concentrated sulphuric acid. If water is added to the acid, there may be a sudden increase in temperature and the acid in the bulk may spurt out. If acid is added to water, water is in bulk and the acid being heavier, settles down and spurting is minimised.

1) Dilute sulphuric acid shows typical properties of acids. It turns blue litmus red.

2) It reacts with metals above hydrogen in the activity series forming corresponding salts.

$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2\uparrow$$

$$Fe + H_2SO_4 \longrightarrow FeSO_4 + H_2\uparrow$$

3) It reacts with carbonates and liberates carbon dioxide.

$$K_2CO_3 + H_2SO_4 \longrightarrow K_2SO_4 + H_2O + CO_2\uparrow$$

4) As a dibasic acid, it reacts with sodium hydroxide giving two types of salts.

$$NaOH + H_2SO_4 \longrightarrow \underset{\text{Sodium hydrogen sulphate}}{NaHSO_4} + H_2O$$

$$2NaOH + H_2SO_4 \longrightarrow \underset{\text{Sodium sulphate}}{Na_2SO_4} + 2H_2O$$

Uses of sulphuric acid

1) Industrial uses : Sulphuric acid is used in

(1) the manufacture of fertilizers such as ammonium sulphate.

(2) making synthetic fibres, plastics, car batteries, dyes, drugs, etc.

(3) in petrol refining and for cleaning metals.

(4) the manufacture of glass,

(5) the manufacture of soaps and detergents.

2) Concentrated sulphuric acid is used for drying gases which do not react with it.

3) Concentrated sulphuric acid is used as a dehydrating agents.

Activity : Place some sugar in a test tube. Add a few drops of concentrated sulphuric acid to it. We observe that sugar chars and turns black. This is because the acid removes hydrogen and oxygen as water leaving behind a black mass of carbon. Sugar is made of carbon, hydrogen and oxygen.

Activity : Place a few crystals of crystalline copper sulphate in a test tube. Note the colour and add a few drops of concentrated sulphuric acid to it. We observe that crystals of copper sulphate slowly turn white. This is due to the removal of water of crystallisation from the crystals of copper sulphate by the acid. The anhydride salt is white in colour.

SELF EVALUATION

Choose the correct answer

1. The most common ore of Aluminium are

   (1) Cryolite (2) Bauxite
   (3) Feldspar (4) Haematite

2. Which of the following is liquid at room temperature ?

   (1) Iodine (2) Bromine
   (3) Invar (4) Duralumin

3. Oil of vitriol is

   (1) $FeSO_4 . 7H_2O$
   (2) $CuSO_4 . 5H_2O$
   (3) $ZnSO_4 . 7H_2O$
   (4) H_2SO_4

4. Oxides of metals are generally
(1) acidic (2) basic
(3) amphoteric (4) neutral

5. The sulphur exists as
(1) S (2) S_8
(3) S_2 (4) S_4

6. The lightest element known is
(1) He (2) H_2
(3) Ar (4) Li

7. A pinch of sugar gets charred when treated with conc. sulphuric acid, this shows that sulphuric acid is a
(1) dehydrating agent (2) fire produces
(3) reducing agent (4) dibasic acid

Fill in the blanks

8. Sodium metal is stored under .....

9. ..... is the most abundant metal in the earth's crust.

10. Oxides of non-metals are ..... in nature.

11. Non-metals are good ..... agents.

12. Solder is an alloy of ..... and .....

13. Steel is heated to high temperature and then suddenly cooled in oil. The process is known as .....

14. Sulphuric acid oxidises carbon to .....

15. ..... is used to prepare the fertilizer ammonium sulphate.

16. Most of the metals have ..... melting points.

17. Volatile metals like zinc and mercury are purified by ..... process.

18. The rocky material found with ores is known as .....

19. Sulphur is used in the ..... of rubber.

Answer briefly

20. Define the terms mineral and ore.

21. Write a short note on froth-floatation process.

22. Explain the terms flux and slag.

23. Name the three commercial forms of iron. How do they differ from each other ?

24. Give equations for the reactions between iron and dilute hydrochloric acid.

25. Why does aluminium lose its shine when exposed to air ?

26. Ammonium hydroxide cannot be kept in aluminium containers. Why ? Write equations for the reactions that may occur.

27. Concentrated nitric acid can be stored in aluminium containers. Give reasons.

28. What is an alloy ? Give example.

29. What are amalgams ? Give example.

30. What do you understand by hydrogenation of oils ?

31. Give important uses of ammonia.

32. What is vulcanisation ? What is the effect of vulcanisation on the quality of rubber ?

33. An iron knife kept dipped in a blue copper sulphate solution, turns the blue solution light green. Why ?

34. Metals act as good reducing agents. Justify.

35. Which of the following elements is a metal?

$_{11}X^{23}$ $_{9}Y^{19}$ $_{10}Z^{20}$

36. Why are metals highly electropositive ?

37. The atom of an element X has the electronic arrangement 2, 8, 14, 2. Without identifying the element state the valency of the element and write whether it is likely to have oxidising or reducing properties.

38. What is activity series ? How does it help us in predicting the relative activities ?

39. Explain, why zinc can displace copper from copper sulphate solution but copper cannot displace zinc from zinc sulphate solution.

40. Give any two addition reactions of sulphur dioxide.

41. Concentrated sulphuric acid is diluted by adding acid to water and not vice versa. Why ?

42. Why is sulphuric acid called the "king of chemicals"?

43. Ag metal does not combine easily with oxygen but silver jewellery tarnishes after sometime. How ?

44. Why is an iron grill painted frequently ?

45. Why do gold ornaments look new even after several years of use ?

46. Which property of graphite is utilised in making graphite electrodes ?

47. An element reacts with oxygen to form an oxide which dissolves in dilute hydrochloric acid. The oxide formed also turns a solution of red litmus blue. Is the element a metal or non-metal ? Explain your answer.

48. Define allotropy. Name one element which shows allotropy.

49. What happens when sulphur reacts with hot conentrated sulphuric acid ? Give the chemical equation of the reaction involved.

50. Natural rubber heated with an element X to make it hard, strong and more elastic. Name the element X. What is this process called?

51. What happens when sulphur dioxide dissolves in water ? Write the equation of the reaction involved.

52. Why are water pipes made of copper rather than iron ? Why are cars made of steel ? Wires made of copper and bells made of bronze ?

53. Arrange these metals in the order of activity, with the most reactive one at the top.

Cu, K, Al, Au, Fe

54. Fifty years ago, people were flown across the Atlantic in airships filled with hydrogen. What property of hydrogen might have enabled it to lift heavy loads ? What property might have made these airships dangerous.

Answer in Detail

55. Describe how hydrogen gas is prepared in the laboratory. Draw a labelled diagram of the apparatus used. Give the chemical equation of the reaction involved.

56. Describe Haber process for the manufacture of ammonia.

57. Describe contact process for the manufacture of sulphuric acid.

58. Explain the following terms.
(a) Metallurgy (b) Flux
(c) Calcination (d) Roasting
(e) Smelting

59. Compare and contrast the properties of metals and non-metals with reference to any four properties.

60. Explain the method used for the extraction of aluminium from its ore. Illustrate your answer with the help of a neat, labelled diagram.

61. With the help of a labelled diagram of a blast furnace, describe the extraction of iron from its ore. Write the chemical equations of the reactions involved in the furnace.

62. Describe the methods for the concentration of ores.

Activities

63. Introduce moist coloured rose petals into a jar of sulphur dioxide. What do you observe and why ?

64. Pass sulphur dioxide gas through Bromine water and acidified potassium dichromate solutions. Observe what happens. Explain.

65. Introduce burning magnesium ribbon into jar of sulphur dioxide ? What do you observe why ?

66. Dip a glass rod into a bottle containing concentrated hydrochloric acid. Now introduce into a gas jar filled with ammonia. What do you observe. Why ?

9. CARBON COMPOUNDS

Cells in our body are made of proteins. The fossil fuels are the important energy resources. The life saving antibiotics and drugs play a vital role in our day to day life. In recent years, many synthetic polymer products like polyethylene terephthalate (PET) polyethylene, nylon, terylene, bakelite, etc. are widely used in various fields.. Soaps, detergents and many cleansing agents are useful for domestic and industrial purposes. The above mentioned products namely, proteins, fossil fuels, antibiotics, drugs, synthetic polymers, soaps and detergents are compounds of carbon.

Carbon exhibits a characteristic property called catenation by which carbon atoms can attach themselves with one another and due to this property, a large number of carbon compounds are existing.

The role of carbon and its compounds in our daily life shows the importance of the study of these compounds. We have learnt that carbon forms a large number of compounds with hydrogen. Compounds containing only carbon and hydrogen are called Hydrocarbons. Many carbon compounds, in addition to hydrogen, also contain some elements like oxygen, nitrogen, halogens (chlorine, bromine and iodine) and sulphur.

Except hydrocarbons, organic compounds consists of two parts, namely a **reactive part** which is known as **Functional group** and a **skeleton of carbon** and **hydrogen atoms** called **alkyl radical.**

Functional group

Functional group may be defined as an atom or group of atoms which is responsible for the characteristic properties of the compound.

The chemical properties of an organic compound are determined by the functional group and the physical properties of an organic compound are determined by the remaining part of the molecule.

Classification of organic compounds based on functional groups

Alcohols

Organic compounds containing -OH as the functional group are known as Alcohols. For example, methan**ol** (CH_3OH), ethan**ol** (C_2H_5OH), propan**ol** (C_3H_7OH), Butan**ol** (C_4H_9OH) etc., are alcohols. Most of the characteristic properties of alcohols are due to the presence of the -OH group.

Aldehydes

Organic compounds containing –CHO as the functional group are known as aldehydes. For example, methan**al** (HCHO), ethan**al** (CH_3CHO), propan**al** (CH_3CH_2CHO), butan**al** ($CH_3CH_2CH_2CHO$) etc., are aldehydes.

Ketones (>C=O)

Organic compounds containing >C=O as the functional group are known as ketones.

For example, propa**none** (CH_3COCH_3), Buta**none** ($CH_3CH_2COCH_3$) are ketones.

Carboxylic acids

Organic compounds containing carboxyl group (-COOH) as the functional group are known as carboxylic acids. For example, methanoic acid (HCOOH), etha**noic** acid (CH_3COOH), propa**noic** acid (CH_3CH_2COOH), buta**noic** acid ($CH_3CH_2CH_2COOH$) etc., are carboxylic acids.

9.1 Alcohols

Alcohols are compounds which contain carbon, hydrogen and oxygen. Alcohols can be derived from alkanes, if a hydrogen (–H) in alkane is replaced by a hydroxyl group (–OH).

For example,

$$\underset{\text{methane}}{CH_4} \xrightarrow[-H \text{ by } -OH]{\text{Replace}} \underset{\text{methanol}}{CH_3OH}$$

$$\underset{\text{ethane}}{CH_3\,CH_3} \xrightarrow[-H \text{ by } -OH]{\text{Replace}} \underset{\text{ethanol}}{CH_3CH_2OH}$$

Generally alcohols are represented as R–OH where R is an alkyl group and –OH is the functional group and the general formula of alcohol is given as C_nH_{2n+1} OH, where 'n' is the number of carbon atoms. There are two ways of naming organic compounds namely **Common** and **IUPAC** system.

The common names of alcohols are derived when the last letter '-ane' in the name of the parent hydrocarbon is replaced by '*-yl*' and it is combined with the word 'alcohol'.

The IUPAC system :

According to this system, the last letter '*-e*' in the name of the parent hydrocarbon is replaced by '*ol*'.

The formulae, common names and IUPAC names of first four members of the series are given in table 9.1.

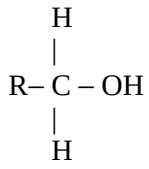
Table 9.1 IUPAC names of alcohol series.

Formula of alcohol	Parent hydrocarbon	Common name	IUPAC name
CH_3OH	Methane (CH_4)	Methyl alcohol	Methanol
C_2H_5OH	Ethane (C_2H_6)	Ethyl alcohol	Ethanol
C_3H_7OH	Propane (C_3H_8)	Propyl alcohol	Propanol
C_4H_9OH	Butane (C_4H_{10})	Butyl alcohol	Butanol

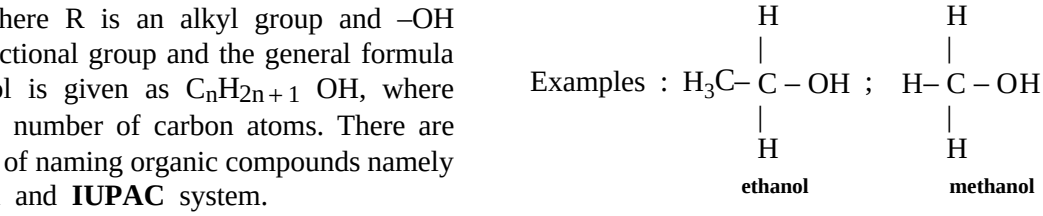
1. Classification of Alcohols

Alcohols are classified as primary, secondary and tertiary alcohols. This depends upon the number of alkyl groups attached to the carbon atom carrying the hydroxyl group.

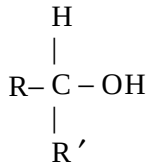
1) A primary alcohol has the general formula,



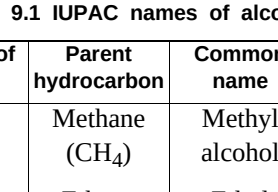
where R is an alkyl group. In primary alcohols, the carbon carrying the hydroxyl group is directly attached to only one alkyl group or none.

Examples : 

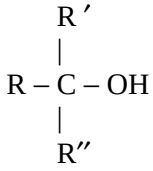
2) A secondary alcohol has the general formula,



wher R and R′ are alkyl groups. R and R′ may or may not be the same. In secondary alcohols, the carbon carrying the hydroxyl group is directly attached to two alkyl groups.

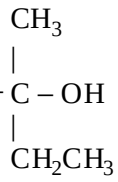
Example :  (butan-2-ol)

3) A tertiary alcohol has the general formula,



where R, R′ and R′′ are alkyl groups and R, R′, R′′ may or may not be the same. In tertiary alcohols, the carbon carrying the -OH group is directly attached to three alkyl groups.

Example :



2. Ethanol

Ethanol is the second member of the alcoholic series. Ethanol is commonly known as alcohol. It is a constituent of all alcoholic beverages namely beer, wine, whisky, some cough syrups, digestive syrups etc. In industries, alcohol is produced by the fermentation of sugar present in molasses. Molasses is a by-product of sugar industry in India. In our country, most of the ethanol is prepared from molasses.

Fermentation

The slow chemical change taking place in an organic compound by the action of enzymes leading to the formation of smaller molecules is called **Fermentation.** In our daily life, there are many instances of fermentation. For example, the change of milk into curd, souring of kneaded flour, etc., are due to fermentation. The fermentation of sugar is a process in which the sugar molecules are broken down into ethanol and carbon dioxide by the action of enzymes called **invertase** and **zymase** present in yeast.

1) Manufacture of Ethanol from Molasses

Molasses is a dark coloured syrupy liquid left after the crystallisation of sugar from the concentrated sugar cane juice. Molasses still contain about 30% sucrose which could not be separated by crystallisation. Molasses is converted into ethanol by the following steps.

(1) Dilution

Molasses is first diluted with water to bring down the concentration of sugar to about 8 to 10 percent.

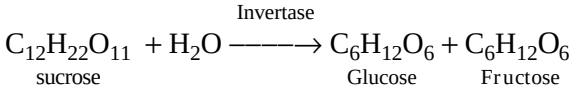
(2) Addition of Ammonium salts

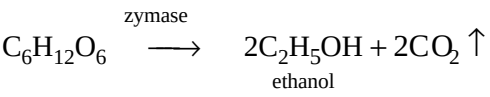
Molasses usually contains enough nitrogenous matter to act as food for yeast during fermentation. If the nitrogen content of the molasses is poor, it may be fortified by the addition of ammonium sulphate or ammonium phosphate.

(3) Addition of yeast

The solution from step (2) is collected in large ‘fermentation tanks’ and yeast is added to it. The mixture is maintained at about 303K for a few days.

During this period, the enzymes **invertase** and **zymase** present in yeast, bring about the conversion of sugar into ethanol.





During this process, the liquor froaths owing to the evolution of carbon-di-oxide which is recovered and used for preparing aerated drinks. The fermented liquid is technically called **wash.**

(4) Distillation of wash

The fermented liquid containing 15 to 18 percent alcohol and the rest water, is now subjected to fractional distillation.

The main fraction drawn, is an aqueous solution of ethanol which contains 95.6% ethanol and 4.4% water. This is called **Rectified spirit.** This mixture is then heated under reflux over quicklime for about 5 to 6 hours and then allowed to stand for 12 hours. On

distillation of this mixture, pure alcohol (C_2H_5OH = 100%) is obtained. This is called **Absolute alcohol.**

2) Physical properties

(1) Ethanol is a colourless liquid having a pleasant smell and a burning taste.

(2) It is a volatile liquid having a low boiling point of 78^oC (351 K).

(3) It is miscible with water in all proportions.

(4) Ethanol does not contain any ions, as it is a covalent compound and has no effect on litmus paper.

(5) The boiling point of alcohols are, in general, much higher than the corresponding alkanes. This is because in alcohols there is intermolecular association of a large number of molecules due to Hydrogen bonding which is absent in alkanes..

3) Chemical properties

(1) Reaction with oxygen or combustion

Ethanol is a highly inflammable liquid (it catches fire easily). It burns with a blue flame to form carbon dioxide and water.

$$\underset{\text{ethanol}}{C_2H_5OH} + 3O_2 \longrightarrow \underset{\text{carbondioxide}}{2CO_2\uparrow} + 3H_2O\uparrow$$

(2) Reaction with sodium.

It reacts with sodium to produce sodium ethoxide and hydrogen.

$$\underset{\text{ethanol}}{2C_2H_5OH} + \underset{\text{sodium}}{Na} \longrightarrow \underset{\text{sodium ethoxide}}{2C_2H_5ONa} + H_2\uparrow$$

Activity

When a small piece of sodium metal is put into ethanol in a dry test tube, brisk effervescence is produced. When a burning splinter is brought near the mouth of the test tube, the gas burns with a 'pop' sound, which is a characteristic property of hydrogen gas. This shows that the gas produced by the action of sodium metal on ethanol is hydrogen.

(3) Esterification

Ethanol reacts with ethanoic acid in the presence of conc. H_2SO_4 to form an ester, ethyl ethanoate and water. The ester formed has sweet smell and the reaction is known as **esterification.**

$$\underset{\text{ethanol}}{C_2H_5OH} + \underset{\text{ethanoic acid}}{CH_3COOH} \xrightarrow{\text{conc. } H_2SO_4} \underset{\text{ethyl ethanoate}}{CH_3COOC_2H_5} + H_2O$$

Activity

Take 3 ml of ethanol in a dry test tube and add an equal volume of glacial acetic acid. Then add a few drops of concentrated H_2SO_4 and warm the test tube in a hot water bath. A fruity odour of ester is noted.

(4) Oxidation with acidified potassium dichromate

Acidified $K_2Cr_2O_7$ oxidises ethanol to ethanoic acid.

$$C_2H_5OH \xrightarrow[K_2Cr_2O_7 / H_2SO_4]{[O]} \underset{\text{ethanoic acid}}{CH_3COOH}$$

(5) Dehydrogenation

When the vapours of ethanol are passed over reduced copper catalyst at 573 K, it dehydrogenates to give acetaldehyde.

$$\underset{\text{ethyl alcohol}}{CH_3CH_2OH} \xrightarrow[573\text{ K}]{\text{Cu}} \underset{\text{acetaldehyde}}{CH_3CHO} + H_2\uparrow$$

(6) Dehydration

Alcohols can be dehydrated on heating with conc. H_2SO_4 or alumina (Al_2O_3) to form alkenes.

$$C_2H_5OH \xrightarrow[Al_2O_3,\ 623\ K]{conc.\ H_2SO_4\ (or)} \underset{ethene}{CH_2 = CH_2} + H_2O$$

(7) Reaction with phosphorous penta chloride

On treatment with phosphorus penta-chloride, ethanol is converted into ethyl chloride.

$$C_2H_5OH + PCl_5 \longrightarrow \underset{ethyl\ chloride}{C_2H_5Cl} + POCl_3 + HCl\uparrow$$

(8) Reaction with bleaching powder

When ethanol is heated with bleaching powder and water, chloroform and calcium formate are produced. The reaction takes place in the following steps.

$$\underset{bleaching\ powder}{CaOCl_2} + H_2O \longrightarrow Ca(OH)_2 + Cl_2\uparrow$$

$$C_2H_5OH + Cl_2 \longrightarrow \underset{acetaldehyde}{CH_3CHO} + 2HCl$$

$$CH_3CHO + 3Cl_2 \longrightarrow \underset{chloral}{CCl_3CHO} + 3HCl$$

$$CCl_3CHO + H_2O \longrightarrow \underset{Chloroform}{CHCl_3} + \underset{methanoic\ acid}{HCOOH}$$

$$2HCOOH + Ca(OH)_2 \longrightarrow \underset{Calcium\ formate}{(HCOO)_2Ca} + 2H_2O$$

4) Uses

Ethanol is used

(1) in the manufacture of paints, varnishes, lacquers and medicines.

(2) in the preparation of organic compounds like ether, chloroform and iodoform.

(3) as an antiseptic to sterilise wounds and syringes in hospitals and dispensaries.

(4) in alcoholic drinks (beverages) like whisky, wine, beer and other liquors. Beer contains around 3 to 6% ethanol, whisky contains 30% ethanol and wine contains 8 to 10% ethanol;

(5) in spirit lamps as methylated spirit (contains ethanol mixed with a small amount of methanol and water).

(6) as power alcohol to generate power in internal combustion engines. Power alcohol is a mixture of 25% absolute alcohol and 75% petrol and it is a good fuel for motor cars. In the present days, due to scarcity of petrol and petroleum products, power alcohol can be used as a substitute for petrol in motor cars which may also reduce pollution of air.

5) Harmful effects of drinking alcohol

We should not use any alcoholic drinks because of the following harmful effects which they produce.

(1) Alcoholic drinks spoil the health of the person concerned. It damages the liver and makes the brain dull.

(2) The drinking of adulterated alcohol containing methanol causes severe poisoning leading to blindness and even death.

(3) Alcohol drinking by the head of a family worsens the economic condition of the family and also has a very bad effect on the psychological development of the children.

9.2 Carbonyl Compounds

Aldehydes and ketones are called carbonyl compounds as they contain the carbonyl group, >C=O. The functional group of an aldehyde is –CHO and that of the ketone is >C=O. Both aldehydes and ketones have the same general formula, $C_nH_{2n}O$. The general formula for aldehydes is R–CHO, where R is an alkyl group and the general formula for ketones is R–CO–R′, where R and R′ are alkyl group which may or may not be the same.

1. Aldehydes

The common names assigned to aldehydes are based on the names of acids produced by their oxidation. For example, formaldehyde and acetaldehyde are so called because on oxidation they produce formic acid and acetic acid respectively. The suffix of the names of acid 'ic' is replaced by 'aldehyde'.

The IUPAC names are derived when the last letter '-e' of the parent alkane is replaced by '-al' to indicate the presence of aldehyde.

The formulae, common names and IUPAC names of first four members of the series are given below :

Table 9.2 IUPAC names of aldehyde series

Formula and IUPAC name	Parent hydro-carbon	Common name of aldehyde	Acid produced on oxidation
HCHO Methanal	Methane	Formaldehyde	Formic acid
CH_3CHO Ethanal	Ethane	Acetaldehyde	Acetic acid
CH_3CH_2CHO Propanal	Propane	Propionalde-hyde	Propionic acid
$CH_3CH_2CH_2CHO$ Butanal	Butane	Butyraldehyde	Butyric acid

2. Formaldehyde or Methanal

Methanal is the first member of the aldehyde series. The chemical formula of methanal is HCHO. The common name of methanal is formaldehyde.

1) Preparation

Formaldehyde is prepared by the controlled oxidation of methanol (CH_3OH) at $873-923K$ using silver, iron oxide or molybdenum oxide as catalyst.

$$\underset{\text{methanol}}{2CH_3OH} + O_2 \xrightarrow[873-923\ K\ \text{catalyst}]{} \underset{\text{formaldehyde}}{2HCHO} + 2H_2O$$

2) Physical properties

(1) It is a colourless, pungent smelling gas.

(2) It is highly soluble in water.

(3) It can be easily condensed into liquid. The liquid HCHO boils at 252K.

(4) It causes irritation of skin, eyes, nose and throat.

(5) Its solution acts as an antiseptic and a disinfectant.

3) Chemical properties

(1) Oxidation

Formaldehyde is oxidised to methanoic acid in the presence of oxidising agents like alkaline potassium permanganate or Tollen's reagent (ammoniacal silver nitrate).

$$\underset{\text{formaldehyde}}{HCHO} + \underset{\substack{\text{nascent}\\ \text{oxygen}}}{[O]} \xrightarrow{\text{Alk. } KMnO_4} \underset{\text{sodium formate}}{HCOONa}$$

$$HCOONa \xrightarrow{HCl} \underset{\text{formic acid}}{HCOOH}$$

(2) Reduction

Formaldehyde is reduced to methanol by treating with hydrogen in the presence of finely divided palladium as catalyst.

$$\underset{\text{formaldehyde}}{HCHO} + H_2 \xrightarrow{Pd} \underset{\text{methanol}}{CH_3OH}$$

(3) Reaction with Ammonia

Formaldehyde reacts with Ammonia to form hexamethylene tetramine (urotropine)

$$6HCHO + 4NH_3 \longrightarrow \underset{\text{urotropine}}{(CH_2)_6N_4} + 6H_2O$$

4) Uses

(1) An aqueous solution of formaldehyde is called **Formalin** which contains about 40% HCHO. It is a powerful disinfectant and antiseptic. It is used for

preserving dead bodies, biological specimens and sterilising surgical instruments.

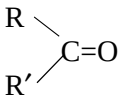
(2) It is used in the manufacture of paints and dyes.

(3) Formaldehyde is condensed with phenol in the manufacture of bakelite, a plastic which is used for making electrical switches.

(4) Formaldehyde is condensed with ammonia to produce urotropine, $(CH_2)_6N_4$ which is an important medicine in urinary ailments.

9.3 Ketones

Like aldehydes, ketones also contain carbonyl group, >C=O. Therefore, ketones are also known as carbonyl compounds. Ketones have two alkyl groups attached to carbonyl carbon,



where R and R′ are alkyl groups.

Common names of ketones are derived by writing the name of the alkyl groups attached to the carbonyl carbon followed by the word 'ketone'. For example, CH_3COCH_3 is called dimethyl ketone.

In IUPAC system of naming ketones, the last letter 'e' of the parent alkane is replaced by 'one' to indicate the presence of ketonic group. The position of the carbon atom present as carbonyl group is also counted in numbering the parent alkane and the numbering is carried out such that the carbonyl carbon gets the lowest number. The formulae, common names and IUPAC names of first three members of the series are given in table 9.3.

Table 9.3 IUPAC series of ketone series

Formula of ketone	Parent hydro-carbon	Common name	IUPAC name
CH_3COCH_3	Propane	Acetone or Dimethyl ketone	Propanone
$CH_3COCH_2CH_3$	Butane	Ethyl methyl ketone	Butan-2-one
$CH_3CH_2COCH_2CH_3$	Pentane	Diethyl ketone	Pentan-3-one

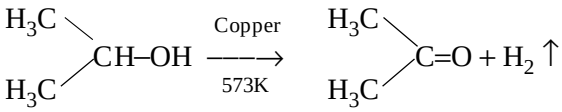
1. Acetone

Acetone is the first member of the ketone series. Its IUPAC name is propanone.

The chemical formula of acetone is CH_3COCH_3.

1) Preparation

Acetone is prepared by the dehydrogenation of isopropyl alcohol using heated copper.



isopropyl alcohol **acetone**

2) Physical properties

(1) Acetone is a colourless, inflammable, volatile liquid with characteristic pleasant smell.

(2) Its boiling point is 329 K.

(3) It is miscible with water, alcohol and ether in all proportions.

(4) It specific gravity is 0.792 g/ml at 293K.

3) Chemical properties

(1) Reduction

(a) Acetone can be reduced to propan-2-ol by reaction with sodium borohydride, $NaBH_4$ or lithium aluminium hydride $LiAlH_4$.

$$CH_3-\underset{\underset{O}{\|}}{C}-CH_3 + 2[H] \xrightarrow{NaBH_4} H_3C-\underset{\underset{OH}{|}}{CH}-CH_3$$

acetone propan-2-ol

(b) Acetone can be reduced to propane by reaction with zinc-amalgam and hydrochloric acid.

$$H_3C-\underset{\underset{O}{\|}}{C}-CH_3 + 4\,[H] \xrightarrow{Zn-Hg/HCl} CH_3CH_2CH_3 + H_2O$$

propane

This reaction is known as **Clemmensen** reduction.

(2) Oxidation

Acetone is oxidised to acetic acid on prolonged treatment with alkaline solution of potassium permanganate.

$$H_3C-\underset{\underset{O}{\|}}{C}-CH_3 \xrightarrow{alk.\,KMnO_4} CH_3COONa$$

sodium acetate

$$CH_3COONa \xrightarrow{dil.\,HCl} CH_3COOH$$

Acetic acid

(3) Chlorination

When acetone is allowed to react with chlorine, hydrogen atoms present in methyl group may be partly or completely substituted by chlorine atoms.

$$\begin{array}{l} H\ O\ H \\ |\ \|\ | \\ H-C-C-C-H \\ |\ \ \ | \\ H\ \ H \end{array} + Cl_2 \longrightarrow \begin{array}{l} H\ O\ H \\ |\ \|\ | \\ Cl-C-C-C-H \\ |\ \ \ | \\ H\ \ H \end{array} + HCl$$

acetone monochloro acetone

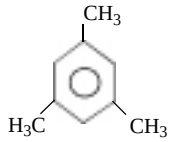
$$\begin{array}{l} H\ O\ H \\ |\ \|\ | \\ H-C-C-C-H \\ |\ \ \ | \\ H\ \ H \end{array} + 3Cl_2 \longrightarrow \begin{array}{l} Cl\ O\ H \\ |\ \|\ | \\ Cl-C-C-\ C-H \\ |\ \ \ | \\ Cl\ \ H \end{array} + HCl$$

trichloroacetone

(4) With conc. H_2SO_4

When distilled with conc. H_2SO_4, three molecules of acetone condense together to form an aromatic hydrocarbon, **mesitylene.**

$$3CH_3COCH_3 \xrightarrow{conc.\,H_2SO_4} \text{mesitylene} + 3H_2O$$



4) Uses

Acetone is used

(1) in the preparation of chloroform, iodoform and sulphonal

(2) as a solvent in paints, varnishes etc.

(3) in the synthesis of rubber

(4) in the manufacture of artificial leather

(5) to clean and dry the parts of precious equipments

(6) as a nail polish remover.

9.4 Carboxylic acids

Carboxylic acids are a class of organic compounds which contain carboxyl group (–COOH) as the functional group. This group is structurally represented as $-\overset{\overset{O}{\|}}{C}-OH$ Formerly, higher members of the carboxylic acids were obtained from fats. Hence, these acids are also called fatty acids. The general formula of carboxylic acid is R-COOH.

Carboxylic acids are classified according to the number of carboxyl groups present in a molecule of the acid. The acids containing a single carboxyl group in their molecules are known as monocarboxylic acids, while those containing two carboxylic groups are called dicarboxylic acids.

Examples for mono carboxylic acids are formic acid, HCOOH and acetic acid, CH_3COOH.

Examples for Dicarboxylic acids are oxalic acid $(COOH)_2$ and malonic acid $CH_2(COOH)_2$.

Common names of monocarboxylic acids have been derived from Latin or Greek names of the sources from which the acids were obtained.

Table 9.4. Common names of monocarboxylic acids

Formula of acid	Occurence	Latin or Greek name of the source	Name of acid
HCOOH	Ants	Ants are called Formica in Latin	Formic acid
CH_3COOH	Vinegar	Vinegar is called acetum in Latin	Acetic acid
$CH_3CH_2CH_2COOH$	Butter	Butter is called butyrum in Latin	Butyric acid

In IUPAC system, naming of monocarboxylic acids, is done by replacing 'e' of the corresponding alkane by 'oic' acid.

The formula, common names and IUPAC names of first three members of the series are given in table 9.5

Table 9.5 IUPAC names of acids

Formula of acid	Parent hydrocarbon	Common name of acid	IUPAC name of acid
HCOOH	Methane (CH_4)	Formic acid	Methanoic acid
CH_3COOH	Ethane (C_2H_6)	Acetic acid	Ethanoic acid
C_2H_5COOH	Propane (C_3H_8)	Propionic acid	Propanoic acid

1. Acetic acid

Acetic acid is the second member of the carboxylic acid series. The formula of acetic acid is CH_3COOH and the IUPAC name of acetic acid is ethanoic acid. A dilute solution of acetic acid in water is called vinegar. **Vinegar** contains 6 to 10% acetic acid.

1) Manufacture of Acetic acid

(1) From Ethanol

Acetic acid is manufactured in the form of vinegar by the bacterial oxidation of ethanol. Ethanol is oxidised by the oxygen in air in the presence of **Bacterium mycoderma aceti** to form a dilute solution of acetic acid called vinegar.

$$CH_3CH_2OH + O_2 \longrightarrow \underset{\text{acetic acid}}{CH_3COOH} + H_2O$$

(2) From methanol

Acetic acid is manufactured by the reaction between methanol and carbon monoxide in the presence of iodine Rhodium catalyst

$$\underset{\text{methanol}}{CH_3OH} + CO \xrightarrow{I_2 - Rh} \underset{\text{acetic acid}}{CH_3COOH}$$

This is a recent commercial method for preparing acetic acid.

2) Physical properties

(1) Acetic acid is a colourless corrosive liquid having a pungent smell.

(2) Acetic acid is miscible with water in all proportions.

(3) When pure acetic acid is cooled, it freezes at 290 K, to form a colourless, icy mass which looks like a glacier. Due to this, pure acetic acid is called glacial acetic acid.

(4) Acetic acid is soluble in water due to intermolecular hydrogen bonding with water molecules.

(5) It turns blue litmus red.

3) Chemical properties

(1) Formation of salt

Acetic acid reacts with sodium hydroxide to form salt and water.

$$CH_3COOH + NaOH \longrightarrow \underset{\text{sodium acetate}}{CH_3COONa} + H_2O$$

(2) Reaction with alcohols

Acetic acid reacts with alcohols in the presence of a little concentrated sulphuric acid to form **esters** with a sweet smell.

$$CH_3COOH + C_2H_5OH \xrightarrow{\text{Conc. } H_2SO_4} \underset{\text{ethyl ethanoate}}{CH_3COOC_2H_5} + H_2O$$

(3) Decarboxylation

Decarboxylation is the process of removal of carboxyl group. When sodium acetate is heated with soda lime (mixture of NaOH and CaO in the ratio 3 : 1), methane gas is formed.

$$\underset{\text{sodium acetate}}{CH_3COONa} + NaOH \xrightarrow{\Delta} \underset{\text{methane}}{CH_4} + Na_2CO_3$$

(4) Reaction with PCl_5

Acetic acid reacts with phosphorous pentachloride to produce acetyl chloride.

$$CH_3COOH + PCl_5 \longrightarrow \underset{\text{acetyl chloride}}{CH_3COCl} + HCl + POCl_3$$

(5) Reaction with ammonia

When treated with ammonia, acetic acid gives ammonium acetate which on heating gets converted into acetamide.

$$CH_3COOH + NH_4OH \longrightarrow \underset{\substack{\text{ammonium}\\\text{acetate}}}{CH_3COONH_4} + H_2O$$

$$\underset{\text{Ammonium acetate}}{CH_3COONH_4} \xrightarrow{\Delta} \underset{\text{acetamide}}{CH_3CONH_2} + H_2O$$

(6) Reduction

Reduction of acetic acid with lithium aluminium hydride ($LiAlH_4$) gives ethanol.

$$CH_3COOH + 4[H] \xrightarrow{LiAlH_4} \underset{\text{ethanol}}{CH_3CH_2OH} + H_2O$$

(7) Dehydration

When acetic acid is heated with a dehydrating agent such as phosphorous pentoxide, P_2O_5, acetic anhydride is formed. Two molecules of acetic acid combine together and one molecule of water is eliminated.

$$CH_3COOH + HOOCCH_3 \xrightarrow{P_2O_5} \underset{\text{acetic anhydride}}{(CH_3CO)_2O} + H_2O$$

Activity

1. Take some acetic acid in a test tube and add sodium bicarbonate to it. You can observe the brisk effervescence due to carbondioxide. This is due to the presence of carboxyl group in acetic acid.

2. Take some acetic acid in a test tube and immerse blue litmus paper. The blue litmus changes to red showing the presence of an acid.

4) Uses

Acetic acid is used

(1) as a food preservative in the preparation of pickles and sauces in the form of vinegar.

(2) in the manufacture of rayon, dye stuffs, perfumes etc.

(3) as a laboratory reagent.

(4) in the preparation of organic compounds such as acetone, ethanol, acetic anhydride etc.

(5) for making cellulose acetate which is an important artificial fibre.

(6) to coagulate rubber from latex.

9.5 Soaps and Detergents

The word 'detergent' means cleansing agent and so the detergents are substances which remove dirt and have cleansing action in water. There are two types of detergents namely soapy and non-soapy. In everyday language, soapy detergents are called 'soaps' and non-soapy detergents are called 'detergents'.

Soap

Soaps are sodium or potassium salts of some long chain carboxylic acids. Sodium salts of fatty acids are known as **hard soaps** and potassium salts of fatty acids are known as **soft soaps.** Hard soaps are prepared from cheap oils, fats and sodium hydroxide. They contain free alkali and are used for washing purposes. Soft soaps are prepared from good oils and potassium hydroxide. They do not contain free alkali, produce more lather and are used as toilet soaps, shaving creams and shampoos.

Preparation

Soap is prepared by heating vegetable oil or animal fat containing Glyceryl stearate with concentrated sodium hydroxide solution. Hydrolysis of fat takes place and a mixture of sodium salts of fatty acids and glycerol is formed. The salts of fatty acids thus formed are used as soap. The alkaline hydrolysis of oils and fats forming soaps is commonly known as **saponification.**

Glyceryl stearate + sodium hydroxide
(animal fat)
$\longrightarrow$ Sodium stearate + Glycerol
(soap)

The big disadvantage of soapy detergents is that their washing action is reduced by hardness in water. Water that contains calcium and magnesium compounds is said to be hard. These compounds destroy the soap by reacting with it and converting into insoluble compounds called scums that floats to the surface. In hard water, a lot of soap is needed to get a good lather and a lot of scum is formed as well.

Detergents

Detergents are sodium salts of benzene sulphonic acids. Thus instead of –COOH group in soaps, detergents contain $-SO_3H$ group. The detergents do not form precipitates with metal ions such as Ca^{2+} and Mg^{2+} present in hard water. Therefore, the cleansing action of detergents are better than soaps.

Preparation of detergents

Detergents are prepared by treating hydrocarbons obtained from petroleum with conc. sulphuric acid. The corresponding sulphonic acids are then converted into their sodium salts.

Washing powders available in the market contain about 15 to 30 percent of detergents by weight. Some other chemicals which are added to detergents for specific cause are given below.

1. Sodium sulphate and sodium silicate added to keep the washing powder dry.
2. Sodium carbonate is added to maintain alkalinity which helps in removing dirt and also in softening water.
3. Carboxy-methyl cellulose (CMC) added to keep the dirt suspended in water.
4. A mild bleaching agent such as sodium perborate is added to produce whiteness in clothes.

Cleansing action of soap

A soap molecule contains two chemically distinct parts that interact differently with water. One part is a long hydrocarbon chain, which is non-polar and water hating (hydrophobic), while the other part is charged carboxylate group –COONa which is polar and water-loving (hydrophilic). The hydrophilic part makes the soap soluble in water. So, a soap molecule

can be thought of as one having a long tail made of hydrocarbon and a short head made of carboxylate group. The long tail is dirt-loving

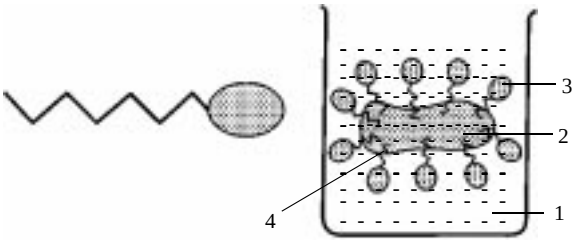


Fig. 9.1 Cleaning action of soaps and detergents

1. Water 2. Hydrophobic end 3. Hydrophilic end
4. Oil or dirt

and water-hating and the short head is water-loving.

The hydrophobic part of the soap molecule traps the dirt and the hydrophilic part makes the entire molecule soluble in water.

When a soap or detergent is dissolved in water, the molecules join together as clusters called miscelles. Their long hydrocarbon chains attach themselves to the oil and dirt. The dirt is thus surrounded by the non-polar end of soap molecules. The charged carboxylate end of the soap molecules make the miscelles soluble in water. Thus, the dirt is washed away with soap.

Advantages of detergents over soaps

Detergents are widely used these days as cleansing agents. The following are the advantages of detergents over soaps.

(1) Detergents can be used even in hard water whereas certain amount of soap gets wasted if water is hard.

(2) Detergents can be used even in acidic medium as they are the salts of strong acids and are not decomposed in acidic medium.

(3) Detergents are more soluble in water than soaps.

(4) They have a better cleansing action than soaps.

(5) They are prepared from hydrocarbons obtained from petroleum which saves vegetable oils used in preparation of soaps.

Disadvantages of Detergents

Detergents made from hydrocarbons having a lot of branching are degraded very slowly by the microorganisms present in water bodies causing water pollution and making water unfit for aquatic life. This problem is overcome by using hydrocarbons with minimum branching due to which the degradation is faster and water pollution is minimised.

Table 9.6 Differences between Soaps and Detergents

	Soap	Detergents
1.	Soaps are sodium salts of long chain fatty acids	Detergents are sodium salts of sulphonic acids.
2.	The ionic part of a soap is $-COO^- Na^+$	The ionic part in a detergent is $-SO_3^- Na^+$
3.	They are biodegradable	Some detergents are not biodegradable.
4.	They are prepared from animal fats or vegetable oils.	They are prepared from hydrocarbons obtained from coal and petroleum.
5.	Soaps form insoluble salts called scums with calcium and magnesium ions which are present in hard water and hence canot be used in hard water.	Calcium and magnesium salts of detergents are soluble in water and therefore can be used even in hard water.

SELF EVALUATION

Choose the correct answer

1. The general formula for aldehydes and ketones is

   (1) $C_nH_{2n}O$ (2) $C_nH_{2n+2}O$

   (3) $C_nH_{2n+1}OH$ (4) C_nH_{2n}

2. The functional group present in ketone is

   (1) $-\overset{\overset{O}{\|}}{C}-H$ (2) $-\overset{\overset{O}{\|}}{C}-$

   (3) -O- (4) $-\overset{\overset{O}{\|}}{C}-OH$

3. Which of the following compounds is an alcohol ?

   (1) HCHO (2) $CH_3CHOHCH_3$

   (3) CH_3COCH_3 (4) CH_3OCH_3

4. The sodium salt of a long-chain carboxylic acid possessing cleansing action is

   (1) an ester (2) a detergent
   (3) a soap (4) a fat

5. The enzyme which converts glucose and fructose into alcohol is

   (1) diastase (2) invertase
   (3) zymase (4) maltase

6. Wine contains

   (1) CH_3OH (2) C_6H_5OH

   (3) C_2H_5OH (4) CH_3COOH

7. Which of the following compounds does not contain carbonyl group ?

   (1) Ethanal (2) Propanone
   (3) Ethanoic acid (4) Ethanol

8. Vinegar is a dilute solution of

   (1) Ethyl alcohol (2) Acetic acid
   (3) Formic acid (4) Methyl alcohol

9. Formalin is an aqueous solution of

   (1) Methanol (2) Methanal
   (3) Propanone (4) Ethanol

10. The functional group in carboxylic acid is

    (1) –OH (2) $-\overset{\overset{O}{\|}}{C}-H$

    (3) $-\overset{\overset{O}{\|}}{C}-OCH_3$ (4) $-\overset{\overset{O}{\|}}{C}-OH$

11. Which of the following liberates hydrogen on reaction with sodium ?

    (1) Metyl acetate (2) Ethanol
    (3) n-Hexane (4) 1-pentene

12. Ethanol is prepared industrially by
    (1) hydration of ethene
    (2) fermentation of molasses
    (3) oxidation of molasses
    (4) reduction of molasses

13. Glacial acetic acid contains
    (1) 10% acetic acid
    (2) 50% acetic acid
    (3) 90% acetic acid
    (4) 100% acetic acid

14. Which one of the following carboxylic acids is present in the sting of red ant ?

    (1) lactic acid (2) formic acid
    (3) acetic acid (4) butyric acid

15. Which one of the following reactions takes place when carboxylic acid is heated with soda lime ?

    (1) Decarboxylation (2) Oxidation
    (3) Dehydration (4) Dehydrogenation

16. When acetone is reduced with Zinc amalgam and HCl, it gives

    (1) propan-2-ol (2) propan-1-ol
    (3) propan-2-al (4) propane

Fill in the blanks

17. Ethanol can be prepared by the fermentation of .....

18. ..... is better than soap for washing clothes when hard water is used.

19. ..... is the functional group present in ethanoic acid.

20. The sodium salt of sulphonic acid having cleansing action is called .....

21. Vinegar is prepared by the bacterial oxidation of .....

22. The organic acid present in vinegar is .....

23. Complete the following equation

$$C_2H_5OH + CH_3COOH \xrightarrow{\text{conc. } H_2SO_4} \text{.....} \quad ?$$

24. Formaldehyde reacts with ..... to form urotropine.

25. ..... is used in the preservation of biological specimens.

26. The reaction of alcohol with carboxylic acid in presence of H_2SO_4 is known as .....

27. The boiling point of ..... an higher than the corresponding hydrocarbons.

28. In an organic compound, ... largely determines its chemical properties.

Answer briefly

29. What is meant by a functional group ?

30. Name the functional groups present in the following compounds.

(i) CH_3COOH (ii) CH_3CH_2CHO

(iii) C_2H_5OH (iv) $CH_3COCH_2CH_3$

31. State the important uses of ethanoic acid.

32. Explain the term decarboxylation with an example.

33. Explain the term 'esterification'.

34. Consider the following organic compounds

$HCHO$, C_2H_5OH, C_2H_6, CH_3COOH, C_2H_5Cl

Choose two compounds which can react in the presence of con. H_2SO_4 to form an ester. Give the name and formula of the ester formed.

35. Why is soap not suitable for washing clothes in hardwater ?

36. State any four uses of ethyl alcohol.

37. Give the equation for the combustion of ethyl alcohol.

38. What is rectified spirit ?

39. Write the formulae of products formed in the following reactions.

(i) Reduction of formaldehyde with H_2 / palladium.

(ii) Oxidation of ethanol with acidified $K_2Cr_2O_7$

40. What are hard and soft soaps ?

41. What are detergents ?

Answer in detail

42. What is fermentation ? How is ethanol prepared by fermentation ?

43. Explain the differences between soaps and detergents and explain their cleansing action.

44. How is soap prepared ? What are the advantages and disadvantages of detergents over soaps ?

45. How is Acetic acid prepared from Ethanol? How does it react with the following ?

(i) P_2O_5 (ii) $LiAlH_4$ (iii) PCl_5

Activity

46. Take an aldehyde in a dry test tube, add Tollen's reagent (ammoniacal silver nitrate) and warm the test tube in a hot water bath. You can see a silver mirror formed on the inner sides of the test tube. This is due to reduction of ammonical silver nitrate to metallic silver which forms a shiny silver mirror.

47. An organic compound 'A' is a constituent of wine and beer. This compound on heating with potassium dichromate forms another organic compound 'B'. Identify compound 'A'. Write the chemical equation of the reaction that takes place and name the compound 'B'.

48. Take any vegetable oil or animal fat in a beaker, add concentrated sodium hydroxide solution and heat. Touch the solution with your hand. How do you feel ? Then add sodium chloride to it. You observe a precipitate. What is the precipitate formed ? Explain.

BIOLOGY

10. LEVELS OF ORGANISATION

The living world shows amazing diversity. This is the result of millions of years of evolution. The environment and the life-forms constantly engage in a two way interaction in which both are altered. The life forms constantly change and diversify to cope with competition amongst themselves and changes in the environment. This has resulted in the wide variety of plants and animals that we see around us. To study all the different forms of life, it is essential to organise and classify them into groups that have similar characters. Then it becomes easy to study a typical organism from a group and understand the organisation of other organisms in the group. Here we study the organisation of different organisms to get an overall understanding of the levels of organisation.

10.1. Viruses

In all the levels of plant and animal organisation, cells were found to be the basic unit. Any cell should consist of three basic features.

1) An outer limiting membrane that separates the cell from the surrounding.
2) Genetic material that has information for control and co-ordination of all the activities in a cell and also transmits this information to its progenies.
3) A metabolic machinery, that consists of enzymes, its reactants and products, that are essential for cellular activities.

Viruses are a unique form because they do not conform to the regular organisation of cell. They lack the regular cell membrane and the metabolic machinery that are found in all cells. Moreover, viruses can be isolated, purified and made in to crystals like sugar. But viruses also have the characteristics of living forms in that they have an inheritable genetic material in them. Thus they have the properties of both non-living and living forms.

1. Definition

Viruses are obligate intracellular parasites. They are active only in living cells. They utilise the metabolic apparatus of the host cell to multiply itself. An intact virus particle is known as a virion. It consists of a nucleic acid molecule enclosed by a protein cover called capsid. In some of the more complex virions, the capsid is surrounded by a lipid envelope derived from the host cell membrane (Fig. 10.1). The nucleic acid

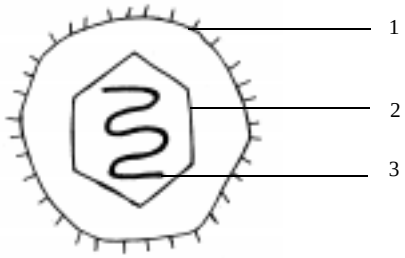


Fig. 10.1 Complex virion with lipid envelope

1. Lipid envelope 2. Capsid 3. Genetic Material

molecule is the inheritable genetic material. Viruses have only one type of nucleic acid, either Deoxyribo Nucleic Acid (DNA) or Ribo Nucleic Acid (RNA). Viruses attack a variety of cells including those of plants, animals and bacteria. Viruses infecting bacteria are called Bacteriophages (phage - to eat).

2. Tobacco Mosaic Virus

Let us study the Tobacco Mosaic Virus (TMV) to know more about the organisation of viruses. It was the first virus to be discovered (Dmitri Iwanowsky, 1892). TMV causes leaf mottling and discolouration in tobacco and many other plants.

It is a rod shaped virus. It consists of a single strand of RNA that is wound into a helix. Protein, that forms the capsid, is found attached to the RNA helix at regular intervals. The protein forms a protective cover for the

RNA. The RNA is the genetic material (Fig. 10.2). To infect a plant cell, the virus needs to cross the plant cell wall. In nature, plant viruses are transmitted from one host to another mainly through vectors, such as insects, which inject the virus particles directly in to the plant cell. Once it infects a plant, the RNA directs the plant cells' metabolic machinery to produce the RNA and proteins of the virus. The RNA and protein thus produced assemble in to new virions.

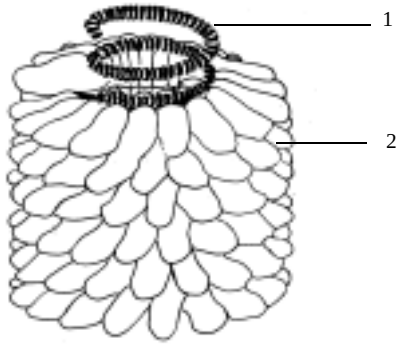


Fig. 10.2 Tobacco Mosaic Virus

1. RNA Helix 2. Capsid (Protein coat)

3. Differences between Plant and Animal viruses

Table 10.1 Differences between plant and animal viruses.

	Animal Virus	Plant Virus
1.	Both RNA and DNA viruses are common.	They are mostly RNA viruses.
2.	Transmission is through aerosols, break in skin, blood or sexual contact.	Transmission by insects, fungi nematodes, seed, pollen or vegetative propagation.
3.	They employ active means to enter animal cells.	They enter plant cells passively.
4.	They break the cell or pinch-off from the host cell to infect nearby cells.	They do not break the plant cell after infection.

4. Diseases caused by viruses

Viruses cause a variety of diseases in plants and animals. In plants, they cause discolouration, stunted growth, necrosis (group of dead tissue) and gal (tumourous growth). In animals, they cause rabies in dog, foot and mouth disease and cowpox in cattle. In human beings diseases like common cold, measles, mumps, small pox, jaundice, polio and AIDS are caused by viruses. Let us see the common cold and AIDS in some detail.

(1) **Common cold :** It is one of the most common diseases. The most frequent cause of common cold is Rhinovirus. It is an RNA virus. It causes upper respiratory tract infection. Symptoms of common cold include sneezing, headache, sore throat and watery discharge from nose. It is transmitted through direct contact, contaminated articles and inhalation of airborne droplets from infected person. It has an incubation period (time required for the virus to show symptoms in a person after infection) of 2 to 4 days. It resolves without treatment in 7 to 10 days. Secondary infection by bacteria is prevented by taking antibiotics.

(2) **AIDS :** It is one of the most dreaded diseases. AIDS stands for Acquired Immuno Deficiency Syndrome. It is caused by the Human Immunodeficiency Virus (HIV). It is an RNA virus with a lipid envelope. It shows non-specific symptoms like chronic diarrhoea, weight loss, fever and fatigue. It destroys the immune system of the person and exposes them to opportunistic infections (TB, Leishmaniasis and fungal infections are common in AIDS patients). AIDS is transmitted from person to person through direct exposure to infected body fluid (blood, semen), sexual contact and sharing unclean hypodermic needles. It is also transmitted from a pregnant woman to her foetus. It has an incubation period of 6 months to 7 years. Vaccines that give total protection against AIDS and medicines that completely cure AIDS

have not yet been found. Hence AIDS prevention is very essential.

10.2 BACTERIA

1. INTRODUCTION

"Oh!,What marvels there are in so small a creature" - Leewenhoek. These are the words uttered by Leewenhoek when bacteria were observed for the first time.

Occurrence :

The word bacteria comes from the greek 'backterion' meaning a small stick. Bacteria (Bacterium. S) occur in air, ocean, lakes, rivers, streams, mountains and food. These are also found in the bodies of human, animal and plants. Bacteria are very minute and they can be seen only under the microscope. In a drop of buttermilk/curd teeming millions of them occur.

Bacteria are unicellular, prokaryotic organisms. But a group of bacteria known as cyanobacteria (= Blue green algae) includes multicellular filamentous forms. e.g. *Nostoc, Oscillatoria.* The cell wall of bacteria is made up of peptidoglycan called murein.

The bacterial cell lacks true nucleus. It's genetic system is called nucleoid or chromatin body. It has no nuclear membrance. Bacterial chromosome is a single, closed, circular DNA molecule. Mitotic division is absent. Nucleolus and membrance-bound organelles are also absent. Bacterial ribosomes are of 70 S type. They are distributed in the cytoplasm. Enzymes required for respiration occur in the cell membrane. In photosynthetic bacteria, enzymes of photosynthesis are located in the photosynthetic membrance. In cytoplasm small, circular, double-stranded DNA called plasmids are present. Bacteria multiply by binary fission.

2. Types based on shape:

Bacteria occur in different shapes. Based on their shape they are classified as follows:

(1) **Coccus** - Spherical shaped eg. *Micrococcus, Leuconostoc*

Fig. 10.3 Coccus

(2) **Bacillus** - Rod shaped eg. *Lactobacillus.*

Fig. 10.4 Bacillus

(3) **Spirillum** - Spirally twisted eg. *Leptospira.*

Fig. 10.5 Spirillum

(4) **Vibrio** - Comma-like, curved eg. *Vibrio cholerae.*

3. Cell Structure

In some bacteria cell is surrounded by viscous substances on the outer surface around the cell wall termed as capsule. The capsule is made up of either polysaccharides or polypeptides. The capsule gives protection against unfavourable environmental conditions. It also enhances its infecting capacity. If the viscous substance is abundant and many cells are embedded in a common matrix, the material is called slime.

Flagella : They are long, hair-like, helical appendages involved in motility. It is made up of flagellin a kind of protein.

In some bacteria flagella are absent. So they are called Atrichous.

Fimbriae or Pili - Generally Gram - negative bacteria are covered by thin, fine hair like threads called fimbriae or pili. A type of pili known as F-pili (sex pili). serves as the port of entry of genetic material during bacterial mating. The pili are shorter than the flagellum.

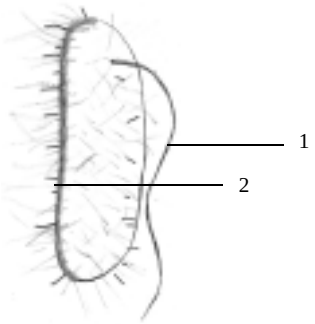


Fig. 10.6. Bacterial Flagella and Pili

1. Flagellum 2. Pili

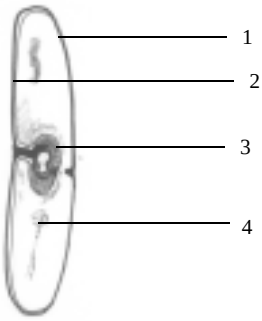


Fig. 10.7. Bacterial Internal structure

1. Cell wall 2. Cytoplasmic membrane 3. Mesosome 4. Nuclear material

The Cytoplasmic membrane

The cytoplasmic membrane is made up of phospholipids and proteins. In some bacteria the membrane is invaginated to form convoluted tubules and vesicles called mesosomes. The cytoplasm contains soluble enzymes, RNA, and 70 S ribosomes. Ribosomes occuring in chains attached to m-RNA are called polysomes. Photosynthetic bacteria have lamellae (thylakoid) or vesicles (chromatophores). The photosynthetic membranes carry bacteriochlorophylls and carotenoid pigments which are involved in photosynthesis.

The Nucleoid: In bacteria true nucleus is absent. The nuclear material is not covered by a nuclear membrane. The nuclear material is called nucleoid. or bacterial chromosome. It consist of single closed, circular DNA strand. Nucleolus is absent.

Plasmids: They are circular, double stranded DNA, occuring in the cytoplasm. These are different from the nucleoid.

Ribosomes: They occur in cytoplasm and are of 70 S type.

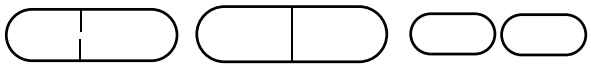
Reserve materials: The bacterial cell contains the following materials in the cytoplasm.

1. Organic polymers - Polysaccharides, lipids.
2. Inorganic metaphosphate granules - volutin granules.
3. Elemental sulphur - present in sulphur - oxidizing bacteria.

Endospores: During unfavourable conditions some bacteria like *Bacillus* and *Clostridium* form resistant structures known as endospores. They are resistant to heat, u-v light, chemicals and desiccation. It contains dipiclonic acid. In favourable enivornmental condition endospore germinates to form a vegetative cell.

4. REPRODUCTION:

Bacteria commonly reproduce asexually by binary fission. The bacterial cell divides into two daughter cells by developing transverse septum. The first step in binary fission is cell elongation which is followed by the inward growth of the cytoplasmic membrane at the middle of the cell to form a septum. It splits the cell into two. The bacterial chromosome is also doubled resulting in the production of two circular chromosomes.



Developing septum | Complete septum | Daughter cells

5. Beneficial and harmful role of bacteria

Bacteria are important to man and other organisms in one way or the other. They play an important role in agriculture, production of antibiotics, preparation of variety of food substances etc.

1) Beneficial role

(1) Nature's scavengers

Bacteria are involved in the decay and disappearance of dead plants, animals and waste organic materials accumulating in the soil. The anaerobic breakdown of proteins with the production of foul smelling compounds like

hydrogen sulfide, ammonia, amines, etc. is called putrefaction.

(2) Bacteria in dairy industry

In the dairy industry, lactic acid bacteria such as *Lactococcus lactis, Lactobacillus, Leuconostoc cremoris* are useful for production of fermented milks with flavour such as cultured buttermilk, bulgarian buttermilk, yogurt, kefir, kumiss.

Souring of milk

Milk becomes curd when a required amount of butter milk (or) curd is added to it. This is due to the fermentation brought about by *Lactobacillus lactis.*

Fermented foods

Idli is prepared from the flour of rice and black gram. The ingredients are washed, soaked separately, ground, mixed and finally allowed to ferment overnight. When the batter has risen enough, it is cooked by steaming.

(3) Biological Nitrogen Fixation

Some bacteria are involved in increasing the fertility of the soil by fixing atmospheric nitrogen. The conversion of molecular nitrogen into nitrogen compounds is known as nitrogen fixation. In asymbiotic nitrogen fixation, free-living bacteria, cyanobacteria, fix nitrogen in soil. e.g., *Azotobacter chroococcum, Anabaena azollae, Nostoc,* etc. Symbiotic nitrogen fixation is favoured in agriculture because of its high yield. The genus *Rhizobium* forms root nodules in leguminous plants. Nitrogen fixation occurs in the nodules.

2) Harmful Role of Bacteria

Among bacteria many of them are harmful in several ways.

(1) Spoilage of food

Bacillus, Micrococcus, Leuconostoc etc, are involved in the spoilage of cereals, vegetables, fruits, sugar, meat, fish, egg and milk.

Spoilage of milk is caused by *Enterobacter,* etc.

(2) Diseases in Plants

(i) **Citrus Canker** : Lesions consisting of depressions of yellowish brown to green with raised margins are called canker. Dead cells appear in leaves and fruits caused by *Xanthomonas citri.* As a result of this the quality of fruit is reduced.

(ii) **Leaf blight**: It is caused by *Xanthomonas oryzae* in rice.

(3) Diseases in man and cattle

(a) **Diseases in Man**

(i) **Botulism**: Food poisoning is caused by ingesting contaminated food containing the neurotoxin produced by *Clostridium botulinum.*

(ii) **Typhoid Fever**: It is caused by *Salmonella typhi.*

(iii) **Leptospirosis**: It is caused by *Leptospira interrogans* in animals and humans.

(b) **Disease in Cattle** : In cattle and sheep, anthrax is caused by *Bacillus anthracis.*

10.3 Penicillium

1. Introduction to Fungi

Fungi are non-green heterotrophic organisms. They occur in different kinds of places i.e.,. air, water, soil, animals and plants both living and dead. Many fungi grow on humus soils as saprophytes eg. Mushrooms; some of them live as parasites on plants eg. *Albugo, Polyporus.*

2. Structure

The body of the fungus is called mycelium. The myceliun consists of hyphae. Each hypha is branched, slender, septate,

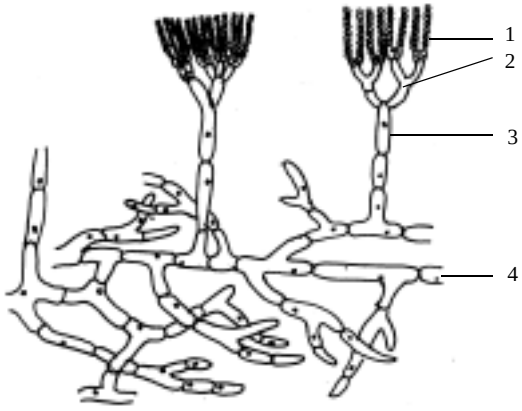


Fig. 10.8 Penicillium

1. Conidium 2. Phialide 3. Conidiophore 4. Mycelium

colourless and thread like. In each cell cytoplasmic organells such as mitochondria, ribosomes, endoplasmic reticulum, golgi bodies

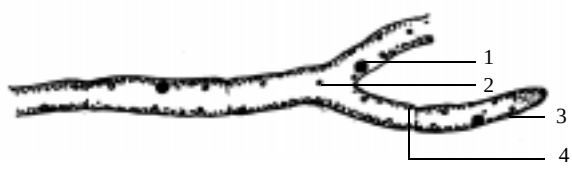


Fig. 10.9 Cell Structure

1. Nucleus 2. Oilglobule 3. Hypha 4. Septum

occur. The cell may be binucleate or multinucleate. The reserve food is oil globules.

3. Reproduction

Penicillium reproduces by the following methods

(1) **Vegetative reproduction :** The hyphae when injured or damaged break into fragments. Each fragment develops into a new mycelium.

In some species of *Penicillium* the mycelium forms compact resting bodies known as the **Sclerotia**. It tides over unfavourable conditions. During favourable conditions it germinates and develops into new mycelium.

(2) **Asexual Reproduction :** By conidia. During asexual reproduction long, septate

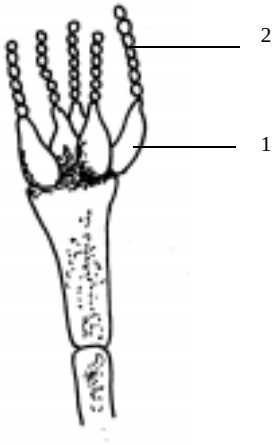


Fig. 10.10 Asexual Reproduction

1. Phialide 2. Conidium

and erect conidiophores arise from the mycelium. The conidiophore bears flask - shaped structure called phialides. Each phialide at its tip produces conidia in chain. Each conidium is ovoid, elliptical, globose or pyriform. It is uni or multinucleate. When they fall on suitable substratum each conidium germinates and develops into mycelium.

(3) **Oidia formation :** Sometimes, when the fungus is grown in the sugar solution, it produces short uninucleate, thin-walled spore like bodies called the oidia or oidiospores. Oidium germinates and develops into normal mycelium.

4. Economic importance

Pencillium is a useful fungus. Some of its uses are as follows :

1) Antibiotic Industry

Antibiotics are microbial substance obtained from microorganisms which are effective on other microorganisms. The wonderful antibiotic penicillin is produced by *Penicillium chrysogenum* and *Penicillium notatum.* Penicillin are of different types. F, G, X, and K or I,II,III & IV. *Penicillium griseofulvum* produces an antibiotic called griseofulvin. It is given for ringworm disease.

2) Cheese Industry

Penicillium plays an important role in the production of cheese. *P. roqueforti* and *P. camemberti* are used for cheese making. The fungus imparts softness, colour and flavour to cheese.

5. Discovery of Penicillin by Alexander Flemming

Penicillin is the first antibiotic discovered by Alexander Flemming in 1927. He was working as microbiologist in St. Mary's Hospital in London. He was doing research to find out new substances against bacteria which cause wound infections. While he was observing bacterial cultures, he found that in some of the plates growth of bacterial colonies disappeared. The bacterial cells near the mold was inhibited or killed. Further studies revealed that it was *Penicillium* that produced a substance which was potent against *Staphylococcus.* In world war II, penicillin

was useful in controlling infections of the wounded soldiers.

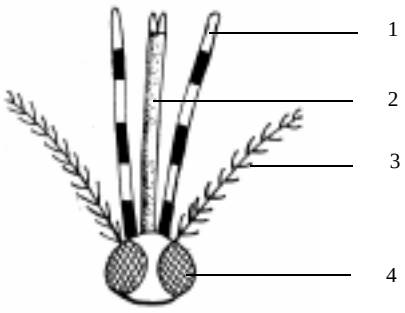
10.4. Medical Entomology

You will be aware of a number of insects that bite or cause nuisance to us. But do you know that they also transmit many deadly diseases? Diseases like malaria and cholera are transmitted by such insects. Despite many efforts, these insects have not been totally eradicated. So it is essential to know their organization so that you can adopt suitable preventive measures in your locality. This could greatly reduce the risk of many deadly diseases.

1. Insect Vectors

An insect which is capable of transmitting or spreading disease is called an insect vector. They may also cause discomfort or injury to humans and his animals. Let us see some of the important insect vectors.

(1) **Anopheles :** It is one of the mosquitoes that bite us at night. It is only the females that bite man. The male Anopheles lives on plant sap. The body of mosquito is divided into head, thorax and abdomen. Head bears the mouth parts that enable them to pierce the skin and suck blood. On either side of the



10.11 Distinguishing features of Anopheles Head Showing Long Palpus

1. Palpus 2. Proboscis 3. Antenna 4. Eye

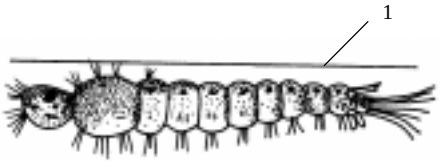
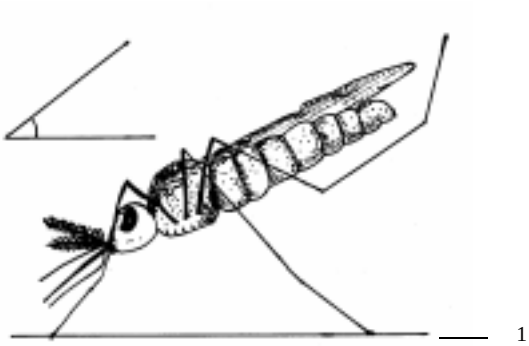


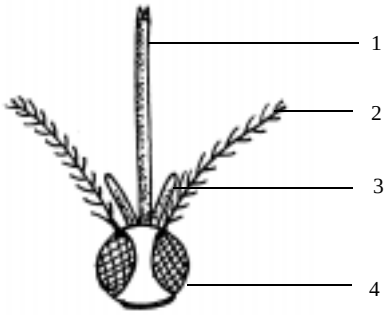
Fig. 10.12 Distinguishing features of Anopheles Larva Floating Parallel to Water Surface

1. Water Surface



10.13 Distinguishing features of Anopheles Abdomen Pointing Upwards While Biting

1. Body Surface



10.14 Distinguishing features of Culex Head Showing Short Palpus

1. Proboscis 2. Antenna 3. Palpus 4. Eye

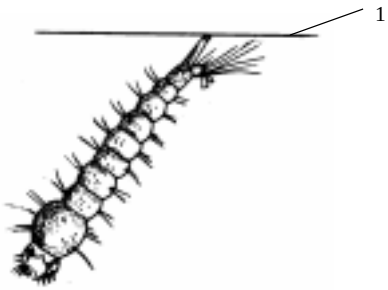
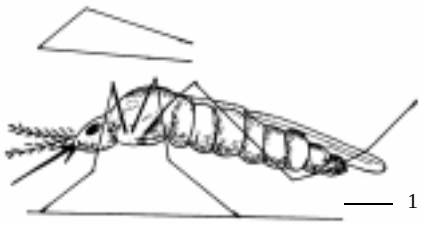


Fig. 10.15 Distinguishing features of Culex Larva Floating with head pointing downwards.

1. Water Surface



10.16 Distinguishing features of Culex Abdomen Parallel while biting

1. Body Surface

mouth parts, Anopheles bears a long palpus. The thorax bears a pair of wings for flying and a pair of halters for balancing. The halters are actually small wings. The Anopheles lays its egg in water. A larva emerges from the egg. It floats parallel to the water surface. It then develops into an adult mosquito through a pupal stage. While biting, Anopheles can be identified by the abdomen that points upward. Anopheles chiefly transmits malaria from one person to another.

(2) **Culex :** It is also a mosquito that bites during night. It can be differentiated from the Anopheles by its short palpus. Its larva floats inclined to the water surface with its head downward. While biting, the abdomen of Culex points parallel to the body. It flies with a humming sound, while Anopheles flies quietly. Culex chiefly transmits filarial worm from one person to another.

(3) **Aedes :** They are mosquitoes that rest in wooded areas and prefer to bite during day time. Head bears short palpus. Each segment on the abdomen shows pale band at the base. The larvae are found in a wide variety of natural and artificial containers containing water including rock holes and used tyres. They transmit diseases like Yellow fever and Dengue

Fig. 10.17 Distinguishing Feature of Aedes

from one person to another.

(4) **Phlebotomus :** It is shaped as a mosquito. Body is covered with dense hair (hairy insect). It can be identified by its wings which are held vertically up while at rest. It also shows characteristic hopping movement. Mouth parts in female are adapted to pierce for taking blood. It bites at night. In males,

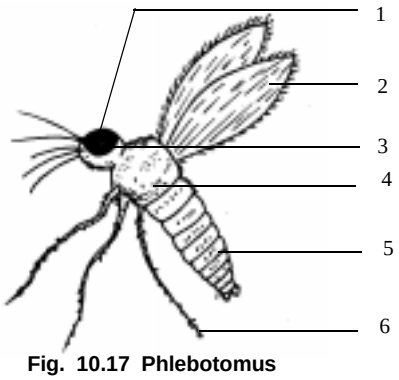


Fig. 10.17 Phlebotomus

1. Eye 2. Wing 3. Head 4. Thorax 5. Abdomen 6. Leg

the mouthparts are poorly developed. It lives on plant and fruit juices. The female spreads a disease called Leishmaniasis. The disease manifests in a cutaneous (skin) form or in a visceral (internal organ) form. Cutaneous leishmaniasis is characterized by skin sores. It lasts from weeks to years. It eventially develops into a scar with raised edges and a central crater. Visceral leishmaniasis causes fever, weight loss, enlargement of liver and spleen and aneamia. In India visceral leishmaniasis is more common.

(5) **Bed bug (Cimex) :** Bedbugs are small (about 8 mm long), nocturnal creatures with a world wide distribution. They feed only on blood. They do not, as far as is known, serve as vectors for any

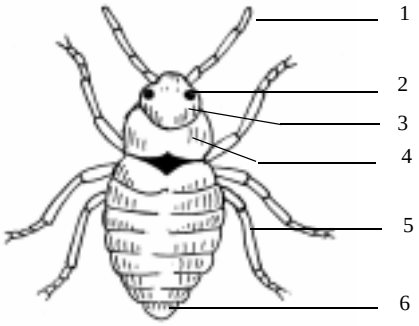


Fig. 10.18 Bed Bug (Cimex)

1. Antenna 2. Eye 3. Head 4. Thorax 5. Leg 6. Abdomen

human disease. Their bite often result in an allergic reaction. When bitten many times, a person will lose considerable

sleep. It may also lead to iron and / or haemoglobin deficiencies due to loss of blood. Because of their small size, bedbugs can be transported from one house to another in furniture, clothing and a variety of other ways. Bedbugs can hide almost anywhere. They tend to be found around the bed, under furniture and even behind wallpaper. Control of bedbug requires careful use of pesticides. Bedbugs can survive more than a year without feeding. So you cannot "starve" the bedbugs out of your house by simply leaving for a few days.

(6) **Head louse (Pediculus) :** Head louse are cosmopolitan parasites of humans. It is a dorsoventrally flattened wingless insect. Body is divisible into a head, thorax and abdomen. Head bears mouth parts adapted for biting and sucking blood. The thorax bears three pairs of

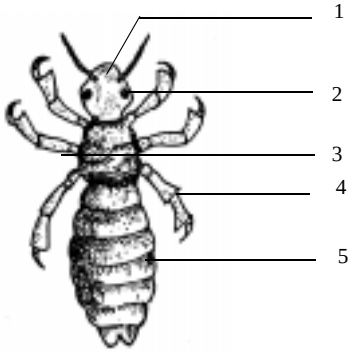


Fig. 10.18 Head louse

1. Head 2. Eye 3. Thorax 4. Leg 5. Thorax

legs. The legs are adapted to hold the hair of the host. Head louse serves as vector for typhus (caused by Rickettsia prowazekie), trench fever (caused by Rochalinaea quintana) and relapsing fever (caused by a spirochete, Borrelia recurrentis). Lice are spread from human to human often by direct contact or contact with contaminated clothing.

Lice can be controlled by treating the hair with medicines like pyrethrins - permethrin or malathian and then combing with a fine-toothed comb. This should be done only after consulting your doctor. Clothing and bed lining should also be washed to prevent recurrence. All members of the family should be observed for head louse and treated simultaneously. This treatment should be repeated after 7 to 10 days.

Prevention

(1) Avoid head to head contact with others

(2) Do not share clothing such as scarves and ribbon.

(3) Do not share your comb.

2. Vector borne diseases

Now let us see some of the diseases that are transmitted by vectors and the organisms that cause those diseases.

(1) **Malaria :** Malaria is caused by a parasite called Plasmodium. It has two cycles of development, one in man and the other in the Anopheles mosquito. The cycle in man is the asexual phase.

When the mosquito bites a person, the sporozoite enters and starts a new infection. The malarial parasite may block the capillaries in the brain. It is called Cerebral malaria. Death occurs if treatment is not given immediately.

(2) **Filariasis :** It is caused by the parasitic worm, Wuchereria bancrofti. The adult worm is white in colour and hair like in form. Male and female worms are generally found coiled together at the dilated lymph nodes. The female worm gives birth to embryos called microfilariae. They normally circulate at night in the peripheral blood. They are taken up by the Culex mosquito while biting an infected person. In the mosquito they pierce the stomach wall and are transformed into infective forms. When the infected mosquito again bites a man, the larvae enter his lymphatic vessels. Here they settle down and attain sexual maturity.

Occassionally the adult parasites cause obstruction to the free flow of lymph. The lymph vessels and glands become swollen and thickened. The affected part grows larger and is called Elephantiasis. The lower extremities,

the scrotum and the hands are some of the organs that are commonly swollen.

(3) **Dengue fever :** Dengue is a viral disease caused by Flavivirus. It causes haemorrhage and fever. It is transmitted by the Aedes mosquitoe. Dengue appears as an epidemic and affects many people. The epidemic gradually dies down before reappearing after an interval. Once a person gets the disease, he becomes immune from further attacks. There are four types of the dengue virus. Thus a person can have four dengue infections during his life time.

(4) **Brain fever :** Brain fever or Japanese encephalitis is caused by a virus. Children in the 2 to 14 years age group are the most vulnerable. Symptoms include headache, reduced consiousness and fits. Culex mosquitoes that breed in rice fields are the carriers of the disease. The virus increases in number in pigs, horses and wild birds. The proximity of pigs to humans increase the chance of transmission. Brain fever occurs mainly during the monsoon season, 10% to 30% of those with brain fever die and about half of the survivors are left with neurological damage. There is no antiviral medicine for the disease. However a vaccine is available that gives immunity against the disease.

(5) **Cholera :** Cholera is an infection of the intestine by the bacterium Vibrio cholerae. Severe cholera causes profuse watery diarrhoea, vomitting and leg cramps. Rapid loss of body fluids leads to dehydration and shock. Without treatment, death can occur within hours. A person may get cholera by drinking water or eating food contaminated with the cholera bacterium. The source of contamination is usually the faeces of an infected person. The disease can spread rapidly in areas with inadequate treatment of sewage and drinking water. Houseflies, sitting on food, can also transfer the bacterium from the facces. Cholera is treated simply by immediate replacement of the fluid and salts lost through diarrhoea. Patients can be treated with oral rehydration solution, a prepackaged mixture of sugar and salts to be mixed with water and drunk in large amounts. Severe cases also require intravenous fluid replacement. Antibiotics can shorten the course and diminish the severity of the illness. Cholera can be prevented by drinking boiled water and eating well cooked food that is still hot.

3. Vector Control

As mentioned earlier, it is very difficult to totally eradicate the insect vector. Its control requires a coordinated effort of several measures. It includes vector surveillance, breeding source prevention and reduction, biological and chemical control and public education.

Mosquitoes can be controlled by spraying the inside surfaces of walls and roof with residual insecticide eg. DDT, organophosphate or carbamate insecticides (eg. malathion, bendiocarb) and pyrethroids. Bednets and screens that are soaked in pyrethroid solution provide good protection. Larvivorous fish (fishes that eat larva eg. Gambusia) can be introduced in water bodies to control mosquito breeding. The toxin extracted from the bacteria, Bacillus thuringiensis, can also be sprayed at breeding sites.

Permethrin is highly effective as an insecticide and as a repellant. Permethrin treated clothing repels and kills ticks, mosquitoes and other arthropods. Repellants containing N.N - diethylmetatoluamide (DEET) repels mosquitoes and other insects when applied to skin. (Avoid DEET near eyes, mouth, cuts, wounds or irritated skin. It is toxic when ingested).

Instead of trying to control the vector, the disease causing organism can be targeted for eradication. Then the vector becomes harmless as it cannot transmit any disease. This was the objective of the National Malaria Eradication Programme (NMEP). It was implemented from 1958. Under the NMEP,

the mosquito population was reduced considerably by applying DDT for two years. During this period, those with malaria were also treated intensively. Thus the lifecycle of Plasmodium, the causative organism of malaria, was broken. After two years, DDT application was stopped. The mosquito population regained its numbers, but there was no Plasmodium to transmit. Though malaria was not totally eradicated, it helped to drastically reduce the incidence of malaria.

In India Vector Control Research Centre (VCRC) was established as a centre of excellence for research and training in vector borne diseases and control. It was established in 1975 at Pondicherry. It develops strategies for prevention and control of vector borne diseases. It works to develop methods for rapid response and disaster management with reference to vector borne disease outbreaks. It also promotes healthy environment by educating people on how to reduce the risk of vector borne disease transmission.

10.5 Multicellular Level of Organisation - Frog

1. Systematic position.

Phylum	:	Chordata
Subphylum	:	Vertebrata
Class	:	Amphibia
Order	:	Anura
Genus	:	Rana
Species	:	hexadactyla.

Frog belongs to class amphibia (Gr. amphi - both, bios-life) that includes animals that live partly in fresh water and partly on land. You have studied the organisation of fish which is an aquatic animal. During the course of evolution, amphibia arose from fish. They are the first group of chordates that invaded land. So they exhibit modifications in their organisation to adapt to their new environment. Though they invaded land, they were not fully successful and they still require water to fulfil some of their biological functions. Evolutionarily they gave rise to the Reptiles that are the true conquerers of land. Thus amphibians show an organisation intermediate between a truly aquatic form (fish) and a truly terrestrial form (reptile).

2. External Morphology

Body consists of a head and a trunk. Neck is absent. Head has a pair of eyes. The eyes are protected by eyelids and a transparent membrane known as the nictitating membrane. Behind and below each eye is a circular membrane called the tympanic membrane. At the anterior end is a wide mouth. Above the mouth are a pair of nostrils. The trunk has a pair of short fore limbs and a pair of long hind limbs. The fore limb has only four digits while the hind limb has five. The digits of the hind limb are connected by a thin membrane-like web which helps in swimming. The long hind limb also helps in locomotion

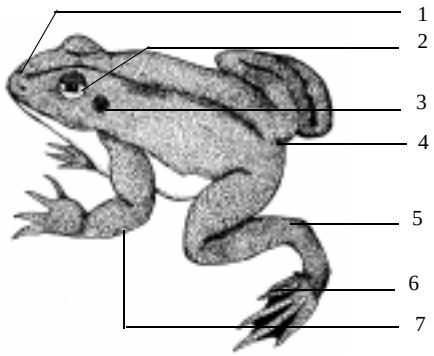


Fig. 10.19 Frog : External Morphology

1. Nostril 2. Eye 3. Tympanum 4. Cloaca 5. Hind limb 6. Web 7. Fore limb

on land by hopping. At the posterior end of the body, in between the hind limbs, there is a cloacal opening through which faeces, urine and reproductive bodies are discharged.

Skin is moist and slippery due to the presence of numerous mucous glands. Frog shows distinct sexual dimorphism (i.e.) a group of visibile characters that enable sexual identification. These characters that aid in sexual function, but are not directly linked to the reproductive system are called secondary sexual characters. The female frog is bigger than the male frog. The male has two vocal sacs below their mouth. It produces crocking sound to attract females during breeding season. The inner digit of the forelimbs are thickened in male frog. It is called the nuptial pad and it helps to hold the female during amplexus

(Frog's reproductive act is called amplexus). The vocal sacs and nuptial pads are absent in females.

3. Digestive System

The digestive system consists of the digestive tract and its associated glands. The digestive tract is a tube starting from the mouth and ending in the cloaca. A wide mouth opens in to the buccal cavity at the anterior end Buccal cavity is enclosed by the upper and lower jaws. A pair of internal nostrils open in the roof of the buccal cavity. A long

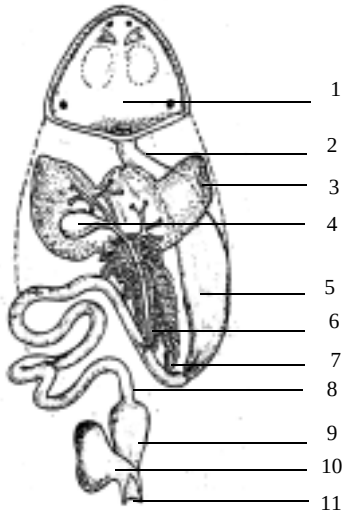


Fig. 10.20 Frog : Digestive system

1. Buccal Cavity 2. Oesophagus 3. Liver 4. Gall Bladder 5. Stomach 6. Bile Duct 7. Pancreas 8. Intestine 9. Rectum 10. Urinary Bladder 11. Cloala

extensible tongue is attached to the floor of the buccal cavity. Mucous glands on the tongue make it sticky and helps it capture insects. Teeth are present only on the upper jaw. They prevent the prey from escaping.

Buccal cavity is continued as a narrow pharynx. Pharynx leads in to a tube-like Oesophagus. Pharynx also has a slit-like opening called the glottis which leads in to the lungs. Glottis is opened during respiration and closed during feeding. Oesophagus ends in a wider stomach. The walls of the stomach secrete hydrochloric acid and pepsin. The hydrochloric acid kills the prey. Pepsin is an enzyme that initiates the digestion of proteins.

Small intestine is located after the stomach. It consists of a curved duodenum and a coiled ileum. Liver and pancreas are the two major digestive glands. They open by a common duct into the duodenum. The walls of the small intestine also secrete a digestive juice called succus entericus. Liver secretes bile which contains bile salts. They disperse fats into small globules so that they can be easily digested. The pancreatic juice contains trypsin (digests proteins), amylase (digests carbohydrates) and lipase (digests fats). The enzymes of succus entericus include lipase (completes fat digestion), peptidase (completes protein digestion), disaccharidases (completes carbohydrate digestion). As a result of digestion carbohydrates are broken down to monosaccharides, proteins into amino acids and fats into fatty acids and glycerol.

The undigested materials are stored in the rectum before being eliminated through the cloaca.

4. Respiratory system

Frog respires through the skin (cutaneous respiration), lining of the buccal cavity (buccal respiration) and the lungs (Pulmonary respiration). The skin of frog is very thin and richly supplied with blood capillaries. It is kept moist by the secretion of the numerous mucous glands on the skin. Oxygen from air

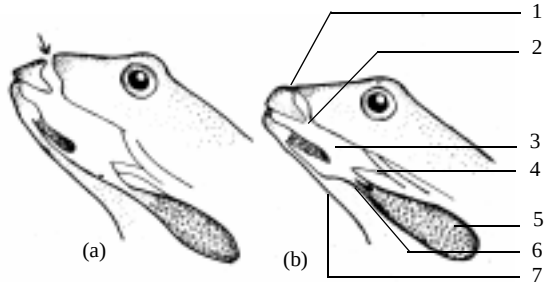


Fig. 10.21 Frog : Process of Drawing air in to the lungs (a) Buccal Floor Lowered (b) Buccal Floor Raised

1. External Nostril 2. Internal Nostril 3. Buccal Cavity 4. Oesophagus 5. Lung 6. Trachea 7. Buccal Floor

or water dissolves first in the mucous and then diffuses in to the blood. The Carbon dioxide passes out from the blood in to the surrounding medium by diffusion. When frog is in water, it respires only through skin.

The mucous lining of the buccal cavity is richly supplied with blood capillaries. The

floor of the buccal cavity is lowered. Air rushes in through the nostrils. Gaseous exchange takes place through the mucous lining. The impure air is then expelled by raising the buccal floor. During this respiration glottis remains closed.

Frog also possesses a pair of lungs. They are elastic sacs that are partitioned in to numerous chambers called alveoli. They are lined with blood capillaries and remain moist with mucous. Air is first drawn in to the buccal cavity by lowering the buccal floor. Nostrils and mouth are closed and the buccal floor is raised. This forces the air in to the lungs. Exchange of gases takes place in the lungs. The nostrils are then opened to push the air out.

5. Circulatory System

Blood is an important tissue. It carries food and oxygen to various parts of the body and transports waste products from them to the excretory organs. It is kept in constant circulation by the circulatory system. The circulatory system consists of a pump (the heart) and a network of tubes (blood vessels)

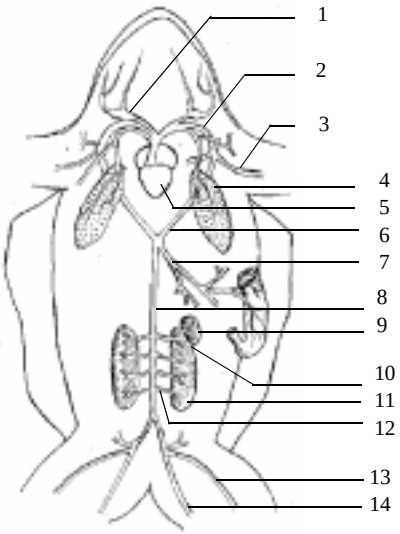


Fig. 10.22 Frog : Arterial system

1. Carotid Trunk 2. Pulmo-Cutaneous Trunk
3. Subclavian Artery 4. Lung 5. Heart 6. Systemic Trunk
7. Coeliaco-Mesentric Artery 8. Dorsal Aorta 9. Gonad
10. Gonadial Artery 11. Kidney 12. Renal Artery
13. Femoral Artery 14. Sciatic Artery

The heart of frog is covered by a protective membrane called pericardium. The heart consists of three chambers - two auricles and one ventricle. The right auricle receives impure blood from different parts of the body. The left auricle receives pure blood from the lungs through the common pulmonary vein. The two auricles empty the blood in to the ventricle. From here it is pumped out through the truncus arteriosus.

Arterial System : The blood vessels that distribute blood from the heart to various organs are called arteries. The truncus arteriosus that emerges from the ventricle gives rise to 3 pairs of blood vessels. The first pair is called the carotid trunks. It supplies blood to the head. The second pair is called the systemic trunks. They join each other dorsally to form the dorsal aorta. It branches in to many arteries and supply blood to different parts of the body. The coeliacomesentric artery supplies the digestive system. The renal and gonadial arteries supply the kidneys and gonads respectively. The femoral and sciatic arteries supply the leg with blood. The third pair of arteries from the truncus arteriosus is the pulmo-cutaneous trunks. They supply blood to the lungs and skin for respiration.

Venous System : The blood vessels that carry blood to the heart from various organs are called veins. Femoral and sciatic veins

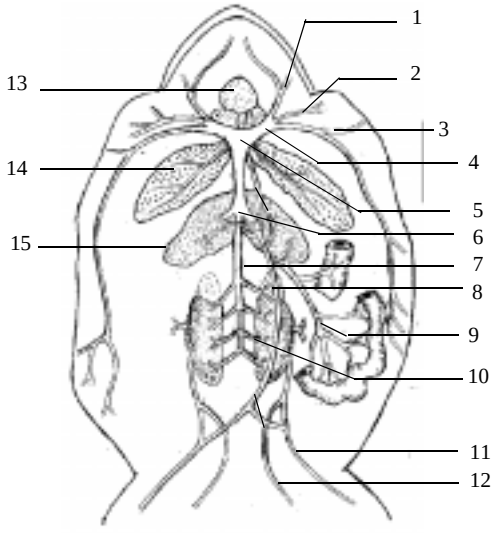


Fig. 10.23 Frog : Venous system

1. External Jugular Vein 2. Innominate Vein 3. Subclavian Vein 4. Precaval Vein 5. Sinus Venosus 6. Hepatic vein 7. Post Caval Vein 8. Gonadial Vein 9. Hepatic Portal vein 10. Renal Vein 11. Femoral Vein 12. Sciatic vein 13. Heart 14. Lung 15. Liver

collect blood from the hind limbs. Renal, gonadial and hepatic veins collect blood from kidneys, gonads and liver respectively. They all join together to form the post caval vein. Blood from the digestive system is taken first to the liver by the hepatic portal vein and then from the liver to the post caval vein through the hepatic vein. Blood from the anterior parts of the body are collected by two precaval veins. The precaval vein of each side is formed by the union of three veins, the external jugular vein, the innominate vein and the subclavian vein. The two precaval veins combine with the post caval vein to form a chamber called the sinus venosus. This chamber empties the impure blood in to the right auricle.

6. Nervous System

The nervous system is concerned with the co-ordination of all the activities of the organism. It consists of the Central Nervous System (CNS) and the Peripheral Nervous System (PNS). The CNS includes the brain and the spinal cord. The brain is enclosed in a protective skull. It consists of three parts called the forebrain, midbrain and hindbrain. The forebrain consists of a pair of olfactory lobes and two cerebral hemispheres. The midbrain includes a pair of optic lobes and the diencephalon. On the dorsal side, the diencephalon bears a small pineal body. Ventrally the infundibulum and the pituitary body are present. The hind brain has the cerebellum and medulla oblongata. The medulla oblongata continues outside the skull as spinal cord. The spinal cord is protected by the vertebral column.

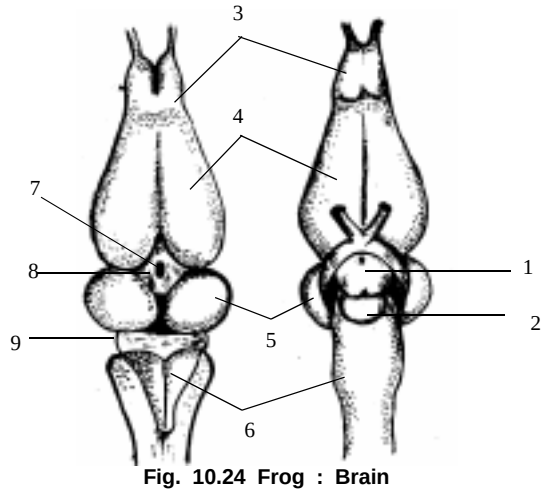


Fig. 10.24 Frog : Brain
(a) Dorsal View (b) Ventral View

1. Infundibulum 2. Pituitary Body 3. Olfactory Lobe 4. Cerebral Hemisphere 5. Optic Lobe 6. Medulla Oblongata 7. Pineal Body 8. Diencephalon 9. Cerebellum

The PNS consists of the cranial nerves, spinal nerves and the Autonomic Nervous System (ANS). Frog has 10 cranial nerves that emerge from the brain and 10 spinal nerves that emerge from the spinal cord. The ANS consists of 2 chains of ganglia that emerge from the brain. They are closely associated with the spinal nerves. The ANS is concerned with internal regulation of the body. The CNS and the cranial nerves are concerned with external regulation.

7. Sense Organs

Sense organs help the animal to receive information from the external environment. They can be grouped under the following heads.

(1) Tango receptors (Organs of touch): The entire skin serves as organs of touch. It is sensitive to touch, heat, cold and effects of chemicals.

(2) Olfacto receptors (Organs of smell): They include a pair of nasal sacs. They communicate with the outside by the external nostrils and with the buccal cavity through the internal nostrils. They help to sense the smell given-off from different substances.

(3) Gustato receptors (Organs of taste): They are the taste buds located in the buccal cavity, chiefly on the tongue. They sense the taste of the substances taken into the mouth.

(4) Photo receptors (Organs of sight) : A pair of prominent eyes are the photoreceptors. They have a lens that focus the light on to a light sensitive layer called retina.Thus they perceive light from the surrounding.

(5) Stato-accoustic receptors (Organs of balance and hearing) : The ear is the organ of balance and hearing.

8. Urino-genital System

The excretory and reproductive systems are closely associated. Hence it is called the urino-genital system. The excretory system consist of a pair of kidneys that remove

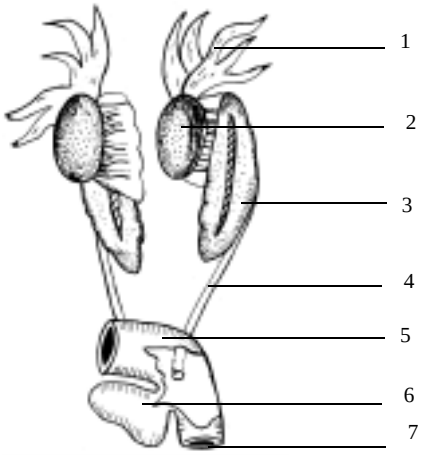


Fig. 10.25 Frog : Male Urino-genital System

1. Fat Body 2. Testis 3. Kidney 4. Ureter 5. Rectum 6. Urinary Bladder 7. Cloaca

nitrogenous wastes and excess water from the blood. The urine thus formed is transported to the cloaca by a pair of ureter. The urine is stored in a urinary bladder before being excreted.

The male reproductive system consists of a pair of testes. They are found near the kidneys. They produce the male reproductive cells called sperm. They are stored in the

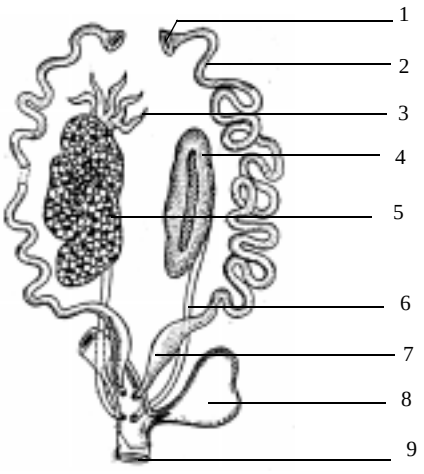


Fig. 10.26 Frog : Female Urino-genital System

1. Oviducal Funnel 2. Oviduct 3. Fat body 4. Kidney (Ovary Removed) 5. Ovary 6. Ureter 7. Ovisac 8. Urinary Bladder 9. Cloaca

anterior part of the ureter. This part is called the seminal vesicle. During breeding, the sperm is pushed out through the ureter.

The female reproductive system consists of a pair of ovaries. They produce the female reproductive cells called ovum. The ova are passed out through seperate tubes called the oviduct. The cloaca serves as a common exit for repreductive cells, undigested material and excretory products.

Frog requires water for reproduction. During rainy season, the male and female reproductive cells are released in to water bodies. The sperm and ovum combine to form an embryo. The embryo after emerging from the egg undergoes a sequential process of growth and development to become an adult. This process is called metamorphosis.

10.6 Plant Physiology

Introduction

The branch of plant sciences that aims to understand how plants live and function. Its ultimate objective is to explain all life processes of plants by utilizing principles founded in Chemistry, Physics & Mathematics.

1. ABSORPTION OF WATER

Higher plants absorb water through roots. Root system is surrounded by water present in the soil called soil water. Roots are provided with root hairs which are the structures of water absorption. In algae and hydrophytes surface absorption occurs. In land plants, absorption takes place through roots. As water is essential for life activities, land plants produce long and extensive root system for the absorption of water.

OSMOSIS : Osmosis is a process by which solvent molecules (water) move from a dilute solution to a concentrated solution when separated by a semipermeable membrane. Otherwise water molecules move from a region where it is more to a region where it is less when separated by a semipermeable membrane.

Thistle Funnel Experiment

Osmosis can be demonstrated by thistle funnel experiment as shown in Fig. The set

up consists of thistle funnel,beaker,egg membrane. The mouth of the thistle funnel is tied with a semi-permeable membrane (egg memebrane or sheep's bladder) which is permeable to water but impermeable to sucrose

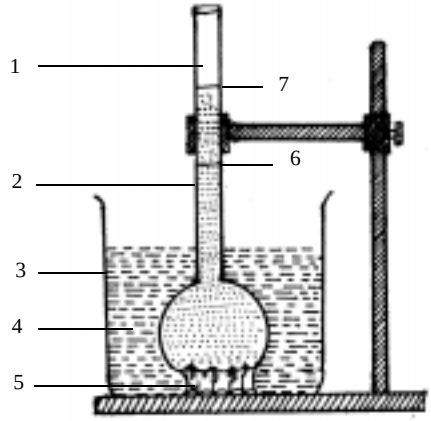


Fig. 10.27 Osmosis - Thistle Funnel Experiment

1. Thistle funnel 2. Sugar Solution 3. Beaker 4. Water
5. Semi-permeable membrane 6. Initial level 7. Final level

molecules. Sucrose solution is taken in the thistle funnel. The level of sucrose solution is marked and placed in the beaker containing water. After sometime the level of the sugar solution raises due to the entry of water across the semi-permeable membrane by osmosis. The pressure that develops in the thistle funnel that acts against the entry of water from the beaker is called osmotic pressure. Osmotic pressure is measured in atmospheres. The semi-permeable membrane allows only solvent molecules (water) to pass through it. But the plasma membrane in the living cell is known as selectively permeable membrane, as it allows both solvent and solute molecules selectively depending on the requirement of the cell.

Entry of water through root hair

Soil water enters root hair by osmosis. (Fig. 10.28) By similar process water from the root hair enters cortex, endodermis, pericycle and reach the xylem due to osmotic gradient. The movement of water from one cell to another cell is due to decreasing water potential. Water potential is represented by the Greek Letter ψ (Psi) and measured in bars.

Root pressure

When the water potential is low in the root hair, movement of water takes place from

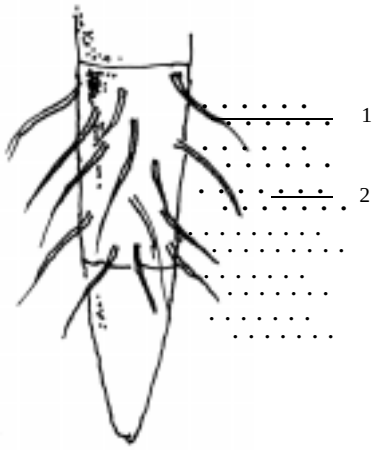


Fig. 10.28 Entry of water through root hair

1. Root 2. Soil Water

soil into the root hairs and enters epidermis, cortex, endodermis, pericycle finally to xylem vessels. When water enters into xylem from pericycle, a pressure is developed in the xylem of roots which can raise the water to certain heights. This pressure is known as root pressure.

2. TRANSPIRATION

Plants are classified into hydrophytes, mesophytes and xerophytes depending on the nature of their habitats. The hydrophyte is one that lives in water; a mesophyte grows in a place where water availability is moderate. Xerophytes are plants which grow in places of water scarcity throughout the year. You know very well that all living organisms from microbes to man require water for life activities. Without water life cannot exist in this planet. This is because, in all living organisms, major portion of the protoplasm is nothing but water only. Water is essential for various biological process like photosynthesis, germination, etc., Plant absorbs large quantities of water from the soil. Only small quantity of water is utilized and the remaining amount of water is lost in the form of vapour through aerial parts, particularly leaves. This process is called transpiration.

3. MINERAL NUTRITION

Mineral elements are very important for the growth and development of the plants. When there is a deficiency for a particular mineral it affects the growth and other activities of the plant. Because of this, deficiency symptoms such as chlorosis, necrosis,etc.,

appear on the plant body. Mineral elements are divided into two categories, namely macroelements and microelements or trace elements. Macroelements are those which are utilised by plants in large quantities, eg., Carbon, hydrogen and oxygen. Microelements or trace elements are required in very small quantities e.g.,Manganese, Zinc, Boron, etc.,

(Chlorosis - Yellowing of leaves in various patterns. Necrosis - Death of tissues.)

Table 10.2 Deficiency Symptoms

	Deficiency of macro elements	Deficiency symptoms
1.	Nitrogen	Chlorosis (Leaves become Yellowish)
2.	Phosphorus	Premature leaf fall purple or red anthocyanin pigmentation
3.	Calcium	Meristematic regions are affected and die. Roots are short, stubby, brown. Chlorosis in margin of young leaves leading to necrosis.
	Micro elements (or Trace Elements)	
1.	Manganese	Chlorotic and necrotic spots in the interveinal areas of the leaf
2.	Zinc	Interveinal chlorosis of the older leaves. Distorted appearance of the plant leaves. Leaves clustered on short branches known as rosettes
3.	Boron	Death of the shoot tip leaves develop thick coppery texture, curl and brittle.

Nitrogen Metabolism

The earth's atmosphere is composed of 80% nitrogen. Nitrogen is an essential element for all living organisms. It is absolutely required for the formation of proteins and nucleic acids. It is also required for producing growth regulators and vitamins. Exepting few bacteria and some blue-green algae, nitrogen present in the atmosphere cannot be utilised by majority of plants. Bacteria such as *Rhizobium*, *Azotobacter*, *Clostridium*, blue-green algae like *Anabaena* and *Nostoc*, make use of the atmospheric nitrogen. The roots of higher plants absorb nitrogen compounds such as nitrates, nitrites and ammonia from the soil. The conversion of the molecular nitrogen of the atmosphere into nitrogen compounds by certain bacteria and blue-green algae is called biological nitrogen fixation. In Leguminous plants like groundnut and beans the atmosphere nitrogen is fixed in the roots by a bacterium called *Rhizobium.* This bacterium occurs inside small spherical structures known as root nodules. The plant and the bacteria form a mutually helpful relationship called symbiosis.

Flowering

The most beautiful part of the plant is the flower. You will be very curious to know how the plant produces flower. Let us study briefly about the flowering in plants. The flowering is controlled by the duration of light and dark periods. The response of the plant to relative lengths of light and dark periods is known as photoperiodism. This was discovered by Garner and Allard in the year 1920-22

Depending on the duration of the photoperiod, plants are classified as follows.

1. Short - day plants: Plants which require short day light period i.e. 8-10 hours and a dark period of about 14-16 hours for flowering eg., *Nicotiana tabacum* and *Glycine max*

2. Long - day plants: plants which require long day light period (14-16hrs) for flowering eg., *Spinacea oleracea* (spinach), *Beta vulgaris* (sugarbeet)

3. Day - Neutral plants: Plants which flower regardless of the duration of light and dark periods are called day - neutral plants

eg: *Lycopersicum esculentum*, *Mirabilis*
In flowering, a pigment called phytochrome is involved. It is suggested that a hormone known as florigen also involved in flowering.

4. Photosynthesis

Definition : Photosynthesis is a biological process in which green plants synthesise carbohydrates, utilising the light

energy, water and carbon-di-oxide. This is an important process because all other organisms, directly or indirectly depend on green plants for food. Photosynthesis occurs only in green plants and photosynthetic bacteria. Plants are the primary producers because they alone synthesize food materials by the process of photosynthesis. All other organisms either directly or indirectly depend upon plants for their food. This process is also of great significance because oxygen is produced, which is a major source for other organisms.

Light and dark reactions

Photosynthesis takes place in two broad stages. The first stage is **light** reaction and the second in **dark** reaction. The former takes place in the grana of chloroplast. Light reaction takes place in the presence of light. The first step in photosynthesis is absorption of light by photosynthetic pigments known as chlorophylls and carotenoids. The light energy absorbed by the pigments is used for the production of two compounds, ATP and $NADPH_2$. With this the light reaction comes to an end. During light reaction water molecules are split and oxygen is liberated. This is known as photolysis of water. In light reaction two groups of pigments system take part. These groups are called Photosystem I & Photosystem II. When light is absorbed by the pigments electron is released. The electron travels through electron carriers. The light energy absorbed by the pigments is used for the production of two compounds ATP and $NADPH_2$. With this, the light reaction comes to an end.

Dark reaction : This is the second and final phase in photosynthesis. It is called dark reaction because light is not at all required for this phase of photosynthesis. Dark reaction is also known as Calvin cycle. It takes place in stroma of the chloroplast. Various biochemical reactions, pathways of this dark reaction were discovered by Melvin Calvin. He was awarded Nobel prize in 1961 for this research in dark reaction. During dark reaction, the CO_2 first combines with Ribulose biphosphate which is known as CO_2 acceptor. By a series of reactions CO_2 is reduced to carbohydrate. For this two compounds are required. They are $NADPH_2$ and ATP. You know that in the first stage of photosynthesis i.e., light reaction these two compounds are synthesised. CO_2 is reduced to carbohydrate using ATP and $NADPH_2$. Here the first formed stable product is a 3 carbon compound so Calvin cycle is also known as C_3 pathway. Dark reaction is enzymatic and it takes place in stroma of chloroplast. Ribulose biphosphate and CO_2 get hydrolysed into 2 molecules of phosphoglyceric acid.

These two molecules of phosphoglyceric acid are reduced to phosphoglyceraldehyde by using $NADPH_2$ and ATP. Of the two phosphoglyceraldehyde one becomes dihydroxyacetone phosphate. From these two fructose, glucose, sucrose are formed. Ribulose biphosphate is regenerated.

5. Respiration

Respiration is a biological process that occurs in all living organisms, ranging from bacteria to animals and plants. There is no living organism on earth that does not respire. One of the important characteristics that differentiates living organisms from the non-living is respiration.

We take different kinds of foods. Plants synthesise their ‘food’ by photosynthesis. Why should we eat ? Why should plants synthesize food ? For the simple reason that all living organisms ranging from minute bacteria to mamooth elephants, plants and human, require energy for growth, movement and reproduction. Where does this energy come from ?

Food that we eat, the starch that is synthesised by plants are sources of energy. In fact, energy is locked up (stored) in food materials. During respiration the food materials are oxidised (degraded). During this reaction, energy is released from the food and it is stored in a special chemical (or) biological substance called ATP (Adenosine Tri phosphate). The energy of ATP is utilised in various activities of cells. Apart from ATP, two other substances are also formed during respiration. They are carbon-di-oxide and water. The process of respiration may be put in the following simple equation.

$$\text{Food} \xrightarrow[\text{respiration}]{} \text{Energy (ATP)} + CO_2 + H_2O$$

Substance that is used in respiration is known as respiratory substrate. Respiratory substrates are of three kinds viz., carbohydrates, fats and proteins.

Types of Respiration :

Depending on whether oxygen is used or not respiration is of two types. 1. Aerobic respiration and 2. Anaerobic respiration.

In majority of living organisms oxygen is utilised during respiration. Respiration that uses oxygen is known as aerobic respiration. In few organisms, oxygen is not utilised for respiration. This type of respiration is known as anaerobic respiration. Here you should keep it in mind that maximum amount of energy is obtained from food substances by aerobic respiration only because the food is completely degraded. As oxygen is used in aerobic respiration it is also known as oxidative process. Unlike aerobic respiration, very little amount of energy is obtained from the food during anaerobic respiration as the food is degraded partially.

1) Aerobic Respiration :

Aerobic respiration takes place in three broad stages.

(1) Glycolysis, (2) Kreb's cycle and (3) Electron transport. Among three kinds of foods viz, carbohydrates, lipids and proteins carbohydrates are commonly used in respiration.

Glycolysis : This is the first stage in respiration. This takes place in the cytoplasm. In glycolysis, glucose (a simple carbohydrate) is converted into two molecules of pyruvic acid. This takes place in a series of reactions and number of enzymes are involved. With the formation of pyruvic acid glycolysis comes to an end. During the conversion of glucose to pyruvic acid there is a net gain of two ATP molecules.

2) Krebs Cycle :

An English Biochemist Hans A. Kreb's (1937) discovered the reactions of Krebs cycle. Because of this it is known as Kreb's cycle. He was awarded Noble Prize for this discovery in 1953.

Pyruvic acid produced in glycolysis is completely oxidised into CO_2 with the production of compounds such as $NADH_2$, $FADH_2$ in Kreb's cycle.

3) Electron Transport Chain :

During electron transport chain electrons are transferred from compounds such as $FADH_2$, $NADH_2$ which travel through different electron carriers. As they travel, ATP is produced at certain places. Finally, the electron and hydrogen join with oxygen to form water. This is the place where oxygen is utilized during respiration. Complete oxidation of a glucose molecule in aerobic respiration produces 36 ATP molecule.

Lactic acid fermentation :

Lactose $\longrightarrow$ Pyruvic acid $\longrightarrow$ Lactic acid

$$\underset{\text{Pyruvicacid}}{CH_3COCOOH} + 2\,NADH + H^+ \longrightarrow \underset{\text{Lacticacid}}{2CH_3CHOHCOOH} + 2NAD$$

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \longrightarrow \underset{\text{Lactic acid}}{2CH_3CHOH.COOH}$$

Here oxygen is not utilised for respiration. So it is called anaerobic respiration which is also known as fermentation. The tasty curd is formed due to lactic acid fermentation. The lactose is converted into lactic acid that reacts with caesin in the milk (a milk protein) and curd is formed. In anaerobic respiration only 2 ATP molecules are formed and rest of the energy still remains in the lactic acid.

Through the fermentation number of alcoholic drinks are produced.

6. Growth

You might have observed that a small mango seedling when planted grows as a taller and broader tree after few years. This is also the case with many types of plants. Growth is an increase in division, enlargement and differentiation of cells into many types of tissues. It is an irreversible process. Plants

have indeterminante growth as they continuously produce new organs and tissues. Plants grow by the activities of meristematic tissues. There are three types of meristems.

(1) Apical, (2) Lateral and (3) Intercalary.

Growth in length is due to apical and intercalary meristems. Whereas growth in width (girth) is due to the lateral meristem.

Growth hormones :

The plant produces natural organic substances synthesized in minute quantities responsible for the growth, development and physiological activities. These are called growth hormones. The term hormone is derived from Greek word 'hormaein' which means "to step up". They are also known as phytohormones. The phytohormones are of four types

(1) Auxins, (2) Gibberellins, (3) Cytokinins, (4) Ethylene

1) **Auxins :** Auxins are natural growth hormones synthesized in the meristematic regions or growing tips. They are produced by the plant in very small quantities

eg: Indole -3- acetic acid (IAA)

Physiological effects of Auxins

(1) It is involved in cell enlargement and differentiation.

(2) Cell elongation

(3) Apical dominance

(4) Root initiation

(5) Prevention of abscission

(6) Parthenocarpy

Synthetic auxins :

The synthesised chemical compounds which have activity similar to auxins are called synthetic auxins.

Examples :

(1) Indole-3-propionic acid

(2) Indole-3-butryic acid

(3) Indole-3-pyruvic acid

(4) 2,4-Dichloro phenoxy acetic acid (2,4-D).

Synthetic auxins plays an important role in agriculture.

(1) It initiates rooting in plants which are vegetatively propagated.

(2) It prevents the premature falling of the fruits.

(3) Commercially parthenocarpic fruits are obtained. eg. seedless oranges, grapes, etc.,

(4) It inhibits sprouting of buds in potato tubers.

(5) In apple and pears it prevents the elongation of internodes so that it can bear fruits.

(6) It is used as herbicide.

10.7 Human Physiology

You have studied the structure of various organ systems under human anatomy in your previous class. Here we deal with human physiology, which is the study of the functions of the various systems in the human body. Physiology attempts to explain all the activities that make up life and hence to explain life itself. Physiology also explains how organisms adapt to environmental alterations and maintains homeostasis (constant internal condition).

1. Physiology of Digestion :

The function of digestion is to break the complex food into simple chemical substances that can be absorbed and assimilated by the body. The process begins in the mouth where the food is physically broken down into small pieces. This process is called mastigation or chewing. The secretions of the salivary glands, saliva, is mixed with the food to make it semisolid. The saliva also contains an enzyme salivary amylase, that initiates the digestions of carbohydrates. The food is then taken to the stomach through the food pipe or oesophagus. The walls of the stomach secrete hydrochloric acid (HCl) and pepsin. The HCl provides an acid medium that kills micro

organisms. Pepsin begins the digestion of proteins. The HCl is highly corrosive. To protect the walls of stomach, mucous is secreted. If the mucous protection is lost, the HCl damages the stomach wall. A wound is caused and it is called a stomach ulcer.

The partly digested food that passes out of the stomach is called the chyme. In the duodenum the secretions of the pancreas and liver are mixed with the chyme. The pancreatic secretion contains.

(i) Sodium bicarbonate that neutralizes the HCl from the stomach

(ii) Pancreatic amylase for digesting carbohydrates.

(iii) Trypsin and chymotrypsin for digesting proteins and

(iv) Pancreatic lipase for digesting fats.

The liver secretion contains bile pigments and bile salts. The bile pigments are bilirubin and biliverdin. They are waste products formed in the liver by red blood cell destruction. The bile salts disperse fats into minute droplets by lowering its surface tension. This process is called emulsification of fats. It aids in fat digestion.

The chyme enters the small intestine. Here it is moved forward by rhythmic contractions called peristalsis. The cells in the intestinal wall secrete.

(i) Disaccharidases that complete carbohydrate digestion by converting disaccharides into monosaccharides.

(ii) Peptidases that break down peptides into amino acids which is the final step in protein digestion.

(iii) The lipases that break fats into fatty acids and glycerol.

The finger-like projections of the small intestine, villi, absorb the nutrients from the digested food. Thus the digested proteins, carbohydrates, fats, vitamins and minerals are absorbed in the villi. The villi contain blood vessels and lymph vessels (lacteals). The lacteals transport the absorbed fats while the blood vessels carry the other digested materials to the liver. The remaining undigested material enter the large intestine. Here they are converted into faeces by bacteria. The faeces are thrown out through the anus by a process called defaecation.

Appendix is a small finger-like structure attached to your large intestine, in the lower right side of your abdomen. The appendix may become swollen due to blockage and is easily infected by bacteria. This infection is called appendicitis. Symptoms include significant abdominal pain (especially around the navel or in the lower right part of the abdomen). fever, loss of appetite, nausea and vomiting, diarrhoea (especially small amounts with mucous). In such cases, the infected appendix needs to be immediately removed surgically. Otherwise a hole may occur in the appendix and spread the infection to the entire abdomen. This may become life threatening.

2. Physiology of respiration :

The cells in the body require energy to perform their activities. This energy is derived by a chemical process called oxidation. Oxidation is nothing but a burning up process. When a wood is burnt, oxygen is taken up and carbondioxide is liberated as smoke. Similarly, the food is burnt up in the cells to derive energy. This requires oxygen and it produces carbondioxide as a waste material. Respiration is the process by which the cells are supplied with oxygen and the carbondioxide produced in the cells are excreted. Respiration takes place at two stages. External respiration is the first stage. It takes place in the lungs. Here oxygen is taken up from the air into blood and carbondioxide from blood is released into the air. Internal respiration is the second stage. It is also called cellular respiration. Here blood supplies oxygen to the cells and takes up carbondioxide from the cells. Thus blood acts as a carrier of oxygen and carbondioxide between the lungs and the cells in different parts of the body.

The lungs are placed in the thoraic cavity. The process of taking air into the lungs is called inspiration. During inspiration the sternum is pushed up and outward and the diaphragm is pulled down. This increases the volume of the thoracic cavity and the pressure

decreases. As a result air from outside rushes into the lungs. The air enters the alveoli in the lungs. Here exchange of gases takes place between the air and the blood. The process of expelling air from the lungs is called expiration. During expiration the sternum is pulled down and inward and the diaphragm is pushed up. This reduces the volume of the thoracic cavity. The pressure increases and as a result air from the lungs is pushed out.

Asthma is a common disease of the respiratory system. It is caused by an allergic reaction. Substances like pollen in air causes allergic reaction. Here the air passage constricts. This causes difficulty in breathing. This is relieved by drugs that relax the air passage.

3. Physiology of circulation :

The function of circulatory system is transport of materials. This requires a fluid tissue called blood. This is kept in constant circulation through blood vessels by a pump called heart.

Composition of blood : Normally in a healthy person the total blood varies from 6% to 8 % of the body weight. Blood consists of a liquid plasma in which formed elements are suspended.

The plasma contains plasma proteins that maintain the osmotic pressure and protect the body from disease causing organisms. They also have the blood clotting factors that prevent loss of blood during injury.

The formed elements of blood include the Red Blood Corpuscles (RBC), the White Blood Corpuscles (WBC) and blood platelets. Human RBCs are circular and biconcave, without a nucleus. They are produced in the bone marrow.They have a life span of about 120 days. They are then destroyed in the liver. There are around 5 million RBCs per cubic millimeter of blood. RBCs contain an iron containing protein called haemoglobin. It gives the characteristic red colour to blood. It helps to transport gases.

WBCs are larger than the RBCs and they have nuclei. They are produced in the bone marrow and lymph nodes. There are about 5000 to 10,000 WBCs per cubic millimeter of blood. They protect the body from disease causing organisms. The platelets are the smallest formed elements. They are formed in the bone marrow. There are about 150,000 to 300,000 platelets per cubic millimeter of blood. They help in blood clotting.

Functions of blood :

The blood performs many important functions.

(a) They carry oxygen from the lungs to the tissues and carbondioxide back from the tissues to the lungs.

(b) They carry food materials, metabolites and hormones to the different body parts.

(c) They protect the body from infections

(d) They distribute heat throughout the body and regulates the body temperature.

(e) Blood is a buffer and maintains acid-base balance of the body.

(f) Since blood is a liquid tissue, it prevents its loss by its ability to clot.

When there is an injury to the blood vessels, the blood loss is stopped quickly by the formation of a clot. However if the injury is deep and severe, the loss of blood is heavy. Also in case of major operations, there is huge blood loss. Such persons require blood transfusion. So blood banks have been set up. They collect blood from normal persons. The blood is screened for any transmittable disease. The blood is then stored and given to needy people.

Any healthy person without any infectious disease in the age group of 16 to 60 years can donate blood. Besides hospitals, several voluntary organisations such as lions club, Rotary club, Red cross, National Service Scheme (NSS) periodically organise blood donation camps. When blood is donated, the body produces new blood cells and compensates for the loss. So blood donation does not affect the health of the donor. Besides it helps save life at times of emergency. Hence make it a habit to donate blood.

4. Physiology of nervous system

The nervous system is concerned with the coordination of the activities of an organism. It is a network of connections through which activities are controlled and coordinated by electrical impulses. A neuron is the functional unit of the nervous system. It consists of a

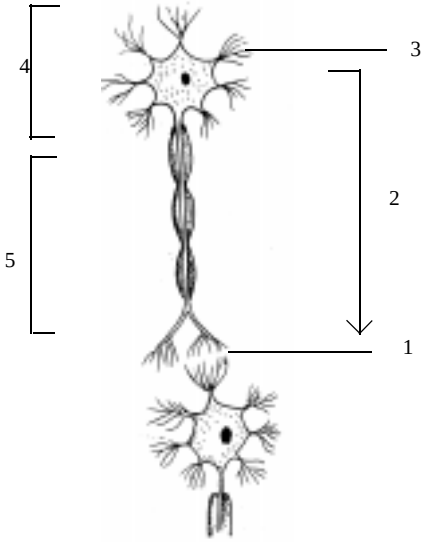


Fig. 10.29 Structure of an Axon

1. Dendrite 2. Movement of action potential 3. Synapse
4. Cell body 5. Axon

cell body that has many dendrites and an axon. The neuron receives impulses from one or more neurons through the dendrites and then transmits them along its axon to other neurons. The transmission of impulse along the axon is called an action potential. When the action potential reaches the end of the axon, it is transmitted to the neighbouring neurons through junctions called synapses.

The brain receives information from and sends messages to the various systems through the neurons. But some information requires immediate action. There isn't enough time for the information to be taken to the brain for processing and a suitable response given back. In such cases, the spinal cord responds with constant responses. Such information with their constant responses is called reflex action. Thus every time something suddenly comes close to the eye, the eyelids close. When the body comes in contact with a hot object, it automatically withdraws.

5. Physiology of excretion

Excretion is the process of eliminating the by-products of metabolism. The metabolic wastes include urea, excess salts and water. Kidneys are the chief excretory organs. The functional unit of kidney is the nephron. The Malpighian capsule of the nephron filters the blood. The fiilrate flows through the tubule of

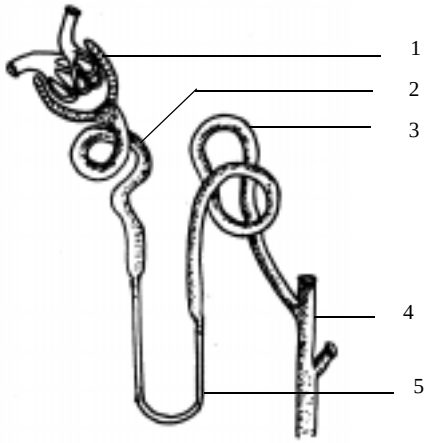


Fig. 10.30 Structure of a nephron

1. Malpighian Capsule 2. Proximal convoluted tubule
3. Distal Convoluted Tubule 4. Collecting Duct
5. Loop of henle

the nephron, where necessary substances are absorbed back into the blood. Glucose from the filtrate is absorbed back from the proximal convoluted tubule. Absorption of water, Na^+ and Cl^- occurs throughout nephrons. The remaining filtrate, which is called urine, is emptied into the collecting duct. The collecting duct collects urine from many nephrons. From the kidney, the urine is taken to the urinary bladder by the ureter. When the urinary bladder becomes full, it is emptied through the urethra.

The output of urine is varied according to the requirements of the body. When the body requires more water, the volume of urine produced is less. Thus during summer, when water is lost as sweat to reduce the body temperature, the urine produced is less. During winter, when there is lesser sweating, more urine is produced.

6. Physiology of sense organs

(1) Eye : Eye is a photo receptor i.e., it senses light from the surrounding. The cornea and lens of the eye help to focus the image on to the inner layer of the eye called the retina. Retina has light sensitive cells called rods and cones. Rods perceive dim light and cones are responsible for colour vision. When a clear image is formed on the retina, by proper adjustment of the lens, the rods and cones convert the light energy into electrical impulses and transmit them to the brain through the optic nerve. The brain preceives the image from the electrical impulses.

Rods require vitamin A for its proper function. When a person is deficient in vitamin A, the rods lose their function. As result, the ability to see in dim light is lost. This condition is called night blindness.

When the cornea and the lens are not able to focus the image exactly on the retina, the person will not be able to see objects clearly. It requires correction by corrective glasses. In the case of short sightedness the lens focus the image before the retina. This is corrected by concave lens. In the case of long sightedness, the lens focus the image beyond the retina. This is corrected by convex lens.

Laser surgery is becoming popular for correcting eye disorders. Here a laser beam is used to surgically adjust the curvature of the cornea to correct problems in focusing. The surgery takes only a few minutes and the patients recover fully in one to three days. Most of them do not require corrective glasses after surgery.

(2) Ear : Ear perceives sound waves and is also an organ of balance. The sound waves cause vibrations on the ear drum. These vibrations are transmitted to the internal ear by the ear ossicles. The inner ear has two sac like organs called utriculus and sacculus. Sacculus has a spirally coiled tube called the cochlea. The cochlea contains the organ of Corti that is sensitive to vibrations. The vibrations are converted into electrical impulses and transmitted to the brain via the auditory nerve. The brain perceives these impulses as sound.

The utriculus is the organ of balance. It contains small crystals of calcium carbonate called otoliths, on the tip of flexible hair-like projections. The orientation of the individual is perceived by the position of the otolith.

SELF-EVALUATION

Choose the correct answer

1. Flavivirus causes
   (1) Filariasis (2) Cholera
   (3) Dengue fever (4) Malaria

2. Mineral elements are divided into two categories, macro elements and
   (1) Essential elements (2) Micro elements
   (3) Carbon (4) Nitrogen

3. Photosynthesis proceeds in sequence of
   (1) Light and dark reaction
   (2) Light reaction alone
   (3) Dark and light reaction
   (4) Dark reaction

4. Respiration in the absence of oxygen is
   (1) Aerobic respiration
   (2) Anaerobic respiration
   (3) Transpiration
   (4) Guttation

5. Blood platelets help in
   (1) immunity (2) gaseous transport
   (3) blood clotting (4) acid-base balance.

Fill in the blanks

6. An intact virus is known as .....

7. The cytoplasmic membrane of a bacterium made up of ..... and .....

8. ..... is a disease in cattle and sheep.

9. The mosquito that prefers to bite during daytime is .....

10. Cholera is caused by the bacterium .....

11. The common outlet for faeces, urine and reproductive bodies is called .....

12. Blood from the digestive tract is taken to the liver by the ..... vein.

13. The partly digested food that passes out of stomach is called .....

14. Rods require ..... for its proper function.

Answer briefly

15. Define a virus.
16. What are the differences between plant and animal viruses ?
17. Give an account of (a) Common cold (b) AIDS.
18. What is a flagellin?
19. Why bacteria is considered to be Natures scavangers?
20. Explain the cell structure in *Penicillium.*
21. How will you identify *(a) Anopheles (b) Culex (c) Aedes and (d) Phlebotomus*
22. Explain briefly (a) Dengue (b) Brainfever
23. What is Elephantiasis ?
24. What is cerebral Malaria ?
25. What is "Dark reaction" in photosynthesis?
26. What is fermentation ?
27. What are synthetic auxins ?
28. Why is the skin slimy in frog ?
29. What is cloaca ?
30. List out the digestive enzymes ?
31. What is a blood bank ?
32. What is short-sightedness and how is it corrected ?
33. What is night blindness ?
34. What is a reflex action ?
35. Urine output varies in different climates. Why?

Answer in detail

36. Explain the structure of TMV with a neat diagram.
37. Why are viruses believed to have the properties of both non- living and living forms ?
38. Describe the cell structure in bacteria.
39. Explain the asexual reproduction in bacteria with suitable diagrams.
40. What is the role of bacteria in biological Nitrogen fixation.
41. Describe the reproduction in *Penicillium.*
42. Give an account of the industrial uses of *Penicillium.*
43. Write an essay on the control of vector and vector borne diseases.
44. Describe the external morphology of frog with a neat diagram
45. How is food digested is the digestive tract of frog ?
46. Explain the different modes of respiration in frog
47. With a neat diagram explain the arterial system of frog.
48. Write an essay on the nervous system of frog.
49. What are the physiological role of auxins ?
50. Write about the practical application of synthetic auxins.
51. Describe the physiology of digestion in man.
52. What is respiration ? Discuss the mechanism of respiration
53. Write an essay on the composition of blood.

Activities

54. Collect virus infected tomato leaves. Look for discolouration and leaf mottling. Compare it with a normal leaf.
55. Look for symptoms of viral infection in the plants around you. Collect plant materials showing necrosis and gal.
56. Note down the control measures taken by the Government against vector.
57. Suggest precautionary methods in your area for vector borne disease.
58. Collect the various stages of frog metamorphosis during rainy season. Observe their habit and habitat.
59. Find out the different types of WBCs and their relative percentage in a healthy person.
60. Analyze why it is difficult to perform severe exercise in high mountains.
61. Construct a model of sarcomere and demonstrate the sliding filament mechanism.

11. CELL BIOLOGY

11.1 Chromosomes and genes

Chromosomes are structures seen in the nucleus. The term chromosome was given by W. Waldeyer in 1888 to structures that stained darkly in the nucleus. They have special organisation and function. They can reproduce independently and they play an important role in heredity, variation and mutation. The molecular organisation of chromosomes is complex. These structures are made up of nucleic acids and proteins. Generally eukaryotic chromosomes are associated with de-oxy ribonucleic acid (DNA), histone and non-histone proteins. Varying amounts of ribonucleic acid (RNA) are also found in addition to the above molecules.

Genes are located on the chromosome. A gene is a segment of DNA that can code for a specific protein. Most genes code for proteins though some code for transfer RNA's and ribosomal RNA's. The genetic information in most organisms is stored in DNA except in some viruses where the genetic information is in the form of RNA.

1. A typical chromosome-structure

The size of the chromosome varies in different species. Plants have larger chromosomes when compared with animals. But the size and number of chromosomes remain constant for a particular species. For example in *Drosophila* the number is eight and in Man the number is 46.

The shape of chromosomes change during different phases of the cell cycle. During the resting phase or interphase stage chromosomes are seen in the form of thin, coiled, elastic, contractile, filament - like stainable structures. These structures are referred to as chromonemata. This is nothing but a single linear DNA molecule with its associated proteins. These thread-like chromonemata then becomes slowly folded and are called as chromomeres. At the metaphase stage the chromosome becomes tightly coiled and it becomes thicker during this stage.

Each chromosome has a region that provides attachment for the mitotic spindle. This part is called as *centromere* or *kinetochore*. The centromere lies within a thinner segment of the chromosome called the primary constriction. Centromeres contain specific DNA sequences with special proteins bound to them. This gives them a disc-shaped structure.

The tips of the chromosome have special properties and are termed as telomeres. Telomeres form the ends of the long linear DNA molecules contained in each chromosome. They have an unusual DNA structure. Certain chromosomes have a rounded body separated from the rest of the chromosome by a secondary constriction called satellite. The satellite and the constriction are constant in shape and size for each particular chromosome. In some secondary constrictions there are areas that contain genes that code for rRNA's. These regions are called as nucleolar organizers. These

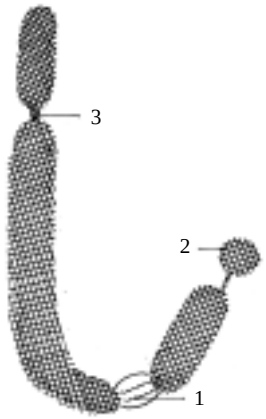


Fig. 11.1 Structure of a typical chromosome

1. Centromere 2. Satellite 3. Secondary Constriction

areas also induce the formation of nucleoli. In Man, the nucleolar organizers are located in the secondary constriction regions of chromosomes 13, 14, 15, 21 and 22.

2. Types of Chromosomes

Chromosomes can be classified based on the functions of the chromosomes, position of centromeres and number of centromeres.

Eukaryotic chromosomes can be classified into autosomes and allosomes. Autosomes are somatic chromosomes controlling body characters. They have no role in sex determination. Allosomes are also called as sex chromosomes or accessory chromosomes. They play an important role in sex determination. They are almost always two in number.

If an animal produces gametes containing similar chromosomes it is termed homogametic. If gametes with two types of chromosomes are produced it is termed as heterogametic. In Man, the female is homogametic (XX chromosomes) whereas male is heterogametic (XY chromosomes). In insects female is homogametic (XX chromosomes) and male has only one X chromosome (XO chromosomes). In birds male is homogametic (ZZ) and female is heterogametic (ZW).

Based on the position of centromere, the chromosomes are classified into metacentric, sub-metacentric, acrocentric and telocentric chromosomes. (Fig. 11.2)

(i) Metacentric chromosomes have two equal or almost equal arms.

(ii) Sub-metacentric chromosomes have arms of unequal length.

(iii) Acrocentric chromosome has one long arm and one very short arm as the centromere is located towards one end of the chromosome.

(iv) Telocentric chromosomes have the centromere located on one end. There is only one arm here.

Based on the number of centromeres chromosomes are classified into monocentric, holocentric, acentric and dicentric chromosomes. Monocentric chromosomes have only one centromere. Holocentric chromosomes have diffuse centromeres with microtubules attached along the length of the chromosome. This type is seen in *Ascaris megalocephala* and in some types of algae. Acentric chromosomes have no centromere. Dicentric chromosomes have two centromeres. Both acrocentric and dicentric forms are seen in some chromosome abnormalities and both types are unstable.

In some animals large-sized or giant chromosomes are seen in some cells at certain

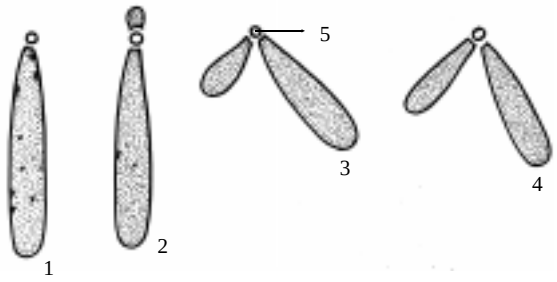


Fig. 11.2 Types of chromosomes based on position of centromere

1. Telocentric 2. Acrocentric 3. Sub-metacentric
4. Metacentric 5. Centromere

stages. Giant chromosomes are of two types namely Polytene (meaning many threads) and Lamp brush chromosomes.

Polytene chromosomes

This was first reported by E.G. Balbiani (1881). They are generally studied in the salivary gland cells of dipteran larvae. Here DNA is replicated repeatedly without subsequent separation of the daughter chromatids. This produces a characteristic morphology of bands and interbands.

Polytene chromosomes are sites of increased gene expression for the purpose of secreting specific proteins needed by the larva.

Lampbrush chromosomes

Discovered by Ruckert (1892). This chromosome has highly extended lateral loops of DNA. They are generally seen in animal oocytes at the diplotene stage of meiosis.

3. Number of chromosomes - Karyotypes.

Chromosomes generally occur in pairs. Similar pairs of chromosomes are called as homologous chromosomes. Dissimilar pairs are called heterologous chromosomes. The term karyotype denotes the different characteristics that enables us to identify a particular chromosome set. The different characteristics include the number of chromosomes, relative size, position of the centromere, length of the arms, secondary constrictions and satellites. A karyotype of an individual is unique and it is represented by a diagram in which the homologous chromosomes are arranged in the order of decreasing size.

Table 11.1 Number of chromosomes in some organisms

S.No	Common name of organism	Scientific name	Total Number of chromosome
1.	Fruit fly	*Drosophila melanogaster*	8
2.	Chicken	*Gallus domesticus*	78
3.	Mouse	*Mus musculus*	40
4.	Gorilla	*Gorilla gorilla*	48
5.	Man	*Homo sapiens*	46
6.	Onion	*Allium cepa*	16
7.	Rice	*Oryza sativa*	24
8.	Maize	*Zea mays*	20
9.	Coffee	*Coffea arabica*	44
10.	Potato	*Solanun tuberosum*	48

4. Genes-sites structure and role - genome

Genes are made up of DNA and they are located on the chromosome. Genes are always present on the chromosome at specific sites or loci. DNA is the genetic material of the cell. It carries information in a coded form from cell to cell and from parents to offspring.

A portion of DNA specifying a single polypeptide chain is termed as cistron. Here the gene acts as an unit of physiological function.

A complete set of chromosomes containing all the genes is called as a genome. Genomes of eukaryotes are more complex than that of prokaryotes.

11.2 Genes and Nucleic acids

1. Gene DNA nucleotides. Nucleoside bases

The genetic material of organisms is made up of nucleic acids. There are two types of nucleic acids namely deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). In most organisms DNA forms the genetic material while some viruses contain only RNA which forms the sole genetic material.

DNA is a macromolecule and it has a high molecular weight. This macromolecule consists of a sugar moiety, nitrogenous bases and phosphoric acid. In DNA, the sugar moiety is deoxyribose which is a pentose sugar. The nitrogenous bases are of two types namely the purines and pyrimidines. Pyrimidines have a single heterocyclic ring. In DNA thymine (T) and cytosine (C) are the two types of pyrimidines seen. In RNA thymine is replaced by another pyrimidine namely, uracil (U). Purines have two fused rings. Adenine (A) and guanine (G) are the purine bases seen in both DNA and RNA.

The combination of a nitrogenous base and a pentose sugar forms what is called as a nucleoside.

For example in RNA adenine and ribose combine to yield adenosine which is the corresponding nucleoside. In DNA adenine and deoxyribose combine to yield deoxyadenosine.

The addition of phosphate groups to the nucleoside gives rise to a nucleotide.

DNA is a long linear polymer of nucleotides. In *Escherichia coli,* there is a single circular DNA molecule having 4.7×10^6 base pairs and a total length of 1.7 mm. In Man the length of DNA in a diploid cell is about 2.0 m.

2. Double helix - Watson and Crick model.

Watson and Crick (1953) proposed a model for DNA structure. The structure composed of two right-handed helical polynucleotide chains that form a double helix around the same central axis. The two polynucleotide chains are referred to as complementary strands.

As shown in the figure the bases are stacked inside the helix in a plane perpendicular to the helical axis. Base pairing is specific and adenine always binds with thymine while

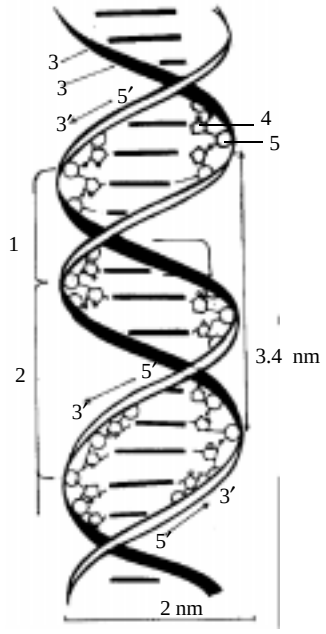


Fig. 11.3 DNA - Double helix

1. Minor groove 2. Major groove 3. Base pairs 4. Sugar 5. Phosphate

guanine binds with cytosine. Adenine pairs with thymine by means of two hydrogen bonds and guanine pairs with cytosine by means of three hydrogen bonds. Chargaff (1949-1953) studied base composition of DNA and found that in all organisms the amount of adenine was equal to thymine. Similarly he found that the number of cytosine was equal to guanine. Therefore, the total number of purine molecules in DNA equals that of pyrimidines. (i.e., A + G = C + T). This is called as Chargaff's rule.

In a DNA molecule the phosphate group can be attached to either the third carbon atom (3′) of the de-oxy ribose sugar or the fifth carbon atom (5′). Attachment is by means of a phosphodiester bond. If on one strand the link is at the 3′ region, on the complementary strand it will be on the 5′ region. This means that the strands are antiparallel in nature. In other words the 3′, 5′ phosphodiester bonds run in opposite directions.

The diameter of the helix is 20Å. This is maintained by the faithful pairing of adenine with thymine and guanine with cytosine. Usually the two helical chains of the DNA molecule are coiled around a common axis in the form of a right handed double helix. The two helical chains are wound in such a way that two grooves are produced. There are a wide groove called as major groove and a narrow groove called as minor groove.

There are many variants of double helical DNA. Most of the bacterial or eukaryotic genome has B-form DNA or B-DNA. This is called as Watson - Crick form and is the most stable form of DNA. The structure explained here is the B form of DNA. In addition there are A-DNA, C-DNA and Z-DNA. A-form and C-form are right handed while Z form is left handed. H-DNA, a triple helix form is seen as an extreme variant.

3. DNA model with strips and beads

Activity : A DNA model can be made by the students using different coloured beads for sugar, bases and phosphates. Bonding can be shown using strips. They can refer the following figure.

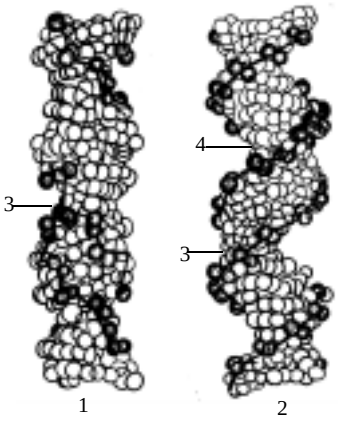


Fig. 11.4 Models of Z and B DNA

1. Z-DNA 2. B-DNA 3. Minor groove 4. Major groove

4. DNA replication

The Watson and Crick model of DNA suggests that replication of DNA is semi-conservative. It means that half of the parental DNA is conserved. That is, only one strand is synthesized while the other half of the original DNA is retained.

DNA is synthesized by enzymes called DNA polymerases. In both prokaryotes and eukaryotes the DNA polymerases need a template DNA. Template DNA refers to the original parent strand on which the new strand is synthesized.

5. Structure of RNA and functions.

Basically RNA is similar to DNA except for the presence of ribose instead of de-oxyribose and uracil instead of thymine. And RNA is single stranded. This unbranched macromolecule consists of a single polynucleotide chain mostly. Though RNA is single stranded, it is not a simple, smooth and linear structure. In some regions of the RNA molecule there can be hydrogen bonds forming between adjacent adenine and uracil molecules and between guanine and cytosine pairs. Since there is only one strand here the adenine content does not necessarily equal its uracil content. Neither does its guanine content necessarily equal its cytosine content as seen in DNA.

There are three major classes of RNA : Messenger RNA (mRNA), transfer RNA (tRNA) and ribosomal RNA (rRNA). All the above classes of RNA are involved in protein synthesis.

Messenger-RNA :- mRNA forms 5% of the total RNA content. This type of RNA carries the genetic information for the sequence of amino acids. mRNA is synthesized on one of the two DNA strands. Therefore mRNA is complementary to chromosomal DNA. This mRNA which is produced in the nucleus is modified and sent to the cytoplasm where it gets translated into the respective protein. The length of the mRNA molecule varies depending upon the length of the protein it is going to code for. In bacteria, mRNA codes for several proteins together and the mRNA molecules are long. This type of mRNA is called as polycistronic mRNA. In eukaryotes mRNA's code for a single protein and this type of mRNA is termed as monocistronic mRNA.

Transfer RNA :- tRNA constitutes about 15% of the total cellular RNA. All tRNAs fold into a typical 'cloverleaf' structure as shown in fig. 11.5.

The tRNA structure shown has the following general structures. It has

(i) an acceptor end to which the specific amino acid binds.

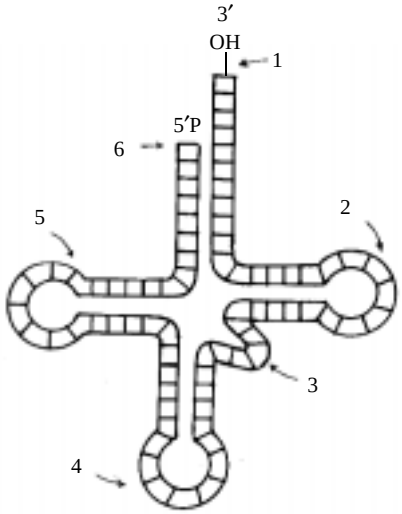


Fig. 11.5 Structure of tRNA

1. Amino acid attachment site 2. T ψ C loop
3. Extra arm (Variable arm) 4. Anticodon loop
5. DHU loop 6. Phosphorylated 5′ terminus.

(ii) The anticodon loop :- This is opposite to the acceptor end. It has three bases

that recognize and form hydrogen bonds with the mRNA codon.

(iii) The D loop :- It contains dihydrouridines and

(iv) The T loop :- It has a conserved sequence T Ψ CG.

(v) The variable loop :- This is a highly variable region which differs greatly in length in different tRNA's.

tRNA's have nucleotides between 75 and 85. They play an important role during protein synthesis where they act as molecular adaptors. tRNA binds to an amino acid specifically and transfers it to the site of protein synthesis.

Ribosomal RNA (rRNA) :- This constitutes about 80% of the total cellular RNA. It is primarily seen in the ribosomes.

Prokaryotic ribosomes contain three types of rRNA molecules namely 16S (S - Svedberg unit) 23S and 5S rRNA. Small subunit contains 16S rRNA and large subunit contains 235 and 5S rRNA. In eukaryotes there are four types of rRNA's. They are 18S in the small subunit and 28S, 5.8S and 5S in the large subunit. Eukaryotic ribosomes and rRNA's are much larger than the prokaryotic ones. About 70% of rRNA is double stranded and helical due to base pairing. The double stranded regions are formed by 'hairpin loops' created between complementary regions of the same linear RNA molecule.

rRNA maintains the ribosome structure and it provides a three dimensional matrix on which enzymes needed for protein synthesis bind.

6. Genetic code and its significance.

The flow of genetic information is from DNA to RNA and from RNA to protein. The information contained in DNA and in RNA is based on 4 nucleotides. These four nucleotides carry the genetic code which is read in groups of three nucleotides. Here triplets of bases specify single amino acids. These units of genetic information are called as codons. The four bases can combine with each other in different combinations to give 64 codons.

These 64 codons code for all the 20 amino acids. The length of a gene is related to the number of amino acids in a protein. For example, a gene containing 1200 nucleotides will constitute 400 codons coding for 400 amino acids. The DNA code is transcribed into an mRNA code. The RNA is complementary to one DNA strand. The mRNA then attaches itself to the ribosomes where the code is read by an adaptor molecule, the transfer RNA. The tRNA molecule carries the amino acid molecule needed for protein synthesis.

Characteristics of the genetic code.

(i) Of the 64 codons, 61 codons code for the 20 amino acids and three codons represent stop codons (UAA, UAG, UGA). Therefore some amino acids have more than one codon specifying them. For example arginine, serine and leucine have 6 codons each. This shows that the genetic code is degenerate.

(ii) The number of tRNA's that carry the anticodons is lesser than 61. This is explained by the wobble in the third base in the anticodon loop of tRNA This means that the third base in the anticodon of tRNA can base pair with more than one base.

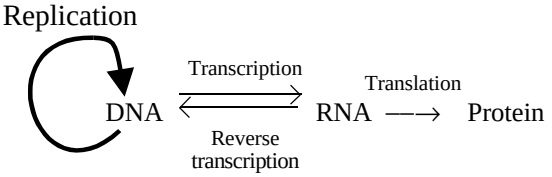
(iii) The initial codon or starting codon is AUG which codes for methionine.

(iv) The genetic code is universal. There is a single code for all living organisms except for mitochondrial DNA and ciliate protozoans.

11.3 Gene expression - Protein synthesis

1. Genic expression through genetic code - DNA, RNA.

As mentioned before, it is the DNA that is responsible for expression of genetic characters. The flow of genetic information is as follows as shown by Francis Crick.



That is genetic information flows from DNA to RNA to protein. The above concepts constitute the central dogma of molecular biology. As shown in the diagram, RNA is sometimes copied into DNA. This is called as reverse transcription and it occurs during the life cycle of some RNA viruses. (e.g.,) Retroviruses.

The translation of RNA into protein is unidirectional and this process cannot be reversed.

2. Genetic code and protein synthesis.

The genetic code has 64 codons where in all except three codons code for amino acids.

Protein synthesis occurs in three different steps.

(i) Transcription
(ii) Translation
(iii) Post translational modification.

An overall view of the process of protein synthesis is given in Fig. 11.6.

Transcription

The process by which an enzyme system converts the genetic information of a segment of DNA or template DNA into an RNA strand with a base sequence complementary to one of the DNA strands is called as transcription. mRNA synthesized on DNA strands contain the message for amino acid sequence in protein synthesis.

RNA polymerase completes transcription in three stages namely

(i) Binding to promoters and chain initiation.

(ii) Elongation and

(iii) Termination.

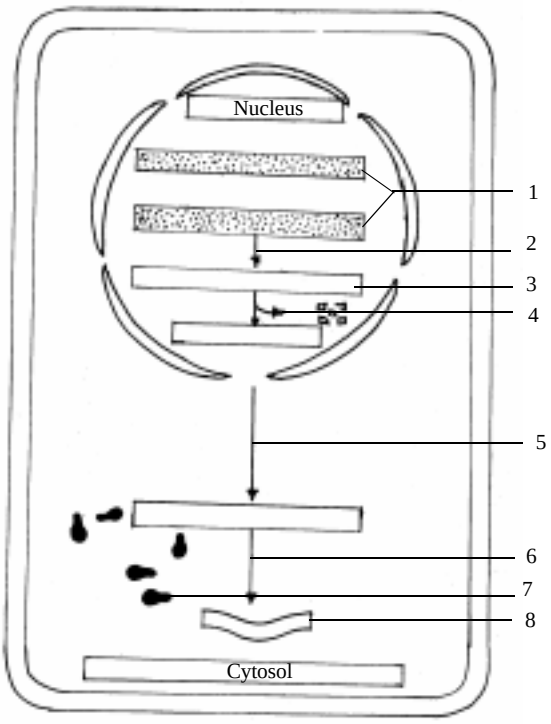


Fig. 11.6 Protein synthesis

1. DNA 2. Transcription 3. mRNA 4. mRNA processing 5. mRNA transport 6. Translation 7. Ribosome 8. Protein

During the first stage the RNA polymerase binds to specific sites on DNA. These regions are called as promoters. Then the polymerase initiates transcription. During elongation RNA polymerase copies the DNA sequence accurately. Elongation occurs in the $5' \rightarrow 3'$ direction. Termination of transcription occurs when the enzyme arrives at a stop signal in the DNA. A termination factor causes the release of completed RNA molecules.

In prokaryotes transcription and translation can occur simultaneously. In the case of eukaryotes, the mRNA produced is processed and sent to the cytoplasm for translation.

Translation :-

The process of tRNA molecules translating the nucleotide sequence of an mRNA into the amino acid sequence of a polypeptide is called translation. In the cytoplasm several ribosomes get attached to a single mRNA molecule. This forms a polyribosome or polysome. In this way a single mRNA molecule can be translated by several ribosomes at the same time. Initially the tRNA molecules get

covalently attached to amino acid molecules. This process is catalysed by amino-acyl tRNA synthetases. tRNA's attached to amino acids are referred to as 'charged tRNA's'. The actual process of translation begins when the initiating aminoacyl tRNA binds to the ribosome and base pairs with the mRNA codon, AUG. This process is promoted by initiation factors. The polypeptide chain then increases in length by covalent attachment of successive aminoacids to the first one. Thereby the elongation of polypeptide chain takes place. This process is promoted by elongation factors. The completion of the polypeptide chain is signalled by a termination codon (UAA, UGA, UAG) present in mRNA. Then the polypeptide chain is released from the ribosome with the help of release factors.

Post translational modifications :

For a protein to become biologically active it has to fold to its 3-dimensional configuration. Before and after folding, either additional proteolytic processing or modification of terminal amino residues or attachment of phosphate, methyl, carboxyl, carbohydrate or prosthetic group occurs. All the above processes are referred to as post-translational modifications.

11.4 MUTATION

1 Mutation

Gene and Chromosome

Definition : Mutation may be defined as a heritable change in a gene or chromosome or change in the number of the chromosome. Mutation may occur spontaneouly in nature (spontaneous mutation) or it may be induced by artificial agents (Induced mutations)

Gene Mutation : The changes that alter the structure of the gene at a molecular level is called Gene mutation. It is also called point mutation. i.e. permanent hertiable changes with in a gene.

Chromosome Mutation

The structural changes occuring in chromosomes which affect the phenotype of the organism are called **chromosomal mutations.**

2. Gene Reaction

Hugo de Vries

Hugo de Vries (1848 - 1935) of Netherlands was born in Haarlem in February 16, 1848, in Holland. de Vries was a professor in plant physiology at the University of Amsterdam in 1881. He gave 'mutation theory' on his observations on *Oenothera lamarkiana*. He noticed "gigas" a large size and "nanella" a dwarf mutant. The mutant "gigas" had 28 chromosomes instead of 14 which is present in parental form. It was a tetraploid mutant.

The mutations described by deVries in *Oenothera lamarckiana* is due to numerical and structural changes in chromosomes.

T. G. Dobzhansky

Theodosius Grigorievitch Dobzhansky was born in Nemirov, Russia on 25 January 1900. He began his scientific career by studying the variation in natural populations of a type of beetles in Europe and Asia. The morphological polymorphism of these beetles led him to reject the usual naming of separate races with geographical ranges. Dobzhansky suggested to determine what was responsible for maintaining the large amount of genetic polymorphism within populations.

T.H.Morgan :

T.H.Morgan (1910) started his work on fruitfly *Drosophila melanogaster*. He reported sudden appearance of white eyed males among red eyed male individuals. The gene for this character is located on X - chromosome and it express itself in male individuals. He was the first to report mutation in *Drosophila.*

3. Molecular basis of gene mutation

Mutation that occurs in the DNA molecule is called molecular gene mutation. This may be of different types :

Transition : - A purine base (A) is replaced by another purine base (G) or pyrimidine base (T) is substituted by another pyrimidine base (C). They occur due to (a) Deamination (b) Base Analogues.

(a) **Deamination :** Some chemicals like nitrous acid cause mutation due to deamination

of DNA bases. The amino group ($-NH_2$) of a DNA is replaced by a hydroxyl (–OH) group. Because of this Adenine instead of pairing with Thymine, pairs with Cytosine.

Adenine $\longrightarrow$ hypoxanthine, which pairs with cytosine

(b) **Base Analogues :** Analogue is a substance that corresponds to the normal DNA base in several characteristics. Because of this the normal base may be replaced by the analogue.

TYPES OF MUTATIONS

(1) **Spontaneous mutation :** It occurs naturally without any artificial induction. Spontaneous mutations arise from errors in DNA replication and spontaneous lesions. Natural exposure of an organism to certain environmental factors such as U-V light may bring about spontaneous mutation.

(2) **Induced mutation :** Mutations which are artifically induced with the help of mutagenic agents are called induced mutations.

(3) **Somatic mutation :** Mutations in somatic cell or non-reproductive cells are called somatic mutations e.g., Mole in humans, they are not transmitted to progeny

(4) **Germinal mutations :** Genes and chromosomes can mutate in reproductive tissues and these changes are called germinal mutations; they are transmitted to the progeny. e.g., X - linked haemophilia in the European royal families.

4. Induced Mutation

The mutations which can be induced artifically in the living organisms using physical or chemical agents are called induced mutations. Such agents are called mutagenic agents.

Mutagenic agents : They are of following types (I) Physical mutagens (II) Chemical mutagens

(i) Physical mutagens :

(1) Radiation : (i) Non-ionizing radiation such as U-V rays, (ii) Ionizing radiation x-rays, gamma rays, beta rays, protons, neutrons and alpha rays.

(ii) Chemical mutagens :

Many chemicals can be used for inducing mutations. C. Auerbach was the first to find that mutation can also be induced due to certain chemicals. She made this discovery during world war II. The chemicals used for inducing mutations were Ethyl methane sulphonate, caffeine, phenol, mustard gas etc.

5. Chromosomal aberrations

The structural changes which affect the phenotype of the organisms is called chromosomal aberration. The structural changes are (1) Deletions (2) Duplications (3) Inversions (4) Translocations.

(1) **Deletions :** It is a type of intrachromosomal aberration. Either terminal or intermediate portion may get deleted. Eg. Maize.

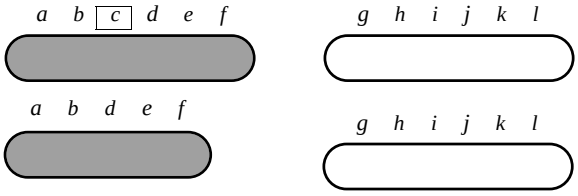


Fig. 11.7 Deletion

E.g., In human beings Cri-du-chat's syndrome. Deletion was in a segment of chromosome 5.

(2) Duplication : It is an intra-chromosomal aberration (within a chromosome). It occurs when a segment of the chromosome is represented 2 or more times in a chromosome of a homologous segment. e.g., Bar-eye in Drosophila:

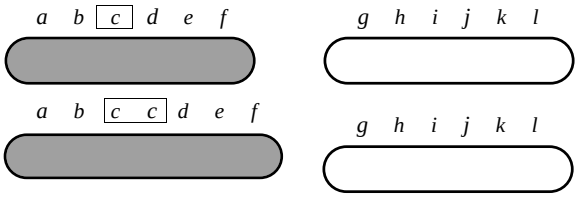


Fig. 11.8 Duplication

(3) Inversion : It is an intra - chromosomal aberration (within a chromosome)

when there are two breaks the intercalary segment is inverted to 180 degrees.

6. Evolutionary significance of mutation

The process of speciation is the most important significance of mutations. Artificial induction and selection of mutants increased a pool of variability to allow more rapid development in plants with desirable traits. Polyploidy results in the formation of new species. Thus mutations are responsible for evolution of new species.

7. Applied Mutation

Applied mutation is making use of mutation procedure to create improved varieties of plants and new strains of animals. New strains of microorganisms show enchanced yields or produce novel products. Beneficial mutations are used in modern agriculture or the industrial fermentation. Mutation breeding in India has been in progress. The establishment of Gamma garden of Bose Research Institute, Calcutta in 1959 & at IARI New Delhi 1960 has opened a new vista for crop improvement.

By the application of mutation techniques, new varieties with desirable qualities have been developed. e.g., Sharbati sonora in wheat, Barley varieties, etc.

Antibiotics Production : Increased yield of penicillin from *Penicillium* is possible by developing newer strains by mutation.

11.5. Genetic Engineering

Manipulation of genes : According to the definition given in Encyclopedia of science and technology Genetic Engineering is the manipulation of genetic material by either molecular biological techniques or by selective breeding. In genetic engineering the DNA molecule of an organism is broken at a desired place and the specific DNA segment is isolated. It is inserted into the DNA of a selected organism to modify it and to get the desired products. In recent years this technique is applied for the production of a newer varieties of substances which include polypeptides, insulin, interferon, growth hormones etc. It is also employed in the transfer of genes involved in Nitrogen fixation (Nif genes) and to control and cure certain genetic diseases. Manipulation of gene is nothing . but handling the genetic material skilfully by employing various techniques to have a desired combination of genes.

1. Tools Used in Genetic Engineering and Host-vector DNA enzymes

The biological tools used in the manipulation of genetic material (DNA) and cells are enzymes, foreign or passenger DNA, vector DNA, cDNA bank and gene bank, suitable host and vector.

1. Restriction Endonucleases : They cut both strands of DNA.
2. DNA Ligases : Ligases are employed for joining the broken DNA fragments.
3. Foreign DNA/Passenger DNA : It is a fragment of DNA molecule which is enzymatically isolated and cloned. The fragment is identified on a genome and pulled out from it.

Vectors are DNA molecules which carry foreign DNA fragment inserted into them. They are also known as vehicle DNA. They are bacterial plasmids, bacteriophages, cosmid and plasmid.

2. Mechanism of Genetic Engineering

The DNA molecule that is chosen is enzymatically fragmented or procured from cDNA or gene bank. The cDNA fragment is prepared using mRNA template. The insertion of a foreign DNA fragment into a vector is done. The mixture of recombinant DNA is taken up by the suitable bacterial cells. The transformed cells are plated onto nutrient medium. The transformed cell grows and give rise to colony. Such cells are isolated and subcultured. Desired new products are obtained from them.

3. Isolation, Cloning and Integration of Nif genes

Nif genes are that part of the genetic material of N_2 fixing bacteria responsible for

Nitrogen fixation. The biological conversion of molecular nitrogen to ammonia is known as biological nitrogen fixation. The ability to fix nitrogen is limited to cyanobacteria (= Blue

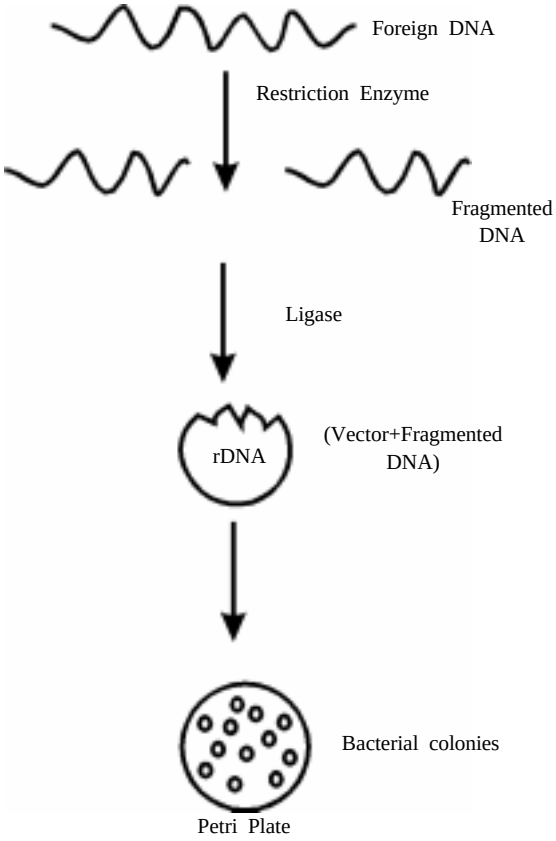


Fig. 11.9 Diagramatic Presentation of Genetic engineering technique

Green algae) and certain bacteria such as Rhizobium, Azotobacter, etc. The genes responsible for N_2 fixation are found in the bacterium Rhizobium. In many countries researches regarding transfer of nif genes into higher plants especially in monocots are carried out. In recent years researches are being carried out to transfer the N_2 fixing ability to plants through tissue culture technique combined with recombinant DNA technology. Since nif genes are prokaryotic in origin scientist are devising methods to transfer them into chloroplast because the chloroplast have several prokaryotic features.

4. Applications of Genetic Engineering

The applications of genetic engineering range from production of newer kinds proteins to engineered organisms. Large amounts of commercially useful proteins can be produced by these techniques. Microorganisms can be designed for special tasks. Plants or animals can be engineered to acquire novel characteristics that are useful in agriculture.

Genetically engineered bacteria are employed to clean up oil spills. Genetic engineering is also useful in developing pest-resistant crop plants. Production of human insulin, monoclonal antibodies of high specificity, human growth hormones used to treat children with hormonal deficiency, several interferons proteins used to treat viral infections and cancer, are also produced by the application of genetic engineering techniques.

11.6 Biotechnology

Biotechnology is defined as the applications of scientific and engineering principles for the processing and production of materials by living organisms. By the application of Biotechnology newer kinds of materials in large scale can be produced economically.

1. Scientific art of using micro organism

In Industrial fermentation processes microorganisms are employed to produce chemicals, proteins, growth hormones, antibiotics etc. A wide variety of microbes such as *Escherichia coli, Saccharomyces cerevisiae,* strains of *Bacilli* are employed.

Among different kinds of micro organisms E.coli is preferred mostly for the introduction of useful genes from some other organisms. By this method useful product can be obtained in large scale economically. The introduction of newer and useful genes from different organisms into a bacterial cell like E-coli is a scientific art. Now-a-days the biotechnologist have made such manipulation of genes as a scientific art. The advantages of employing E-coli are as follows.

(1) It has a well-defined genetic (DNA) system

(2) It can be genetically manipulated or modified easily.

(3) It has fast growth rate

(4) It has the capacity to produce the desired product in large scale in a short period of time economically.

2. Applications of Biotechnology in production industries

Scientists are engaged in the development of newer kinds of micro organisms containing genetic materials drawn from different types of organisms for the mass production of growth hormones, insulin, vaccines, immunogenic proteins and polypeptides. These organisms are also employed in gene therapy, production of biofertilisers, biopesticides, enzymes, antibiotics, organic acids, alcoholic beverages and producing resistant plants resistant to disease and stress. Scientists by using genetic engineering techniques perfected the scientific art of transferring genes from one organisms to another. In recent years revolution in biology has occurred due to developments in the field of biotechnology. Several techniques have been developed to produce a rare medicinally valued molecules, to change the characteristics of plants, animals, microbes, to diagnose diseases and clean up the polluted environment. Thus biotechnology has great impact in the fields of agriculture, health and environmental protection. Biotechnology in short is one of the most promising areas of economic growth.

3. Products of Biotechnology :

Different kinds of economically important materials are produced by the application of biotechnology there as follows :

Table 11.3 Products of Bio-technology

	Products	Uses
1.	Insulin	Therapeutic product.
2.	Somatotropin	Human growth hormone.
3.	Human Interferons	It is used to cure viral diseases such as common cold, hepatitis.
4.	Vaccines	Vaccines for hepatitis B virus, rabies virus, polio virus.
5.	Antibiotics	Cure human diseases caused by Bacteria, fungus & protozoa.
6.	Alcoholic Beverages	Wine, beer, rum, whiskey, sake.
7.	Organic acids	Acetic acid-food industry & research fumaric acid-resins citric acid and lactic acid.
8.	Vitamins	Vit B_{12} - medicine and feed supplements.
9.	Biofertilizers	Increases soil fertility add sufficient organic matter in soil.
10.	Enzymes	Therapeutic uses, Analytical uses, Industrial uses like dairy industry, detergent industry, starch industry.
11.	Monoclonal antibodies	Diagnostic tests cancer therapy.

4. Future Of Biotechnology

In developing countries like India biotechnology has bright prospects. Realizing the importance of Biotechnology, Government of India has set up in 1982 an offical agency "The National Biotechnology Board" (NBTB) which started fuctioning under the Department of Science and Technology (DST). In 1986, NBTB was upgraded into a full fledged department, the Department of Biotechnology (DBT), in the Ministry of science and Technology for planning, promotion and co-ordination of various biotechnological programmes. The United Nation Industrial Development Organisation (UNIDO) recognising the potential of biotechnology in the economic progress of developing countries has set up an agency called ICGEB throughout the world. The future economic prospects of any country is directly related to the progress made in the field of biotechnology only. At present, biotechnology has paved way for the transfer of genes between different organisms and utilising the genetically modified organisms of different kinds. Its beneficial uses as mentioned before. In the very near future the application of Biotechnological procedures will result in the development of efficient Biosensor,

Biochips and production of newer kinds of drugs or pharmaceutical products, chemicals, biofuels.

Some of the newer future products of Biotechnology.

Bio-sensor : It is a device consisting of immobilised layer of biological materials like enzyme, antibody, hormones, nucleic acids, organelles or whole cells and its contact with a sensor. The sensor converts biological signal into an electical signal. It is used is medicine & industry e.g., (1) Detections of blood glucose (2) Production of any toxin in body due to infection can be detected

It is also used in pollution control to monitor drinking water for pesticides. It is used to measure odour, freshness & taste of foods.

Biochips - Biochips are the microchips developed employing techniques of biotechnology. In future biological computers can be developed using biochips. The possible areas of uses of biochips include (i) Defence (ii) Medicine etc.

SELF-EVALUATION

Choose the correct answer

1. Which of the following is not a constituent of the chromosome ?
   (1) Nucleic acids (2) Histone proteins
   (3) Non-histone proteins (4) Pigments

2. The function of the nucleolar organizer regions is to
   (1) to code for proteins
   (2) to code for rRNA
   (3) to code for tRNA
   (4) to code for mRNA

3. Chromosome tips have unusual DNA structure. These are called as
   (1) Centromeres
   (2) Satellites
   (3) Telomeres
   (4) Nucleolar organizers

4. Which of the following is not a stop codon?
   (1) UAA (2) UAG
   (3) UAC (4) UGA

5. Eukaryotes contain all the following types of rRNA except
   (1) 16S rRNA (2) 18S rRNA
   (3) 28S rRNA (4) 5.8S rRNA

6. The semiconservative model of DNA replication was verified by
   (1) Watson and Crick
   (2) Meselson and Stahl
   (3) Chargaff
   (4) E.G. Balbiani.

7. Which of the following is not needed for DNA replication ?
   (1) Deoxyribonucleoside triphosphates
   (2) DNA polymerases
   (3) RNA primer
   (4) tRNA.

8. Which of the following factors is not involved in translation ?
   (1) Initiation factors.
   (2) Elongation factors.
   (3) Release factors
   (4) Promoters.

9. Mutations which occurs in nature
   (1) Induced mutations
   (2) Spontaneous mutations
   (3) Morphological mutations
   (4) Lethal mutations

10. Chromosome lacks a chromosomal segment
    (1) Duplications
    (2) Deletions
    (3) Inversions
    (4) Translocation

11. Bacteriophage is a
    (1) Bacterium (2) Virus
    (3) Protozoa (4) Fungus

12. Insulin is a
    (1) Human growth hormone
    (2) Therapeutic product
    (3) Vaccine
    (4) Organic acid

13. Monoclonal antibodies
    (1) Enzymes
    (2) Diagnostic tests in cancer Therapy
    (3) Biofertilizer
    (4) Antibiotics

Fill in the blanks

14. Accessory chromosomes are also called as ..... or .....
15. The salivary gland cells of dipteran larva contain ..... chromosomes.
16. Animal oocytes contain lampbrush chromosomes at ..... of meiosis.
17. Messenger RNA constitutes ..... of the total RNA content
18. In the lagging strand synthesis is in the form of short segments of DNA called as .....
19. In bacteria ..... type of mRNA is seen.
20. The central dogma of molecular biology was given by ..... .
21. The genetic code has ..... codons.
22. The reaction of covalent attachment of amino acid molecules to tRNA's is catalysed by ..... .
23. The process of ..... is the most important significance of mutations.
24. ..... are employed for joining the broken DNA frogments.

Answer Briefly

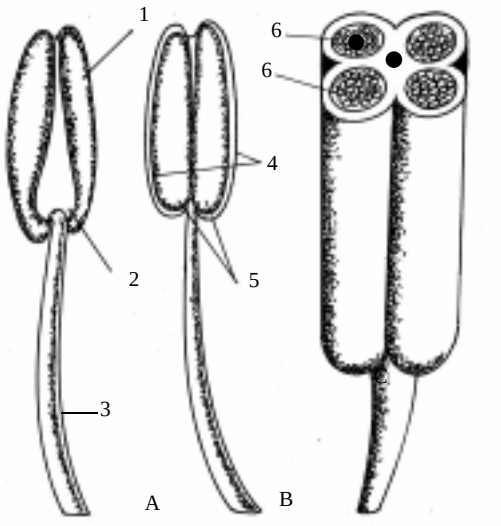
25. List the different types of chromosomes which are classified based on the position of the centromere.
26. Write short notes on lampbrush chromosomes.
27. Briefly explain the term karyotype.
28. What is template DNA ?
29. Mention the different variants of DNA.
30. Briefly explain 'cloverleaf' structure of tRNA.
31. What is meant by degeneracy of genetic code ?
32. Briefly explain the central dogma of molecular biology.
33. Explain the process of post transcriptional modification briefly.
34. What is mutation ?
35. What are the types of mutation ?
36. What is genetic engineering ?
37. Define Biotechnology.
38. Write briefly about the scientific art of using microorganisms.

Answer in Detail

39. Explain the structure of a chromosome in detail with the help of a diagram.
40. What is a genome ? Add a note on its nature of complexity in different organisms.
41. Explain in detail how chromosomes are classified based on the number of centromeres.
42. What is a gene ? Explain briefly its function.
43. Write short notes on ribosomal RNA and add a note on its function.
44. Explain Watson and Crick model of DNA with the help of a diagram.
45. Write short notes on mRNA.
46. Explain the process transcription in detail.
47. Explain the process of protein synthesis in detail using a diagram.
48. Explain chromosomal aberrations in detail.
49. What are the tools used in genetic engineering?
50. Write about the applications of Biotechnology in production industries.

12. REPRODUCTIVE BIOLOGY

Reproduction is a special biological process. It is a process by which new individuals of the same species are produced by existing organisms. Flower is the reproductive part in higher plants. Majority of plants are bisexual i.e., both male and female reproductive parts are present in the same flower. Generally, each flower is made up of calyx, corolla, androecium and gynoecium. Androecium and gynoecium constitute the male and female reproductive parts respectively. Androecium is made up of stamens. Each stamen has a filament ending with two anther lobes. Anther lobes are connected by means of a tissue called connective tissue. Fig. (12.1) The anthers produce pollen grains. A mature pollen grain consists of two cells, known as



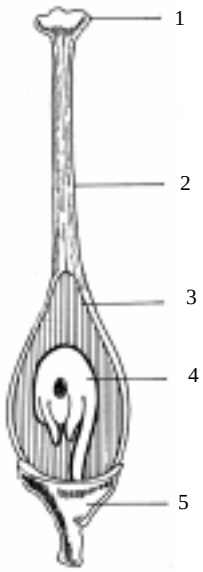
12.1 STAMEN AND ITS PARTS

A. Dorsal View B. Ventral View
C. Enlarged portion showing T.S. of Anther.

1. Anther 2. Connective 3. Filament
4. Suture 5. Anther Lobes 6. Pollen Chamber

vegetative and generative cells. The generative cell ultimately forms two gametes.

Gynoecium consists of a swollen ovary at the base, an elongated style and a terminal



12.2 GYNOECIUM

1. Stigma 2. Style 3. Ovary 4. Ovule
5. Thalamus

stigma (Fig. 12.2). The ovary contains ovules. Each ovule has an egg which is the female gamete.

12.1 Pollination and Fertilization

Transfer of pollen grains from anther to stigma is called pollination. Pollen grains are transferred mainly by wind, water, and insects. These are called pollinating agents.

Pollination is an important and first event in the development of the fruit and seed. Pollination is followed by fertilization.

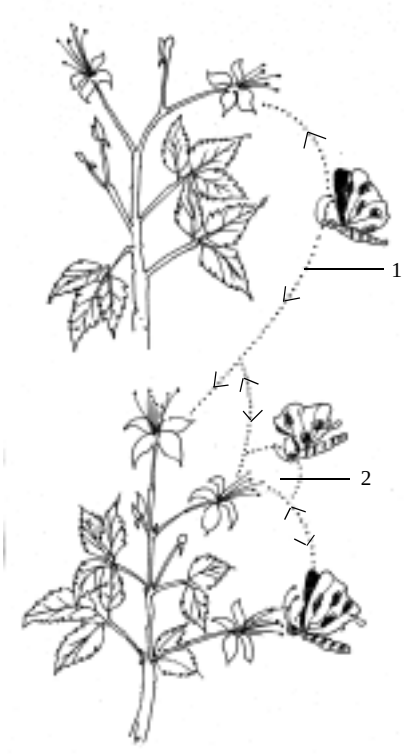
1. Types of Pollination

Pollination is of two types. They are (i) Self pollination : (ii) Cross pollination

(i) Self pollination : Self pollination is also known as autogamy. The transfer of pollen grains from the anther of a flower to the

stigma of the same flower or another flower of the same plant is known as self pollination.

(ii) Cross pollination : The deposition of pollen grains of a flower to the stigma of another flower of a different plant of the same species is cross pollination or allogamy. (Fig. 12.3).



12.3 SELF AND CROSS POLLINATION

1. Cross Pollination 2. Self Pollination

Advantages of cross pollination :

Cross pollination is more advantageous to plants. Unisexual flowers are cross pollinated. In majority of bisexual flowers cross pollination occurs commonly than self-pollination. The seeds produced as a result of cross pollination develop, germinate properly and grow into better plants. i.e., cross pollination leads to the production of new varieties. These varieties have greater adaptability to new environments. In order to bring about cross pollination it is necessary that the pollen should be carried from one flower to another on a different plant. This takes place through the agency of animals, wind and water.

2. Contrivances for cross pollination

As cross pollination is more advantageous, majority of plants have adaptations to promote and ensure cross pollination. These adaptations are as follows :

1) Dicliny or Unisexuality

Self pollination is possible only when the flower is bisexual. By the development of unisexual flowers, self pollination is rendered impossible. Plants with unisexual flowers are always cross pollinated plants (e.g.,) *Palmyra, Pumpkin, Cucurbita, Sunflower* (ray floret).

2) Dichogamy or Maturity of anther and gynoecium at different times

In bisexual flowers, it is only when anthers and stigma mature at the same time self-pollination is possible. But in *Helianthus, Leucas, Oxalis* and *Hibiscus* the anther matures earlier than the stigma, and it is known as protandry. In *Sorghum, Triticum, Oryza* and *Ficus* it is the stigma that matures first ; anthers mature after sometime. This condition is called protogyny.

3) Self-sterility

In some plants such as *Abutilon* and *Passiflora*, the pollen has no effect on the stigma of the same flower. On the other hand if the pollen falls on the stigma of an altogether different flower, it will germinate. This condition is known as self-sterility.

4) Pollen - pre-potency

The pollen of a plant is more effective and germinates more readily when deposited on the stigma of a flower of different individual (same species). This condition is common in several leguminous plants.

5) Herkogamy

In many bisexual flowers, self-pollination is prevented because of the position of the anthers and stigma to each other. The stigma may project far beyond the anthers or anthers may be placed just above the non-receptive part of the stigma. In such cases the stigma

Fig. 12.4 Herkogamy - Vihca-rosea

is sticky and receptive only on the lower side as in *Vinca rosea.* (= *Catharanthus roseus*) (Fig. 12.4)

6) Heterostyly

In some plants like *Oxalis* and *Jasminum*, some flowers have short styles and long stamens, while the others have long styles and short stamens. (Fig. 12.5)

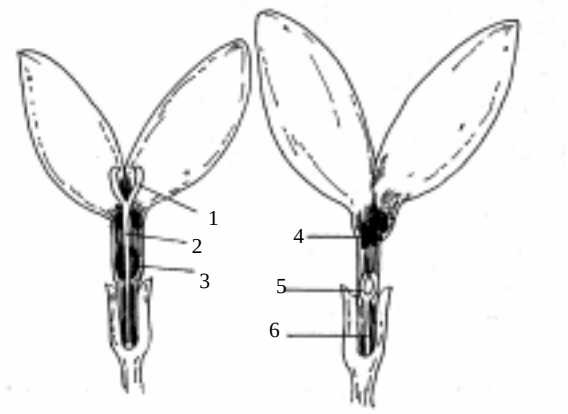


Fig. 12.5 Heterostyly. Left long style flower, Right short style flower

1. Stigma 2. Style 3. Anther
4. Anther 5. Stigma 6. Style

You have already studied that flower is the reproductive organ in a plant. Recollect the parts of a flower. In sexual reproduction androecium and gynoecium are involved. Androecium which is a male reproductive structure consists of stamens. Each stamens has a sac like structure known as anther. The anther is also known as microsporangium.

Gynoecium

The gynoecium is the female reproductive structure. It is made up of carpels. The gynoecium is usually differentiated in to stigma, style and ovary. The ovary is a sac like structure containing ovules.

Ovule. (Megasporangium)

Ovule is otherwise known as megasporangium. The ovary contains ovules. They are attached to a tissue called placenta by a small stalk known as funicle. Ovule is provided with two protective coverings known as integuments. Integuments leave a small opening at the top of the ovule known as micropyle. The young ovule contains the embryosac. (Fig 12.6).

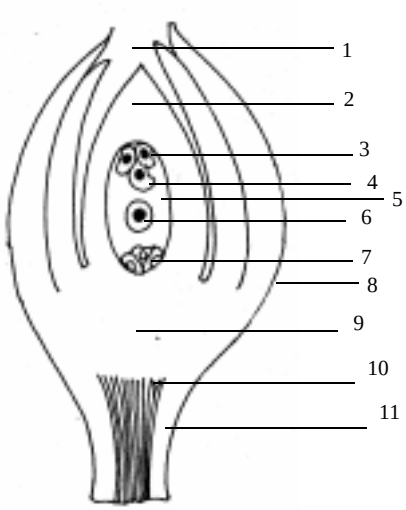


Fig. 12.6 Ovule L.S

1. Micropyle 2. Nucellus 3. Synergids 4. Egg
5. Embryosac 6. Secondary Nucleus 7. Antipodal cells
8. Integuments 9. Chalaza 10. Vascular Bundle 11. Funicle

3. Fertilization

Definition : Recollect what you have studied about pollination. It is the transfer of pollen grains from the anther to the stigma.

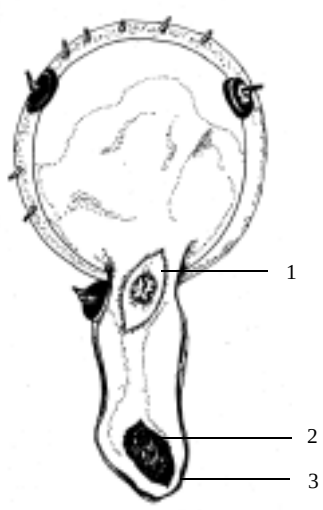


Fig. 12.7 Intine coming out through a germpore as a pollentube

1. Generative cell 2. Tube or vegetative nucleus
3. Pollen tube

Each pollen grain has protective walls called exine and intine. The outer wall exine is thick and it has small pores called germination pores. The inner wall is thin and elastic. If pollen grain falls on a suitable stigma, it starts germinating. Fig. 12.7 (pollen germination). A mature pollen consists of two cells. The larger one is the vegetative cell and the smaller is generative cell. The vegetative cell starts growing and emerges out through the germination pore. It develops through the style as a long tube known as pollen tube. The generative cell gets into the tube and divides into two male gametes. The pollen tube enters into the embryo sac through micropyle. (Fig 12.8) At this time the pollen tube bursts open; gametes released from the pollen tube enter into the embryo sac. One of the gametes fuses with the egg and other fuses with the secondary nucleus. The fusion of a male gamete with egg is known as fertilization. The fertilized egg is known as zygote which develops into embryo.

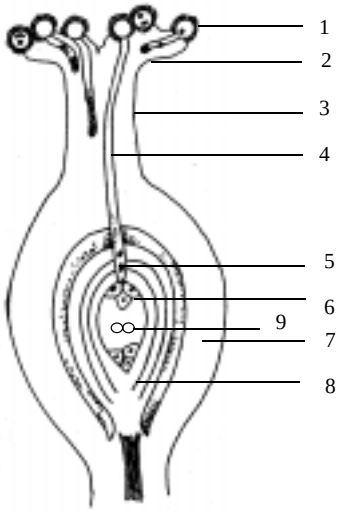


Fig. 12.8 Diagram of pistil, showing pollination and fertilisation

1. Pollengrain 2. Stigma 3. Style 4. Polle tube
5. Male gametes 6. Embryo sac 7. Ovary 8. Ovule
9. Secondary nucleus

4. Double Fertilization

The other gamete fuses with the secondary nucleus. This was first observed in 1898 by Nawschin in *Lilium* plant. The secondary nucleus is diploid in nature. So the fusion of this nucleus with the second male gamete is known as triple fusion. The triple fusion nucleus is called endosperm nucleus because it develops in to endosperm. Endosperm is a nutritive tissue meant for the development of the embryo. The process of fusion of a male gamete with egg and the other gamete with secondary nucleus is known as double fertilisation.

5. Post Fertilization Changes in a flower

After fertilization the ovule develops in to seed. The integuments of the ovule develop in to seed coat. In the meantime, the ovary enlarges and develops in to fruit.

12.2. DISPERSAL OF FRUITS AND SEEDS

Generally plants produce numerous fruits and seeds. If they fall and germinate under the mother plant there will be struggle for nutrients, water, oxygen and sunlight due to over crowding. Soon the nutrients of the soil may get depleted, due to competition. It will be advantageous if the seeds are widely distributed. There will be a greater chance for the survival of the species. Hence it is necessary that the seeds and fruits should be distributed widely. Such distribution is known as dispersal.

1. Agents of Dispersal and Adaptation

Indehiscent fruits, as such, are dispersed in nature. In plants such as paddy it is difficult to distinguish fruit from seed. Many fruits are one seeded; in such cases fruits and seeds are dispersed as a unit. In the case of dehiscent fruits, the seeds become exposed and dispersed.

In majority of plants the seeds and fruits have structural modifications, which are helpful in dispersing them over greater distance. Several kinds of agents are involved in dispersal of fruits and seeds. These include wind, water and animals (birds, insects and mammals including man).

(1) Dispersal of Fruits and Seeds by Wind

Wind dispersed fruits and seeds are light and small. The have adaptive features to suit wind dispersal. This is effected in various ways.

Wings are outgrowths of seed coat (or) modifications of floral parts and fruit wall. Wings are flat, thin, lateral expansions, found either on the fruit or the seed winged fruits are produced by *Shorea, Pterocarpus, Hiptage, Ventilago* and *Pterolobium*. Fig. 12.9

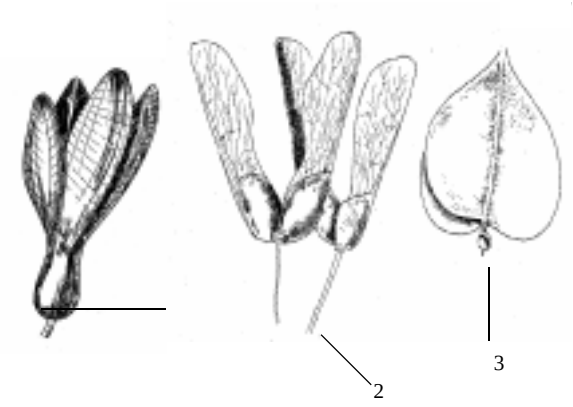


Fig. 12.9 WINGS FOR DISPERSAL

1. Shorea robusta (Calyx becomes wings)
2. Acer (Pericarp)
3. Dioscorea

In *Calycopteris, Gyrocarpus, Dipterocarpus* the wings are developed from the persistent perianth;

Hairs on seeds & fruits Parachute mechanism

Seeds having tufts of hairs are known as comose seeds and these are found in plants such as *Calotropis*, and *Wrightia*. In *Gossypium*

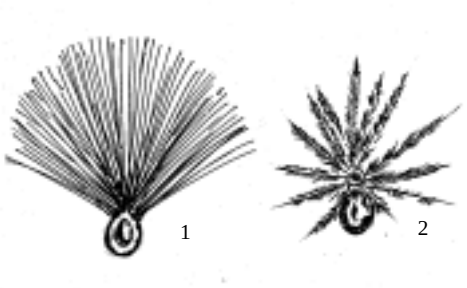


Fig. 12.10 TUFTED SEEDS AND FRUIT

1. Calotropis (Seed) 2. Tridax (Fruit)

(cotton), however the hairs completely cover the seeds. In *Tridax*, and *Vernonia*, a tuft of hairs is found on the top of the fruit; these hairs are developed from the persistent calyx and constitute the pappus. These are feathery and function like a parachute. (Fig. 12.10)

Smallness : Orchids seed are very small, dry dusty and light. These seeds as in the case of pollen, are carried by wind. Seeds of *Cinchona* are also extremely small and at the same time they are winged.

(2) Dispersal by Water

The role of water in the dispersal of fruits and seeds almost as important as that of wind. Seeds and fruits, large or small are carried over short distances by rain; characteristics useful in dispersal by water include weightlessness and salt resistance. They are also waterproof in nature.

Seeds and fruits of some plants are adapted to dispersal by water. For this, they must be able to float upon the water and the seeds must be well protected. In many cases the fruitwall contains considerable amount of air so that the fruits float easily and they are

carried to considerable distances by rivers and ocean currents.

The coconut palm grows especially along the coast of tropical seas. Its fruit is a large drupe, which has fibrous air filled mesocarp around the hard endocarp. (Fig. 12.11)

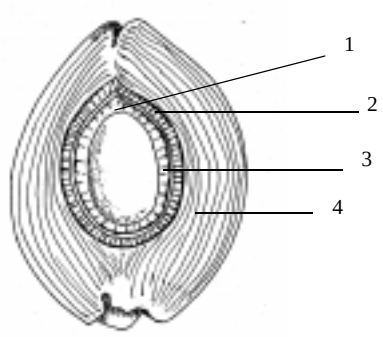


Fig. 12.11 COCONUT FRUIT

1. Embryo 2. Endocarp 3. Endosperm 4. Fibrous mesocarp

The fruit floats due to the fibrous mesocarp . The dry fruits of *Thespesia* and *Casuarina* are very light and float freely. In waterlily the seeds are provided with a spongy aril and in Lotus the thalamus containing the seeds is dry and gets detached and floats in water.

(3) Dispersal of Fruits and Seeds by Animals

Dispersal of seeds and fruits by animals is a very effective method of dispersal. Dispersal by animals takes place in many ways. In some cases the fruits are provided with spines and hooks. When animals brush against the plants the fruits cling to their bodies and are thus carried and dispersed at various places.

In *Martynia* two hooks are found on each fruit (Fig.12.12) *Achyranthus* fruits have persistent perianth which is sharp at the tip.

The fruit of *Xanthium* is provided with small hook like structures, (fig 12.12) and the fruit of *Tribulus* has sharp spikes on them which help their dispersal. In some plants seeds have some resemblance of insects. Because of this, birds mistake seeds for insects and carry them away e.g. *Abrus, Ricinus.* In *Abrus* the seed is of bright scarlet colour with a black patch. In *Ricinus* the seed coat is dark purple and is mottled with white patches. It is also

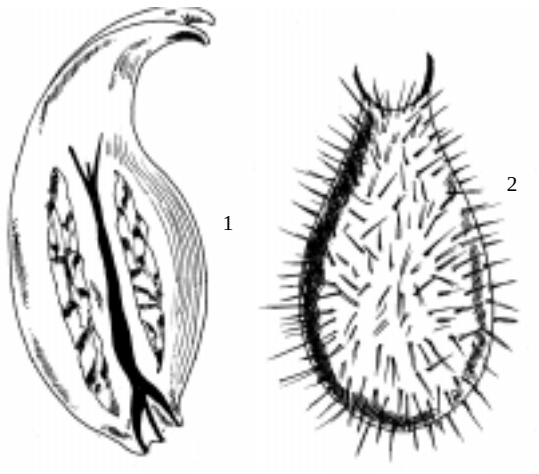


Fig. 12.12 Hooked Fruit (Martynia) Barbed Fruit (Xanthium)

provided with a caruncle so that from distance the seed looks like a small beetle. Many fleshy, succulent fruits are edible. Birds and other animals eat the fleshy portion and drop the seeds in various places. In many cases, when fruits are eaten the seeds pass through the alimentary canal without injury. These seeds come out mixed in the excreta. In this manner,

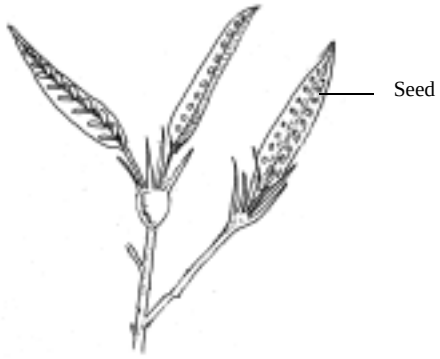


Fig. 12.13 Explosive mechanism *(Ruellia)*

seeds are dispersed through animal excreta far away from the place of their origin. Numerous herbivorous animal like birds, bats, squirrels, monkeys etc are responsible for such dispersal. Various economically important plants are distributed, all over the world by human beings. In Banyan, the birds swallow the fruits and seeds are thrown out in the excreta.

(4) Mechanical Dispersal :

In certain capsular fruits when they dry up the pericarp splits open into two valves with a sudden explosive force. Seeds are shot out to some distances. (e.g.) *Ruellia, Balsam* and *Crossandra.*

In legumes like *Clitoria,* after the fruit dehisces into two halves and coil round spirally, the seeds are ejected.

Activity : Collect different types of seeds and fruits that are dispersed by wind, water and animals from your area.

12.2(a) GERMINATION

In all seeds you can see a small tiny plant called embryo. The embryo is in a dormant state. When favourable conditions available the embryo becomes active and starts growing. (i.e) germination of the seed starts. Germination is resumption of growth of embryo into a young plant. It is completed with the appearance of the radicle outside the seed coat. All the changes that take place from the time the seed is put in the soil under favourable conditions to the time a young plant is developed, are included under the term germination. It is really the awakening in to activity of the dormant embryo (miniature plant) found inside the seed.

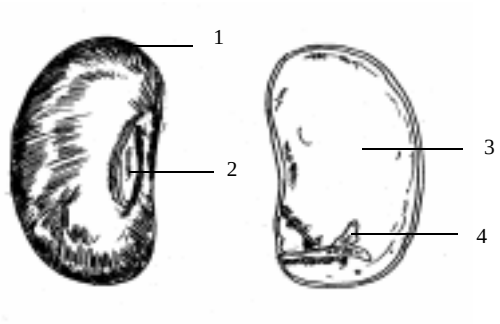


Fig. 12.14 PARTS OF BEAN SEED

1. Seed Coat 2. Raphe 3. Cotyledon 4. Embryo

(1) Structure of Bean Seed

The seed is bulky, oval and slightly indented on one side. On this side there is a short longitudinal, whitish ridge called the raphe. At one end of the raphe there is a minute opening known as germpore. If a water soaked seed is pressed gently, a small drop of water along with air bubbles, will be found coming out through the micropyle.

The embryo is enclosed by the seed coat. It consists of cotyledons attached to the primary axis. There is no endosperm. The primary axis has a rudimentary root portion called the radicle and a rudimentary stem portion known as plumule. The tip of the radicle projects outside and is nearer to the micropyle. The plumule is placed between the two cotyledons and consists of a short axis,

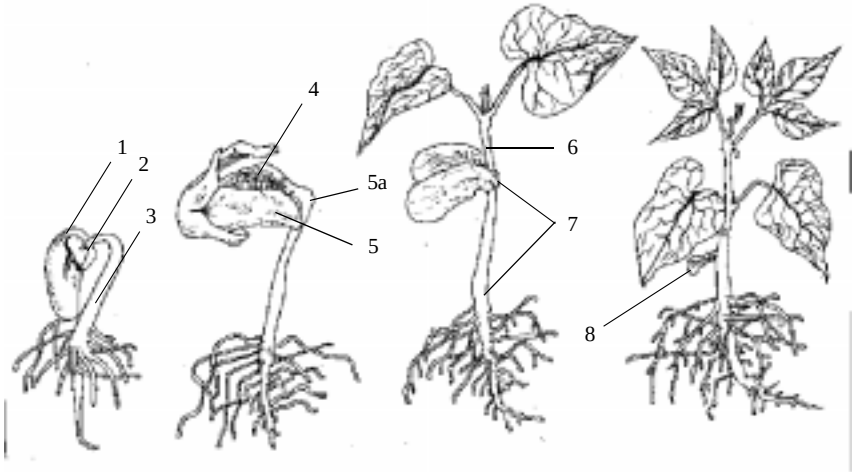


Fig. 12.15 STAGES IN THE GERMINATION OF THE COMMON BEANS

1. Seed coat 2. Cotyledons 3. hypocotyl 4. Foliaga Leaf 5. Cotyledons
5a. Epicotyl 6. Epicotyl 7. Hypocotyl 8. Withered cotyledon

and small bud having two tiny little folded leaves. Fig: 12.14.

(2) Germination of Bean

The first sign of the germination is the swelling up of the seed due to the imbibition of water by the seed, particularly through the micropyle. The dormant embryo in the seed becomes active as soon as it comes in contact with water. The radicle absorbs water and it begins to elongate. This exert pressure on the seed coat and as a result the seed coat ruptures close to the micropyle. Through this slit the radicle grows out of the seed. Radicle is the first part to come out in the germinating seed. It is positively geotropic and in whatever position the seed is placed, the radicle always grows down, and develops in to primary root.

In the early stages of germination, the plumule remains between the two cotyledons enclosed by the seed coat. The upper portion of the radicle, which is immediately below the point of attachment of the cotyledons, is known as the hypocotyl. After the root has entered into the soil, the hypocotyl begins to elongate and enlarge. This results in the bringing out of the cotyledons above the soil. Because of this, germination is called epigeal germinitation. The two coyledons are pulled out of the seed coat and brought above the soil. The plumule is well protected since it is placed between the cotylendons. After coming out of the soil, the two cotyledons unfold, spread out on either side and they become green. The plumule now elongates, it draws the nourishment from the cotyledons. As the plumule develops, the cotyledons become thinner and finally drop off. By this time the plumule has grown well and the two leaves at the tip expands. Rootlets develop from the primary root and the seedling is well established in the soil. The radicle develop primary root. Other examples are Tamarind, *Erythrina* etc.,

(3) Paddy-Monocot Seed Germination

In paddy, the so called seed is actually a fruit. It is a simple indehiscent one seeded fruit known as caryopsis. The seed coat is very thin. The fruit wall (pericarp) is thin and fused with the seed coat. The fruit is covered by generally yellowish bract and bracteoles which are commonly known as chaff. The embryo consists of single cotyledon called scutellum and a short axis. The lower part of the axis is the radicle, covered by a sheath called coleorhiza (root sheath). The upper part is known as plumule which is covered by a sheath called coleoptile. In a day or two, after

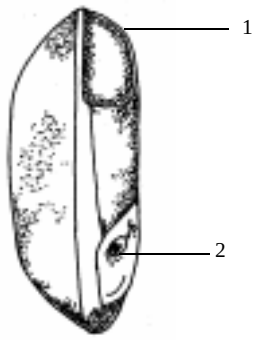


Fig. 12.16. STRUCTURE OF PADDY SEED

1. Seed Coat 2. Embryo

the seed is placed in a moist soil, the coleorhiza pierces the base of the seed. The radicle comes out next after splitting coleorhiza. The radicle does not form the root system. Meanwhile, roots are formed from the from lower most nodes of the stem. These roots are called adventious roots. These adventitious roots form fibrous root system of mature plant.

During germination the cotyledon does not come out of soil. Hence it is known as hypogeal germination. (Fig. 12.17)

12.3 GAMETOGENESIS

The first stage in sexual reproduction of animals is gametogenesis. During gametogenesis, certain cells of the gonads are transformed into specialized cells namely the eggs or ova in female and the spermatozoa or sperm in male.

1. Testis - Spermatogenesis

The development of spermatozoa takes place in the male gonads, the testis, which are

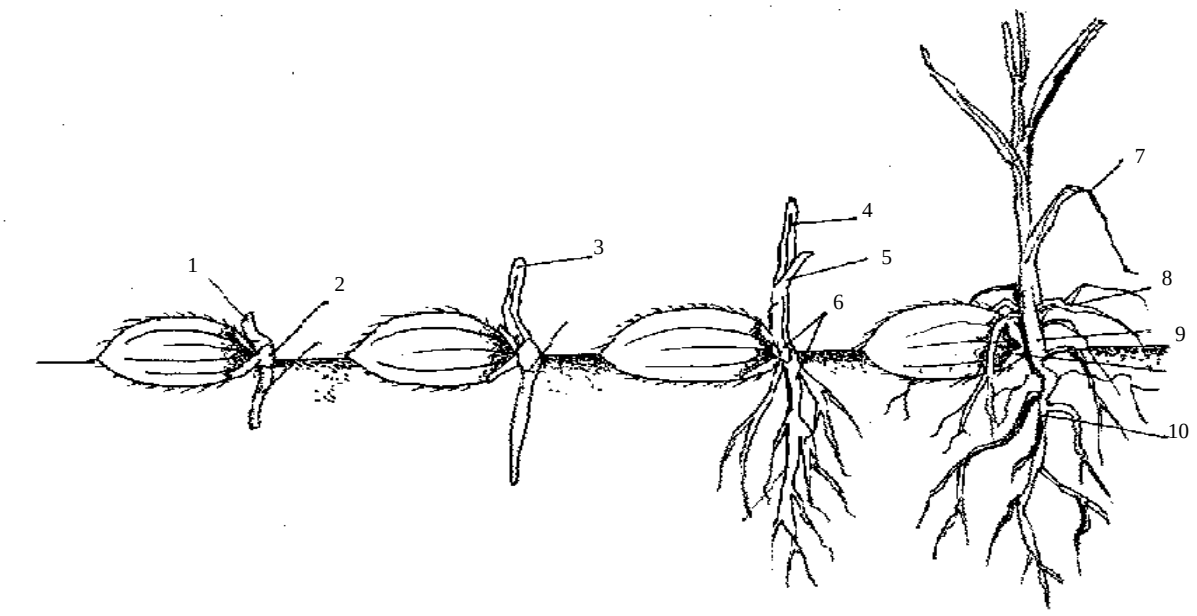


Fig. 12.17 MONOCOTYLEDONOUS SEEDS PADDY-SEED GERMINATION

1. Coleoptile 2. Coleorhiza 3. Coleoptile 4. Plumule 5. Coleoptile 6. Seminal roots
7. Coleoptile 8. Adventitious roots 9. Mesocotyl 10. Roots

paired structures in most vertebrates. The testis are composed of many seminiferous tubules, which are separated by interstitial cells or Leydig cells. The leydig cells secrete male sex hormones called androgens. The lining of the

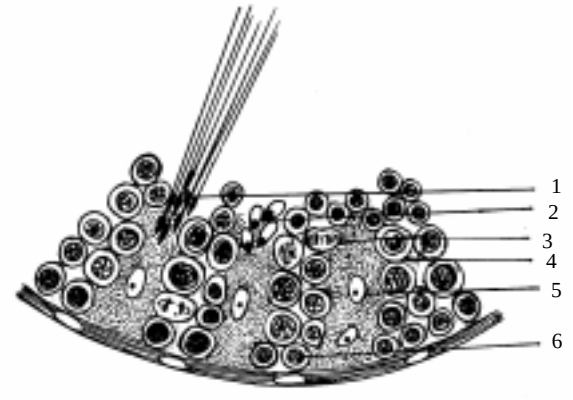


Fig. 12.18 A part of the mammalian testis showing various parts.

1. Spermatoza 2. Spermatid 3. 2nd Meiotic Division
4. Spermatocyte 5. Sertoli cells 6. Spermatogonium

seminiferous tubules constitutes the seminiferous epithelium and it contains cells called sertoli cells and the germ cells. The germ cells are transformed into spermatozoa by a process called spermatogenesis.

The cells of germinal epithelium which produce the spermatozoa are called primary germinal cells or primordial germ cells. The primordial germ cells undergo the 3 phases. namely - multiplication- growth- maturation.

2. Multiplication phase

An undiffentiated germ cell or primordial germ cell contains a large sized chromatin rich nucleus. It divides by repeated mitotic cell divisions and produces the sperm mother cell or spermatogonia. (Gr. Sperma-sperm or seed; gone - offspring). The spermatogonia are diploid cells.

(1) Growth phase

The second stage in spermatogenesis, is growth period, characterized by the cessation of cell division and transformation of the spermatogonia into primary spermatocytes. A limited growth of spermatogonia takes place, so that their volume become double.

(2) Maturation phase

The growth period is followed by the maturation period during which the diploid primary spermatocytes are reduced to haploids. The primary spermatocytes undergo the first and second meiotic divisions. The first meiotic

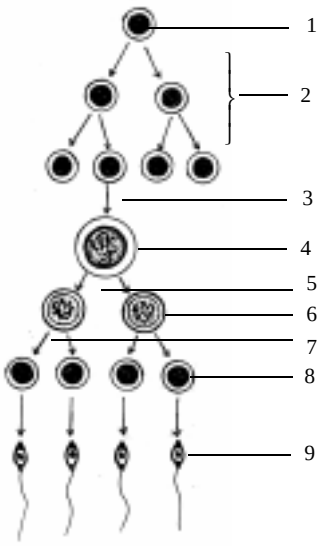


Fig. 12.19 Spermatogenesis

1. Spermatogonium 2. Mitosis 3. Growth phase
4. Primary Spermatocyte 5. I Meiotic Division
6. Secondary Spermatocyte 7. II Meiotic Division
8. Spermatid 9. Spermatozoa

division results in two secondary spermatocytes which inturn undergoes second meiotic division. Thus a single primary spermotocyte produces four spermatids of equal size.

(3) Spermiogenesis

These spermatids undergo a process of differentiation called spermiogenesis. The series of changes resulting in the transformation of spermatids into spermatozoa is known as spermiogenesis. These include.

1. formation of the acrosome

2. condensation of the nucleus

3. concentration of mitochondria around the axial filament in the middle piece

4. shedding of most of the cytoplasm.

In human, the time required for a spermatogonium to develop into a mature spermatozoon is approximately 64 days.

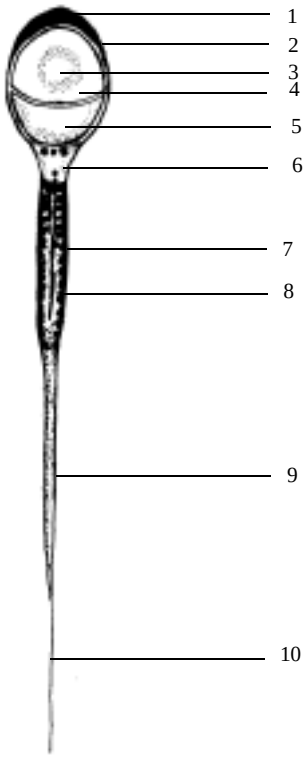


Fig. 12.20 Human Spermatozoon

1. Acrosome
2. Surface membrane
3. Vacuole
4. Anterior Head Cap
5. Posterior Head Cap
6. Neck
7. Body
8. Mitochondria
9. Chief Piece of Tail
10. End Piece of Tail.

(4) Structure of Sperm

Structure of spermatozoon (sperm)

The spermatozoon is 60 μ long and consists of head, neck, body and tail. Head is oval shaped and formed by a condensed nucleus, thin cytoplasm and cell membrane. Acrosome which is made up of mucopolysaccharide and acid phosphotase is present at the anterior end and consists of hyaluronidase. The head is connected by a short neck which consists of centriole from which the axial filament of body starts. The body is cylindrical and along with the axial filament, is surrounded by a closely wound spiral filament of mitochondria. The tail consists of the chief piece and the end piece.

3. Ovary

The ovary is the female gonad. In human female they are bean shaped, about 40 mm long supported in the backpart of the abdominal cavity by mesenteries. The outer layer of each ovary is the germinal epithelium, from which the eggs develop.

4. Oogenesis

The Oogenesis or manufacturing of female gametes, the ova or eggs occurs in the ovaries. The oogenesis results in four unequal haploid cells. In addition, the egg acquires the reserve food material which would be later utilized by the embryo. The cells of the germinal epithelium or primordial germ cells undergo the process of oogenesis and this

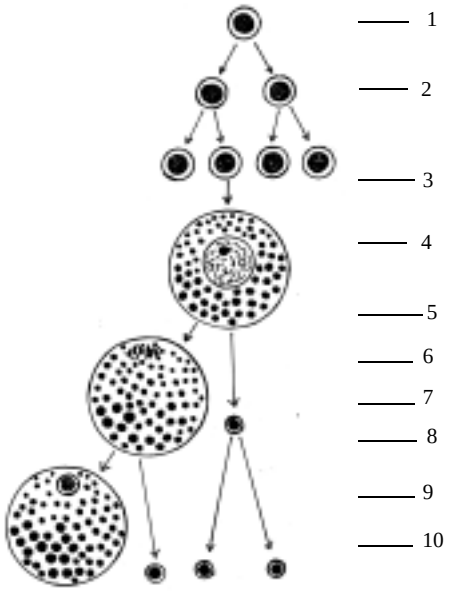


Fig. 12.21 Oogenesis

1. Oogonium 2. Mitosis 3. Growth phase 4. Primary oocyte 5. I Mieotic division 6. Secondary oocyte 7. 1st Polar body 8. II Meiotic division 9. Ootid

includes (i) - multiplication phase (ii) - growth phase (iii) - maturation phase

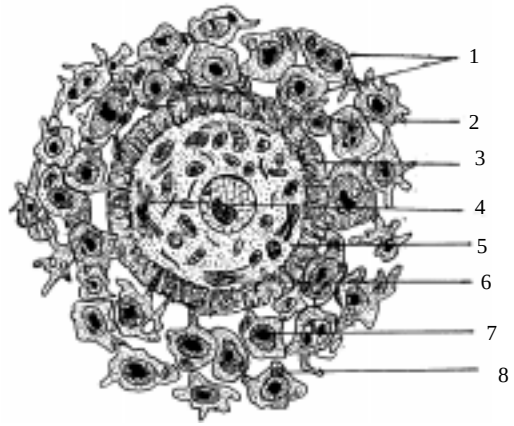


Fig. 12.22 Young Oocyte Of Mammal

1. Follicle cells 2. Zona pellucida 3. Microvilli 4. Golgi complex 5. Oocyte 6. Desmosome 7. Nucleus 8. Mitochondria

Multiplication phase : Mitotic division takes place in the ovary and oogonia are formed from primordial germ cells.

Growth period is characterized by the cessation of cell division and transformation of the oogonia into primary oocytes accompanied by the accumulation of yolk material.

The growth period is followed by the maturation period, during which the primary oocyte undergoes the first meiotic division and produce a secondary oocyte almost as large as the primary oocyte and a very small first polarbody. The chromosome content of these two cells are the same. In the second meiotic division, the secondary oocyte produces a large sized ootid and a small second polar body. At the sametime the first polar body also undergoes division. Thus from a single primary oocyte four cells are produced i.e., a large ootid, which develop into egg or ovum and three small polar bodies. The latter play no further role in development.

(1) Menstrual Cycle

The cyclic events that takes place in a rhythmic fashion during the reproductive period of a woman's life is called menstrual cycle.

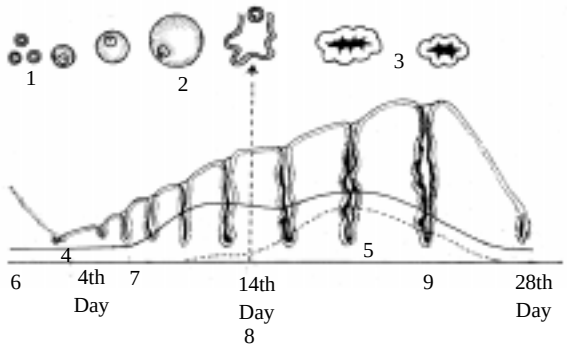


Fig. 12.23 Uterine Changes at Menstrual Cycle

1. Growing follicle 2. Graafian follicle 3. Coropus Luteum 4. Blood Estrogen 5. Blood progesterone 6. Menstrual phase 7. Follicular phase 8. Ovulatory sphase 9. Luteal phase

The menstrual cycle starts at the age of 13 - 15 years which marks the onset of puberty. The menstrual cycle is marked by periods of bleeding, known as menstruation, which occur about every 28 days and lasts about four days.

The menstrual flow consists of pieces of ruptured uterine lining and blood from its vessels.

The changes in ovary occur in two phases during each menstrual cycle. (i) Follicular phase (ii) Luteal phase

(i) Follicular phase (Proliferative phase) : This extend from the 5th day of the cycle till the time of ovulation which takes place at about 14 days. During this phase, the primordial follicle of the ovary develops into a graafian follicle. On the 14th day of menstrual cycle, the graafian follicle is ready to release the ovum. Ovulation is the process in which there is rupture of graafian follicle and ovum enters the follopian tube. This is influenced by Leutinizing hormone (LH)

(ii) Luteal phase : This phase extends between 15th to 28th day of menstrual cycle. After ovulation, the ruptured follicle develops into a yellowbody called corpus luteum, which under the stimulation of LH and prolactin secretes another hormone involved in the menstrual cycle, namely progesterone. This hormone completes the development of the uterine lining, preparing it to receive a fertilized egg. If the egg has not been fertilized about 27 days after the beginning of the previous menstrual period, the corpus luteum undergoes regression thus terminating the secretion of progesterone. This marks the beginning of its breakdown and menstrual flow begins. In the ovary another follicle begin to ripen and the next menstruation cycle starts.

(iii) Menstrual phase : This is the phase during which bleeding occurs and its duration lasts for about 4 - 5 days. The day when bleeding starts is considered as the first day of the menstrual cycle. The reduced level of estrogen and progesterone is responsible for menstruation.

12.4 Types of vertebrate Eggs

1. Egg Cell

The fully developed female gamete is termed ovum or egg. The eggs are larger than other types of cells. The animal egg, (a) supplies a haploid set of chromosomes to future embryo. (b) provides most of the cytoplasm to the embryo. (c) supplies nutrients for the developing embryo.

2. Size and Shape

Many marine invertebrates produce small eggs which range from 50 μ in diameter (polychaete worm), to about 150 μ (ascidian). Larger eggs with more yolk are produced in some fishes (shark, rays) reptiles and birds. Size varies from 0.07 mm in (mouse) to about 3.5 inches diameter (ostrich). The eggs of mammals are minute, almost yolkless and measure about 100 μ in diameter.

Generally the eggs are spherical in shape and in few animals they are elongated. (Eg. Insects). The eggs of birds are oval in shape.

3. Types of animal eggs

The animal eggs are classified on the basis of (1) amount of yolk (2) distribution of yolk, (3) presence or absence of shell and (4) types of development.

(1) Amount of yolk

(i) **Alecithal** : In mammalian egg yolk is absent. If present, it is in a negligible quantity. This type is called as **alecithal.** (ii) **Microlecithal** : The eggs containing small amount of yolk are called **microlecithal** or **oligolecithal**. Example: Amphioxus. (iii) **Mesolecithal** : Moderate amount of yolk is found in these eggs. Example : Amphibian. (iv) **Macrolecithal** : Enormous amount of yolk is present. Example : birds.

(2) Distribution of yolk

(i) **Isolecithal** or **Homolecithal** : Yolk is in small amount and distributed evenly throughout the cytoplasm (e.g., Amphioxus). (ii) **Telolecithal :** Distribution of yolk is unequal. Yolk is more in the lower part. i.e., it is collected eccentrically in the vegetal pole of the egg (e.g., frog). (iii) **Centrolecithal** : Yolk is concentrated in the centre of the egg (e.g., insects). (iv) **Discoidal** : The amount of yolk is enormous and occupies the major portion except a small disc shaped area of cytoplasm and nucleus called blastodisc (e.g., birds).

(3) Presence or absence of shell

(i) **Cleiodoic** : These eggs are laid on land and fully surrounded by a waterproof shell. eg., reptiles, (ii) **Non-cleiodoic** : These eggs are laid in water and not protected by shell. e.g., amphibian.

(4) Type of development

(i) **Determinate or Mosaic eggs** : In some animals (eg. Molluscs, Annelids), the fate of the blastomeres are determined even at the 2 celled stage. Such eggs are called determinate eggs.

(ii) **Indeterminate or Regulative eggs:** In this type of eggs, the fate of the various parts of the egg is usually not fixed until three cleavage divisions are completed. If any of the blastomeres are separated before this stage, each develops as a whole embryo. Such eggs are called indeterminate or regulative eggs. e.g., echinodermata, vertebrates.

4. Egg Membranes

Eggs like other animal cells have the cell membrane or plasmalemma. In addition to plasmalemma, all animals, except sponges and some coelenterates have special membranes. They are the (a) primary membranes and (b) secondary membranes.

Primary membranes : Primary membranes develop in the ovary between oocytes and the follicle cells. In insects, molluscs, amphibians and birds it is named as vitelline membrane. In tunicates (ascidians) and fishes it is called chorion. Mammalian zona pellucida and the jelly coat of sea urchin eggs are also primary membranes.

Secondary membranes : Secondary membranes are secreted by oviducts and other accessory parts of genital organs. In amphibian eggs, the jelly layer which protects and helps the eggs to adhere to objects is the secondary membrane.

In bird's egg, more complicated five membranes are present. The plasma membrane is followed by a vitelline membrane which is a converted form of zona radiata. The next egg membrane is the white albumen. Next to the egg white comes two layers of shell membranes. The calcareous shell protects all the above mentioned membranes.

5. Amphioxus egg

The egg of amphioxus is small and measures 0.10 mm to 0.12 mm in diameter. It is microlecithal and isolecithal. The cytoplasmic contents remain bound by a plasma membrane; which in its turn remains surrounded by a thin membrane of mucopolysaccharides called vitelline membrane.

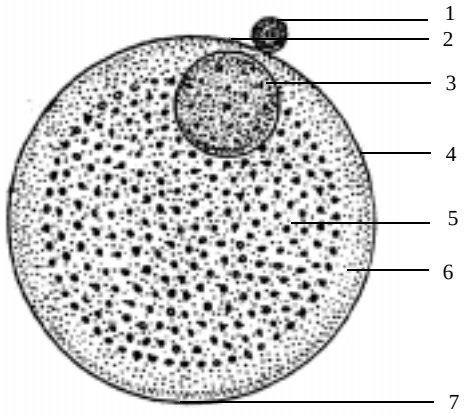


Fig. 12.24 Amphioxus Egg

1. First polocyte 2. Animal pole 3. Nucleus 4. Vitelline membrane 5. Yolky inner cytoplasm 6. Clear peripheral cytoplasm 7. Vegetal pole

The egg of Amphioxus has well determined polarity. The large-sized egg nucleus or germinal vesicle lies at one pole, the animal pole and the opposite side of the egg is called as vegetal pole. The yolk granules remain uniformly distributed throughout the cytoplasm except near the nucleus at the animal pole and peripheral cytoplasm of egg.

6. Hen's egg-Typical structure

Hen's egg is elliptical in shape and enormous yolk is present in the centre. The calcareous shell form the outermost covering. Immediately underneath are two shell membranes. The two membranes are in close contact throughout the inner surface of the shell except the broader end where they are separated by an air space towards the blunt end.

Longitudinal section of Hen's Egg

The space between the shell membranes and vitelline membrane is filled with albumen or white of egg. The albumen is a simple protein. It surrounds the centrally situated yolk

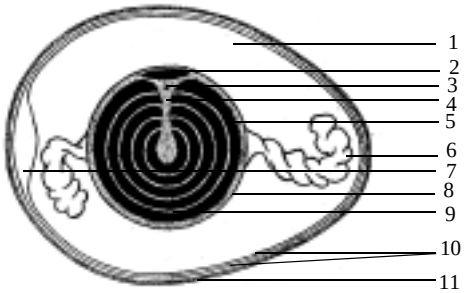


Fig. 12.25 Hen's Egg

1. Albumin 2. Blastodisc 3. Nucleus of Pander 4. Latebra 5. Yellow yolk 6. Chalaza 7. Air space 8. Vitelline membrane 9. White yolk 10. Shell membranes 11. Calcareous shell

and forms spirally twisted cord like strands called chalaza on both the sides. The chalaza are formed due to the rotation of egg white passing through the oviduct. Yolk is a spherical body occupying the central position. It is enveloped by a transparent vitelline membrane secreted by the follicle cells of the ovary. The yolk is formed of two different types of materials and are distinguished as yellow and white yolk. The white yolk is represented by a central flask shaped mass below the blastoderm which is known as latebra surrounded by alternate concentric rings of yellow and white yolk. The outer part of the latebra just beneath the blastodisc is called as nucleus of pander. The proteins of the avian yolk are phosvitin and lipovitelline.

Table 12.1 Composition of yolk

1.	Water	48.7%
2.	Phospholipids & Fats	32.6%
3.	Proteins	16.6%
4.	Carbohydrates	1%
5.	Other chemical molecules	1.1%

12.5. FERTILIZATION

Fertilization is a complex process which involves the fusion of a male gamete and a female gamete. It has dual functions. - (i) to activate the egg (ii) to inject a male haploid nucleus into the egg cytoplasm.

When the fertilization occurs in the aquatic medium outside the bodies of the parents, it is called external fertilization. Eg. Frog

In oviparous (egg laying) and viviparous (giving birth to youngones) animals, the spermatozoa are delivered internally (in the body of the female) by some type of copulatory mechanism of male and fertilization takes place inside the body of the female. This type of fertilization is called as internal fertilization.

1. Mechanism of fertilization

The phases of fertilization includes attraction, penetration, activation and fusion.

(1) The meeting of gametes-Attraction

During this stage, when spermatozoon come into contact with the surface of the egg, a chemical lock is established between the antifertilizin molecules of spermatozoa and fertilizin molecules of unfertilized egg. The fertilizin is a glycoprotein or mucopoly-saccharide. The surface layer of the cytoplasm of spermatozoa contains protein molecules called antifertilizin. The remarkable pecularity of the fertilizin and antifertilizin is that they

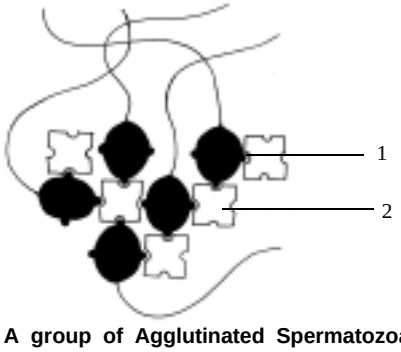


Fig. 12.26 A group of Agglutinated Spermatozoa

1. Sperm 2. Particle of Fertilizin

are specific. i.e. the egg fertilizin of one animal species will react and form a chemical lock only with the antifertilizin of sperm of same species.

(2) Acrosome reaction and penetration

When a spermatozom is attached with the surface of the egg, it becomes motionless and its penetration through the egg membranes is not achieved by mechanical activity of the sperm, but by some physico - chemical activity of the acrosome of the sperm. In mammals when the egg is released from the ovary, it is commonly encased with a layer of follicular cells called corona radiata. These cells are held together by an adhesive cementing substance called hyaluronic acid (a mucopolisaccharide). The corona radiata, thus acts as a barrier through which the spermatozoon must penetrate to reach the plasma membrane of the egg. To do so, the sperm's acrosome produces an enzyme, hyaluronidase, which dissolves the cementing hyaluronic acid and disperse the cells of corona radiata. This paves the way for the entry of sperm.

(3) Activation of ovum

When the acrosomal tubule of a spermatozoon touches the surface of the egg plasma membrane, very important changes occur in the egg and is called the activation of ovum. It includes, 1. Fertilization cone formation 2. Cortical reactions and fertilization membrane formation 3. Metabolic activation.

(i) Fertilization cone formation

Immediately after the fusion of the plasma membrane with the acrosomal tubule, the cytoplasm of the egg bulges farward at the point of their contact, producing a conical protrusion called fertilization cone. It gradually engulfs the spermatozoon and then begins to retract. During this process, the sperm nucleus and other sperm strucures like centriole, mitochondria and the mid piece of the spermatozoon pass through the cone.

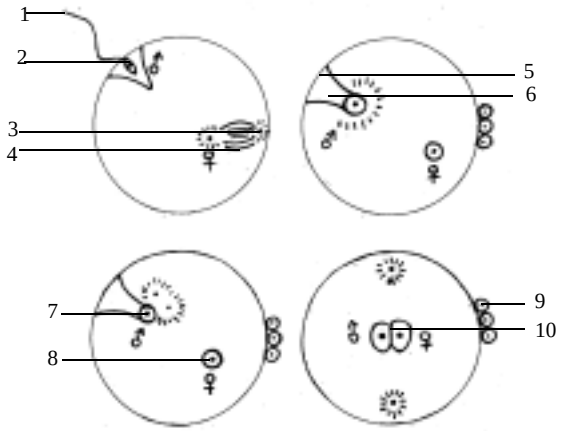


Fig. 12.27 Stages in fertilization

1. Tail 2. Head of sperm 3. Astral rays 4. Spindle fibres 5. Entrance cone 6. Entrance path 7. Male pronucleus 8. Female pronucleus 9. Polar bodies 10. Union of pronuclei of male and female

(ii) Cortical reactions and Ferilization membrane formation

The formation of the fertilization cone is followed by a chain of physico-chemical reactions in the cortex of egg cytoplasm which are collectively called as cortical reactions and culminate in the formation of the fertilization membrane. The vitelline membrane and the contents of cortical chemical granules forms the fertilzation membrane. The fertilization membrane blocks the entry of other spermatozoa.

(iii) Metabolic activation

In addition to the formation of the fertilization cone and fertilization membrane, a series of cytoplasmic reactions are initiated. The following metabolic changes occurs in the egg. (1) The permeability of plasma membrane increases (2) The rate of respiration increases (3) Initiation of mitosis for cleavage.

(4) Migration of pronuclei and Amphimixis

As the sperm nucleus moves inward from the site of the fertilization cone, it soon rotates through the angle of 180^{o}, so that its mitochondria and centriole assume the leading position. Besides this rotation, the sperm nucleus starts swelling and its chromatin which is very closely packed, becomes finely granular and then vesicular and is called male pronucleus. As the male pronucleus develops and migrates towards the site of amphimixis, the sperm aster which formed in the egg cytoplasm seems to lead it. This is called the penetration path. Before amohimixis, the nucleus of the egg also undergoes certain changes and forms the female pronucleus which swells, increases in volume and becomes

vesicular. The two pronuclei fuse together, i.e. the nuclear membranes of both pronuclei are broken at the point of their contact and the contents of both pronuclei unite into one mass, which is ultimately bounded by a common nuclear membrane, called zygote nucleus. Now the fertilized egg is called as zygote.

2. Significance of fertilization

(1) It activates the egg, (2) The fusion of male and female pronuclei is called amphimixis. It introduces genetic variation in the species. (3) Restores the normal diploidy in organism. (4) Determination of the sex (chromosomal sex of the embryo is determined at fertilization

12.6. Cleavage

The splitting of an activated egg by a series of mitotic cell divisions into a multitude of cells which become the building units of future organism is called cleavage. It divides the substance of the egg into an increasing number of cells of progressively decreasing size. The number of successive division accordingly depends on the availability of the reserves such as yolk. The resultant cells of cleavage process are called blastomeres and the general shape of the embryo does not change and no growth occurs. At the end of cleavage, the blastula with single layered blastoderm enclosing blastocoel is formed.

1. Planes of cleavage

(1) **Meridional plane :** When cleavage furrow passes through the centre of animal - vegetal axis and bisects both the poles of the egg, then such plane of cleavage is called meridional plane. (eg. frog - I,II cleavage.)

(2) **Vertical plane :** The vertical plane of cleavage is a furrow which tends to pass in a direction from the animal pole towards the vegetal pole. But like meridional plane, it does not pass through the median axis of the egg, but courses to one side of this axis. (eg. third cleavage furrow in chick).

(3) **Equatorial plane :** The equatorial plane of cleavage bisects the egg at right angles to the main axis and half way between the animal and vegetal poles-I (eg. 3rd cleavage in eggs of higher mammals).

(4) **Latitudinal plane :** The latitudinal plane of cleavage is similar to equatorial, but it courses through the cytoplasm on either side of the equatorial plane. It is also called transverse or horizontal plane. (eg. 3rd cleavage planes of Amphioxus and frog.)

2. The amount and distribution of yolk determine the cleavage

In microlecithal egg, total, complete or holoblastic type of cleavage takes place in which the cleavage furrows bisects the entire egg and produces blastomeres of equal size. Eg. Amphioxus.

In Amphioxus, the cleavage is holoblastic and equal. The first cleavage is meridional which cuts through the egg along its median axis. The second cleavage is also meridional but right angle to the first resulting in four

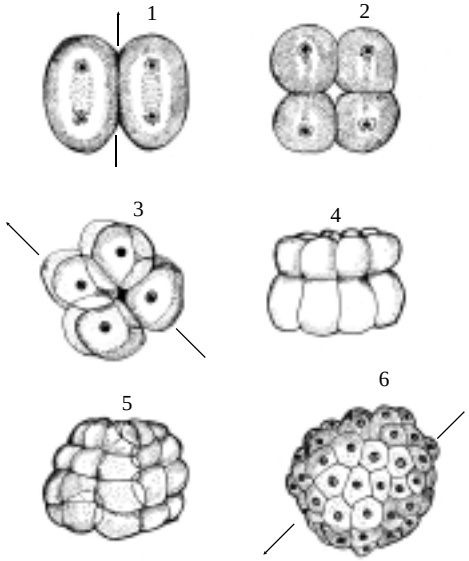


Fig. 12.28 Cleavage in Amphioxus

1. 2-cell stage 2. 4-cell stage 3. 8-cell stage
4. 16-cell stage 5. 32-cell stage 6. Morula stage

equal blastomeres. The third division is horizontal or transverse resulting in eight blastomeres. The fourth cleavage planes are meridional and all the eight blastomeres divide synchronously which result in 16 celled stage. The fifth cleavage planes are latitudinal (horizontal) and synchronous resulting in 32 cells arranged in four layers. The sixth set of

cleavage planes are approximately meridional and synchronous producing 64 blastomeres. Further cleavage is irregular and at the end of the cleavage, the embryo is in the form of a hollow ball of cells. These cells are called blastomeres.

These blastomeres are rearranged by a process called blastulation. The blastomeres are arranged in a single layered structure called blastoderm which encloses a fluid filled blastocoel.

At the end of cleavage and blastulation blastula is formed. The single layed blastula undergoes gastrulation resulting in three layered structure called gastrula. Thus the single cell

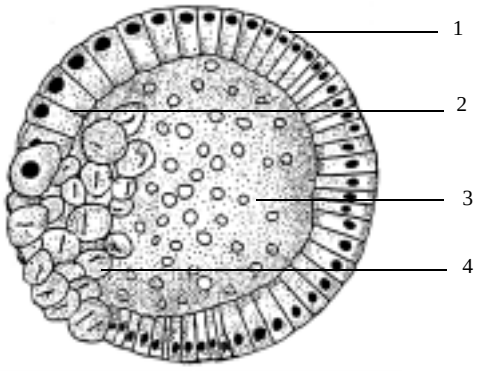


Fig. 12.29 Blastula

1. Ectoderm 2. Endoderm 3. Blastocoel
4. Mesodermal cresent

namely zygote, by repeated division give rise to multicellular blastula. This in turn gives rise to three germinal layers. The three germinal layers are the outer ectoderm, middle mesoderm and inner endoderm. These germinal layers by a process called organogenesis give rise to various organs.

12.7. Applied Embryology

Applied Embryology deals with the application of the knowledge of reproductive biology to futher human welfare. Several techniques have been developed that has greatly enhanced our understanding of human and animal reproduction. Some of them are as follows.

(1) **Treating infertility :** Invitro fertilization has helped to overcome infertility to a great extent. It resulted in the birth of the first test tube baby in 1978. Thousands of test tube babies have born since then.

(2) **Hormone replacement :** In women during menopause, the levels of many hormones fluctuate leading to diseases like depression, osteoporosis etc. This has been managed by supplementing with hormones.

(3) **Amniocentosis :** It is a technique that allows to diagnise the genetic defects in babies even before birth. This would enable us to take suitable remedial measures.

(4) **Artificial insemination :** It helps in the development of superior breeds and hybrids of cattle and other animals. Induced spawning is a technique utilized in aquaculture.

Thus applied embryology has numerous applications in reproduction, health, medical field and economic improvement.

1. Tissue Culture - Technique and Application

Growing plant or animal tissue outside the body of the organism (Invitro) is called tissue culture. The technique involves isolation of the tissue of our choice and growing them in a medium that provides all the nutrient requirements of the tissue. Such a medium is called a culture medium.

When plant tissue is grown in an appropriate medium, it grows into a group of cells called callus. To grow a callus, appropriate plant tissue should be selected. The culture medium should contain growth regulator. It should be grown in an aseptic condition.

Tissue cultured cells can be induced to form the whole palnt by altering the growth medium. This is called micropropagation. It helps in quite vegetative propagation of specific plant varieties. The plant cells also could be genetically altered before micropropogation. This leads in the production of genetically modified plants. Drought resistance, disease resistance, higher yield, nutrient enrichment are some of the objectives of genetically modified plants.

2. Cloning Technique - Cloned Animals

An exact copy of the animal to be cloned can be produced by the cloning technique. The body pattern and features of an animal are determined by the genetic material present in its nucleus. The nucleus of the animal to be cloned is isolated from its body cell. It is then introduced into an oocyte using a microinjection - after removing its nucleus. Now the oocyte has the nucleus from the animal to be cloned. This oocyte is now stimulated to undergo embroyonic development. The oocyte develops under the command of the nucleus which directs it to produce the animal from which it was extracted. This results in the development of an animal that is genetically identical to the one from which the nucleus was obtained. In 1997 a sheep by name ‘Dolly" was the first to be cloned by Dr lan Wilmut. Mice, piglets, cats and horse have also been cloned after Dolly. These successes have raised hopes of preserving endangered animals and even bringing extinct animals back to life.

In future, specific genes that produce desired products or genes that help to cure diseases could be inserted into adult cells grown in the laboratory. The nuclei from such genetically modified cells would then be used to clone entire animals. These animals would then breed conventionally to form flocks of genetically engineered animals. These animals would produce the desired product or help cure diseases. Genetically modified cow could be made to produce milk with medicine in it. Pigs could be genetically altered to make them a source for organ transpiration.

3. Stem cells - Maintenance of cell lineages

Stem cells are undifferentiated cells i.e., they have not been converted into any particular tissue. They have the potential to form any tissue of the body such as bone, blood and brain cells. They also have the ability to copy itself to maintain a stock of stem cells. The cells present in the blastula are capable of differentiating into several other tissues. The study of the fate of particular blastomere is called cell lineage.

There are two types of stem cells

(i) Embryonic stem cells : They are derived from the early human embryos. They could develop into any of the more than 200 different known cell types in the body. Such cells are termed pluripotent i.e. they have the ability to differentiate into any tissue of the human body.

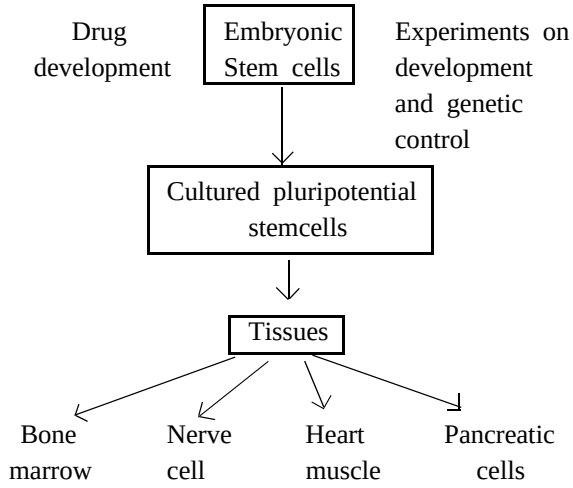
(ii) Adult stem cells : They are undiferentiated cells that occur in a differentiated tissue in the body. It can be differentiated to become any one of the specific cell types of the tissue in which it originated Eg. haemopoietic stem cells normally make only blood cells; brain stem cells make only brain cells. Such stem cells are termed multipotent. However recent findings show that multipotent stem cells have the potential to develop into the tissues of other organs under certain conditions

1. Applications

Because of this innate capacity into diverse tissues, they are prime importance in the field of medicine with the following applications.

1. The stem cells are used in transplantation, because different organs can be developed from the stem cells and which are not rejected after transplantation (histocompatability)
2. The stem cells can be used to replace the dead nerve cells to cure the disease like parkinsons’ disease, Alzhamier’s disease
3. By using pluripotent stem cells the immune system can be replaced
4. Diseases of bone and cartilage - physical damages can be treated by using stem cells.
5. Leukemia can be treated with bone marrow stem cells.

Future scope of stem cell (organ repair)



Thus stem cells are of prime importance because of their innate capacity to develop into several other tissues and organs. Infact it offers tremendous research potential.

SELF-EVALUATION

Choose the correct answer.

1. Transfer of pollen grains from the anther of a flower to the stigma of another flower is known as
   (1) Autogamy (2) Dichogamy
   (3) Allogamy (4) Herkogamy
2. The male gametophyte is
   (1) Pollenmother cell
   (2) Male gamete
   (3) Pollen tube
   (4) Pollen tube with two male gametes.
3. After fertilisation the integument develops into
   (1) Seed coat (2) Endosperm
   (3) Micropyle (4) Raphe
4. During fertilization this part of the sperm is useful to penetrate the ovum
   (1) Head (2) Manchette
   (3) Acrosome (4) Centriole
5. The cyclic events that takes place in a rhythmic fashion during the reproductive period of a woman life is
   (1) Reproductive cycle
   (2) Menstrual cycle
   (3) rhymic cycle
   (4) growth period
6. The chromosomal number of zygote is
   (1) Haploid (2) Diploid
   (3) Tetraploid (4) Polyploid
7. The substance secreted by the sperm to enter into the egg is
   (1) Hyaluronic acid (2) Antiferilizin
   (3) lysin (4) Hyaluronidase
8. The study of the fate of particular blastomere is called
   (1) Tissue culture (2) Cloning
   (3) Cell lineage (4) Cytology

Fill in the blanks

9. The pollinations is the transfer of pollen grains to the ..... of the flower.
10. The stalk of the ovule is called .....
11. The pollen tube with the two male gametes is called the .....
12. The pollen tube usually enters the ovule through the .....
13. The chromosomal number in primary spermatocyte is .....
14. Acrosome is made up of ..... and .....
15. The secondary egg membranes are produced by the .....
16. The eggs of reptiles are of ..... type
17. The mixing of paternal and maternal chromosome is .....
18. Culture arising directly from the differentiated tissue is referred to as .....

Answer briefly :

19. Define pollination.
20. Mention the wall layers of anther
21. What is protogyny ?
22. What do you meant by triple fusion ?
23. Mention any two post fertilisation changes
24. What is the speciality of the secondary nucleus ?
25. What is cross pollination ?

26. What is germination ? Define epigeal germination.
27. Which part of the bean seed coming out first during germination ?
28. What is meant by menstrual cycle ?
29. What are alecithal eggs ?
30. Define cleidoic and non-cleidoic egg.
31. What are primary egg membranes.
32. Write the composition of bird's yolk.
33. What is latebra ?
34. What is blastodisc.
35. What is meant by regulative egg ?
36. What is the importance of egg shell.
37. What is amphimixis ?
38. What is fertilization ?
39. What are the two types of fertilization ?
40. What is fertilization cone ?
41. What is the importance of fertilization membrane.
42. Define cleavage.
43. What is meant by holoblastic cleavage.
44. Define plane of cleavage.
45. What is meant by blastulation ?
46. What is meant by incomplete cleavage.
47. What is microlecithal egg ? Give example.
48. What is tissue culture ?
49. What is meant by amniocentosis.
50. Do you like to be cloned ?
51. What is meant by pluripotent ?
52. What are established cell lines.
53. What is a callus ?
54. What is a culture medium.

Answer in detail.

55. Describe the L.S. of ovule with diagram.
56. Describe the contrivances of cross pollination
57. What are the post fertilisation changes ?
58. What is meant by double fertilisation and triple fusion ?
59. Describe the process of fertilisation.
60. Write notes on pollination and their types
61. Draw and describe the parts of a bean seed.
62. Describe the seed germination in paddy.
63. What are the advantages of dispersal ?
64. Give examples for wind dispersed seeds.
65. How are seeds and fruits adapted for dispersal by various agents ?
66. Draw a labeled diagram of sperm.
67. Explain the process of spermatogenesis.
68. Describe the various phases of menstrual cycle.
69. Draw a labeled diagram of an egg of hen.
70. Explain the process of oogenesis.
71. Explain corpus laterm.
72. On the basis of distribution and amount of yolk explain the various types of eggs.
73. Explain the mechansim of fertilization.
74. What are the significance of fertilization.
75. Explain the structure of blastula with labelled diagram.
76. Explain how the single celled egg results in a multicellular blastula through cleavage?
77. Explain the process of cleavage in Amphioxus.
78. Define the various patterns of cleavage in Amphioxus.
79. What are the two types of stem cells? Explain briefly.
80. What are the future hope of stem cells.
81. What are the verious applications of the stem cells.

13. DISEASES AND IMMUNOLOGY

13.1. Medicinal plants

Plants are indispensible for man in many ways. Food, clothing and shelter and a variety of other useful materials are supplied by the plant kingdom. In the past, almost all the medicines used were from plants only. Crude drugs are obtained from different parts of plants. Roots, stem, leaves, flowers, fruits, seeds are sources of drugs.

Forests in India are one of the major sources for hundreds of medicinal plants ; some of them are used for the production of patented drugs while others are used in indigonous medicine. From earliest times mankind has used plants in an attempt to cure diseases, wounds and to get relief from physical sufferings.

1) Importance of Plants as a source of drugs for various kinds of ailments

1) Drugs obtained from roots :

Rawolfia serpentina : Apocyanceae **(Tamil : Sarbakandhi) :** A large climbing or twining shrub, found in the tropical Himalayas and plains. The plant is mentioned in ancient literature including the works of Charaka (1000 - 800 B.C.) where it is described under its Saskrit name Sarpagandha, as a useful antidote against snake-bite and insect stings.

The dried roots of **Rauwolfia serpentina** reduces blood pressure and is used to cure mental illness. It has been recently used in numerous other diseases like skin disorders, such as Psoriasis, excessive sweating and itching ; roots of **Vinca rosea** is also effective remedy for blood cancer and asthma.

2) Drugs obtained from under ground stem

(i) Turmeric : *Curcuma longa* - *Zingiberaceae* : (Tamil : Manjal)

A herb, cultivated commonly in Tamil Nadu, Bengal and Andhrapradesh. The rhizome is aromatic. It is given for jaundice, purification of blood, liver disorders and urinary infections. A little turmeric paste applied on a burn helps it to heal quicker. It is believed that addition of a little turmeric every day in the food helps to protect your liver.

(ii) Allium cepa : *Liliaceae* - *Onion* (Tamil : Vengayam)

This is a bulbous biennial herb with a peculiar smell. It is widely cultivated throughout India. It's decoction is given for reducing cough ; with vinegar, the bulb is given for curing jaundice.

(iii) Allium sativum - *Liliaceae* - *Garlic* (Tamil : Vellaipoondu)

This is a strong smelling, bulbous rooted; about a foot in height. Garlic is of great medicinal value. It is given in fevers, cough, disorders of nervous system, bronchitis and it is a well known blood purifier.

3) Drugs obtained from barks : Quinine : *Chinchona calisaya ; Rubiaceae* (Tamil : Koyna maram) : The quinine tree is native to the Andes of South America. The first **Chinchona** plantation was established in Nilgiris, Tamilnadu by the British.

The most important constituent of **Chinchona** bark is quinine, a very bitter white granular substance. Quinine is used in the treatment of malarial fever and amoebic dysentry.

4) Drugs obtained from stems and wood.

Santalum album : *Sandal wood* - *Santalaceae* (Tamil : Santhana maram)

Tamil Nadu and Karnataka are the important centres for sandalwood. It is a tree. The paste of wood has cooling effect and reduces inflammatory skin diseases. It is also effective in patients with headache and fever. The oil is used for chronic bronchitis and intermitent fevers. The oil is applied for skin diseases.

5) Drugs obtained from leaves :
Indian Aloe : *Aloe barbedensis* - *Agavaceae* (Tamil : Katrazhai)

After removing the outer covering of leaves the juicy inner contents are given to reduce the enlargement of the liver, spleen. It is also a cure for piles, jaundice. The leaf juice is given as a remedy for intestinal worms in children.

Flowers :
***Eugenia caryophyllata* :**
(Tamil : Ilavangam)

Clove oil is prepared from the dried flower buds of *Eugenia* which is used as a pain releiver in toothache.

Fruits and seeds :
Emblica officinalis: *Euphorbiaceae*
(Tamil : Nelli maram)

The common goose berry is used in treating scurvy. The oil obtained from the seeds is used as a purgative.

Activity : In a chart list important plants that meet the basic requirements of man.

13.2 Medical Practices

1. Types of Indian Medicine

(i) Siddha : Siddha system is one of the oldest system of medicine practised in India. The terms siddha means achievement and 'Siddhars' were saintly figures who contributed a lot in medicine through the practice and yoga.

Eighteen siddhars, seem to have contributed towards the development of this medicinal system. The system is also called Agasthyar system. It is the name of famous sage Agasthya. The siddha system is largely therapeutic in nature.

According to this system the human body is the replica of the universe and so are the food and drugs irrespective of their origin.

Like Ayurveda, this system believes that all objects in the universe including human body are composed of five basic elements namely earth, water, fire, air and space. They combine to form the three principles of *vatah, piththa* and *kapha.*

The diagnosis of disease is based on examination of tongue complexion, voice, eye, touch, stool and pulse. The treatment for disease is essentially by adoption of right food, life style, yoga and also with drugs derived from plants, animals, metals and minerals.

Though some materials used are toxic it is essential to start treatment with plant parts. Because of which herbs have a major role in this system. Both internal medicines and external applications find a place in this system. Varma and physical therapy are also recommended ; kayakalpa or longivitiy therapy is a speciality of this system. Herbs that are grown in different parts of the country and some herbs that are not native but imported also used. Over 1400 plants are used in siddha systems.

Siddha system originated and still practised in Tamilnadu. Siddha system is mainly based on medicinal plants and it is also called as siddha maruthuvam ; it also makes uses of materials of mineral and animal origin.

(ii) Naturopathy : Naturopathy is a kind of treatment for certain ailments. It involves adoption of appropriate habits. It is based mainly on the ancient practice of the application of the simple laws of nature. Advocates of naturopathy pay particular attention to eating and living habits, cold packs, mud packs, baths, massage etc.

Water, dilute fruit juices and several kinds of herbals are mainly used in naturopathy. Properly organised way of life and food habits recommended in naturopathy allow us to live a disease free life. Nature cure helps in all kinds of illness except those which require surgery.

Basic principles of Yoga : The system of yoga as propounded by Pathanjali about 2500 years ago is as old as Ayurvedha.

Yoga practice involves eight components namely restraint, observance of austerity, physical postures, breathing exercises, restraining of sense organs, meditations, contempletion and samadhi, and also recommends vegetarianism including the use of medicinal herbs.

A number of physical postures, described in yogic works are to improve bodily health, to prevent disease, and to cure illness.

Meditation is another exercise which can stabilise emotional changes and prevent abnormal functions of vital organs of the body.

The national health policy recognises the role of naturopathy and yoga for promotion of health and prevention of diseases. National Institute of Naturopathy is located in Pune.

(iii) Homeopathy : Dr. Samuel Hainnemann is the father of Homeopathy. This system was introduced by him through his work "organon of the art of healing" (1810).

Fig. 13.1 Samuel Hainnemann - Father of Homeopathy

He discovered that there is a law in medicine called the "Law of similars" and similarity between drugs and diseases.

Ayurveda and Unani more relevant in modern days. Day by day homeopathic system of medicine gains reputation all over the world for its many positive features. In 1954 Government constituted a homeopathy Advisory Committee.

Homeopathy has been taught in India for the last 100 years and the homeopathy institutions award diploma like DHMS, DMS or LCEH etc. The National Institute of Homeopathy an autonomous organisation under the Ministry of Health and Family Welfare, was established, on 10th December 1975 as a model - teaching and research institute so as to promote the growth and all round development of Homeopathy.

There are approximately 700 drugs manufacturing units in the country. The Central Council for Research in Homeopathy was formally constituted on 30th March 1978 as an autonomous organisation.

Homeopathy is a system of medicine that uses natural substances. The natural substances come from the mineral and animal kingdoms.

(1) Homeopathy is based on basic natural principles.

(2) In order to find out full symptoms of a medicine, it is tested on healthy persons.

(3) Homeopathic medicines are prepared from plants roots, bark, stem, buds, leaves, greens, oils etc. or whole plants.

(iv) Unani system of medicine History : Unani was introduced in India by Arabs and Persians sometime around eleventh century. The Greek philosopher and Physician Hippocrates (BC - 46) is considered as the fatehr of unani system of medicine. The system was further developed and enriched by Aristotle (about 60 A.D.)

The Unani system was further developed by the Moghul rule in India. They adopted many principles and practices of Ayurvedic system of medicine.

The Unani system of medicine is primarily based upon the pythagorian theory of four qualities and Hippocratic theory of 4 humours, viz., blood, phlegm, yellow bile, and black bile.

The physicians who follow the fundamentals of unani system, prefers to judge the nature of the functional disturbance of the human system by feeling the pulse, visual examination of the sputum, urine and stool.

The unani system of medicine classifies drugs in to three groups. Vegetables, animal and mineral.

Vegetable drugs are prepared from bark, flowers, fruits and seeds. About 3000 drugs of plant origin are recognised by the unani system of medicine.

In unani system of treatment, food plays a key role. By regulating the quality and quantity of food, several ailments are treated successfully.

India is known for its rich wealth of medicinal plants which play a very important role in Unani medicine. Considering the importance of unani system of medicine, the Government of India has established National Institute of Unani Medicine at Bangalore - Karnataka (1975).

(v) Ayurvedic System of Medicine : The history of medicine in India can be traced to very ancient times. Medicinal uses of plants are mentioned in Rig veda. (2500 to 600 B.C.) which is one of the oldest written records of human knowledge.

Ayurveda means science of life. Ancient Ayurvedic practitioners like Sushruta (father of surgery) and Charaka (founder of Ayurveda) made significant contributions in Ayurveda.

Independently Sustruta's work is mainly about surgery and Charakas work known as Charaka samhita deals with medicine. In this work there are several records of medicinally useful plants, their properties and uses.

It is in Ayurveda, more information is available on the medicinal uses of plants, properties of drugs and their uses. It deals with different aspects of the science of life and the art of healing.

Sir George Watt wrote monumental work known as **A dictionary of the economic products of India.** It was published in 1895. Kritikar and Basu published 'Indian Medicinal Plants' that contains information on Ayurveda.

Life in Ayurveda is conceived as the union of body, senses, mind and soul. The National Institute of Ayurveda was established in 1971-72 at Jaipur.

Ayurveda being one of the oldest system of medicine can be expected to have a very rich and it varied information about the drugs and their therapeutic uses. It is said to have 70 books containing more than 8000 receipes.

It is known for its successful treatment of chronic diseases such as diabetes, arthritis bronchial asthma, epilepsy etc.

Like Siddha medicine this system also uses metals, mineral, herbs and animal products. The herbs used are classified according to their life period. This concept is similar to modern concept of Botany.

2. Study of few common medicinal plants and their uses

Azadirachta indica - Neem - (Ta : Vembu) Meliaceae

Distribution : Distributed throughout India, in deciduous forests, also widely cultivated. A medium to large sized tree.

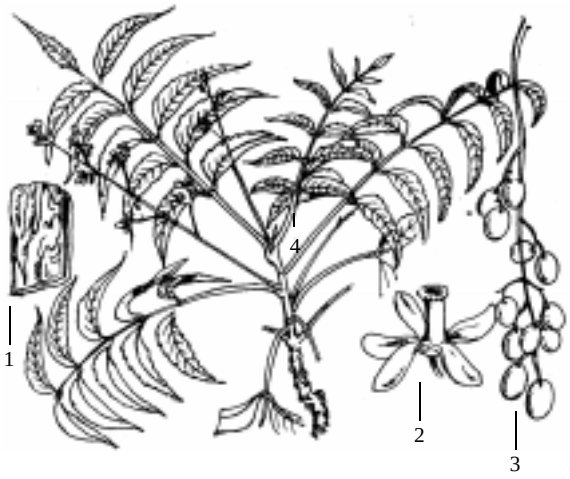


Fig. 13.2 Azadirachta indica

1. Bark 2. Flower 3. Bunch of fruits 4. A twig

Medicinal properties and uses :

The bark is bitter, astringent, liver tonic. It is useful in vitiated conditions of pitta, leprosy, skin diseases, eczema, leucoderma, malarial fevers, wounds, ulcers, tumour, vomitting, diabetes and inflammation.

The leaves are bitter, antiseptic, appetiser, and insecticidal. They are useful in burning sensation, leprosy, skin diseases, ulcers and tuberculosis, boils, eczema and malaria, intermittent fever.

The flowers are bitter, stomachic and tonic. The seeds are bitter, astringent. They

are useful in tumours, leprosy, skin diseases, wounds, ulcers and diabetes. Useful in chronic skin diseases, chronic malarial fever and leprosy.

Catharanthus roseus (Vinca rosea) (Ta : Nithyakalyani, Sudugattumalli- Apocynaceae

Distribution : A native of Madagascar, now found throughout India. In waste lands ; also cultivated in gardens.

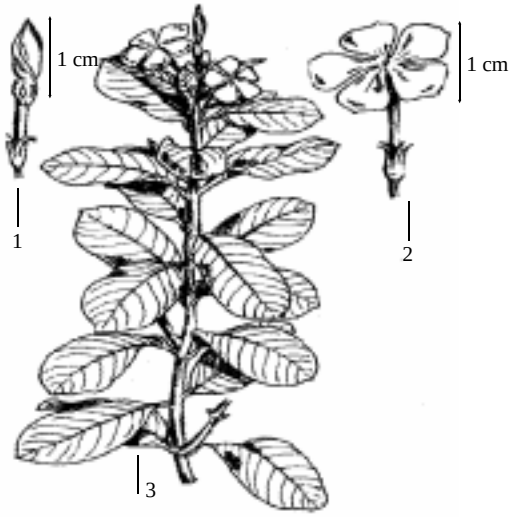


Fig. 13.3 Catharanthus roseus

1. Flower bud 2. Flower 3. Twig

An erect, handsome, herbaceous, annual; leaves dark green, oval, oblong, glossy. Flowers in cymose axillary clusters, white or deep rose coloured ; fruits are pair of follicles.

Medicinal properties and uses :

The root bark contains alkaloids having hypotensive, sedative and tranquilising properties. It is used as a folk remedy for diabetes. The root is toxic, bitter, stomachic and tonic. The juice of leaves is good for wasp-stings. The 'Vincristine' obtained from this plant is used in the treatment of leukemia.

3. *Zingiber officinale (Ta : Inji) Zingiberaceae*

Distribution : Cultivated throughout ; occurs wild is some places in the western ghats.

The plant : A slender, perennial rhizomatous herb, leaves linear, sessile, flowers yellowine green in oblong cylindric spikes, fruits occur as oblong capsules.

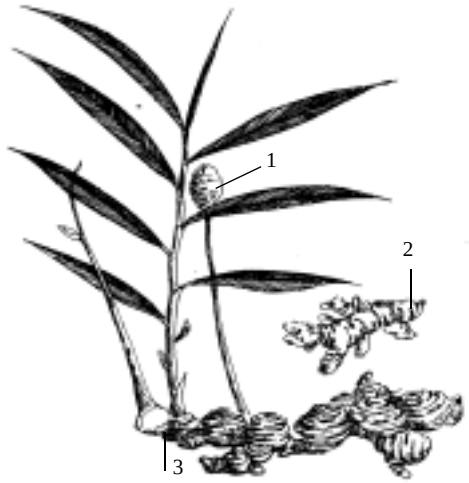


Fig. 13.4 Zingibev officinale

1. Inflorescence 2. Rhizome 3. Plant

The rhizomes are white as yellowish brown in colour. Irregularly branched, laterally flattened.

The growing tips are covered by few scales. The surface of the rhizome is smooth and if broken a few fibrous elements of the vascular bundles project out from the cut ends.

Parts used : Rhizome (raw as well as dry).

Medicinal properties and uses : The raw ginger is acrid, laxative and digestive. It is useful in anorexia, vitiated condition. The dry ginger is called sukku; it is a good appetiser, laxative, stomachic stimulant, anthelmintic and for patients suffering from diarrhoea, cholera, nausea, vomiting and inflammations. It is also much used in several domestic preparations. The rhizome is used as a stimulant and flavouring agent. It is administered as an adjunct to many tonic and stimulating remedies. The juice of fresh rhizome with honey is a remedy for cough and asthma. A paste of ginger is a local stimulant. It is also employed in headache and tooth ache.

4. *Ocimum tenuiflorum (Ta : Thulasi) - Lamiaceae*

This is a small herb found throughout India and cultivated near temples and gardens.

Part used : Leaves, seeds, root and flower. Ocimum is an erect, hairy, annual, herb, leaves ovate. Inflorescence of elongate racemes; flowers closely whorled.

Fig. 13.5 Ocimum tenuiflorum

Family : Labiatae

The leaf contains the highest percentage of essential oil. Dried plant is stomachic and expectorant.

Medicinal properties and uses :

Juice of the leaves is given in malaria and as a stomachic in gastric diseases of children and hepatic affection and also very effective in skin diseases such as itches and leprosy, and in impurities of the blood.

Dried plant decoction is a domestic remedy for bronchitis and diarrhoea. Fresh leaves also cure chronic fever, hamorrhage, dysentry and dyspepsia.

With honey the ginger juice is a good expectorant ; useful in cough bronchitis and fever ; popular as herbal tea.

13.3 Non communicable diseases

Non-communicable disease refers to impairment of bodily structure or function due to metabolic disorder that necessitates a modificaton of the patients' normal life. Diabetes, Coronary heart disease (CHD), Rheumatic heart disease (RHD), anorexia nervosa, renal failure, obesity and protein deficiency diseases are non communicable diseases.

1. Diabetes

Diabetes means that our blood glucose (often called blood sugar) is too high. Our blood always has some glucose in it because our body needs glucose for energy to keep us going. But too much glucose in the blood is not good for our health.

Glucose comes from the food we eat and also by glycogen conversion in our liver and muscles. Our blood carries glucose to all the cells in our body. Insulin is a hormone synthesized by beta cells of pancreas, and released into the blood. If our body doesn't produce enough insulin or if the insulin does not work the way it should, glucose cannot get into our cells and stays in our blood. Then our blood glucose level increases, causing diabetes.

Symptoms

Diabetes exhibits the following symptoms.

(i) Polyurea - excretion of increased quantity of urine.

(ii) Polydipsia - excessive thirst leading to increased consumption of water.

(iii) Polyphagia - excessive appetite leads to increased intake of food. Inspite of over eating diabetic patient looses weight.

(iv) Weakness and body pain.

Prevention

(1) Maintenance of normal body weight through adoption of controlled nutritional habits and physical exercise.

(2) Alcohol and smoking should be avoided.

(3) Control of blood pressure, cholesterol and triglycerides levels.

(4) Routine checking of blood sugar.

Severe diabetes is a major cause of blindness, kidney failure, coronary thrombosis etc.

2. Coronary heart disease (CHD)

Coronary heart disease is the most common form of heart disease which often results in heart attack. The heart works for 24 hrs a day. To function normally, it needs a constant supply of oxygen and nutrients which is delivered by the blood through the coronary artery. The blood flow can be reduced by a process called atherosclerosis in which fatty substances build up inside the surface wall of blood vessels. In CHD atherosclerosis affects the coronary artery which supplies blood to the heart muscles by reducing the lumen of the artery.

Symptoms : Symptoms of CHD are chest pain or shortness of breath, with or without discomfort and at times the first symptom of CHD is a heart attack or cardiac arrest (a sudden, abrupt loss of heart function).

Chest pain is caused when the blood flow to the heart is critically reduced and does not match the demands placed on the heart called Angina. The same inadequate blood supply also may cause no symptoms, a condition called silent ischemia.

In men, angina is felt behind the sternum and may radiate up the left arm, neck, shoulder etc. Women may get a less typical form of angina with a feeling of shortness of breath and congestion and can linger behind the sternum.

Risk factors : Cigarette smoking, high blood cholesterol, high blood pressure, over weight/obesity, physical inactivity and diabetes.

3. Rheumatic heart disease (RHD)

Rheumatic heart disease is a condition in which permanent damage to heart valves is caused by rheumatic fever. This damage generally begins with a strep throat infection caused by bacteria called streptococcus, and followed by rheumatic fever. Rheumatic fever is an inflammatory disease that can affect many connective tissues, especially in the heart, joints, skin or brain. The infection often causes heart damage particularly scarring of the heart valves, forcing the heart to work harder to pump the blood. The damage may resolve on its own, or it may be permanent, eventually causing congestive heart failure, a condition in which the heart cannot pump out entire blood that enters it, which leads to an accumulation of blood in the heart and the blood vessels.

Symptoms : The earlier symptoms are fever, weightloss, fatigue and stomach pain.

Treatment for RHD

The treatment is based on (i) patient's overall health and medical history, (ii) duration of the disease, (iii) patient's tolerance for specific medications.

The best treatment for RHD is prevention Antibiotics can usually treat strep throat (a streptococcus bacterial infection) and stop acute rheumatic fever from developing. Antibiotic therapy sharply reduces the incidence and mortality rate by rheumatic fever and rheumatic heart disease. If inflammation of the heart has developed patients may be placed on bed rest. Medications may be given to reduce inflammation and antibiotics to treat infection. If heart valve damage occurs, surgical repair or replacement of the valve may be considered.

An **angiogram** is an examination of our blood vessels using X-rays. A doctor (physician) specially trained in interventional radiology performs this procedure. The doctor will insert a small tube (catheter) into the blood vessel and then inject X-ray dye (contrast) that makes the vessels visible. When the X-ray pictures are being taken, it allows the doctor to determine how well the blood moves through the vessels.

Angioplasty is a form used to describe a procedure for treating blockages and blood clots in the blood vessels. The procedure involves the use of thin balloons and other devices that are threaded through a blood vessel into the coronary artery. The balloon is inflated to squash the blockage or blood clot and stretch the artery open restoring normal blood flow.

ICCU - Intensive coronary care unit

The intensive coronary care unit is designed for patients who require very close observations and careful nursing care around

the clock. All staff are well trained in cardiac treatment. Intensive monitoring is provided for all patients so that the staff may quickly assist and respond to any change.

4. Anorexia nervosa

In this condition patients aim to become slim and remain as such. The determination to diet (loss of appetite) is a desired disorder. In this, young girls are mainly affected and boys react more rarely ; hostile relationship with their mothers occur and also they will be affected by depression.

Treatment : Psychotherapy to achieve emotional maturation is usually necessary in hospital in addition to correction of the eating disorders.

5. Renal failure

Renal failure occurs when the kidneys lose their ability to filter out wastes as a result toxins build up in the body and becomes fatal, if neglected

Two different forms of the disease exist : 1. acute renal failure, 2. chronic renal failure

(1) If the kidney function stops suddenly the disease is considered acute. Acute renal failure (ARF) is often caused by blockages in the blood vessels leading to the kidney.

(2) Chronic renal failure (CRF) is characterised by a gradual decrease in organ function. CRF is often caused by other medical conditions, including hypertension and diabetes.

Symptoms

1. fatigue
2. fluid retention
3. tissue swelling
4. oliguria (low urine output)
5. coma
6. seizures
7. swelling in legs

Once organ function drops to less than 10%, the kidneys can no longer process wastes effectively enough to maintain life. Dialysis or a kidney transplant is required. Dialysis provides an artificial filtering system to replace lost organ function. Dialysis is carried out by a machine called artificial kidney to filter impurities from the blood stream.

Dialysis is not a cure but only a temporary arrangement to remove nitrogenous wastes. Infections and malnutrition may occur and long-term dialysis has been linked to a increased risk of renal cancer. A kidney transplant is a more permanent solution to renal failure.

6. Obesity

Obesity is defined as an excessive high amount of body fat or adipose tissue in relation to lean body mass.

Overweight and obesity result from an energy imbalance. This involves eating too many calories and not getting enough physical activity.

Body weight is the result of genes, metabolism, behaviour, environment, culture and socio-economic status.

Behaviour and environment play a large role causing people to be overweight and obese.

When the number of calories consumed is not equal to the number of calories used.

Weight gain :

Calories consumed > calories used

Weight loss :

Calories consumed < calories used

No weight change :

Calories consumed = calories used

(Energy balance is like a scale. When calories consumed are greater than calories used weight gain results).

7. Protein deficiency diseases

Protein deficiency diseases are due to the result of inadequate intake of protein. Infants and young children are especially suceptible as they need protein nutrients to grow and develop normally. Marasmus and kwashiorkor are the examples for protein defeciency diseases.

(1) Marasmus

Marasmus is the term applied when there is a severe muscle wasting in an infant with sunken features, loss of sub cutaneous fat and

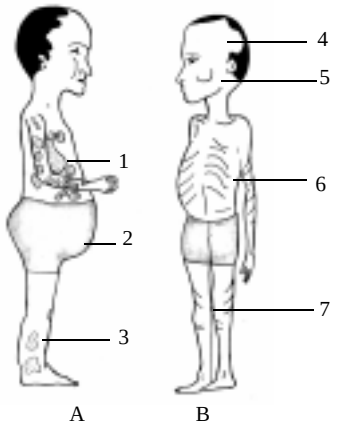


Fig. 13.6 (i) Kwashiorkaor (ii) Marasmus

1. Scalyskin 2. Distended abdomen 3. Swollen ankles (oedema) 4. Hair loss 5. Old person's face 6. Wrinkled skin 7. Severe muscle wasting.

pyloric obstruction. The commonest cause is malnutrition, namely inadequatic amount of breast milk or cow's milk or of a digestible diet.

Most of the infants who suffer from marasmus are fed artificially with overdiluted formulas. Marasmus is a clinical syndrome. Weight loss of more than 60% is much more common in infants than in older children. This is particularly true with premature babies.

(2) Kwashiorkor

This is mainly caused by protein deficiency and occurs in infants and children in some developing countries where there has been serious drought and crop failure. Growth stops and there is loss of weight. The other features are

1. discolouration of skin and hair
2. alimentary disturbances
3. liver enlargement
4. associated vitamin deficiencies

Poverty is an important predispising factor in the causation of malnutrition.

13.4 Addictions

Addictions to alcohol or drugs represents a form of psychological dependance and indicates that the patient has been unable to attain adequate satisfaction or self esteem in his/her personal life. Addiction to drugs and to alcohol are associated with a high risk of death.

1. Alcoholism and ill effects

Alcoholism is one of the most serious public health problems in developed as well as in developing countries. Mental disorders due to alcoholism are responsible for a large proportion of admissions in mental hospital. The fully established syndrome of alcoholism is characterised by

(i) a need for alcohol for customery activities being difficult to perform without it.

(ii) taking alcohol as a routine habit apart from social occasion.

(iii) unpleasant exhibits occur without alcohol.

like tremor, sweating, tension, and loss of tolerance etc.

Alcohol abuse refers to any mental physical or social harm resulting from excessive consumption. Alcoholism is a chronic and progressive habit that leads to severe physical and social problems. As a serious health problem that cannot be neglected, the habit of addiction require intervention and treatment.

Alcohol provides a lot of empty calories without any nutritive value. Many people think that alcohol is a stimulant which is not true. Alcohol is a depresent and it slows down the activity of the nervous system.

2. Abuse of tobacco : Various forms of usage

Man has started using tobacco from very ancient times. At present tobacco is consumed for smoking (beedi, cigarette, cigar etc., and chewing) Tobacco is highly a habit forming agent. Several studies have shown that the first

cigarette exposes the individual and the addiction will occur even with the second or third smoke. One third of the cancers reported from western countries are probably tobacco related.

In India tobacco is cultivated mainly in Gujarat and Andra Pradesh. The varieties of tobacco include Virginia tobacco (cigarette tobacco) and non virginia tobacco. Persons may be exposed to tobacco during agricultural operations or curing processes. Ill effects of tobacco are considered to be due to absorption of nicotine through the skin or respiratory tract.

Cigarette smoking is considered as a status symbol. Smoking is contagious. Tobacco smoking has become the most addictive habit known to man. Fig 13.7

Fig. 13.7 Some addictions

Mortality from cancer, cerebral vascular stroke, bronchitis and peptic ulcers are due to smoking.

3. Drugs, narcotics - types - severe addiction dependence

Drug abuse refers to use of a drug by self medication in a manner and amount that deviates from the approved medical and social patterns in a given culture at a given time. Drug abuse refers to any use of an illicit drug.

Drug addiction is a pattern of compulsive drug use characterised by an overwhelming use of a drug. The drugs which are commonly used are marijuana, heroin, cocaine, morphine etc. Chronic consumption of drugs and alcohol leads to changes in behaviour. The need to consume becomes a priority over everything else, and it also leads to health and social problems.

4. Deaddiction methods

The management of drug abuse and addiction must be individualised according to the drugs involved and to the associated psychological problems of the individual pattern. Pharmacological interventions have been described for each category when medications are available. An understanding of the pharmocology of the drug or combination of drugs ingested by the patient is essential for rational and effective treatement. It must be recognized however that the treatement of the underlying addictive disorder requires months or years of rehabilitation. The behaviour patterns encoded during thousands of prior drug ingestions do not disappear with detoxification from the drug, even after a typical 28 days in-patient rehabilitation programme. Long periods of outpatient treatments are necessary. Long term treatment is accompanied by improvements in physical status as well as in mental, social and occupational function.

Due to ignorance and lack of information regarding the ill effects of alcoholism and drug abuse of the individual, Government has taken steps to create an awareness through mass media. Several Radio and T.V. programmes have been launched to create awareness about the role of parents and teachers in the prevention and control of drinking and drug abuse.

A number of voluntary organizations are being financially assisted to undertake educative work in various communities. Posters, debates, competition and exhibitions are organized for students through their own groups. The problem of drug abuse has to be tackled by reducing both the supply and the demand for drugs.

5. Social aspects

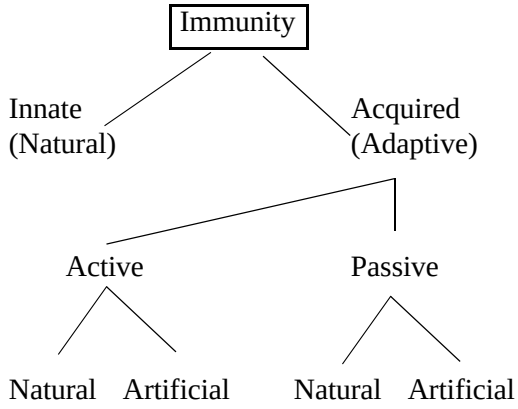
Excessive drinking/smoking/in take of drugs are liable to cause profound social disruption particularly in the family. The home atmosphere is often detrimental to the children because of quarelling and violence of a drunken person who provides a poor role model.

At work, a healthy drinker often progresses through declining efficiency, lower grade jobs and repeated dismissal to lasting unemployment. There is a strong association between road accidents and alcohol abuse. Excessive drinking is also associated with petty offences, sexual offences and crimes of violence including murder.

13.5 Health-Artificial Immunisation

Immunisation prevents specific infectious disease and the consequent serious complications. It is therefore mandatory to administer the appropriate vaccines which stimulate the body's own defence mechanism aganist infections at the appropriate time. The importance of immunisation has been emphasised by WHO which has chosen the theme for World Health Day 1977: Immunise and protect your child. Immunity is defined as the resistanve to invasion and multiplication of a disease producing agent.

1. Types of immunity



Artificial passive immunity

Transfer of immunity from an immunised donor to a non-immune recipient by transforming antibodies or immunised lymphocytes is known as artificial passive immunity. This is therapeutically used in the treatment of tenanus, diphtheria etc.

Artificial Active Immunity

Artificial active immunity, is attained by the host in response to the antigen got by vaccination. Vaccines are preparation of live or killed microorganisms or their products (toxids).

Natural Immunity

All living organisms are naturally gifted with the resistance to certain infection from birth and this natural mechanism is known as innate immunity or natural immunity. It includes the general protective reactions of organisms against any invasion and not against any particular micro organism. It is also called as non-specific immunity. For example a person attacked by measles or small pox develops natural active immunity as he recovers from the disease. The immunity acquired by way of such infections is also long lasting in many cases. Natural passive immunity is transferred passively from mother to child through placenta.

2. Development of Vaccines (History of vaccine)

Some specific chemicals (antibiotics) extracted from micro organisms to cure the infection has greatly reduced human mortality. The discovery made by the British Physician, Edward Jenner, that milkmen and maids seldom suffered from the dreaded disease of small pox was very important. To explain this, he assumed that their resistance to small pox was perhaps caused by their continued exposure to cows who often suffered from cowpox. He accordingly proceeded (1798) to inject a small amount of matter from a cowpox sore into the arm of his son to ensure protection from small pox, although he did not at that time understand the mechanism which produced this effect.

Later, Pasteur established that many diseases including the small pox, were caused by viruses. At that time, the practice of injecting a small amount of the pathogen into the body to develop resistance against a specific disease, was applied to other disease such as rabies, cholera and tuberculosis. Pasteur called this practice VACCINATION derived from 'vacca' meaning 'cow' in Latin.

Vaccine is an antigenic preparation of micro organisms such as bacteria or virus,

administrated for prevention or treatment of infectious diseases.

Vaccines are now made in large quantities by growing the respective micro organisms in factories, and a number of processes are available for making live or attenuated (not fully active) micro organisms. You might wonder how a small quantity of these cells when infected into the body make it resistant to further attack instead of producing the disease itself. Later, you will be acquinted with the fascinating mechanism whereby the body, when vaccinated, learns to recognize a future intruder and deal with it. In simple words, it can be explained as follows.

When the cells in our blood encounter the infected viral cells, they produce some specific chemical molecules that kill the infected cells. These defending molecules once formed, tend to persist in the body for sometime during which period they successfully eliminate any infection caused by that particular virus. Such resistance created in our body to fight infection is known as immunity and the process of vaccination against diseases is called immunization.

(i) Antigen : A substance that can produce specific immune response when it is introduced into the tissues of an animal and that can react specifically with the products (antibodies or sensitised cell) is known as an antigen.

(ii) Booster dose : A dose of antigen (secondary) given after the primary dose stimulates accelerated production of large amounts of antibody. If booster doses are given, the immunity can be maintained.

(iii) Antibody : When an immunoglobulin reacts with a specific antigen it is called an antibody. They can specifically react with the antigen, destroying it or neutralizing it, and thus protects the body from the effect of the antigen. All antibodies are immunoglobulin but all immunoglobulins may not be antibodies.

3. Immunization Scheme

Days	Immunization	Place	Immunization against diseases
14 days	Oral polio	All the Govt. Hospitals and primary health centres	Polio
within 1 month	BCG		Tuberculosis
1½ months	DPT Polio		Diptheria/Pertussis/Tetanus and polio
2½ months	DPT polio	"	"
3½ months	DPT polio	"	"
9 month 270 days	vaccination	"	
1½ years	DPT polio (booster)	"	"
5 years	DT.	"	Diptheria / Tetanus
10 years	TT	"	Tetanus
16 years	TT	"	Tetanus

Pregnant woman, 3rd month, TT I dose
4th month TT II dose

DPT - Diphtheria, Pertusis (whooping cough) Tetanus

DT - Duel antigen

TT - Tetanus toxoid

BCG - Bacille Calmette Guerin

SELF-EVALUATION

Choose the correct answer

1. Active immunization is known as
   (1) antigen (2) antibody
   (3) vaccination (4) Immunoglobin.
2. Rheumatic fever is caused by
   (1) streptococcus (2) staphylococcus
   (3) E-coli (4) vibrio cholerae
3. Excessive appetite leading to increased intake of food is known as
   (1) polyurea (2) polydipsia
   (3) polyphagia (4) polymorphia
4. Example for non communicable disease
   (1) Cholera (2) malaria
   (3) coronary heart disease (4) Aids

Fill up the blanks

5. ..... is useful as an antidote against snake-bite and insect stings.
6. The roots of ..... is also effective remedy for blood cancer and asthma.

7. ..... is used in the treatment of malarial fever.
8. ..... system is also called Agastyar system.
9. Ayurveda means ..... , ...
10. ..... is the father of Homeopathy.
11. The pancreatic Beta cell releases a hormone called .....
12. The first symptom of CHD is a .....
13. Strep throat is caused by a bacteria called .....
14. Smoking is .....
15. Antibodies are formed of .....
16. Vaccination form is derived from 'vacca' meaning .....

Answer briefly :

17. What are the sources for quinine ?
18. Where is the Cinchona species distributed?
19. What is the chemical composition of Cinchona bark ?
20. Write the botanical and Tamil names of any two plants which yield drugs from roots ?
21. Where is *Vinca* distributed ?
22. What are the uses of *Vinca rosea* ?
23. What is naturopathy ?
24. What are the drugs obtained from stems and wood ?
25. Mention the names of drugs obtained from leaves, flowers and fruits.
26. What is meant by diabetes ?
27. What is meant by non communicable diseases?
28. What is Angina
29. What is an angioqram ?
30. What is Ischemia ?
31. What is angioplasty ?
32. What is the importance of booster dose?
33. What are antigens ?
34. What is immunization ?
35. What is meant by addiction ?
36. What is dialysis ?

Answer in Detail :

37. Give an account of the history of employing plant drugs in medicine.
38. Mention the uses of turmeric, Allium cepa, Allium sativum.
39. Write notes on siddha medicine.
40. What are the basic principles of yoga ?
41. Explain the history of Homeopathy.
42. Mention the characteristic features of plants of *Catharanthus roseus.*
43. Write notes on *Zingiber officinale.*
44. Write notes an Ayurvedic system of medicine.
45. Write notes on history of unani system of medicine.
46. Mention the medicinal properties and uses of *Ocimum tenuiflorum.*
47. Write notes on medicinal uses of *Azudirachta indica* - (any three).
48. Explain the protein deficiency diseases.
49. Describe Anorexia nervosa.
50. Explain the types of symptoms and treatment in renal failure.
51. What is obesity ? Explain the causes
52. Draw the immunization chart.
53. Explain the history of vaccine.
54. Write notes on deaddiction methods.

14. OUR ENVIRONMENT

14.1. Social Forestry

The word 'Forest' is derived from Latin 'Foris' meaning 'outside' that may be village boundary or fence including uncultivated and uninhabited land. Forests are the most valuable assets of any nation. Survival of man depends on the existence of plants and animals as they have traditional link with forests.

Total area of land mass of our planet is 13075 m.ha.; forest cover 440 m.ha of which 90 m.ha are man-made forests. In our country, forest cover is only about 22.7% - (75 m.ha.)

1. Deforestation

Forests provide fuel, food, fodder, medicines, timber etc. But without knowing the importance of forests, we destroy millions of hectares of forests every year. Removal of forest cover and undergrowth in any area is called "Deforestation". It leads to change in the environment, loss of animals, erosion of soil, reduced rain-fall and imbalance in ecosystem.

The causes and effects of deforestation

Overgrazing : Animals such as goat, sheep, cattle, elephants, camel, giraffe, deer, bison etc over feed on forest plants, particularly feed on growing shoot tips that greatly reduces the regeneration capacity of forest plants.

Reasons for the reduction in forest cover : The growing hunger for land, activities like urbanization, industrialization, road and dam construction, laying power lines, valley projects, cutting trees for fuel, fodder and medicinal purposes lead to great reduction in forest cover.

Over-exploitation of forest resources like timber, lac, resins, oils and pulp for paper industry makes forests to shrink.

Effects of deforestation : The effects of deforestation result in erosion of soil due to floods and wind that amounts to a loss of several crores of rupees every year.

(1) India looses about 6000 millions ton of fertile top soil due to deforestation and 1.5 million hectares of forest cover every year.

(2) 1% of forest land becomes barren every year and rainfall declined to 3-4% in the Himalayas.

(3) Erosion loss comes around Rs. 16,400 crores per year in India.

Deforestation indirectly cause imbalance in ecosystem affecting both forest and domestic animal population, birds, insects and many micro organisms which depend upon the forest vegetation.

Deforestation increases CO_2 in the atmosphere that may cause global warming or green house effect, increase in temperature, increase in the level of sea leading to submergence of many important coastal areas and cities.

Removal of forest trees means loss of valuable forest products like medicinal products, essential oils, lac, tannin, timber, fuel wood, fodder, fruits etc.

Soil fertility is also greatly affected due to deforestation; the pH may also be altered. This makes the soil unsuitable for cultivation; in course of time soil becomes barren.

People depending wholly on forests for drinking water are also badly affected by deforestation.

Prevention of Deforestation

Deforestation can be prevented by conservation and management of forests. The following measures may be useful.

(1) By making stringent forest laws.

(2) Creation of awareness among people about the importance of forests.

(3) Educating people living near the forests to participate in protecting, managing forests under social forestry programmes.

Afforestation

Afforestation is nothing but establishment of forest in an area that may be barren or area where trees were absent previously. This is done by planting fast growing trees like *Eucalyptus, Acacia* or conifers like *Pinus* to provide commercial timber and fuel wood. Afforestation may be done either by government agencies or the community. If people are involved it is also known as *social forestry.*

The main objective of afforestation is to prevent people from cutting and felling our valuable forest trees. In order to prevent this, area surrounding the forests may be selected and given for afforestation and for creation of social forests benefiting human population.

Social forestry is growing trees on available land for the purpose outside natural forest areas and managing the same with intimate involvement of the local people.

2. Advantages of social forestry :

(i) It prevents soil erosion and degradation of land.

(ii) Increases availability of timber for construction, fire wood and charcoal.

(iii) Optimum utilisation of land and human resources

(iv) Generates direct and indirect employment opportunities.

(v) Improves environmental conditions of the rural communities.

(vi) Controls pollution and diseases.

(vii) Increases local rainfall, shelter for birds and animals.

(viii) Provides food, fodder, fuel wood to the society.

(ix) Makes available many raw materials for cottage industries like basket & furniture making, wood carvings, cricket bats, paper, pencil and match stick making and forest products like honey, gum, lac, oleoresin, essential oils etc.

(x) Regulates flow of water, helps in water conservation, catchment area protection and flood control.

Social forestry brings about a healthy and harmonious relationship between man, animals and the forest. By educating the people who live surrounding the forests to protect the native forests, social forests are generated. Particularly skilled persons, educated and unemployed youth of the villages may be trained to cultivate many species of plants particularly useful to them commercially.

3. Plants chosen for social forestry :

While choosing plants for social forestry, suitability of the plant to the given area and economic benefits of the selected plant are to be considered. The species selected should meet the basic needs of the society for food, fuel, fodder and shelter for housing. It should also provide raw materials for rural industry and subsidiary operations.

Plants chosen should be multipurpose, fast growing and high yielding, easy to raise with least expenditure and should consist of fruit, timber, fodder and fuel trees.

The following criteria may be taken into consideration while selecting the species.

1. Non interference with main trees

2. Easy establishment and fast growth

3. Easy decomposition of litter

4. Ability to fix atmospheric nitrogen

5. No toxic effects on soil and crops

6. Multiple use and high yield

7. Tolerance to pruning

8. Adaptable to all human interference

9. Resistance to pests, diseases and climatic stresses.

14.2 Global Environmental Issues

Introduction: Our environment is composed of atmosphere, earth, water and space. In normal circumstances if it remains clean it is enjoyable. The interaction of the atmosphere, lithosphere, hydrosphere with biosphere always continues. Unfortunately, on account of industrialization, construction, transportation, etc., the composition and complex nature of environment gets changed. These activities affect the health of the environment ie. they pollute the environment. Now there are many environmental problems at the global level which have become the global issues. They are as follows :

1. Atmospheric pollution-air pollution, 2. Water pollution, 3. Chemical-pesticide pollution, 4. Solid waste problem, 5. Metal pollutants, 6. Environmental carcinogens, 7. Soil pollution due to fertilisers, 8. Noise pollution, 9. Global warming, 10. Global ozone problem, 11. Acid rain, 12. Radiation hazards, 13. Effects of modernization of Agriculture.

1. Global Warming

Definition: Abnormal increase of the temperature in the environment due to the continuous accumulation of gaseous pollutants is known as global warming.

Global Warming - A crisis: The earth receives shortwave radiation form the sun, 1/3rd of which is reflected and the 2/3rd is absorbed by the atmosphere,ocean,ice,land and biota.

The ideal situation is

Energy received from sun = Energy emitted from earth

The energy absorbed is balanced by outgoing radiation from the earth and atmosphere. If this balance is altered it results in imbalance, particularly it causes green house effect. Green house effect is a very serious environmental problem faced by us. This effect is enhanced by human activities that destabilises the natural balance. Green house gases (GHG) like CO_2, Methane CH_4, Nitrous oxide N_2O, Water Vapour H_2O and Ozone O_3, Hydroflurocarbon HFC in the atmosphere increase Green House Effect.

Table 14.1. Sources of Green House Gases

Green House Gas	Main sources
Carbon dioxide CO_2	Fossil fuel burning, woodfuel, Deforestation, Cement manufacture
Methane CH_4	Release from gas, oil or coal production or transmission Enteric fermentation from ruminants (sheep, cattle) Wetland rice cultivation Burning and decay of Biomass
Chloroflurocarbon (CFC)	Use of solvents, refrigerants, aerosol spray propellants, foam packaging.
Nitrous oxide N_2O	Fertilisers, fossil fuel burning, tropical deforestation, wild fires, forest fires land conversion for agriculture.

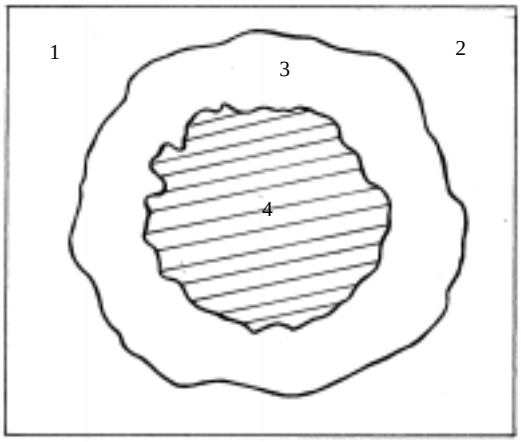


Fig. 14.1 Afforestation

1. Area inhabited by people 2. Area used for agriculture
3. Area allowed for social forests and afforestation 4. Forest

If the current trend continues, an average global warming over the 21st century will be at 0.3^oC per decade which may change regional climate and sea level rise averaging about 6 cms per decade.

2. Green House Gases

Two important human activities which are responsible for gradual rise of CO_2 level in the atmosphere :

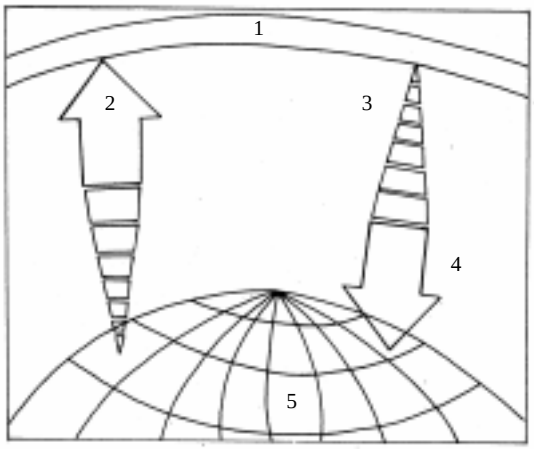


Fig. 14.2

1. Green house roof 2. CO_2 and other gases
3. Environmental threats 4. Rise in temperature, rise in sea level change in climate and rainfall 5. Earth

(1) Increasing burning of fossil fuels.

(2) Loss of CO_2 through loss of (due to deforestation, oil and coal consumption) natural resources

(3) Rise in temperature due to GHG

3. Effects of Global Warming:

The rise in volume of green house gases and consequent global warming affect earth's climate and ecosystem. They are

(1) Sea level change: There is a rise in sea level which may be due to the following major changes : (a) Thermal Expansion of atmosphere (b) Mountain glaciers melting (c) Greenland ice sheet melting (d) Antarctic ice sheet melting.

All brought about by global warming.

If the amount of CO_2 in the environment increases without any control, the sea level may increase upto 18-28 cms around the year 2030. Currently global sea levels are rising a few cms per decade. Two third of the rise is due to global warming and remaining one third is due to deforestation, draining of wetlands, and large scale pumping of ground water. Mean global temperature are likely to rise by $1.4^oC \pm 0.7^oC$ by the year 2030 and $2.1^oC \pm 0.8^oC$ by the year 2050. Mean global seawater level which has risen 10-15 cm in the last

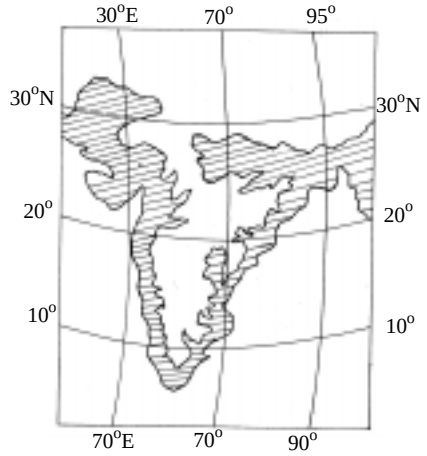


Fig. 14.3 Possible sub-mersion of land due to sea level rise in India

Shaded Region likely to get submerged if sea level rises by 2 metres. (6-6 foot)

century may rise by another 10-20 cms by 2025 and 50-200 cms by 2100. This will cause extensive flooding of low lying areas in the world. Many famous cities are coastal, so even a moderate rise in sea level would flood cities in Bangladesh, India, Egypt, Thailand and China. Entry of salt water makes land unsuitable for cultivation of natural crops. Many plants and animals will become extinct because of rapid change in temperature.

Shadowed region likely to get submerged if sea level rises by 2 metres (6.6 foot) (Fig. 14.3)

(2) **Crop yield:** CO_2 rise will result in increase in yield of crops upto 60-80%. But other factors will effect regional climate change and loss of ecosystem.

(3) **Water balance:** The water availability is likely to be more serious and perhaps more expensive to solve. In future the warmer world will have water crisis in some parts while in other region it will be wetter than today. Global warming may even affect future rain pattern that may have pronounced effect on agriculture and ecosystem.

(4) **Reduction in water supplies:** Lakes, Streams and aquifers could shrink or dry up altogether forcing the entire population to migrate to other areas.

(5) **Change in forests:** Temperate and subarctic forests will get reduced to grasslands and shrublands. Forest fire would add more CO_2 to atmosphere.

(6) **Reduction in biodiversity:** Large scale deforestation would also cause extinction of species. Reduction in parks, wild life sancturies, wetlands, coral reefs lead to loss of biodiversity.

(7) **Weather extremes:** Due to global warming continuous heat waves and droughts would become a regular problem in many areas. As the upper layer of sea water becomes warmer, hurricanes and typhoons would occur more frequently and blow more fiercely.

(8) **Threats to human health :** Global warming would disrupt supplies of food and water, displace many people and altering disease patterns. Tropical diseases like malaria, elephentiasis, yellow fever, dengue fever may spread from the tropics to temperate zones. Sea level rise could spread infectious diseases by flooding sewage and sanitation systems in coastal cities.

How to prevent global warming ? 1. 25-35% reduction in green house gas emissions. 2. Stopping production of CFC (chloroflurocarbon) 3. Billions of trees should be planted. 4. Finding less polluting alternate sources of energy.

2. Ozone Layer

Ozone, a form of oxygen with 3 molecules is a gas that is blue in colour. It has a characteristic pungent smell. It occurs throughout the atmosphere but in small quantities. It forms a shield above the earth in the atmosphere amounting only to 3mm thickness. Under average conditions, at ground level, each cm of air contains around 10^{19} molecules of all gases of which ozone constitute only about 0.1ppm. 90% of ozone lies in the stratosphere which is located in between 15-50 km above the earth surface.

Ozone acts as a filter around the earth and shields harmful rays such as u.v. reaching the earth thus protecting the earth.

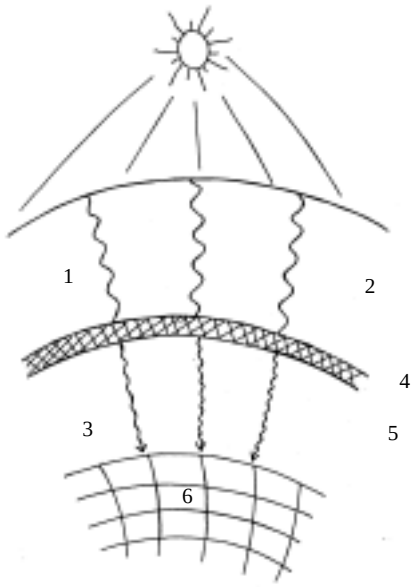


Fig. 14.4 The ozone shield protecting the earth from lethal ultra violet radiation

1. UV Radiation 2. Stratosphere (10-20 km) 3. Reduced UV radiation 4. Ozone Shield 5. Troposphere (0-10 km) 6. Earth

Causes of ozone depletion: When gas such as NO, NO_2, Cl are released they easily react with ozone. Because of this the amount of Ozone in the atmosphere is reduced. This is known as ozone depletion.

Ozone hole: CFC that is mixed with deodorants, hairsprays, shaving creams, insecticides from spray cans, coolant in Air conditioners and refrigerants accumulate in the stratosphere.

It is estimated that CFCs and other ozone depleting atmospheric gases so far removed 50% of the protective ozone layer of the Antarctica and made a big hole in ozone shield (approximately. 20 million square kilometres) (NASA 2000). Ozone hole is increasing in Arctic region also.

Effects of Ozone depletion

1. The harmful u.v. radiation towards earth increases; U.V. induces change in DNA which is responsible for skin cancer.

2. Immune System suppression.

3. Crops (aquatic and terrestrial ecosystem) would be adversely affected (crop yield and quality get reduced)

4. Affects quality of air, splitting of O_3 and production of hydrogen peroxide (H_2O_2) that will affect human health, terrestrial plants and outdoor materials.

5. Affect sea food production; particularly early developmental stages of fish, crab, amphibians, other animals are affected.

Ozone depletion extending over the entire Antarctic formed a hole in the ozone layer known as **"Ozone hole".**

The biologically active part of UV called UV-B penetrates all the way to the ground. It causes health hazards in human, animals and wetland plants. If UV-B is not filtered by this ozone shield it causes,

1. skin cancer 2. changes in melanin pigmentation 3. seriously suppresses our body's immune responses 4. causes damage to eyes resulting in cataracts. 5. increases in the incidence of severity and infectious diseases in tropical and sub tropical regions.

Plants sensitive to UV-B show reduced growth and smaller leaves. Photosynthetic rate falls down, resulting in poor seeds and fruits. Change in chemical composition of these plants results in poor food quality.

Aquatic ecosystem - affects Zooplanktons,slowing the rate of photosynthesis in Phytoplanktons.

Climate : Ozone depletion changes temperature of earth to some extent - warming or cooling.

Control measures : CFC's to be phased out completely. Halogens Carbon tetrachloride, Methanol, Chloroform are also to be phased out. Vehicular pollution to be controlled; fossil fuel use to be minimised.

3. Earth summits

In recent years, environmental concern has been at the forefront of public attention. Because of this many countries have formulated environmental rules and regulation to protect the environment.

Members of public and Non governmental organisation promote and work on such global issues. (e.g)

UNEP - United Nations Environment Programme.

IUCN - International Union for Conservation of Nature and natural resources

WWF - World Wide Life Foundation

IUPN - International Union for the Protection of Nature.

SPWFE - Society for Preservation of Wild flora of the Empire.

In India : Chipko movement, Silent Valley movement, Appiko movement, Narmada Bachan Andolan, etc are organisations or movements involved in protection and preservation of nature.

During the past several decades at the global level, several national governments made several treaties and agreements to protect the environment.

United Nations in UNEP, 1989, listed several issuses like ozone layer depletion, air pollution, endangered wild life, hazardous wastes for discussion. Earth summit at Rio, brought important treaties. They are 1. Convention on biodiversity 2. U.N. convention on climate change.

All these efforts made by UN and other Organisations resulted in reducing the damage to the environment to a certain extent. Public awareness about the advantages of cleaner, healthier environment and their involvement, co-operation in this direction alone will make our earth a safer place to live.

14.3 Fresh water crisis and management

Role of water in animal system

Each and every cell of our body depends upon water to function properly or else it will die within few days. So it is a very essential vital nutrient. Water helps you to digest and absorb all the nutrients and get rid of both solid and liquid wastes from our system. Inadequate liquid intake will result in chronic constipation.

It is also an essential component of blood; it transports oxygen as well as infection fighting cells and antibodies to where they are very much needed. It lubricates joints, keeps internal organs from sticking together and skin

from shrivelling and drying out. Salts dissolved in drinking water maintains electrolyte balance inside and outside cells. It is also part of our body's air-conditioning system, the water lost through (perspiration) your skin helps to cool your body. During pregnancy it provides a protective cushion for the growing foetus.

(1) Recommended Daily Allowance for water may be atleast 6-8 glasses of water a day, more during summer and warmer days.

(2) Less water intake results in muscle fatigue and poor performance, even life threatening during extremely hot weather.

55% to 75% of man's body is made up of water.

Average adult body holds 35-50 litres of water, of which 2 to 2.5 litres are lost everyday through excretion and perspiration.

1. Availability of fresh water :

India receives an average rainfall of around 1140 mm annually which is highest in the world comparing its area and population with other countries.

According to UN estimates the amount of water present on earth is about 1400 million cubic kilometres covering the 3/4 th of surface of the earth. But only 2.7% of the total water available on earth is fresh water of which 75.2% lies in the frozen polar regions and 22.6% is present as ground water. Hence the importance of water should be recognised and greater efforts should be made to use it economically.

India receives rainfall over 500 mm from may to Oct. (Southwest monsoon) and Nov. to April (North east monsoon)

Monsoon climate includes four main seasons. They are (i) Cold season (December January February) (ii) Hot season (March, April, May) (iii) Advancing monsoon season (June to September) (iv) Retreating monsoon season (October and November)

Temperature and Rainfall varies according to these different seasons.

Rainwater is the ultimate source of fresh water to improve water table and quality of ground water.

2. Depletion

With rapid increase in population, industrialization, urbanization, the demand for water has increased manifold. So the stored ground water is extracted by means of dug/tube/bore wells in large scale. Thus over extraction of ground water leads to decline in ground water levels results in dry wells.

In Coimbatore, Salem and Namakkal districts of Tamil Nadu, the ground water levels have gone down upto 40 meters, in coastal areas over drawal of water made sea-water movements towards land area.

The effluents discharged from factories and tanneries get into the ground water and makes it unsuitable for human use.

3. Conservation of water :

Due to increasing demands for water and reduced availability of fresh ground water resources, urgent measures are to be taken to conserve each and every drop of water that is available.

It is also essential to make necessary methods to ground water storage by simple rainwater recharge methods.

Run-off water during monsoon rain can be prevented from flowing into the rivers and mixing with sea finally. This surplus water can be easily harvested and made to recharge underground water table efficiently.

Water conservation even solves the problem of sea water inward movement in coastal areas and helps to push back the sea water from mixing with fresh water.

Change in irrigation practices, adoption of modern irrigation methods like drip irrigation and sprinkler irrigation, prevention of seepage losses, moisture conservation of soil, water efficient cultural practices will save more water.

Runoff water can be minimised by establishing plant covers. The greatest tamil work "Thirukural" brings out the importance of water for life on earth. The very second chapter of this is devoted only for the importance of water.

4. Rain Water Harvesting

It is the activity of direct collection of rain water which can be stored in sumps or

can be recharged into the ground water aquifer in use.

During monsoon within a span of two or three months time, 1,60,000 litres of rainwater can be harvested per ground (223 sq.m) approximately.

5. Methods of rain water harvesting

(1) Roof top Harvesting : Wherever open wells or borewells are available, rooftop water can be used for direct recharging of these wells.

(2) Open-space Harvesting : Open spaces around the buildings and offices are also used for rain water harvesting, by following simple and less expensive methods.

(1) Percolation / Recharge pits (with or without bore)

(2) Recharge Trenches (with or without bore)

(3) Recharge wells (small and large diameters)

For effective recharge of rain water, combination of different structures may be used as per the site requirement particularly the size and area of the building, open spaces and soil conditions.

RWH involves three important steps.

(1) Collection of rainwater, (2) Filtration, (3)Recharge of rain water into well or ground

6. Benefits of RWH

1. Ground water level is increased.

2. Recharges the well and reduces the cracking of building structures.

3. Improves the quality of ground water by diluting the salt content in the well.

4. Reduces the amount of run-off wate; soil erosion, loss of valuable top soil and evaporation rate.

5. Helps growth of plants and trees.

6. A dangerous phenomenon called sea water intrusion towards the land is arrested.

7. Reduces drinking water problem.

14.4 Effluent Treatment

The chief sources of water pollution are effluents from domestic, agricultural and industrial activities. These effluents must, therefore, be treated to ensure good water quality and to prevent environmental pollution.

1. Industrial Effluents

The effluents could be classified as organic and inorganic. Domestic and agricultural activities chiefly produce organic effluents that include organic wastes from fruits and vegetables, human refuse, pesticide residues and harmful microbes. When organic wastes are dumped in to water bodies, they cause excessive growth of aquatic vegetation. This is called Eutrophication. When these plants die, their decay causes depletion of dissolved oxygen. This leads to death of aquatic animals and foul smell. The water is rendered useless as a result of this. Moreover, the harmful microbes cause a variety of serious diseases like Polio and Cholera.

Industrial effluents consists of both organic and inorganic substances. Agro-based industries like sugar factories, paper industries and food processing centres produce organic substances as their chief effluents. Other industries like chemical factories, petroleum refining, leather and textile industries, mining and steel plants produce effluents containing chiefly inorganic substances like heavy metals, industrial salts, acids and other toxic substances.

2. Heavy metals and their effects on organisms

Lead, Mercury, Arsenic, Cadmium are some of the heavy metals found in various effluents. Besides, other metals that affect organisms are Aluminium, Chromium, Cobalt, Manganese, Nickel, Selenium, Tin and Thallium. The metals get concentrated in different organs like bones, fat cells, liver etc. This phenomenon is called 'Biological accumulation'. Moreover, heavy metals tend to increase in concentration as we go up the food chain. For example, a snake might eat several frogs and accumulate the heavy metals from all of them. Thus animals in the upper

levels of the food chain are more prone to heavy metal toxicity. This phenomenon is called 'Biological Magnification'.

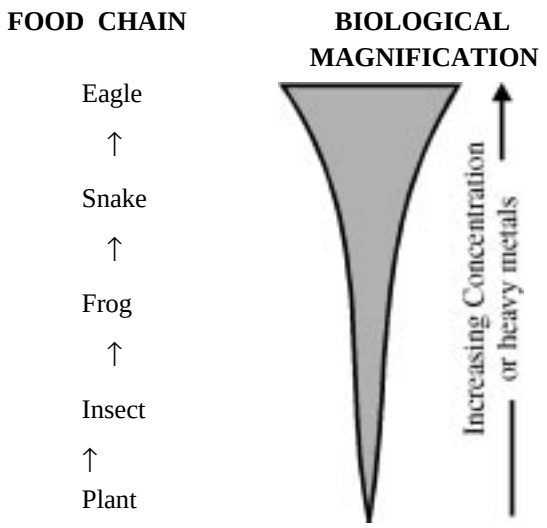


Fig. 14.5 Biological Magnification

The common effects of heavy metal toxicity include damage to the nervous system and kidneys, gastrointestinal upsets, vision problem and mental confusion.

3. Common Effluent treatment Plants and their importance.

Effluent treatment aims at removing the polluting components, so that the water could be recycled or atleast made less harmful to the environment. It is carried out in three stages. In the primary treatment of effluents, suspended impurities are removed by sedimentation. Secondary treatment involves biological treatment to remove organic material. Active aeration is provided to aid microbial degradation of organic pollutants. Finally, chemical substances are removed in the tertiary effluent treatment. It is the most expensive part of effluent treatment. It involves such methods as reverse osmosis and use of specific membranes to remove inorganic substances. The water, thus purified, can then be released in to the environment or reused.

The Central Pollution Control Board (CPCB) has identified 1551 large and medium industries as highly polluting industries, contributing maximum to the pollution load. They are required to install their own pollution control equipments. However, small scale industries cannot instal their own effluent treatment plant because of their financial and technical constraints. In areas where small scale units are in a cluster, Common Effluent Treatment Plants (CETP) have been proposed. Here, the effluent from all the small industries are pooled together and treated. Thus CETP allows the small scale industries to treat their effluents in an economic manner by cooperation. The government offers financial assistance for the establishment of CETPs. The government has also allowed large and medium scale industries, other than the 1551 heavily polluting industries, to join the CETP.

The CETP offers the following advantages.

(1) It makes pollution control economical by reducing the cost of effluent treatment for each individual industry.

(2) Problems arising due to lack of trained personnel can be minimised because fewer treatment plants would require fewer people to manage them.

(3) Most of these industries may not have adequate space to house an effluent treatment plant in their premise. This problem is solved by establishing a CETP, which is located in a common area.

(4) Effluent treatment plants require constant monitoring to ensure that the treated effluents conform to the prescribed standards. CETP makes monitoring easy by reducing the number of such treatment plants.

14.5 Air Pollution

Any undesirable change in the physical, chemical or biological characterisitics of air, land and water that affect human life adversely is called ''pollution''. The major causes for pollution are enhanced pace of developmental activities and rapid urbanization. The increase

in pollution in various environmental media has resulted in deterioration of air and water quality, higher noise levels, increase in vehicular emission etc.

Condition of the atmosphere in which a pollutant is present in such a quantity as to (i) be injurious to public health or (ii) have a harmful effect on flora or fauna (iii) impair or interfere with the environment is termed as "Air pollution"

Various substances in air which arise from natural processes and human activity which may impair the health of plants, animals or human beings are called "Air pollutants". Pollutants present naturally are termed as natural or primary pollutants eg. ash from volcanic eruptions, salt particles, smoke from forest fire, etc. Pollutants resulting from human activities are termed as anthrogenic pollutants eg. mining and industrial operations

1. Pollutants

Let us know more about some of the major air pollutants in detail

Carbon monoxide (CO) :

Carbon monoxide is a colourless, odourless poisonous gas produced by incomplete combustion of fossil fuels. Motor vehicles are the major source of carbon monoxide.

When inhaled, carbon monoxide combines with haemoglobin because it has higher affinity than oxygen. This stops blood from carrying oxygen efficiently to various organs of the body. Carbon monoxide can cause headaches, tiredness, nausea, chest pain and vision problems. It can also cause death.

Sulphur dioxide (SO_2) :

It is an acid smelling gas produced by burning sulphur containing fuel. Chemical industries, paper factory and fuel factory are the major source of sulphur dioxide.

Sulphurdioxide is a respiratory irritant. It aggravates asthma. It also causes irritation of eyes, nose and throat. Sulphur dioxide is one of the air pollutants that contributes to formation of acid rain. Sulphur dioxide dissolve in water (H_2O) to form suphuric acid ($H_2 SO_4$), a corrosive substance which has destructive effect. Acid rain reduces the fertility of soil thereby reducing its productivity.

Nitrogen Oxides (NO_x)

NO_x is a generic term for a group of highly reactive gases containing Nitrogen (N_2) and Oxygen (O_2) in varying amounts. The major pollutants in this range of compounds are Nitrous oxide ($N_2 O$) and Nitrogen dioxide (NO_2). These gases are produced by burning fossil fuels. The phenomenon by which more amount of heat from the sun is trapped by the earth, thus increasing its temperature, is known as ''Green house Effect''. Gases that aid in trapping heat are called greenhouse gases. Nitrous oxide is one of the greenhouse gases. Therefore it contributes to global warming. Apart from nitrous oxide (N_2O) other greenhouse gases are carbondioxide (CO_2), methane (CH_4), Hydroflorocarbons (HFC_s), Perfluorocarbons (PFC_s) and Sulphur hexaflouride (SF_6). You have already studied about Green House Gases in greater detail under Global Environmental issues.

Nitrogen oxides react to form nitrate particles and acid aerosols which cause respiratory problems. It contributes to formation of acid rain. It also triggers asthma. Nitrogen oxides play a major role in chemical reaction which generate photochemical smog. Thus it contributes to formation of atmospheric particles that reduces visibility.

Other important pollutants that reduce air quality are lead, particulate matter and ground level Ozone. The effect of the major pollutants that have been discussed are as tabulated below.

Table: 14.2 Major air pollutants and their effects

Pollutant	Effects	
Carbon monoxide	(i)	reduces oxygen supply to various organs of the body.
	(ii)	causes heart diseases.
	(iii)	reduces ability to work or learn
	(vi)	contributes to formation of smog and causes respiratory problems.
Sulphur dioxide	(i)	Contributes to formation of acid rain thus making soil and water acidic.
	(ii)	Contributes to formation of atmospheric particles causing visual impairment.
	(iii)	causes irritation of eyes, nose and throat
	(iv)	it is a respiratory irritant
Nitrogen Oxides	(i)	contributes to formation of acid rain.
	(ii)	it is a respiratory irritant.
	(iii)	involved in formation of smog and ozone.
	(iv)	contributes to global warming
Ground level Ozone	(i)	causes asthma attacks, sore throats, coughs
	(ii)	causes damages to plants and crops.
Particulate matter	(i)	causes respiratory problems and asthma attacks
	(ii)	causes premature death
Lead	(i)	causes nervous and kidney problems.
	(ii)	increases chances of heart attacks and strokes.

2. Control of air pollution

(1) Technically upgraded equipments and machines which are more efficient and less polluting should replace inefficient older ones.

(2) Equipment and machines should be maintained properly and inspection should be done regularly.

(3) Vehicular emission standards should be set up

(4) Quality of fuel should be improved. Use of ethanol blended petrol, biodiesel and compressed natural gas (CNG) should be promoted as they are less polluting

(5) Use of Non-fossil fuels and renewable energy sources such as solar energy, tidal energy, hydro energy should be encouraged.

(6) Industrial zone should be separated from living space; Industries should be surrounded by a green belt to prevent polluting gases from reaching residential areas.

(7) Smoking should be banned in public places.

3. Noise Pollution :

Any sound that has the potential to cause disturbance, discomfort, physical damage or psychological stress to a person exposed to it is termed as ‘‘Noise Pollution’’ High intensity sound emitted by industrial machines, aircraft etc., when continued for long periods of time, can permanently damage hearing. Even low level noise, such as noise generated by radio, highway or crowd, can cause emotional stress. So noise is considered a potentially serious pollutant.

Sound is measured on the decibel (dB) scale, which is a logarithmic scale of sound intensity

The human hearing capacity varies in intensity from 10 to greater than 120 decibel. Ordinary conversation registers between 30 and 60 dB. Any sound above 120 dB causes physical discomfort and pain in the ears. Sensitivity to noise is greater at night than during the day.

Table 14.3 Various decibel levels of sound :

dB	Description
0	Absolute silence
10	Threshold of hearing
25	Quiet room
35	Rural night time setting
55	Daytime busy roadway
70	Noisy restaurant, Loud radio in an average house (difficult to use the phone)
80	Road construction site (voice has to raised to be heard)
90	Printing press plant (Annoying and causes damage to ears after 8hrs of continuation)
100	Railway locomotive.
120	Uncomfortably loud. Conversation impossible
130	Intolerable
140	Causes pain in ears

Effects of noise pollution:

There are three general categories of effects of noise on people

(i) subjective effects of annoyance, nuisance, dissatisfication

(ii) interference with activities such as speech, sleep, learning etc.,

(iii) physiological effects such as startling, hearing loss, etc.

Control measures : A major problem in noise control lies in the difficulty of evaluating complex noise, that is, the kind of noise that is most often irritating.

(1) Enforced zoning and planning should be done to separate industrial zone and highways from living space

(2) Noise limits for vehicles should be set

(3) Open use of loudspeakers and public address system should be restricted during night

(4) Plants are efficient absorbers of noise, especially noises of high frequency. Therefore planting should be encouraged. It will be more effective if plantings are lower towards the noise source and higher towards the listener, thus not only absorbing but also deflecting the noise upward.

(7) Specific guidelines for the level of noise allowable at certain times of the day and for certain activities should be set

Air and noise pollution are a serious threat to human beings and animals. They affect different aspects of our lives causing a number of diseases. Pollution control is a herculean task. Apart from government efforts to improve conditions, each individual should become conscious of the hazards of a polluted environment. An environment free of pollution and unwanted noise will help man lead a happy and healthy life.

14.6 Wildlife protection

Wildlife

All non-domesticated and non-cultivated biota found in natural habitat are termed ‘wildlife’. It includes all the natural flora and fauna of a geographic region. Wildlife is an asset to be protected and preserved to our own advantage and to the benefit of future generations.

1. Need for protection - Conservation

India has a rich and wide variety of wildlife. India is one of the 12 countries identified as mega-centres of biological diversity. India’s immense biological diversity comprises 7% of world’s flora and 6.5% of world’s fauna. Forests comprises about 19% of land area of India. But there has been drastic changes in the environment due to human intervention, industrialization and deforestation.

It is essential to protect and conserve wildlife because they are of aesthetic, ecological, educational, historical and scientific value. A good biotic diversity is essential for ecological balance. Large scale destruction of wildlife could lead to ecological imbalance.

Wildlife also add aesthetic value and are a big boost to tourism. Eco-tourism is being promoted in a big way by many countries. The wildlife and their products could be of great economic value if exploited properly. The innumerable plants could yield products of immense medicinal value in the future. The wildlife are also a store of vast genetic diversity which could be exploited with advances in genetic engineering. Thus wildlife has been of great value in the past and will continue to be so in the future. Protection and conservation of wildlife, therefore gains importance.

The Government of India instituted the Central Board for wildlife in 1949 which was renamed as the Indian Board of Wildlife (IBWL) in 1952 to safeguard and monitor wildlife. IBWL aimed at

(1) conservation of wildlife through legistation and other measures.

(2) establishment of national parks, sanctuaries and zoological gardens

(3) promotion of public interest and education in wildlife

(4) formulating import and export policy of wildlife and its products.

The central legislation called Wildlife (Protection) Act was enacted in 1972 for providing special legal, protection to wildlife and to endangered species of flora and fauna. By this act State governments are empowered to declare an appropriate area a sanctuary for developing wildlife and its environment.

The Government of India launched the Project Tiger scheme in 1973 and Project Elephant Scheme in 1992 to safeguard tigers and elephants respectively from the brink of extinction.

2. Indian wildlife fauna and flora

Being a vast country with diverse physical and climatic conditions and vegetation India boasts a wide variety of flora and fauna. There are approximately 400 varieties of reptiles, 200 varieties of amphibians, 3000 varieties of fishes, 3000 species of birds and 20,000 species of flowering plants found in the country according to the latest census estimate.

According to the distribution of the flora, India can be classified into Western Himalayas, Eastern Himalayas, Assam, Indus plain, Ganga plain, Deccan, Malabar and the Andamans. The Western Himalayas region consists of chirpine, deodar, blue pine, spruce, silver fir, and junipers. The Eastern Himalayan region abounds in oaks, laurels, maples, rhododenderons, alder, birch, and dwarf willows. The Assam region is full of evergreen forests with lots of bamboo and tall grasses. The Indus plain supports scanty vegetation and Ganges plain is under cultivation. The Deccan region is full of shrubs and mixed deciduous forests. The Malabar region is under commercial crops like coconut, betal, pepper, coffee and tea. The Andaman region abounds in evergreen and mangrove forests. Of the deciduous trees, sal and teak are important. Deodars, pines, cedars and spruce are found in the foot hills of Himalayas, Sandalwood is found on Karnataka and TamilNadu. Coconut palms are dominant in Kerala.

Much of the wildlife of India is found nowhere else in the world. The wild asses are confined to the arid areas of the Rann of Kutch. The elephant typical of hot wet equatorial forests is found in Assam and Kerala. The one-horned rhinoceros which is unique to India and Nepal is found in swampy and marshy lands of Assam and North of WestBengal. Indian bison, Indian buffalo, the Nilgai, black buck, chinkara, lion tailed macaque, chital, sambhar, wild boar, pigmy hog also form India's exclusive fauna.

The other animals include four horned antelope, gazel, Kashmir stag, swamp deer, musk deer, mouse deer etc. The Asiatic Lion is confined to Gir forests in Gujarat. The

Bengal Tiger has its natural habitat in the tidal forests of Sunderbans. Snow leopards are confined to the upper Himalayas. Golden langur is unique and confined to Manas in Assam.

A huge number of snake varieties, lizards and crocodiles account for the reptile count. Snakes include the deadly. King Cobras and Kraits. Gharial is found in River Ganga. Scorpions and insects are numerous in number. Harmful insects like mosquitoes, locusts, etc and useful insects like bees, silkworm, lac insect are also found.

The birds include the beautiful peocock, parrot and the other immigrant birds. Other common birds are pheasants, geese, ducks, mynahs, parakeets, pigeons, cranes, hornbills, vultures, golden eagles, great horned owl, sand grouses and spotted billed pelicans.

3. Sanctuaries - Other protection methods.

Wildlife sanctuary is an area constituted by competent authority in which hunting or capturing of animals is prohibited except by or under control of the highest authority responsible for management of the area. National Park is an area dedicated to conserve the environment, the natural objects and the wildlife therein. Reserved Forest is an area in which wildlife is protected under forest laws. Protected Area is an area where special protection is granted to reestablish wildlife on the verge of extinction.

Wildlife sanctuaries were established in India in the pursuit of conserving wildlife which was suffering due to ecological imbalances caused by human activities. There are 89 National Parks, 500 Wildlife Sanctuaries, 27 Tiger reserves, 200 Zoos and 13 Biosphere reserves in the country covering an area of 1.6 lakh sqkm.

Table 14.4 Important sanctuaries in Tamil Nadu.

No.	Name	Location	Animals
1.	Indira Gandhi Wildlife, Sanctuary.	Western Ghats.	Tiger, leopard, porcupine, Nilgiris tahr, civet cat, elephant, gaur, pangolin.
2.	Kalakkadu Wildlife Sanctuary.	Tirunelveli district.	Lion tailed macaque, sambhar, sloth bear, gaur, flying squirrel.
3.	Srivillipathur Grizzled Squirrel Wildlife Sanctuary.	Virudhunagar district.	Grizzled squirrels, mouse deer, barking deer, tree shrew.
4.	Vedanthangal Bird's Sanctuaries.	Kancheepuram district.	Cormorants, egrets, grey heron, open-billed stork, white ibres, shovellers, pintails, stilts, sandpipes
5.	Mudumalai Wildlife Sanctuary.	Nilgiri Hill.	Elephants, gaur, langur, tigers, leopards, chital, sloth bear, sambhar, wildbear, jackal, porcupine, mangoose.
6.	Viralimalai.	Tiruchy district.	Wild peacocks
7.	Gulf of Mannar Marine National Park.	Coast of Ramnad and Tuticorin district.	Coral reefs, dugong, turtles, dolpins, balanoglossus.
8.	Mundhanthurai Wildlife Sanctuary.	Tirunelveli district.	Tiger, bonnet macaque, langurs, sloth bear, wild dog
9.	Vallanudu Blackbuck Sanctuary.	Tuticorin district.	Blackbuck, jungle cat, hare, mangoose.
10.	Arignar Anna Zoological Park.	Vandalur.	Lion, elephant, tiger, monkeys.
11.	Mukkurthi National Park.	Nilgiri Hills.	Tigers.
12.	Point Calimere Wildlife Sanctuary.	Nagapattinam district.	Chital, wild boar, plovers, stilts, bonnet macaque.
13.	Anamalai Wildlife Sanctuary.	Slopes of Western Ghats.	Civet cat, porcupine, gaur, tiger, leopard, Nilgiri tahr.

Table 14.5 Important National Parks, Wildlife sanctuaries and reserves.

No.	Name	Location	Animals
1.	Bandhipur National Park (It is a tiger reserve too).	Karnataka.	Indian bison, chital, sloth bear, elephants
2.	Corbett National Park (India's first national park) (Tiger reserve too).	Uttaranchal.	Tigers, chital, elephants, leopard, jungle cat and sloth bear
3.	Gir National park.	Gujarat.	Asiatic Lion
4.	Kanha National Park (Tiger reserve).	Madhya Pradesh.	Swamp deer, tiger, chital, black buck, leopard, hyena
5.	Kaziranga National Park.	Assam.	One-horned rhihoceros
6.	Bharathpur Bird Sanctuary	Rajasthan.	374 species of bird, eg:Indian darters, spoonbills, painted stork, open billed stork, black necked stork etc.
7.	Manas Wildlife Sanctuary (Tiger reserve).	Assam.	Hispid hare (rare), pygmy hog, golden langur.
8.	Sunderbans National Park (Tiger reserve).	West Bengal.	Unique royal Bengal Tigers

Marine reserves are areas protected to preserve the marine diversity. They include wetlands, mangroves and coral reefs. 24 wetlands, 33 mangroves and 4 coral areas. Mangroves are salt-tolerant forest ecosystem mainly found in tropical and sub-tropical inter-tidal regions. They stabilize the shoreline and act as reservoirs of a large number of plants and animal species. Important mangrove areas in India are Andamans and Nicobar Islands, Sunderbans (West Bengal), Krishna Estuary (Andhra), Pitchavaram and Point Calimere (Tamil Nadu), Gulf of Kutch (Gujarat), Vembanad (Kerala), Godavari delta and Mahanadi delta. Coral reefs are shallow water tropical marine ecosystems characterized by high biomass production and rich flora and fauna. The four Indian coral reefs are Gulf of Mannar, Andaman and Nicobar Islands, Lakshadweep Islands and Gulf of Kutch.

Biosphere reserves are multipurpose protected areas to preserve the genetic diversity. Its objectives are

(1) to promote research on ecological conservation and other environmental impacts.

(2) to conserve diversity and integrity of plants, animals and micro-organisms.

(3) to provide facilities for education, awareness and training.

There are 13 biosphere reserves in India at present.

4. Extinct and endangered species

Extinction is a natural process by which whole species die out without leaving any offsprings. But today, many species have been pushed to the verge of extinction by man-made conditions. This man-made extinction could cause ecological imbalance and thereby produce catastropic effects. Primary reasons for man-made extinction are

(1) **Habitat loss :** Human population pressure is the major cause for habitat loss. Clearing forest land for agricultural purposes, human settlements, mining and other industrial activities have led to the shrinkage of the natural habitat of wildlife. As a result of this human intervation most of the wild species could not adapt themselves to the changed conditions and perished.

(2) **Introduction of new species :** New species introduced by man into an area have wrecked havoc into the wildlife population of that area. These introduced species either compete with the wildlife for the limited resources like food, water and space or they directly prey on the wildlife. Overgrazing by domestic cattle has greatly reduced the wild herbivore population. Dogs and cats, introduced by human beings have killed wild animals which could not adapt to such predators.

(3) **Over exploitation :** Cutting down trees for human use, hunting animals for their parts like tusks and skin, overfishing have caused a decline of the wild population.

(4) **Pollution :** Pollution leads to deteriotion of the quality of environment. Water pollution causes new diseases in the wild animals. Soil erosion leads to loss of soil fertility and decreases the productivity of the forests. These have also led to extinction of species.

Some of the recently extinct animal species are mountain quail, pink headed duck, and streamlined spotted feline cheetah. Hispid hare, lion tailed macaque and pygmy hog are considered rare and near extinction.

India is home to some of the most exotic wildlife, many of which are endangered bordering on the brink of extinction. When the population of wild species comes down, the genetic variability is lost. This leads to a decreased ability of the species to adapt to environmental change. They become highly prone to extinction. When their population goes below a critical number, they fail to reproduced sustainably, leading to elimination of the species. Such species with decreased population, that are on the verge of extinction are called **endangered species.**

IUCN (International Union for Conservation of Nature and Natural Resources) has categorized plants and animals into four types according to their distribution, population, abundance, habitat and potential. They are

(i) endangered, (ii) vulnerable, (iii) rare and (iv) threatened. IUCN has listed 103 animals of India as endangered species. These include mongoose, vultures and hill myna.

5. Governmental and NGO agencies

A number of governmental and non-governmental organizations (NGO) are actively involved in wildlife conservation. Some of them are as follows :

(1) Bombay Natural History Society

Ths society was started in 1883. This society is engaged in collecting information and specimens of fauna and flora all through the country and played an important role in drawing public attention to the need of wildlife conservation. It has a museum which exhibits the skins of rare animals, stuffed birds, reptiles and other animals. It has been carrying out various useful research projects on Indian flora and fauna. It has published excellent books like 'The Book on Indian Natural History' and 'Some Beautiful Indian Climbers and Shrubs.'

(2) Zoological Survey of India(ZSI)

It was established in 1916 to promote survey, exploration and research leading to the advancement of faunal resources. Its head office is located in Calcutta with 36 offices located all over India.

(3) Wildlife Institute of India(WII)

This institute was set up in 1982 by Ministry of Environment and Forest, Government of India. WII's aim is to develop wildlife science and promote its application in the field according to India's economic and socio-culture background. Research in Wildlife is the major activity of WII.

(4) Wildlife Preservation Society of India

This society was founded in 1958 in Dehradun. Its main objectives are

(i) impart knowledge about conservation

(ii) promote wildlife tourism

(iii) promote interest in conservation through journals, monographs, films and bulletins

(iv) assist in forming Wildlife Protection Act

(v) help Wildlife administrators in maintenance and protection of National Parks and Sanctuarries.

(5) World Wildlife Foundation (WWF) in India

This foundation was formed in 1961. Its headquarters is in Switzerland. It takes up conservation projects all over the world. It is supported by the United Nations. WWF

supports a number of projects in India and its most successful one is 'Project Tiger' which is the single largest conservation project of its kind in the world.

SELF - EVALUATION

Choose the Correct answer.

1. Removal of forest cover and undergrowth in any area is called
   (1) Over grazing (2) Afforestation
   (3) Deforestation (4) Exploitation

2. Increase in concentration of heavy metals along the food chain is called
   (1) Biological accumulation
   (2) Chemical accumulation
   (3) Biological magnification
   (4) Chemical magnification

3. Global warming is caused by
   (1) Lead
   (2) Carbon monoxide
   (3) Nitrogen oxides
   (4) Particulate matter

4. Sound is measured in
   (1) Ampere (2) Decibel
   (3) Light year (4) Pascal

5. Assam region abounds on
   (1) Conifers (2) Deciduous forests
   (3) Evergreen forests (3) Mangrove forests

6. Wild asses are confined to
   (1) Gir forest (2) Rann of kutch
   (3) Sunderbans (4) Nilgiri Hills

7. Coral reefs are abundant in
   (1) Gulf of Mannar
   (2) Sunderbans
   (3) Keoladeo
   (4) Bharathpur

Fill in the blanks

8. Growing trees on available lands outside natural forest area with the involvement of local people is called .....

9. CFC is ..... Gas.

10. CPCB stands for .....

11. CETP stand for .....

12. Pollutants present naturally are known as.....

13. Pollutants resulting from human activities are known as .....

14. ..... is the first National Park in India.

15. ..... Act was enacted 1972 to protect wildlife and endangered species.

16. ..... is an area dedicated to conserve the environment and the natural objects and the wildlife therein.

17. ..... is an area in which wildlife is protected under forest laws.

18. ..... is an area where special protection is granted to wildlife on verge of extinction to reestablish them.

19. WWF has its headquarters in .....

20. Golden langur is confined to ..... in Assam.

Answer briefly

21. What are the benefits Rainwater harvesting?

22. What are the fruit trees choosen for the social forestry ?

23. What is social forestry ?

24. What are the greenhouse gases ?

25. What is Eutrophication ?

26. What are the types of effluents ?

27. What is biological accumulation ?

28. What is biological magnification ?

29. Can we recycle industrial water ?

30. Enumerate the advantages of CETP.

31. What is meant by green house effect?

32. How is acid rain formed?

33. What are the effects of noise pollution?

34. What are the common air pollutants?

35. What is decibel?

36. What are the effects of
   (1) CO (2) SO_2 (3) NO_x.

37. What are the objectives of Wildlife (Protection) Act ?

38. What is a marine reserve ?

39. What is a biosphere reserve ?

40. How do you declare an organism as extinct?

41. What are the reasons for extinction of an organism ?

42. What are the governmental and NGO agencies of India involved in Wildlife conservation ?

43. Give a brief account on the sanctuaries of Tamil Nadu.

Answer in detail.

44. Describe the methods of Rainwater harvesting.

45. Write about the role of water in animal system.

46. Give an account of the advantages of social forestry.

47. Give a detailed account of heavy metals and their effects on organisms.

48. Comment on the methods of effluent treatment. Add a note on CETP and its importance.

49. Describe the control measures for air pollution.

50. Describe the control measures for noise pollution.

51. Write an essay on Indian wildlife.

52. Write an essay on need for protection and conservation of wildlife.

Activities :

53. Prepare a chart showing the various stages of effluent treatment.

54. Collect pictures of wild animals present in your area.

55. Map the following : (a) Important National parks and wildlife sanctuaries (b) Marine reserves of India (c) Biosphere reserves of India.

15. APPLIED BIOLOGY

15.1. Sustainable Agriculture

Sustainable agriculture is one of the methods of ecofriendly farming practices that aims to increase crop productivity without adversely affecting the environment and the society. In sustainable agriculture, organic farming, water management are more emphasised.

The goals of sustainable agriculture are

(1) Increased profitability

(2) Natural resource conservation

(3) Use of environmentally suitable farming

(4) Adopting practices such as crop rotation, cultivating nitrogen fixing plants, drip irrigation, avoiding water-hungry crops, using environment friendly nutrients and adopting vermicultural practices.

(5) The use of natural processes for providing fertility and managing pests thereby limiting the use of synthetic fertilizers and insecticides.

Farmers play a key role in this system who manage skillfully by using innovative methods of agriculture to achieve maximum yield continuously.

1. Mixed cropping

Mixed cropping involves the growing of two or more crops together in the same area at the same time. There are different ways in which mixed cropping is managed.

(1) Planting a slow growing crop with a faster growing one ((e.g.,) radishes and greens)

(2) The cultivation of low or short growing crops beneath the taller ones (radishes and sweet corn)

(3) The use of space between the rows of a maturing crop as a seed bed for the production of young plants.

Advantages of mixed cropping

(1) Makes more efficient use of the available land so that productivity is increased.

(2) Making more efficient use of available sunlight by having a denser plant cover.

(3) More mature or taller plants providing protection for smaller and developing ones.

(4) Reduces spread of many weeds.

(5) Reduces soil erosion as the land is covered with plants for longer time.

(6) Gives more profits for the farmer who benefits from the income from two crops instead of one crop.

(7) Increases the fertility of the soil by growing leguminous crop as mixed crop.

2. Crop-rotation and benefits

Crop-rotation is the growing of multiple crops on the same piece of land, one after the other. The entire field is planted with one crop species in one season, followed by a different species in the next reason. For example in one season paddy is cultivated, in the following season groundnut is cultivated.

Benefits of crop-rotation depends on careful choice and order of cropping.

(e.g.,) After the cultivation of legume crop, next crop (rice) grows very well because of more amount of nitrogen present in the soil.

(2) Crop rotation helps to reduce the incidence of pest effectively.

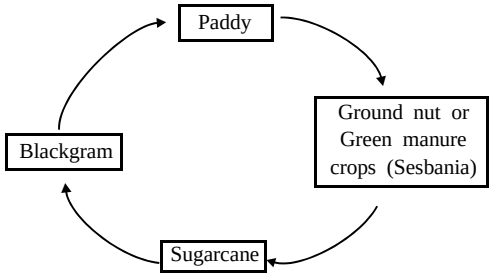


Fig. 15.1 Crop rotation

Methods to be followed in Crop Rotation

(1) Cultivate a deep rooted crop, after a shallow rooted crop for good maintenance of soil structure.

(2) Alternate between crops with high root biomass and those with low root biomass, where high root biomass provides food for soil micro organisms.

(3) Include green manures and soil binding crops to prevent soil erosion and nutrient leaching and to accumulate N_2.

(4) Include nitrogen-fixing crops, and alternate with crops of high nitrogen demand.

3. Green Revolution

The term Green Revolution was introduced in 1968 by William S. Gaud. It is the transfer of technology-based cereal agriculture from the temperate countries (which developed it) to tropical countries operating at lower levels of both inputs and yields - including plant breeding, agronomy, irrigation, fertilizer use and pest control.

The chosen crops in Green Revolution were wheat, potato and rice.

A variety of paddy known as IR8, which is early maturing with erect leaves to promote photosynthetic efficiency was introduced. But later disliked by many people due to its chalky brittle grain quality and its poor cooking quality and less disease resistance.

Green revolution also refers to surplus production of food grains by the genetically engineered high yielding varieties of key crops such as rice, wheat and corn. This brought about revolution in the field of agriculture what is commonly referred as green revolution. It combines both modern agricultural practices and technologies.

Because of green revolution our country has become self-sufficient in food production. Some of the varieties which has brought green revolution in India are :

(1) New rice varieties like I.R.8, I.R.24, I.R.50, ADT-37.

(2) Wheat - Sonara 64.

Norman Borlaug - Father of Green Revolution was awarded Nobel prize in the year 1970. *Dr. M.S. Swaminathan* is regarded as father of G.R. in India. Contributions made by *Bharatha Ratna Thiru C. Subramaniam* and many laid the foundation for green revolution in India.

4. Plant Breeding

Definition : Plant breeding means developing new varieties of crop with desirable traits by crossing different crops.

Aims in plant breeding :

(1) To increase yield

(2) To improve quality

(3) To extend the range of crop

(4) To save a crop from extinction

(5) To develop insect and disease resistance

(6) To develop drought resistance

(7) To simplify harvesting operations

New varieties with desirable characteristics can be obtained by the following means :

(1) Conventional method in which two plants are crossed together to get a hybrid with desirable quality.

(2) Crossing of different varieties or species (hybridization)

(3) Protoplast fusion - cells of two different plants are fused by their protoplast, the resultant cell is allowed to grow into a new hybrid plant.

(4) Genetic Engineering (Recombinant DNA Technology). By this method desired DNA segments responsible for a better quality are obtained, multiplied and introduced into cells inorder to improve it. By this method vitamin A is incorporated into rice which is called "Golden Rice".

In most plant breeding programmes, generally 3 steps are involved.

(1) Selection of parents

(2) Hybridization

(3) Selection of superior lines most nearly resembling the variety desired.

The method of breeding mainly depends on the breeding system of the plants. That is some plants are predominantly self pollinated (e.g., cotton, pea, peanut, rice, wheat) while others are predominantly cross pollinated species. (e.g., corn, onion, potato, pumpkin, sunflower, cucumber)

Hybridization : It is a cross involving two or more parents, varieties, species or even genera. It is performed for

(i) Bringing desired characters together

(ii) Hybrid vigour - superiority of hybrid over either of the parents in growth, yield and resistance.

2. Polyploid Breeding : This is done with the help of a chemical called colchicine. In this method number of the chromosomes is increased, which results in the formation of new varieties (polyploid) with desirable quality both in quantity and quality.

3. Induced Mutation : In this method irradiation of seeds are done by using X rays and other rays like β, γ rays. Genes are mutated to develop newer varieties. Mutant wheat varieties are produced by this method. Mutations have reduced the duration of crop from 18 months to less than 10 months in sugarcane.

The hybrid plant is superior to its parents because it possesses the following characteristics.

1. They show early maturing.
2. Dwarf structure
3. Improved photosynthetic ability
4. Yield stability
5. Better quality
6. Increased disease, pest, drought resistance
7. Capable of utilising fertilisers efficiently.

5. Ecofriendly Agriculture

Definition : Farming methods and practices which will not harm the environment constitute the ecofriendly agriculture. Otherwise in ecofriendly agriculture, soil and water polluting chemicals including fertiliser and pesticides are avoided Biofertilisers and biopesticides are used. It also recommends judicious use of water for irrigation like drip irrigation, irrigation by sprinklers, etc.

Biofertilisers : Definition : Biofertilisers may be defined as nutrients of biological origin used for plant growth. There are different kinds of biofertilisers.

1) Bacterial Biofertilisers : Include bacteria such as *Azotobacter, Rhizobium* and *Azospirillum* which enrich the soil with nitrogen compounds (by way of nitrogen fixation). Crops grown in such soil show increase in yield. These bacteria can be added to the soil by

(1) Soaking the seeds in a bacterial solution before sowing.

(2) By mixing it with irrigation water.

(3) Mixing it directly into the soil.

2) Algal Biofertilisers : Blue green algae such as *Anabaena, Nostoc, Cylindrospermum, Plectonema* and *Tolypothrix* are used as biofertilisers which multiply faster in the soil and fix up atmospheric nitrogen, thus increasing the soil fertility.

3) Mycorrhiza as biofertiliser : The association between roots of certain plants like *Pinus* and a fungus is called mycorrhiza. This is mutually beneficial for both.

The fungal component makes the insoluble nutrients in the soil to soluble form which can be easily absorbed by the roots.

4) Green manure crops as biofertilisers : It is a farming practice adopted by farmers from time immemorial. This involves growing leguminous plants like *Glyricidia, Indigofera* and *Sesbania* soon after harvesting a crop particularly paddy. These plants, rich with nitrogenous compounds are

ploughed in the soil before planting the next crop. *Azolla pinnata*, aquatic fern is also used as a biofertiliser. Leaves of this plant harbours nitrogen fixing bacterium *Anabaena azollae.*

5) Organic Manures as Biofertilisers : Farm yard refuses, fallen leaves, twigs, rotten vegetable matter are subjected to composting. During composting the complex nutrients are converted into simple soluble forms by a variety of microorganisms. It improves soil conditions as well as soil fertility. Crops grown in such soil show increase in yield upto 30%.

15.2 Natural Resources

Any part of our natural environment such as land, water, air, minerals, forest range, land, wild life, fish or even human population that can be utilised to promote welfare of living being may be called as a natural resource. Plants and animals utilise all these in order to develop a better life.

Types of Natural Resources

Some authors classified resources into biotic and abiotic. i.e.,

1) Biotic (or) Living Resources - Forest, agriculture, fish and wild life. etc.

2) Abiotic (or) Non-living Resources - Water, land, minerals etc.

Some even classify them into Inexhaustible and exhaustible natural resources.

(1) Inexhaustible Natural Resources are found in plenty ; e.g., ar water and radiation which are not exhaustible by human activities.

(2) Exhaustible Natural Resources : Soil, forests, wildlife, minerals, coal, petroleum which are found in limited quantities and exhausted easily by human activities.

1. Air

Air is one of the important natural resources found on earth which is essential for the survival of all life forms. Air we breath contains a mixture of gases in different proportions (i.e.,) Nitrogen (78%), Oxygen (21%), Carbondi-oxide, Ammonia, Ozone, Argon, Helium etc about 1%. The layer surrounding the earth is divided into several zones. 10-12 kms just above the earth's surface is called Troposphere. Above the troposphere, a zone of ozone is observed which is called stratosphere. The layer of ozone absorbs the harmful rays of the sun, thus preventing many inflammatory diseases of skin cancer and cataract in humans. Harmful rays of sun includes ultraviolet rays, which are further classified into UV-a, UV-b, UV-c.

This important resource is polluted by various air-pollutants, which can be prevented by strict control measures under environmental protection rules and regulations.

2. Water

Volatile components present in earth's crust were condensed to form ocean water and atmospheric water through processes like volconos, rock movements and hot springs. It is a remarkable combination of hydrogen and oxygen to become an indispensable component of our environment.

Water moves from ocean to air and land and back to ocean in a cyclic pattern called *hydrological cycle.*

Main source of water is rainfall which percolates into the ground as ground water. It is also stored in wells, tanks, reservoirs and dams. So these structures are to be properly maintained for conservation and also for maintaining the quality of water.

Agriculture is dependant on water, may it be rainfall or surface or ground water irrigation. It is eventually a more important category in India because agrarian economy depends critically on water. Huge protein rich food in the form of fish, shell fish, prawn is obtained only through Aquaculture.

Gravitational form of water is tapped and transformed into electricity called hydropower without any pollution and it is the cheapest world over.

Industries can do nothing without water. So it is a raw material, solvent, electrical reactant, coolent and cleansing agent.

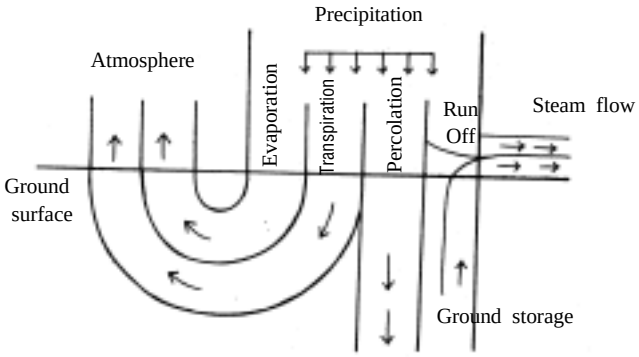


Fig. 15.2 Rainfall and Rainwater Disposal

Sanitation and washing totally depends on water availability.

Water at many places serves as a very convenient means of navigation, besides it adds to the aesthetic value of landscapes, provides opportunities for recreation and sports.

Water pollution should be given much importance and steps should be taken to minimise pollution. Now the rain water is harvested by various methods available. (rainwater harvesting techniques).

Sources of water supply : It may be classified as

(a) Surface waters

1. River
2. Lakes
3. Man made reservoirs.

(b) Ground Waters

1. Springs
2. Infiltration - galleries (covered wells made near river banks)
3. Wells

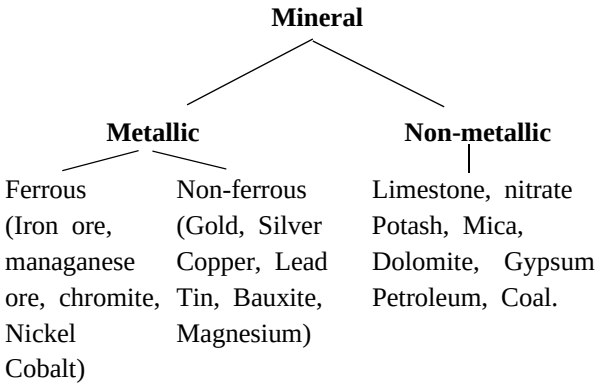
3. Soil

It consists of the weathered layer of earth's crust with living organism and their dead matters. Plants grow on them and supports all living beings, Plants absorb life sustaining nutrients and water for the synthesis of food. Man and all animals, in turn depend upon plant for food directly or indirectly. Foods, oils, fats, forage for livestock, fibre, wood, medicines are products come from soil.

Nation's economic well being is linked with the fertility and abundance of soil resources. So nutrients, moisture, fertility, nature of soil should be maintained and managed from getting polluted by various activities.

4. Minerals

Minerals are naturally formed chemicals on earth by various geological processes existing in the form of ores and rock found in different types of rocks, like igneous and sedimentary rocks. They are mainly classified into two categories metallic and non-metallic.



Minerals are non-renewable; once mined out, the deposits get depleted and lost for ever without any chance of replenishment. Minerals are very localised in their occurence and far limited in quantity. For (e.g.,) Kolar gold fields of India occupy an area of 12 km; coal and petroleum fields are in general bigger as compared to metal deposits. The coal occupy 4% of the country's total area.

Geologists estimate that the known resources of minerals may not last long and most of them will be exhausted within 100-200 years. Sea beds are also nowadays scanned for mineral resources.

At present, ilmenite, nickel, tin ore, diamond, sulphur, coal, petroleum and calcareous, ferruginous sea sands are largely mined from the sea coast and sea beds.

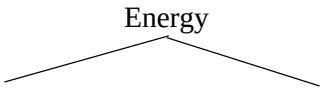
Zircon, monazite, sillimanite are obtained from beach sands of Madras and Kerala.

Coral lime stone for production of calcium carbide and calcarcous sand for cement is obtained from limestone deposits and sea bed of Tamil Nadu and Gujarath (Dwaraka) respectively.

In order to avoid the loss of minerals, we should recycle the metals, and to find alternatives or substitutes to minimise for the use of future generations.

5. Energy

Energy is required for all activities. It is classified into manual and electrical. Electrical energy which operates many machines is the back bone of modern industry. There are several sources of energy. They are



Conventional	Non-conventional
(1) Coal	1. solar energy
(2) petroleum	2. wind energy
(3) natural gas	3. tidal energy
(4) electricity **(both thermal & hydro)**	4. atomic energy
	5. biogas

Conventional Energy : Coal occurs as anthracite, bitumen, lignite and peat. All contain carbon in different quantities. Lignite is produced in Neyveli of T.N. Coal is the main source of electric power, only 15% of it is used for making iron, steel, cement and chemical fertilisers.

Petroleum is obtained from sedimentary rocks. India imports more than 50 million tonnes of it from various countries.

Natural gas is found alongwith petroleum. Large source of it occur in Andaman, Andhra, Gujarath, Maharashtra and Assam. Krishna-Gowdavari basin also has huge reserves of natural gases.

Electricity is obtained by using coal, petroleum and natural gas is called Thermal energy. Nearly 310 thermal power plants are situated in India.

Hydro - electricity which uses water for its production is cheaper & convenient to generate electricity. 23,488 megawatt electric power is obtained by this method in India.

Electricity produced by using uranium and thorium is called nuclear energy; 6 nuclear power stations generate electricity in India.

Non-conventional Energy

Solar energy : India is located near equator receives maximum sunlight throughout then year except few months; by using photo - voltaic technology we can cook, heat water, pumpout water and give power to refrigerator and street lights.

Wind energy : Tamil Nadu is the largest wind energy producer. Wind farms are now established in southern part of Tamil Nadu near Kanyakumari. 85 important places in India produce this type of energy (nearly 4500 megawatts).

Biogas : Decomposition of organic matter obtained from farm wastes, animals and human wastes produce biogas which can be utilised for domestic consumption in rural areas of India.

Energy obtained from all these sources are to be used carefully. To conserve energy we should respect energy conservation act of 2001 by simply following conservative measures like power saving devises, reducing individual use of vehicles, using new forms of energy obtained from plants (*Euphorbia*, *Asclepias* and *Jatropha*) and hydrogen gas (separated from water).

6. Flora and Fauna

Flora refers to a list of plants of a particular area or particular period. Assemblage of many plant species living in association with each other forms vegetation. Vegetation can be better understood by studying forests of any region. India has many types of forests (tropical to Alpine, tundra vegetation).

Forests have three functions.

(1) **Protective :** role of forests against soil erosion, droughts, floods, intense radiation etc.

(2) **Productive :** as source of wood and many products. (gums, resins, fibres, medicines, honey, bidi wrappers, pulp, paper etc.)

(3) **Accessory :** role in recreation, aesthetics, and as habitat of diverse wild life and wild plants.

Forests are important both.
ecologically and economically.

1. Ecologically it regulates the earth's atmosphere and hydrologic cycle. Prevents soil erosion, flood; litter makes the soil fertile by returning the nutrients. It is a refuge for animals.

2. Timber, coal, ash, etc. are obtained from forests they they are economically important.

7) Management of Natural Resources

Wild life Management : Wild life management is the management of natures living resource if we consider conservation of wildlife as consisting of both wild animals and wild plants i.e., maintanance of habitats suitable of the fauna and flora of the different species.

During past decades wild life management aimed at understanding, increasing and controlling of some species.

Sanctuaries and national parks were mostly meant to protect a particular species or a group of species and to a limited extent for tourism and recreation.

Today however, the emphasies is shifting from the management of the species to the management of ecosystem.

The main objectives of Wile Life Management are,

1. To maintain both biotic and abiotic components of ecosystem.

2. To preserve genetic diversity - depending mainly on breeding programmes for the protection and improvements of plants and domesticated animals.

3. Proper utilization of wild animals for game forest and grazing and to achieve forest economy.

Ways and means employed in wild life conservation.

(1) Protection of breeding stocks by enacting Laws and developing wildlife refuges.

(2) Artifical stocking including introduction of exotics.

(3) control of predators.

(4) habitat improvement

(5) game farming.

15.3 Crop Production

Importance of crops for man

Human and other animals require energy, aminoacids, vitamins and minerals for proper growth and development. Vital nutrients are obtained from carbohydrates, fats, proteins for humans. Plants are the major sources for all nutrients.

Crops are a major source of food, feed and fiber for humans and livestock. Cereal crops are especially wheat, rice, corn are the most important food crops in the world. Fibers for clothing and textiles are obtained from cotton, and many other fibre yielding plants. Forage crops which are essential for livestock include alfalfa and sudan grass.

1. Cultivation of crops

Food and cash crops : Crop is a group of economically important plants which is being cultivated by mankind for their use. Crops are classified in many ways, based on season (summer crop, winter crop), economic importance (vegetable crops, food crops, fibre crops etc). We are going to study the cultivation procedures of. Rice and Ragi (food crops) and sugarcane (cash crop) in detail.

Paddy (Rice) : *Oryza sativa (Poaceae)*

Among the food crops, rice occupies an extremely important position. It is the main source of food throughout Asia and other parts of the world. Rice occupies the first position among food crops in respect of area of cultivation and production. Because it can be grown under a wide range of soil and environmental conditions, such as monsoonal conditions existing in India. Rice grows best in the hot and humid climate on clay loam soils.

Table 15.1 Chart showing different crops

Major food crops	:	Wheat, Rice, Corn, Potato, Barley, Grapes, Cassava, Oats, Soyabeans, Millets, Sugarcane, Banana, Tomato, Oranges, Coconut, Apple, Yam. Peanut, Watermelon, Cabbage, Onion, Beans, Peas, Sunflower.
Major feed grains Cereals used to feed livestock and poultry	:	Corn, Sorghum, Barley, oats, Bran, spent grain from breweries are used as feed.
Major oil crops	:	Olive - *Olea europea* Linseed - *Linum usitatissimum* Sesame - *Sesamum indicum* Sunflower - *Helianthus annuus* Soyabean - *Glycine max* Coconut - *Cocos nucifera* Palm - *Elaeis guiniensis* Corn - *Zeamays* Peanut oil - *Arachis hypogea*
Major fiber crops	:	Cotton fiber - Gossypium Bast fibre - Linum, Cannabis (Flax) (Hemp) Kenaf (Hibiscus cannabinus) Jute (Corchorus) Vegetable fibres - Fibres from leaves are called hard fibers like (1) Manila hemp - Musa textilis (2) Sisal - Agave sisalius (3) Henguen - Agave four roydes
Major forage crops	:	They are grown primarily for vegetative parts that are used for feeding livestock (eg) alfalfa clovers, sudan grass, Johnson grass, Paddy straw.

There are two types of varieties in Rice (1) Traditional Tall type (2) High yielding dwarf type

Traditional tall varieties have tall and weak culms. These are not efficient in utilising sunlight and nutrients from the soil and liable to lodging. Traditional varieties are less responsive varieties are poor yielders.

High yielding dwarf varieties have short, photosynthetically active green leaves and thick stiff culums, which prevent lodging. These varieties utilise fertilizers effectively. They exhibit high grain yield.

First dwarf variety was developed in Taiwan and later IR - 8 - dwarf high yielding variety was developed at the International Rice Research Institute, Manila, Philippines.

Table 15.2 New varieties of Rice

Duration of crop	Varieties
80 - 120 days	Bala, Cauvery, Rasi, Pusa 2-21 Jasmina, Kanchi, Krishna
125 - 140 days	Sita, IR-8, Jaya, Sujata IR-36, IR-20, Vijaya
More than 150 days	Pankaj, Mahsuri, Radha, Jagannath

Cultural Practices :

Two kinds of cultivation practices are followed in India (a) dry or direct sowing method (b) Wet or transplantation method

(a) **Dry or direct sowing :** This is followed in rainfed and water stagnating areas

(1) **Preparation of land :** The land is well pulverised by 3-4 ploughings to obtain a good soil condition

(2) **Seed Rate :** 60-180 kilogram of seed per hectare is used for sowing

(3) **Sowing time :** In rainfed regions the seeds are directly sown after the onset of rains. In water stagnating areas, the seeds are sown directly just before the arrival of rains, so that the seedlings may attain the required age and height before flood water starts entering the fields.

(4) **Fertiliser dose :** Generally the fertiliser dose is 40 kg of nitrogen 20 kg of phosphorous and 20 kg of potash per hectare.

(5) Weed control, diseases and pests control is normally done.

Cash crop - sugarcane *(Poaceae)*

Botanical Name - ***Saccharam officinarum***

It is one of the most important cash crops. Utterpradesh has the largest acreage followed by Maharashtra and Tamil Nadu.

Hot and humid climate favours vegetative growth, while cool dry weather is necesary for the ripening of the cane. Climatically South India is more suitable than North India.

Season : Sugarcane is generally planted in July - August.

Varieties : A number of high yielding varieties have been developed. Co419, Co62175 and Co6304 are high yielding and resistant to diseases (Red rot and smut). Co525 is recommended for Tamil Nadu.

Preparation of land : Sugarcane remains in the field for about 12 months and its root extend upto 2 metres. So deep ploughing and better drainage and aeration is necessary.

Planting : Top portion of canes with immature buds of good viability is taken as seeds. (Setts - a small portion of stem with two or three buds). For one hectare 30000 setts are required. The land is ploughed and levelled. After that shallow furrows are opened with plough. The distance between rows are kept at 75 - 90 cm. The cane setts are then planted and covered with 5 - 7 cm of soil.

Fertiliser dose : Sugarcane is aheavy feeder. So 250 kg of nitrogenous fertiliser, 125 kg of phosphate and 25 kg of potash per hectare is needed. The full dose of phosphatic and potassic fertiliser, should be applied at the time of planting. There is no need for nitrogenous fertiliser because setts contain enough nutrition for initial growth. After 6-8 weeks first dose of nitrogen (50%) is top dressed, second dose (50%) is followed after 12 - 14 weeks of planting. Water about 200 to 300 cm is required. Diseases like red rot, Wilt, Smut. can be controlled by using resistant varieties like Co419, Co527, Co617. Termites can be controlled by BHC 10% at 25 Kg/ha.

Harvesting : Stalks are cut at the ground level with yield ranging from 700 - 1000 quintals/hectare.

2. Nutrients required for the Crop (Organic)

Crops derive nutrients from the following sources

(a) Green Manures : *Glyricidia*, *Leucaena*, cow pea, green gram and other plants with green leaves and tender green twigs are collected and added to the soil. They are ploughed into the soil and allowed to get decomposed.

(b) Organic Manures : Some of the organic wastes or by products (excreta of animals & birds) litter, crop refuse and other by products like oil cakes, bones, horns & hooves either decomposed or treated or fresh are used to enrich the soil fertility. These are called organic manures which include farmyard manure and compost. (compost contains more concentrated nutrients than farymyard manure).

(c) Commercial Fertilisers : Fertilisers are the organic or inorganic materials of natural or synthetic origin which are added to supply certain elements essential for the growth of plants.

Fertilisers are classified according to the nutrient contents present in them.

(1) Nitrogenous Fertilisers : Nitrogen containing fertilisers are of three types. (a) Nitrate fertilisers like sodium nitrate & calcium nitrate. (b) Ammoniacal fertilisers ammonium sulphate, ammonium phosphate, ammonium chloride. (c) Nitrate & Ammonia fertilisers-Ammonium nitrate, calcium nitrate, Ammonium sulphate, nitrate. (d) Amide fertilisers-Urea and calcium cyanamide. These are classified based on their solubility in water and decomposing quality.

(2) Phosphatic fertilisers : The phosphorus content is expressed in terms of phosphorus peroxide.

(eg.) Single super phosphate, Ammonium phosphate, Dicalcium phosphate, Rock phosphate, Raw bone meal

(3) Potassic fertilisers contain potassium : (eg.,) muriate of potash, Potassium sulphate.

Potasium nitrate, Nitrophosphate, Mono ammonium phosphate, Diammonium phosphate (DAP) are also used as fertilisers.

3. Nutrients required for the crops (Inorganic)

One hundred and nine elements have been identified to exist in the earth mantle, crust and soil. Plants take up some elements in large quantities and some others in relatively smaller quantities and completely reject most others.

A nutrient element is one that in required to complete the life cycle of the organism and its relative deficiency produces specific deficiency symptoms.

Essential Nutrients : Elements needed by a plant without which it will not be able to survive are called "essential Nutrients". Some of the essential nutrients are

(1) Carbon (C)
(2) Hydrogen(H)
(3) Oxygen (O)
(4) Nirogen (N)
(5) Phosphorous (P)
(6) Potassium (K)
(7) Calcium (Ca)
(8) Magnesium (Mg)
(9) Sulphur(S)
(10) Iron (Fe)
(11) Maganese (Mu)
(12) Copper (Cu)
(13) Boron (B)
(14) Molybdenum (Mo)

Depending upon the quantity required by the plant, nutrients are classified into **Macronutrients** & **Micronutrients**.

Macronutrients : are major nutrients becuase they are required in large quantities. These include C, H, O, N, P, K, Ca, Mg and S.

Carbon, Hydrgen and Oxygen constitute 90-95% of the plant dry matter weight and are supplied through CO_2 and H_2O. Remaining six major nutrient i.e., N, P, K, Ca, Mg and S are further subdivided into Primary & Secondary nutrients.

Primary Nutrients : Nitrogen, Phosphate and Potassium are termed primary nutrients because of their larger requirements by the plants deficiencies may be corrected with the application of commercial fertilisers.

Secondary Nutrients : Calcium, Magnesium and Sulphur are termed secondary nutrients because of their moderate requirments by plants.

Micronutrients : Nutrients that are required in relatively smaller quantities but are as essential as macronutrients are termed 'micronutrients'. These include Fe, Mn, Zn, Cu, B, Mo and Cl.

Let us understand, the role of certain individual nutrients in plant growth.

4.Water Requirement

Method of irrigation, depth of water applied each time and the water distribution efficiency influence the frequency of irrigation. Irrigation method is decided mainly on the type of soil, its porosity and its water retaining, capacity.

Definition - Water Requirement of a crop refers to the amount of water required to raise a successful crop in a given period. It comprises the water lost as evaporation from crop field, water transpired and metabolically used by the crop plants; water lost during application and the water used for land preperation, tilling, salt leaching and so on.

The water requirement is usually expressed as the surface depth of water in millimeters (or) centimeters.

Water required by crops is essentially met from rainfall, irrigation and ground water.

Determination of water requirement is essential (i) to decide the best cropping schedule in a farm (or) in an area. (ii) to make maximum use of available water supplies during any seasons. (iii) to plan and design an irrigation project (iv) to plan water resource development in an area (v) to assess the irrigation requirement of the area and (iv) to manage water supply from various sources.

5. Crop Protection

The environment around the cultivated crops also favours the weeds which compete for moisture and nutrients. The parasitic fungi, insects, spiders, mites, bacteria, eelworms and viruses make serious loss of the crops. After harvest of the crop, serious losses result again from storage pests and rats.

Many methods are now available to reduce the loss of crop from pests and diseases. The object of all control measures is to attack the parasite, defend and strengthen the host as follows :

We can attack the parasite by

(i) Keeping the pest out by **strict plant Quarantine** (Restriction of the import of plant materials across countries)

(ii) Use of clean seed - that is virus & pathogen free (or) seed treatment before use.

(iii) Destroying the outbreak (Localised eradication of diseased crops & saving future crops)

(iv) Destroying the alternate host plants

(v) The entire remnants of the harvested plants from the field - are burnt so that no pest can thrive.

(vi) Crop rotation to prevent pest levels building up.

(vii) Destroying the sources of infection.

(viii) Chemical attack on the parasite.

(ix) Use of insecticides. (DDT, Aldrin, heptochlor, parathion, malathion) pyrethriads.

(x) Biological control of diseases by using microbes.

We can indirectly protect the crops by defending them by following steps. (i) Growing the crops at a time unfavourable to the pest by choosing a planting date.

15.4 Aquaculture and Vermiculture

1. Aquaculture

Aquaculture is the farming of economically important aquatic animals and plants under controlled conditions. Aquaculture is an ancient practice. It originated in China several thousand years ago. The Chinese have perfected aquaculture to such an extent that it plays an important role in their economy. People of developing countries have viewed the oceans as a means of providing food and livelihood. As such, aquaculture will definitely reduce food shortage common in developing countries like India.

Aquaculture includes fresh water culture, brackishwater culture, mariculture and metahaline culture.

1) Cultivable organisms

Aquaculture includes culture of fish, prawns, crabs, oysters, mussels and algae. Among fishes, different types of carps, cat-fishes, trouts, mullets, etc. can be grown. Freshwater and brackish-water prawns can be cultured. Among crabs, marine and estuarine species are of commercial importance and estuarine species are cultured in India. Different types of algae can be cultured. Algae ranging from microalgae to large sea weeds are cultured. In mussel culture, only marine species are cultured.

2) Fish varieties

Fishes belonging to fresh water, estuarine and marine habitats can be cultured. Freshwater fishes such as the common carp (***Cyprinus carpio***), grass carp (***Ctenopharyngodon idella***),

Fig. 15.3 Labeo rohita

Fig. 15.4 *Catla catla*

Fig. 15.5 *Cirrhinus mrigala*

Catla (***Catla catla***) Fig. (15.4), rohu (***Labeo rohita***, Fig. 15.3), mrigal (***Cirrhinus mrigala***, 15.5), tilapia (***Oreochromis mosambicus***, Clarias cat fish (***Clarias lazera***) and trouts (eg ***Salmo gairdnerii***) can be cultured. Estuarine fishes such as milk fish (***Chanos chanos***), mullets (eg ***Mugil cephalus***), cock-up fish (***Lates calcarifer***), pearl spot fish (***Etroplus suratensis***) etc. can be cultured. Marine fishes such as plaice (***Pleuronectes platessa***), yellow tail (***Seriola quinqueradiata***), etc. are cultured in foreign countries.

Fish culture

Culture of fish is called pisciculture. Fish can be cultured in a fish farm. A typical fish farm has different types of fish ponds. They include nursery ponds, rearing ponds, production ponds and breeding ponds.

Fish ponds usually have inlets and outlets to ensure proper water supply and drainage. Both inlets and outlets are fitted with meshes to prevent entry of unwanted fish and loss of fish that is being cultured. During fish culture, fishes pass through different ponds. Fish seed can be obtained from natural sources or artificial production.

(i) Nursery ponds : This is the smallest of all fish ponds. It is used for nursing the hatchlings (Fish eggs after hatching are called hatchlings till they attain a specified size) for a period of two to three weeks. During this period the tiny hatchlings become slightly larger fishes called 'fry'. Then they are transfered to rearing ponds.

(ii) Rearing ponds : It is larger than a nursery pond. After a few days supplementary feed is given to fry. Here the fry are grown for about two months until they attain finger length. Once they become finger length, these fry are called as fingerlings. Then the fingerlings are transfered to production ponds.

(iii) Production ponds : These are larger than other ponds. This is also called as stocking pond. The fingerlings are stocked here and grown for about one year or until they attain marketable size. Once the fishes grow upto the required size, they are harvested. Harvesting of fish in production ponds is done after gradual draining of water. Harvesting is done early in the morning or late in the evening to keep fish in a healthy condition for marketing. Sometimes fishes for breeding are selected from here and are transferred to breeding ponds. These fishes are referred to as breeders.

(iv) Breeding ponds : Here male and female breeders are stocked separately for a few months before actual breeding. Breeding is induced artificially. The practice of prompting fish to breed in confined waters is known induced breeding. Indian scientists have successfully performed induced breeding in many types of carps. This is especially useful as fish seed from natural sources cannot meet demand.

3) Prawn culture

Prawn culture is important as prawns are of export value. There are different kinds of local methods of prawn culture in our country. Examples of cultivable prawns include ***Penaeus indicus*** (fig. 15.6) and ***P. monodon*** (Fig. 15.7). About three types of prawn culture are briefly explained below.

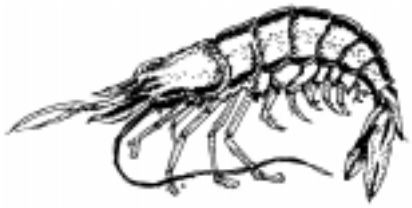


Fig. 15.6 ***Penaeus indicus***

Fig. 15.7 ***Penaeus monodon***

(i) Juvenile holding method : The low lying fields near the backwaters or the sea shore are used for culture of prawns. The larvae and juvenile prawns that come into these fields during high tide are trapped. They are not allowed to escape and they are allowed to grow. During their growth these prawn larvae feed on naturally available organisms.

(ii) Seed collection method : Prawn seed (larvae) are naturally available in open estuaries, coastal lagoons and backwaters. Prawn seeds are collected and allowed to grow. This method is similar to the above method. Here also the prawns feed on naturally available organisms.

(iii) Hatchery methods : Here prawns are allowed to reproduce under captive conditions. This is called induced spawning. Gravid females (females with eggs) are collected from the sea and allowed to spawn. The juvenile prawns are grown in culture ponds. Here the prawn larvae are provided with supplementary feed.

4) Crab culture

Crabs are prized for their delicious meat and export value. Mud crabs namely ***Scylla serrata*** and ***S. tranquebarica*** (fig. 15.8) can be cultured. These crabs are marine in origin. But they migrate to estuaries, backwaters and coastal lagoons during their juvenile stages. At

Fig. 15.8 ***Scylla sp***

present, mud crabs are collected from their estuarine habitats. Then they are cultured or fattened on a small scale. Crabs cultured like this are of export value. Research has been done by Central Institute of Brackish-water Aquaclture on controlled breeding of mud crabs.

5) Algal culture

Algae have a number of beneficial uses. They are used as food by man and animals. They are also used as bio-fertilizers. Both sea weeds (marine algae) and freshwater species can be cultured.

Spirulina, a blue-green algae, has been cultured since 1983 in Central Food Technological Research Institute, Mysore. Here this algae is grown in clean water along with additional chemical fertilizers. This algae is used as food for humans. In Lucknow, ***Spirulina*** is grown in sewage water. It is grown in cement ponds containing sewage water. To this sodium bicarbonate is added. Compressed air is bubbled. The algae grows well 2 - 3 weeks after innoculation. The grown alga is filtered through a polyster or nylon mesh cloth. It is sun-dried and used as animal feed. In ***Spirulina*** 60 - 70% of its dry weight contains protein. Therefore, it has a high nutritional value.

Other edible algae, such as ***Porphyra*** and ***Chlorella***, are also cultured.

6) Pearl Oyster culture

Pearl oysters are usually found on the ridges of rocks where they form pearl oyster beds. Pearls of high value are obtained from oysters of the genus ***Pinctada***. In India, the commomost and important species is ***Pinctada vulgaris***. Because of their economic value, pearl oysters are grown and artificial pearls are produced. Here pearl oysters are collected and acclimatized to the farm conditions. Then the oysters are anaesthetized with methanol and an incision is made at the base of the foot and the viscera. Then a shell bead is introduced along with a piece of mantle tissue. Oysters treated like this are placed in cages and again suspended into the shallow sea from floating rafts. The inserted mantle strip grows around the bead and forms the ‘pearl sac’. The pearl sac secretes pearl material around the bead. Cultured pearls take 3 to 18 months to develop depending upon the size. Then the pearls are harvested and sold.

7) Mussel culture

Mussels are cultured for its food value in many countries. ***Perna viridis*** and ***P.indica*** are cultured in India. In India rope culture method is followed. Mussel seeds are collected near inter-tidal rocky zone of the sea. It is collected on suitable material called as ‘cultch’. Nylon rope, fibres, roofing tiles etc. are used

as cultch. The seeds are then spread on strips of old net material. Wooden pegs are fitted at intervals on seed rope to prevent loss of seed. Then these seed ropes are suspended from floating rafts and allowed to grow. Harvest is done after 5 months.

2. Vermiculture

Vermiculture is the culture of earthworms. Earthworms form a major component of the soil system. They silently plough the land and they assist in the recycling of organic nutrients. The compost thus formed helps in efficient growth of plants. The compost prepared by using earthworms is called vermicompost. The process of converting organic wastes and crop residues into compost using earthworms is called vermicomposting.

Large scale use of chemical fertilizers changes the soil structure drastically. Therefore there is an urgent need for production of alternate organic manure. Vermiculture seems to be an apt answer.

Species of Earthworms

There are more than 500 species of earthworms in the country. Ecologically earthworms can be classified into three types. They are epigeics, anecics and endogeics.

These worms are used in converting organic waste into vermicompost.

Of the three types, the epigeics and anecics are used in vermicomposting process.

Vermicomposting : A simple method of vermicomposting on a small scale is given as follows. A wooden box of 30 cm $\times$ 30 cm $\times$ 30 cm dimension can be used. (Fig. 15.9)

Here a 4" sand layer is placed. Then a 2" fibre layer is spread above it. Sand and fibre layer ensure drainage of excess moisture of the compost. About 250 adult worms are sufficient for a box of the above size. A thin layer of loamy soil may be spread over the coir fibre before putting worms. Daily waste and plant waste can be spread over it. This is covered with a moist jute sack piece. Every week the compost may be turned to aerate it. When the box is full the box is left undisturbed for 5 - 6 days. Water logging is prevented as it can kill the worms. When the compost is

Fig. 15.9 Vermicompost box

formed, the box is kept for 1-2 hours in the open light. The worms will settle down. The top layer comprising of compost can be removed. It is dried under shade and stored.

Vermitech products and uses

Vermitech is a term coined by Dr. Sultan Ismail (1992). The technology of using both epigeic and anecic earthworms together for the process of vermicomposting is called as vermitech.

There are two major vermitech products.

(i) Vermicompost : Vermicompost formed during the process of vermicomposting contains major and micronutrients needed by plants. This can be used instead of chemical fertilizers on plants.

(ii) Vermiwash : This is a liquid fertilizer collected after passing water through a vermicomposting pit. This is used as a leaf spray. It is used on grass lawns and on orchids.

15.5 Biomedical Instrumentation

Various instruments are used to study different aspects of human body. A few of the important bio-medical instruments used are given here. All these instruments and techniques are used in clinical diagnosis. Some important treatment techniques are also given.

1. ECG - Equipment usage

Our heart is made up of cardiac muscle that helps in pumping blood. The heart contracts under electrical stimulus in the electro conduction system. When the heart pumps blood, the muscle cells of the heart contract creating their action potential. This potential creates currents that spread from the heart throughout the body. Thus the electrical potential differs between various parts of the body. These potentials can be detected and

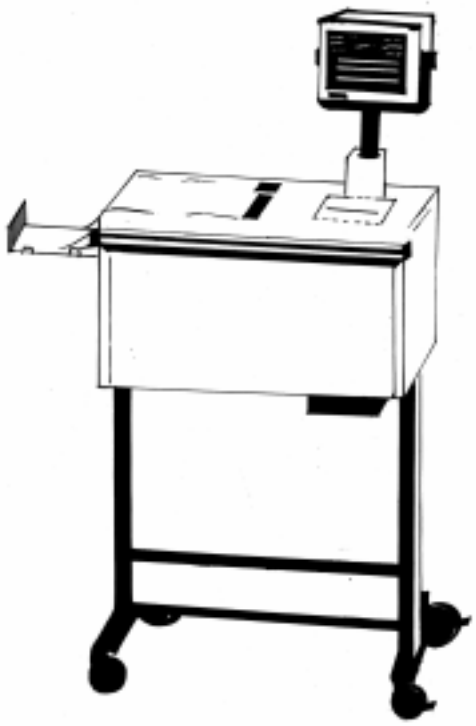


Fig. 15.10 A portable Electrocardiograph machine

recorded through surface electrodes attached to the skin. These potentials can be recorded by an electrocardiograph machine (ECG machine). The waveform produced by these biopotentials is called electrocardiogram (ECG). An ECG machine is used to detect abnormalities in heart function.

2. Sphygmomanometer

A sphygmomanometer is used to measure blood pressure. Sphygmomanometry is the most popular method of measuring blood pressure. This is an indirect method. This instrument has an inflatable rubber bladder called the cuff, a rubber squeeze-ball pump and valve assembly and a manometer. The manometer is usually a mercury column.

Sphygmomanometry was first used by Korotkoff in 1905. It is the most widely used blood pressure measurement method. Blood pressure is often monitored as people with high blood pressure are at a high risk for heart disease.

3. CT Scanner - Application

A Computerised Tomography (CT) scanner is a special type of X-ray machine. It is used to produce pictures of the inside of the body. A CT scan creates images of 'sections' of the body on a computer screen. These images can be viewed in three dimensions. CT scans may be used to make images of all parts of the body. During scanning, dyes may be used to make some tissues show up more clearly.

CT scans are useful in analysing damages to the nervous system during accidents. They

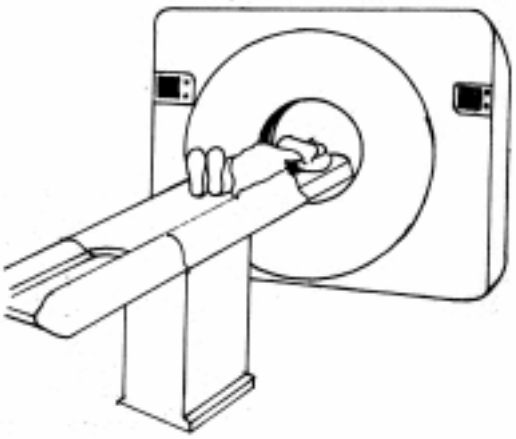


Fig. 15.11 C.T. Scanner

are useful in studying tumours of the nervous system. CT scans are also used to observe other parts of the body.

4. Angiogram - application

Angiography is a technique that is used to examine the blood vessels of the circulatory system as they are functioning. This technique uses X-rays. This technique can be used to study the blood vessels of the brain, heart and

other organs. A contrast radiopaque medium is injected into an artery and after a few seconds X-ray images are taken. These X-ray images provide an angiogram of the blood vessels. The contrast medium enables one to see the size, position and lumen etc. of the blood vessels being studied. This technique can be used to detect blockages in the arteries.

5. Dialysis-various techniques-need

Kidneys are responsible for filtering waste products from the body. It is the job of the kidneys to regulate the body's fluid balance. Sometimes both the kidneys of the body can fail. In such patients dialysis helps the body by performing the functions of the failed kidneys. Dialysis is a procedure substituting the normal functions of the kidneys. In this procedure waste products in the blood are filtered out using a membrane. There are two types of dialysis. They are haemodialysis and peritoneal dialysis.

Haemodialysis : Haemodialysis uses a special type of filter to remove excess waste products and water from the body. During this procedure, blood passes from the patient's body through a filter in a dialysis machine. This filter is called a dialysis membrane. Blood from patient passes to the dialysis machine, through the filter and back to the patient.

Peritoneal dialysis This type of dialysis uses the patients own body tissues in the abdominal cavity to act as a filter. A plastic tube called a 'dialysis catheter' is placed through the abdominal wall into the abdominal cavity. A special fluid is then flushed into the abdominal cavity and washes around the intestines. The intestinal walls act as a filter between this fluid and the blood stream. By using different types of solutions, waste products and excess water can be removed from the body through this process.

6. Laproscopy and Endoscopy - applications

Both the above techniques use fibre-optics. In fibre-optics light is passed through a plastic or glass fibre so that it can be directed to a specific location.

Endoscopy : Fibre-optic endoscopes can be used to inspect the interior of a patient's body by passing the endoscope through the mouth or through a surgical incision. This technique is called as endoscopy. Fibre-optic endoscopes can be used to inspect the stomach

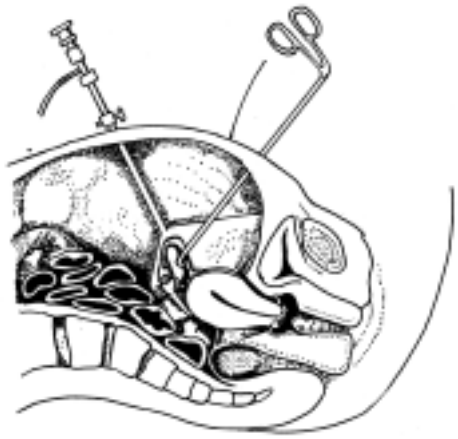


Fig. 15.12 Laparascope usuage

and gastro-intestinal tract. They are useful in detecting lesions and tumours of the alimentary canal.

Laproscopy : The internal organs in women can be studied using a laproscope. A laparascope is similar to an endoscope. It is introduced through a tiny incision in the abdomen of the patient. Once introduced it can be used to study the ovaries, uterus, fallopian tubes etc for abnormalities.

Endoscopy and laproscopy enable a surgeon to study internal organs without using surgery.

7. Eye lens implantation

Eye lens transplantation involves the transplantation of the cornea. The cornea is the transparent layer of tissue in front of the eye. Corneal transplant is used when vision is lost in an eye because the cornea has been damaged by disease or traumatic injury. In a corneal transplant, a disc of tissue is removed from the center of the eye and replaced by a corresponding disc from a donor eye.

Most corneas are procured and stored in eye banks. After collecting, corneas can be stored in special tissue culture medium for upto 28 days. Corneas can be obtained from donors within 6 - 12 hours of death or from brain dead multi-organ donars. Cornea donation by HIV positive, Hepatitis B and C positive individuals is not accepted. Similarly people whose death was due to rabies infection are not accepted as donors.

This is the most common type of human transplant surgery. It has the highest success rate. Survival after corneal transplantation is usually upto 90%.

8. Organ transplantations - precautions and care :

Diseased organ can be replaced by means of organ transplantation. Tissues and whole organs can be transplanted. Organs such as bone marrow, kidney, heart, lung, liver, cornea and pancreas can be transplanted. Transplanted tissue or organ is called a graft. There are different types of transplantation. They are isograft transplantation, allograft transplantation and xenograft transplantation. A transplant of a tissue or whole organ from one identical twin to another is called an isograft transplantation. A transplant between individuals of same species is called an allograft transplantation. A transplant between individuals of different species is called a xenograft.

In isografts, cells in the transplant will almost always live if adequate blood supply is there. But in allografts and xenografts, immune reactions occur. In xenografts the reaction seen is more than in allografts. This kind of immune reaction will persist till all the cells in the graft are rejected. This phenomenon is called graft rejection.

Graft rejection is caused by antigens present on the cell surface. The most important antigens that cause graft rejection are a complex called the Human Leucocyte Antigen (HLA) complex. These antigens are sub-divided into three classes : class I, II and III. Class I antigens are present on all cells of the body. Because they are present on all the cells of the body, these are responsible for graft rejection. Except in identical twins, no two people can have the same HLA class I antigens.

Precautions and care : Therefore HLA class I typing is done between the donor and recipient. Though a precise match is impossible in allografts, a close match is obtained. Graft rejection can also be prevented by suppressing the immune system. For this purpose, immune-suppressants are given. Azathioprine, cyclosporine and glucocorticoid hormones act as immune-suppressants in organ transplantation. But the use of immune-suppressant leaves a person unprotected from disease. Bacterial and viral infections are common in transplant patients. Therefore care is taken to see that transplant patients are well protected from infections.

9. Blood transfusion

Severe blood loss can lead to death of an individual. In case of accidents and surgeries, blood lost has to be replaced. Replacement of lost or diseased blood using donor blood is called blood transfusion.

Blood groups

About 400 blood group antigens have been recognised.

All the antigens if mismatched can cause haemolytic transfusion reaction. In this reaction, clumping of blood cells occur. ABO and Rhesus D groups are the major clinically significant ones.

ABO system

It consists of three allelic genes, A, B and O. Gene A produces A antigen while gene B produces B antigen. These antigens are expressed on RBC surface. O allele does not produce any antigen but it produces antibodies against both antigens. In individuals having antigen A, antibodies against antigen B are produced. Similarly in individuals having antigen B, antibodies against antigen A are

produced. In this system there can be four blood groups as shown in table 15.3.

Table 15.3. The ABO blood group system

Blood group	Red-cell antigen	Antibody
A	A	Antibody B
B	B	Antibody A
AB	A and B	None
O	None	Antibody A and B

Rhesus D (Rh D) blood group system: Rh D is a red cell antigen that is expressed on the red blood cells. If RhD antigen is present, the individual is called Rh D positive. If the antigen is absent, the person is called Rh D negative.

Before transfusion, pre-transfusion testing is done. The patient's blood sample is tested to determine the ABO and Rh D type and other red cell antibodies that could haemolyse transfused red cells. This is done to prevent agglutination of RBC's in the patient.

Blood banks : Sterile blood, to be used for transfusion, can be stored in blood banks. Here blood and blood products are stored under optimum conditions. In blood banks, blood is stored in ready-made sterile blood bags. These blood bags are stored with blood that is tested for HIV, Hepatitis B, Hepatitis C, Syphilis and the different blood groups. Then these blood bags are labelled properly and stored.

Blood transfusion technique : Transfusion of blood products should be prescribed and performed under medical supervision. Blood products are transfused in normal saline (0.9% sodium chloride).

Transfusion is generally given through veins of the hands, wrists and feet. Care should be taken so as to complete infusion within four hours. Blood products are administered through filters. The filters protect the recipients from blood clots or particles in the blood products.

10. Scope for further studies - Institutes

Medical research in India has developed to a large extent. There are many research institutes in our country dedicated to various fields in medicine. Some of the important institutes of our country are given in table.

Table 15.4 Medical Research Institutions

Name of Institute	Location	Research work doing undertaken the institute
Indian Council of Medical Research	Delhi	An apex body for medical research
Indian Cancer Research Centre	Mumbai	Research on cancer biology
Central Drug Research Institute	Lucknow	research on new drugs and herbal alternatives
National Institute of Nutrition	Hyderabad	research on nutritional aspects of Indian cereals, herbs etc.
National Institute of Immunology	Delhi	Immunology related research
National Institute of Health and Family Welfare	Delhi	Promotes family welfare programmes.

SELF - EVALUATION

Choose the correct answer

1. The term Green Revolution was coined by
   (1) Gaud
   (2) M.S. Swaminathan
   (3) Borlaugh
   (4) Raman

2. Which of the following is a type of carp ?
   (1) *Ctenopharyngodon idella*
   (2) *Chanos chanos*
   (3) *Mugil cephalus*
   (4) *Salmo gairdnerii*

3. Aquaculture does not include
   (1) Fresh water culture
   (2) Vermiculture
   (3) Mariculture
   (4) Brackish water culture

4. Which of the following machines is used to take sectional images of the body ?
   (1) Endoscope (2) Laproscope
   (3) CT scanner (4) ECG machine

Fill in the blanks.

5. Self pollinated crop is .....

6. X-ray is used in .....

7. Azadirachtin is .....

8. Monazite is obtained from .....

9. Non-Conventional energy is .....

10. Cauvery is a .....

11. Culture of fishes is called as .....

12. *Spirulina* is a ..... alga.

13. ..... and ..... are cultivable species of mussels in India.

14. ..... is used to examine the alimentary canal of man.

15. ABO blood group system has ..... allelic genes.

Answer briefly

16. Explain the benefits of mixed cropping.

17. Write about biofertilizers.

18. What are the essential elements required by plants ?

19. What are the role of phosphorus and calcium in the growth of a plant ?

20. Write any four species of cultivable fishes.

21. Write short notes on vermiwash.

22. What is fibre-optics ?

23. Mention any four blood group systems.

24. What are the three different types of transplantations ?

25. Give two examples of immuno-suppressants.

Answer in detail.

26. Write about aims of plant breeding.

27. Give an account of Natural resources.

28. Explain the importance of non-conventional energy.

29. Explain a simple method of vermicomposting.

30. Explain mussel culture in detail.

31. Explain application of angiography.

32. Explain in detail how ECG machine measures heart function.

33. Explain in detail the different types of dialysis.

34. Explain ABO blood group system in detail.