SCIENCE AND TECHNOLOGY

Standard 10

PLEDGE

India is my country.
All Indians are my brothers and sisters.
I love my country and I am proud of its rich and varied heritage.
I shall always strive to be worthy of it.
I shall respect my parents, teachers and all my elders and treat everyone with courtesy.
I pledge my devotion to my country and its people.
My happiness lies in their well-being and prosperity.

રાજ્ય સરકારની વિનામૂલ્યે યોજના હેઠળનું પુસ્તક

तमसो मा ज्योतिर्गमय

Gujarat State Board of School Textbooks
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PREFACE

The Gujarat State Secondary and Higher Secondary Education Board has prepared new syllabi in accordance with the new national syllabi prepared by the NCERT based on NCF-2005 and core-curriculum. These syllabi are sanctioned by the Government of Gujarat.

It is a pleasure for the Gujarat State Board of School Textbooks to place before the students this textbook of **Science and Technology, Standard 10** prepared according to the new syllabus.

Before publishing the textbook, its manuscript has been fully reviewed by experts and teachers teaching at this level. Following suggestions given by teachers and experts. We have made necessary changes in the manuscript before publishing the textbook.

The Board has taken special care to ensure that this textbook is interesting, useful and free from errors. However, we welcome any suggestion, from people interested in education, to improve the quality of the textbook.

Dr. Bharat Pandit
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Date : 3-3-2015

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FUNDAMENTAL DUTIES

It shall be the duty of every citizen of India

(A) to abide by the Constitution and respect its ideals and institutions, the National Flag and the National Anthem;

(B) to cherish and follow the noble ideals which inspired our national struggle for freedom;

(C) to uphold and protect the sovereignty, unity and integrity of India;

(D) to defend the country and render national service when called upon to do so;

(E) to promote harmony and the spirit of common brotherhood amongst all the people of India transcending religious, linguistic and regional or sectional diversities; to renounce practices derogatory to the dignity of women;

(F) to value and preserve the rich heritage of our composite culture;

(G) to protect and improve the natural environment including forests, lakes, rivers and wild life, and to have compassion for living creatures;

(H) to develop the scientific temper, humanism and the spirit of inquiry and reform;

(I) to safeguard public property and to abjure violence;

(J) to strive towards excellence in all spheres of individual and collective activity so that the nation constantly rises to higher levels of endeavour and achievement;

(K) to provide opportunities for education by the parent or the guardian, to his child or a ward between the age of 6-14 years as the case may be.

* Constitution of India : Section 51-A

INDEX

UNIT

1

AN INTRODUCTION TO NANOTECHNOLOGY

1.1 Introduction

The word 'Nanotechnology' comprises of two words : Nano and Technology. 'Nano' is a Greek word meaning dwarf or small. In mathematical notation, nanometer means one billionth of a meter, i.e.

$$1 \text{ nanometer (nm)} = \frac{1}{1{,}000{,}000{,}000} = 10^{-9} \text{ meter (m)}$$

In the present context 'technology' means the technique to convert scientific principles to design or synthesis new materials, devices for prosperity, comforts and betterment of human life. It is in turn also useful to explore and understand the basic ideas underlying any scientific happenings.

The fantasy of the 'nano-world' is realised as many materials when reduced below 100 nm in size they show markedly different properties compared to their bulk properties. For example, improved mechanical strength, higher thermal and electrical conductivity, different optical properties, etc. These features are always invitable for future technological and engineering developments. In the words of Nobel Laureate Physicist of California Institute of Technology, Prof. Richard P. Feynman (1959). "There is Plenty of Room at the Bottom." He emphasised on the concept of "miniaturisation" in order to improve the functional efficiency of the material or device. However, it was much later in 1980s, K. Eric Drexler first coined the word 'Nanotechnology.'

For Information Only

Richard P. Feynman

Birth	:	May 11, 1918. Far Rockaway, Queens, New York, U.S.
Death	:	February 15, 1988. Los Angeles, California, U.S.
Nationality	:	American
Research Field	:	Theoretical Physics
Alma Mater	:	B.S. (Massachusetts Institute of Technology) Ph.D. (Prineceton University)
Awards	:	Albert Einstein Award (1954), E.O. Lawrence Award (1962), Nobel Prize in Physics (1965), Oersted Medal (1972), National Medal of Science (1979)

1.2 Nanotechnology and Nanoscience

We may now ask " What actually a nanotechnology is ? " According to CRN's (Center for Responsible Nanotechnology) definition, it is the engineering of tailoring of functional systems at the molecular or atomic scale. Before we go into details of nanotechnology, let us define what is nanoscience.

Nanoscience involves the understanding of matter whose at least one of the dimensions is 1 nm – 100 nm or less then it. It is the study of fundamental principles that the nature permits at the nanoscale or less than that i.e. the 'Quantum Mechanics.'

For Information Only

At nanoscale, laws of Newtonian mechanics fail and we require to invoke Quantum mechanics (which you will learn in higher studies) to understand interactions/forces prevailing among atoms and molecules.

On the otherhand, nanotechnology uses the understanding gained through the nanoscience to fabricate or synthesis improved materials and devices. Prof. Feynman described such atomic scale fabrication as a **'bottom-up'** approach, as opposed to conventional **'top-down'** technological approach.

For Information Only

"The principles of physics as far as I can see, do not speak against the possibility of maneuvering things atom-by-atom. It is not an attempt to violate any laws, it is something, in principle, that can be done, but in practice, it has not been done because we are too big." **- R. P. Feynman, 29th December, 1959**

In bottom-up manufacturing of devices, positionally - controlled atom-by-atom or molecule by - molecule nanostructures or nanoparticles are designed to achieve desired properties. In nanotechnology, a 'particle' is defined as a small object which behaves as a whole unit in terms of its transport and other properties. With this view, **'nanoparticles'** are sized 1 – 100 nm. Even if the size of most molecules would fit into this limit, individual molecules are generally not considered as nanoparticles.

Although, nanotechnology is considered as an invention of modern science, its use has been identified from long past. For example, nanoparticles were used by artisans as far back as the 9th century for generating a glittering effect on the surface of pots. A hair-dye formula used 2000 years ago by Greeks and Romans, works by causing tiny nanoparticles. Ancient Egyptians were using nano-lead compound for eye-make up. The Damascus steel with carbon nanoparticles on the surface was found on the surface of the sword of Tipu Sultan (Figure 1.1). 'Bhasmas' an ayurvedic medicines - are actually metallic mineral preparations of biologically produced nanoparticles. And history is long - it is Michael Faraday (1857) who gave first scientific description about how materials show drastically different and unique properties at the nano-scale.

As the invention of electricity and transistor gave new technological path ways, nanotechnology too will enable us to allow radical new things in virtually every technological and scientific arena;

whether it is communication or transportation, agriculture or industry, engineering or military affairs (weapons, etc.), medicines or cosmetics, space engineering or domestic purposes, economics or environmental issues, clean and abundant energy problems or whatever you name it. Thus, nanotechnology seems to be the general purpose technology. Higher efficiency meaning higher performances that is the reason to call it correctly the 'Green technology.'

Fig. 1.1 A sword of Tipu Sultan made up of damascus steel.

Scientists and technocrets expect fully matured nanotechnology to be functioning by the year 2025.

Dear students, you have enough scope to shape your career in this exciting area of science and technology.

1.3 Dimensions of the Physical World

To visualize / feel the size / dimension of different physical objects, moving from macrosystems → microsystems → nanosystems, pictorial comparison is given in the figure 1.2.

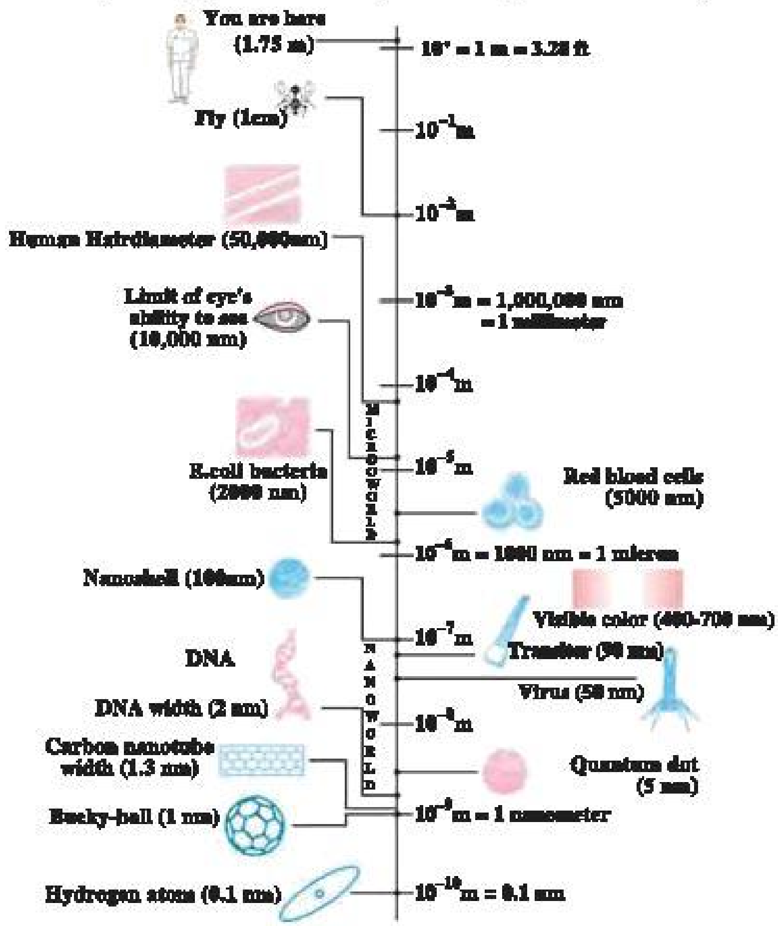


Fig. 1.2 Dimensional details of materials and things around us

We take 1 nanometer (nm) as reference to measure size of different objects in figure 1.2. Average height of a man (1.75 m) 1750,000,000 nm is too big compared to human hair with a diameter 50,000 nm. The size of Red blood cells and E-coli becteria are 5000 and 2000 nm, respectively. Transistor printed on IC (Integrated Circuit) is around 90 nm, while the size of virus is about 50 nm. Falling truly into nano-regime are the carbon nanotubes or bucky-balls. They are approximately 1 nm in size. The width of a typical DNA is around 2.0 nm. While the diameter of hydrogen atom is in sub-nano range (0.1 nm).

Size of human hair, becteria, red and white blood cells, fly ash, typically few thousands nm or greater, can be conveniently written in micrometer (10^{-6}m = 1 μm) scale.

The capacity of a normal human eye to see the smallest objects is 10,000 nm = 10 μm. It is thus obvious that in order to place atom or molecule to form specific nanostructure, microscope with very high magnification is required. In fact, due to advent of Scanning Tunneling Microscope (STM) and Atomic Force Microscope (AFM) arrangement of atom and molecules can be done efficiently while developing desired nanostructures.

1.4 Nanotechnology Plays by Different Rules

The prime goal of nanotechnology is to design nanostructures or nanoparticles for specific applications. It also provides a bridge between bulk or macro materials with atomic and molecular structures. Unlike the top-down approach, where methods for manufacturing involve the construction of parts through carving, cutting, molding, etc., special techniques are required for synthesis of nanomaterials. Depending upon types of atoms or molecules involved in the process, there are several methods available. These involve grinding (ball-mill) methods, use of thermal plasma, inert-gas condensation technique, wet-chemical technique or chemical solution deposition etc..

Another striking feature of nanostructures is their size and shape dependent on physical properties. Whereas bulk materials have almost constant properties regardless of their size and shape under the given physical conditions. An important parameter that determines the functioning of a nanomaterial is the surface area (SA) to volume (V) ratio. It is known that the reaction takes place at the surface of a chemical or material. The greater the surface area for the same volume, the greater is the reactivity. For nanostructured materials SA to V ratio, (i.e. SA/V) is large, which improves the reactivity drastically. This is the reason for showing different physical properties by the same material at the nanoscale.

Activity : 1

Take two cubes of length 1 unit and 10 unit respectively. Using the given formula calculate the following :

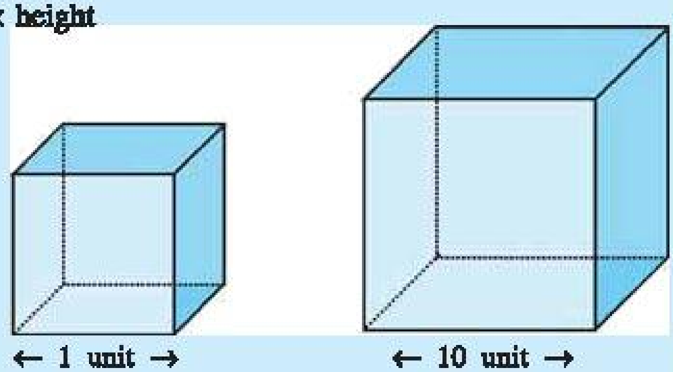
(i) Total surface area (SA) = length × breadth × number of sides

(ii) Volume (V) = length × breadth × height

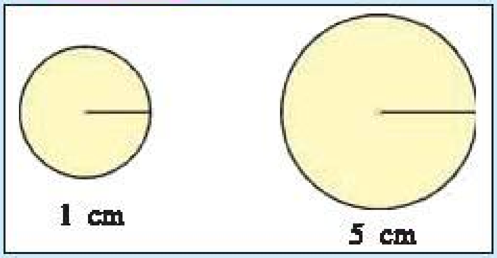
(iii) Ratio, $\frac{SA}{V}$

Question :

Which cube has a large $\frac{SA}{V}$?



Activity : 2



Find $\frac{SA}{V}$ for two spheres with radii 1 cm and 5 cm, respectively and give your conclusion.

Activity : 3

Why sugar granules (or powdered sugar) dissolve faster in water than a sugar-cube ? How thousands of folds and subfolds in the small intestine help in digestion ?

Further, due to large surface area to volume ratio, friction and sticking effects are also very important in nanomaterials. Nanomaterials with same dimensions but with different structures may show different physical properties. Also, as already mentioned, forces among nanoparticles are determined by the laws of quantum mechanics rather than the classical Newtonian laws of motion.

Truly, "Nanotechnology plays different rules !"

1.5 Fundamental Carbon-based Nanostructures

Carbon forms the backbone of biology of life on earth. This is in the form of complex molecules bonded with other elements, especially, oxygen, hydrogen and nitrogen (e.g. nucleic acid, enzymes, proteins, carbohydrates, etc.). It is also a major constituent in the conventional sources of energy. Further, materials containing carbon, exhibit a wide spectrum of properties. These properties are due to the following fundamental reasons :

First, carbon atom can bond with many different types of atoms including other carbon atoms by forming covalent bonds at a time. This helps to form long chains of atoms. This characteristic results in varieties of carbon allotropes; namely diamond, graphite, graphene, amorphous and glassy carbon and fullerenes, all showing different properties. Second, and most important, property of carbon is that it bonds strongly to other carbon atoms, by sharing different number of electrons. In fact, this strong cohesion is responsible for most stable biochemical compounds necessary for life. This is the reason why carbon is considered as a basis for the chemistry of life.

Due to versatile character of the carbon, we shall now discuss its nano-scale allotropes.

Fullerene :

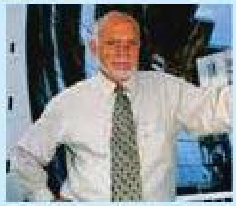
The common name for carbon-based nanostructures is 'Fullerene'. Fullerene is any molecule composed of carbon in the form of hollow sphere, ellipsoid or tube. Fullerenes are similar in structure to graphite, which is composed of stacked graphene

Fig. 1.3 Carbon Fullerene (C_{60})

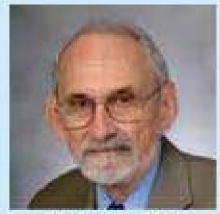
(a monolayer of graphite) sheets of interlinked pentagonal, hexagonal, and sometimes heptagonal rings. The fullerene was discovered by Robert F. Curl, Jr. Harold W. Kroto, James Heath, Richard E. Smalley and Sean O'Brie in 1985, through their mass spectrograph experiment. It was made up of 60 carbon atoms (C_{60}) in a dome-shaped hollow sphere (figure 1.3). The suffix "ene" in the word fullerene indicates that each C-atom is covalently bonded to three atoms with one "double - bond".

For Information Only

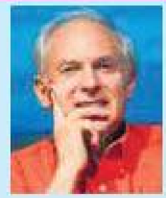
Jr. H. W. Kroto, R. E. Curl and R. E. Smalle were awarded Nobel Prize in 1996 in Chemistry for their work on Fullerenes.



R. E. Curl



R. E. Smalle



Jr. H. W. Kroto

Bucky-ball

Fullerene was named after Richard Buckminister Fuller, an architect known for his design of geodesic domes similar in shape to spherical C_{60} molecule. Since spherical fullerenes resemble to the football used in Association Football, they are also known as "bucky-ball" (figure 1.3). It is about 1nm in diameter.

Existence of fullerene is now identified naturally in candle soot and lightning discharge in the atmosphere. Recently, in 2010, scientists in NASA have found C_{60} present in a cloud of cosmic dust surrounding to a star 6500 light years away. According to one belief, bucky-balls that from outer space have provided seeds for life on Earth !

Bucky-balls with different numbers of C-atoms, C_{60}, C_{70}, C_{76}, C_{85} are also reported with smallest cluster of C_{20} to largest C_{540}.

Bucky-balls are extremely strong. However, due to special bonding among C-atoms, they can easily trap other atoms or molecules. Their purification is therefore a challenge to scientists and hence they are costly.

For Information Only

- In 2007, bucky-ball of Boron atoms, B_{80}, has been reported.
- Bucky-ball C_{20} doped with very few metal atoms, called metallofullerenes, are also prepared.

Carbon nanotubes

Carbon nanotubes are cylindrical fullerenes. In a sense, they are bucky-balls without the ends closing, which form long tube - like structure. Nanotubes of micrometers to millimeters in length are possible. The carbon nanotube derived from bucky-ball is also called a "bucky-tube". In the year 1991, a scientist of NEC laboratory, Sumio Tijima, prepared and explained the nanotube structure. Following figure 1.4 conceptualize how nanotube is constructed by stitching the bucky - balls.

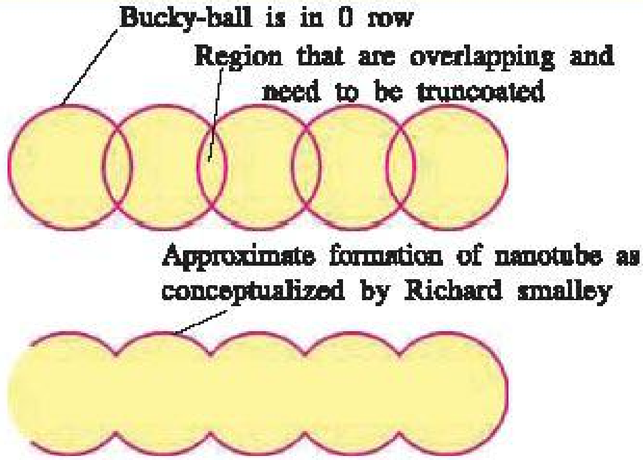


Fig. 1.4 Conceptualization of a Carbon Nanotube

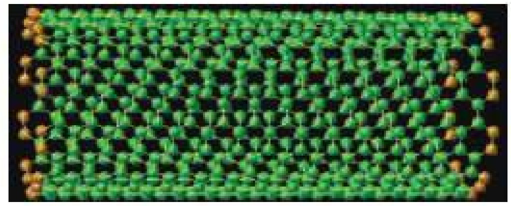


Fig. 1.5 Single Walled Nanotube (SWNT)

Nanotubes can be found with either closed-ends or open-ends. Nanotubes with reducing diameter (thickness) towards one of the ends can also be designed. Nanotubes with single cylinder (Figure 1.5), called Single Walled Nanotube (SWNT), and multiple concentric nano-cylinders with varying diameters; called Multi-Walled Nanotube (MWNT) can also be obtained (Figure 1.6).

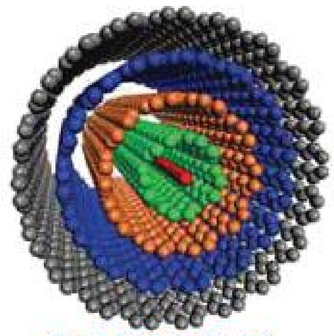


Fig. 1.6 Multi-Walled Carbon Nanotube (MWNT)

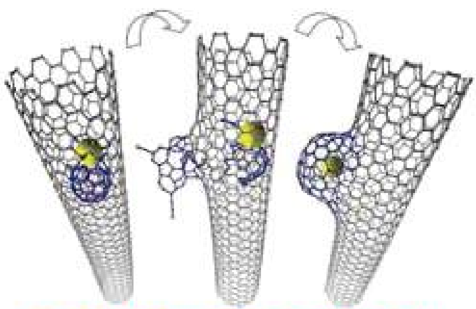


Fig. 1.7 Carbon nanotube - nanobud

Carbon nanobuds

Carbon nanobuds are newly discovered allotrope of carbon in which fullerene 'buds' are covalently attached to the outer part of the carbon nanotubes. This hybrid material has mixed properties of both fullerenes and nanotubes required for some special applications (figure 1.7).

1.6 Properties of Nanotube

These cylindrical carbon molecules have novel properties, making them potentially useful in many basic research and technological applications. A few physical properties of carbon nanotube are therefore listed below :

(1) Tensile and Compressive Strength : Their tensile strength is enormously large compared to many bulk materials including steel. This strength results from the covalent sp^2 bonds between carbon-carbon atoms. For example, a MWNT has tensile strength of 63×10^9 pascal (Pa) which is equivalent to having a mass of 6422 kg on a wire with 1 mm^2 of cross-section ! However, under excessive tensile strain nanotubes show permanent deformation. Compared to their tensile strength, compressive strength is low. Also, along the radial direction nanotubes are much softer, permitting bending like a rubber-tube.

(2) Hardness : Hardness of a standard SWNT is about 25×10^9 Pa, while its bulk modulus is higher than the diamond. The C_{60} fullerenes in crystalline form, known as 'Fullerites' are prepared under high-pressure and high-temperature conditions. They have remarkable mechanical properties, and hence, they are also named as 'Ultrahard Fullerites'.

(3) Electrical : Metallic nanotubes can carry electric current of 10^9 Ampere per cm^2 cross-section of the tube, which is 1000 times more than conducting copper metal. MWNT also show superconductivity upto the temperature of 12 K.

(4) Thermal : The carbon nanotubes have good thermal conductivity along with their length. For example, SWNT has thermal conductivity of 3500 $\frac{W}{mK}$. While the same for copper is only 385 $\frac{W}{mK}$ at room temperature. Interestingly, along the axis of the tube, nanotubes are good insulators. The thermal stability in vacuum is upto 3100 K, but only 1000 K in air.

1.7 Glimpses of The Benefits of Nanotechnology to Mankind

Eversince the production of first fullerene, the science of nanostructured designing evolve dramatically. As a result, we are able to harvest following benefits of the nanotechnology and many more to be realized in near future.

The major areas where nanotechnology can bring revolution to mankind are as follows :

Health Sector :

Higher functional efficiency of nano-devices results into better, cheaper and faster diagnostics and drug applications. Accurate and precise diagnosis improves medical treatment. It is possible to design a nano-drug which acts only at the infected site in our body, thus it reduces the side effect to other metabolic functions. For instance, anticancer nano-drug can be transported to cancerous cells, and upon excitation through laser beam, these nanodrugs are heated to destroy cancerous cells. Carbon nanotubes and their polymer nano-composites are suitable scaffold materials for bone cell proliferation and bone formation.

Energy resources :

Due to tunable electrical and optical properties, specially designed nano - materials can interchange electricity and light with minimum energy loss. They are more efficient than any of the conventional devices. Carbonic solar cells and hydrogen fuel cells will be shortly commercialized. Automobile engineering will improve to design lighter, stronger and fuel efficient vehicles. A paper thin sheet of cellulose infused with carbon nano - tubes act as highly efficient battery.

Security :

Due to lighter yet stronger mechanical properties of nanomaterials, they have found large applications in security. They are now used to construct light and strong battle tanks, spacecrafts, bridges, cranks, etc. Weaving them into clothes to create bulletproof clothing is possible. Since nano-particles have size - dependent melting point, they have found applications in industry as thermal security devices. Large structure of carbon nanotubes are used for thermal management of electronic circuits.

Other :

Research shows that ultrafast computing systems are possible with nanotechnology. Highly sensitive chemical sensors are possible which detect even a single molecule among different billion molecules. Nano-aluminum molecules are chemically so reactive that they are used to control explosions causing minimum collateral damage. Water purification using the nanotechnology is beneficial compared to current techniques. Many cosmetic products are now prepared based on the nanotechnology.

1.8 Importance of Nanotechnology

Various properties of materials such as electronics, thermal, mechanical, optical and chemical have been vastly improved at the nanoscale. Therefore it is possible to achieve exceptional performance in components and devices. Tunable chemical property is the great thrust in biological and medical sciences. Almost in every aspect of life, nanotechnology has important applications, however, there are certain points of concern. Large doses of specific nanodrugs have shown toxicity, which may cause damage to genetical functioning. Use of nanotechnology in designing more destructive weapons should be discouraged.

1.9 What one expect to improve in near future due to nanotechnology ?

Following are the main sectors in which we expect more improvement in near future due to nanotechnology :

(1) **Biotechnology :** Anti-aging drugs, Genetic engineering, Gene-therapy, Regenerative medicine, Synthetic genomics

(2) **Energy :** Renewable energy like biofuels, concentrated solar power, fusion power, Grid energy storage, nanowire battery, wireless energy transfer

(3) **Information Technology :** 3-dimensional (3D) printing, 3D optical data storage, Holographic data storage, optical computing, Quantum computing, Quantum Cryptography, Spintronics 3D - IC (Integrated circuit)

(4) **Material Science :** Superconductivity at high temperature, superfluidity at high temperature, multifunction structures, Programmable materials, Quantum dots

(5) **Robotics :** Nanorobotics, self-reconfiguring, modular robot, Swarm robotics

(6) **Others :** Projector phone, automatic train operation, driverless car, supersonic transportation, magnetic refrigeration

1.10 Some Important Areas of Nanotechnology

- Nanotubes and Bucky-balls
- Synthesis and characterization
- Nanocomposite
- Metallic nanotubes
- Bio and carbonic nano-sensors
- Nano energy storage devices

1.11 Future Challenges Using Nanotechnology

- Environmental problems can be solved.
- Efficiency of renewable sources can be greatly improved.
- It may help to grow life in outer space/planet.
- It helps in sustaining the planet for future generation.

What have you learnt ?

- 1 nm = 10^{-9} m
- Nanomaterials are manufactured by bottom-up approach, in which positionally - controlled atom-by-atom nanostructures are fabricated with desired properties.
- Size of nanoparticles range between 1-100 nm.
- Nanomaterials vastly differ in properties, their preparations, reactivity, in describing interactions among nanoparticles, etc. compared to corresponding bulk properties.
- Fullerene, Bucky-ball, graphene, metallolfullerences, nanotubes, nanobuds are some allotropes of carobn nanostructures.
- Carbon nanostructures show markedly different physical properties like high strength, high hardness, typical electrical and thermal conductivity, etc.
- Energy sector, security, biotechnology, information technology, Robotics, etc. are the areas which will improve greatly due to nanotechnology.

EXERCISE

1. Select the proper choice from the given multipule choices :

(1) 10 nanometer = ... meter

(A) 10^{-8} (B) 10^{-7} (C) 10^{-9} (D) 10^{-10}

(2) Size of nanoparticles range between .... nm.

(A) 100 to 1000 (B) 0.1 to 10 (C) 1 to 100 (D) 0.01 to 1

(3) Diameter of hydrogen atom is .... mn.

(A) 1 (B) 10 (C) 0.1 (D) 0.01

(4) Carbon atoms form .... bonds with other carbon atoms.

(A) covalent (B) ionic (C) metallic (D) hydrogen

(5) Fullerene or bucky-ball is made-up of .... carbon atoms.

(A) 100 (B) 20 (C) 75 (D) 60

(6) Thermal conductivity of standard SWNT along its length is .... $\frac{W}{mK}$.

(A) 3500 (B) 385 (C) 35,000 (D) 35

2. Answer the following questions in brief :

(1) What is nanoscience ?

(2) Mention the difference between bottom-up approach and top-down approach of synthesizing materials.

(3) Give two examples of use of nanostructures from earlier times.

(4) Name two microscopes which are used to develop nanostructures.

(5) What are carbon nanobuds ? Explain in brief.

(6) Give account of electrical properties of carbon nanotube.

(7) Name four energy sectors where nanotechnology is useful.

(8) Name important areas related to nanotechnology.

3. Write answer of the following questions :

(1) Explain how surface area to volume ratio is important for nanostructured materials.

(2) 'Carbon forms backbone of biology of life on earth'. Justify.

(3) Give detailed note on strength of carbon nanotubes.

(4) Write a note on thermal properties of carbon nanotubes.

(5) Explain how nanotechnology will be useful in health sector.

4. Answer the following questions in detail :

(1) Justify the statement 'Nanotechnology plays by different rules.'

(2) Write a detailed note on bucky-ball.

(3) Write a detailed note on a nanotube.

(4) Show how nanotechnology is important to us.

UNIT

2

LIGHT : REFLECTION AND REFRACTION

2.1 Introduction

The variety of objects in the world around us are visible due to the light entering into our eyes after its reflection from the object. We cannot see anything in a complete dark place.

Then ultimate question that arises is : "What is light ? How can it reaches to our eyes after the reflection from the object ?"

Light is an electromagnetic radiation which produces sensation in our eyes. It enters into our eyes after being transmitted through the transparent medium.

In previous standard, you have studied about some of the aspects regarding the reflection and refraction of light. In this chapter you will study more about these properties of light.

2.2 Nature of Light and its Basic Properties

Dear students,

As intimated earlier, now you know that light is an electromagnetic radiation producing sensation in our eyes. The light waves, known to be electromagnetic waves, do not require any material medium for its propagation (**That is why they are also known as non-mechanical waves**) and travel with the speed of 3×10^8 m s^{-1} in vacuum. When such a wave travels through transparent medium, its speed decreases notably which depends upon the medium. The wave length of visible region ranging from 4×10^{-7} m to 8×10^{-7} m is very short compared to the size of the normal object. In such a situation light waves can be considered to be travelling along a straight line path joining one point to another.

A straight line path joining one point to another in the direction of propagation of light is known as ray of light and a group of such rays of light is known as beam of light.

> **For Information Only**
>
> When there is an obstacle in the path of motion of light, the light has a tendency to bend around it, which is known as diffraction of light. To explain this phenomenon of light, its wave nature is considered which you will study in higher standards.

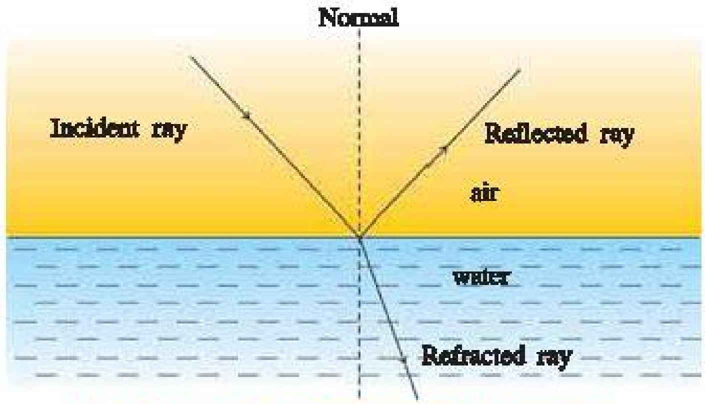


Fig 2.1 Reflection, refraction and absorption of light at water surface

As seen from Figure 2.1, when a ray of light is incident on a surface separting two transparent media (e.g. air and water), it may be reflected, refracted and absorbed partially.

The incident light gets reflected mostly from the completely polished shining plane surface whereas the light incident on the transparent medium is mostly refracted. The mirror through the reflection of light and a lens through the refraction in a transparent medium focus the light rays.

When many rays starting from one point meet at another point, after reflection or refraction, the image of the first point is said to be formed at this point. If the rays actually meet at some point then the image formed by them is real. If the rays do not meet actually, but appear to meet when extended backwards, the image is virtual. A real image of an object can be obtained on the screen while the virtual image cannot be obtained on the screen.

Thus, the image of an extended object with finite size can be obtained by collecting image points, corresponding to different points of an object.

2.3 Reflection of Light : Regular and Irregular Reflection of Light

Dear student,

As mentioned earlier, we can see the objects around us only due to the reflection of light from them. If it is not so, the world would have become dark !

A moon in a full swing could not be seen !

Thus, a phenomenon of returning the light from the surface of an object, when the light incident on it, is a reflection of light.

The reflection of light takes place in two ways : (i) Regular reflection (ii) Irregular reflection

(i) Regular reflection :

When a parallel beam of light is incident on shining plane or smooth surface, a beam remains parallel after reflection in a specific direction. Such reflection of light is called **regular reflection**. The reflection of light by a mirror is an example of regular reflection (Figure 2.2).

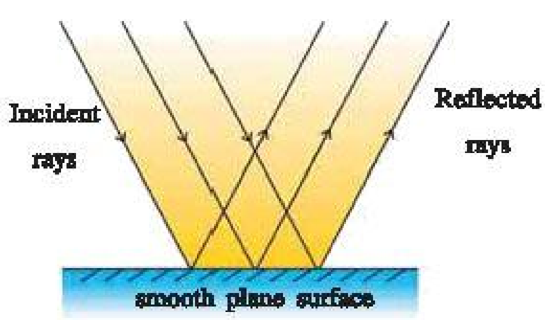


Fig. 2.2 Regular reflection of light

(ii) Irregular reflection : When a parallel beam of light is incident on rough or irregular surface, the beam does not remain parallel but spreads over wide region after reflection. Such a reflection of light is known as an **irregular reflection** (Figure 2.3).The object around us such as book, chair, table etc. can be seen as a result of irreguler reflection of light.

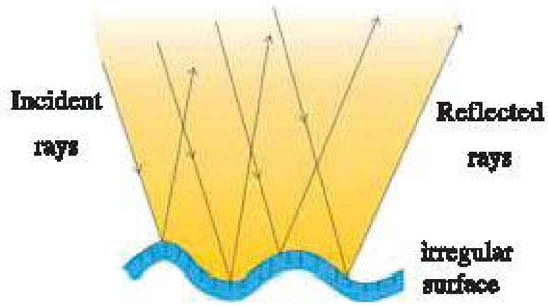


Fig. 2.3 Irregular reflection of light

2.4 Laws of Reflection

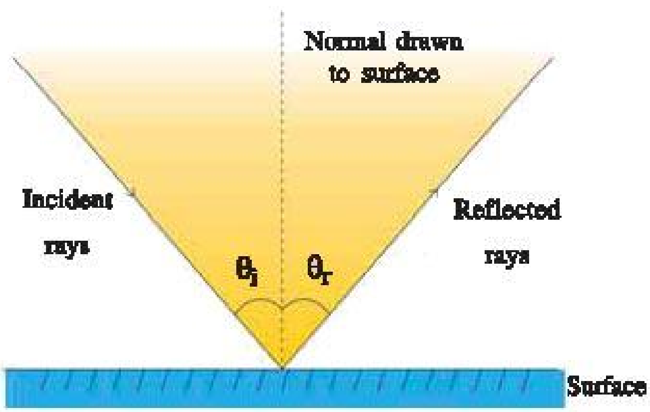


Fig. 2.4 Reflection of light

Before we state the laws of reflection, let us remind the terms associated with them.

Angle of incidence (θ_i) :

The angle made by an incident ray with the normal drawn at the point of incidence is known as angle of incidence (θ_i).

Angle of reflection (θ_r) :

The angle made by reflected ray with the normal drawn at point of incidence is known as angle of reflection (θ_r).

In figure 2.4, θ_i represents angle of incidence and θ_r represents angle of reflection. The laws of reflection using above terminology are stated as under :

(1) The angle of incidence is equal to angle of reflection i.e. $\theta_i = \theta_r$.

(2) The incident ray, the normal to the mirror at the point of incidence and the reflected ray all lie in the same plane.

The laws of reflection are equally applicable to plane as well as spherical mirrors. Moreover, they are also applicable to regular as well as irregular surfaces.

2.5 Reflection by A Plane Mirror

As shown in Figure 2.5, an extended object AO of height h represented by an arrow is kept in front of a plane mirror MM' at a distance u.

Here, each small portion of an extended object facing the mirror acts like a point source, the position of an image obtained in this way is located by the following way :

The incident rays AN and AQ are drawn from points A of the object.

The corresponding reflected rays NA and QR are drawn applying laws of reflection.

As the reflected rays NA and QR are divergent rays, they cannot meet in front of the mirror, but they intersect at A' in extending them behind the mirror which is shown in Figure 2.5. Thus A' is the virtaual image of A. In the similar way, all the point sources between A and O will form corresponding images between A' and I.

It is clear from Figure 2.5 that

(1) A plane mirror forms virtual and erect image A'I at a distance v from it.

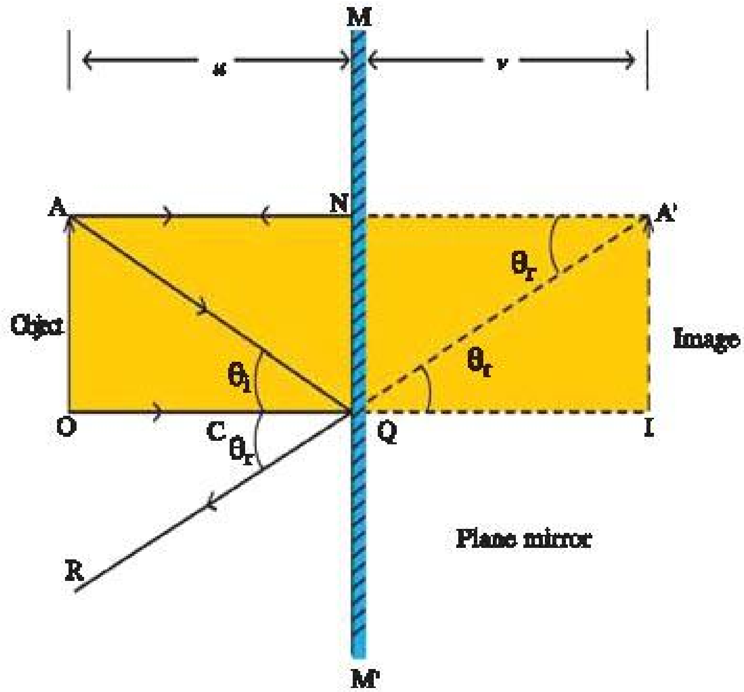


Figure 2.5 Reflection by a plane mirror

(2) The image A'I is formed at the same distance behind the mirror as that of an object AO kept in front of mirror.

(3) The size (height) of an image is same as the object but is laterally inverted.

Activity : 1

Stand in front of a plane mirror in your house and observe the image. Now raise your left hand and observe the image in a mirror.

The virtual, erect and of same size as the object, will be obtained at the same distance as the object behind the mirror. When you raise your left hand, the image appears to raise the right hand. This type of image obtained from the plane mirror is called **laterally inverted** image.

2.6 Reflection by Spherical Mirror

The spherical mirrors are formed by cutting the circular cross section of spherical shell whose inner or outer curved surface are reflecting.

A spherical mirror having inner curved reflecting surface is known as concave mirror.

A spherical mirror having outer curved reflecting surface is known as convex mirror.

In order to study the reflection by spherical mirror, we need to understand the definitions of a few necessary terms.

For this, see Figure 2.6 showing reflection by spherical mirror.

Radius of curvature (R) and centre of curvature of mirror (C) : The radius of a spherical shell from which the mirror is curved, called radius of curvature (R) of mirror and the centre of this spherical shell is called centre of curvature (C) of mirror.

Remember that centre of curvature is not a part of spherical mirror.

Pole : A centre of reflecting surface of a spherical mirror is called pole (P) of the mirror.

Principal axis : An imaginary line passing through pole (P) and centre of curvature (C) of mirror is called principal axis of mirror.

Aperture : The diameter of the reflecting suface of the mirror is known as aperture of the mirror.

Principal focus : The point on the principal axis where the parallel rays meet after the reflection from concave mirror or appear to meet after reflection from convex mirror, is called principal focus (F) of the mirror.

Focal length : The distance between pole (P) and principal focus (F) of mirror is called focal length *(f)*.

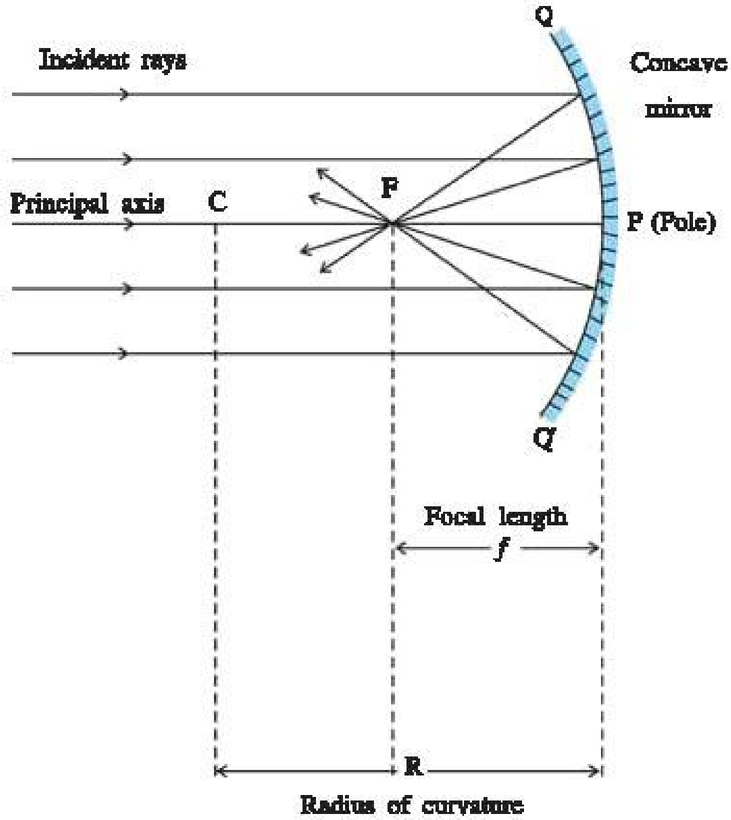


Fig. 2.6 Reflection by spherical mirror

The image of an object formed by spherical mirror can be located by constructing a ray diagram. For this, we may arbitarily consider a large number of rays emanating from a point, but for the sake of clarity of ray diagram, it is more convenient to consider only two rays because, at least two rays are required to locate the position of an image of point object.

The rays reflected from spherical mirror in different ways are represented by Figure 2.7 to 2.10.

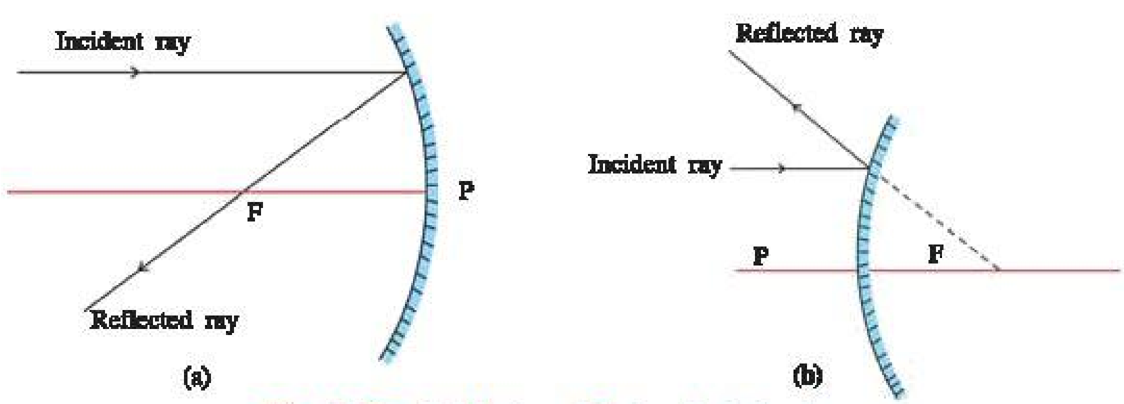


Fig. 2.7 Ray incident parallel to principal axis

A ray parallel to the principal axis after reflection will pass through the principal focus (F) in case of a concave mirror or appears to diverge from the principal focus (F) in case of a convex mirror (Figure 2.7).

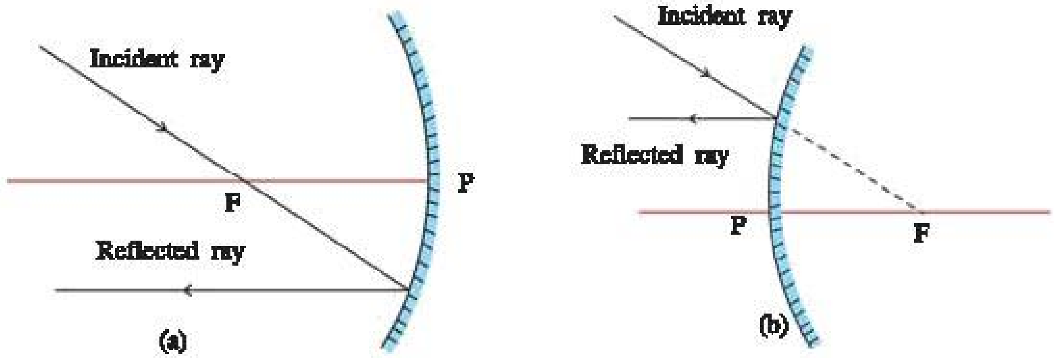


Fig. 2.8 (a) Ray passing through principal focus of concave mirror
(b) Ray directed towards principal focus of convex mirror

A ray passing through the principal focus (F) of a concave mirror or a ray which is directed towards the principal focus (F) of a convex mirror will emerge parallel to principal axis (Figure 2.8).

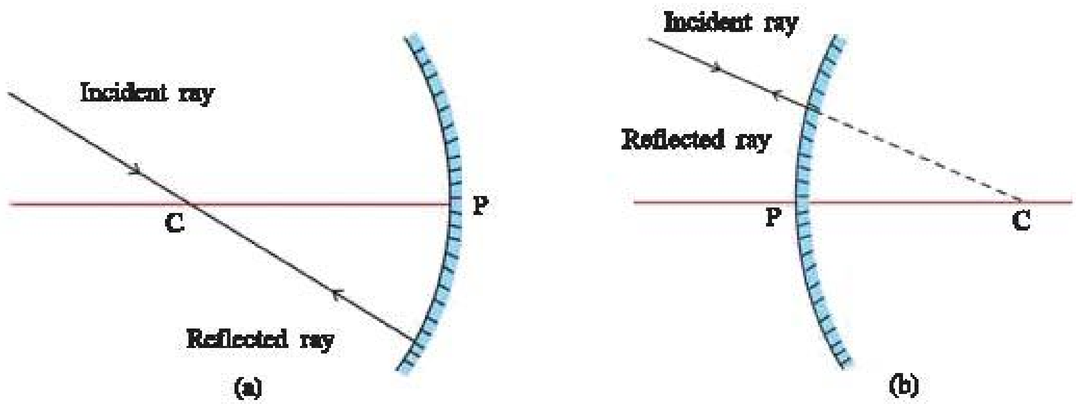


Fig. 2.9 (a) A ray passing through centre of curvature (C) of concave mirror
(b) A ray directed toward centre of curvature (C) of convex mirror

A ray passing through the centre of curvature of a concave mirror or directed towards the centre of curvature of a convex mirror after reflection, is reflected along the same path.

Fig 2.10 a ray incident obliquely to principal axis towards pole of a mirror

A ray incident obliquely to the principal axis towards pole (P) of a concave or a convex mirror is reflected obliquely follows the laws of reflection.

2.7 Image Formation by Concave Mirror

The images formed by a concave mirror MM' of a small aperture for different positions of object AB is shown in Table 2.1.

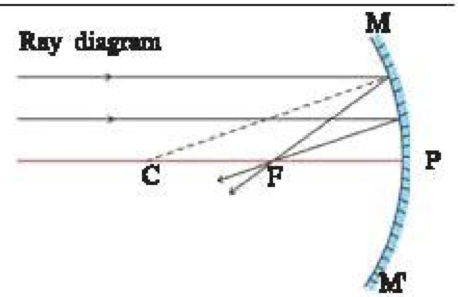
Table 2.1 Image Formation by Concave Mirror

(1) **Position of an object :** At infinity

Position of image : At focus (F)

Nature : Real and inverted

Size : Highly diminished (Pointlike)

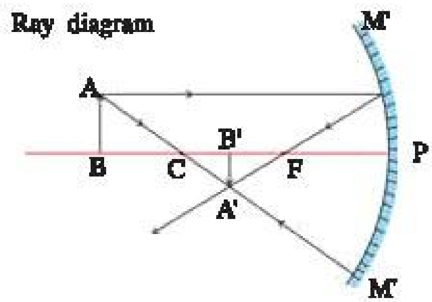


(2) **Position of an object :** Beyond centre of curvature (C)

Position of image : Between centre of curvature (C) and focus (F)

Nature : Real and inverted

Size : Diminished (small)

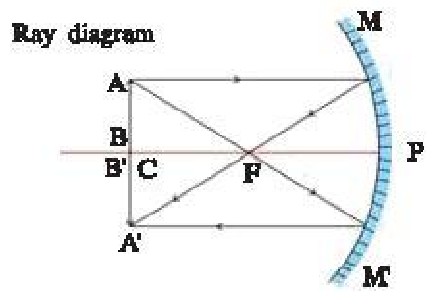


(3) **Position of an object :** At centre of curvature (C)

Position of image : At centre of curvature (C)

Nature : Real and inverted

Size : Same as object

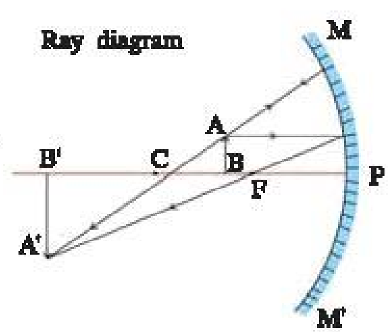


(4) **Position of an object :** Between centre of curvature (C) and principal focus (F)

Position of image : Beyond the centre of curvature (C)

Nature : Real and inverted

Size : Magnified (enlarged)

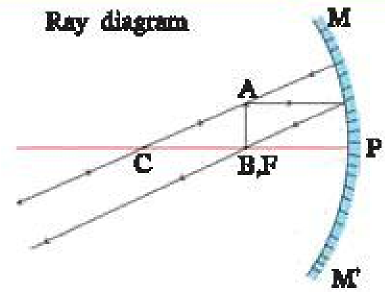


(5) **Position of an object :** At principal focus (F)

Position of image : At infinity

Nature : Real and inverted

Size : Highly magnified

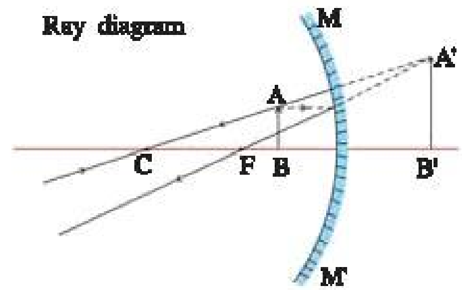


(6) **Position of an object :** Between pole (P) and principal focus (F)

Position of image : Behind the mirror

Nature : Virtual and erect

Size : Magnified (enlarged)



Activity : 2

Hold a concave mirror in your hand and direct its reflecting surface towards the Sun. Then direct the light reflected by a mirror on to a sheet of paper held close to mirror. Move the sheet of paper back and forth until the bright sharp spot is obtained. What do you observe ?

As the paper sheet is at the focus of concave mirror, the light from the Sun is converged at the focus of the mirror which produces a sharp bright spot. The heat produced due to the concentration of sunlight ignites the paper. The distance of spot on paper from concave mirror gives its approximate focal length.

Activity : 3

Draw a neat ray diagram for the object having 1 cm height placed at 6 cm distance from the concave mirror of focal length 4 cm. Take any two rays mentioned in Section 2.6 to locate the image. Compare your ray diagram with that given in Table 2.1. You will obtain real, inverted and having height twice to that of an object at 12 cm distance from the mirror (Figure 2.10.1)

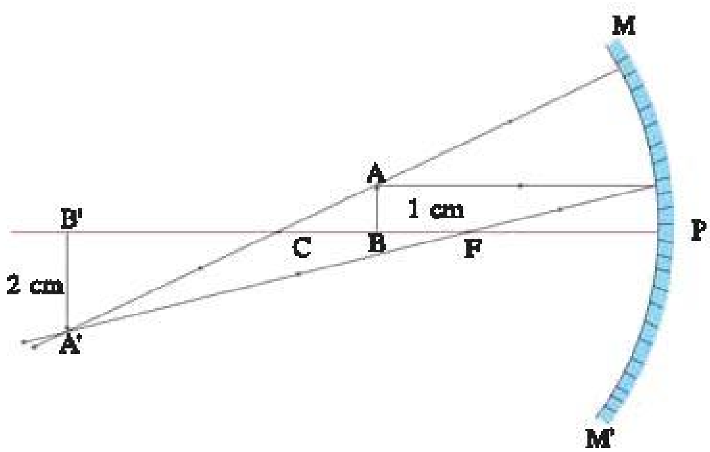


Fig. 2.10.1 (Ray diagram) Image formation by concave mirror

2.8 Image Formation by Convex Mirror

The image formed by a convex mirror MM' of a small aperture for different positions of object is shown in Table 2.2.

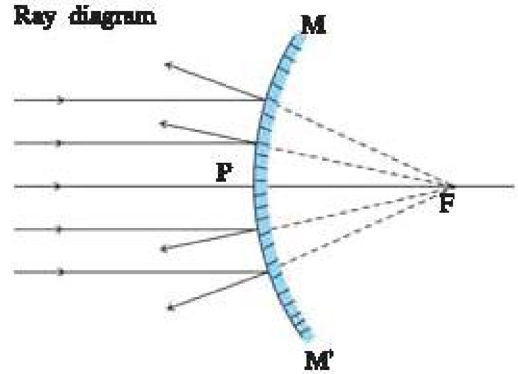
Table. 2.2 Image Formation by Convex Mirror

(1) **Position of an object :** At infinity

Position of image : At focus (F) behind mirror

Nature : Virtual and erect

Size : Highly diminished (point like)

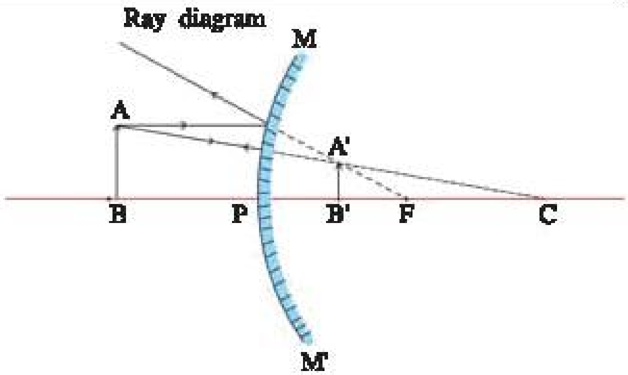


(2) **Position of an object :** Between pole (P) and infinity

Position of an image : Between pole (P) and focus (F) behind mirror

Nature : Virtual and erect

Size : Diminished (small)



Activity : 4

Hold the convex mirror in one hand and hold pencil with its tip pointing upward in other hand. View its image in the mirror. Is the image erect or inverted ? Is the image magnified or diminished ? Now when a pencil is moved away from the mirror, what will be the change in the position and size of an image ?

The erect and diminished image of a pencil is obtained by a convex mirror. On moving the pencil away from the mirror, the size of an image goes on decreasing and it moves toward the focus.

The full length image of a tall building or a tree can be viewed by a convex mirror. One such convex mirror is fitted on the wall of Agra fort. When you visit the Agra fort, try to observe the full-length image of distant tall building.

2.9 Cartesian Sign Convention for Reflection by Spherical Mirror

As shown in Figure 2.11, the pole (P) of a mirror is taken as the origin of cartesian co-ordinate system. The principal axis of the mirror is taken as X-axis and the axis drawn perpendicular to principal axis at pole (P) is considered as Y-axis.

The following sign convention is used to represent the distances related with the reflection by spherical mirror.

(1) The object is on the left side of a mirror means the light rays are incident from the left side of a mirror.

(2) All the distances are measured from the pole (P) of a mirror parallel to the principal axis.

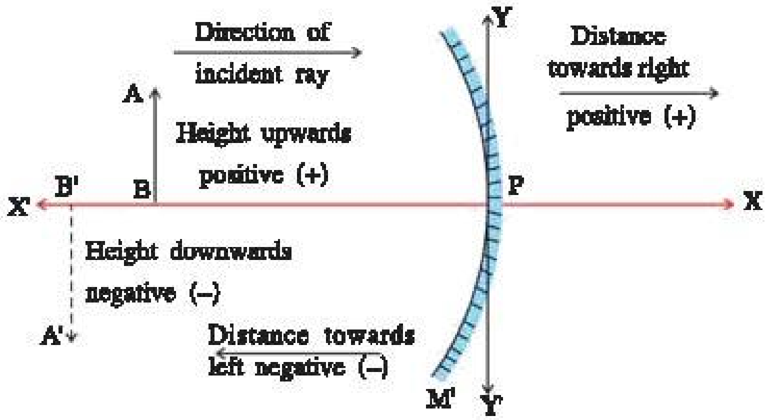


Fig. 2.11 Cartesian sign convention for spherical mirror

(3) The distances measured in the direction of incident ray (toward right) are taken positive.

(4) The distances measured in the direction opposite to incident ray (toward left) are taken negative.

(5) The height measured upward and perpendicular to principal axis is taken positive.

(6) The height measured downward and perpendicular to principal axis is taken negative.

2.10 : Mirror Formula and Magnification of Image

The formula which gives relation between object distance (u), image distance (v) and focal length (f) of mirror is known as mirror formula.

As shown in Figure 2.12, the object AB of height h is placed at a distance u from the pole (P) in front of a concave mirror of small aperture just beyond centre of curvature (C). Therefore, its real, inverted and diminished image B'A' of height h' will be formed at a distance v in front of the mirror.

According to Cartesian sign convention,

Object distance (PB) = $-u$

Image distance (PB') = $-v$

Focal length (PF) = $-f$

Radius of curvature (PC) = $-R$.

It is clear from the geometry of Figure 2.12 that right angle ΔABP and ΔA'B'P are similar.

(See the following figure to understand.)

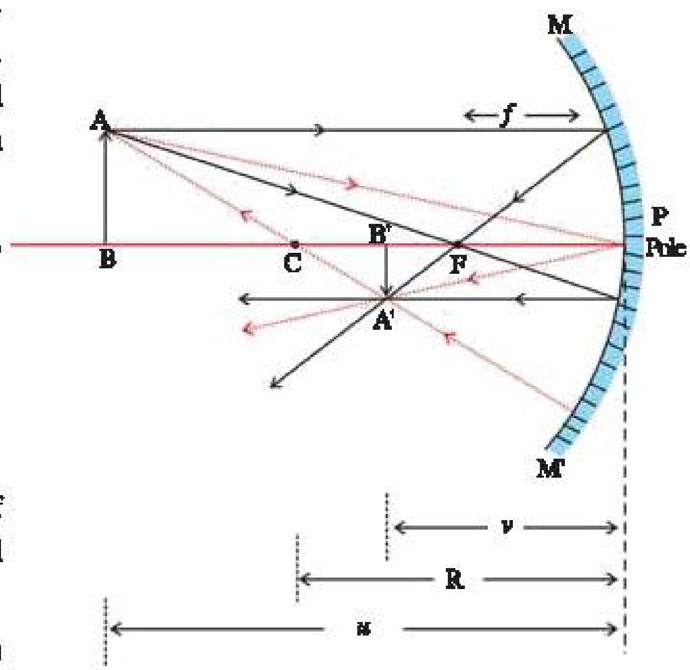
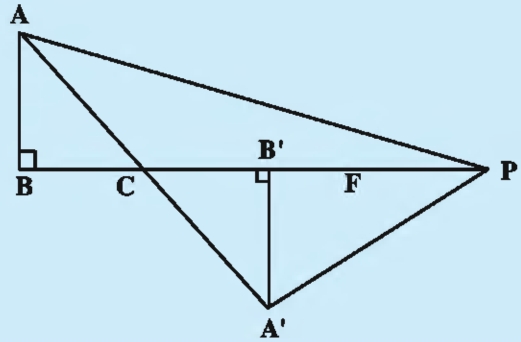


Fig. 2.12 Reflection by a concave mirror

For Information Only



$$\therefore \frac{A'B'}{AB} = \frac{PB'}{PB} = \frac{-v}{-u}$$

$$\therefore \frac{A'B'}{AB} = \frac{v}{u} \qquad (2.10.1)$$

In the similar way Δ ABC and Δ A'B'C are similar

$$\therefore \frac{A'B'}{AB} = \frac{CB'}{CB} \qquad (2.10.2)$$

From Figure 2.12

$CB' = PC - PB' = -R - (-v) = -R + v$ (Do not forget to use sign convention)

and $CB = PB - PC = -u - (-R) = -u + R$

$\therefore$ From equation (2.10.2)

$$\frac{A'B'}{AB} = \frac{-R + v}{-u + R} \qquad (2.10.3)$$

Comparing equation (2.10.1) and (2.10.3) $\frac{v}{u} = \frac{-R + v}{-u + R}$

$\therefore -uv + Rv = -Ru + vu$

$\therefore Rv + Ru = 2uv$

$$\therefore R(v + u) = 2uv \qquad (2.10.4)$$

Dividing equation (2.10.4) by Ruv on both the sides, $\frac{v + u}{uv} = \frac{2}{R}$

$$\therefore \frac{1}{v} + \frac{1}{u} = \frac{2}{R} \qquad (2.10.5)$$

Now when the object is placed at an infinite distance, its image will be formed at the principal focus (F).

$\therefore$ Object distance $u = \infty$ and image distance $v = f$

Putting these values in equation (2.10.5)

$$\frac{1}{f} + \frac{1}{\infty} = \frac{2}{R}$$

$$\therefore \frac{1}{f} = \frac{2}{R} \qquad \left(\because \frac{1}{\infty} = 0\right)$$

$$\therefore f = \frac{R}{2} \qquad (2.10.6)$$

This shows that the principal focus (F) is a mid point between pole (P) and centre of curvature (C) along principal axis.

Substituting the value of R from equation (2.10.6) into (2.10.5)

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \qquad (2.10.7)$$

This equation is known as **mirror formula.**

This mirror formula is true for both types of spherical mirrors for all the positions of object.

Magnification of an image

The ratio of height of image to the height of an object is known as magnification of an image which is denoted as m.

$$m=\frac{\text{Image height}}{\text{Object height}}=\frac{h'}{h} \qquad (2.10.8)$$

From figure 2.12,

$$\frac{A'B'}{AB}=\frac{PB'}{PB}$$

Where A'B' = Image height (h'), AB = object height (h)

PB' = Image distance (v), PB = object distance (u)

$$\therefore \frac{h'}{h}=\frac{-v}{-u}=\frac{v}{u} \qquad (2.10.9)$$

From equations (2.10.8) and (2.10.9) $m=\frac{v}{u}$

Now according to cartesian sign convention, A'B' = – h' and AB = h

$$\therefore \text{ Magnification } \therefore m=\frac{-h'}{h} \qquad (2.10.10)$$

Note that the object height (h) is always positive.

The image height (h') will be positive in case of erect image, hence its magnification will be positive.

The positive value of magnification represents virtual image of an object.

The image height (h') will be negative in case of an inverted image, hence its magnification will be negative.

The negative value of magnification represents real image of an object.

Now consider the case of a plane mirror.

In this case, Image height (h') = object height (h)

$\therefore m = +1$

Therefore, the image formed by a plane mirror is virtual, erect and of the same size as the object.

magnification $m = -\frac{v}{u}$

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

$$\therefore v = -u$$

This shows that the image formed by a plane mirror is at the same distance as the object but behind the mirror.

In case of plane mirror try to obtain the position of an image using mirror formula.

The following Table 2.3 shows the type and size of an image and the type of mirror corresponding to magnification value (m).

Table 2.3 Magnification and Type of Image and Mirror

Number	Magnification (m)	Type of image and its size	Type of mirror
1	+ 1	Virtual, erect and of same size as an object	Plane
2	– 1	Real, inverted and of same size as an object	Concave
3	> 1 and negative	Real, inverted and magnified	Concave
4	< 1 and negative	Real, inverted and diminished	Concave
5	> 1 and positive	Virtual, erect and magnified	Concave
6	< 1 and positive	Virtual, erect and diminished	Convex

Verify this table by comparing the images formed by concave and convex mirror given in Table 2.1 and 2.2.

Illustration 1 :

Determine nature and size of image, and the type of mirror for the image formed by mirrors corresponding to magnification values + 1, – 1, + 0.5, – 0.5 + 5.0 and – 5.0.

From the above Table 2.3, solution will be as under :

Number	Magnification (m)	Nature and Size of Image	Type of Mirror
1	+ 1	Virtual erect and of same size as an object	Plane
2	– 1	Real, inverted and of same size as an object	Concave
3	+ 0.5	Virtual, erect and diminished	Convex
4	– 0.5	Real, inverted and diminished	Concave
5	+ 5.0	Virtual, erect and magnified	Concave
6	– 5.0	Real, inverted and magnified	Concave

Illustration 2

An object of 4 cm height is placed at a distance of 18 cm from concave mirror having focal length 12 cm. Find the position, nature and height of the image.

Solution : Object height $h = 4$ cm

Object distance $u = -18$ cm

Focal length $f = -12$ cm

From mirror formula, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

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

$$\therefore \frac{1}{v} = -\frac{1}{12} + \frac{1}{18}$$

$$\therefore \frac{1}{v} = -\frac{1}{36}$$

$$\therefore v = -36 \text{ cm}$$

Magnification $m = -\frac{v}{u} = +\frac{36}{-18} = -2$

$$\therefore \text{From } m = \frac{h'}{h}$$

$$h' = m \times h = -2 \times 4 = -8 \text{ cm}$$

This forms real, inverted and enlarged image of an object beyond the centre of curvature (C) at 36 cm from the pole.

Illustration : 3

A convex mirror is fitted on an automobile with focal length of 3 m. If a vehicle behind is at a distance of 5 m, determine the position and nature of an image.

Solution : Object distance $u = -5$ m

Focal length $f = 3$ m

From mirror formula

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

$$\therefore \frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{3} + \frac{1}{5}$$

$$\frac{1}{v} = \frac{8}{15}$$

$$v = \frac{15}{8} = 1.875 \text{ m}$$

Here, v is positive and $v < u$

$\therefore \ m < 1.$

Therefore, virtual, erect and diminished image behind the convex mirror is obtained at a distance 1.875 m from the mirror.

2.11 Refraction of Light and Its laws

You have studied refraction of light from prism and rectangular glass slab in Standard 8.

When a ray of light enters oblique from one transparent medium to another transparent medium, its velocity changes due to which it gets deviated from its original direction at the surface separating two media. This phenomenon is called refraction of light.

Experiments show that the refraction of light occurs according to certain laws which are shown as under :

(1) The incident ray, the refracted ray and the normal to the surface separating two media at the point of incidence all lie in the same plane.

(2) The ratio of sine of angle of incidence to the sine of angle of refraction remains constant subject to certain situations. This law is known as Snell's Law of Refraction.

Remember that this law holds for a given colour (wave length) of light and for a given pair of media.

As shown in Figure 2.13, an incident ray PQ is incident at a point Q on the surface separating medium 1 and medium 2. QR is the ray refracted from the surface and MQN is the normal to the surface at the point of incidence Q.

From Figure 2.13,

$\angle$ PQM = angle of incidence (θ_1)

and $\angle$ RQN = angle of refraction (θ_2)

According to Snell's Law,

$$\frac{\sin\theta_1}{\sin\theta_2} = \text{constant} \qquad (2.11.1)$$

The constant in equation (2.11.1) is known as refractive index of medium 2 relative to medium 1 and is denoted as n_{21}.

$$\therefore n_{21} = \frac{\sin\theta_1}{\sin\theta_2} \qquad (2.11.2)$$

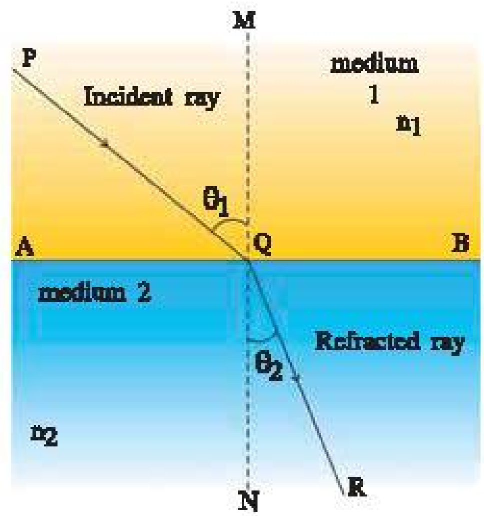


Figure 2.13 Refraction of light

In terms of ratio of velocity of light in two media, the refractive index of light is represented as under :

The ratio of velocity of light v_1 in medium 1 to the velocity of light v_2 in medium 2 is called refractive index of medium 2 with respect to medium 1.

$$n_{21} = \frac{v_1}{v_2} \qquad (2.11.3)$$

In vacuum, light travels with the speed of 3×10^8 m s^{-1}. In air the speed of light is marginally less compared to that in vacuum. Therefore, in practice, the speed of light in air is considered same as that in vacuum.

The refractive index of the transparent medium with respect to vacuum is called an **absolute refractive index** of a medium. It is commonly known as refractive index.

Let n_1 = absolute refractive index of medium 1 n_2 = absolute refractive index of medium 2

v_1 = velocity of light in medium 1 v_2 = velocity of light in medium 2

and c = velocity of light in vacuum then

$$n_1 = \frac{c}{v_1} \text{ and } n_2 = \frac{c}{v_2}$$

$$\therefore n_{21} = \frac{n_2}{n_1} = \frac{c/v_2}{c/v_1}$$

$$\therefore n_{21} = \frac{n_2}{n_1} = \frac{v_1}{v_2} \qquad (2.11.4)$$

From equations (2.11.2) and (2.11.4), $\frac{n_2}{n_1} = \frac{\sin\theta_1}{\sin\theta_2}$

$$\therefore n_1 \sin\theta_1 = n_2 \sin\theta_2 \qquad \text{... (2.11.5)}$$

The equation (2.11.5) is called general form of **Snell's Law.**

The absolute refractive indices of some useful material media are given in Table 2.4

Table 2.4 Absolute Refractive Indices of Some Material Media

(For Information Only)

Material Medium	Refractive Index	Material Medium	Refractive Index
Air	1.0003	Crown glass	1.52
Ice	1.31	Canada Balsam	1.53
Water	1.33	Rock salt	1.54
Alcohol	1.36	Dense flint glass	1.65
Kerosene	1.44	Ruby	1.71
Glycerine	1.47	Saphire	1.77
Normal glass and Benzene	1.50	Diamond	2.42

When a light ray travels from optically rarer to optically denser medium, it moves toward the normal and when it travels from optically denser to optically rarer medium it moves away from the normal.

Remember that optical denser and optical rarer property of media are related to their refractive indices. The optical denser medium has larger refractive index compared to optical rarer medium.

It is to be noted here that the medium that has larger mass density is not necessarily optically denser. For example, kerosene is optically denser than water as it is having larger refractive index (Table 2.5) though its mass density is less than that of water. (Generally, in practice mass density is considered as the density of a material.)

Illustration : 4

Light enters from air to glass having refractive index 1.5. What is the speed of light in glass ? The speed of light in vacuum is 3×10^8 m/s.

Solution :

Absolute refractive index of glass

$$n = \frac{c}{v} \qquad \text{and} \qquad c = 3 \times 10^8 \text{ m s}^{-1}$$

$$\therefore v = \frac{c}{n}$$

$$= \frac{3 \times 10^8}{1.5} \text{ m s}^{-1} \ (n = 1.5)$$

$$= 2 \times 10^8 \text{ m s}^{-1}$$

Illustration : 5

A light ray enters from air to the water medium having the absolute refractive index 1.33. If the angle of refraction of light is 17° 30', what will be the angle of incidence at the surface seprating the two media ?

Take absolute refractive index of an air as 1.00.

Solution :

Taking air as medium 1 and water as medium 2,

$n_1 = 1 \ n_2 = 1.33 \quad \theta_2 = 17^0 \ 30'$

According to Snell's law

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

$$\sin \theta_1 = 1.33 \times \sin 17^0 \ 30'$$

The value of sin 17°30' is determined from the mathematical table of natural sine.

From the Table of natural sine

$$\sin 17^0 \ 30' = 0.3$$

$$\therefore \sin \theta_1 = 1.33 \times 0.3 = 0.4$$

$\therefore$ From the table of natural sine

$$\sin 23^0 \ 36' = 0.4007$$

$$\therefore \theta_1 = 23^0 \ 36'$$

$\therefore$ Angle of incidence = 23°36'

2.12 : Refraction of Light Through Rectangular Glass Slab

A line drawn on a piece of paper appears to be raised or shifted up when a glass slab is placed on it. Similarly any thing lying on the bottom of a swimming pool appears to be raised. These facts result due to the phenomenon of refraction of light.

As shown in Figure 2.14,

A light ray AB is incident at angle θ_1 at point B on the surface PQ of a glass slab. After the refraction from point B, a refracted ray BC is incident at point C on surface RS at an anlge θ_3 and emerges as a ray CD from the glass slab.

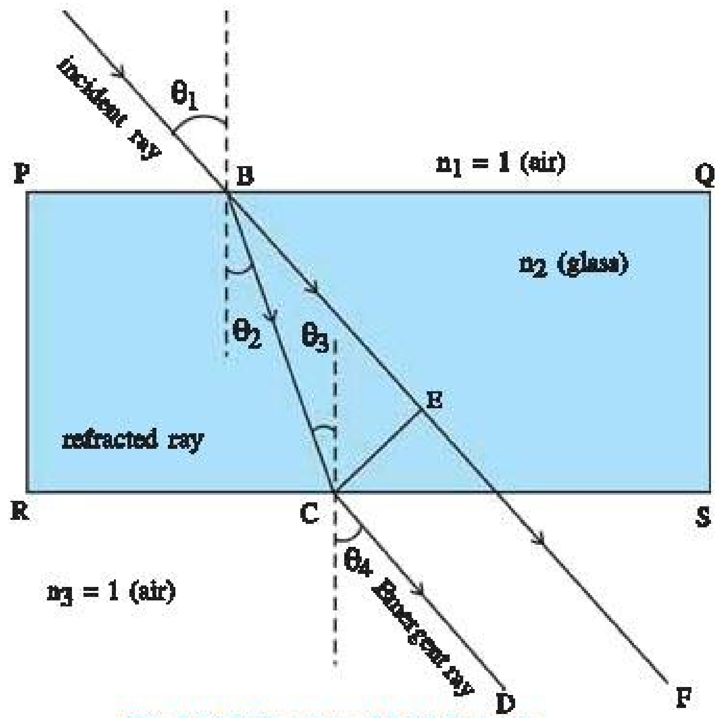


Fig. 2.14 Refraction of light through rectangular glass slab

Let us determine the direction of an emergent ray using the laws of refraction.

Here, $n = 1$, for the medium of an air at the surface PQ.

Therefore, from Snell's Laws $n_1 \sin\theta_1 = n_2 \sin\theta_2$

$$\therefore \quad \sin\theta_1 = n_2 \sin\theta_2 \quad (\because n_1 = 1) \qquad (2.12.1)$$

Similarly for the surface RS parallel to PQ,

$$n_2 \sin\theta_3 = n_3 \sin\theta_4$$

$$\therefore n_2 \sin\theta_3 = \sin\theta_4 \ (n_3 = 1 \text{ for an air})$$

$$\therefore n_2 \sin\theta_2 = \sin\theta_4; \ (\theta_2 = \theta_3 \text{ as they are alternate angles}) \qquad (2.12.2)$$

From equation (2.12.1) and (2.12.2)

$$\sin\theta_1 = \sin\theta_4$$

$$\therefore \theta_1 = \theta_4 \qquad (2.12.3)$$

It is clear from Figure 2.14 and equation (2.12.3) that the emergent ray CD travels in the same direction as an incident ray AB, but it is displaced by a perpendicular distance CE.

Thus, when a ray of light is refracted from two parallel refracting surfaces, the emergent ray is displaced from the direction of incident ray. This kind of displacement is called **lateral shift**. The amount of lateral shift depends upon perpendicular distance between two parallel refracting surfaces as well as upon the angle of incidence and refractive index of medium.

Activity : 5

Place a rectangular glass slab on a piece of paper and draw outline of the slab with a pencil. Fix two pins on one side of a slab. Fix other two pins on another side of slab such that all four pins appear to be on a straight line. Trace the path of a ray after removing pins and slab. Take other rectangular glass slabs of different size and prove that the extent to which lateral shift produced depends upon the perpendicular distance between two parallel refracting surface.

2.13 Image Formation by Convex and Concave Lens

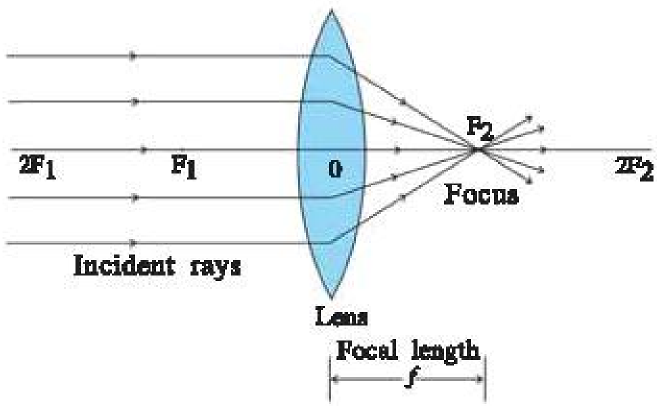


Fig. 2.15 Image formation by convex lens

Let us remember the definition of some of the terms associated with the lens to understand the image formation by lens.

For this consider the Figure 2.15 showing the image formation by convex lens.

The centres of the respective spheres of which the surfaces of a lens can be considered as part, are the centres of curvature of the respective surfaces.

Radius of Curvature (R)

The radii of spheres from which the curved surfaces are formed are known as radii of that surface of the lens. The radii of the curvatures of the two surfaces are R_1 and R_2.

Principal Axis of A Lens

An imaginary straight line passing through the centres of curvature of lens is called **principal** axis.

Optical centre

The central point of a lens on principal axis is called an optical centre of lens. It is denoted as O.

Principal focus :

When rays parallel to the principal axis of convex lens are refracted through lens, they converge at a point on the principal axis. This point is called principal focus of a convex lens. A convex lens has two principal focii F_1 and F_2 on either side of lens.

The rays parallel to the principal axis of concave lens are refracted such that they appear to be diverging from a point on principal axis. Such point is called focus of concave lens. Concave lens also has two focii F_1 and F_2 on either side of lens.

Focal length (*f*) :

The distance between optical centre (O) and principal focus (F) is called focal length of a lens. It is denoted by *f*.

To locate the image formed by spherical lens, a ray diagram is constructed by considering any two of the following rays coming from the object point.

A ray of light from the object parallel to the principal axis of convex lens passes through the principal focus after refraction from convex lens on other side of lens (Figure 2.16 (a)).

In case of a concave lens, the ray appears to diverge from the principal focus located on the same side of lens as the object (Figure 2.16 (b)).

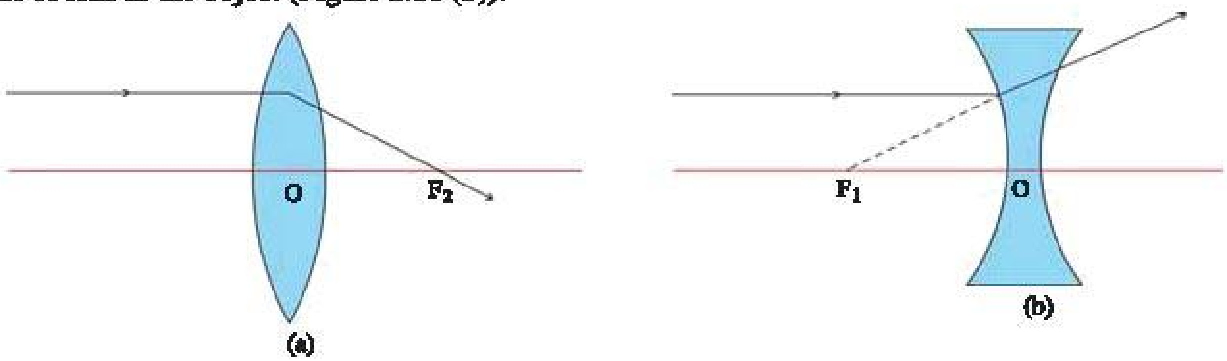


Fig. 2.16 Ray Incident Parallel to Principal Axis

A ray of light passing through a principal focus after refraction from a convex lens will emerge parallel to principal axis (Figure 2.17 (a)).

A ray of light moving toward the principal focus of a concave lens will emerge parallel to principal axis (Figure 2.17 (b)).

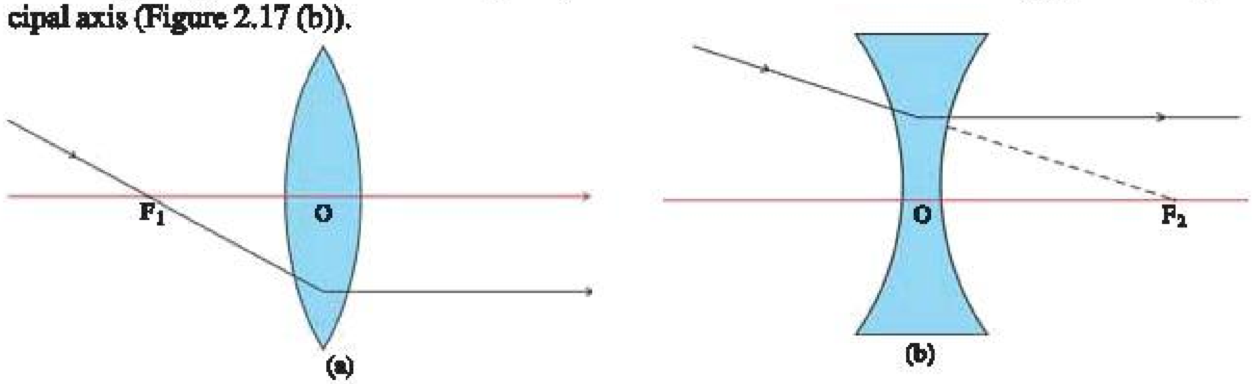


Fig. 2.17 (a) Ray passing through principal focus of convex lens

(b) Ray passing toward principal focus of concave lens

A ray of light passing through the optical centre (O) of convex or concave lens will emerge without any deviation. (Figure 2.18 (a) and 2.18 (b)).

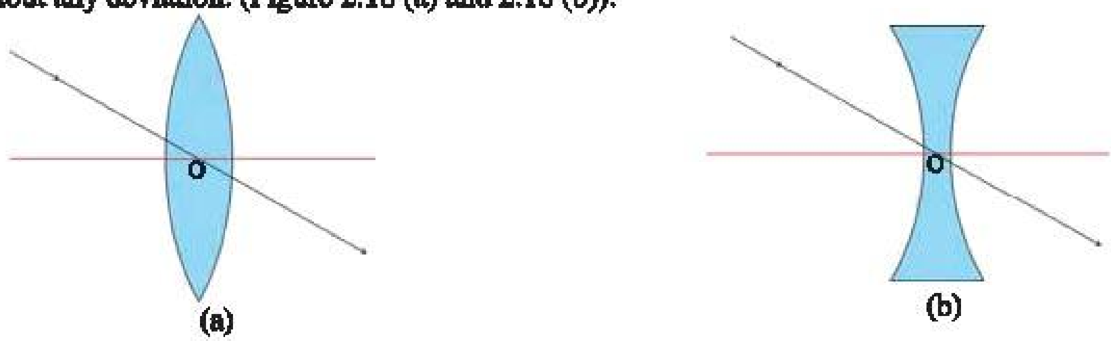


Fig. 2.18 Ray Passing Through the Optical Centre of Lens

Image Formation by Convex Lens

The table 2.5 shows the image formation by a convex lens for different situations of and extended object AB.

Table 2.5 Image Formation by Convex Lens

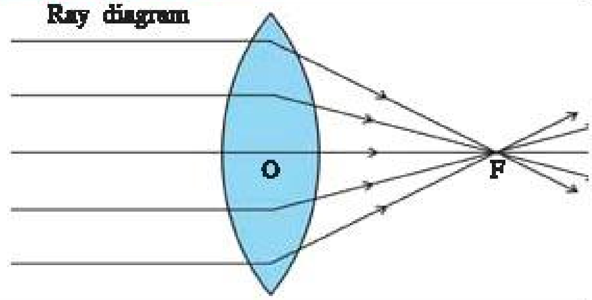
(1) **Position of an object :** At infinite distance

Position of image : On other side of lens at principal focus (F)

Nature : Real and inverted

Size : Highly diminished (point size)

Ray diagram



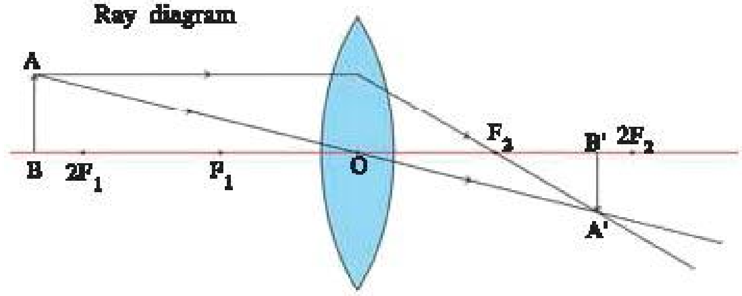
(2) **Position of an object :** Beyond the 2F

Position of image : On other side of lens between principal focus (F) and 2F

Nature : Real and inverted

Size : Smaller than object

Ray diagram



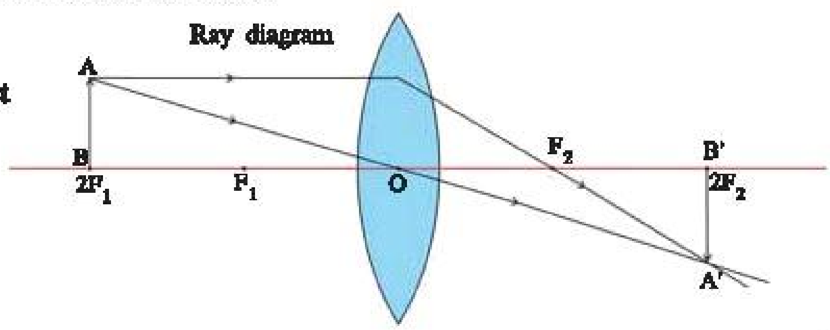
(3) **Position of an object :** At 2F

Position of an image : On other side of lens at 2F

Nature : Real and inverted

Size : Same size as the object

Ray diagram



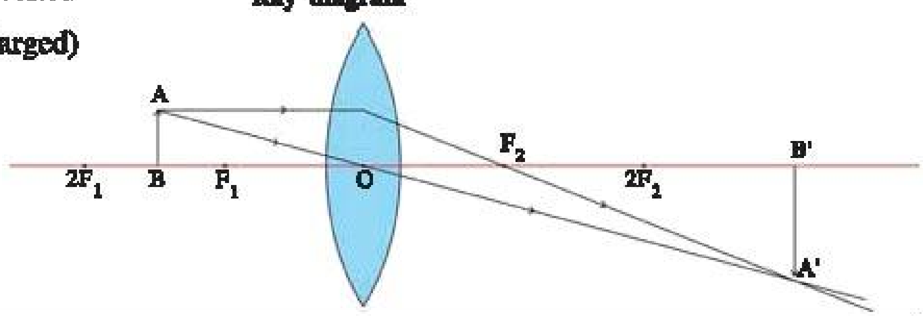
(4) **Position of an object :** Between principal focus (F) and 2F

Position of image : On other side of lens beyond 2F

Nature : Real and inverted

Size : Magnified (enlarged)

Ray diagram

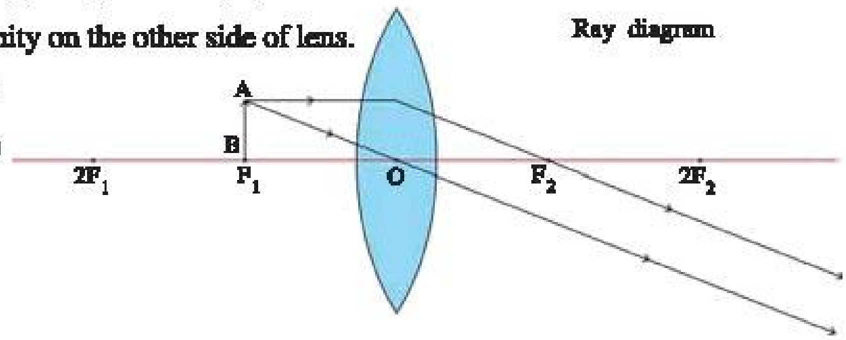


(5) **Position of object :** At the principal focus (F)

Position of image : At infinity on the other side of lens.

Nature : Real and inverted

Size : Magnified (enlarged)

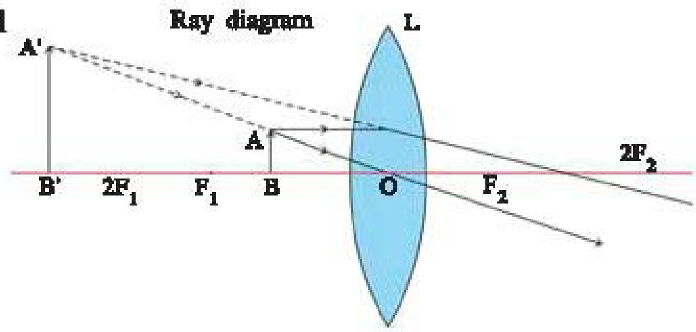


(6) **Position of object :** Between principal focus (F) and optical centre (O)

Position of image : On the same side of the lens as the object beyond 2F

Nature : Virtual and erect

Size : Magnified (enlarged)



Activity : 6

Hold a convex lens in your hand facing a distant object such as a pole. Move the lens back and forth gradually to get a sharp image of the distant object on the wall or screen. Measure the distance of screen from the lens using meter scale. The distance between screen and lens will give an approximate focal length of a convex lens. If you direct a convex lens towards the sun and get sharp bright spot on paper sheet, the paper starts buring with smoke. The bright spot on paper sheet is the real image of sun where the parallel rays from sun are concentrated and generates heat.

Image Formation by Concave Lens

The Table 2.6 shows the image formation by concave lens for the different positions of an extended object.

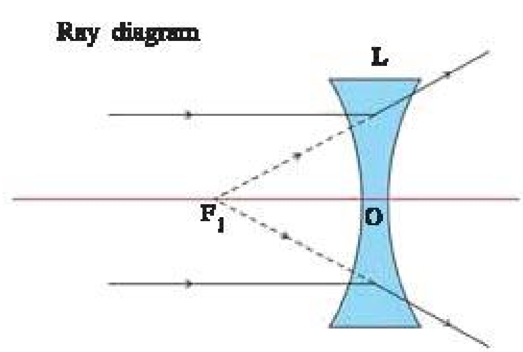
Table 2.6 Image Formation by Concave Lens

(1) **Position of object :** At an infinite distance

Position of image : On the same side of a lens as an object at principal focus F

Nature : Virtual and erect

Size : Highly diminished



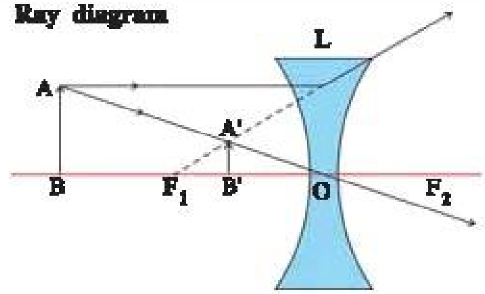
(2) Position of object : Between infinite point and optical centre (O).

Position of image : On the same side of lens as the object between focus (F) and optical centre (O).

Nature : Virtual and erect.

Size : Small (Diminished)

Ray diagram



Activity : 7

Take a concave lens and place it on the lens stand. Keep a burning candle on one side of the lens, observe its image by looking from other side of lens. Try to obtain image on a screen if possible. Otherwise observe the image directly througth the lens. Note the position, nature and approximate size of the image. Now move the candle away from the lens and note the change in the size of an image.

What conclusion can you draw from the observations ?

A concave lens always forms virtual, erect and diminished image irrespective of the position of the object.

2.14 : Sign Convention for Spherical Lens

We follow the same sign conventions for spherical lenses as that used for spherical mirrors given in section 2.9. All the measurements are taken from the optical centre of the lens. For height of object and image also we use same sign convention as mirror. According to the sign convention, **the focal length of convex lens is positive and that of concave lens is negative.**

2.15 : Lens Formula and Magnification of Image

The equation which gives relation between object distance *(u)*, image distance *(v)* and focal length *(f)* is known as lens formula for a thin spherical lens of small aperture.

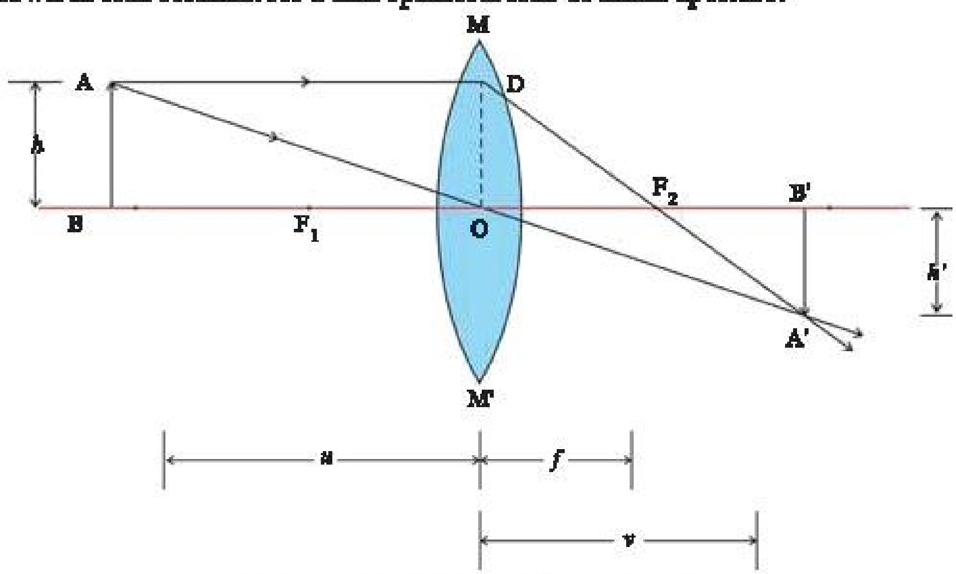


Fig. 2.19 Image formation by convex lens

As shown in Figure 2.19, object AB of height h is placd just beyond the centre of curvature at a distance u from the convex lens. Therefore, its real, inverted and diminished image B'A' will be formed at a distance v on the other side of the lens.

According to cartesian sign convention,

Object distance (OB) $= -u$

Image distance (OB_1) $= +v$

Focal length ($OF_1 = OF_2$) $= +f$

From Figure 2.19, right angled triangles Δ ABO and Δ A'B'O are similar.

$$\therefore \frac{AB}{A'B'} = \frac{OB}{OB'} = \frac{-u}{v} \tag{2.15.1}$$

Similarly, right angled triangles Δ ODF_2 and Δ $B'A'F_2$ are similar.

$$\therefore \frac{OD}{A'B'} = \frac{OF_2}{F_2B'}$$

$$\therefore \frac{AB}{A'B'} = \frac{OF_2}{F_2B'} \quad (OD = AB \text{ as they are opposite sides of rectangle } \square \text{ ABOD})$$

$$\therefore \frac{AB}{A'B'} = \frac{OF_2}{OB' - OF_2}$$

$$\therefore \frac{AB}{A'B'} = \frac{f}{v - f} \tag{2.15.2}$$

From equations (2.15.1) and (2.15.2)

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

$$\therefore -u\,(v - f) = vf$$

$$\therefore -uv + uf = vf$$

Dividing each term by uvf,

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

$$\therefore \frac{1}{v} - \frac{1}{u} = \frac{1}{f} \tag{2.15.3}$$

This equation (2.15.3) is known as **lens formula.**

Magnification of Image :

The magnification of an image formed by lens is defined as a ratio of height of image to the height of an object.

$$\therefore \text{ magnification } \quad m = \frac{\text{Image height}}{\text{Object height}} = \frac{h'}{h} \qquad (2.15.4)$$

In terms of object distance *(u)* and image distance *(v)*

$$\text{Magnification} = \frac{v}{u}$$

$$AB = h \qquad A'B' = -h'$$

$\therefore$ From (2.15.4)

$$m = \frac{-h'}{h} \qquad (2.15.5)$$

$$\frac{v}{u} = \frac{-h'}{h} \qquad (2.15.5)$$

As u is negative and v is positive. So, magnification

$$m = \frac{v}{u} \qquad (2.15.6)$$

2.16 Power of Lens

The ability of a lens to converge or diverge light rays depends on its focal length. The convex lens of short focal length bends the light rays through large angles by focussing them closer to the optical centre. Similarly concave lens of very shorter focal length causes higher divergence than the one with larger focal length. The efficiency with which a lens converge or diverge the light rays is expressed in terms of its power.

The reciprocal of focal length of the lens is called a power of lens (p).

$$p = \frac{1}{f} \qquad \text{... (2.16.1)}$$

The SI unit of power of lens is dioptre and is denoted by symbol D.

1D means the power of lens having 1m focal length.

Power of convex lens is positive and that of concave lens is negative. The optician prescribes corrective lens by indicatng their powers. The lens of power + 2.0 D represent the convex lens of focal length 0.5 m. The lens of power - 2.5 D represent the concave lens of focal length –0.4 m. The instrument used for measuring the power of lens is known as dioptremeter.

For Information Only

Many optical instruments consist of number of lenses. The combination of lenses increases magnification and sharpness of the image.

The resultant power (p) of lenses placed in contact is given by the algebraic sum of their individual powers p_1, p_2, p_3, ... as

$$p = p_1 + p_2 + p_3 + ...$$

The use of power instead of focal length of lenses is convenient for opticians. During the eye testing, an optician puts several different combinations of corrective lenses of known power as the total power is the simple algebraic addition. For example, combination of lenses of power + 2.0 D and + 0.25 D is equivalent to single lens of power + 2.25 D. The certain defect in the images produced by a simple lens can be minimised by combined lens system. Such systems are commonly used in the design of camera lenses and in the objective lenses of compound microscopes and telescopes.

Illustration : 6

A convex lens forms a real and inverted image of an object at a distance of 40 cm from it. What will be the distance of an object if size of an image is same as the object ? Determine the power of lens.

Solution :

As size of image = size of an object

$\therefore\ m = -1$ for convex lens

$\therefore$ Object distance u = Image distance v

from $m = \frac{v}{u}$

$u = -40$ cm

Substituting the value of u and v in formula of lens : $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$$\frac{1}{40} + \frac{1}{40} = \frac{1}{f} \Rightarrow \frac{1}{20} = \frac{1}{f}$$

$\therefore$ Focal length of lens $f = 20$ cm = 0.2 m

$$\therefore \text{Power of lens} = p = \frac{1}{f} = \frac{1}{0.2} = +5.0\,\text{D}$$

Illustration : 7

A concave lens has a focal length of 20 cm. At what distance should the object from the lens be placed a so that it forms the image at a distance 10 cm from the lens ?

Solution : Image fromed by concave lens is virtual, erect and on the same side of a lens as an object.

Image distance $v = -10$ cm

Focal length $f = -20$ cm

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

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

$$\therefore \frac{1}{u} = \frac{-1}{10} + \frac{1}{20}$$

$$= \frac{-1}{20}$$

$$\therefore u = -20 \text{ cm}$$

$\therefore$ The object should be 20 cm from concave lens on left.

Illustration : 8

The object of 5 cm height is placed at a distance 25 cm from the centre of convex lens of focal length 10 cm. Draw a ray diagram and find position, nature and the size of an image formed.

Solution :

Take a scale 2.5 cm = 1 unit on principal axis and draw a ray diagram. The ray diagram will be number 2 of Table 2.5.

This shows that real, inverted and diminished image of an object is formed on other side of lens at a distance of 8.3 cm from the lens.

2.17 Optical Instruments

On the basis of images formed by convex lenses by keeping the object at different positions, we shall discuss some optical instruments as under :

(1) Simple Microscope

When an object is placed between optical centre and focus of a convex lens, its virtual, erect and magnified image behind the object, is obtained. Simple microscope works on this principle.

A convex lens used for obtaining magnified image of the object is known as a simple microscope.

(2) Compound Microscope

The simple microscope cannot form clear magnified image beyound certain limit. The compound microscope having two lenses can form the magnified image of the object with better clarity. The ray diagram for the compound microscope is shown in Figure 2.20.

The lens towards the object is called objective lens and the lens near the eye is called eye piece. The focal length of objective lens is small compared to the eye piece.

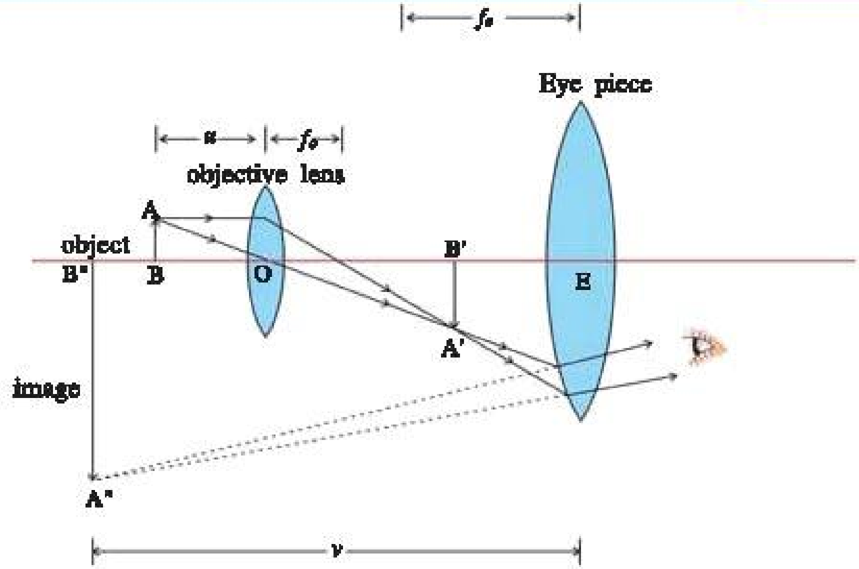


Fig. 2.20 Ray Diagram of compound Microscope

Working :

The object AB to be observed is placed at a distance slightly more than focal length (f_o) of objective lens so that its real, inverted and magnified image A'B' is obtained beyond the centre of curvature (C) of objective lens. The image A'B' becomes an object for the eye piece. The position of an image A'B' is adjusted such that it will be within the focal length (f_e) of eye piece. The eye piece forms virtual, erect and magnified image A"B" of the object.

Thus, the final image formed by compound microscope is virtual, inverted and magnified behind the object.

(3) Astronomical Telescope

The far distant objects such as planets, stars and moon etc. appear very small and close to each other. They can be observed by astronomical telescope.

The ray diagram for astronomical telescope is shown by Figure 2.21.

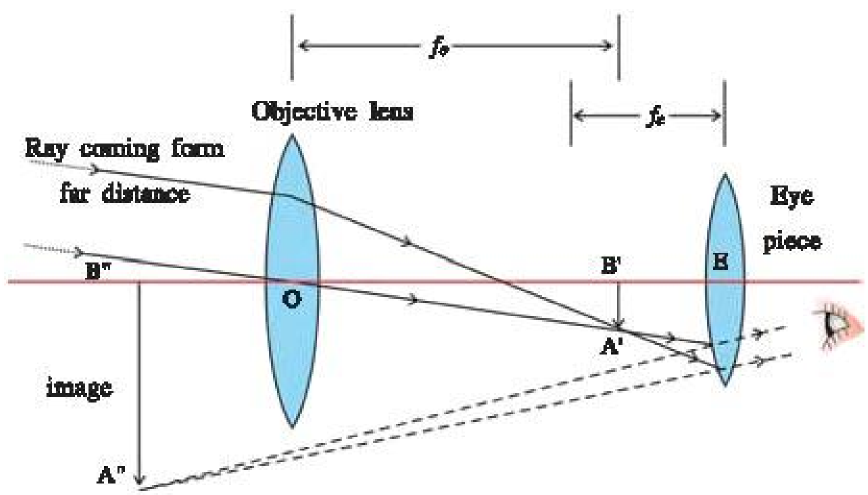


Fig. 2.21 Ray Diagram of Astronomical Telescope

Construction :

Astronomical telescope has co-axial arrangement of two convex lenses. Lens towards the object is called objective lens and the convex lens near the eye is called the eye piece.

The focal length of objective lens (f_o) is large as compared to the eye-piece.

Working :

When telescope is focussed on a distant object, parallel rays coming from the object form real, inverted and diminished image A'B'. This image acts as an object for eye piece arranged in such a way that its virtual, magnified and erect image A"B" will be formed.

Thus final image of object is virtual, inverted and diminished.

For Information Only

Telescope used for the observation of distant object on earth is known as terrestrial telescope. One more convex lens is introduced between objective lens and eye piece so that the final image of an object is erect. The astronomical telescope forms inverted image of the object.

Hubble telescope was launched into orbit around earth in 1990 to obtain the information about universe in the visible, infrared and ultraviolet region of an electromagnetic spectrum. It is named after the well known American astronomer Sir Edwin Powell Hubble (1889-1953).

The various centres for Astronomy and Astrophysics in India use Radio Telescopes for their research programmes. Giant Meterwave Radio Telescope (GMRT) world's largest array of radio telescope, is situated at Narayangaon, 80 km from Pune, India. It is an institute of international acclaim, where astronomers from all over the world visit and use GMRT to observe many astronomical objects such as Galaxies, Pulsars and Supernovae. GMRT is a unique facility provided by National Centre for Radio Astronomy (NCRA), a branch of Tata Institute of Fundamental Research (TIFR), Bombay.

Some other well known centres in India are at Ooty (Tamilnadu) Gauribidnaur (Karnataka), Girishikhar, Mount Abu (Rajasthan), Kodaikanal (Tamilnadu) that offer facilities of radio telescope.

What have you learnt ?

- Light is an electromagnetic wave which produces sensation in our eyes.
- Light travels with the speed of 3×10^8 m s^{-1} in vacuum.
- A straight line path joining one point to another in the direction of propagation of light is called a ray and a bundle of such rays is known as a beam of light.
- A mirror can focus the beam of light through reflection whereas a lens can focus the beam of light through refraction.

- In regular reflection, a beam remains parallel after reflection whereas in irregular reflection beam spreads over wide area after reflection.
- The images formed by plane mirror is always virtual and erect.
- The phenomenon due to which the right side of an object appears as left and left side of an object appears right is called lateral inversion.
- A concave mirror has inward reflecting surface and convex mirror has outward reflecting surface.
- The concave mirror forms real as well as virtual image. The convex always forms virtual and erect image.
- Focal length is positive for convex mirror and convex lens.
- Focal length is negative for concave mirror and concave lens.
- The distance of an object is always negative while its height is always positive.
- Radius of curvature = 2 × focal length.
- Mirror formula : $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ Lens formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$
- Rules for ray diagram to locate the image formed by concave mirror :
  - (i) A ray of light parallel to the principal axis, after reflection passes through the principal axis.
  - (ii) A ray of light passing through the principal axis of a mirror, gets parallel to the principal axis after reflection.
  - (iii) A ray of light passing through the centre of curvature of mirror is reflected along the same path.
  - (iv) A ray of light incident obliquely towards the pole of mirror reflects obliquely as per the laws of reflection.
- The ratio of the height of image to the height of the object is called the magnification of an image.
- Magnification is positive for virtual image and negative for real image.

  Magnification for mirror : $m = -\frac{v}{u}$ Magnification for lens : $m = \frac{v}{u}$
- The phenomenon of change in velocity of light from one transparent medium to another is called refraction of light..
- The angle formed between the incident ray and the normal at the point of incidence is called angle of incidence.
- The angle formed by refracted ray with the normal at the point of incidence is called angle of refraction.
- When a ray of light passes from a rarer medium to denser medium, it moves towards the normal.

- When a ray of light passes from a denser medium to rarer medium, it moves away from the normal.
- Snell's law of refraction :

$$n = \frac{\sin i}{\sin r}$$

- The ratio of speed of light in vacuum to the speed of light in a medium is called the absolute refractive index of the medium.
- The shift of emergent ray side ways from the direction of incident ray is called lateral shift.
- The extent of lateral shift depends upon angle of incidence, refractive index of medium and the distance between two parallel refracting surfaces.
- The optically denser medium has larger absolute refractive index compared to optically medium rarer.
- The convex lens converges the ray of light whereas cancave lens diverges a ray.
- Power of lens is the reciprocal of its focal length. Its SI unit is Dioptre.
- **Nature, size and position of images formed by concave mirror :**

Position of Object	Position of Image	Nature of Image	Size
(1) At infinity	At focus F	Real and inverted	Highly diminished
(2) Beyond C	Between C and F	Real and inverted	Diminished
(3) At centre of curvature C	At centre of C	Real and inverted	Same as object
(4) Between C and F	Beyond C	Real and inverted	magnified
(5) At focus F	At infinity	Real and inverted	highly magnified
(6) Between pole P and focus F	Behind mirror	Virtual and erect	magnified

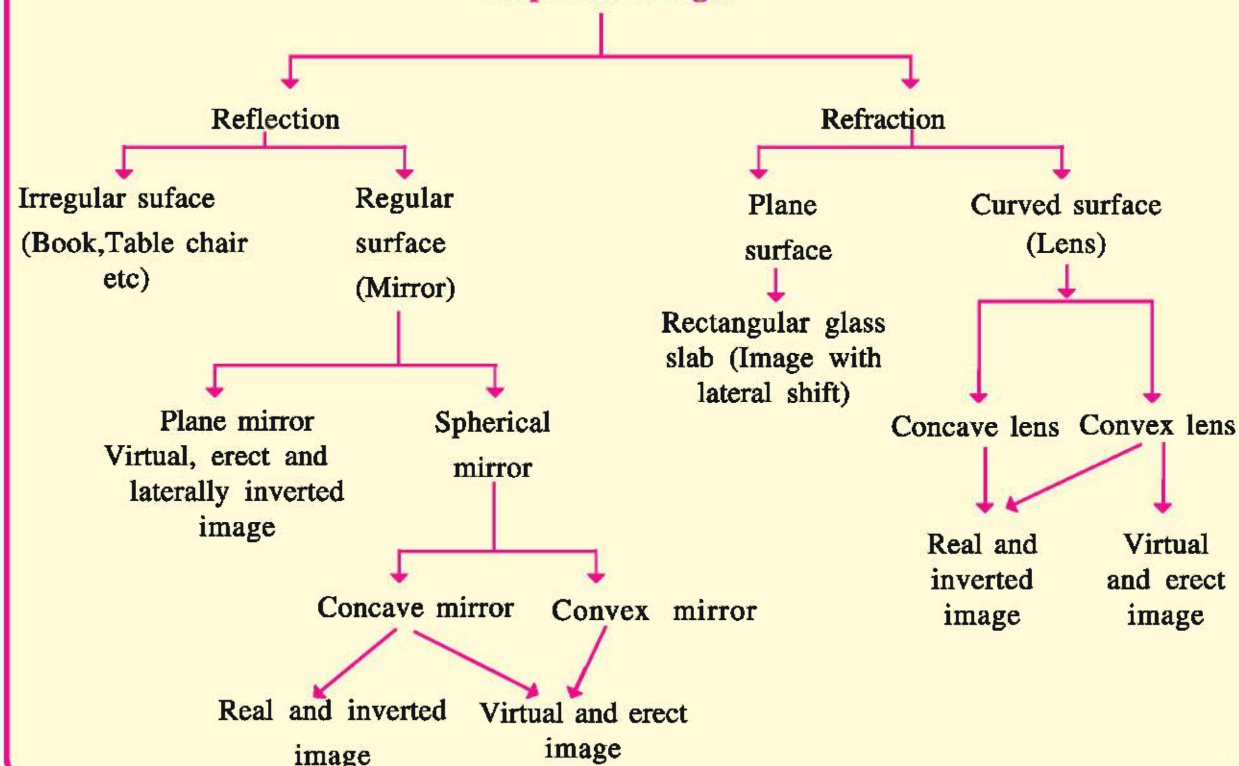
- Position, nature and size of image formed by convex mirror

Position of Object	Position of image	Nature of image	Size
(1) At infinity	At focus F behind mirror	Virtual and erect	Highly diminished (point sized)
(2) Between infinity and pole	Between pole P and Focus F behind mirror	Virtual and erect	Diminished

- When image formed by convex lens is real, its position, nature and relative size are same as that by the concave mirror. In concave mirror, the image is formed on the same side of object whereas in convex lens it is on another side of an object. The optical centre (O) in the convex lens plays role of pole (P) that is in concave mirror. The images formed by concave mirror and convex lens for an object placed at a distance less than focal length show different characteristic.

- The nature and relative size of an image formed by convex mirror and concave lens are same. The position of an image formed by concave lens is on the same side as the object while for convex mirror it is behind the mirror.
- When a convex lens is used for obtaining the magnified image of an object, it is called simple microscrope.
- The focal length of objective lens is smaller compared to that of eye piece in a compound microscope.
- The objective lens has larger focal length compared to that of eye piece in astronomical telescope.

Properties of Light



EXERCISE

1. Select the proper choice from the given multiple choices :

(1) What is the wavelength range of visible light ?

(A) 4×10^{-7}m to 8×10^{-7}m (B) 4×10^{-9}m to 8×10^{-9}m

(C) 4×10^{-5}m to 8×10^{-5}m (D) 4×10^{-6}m to 8×10^{-6}m

(2) What is the relation between radius of curvature (R) and the focal length (f) of a spherical mirror ?

(A) $R = f/2$ (B) $R = f$ (C) $R = 2f$ (D) $R = 3f$

(3) Which type of reflection will be represented by a light reflected from a book ?

(A) Regular (B) Irregular (C) Both types (D) None

(4) Through which of the following points, a ray passing through a centre of curvature and reflected by concave mirror will pass through ?

(A) Focus (B) Centre of curvature

(C) Pole (D) All

(5) At what distance in front of the concave mirror should an object be placed to get its virtual and erect image ?

(A) At centre of curvature (B) Beyond centre of curvature

(C) Between focus and pole (D) At focus

(6) The magnification of plane mirror is always ....

(A) More than 1 (B) 1

(C) Less than 1 (D) Zero

(7) The focal length of plane mirror is ....

(A) Zero (B) Infinity

(C) Uncertain (D) Equal to object distance.

(8) The distance between the object at 2 m from a plane mirror and its image is ....

(A) 4 m (B) 1 m (C) 2 m (D) 3 m

(9) At what distance should an object be placed to obtain its real, inverted and of same height as the object by a convex lens ?

(A) At focus (B) Between focus and centre of curvature

(C) At centre of curvature (D) Between optical centre and focus.

(10) Which of the following materials has maximum optical density ?

(A) Glass (B) Water (C) Pearl (D) Diamond

(11) The absolute refractive index of any medium is always......

(A) 1 (B) > 1 (C) < 1 (D) Zero

(12) Which of the lenses with focal length 10 cm, 20 cm, 25 cm, and 50 cm has maximum power ?

(A) 50 cm (B) 25 cm (C) 20 cm (D) 10 cm

(13) What is the focal length of a convex lens having power + 5.0 D ?

(A) – 10 cm (B) – 20 cm (C) + 10 cm (D) + 20 cm

(14) If the absolute refractive indices of water, benzene, and saphire are 1.33,1.50 and 1.77 respectively, then which medium has maximum relative refractive index ?

(A) Saphire relative to water (B) Saphire relative to benzene

(C) Benzene relative to water (D) Water relative to benzenes

(15) Which type of an image is formed by a plane mirror ?

(A) Real and inverted (B) Real and erect

(C) Virtual and erect (D) Virtual and inverted

(16) If the absolute refractive indices of water and glass are 4/3 and 3/2 respectively, then what will be the ratio of velocity of light in water to that of glass ?

(A) 2 (B) 8/9 (C) 9/8 (D) 1/2

(17) The absolute refractive indices of water glass and diamond are 1.77, 1.50 and 2.72 respectively, which medium is most optically denser ?

(A) Water (B) Glass (C) Diamond (D) None

(18) Which of the following always form virtual image ?

(A) Concave mirror and convex lens (B) Convex mirror and concave lens

(C) Convex mirror and convex lens (D) Concave mirror and concave lens

(19) What will be the angle of refraction for the light ray incident normal at the surface ?

(A) 90^0 (B) 60^0 (C) 30^0 (D) 0^0

(20) The compound mirroscope consists of two convex lenses of 5 cm and 20 cm focal length, then which of them will be object lens and eye piece ?

(A) Object lens with 20 cm focal length and eye piece with 5 cm focal length.

(B) Object lens with 5 cm focal leugth and eye piece with 20 cm focal length.

(C) Both should have 20 cm focal length.

(D) Both should have 5 cm focal length.

2. Answer the following questions in brief :

(1) What is called regular and irregular reflection of light ?

(2) Write the laws of reflection of light.

(3) What are called centre of curvature and radius of curvature of mirror ?

(4) Draw a ray diagram showing position, nature and size of an image formed by concave mirror when the object is placed beyond the centre of curvature.

(5) Draw a ray-diagram showing position, nature and size of an image formed by concave mirror when the object is placed between pole and principal focus.

(6) Draw a ray-diagram showing position, nature and size of an image formed by convex mirror when the object is placed between infinite distance and pole.

(7) Obtain the position, nature and size of an image formed by a plane mirror from the formula of magnification.

(8) Write laws of refraction of light.

(9) What is called the absolute refractive index of a medium ? Obtain the general form of Snell's law in terms of refractive indices of two media ?

(10) Draw a ray-diagram showing the position, nature and size of an image formed by convex lens when the object is placed at centre of curvature of lens.

(11) Draw a ray-diagram showing the position, nature and size of an image formed by a convex lens when object is placed between its optical centre and focus.

(12) Draw a ray-diagram showing the position, nature and size of an image formed by a concave lens when the object is placed between an optical centre and infinite point.

(13) What is called the magnification of an image ? Derive the formula of magnification for spherical lens.

3. Write answers of the following questions :

(1) Explain the reflection by a plane mirror by drawing suitable figure.

(2) Give the cartesian sign convention for the reflection by spherical mirror.

(3) With the necessary figure, explain the refraction of light through a rectangular glass slab.

(4) Obtain the lens formula for spherical lens.

(5) Explain how the position of an image is located for spherical mirror by considering the different rays using necessary ray-diagrams.

(6) Write a note on power of lens.

4. Answer the following questions in detail :

(1) Derive the formula for spherical mirror

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

(2) Explain the construction and working of a compound microscope with a neat ray-diagram.

(3) Write a note on astronomical telescope.

5. Solve the following problems :

(1) An object of height 5 cm is placed at a distance of 10 cm from convex mirror of focal length 15 cm. Find the position, nature and size of an image.

(**Ans :** Virtual, erect and diminished image at a distance 6 cm behind the mirror. Height of image = 3 cm)

(2) An object of height 6 cm is placed at a distance of 15 cm from a concave mirror of focal length 10 cm. Find position, nature and height of an image.

(**Ans :** $v = -30$ cm, height = 12 cm, Real, inverted and magnified)

(3) The rays of light are entering from glass into glycerine. If the absolute refractive indices of glass and glycerine are 1.5 and 1.47 respectively, find the refracting index of glycerine relative to glass. (**Ans :** 0.98)

(4) The refractive index of light entering glass from water is 1.12. Find absolute refractive index of water if the absoute refractive index of glass is 1.5.

(**Ans :** 1.34)

(5) When the light entering from glass to water, refractive index of water with respect to glass is 0.9. The angle of incidence at the surface seprating two media is 26°48'. Find the angle of refraction at the surface.

Take sin 26°48' = 0.45 approximately.

(**Ans :** Angle of incidence = 30°)

(6) An object is placed perpendicular to the principal axis of a convex lens having focal length 10 cm. The distance of an object from the lens is 15 cm. Find the position of an image.

(**Ans :** v = 30 cm)

(7) An object is placed perpendicular to the principal axis of concave lens of focal length 30 cm. Find the position of an image when the object is at a distance 20 cm from the lens.

(**Ans :** v = – 12 cm)

(8) A power of convex lens is + 4.0 D. At what distance should the object from the lens be placed to obtain its real and inverted image of the same size on the screen ?

(**Ans :** u = 50 cm. At the centre of curvature of lens)

UNIT

3

DISPERSION OF LIGHT AND NATURAL OPTICAL PHENOMENA

3.1 Introduction

Dear student,

In Chapter 2, you have studied about reflection and refraction of light. In addition to that position, nature and size of the image formed by mirrors and lenses were also discussed. You have also obtained the understanding about the formation of the image in Compound Microscope and Astronomical Telescope using convex lens. This technique is very helpful in understanding the functioning of lens in human eye. The lens also plays an important role correcting the defect of vision in human eye. The reflection and refraction of light are very useful in explaining natural phenomena like the formation of rainbow, twinkling of stars and mirage formation. In this chapter you are going to study some natural phenomena based on refraction, dispersion and the scattering of light.

3.2 Dispersion of White Light Through a Glass Prism

In the monsoon season the phenomenon of rainbow indicates the fact that "White light is composed of seven colours". To understand the dispersion of white light into seven colours consider the following activity.

Activity : 1

- Take a glass prism.
- Incident the sunlight on one of the face of prism through a narrow slit.
- Turn the prism slowly until the light is emerged from the prism and capture on the screen.
- What do you obsevre ?

You will get beautiful bands of different colours on screen. The prism splits incident white light into seven colours in the sequence, " Violet, Indigo, Blue, Green, Yellow, Orange and Red." as seen from Figure 3.1. The acornym "VIBGYOR" is useful to remember the sequence of colours.

The phenomenon of splitting of white light into its constituent colours is called dispersion of light.

The band of seven colours obtained from the splitting of white light is called spectrum.

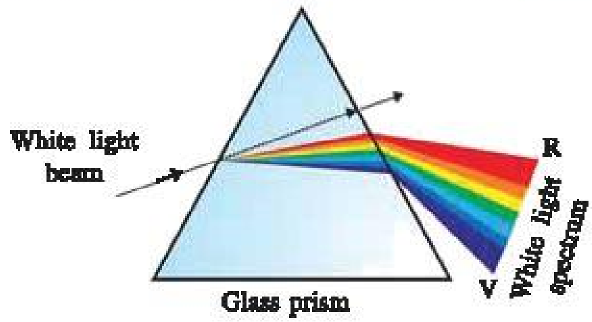


Fig. 3.1 Dispersion of white light by the glass prism.

All the constituent colours of a white light have same velocity in vacuum. When it passes through a transparent medium like glass, water, glycerin etc., their velocity changes and due to that deviation of the different constituent colours occur at different angles. In a transparent medium, violet coloured light is deviated maximum and the red coloured light is deviated minimum because in a medium, the velocity of violet coloured light is minimum and that of red coloured light is maximum (figure 3.1). Thus, the dispersion of white light occurs due to the refraction of constituent colours at different angles. In similar way the white light is obtained by recombination of these seven constituent colours. This is explained by the following activity :

Activity : 2

- Take two prisms P_1 and P_2 of same prism angles.
- Arrange them as shown in Figure 3.2.
- Now allow a narrow beam of white light to incident on one face of prism P_1.
- Observe the beam of light emerging from pirsm P_2 on nearby screen or wall.
- Show your observation.

As shown in Figure 3.2, the first prism P_1 disperses the white light into seven constituent colours. The second prism P_2 recombines these seven colours into a beam of white light. Therefore, a white light is again observed on the screen.

From this experiment, Newton established that a white light is composed of seven constituent colours. Thus, the structure of white light can be understood through the phenomenon of dispersion of light.

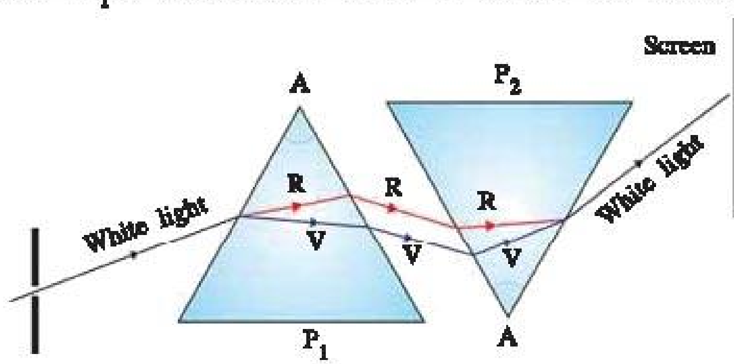


Fig. 3.2 Recombination of spectrum of white light

3.3 Primary Concept of Colours of Objects

The colour sensed by our eyes depends upon the colour of rays entering into our eyes. Out of the spectrum of white light obtained by a prism as a band of seven colours, green colour of leaf and red colour of rose entering our eyes are its known examples.

To explain why the objects are seen colourful, consider the following activity.

Activity : 3

- Take a torch that produces white light.
- Take blue, green and red coloured plates or transparent papers.
- Obtain green coloured light by passing a white light through green plate. Incident this light on green coloured object (e.g. green leaf) which will appear green coloured.
- Now obtain blue and red coloured light in the similar way and incident them on the same green coloured object which will appear black coloured.
- Now observe the red coloured object under blue and green coloured light and the blue coloured object under red and green coloured light which will also appear black coloured.

When the light is incident on the object, the absorption of some colours and reflection of some colours from the object takes place. The colour of light which is reflected from the object determines the colour of an object. When the white light is incident on green leaf, all the colours except green colur are absorbed and the green colour is reflected, so the leaf appears green coloured. Due to the same reason, the red colour of rose is to be seen.

Now when green coloured light is incident on red coloured rose, it will be absorbed and no light will be reflected from it, hence it appears black.

When the object appears black coloured, there will be no reflection of any constituent colour of light.

When all the constituent colours are reflected from the object, it appears white.

Primary colours of light and their superposition :

In the dispersion of white light, we have seen that the white light has seven constituent colours and from the recombination of these colours white light is obtained.

However, it is not necessary to combine all these constituent colours to obtain white light. The combination of only red, blue and green in proportion also gives white light.

Thus red, blue and green colours are said to be primary colours of white light.

The method of producing a wide range of colours by the appropriate mixture of these primary colours is known as an **additive mixture method.** The colours obtained by the mixture of primary colours in this way are known as **composite colours**.

Consider the following activity to know how the composite colours are obtained :

Activity : 4

- Take three torches and transparent glass plates of red, blue and green colours and obtain light of these three colours.
- Now place a white paper on a table. Arrange these three torches horizontally on a table in such a way that the patches of all three colours are seen (Figure 3.3).

You will observe that,

- The portion of the white paper where all the three patches superimpose on one another will appear white.
- The portion of the screen where blue and green light superimpose appears cyan.
- The portion where blue and red colour superimpose appear magenta and it will be yellow at the superposition of red and green colour.

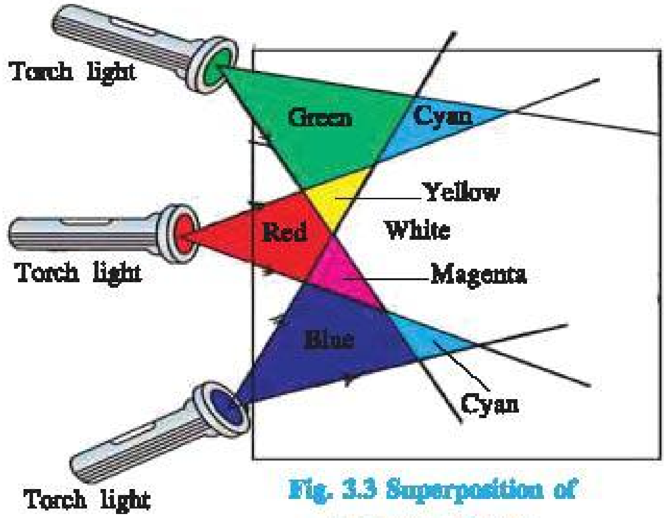


Fig. 3.3 Superposition of primary colours

Thus, combining primary colours as shown in Figure 3.4 and Table 3.1 shades of different colours are obtained.

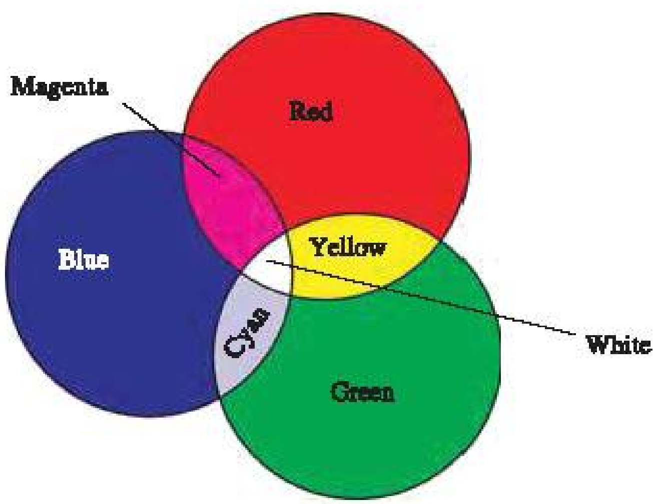


Fig. 3.4 Mixing of primary coloUs of light

Table 3.1 Superposition of primary and composite colours

Number	Colours for mixing	Resultant colour
1.	Blue, Red	Magenta
2.	Blue, Green	Cyan
3.	Red, Green	Yellow
4.	Blue, Green, Red	White
5.	Blue, Yellow	White
6.	Green, Magenta	White
7.	Red, Cyan	White

Any two colours, which on mixing, produces a light of white colour are called complementary colours.

From Table 3.1, blue and yellow, green and magenta, red and cyan are complementary colours.

Note that mixing of primary colours of light in various proportion gives the entire spectrum of colours. This technique is used to obtain colourful picture in a colour television, computer etc.

Colours and pigments :

The coloured substances which are used as a paint are known as pigments. The paints used for drawing and painting the infrastructures are well known examples of pigments.

The cyan, magneta and yellow are the primary pigments.

Just as the white light is obtained by mixing the primary colours of light using additive method, the white pigment cannot be obtained on mixing the primary pigments. In order to obtain the various pigments, the **substractive method** is used for mixing the pigments.

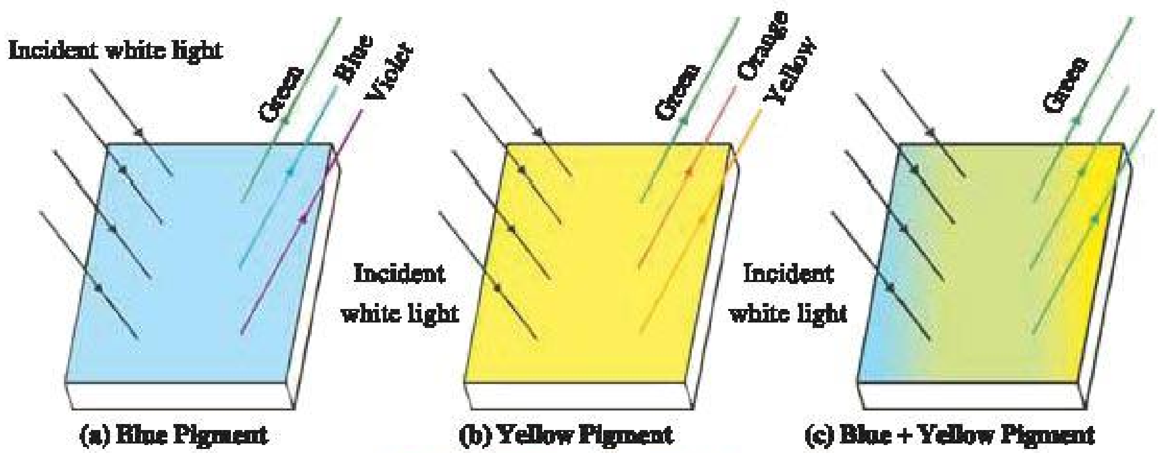


Fig. 3.5 : Reflection of light from pigments

As shown in Figure 3.5 (a), when the white light is incident on blue pigment blue, violet and green colours are reflected and the remaining colours are absorbed. If the white light is incident on yellow pigment, only yellow, green and orange colours are reflected (Figure 3.5 (b)). Thus, the green colour of light is not absorbed by yellow and blue pigment. Therefore, if blue and yellow pigments are mixed, then they will reflect only green coloured light (Figure 3.5 (c)).

Thus, by substractive mixture method, various pigments are obtained.

3.4 Human eye

The human eye is the best natural optical instrument whose construction can be compared with that of the camera. We can view the wonderful world around us through the eyes.

A simple sketch of human eye along with the labelling of its main parts is shown in the Figure 3.6.

The light rays coming from the object first enter the eye through cornea. A muscular diaphragm behind the cornea is known as an iris which can control the amount of light that enters into the eye. An aperture of an eye behind the cornea at the center is known as pupil whose size can be controlled by Iris. After passing through the pupil, the light rays are incident on a jelly like elastic material known as an eye-lens. The muscular structures which hold the eye-lens in its position are known as ciliary muscles. They change the focal length of an eye-lens by changing its thickness. Position of image where image formed due to refraction by eye-lens is called retina. When the light rays fall on retina, the light sensitive cells generate electrical signals. The signals are sent to the brain through the optic nerves where the image of an object is interpreted.

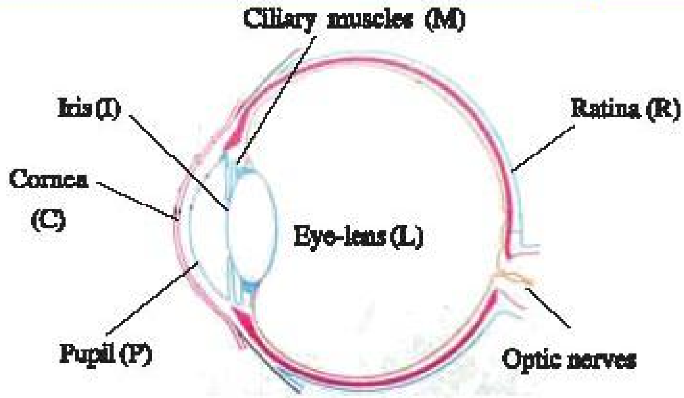


Fig. 3.6 Construction of human eye

Accommodation power of an eye :

The ciliary muscles can modify the curvature of lens of human eye up to certain extent only. The focal length of lens changes with the change in the curvature of an eye-lens. In the normal situation of ciliary muscles, the lens is thin and its focal length is more. This enables eye to see the distinct oject clearly. When the ciliary muscles contract, the focal length is decreased due to the increase in the curvature of an eye lens and an eye will be able to see nearby object clearly.

The ability of an eye-lens to adjust its focal length as per requirement is called accommodation power of an eye.

The minimum distance at which the object can be seen clearly without contraction of eye-lens is called the least distance of distinct vision. This distance is also called **near point of an eye**. For young adult with normal vision the value is 25 cm.

The farthest distance upto which the eye can see objects clearly is called **far point of an eye**. It is infinite for the person having normal vision.

Thus, a person with normal vision can see object clearly from 25 cm to infinite distance.

Defects of vision and its remedies :

You know that the light rays coming from the object forms the image on retina after being refracted by an eyelens. To see the clear image of an object, its image should be formed exactly on retina. When cilliary muscles cannot change the thickness of eye-lens as per requirement, the defect of vision arise.

Generally, three main types of common defects of vision arise in eye :

(i) Near-sightedness or Myopia. (ii) Far-sightedness or Hypermetropia. (ii) Presbyopia

(i) Near-sightedness : If eye-lens does not become thin as per requirement, the light rays from distinct object are focussed at the distance shorter than retina after being refracted from eye-lens. So the distant object cannot be seen clearly, this type of defect is called **near-sightedness or myopia** (Figure 3.7). Though nearby object may be seen clearly. This defect can be corrected by using a concave lens of suitable power as shown in Figure 3.8.

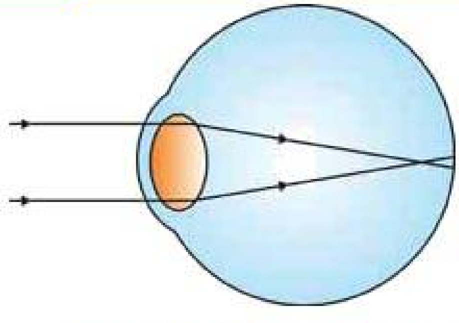


Fig. 3.7 Defect of near-sightedness

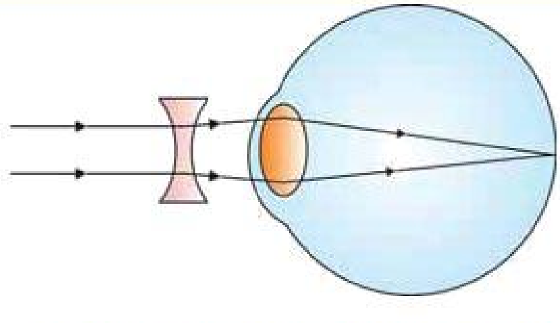


Fig. 3.8 Correction (Remedy) of near-sightedness using concave lens

(ii) Far-sightedness or Hypermetropia : If the eyelens does not become thick as per requirement, the rays coming from nearby object will be focussed beyond the retina. Thus nearby object cannot be seen clearly, this type of defect of an eye is known as **far-sightedness or hypermetropia** (Figure 3.9). Though the distant object may be seen clearly. This defect can be corrected by using a convex lens of appropriate power (Figure 3.10).

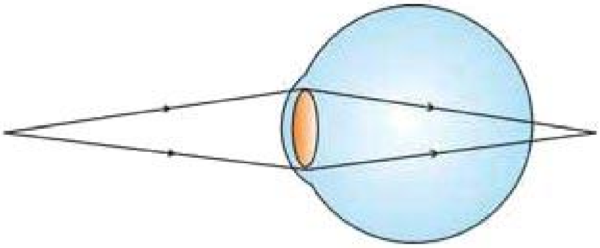


Fig. 3.9 Defect of far-sightedness

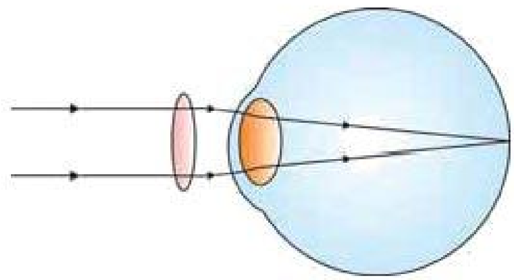


Fig. 3.10 Correction of far-sightedness using convex lens

(iii) Presbyopia : The power of accommodation of an eye usually decreases with ageing. The near point of aged persons recedes and they find it difficult to see nearby objects clearly without spectacles. Moreover, some times they also find difficult to see a distant object without spectacles. This defect of an eye arises due to weakening of cilliary muscles and loss of elasticity of eyelens. This defect is called presbyopia. For the remedy of this defect, spectacles of bifocal lens are used. Generally upper part bifocal lens is made up of concave lens and a lower part of a small circular section is made up of convex lens.

In present times, contact lens and laser surgery are widely used to remove the defect of eyes.

When a milky and cloudy layer is formed on the eye lens of old age persons, they loose their vision partially or completely. This type of situation is called **cataract**. It can be removed by surgery.

3.5 Formation of Rainbow

A rainbow is a natural spectrum visible in the sky after rainshower. It is caused by the dispersion of sunlight by tiny water droplets present in the atmosphere. A rainbow is always formed in the direction opposite to that of sun. The water droplets act like small prisms. They disperse the incident light first, then reflect it internally (not necessarily total internal refleciton) and finally refract it again while it comes out of rain drop as shown in the following Figure 3.11.

The different colours of light enter into our eye due to the dispersion and internal reflection of light. Looking from lower to higher order colours form violet toward red arc is known as **primary rainbow**.

Some times you may have seen two rainbows in the sky out of which the order of colours in upper rainbow is reverse to the primary rainbow is called **secondary rainbow.**

You may also see a rainbow on a sunny day when you look at a water fall with the sun behind you.

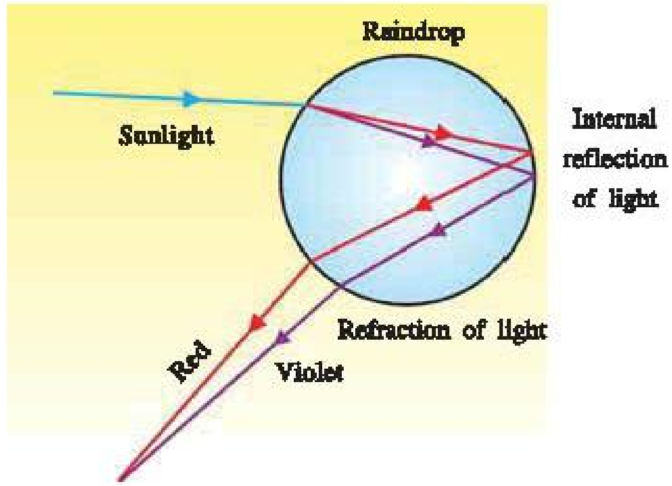


Fig. 3.11 Formation of rainbow

3.6 Atmospheric refraction

The density of earth's atmosphere is non-uniform everywhere as it consists of layers of different densities. The layer at lower altitude from the earth has more density than that at the higher altitude. As a result of this, the refractive index of atmosphere decreases continuously from lower to higher altitude. Here, the physical situations of refracting medium (atmospheric air) are also not steady, so the apparent position of the object also fluctuates. This phenomenon is known as an atmospheric refraction or the refraction of light by earth's atmosphere.

The phenomena like twinkling of stars, early sunrise and delayed sunset occur due to this effect.

Twinkling of Stars :

As the stars are very far, they may be considered to be point sources of light. When star light passes the atmosphere, it bends continuously towards the normal till it enters our eye due to the refraction so that its apparent position is slightly higher than its actual position. Due to the mobility of an air and changes in temperature, the refractive index of atmosphere goes on changing continuously and randomly. Therefore, apparent position of star is not sleady, but it changes slighty. Therefore, the stars look twinkling (Figure 3.12).

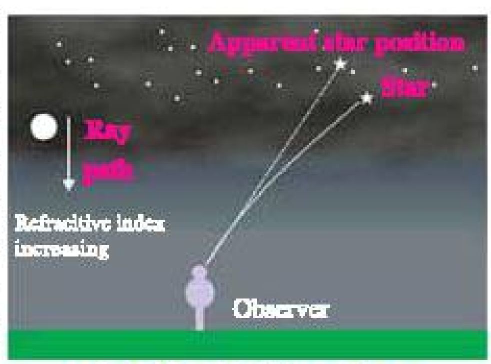


Fig. 3.12 : Twinkling of stars

The planets are nearer to earth so they can act as extended sources. That means they are considered as a collection of point sources due to which the twinkling does not occur and hence, the planets do not twinkle.

Early sunrise and delayed sunset :

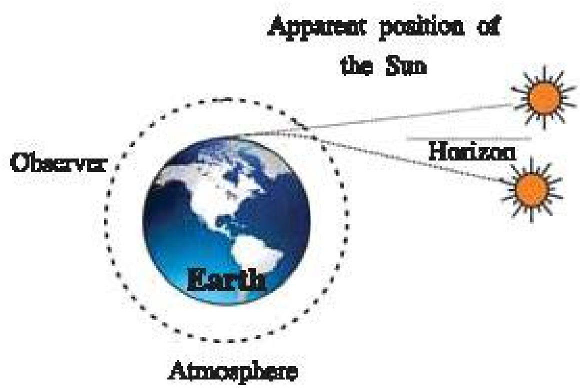


Figure 3.13 : Actual and apparent position of sun at sunrise.

The sun is visible to us about two minutes before the actual sunrise and two minutes after the actual sunset because of the refraction of the light by an atmosphere.

Actual sunrise means actual appearance at the horizon by the sun. Figure 3.13 shows actual and apparent positions of sun with respect to horizon.

When the sun is below the horizon, sunlight reaches to our eyes after being refracted in the atmosphere. Thus, the sunrise is experienced to be two minutes earlier. In the same way when the sun moves below the horizon, it is seen for two minutes after sunset.

Thus, the duration of the day increases by four minutes.

3.7 Scattering of Light

The deflection of light by minute particles and molecules in all the directions is known as scattering of light.

The colour of scattering light depends upon size of scattering particles. Due to the small size, minute particles scatter the light of small wave length such as blue colour. The particles with bigger size scatter the light of larger wavelength. If the size of scattering particle is much bigger the scattering light appears white.

Tyndall effect :

The earth's atmosphere is a heterogenous mixture of smoke particels, tiny water droplets and air particles. When light falls on such colloidal particles, the path of light beam becomes visible. This phenomenon is known as Tyndall effect. The light rays reach us after the deflection of light in all the directions from these particles.

When a fine beam of sunlight enters a smoke filled room through a small hole, a path of beam becomes visible due to this phenomenon. When the sunlight enters a canopy of dense forest, Tyndall effect is also seen due to the scattering of light through the tiny water droplets in mist. Some times the smoke emitted by the combustion of engine oil apperars blue in colour due to the Tyndall effect. This phenomenon is devloped commercially to determine size and density of aerosol and other colloidal particles.

Blue Colour of clear Sky :

The molecules of air and other fine particles in the atmosphere have their size smaller than the wavelength of visible light. These particles are more effective in scattering of light of visible shorter wavelength at the blue end than the light of longer wavelength at the red end. The wavelength of red coloured light is about 1.8 times more than that of blue colour. Thus, when sunlight passes through the atmosphere, the fine particles in the air scatter blue colour more strongly than red; so that sky appears blue. If the earth had no atmosphere, the sky would have appeared dark in the absence of scattering.

Why the signal lights for danger are red in colour ?

The red coloured light scatters least by fog or smoke so it can be seen from a long distance. Therefore, it is used in signals showing danger.

Reddish colour of the sun at sunrise and sunset :

To understand the reddish colour of sun at sunrise and sunset, we consider the following activity :

Activity : 5

- Place a strong source (S) of a white light at the focus of convex lens. (L_1) as shown in figure 3.14 to produce a parallel beam of light.
- Allow the light beam to pass through a tranparent glass vessel (V) containing clean water.
- Now allow the beam of light to pass through the circular hole (C) made in card-board and obtain sharp image of the circular hole on screen using second convex lens (L_2).
- Dissolve 100 g of sodium thiosuphate in about 1 litre of clean water in tank. Add 1 to 2 ml of concentrated sulphuric acid to water.
- What will be your observation ?

After some time you will see blue colured light when looking from side of a vessel and the crimson red colour will be seen on screen.

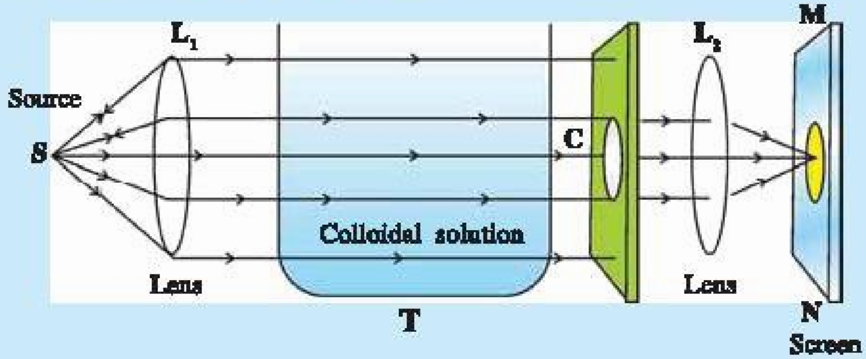


Fig. 3.14 Experimental arrangement for the observation of scattering of light through colloidal solution

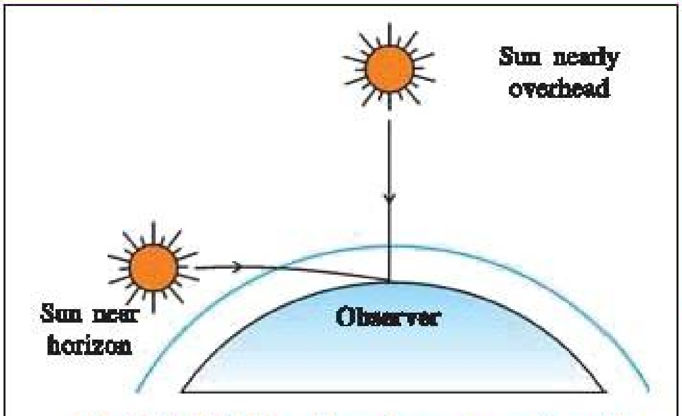


Fig. 3.15 Reddish colour of sun at sunrise and sunset.

The conclusion of this activity is that, the vessel is seen blue coloured while looking from one side due to more scattering of blue colour among white light, while the light of reddish colour (longer wave length) is less scattered so that it reaches to the screen and the screen appears reddish.

White light coming from sun has to travel more distance in the atmosphere before reaching to the observer. During this, the scattering of blue light takes place so that the light corresponding to reddish colour reaches to the observer and hence sun appears reddish. The similar situation also results at sun set. Rising and setting of full moon from the horizon appears reddish due to this reason.

For Information Only

Dr. Chandrashekhar Venkat Raman presented his paper "Scattering of light." on February 28, 1928. For this outstanding work he was given Nobel Prize in 1930. He was the first Nobel Prize winner in Physics from India. Government celebrates National Science Day on February 28 every year in his memory.

Various types of scattering based upon size of scattering particles are shown as under :

(i) Rayleigh scattering (ii) Mie scattering (iii) Tyndall scattering (iv) Brillouin scattering (v) Scattering of X-rays by crystal planes (vi) Raman scattering


Dr. Chandrashekhar Venkat Raman

3.8 Total Internal Reflection of Light

When a ray of light travels from optically denser medium to optically rarer medium, it bends away from the normal at the surface separating two media.

As the angle of incidence increases, the angle of refraction also increases and the ray of light moves farther away from the normal after refraction. The angle of incidence at which the angle of refraction is 90° is called critical angle (C). For the angle of incidence greater than cirtical angle, the light is completely reflected in the denser medium. The surface separating these two media acts like a "mirror". This phenomenon is known as **total internal reflection of light** (Fig.3.16).

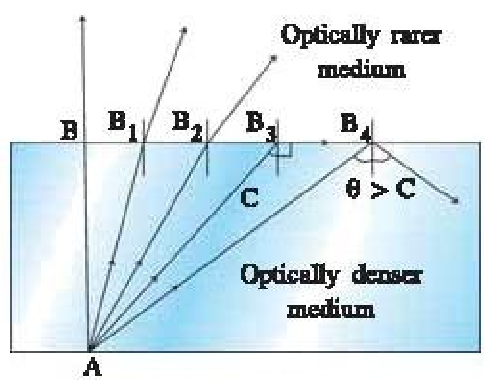


Fig. 3.16 Total internal reflection of light

The sparkling of diamond is also due to total internal reflection. The optical fibres used in signal commnication also work on this principle.

Mirage formation :

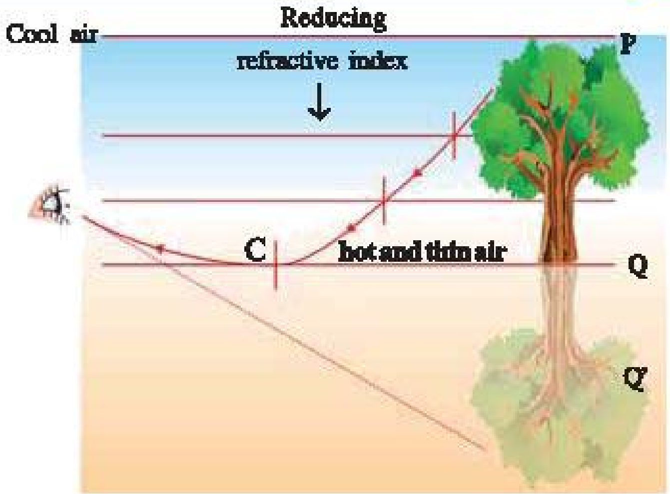


Fig. 3.17 Mirage Formation.

Mirage is an optical illusion usually seen in desert. It is also seen on coal tar road during summer. In summer, the air near the surface of the earth is hotter than the air above it. Therefore, the air near the earth is rarer than that above it. So as we move up above the surface of the earth, the refractive index increases continuously.

As shown in figure 3.17, the light rays coming from a point of a tall object like a tree pass through the air of gradually decreasing refractive index towards the ground, light rays bend gradually more and more away from the normal and their angle of refraction increases gradually so that they enter observer's eye after the total internal reflection occurs. Thus, the virtual and inverted image of an object appears to be as it is reflected from the water surface.

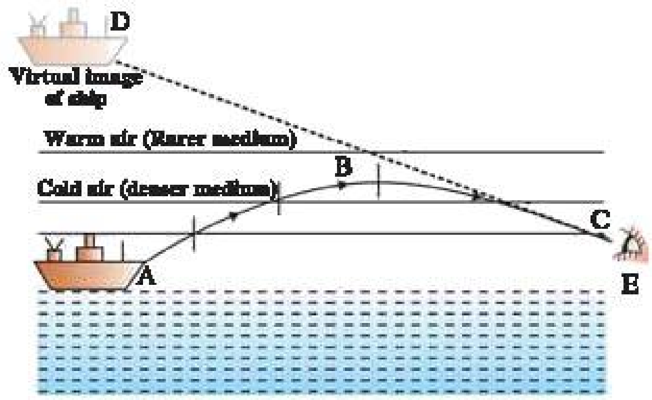


Fig. 3.18 Looming caused by total interval reflection

Looming is such a kind of mirage observed in very cold regions in which distant object appears to be hanging mid way in the air. It is produced by the total internal reflection of light (in downward direction) caused by atmospheric refraction. The looming produces virtual and erect image of an object above horizon where the warmer (optically rarer) air remains above the colder (optically denser) air in the atmosphere (Figure 3.18).

What have you learnt ?

- The splitting of white light into its constituent colours is known as dispersion of light.
- The violet coloured light is deviated maximum and the red coloured light is deviated minimum through the glass prism.
- If all the colours of light are reflected from the object, then it is seen white. If all the colours of light are absorbed by the object, it will appear black.
- Red, green and blue are primary colours.
- Magenta, yellow and cyan are primary pigments.
- The ability of an eye to adjust focal length of the eye-lens as per requirement is known as accommodation power of an eye.

- The minimum distance at which the nearby object can be seen clearly without contraction of an eye-lens is called least distance of distinct vision. It is also known as near point of an eye.
- The far distance up to which an eye can see the object clearly is known as far point of an eye. Generally, far point is at an infinite distance.
- An accommodation power of an eye for the person with normal vision is from 25 cm to infinity.
- The focal length of an eye-lens can be changed with the help of cilliary muscles.
- If the eye-lens can not become thin as per requirement, the defect of nearsightedness occurs. This defect can be corrected using a concave lens of appropriate power.
- If the eye-lens can not become thick as per requirement, the defect of far sightedness occurs. This defect can be corrected using a convex lens of an appropriate power.
- Because of the increasing age of a person, the cilliary muscles weakens and the elasticity of an eye-lens is reduced, so sometimes the nearby as well as far distant objects can not be seen clearly. This type of defect is called presbyopia. It is corrected using bifocal lens of appropriate power.
- A rainbow is caused by the dispersion, internal reflection and refraction of sunlight by tiny water droplets present in the atmosphere.
- When the light ray passes through the atmosphere, it gets refracted continuously due to the continuous change in density of atmosphere. This phenomenon is known as atmospheric refraction of light.
- The sun appears two minutes earlier than its actual sunrise and two minutes later than its actual sun set.
- The deflection of light by minute particles and molecules in all the directions is known as scattering of light. The phenomenon of scattering depends upon the colour of light and the size of scattering particles.
- The scattering by minute and fine particles is more for the light of smaller wavelenght i.e. for blue coloured light. The particles of large size scatter the light of larger wavelength by more amount.
- When a ray of light travels from denser medium to rarer medium, the angle of incidence at which the angle of refraction of light will be 90°, which is known as critical angle.
- Mirage is an optical illusion generally observed in hot region due to total internal reflection.
- Looming is an optical illusion observed in cold region in the atomosphere above horizon due to the total internal reflection of light.

EXERCISE

1. Select the proper choice from the given multipule choices :

(1) By which optical phenomenon, the splitting of white light into seven constituent colours occur ?

(A) Refraction (B) Reflection (C) Dispersion (D) Interference.

(2) Which colour of light deviates maximum in the dispersion of white light by prism ?

(A) Violet (B) Blue (C) Green (D) Red

(3) Which of the following are the primary colours ?

(A) Red, Blue, Yellow (B) Red, Green, Violet.

(C) Yellow, Green Blue (D) Red, Green, Blue.

(4) Which of the following are primary pigments ?

(A) Yellow, Green and Magenta (B) Magenta, Yellow and Cyan

(C) Blue, Green and Violet (D) Red, Green and Yellow.

(5) In human eye, the image of an object is formed at ---------------

(A) Iris (B) Pupil (C) Retina (D) Cornea

(6) Which is the complementary colours of blue colour ?

(A) Red (B) Yellow (C) Green (D) Magenta

(7) Which colour is obtained by mixing the blue and red colours ?

(A) Green (B) Magenta (C) Cyan (D) Yellow.

(8) The focal length of an eye lens is changed due to the action of ------------------.

(A) Pupil (B) Retina (C) Cilliary muscles (D) Cornea.

(9) Which colours are reflected when white light is incident upon blue pigment ?

(A) Yellow, Orange, Green (B) Violet, Green, Blue

(C) Violet, Yellow, Green (D) Yellow, Green, Blue

(10) -------------- lens is used to correct the defect of vision termed as presbyopia.

(A) Convex (B) Concave (C) Bifocal (D) Contact

(11) Which phenomenon does not play a role in the formation of rainbow ?

(A) Reflection (B) Refraction (C) Despersion (D) Absorption

(12) For which of the following cases, the total internal reflection of light will be possible ?

(A) Angle of incidence is less than critical angle.

(B) Angle of incidence is equal to critical angle.

(C) Angle of incidence is more than critical angle.

(D) Angle of incidence is equal to angle of refraction.

(13) Where is the image in eye formed for a person suffering from defect of near sightedness ?

(A) On retina (B) On backward region of retina

(C) On a region ahead of retina (D) On pupil.

(14) Which phenomenon is responsible for the twinkling of stars ?

(A) Atmospheric reflection (B) Atmospheric refraction

(C) Reflection (D) Total internal reflection.

(15) Due to which phenomenon of light does Tyndall effect result ?

(A) Reflection (B) Refraction (C) Scattering (D) Dispersion

(16) What is the time difference between actual sunset and apparent sunset ?

(A) 2 s (B) 20 s (C) 2 minute (D) 20 minute

(17) Which colour of light scatters maximum due to atmosphere ?

(A) Blue (B) Yellow (C) Green (D) Red.

(18) Which coloured light has minimum velocity in the glass prism ?

(A) Red (B) Green (C) Blue (D) Violet

2. Answer the following questions in brief :

(1) What is the dispersion of light ? Which are the colours of the spectrum obtained from the dispersion through a glass prism ?

(2) Write the name of primary colours of light. Write the name of colours obtained from their mixture ?

(3) What are called pigments ? Give the names of primary pigments.

(4) Write the function of cilliary muscles and retina in human eye.

(5) What is an accommodation power of an eye ? What is the least distance of distinct vision ?

(6) What is called atmospheric refraction ? Which phenomenon results from it ?

(7) Give the reason for two minute early sunrise.

(8) What is the scattering of light ? On what factors does it depend ?

(9) Why are the danger signal lights red in colours ?

(10) Why does the sun appear reddish at sunrise and sunset ?

(11) What is the total internal reflection of light ? Give its illustrations.

(12) What is looming ? How is it formed ?

3. Write answer of the following questions :

(1) Explain the superposition of primary colours of light with necessary illustration.

(2) Explain the function of main parts of an eye by drawing a simple sketch of it.

(3) Explain the formation of rainbow with a neat figure.

(4) Write a note on "twinkling of stars."

(5) Describe Tyndall effect.

(6) Why does the clear sky appear blue in colour ?

4. Answer the following questions in detail :

(1) Explain the dispersion of white light by a glass prism using necessary figure.

(2) Describe the fomation of mirage through an appropriate figure.

5. Answer the following questions pointwise :

(1) What is the defect of vision in the human eye ? State its types and explain in detail.

UNIT

4

ELECTRICITY

4.1 Introduction

Student, have a look at the drawing room of your house. You will see the appliances like television, fan, tube light etc. Now if you look at your kitchen you will find the appliances like refrigerator, microwave oven, mixer etc. If you peep into your study room you may see the instruments like computer, air conditioning machine. In all these appliances, the common thing is that they all are operated by electricity (electical energy). Now imagine that the electrictiy fails in our house ! Our situation will be worse. The electricity empowers the places like schools, offices, industries, hospitals etc. In modern age, the electrical energy among the different forms of energy has more importance in creating luxurious lives for human beings. Electrical energy can easily be stored as well as it can be easily transformed into other forms of energy.

In the present chapter, we shall study the concept of physical quantities like electric current, electric potential, resistance etc. Also we shall get some information about electrical energy and its uses.

Firstly, we shall know about the foundation stone of electricity namely an electric charge.

4.2 Electric Charge

We have studied in Standard 8 that the small pieces of papers can be attracted by a plastic comb after combing through dry hair. Similarly, the attractive force results when a glass rod rubbed with a silk and a plastic rod rubbed with a fur. In this process, the charges resulting on the glass and plastic rod are of opposite type. During the friction, the glass rod acquires positive charges while the plastic rod acquires negative charges.

Thus, the electric charges are of two types : Positive electric charge (proton) and negative electric charge (electron). Electric charge is an intrinsic property of electron and proton like mass, which is difficult to define.

In SI unit system, charge is measured in coulomb (C). Conventionally electric charge of proton is considered positive and the electric charge of electron to be negetive. But their magnitudes are the same.

Charge on proton $e = 1.6 \times 10^{-19}C$

Charge on electron $e = -1.6 \times 10^{-19}C$

During the interaction among the electric charges, repulsive force is exerted between two like charges (e.g. electron-electron or proton-proton) and the attractive force is exerted between two unlike charges (e.g. electron-proton). The magnitude of electric force between the charges can be calculated from the law devised by French Scientist Charles Coulomb which you will study in Standard 12.

4.3 Electric Current

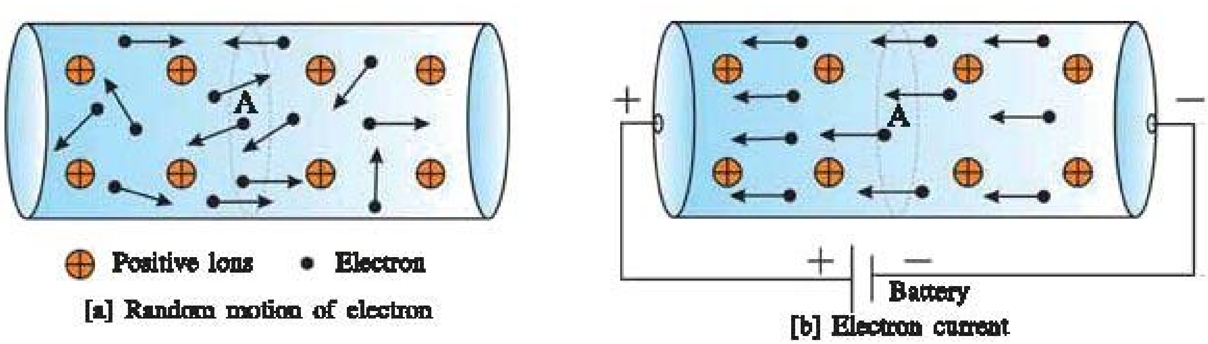
We are familiar with the flow of water. The quantity of water flowing in the river is called water current. Similarly, the amount of charge flowing through the conductor (e.g. Copper wire) is known as electric current.

In atoms, the electrons move around the nucleus whereas the protons remain binded. In the atoms of metallic materials, under the normal circumstances the attractive force between the valence electrons (electrons of the outermost orbit) and the nucleus (positive electric charge) is comparatively very small.

During the formation of metallic materials, these electrons get separated from their parent atoms and move in a random manner. Such electrons are known as 'Free electrons.'

Such free electrons are responsible for the conduction of electric current. Metallic materials like copper, silver and aluminium have plenty of such free electrons. The conduction of an electric current can easily take place in such materials. So they are called "Conductors." The materials like rubber, glass, plastic do not have free electrons so the conduction of electric current through them is not possible. So they are called "Insulators."

In Figure 4.1 (a), the random motion of free electrons in a conducting wire is shown. The motion of electrons is uniform in all the directions. Now think about any one cross-section A which is perpendicular to this conducting wire. In any given interval of time, the number of electrons moving to the right side of cross-section equals to that moving to the left, so that the net quantity of electric charge passing through cross-section is zero. Therefore, the electric current is not formed even though there is a motion of free electrons in conducting materials. As shown in Figure 4.1 (b), if the energy is provided to the conducting wire through the battery, the flow of free electrons can be obtained in a conducting wire from negative terminal to positive terminal of battery. Thus, the net quantity of electric charge passing through the cross-section A does not remain zero and the electric current is said to be formed in a conductor.



[a] Random motion of electron

[b] Electron current

Fig. 4.1 Electric current in a conductor

Earlier, scientists believed that the electric current results only due to the motion of positive charges, so the direction of motion of positve electric charges, was considered as the direction of electric current. But after the invention of an electron by J.J. Thomson (1856-1940), it was to know that the electric current in the conductors results due to the motion of electrons. At present, we also take the direction of electric current in the direction of motion of positive electric charge which is known as conventional electric current. Thus, the direction of conventional electric current is oppsite to the direction of flow of electrons.

After this primary explanation we shall define electric current.

"Electric current means rate of flow of an electric charge."

That means, the net quantity of an electric charge flowing through any cross section of conductor is defined as electric current.

$$\text{Thus, electric current} = \frac{\text{Quantity of electric charge}}{\text{time}}$$

If Q is the amount of electric charge passing through any cross section of conductor in time t,

$$I = \frac{Q}{t} \qquad \text{... ... ... (4.1)}$$

Thus from above equation (4.1), if the quantity of electric charge equals to one coulomb passing through the conductor in one second, the electric current of one ampere (1A) is said to flow through the conductor.

In SI system, the unit of electric current is coulomb/second (C/s). In the name of French Scientist Andre Ampere, it is also represented in Ampere (A)

The small units of electric current are milliampere mA and microampere (μA)

$$1 \text{ mA} = 10^{-3} \text{ A}$$

$$1 \text{ μA} = 10^{-6} \text{ A}$$

The electric current flowing through the conductor is measured by an instrument called 'Ammeter.'

If the number of electrons passing through the cross-section of conductor in time t equals to n, then the quantity of charge passing through the cross-section will be

$Q = ne$

Equation (4.1) can also be represented as

$$I = \frac{ne}{t} \qquad \text{... ... ... (4.2)}$$

where $e = 1.6 \times 10^{-19}$ C, charge of an electron.

Illustration 1 :

If an electric bulb burns on 0.5 A current for 1 hour, how much electric charge will pass through it ? ($e = 1.6 \times 10^{-19}$ C)

How many electrons will pass through it ?

Solution : I = 0.5 A, t = 1 Hour = 3600 s

From equation (4.1)

$$Q = I \times t$$
$$= 0.5 \times 3600$$
$$= 1800 \text{ C}$$

From Q = ne

no of electron passing through the bulb

$$n = \frac{Q}{e}$$
$$= \frac{1800}{1.6 \times 10^{-19}}$$
$$= 1125 \times 10^{19} = 1.125 \times 10^{22} \text{ electrons}$$

Illustration 2 :

While connecting a torch with battery, an electric current of 64 mA flows through the bulb. If this torch glows for 10 min, how may electrons will pass through the bulb ?

(charge of electron = e = 1.6×10^{-19} C)

Solution : $I = 64 \text{ m A} = 64 \times 10^{-3}$A, t = 10 min = 10 × 60 = 600 s, e = 1.6×10^{-19} C

Electric current $I = \frac{ne}{t}$

No of electrons = $\frac{I \times t}{e}$

$$n = \frac{64 \times 10^{-3} \times 10 \times 60}{1.6 \times 10^{-19}}$$
$$= 24000 \times 10^{16}$$
$$n = 24 \times 10^{19} \text{ electrons.}$$

4.4 Electric Potential and Electric Potential Difference

Electric Potential : We have seen that the flow of electric charge is necessary to obtain an electric current. How can this electric charge be made to flow in a conductor ?

To understand this, we shall first understand the flow of water.

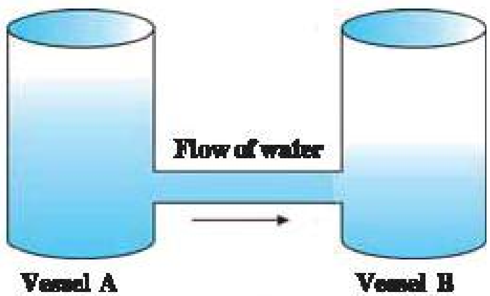


Fig. 4.2 Flow of water

As shown in Figure 4.2, pour more amount of water in vessel A and less amount of water in vessel B. Now when these vessels are connected through a tube, the water flows from vessel A to vessel B.

Here, the water pressure is more in vessel A and the water pressure is less in vessel B.

Thus due to the pressure difference, the water flows through the tube.

In the similar way, if we produce the electrical potential difference, then the electric current can be obtained. This difference in the electric potential is known as electric potential difference. We shall discuss electric potential first.

On bringing some electric charge near any other charge, an attractive or repulsive force exerts on it. Thus, the work is to be done against this force keeping a charge in equilibrium and to move another near or far from it. This work is stored in the form of potential energy. This work done on the charge is called as an electric potential. Electric potential is defined as under :

"The work required to bring the unit positive charge from infinity to any point against the electric force is known as electric potential at that point."

$$\text{Electric potential} = \frac{\text{Work done (W)}}{\text{Electric charge (Q)}}$$

Electric potential is represented in voltage in the memory of Italian Scientist Alexandro Volta. Its symbol is V.

$$\therefore V = \frac{W}{Q}$$

The SI unit of electric potential is joule/coulomb or volt (V).

Electric potential difference :

In practice, electric potential has no importance, but changes in electric potential are important which are defined as under :

"The electric potential difference between any two points A and B in an electric field means the work done to bring the unit positive charge from point A to B against the electrical force."

$$\text{Electric potential difference (V)} = \frac{\text{Work to be done (W)}}{\text{Electron charge (Q)}}$$

$$\therefore V = \frac{W}{Q}$$

Electrical potential difference, in general, is known as voltage. Its SI Unit is joule/coulomb or volt.

If the work done to bring 1 coulomb electric charge from one point to other is 1 joule, then the potential difference between these two points is called 1 volt.

$$1\,\text{volt} = \frac{1\text{ joule}}{1\text{ coulomb}}$$

The electric potential difference is measured with the device called **voltmeter.** The voltmeter is connected in parallel across two points of which the potential difference is measured.

Now, we shall understand from the activity that how potential difference is produced from the battery.

Activity : 1

Volta's Cell :

As shown in Figure 4.3, take solution of dilute sulphuric acid (H_2SO_4) in a beaker. Dip one copper plate and another zinc plate in the solution in such a way that they do not touch each other. These two plates get electrically charged due to the process between these two plates and the solution. The positive charge at copper plate and negative charge at zinc plate get deposited. Thus electric potential difference is produced between two plates. Positive charge plate is called positive pole of battery or anode and the negatively charged plate is called negative pole of battery or cathode. Such simple battery was invented by Italian Scientist Alexandro Volte (1745-1827). Therefore it is also known as Volta's cell.

Now connect a small bulb between these two poles of a battery. See what happens.

You will see that the bulb will light up. Here the electrons leaving negative terminal of battery move towards positive pole of battery by forming an electric current in the bulb. The bulb lights up due to this electric current. Thus, in bulb the electron flows from negative to positive pole. But the direction of conventional current is opposite to flow of electron, so it is said that it flows from positive toward negative pole of battery.

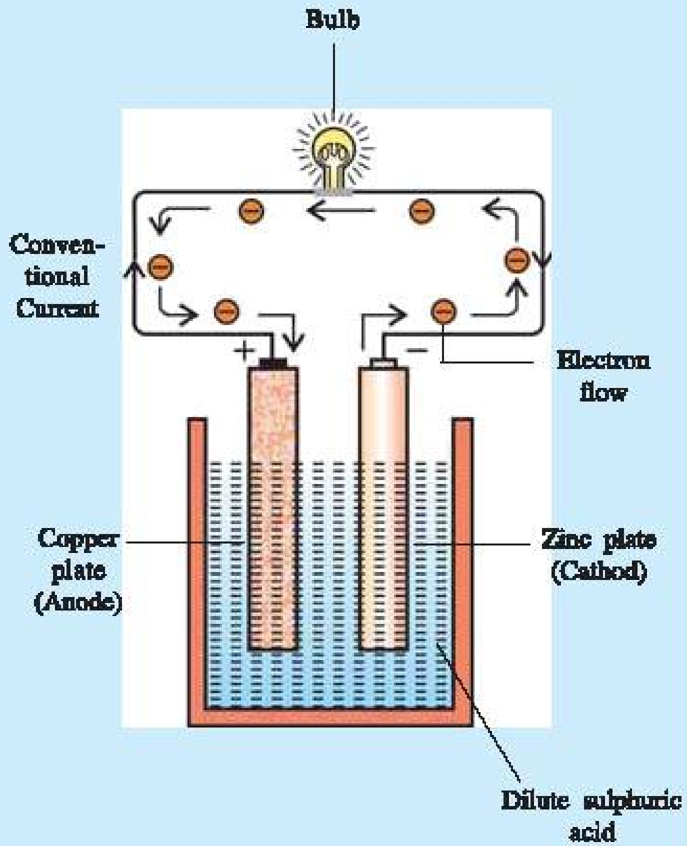


Figure 4.3. : Volta's electric cell

The electrons deposited at anode go back to cathode by taking energy form chemicals and enter the conductor. Thus, the function of battery is to give energy to electrons continuously and to flow the electric current continusly by keeping them in motion.

Thus, volta's cell converts chemical energy into electrical energy. By connecting more than one batteries in series the large electric potential is obtained and large amount of current is obtained in a conductor

Illustration 3 :

How much work is to be done to take 2 C electric charge form the potential of 6 V to the potential of 12 V ?

Solution : Q = 2 C

Electric potential difference $V = 12\ V - 6\ V = 6\ V$

$$\text{Now } V = \frac{W}{Q}$$

$$\therefore \text{ Work } W = VQ = 6 \times 2 = 12\ J$$

4.5 Electric Circuit and Symbols

When electrical compoments such as battery, key, bulb, etc are connected through a conducting wire, then such an arrangement is called electric circuit. The electric bulb glows due to the formation of close loop of circuit. In the following Figure 4.4, electric circuit is shown by representing electrical components with their symbols :

The useful symbols for electric circuit are given in the following Table 4.1

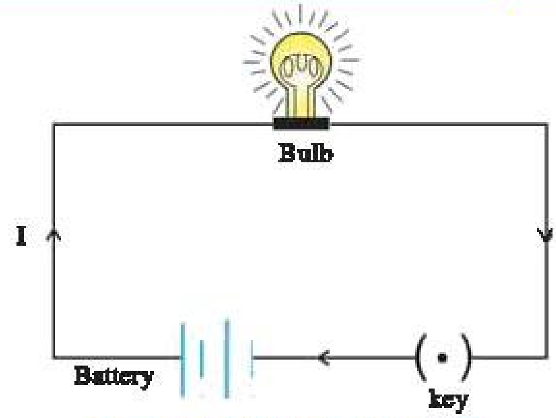
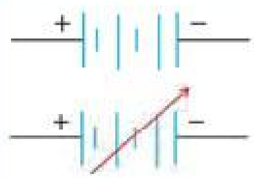
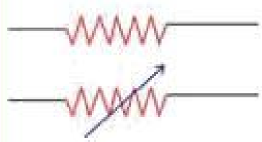
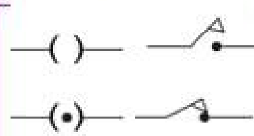
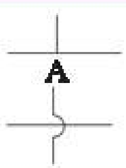


Figure 4.4 Simple electric circuit

Table 4.1 Some useful symbols for electric circuit

No.	Component	Symbol	Description
1.	Electric cell		Gives electrical energy to circuit
2.	Battery (Combination of electric cells)		Gives electrical energy to circuit Variable battery whose voltage value can be changed as per need
3.	Resistance		Provides resistance in the path of electric Current Variable resistor
4.	Key		Key (When open) Key (When closed) It is used to switch on or off.
5.	Connection of conducting wire		Two conducting wires connected at A Two wires passing above each other but not connected.
6.	Galvanometer		Device to detect the presence of electric current
7.	Ammeter		Device to measure an electric current
8.	Voltmeter		Device to measure electric potential difference

4.6 Ohm's Law

Is there a relation between the current (I) passing through the conductor and the potential difference (V) resulting across two ends ? German scientist George Ohm (1789-1854) derived the relation between current (I) and voltage (V) which is known as ohm's law. Perform the following activity to understand this relation.

Activity : 2

For this activity, take 0.5 meter long nichrome wire, four to five batteries of 1.5 V, Voltmeter, Ammeter and key.

As shown in Figure 4.5, first connect nichrome wire (Nichrome is an alloy of nickel, chromium, manganese and iron) with 1.5v battery and ammeter. Now connect the voltmeter between its two ends.

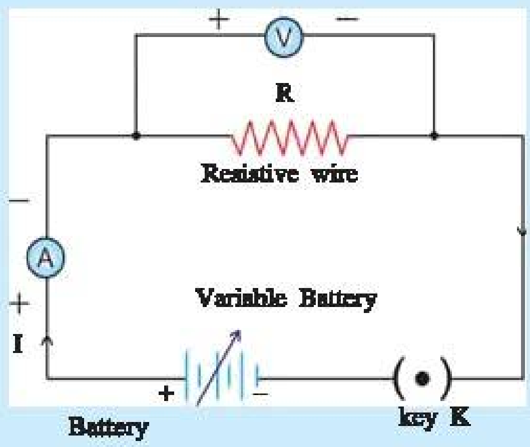


Fig. 4.5 Electric circuit for ohm's law

This experiment can also be perfomed by connecting bulb instead of nichrome wire. Now when the key is on, the electric current will flow through the wire. Measure the magnitude of the current in ammeter and the potential difference across its two ends in voltmeter and note in the observation table. Now connect two batteries instead of one and note the magnitudes of current (I) and voltage (V). In this way, repeat the experiment by connecting three batteries and there after four batteries.

Observation table :

Number	No of Batteries	Voltage across two ends of wire (V)	Current flowing through wire (I)	V/I
1	1			
2	2			
3	3			
4	4			

Now, from the observations, draw the graph of I versus V. What is the type of this graph ?

This graph will be a straight line passing through the origin (Figure 4.6).

The following points are concluded from the graph :

(i) The electric current in the conductor increases in same proportion with the increase in voltage.

(ii) I – V graph is a straight line.

(iii) The ratio of V and I remains constant every time.

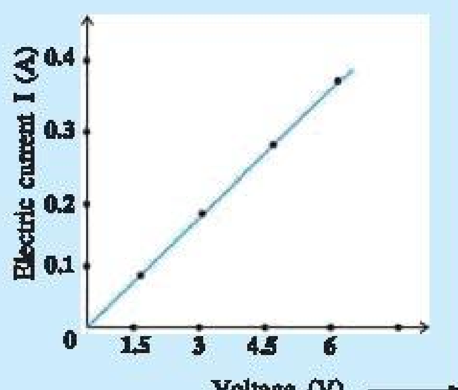


Fig. 4.6 Graph of I versus V

From this type of experiment, Ohm deuced the relation between electric current (I) and voltage (V) which is termed as Ohm's Law. It is stated as under.

Ohm's Law : "In the definite physical situation the electric current flowing through the conductor is directly proportional to the potential difference applied across it.

That means, $I \propto V$

It is also written as, $V \propto I$

$\therefore V = IR$

Where the proportionality constant R represents the resistance of the circuit.

From above equation,

$$\text{Resistance (R)} = \frac{\text{Voltage (V)}}{\text{Electric current (I)}}$$

The SI unit of resistance is volt/ampere which is known as 'ohm'. Its symbol is Ω(omega).

$\therefore$ 1 ohm = 1 volt / 1 ampere

When 1 volt potential difference is applied across the conductor and 1 ampere current flows through it then resistance of the conductor is said to be 1Ω.

The symbol —WWW— is used to represent the resistance in the electrical circuits.

The resistance of substance depends upon the kind of substance and its physical situation (e.g. temperature). In metallic substance, the resistance increases with the increase in temperature. In a conductor, the free electrons collide with the positive ions during their motion so that their motion gets opposite. Thus, the motion of electrons means the motion of electric current get opposed which is called resistance of conductor (R).

The metallic substance such as Copper, Aluminium have less resistance. Therefore, we use the copper wire as a conducting wire. The resistance of insulators is very large. The alloys like nichrome are used to make resistive wires. The resistors used in instruments like TV, Radio etc are made from the mixture of carbon and graphite.

Illustration 4 :

If an electric bulb connected to 220 V line draws an electric current of 0.5 A, then what will be the resistance of filament of a bulb ?

Solution : I = 0.5 A, V = 220 V

According to ohm's law, $R = \frac{V}{I} = \frac{220}{0.5} = 440\ \Omega$

Illustration 5 :

When an electric heater is applied 120 V, an electric current of 2 A passes through it. If the heater is applied 240 V, how much electric current will flow through it ? What will be the resistance of the coil of a heater ?

Solution : $V_1 = 120$ V, $I_1 = 2$ A, $V_2 = 240$ V, $I_1 = ?$

Resistance of heater coil $R = \frac{V_1}{I_1} = \frac{120}{2} = 60\ \Omega$

Now, according to Ohms' law, $R = \frac{V_2}{I_2}$

$$\therefore I_2 = \frac{V_2}{R} = \frac{240}{60} = 4\text{ A}$$

4.7 Resistivity

Activity : 3

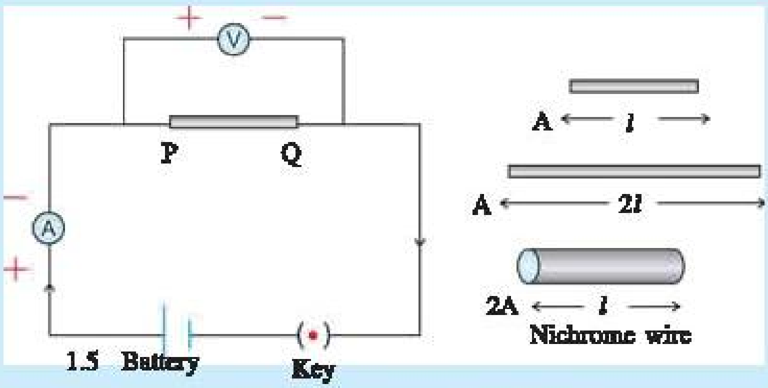


Fig. 4.7. The effect of resistance on its size.

(i) As shown in the Figure 4.7, connect the resistance wire (nichrome wire) of cross section (A) and length l (e.g. 0.5 m) in the circuit between the points P and Q. Now measure the current (I) and voltage (V) by closing a key and determine the resistance R_1 from equation R = V/I.

(ii) Now connect the resistive wire of cross section A and length $2l$ (1m) in the circuit and determine its resistance as R_2.

(iii) In the same way take the resistive wire having cross-sectional area 2A and length l and determine its resistance as R_3.

Give your conclusions about R_1, R_2 and R_3.

In the activity, you will get $R_2 = 2\ R_1$.

In this case, the area of cross section of wire is double, so its resistance is doubled. Now, for the resistance R_3, you will get $R_3 = \frac{R_1}{2}$. In this case, the length of wires l is the same, but the area of cross section of the third wire is twice compared to that of the first one. Therefore, its resistance to be obtained is half to that of R_1.

Thus, the magnitude of resistance depends upon the type and also on size of material.

The resistance of any conduction substance is directly proportional to length and inversely proportional to area of cross section of the substance.

If the length of conductor and its area of cross-section are represented as l and A respectively then,

$$R \propto l, \quad R \propto \frac{1}{A}$$

$$\therefore R \propto \frac{l}{A} \qquad \therefore R = \rho \frac{l}{A}$$

Here, ρ is called the resistivity of conducting material. From above equation $\rho = R\frac{A}{l}$

$$\text{The unit of } \rho = \frac{\text{Unit of resistance} \times \text{Unit of area}}{\text{Unit of length}}$$

$$= \frac{\Omega \times m^2}{m} = \Omega m$$

Table 4.2 represents resistance of some metals, semi-metals and insulators :

Table 4.2 Resistivity of some substances (at 20°C)

Type	Substance	Resistivity ρ (Ωm)
Metals	Aluminium	2.63×10^{-8}
	Copper	1.62×10^{-8}
	Silver	1.6×10^{-8}
	Iron	10×10^{-8}
	Tungsten	5.2×10^{-8}
Alloys	Manganin	44×10^{-6}
	Nichrome	100×10^{-6}
Insulators	Glass	$10^{10} - 10^{14}$
	Rubber (Hard)	$10^{13} - 10^{16}$
	Diamond	$10^{12} - 10^{13}$
	Paper (dry)	10^{12}

It is clear from Table 4.2 that the resistivities of conductors and alloys are less whereas it is very large for insulators. The resistivity of elements such as silicon (Si) and germanium (Ge) is more than conductors but less than insulators. So they are called semiconductors. Such elements are widely used in the fabrication of electronic components.

Illustration 6 : The resistance of a resistive wire having length l and area of cross-section A is 4 Ω. If the length of same type of wire is $l/2$ and the area of cross-section 2A, what will be the resistance of wire ?

Solution : For the first wire, $R = \rho \frac{l}{A}$, for the second wire, $R' = \rho' \frac{l'}{A'}$ From $l' = \frac{l}{2}$ and $A' = 2A$

$$\therefore R = \rho \frac{l/2}{2A} = \frac{1}{4}\rho\frac{l}{A} = \frac{1}{4} \times R = \frac{1}{4} \times 4 = 1\Omega$$

Illustration 7 :

The resistance of copper wire of length 2 m and 1.7 × 10^{-6} m^2 area of cross-section is 20×10^{-2} Ω. What is its resistivity ?

Solution : $l = 2$ m, $A = 1.7 \times 10^{-6}$ m^2, $R = 2 \times 10^{-2}$ Ω

$$\text{From } R = \rho \frac{l}{A}$$

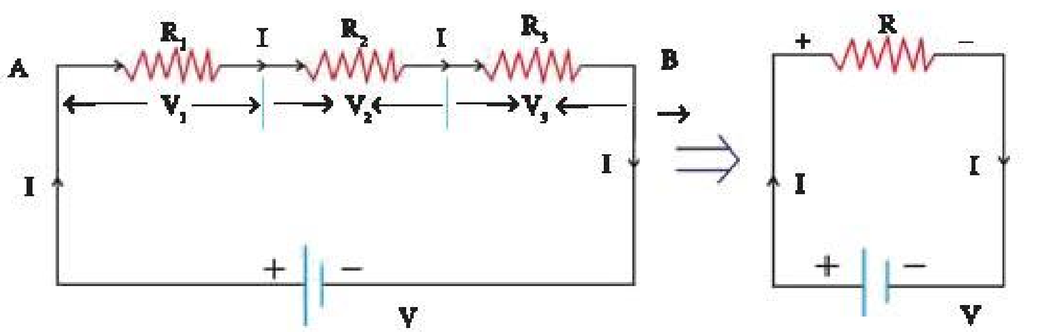
$$\therefore \rho = \frac{R \times A}{l} = \frac{2 \times 10^{-2} \times 10^{-6}}{2} = 1.7 \times 10^{-8}\ \Omega\text{m}$$

4.8 Combination of Resistance

Students, have you seen your pocket radio from inside ? You will see the various resistors connected together in a complex manner. These resistors magnitude in the instrument (radio) control the current in the different circuits. For this, sometimes large magnitude and sometimes small magnitude of resistance are required. To get the desired magnitude of resistance, we connect some resistors in series or in parallel or in series and parallel both. Here we shall study about series and parallel connection of resistors.

(1) Series connection of resistors :

The resistors are connected across two points in the circuit in such a way that the current flowing through each resistor is the same and only one path is availble for it to flow, then the resistors are said to be connected in series.



(a) Electric circuit

(b) Equivalent circuit

Fig. 4.8 Series connection of resistors

In figure 4.8(a), three resistors R_1, R_2 and R_3 are connected in series across the points A and B.

Here, current (I) flowing through each of the resistors R_1, R_2 and R_3 is the same, but the total voltage of the battery V is divided according to the resistance values.

If the voltage drops across R_1, R_2 and R_3 are V_1, V_2 and V_3 respectively then,

$$V = V_1 + V_2 + V_3 \qquad (4.8.1)$$

Now, if the resistor R instead of these three resistance R_1, R_2 and R_3 is connected in such a way that the current flowing through the circuit remains the same, then R is called equivalent resistance of the circuit. (Fig. 4.8 (b)).

For an equivalent resistor $V = IR$ (4.8.2)

According to Ohm's law,

R_1 voltage drops across, $V_1 = IR_1$ (4.8.3)

R_2 voltage drops across $V_2 = IR_2$ (4.8.4)

R_3 voltage drops across $V_3 = IR_3$ (4.8.5)

From (4.8.3), (4.8.4) and (4.8.5) $IR = IR_1 + IR_2 + IR_3$

$$\therefore \ R = R_1 + R_2 + R_3 \qquad (4.8.6)$$

From this we say that the equivalent resistor R can be obtained by the summation of all the resistors connected in series.

We shall note some important points about the series connection.

(1) In this type of connection, the current flowing through each resistance is the same.

(2) The total voltage drops across all the resistors connected in series equals to the sum of voltage drops across each resistor.

(3) The magnitude of equivalent resitance is always greater than the largest resistance.

Illustration 8 :

In order to get the current 0.5 A in the circuit by connecting a bulb of resistance 20 Ω with 12 V battery how much should be the value of resistance connected in series ? What will be the voltage drop across the bulb ?

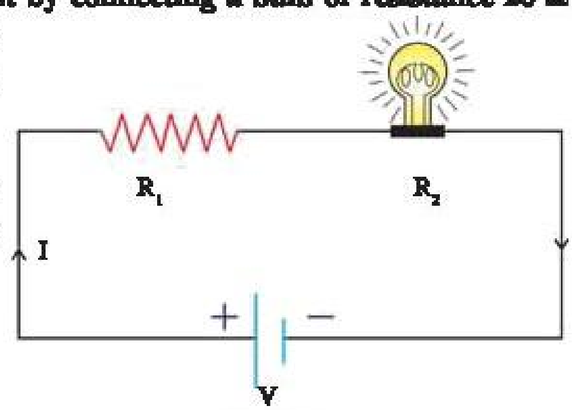


Fig. 4.9

Solution : If the resistance connected in series with bulb is R_1 and resistance of bulb is R_2 then, the circuit will be as shown in Figure 4.9.

$V = 12$ V, $I = 0.5$ A, $R_2 = 20\ \Omega$, $R_1 = ?$

using Ohm's law, $R = \frac{V}{I} = \frac{12}{0.5} = 24\,\Omega$

Here, bulb and R_1 are in series, therefore equivalent resistance

$R = R_1 + R_2$ ... ... (1)

Substituting the value of R and R_2 in equation (1)

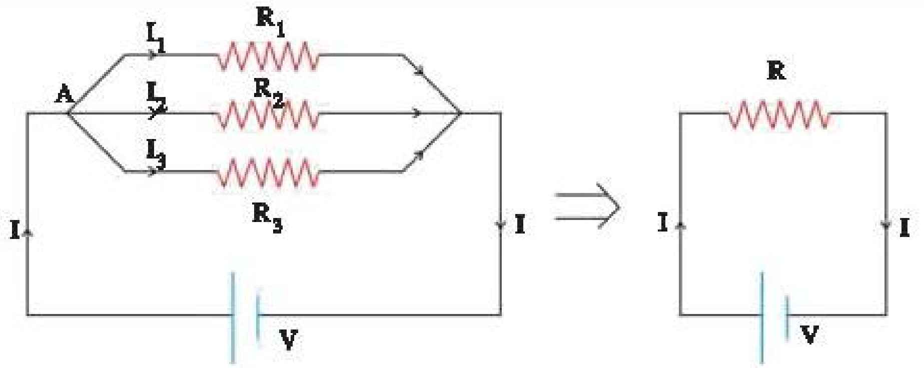
$$24 = 20 + R_2$$

$$\therefore \ R_2 = 24 - 20 = 4\ \Omega$$

The voltage drop across the bulb, $V_2 = I\,R_2 = (0.5)\ (4) = 2$ V

(2) Parallel connection of resistors :

When more than one resistances are connected across two points in the circuit such that more than one path are available for the current to flow and the voltage drops across two ends of each resistor are same, then the resistors are said to be connected in parallel between these two points.



(a) Electric circuit (b) Equivalent circuit

Fig. 4.10 Parallel connection of resistors

As shown in Figure 4.10(a), three resistors R_1, R_2 and R_3 are shown connected parallel across A and B. Here, one end of resistors are connected at common point A and the other ends are connected at another common point B. The electric current I at point A is divided into three parts. The current flowing through each resistor depends upon their resistance values.

Suppose the current flowing through resistors R_1, R_2 and R_3 are I_1, I_2 I_3 respectively, then the total electric current is equal to the electric current flowing through the circuit.

$$\therefore I = I_1 + I_2 + I_3 \qquad (4.8.7)$$

In parallel connection of resistors, the voltage drop across every resistor is equal to battery voltage V.

Therefore, according to Ohm's law,

$$I_1 = \frac{V}{R_1}, \quad I_2 = \frac{V}{R_2}, \quad \text{and} \quad I_3 = \frac{V}{R_3}$$

from equation (4.8.7) $I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$

Now, if one such resistor R instead of three resistors R_1, R_2 and R_3, is connected across the battery, the current flowing through the circuit will be same as I (Fig. 4.10 (b))

$$I = \frac{V}{R}$$

$$\therefore \frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\therefore \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \qquad (4.8.8)$$

Here, R is called the equivalent resistance of parellel connection of three resistors.

We shall note the following points for the parallel connection of resistors :

1. The reciprocal of equivalent resistance R is equal to the sum of reciprocal of individual resistors.

2. The voltage drop across each resistor remains the same.

3. The sum of the current flowing through each resistor equals to total current flowing through the circuit.

4. The magnitude of equivalent resistance is always smaller than the smallest resistance.

Illustration 9 :

The three resistors are connected in parallel with the 30 V battery. The electric current of 7.5 A flows through circuit from battery. If the values of two resistors are 10 Ω and 12 Ω, determine the value of the third resistor.

Solution : $V = 30\ V$, $I = 7.5\ A$, $R_1 = 10\ \Omega$, $R_2 = 12\ \Omega$, $R_3 = ?$

The equivalent resistance of circuit $R = \frac{V}{I} = \frac{30}{7.5} = 4\ \Omega$

Now, R_1, R_2 and R_3 are connected in parallel.

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\therefore \frac{1}{R_3} = \frac{1}{R} - \frac{1}{R_1} - \frac{1}{R_2}$$

$$= \frac{1}{4} - \frac{1}{10} - \frac{1}{12} = \frac{15-6-5}{60} = \frac{1}{15}$$

$$\therefore R_3 = 15\ \Omega$$

Illustration 10 :

For the circuit shown in Figure 4.11, determine the equivalent resistance between A and B. Also find the current flowing from the battery.

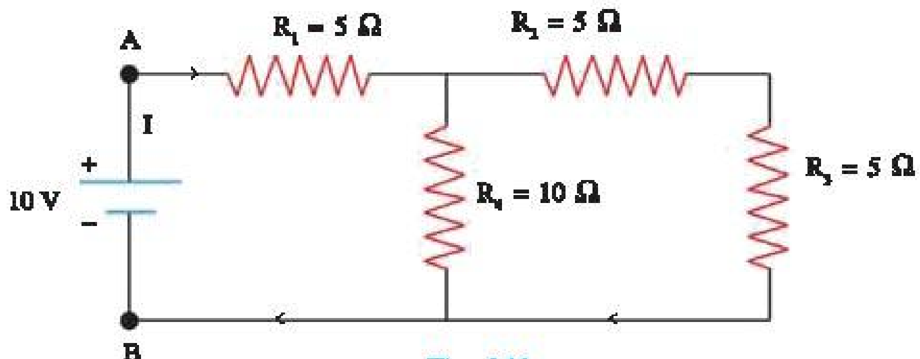


Fig. 4.11

Solution :

As shown in Figure 4.12 (a), R_2 and R_3 are connected in series, their equivalent resistance

$R' = R_2 + R_3$

$= 5 + 5$

$= 10\ \Omega$

Now R' is parallel with R_4 (Figure 4.12 (b)) Equivalent resistance,

$$\therefore \frac{1}{R''} = \frac{1}{R_4} + \frac{1}{R'}$$

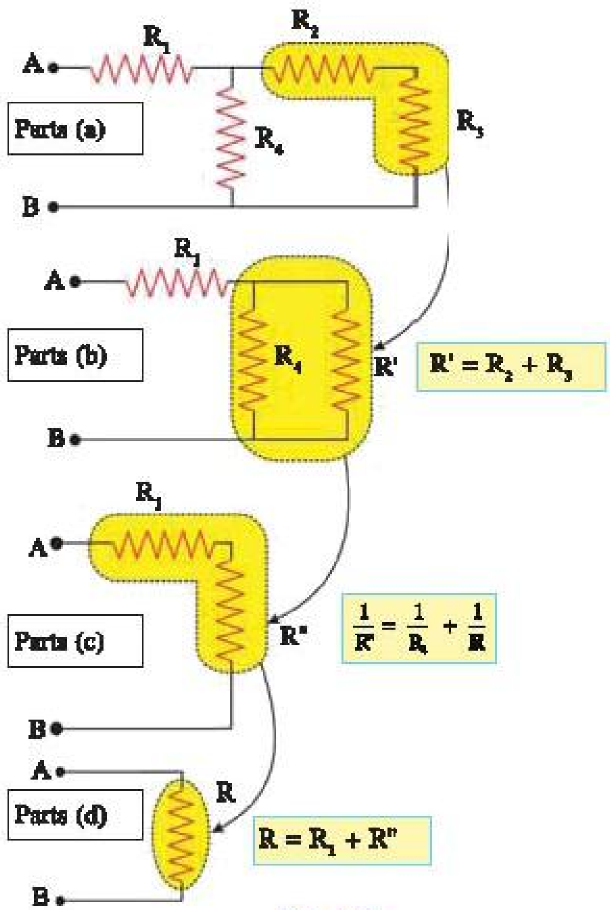


Fig. 4.12

or

$$R'' = \frac{R_4 \times R'}{R_4 + R'}$$

$$= \frac{10 \times 10}{10 + 10}$$

$$= 5\ \Omega$$

Now R" and R_1 are connected in series (Figure 4.12 (c)). Equivalent resistor across A and B,

$$R = R'' + R_1$$

$$= 5 + 5$$

$$= 10\ \Omega$$

The current flowing from the battery,

$$I = \frac{V}{R} = \frac{10\,V}{10\,\Omega} = 1\,A$$

Illustration 11 :

Determine the equivalent resistance between points A and B in the circuit :

Solution : First of all, R_1 and R_2 are in series.
$R' = R_1 + R_2 = 3 + 3 = 6\ \Omega$

Similarly R_3 and R_4 are in series

$R'' = R_3 + R_4 = 3 + 3 = 6\ \Omega$

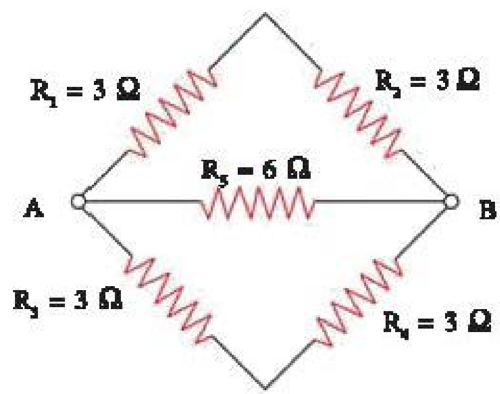


Figure : 4.13

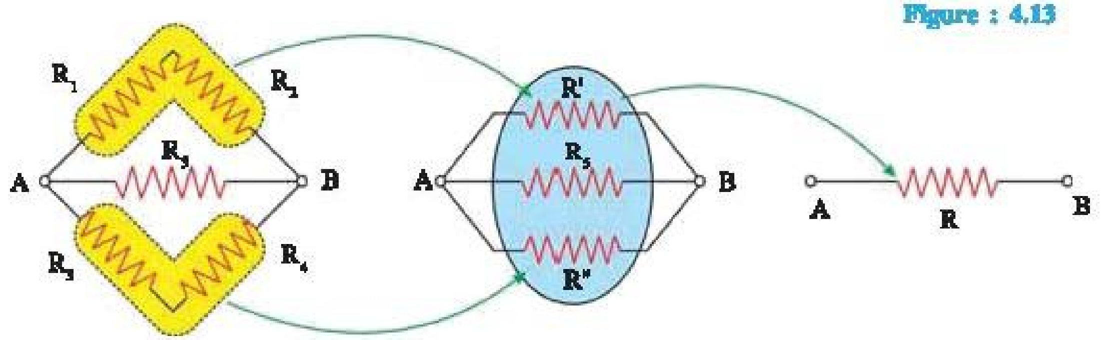


Fig. 4.14

Now, R_5, R' and R" are parallel between A and B

$$\therefore \frac{1}{R} = \frac{1}{R_5} + \frac{1}{R'} + \frac{1}{R''}$$

$$\therefore \frac{1}{R} = \frac{1}{6} + \frac{1}{6} + \frac{1}{6} = \frac{3}{6} = \frac{1}{2} \quad \therefore R = 2\ \Omega$$

(3) Merits and demerits of series and parallel connections of resistors :

The total resistance of the circuit increases by connecting the resistors in series hence, the current decreases. Thus, to control the current in the circuit, series connection of resistors is useful. Moreover, the fuse is connected in series with 230 V AC mains as well as in electrical appliance and in the domestic electric connection. Therefore, whenever short circuit occurs in any electrical appliance, the fuse wire melts and stops electric current. As a result, damage of the electrical appliance can be prevented.

If the electrical appliances are connected in series, the applied voltage is divided, e.g. the three bulbs operating on 240 V when connected in series each gets 80 V. They cannot give the light efficiently because of this less voltage. In series connection, if fault occurs in one appliance or the circuit breaks, the current does not flow in the circuit and all other appliances stop working, e.g. if one of the 3 bulbs get fused, other bulbs do not light up.

But if these three bulbs are connected in parellel with 240 V supply, all the three bulbs get same voltage. If any one bulb gets fused, the current continues to flow through other two bulbs and they will work. Thus in the parallel connection break up does not occur. In our house, the appliances such as fan, bulb light, TV, refrigerator etc are connected in parallel with 240 V AC mains line. The equivalent resistance in the parallel connection of resistor decreases, hence, more current can be obtained.

4.9 Heating Effect of Electric Current

When we pass the electric current in the bulb, our experience says that after a while it becomes hot. In the same way, by flowing an electric current through electrical appliances like iron or heater, the heat is produced. Here, electrical energy is converted into heat energy which is known as heating effect of an electric current. In the same way the electrical energy is transformed into heat energy due to the resistance.

Electrical energy :

Suppose the electric current is flowing through some resistor (R). To flow this current continuously the battery has to provide energy to every electric charge. Now, the work required to keep the charge Q in motion by the battery of voltage V is,

$$W = VQ$$

From the definition of the electric current,

$$Q = I\,t$$

$$\therefore \quad W = V\,I\,t$$

According to Ohm's law, $V = I R$

$$\therefore W = (IR)(I)(t)$$

$$\therefore W = I^2Rt$$

Thus, the current flowing through a resistor R for time t is I, the electrical energy consumed to be W which is converted into heat energy.

$$\therefore \text{Heat energy } (H) = I^2Rt$$

The obove equation is called **Joule's Law.**

Thus the energy produced in a resistor is,

(1) directly proportional to the square of current passing through it.

(2) directly proportional to the resistance for a given current.

(3) directly proportional to the time t for a given current and resistance.

The SI unit of an electrical energy or heat energy is joule (J).

The thermal effect of an electrical current is used in many instruments used in a daily life. e.g. electric heater, electric iron, water heater, toaster, oven etc. Though in some other appliances like fan, computer, generator, electric motor etc, the heat generated due to the electric current is useless.

Electrical power :

"Electrical power means the rate of electric energy." That means the electrical energy consumed (or heat generated) in unit time is defined as an electric power.

It is denoted as symbol P.

$$\therefore \quad P = \frac{\text{Electrical energy consumed}}{\text{Time}}$$

$$= \frac{W}{t} = \frac{I^2Rt}{t}$$

$$\therefore \quad P = I^2 R \qquad (4.9.1)$$

$$\text{or} \quad P = I V \quad (\because I R = V) \qquad (4.9.2)$$

$$\text{or} \quad P = \frac{V^2}{R} \quad (\because I = \frac{V}{R}) \qquad (4.9.3)$$

The SI unit of power is joule/second or watt (W).

If 1 A current flows through the circuit from 1V battery, the power consumed to be 1W.

From equation (4.9.2)

$$1 \text{ watt} = 1 \text{ volt} \times 1 \text{ ampere}$$

$$= 1 \text{ VA}$$

Practical unit of electrical energy :

According to definition of electrical power,

$$P = \frac{W}{t}$$

$$\therefore \quad W = P \times t$$

$$\therefore \quad 1 \text{ joule} = 1 \text{ watt} \times 1 \text{ second}$$

The unit 'watt sec' is smaller for electrical energy, so in practice a unit kilo watt hour (kWh) is used.

$$1 \text{ kWh} = 1000 \text{ watt} \times 3600 \text{ second}$$

$$\therefore \quad 1 \text{ kWh} = 3.6 \times 10^6 \text{ joule}$$

The electricity which you use in your house for domestic purpose is calculated in kWh. It is called "unit."

$$\therefore \quad 1 \text{ unit} = 1 \text{ kWh} = 3.6 \times 10^6 \text{ joule}$$

When 1000 W bulb is on for 1 hour, the energy consumed is equal to 1 unit.

Illustration 12 :

The 5 A current flows through an electric iron. If the resistance of electric iron is 44 Ω then how much energy will be consumed in 5 minutes ?

Solution : $I = 5$ A; $R = 44\ \Omega$, $t = 5$ min $= 5 \times 60 = 300$ s

Electrical enerey $\quad W = I^2 R t$

$$= (5)^2 (44) (300) = 330000 = 3.3 \times 10^5 \text{ J}$$

Illustration 13 :

A bulb is marked 220 V, 100 W, what will be the resistance of this bulb ? What will be the current passing through it when connected across 220 V supply ?

Solution : $\quad V = 220$ V, $P = 100$ W, $R = ?$ $\quad I = ?$

From $\quad P = \frac{V^2}{R}, \qquad R = \frac{V^2}{P}$

$$= \frac{220 \times 220}{100} = 484\ \Omega$$

From $\quad P = V I$

$$I = \frac{P}{V} = \frac{100}{220} = 0.45 \text{ A}$$

Illustration 14 :

In a house, if three bulbs of 100 W, 60 W and 40 W are used 2 hours per day, how many units of electrical energy will be consumed in 30 days ?

Solution : Evergy consumed per sec $\quad P = 100 \text{ W} + 60 \text{ W} + 40 \text{ W}$

$$= 200 \text{ W}$$

$\therefore$ Energy consumed per day $\quad = P \times t$

$$= 200 \times 2 \times 3600 \text{ W}$$

$$= 144 \times 10^4 \text{ W}$$

$$= \frac{1440 \times 10^3}{1000 \times 3600}$$

$$= 0.4 \text{ kWh}$$

$\therefore$ Energy consumed in 30 days $\quad W = 0.4 \times 30$

$$= 12 \text{ kWh}$$

Now, 1 unit = 1 kWh

$\therefore$ Energy consumed in 30 days = 12 kWh = 12 units

4.10 Chemical Effect of An Electric Current

The chemical reaction is responsible to get the electrical current means the chemical energy is converted into electrical energy by the battery. Then, can electrical energy be used for the chemical reaction ? Can electric current pass through any chemical ? To understand this let us perform the following activity :

Activity : 4

Take two carbon rods (You may get the rods from the core part of a used up dry cell by breaking it.) Now dip these rods in to a beaker filled with dist. water. Connect small bulb, 12V battery and a key to these rods. What happens when the key is on ? Has the bulb glown ? You may have seen that bulb does not glow. Do not worry, now add some salt into water (or take a tap water instead of distilled water)

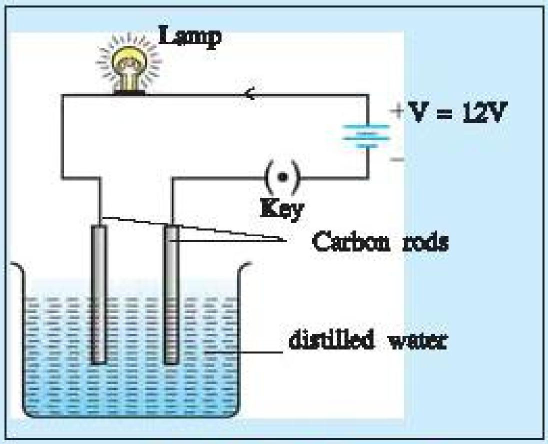


Fig. 4.15 Electric current through water

Now you can see that the bulb glows. Thus distilled or highly pure water does not conduct electricity. When a normal water which we use daily is conductor of electricity (That is why we should not touch the electric switch with the wet hand or foot). The solutions that conduct electricity are called "electrolytes." In the electrolytes, the electric current flows due to positive and negative ions.

Electroplating

You must have seen the metallic ornaments which are gold plated so as to look like real gold. The metals may be even copper plated or silver plated. This is carried through a process known as electroplating. To understand this, take a solution of copper sulphate ($CuSO_4$) in a beaker. In this solution, the iron spoon which is to be electro-plated and a copper plate are taken as electrodes and are connected with battery and key as shown in Figure 4.16. Pass the current in circuit for some time, you will observe that Cu is plated on metallic spoon. How did this happen ?

Here copper sulphate ($CuSO_4$) is taken as an electrolyte. On passing the current through this solution, it is decomposed into Cu^{+2} and SO_4^{2-} ions. As Cu^{+2} ion is positively charged, so it moves towards negative terminal i.e. metal spoon and deposits on iron spoon. Thus on iron spoon the plating takes place. Though there is no scarcity of Cu atoms because the copper atoms go into the solution from positive terminal i.e. copper plates, the above process is called electro-plating.

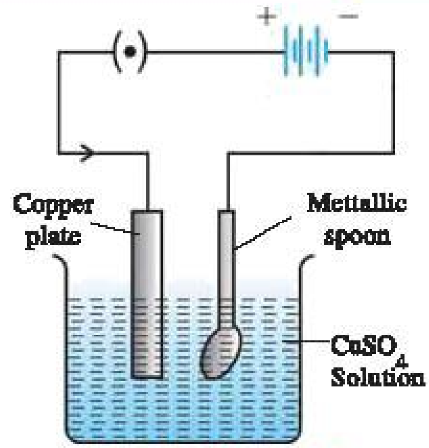


Fig. 4.16 Electroplating

By the method of electropating, the layers such as copper, nickel and chromium are coated on the things of iron in order to protect them against rusting and to keep them shining.

Faradays laws of electrolysis :

On passing the electric current through the electrolytic solution, negative ions move towards positive terminal and the positive ions move towards negative terminal. The process of separating the ions is called electrolysis.

Michael Faraday (1791-1867), studied it in detail and gave two rules to calculate how much metal is deposited on the electrode in the process of electrolysis.

Faraday's First Law :

The mass of the substance (metal) deposited at cathode on passing the electric current through electrolytic solution is proportional to charge passing through it. $m \propto Q$

Faraday's Second Law :

For a given amount of current passed, the masses of different elements deposited on cathode is proportional to their chemical equivalent (e). Chemical equivalent of any atom is the ratio of atomic mass and its valency. $\left(\frac{m_1}{m_2} = \frac{e_1}{e_2}\right)$

What have you learnt ?

- **Electric charge :** Electric charge is an intrinsic property of electrons and protons situated in atom. Electric charges are of two types : (1) Positive electric charge and (2) Negative electric charge.
- **Electric current :** The net amount of electric charge flowing through any cross-section of conductor in unit time is known as an electric current.

  $$I = \frac{Q}{t}$$

  The unit of an electric current is ampere (A).

  The direction of conventional electric current is opposite to that of flow of electrons in the conductor.
- **Electric Potential :** The work required to bring the unit positive charge from infinity to any point in the electric field is known as electric potential at that point.

- **Electric Potential Difference :** The electric potential difference between any two points A and B in the electric field means work done to take unit positive charge from A to B against electrical force.

$$V = \frac{W}{Q}$$

The unit of electric potential and electric potential difference is J/C or volt.

- **Ohms' Law :** In the definite physical condition, the current passing through the conductor is proportional to the applied electric potential difference across the conductor ($1 \alpha V$)

In the form of formula, $V = I R$ or $R = \frac{V}{I}$.

R is the resistance of conductor and its unit is Ω.

- The resistance of conductor depends upon the kind of material and its dimensions.

$$R = \rho\frac{l}{A}$$ where ρ = resistivity of material, l = length of resistive wire,

A = Area of cross-section of resistive wire

- **Series connection of resistors :** Connecting the resistors R_1, R_2, R_3..., R_n in series, their equivalent resistance will be $R = R_1 + R_2 ..... + R_n$.

In the series connection of resistors, the current flowing through each resistor is the same, but the potential difference across each resistor is different (voltage drops).

- **Parallel connection of resistance :** Connecting the resistance R_1, R_2, R_3..., R_n in parallel their equivalent resistance will be $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ... + \frac{1}{R_n}$

In this type of connection, the voltage drop across each resistor remains the same, where as the current flowing through them is different.

- **Elctrical Energy :** The energy consumed on passing the current (I) through the resistance (R) conductor for some difinite time (t) is $W = I^2 Rt = \frac{V^2}{R}t = V I t$.

The unit of electric energy is joule. Its conventional unit in practice is kWh or unit.

- **Electrical Power :** The electrical energy consumed in unit time is difined as an electric power (P). Its unit is watt. $P = \frac{W}{t} = I^2R = \frac{V^2}{R}$

- **Electroplating :** The process of depositing of one metal on another metal using the chemical effect of electric current is called electroplating.

The object on which the metal to be deposited is connected with negative terminal and the metal which is to be deposited is connected with the positive terminal of battery.

EXERCISE

1. Select the proper choice from the given multiple choices :

(1) The SI unit of electric charge is ......

(A) ampere (B) volt (C) watt (D) coulomb

(2) What number of electrons will be there in 1.6 C charge ?

(A) 10^{17} (B) 10^{18} (C) 10^{19} (D) 10^{20}

(3) $1\mu A$ = ---------- mA.

(A) 10^{-16} (B) 10^{-3} (C) 10^{3} (D) 10^{6}

(4) Which of the following materials has more number of free electrons ?

(A) Copper (B) Glass (C) Rubber (D) Iron

(5) According to Ohm's law,

(A) The resistance increases with the increase in current.

(B) The resistance increases with the increase in voltage.

(C) The current increases with the increase in voltage.

(D) The resistance and current both increase with the increase in voltage.

(6) The formula for an electric current is --------.

(A) $I = Q\ t$ (B) $I = \frac{Q}{t}$ (C) $I = \frac{t}{Q}$ (D) $I = Wt$

(7) The amount of 2 A electric current is passed for 1 minute through one conducting wire. How much total electric charge will pass through this wire ?

(A) 2 C (B) 30 C (C) 60 C (D) 120 C

(8) In an electrical appliance, the electric current of 4.8 A is passed, then the number of electrons passing through it in one second will be ----------

(A) 0.33×10^{19} (B) 3.3×10^{19} (C) 3×10^{19} (D) 4.8×10^{19}

(9) Which of the following formula represents the voltage ?

(A) $\frac{\text{Work}}{\text{Current} \times \text{Time}}$ (B) $\frac{\text{Work} \times \text{Time}}{\text{Current}}$

(C) Work × electric charge (D) Work × electric charge × time

(10) The unit of electric potential difference is --------

(A) J (B) J/C (C) J C (D) C/J

(11) If the work is to be done to take 3 C electric charge from one point to another point is 15 J, what will be the potential difference between these two points ?

(A) 3 V (B) 15 V (C) 5 V (D) 45 V

(12) The resistance of one conducting wire is 10 Ω. How much electric current will flow by connecting it with a battery of 1.5 V ?

(A) 0.15 mA (B) 1.5 mA (C) 15 mA (D) 150 mA

(13) On which factors does the resistivity of conducting wire depend ?

(A) Length of wire (B) Area of cross-section of wire

(C) Volume of wire (D) Material of wire.

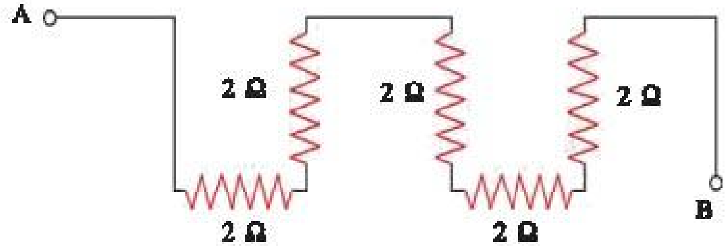
(14) If the five equal pieces of a resistance wire having 5 Ω resistance each is connected in parallel, then their equivalent resistance will be ———

(A) 1/5 Ω (B) 1 Ω (C) 5 Ω (D) 25 Ω

(15) The unit of resistivity of the material is ———.

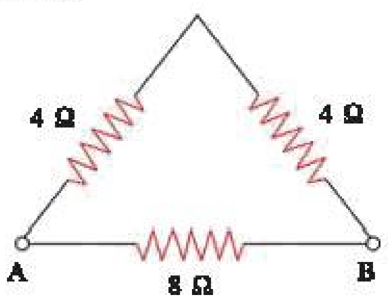
(A) Ω (B) Ω m (C) Ω/m (D) m/Ω

(16) What will be the equivalent resistance between points A and B of the following electric circuit ?



(A) 1 Ω (B) 2 Ω (C) 5 Ω (D) 10 Ω

(17) What will be the equivalent resistance between points A and B of the following electric circuit ?



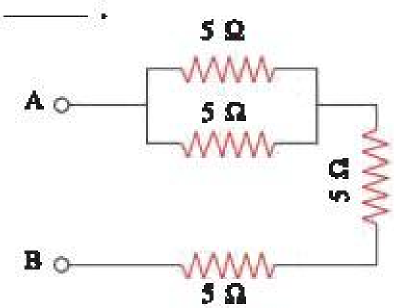
(A) 4 Ω

(B) 8 Ω

(C) 2 Ω

(D) 16 Ω

(18) The equivalent resistance between points A and B in the following electric circuit is ——— .



(A) 2.5 Ω

(B) 5 Ω

(C) 12.5 Ω

(D) 20 Ω

(19) Which physical quantity has a unit of kWh ?

(A) Work (B) Electric power

(C) Electric current (D) Electric potential.

(20) 1kWh = ------------- joule

(A) 3.6×10^{6} (B) 3.6×10^{3} (C) 3.6×10^{-6} (D) 3.6×10^{-3}

(21) An electric heater consumes 1.1 kW power when 220 V voltage applied to it. How much current will be flowing through it ?

(A) 1.1 A (B) 2.2 A (C) 4 A (D) 5 A

(22) What makes the electric current flow through electric solution ?

(A) Only free electrons (B) Only positive ions.

(C) Only negative ions (D) Positive and negative ions.

(23) The distilled water acts as ------ for the electricity.

(A) Conductor (B) Insulator (C) Semiconductor (D) None.

2. Answer the following questions in brief.

1. What is an electric charge ? Give its types and write its unit.
2. What is a free electron ? Explain conducting and non-conducting materials in terms of it.
3. Give the definition of an electric current and define its unit.
4. Give advantages and disadvantages of series and parellel connection of resistors.
5. Write Faraday's laws of electrolysis.

3. Write the answers of following questions :

1. What is an electric potential ? Give the definition and unit of electric potential.
2. Explain the series connection of resistors and derive the formula of equivalent resistance.
3. Explain the parallel connection of resistance and derive the formula of equivalent resistance.
4. Explain electrical energy and derive its formula.

4. Answer the following questions in detail :

1. Draw the figure of voltaic cell and explain its construction. Explain flow of current in conductor through this cell.
2. What is electrolyte ? Describe the experiment showing flow of current in electrolyte.

5. Answer the following questions pointwise :

1. Write Ohm's law. Describe the experiment showing Ohm's law and write its conclusions.
2. What is electroplating ? Explain it with example.

6. Solve the following examples :

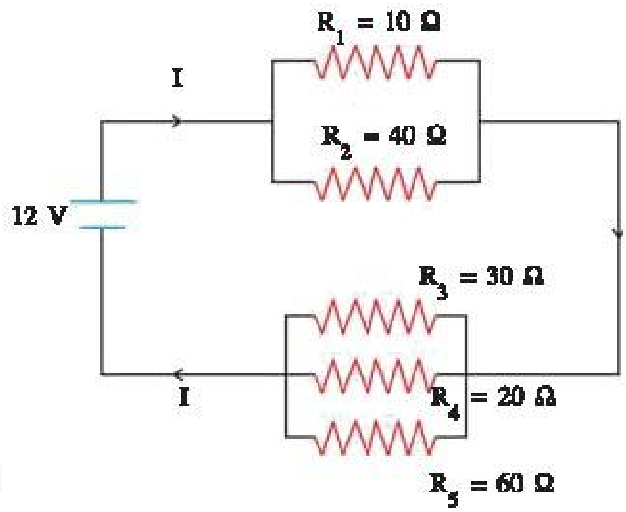
1. If 400 mA current flows through the bulb for 1 minute, how many electrons will pass through it ? (Ans : 15×10^{19} electrons)

2. The 1800 C electric charge is passing through an electic bulb in one hour. How much current will pass through an electric bulb ? (Ans : 0.5 A)

3. The three resistors of resistance 5 Ω, 10 Ω and 30 Ω are connected with a 12 V battery in parallel. Determine (a) total current in the circuit (b) equivalent circuit resistance.

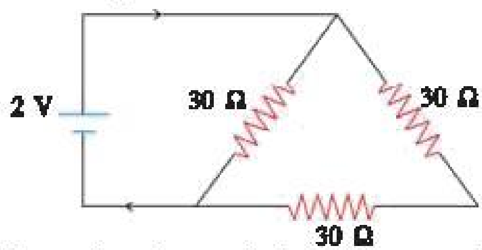
(Ans : I = 4 A, R = 3 Ω)

4. As shown in the figure the resitance are connected with a 12 V battery. Determine (a) Equivalent curcuit resistance (b) Current flowing through the circuit.



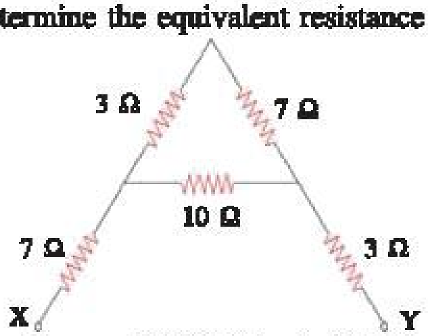
(Ans : (a) R = 18 Ω (b) I = 0.66 A)

5. Find the electric current in the following circuit :



(Ans : 0.1 A)

6. Determine the equivalent resistance between points X and Y in the following circuit.



(Ans : 15 Ω)

7. Two lamps of 100 W and 60 W are joined in parallel with 220 V line. How much current will flow through the circuit ? (Ans : 0.73 A)

8. An electric heater consumes 4.4 kW power when connected with a 220 V line voltage then,
   (i) Calculate the current passing through the heater.
   (ii) Calculate resistance of a heater.
   (iii) Calculate the energy consumed in 2 hours.

(Ans : (i) 20 A (2) 11 Ω (3) 3.168×10^7 W)

UNIT

5

Magnetic Effects of Electric Current

5.1 Introduction

In the earlier chapter, we have studied the heating and chemical effects of an electric current. In the present chapter, we shall study the magnetic effect of an electric current.

During 1819-20, a science teacher H.C. Oerstead discovered that the magnetic field is produced by an electric current in opposite to that the scientists named Michael Faraday, Andre Ampere etc. had produced an electric current from the magnetic field. It was proved from many experiments that electricity and magnetism are associated with each other. This branch of physics that covers universal study of electricity and magnetism is called electromagnetic or electrodynamics. The electromagnetic principles are widely used in loud speaker, electric motor, magnetic train (maglev), hard disk of computer, communication etc.

In the present chapter, we shall study the characteristics of magnetic field produced by electric current carrying conducting wire, coil, solenoid and the Faraday's experiments induced by magnetic field. In addition, we shall obtain the primary idea about electric motor and electric generator based on the principle of magnetism.

5.2 Magnetic Field and Magnetic Field Lines

Students, you have seen a bar magnet in the laboratory. You have studied about it in the Standard 8.

A bar magnet has two magnetic poles : (1) North pole (N) and (2) South pole (S). When a bar magnet is suspended freely through the string, the pole which becomes steady toward the north pole of an earth is called north pole (N) of a magnet and the other pole is called south pole (S). A repulsive force is resulted on bringing N-N or S-S poles of two different magnets nearer to each other while the attractive force is produced on bringing N-S poles. Magnetism of magnets is maximum at their poles. The magnetic force is represented by a magnetic field.

A magnetic needle experiences deflection when it is placed in the region near a bar magnet. Thus, a magnetic force experienced around the region of a magnet is called a magnetic field of a magnet. The magnetic field lines can be drawn to describe or to study this magnetic field.

The magnetic field lines are the pictorial representation of a magnetic field.

At first, we shall see how the field lines of a bar magnet can be drawn with the help of the following activity.

Activity :1

- For this activity, you need a bar magnet, magnetic needle, a white paper, a drawing board and a pencil.

(1) Place the white paper on a drawing board, then put the magnet in centre and mark its position with pencil.

(2) Now, place a magnetic needle near the north pole of a magnet. You will see that its south pole will be in the direction of magnetic north pole and the north pole of magnetic needle will be in the outward direction from the magnet. Mark the position of these two ends of magnetic needle with the pencil. In Figure 5.1 points A and B indicate the position of south and north pole respectively.

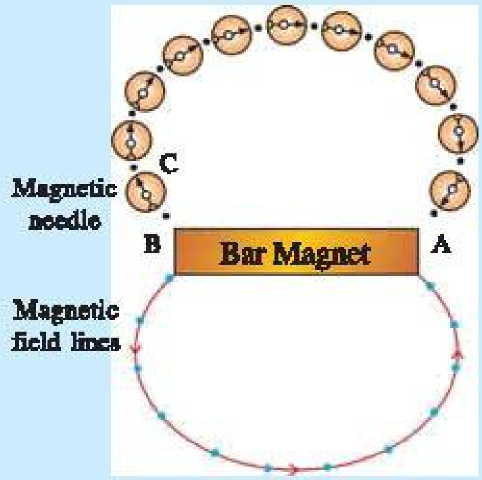


Fig. 5.1 Draw the magnetic field lines

(3) Now arrange the magnetic needle such that the south pole of needle is arranged on point B. In this position, mark the position (Point C) of north pole of magnetic needle.

(4) Thus, mark the positions of north pole of magnetic needle up to south pole of magnet by arranging it at the positions one after the other.

(5) Now draw a curve joining all of these points. This curve shows a magnetic field lines of a magnet. Draw magnetic field lines by placing a magnetic needle at different possible positions. This magnetic field lines show a magnetic field around the magnet.

The magnetic field lines for a bar magnet are shown in Figure 5.2

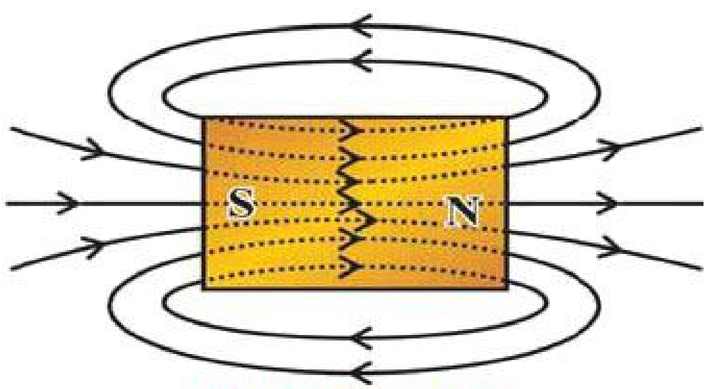


Fig. 5.2 Magnetic field lines of Bar magnet

Now let us see some characteristics of these magnetic field lines :

(1) The magnetic field lines of a magnet start from the north pole (N) and reach to the south pole (S) and these lines are in the direction from south pole (S) to the north pole (N) inside the magnet. Thus, they form close loops.

(2) The region in which the field lines are at close distance to each other has a strong magnetic field and if the field lines are at far distance from each other, the region has a weak magnetic field. Near the poles of a magnet the field lines are at close distance from each other so there is a strong magnetic field.

(3) The magnetic field is a vector quantity. So it has a magnitude and a direction both. The tangent drawn at any point of a magnetic field line (that means the direction of magnetic needle at that point) shows the direction of magnetic field at that point.

(4) Magnetic field lines do not intersect each other.

5.3 Magnetic Field Due to a Current Carrying Straight Conductor

In 1819, a science teacher H.C. Oerstead in a school in Denmark investigated that when an electric current is passed through the conducting wire, a magnetic field is produced in a region around it. We shall obtain its explanation through an activity.

Activity : 2

As shown in Figure 5.3 (a), connect a straight conducting copper wire in series with a battery and a key. Arrange a magnetic needle on a copper wire and arrange the wire such that it remains parallel to the magnetic needle.

Now make the electric current to flow through the wire by closing a key in the circuit and observe the magnetic needle. You will see the deflection in a magnetic needle (Figure 5.3 (b). On reversing the polarity of a battery in the circuit, the current will flow through the wire in a reverse direction, magnetic needle will also move in the opposite direction.

From this activity, we can say that, on passing the electric current through the wire it acts as a magnet and it possesses its own magnetic field so that the magnetic needle gets deflected. On reversing the direction of electric current, the direction of magnetic field is also reversed.

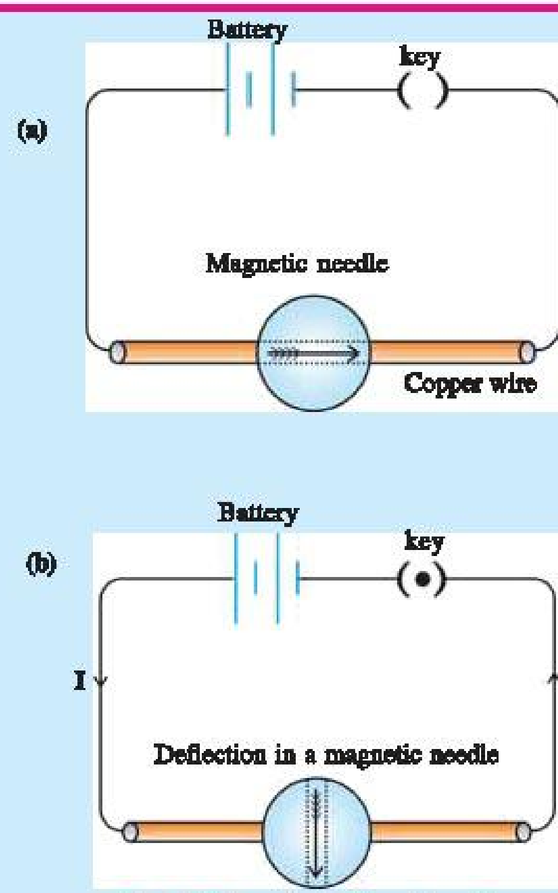


Fig. 5.3 Magnetic field produced by conducting wire

To understand the characteristics of magnetic field and the field lines of current carrying conductor perform the following activity :

Activity : 3

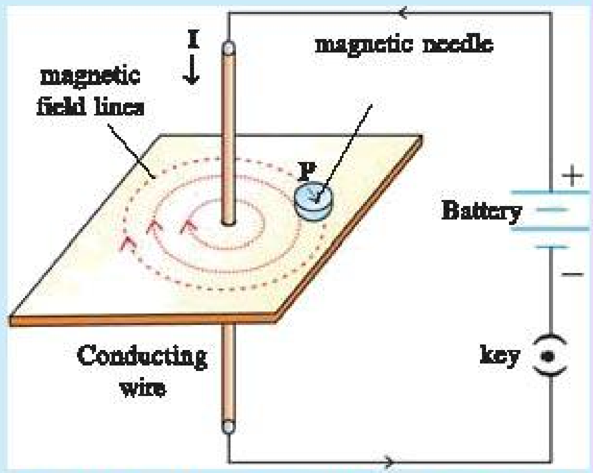


Fig. 5.4 Field lines of magnetic field produced by a conducting wire

Make a hole in the center of a cardboard and pass the conducting wire through it. Connect a battery and key in series with this conducting wire. Spread the iron filings uniformly on the cardboard around the conducting wire.

Now, pass an electric current through wire by placing the key such that cardboard remains steady and tap the board two to three times. Look at the cardboard that what is the effect of an electric current on iron filings. You will see that the iron filings will get arranged in a concentric circular shape around a conducting wire. This circular pattern represents a magnetic field resulting from an electric current through the wire.

To know the direction of this magnetic field, place a magnetic needle near some point P. The direction in which a north pole of magnetic needle (arrow) points indicates the direction of magnetic field at that point.

Now on reversing the direction of an electric current you will see that the direction of needle placed at point P also get reversed.

The magnetic field produced due to the current flowing through the conducting wire is directly proportional to electric current through the conducting wire (Magnetic field α electric current). The field lines of this magnet are arranged circularly around the conducting wire in a plane perpendicular to an electric current. A magnetic field decreases inversely at a distance while moving away from the conducting wire. (Magnetic field a $\frac{1}{\text{distance}}$)

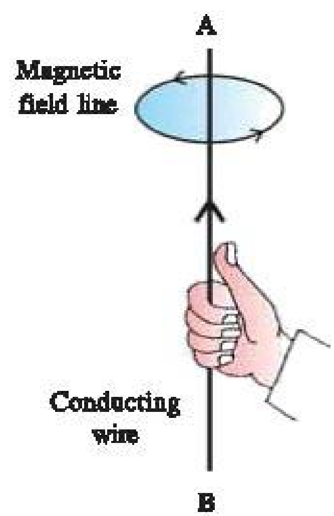


Fig. 5.5 Right hand thumb rule

Right hand thumb rule :

To known the direction of magnetic field produced by a current passing through any conductor, the right hand thumb rule is used.

Hold the wire in right hand (such that you do not get shock due to electric current !) such that the thumb pointing along the direction of current and the fingers are wraped on wire. In this situation, the magnetic field lines are such that the fingers wrap on wire as to forming the circular closed loops. (Figure 5.5)

5.4. Magnetic Field Produced by a Current Carrying Coil

We have seen that the magnetic field is produced while passing an electric current through a straight wire. If a wire is bent circularly and electric current is passed through it, the magnetic effect of current increases.

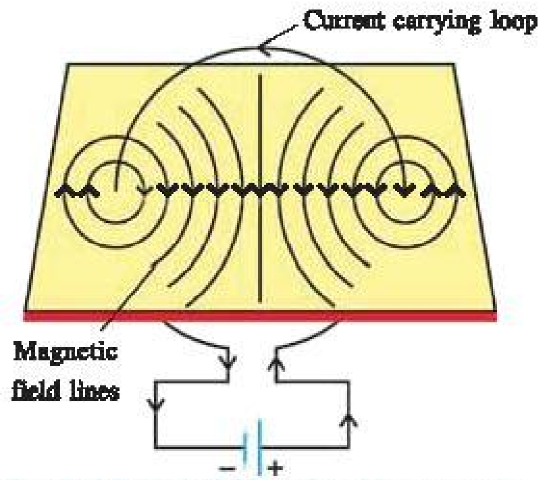


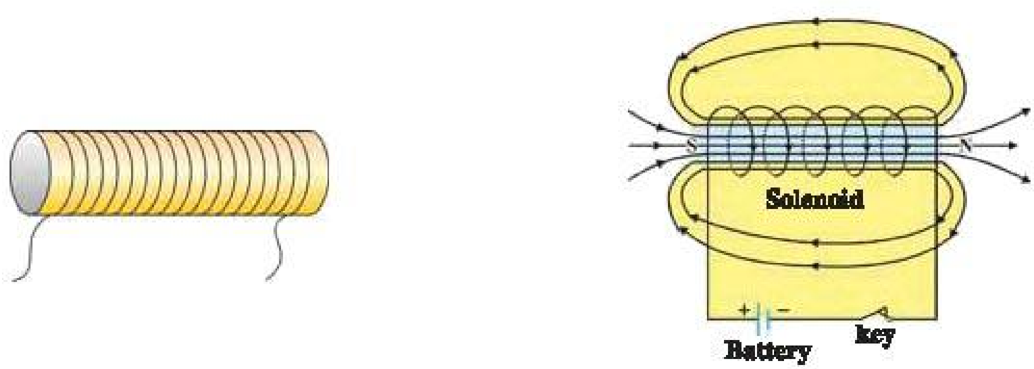
Fig. 5.6 Magnetic field produced in a current carrying ring (loop)

In Figure 5.6, the magnetic field produced by passing the current through a circular ring (loop) is shown. The field lines are circular near the wire of a ring. These circles get enlarged. While moving away from the wire, these circles near the center of ring (loop) turn into straight lines. Near the center of a ring, the field lines are at a close distance, so the magnetic field is stronger at the center. The direction of magnetic field is determined by a right hand thumb rule. The magnetic field at the centre of loop is linearly proportional to the electric current passing through the ring and inversely proportional to the radius of ring.

If a ring is made up of closely spaced N turns, the magnetic field at the center of ring will be N times stronger.

5.5 Solenoid

When an insulated straight conducting wire is bent into a coil (loop) having N turns, an arrangement like hollow cylinder is formed. **A construction like a coil made by a conducting wire wound closely and separately in a form of cylinder is called a solenoid.** In a Figure 5.7 (a) one such solenoid is shown.



(a) Solenoid (b) Magnetic field of a solenoid

Fig. 5.7 Solenoid and its magnetic field

As shown in Figure 5.7 (b), passing an electric current through a solenoid, an electric current will flow in the same direction through N turns of a coil.

The magnetic field resulting per each turn will add on as the direction of an electric current in each turn will be the same. As solenoid has N turns, the magnetic field resulting by it is N times stronger than the magnetic field resulting by each circular coil. The magnetic field lines resulting by a solenoid are shown by Figure 5.7 (b). It can be understood by comparing Figure 5.2 and Figure 5.7(b) that the magnetic field of a solenoid is just like a magnetic field of a bar magnet. Thus, one end of a solenoid behave like a north pole and the other end like a south pole. In the inner region of a solenoid the field lines are parallel that means the magnetic field is uniform at every point inside the solenoid. This magnetic field is directly proportional to the number of turns wound in a solenoid as well as it is directly proportional to the current passing through it.

By placing an iron like metal (e.g. large iron nails) inside the solenoid, its magnetic field becomes stronger. On passing the current through a solenoid, it behaves as a temporary magnet. Such magnets are called 'electromagnets.' Electromagnets are used in crane to lift the heavy objects (e.g. car).

5.6 Force on a Current Carrying Wire Placed in a Magnetic Field

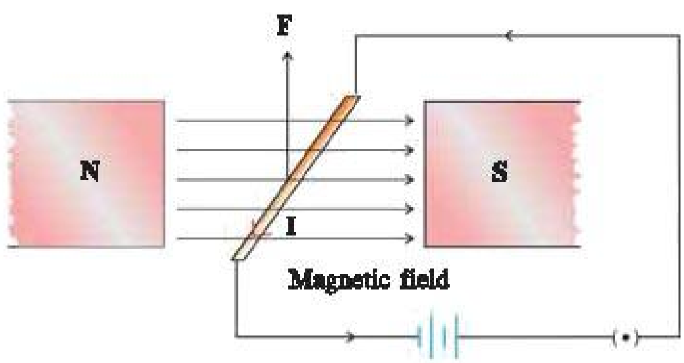


Fig. 5.8 Force acting on current carrying wire

Within a few days after the repetition of observations recorded by Oersted, a scientist, Ampere made another observation. He observed that the force is exerted on a current carrying wire placed in a strong magnetic field.

As shown in Figure 5.8, place a conducting wire in a strong stationary magnetic field.

Arrange a linear light conducting wire in a magnetic field perpendicular to it after tying it with a rigid base on both the ends. Now pass the electric current through the wire. You will see that the wire bends upwards. On reversing the polarity of battery and by flowing the current in the oppisite direction, the wire bends downwards.

When the electric current flows through the wire, a magnetic field is produced around it. During the interaction between the magnetic field of this wire and the magnetic field of a strong magnet, the wire and the magnet exert the force of equal magnitude on each other in the mutual and opposite direction. Here, the magnet is stationary and heavy so that it does not move, but the wire bends upwards as it is light in weight.

The magnetic force acting on a conducting wire is proportional to the electric current, magnetic field of a magnet and the length of a wire remain in the magnetic field. When the direction of an electric current through the conductor is perpendicular to the direction of magnetic field, maximum force is exerted on wire. The direction of this force is always perpendicular to the direction of an electric current and that of a magnetic field. When the direction of an electric current is in the direction of magnetic field or in the opposite direction, the force does not exert on a wire. The direction of magnetic force can be understood from Fleming's left hand rule.

Fleming's left hand rule :

Arrange the left hand such that the forefinger, the center finger and thumb remain at right angle to one another. Arrange the forefinger pointing in the direction of magnetic field and the center finger in the direction of an electric current, the direction of thumb gives the direction of magnetic force. (Figure 5.9).

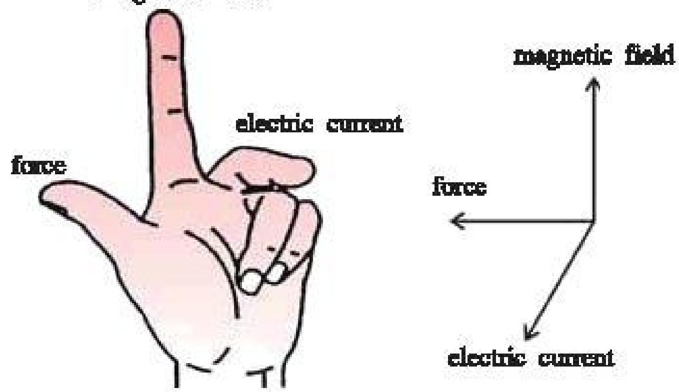


Fig. 5.9 Fleming's left hand rule

Friends, now decide the direction of magnetic force acting on a wire shown in the above experiment.

5.7 Electric Motor

An electric motor is a device that converts electrical energy into mechanical energy. The force acts on a current carrying wire placed in a magnetic field. The electric motor works on this principle.

The construction of an electric motor is as shown in Figure 5.10.

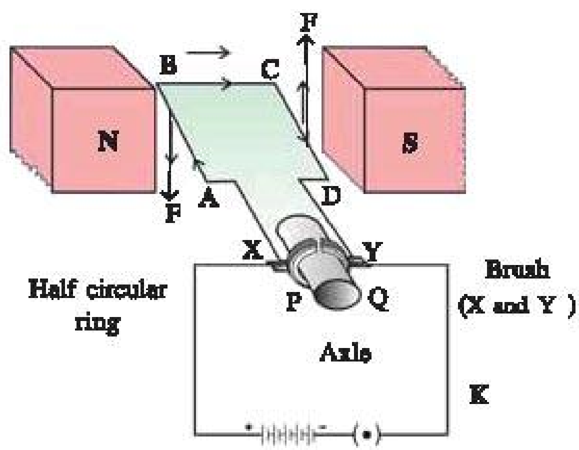


Fig. 5.10 Construction of an electric motor

A loop ABCD of an insulated copper wire is placed in a permanent magnetic field such that AB and CD remain perpendicular to the magnetic field. The ends of this wire are connected to the two semicircular rings P and Q. The inner part of both the rings is insulated. Both the rings are arranged on an axle such that they can rotate easily on it. The outer position of the ring is in contact with a stationary brush X and Y. (In actual motor, a loop containing many turns is arranged on axis. This arrangement is called an armature).

The electric current flows through a loop ABCD by connecting a battery between the brushes X and Y. The current flowing through BC and AD is either parallel or antiparallel to magnetic field, so force does not act on them. But the currents flowing in wires AB and CD are perpendicular to the magnetic field, henec force acts on them. The direction of this force is obtained from Fleming's left hand rule. As shown in Figure 5.10, the force on AB acts in the downward direction and the force on CD acts in upward direction. As these two forces are in the mutual opposite directions, the loop ABCD is rotated.

After the completion of half rotation, the ring Q comes in contact with the brush X and the ring P with the brush Y, so that the direction of an electric current gets reversed. Due to this, the direction of force acting on AB and CD is also reversed. As a result, the loop continues to rotate in the same direction. At the end of one rotation loop comes to the earlier position. Thus, after every half rotation the direction of an electric current in a loop changes and loop rotates continuously.

The electric motor is used in the appliances like electric fan, mixer, washing machine, CD/DVD player etc. Make a list of other electrical appliances where an electric motor is used.

5.8 Electromgnetic Induction

We have seen that a magnetic field can be produced on passing the current through a conducting wire, circular ring and solenoid. Then is it possible to obtain electric current from the magnetic field ? A British scientist Michael Faraday, in 1831, gave the answer to this question. He had shown that how an electric current can be obtained with the help of a magnetic field through many experiments and from that gave principle 'of electromagnetic induction'. To understand this principle consider the following activity.

Activity: 4

- As shown in Figure 5.11, make a circular loop of a conducting wire and connect a galvanometer with it to record the presence of an electric current.

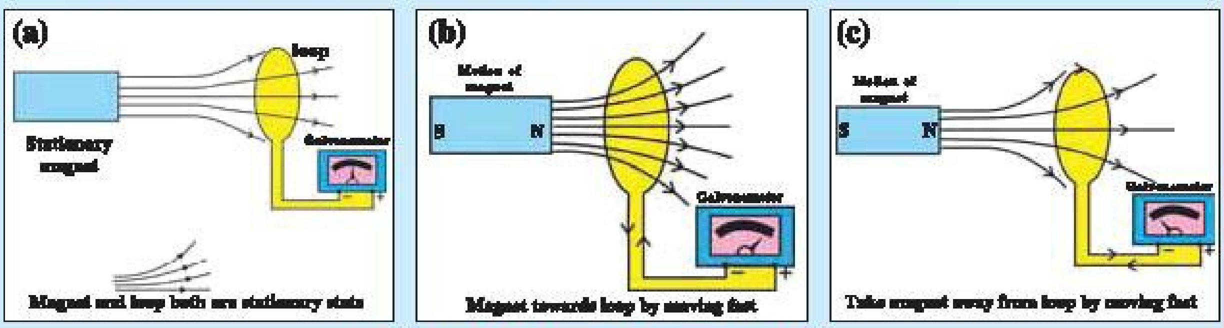


Fig. 5.11 Induce electric current in a loop

(i) Take a bar magnet and keep it stationary near the loop. You will see that the galvanometer does not show any deflection, (Figure 5.11 (a)).

(ii) Now move the N pole of a magent rapidly towards the loop and see that the galvanometer indicates the deflection on one side, which shows the presence of an electric current (Figure 5.11 (b)).

(ii) Now take the magnet away from the loop rapidly. Here the galvanometer will show the deflection in the opposite direction (Figure 5.11 (C)). This also indicates the presence of an electric current.

(iv) In the same way by taking S pole of a magnet the deflection in the galvanometer will be opposite to both the cases mentioned above.

(v) Above observation can also be verified by moving a loop instead of magnet. From this experiment it is so concluded that if the magnet and loop are moved relatively, an electric current flows in a circuit. This electric current is not produced by any battery, but it is induced by the motion of a magnet. Such an electric current is called **'induced electric current.'**

This phenomenon is known as an electromagnetic induction.

Because of the change in rate of change of number of magnetic field lines linked with the loop during the motion of magnet (or loop), an electromotive force (that means electrical potential difference) induces due to which the induced current is obtained in a loop.

If the speed of magnet is more, the change in rate of number of magnetic field lines will be increased and a large amount of induced current will be obtained. If the magnet becomes stationary, the change in number of field lines will be zero and the induced current will not be obtained.

The induced electromotive force resulting in loop or (induced electric current) is proportional to the change in rate of number of magnetic field lines and the number of turns of a loop.

In the phenomenon of an electromagnetic induction, the induced electric current is obtained only when a conductor moves in a magnetic field or the magnetic field around the conductor is changed. Normally, induced electric current can be obtained easily by moving a conductor in magnetic field. When the motion of conductor is in a direction perpendicular to the magnetic field, the large induced electric current is obtained.

The direction of an electric current is decided from the direction of a magnetic field and the direction of motion of a conductor. For this, Fleming's right hand rule is useful.

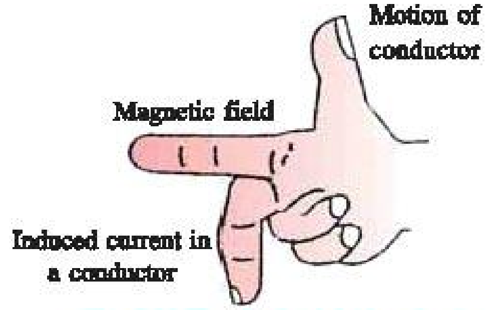


Fig. 5.12 Fleming's right hand rule

Fleming's right hand rule :

Arrange the forefinger, centre finger and thumb of a right hand at right angle to one another. Adjust a forefinger in the direction of magnetic field, and thumb pointing in the direction of motion of conductor. The direction of center finger indicates the direction of an induced electric current.

5.9 Electric Generator

We have seen that an electric current in the circuit can be obtained by the magnetic field. The electricity used in our house is also produced in this way. The device through which an electricity can be produced is known as an **electric generator. Electric generator converts mechanical energy into electrical energy. It works on the principle of an electromagnetic induction.**

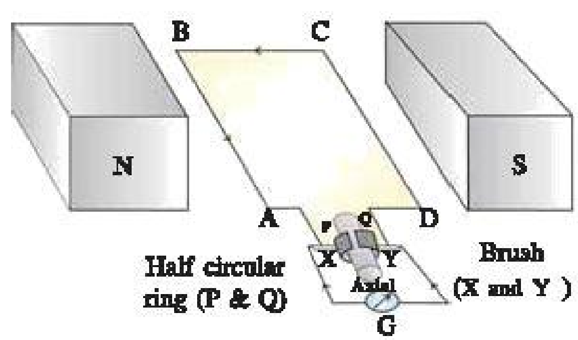


Fig. 5.13 Construction of an electric generator

The construction of an electric generator is like the construction of an electric motor which is shown in Figure 5.13. The two ends of a loop ABCD rotating in a magnetic field are connected with two semi-circular rings P and Q. These two rings are insulated from each other. These rings can slide while remaining in contact with the brushes X and Y. A galvanometer is connected between the two ends of brush. By applying mechanical rotation to the loop ABCD in the magnetic field, the number of magnetic field lines associated with it changes so that an electric current is induced which is observed from the deflection of galvanometer. Thus, the mechanical energy is converted into electrical energy.

By rotating the loop in a magnetic field, the side AB moves upward and the side CD moves downwards. The direction of an induced electric current in wire AB and CD can be known by Fleming's right hand rule. As shown in the Figure 5.13, induced electric current flows in a path B-A-G-D-C.

After the half rotation of a loop, the ring P comes in the contact with brush Y and the ring Q with the brush X. Here, the brush X is always in contact with the side moving upwards while the brush Y is always with the side moving downwards as a result of which the current flows only in one direction. This current is called direct or DC current. This type of generator is called DC generator. Similarly instead of half ring if full ring is used then A.C. current can be generated and such generator is called A.C. generator.

In practice, electric generator has a coil with many turns instead of loop. In the electric generator, to rotate coil, different types of energies are used, e.g. in wind mill, the electricity is produced by rotating its coil through wind energy. If the coil is rotated by using a flow or the fall of water stored in a dam, the electrical energy in large amount can be obtained. In generators used in hospital or theatre the coil is rotated with the help of a diesel engine and the necessary electricity is obtained during emergency.

5.10 Electric Bell

The electric bell works on the principle of an elecromagnet. Electric bell is made up of an electromagnet, bell (metallic cup), a soft iron strip and a contact screw. Bell is a cup shaped device made up of a metal. A soft iron strip works as a small hammer. The construction of an electric bell is shown in Figure 5.14.

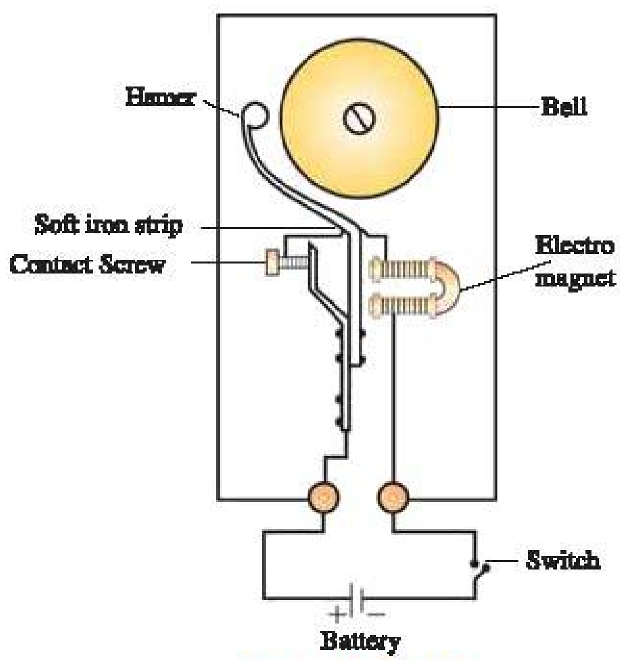


Fig. 5.14 Electric bell

When the circuit is switched on, an electric current returns in the battery after passing through an electromagnet, a soft iron strip and a contact screw. While passing a current through an electromagent acts as a magnet and attracts an iron strip. As iron strip (hammer) being elastic, it strikes with the bell. Simultaneously its contact with a contact screw is broken and current flows through electro-magnet stops. The iron strip comes in contact with the screw by obtaining an original position and again the electric current passes through an electromagnet.

This phenomenon occurs many times in a second and a hammer strikes many times with the bell, as a result the bell rings. The bell rings till the circuit is switched off.

Electric bell is used in school, home, telephone, security system, fire alarm etc.

5.11 : DC Current and AC Current

The electric currents are of two types :

(1) Direct current or DC and (2) Alternating current or AC.

We use two types of electric appliances for domestic purpose. In some appliances, we use battery e.g. radio, cell phone, watch, laptop etc. The current obtained from the battery is direct current in which the current flows from the positive terminal to negative terminal of battery through an appliance. That means it flows only in one direction. The magnitude of this current remains constant with time and its direction also does not change (Fig. 5.15 (a)) DC current is also produced by DC generator.

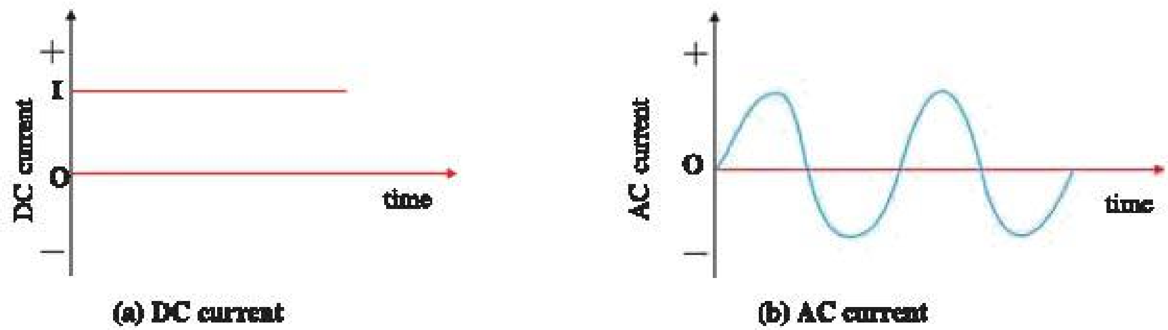


Fig. 5.15 DC and AC current

Another type of appliances such as refrigerator, mixer, electric iron, fan etc. work on AC current. In order to obtain the AC current, AC generator is used. AC voltages and currents are changed from positive to negative and negative to positive with time. In a house the electricity which we use, the direction of an AC voltage current changes 100 times in one second. So its frequency is 50 Hz.

The main advantage of using AC voltage or current is that it can be transmitted over long distance without much loss of electrical energy. While the generation of DC voltage is comparatively more costly. (Ask the price of 1.5 V battery in market).

5.12 : Domestic Electric Circuits

The electricity is generated in a power station. From the power station, this electricity reaches to our house through thick underground copper cables or through the overhead electric-poles. In the following Figure 5.16 how this electricity reaches to every place in the house is shown.

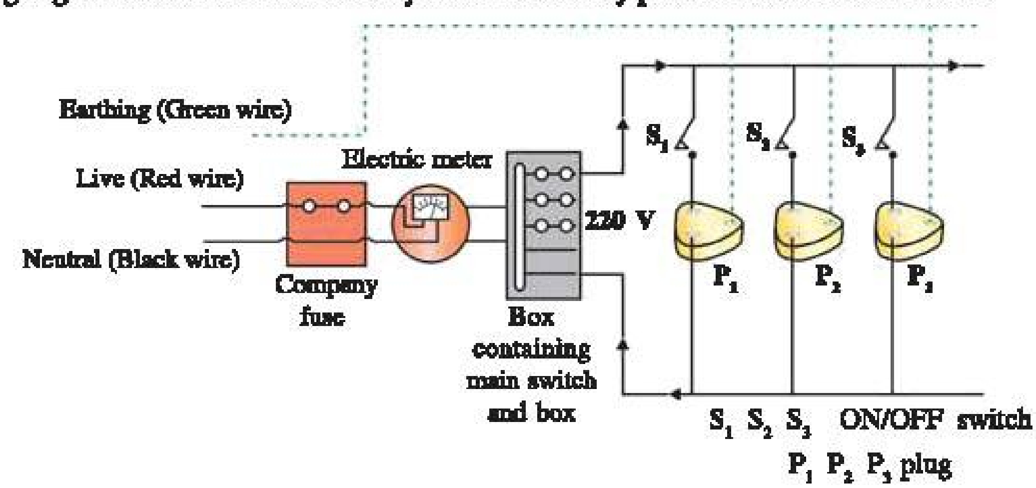


Fig. 5.16 Domestic electric circuit

One of the red coloured insulated wire brought to our house is known as live (positive) wire. Another black coloured insulated wire is known as neutral (negative) wire. The potential difference between these two wires is about 220 V. The current flowing in wire is AC whose frequency is 50 Hz. (In other countries like America this voltage is 110 V with 60 Hz frequency).

In the meterboard in the house, these wires pass into electric meter through main fuse. In the main switch board the fuses are kept for different circuits as per requirement. Through the main switch they are connected to line wired in house.

These wires carry two different values of current in the house. (1) 15 A current line is connected to the appliances of higher power ratings e.g. air conditioning machine, geaser, heater etc. (2) 5 A current line is connected to low power rating, e.g. tubelight, T.V., bulb, etc.

The third green coloured insulated wire is called **earthing wire**. This wire is connected with a metal plate and dumped near the house. Whenever there is a leakage of current in the appliances such as electric iron, toaster, table fan etc., it reaches to metallic surface due to which there is a danger for getting a shock. This earthing wire is connected with the metallic surface of such appliances so that the leaked out current goes directly to the ground through the earthing wire and electric shock can be avoided. In a house, every electric appliance is connected in parallel.

5.13 : Safety Measures in the Use of Electricity

The electricity is a form of energy. Therefore, many precautions are necessary while using the electricity. After knowing the various uses of an electrical energy, let us discuss what kind of precautions should be taken while using the electricity. We know that an electrical shock and fire are the main accidents caused by electricity.

Sometimes short circuit occurs in an electrical circuit. Short circuit means when positive and negative wires are connected with each other accidentally. If the insulating layer of wires or appliance in the circuit is defective, then short circuit may occur. In this circumstances, the total resistance of circuit suddenly decreases and an excessive electric current flows according to Ohm's law, which results in lots of heat and a spark is produced at a point of short circuit. Therefore, there is a possibility of a fire. (Sometimes overloading may also lead to the increase in current).

To prevent this a fuse is constructed. You have learnt somewhat about a fuse in the earlier chapter while studying heating effect of an electric current. Let us understand the construction of a fuse which is shown in the following Figure 5.17.

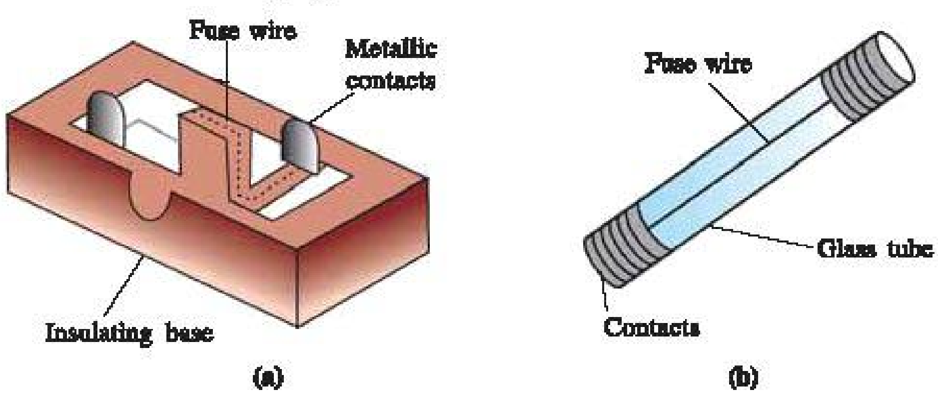


Fig. 5.17 Fuse construction

A conducting wire having a low melting point is connected with the metallic contacts on an insulator base. In Figure 5.17 (b) a fuse wire in a small glass tube connected with metallic contacts is shown. Such small fuses are used in the domestic appliances such as T.V., refrigerator. Due to some reason if current increases in the circuit, the fuse wire burn off immediately due to the heat produced and the electric current stops to flow, and major damage can be prevented.

Many types of fuse wires are available. The fuse wires are prepared from a pure tin or an alloy of lead and tin. Apart from this, while using appliances with large power consumption, a three-pin plug is employed. The third pin indicates earthing with the help of which we can prevent an electric shock.

What have you learnt ?

- **Magnetic field and magnetic field lines :** A magnetic field is around the region of a magnet. This magnetic field is shown by magnetic field lines. In the region outside the magnet, the magnetic field lines are pointing north pole (N) towards the south pole (S) and they form close loops. A magnetic needle placed any point of these field lines indicates the direction of magnetic field. Magnetic field lines never intersect with each other.
- **Magnetic field of a current carrying straight conducting wire :** The concentric magnetic field is produced around a linear conducting wire while passing on electric current through it. This magnetic field is directly proportional to electric current and inversly proportional to the distance from a wire.
- **A magnetic field of a current carrying circular ring (coil or loop) :** A magnetic field produced near a wire in a circular ring is concentric circular shaped. Near the center of a coil, these circles turn into straight lines. The magnetic field produced at the centre of a coil is directly proportional to an electric current and inversely proportional to radius.
- **Solenoid :** A coil like construction in a cylindrical form wound closely and separately from a conducting wire is called solenoid. Its magnetic field is like the magnetic field of a bar magnet.
- **Force acting on a current carrying wire :** While placing a current currying wire in a magnetic field, a magnetic force is exerted on it. This force is perpendicular to a magnetic field. The magnitude of this force is proportional to an electric current. If the conducting wire is parallel to the magnetic field, the force does not act on it. The force acting on the wire is determined by Fleming's left hand rule.
- **Electric motor converts electrical energy into mechanical energy :** While placing a conducting wire loop in a magnetic field, an equal but opposite magnetic force on its opposite sides acts as a result of which it rotates.
- **Electromagnetic induction :** Due to the relative motion between the loop and magnet, the number of magnetic field lines linked with the loop are changed. Therefore, an electromotive force is induced in the loop due to which an induced electric current is obtained in a coil. This is known as an electromagnetic induction. The direction of an induced current is determind by Fleming's right hand rule.
- **Electric generator :** The mechanical energy is converted into electrical energy with this instrument. The electric motor works on the principle of an electromagnetic induction.

- **AC and DC current :** The current which does not change with time and flow only in one direction (from positive to negative) is called undirectional current or DC current.

  The current whose direction is regularly changed from positive to negative, and from negative to positive is called an alternating current or AC current. In our house, we use 220V. AC voltage having frquancy of 50 Hz.

EXERCISE

1. Select the proper choice from the given multipule choices :

1. The direction of magnetic field lines in a region outside the bar magnet are ————
   (A) From the N pole towards the S pole of a magnet.
   (B) From the S pole towards the N pole of a magnet.
   (C) In the direction coming out from both the poles of magnet.
   (D) In the direction entering in both the poles of magnet.
2. Which of the following statements is false ?
   (A) The direction of magnetic field line is from N to S.
   (B) In the region where the magnetic filed lines are at a close distance form each other, there will be a strong magnetic field.
   (C) The magnetic field lines form close loops.
   (D) The magnetic field lines can cross each other.
3. By which instrument the presence of magnetic field can be determined ?
   (A) Voltmeter (B) Ammeter
   (C) Galvanometer (D) Magnetic needle.
4. Who had first obseved the magnetic effect of an electric current ?
   (A) Faraday (B) Oersted (C) Volta (D) Ampere.
5. With the help of which law the direction of a magnetic field can be decided ?
   (A) Faraday's law (B) Fleming's right hand rule.
   (C) Right hand thumb rule (D) Fleming's left hand rule.
6. According to right hand thumb rule, whose direction is indicated by a thumb ?
   (A) Electric current (B) Magnetic field.
   (C) Magnetic force (D) Motion of a conductor.
7. The magnetic field produced in a straight conducting wire on passing the current through it is ————
   (A) in the direction of current. (B) in the direction opposite to the current.
   (C) circular around the wire. (D) in the direction parallel to the wire.
8. What is the field line of a magnetic field passing through the centre of current carrying circular ring ?
   (A) Circular (B) Straight line
   (C) Ellipse (D) Magnetic field is zero at center.

9. Whose magnetic field is like a magnetic field of a bar magnet ?

(A) Current carrying wire (B) Current carrying ring.

(C) Current carrying solenoid (D) Current carrying rectangular loop

10. Who gave the principle of electromagnetic induction ?

(A) Faraday (B) Oersted (C) Ampere (D) Volta.

11. Which is the direction of magnetic force acting on a current carrying wire placed in a magnetic field ?

(A) along magnetic field (B) along the electric current.

(C) perpendicular to magnetic field (D) opposite to magnetic field.

12. How is a current carrying wire placed in a magnetic field so that magnetic field does not act on it ?

(A) Parallel to magnetic field (B) Perpendiculr to magnetic field.

(C) At an angle 40° with magnetic field (D) Can be arranged any way.

13. From which of the following cases, the induced current in the loop will not be obtained ?

(A) The loop is moved in the direction of the magnet.

(B) The magnet is moved in the direction of the loop.

(C) The loop and magnet are moved in the opposite directions with the same speed.

(D) The loop and magnet are moved in one direction with the same speed.

14. Which instrument is used in converting electrical energy into mechanical energy ?

(A) Electric generator (B) Electric motor.

(C) Electric iron (D) Electric oven.

15. On which principle does the electric generator work ?

(A) Electrical energy is converted into mechanical energy.

(B) Electrical energy is converted into thermal energy.

(C) Mechanical energy is converted into electrical energy.

(D) Electrical energy is converted into light energy.

16. The magnitude of an AC voltage used in India is ——— and the frequancy is ———

(A) 110V, 60Hz (B) 110V, 50 Hz (C) 220V, 50Hz (D) 220V, 60 Hz

17. Which coloured wire is used for earthing ?

(A) Red (B) Black (C) Green (D) can be of any colour.

18. Which type of current is obtained from a battery ?

(A) DC current (B) AC current.

(C) Current of AC and DC both (D) Depends upon type of battery.

19. Which instrument is used to know the presence of an electric current ?

(A) Fuse (B) Galvanometer

(C) Voltmeter (D) Magnetic needle

20. A fuse wire is ———————

(A) conductor (B) insulator

(C) semiconductor (D) made up of any meterial.

21. ____________ rule is used to know the direction of an induced current in the circuit.

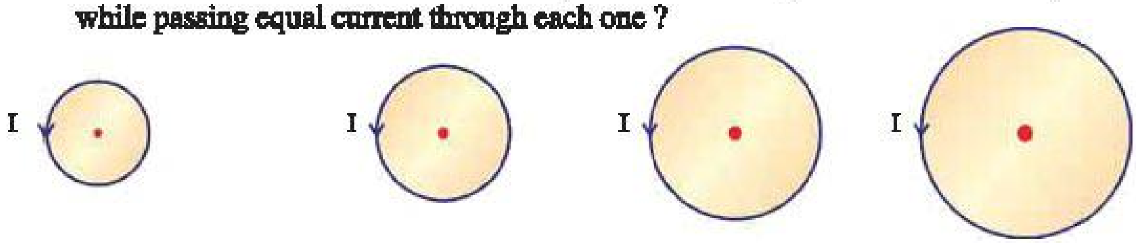
(A) Fleming's left hand (B) Fleming's right hand.

(C) Right hand thumb (D) Ampre's

22. How many times does an AC electric current with the frequency 50Hz change its direction ?

(A) 25 (B) 50 (C) 100 (D) 200

23. At the center of which of the following four circular rings has maximum magnetic field while passing equal current through each one ?



(A) (B) (C) (D)

2. Answer the following questions in brief :

1. Give the characteristics of magnetic field lines.
2. Explain the 'right hand thumb rule' to know the direction of magnetic field.
3. What will happen while placing a current carrying conductor in a magnetic field ? Explain.
4. By which law can the direction of an induced electric current can be determined ? Give the explanation of that law.
5. Explain the provision of an earthing wire.
6. Mention the usefulness of a fuse in a domestic electrical circuit.

3. Write Answers of the following questions :

1. Discuss the magnetic field resulting from a current carrying circular ring.
2. What is a solenoid ? Give the charcteristics of magnetic field resulting from solenoid.
3. What precautions should be taken during the use of electricity ?

4. Answer the following questions in pointwise :

1. Describe the experiment that explains the phenomenon of an electromagnetic induction and give its conclusions.
2. Write a short note on electric bell.
3. Describe domestic electric circuit with the help of a diagram..

5. Answer the following questions in detail :

1. Describe the principle, construction and working of an electric motor along with a figure.
2. Describe the principle, construction and working of an electric generator with a figure.

UNIT

6

UNIVERSE

6.1 Introduction

Man's curiosity to know the mysteries of the universe is as old as human civilization, and seems to be of undiminishing interest. The movement and the behavior of the heavenly bodies have always fasenated us. Scientific and technological developments try to resolve many questions regarding our understanding of the universe; many more have been emmerging while conflicting some of the conventional beliefs! With an intension to provide a scientific platform to explore the universe, we shall study the developments in space research, different tools to study them and, in particular, our solar system in detail. Brief outline of the space science program in India is also included.

6.2 Space Research : An Overview

Early scientific observations for space exploration is traced back to 17^{th} century when Galileo with his telescope could discover the four large moons of Jupiter and confirmed the different phases of Venus. In fact, till 1940s, almost all the information about the universe and solar system were derived from the observations made by such optical telescopes. Since optical telescopes have certain limitations, huge radio telescopes were later invented and installed. They provided us more accurate information about the celestial objects. They are usually located at higher altitudes far from population to avoid electromagnetic interference from radio, TV, radar, etc.. They are superior to the optical telescopes, as they are not sensitive to optical (visible light) pollution. For example, the Hubble - space telescope provides great deal of informations using optical, ultraviolet and infrared waves.

In order to have deeper understanding of neutron star, black hole and supernova as a link to explore the existence of the universe. The scientists realized that they required X-ray telescope. In this view, the first imaging X-ray telescope 'Einstein' (HEAO - 2), was launched into orbit by NASA (National Aeronautics and Space Administration) in 1978. It was renamed and launched as 'Chandra' in 1999. The Chandra X-ray observatory sends X-ray pictures of the distant galaxies also.

6.3 Changing Views on the Universe

Early astronomers studied celestial phenomena through observations. Many astronomical happenings cannot be observed more than once in life and they cannot be reproduced in the laboratories. So their records had taken very long time to get finalized in the reported forms, and inferences drawn from these observations were mostly through intuitive philosophy. For instance, Greek astronomer Ptolemy thought that all celestial objects orbit round the earth. Earth, in the centre of the universe, does not move at all. This **'earth - centred'** or **'Geocentric'** models of Ptolemy was challenged by Polish mathematician and astronomer Nicholas Copernicus through his mathematical model. He suggested that all planets orbit round the sun including the earth, while moon revolves round the earth. The sun is in the centre of the universe and is stationary. Copernicus model is known as **'Sun-Centred'** or **'Heliocentric'** model. In common, both these models have assumed circular orbit for celestial objects. It is worth mentioning that, historically, Copernicus model was the first predictive geometrical model. This heliocentric notion of the universe was also supported by Galileo's telescopic observations.

In the sixteenth century, John Kepler, like Newton's laws of motion, discovered laws of planetary motion. He considered elliptical orbit to explain the motion of Mars. Later, it is realized that even within the solar system, the sun is not at the geometric centre of any of planet's orbit. It is rather at one of focii of the elliptical orbit. Over the course of 18^{th} and 19^{th} centuries, the status of the sun was confirmed as one star among many. In the beginning of 20^{th} century, the picture of 'Akash Ganga' (Milky-way) galaxy became clear. It is proved that the sun is at a distance of 30,000 light years from the galactic centre.

For Information Only

Astronomers measure distance in Astronomical Units (AU). One AU is equal to the average distance between the centre of the earth and the sun.

i.e. $1 \text{ AU} = 149{,}598{,}000 \text{ km} \approx 1.496 \times 10^8 \text{ km}$

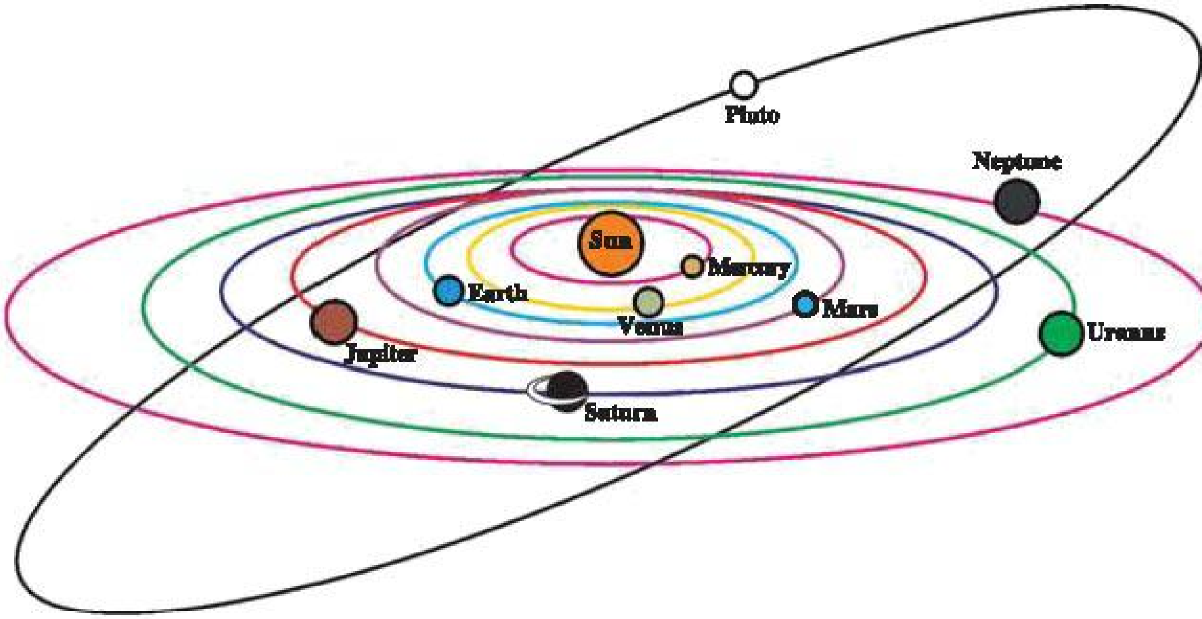
Another unit to measure celestial distances is light year.

$1 \text{ light year} = 9.46 \times 10^{12} \text{ km} = 63{,}240 \text{ AU}$

However, the **"principle of relativity"** given by Albert Einstein suggests that there is no obvious centre of the universe. Further, Hubble and X-ray telescopes have revealed the fact that the universe is expanding and stars and other heavenly bodies are receding away from each other. According to famous theoretical physicist, Stephn Hawking, there may be many more such universes !

6.4 Solar System

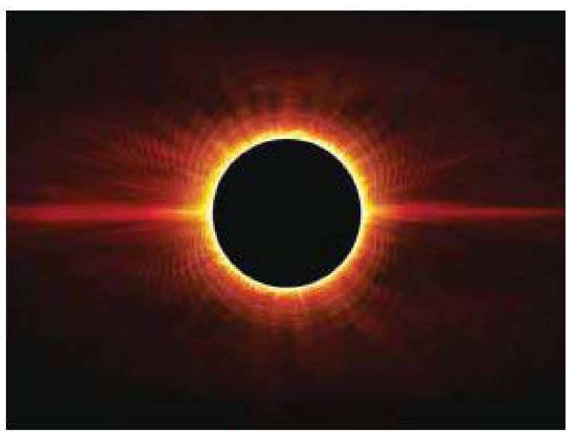
Formation and evolution of the solar system is estimated to have begun 4.568 billion years ago due to the gravitational collapse of a small part of a giant molecular cloud. Most of the collapsing mass assembled in the centre and the sun was formed. Therefore, the sun contains 99.86% mass of the solar family. Remaining mass was flattened into orbits and planets, moons (satellites), asteroids, meteors, comets, etc. were formed. In the Figure 6.1 orbits of nine planets are shown. However, Pluto is now considered as a dwarf planet. The centripetal force required to keep them in respective orbits is provided by the gravitational force between the sun and the planets.



6.1 Orbits of the planets in the solar system

The sun is the main source of energy for us. We receive just desired amount of energy, which keeps water in liquid state. This is essential for the origin and evolution of life on the earth. As the sun is essential for the existence of the solar system, we shall first study the sun.

(1) Sun : Its diameter is about 13,92,000 km. Temperature of the core region in the sun is about 1.5 crore K. Due to such high temperature matter in the core region is in the plasma state. Further, due to high density, pressure in the central part of the sun is also very high. These conditions are responsible for thermonuclear fusion of 4 hydrogen nucleii into a helium nucleus. During this process some mass of hydrogen nuclei is converted into energy as per the Einstein's mass-energy relation, $E = \Delta mc^2$, where c, is the speed of light in vacuum. This large amount of liberated energy is in fact the source of energy for us. This also gives self-luminous to the sun.



6.2 Corona

However, towards the surface its temperature reduces and is about 6000 K at the surface. Thus, sun looks like a sphere of hot gases. Matter (plasma) in the sun is confined by strong magnetic field surrounding it. Variation in magnetic field gives rise to sun spots. Number of sun spots keep on changing periodically with time. Its period is of 11 years.

About the 400 km thick, bright layer around the sun is known as 'photosphere'. The density of photosphere is very low as gases above the photosphere are very hot, hence this layer is seen only during the solar eclipse. It is known as 'Corona', meaning crown (Figure 6.2).

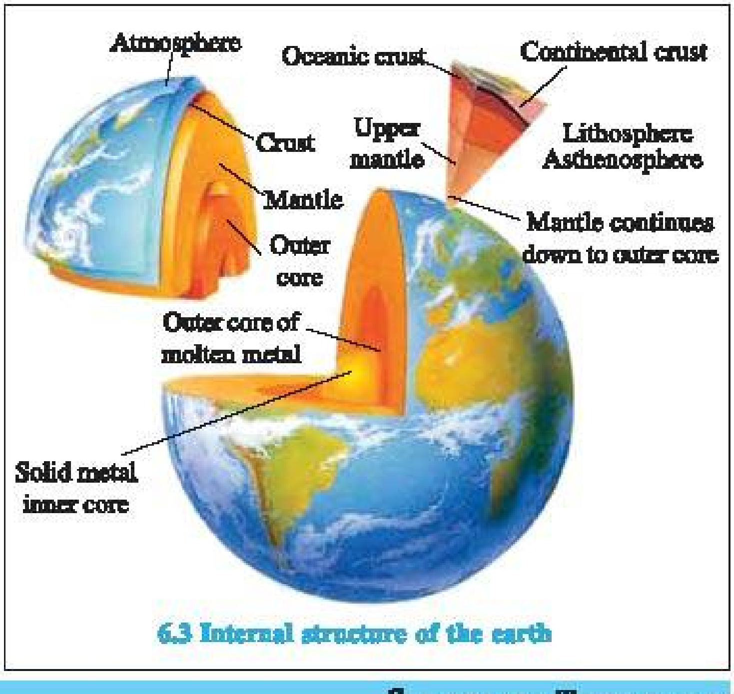
Currently, the sun is in its matured state. It is estimated that the sun will die in approximately 5 billion years. Before that it will expand in size and will become red-giant. Sun's planets may be carried away by nearly passing heavy celestial objects or they may be destroyed or ejected into the interstellar space.

(2) Terrestrial Planets : After the sun, other important members of the solar family are the planets. Our solar system has nine planets. They can be classified into two : (1) Planets which are found inside the orbit of Mars, known as terrestrial planets. (2) Planets which are found outside the orbit of Mars, known as jovian planets. Mercury, Venus, Earth and Mars are the terrestrial planets. Structure of these planets resemble to earth. These planets have fewer number of natural satellites and have thin atmosphere.

Mercury : **It is the smallest planet in the solar system.** Its mass is approximately $\frac{1}{18}$th mass of the earth. It contains metals like nickel (Ni) and iron (Fe) at the centre. Its outer surface is rocky. Strength of its gravitational force is approximately one third of the earth. Due to weak gravitational field and short distance from the sun, it has a very thin atmosphere containing vapours of potassium and sodium. As a result, difference between day and night temperatures is very large. Temperature of the side facing the sun is 427°C whereas night temperature is -173°C. Due to such extreme temperature difference life is not possible on mercury. Its surface has many craters. Some of them are volcanoes. Most of the craters were formed due to hitting of meteors. Mercury has no moon.

Venus : It is the second planet of the solar system and is the neighbour of the earth. It is the most bright planet. Its outer atmosphere consists of white clouds of carbon dioxide (CO_2). It is the only planet that is spinning from east to west, which is in the opposite direction to other planets. Due to this reason, **the sun rises in the west and sets in the east on the venus.** Its orbit is more circular. The surface of the venus contains large mountains, valleys and volcanoes. It also has no moon.

Earth : The third planet in the solar family is the earth. **This is the only planet in the solar family which supports life.** It has thin layer of atmosphere. Thickness of this layer is about 800 to 1000 km. Thanks to atmosphere that when meteorus strike the earth they burn due to friction and get converted into gaseous matter. Thus, atmosphere protects us from meteors. Moreover, it contains thin layer of ozone gas. This ozone layer absorbs ultraviolet rays of the sun and reduces



6.3 Internal structure of the earth

their harmful effects on the living organisms. Atmosphere produces green-house effect, which maintains suitable temperature necessary to sustain life. Due to such favourable circumstances, life has originated on the earth.

Outer layer of the earth is made up of mud or rocky stones (silicate). Here, proportion of silicon dioxide (SiO_2) is very large. Its core region contains semi-liquid made up of molten iron, magnesium and silicate like substances (Figure 6.3). It has one satellite, the moon (Chandra).

Mars : Mars is also our nighbouring planet away from the sun. It is reddish in colour. The surface of the mars has large valleys, mountains and dry rivers. It has negligible atmosphere (1% of the atmosphere of the earth). This atmosphere mainly contains carbon dioxide. It also contains nitrogen (N_2) and argon (Ar) in small amounts. **It is believed that its poles are covered by dry ice (solid CO_2).** Information available from Path Finder Mission of 1997 indicates existence of flowing water on the mars in the past. At present, probability of existence of life on the mars is negligible. It has two moons, namely Phobos and Demos.

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NASA of USA has launched a space vehicle known as Mars Reconnaissance Orbiter (MRO) for detailed study of the mars in August 2005. This un-manned vehicle landed on the mars on 10^{th} March 2006 after seven months journey. It sends informations and photographs regarding its atmosphere. NASA has taken up a mission to send a man on the Mars in next 10 years. Scientists of NASA are of the firm opinion that in the near future human beings will be sent to Mars.

(3) Jovian Planets : Planets of the solar system with their orbit outside the orbit of the Mars and composition similar to Jupiter are known as Jovian planets. These planets are bigger in size but with lesser density. They are mainly made up of Hydrogen, Ammonia and Helium. Rings are usually seen around them. They have moons of bigger in size.

Jupiter : Jupiter is the fifth planet in our solar system. It is a luminous planet. **It is the biggest planet in the solar system.** It is about 1400 times bigger than the earth. Bands of hazy brownish colour are present on the jupiter. Colour concentration of these bands changes continously. Due to its brightness, this planet can be seen with naked eye also. It has relatively rocky core and no real surface. Jupiter has more than 60 moons.

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Because of its mass, Jupiter has a strong gravitational field and due to this strong gravitational field comets passing near by it gets deviated. Sometimes they break up into pieces. The reason is very clear. The part of comet nearer to the jupiter experinces more gravitational force compared to the part of the comet away from the Jupiter. In 1994, comet Levy Shoemaker was broken into more than two pieces while passing by this planet. Some of the pieces fell on this planet also. Observations of the jupiter through radio telescope indicates that jupiter radiates two to three times more energy than the energy it receives from the sun. Possible reason behind this might be thermonuclear process taking place on a large scale at its core.

Saturn : Saturn is the second largest planet of the solar family. Its size is 850 times that of the earth. **Three beautiful luminous rings add to its beauty.** Some of the scientists believe that saturn is completely made up of hydrogen. Its core region is made up of solid hydrogen while its crust is made up of fluid hydrogen. While some other scientists argue that its core is made up of rocks and metals surrounded by thick layer of ice and atmosphere. Its surface temperature is very low. Its largest moon is Titan.

Uranus : Uranus was discovered by William Harshall in 1781. Its size is 64 times than the earth. Its diameter is 3.7 times larger than the earth. Its core contains iron, magnesium and silicate rocks. It has layers of hydrogen and helium surrounded by the clouds of methane and ammonia in the ice from. **This planet is surrounded by narrow rings of ash colour.**

Neptune : Neptune is bluish in colour. It has two luminous and two hazy rings. Thus, in total, it has four rings. Its core region is made up of silicate rocks and ice. Its upper crust contains rocks of methane, ammonia and water in the ice form. It is a very cold planet. Triton and Nerid are its well known moons.

Pluto : As per the new classification of the planets, pluto is known as a dwarf planet. It is very cold, dark and yellowish planet. Its surface density is similar to that of the earth. Therefore, it is also considered to be terrestrial planet. Its orbit is highly elliptical. Its core region has silicate rocks surrounded by water, methane and carbon monoxide in the solid form. Its outer most thin layer contains nitrogen, methane and carbon monoxide. Its atmosphere mainly consists of methane gas. **Pluto and its moon, Sheron form a binary system, and they revolve around their common centre of mass.**

Uranus, Neptune and Pluto cannot be seen with naked eye. Therefore in ancient days only 6 planets were known. Last three planets were discovered using telescope.

6.5 Asteroids

The rocks that failed to form a planet during the time of the formation of the solar system are known as asteroids. Majority of them are found in a belt lying between the Mars and Jupiter (Figur 6.4). Such rocks are of various sizes. They revolve around the sun. Number of asteroids are approximmately more than 1 lac out of which orbits of more than 4000 asteroids are now determined. Asteroids have irregular shapes. Size of these asteroids can be estimated on the basis of their luminosity. The first ever discovered and the largest asteroid is Ceres. Its diameter is approximately 1000 km. Luminous asteroid vesta is approximately 400 km.

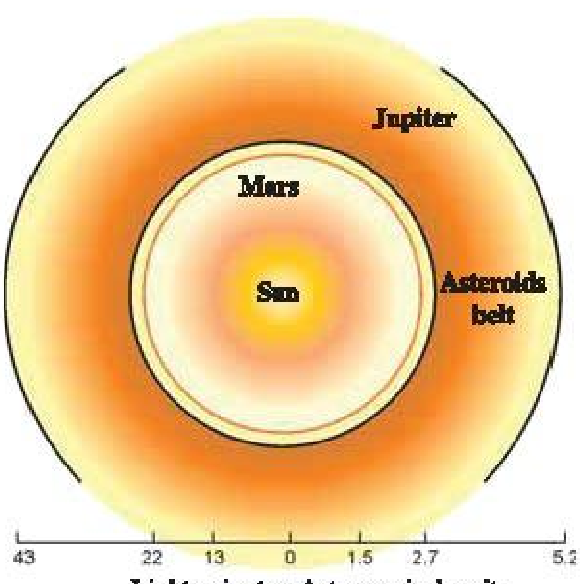

Figure 6.4 Asteroids belt

While revolving around the sun these asteroids keep colliding with each other and keep on breaking. Sometimes their debris come to the earth in the form of meteors. Some of them are very large, which are known as meteorites.

Asteroids are composed of silicon, nickel, chromium and calcium. Gold and platinum are also the probable coustituents.

6.6 Shooting Stars

Various substances of different sizes keep on coming to the earth regularly. Such substances are known as meteors. When they enter the earth's atmosphere, they burn due to friction cause by the earth's gravity and a streak of light is seen. This, in ordinary language, is called shooting star (Figure 6.5). In fact, they are not stars. Maximum number of meteors are seen in the period between August to November. Sometimes, the heavenly body of large size cannot burn completely and strike the earth surface as fire ball. Such burning fire balls are known as meteorites.

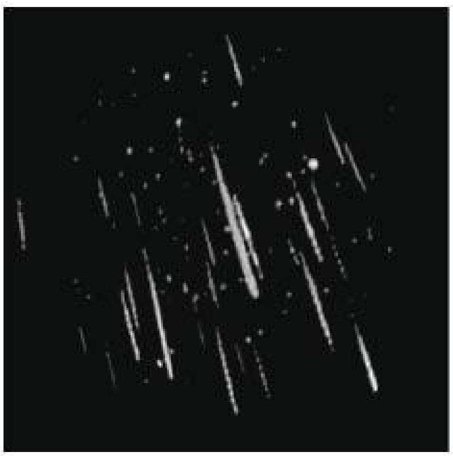

Fig. 6.5 (a) Shooting stars

Fig. 6.5 (b) Meteorite

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When very large meteorites strike the earth they create craters. Some of such craters are converted into lakes. Lonar lake of Maharashtra is the example of it. One such crater in Arizona in America is 180 m deep and 1300 m broad. The meteorite which produced this crater is believed to be having 10 lac ton mass. In 1976, near Dhajala village of Surendranagar district, a meteorite weighing 40 kg struck. This meteorite is known as Dhajala Ulka (Ulka means meteorite). Actual origin of these meteorits is unknown but they are suspected to be from the belt of the asteroids.

It is found that compositions of meteorites is largely due to sand, iron, nickel, etc. This gives an idea of what is the composition of other planets of the solar system. However, it is difficult to say with surety unless we know the exact origin of the meteorites.

In the desert of western Australia numerous meteorites are found. Here, an automatic station is established, which provides more informations about the origin of meteorites and locations of their landing.

6.7 Comets

Around the solar system far from Pluto there is a group of about 10 billion celestial objects, which are known as cloud of Urt. Due to gravitational force of the sun and other stars, they start moving towards the sun. They are known as comets. Most of the comets revolve around the sun in an elliptical orbit (See Figure 6.6). Comets are spheres of dust and icy rocks. As they come closer to the sun, ice vapourizes and a long bright tail is formed. When comet is nearest to the sun its luminous tail is the longest and points opposite to the sun. As it moves away from the sun, its tail becomes shorter and eventually vanishes.

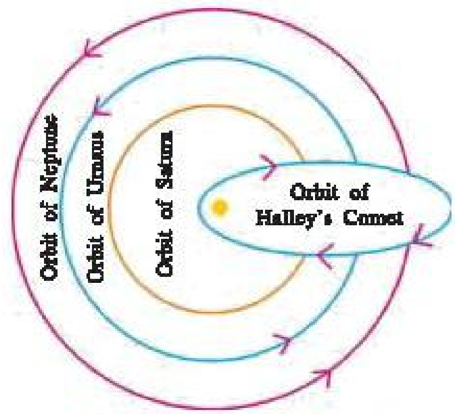


Fig. 6.6 Orbit of a Comet

Since tail is seen from the earth, comet is also called a tailed-star. In fact it is not a star and tail is not permanent.

Uptill now, orbits of 750 comets have been discovered. The most famous of them is Halley's comet. It comes close to the sun at every 76 years. It was last seen in 1986 and will be seen again in 2062. It is named after Edmond Halley, who studied it in detail.

In 1997, Helbopp, another brilliant comet, was seen for about 19 months with naked eye.

Comets are basically made up of water, carbon dioxide, ammonia and other frozen gases along with dust particles. Since their compositions resemble to the composition of the other members of the solar family, they are of great importance to scientists. Detailed study of their tail has shown that it contains the molecules of CO and HCN. These molecules are essential to form complicated compounds necessary for the origin of life. Hence, some of the scientists believe that such molecules must have arrived at the earth through comets, and life had originated on the earth.

In ancient days arrival of the comet was considered as the bad omen and was believed to be responsible for war, epidemic or natural calamity like flood. But modern science has proved that the arrival of a comet is just a normal event and there is no need to panic about it.

6.8 Stars

The celestial self luminous objects which produce energy on their own in the form of radiation due to thermonuclear fusion process are called stars. Stars are hot spheres of gases like hydrogen and helium. The sun is also one such star. There are numerous stars of various sizes. Stars bigger in size compared to the sun have carbon-nitrogen thermonuclear fusion process in their cores.

The stars seem to be permanent and of the same nature as if they do not undergo any changes. But they are born, grow and eventually die. Sun-like stars die as white dwarf while those much larger in size end up in black holes. Different phases of their life span depends on their sizes.

Stars appear in different colours. The star having red colour has the lowest surface temperature and the star having blue colour has the highest surface temperature. Colour and surface temperature depends on their phases. Their physical characteristics change with time.

6.9 Nakshatra

An imaginary sphere covering the sky with the earth at its centre is known as the celestial sphere. The ecliptic of the celestial sphere is divided into 27 equal parts, which are known as **Nakshatra**. Their angular region is $360^\circ \div 27 = 13^\circ 20'$. (Read as thirteen degree twenty minutes.) Our moon undergoes $13^\circ 20'$ angular displacement every day along the elliptic path. Thus, moon remains in one nakshatra for a day, while the sun remains in one nakshtra for $365 \div 27 = 13.5$ days. Nakshatra are given names on the basis of imaginay figures formed by joining stars or by luminous stars belonging to the nakshatra. Pushya, Swati, Ardra, etc. are some of the well known nakshatras. In India, they have religious importance too.

6.10 Night-Sky

You might have noted that the star rises four minutes earlier compared to the previous day. It is because the earth takes 23 hours 56 minutes to complete one rotation about its own axis while day is made up of 24 hours. During these 4 minutes stars in the celestial sphere undergo angular displacement of 1°. In a month their angular displacement becomes 30°. If you watch them at particular time everyday, within six months they undergo angular displacement of 180° (i.e. from horizon to horizon). Thus, after the six months the same stars are not seen. This shows that night-sky changes everyday. But this change is not noticeable in a single day and one should observe the sky for considerable time like a month or so.

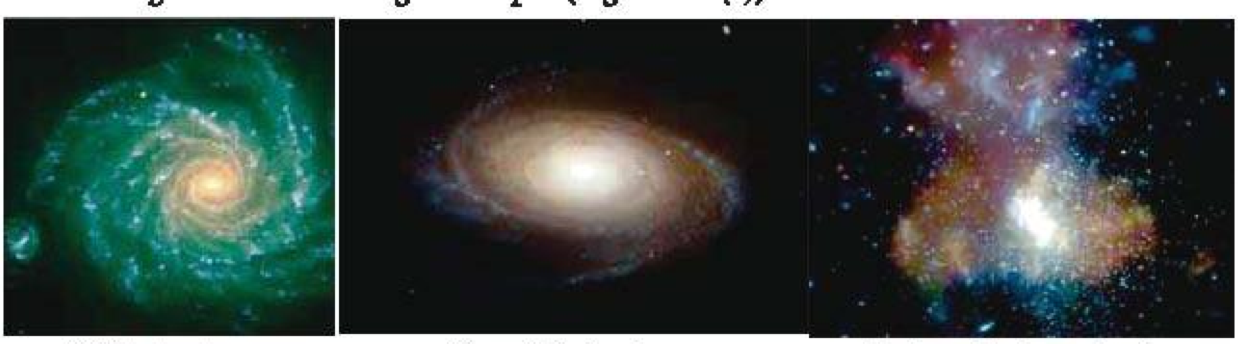
6.11 Milky-Way and Other Galaxies

Numerous stars in the universe are not distributed uniformly. But they are found in big clusters. Such a big cluster of stars is known as a galaxy. During dark and clear sky, we can see a milky belt stretching from north to south. It looks like flowing river Ganga, and hence the name Milky-way. If milky-way is viewed from the side, bulging is seen at the centre and tapered towards the ends. When it is viewed from the top it is seen spiral in shape. Its diameter is about 1 lac light years and the thickness of the middle part is about 15 to 20 thousand light years.

As already noted, our sun is at 30,000 light years away from the galactic center. It completes one revolution around the galactic centre in 22.5 crore years at the speed of 250 km per second. There are about 10^{11} galaxies and each galaxy contains about 10^{11} stars. Thus, in all there are about 10^{22} stars. Galaxies are of different shapes, of which following two are the main :

(1) Spiral galaxy (Figure 6.7 (a)) (2) Elliptical galaxy (Figure 6.7 (b))

Other galaxies are of irregular shapes (Figure 6.7 (c)).



(a) Spiral galaxy (b) Elliptical galaxy (c) Irregular Shaped galaxy

Fig. 6.7 Different types of Galxies

Most of the stars in elliptical galaxies are very old and red in colour. Whereas in spiral galaxies most of the stars are bluish and they are young. So it is believed that elliptical galaxies are older than spiral galaxies. In the universe, number of spiral galaxies are more.

6.12 Blackhole and Pulsar

Blackhole : A blackhole is a region of space from which nothing can escape. Gravitational collapse occurs when outward internal pressure is insufficient to resist the star's own gravity. When massive star (whose mass is larger compared to solar or sun's mass) at the end of its life cycle collapse in a supernova, and eventually ends up into a black hole. Once a black hole is formed it can continue to grow in mass by absorbing mass from its surroundings and may become supermassive black hole with millions of solar mass. It is believed that star formation in the young universe might have produced such massive blackholes of mass 1000 times greater than the solar mass. Such blackholes are found at the centers of most galaxies. There is a strong evidence of a blackhole of more than 4 million solar mass at the center of our Milky-way.

Around a blackhole, we may imagine a surface, called an "event horizon", which marks the points of no return. Light reaching to event horizon will be absorbed like a black body in thermodynamics, so it is called 'black'. However, quantum mechanics predicts that even black holes emit radiation at finite temperatures. Since temperature of a blackhole is inversely proportional to its mass, they radiate by small amount. This makes very difficult to observe this radiation, and astrophysicists have to rely on indirect observations. Its existence can sometimes be inferred by observing its gravitational interactions with its surrounings. For example, X-ray binaries (binary star which emits radiation in X-ray region of the electomagnetic spectrum) are formed due to accreating matter by one star (accreation-star) from the other (regular-star). By studying regular star we can determine the presense of the blackhole.

Classification of blackholes based on their mass, electric charge and angular momentum. However, still it is a mystery to astrophysicists that what mechanism is responsible for restricting gravitational collapsing to zero.

Prediction of neutron stars through Einstein's general theory of relativity sparked interest in such gravitationally collapsed objects. This was then supported by the discovery of rapidly rotating neutron stars, pulsar, in 1967.

Pulsar : The core of massive star when compressed during supernova becomes a neutron star. However, so formed neutron star retains its original angular motion. But due to its reduced size it rotates faster. This infalling matter and high speed rotation results into the emission of high energy radiation along its magnetic axis. Howerer, alignment of magnetic axis and rotation axis are generally not same. This misalignment causes the electromagnetic radiation to be seen twice during its one rotation. Thus, it appears as if the star radiates in pulsar. Hence the name is given pulsar. In fact, it is the abbreviation of a pulsating star. This process of pulsating energy stops after about 10-100 million years when pulsar stops rotating. To date, the slowest observed pulsar has period of 8 seconds.

6.13 History of Space Exploration

Space exploration is the term used to explore the outer space using the principles of space technology and astronomy. While the observation of objects in space is known as astronomy, it was the development of large rockets during the early 20^{th} century that allowed physical space exploration to become a reality. The pioneer of space travel was a Russian, Konstantin Tsiolkowsky (1857-1935). He realized that only a rocket could take us to near space. He also proposed that a rocket should be built in stages so it would dump each stage when its fuel (propellant) would be exhausted. We know that rocket works on the Newton's third law of motion. Fuel in the rocket engine burns very quickly, thus producing large amount of gases. These gases come out of the nozzle with large momentum and rocket is pushed upwards. This action requires special kind of fuel. For example, a mixture of liquid hydrogen and oxygen is used as a liquid fuel, while powdered mixture of ammonium perchlorate or ammonium nitrate and aluminum are used as solid fuel. Rockets are disgined to carry scientific devices or instruments, which are called payloads.

A multistage rocket has two or more stages, each of which contains its own engines and fuels. The main advantage of multistage rockets and boosters is that once the fuel is exhausted, stages are dropped off to reduce the weight of the rocket. This provides more acceleration to the remaining assembly with less fuel requirement. Indeed, these multistage rockets have done tremendous jobs to push space exploration truly into the multifold discipline.

For example, the Russians have launched first artificial satellite, Sputnik-I on 4^{th} October 1957. Immediately, America launched its first satellite Explorer-I in January 1958. The first human being, Yuri Gagarin, was sent in space by Russia on 12^{th} April 1961, while the first space walk was done by Aleksi Leonov on 18^{th} March 1965. In the subsequent years scientists launched series of satellites to investigate different planets and moon of a solar system. On 21^{th} July 1969, astronaut Neil Armstrong of Apollo 11 mission landed and stepped on the moon. In 1971 and 1973, Russians and Americans launched their space stations, Salyut - I and Skylab, respectively. **In 1980, India has launched its first satellite, Rohini.**

In fact, after the first 20 years of space exploration, scientists of different countries have realized that space exploration is a very costly mission. Therefore, they have shifted focus from competition to cooperation, and have jointly built International Space Station (ISS). As a result, many more countries have participated in space exploration programme.

Multistage rockets have couple of major drawbacks (i) staging may result into failures like separation ignition or stage collision, and (ii) the cost factor. This led to the foundation of a reusable launch system – orbital space craft and the space shuttle. It carries different payloads to low earth orbit, provides crew rotation for ISS and performs servicing missions. It can also be used to recover satellites and other payloads from orbit to earth or it may repair the damage part in the orbit itself.

Space Shuttle :

The first space shuttle, Colombia, was launched on 12^{th} April 1981, followed by Challenger, Discovery, Atlantis. Hubble telescope was launched from the space shuttle Discovery (Figure 6.8) in April 1990.

Space shuttle is composed of threee main parts : The reusuable Orbiter Vehicle (OV), the expandable external tank (ET), and the two reusable solid rocket boosters (SRBs). The space

6.8 Discovery Space Shuttle

shuttle is lanuched vertically like a conventional rocket, revolves around the earth, does its job and returns to earth, like an aeroplane. After which it is repolished for reuse. During the flight of space shuttle, the SRBs are dropped with the help of parachute to a predecided location in the ocean. During the descent the orbiter passes through different layers of atmosphere and slows down, primaily, by aerobraking. Howerer, speed of the space shuttle remain still so high that air-friction generates large heat energy. To protect against this heat, outer surface of the space shullte is made up of a special alloy. Once the space shuttle comes to very low altitudes, pilot takes over the control of space shuttle and it lands like an aeroplane.

All space shuttles are launched from Kennedy Space Centre due to favourable geographic conditions.

However, space shuttle flights are not always safe. On 28th January 1986, Challenger disintegrated just after its launch, and all the seven crew members died. On 1st February 2003, Colombia met an accident during its re-entry to the earth. Again all seven astronauts were killed including Kalpana Chawla of Indian origin.

Apart from physical space exploration to understand the nature and existence of the universe, scientists try to simulate conditions in the laboratories similar to the one which was supposed to be just after the big bang. For example, Large Hedron Collider (LHC) is the world's largest particle accelerator experiment. Scientists expect novel insight to understand deepest laws of nature, existence of dark matter, origin of universe, etc. from this experiment.

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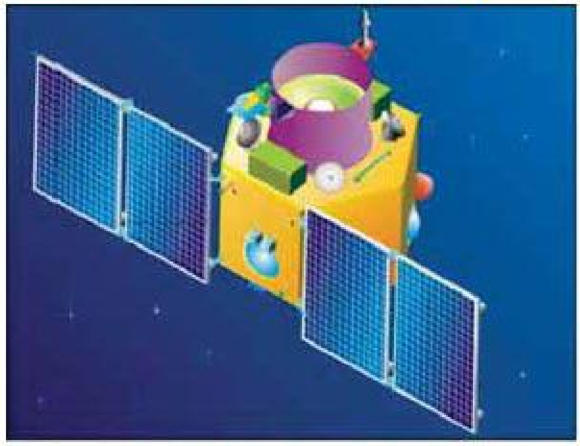
The LHC lies in a 27 km long circular tunnnel at a depth of 175 m at the Franco - Swiss border near Geneva. It is designed to collide opposing beams of very high energy protons. They are accelerated to almost the speed of light in vacuum. It is built by European Organization for Nuclear Research. Total cost of the experiment is expected to be approximately $ 4.4 billion !

The term hadron refers to particles composed of quarks. e.g, proton.

6.14 Various Types of Artificial Satellites and Their Orbits

A smaller heavenly object revolving around a bigger object is known as satellite. Moon is the natural satellite of the earth. "A man-made automatic system launched in the space with a special purpose and revolving around the earth is known as an artificial satellite."

Modern artificial satellite are equipped with transpondors, high resolution cameras, radio meters, solar panels and necessary fuels. These satellites receive signals from the earth-station and send observations taken by various equipments in a proper format to the earth station. India launched its first satellite Rohini on 18th July 1980 using SLV-3 rocket, and became the seventh nation in the space-club. So far, India has launched Rohini, SROSS, IRS series, Resource sat, Carto sat satellites (Figure 6.9) using our own rockets. We have also launched INSAT series with the help of other countries.



6.9 Cartosat Satellite

Fig. 6.10 Trajectory of projectile

To understand the principle of satellite launching we have to go back to gravitation. Suppose you throw a stone in the horizontal direction from the top of a tower, what do you observe ? You would observe that the path of the stone is perabolic and it returns to the earth. If the object is thrown with more speed, it travels longer distance in the horizontal direction. Gradually, if we increase the speed in this way then at some speed the object will start revolving around the earth instead of falling on the earth Figure 6.10. The minimum speed required is 8 km/sec. to revolve around the earth in orbit. Before projecting the satellite in this way it is taken to a height of 200 km to minimize the friction due to atmosphere.

Orbits of the Artificial Satellites :

Usually artificial satellites are kept in one of the following orbits :

(i) Equatorial orbit and (ii) Polar orbit.

"The orbit which is parallel to the equator is known as an equatorial orbit."

"The orbit which is parallel to meridian is known as a polar orbit." (Figure 6.11)

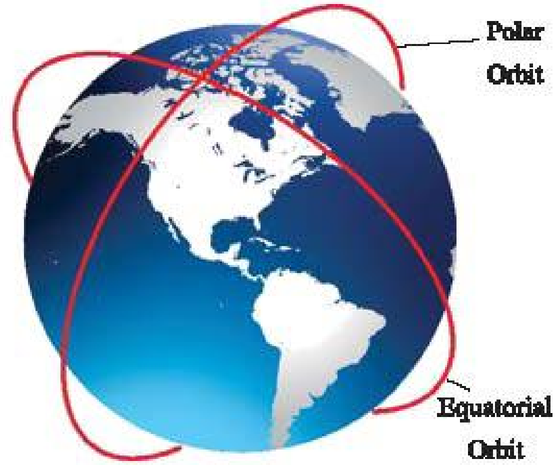


Fig. 6.11 Orbits of Artificial Satellites

The revolution period of a satellite having height from the earth's surface equal to 35,786 km is 24 hours. Therfore, such satellite is seen to be stationary when viewed from the earth. It is called **geo-stationary satellite** and such orbit is known as **geo-stationary orbit**. Satellites in such orbits do not require any energy for its revolution. By arranging three geo-stationary satellites at proper place in the orbit, the entire earth can be linked and signals from any corner of the earth can be sent to any other place on the earth.

Some of the satellites are launched in polar orbits. Their height from the surface of the earth is about 1000 km and their revolution period is 2 hours or less. Such satellites have a number of revolution around the earth in a day, and they pass through a location on the earth at a regular interval of time. This interval of time is called repeating time. Remote sensing satellites of India and America's landset visit any location on the earth at the interval of 21 days and 16 days, respectively. During these days they scan the entire earth.

Useful life time of the satellite depends on stability of their orbits. So their path is constantly observed and they are re-established in their orbit using rocket engines attached to them.

Orbits of artificial satellites like natural satellites are elliptical due to the effect of gravity. However, to calculate the revolution period orbits are considered circular for the sake of simplicity.

6.15 Uses of Artificial Satellites

Using artificial satellites we are able to see events happening in any corner of the world on our television. We also get weather forecast. In the field of education, country-wide classroom becomes the reality. Tele-conferencing enables us to have a meeting with people separated by long distances. Satellites are also useful in space research, communication, remote sensing, defence, etc. Human beings have lots of advantages due to satellites. Some of the uses are discussed below.

For Communication : In the field of communication, we use satellites for telecomunication, television transmission, radio networks and computer networks. Country-wide classroom and tele-conferencing have enabled us to spread education in remote villages of the country. For this purpose India has launched INSAT series. So far we have launched INSAT 1,2,3 series for these purposes.

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British scientist Arther Clark, in 1945, had suggested that a geo-stationary satellite can be used for communication purpose for microwave relays.

For Weather Forecast : We can also get information regarding weather using satellite of INSAT series. These satellites can take photographs of clouds, provide useful information about surface temperature of the oceans, temperature of various layers of atmosphere, humidity in the atmosphere, etc. They also provide forecast regarding monsoon or sudden climatic changes that can cause storms or hurricanes.

For Remote Sensing : "Remote sensing is the method by which information about a substance or a phenomenon can be obtained using scientific instruments without direct contact with them."

Using satellite we can carry out geological survey of metallic ores present in the earth's crust, changes in the forest and environment, water resources, agriculture resources, etc. It also provides information about diseases that can spread in the crops. It is also used in oceanography and study about movements of fishes. The installation of sensors in the remote sensing satellites covers the area of 10 sq. m to 6400 sq. m, and they send the information to the earth-station.

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Remote sensing techniqes basically depends on solar radiation and enerey. Each and every substance on the earth emits energy in certain amount depending on their temperature. They also reflect incident solar energy in various amounts. The sensors kept in the satellites receive these radiations and send its information to the earth-station. Study of such information enables us to interpret the situation of the surface of the earth. Of course, it requires special training to interpret these data or informations.

6.16 Indian Space Research Programme

Artificial satellites have potential applications in the field of mass communication, weather forecasting and remote sensing. ISRO (Indian Space Research Organigation) has developed and launched various satellites.

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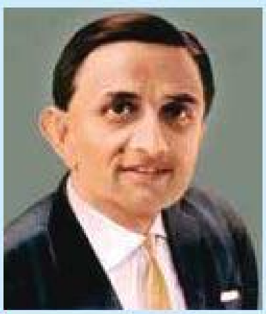


Dr. Vikram Ambalal Sarabhai (1919-1971) was born in Ahmedabad on August 12, 1919. He carried out his research on cosmic waves and obtained Ph.D. degree from the Cambridge University. He established 'Physical Research Laboratory' (PRL) and 'Ahmedabad Textile Industry Research Association' (ATIRA) in Ahmedabad. He has given valuable contributions in the development of rockets and space research in India. He is known as the Father of India's space programme. Scientists contributing remarkably in this field are given Dr. Vikram Sarabhai Memorial Prize.

They are widely used for transmission of TV signal and communication, along with a geological survey for mineral resource, for agricultural purpose and study of marine life.

The rocket launching programme of ISRO have been utilized on commercial basis by other countries also.

6.17 Programmes Conducted by ISRO

- INSAT (Indian National Satellite System) has its series INSAT - 1, 2, 3 were launched in the space and INSAT - 4 was launched on 22nd December 2005 from Guana (France) which will be useful for Direct To Home (DTH) service for TV transmission.
- IRS (Indian Remote Sensing) satellites have been launched. IRS -1, IRS - P series which is meant for commercial purpose, whereas METSAT (Meteorological satellite) is used for weather forecasting.
- The Resource satellites are used for the study of oceanography.
- Carto sat is used for geographical survey.
- Rohini satellite series is for astronomical observations.
- PSLV (Ploar Satellite Launching Vehicles) is used for launching 1000-2000 kg class of remote sensing satellite.
- GSLV (Geo Synchronous Satellite Lauch Vehicle) launched 'EDUSAT' nearly weighing 2500 kg in space, in September 2004.

What have you learnt ?

- Limitations of optical telescopes have led foundation for X-ray telescopes. The 'Chandra' X-ray observatory takes X-ray pictures of astronomical happenings.
- Our views on the universe continuously change. From earh-centred to sun-centred, expansion of the universe, many universes, etc.
- Our solar system is made up of nine planets, satellites, asteroids, meteors, comets, etc.
- Planets which are found inside the orbit of Mars and having structure similar to the earth are known as **Terrestrial planets.**
- Planets which are found outside the orbit of Mars and having composition similar to Jupiter are known as **Jovian planets**.
- Venus is the only planet in the solar system, which revolves around the sun in opposite direction to other planets.
- Asteroids are the rocks that failed to form a planet. They are found between Mars and Jupiter.
- Asteroids keep on colliding with each other, and keep on breaking. Their debris coming to the earth are known as **meteors**. Meteors of large sizes are known as **meteorites.**
- Due to earth's atmosphere, meteors coming to earth burn and produce a streak of light. This appears as a shooting star.
- Comets are also known as tailed-star. Its tail is longest and point in opposite to the sun when it is nearest to the sun. They revolve round the sun at a regular interval of time.
- The celestial self luminous objects due to thermonuclear fusion are known as stars. Stars are not permanent. But they born, grow and eventually die.
- 27^{th} part of the ecliptic sphere is known as nakshatra.
- Stars are found in big clusters, known as galaxies. Our solar system belongs to Milky-way galaxy. There are about 10^{11} galaxies each containing 10^{11} stars. They are mainly found in two shapes : spiral and elliptical.
- Black holes are supermassive celestial objects such that no radiation can escape from their strong gravitational pull. Their existence, usually, can be found through X-ray binaries.
- Pulsating neutron stars are known as pulsar.
- Rockets require special kind of fuels (propellant)
  Liquid fuel : Liquid hydrogen and oxygen.
  Solid fuel : Mixture of ammonium perchlorate or ammonium nitrate and aluminum.
- Space exploration is now done using space shuttle. Important parts of it are Orbiter vehicle (OV), expandable external tank (ET) and solid recket boosters (SRB).
- Man-made satellites are known as artificial satellites. They are used for the benefit of the mankind. Geostationary satellites and polar satellites are the two types of artificial satellites.

EXERCISE

1. Select the proper choice from the given multipule choices :

(1) Which of the following is a star ?

(A) Sun (B) Phobos (C) Asteroids (D) Comet

(2) Which of the following is not a member of the solar system ?

(A) Asteroids (B) Shooting Star

(C) Sun (D) Artificial satellite

(3) What is the periodic time of Halley's comet ?

(A) 67 yrs (B) 76 yrs (C) 86 yrs (D) 100 yrs

(4) Matter in the core region of the sun is in .... state.

(A) Solid (B) Liquid (C) Gaseous (D) Plasma

(5) .... is the most brilliant planet of the solar system.

(A) Earth (B) Venus (C) Jupiter (D) Mars

(6) Poles of Mars are covered by ....

(A) dry-ice (B) water-ice (C) nitrogen (D) iron

(7) .... was the first person to land the moon.

(A) Yuri Gagarin (B) Aleksi Leonov

(C) Kalpana Chawla (D) Neil Armstrong.

(8) Distance of geostationary satellite from the earth's surface is .... km.

(A) 43,000 (B) 37, 956 (C) 35, 786 (D) 23, 123.

2. Answers the following questions in brief :

(1) Write the two uses of artificial satellites.

(2) What are stars and what are they made up of ?

(3) Give difference between earth-centred and sun-centred models.

(4) How X-ray astronomy is useful in space exploration ?

(5) Explain the formation of the solar system in brief.

(6) What are terrestrial planets ?

(7) What are jovian planets ?

(8) Explain equatorial and polar orbits of artificial satellites.

3. Write answers to the following questions :

(1) Write notes on :

(i) Mercury (ii) Venus (iii) Mars (iv) Saturn
(v) Pluto (vi) Shooting Stars (vii) Night-sky (viii) Milky-Way galaxy

(2) How artificial satellites are useful in communication ?

(3) What is remote sensing ? How satellites are useful in remote sensing ?

4. Answer the following questions in detail :

(1) Give a detailed note on the program conducted by ISRO.

(2) Write a note on the blackholes.

(3) Write a note on the Earth.

(4) Write a note on Nakshatra.

5. Answer the following questions pointwise :

(1) Write a detailed note on comets.

(2) What are galaxies ? Give detailed account of different types of galaxies.

(3) Write a note on Space shuttle.

UNIT

7

Acids, Bases and Salts

7.1 Introduction

From the studies in earlier standards, it can be said that juice of sour fruits, juice of lemon, solution of tamarind and butter milk, used in everyday life have acidic nature. Aqueous solutions of baking soda and washing soda have basic nature; while aqueous solution of common salt has neutral nature. The acidic, basic and salt nature of aqueous solutions is due to the acid, base or salt present in them. Thus, the utility of acid, base and salt is specific in our everyday life. The aqueous solutions of these salts are very important in biological systems and chemical industries. We shall obtain more information about acid, base and salt in this unit.

7.2 Theories of Acid and Base

What are acid and base ? Many scientists have proposed different theories for the answers to these questions. About 300 years ago, Robert Boyle defined acid and base on the basis of chemical properties. Acids are sour in taste, turn wet blue litmus paper into red and liberates dihydrogen gas (H_2) by reaction with metal; while bases are bitter in taste, turn wet red litmus paper into blue. By neutralisation reaction between acid and base, salt and water are produced. This type of definition is called operational definition because it is based on its properties. This definition is also called old definition. In the modern definitions of acid-base – Arrhenius, Bronsted - Lowry, Lewis acid-base theories are included. We shall understand the first two from them – Arrhenius and Bronsted-Lowry theories.

(1) Arrhenius Acid-Base Theory

The definite concept about acid and base was given in 1884, by Sweedish Scientist Svante Arrhenius. According to his opinion **"Acid is a substance containing hydrogen which produces hydrogen ion (H^+) in its aqueous solution, and base is a substance containing hydroxide which produces hydroxide ion (OH^-) in its aqueous solution."** It can be said on the basis of Arrhenius acid-base theory that acid ionises in water and produces H^+ and base ionises in water and produces OH^- ion. Thus, the theory of ionisation is involved in the basis of this theory.

HA (aq) $\xrightarrow{H_2O}$ H^+(aq) + A^-(aq) A^- = Negative ion (e.g. Cl^-, Br^- NO_3^-)

Acid Hydrogen ion

HNO_3 (*l*) $\xrightarrow{H_2O}$ H^+(aq) + NO_3^-(aq)

Nitric acid Nitrate ion,

HCl (*l*) $\xrightarrow{H_2O}$ H^+(aq) + Cl^-(aq)

Hydorchloric acid Chloride ion

MOH (s) $\xrightarrow{H_2O}$ M^+(aq) + OH^-(aq) M^+ = metal ion or NH_4^+

Base Hydroxide ion

NaOH (s) $\xrightarrow{H_2O}$ Na^+(aq) + OH^-(aq)

Sodium hydroxide Hydroxide ion

KOH (s) $\xrightarrow{H_2O}$ K^+(aq) + OH^-(aq)

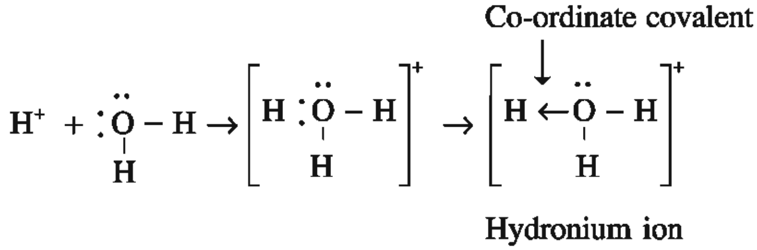
Potassium hydroxide Hydroxide ion

Arrhenius acid-base theory became very powerful yet, three limitations were observed. (1) It is applicable only to aqueous solutions. (2) Ammonia (NH_3) does not contain hydroxide ion even then its aqueous solution acts as base. It could not explain this. (3) According to this theory, H^+ is highly unstable, because it is hydrogen atom without electron i.e. positive hydrogen ion or proton. Its independent existence is not there, because it combines immediately with solvent viz $H^+ + H_2O \rightarrow H_3O^+$ Hydronium ion.

(2) Bronsted-Lowry Acid-Base Theory

To explain the limitations of Arrhenius acid-base theory, in 1923 Danish Chemist Johannes Bronsted and British Chemist Thomas Lowry presented a detailed concept of acid-base. It is known as Bronsted-Lowry acid-base theory. This theory can be applied to aqueous and non-aqueous solutions. In addition it can also give the explanation about the aqueous solution of a substance like ammonia to be base even though it does not contain hydroxide.

The substance which donates a proton ((H^+) to other subtance is called Bronsted-Lowry acid. The substance which accepts a proton from other substance is called Bronsted-Lowry base. In short, Bronsted-Lowry acid is a proton donating substance and Bronsted-Lowry base is a proton accepting substance. Thus, on the basis of this theory the concept of proton transfer is involved. According to this theory, the species responsible for acidity is not (H^+) but H_3O^+, because H^+ forms bond with water (H_2O) and forms hydrated hydrogen ion (H_3O^+). Generally, H_3O^+ is known as hydronium ion. In H_3O^+ there is a co-ordinate covalent bond between H^+ and H_2O, because the bond between them is formed by sharing of electron pair on oxygen atom of water.

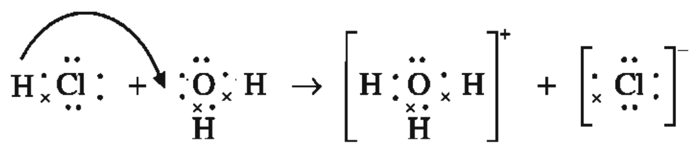


Now, we shall understand the Bronsted-Lowry acid-base concept by an example.

When hydorgen chloride gas is dissolved in water, hydrogen chloride gas donates proton to water; so hydrogen chloride gas is Bronsted-Lowry acid and as water accepts a proton, water is Bronsted-Lowry base.

$HCl(g)$ + $H_2O(l)$ → $H_3O^+(aq) + Cl^-(aq)$

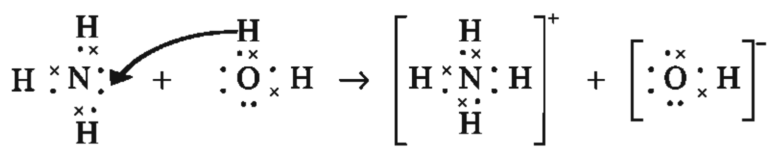
Acid Base



When ammonia gas (without hydroxide ion) is dissolved in water, ammonia gas water donates a proton to Bronsted-Lowry base, i.e. ammonia gas. Hence water is a Bronsted-Lowry acid.

$NH_3(g) + H_2O(l)$ → $NH_4^+(aq) + OH^-(aq)$

Base Acid



Here, in both the examples water acts as base and acid respectively. Thus, water acts both as acid or base according to the reaction; so it is called amphoteric. The amphoteric nature of water can be well understood by reaction between two molecules of water.

$H_2O(l)$ + $H_2O(l)$ $\rightleftharpoons$ $H_3O^+(aq) + OH^-(aq)$

Base Acid

7.3 Chemical Properties of Acids and Bases

Before the study of chemical reactions let us discuss acid-base, and how acid and base are formed. The reaction of oxide of non-metal with water, acid is formed, i.e.

oxide of non-metal + water → acid

e.g. $SO_3(g) + H_2O(l)$ → $H_2SO_4(aq)$

Sulphur trioxide Sulphuric acid

$CO_2(g) + H_2O(l) \rightarrow H_2CO_3(aq)$

Carbon dioxide → Carbonic acid

By reaction of oxides of metal with water, base is formed i.e.

Metal oxide + Water → Base

$Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$

Sodium oxide → Sodium hydroxide

$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq)$

Calcium oxide → Calcium hydroxide

$Li_2O(s) + H_2O(l) \rightarrow 2LiOH(aq)$

Lithium oxide → Lithium hydroxide

Chemical Properties of Acids

For the chemical reactions of acid, H^+ or H_3O^+ present in its aqueous solution; is responsible.

(1) Reaction of acid with metal: By reaction of acid with metal, salt corresponding to metal and dihydrogen gas are produced.

Acid + Metal → Salt of Metal + Dihydrogen gas

e.g.

$2HCl(aq) + Ca(s) \rightarrow CaCl_2(aq) + H_2(g)$

Hydrochloric acid → Calcium chloride

$H_2SO_4(aq) + Mg(s) \rightarrow MgSO_4(aq) + H_2(g)$

Sulphuric acid → Magnesium sulphate

Nitric acid being oxidising agent, by reaction with metal, water is produced instead of dihydorgen.

$8HNO_3(aq) + 3Zn(s) \rightarrow 3Zn(NO_3)_2(aq) + 2NO(g) + 4H_2O(l)$

Nitric acid → Zinc nitrate

Generally, noble metals like, Au, Ag, Pt do not react easily with acid.

(2) Reaction of acid with base : Salt and water are formed by reaction of acid with base. This reaction is called neutralisation reaction.

Acid + Base → Salt + Water

e.g. $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

Sodium chloride

$H_2SO_4(aq) + 2KOH(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$

Potassium sulphate

$2HNO_3(aq) + Ca(OH)_2(aq) \rightarrow Ca(NO_3)_2(aq) + 2H_2O(l)$
Calcium nitrate

$H_2CO_3(aq) + 2NaOH(aq) \rightarrow Na_2CO_3(aq) + 2H_2O(l)$
Sodium carbonate

$HCl(aq) + NH_4OH(aq) \rightarrow NH_4Cl(aq) + H_2O(l)$
Ammonium chloride

(3) **Reaction of acid with metal oxide :** This reaction is similar to the reaction of acid with base which means that by reaction of acid with metal oxide, salt and water are formed.

Acid + Metal oxide $\rightarrow$ Salt + Water

e.g. $2HCl(aq) + Na_2O(s) \rightarrow 2NaCl(aq) + H_2O(l)$
Sodium oxide

$H_2SO_4(aq) + MgO(s) \rightarrow MgSO_4(aq) + H_2O(l)$
Magnesium oxide — Magnesium sulphate

$2HNO_3(aq) + CaO(s) \rightarrow Ca(NO_3)_2(aq) + H_2O(l)$
Calcium oxide — Calcium nitrate

(4) **Reaction of acid with metal carbonate or metal hydrogen carbonate :** Most of the acids produce salt, water and carbon dioxide by reaction with metal carbonate or metal hydrogen carbonate.

Acid + Metal carbonate / Metal hydrogen carbonate $\rightarrow$ Salt + Water + Carbon dioxide gas

e.g. $2HCl(aq) + Na_2CO_3(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$
Sodium carbonate

$H_2SO_4(aq) + MgCO_3(s) \rightarrow MgSO_4(aq) + H_2O(l) + CO_2(g)$
Magnesium carbonate

$2HNO_3(aq) + K_2CO_3(aq) \rightarrow 2KNO_3(aq) + H_2O(l) + CO_2(g)$
Potassium carbonate

$HCl(aq) + NaHCO_3(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g)$
Sodium hydrogen carbonate

$H_2SO_4(aq) + 2NaHCO_3(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l) + 2CO_2(g)$

$HNO_3(aq) + NaHCO_3(aq) \rightarrow NaNO_3(aq) + H_2O(l) + CO_2(g)$
Sodium nitrate

Chemical Properties of Bases :

For the chemical reaction of base, the OH^- present in its aqueous solution is responsible.

(1) **Reaction of base with acid:** Reaction of base with acid forms salt and water. This reaction is called neutralisation.

Base + Acid $\rightarrow$ Salt + Water

e.g., $NaOH(aq) + HCl(aq) \rightarrow NaCl\ (aq) + H_2O(l)$

$2KOH(aq) + H_2SO_4(aq) \rightarrow K_2SO_4\ (aq) + 2H_2O(l)$

$Ca(OH)_2(aq) + 2HNO_3(aq) \rightarrow Ca(NO_3)_2(aq) + 2H_2O(l)$

$2NaOH(aq) + H_2CO_3(aq) \rightarrow Na_2CO_3(aq) + 2H_2O(l)$

$NH_4OH(aq) + HCl(aq) \rightarrow NH_4Cl(aq) + H_2O(l)$

(2) **Reaction of base with non-metal oxide:** This reaction is similar to the reaction of base with acid, that is, salt and water are formed by reaction of base with non-metal oxide.

Base + Non-metal oxide $\rightarrow$ Salt + Water

e.g., $Ca(OH)_2(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$
Calcium carbonate

$2NaOH(aq) + SO_3(g) \rightarrow Na_2SO_4(aq) + H_2O(l)$
Sodium sulphate

(3) **Reaction of base with some metals :** By reaction of strong base (see point 7.2) like sodium hydroxide with certain amphoteric metals (Zn, Al), salt and hydrogen gas are produced.

Base + Metal $\rightarrow$ Salt + Dihydrogen

e.g., $2NaOH(aq) + Zn(s) \rightarrow Na_2ZnO_2\ (aq) + H_2(g)$
Sodium zincate

$2KOH(aq) + 2Al(s) + 6H_2O(l) \rightarrow 2KAl(OH)_4\ (aq) + 3H_2(g)$
Potassium aluminate

Sodium zincate and Potassium aluminate are complex salts.

7.4 Solution and Its Concentration

We know that when common salt is dissolved in water, what is obtained is called solution of common salt. Here, common salt is a solute because its proportion in solution is less and water is a solvent because its proportion is more. Thus, **the system resulting when solute is dissolved in solvent is called solution.**

If we take same amount of water in three cups and add one, two and three table spoon common salt to first, second and third cups respectively, there will be difference in salty nature of solution in the three cups. The reason for this is that the amount of solute (common salt) in the same amount of solvent (water) is different. Similarly we can take one tea spoon common salt in the three cups and add one, two and three cups of water to first, second and third cups having common salt; even the difference is observed in the salty nature of the salt solution. The reason for this is that same amount of solute is dissolved in different volumes of solvent. Thus, the salty nature of solution depends on the relative amounts of solvent and solute. In scientific language, the amount of solute, in relation to amount of solvent is called concentration. Out of the two solutions, one having more salty nature has more concentration of common salt.

The solutions having definite concentrations are required in experiments of chemistry. The concentrations of solutions are expressed in different ways, viz percentage proportion, normality, molarity, molality, formality, ppm (parts per million). Units out of these normality and molarity are used more. Here, we will discuss only molarity. We will study the other units, in Standard 11 and 12. The molarity of solution means molelitre^{-1} concentration. **If 1 mole solute is dissolved in 1 litre solution, then the concentration of solutioin has 1 molarity.** In practice, 1 molarity is called 1 molar which is expressed in short as 1 M. If 2 moles of common salt are dissolved in 1 litre solution of common salt, it is said that concentration of the solution is 2 M. Similarly, if 1 mole glucose is dissolved in 500 ml solution, the concentration of solution is considered as 2 M. Because in 1 litre solution, 2 mole glucose dissolves as obtained by calculations. Now, if we wish to prepare 3 M NaCl aqueous solution, then 3 moles of NaCl should be dissolved in 1 litre solution i.e. 3 moles of NaCl should be dissolved in water and its total volume should be made 1 litre and not to add weight equal to 3 moles of NaCl in 1 litre water solvent. But the question arises, how to take 3 moles of NaCl ? On thinking, it will be found that it can be taken by weight. Hence, if NaCl is to be taken in mole, the relation between mole and mass should be thought of.

We have studied in Standard 9, about molecular mass (molecular weight) having relation between mole and mass. The unit of molecular mass is gram mole^{-1}. The molecular mass of NaCl is 58.5 gram mole^{-1}, i.e The amount 58.5 gram NaCl is called one mole amount of NaCl. Thus, **one mole of any amount equals to gram molecular mass should be taken.** Here, we should be more clear that **if the substance is in elemental form, then its atomic mass will have to be considered for 1 mole amount.** If the substane is in ion form even then its atomic mass is taken because there is no change in mass because of number of electric charge. Thus, the effect of gain or loss of electrons is not considered on its mass. Hence : 1 mole Na=1 mole Na^+ = 23 gram and 1 mole Cl = 1 mole Cl^- = 35.5 gram Cl. Thus, to prepare 3 M aqueous solution of NaCl, 3 moles of NaCl equal to $3 \times 58.5 = 175.5$ gram NaCl will have to be taken. 3 M NaCl solution can be prepared by dissolving 175.5 gram NaCl in some water and it gets dissolved, additional water should be added to make total volume equal to 1 litre. If this solution is to be prepared in 250 ml then, $\frac{175.5}{4} = 43.88$ gram NaCl quantity should be dissolved and the final volume will be 250 ml.

Example : 1

How will you prepare 100 ml aqueous solution of 2 M NaOH ?

Solutiion :

Molecular mass of NaOH = (Atomic mass of Na) + (Atomic mass of O) + (Atomic mass of H)

$$= (23) + (16) + (1)$$

$$= 40 \text{ gram mole}^{-1}$$

According to the definition of molarity to prepare 1000 ml. 1 M NaOH solution, 40 gram NaOH will be required.

1000 ml. 1 M NaOH solution, 40 gram NaOH will be required.

$\therefore$ To prepare 100 ml. 2 M NaOH solution, $\frac{100 \times 2 \times 40}{1000 \times 1}$ gram NaOH will be required.

$$= 8 \text{ gram NaOH}$$

Thus, 8 gram NaOH should be dissolved in water and the total volume of solution will be made 100 ml so that 2 M aqueous solution of NaOH can be prepared.

Example : 2

How will you prepare 250 ml 0.5 M aqueous solution of HCl ?

Solution :

Molecular mass of HCl = (Atomic mass of H) + (Atomic mass of Cl)

$$= (1) + (35.5)$$

$$= 36.5 \text{ gram mole}^{-1}$$

According to definition of molarity,

To prapare 1000 ml 1 M HCl 36.5 gram HCl will be required

$\therefore$ To prepare 250 ml. 0.5 M HCl solution $\frac{250 \times 0.5 \times 36.5}{1000 \times 1}$ gram HCl will be required.

$$= 4.56 \text{ gram HCl.}$$

Thus, by dissolving 4.56 gram HCl in water and making the total volume 250 ml, 250 ml 0.5 M aqueous solution of HCl can be prepared. We shall do the activity of filling in the blanks shown in Table 7.1 in order to prepare solutions of definite concentration.

Table 7.1 Aqueous solution of definite molarity of some substances.

Substance	Molecular mass (gram mole^{-1})	Concentration of solution (M)	Volume of solution (ml)	Mass of substance (gram)
HCl	36.5	1	1000	36.5
NaOH	40	2	250	——
KOH	56	——	500	28
H_2SO_4	98	0.5	500	——
HNO_3	63	1	2000	——
$NaHCO_3$	84	1	——	21
Na_2CO_3	106	——	1000	53
$CuSO_4 .5H_2O$	249.5	0.1	1000	——
$FeSO_4 . 7H_2O$	278	1	——	139

7.5 pH of Solution, pH Scale and Measurement of pH

Hydrogen ion concentration $[H^+]$ plays an important role in chemical and biochemical reactions. Some important reactions can be controlled by less concentration of hydrogen ion. The concentration of hydrogen or hydronium ion H_3O^+ in aqueous solution will have to be mentioned in molarity i.e. 2.8×10^{-4} M or 3.5×10^{-5} M or 4.9×10^{-9}M. The concentrations of hydronium ion in different substances can be as less as 10^{-7} M and as high as 1 M. If a graph is to be plotted of concentrations with such a high difference will be difficult. Thus, to remove the difficulties in expressing concentrations of hydronium ion in aqueous solution, biochemist of Denmark, S.P.L. Sorensen suggested a simple and convenient method to express concentration of hydronium ion in aqueous solution. It is known as pH scale.

Solution of pH and pH scale :

Generally pH expresses the concentration of hydronium ion in aqueous solutions. **Mathematically the negative logarithm to the base of 10 of molar concentration of H_3O^+ in aqueous solution is called pH.** If we write in the form of an equation, then,

$$pH = -\log_{10} [H_3O^+]$$

Distilled water is used as solvent in aqueous solution. H_3O^+ and OH^- ions are produced by self-ionisation of water

$$H_2O + H_2O \longrightarrow H_3O^+ + OH^-$$

Experimentally, it is proved that, $[H_3O^+]$ = $[OH^-]$ = 10^{-7} M are present in distilled water at 298 K. We know that $[H_3O^+]$ of a solution is responsible for acidity and $[OH^-]$ of a solution is responsible for basicity. As concentrations of H_3O^+ and OH^- are same in distilled water, it acts as a neutral solvent. Hence, in aqueous solution of any substance if the concentration of H_3O^+ is more than 10^{-7} M the aqueous solution becomes acidic or if concentration of OH^- is more than 10^{-7} M, the aqueous solution becomes basic. The pH of acidic and basic solutions having different concentrations are shown respectively in Tables 7.2 and 7.3

Table 7.2 pH of aqueous acidic solutions

$[H_3O^+]$ in aqueous solution (In molarity)	pH = – $log_{10}[H_3O^+]$	pH of aqueous solution
10^{-6}	$pH = -log_{10}10^{-6} = 6\ log_{10}10 = 6$	6
10^{-5}	$pH = -log_{10}10^{-5} = 5\ log_{10}10 = 5$	5
10^{-4}	$pH = -lo10g10^{-4} = 4\ log_{10}10 = 4$	4
10^{-3}	$pH = -log_{10}10^{-3} = 3\ log\ _{10}10 = 3$	3
10^{-2}	$pH = -log_{10}10^{-2} = 2\ log_{10}10 = 2$	2
10^{-1}	$pH = -log_{10}10^{-1} = 1\ log_{10}10 = 1$	1
$10^{0} = 1$	$pH = -log_{10}10^{0} = 0\ log_{10}10 = 0$	0

$[H_3O^+]$ increases ↓

pH decreases ↓

It can be said from the Table 7.2 that,

(i) In, aqueous acidic solution the value of $[H_3O^+]$ is more than 10^{-7} M and so the value of pH is less than 7 viz

$$\boxed{\text{For acidic solutions } [H_3O^+] > 10^{-7}M \text{ and pH} < 7}$$

(ii) The acidity of a solution increases as concentration of H_3O^+ increases in aqueous acidic solution and so pH decreases. Opposite to this, as the concentration of H_3O^+ decreases, the acidity of the solution decreases and so pH increases. Thus, aqueous solution having pH 2 is more acidic than the solution having pH 4.

Like pH, the concentration of hydroxide ion OH^- in aqueous solution can also be expressed. **Mathematically, the negative logarithm to the base 10 of concentration of OH^- in aqueous solution is called pOH.** If we write as a formula, then

$$pOH = -\ log_{10}\ [OH^-]$$

As we have discussed earlier, distilled water is neutral and in disstilled water at 298 K,

$$[H_3O^+] = [OH^-] = 1\times\ 10^{-7}M$$

$\therefore \quad [H_3O^+] \times [OH^-] = 10^{-7} \times 10^{-7} = 10^{-14} M$

$\therefore \quad \log_{10}[H_3O^+] + \log_{10}[OH^-] = -14 \log_{10}10$

$\therefore \quad -\log_{10}[H_3O^+] - \log_{10}[OH^-] = 14 \log_{10}10$

$\therefore \quad \boxed{pH + pOH = 14}$

Table 7.3 pH of aqueous basic solutions

$[OH^-]$ in aqueous solution (in molarity)	$pOH = -\log_{10}[OH^-]$	pOH of aqueous solution	pH of aqueous solution
10^{-6}	$pOH = -\log_{10}10^{-6} = 6 \log_{10}10 = 6$	6	8
10^{-5}	$pOH = -\log_{10}10^{-5} = 5 \log_{10}10 = 5$	5	9
10^{-4}	$pOH = -\log_{10}10^{-4} = 4 \log_{10}10 = 4$	4	10
10^{-2}	$pOH = -\log_{10}10^{-3} = 3 \log_{10}10 = 3$	3	11
10^{-2}	$pOH = -\log_{10}10^{-2} = 2 \log_{10}10 = 2$	2	12
10^{-1}	$pOH = -\log_{10}10^{-1} = 1 \log_{10}10 = 1$	1	13
$10^{0} = 1$	$pOH = -\log_{10}10^{0} = 0 \log_{10}10 = 0$	0	14

$[OH^-]$ increases ↓   pH increases ↓

It can be said from Table 7.3 that

(i) In basic aqueous solutions, $[OH^-]$ is more than 10^{-7}M and so its pOH value is less than 7 and the value of pH is more than 7 viz.

$\boxed{\text{For basic aqueous solution } [OH^-] > 10^{-7}M,\ pOH < 7 \text{ and } pH > 7}$

(ii) In aqueous basic solution, as the concentration of OH^- increases, basicity of the solution also increases, and pOH decreases but pH increases. Opposite to this as the concentration of OH^- decreases the basicity of the solution also decreases and pOH increases but pH decreases. Hence an aqueous solution having pH 12 is more basic than the aqueous solution having pH 9.

It is important here, to remember that in every acid, OH^- is present in addtion to H_3O^+ and in every base in addition to OH^-, H_3^+O ions are present if one is more than the other will be less but the product of their concentrations, 10^{-14} remains constant.

In neutral solution concentrations of $[H_3O^+]$ and $[OH^-]$ are equal. As discussed earlier, in distilled water like neutral solution $[H_3O^+] = [OH^-] = 1 \times 10^{-7}$ M at 298 K. Hence, the pH of distilled water becomes 7. Thus, the pH of neutral aqueous solution is 7 viz.

$\boxed{\text{For neutral aqueous solution } [H_3O^+] = [OH^-] = 10^{-7}M \text{ and } pH = 7}$

Thus, from the overall discussion of pH scale, it can be said that pH scale is from 0 to 14. pH scale can be shown as in Fig 7.1

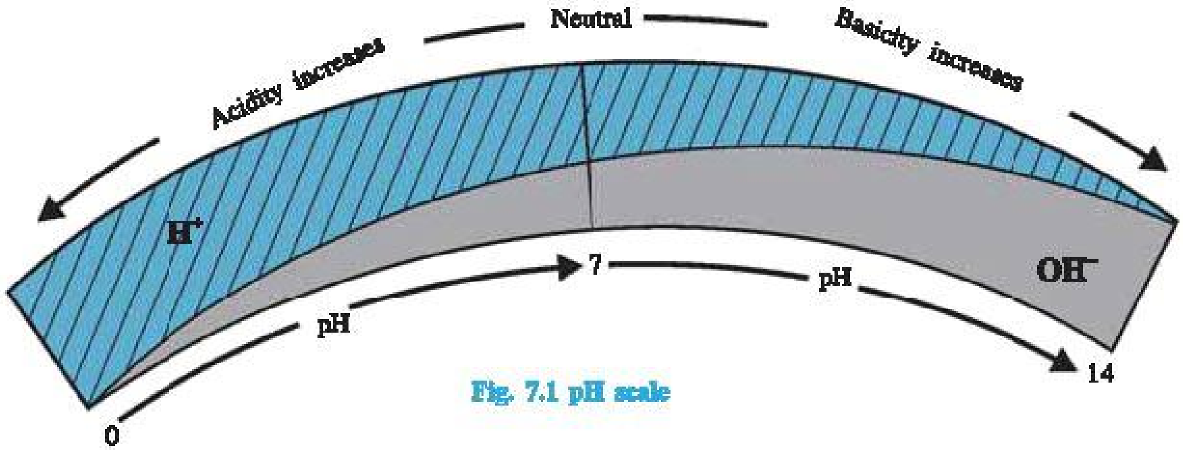


Fig. 7.1 pH scale

Limitations of pH scale :

(1) pH scale is applilcable to aqueous solutions only.

(2) pH scale is applicable to aqueous solutions having concentration of hydornium ion less than 1 M. Hence, pH scale is from 0 to 14.

Measurement of pH :

pH of aqueous solution can be measured by different methods. To measure approximate range of pH of aqueous solution, litmus paper; or approximate pH paper or universal indicator is used and for exact pH measurement the instrument called pH meter is used.

(1) To measure approximate pH range : Red and blue litmus papers are used to measure approximate pH range of aqueous solution. If a blue litmus paper is dipped into a solution, and if it turns red, then it can be said that the aqueous solution has acidic pH. In the same way, if a red litmus paper is dipped into a solution and if turns blue, then it can be said that the solution has basic pH. i.e. the value of pH can be considered between 7 and 14. If no effect is found on red or, blue litmus paper, that is, if red litmus paper remains red and blue litmus paper remains blue then it can be said that the solution is neutral. The pH of such solution is 7. Acidic or basic medium is important for certain reactions in industry. Litmus paper becomes useful in test for the nature of solution.

Fig 7.2 The value of pH according to change in colour of pH paper

(2) Approximate pH measurement : To measure approximate pH of aqueous solution, pH paper or universal indicator is used.

(i) Use of pH paper : Like litmus paper, if the pH paper is dipped into a solution whose pH value is to be known. Generally, the pH paper is of very light yellow colour. The pH of a solution can be determined by noting the change in the colour of pH paper. The information about what will be the pH of the solution when and what colour is obtained, is given with pH paper as shown in Fig 7.2.

If the pH paper is dipped in an aqueous solution and if turns pink, then the apprximate pH of the solution will be 2 . If the pH paper turns light green, then the approximate pH of the solution will be 7. Similarly, if pH paper turns blue then the approximate pH of solution will be 10.

(ii) **Use of Universal indicator :** One or two drops of universal indicator is added to a solution to know the value of pH. The pH of the solution is determined from the colour of the solution obtained during the process. Which colour is obtained is noted and what will be its pH is obtained by comparing with the colours shown on the bottle of the indicator. pH corresponding to the colour will be the pH of the solution. pH paper or universal indicator is mostly used for measurement of approximate pH of the solution during chemical reactions in industry and biochemical reactions.

Fig.7.3 Universal Indicator

(3) **To measure exact pH :** The instrument known as pH meter is used to determine the exact value of pH of aqueous solution. Two elecrodes of the pH meter are dipped in the solution whose exact pH is to be determined. The reading that is shown by the needle of pH meter indicates the exact pH of that solution. pH meter is standardised by a solution of known pH before it is used. Hence, exact pH of unknown solution can be measured. The pH-meter is an essential instrument for chemical industries. Now, we will do the activity of measuring pH of aqueous solutions of different substances.

Activity : 1

pH measurement of different aqueous solutions :

During this activity, ideally distilled water should be used to prepare aqueous solutions of different substances; but tap water can also be used for this activity because we do not have to carry out comparative study of the results.

- First of all take nine test tubes and number them from 1 to 9.
- In the test tube with numbers 1 to 4, take one tea spoon lemon juice, one tea spoon tomato juice, pinch of baking soda and pinch of washing soda respectively. Add water to all those four test tubes to half its level. Shake well each test tube and keep them as side.
- In the remaining 5 to 9 number test tubes take your urine, tap water, distilled water, dilute hydrochloric acid and dilute solution of sodium hydroxide to half its level.
- Arrange those nine test tubes in order in a test tube stand.
- Now, take test tube no.1 and distribute the solution in four equal volumes in three other empty test tubes. Thus, you will have No.1 test tube (lemon juice) solution in all the four test tubes.
- In all the four test tubes add successively red litmus paper, blue litmus paper, pH paper and two drops of universal indicator.
- Note in the observation table, the change in colour of litmus paper, and change in colour of pH paper and the change in colour of the solution to which universal indicator is added. Note also the approximate pH range and pH of solution on the basis of the change in colour.

- On the basis of the pH of the solution, determine its nature (acidic/basic/neutral) and also note them in the observation table.
- In the same way, measure the pH of solutions in test tubes No.2 to 9 and note your observations in the observation table.

Observation Table

Test tube. No.	Solution	Litmus paper			pH paper		Universal Indicator		Nature of Solution
		Change in colour of litmus paper		Approximate pH	Change in colour of pH Paper	Approximate pH	Change in colour of solution	Approximate pH	(Acidic or basic or neutral)
		Red Litmus paper	Blue Litmus paper						
1.	Lemon juice								
2.	Tomato Juice								
3.	Aqueous solution of baking soda								
4.	Aqueous solution of washing soda								
5.	Urine (self)								
6.	Tap water								
7.	Distilled water								
8.	Dilute hydrochloric acid (having concentration less than 1 M)								
9.	Dilute sodium hydroxide (having concentration less than 1 M)								

After finishing this activity, you will be competent to measure pH of aqueous solution of any substance, in this way.

7.6 Importance of pH in Everyday Life

(1) Importance of pH in existence of living beings : The physiological reactions occurring in human body take place in the range of 7.0 to 7.8 pH. Other living beings are not able to bear more change in pH. e.g When the water of acid rain mixes into water reservoirs like river or pond, then the pH of their water decreases. The existence of aquatic life kingdom like fish, micro-organisms and aquatic vegetation are being risked.

(2) Importance of pH in digestion of food : We know that stomach plays an importnat role in the digestion of food. As the food enters the stomach, hydrochloric acid is secreted in the stomach. The pH of this acid changes between 1 and 3. At this low value of pH the enzyme named pepsin becomes active. It becomes helpful in the digestion of protein in the food.

The proportion of protein is much more in food like fish, eggs, meat etc. Hydrochloric acid is secreted more for the digestion of such food. Because of this, sometimes, there is pain or irritation in the stomach. In common language, we call it 'acidity'. Basic substances are taken for the remedy of the acidity. They are known as antacids. Mostly, sodium hydrogen carbonate (Baking soda $NaHCO_3$) and magnesium hydroxide (Milk of magnesia $Mg(OH)_2$)) are used as antacids. Over and above, calcium carbonate ($CaCO_3$) and aluminium hydroxide ($Al(OH)_3$) are also known as antacid substances. Such liquid mixtures and cetrain tablets are available in market.

(3) Importance of pH in soil : The soil whose pH is between 6.5 to 7.3, the growth and development of shrubs is good. The soil having pH value less than 6.5 is called acidic soil. The farmers add lime (CaO) to the soil to neutralise this soil. The soil whose pH is more than 7.3 is called alkaline soil. The farmers add gypsum ($CaSO_4 . 2H_2O$) to neutralise this soil. Now, we will determine the type of the soil of our school, or house or garden or field by doing the activity of measuring pH of soil.

Activity : 2

- **To measure pH of soil and to determine its type.**
- Generally, to determine the pH of soil, the sample of soil is taken at the depth of nine inch in the soil, because the roots of most of the plant and the shrubs in the garden reach to the depth of nine inch. (The sample of soil can be collected from school, garden of the house or a field of the village).
- To prepare the solution of the sample of soil, take about 2 grams of soil sample in a test tube and add 5 ml. distilled water to it. Shake the test tube for a longer period so that soil and water mix properly (For preparation of solution of soil, the proportion of soil and water as 1:2.5 is considered ideal).
- Put the test tube in the stand without disturbance till the soil settles down in the test tube.
- After some time, filter the water layer that has separated in the test tube with the help of filter paper, collect the filtrate in other test tube. The filtrate must be a half to one ml. (Sometimes, the sample of soil is such that added 5 ml of water is being absorbed by the soil and the filtrate is not obtained). In such a case the activity should be repeated by adding 10 ml water instead of 5 ml water).
- Measure the pH of the obtained filtrate with the help of pH paper or universal indicator.
- Determine the type of the soil – acidic, basic or neutral on the basis of value of pH.

(4) Importance of pH in stopping decay of teeth : When the pH of the innerside of the mouth is less than 5.5, the decay of teeth takes place. The outer layer of teeth is made up of hard substance like calcium phosphate ($Ca_3(PO_4)_2$). It does not dissolve in water, but gets decayed when pH of inner side of mouth becomes less than 5.5. Acid is produced by decomposition of particles of food and sachharides by bacteria inside the mouth after taking meals. It decreases the pH inside the mouth. Hence decay of teeth takes place. To protect your teeth, good habit should be formed to clean the teeth after taking meals. The tooth powder and the tooth paste that are used for teeth cleaning possess basic nature. They neutralise the acid produced inside the mouth and protect teeth from decay.

(5) In the remedy of effect of bite of honeybee: We know that when red ant bites we feel irritation. The reason for this is the entry of formic acid in our body. Similarly, when the honey bee bites, we feel pain and irritation at the place of bite. Also, there is swelling around the place of bite: because the poison that is added in our body by the bite of honey-bee is acidic. In this poison, more acidic natured substance Melittin is present. Melittin is a polypeptide containing 26 amino acids. To get relief from the effect of bite of honey-bee, aqueous solutions of basic substance like baking soda is applied around the place of bite, which neutralises the acidic poison.

Table 7.4 The pH values, at 298 K, of some solutions associated with everyday life

No.	Solution	pH
1.	Pure water	7.0
2.	Sea water	8.5
3.	Stomach fluid	1.0 - 3.0
4.	Saliva	6.5 - 7.5
5.	Blood	7.4
6.	Urine	5.5 - 7.5
7.	Milk	6.3 - 6.6
8.	Lemon juice	2.2 - 2.4
9.	Tomato juice	4.0 - 4.4
10.	Coffee	4.5 - 5.5
11.	Aqueous solution of baking soda	8.5
12.	Aqueous solution of washing soda	12.0
13.	Milk of magnesia	10.5
14.	Vinegar (4%)	2.5

Example 3 :

Calculate pH of aqueous solution whose H_3O^+ concentration is 2.5×10^{-5}M. Which nature–acidic, basic or neutral – this solution will possess ?

Solution : In aqueous solution $[H_3O^+] = 2.5 \times 10^{-5}$ M

$$\text{Now,} \quad pH = -log_{10}[H_3O^+]$$

$$= -log_{10}(2.5 \times 10^{-5})$$

$$= -log_{10}(2.5) - \log_{10} 10^{-5} \quad (\because log(mn) = logm + logn)$$

$$= -log_{10}(2.5) + 5 \log_{10}10$$

Using logaritham table,

$$= -0.3979 + 5 \quad (\because \log_{10}10 = 1)$$

$$\therefore \quad pH = 4.6021 \simeq 4.60$$

Thus, the value of pH of an aqueous solution having concentration 2.5×10^{-5} M will be 4.60. The concentration of H_3O^+ is more than 10^{-7}M and pH is less than 7, so the solution will possess acidic nature.

Example 4 :

Calculate concentration of H_3O^+ in an aqueous solution whose pH value is 5.5.

Solution : $\quad pH = -log_{10} [H_3O^+]$

$$\therefore \quad 5.5 = -log_{10} [H_3O^+]$$

$$\therefore \quad log_{10}[H_3O^+] = -5.5$$

$$\therefore \quad log_{10}[H_3O^+] = 6 - 5.5 - 6$$

$$\therefore \quad log_{10}[H_3O^+] = -6 + 0.5$$

$$\therefore \quad log_{10}[H_3O^+] = \bar{6}.5000$$

$$\therefore \quad [H_3O^+] = \text{antilog}\ (\bar{6}.5000)$$

$$= 0.3162 \times 10^{-5} \text{ M}$$

$$\therefore \quad [H_3O^+] = 3.162 \times 10^{-6} \text{ M}$$

$$\therefore \quad [H_3O^+] = 3.16 \times 10^{-6} \text{ M}$$

Thus, the value of pH is less than 7 and concentration of H_3O^+ in aqueous solution is more than 10^{-7} M and so the solution will be acidic.

7.7 Comparison of Concentrations of Acid-Base on the Basis of pH

Earlier in point 7.5 we have understood that the aqueous solution having pH 2 is more acidic than, the aqueous solution having pH 4 and the aqueous solution having pH 12 is more basic than the aqueous solution having pH 9. But the question will arise that how many times acidic or basic those solutions will be ? Let us understand this matter with an example.

Example 5 :

How many times the aqueous solution having pH 2 will be more acidic than aqueous solution having pH 4 ?

Solution : For aqueous solution having pH 4,

$pH = -log_{10}[H_3O^+]$

$\therefore \quad -log_{10}[H_3O^+] = 4$

$\therefore \quad log_{10}[H_3O^+] = -4$

$\therefore \quad [H_3O^+] = 10^{-4}$ M $\quad (\because log_a b = m$ for $a^m = b)$

Similarly $[H_3O^+]$ in aqueous solution having pH 2 = 10^{-2}M

$$\frac{[H_3O^+] \text{ in aqueous solution having pH 2}}{[H_3O^+] \text{ in aqueous solution having pH 4}} = \frac{10^{-2}M}{10^{-4}M} = 10^2 = 100$$

Thus, the concentration of aqueous solution having pH 2 is 100 times more concentrated than the aqueous solution having pH 4, i.e. it will be 100 times more acidic.

Thus, the comparison of acidity of the aqueous solutions A and B having different pH can be carried out according to Table 7.5.

Table 7.5 Comparison of acidity of two acidic aqueous solutions

pH of solution A	pH of Solution B	$[H_3O^+]$ in Solution A (in molarity)	$[H_3O^+]$ in Solution B (in molarity)	How much less is the pH of Solution A than pH of Solution B	How many times is the concentration of H_3O^+ in solution of A than the concentration in solution of B ?
5	6	10^{-5}	10^{-6}	1	10^1 = 10
3	5	10^{-3}	10^{-5}	2	10^2 = 100
2	5	10^{-2}	10^{-5}	3	10^3 = 1000
2	6	10^{-2}	10^{-6}	4	10^4 = 10000
1	6	10^{-1}	10^{-6}	5	10^5 = 100000
2	4.5	10^{-2}	$10^{-4.5}$	2.5	$10^{2.5}$ = antilog(2.5) = 316.2
1.9	5.3	$10^{-1.9}$	$10^{-5.3}$	3.4	$10^{3.4}$ = antilog (3.4) = 2152

Thus, it can be said from Table 7.5 that if the diffrence in pH of two acidic aqueous solutions is x, then solution having less pH will possess H_3O^+ concentration 10^x times or antilog x times more acidic.

Now, we shall study Table 7.6 to compare the basicity of two basic aqueous solutions A and B having different pH values.

Table 7.6 Comparison of basicity of two basic aqueous solutions

pH of Solution A	pH of Solution B	pOH of Solution A	pOH Solution B	$[OH^-]$ in Solution A (in molarity)	$[OH^-]$ in Solution B (in molarity)	How much more is the pH of Solution B than pH of Solution A	Concentration of OH^- in Solution B is how many times more than that of Solution A
12	13	2	1	10^{-2}	10^{-1}	1	$10^1 = 10$
11	13	3	1	10^{-3}	10^{-1}	2	$10^2 = 100$
9	12	5	2	10^{-5}	10^{-2}	3	$10^3 = 1000$
8	12	6	2	10^{-6}	10^{-2}	4	$10^4 = 10000$
8	13	6	1	10^{-6}	10^{-1}	5	$10^5 = 100000$
9.3	12.8	4.7	1.2	$10^{-4.7}$	$10^{-1.2}$	3.5	$10^{3.5}$ = antilog(3.5) = 3612
8.9	11.5	5.1	2.5	$10^{-5.1}$	$10^{-2.5}$	2.6	$10^{2.6}$ = antilog(2.6) = 398.1

Thus, it can be said from Table 7.6, that if x is the difference between pH of two basic aqueous solutions, then solution having more pH possesses, OH^- concentration 10^x or antilog x times more than the solution having less pH, i.e. that solution will be 10^x or antilog x times more basic.

(1) Strong and Weak Acids :

If we try to prepare the list of known acids, then we can conclude that acids like hydrochloric acid, sulphuric acid, nitric acid are used in laboratory and acids like acetic acid (in vinegar), lactic acid in curd, butter milk, citric acid (in lemon, orange), tartaric acid (in tamarind), oxalic acid (in tomato) are used in everyday life. Out of these acids, if mineral acids like hydrochloric acid, sulphuric acid and nitric acid, when dissolved in water, they get completely ionised. These acid subtances are known as strong acids. In the aqueous solution of strong acid, total solute substance is in the form of ions, i.e. the solute substance is ionised to H_3O^+

Example :

(1) In 1 M HCl aqueous solution, concentrations of H_3O^+ and Cl^- are 1 M

$$\underset{1\,M}{HCl(aq)} + H_2O(l) \rightarrow \underset{1\,M}{H_3O^+(aq)} + \underset{1\,M}{Cl^-(aq)}$$

(2) In 1 M H_2SO_4 aqueous solution, concentrations of H_3O^+ and SO_4^{2-} are 2 M and 1 M respectively, because two moles H_3O^+ are formed by ionisation of one mole H_2SO_4.

$$\underset{1\ M}{H_2SO_4(aq)} + 2H_2O(l) \rightarrow \underset{2\ M}{2H_3O^+(aq)} + \underset{1\ M}{SO_4^{2-}(aq)}$$

When acetic acid, lactic acid, citric acid, tartaric acid, oxalic acid are dissolved in water, there is incomplete ionisation of them. These acid-substances are known as weak acids. In aqueous solutions of weak acid, very less amount of solute is ionised to H_3O^+, the remaining amout exists in undissociated form, i.e. concentration of H_3O^+ is not 1 M in 1 M CH_3COOH aqueous solution but it is very less (Approximately 2 to 3%). Immediately, a question will strike to our mind, that what will be H_3O^+ concentration in this solution. To get the answer of this questions we need first to know ionisation constant K_a of CH_3COOH and will have to do some calculations. We shall study these calculations in Standard 11. At present, we shall study that **the acid which ionises or dissociates completely in aqueous solution is called strong acid, and the acid which ionises or dissociates incompletely is called a weak acid.**

We use the words like concentrated and dilute in the laboratory. e.g. concentrated hydrochloric acid, dilute hydrochloric acid, concentrated sulphuric acid, dilue sulphuric acid, concentrated nitric acid, dilute nitric acid etc. In concentrated solution the amount of solute substance is in larger propotion while in dilute solutions it is much less. Hydrochloric acid having concentration 35-38%, sulphuric acid having concentration 98%, nitric acid having concentration 70-72% and acetic acid having concentration 100% are concentrated acids. To prepare dilute solutions of these acids, three parts of water is taken to which one part of acid is added. Both strong and weak acids can be concentrated acid and dilute acid. We find this acid in laboratory in both the concentrated and dilute forms. Similarly acetic acid is a weak acid and it is available in laboratory, in both the concentrated and dilute forms. We should clearly understand that concentrated and dilute have no relation with strong and weak. Storng and weak types are called on the basis of their ionisation while concentrated and dilute show their magnitude or the amount of solute dissolved.

(2) Strong and Weak Bases :

Strong and Weak Bases : Sodium hydroxide, potassium hydroxide when dissolved in water, they are completely ionised. These basic substances are known as strong bases. In aqeuous basic solution, total solute substance is in the form OH^- ions because of its complete ionisation, i.e. the total solute substance is ionised in the form of OH^- .

Example :

1 M NaOH aqueous solution, the concentrations of Na^+ and OH^- are 1 M .

$$\underset{1\ M}{NaOH(aq)} \rightarrow \underset{1\ M}{Na^+(aq)} + \underset{1\ M}{OH^-(aq)}$$

The known bases like ammonium hydroxide (NH_4OH) when dissolved in water, they are incompletely ionised. These substances are called weak bases. Aqueous solution of calcium hydroxide is weak base. In the aqueous solution of weak base, very less amount (2 to 3%) of solute is ionised to OH^- i.e. In aqueous solution of 1M NH_4OH, the concentration of OH^- is not 1 M but it is very less. We shall study the calculation of OH^- concentration in weak base in Standard 11. At present we shall study only this much that **the base which ionises or dissociates completely is called strong base and the base which ionises or dissociates partially or incompletely is called weak base.**

Example 6 :

Calculate pH of aqueous solution of 0.05 M HCl

Solution : HCl being a stong acid ionises completely in water.

$$HCl(aq) + H_2O(l) \xrightarrow[\text{ionisation}]{\text{complete}} H_3O^+(aq) + Cl^-(aq))$$

0.05 M   0.05 M

Here, $[H_3O^+] = 0.05$ M

$$\begin{aligned} \text{Now, pH} &= -\log_{10}[H_3O^+] \\ &= -\log_{10}(0.05) \\ &= -\log_{10}(5 \times 10^{-2}) \\ &= -\log_{10}5 + 2\log_{10}10 \\ &= -0.6990 + 2 \\ &= 1.3010 \\ &\approx 1.30 \end{aligned}$$

Thus, pH of aqueous solution of 0.05 M HCl will be 1.30.

Example 7 :

Calculate pH of aqueous solution of 0.007 M NaOH

Solution : As NaOH is a strong base, it is completely ionised.

$$NaOH(aq) + H_2O\ (l) \xrightarrow[\text{ionisation}]{\text{complete}} Na^+(aq) + OH^-(aq)$$

0.007M   0.007M

Here, $[OH^-] = 0.007$ M

$$\begin{aligned} \text{Now, pOH} &= -\log_{10}[OH^-] \\ &= -\log_{10}(0.007) \\ &= -\log_{10}(7 \times 10^{-3}) \\ &= -\log_{10}7 + 3\log_{10}10 \\ &= -0.8451 + 3 \\ \therefore \quad \text{pOH} &= 2.1549 \end{aligned}$$

But NaOH being base, its pH can be calculated as follows :

We know that pH + pOH = 14

$\therefore \quad pH = 14 - 2.1549$

$\therefore \quad pH = 11.8451 \approx 11.85$

Thus, pH of 0.007 M aqueous solution of NaOH will be 11.85

Example 8 :

3 litre aqueous solution is prepared by dissolving 4.9 gram H_2SO_4 in water, calculate pH of this solution.

Solution : To calculate pH of an aqueous solution, we should know concentration of H_3O^+ in the solution, in molelitre^{-1}.

Molecular mass of H_2SO_4 is 98 gram mole^{-1}

$$\text{Moles of } H_2SO_4 = \frac{\text{Weight of } H_2SO_4}{\text{Molecular mass of } H_2SO_4}$$

$$= \frac{4.9 \text{ gram}}{98 \text{ gram mole}^{-1}}$$

$$= 0.05 \text{ mole}$$

$$\text{Concentration of } H_2SO_4 \text{ (mole litre}^{-1}) = \frac{\text{Moles of } H_2SO_4}{\text{Volume of solution (Litre)}}$$

$$= \frac{0.05 \text{ mole}}{3 \text{ litre}}$$

$$= 0.0167 \text{ mole litre}^{-1}$$

H_2SO_4 is a storng acid and it is completely ionised in water.

$$\underset{0.0167\text{ M}}{H_2SO_4(aq)} + 2H_2O(l) \xrightarrow[\text{ionisation}]{\text{complete}} \underset{\substack{2 \times 0.0167\text{ M} \\ = 0.0334\text{ M}}}{2H_3O^+(aq)} + SO_4^{2-}(aq)$$

Here, $[H_3O^+] = 0.0334$ M

$$\begin{aligned}
\text{Now, } pH &= -\log_{10}[H_3O^+] \\
&= -\log_{10}(0.0334) \\
&= -\log_{10}(3.34 \times 10^{-2}) \\
&= -\log_{10}(3.34) + 2\log_{10}10 \\
&= -0.5237 + 2 \\
&= 1.4763 \\
&\approx 1.48
\end{aligned}$$

$\therefore \quad pH = 1.48$

Thus, pH of H_2SO_4 solution will be 1.48

Example 9 :

An aqueous solution of nitric acid has pH 2.32 at 298 K temperature. The volume of this solution is made eight times than its original volume. What will be the pH of this dilute solution obtained ?

Solution : Here, pH of aqueous solution of nitric acid is 2.32.

$$pH = 2.32$$

$$\therefore \quad -\log_{10}[H_3O^+] = 2.32$$

$$\therefore \quad \log_{10}[H_3O^+] = -2.32$$

$$\therefore \quad \log_{10}[H_3O^+] = 3 - 2.32 - 3$$

$$\therefore \quad \log_{10}[H_3O^+] = 0.68 - 3$$

$$\therefore \quad \log_{10}[H_3O^+] = \bar{3}.68$$

$$\therefore \quad [H_3O^+] = \text{antilog}\ (\bar{3}.68)$$

$$= 0.4786 \times 10^{-2}\ M$$

When water is added to aqueous solution of nitric acid and the original volume of the solution is increased by 8 times, the concentration of solution will be decreased by 8 times.

$\therefore$ $[H_3O^+]$ in diluted aqueous solution of nitric acid $= \dfrac{0.4786 \times 10^{-2}\ M}{8}$

$$= 0.0598 \times 10^{-2} M$$

$$= 5.98 \times 10^{-4} M$$

Now, $\quad pH = -\log_{10}[H_3O^+]$

$$= -\log_{10}(5.98 \times 10^{-4})$$

$$= -\log_{10}(5.\ 98) + 4\ \log_{10}10$$

$$= -\ 0.7767 + 4$$

$$= 3.2233$$

$$\approx 3.22$$

$$\therefore\ pH = 3.22$$

Thus, pH of diluted nitric acid will be 3.22.

7.8 Neutralisation

Salt and water are formed by reaction of acid with base or base with acid. This reaction is known as neutralisation. With the help of the experiment based on this reaction, the concentration of unknown acid or base can be known. This experiment is called neutralisation titration.

Its general study has been done by you in earlier standards, and detailed understanding through experiments will be studied in next standards. Now, we study neutralisation reactions between some acids and bases.

(1)	$HCl(aq)$	+	$NaOH(aq)$	$\rightarrow$	$NaCl(aq)$	+	$H_2O(l)$
	Strong acid		Strong base		Salt		Water
(2)	$HNO_3(aq)$	+	$KOH(aq)$	$\rightarrow$	$KNO_3(aq)$	+	$H_2O(l)$
	Strong acid		Strong base		Salt		Water
(3)	$H_2CO_3(aq)$	+	$2NaOH(aq)$	$\rightarrow$	$Na_2CO_3(aq)$	+	$2H_2O(l)$
	Weak acid		Stong base		Salt		Water
(4)	$CH_3COOH(aq)$	+	$NaOH(aq)$	$\rightarrow$	$CH_3COONa(aq)$	+	$H_2O(l)$
	Weak acid		Stong base		Salt		Water
(5)	$HCl(aq)$	+	$NH_4OH(aq)$	$\rightarrow$	$NH_4Cl(aq)$	+	$H_2O(l)$
	Strong acid		Weak base		Salt		Water
(6)	$HNO_3(aq)$	+	$NH_4OH(aq)$	$\rightarrow$	$NH_4NO_3(aq)$	+	$H_2O(l)$
	Strong acid`		Weak base		Salt		Water
(7)	$CH_3COOH(aq)$	+	$NH_4OH(aq)$	$\rightarrow$	$CH_3COONH_4(aq)$	+	$H_2O(l)$
	Weak acid		Weak base		Salt		Water
(8)	$H_2CO_3(aq)$	+	$2NH_4OH(aq)$	$\rightarrow$	$(NH_4)_2CO_3(aq)$	+	$2H_2O(l)$
	Weak acid		Weak base		Salt		Water

Will the pH of all the salts produced by all these reactions will be neutral or pH will be 7 ? No. The pH of aqueous solutions of salts Na_2CO_3 and CH_3COONa produced by reactions (3) and (4) is more than 7, because the salt hydrolyses in water and produces OH^-.

(9) $Na_2CO_3(aq) \xrightarrow{\text{Ionisation}} 2Na^+(aq) + CO_3^{2-}(aq)$

$CO_3^{2-}(aq) + H_2O(l) \xrightarrow{\text{Hydrolysis}} HCO_3^-(aq) + OH^-(aq)$

(10) $CH_3COONa\ (aq) \xrightarrow{\text{Ionisation}} CH_3COO^-(aq) + Na^+(aq)$

$CH_3COO^-(aq) + H_2O(l) \xrightarrow{\text{Hydrolysis}} CH_3COOH(aq) + OH^-(aq)$

Thus, the aqueous solutions or the salts produced by neutralisation of weak acid with strong base possesses basic nature. The pH of aqueous solution of salts NH_4Cl and NH_4NO_3 produced by reactions (5) and (6) have pH less than 7, because the salt hydrolyses in water and produces H_3O^+.

(11) $NH_4Cl(aq) \xrightarrow{\text{Ionisation}} NH_4^+(aq) + Cl^-(aq)$

$NH_4^+(aq) + H_2O(l) \xrightarrow{\text{Hydrolysis}} NH_3(aq) + H_3O^+(aq)$

(12) $NH_4NO_3(aq) \xrightarrow{\text{Ionisation}} NH_4^+(aq) + NO_3^-(aq)$

$NH_4^+(aq) + H_2O(l) \xrightarrow{\text{Hydrolysis}} NH_3(aq) + H_3O^+(aq)$

Thus, **the aqueous solutions of salts produced by neutralisation of weak base and strong acid possess acidic nature.** The pH of aqueous solution of salts NaCl and KNO_3 produced by reaction (1) and (2) have pH 7, because they do not hydrolyse like the salts produced by reactions (3) to (6). Thus, **the aqueous solutions of salts produced by strong acid and strong base possess neutral nature.**

The pH of the aqueous solutions of the salts CH_3COONH_4 and $(NH_4)_2CO_3$ produced by reactions (7) and (8) have pH 7 and slightly more than 7 respectively. The pH of the aqueous solutions of this type of salts have sometimes pH less than 7. If **acid and base are equally weak then the aqueous solution of the salt produced is neutral, otherwise, it may be acidic or basic according to difference in their weakness.**

The discussion about nature of aqueous solutions of salts produced during neutralisation is given in Table 7.7

Table 7.7 Nature of aqueous solution produced during neutralisation

Acid	Base	Example of salt produced	Nature of aqueous solution of salt
Strong	Strong	NaCl, KNO_3	Neutral
Strong	Weak	NH_4Cl, NH_4NO_3	Acidic
Weak	Strong	Na_2CO_3, CH_3COONa	Basic
Weak	Weak	CH_3COONH_4, $(NH_4)_2CO_3$	Neutral or slightly acidic or slightly basic

If you desire, you can test the nature of the salts mentioned in Table 7.7 by preparing the aqueous solution of the salt in distilled water and test with the help of litmus paper, pH paper or universal indicator.

7.9 Salt

Salt is available in large proportion in nature. The minerals and rocks in the form of the cover of the earth are directly or indirectly salts. Common salt (NaCl), baking soda ($NaHCO_3$) and washing soda ($Na_2CO_3.10H_2O$) used in everyday life are salts. The substances like sodium chloride (NaCl), sodium sulphate (Na_2SO_4), ammonium chloride (NH_4Cl), calcium chloride ($CaCl_2$), calcium sulphate ($CaSO_4$), barium sulphate ($BaSO_4$), potassium sulphate (K_2SO_4), silver nitrate ($AgNO_3$), silver chloride (AgCl), barium chloride ($BaCl_2$) etc. are also the examples of the salt. Salt can be prepared in the laboratory by reaction of acid with base or base with acid. Like acid and base, salts also exhibit chemical properties.

Chemical Properties of Salts

(1) **Reaction of salt with acid :** Salt reacts with certain acids and forms other salt and acid.

$$\text{Salt} + \text{Acid} \rightarrow \text{Other salt} + \text{Acid}$$

e.g.

$$BaCl_2(aq) + H_2SO_4(aq) \rightarrow BaSO_4(s) + 2HCl(aq)$$

$$AgNO_3(aq) + HCl(aq) \rightarrow AgCl(s) + HNO_3(aq)$$

(2) **Reaction of salt with base :** Salt reacts with certain bases and form other salt and base.

$$\text{Salt} + \text{Base} \rightarrow \text{Other salt} + \text{Base}$$

e.g.

$$Na_2SO_4(aq) + Ba(OH)_2(aq) \rightarrow BaSO_4(s) + 2NaOH(aq)$$

$$K_2SO_4(aq) + Ca(OH)_2(aq) \rightarrow CaSO_4(s) + 2KOH(aq)$$

(3) **Reaction of salt with other salt :**

$$\text{Salt} + \text{Other Salt} \rightarrow \text{New Salt} + \text{New salt}$$

e.g.

$$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$$

$$CaCl_2(aq) + Na_2SO_4(aq) \rightarrow CaSO_4(s) + 2NaCl(aq)$$

You can test the properties of all the three salts in the laboratory.

What have you learnt ?

- About three hundred years ago Robert Boyle defined acid-base on the basis of chemical properties. This type of definition is known as operational or old definition.
- **Modern concepts about acid-base.**

(1) **Arrhenius Acid-Base theory :** "Acid is a compound containing hydrogen which produces hydrogen ion (H^+) in its aqueous solution and base is a compound containing hydroxide which produces hydroxide ion in its aqueous solution." In the basis of this theory the concept of ionisation is involved.

(2) **Bronsted-Lowry Acid-Base theory :** "The substance which can donate a proton (H^+) to other substance is called Bronsted-Lowry Acid. The substance which accepts a proton (H^+) from other substance is called Bronsted-Lowry base." Thus, on the basis of this theory, the concept of proton transfer is involved.

- **From which and how acid and base are prepared ?**

(1) Non-metal oxide + Water $\rightarrow$ Acid

(2) Metal oxide + Water $\rightarrow$ Base

- **Chemical properties of Acid :**

(1) Acid + Metal $\rightarrow$ Salt + Dihyrogen gas

(2) Acid + Base $\rightarrow$ Salt + Water

(3) Acid + Metal oxide $\rightarrow$ Salt + Water

(4) Acid + Metal carbonate / Metal hydrogen carbonate $\rightarrow$ Salt + Water + Carbon dioxide gas

- **Chemical properties of base :**

(1) Base + Acid → Salt + Water

(2) Base + Nonmetal oxide → Salt + Water

(3) Base + Metal → Salt + Diyhdrogen gas

The concentration of aqueous solutions of acid, base and salt are generally expressed in molarity. Molarity means concentration in molelitre^{-1}. If 1 mole solute is dissolved in 1 litre solution then it can be said that the molarity of the solution is 1. In other words, if we say, if an amount equal to one gram molecular mass of a solute is dissolved in 1 litre solution then the concentration of solution (molarity) can be said to be 1 (1 molar or 1 M)

In 1929, Biochemist of Denmark, S.P.L Sorensen suggested a simple and convenient method to express concentration of hydronium ion in aqueous solution, which is known as pH scale.

- $pH = - \log_{10}[H_3O^+]$
- $pOH = - \log_{10}[OH^-]$
- $pH + pOH = 14$
- For acidic aqueous solution $[H_3O^+] > 10^{-7}$ M and pH < 7 and as $[H_3O^+]$ inceraes pH decreases.
- For basic aqueous solution $[OH^-] > 10^{-7}$ M, pOH< 7 and pH > 7 and as $[OH^-]$ increases pOH decreases but pH increases.
- For neutral solution $[H_3O^+] = [OH^-] = 10^{-7}$ M and pH = 7
- pH scale ranges from 0 to 14.
- pH scale is applicable to aqueous solutions.
- pH scale is applicable to aqueous solutions having hydronium ion concentration less than 1 M.
- To measure approximate pH range of an aqueous solution, litmus paper, for approximate pH, pH paper or universal indicator and for exact pH measurement, pH meter instrument is used.
- If the difference between pH of two aqueous acidic solutions is x, then the solution having less pH possesses H_3O^+ concentration 10^x or antilog x times more than the aqueous solution having more pH, i.e. that solution is 10^x or antilog x times more acidic.
- If the difference between pH of two aqueous basic solutitons is x, then the pH of the aqueous solution having more pH has concentration 10^x or antilog x times more than the concentration of OH^- of the aqueous solution having less pH i.e. the solution is 10^x or antilog x times more basic.
- The substances like acid or base which ionise completely in water when dissolved are called strong acid or strong base and if ionisation is incomplete, they are called weak acid or weak base.
- **Strong acids :** HCl, HNO_3, H_2SO_4

- **Weak acids :** Acetic acid, lactic acid, citric acid, tartaric acid, oxalic acid.
- **Strong base :** NaOH, KOH
- **Weak base :** NH_4OH, $Ca(OH)_2$

Reaction of acid with base or base with acid results in the formation of salt and water. This reaction is called neutralisation reaction.

Type of acid	Type of Base	Example of Salt formed	pH of aqueous solution of salt and its nature
Strong	Strong	$NaCl$, KNO_3	pH = 7 (Neutral)
Stong	Weak	NH_4Cl, NH_4NO_3	pH < 7 (Acidic)
Weak	Strong	Na_2CO_3, CH_3COONa	pH > 7 (Basic)
Weak	Weak	CH_3COONH_4, $(NH_4)_2CO_3$	pH = 7 or slightly more or less than 7 (Neutral or Slightly acidic or slightly basic)

- **Chemical properties of salts :**

(1) Salt + Acid $\rightarrow$ Other salt + Other acid

(2) Salt + Base $\rightarrow$ Other salt + Other base

(3) Salt + Other salt $\rightarrow$ New salt + New salt

EXERCISE

1. Select the proper choice from the given multipule choices :

(1) What is formed by reaction of non-metal oxide with water ?

(A) Acid (B) Base (C) Salt (D) Metal

(2) Acid + Metal-oxide $\rightarrow$?

(A) Base + Water (B) Salt + Water (C) Base + Salt (D) Metal + Salt

(3) Which gas is produced by reaction of base with metal ?

(A) Carbon dioxide (B) Dioxygen (C) Dihydrogen (D) Dinitrogen

(4) 500 ml aqueous solution is prepared by dissolving 2 moles of HCl in water. What will be the molarity of this solution ?

(A) 1 (B) 2 (C) 3 (D) 4

(5) What is correct for acidic aqueous solution ?

(A) $[H_3O^+] = 10^{-7}$ M (B) $[H_3O^+] < 10^{-7}$M

(C) $[H_3O^+] > 10^{-7}$ M (D) $[H_3O^+] < [OH^-]$

(6) Which of the following solutions is the most basic ?

(A) pH = 8.2 (B) pH = 9.3 (C) pH = 11.5 (D) pH = 10.6

(7) Which statement is incorrect ?

(A) pH scale was presented by S.P.L Sorensen.

(B) pH scale ranges between 0 to 14.

(C) pH scale is applicable to only non-aqueous solutions.

(D) pH scale is applicable to only aqueous solutions.

(8) How is the exact pH of an aqueous solution measured ?

(A) pH paper (B) Litmus paper

(C) pH meter (D) Universal indicator

(9) Which of the following substances is an antacid ?

(A) NaCl (B) $Mg(OH)_2$ (C) HCl (D) H_2SO_4

(10) The aqueous solution having pH 11 is how many times less basic than aqueous solution having pH 8 ?

(A) 3 (B) 30 (C) 300 (D) 1000

(11) Which of the following is strong acid ?

(A) Acetic acid (B) Citric acid (C) Nitric acid (D Oxalic acid

(12) What type of substance is NH_3 ?

(A) Strong acid (B) Weak acid (C) Strong base (D) Weak base

(13) pH + pOH = ?

(A) 7 (B) 0 (C) 14 (D) 10

(14) Which formula is correct ?

(A) Mole = Molecular mass / Weight (B) Mole = Weight / Molecular mass

(C) Mole = Weight / Litre (D) Mole = Molecular mass / Litre

(15) What will be the pH of aqueous solution of NH_4 Cl ?

(A) pH = 7 (B) pH > 7 (C) pH < 7 (D) pH = 0

(16) Which of the following solutions will have pH = 2 ?

(A) 0.01 M HCl (B) 0.02 M HCl (C) 0.01M H_2SO_4 (D) 0.02M H_2SO_4

(17) What will be OH^- concentration in aqueous solution having pH = 8 ?

(A) 1×10^{-8} M (B) 1×10^{-6} M (C) 8×10^{-6} M (D) 8×10^{-8} M

(18) If the pH of aqueous solutions A, B, C and D are 1.9, 2.5, 2.1 and 3.0 then what will be the order of acidity ?

(A) A < C < B < D (B) D < C < B < A

(C) D < B < C < A (D) D > C > B > A

(19) Which solution will be basic ?

(A) $[H_3O^+] = 10^{-5}$M (B) $[H_3O^+] = 10^{-12}$M

(C) $[H_3O^+] = 10^{-7}$M (D) $[H_3O^+] = 10^{-4}$M

(20) Which substance is present in poison of honey bee ?

(A) Lime (B) Calcium phosphate

(C) Mellitin (D) Pepsin.

2. Answer the following questions in brief :

(1) Write names of two Arrhenius acids and bases.

(2) Write products of reaction of acid with metal.

(3) Mention names of four methods of expressing concentration of a solution.

(4) Which scientist presented pH scale ? Write the formula of pH.

(5) Write names of two methods to measure approximate pH of aqueous solution.

(6) Mention names of two strong acids and two strong bases.

(7) Write names of two weak acids and two weak bases.

(8) Give definitions :

(i) Arrhenius acid, (ii) Arrhenius base, (iii) Bronsted-Lowry acid, (iv) Bronsted-Lowry base, (v) Concentration of solution, (vi) pH of solution, (vii) pOH of solution, (viii) Strong acid, (ix) Weak acid, (x) Strong base, (xi) Weak base, (xii) Neutralisation reaction, (xiii) 1 M concentration

(9) Mention the formula, name and physical state of the products of following reactions :

(1) $CO_2(g) + H_2O(l) \rightarrow$ (2) $Li_2O(s) + H_2O(l) \rightarrow$

(3) $H_2SO_4(aq) + 2KOH(aq) \rightarrow$ (4) $2HCl(aq) + Ca(s) \rightarrow$

(5) $2HNO_3(aq) + CaO(s) \rightarrow$ (6) $2HCl(aq) + Na_2CO_3(aq) \rightarrow$

(7) $NaOH(aq) + HCl(aq) \rightarrow$ (8) $BaCl_2(aq) + H_2SO_4(aq) \rightarrow$

(9) $Ca(OH)_2(aq) + CO_2(g) \rightarrow$ (10) $HNO_3(aq) + NH_4OH(aq) \rightarrow$

(11) $Na_2SO_4(aq) + Ba(OH)_2(aq) \rightarrow$ (12) $AgNO_3(aq) + NaCl(aq) \rightarrow$

3 (A) Answer the following questions :

(1) Write two chemical properties of acid.

(2) Write two chemical properties of base.

(3) Write two chemical properties of salt.

(4) Deduce pH + pOH = 14

(5) Explain the importance of pH in digestion of food.

(6) Write chemical equations of four neutralisation reactions.

(B) Solve the following problems :

(1) Calculate pH of an aqueous solution having H_3O^+ concentration equal to 7.9×10^{-11} M. Which nature, acidic, basic or neutral will be possessed by this aqueous solution.

(2) Calculate pH of 0.00424 M aqueous solution of KOH.

(3) How many times concentrated will be the aqueous solution having pH 11.9 as compared to aqueous solution having pH 8 ?

(4) How will you prepare 500 ml aqueous solution of 0.2 M H_2SO_4 ?

(5) How will you prepare 125 ml 0.03 M aqueous solution of KOH.

4. (A) Answer the following questions in detail :

(1) Explain giving example, Arrhenius acid-base theory. Mention the limitations of this theory.

(2) Discuss Bronsted-Lowry Acid-base theory.

(3) Discuss methods to measure pH of aqueous solution.

(B) Solve the following problems :

(1) $[OH^-]$ in aqueous solution A is $= 4.3 \times 10^{-4}$ M and $[H_3O^+]$ in aqueous solution of B is 7.3×10^{-10} M, pH of which solution will be less ? Which solution will be more basic ?

(2) Calculate the concentration of OH^- in aqueous solution having pH value 9.3.

(3) 8 gram NaOH is dissolved in water and the aqueous solution is made to 5 litres. Find pH of this solution.

5. (A) Answer the following questions in detail :

(1) With reference to pH scale,

(i) Write formula of pH and pOH

(ii) Mention pH and concentration of H_3O^+ or OH^- in acidic, basic and neutral aqueous solutions.

(iii) Mention limitations of pH scale.

(2) Explain importance of pH in everyday life.

(3) "The aqueous solution of the salt produced by neutralisation of weak acid and strong base possesses basic nature, while aqueous solution of salt produced by neutralisation of weak base and strong acid possesses acidic nature" - Explain.

(B) Solve the following problems :

(1) pH of aqueous solution of potassium hydroxide at 298 K temperature is 11.65. The initial volume of this solution is made 6 times by addition of water. What will be the pH of the diluted solution ?

(2) What will be the change in the value of pH if the concentration of aqueous solution of HNO_3 is increased to 0.05 M from 0.03 M ?

UNIT

8

METALS

8.1 Introduction

As studied in Standard-9, 114 elements are discovered till today. These elements are classified into metals, non-metals and semimetals (metalloids). Most of these elements are metals. They differ from other metals because of their individual property. Different metals are used at different places on the basis of their properties, viz. Aluminium is a light metal. A thin and strong foil like paper can be prepared from it. Also, it does not get corroded. Hence, aluminium metal is used for packing food materials and food products as well as filling vessels for cold drinks. Copper is useful in preparation of wires for conduction of electricity as it is a good conductor and is ductile. Gold, silver and platinum metals are inert and possess high lustre and they are used in preparation of ornaments. Liquid metal like mercury is used in thermometers. Lead metal is used in industries as a waterproof layer around the walls of the chimney. Lead metal is used in preparation of pipes for flow of water and to get protection from radiations. Thus pure forms of metals like gold, silver, copper, platinum, aluminium, mercury and lead are used in greater proportions, but we see certain things around us which are formed of more than one metal viz, steel, stainless steel, things of brass etc. If you will prepare a list of things made up of metals, you will be able to understand the importance of metals in our everyday life. In this unit we shall study in detail about the metallic elements.

8.2 Earth as Treasure of Elements

Different elements are obtained directly or indirectly from below mentioned three parts of the earth :

(1) Lithosphere : This part of the earth is formed of sand, clay and stone, in which metal elements like aluminium, copper, iron, calcium, sodium, etc. are in the forms of oxide or sulphide.

(2) Hydrosphere : In this part of the earth; water of seas, rivers, lakes and the ice of polar regions are included. In this part, non-metals like chlorine, fluorine and metals like sodium, potassium, magnesium, calcium etc. are obtained in the combined forms.

(3) Atmosphere : The cover of gases around the earth is called atmosphere. Mostly, non-metallic gases like nitrogen, oxygen, carbon dioxide etc. are mainly present.

Various metals are in larger proportion in the earth's crust, some metals are available in free state (form) from the crust of the earth, while some metals are obtained in the combined form. Metals whose activity is less are available in free state in nature. They are called noble metals e.g. Gold, silver, platinum etc. Metals having more activity are available in combined form in nature e.g. potassium, sodium, calcium, magnesium etc. **The inorganic elements or compounds which are available naturally from earth's crust are called minerals. If the proportion of a certain metal is more and if its extraction is advantageous, then the mineral is called ore.** In ores the impurities are minerals of other metals, clay, sand, etc. Ores are chiefly in the combined forms like silicate, carbonate, oxide, phosphate, sulphide etc. The chief ores available in India and their occurrences are shown in Table 8.1

Table 8.1 Metals and their Chief Minerals

Name of metal	Name of Mineral	Chemical formula of Chief Component	Occurrenes in India
Iron	Haematite Magnetite Siderite Iron Pyrites	Fe_2O_3 Fe_3O_4 $FeCO_3$ FeS_2	Madhya, Pradesh, Tamilnadu, Orissa, Bihar Goa
Aluminium	Bauxite	$Al_2O_3.2H_2O$	Gujarat, Maharashtra, Madhya Pradesh, Bihar
Copper	Cuprite Copper Pyrites Copper Glance Malachite	Cu_2O $CuFeS_2$ Cu_2S $Cu(OH)_2$	Bihar, Rajasthan
Calcium	Lime stone Dolomite Gypsum	$CaCO_3$ $CaMg(CO_3)_2$ $CaSO_4.2H_2O$	Gujarat, Rajasthan Madhya Pradesh
Silver	Horn Silver Silver Glance	$AgCl$ Ag_2S	Bihar

8.3 Metallurgy

The metal is separated from its ore and is purified (refined) to make it more useful. **The process of separating metal from ore and purifying (refining) it is known as metallurgy**. The process of obtaining pure metal from ore is divided into five steps. (1) Powder from ore (2) Concentration of ore (3) Roasting, calcination and smelting (4) Reduction (5) Refining of metal

(1) Powdering of ore : Ores are obtained by digging from the earth's crust, in which minerals of other metals, clay, silica etc, are present as impurities. The bigger pieces of this ore is powdered by grinding in big mills of special type.

(2) Concentration of ore : The ores are concentrated on the basis of type of impurities and their percentage proportions. As a result most of the impurities are removed and the proportion of ore is increased. This process is called concentration of ore. For this, (i) concentration or centrifugation on the basis of difference in densities (ii) froth flotation and (iii) magnetic separation methods are used.

(i) Concentration or Centrifugation on the basis of difference in densities : When there is large difference between densities of ores and the impurities in them, concentration of ore can be done by this method. In this method, the fine powder of ore is placed on a moving table with slots and it is moved rapidly so that the light particles of metal remain in the slot in the table because of centrifugal force. This process is known as centrifugation.

(ii) Froth Flotation method : Froth flotation method is used for concentration of the ores of the metals whose ores are in sulphide form. The concentration of sulphide ores of copper, lead and zinc metal are carried out by this method. In this method, the fine powder of the ore, and water are filled in a big vessel. The substances like pine, or turpentine oil are added to it. The sulphide particles of metals get wet and stick to it, while clay, particles of sand, do not get wetted. In this liquid mixture, air is passed with pressure through a tube as shown Fig 8.1. Hence, the froth is produced around the light particles of the sulphide ore and comes on the surface of the liquid mixture. Heavy particles like clay, sand etc, become wet by water and settled down at the bottom.

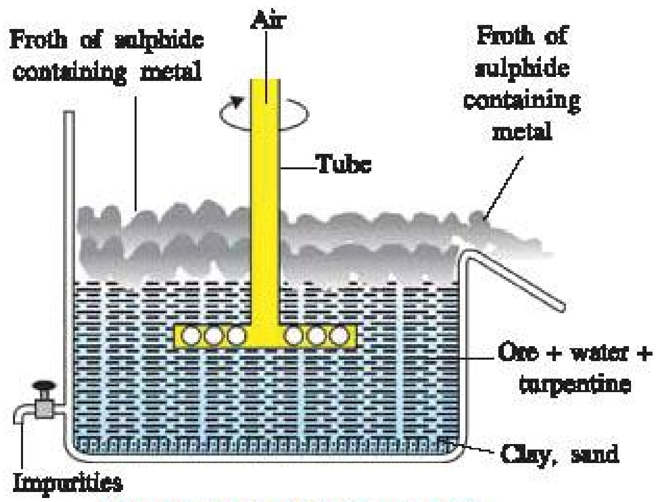


Fig. 8.1 Froth Flotation method

The sulphide ore of metal is removed with sieves in a second vessel and washed with water. By this method ores like copper pyrites are concentrated and clay, sand etc. are removed.

(iii) Magnetic separation : If impurity of iron is there in the ore, then the fine powder of the ore is allowed to fall on belt of leather. As shown Fig 8.2, there is a magnet at one end of the belt which attracts the iron particles and fall nearer, the remaining particles fall away because of not being attracted. Thus, by this method impurity of iron is removed from the ore. In the same way other impurities of the ores of iron are removed by this method.

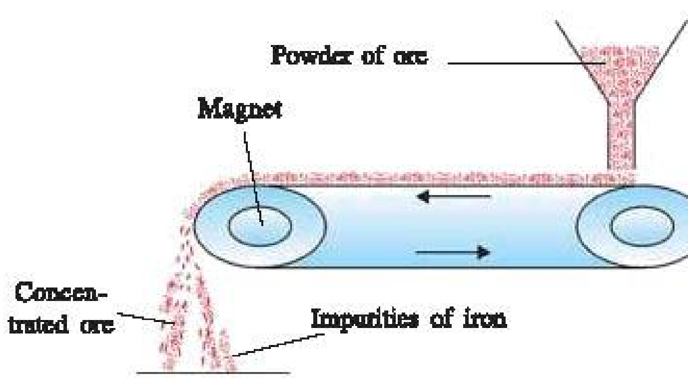


Fig. 8.2 Magnetic separation

(3) Roasting, calcination and smelting : Methods like roasting, calcination and smelting are used in conversion of concentrated ore into metal oxide.

Roasting : When sulphide containing ore is heated for a long time in presence of excess air, it is converted into metal oxide. **This method of converting sulphide containing ore into metal oxide is called roasting.**

$$2ZnS(s) + 3O_2(g) \xrightarrow{\Delta} 2ZnO(s) + 2SO_2(g)$$

$$2HgS(s) + 3O_2(g) \xrightarrow{\Delta} 2HgO(s) + 2SO_2(g)$$

$$2PbS(s) + 3O_2(g) \xrightarrow{\Delta} 2PbO(s) + 2SO_2(g)$$

Calcination : When carbonate containing ore is heated for a long time in absence of air it is converted into metal oxide. **This method of converting carbonate containing ore into metal oxide is called calcination.**

$$MgCO_3(s) \xrightarrow{\Delta} MgO(s) + CO_2(g)$$

$$ZnCO_3(s) \xrightarrow{\Delta} ZnO(s) + CO_2(g)$$

Smelting : If the ore is in melted form then it is called smelting.

(4) Reduction : Reduction is carried out to obtain metal from metal oxide. In reduction process the metal oxide is reacted with reducing agent like carbon or carbon monoxide. Also, any other reducing agent (metal) when reacted with metal oxide, a more stable, oxide forming metal by attracting more proportion of oxygen, metal is obtained.

Chemical Reduction : When metal oxide is heated in a blast furnace with carbon or carbon monoxide, metal is obtained.

$$MnO_2(s) + 2C(s) \xrightarrow{\Delta} Mn(s) + 2CO(g)$$

$$ZnO(s) + C(s) \xrightarrow{\Delta} Zn(s) + CO(g)$$

$$Fe_2O_3(s) + 3C(s) \xrightarrow{\Delta} 2Fe(s) + 3CO(g)$$

$$Fe_2O_3(s) + 3CO(g) \xrightarrow{\Delta} 2Fe(s) + 3CO_2(g)$$

When oxides of metals like chromium, iron, and manganese are heated with aluminium powder, metal is obtained by reduction of metal oxide.

$$Cr_2O_3(s) + 2Al(s) \xrightarrow{\Delta} 2Cr(l) + Al_2O_3(s)$$

$$Fe_2O_3(s) + 2Al(s) \xrightarrow{\Delta} 2Fe(l) + Al_2O_3(s)$$

$$3MnO_2(s) + 4Al(s) \xrightarrow{\Delta} 3Mn(l) + 2Al_2O_3(s)$$

Electrochemical Reduction : Some metals cannot be obtained by reaction of carbon with oxide of active metal. Oxides of active metals like sodium, magnesium, calcium, aluminium cannot be reduced by carbon, i.e. metals cannot be obtained by carbon from their corresponding metal oxides, because these metals possess more attraction towards oxygen than carbon. Hence, other method - electrochemical reduction method is used to obtain metals from oxides of active metals. In this method, electrodes of inert metals like graphite or platinum are used in electrochemical cell

Example : By electrochemical reduction of alumina (Al_2O_3), molten aluminium is obtained at cathode and dioxygen gas at anode.

Cathode (Negative pole) : $2Al^{3+}(l) + 6e^- \rightarrow 2Al(l)$

Anode (Positive pole) : $3O^{2-}(l) \rightarrow \frac{3}{2}O_2(g) + 6e^-$

Here, cathode (negative pole) works as a reducing agent.

(5) Refining of metals : The metal obtained by reduction method is not very pure. The method to obtain about hundred percent pure metal by removing impurities present in very small amounts in metal, is called refining. Refining of metals is mainly carried out by three methods :

(i) Electrolysis (ii) Liquefaction (iii) Zone refining

(i) Electrolysis : Metals like copper, zinc, gold and silver are refined by this method. In this method, the rod of impure metal is taken as anode and rod of pure metal is taken as cathode. The aqueous solution of salt of metal, is used as electrolyte. On passing electric current through electrolyte, anode dissolves in the electrolyte. The metal in the proportion of being obtained by dissolution of anode, is added to the electrolyte, the same proportion of metal is being deposited at the cathode. As there is no impurity in the metal deposited at the cathode, it is very pure. **Out of the impurities added to electrolyte by dissolution of anode, soluble impurities remain in the solution and insoluble impurities are collected at the bottom of the anode. It is called anodic mud.**

If copper is refined by this method, then rod of impure copper is arranged as anode and the rod of pure copper as cathode as shown in figure 8.3. The aqueous solution of copper sulphate is taken as the electrolyte. A little dilute sulphuric acid is added to it. When electric current is passed through the electrolyte the proportion in which copper from anode is dissolved in aqueous solution of copper sulphate, copper in the same proportion from copper sulphate solution is deposited at the cathode. Thus, the copper deposited at the cathode in this way has almost 100 % purity.

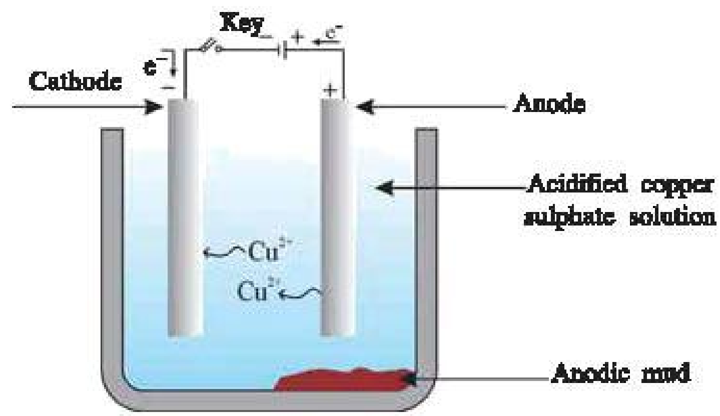


Fig. 8.3 Refining of copper by electrolysis

Anode (Positive pole) : $Cu(s)$ (Impure) $\rightarrow Cu^{2+}(aq) + 2e^{-}$ (oxidation)

Cathode (Negative pole) : $Cu^{2+}(aq) + 2e^{-} \rightarrow Cu(s)$ (reduction)

Net reaction : $Cu(s)$ (Impure) $\rightarrow Cu(s)$ (Pure)

(ii) Liquefaction : This method is used for refining of metals having low melting point i.e. metals like tin, lead etc. which melt easily. In this method, a furnace having a slope is used. The temperature of this furnace is kept slightly higher than the melting point of the metal, so that when impure metal is passed on the slope, the metal in it is melted and collected in the vessel kept below. The melting points of impurities are higher and so do not melt at this temperature and found in solid form on the slope.

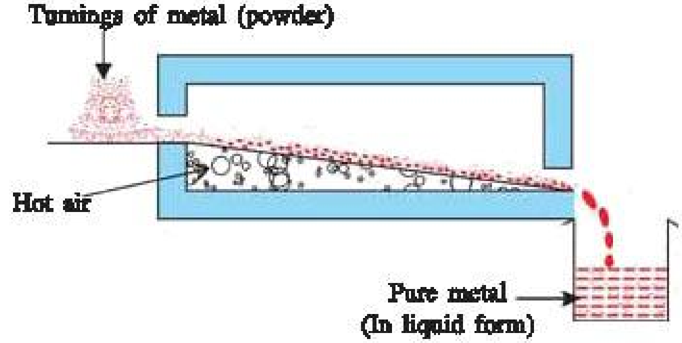


Fig. 8.4 Refining of metal by liquefaction method

(iii) Zone Refining : Trace impurities present in metal are removed by this method on the basis of the principle of fractional crystallization. Generally, these impurities remain more soluble in the form of molten metal. As the molten metal gets cooled, the solubility of impurities decreases and separates from the metal in the form of crystals, semi-metals like silicon, boron, germanium are used as semiconductors. The refining of these semi-metals is carried out by zone refining method.

After understanding the five steps of metallurgy, now we shall study the metallurgy of aluminium and iron.

8.4 Extraction of Aluminium From Bauxite

Aluminium is the most abundant metal available on the earth. The use of this metal on a larger scale started from the end of the nineteenth century because the extraction of this metal was very costly before this. Aluminium is extracted from bauxite ($Al_2O_3.2H_2O$). The extraction of aluminium from the ore bauxite is carried out in two steps : (1) To obtain alumina from bauxite ore. (2) To obtain aluminium metal from alumina by electrochemical reduction.

(1) To obtain alumina from bauxite ore : In bauxite, in addition to aluminum oxide (Al_2O_3) impurities like iron oxide (Fe_2O_3) and sand (SiO_2) are also present. On refining bauxite by Bayer's method, pure aluminium oxide is obtained which is also called alumina. In this method, bauxite powder is taken and concentrated (45%) sodium hydroxide solution is added and then heated in closed vessel at 433 K temperature and 5 to 6 bar pressure, for 6 to 8 hours, so that aluminium oxide present in bauxite is converted into sodium aluminate which is soluble in water.

$$\underset{\text{(Present in bauxite)}}{Al_2O_3(s)} + 2NaOH(aq) \rightarrow \underset{\text{(Sodium aluminate)}}{2NaAlO_2(aq)} + H_2O(l)$$

Iron oxide does not dissolve in sodium hydroxide. Hence, it can be removed by filtration, silica forms sodium silicate which is soluble in water. This sodium aluminate and sodium silicate are there in the filtrate. Excess of water is added to it and continuously stirred so that hydrolysis of sodium aluminate takes place and precipitates of aluminium hydroxide are obtained and the sodium silicate remains as impurity in the solution. Some precipitates of aluminium hydroxide are added from outside in order to make reaction simple and fast.

$$\underset{\text{Sodium aluminate}}{NaAlO_2(aq)} + 2H_2O(l) \rightarrow \underset{\text{Aluminium hydroxide}}{Al(OH)_3(s)} + NaOH(aq)$$

The precipitates are washed repeatedly with water, dried and on heating at 1473 K temperature pure aluminium oxide (alumina) is obtained.

$$\underset{\text{Aluminium hydroxide}}{2Al(OH)_3(s)} \xrightarrow{1473\,K} \underset{\text{Alumina}}{Al_2O_3(s)} + 3H_2O(g)$$

About 99.5% pure alumina is obtained by Bayer's method.

(2) To obtain aluminium from alumina by electrochemical reduction : The method to obtain aluminium from alumina by electrochemical method was invented by American chemist Charles Martin Hall and French scientist Paul Heroult in 1886. Hence, this method is also known as Hall-Heroult method.

Electric current cannot pass through solid form of alumina. Also, melting point of aluminia is very high 2348 K. Electrolysis at such a high temperature is very expensive. Hence, cryolite (Na_3AlF_6) is added so that electrolysis can be carried out easily. This mixture works as better

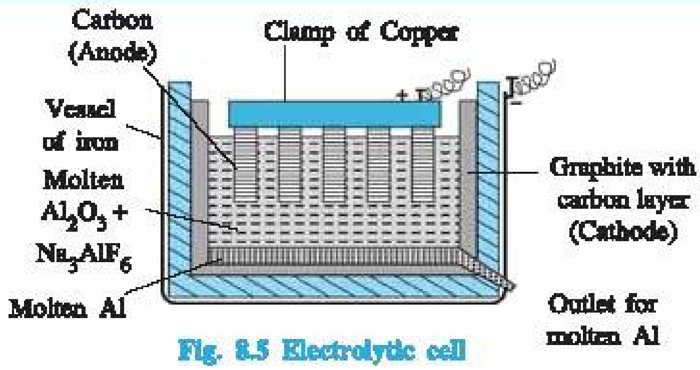


Fig. 8.5 Electrolytic cell

electric conductor than melted alumina. The melting point can be brought still lower by addition of feldspar (CaF_2).

As shown in Fig 8.5, the mixture of alumina, cryolite and feldspar is electrolysed in a vessel of iron having inner surface layered with carbon. In this cell, the rods of carbon are joined by copper clamp as anode and carbon layered graphite is taken as cathode. On passing the electric current molten aluminium is deposited on cathode and dioxygen gas is produced at the anode. The molten aluminium collected at the bottom of the cell is taken out.

$$\text{Cathode :} \quad 2Al^{3+}(l) + 6e^- \rightarrow 2Al(l)$$

$$\text{Anode :} \quad 3O^{2-}(l) \rightarrow \frac{3}{2}O_2(g) + 6e^-$$

The dioxygen gas produced at the anode reacts with rod of carbon and forms carbon dioxide. As a result anode is corroded. Hence, they are frequently replaced.

$$C(s) + O_2(g) \rightarrow CO_2(g)$$

8.5 Extraction of Iron by Blast Furnace

We have been using iron from a very long time (iron era). Iron has the second position amongst the elements available in most abundance on the earth. Iron reacts rapidly with moisture and oxygen and so it is not available in free state in nature. It is obtained in its oxide form (haematite Fe_2O_3, magnetite - Fe_3O_4), in carbonate form (siderite - $FeCO_3$) and sulphide form (iron pyrites - FeS_2) which are its minerals. Iron is mostly obtained by reduction of haematite in blast furnace. The blast furnace is narrow on the upper part, wide in the middle part and narrow at the bottom part. Its inner walls are prepared of fireproof bricks. Hot air is blown from the lower part of blast furnace.

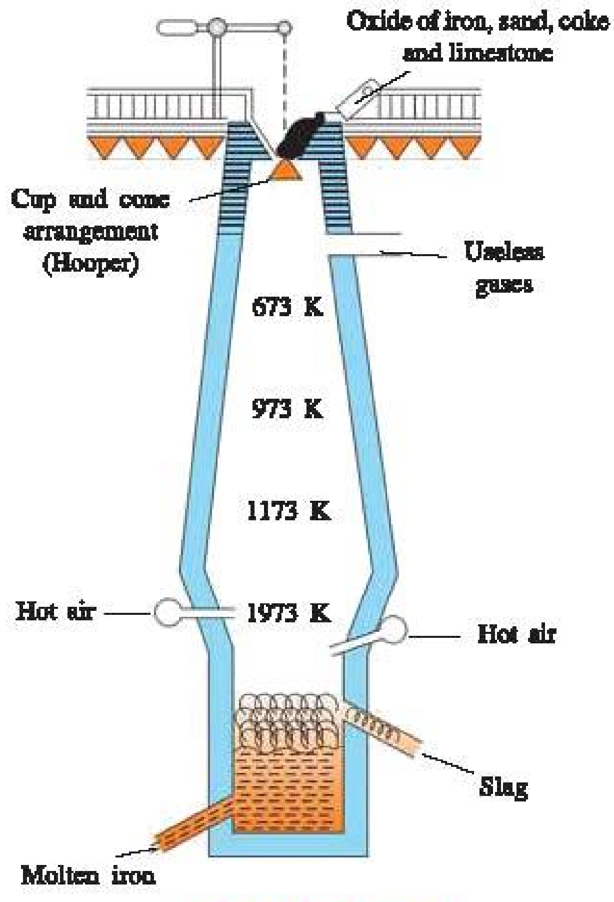


Fig. 8.6 Blast furnace

Most of the impurities present in haematite are removed, and then, the concentrated ore is added into the blast furnace with the help of hooper as shown in Fig 8.6, with coke and lime stone. Because of high temperature in blast furnace, certain reactions take place and molten iron is obtained.

(i) Coke combines with oxygen and forms carbon dioxide. This reaction being exothermic, the temperature of the furnace becomes 1773 K to 1973 K.

$$C(s) + O_2(g) \rightarrow CO_2(g) + \text{Heat}$$

(ii) Calcium oxide and carbon dioxide are formed in the blast furnace by decomposition of lime stone due to high temperature in blast furnace.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

(iii) Hot carbon dioxide when goes up in the furnace combines again with coke and forms carbon monoxide. As this reaction is endothermic, the temperature of the furnace comes down to 1173 K

$$CO_2(g) + C(s) \rightarrow 2CO(g)$$

(iv) When temperature of the furnace is 673 K to 973 K, the iron oxide present in haematite is reduced to liquid iron.

$$3Fe_2O_3(s) + CO(g) \rightarrow 2Fe_3O_4(s) + CO_2(g)$$

$$Fe_3O_4\ (s) + CO(g) \rightarrow 3FeO(s) + CO_2(g)$$

$$FeO(s) + CO(g) \rightarrow Fe(l) + CO_2(g)$$

Calcium oxide formed during reaction (ii) combines with the impurity silica present in haematite and forms calcium silicate. It is known as slag.

$$CaO(s) + SiO_2(s) \rightarrow \underset{\text{Calcium silicate (Slag)}}{CaSiO_3(l)}$$

As this slag is lighter in weight than iron, it floats in molten iron. The important advantage of this is that molten iron is not converted into its oxide by oxygen. The moltern iron and slag are removed out by different paths from the bottom of the furnace. The molten iron cools down to solid form and iron blocks are prepared, while liquid slag is changing into a solid form by cooling and useful in construction of roads.

The extraction of iron from haematite is a continuous process. Once it starts operating the blast furnace can continue for ten years. The extraction of iron is carried out in India, at Bhilai, Durgapur, Rourkela, Jamshedpur etc.

8.6 Activity Series of Metals

The activity of every metal is not same. Some metals are more active and some metals are less active. The metals which lose electron easily and form ions are called more active metals. e.g. Fe, while less active metals do not lose electron easily. e.g. Au. The comparison of activity of metals can be done by comparison of reactions with oxygen, water and acid; but all the metals do not give these reactions. Hence, for the determination of activity of metals, displacement reaction is used. For the explanation of results obtained by displacement reaction, the principle taken into consideration is : **Less active metal can be displaced from the solution of its salt by the more active metal.'** For example, if piece of zinc metal is placed in a solution of copper sulphate, it becomes light blue coloured and at the end becomes colourless and red brown coloured layer of copper is deposited on piece of zinc metal. If it is kept for a longer period, grains of red brown colour are obtained at the bottom.

$$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$$

If a piece of copper metal is placed in a solution of zinc sulphate, chemical reaction like deposition of metal does not occur. Thus, zinc is more active metal than copper. You can do the activity in the laboratory for the study of this reaction, we shall try to determine the order of activity of metals by this type of activity.

Activity : 1

To determine order of activity of Zn, Fe, Cu and Ag metals.

- First of all take three test-tubes. Give them numbers 1 to 3.
- In test tube 1, 2 and 3 take the substances. 0.1 gram ferrous sulphate ($FeSO_4.7H_2O$), 0.1 gram copper sulphate($CuSO_4.5H_2O$) and 0.1 gram silver nitrate ($AgNO_3$).
- Add 10 ml. of distilled water to each test tube and dissolve the substance in it.
- With this keep ready a piece of zinc metal, iron nail or screw and piece of copper wire. (A thick copper wire can be taken out from electric wire) or copper strip.
- Now add piece of zinc metal in test tube - 1, iron nail or screw in test-tube-2 and piece of copper wire or thin strip in test tube-3.
- Place the three test tubes in order and observe the solutions and metal in each test tube.
- In about 5 minutes, you will see the metal from the solution being deposited on the metal added.
- After half an hour when observation of all the three test tubes is carried out, it will be observed that in test tube-1, iron metal showing colour of iron metal is deposited in the shining piece of zinc. In test tube-2, the nail or screw will appear brown coloured due to deposition of copper on it. In test tube-3, silver as shining white colour deposited on the wire or strip of copper.

  By keeping the test tubes for more than half an hour, more amount of metals will be found deposited.
- The colour of the solutions in the three test tubes will be respectively colourless from light green colour, light blue from dark blue colour and light blue colour from colourless.
- We will be able to conclude at the end of this activity that Zn is more active metal than Fe because Fe is displaced from solution of $FeSO_4$ by Zn i.e Zn>Fe. Fe is more active metal than Cu because Cu from solution of $CuSO_4$ is displaced by metal Fe. i.e Fe>Cu. Cu is more active metal than Ag because Ag is displaced from solution of $AgNO_3$ by Cu metal i.e Cu > Ag. Thus the order of activity of all the four metals will be Zn > Fe > Cu > Ag.

By such experiments, the activities of different metals can be determined and can be arranged in their descending (decreasing) order. This order is known as activity series. viz.

K > Na > Ca > Mg > Al > Zn > Fe > Pb > [H] > Cu > Hg > Ag > Au

Now, we shall study properties of metals.

8.7 Physical Properties of Metals

(1) Generally, the surface of metals is shining and can be polished.

(2) Generally metals are in solid form and heavy in weight but metals like mercury and gallium (at higher than normal temperatures) exist in the liquid form. Sodium, potassium, magnesium, aluminium etc. are relatively lighter metals.

(3) Most of the metals are hard, the hardness of various metals are different; metals like iron and copper can comparatively be cut with a knife, metals like sodium, potassium are relatively soft and can be easily cut with a knife.

(4) Some of the metals can be hammered and foils can be prepared by hammering. This property of the metals is known as malleability. This property is specially found in metals like gold, silver and aluminium. Hence, thin foils like thin strips are prepared from gold and silver and very thin foil like paper can be prepared from aluminium. Some metals are ductile and so thin wires of these metals can be prepared by drawing the metals. This property of metals like gold and silver has special property of ductility. 2 kilometer long wire can be drawn from one gram gold. Wires can also be prepared from metals like copper and aluminium, by drawing.

(5) Metals are good conductors of heat and electricity. The power of conduction of heat and electricity is very high for copper, silver and gold metals. Metals like lead and mercury are poor conductors of heat and electricity.

(6) Melting points and boiling points of metals are high. e.g. melting point of iron (1812 K) is very high.

(7) Metal can produce ringing sound by striking

(8) Alloy can be prepared by adding one metal to the other. They possess properties different from the original metals. Brass, German silver, gold ornaments are the examples of alloys.

8.8 Chemical Properties of Metals

Metal loses electron and changes to positive ion. Hence, they are called electropositive elements. The number of electrons lost by the metal is the valency of the metal.

$$Na \rightarrow Na^{+} + e^{-}$$

$$Mg \rightarrow Mg^{2+} + 2e^{-}$$

$$Cu \rightarrow Cu^{2+} + 2e^{-}$$

$$Al \rightarrow Al^{3+} + 3e^{-}$$

The metals show definite chemical properties because of the electrons in the outermost orbit of the metals.

(1) Reaction of metal with dioxygen : Metal elements can easily give electrons to dioxygen atom. Hence, metal elements combine with oxygen and form the oxides.

Metal + Dioxygen gas → Metal oxides.

$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

Magesium oxide.

Generally oxides of metal are basic. Oxides of metals like zinc oxide and aluminium oxide possess both acidic and basic properties. Such metal oxides are called amphoteric oxides. Most of the metal oxides are insoluble in water but some oxides dissolve in water and form alkali.

$Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$

Sodium oxide → Sodium hydroxide

$K_2O(s) + H_2O(l) \rightarrow 2KOH(aq)$

Potassium oxide → Potassium hydroxide

All the metals do not react with dioxygen with the same rate that is the reactivity of various metals with oxygen is different viz. metals like sodium and potassium if kept open in air, they burn. Hence, they are kept in kerosene. At normal temperature, thin layer of oxide is observed on metals like magnesium, aluminium, zinc and lead. This layer stops further oxidation of metal. If magnsium is heated at a temperature at which it can burn, then it burns with dazzling light and forms magnesium oxide. When iron is heated, it does not burn but becomes red hot. When copper is heated it also does not burn but the black colour substance observed on hot copper is copper oxide. Metals like gold, silver etc. do not react with dioxygen at high temperature.

(2) Reaction of metal with water : Metals on reaction with water form metal hydroxides or oxides and produce dihydrogen gas. But all the metals do not react with water. Metals like sodium and potassium react vigorously with cold water. The dihydrogen gas produced by vigorous reaction of sodium or potassium with water explodes and burns speedily.

Metal + Water → Metal hydroxide or Metal oxide + Dihydrogen gas.

$2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$

$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$

The reaction of calcium with water is less vigorous.

$Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$

Magnesium metal does not react with cold water but by reaction with hot water, it forms magnesium hydroxide and dihydrogen gas.

$Mg(s) + 2H_2O(l) \rightarrow Mg(OH)_2(aq) + H_2(g)$

Aluminium, zinc and iron metals do not give reactions with cold or hot water, but react with water vapour and form oxides and dihydrogen gas.

$2Al(s) + 3H_2O(g) \rightarrow Al_2O_3(s) + 3H_2(g)$

$Zn(s) + H_2O(g) \rightarrow ZnO(s) + H_2(g)$

$3Fe(s) + 4H_2O(g) \rightarrow Fe_3O_4(s) + 4H_2(g)$

While, metals like lead copper, gold and silver do not react with water.

(3) Reaction of Metals with Acid : All the metals do not react with dilute acids but when the metal reacts with dilute acid, salt corresponding to metal and dihydrogen gas are produced.

Metal + dil.acid $\rightarrow$ Salt corresponding to metal + Dihydrogen gas

$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

$2Al(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2(g)$

$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$

$Fe(s) + H_2SO_4(aq) \rightarrow FeSO_4(aq) + H_2(g)$

Dihydrogen gas is not produced by reaction of metals with dilute nitric acid (HNO_3) because HNO_3 is a strong oxidising agent. It oxidises H_2 produced during the reaction to H_2O. Even then, magnesium and manganese metals produce dihydrogen gas with very dilute nitric acid.

(4) Reaction of Metals with Dichlorine : Metal reacts with dichlorine and forms metal chorides.

Metal + Dichlorine gas $\rightarrow$ Metal chlorde

$Ca(s) + Cl_2(g) \rightarrow CaCl_2(s)$
Calcium chloride.

$Mg(s) + Cl_2(g) \rightarrow MgCl_2(s)$
Magnesium chloride.

(5) Reaction of Metal with Dihydrogen : Generally metals do not give reaction with dihydrogen because metals have a tendency to lose the electron and so react with those elemen which can accept electron. But dihydrogen does not accept electron. They form compounds with other elements by electron sharing or losing electron.

Some active metals like Na, K, Ca combine with hydrogen and form hydrides of that metal.

Active metal + Dihydrogen $\rightarrow$ Metal hydride

$2Na\ (s) + H_2(g) \rightarrow 2NaH(s)$
Sodium hydride.

$2K(s) + H_2(g) \rightarrow 2KH(s)$
Potassium hydride.

$Ca(s) + H_2(g) \rightarrow CaH_2(s)$
Calcium hydride.

8.9 Corrosion

The effect of air and water is observed on the surface of many metals. e.g. if the things of iron remain in presence of moist air for a longer period, then their surface becomes brown coloured. Sometimes we find small foils coming out of it. The things of copper when remain in air for a longer time then green coloured layer of copper carbonate forms on its surface. **The erosion reaction of any metal with water or moisture when it comes in its contact is called 'metallic corrosion'** : Inert metals - gold, silver etc – are not corroded. Sometimes metallic corrosion reaction is advantageous because the layer formed by corrosion prevents the metal below this layer and it is not corroded. e.g. When aluminium metal is kept open in air, the thin layer of aluminium oxide is formed on the surface of the metal. It prevents the corrosion of the metal layers below this corroded layer. Hence, things of aluminium do not corrode. We shall test the reason for corrosion by doing an activity.

Activity : 2

To test the reason for corrosion :

- First of all take three test tubes and place three iron nails in each of them.
- Name the three test tubes as A, B and C.
- Pour water in test tube - A in such a manner that half the part of nails sink in water and then close the test tube with cork.
- Add boiled distilled water in test tube B so that the nails sink completely and add about 1 ml. oil. Close this test tube with cork.
- In test tube C, add little powder of anhydrous calcium chloride.
- By doing this, the nails in test tube A are in contact with both air and water. In test tube-B the nails are in contact with water only, they do not get air. In test tube-C anhydrous calcium chloride is present which is mositure absorbing (hygroscopic), and so dry air is in test tube C.

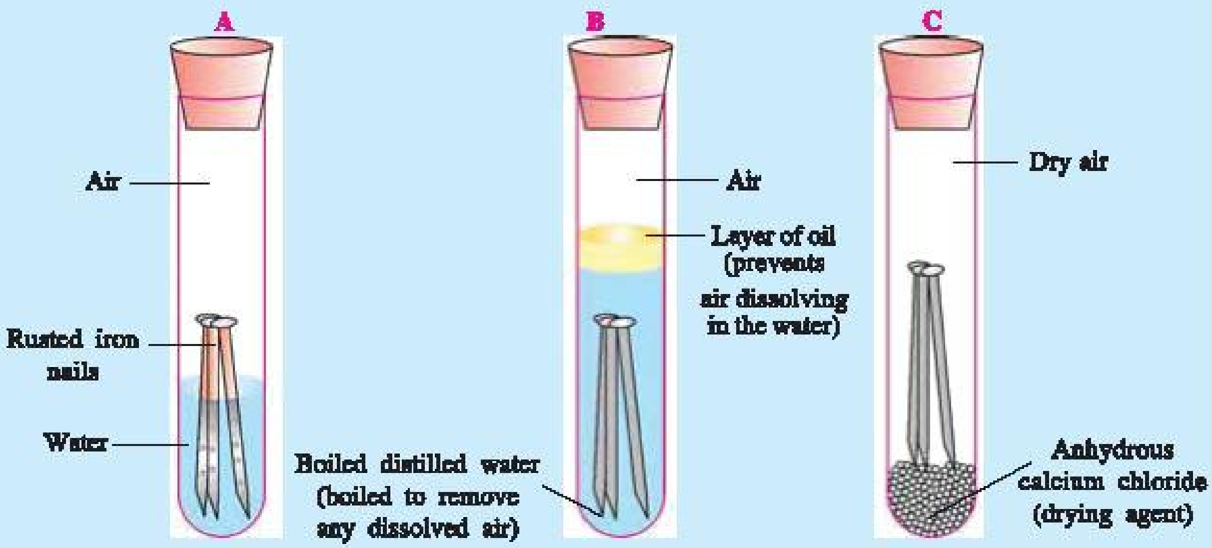


Fig. 8.7 Corrosion of metals

- Observe the nails in all the three test tubes after some days.
- On observation, we will find that nails in test tube A are corroded but nails in test tubes B and C are not corroded. This indicates that corrosion of metal takes place due to contact with both air and water.
- Perform this experiment in your laboratory after comprehending this experiment explained in detail in your practical book.

Loss of crores of rupees occur in the world due to corrosion. Hence, to decrease this loss, remedies to prevent corrosion become inevitable for us. By the activity we confirm our understanding that, corrosion takes place due to air and water both. Hence, it is clear that to prevent corrosion, the surface of the metallic things should be kept away from air and water.

Remedies for Prevention of Corrosion : (1) The easy and cheap method to prevent corrosion of iron is to apply paint on the surface of iron. The body of a car windows or pillars of iron can be coloured and protection against corrosion can be obtained. If the applied colour is removed the corrosion reaction of that thing starts. Hence, it becomes essential to apply colour at the interval of definite periods.

(2) Sometimes protection against corrosion can be done by applying oil on the surface of things of iron, because the layer of oil does not allow the things of iron to come in contact with air or moisture. This method is practical for small tools of iron, like hammer, gardener's scissors, scissors for cutting metals, etc. But it is not favourable for huge things because at the end of very small interval of time, it becomes necessary to apply oil again.

(3) The corrosion of iron can be prevented by coating very fine layer of zinc metal on the surface of iron. In the iron coated with zinc if zinc is removed from the surface of iron, it does not get corroded because the more active zinc metal spreads over the open surface and prevents iron from corrosion. The iron sheets used in the roof of the house are galvanised sheets.

(4) To prevent corrosion of the iron plates of the steamer, metals like magnesium or block of zinc is used which is more active with the plates of iron in sea-water. By doing so, the plate of iron acts as anode. The corrosion of this zinc block takes place continuously in sea water. They are to be replaced at intervals. This is called sacrificial anode.

(5) Suitable chemicals which are called inhibitors can also be used so that they combine with the surface of the metal by chemical bond and prevent corrosion.

(6) Corrosion can be prevented by applying enamal paints on iron.

(7) As an effective remedy to prevent corrosion metal or non-metal and introducing changes in its properties, it can be saved from corrosion viz the stainless steel alloy prepared from 70% iron, 20% chromium and 10% nickel has no effect of air, water or alkali and it also does not get corroded. Hence, the utensils used in kitchen, instruments used in surgery, big vessels used in industries are prepared from stainless steel.

8.10 Alloys

We know that iron is the metal that is maximum used, but it is not in its pure form. The reason for this is that when it is hot, it is soft and gets easily pressed. But if very small amount of carbon (about 0.05%) is added, it becomes hard and strong. If nickel and chromium are added to iron, stainless steel is obtained. It is strong and does not get corroded. Thus, when any other substance is added to iron, its properties are changed. The substances added to it may be metal or non-metal. Thus, **homogeneous mixture of two or more metals or metal and non-metal is called an alloy.**

In preparation of alloy, firstly the chief metal is melted and the substance which is to be mixed is added in definite proportion and then melted again. Then this molten mixture is cooled. The alloy prepared by adding zinc metal to copper is known as brass. Cooking vessels, parts of machines, instruments of music are prepared from it. If one of the metals in an alloy is mercury, then it is called amalgam. The electrical conductivity of an alloy is less than that of pure metal. e.g., if impurity is there in copper, its electrical conductivity is less than that of pure copper. The melting point of an alloy is less than those of component elements. e.g. The meting point of the alloy prepared from lead and tin, is less and so it is used in soldering the electric wires. Components of some alloys, their properties and uses are shown in Table 8.2.

Table 8.2 Alloys, their compositiones, properties and uses

Alloy	Components	Properties	Uses
Steel	Iron, carbon	Hard and strong	In construction of building and bridge, manufacture of ships, and manufacture of spare parts of motorcycles.
Stainless steel	Iron, nickel chromium	Air, water and alkali do not affect and do not get corroded.	In preparation of utensils, blades, surgical instruments
Brass	Copper, zinc	Malleable, strong, corrosion resistant and can be easily shaped	In preparation of cooking utensils, parts of machines and instruments of music
Bronze	Copper, tin	Stronger and more corrosion resistant	In preparation of statues, coins and medals.
Magnalium	Aluminium, magnesium	Very light and hard	In preparation of scientific balance and light instruments.
Duralumin	Aluminium, copper and magnesium in trace proportions	Light, strong and corrosion resistant	In preparation of aircraft and pressure cookers.

8.11 Purity of Gold in Carat Unit

The purity of gold is expressed in carat unit. Pure gold is considerd as 24 carat. As it is very soft, the shapes of the ornaments prepared from gold get deformed in shapes, even if small pressure is applied. But if copper or silver is added in small proportion to pure gold, its strength can be increased. In our country, generally ornaments are prepared of 22 carat gold. 22 carat gold means the alloy of 22 parts pure gold and 2 parts copper or silver.

What have you learnt ?

- The inorganic elements or compound available naturally are called minerals.
- If the proportion of any definite metal is larger and extraction of that metal is advantageous, then the mineral is called ore of that definite metal.
- Ore is generally in the form of silicate, carbonate, oxide, phosphate, sulphide etc.
- The process of separating the metal from its ore and purifying it is known as metallurgy.
- **Five steps of metallurgy :** (1) Powder from ore (2) Concentration of ore (3) Roasting, Calcination and Smelting (4) Reduction (5) Refining of metal.

- **Two steps of extraction of aluminium from bauxite :** (1) To obtain alumina from bauxite ore (2) To obtain aluminium from alumina by electrochemical reduction.
- Fe is extracted from haematite (Fe_2O_3) by blast furnace
- **Activity series of metals :** K > Na > Ca > Mg > Al > Zn > Fe > Pb > [H] > Cu > Hg > Ag > Au

Physical properties of metals

- Metals are lustrous in solid form (except : Hg, Ga), Hard (except: Na, K). Heavy in weight (except : Na, K, Mg, Al).
- Possess property of ductility and malleability
- Melting points and boiling points are high
- Metals produce ringing sound when they are struck.
- Alloys can be prepared by adding one metal to the other metal.

Chemical properties of metals :

- Metal + dioxygen gas → oxide of metal
- Metal + water → metal hydroxide or metal oxide + dihydrogen gas
- Metal + dilute acid (HCl / H_2SO_4) → Salt of metal + dihydrogen gas
- Metal + dichlorine gas → metal chloride
- Active metal (Na, K, Ca) + Dihydrogen gas → Metal hydride
- The process of erosion of any metal when its surface comes in contact with air, water or moisture, is called corrosion.
- The homogeneous mixture of two or more metals or mixture of metal and non-metal is called an alloy. Stainless steel, brass, bronze, magnalium, duralumin and 22 carat gold are the examples of alloy.

Metallurgy
- → Powder from ore - ore is ground and made powder
- → Concentration of ore (Most of the impurities are removed and the ore is concentrated)
  - → Concentration on the basis of difference in densities (when greater difference is there between densities of ore and impurities)
  - → Froth flotation process (For concentration of sulphide containing ores)
  - → Magnetic separation (when ore or impurity is iron)

- Metallurgy
  - Roasting, calcination, smelting (Conversion of concentrated ore into metal oxide)
    - Roasting (Metal oxide is formed from sulphide containing ores)
    - Calcination (Metal oxide is formed from carbonate containing ores)
    - Smelting (Ore is in molten form)
  - Reduction (To obtain metal from metal oxide)
    - Chemical reduction (Metal oxide + C or CO $\xrightarrow{\Delta}$ metal)
    - Electrochemical reduction (Molten metal at cathode, oxygen gas at anode)
  - Refining of metal (to change metal in very pure form)
    - Electrolysis
      Anode : Impure metal
      Cathode : Pure metal from metal ion
    - **Liquefaction**
      (Metal is converted to liquid form, impurities remain in solid form.)
    - **Zone refining**
      (Impurities separate as crystals)

EXERCISE

1. Select the proper choice from the given muitiple choices :

(1) What is the chemical formula of alumina ?

(A) Al_2O_3 (B) $Al_2O_3.\ 2H_2O$ (C) $Al_2O_3.\ H_2O$ (D) $NaAlO_2$

(2) Which of the following reactions is called roasting ?

(A) $ZnCO_3(s) \xrightarrow{\Delta} ZnO(s) + CO_2(g)$

(B) $2ZnS(s) + 3O_2(g) \xrightarrow{\Delta} 2ZnO(s) + 2SO_2(g)$

(C) $ZnO(s) + C(s) \xrightarrow{\Delta} Zn(s) + CO(g)$

(D) $Zn(s) + H_2O(g) \xrightarrow{\Delta} ZnO(s) + H_2(g)$

(3) Which of the following is an alloy ?

(A) Silver (B) Galium

(C) 22 carat gold (D) 24 carat gold

(4) During which reaction dihydrogen gas is not produced under normal conditions ?

(A) Metal + dilute sulphuric acid (B) Metal + dilute hydrochloric acid

(C) Metal + dilute nitric acid (D) Metal + water

(5) In which of the following, displacement reaction is possible ?

(A) Solution of NaCl + coin of copper (B) Solution of $MgCl_2$ + coin of aluminium

(C) Solution of $FeSO_4$ + coin of silver (D) Solution of $AgNO_3$ + coin of copper

(6) Which of the following reactions is not possible ?

(A) $Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$

(B) $Zn(s) + FeSO_4(aq) \rightarrow ZnSO_4(aq) + Fe(s)$

(C) $Fe(s) + CuSO_4(aq) \rightarrow FeSO_4(aq) + Cu(s)$

(D) $Cu(s) + FeSO_4(aq) \rightarrow CuSO_4(aq) + Fe(s)$

(7) By which reaction metal is obtained from metal oxide ?

(A) Liquefaction (B) Reduction (C) Calcination (D) Roasting

(8) Which of the following statements is incorrect ?

(A) Corrosion of copper takes place by contact with air and water

(B) The melting points and boiling points of metals are low.

(C) The method to convert carbonate containing ore to metal oxide is called calcination.

(D) The displacement of less active metals from their solution takes place by more active metal.

(9) Which alloy is used to solder the electric wires ?

(A) Copper + zinc (B) Aluminium + magnesium

(C) Lead + tin (D) Copper + tin

(10) Which metal is available in highest proportion on the earth ?

(A) Iron (B) Copper (C) Aluminium (D) Silver

(11) Which metal is used in thermometer ?

(A) Silver (B) Mercury (C) Sodium (D) Copper

(12) Which of the following substances is hygroscopic ?

(A) Cryolite (B) Feldspar

(C) Anhydrous calcium chloride (D) Slag

2. Answer the following questions in brief :

(1) In which three sections elements are classified ?

(2) Which metals are available in free state in nature ?

(3) In which form ores are available in nature ?

(4) Write names and formulas of two ores of iron.

(5) Write names and formulas of two ores of copper.

(6) Write names of the three methods for concentration of ores.

(7) Which two methods are used for reduction of metal oxides ?

(8) Write names of three methods used for refining of metals.

(9) What has been taken as anode and cathode for refining of metals in electrolysis method ?

(10) Which chief impurities are present in bauxite ?

(11) Which two substances are added along with alumina to obtain aluminium from alumina by electrochemical reduction ?

(12) Which substance is called slag ?

(13) Mention use of slag.

(14) Which general principle is taken into consideration in determination of activity series of metals ?

(15) Mention names of two softer metals.

(16) Write names of two metals which are bad conductors of electricity.

(17) Write names of two metal oxides which form alkali by dissolving in water.

(18) Which two metals burn with explosion in reaction with water ?

(19) Mention two examples of metals forming metal hydride with hydrogen.

(20) Which two metals are generally not corroded ?

(21) Stainless steel is a homogeneous mixture of which three metals ?

(22) Mention examples of two alloys.

(23) Write chemical formula of rust.

(24) Explain the following terms :

(i) Mineral
(ii) Ore
(iii) Metallurgy
(iv) Centrifugation
(v) Roasting
(vi) Calcination
(vii) Anodic mud
(viii) Metallic corrosion
(ix) Alloy
(x) Galvanizing

(25) Mention the formulas, names and physical states of the products in the following reactions :

(i) $2PbS(s) + 3O_2(g) \rightarrow$

(ii) $MgCO_3(s) \xrightarrow{\Delta}$

(iii) $Fe_2O_3(s) + 3CO(g) \xrightarrow{\Delta}$

(iv) $Fe_2O_3(s) + 2Al(s) \xrightarrow{\Delta}$

(v) $2Al(OH)_3(s) \xrightarrow[\Delta]{1473\,K}$

(vi) $CaO(s) + SiO_2(s) \rightarrow$

(vii) $K_2O(s) + H_2O(l) \rightarrow$

(viii) $Mg(s) + 2H_2O(l) \rightarrow$

(ix) $Zn(s) + 2HCl(aq) \rightarrow$

(x) $Ca(s) + Cl_2(g) \rightarrow$

3. Answer the following questions :

(1) Describe the method to remove impurity of iron from ore.

(2) Explain the method of concentration of copper pyrites - the ore of copper.

(3) By which method conversion of ZnS and $ZnCO_3$ into ZnO can be carried out ? Explain writing chemical equation.

(4) Explain the refining of copper by electrolysis.

(5) Write four physical properties of metals.

(6) Write chemical equations of the reaction of magnesium metal with dioxygen gas, water, dilute hydrochloric acid and dichlorine gas.

(7) Mention the components and uses of brass and bronze.

4. Answer the following questions in detail :

(1) Write a short note : Earth – Treasure of elements

(2) Explain different methods of concentration of ores.

(3) Explain roasting, calcination and smelting.

(4) Explain chemical reduction and electrochemical reduction.

(5) Explain liquefaction and zone refining method for refining of metals.

5. Answer the following questions pointwise :

(1) Discuss the extraction of aluminium from bauxite.

(2) Explain extraction of iron from haematite.

(3) Write the activity series of metals. Discuss the experiment for determination of activity series of Fe, Cu and Ag metals.

(4) Discuss chemical properties of metals.

(5) Mentioning reasons for metallic corrosion describe the remedies to prevent it.

(6) What is an alloy ? Mention its advantages. Mention the name of three alloys and also mention the components in them, properties and uses.

UNIT

9

NON-METALS

9.1 Introduction

Out of 114 elements known till today in chemistry, 18 elements do not act like metals. These elements are called non-metallic elements. Non-metallic elements are shown on the right hand side in the modern Periodic Table. Non-metallic elements are found mainly in solid or gaseous form at room temperatures. Only bromine is found in the liquid form. Hydrogen, nitrogen, oxygen, chlorine, etc. are the examples of gaseous non-metal elements and carbon, sulphur, phosphorus etc. are the examples of non-metals in solid form. Number of non-metallic element is less but their contribution in everyday life is much more, viz dihydrogen gas (H_2) is used in the hydrogenation reaction in preparation of vegetable ghee from vegetable oil. Compounds of ammonia are used as fertilisers. In the production of ammonia in addition to dinitrogen, dihydrogen gas is used in a large amount. We know that vitamins, proteins, carbohydrates, enzymes, etc. play an important role in the development of every living entity. Carbon element is in the base of these components. In electrolysis cell and dry cell, carbon in the graphite form is used as an electrode. Oxygen of the air becomes useful for the living kingdom to exist and in combustion reaction. Sulphur is there in the elements present in plants and animals. It is present in protein, hairs, wool, onion, garlic, etc. Sulphur is used as fungicides and in the preparation of gun powder for guns. In this unit we shall study non-metals like hydrogen and sulphur and their important compounds.

9.2 Physical Properties of Non-metals

Non-metals possess physical properties opposite to those of metal. Non-metals do not possess properties of ductility and malleability. Non-metallic elements in solid form are brittle. The surface of non-metals is not lustrous, but as an exception iodine possesses luster. Non-metallic elements are generally soft but diamond is the hardest substance. Non-metallic elements are bad conductors of electricity and heat but **graphite is known as a good conductor of electricity.**

9.3 Chemical Properties of Non-metallic Elements

Non-metallic elements receive electrons easily and form negative ions. Hence, non-metallic elements are called electronegative elements.

$Cl + e^- \rightarrow Cl^-$

$O + 2e^- \rightarrow O^{2-}$

$S + 2e^- \rightarrow S^{2-}$

Now, we shall discuss the chemical properties of non-metallic elements.

(1) Reaction of non-metal with dioxygen gas : Non-metallic elements combine with dioxygen gas and form oxides. These oxides are either acidic or neutral but are not basic.

$$C(s) + O_2(g) \rightarrow \underset{\text{Carbon dioxide}}{CO_2(g)}$$

$$S(s) + O_2(g) \rightarrow \underset{\text{Sulphur dioxide}}{SO_2(g)}$$

$$P_4(s) + 5O_2(g) \rightarrow \underset{\text{Phoshorus pentoxide}}{2P_2O_5 \text{ or } P_4O_{10}(g)}$$

Carbon dioxide, sulphur dioxide and phosphorus pentoxide are acidic. They form acids by reaction with water.

$$CO_2(g) + H_2O(l) \rightarrow \underset{\text{Carbonic acid}}{H_2CO_3(aq)}$$

$$SO_2(g) + H_2O(l) \rightarrow \underset{\text{Sulphurous acid}}{H_2SO_3(aq)}$$

$$2P_2O_5(g) + 6H_2O(l) \rightarrow \underset{\text{Phosphoric acid}}{4H_3PO_4(aq)}$$

Carbon monoxide (CO), nitrous oxide (N_2O) and water (H_2O) are examples of neutral oxides.

(2) Reaction of non-metal with acid : Non-metallic elements are electron accepting elements. Hence, they are not able to displace easily hydrogen present in acid. Thus, the effect of dilute acids on non-metallic elements is not observed, viz. carbon and sulphur do not react with dilute hydrochloric acid or dilute sulphuric acid.

(3) Reaction of non-metal with dichlorine gas : Chlorides of non-metal are formed by reaction of dry dichlorine gas with non-metallic elements. These chloride compounds are generally volatile liquids or are in gaseous forms.

$$P_4(s) + 6Cl_2(g) \rightarrow \underset{\text{Phosphorus trichloride}}{4PCl_3(g)}$$

(4) Reaction of non-metal with dihydrogen : Non-metallic elements on reacting with dihydrogen gas, form stable hydride compounds. These hydride compounds are formed by sharing of electrons between non-metallic element and hydrogen, e.g ammonia (NH_3), water (H_2O), methane (CH_4), hydrogen sullphide (H_2S) etc.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

$$O_2(g) + 2H_2(g) \rightarrow 2H_2O(l)$$

$$C(s) + 2H_2(g) \rightarrow CH_4(g)$$

$$S(s) + H_2(g) \rightarrow H_2S(g)$$

9.4 Hydrogen

The word hydrogen is derived from the two Greek words - 'Hydro' means water and 'Gene' means to produce, i.e. it is known as water producer. The symbol of hydrogen is H. The discovery of hydrogen was made by a scientist from England - Henry Cavendish, in 1766. Hydrogen takes first place in the periodic table. It is the lightest element. Hydrogen atom being very active, does not possess independent (free) existence, but it possesases stable existence in the form of a dihydrogen (H_2) molecule or in combined form with any other element. Three out of the four parts of the earth are full of water which is a compound of hydrogen and oxygen. In living substances also it is in combined form with carbon element. Hydrogen is also observed in the space. When hydrogen is converted to helium by fusion reaction, then solar energy is produced.

(1) Preparation of Dihydrogen Gas : Dihydrogen gas can be prepared by reaction of metal with water or dilute acid. Dihydrogen gas is produced by reaction of very active metals like potassium, sodium or calcium with cold water.

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$$
$$Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$$

Less active metals like magnesium, zinc, iron etc, produce dihydrogen gas by reaction with vapour of water :

$$Mg(s) + H_2O(g) \rightarrow MgO(s) + H_2(g)$$
$$Zn(s) + H_2O(g) \rightarrow ZnO(s) + H_2(g)$$
$$3Fe(s) + 4H_2O(g) \rightarrow Fe_3O_4(s) + 4H_2(g)$$

(2) Preparation of Dihydrogen Gas (H_2) in Laboratory : In laboratory, for the preparation of dihydrogen gas, generally granular, pieces of zinc metal are taken in 500 ml conical flask as shown in Fig. 9.1. Dilute hydrochloric acid or dilute sulphuric acid is added through Thistle funnel. Dihydrogen gas is produced by the reaction between them. This gas is collected in a gas jar by downward displacement of water because it is a gas lighter than water.

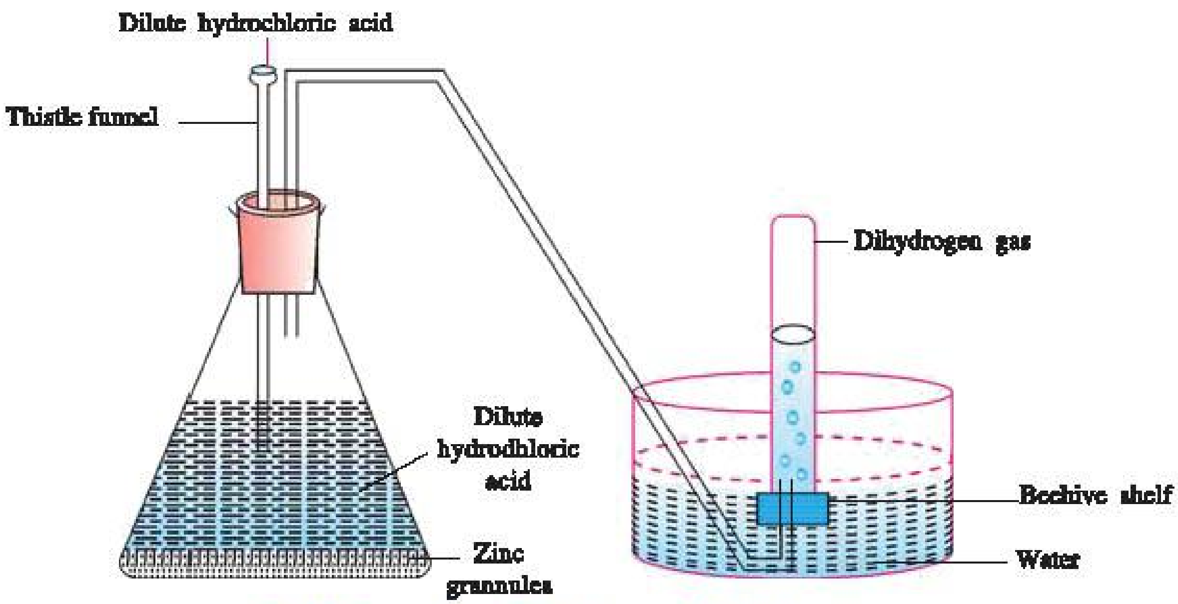


Fig 9.1 Preparation of dihydrogen Gas in Laboratry

Reaction :

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$$

(3) Industrial Manufacture of Dihydrogen Gas

In recent times, hydrogen gas is widely used in industries. The production of hydrogen gas can be carried out from natural gas. The chief component in natural gas is methane. When natural gas mixed with vapour of water is passed on a nickel catalyst at the temperature 1073 K and 30 bar pressure, chemical reaction takes place and a mixture of carbon monoxide and dihydrogen gas is obtained. This gaseous mixture is called **water gas.**

$$CH_4(g) + H_2O(g) \xrightarrow[1073\,K\ 30\,bar]{Ni} CO(g) + 3H_2(g)$$

By reaction of water gas again with vapour of water, more dihydrogen gas is produced and carbon monoxide is removed.

$$CO(g) + H_2O(g) \rightarrow CO_2(g) + H_2(g)$$

To separate dihydrogen gas from this gaseous mixture, it is passed through water at 30 bar pressure because, carbon dioxide gas dissolves in water as it is soluble in water but dihydrogen gas is insoluble in water and so it can pass through and dihydrogen gas is obtained. This way it can be collected in gas jar.

Also, pure dihydrogen gas can be obtained by electrolysis of pure water by using the apparatus called voltameter.

(4) Physical Properties of Dihydrogen Gas

- Dihydrogen is colourless, odourless and tasteless gas.
- Normally it is insoluble in water.
- It is lighter than air and also lighter than all other gases, so it is the lightest gas.
- As it does not show any effect on wet blue or red litmus paper, it is a neutral gas.

(5) Chemical Properties of Dihydrogen Gas :

(1) Reaction with dioxygen gas : Water is formed by reaction of dihydrogen gas with dioxygen gas

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$$

Dihydrogen gas forms explosive mixture with dioxygen gas.

When the mixture of these two gases burns, it explodes. As large amount of energy is produced by this reaction, it is used as fuel in space rockets.

Here, we should understand that when an ignited match stick is put into a gas jar it extinguishes. This shows that dihydrogen gas is not the supporter of combustion but when dihydrogen gas is burnt in presence of air or oxygen, it burns with a blue flame and produces steam i.e. H is combustible. Water can be obtained by cooling this steam.

(2) **Reaction with Metal Oxide :** Dihydrogen gas is a good reducing agent. It reduces easily, the metallic oxides of elements less active than zinc in the activity series and converts into metals viz. when copper oxide is heated in presence of dihydrogen, then it is reduced to copper metal and water is formed by oxidation of dihydrogen gas.

$$CuO(s) + H_2(g) \rightarrow Cu(s) + H_2O\ (g)$$

(3) **Reaction with Dichlorine Gas :** Dichlorine possesses more attraction towards dihydrogen. The mixture of equal proportions of dihydrogen and dichlorine explodes in presence of sunlight and produces fumes of hydrogen chloride gas in absence of sunlight.

$$H_2(g) + Cl_2(g) \xrightarrow{\text{Absence of light}} 2HCl\ (g)$$

(4) **Reaction with Active Metal :** Dihydrogen gas combines with certain active metals like Na, K, Ca and forms the metallic hydride of that metal.

$$H_2(g) + 2Na(s) \rightarrow 2NaH(s)$$

$$H_2(g) + 2K(s) \rightarrow 2KH(s)$$

$$H_2(g) + Ca(s) \rightarrow CaH_2(s)$$

(6) Uses of Dihydrogen Gas :

- As one of the reactants in the production of ammonia gas by Haber's process.
- In hydrogenation reaction of preparation of vegetable ghee from vegetable oil in presence of nickel catalyst.
- In welding of metals and in oxyhydrogen flame for cutting metals.
- In industrial production of methanol and hydrochloric acid, as fuel in rockets and fuel cell for production of electricity.
- Dihydrogen gas gets adsorbed on solid alloy and can be released whenever required and can be stored to use it again.
- The calorific value of dihydrogen gas is the highest of all other fuels. By combustion of dihydrogen gas, water is produced and so there is no question of pollution. Thus, there is a possibility of hydrogen being an important source of energy in future.

9.5 Ammonia

Ammonia is a very important chemical. It is used in production of nitric acid, polymers and in production of artificial fertilisers. Ammonia was synthesized by German Chemist Haber. Hence, this method of production is known as Haber's process.

(1) **Industrial Production of Ammonia Gas :** Industrial production of ammonia gas is carried out by Haber's process. In this method dihydrogen and dinitrogen gases are mixed in 3:1 proportion by volume and then passed over iron catalyst at 200-300 bar pressure. Temperature about 773 K is maintained during this reaction. Substances like Al_2O_3, K_2O are added to increase the efficiency of the catalyst. Hence, they are called **promoters.** By cooling the reaction mixture at temperature lower than 273 K, ammonia can be separated from the unreacted N_2 and H_2 gases.

Thus, ammonia is obtained in the liquid form and N_2 and H_2 remained without reaction can be used again to take part in the reaction.

$$N_2(g) + 3H_2(g) \xrightarrow[200\text{-}300\ \text{bar}\ [Fe]]{773\,K} 2NH_3(g) + \text{Heat}$$

(2) Physical Properties of Ammonia Gas :

- Ammonia is a colourless gas.
- It possesses very intensive smell, causing irritation in the nose and eyes.
- It is lighter gas than air
- It is highly soluble in water.
- Aqueous solution of ammonia acts as a weak base. The concentrated solution of ammonia is called **liquor ammonia.**

(3) Chemical Properties of Ammonia Gas :

(1) Reaction with hydrogen chloride gas : By reaction of ammonia gas with hydrogen chloride gas, solid ammonium chloride is obtained.

$$NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$$

When a glass rod dipped in concentrated hydrochloric acid is placed near the vessel containing ammonia gas while dense fumes are produced of ammonium chloride is formed as small particles. In laboratory, this reaction is useful in testing of ammonia gas.

(2) Effect of ammonia as reducing agent : On passing ammonia gas over the hot cupric oxide (CuO) black coloured oxide is reduced and red brown coloured copper metal is obtained.

$$2NH_3(g) + 3CuO(s) \rightarrow 3Cu(s) + 3H_2O(l) + N_2(g)$$

(3) Catalytic oxidation of ammonia : On passing the mixture of ammonia and dioxygen gas over platinum catalyst heated at 1073 K temperature ammonia is oxidised to nitric oxide.

$$4NH_3(g) + 5O_2(g) \xrightarrow{[Pt]\ 1073K} 4NO(g) + 6H_2O(g)$$

The produced nitric oxide immediately combines with oxygen and gives brown coloured fumes of nitrogen dioxide.

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

This nitrogen dioxide reacts with water and forms nitric acid. This process to obtain nitric acid from ammonia gas is known as Ostwald's process.

$$3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(aq) + NO(g)$$

(4) Effect of ammonia gas on litmus paper : Dry ammonia gas does not show any effect on litmus paper but aqueous solution of ammonia turns red litmus paper into blue. This indicates that aqueous solution of ammonia shows basic nature, because ammonia gas dissolves in water and forms weak base ammonium hydroxide which gives OH^- ion by ionisation in less proportion.

$$NH_3(g) + H_2O(l) \rightleftharpoons NH_4OH(aq) \rightleftharpoons NH^+_4(aq) + OH^-(aq)$$

Aqueous solution of ammonia is basic. Salt and water are formed by its reaction with acid, e.g. by reaction of aqueous hydrochloric acid with aqueous solution of ammonia. (NH_4OH) ammonium chloride (salt) and water are formed.

$$NH_4OH(aq) + HCl\ (aq) \rightleftharpoons NH_4Cl(aq) + H_2O(l)$$

(5) Reaction with metal ion : By reaction of aqueous solution of ammonia with aqueous solution of metal ion, metal hydroxide insoluble in water is formed, viz. blue coloured precipitates of cupric hydroxide are obtained by addition of solution of ammonium hydroxide to aqueous solution of cupric sulphate.

$$CuSO_4(aq) + 2NH_4OH(aq) \rightarrow Cu(OH)_2(s) + (NH_4)_2SO_4(aq)$$

But if excess of NH_4OH is added then precipitates dissolve and dark blue coloured solution is obtained, which is due to the formation of complex salt of copper with ammonia.

$$Cu(OH)_2(s) + 4NH_4OH(aq) \rightarrow [Cu(NH_3)_4]\ (OH)_2(aq) + 4H_2O(l)$$

Similarly ammonium hydroxide with ferrous sulphate, magnesium sulphate and aluminium chloride forms ferrous hydroxide, magnesium hydroxide and aluminium hydroxide respectively.

$$FeSO_4(aq) + 2NH_4OH(aq) \rightarrow Fe(OH)_2(s) + (NH_4)_2SO_4(aq)$$

$$MgSO_4(aq) + 2NH_4OH(aq) \rightarrow Mg(OH)_2(s) + (NH_4)_2SO_4(aq)$$

$$AlCl_3(aq) + 3NH_4OH(aq) \rightarrow Al\ (OH_3)(s) + 3NH_4Cl\ (aq)$$

(4) Uses of Ammona Gas :

- The important use of ammonia is in the preparation of fertilisers like ammonium nitrate, ammonium sulphate and diammonium phosphate.
- In preparation of nitric acid by Ostwald's process.
- In preparation of dyes, explosives and nylon etc.
- In preparation of baking soda and washing soda.
- In preparation of certain medicines like para aminobenzoic acid, folic acid, etc.

9.6. Sulphur

Many years ago sulphur was used as medicine in Ayurvedic medicines. Sulphur is available in nature in both free and combined forms. Sulphur is obtained in combined form with certain metal ions viz copper pyrites ($CuFeS_2$), zinc blende (ZnS), galena (PbS) etc. Sulphur is in noticeable proportion in petroleum and natural gas. The place of sulphur is in group-16 below oxygen in periodic table. The atomic number of sulphur is 16. Hence, its electronic configuration is 2,8,6. Sulphur also possesses property of catenation.

(1) Extraction of Sulphur : The method that is used for direct extraction of sulphur from the core of the earth is called Frasch method. This method is based on the low melting point of sulphur. In this method, as shown in Figure 9.2 three concentric pipes are passed below in the soil so that they touch the layer of the sulphur. Superheated water vapour is passed at 443 K temperature in the soil through the outermost cylinder. Sulphur melts because of its low melting point. Afterwards, air at high pressure is passed through the innermost cylinder so that sulphur and water in the central cylinder come out on the outer surface and gets cooled. Sulphur is insoluble in water and so it can be easily separated.

Sulphur is also obtained from petroleum and natural gas. Firstly, sulphur compounds are converted into hydrogen sulphide (H_2S). Sulphur dioxide is obtained by its combustion. Sulphur is obtained in free state when sulphur dioxide is heated with H_2S in presence of Fe_2O_3 catalyst.

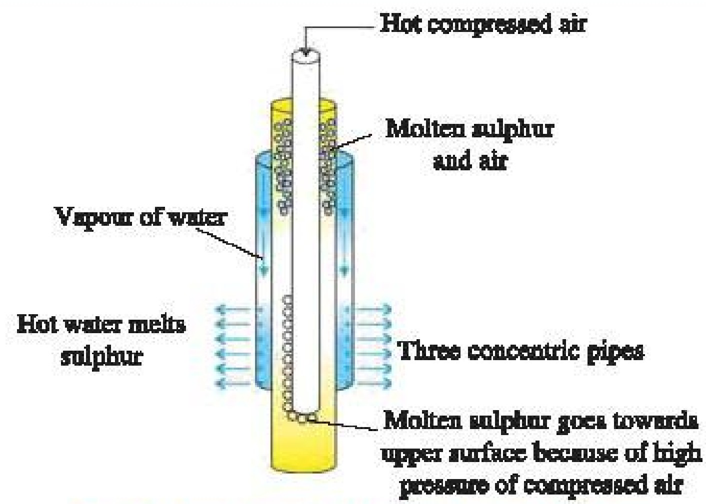


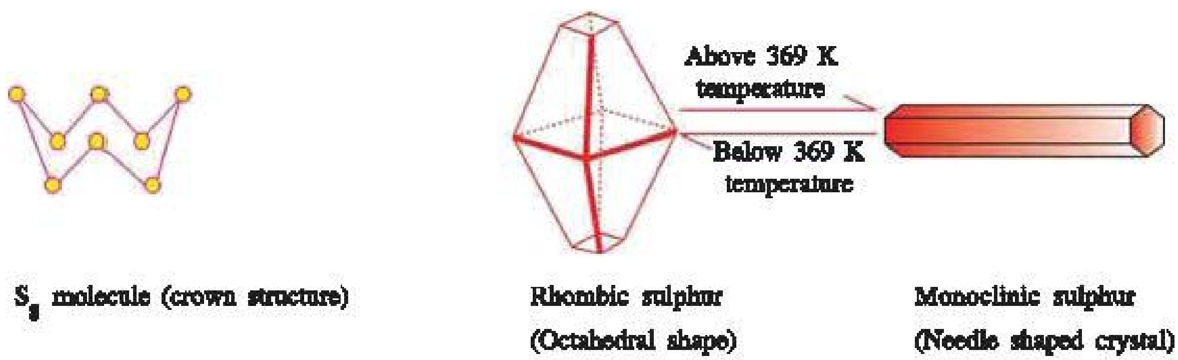
Fig. 9.2 Frasch method for production of sulphur

$$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(g)$$

$$SO_2(g) + 2H_2S(g) \xrightarrow[{[Fe_2O_3]}]{573\,K} 3S(s) + 2H_2O(g)$$

(2) Allotropes of Sulphur :

Two or more forms of an element having existence because of the different arrangements of atoms in allotropes of that element is called **allotropy**. There are two crysalline forms of sulphur in solid state like rhombic sulphur and monoclinic sulphur. These two forms are called **allotropes** of sulphur. Rhombic sulphur is stable at temperature lower than 369 K and monoclinic sulphur is stable at temperature higher than 369 K. Both these forms i.e. allotropes have same chemical properties but different physical properties because the crystal structures of allotropes are different. Rhombic sulphur possesses octahedral structure, while monoclinic sulphur possesses needle like crystals.



S_8 molecule (crown structure) Rhombic sulphur (Octahedral shape) Monoclinic sulphur (Needle shaped crystal)

Fig. 9.3 Allotropes of Sulphur

There is S_8 ring in both the allotropes of sulphur. When sulphur is heated then this ring will break, but as we go on heating the pieces of the ring, they combine with each other and get converted into small particles after being viscous. As a result of this liquid sulphur starts boiling.

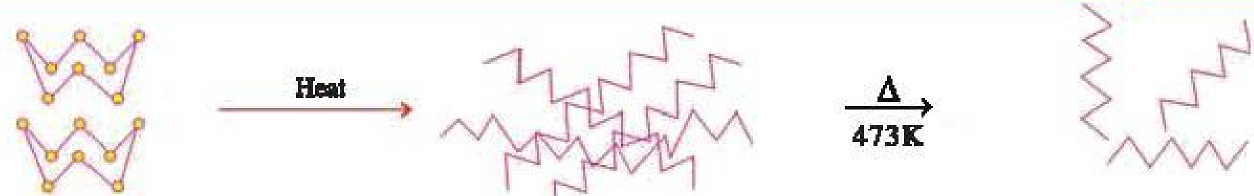


Fig. 9.4 Effect of temperature on sulphur

(3) Physical Properties of Sulphur :

- Sulphur is yellow coloured solid substance having different allotropes.
- It is insoluble in water but is soluble in organic solvents like carbon disulphide and toluene.
- Its melting point is low (388 K).

(4) Chemical properties of Sulphur :

(1) Reaction with acid : In reaction of sulphur with hot concentrated sulphuric acid, sulphur dioxide is formed by oxidation of sulphur.

$$S(s) + 2H_2SO_4(l) \rightarrow 2H_2O(l) + 3SO_2(g)$$

On oxidation of sulphur by concentrated nitric acid, sulphuric acid is formed

$$S(s) + 6HNO_3(aq) \rightarrow H_2SO_4(aq) + 6NO_2(g) + 2H_2O(l)$$

(2) Reaction with dihydrogen gas : Hydrogen sulphide is obtained by reaction of boiling sulphur with dihyrodgen gas.

$$S(l) + H_2(g) \rightarrow H_2S(g)$$

(3) Reaction with carbon element : Carbon disulphide is formed by the reaction of carbon with sulphur at high temperature.

$$C(s) + 2S(s) \rightarrow CS_2(l)$$

(5) Uses of Sulphur :

- In manufacture of sulphuric acid.
- In production of solvent like carbon disulphide.
- As antiseptic and fungicide in skin diseases.
- In vulcanization of rubber, preparation of fire crackers, preparation of dyes and preparation of insecticides.

9.7 Sulphur Dioxide

Sulphur dioxide gas is formed by reaction of sulphur with dioxygen.

$$S(s) + O_2(g) \xrightarrow{\Delta} SO_2(g)$$

Sulphur dioxide gas is present in the fumes exhausted by industries and in use of sulphur containing fuels by the automobiles. It is considered as a chief pollutant in spreading air pollution. Sulphur dioxide is responsible for the acid rain. This sulphur dioxide is oxidized into sulphur trioxide which forms sulphuric acid by dissolving in rain water. Buildings, bridges and trees are destroyed because of acid rain.

(1) Physical properties of sulphur dioxide :

- It is a colourless gas.
- It has intense smell that causes coughing and suffocation.
- Aqueous solution of sulphur dioxide possesses acidic property because it is an oxide of non-metal.

(2) Chemical properties of sulphur dioxide gas :

(1) Reaction with gas : Sodium sulphite is formed by passing sulphur dioxide gas through the solution of sodium hydroxide because sulphur dioxide is an acidic oxide.

$$SO_2(g) + 2NaOH(aq) \rightarrow \underset{\text{Sodium sulphite}}{Na_2SO_3(aq)} + H_2O(l)$$

Lime water becomes milky due to formation of calcium sulphite when sulphur dioxide gas is passed through decanted lime water.

$$SO_2(g) + Ca(OH)_2(aq) \rightarrow \underset{\text{Calcium sulphite}}{CaSO_3(s)} + H_2O(l)$$

But if sulphur dioxide in large proportion is passed through this solution the milky colour of solution disappears because of formation of soluble calcium hydrogen sulphite.

$$CaSO_3(s) + H_2O(l) + SO_2(g) \rightarrow \underset{\text{Calcium hydrogen sulphite}}{Ca(HSO_3)_2(aq)}$$

(2) Reaction with dioxygen gas : On reaction of sulphur dioxide gas with dioxygen gas in presence of vanadium pentoxide (V_2O_5) catalyst, sulphur trioxide gas is formed by oxidation of sulphur dioxide.

$$2SO_2(g) + O_2(g) \xrightarrow[723\,K]{[V_2O_5]} 2SO_3\ (g)$$

(3) Reaction with hydrogen sulphide gas : Sulphur is formed by reaction of sulphur dioxide gas with hydrogen sulphide gas. Here, sulphur dioxide acts as an oxidising agent and so H_2S is oxidised to S and SO_2 is reduced to S.

$$SO_2(g) + 2H_2S(g) \rightarrow 3S(s) + 2H_2O\ (l)$$

(4) Effect of sulphur dioxide as reducing agent : Sulphur dioxide gas reduces acidic potassium dichromate ($K_2Cr_2O_7$). Hence, orange coloured solution becomes green coloured solution due to the formation of chromic ion (Cr^{3+}) in the end.

$$3SO_2(g) + 2H^+\ (aq) + \underset{\text{Orange colour}}{Cr_2O_7^{2-}(aq)} \rightarrow 3SO_4^{2-}(aq) + H_2O(l) + \underset{\text{Green colour}}{2Cr^{3+}(aq)}$$

(3) Uses of Sulphur Dioxide Gas :

- In manufacture of sulphuric acid.
- It inhibits the growth of bacteria, hence it is used as preservative in juice of fruits, in jam and drying of fruits.
- Used for bleaching of wooden pulp in paper industry. Thus, it is a weak bleaching agent.

9.8 Sulphuric Acid

Sulphuric acid is an important industrial chemical. It is called the "King of Chemicals" because sulphuric acid is widely used in the production of most of the chemicals like fertilisers, paints synthetic fibres, soap and detergents.

(1) Production of Sulphuric Acid : Sulphuric acid is produced by contact process. In this process sulphur is burnt in air so that sulphur dioxide gas is formed. Sulphur dioxide gas with excess air is passed over solid vanadium pentoxide (V_2O_5) catalyst at 723 K so that sulphur trioxide gas is formed. For this reaction platinum catalyst was used but it became useless due to catalytic poisoning. In its place vanadium pentoxide is used.

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

$$2SO_2(g) + O_2(g) \xrightarrow[723\,K]{[V_2O_5]} 2SO_3(g)$$

When sulphur trioxide is dissolved in water it forms sulphuric acid with very corrosive fumes but if sulphur trioxide gas is absorbed in concentrated sulphuric acid, fuming viscous liquid is formed. It is called fuming sulphuric acid or oleum ($H_2S_2O_7$). Oleum is diluted with water and sulphuric acid of desired concentration can be obtained.

$$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$$

$$SO_3(g) + H_2SO_4(l) \rightarrow \underset{\text{Oleum}}{H_2S_2O_7(l)}$$

$$H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(aq)$$

The production of sulphuric acid can be carried out by another method like Lead Chamber process. In this method sulphur dioxide is oxidised to sulphur trioxide by nitrogen dioxide (NO_2). The acid obtained by this method, is not of higher concentration and this process is also slow. Hence, contact process is used as the modern method for production of sulphuric acid.

(2) Properties of Sulphuric Acid : Sulphuric acid is used as concentrated sulphuric acid and dilute sulphuric acid is used in industries and laboratory. Here, we shall study its properties.

Properties of Concentrated Sulphuric Acid :

- Concentrated sulphuric acid is a colourless dense viscous liquid.
- 98% H_2SO_4 and 2% H_2O are there in it.
- It acts as an oxidising agent. It oxidises carbon and sulphur atoms into carbon dioxide and sulphur dioxide.

$$C(s) + 2H_2SO_4(aq) \rightarrow 2H_2O(l) + 2SO_2(g) + CO_2(g)$$

$$S(s) + 2H_2SO_4(aq) \rightarrow 2H_2O(l) + 3SO_2(g)$$

- It is a strong dehydrating agent. Hence, utmost care is to be taken while using it. If concentrated sulphuric acid falls on sugar, paper, wood etc. it removes water from it and burns it. Similarly, if this acid falls on skin, it absorbs water from muscular tissue and burns it. Now, we shall study the property as strong dehydrating agent of sulphuric acid by an activity.

Activity : 1

Test of Sulphuric acid for the property of Sulphuric acid as a strong dehydrating agent :

- First of all take some sugar in a test tube. Add few drops of concentrated sulphuric acid to it.
- Now you observe the substance in the test tube.
- On observing, you will find the sugar in the test tube being changed to black coloured substance. Now, the question will arise that why this has happened ?

Sugar contains carbon, hydrogen and oxygen elements. The concentrated sulphuric acid removes hydrogen and oxygen from the sugar as water. Carbon remaining in sugar is left as black substance, by burning.

$$\underset{\text{Sugar (sucrose)}}{C_{12}H_{22}O_{11}(s)} \xrightarrow{\text{Concentrated } H_2SO_4} \underset{\text{Black substance}}{12C(s)} + 11H_2O(l)$$

- In a test tube take little crystalline copper (II) sulphate ($CuSO_4.5H_2O$). Note the colour of the substance.
- Add few drops of concentrated sulphuric acid in the test tube.
- Now, you continue observing colour of the substance in the test tube.
- On observation, you will find that the crystal of copper sulphate slowly changes into white.

The reason for this is that by addition of concentrated sulphuric acid to copper sulphate ($CuSO_4 \cdot 5H_2O$) the water of crystallization in it is removed. Anhydrous copper sulphate ($CuSO_4$) obtained this way, is colourless.

$$(CuSO_4 \cdot 5H_2O) \xrightarrow{\text{Concentrated } H_2SO_4} CuSO_4(s)$$

Properties of dilute sulphuric Acid :

- In dilute sulphuric acid, there is 10% sulphuric acid and 90% water.
- Dilute sulphuric acid can be prepared by adding concentrated sulphuric acid slowly to water. As heat is produced during this, pieces of ice are placed around the vessel. At this stage, we will have the definite idea that dilute sulphuric acid cannot be prepared by adding water to concentrated sulphuric acid. Definitely, it can be prepared but the difficulty is that when concentrated acid is added to water, heat is produced in large proportion and so there is possibility of drops of acid to fall on our body.
- It turns blue litmus into red.
- It produces sulphate of metal and dihydrogen gas when reacted with metal.

$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(q)$$

$$Fe(s) + H_2SO_4(aq) \rightarrow FeSO_4(aq) + H_2(g)$$

- It produces sulphates of metal, water or carbon dioxide gas when reacts with oxides, hydroxides or carbonates of metal.

$ZnO(s) + H_2SO_4(aq) \rightarrow ZnSO_4 (aq) + H_2O(l)$

$CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4 (aq) + H_2O(l)$

$2NaOH(s) + H_2SO_4(aq) \rightarrow Na_2SO_4 (aq) + 2H_2O(l)$

$CaCO_3(s) + H_2SO_4(aq) \rightarrow CaSO_4 (aq) + H_2O(l) + CO_2(g)$

- It produces sodium sulphate and carbon dioxide by reaction with sodium carbonate or sodium bicarbonate.

$Na_2CO_3(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + H_2O(l) + CO_2(g)$

$2NaHCO_3(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + H_2O(l) + CO_2(g)$

- As two hydrogen atoms of sulphuric acid can be displaced, it is known as dibasic or diprotic acid. If one hydrogen atom is displaced, then hydrogen sulphate (acid-salt) and if two hydrogen atoms are displaced, then sulphate salt (neutral salt) is formed.

$NaOH(aq) + H_2SO_4(aq) \rightarrow NaHSO_4(aq)$ (Acid salt) $+ H_2O(l)$

$2NaOH (aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq)$ (Neutral salt) $+ 2H_2O(l)$

(3) Uses of Sulphuric Acid :

- In industries for production of fertilisers, plastic, fibers, dyes, pigments, paints, detergents.
- As a reagent in analysis of chemical substances in laboratory.
- To obtain acids like HCl, HBr from their salts.

What have you learnt ?

Only 18 elements out of 114 elements known till today, do not behave as metals. These elemetns are called non-metallic elements.

Some important Non-metallic Elements

Non-metallic Elements	Physical State	Importance
Carbon	Solid	Element carbon is present in vitamins, proteins, carbohydrates, enzymes etc. Graphite used in electrolysis and dry cell in the form of carbon.
Sulphur	Solid	It is present in the substances present in plants and animals. It is also present in proteins, hair, wool, onion and garlic. Sulphur is used as fungicide and in gun powder.
Hydrogen	Gas	In hydrogenation reaction of preparing vegetable ghee, in production of ammonia gas.
Nitrogen	Gas	Used as dinitrogen gas in production of ammonia gas.
Oxygen	Gas	Oxygen of air is useful for living kingdom to survive and in combustion reaction.

Physical Properties of Non-metallic Elements

- Brittle
- Soft (Exception Diamond)
- Lustreless (Exception Iodine)
- Bad conductors of electricity and heat (Exception graphite – good conductor of electricity)

Chemical Properties of Non-metallic elements

Non-metallic Element →
- $\xrightarrow{O_2(g)}$ Oxide
- $\xrightarrow{\text{Dilute acid}}$ Reaction does not occur
- $\xrightarrow{Cl_2(g)}$ Chloride of non-metal
- $\xrightarrow{H_2(g)}$ Stable hydride

Hydrogen : Hydrogen atom does not exist free because it is very active. But as a dihydrogen molecule (H_2) or in compound with other element, it possesses stable existence.

Physical properties of dihydrogen gas :

$$CH_4\ (g) + H_2O\ (g) \xrightarrow[1073\,K\ 30\,bar]{Ni} CO(g) + 3H_2(g)$$

$$CO(g) + H_2O(g) \rightarrow CO_2(g) + H_2(g)$$

In addition, pure dihydrogen can be obtained by electrolysis of pure water using apparatus voltameter

Physical properties of dihydrogen gas

- Colourless Odourless Tasteless
- Insoluble in water
- Lightest gas
- Neutral towards litmus

Chemical properties of dihydrogen gas :

Dihydrogen gas (H_2) →
- $\xrightarrow{O_2(g)}$ water
- $\xrightarrow{\text{Metallic oxide of the metal less active than zinc}}$ Corresponding metal
- $\xrightarrow[\text{Absence of sunlight}]{Cl_2(g)}$ Hydrogen chloride gas
- $\xrightarrow{\text{Active metal}}$ Metallic hydroxide of corresponding metal.

Ammonia :

Industrial production of ammonia gas (Haber's Process)

Dihydrogen gas + Dinitrogen gas (Volume 3 : 1) $\xrightarrow[\text{Al}_2\text{O}_3,\ \text{K}_2\text{O (Promoters)}]{\text{200-300 bar, 273 K [Fe]}}$ Ammonia gas $\xrightarrow{\text{Lower than 273 K}}$ Liquid ammonia

$$N_2\,(g) + 3H_2\,(g) \xrightleftharpoons[\text{Al}_2\text{O}_3,\ \text{K}_2\text{O (Promoters)}]{\text{773 K [Fe]}} 2NH_3\,(g) + \text{Heat}$$

Physical properties of ammonia gas

- Colourless
- Intense odour
- Lighter than air
- Highly soluble in water
- Aqueous solution is basic

Chemical properties of ammonia gas

Ammonia gas (NH_3) →

- $\xrightarrow{\text{HCl(g)}}$ Ammonium chloride
- $\xrightarrow{\text{Hot CuO(s)}}$ Copper metal
- $\xrightarrow[\text{[Pt]1073 K}]{O_2\,(g)}$ Nitric oxide
- $\xrightarrow{\text{Aqueous solution of salt of metal}}$ Metal hydroxide insoluble in water

Sulphur : Sulphur is obtained free and in combined form in nature. Sulphur possesses property of catenation

Extraction of Sulphur : The method used directly to extract sulphur from the earth is called Frasch method.

$$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2(g)$$

$$SO_2(g) + 2H_2S(g) \xrightarrow[\text{[Fe}_2\text{O}_3]]{573\text{ K}} 3S(s) + 2H_2O(g)$$

Allotropes of Sulphur : Two or more than two forms of an element having existence because of different arrangements of atoms of element in similar physical state are called allotropes. This property of the elements is called allotropy. The chemical properties of allotropes are same but physical properties are different. Sulphur has two allotropes : rhombic sulphur and monoclinic sulphur in solid state.

$$\text{Rhombic sulphur} \xrightleftharpoons[\text{Temperature less than 369 K}]{\text{Temperature higher than 369 K}} \text{Monoclinic sulphur}$$

Physical properties of Sulphur

- Yellow coloured
- Insoluble in water, soluble in organic solvent
- Low melting point (388 K)

Sulphur Dioxide :

Sulphur dioxide gas is formed by reaction of sulphur with dioxygen gas.

$$S(s) + O_2(g) \xrightarrow{\Delta} SO_2(g)$$

Physical properties of Sulphur Dioxide

- Colourless
- Intensive odour
- Aqueous solution acidic in nature

Sulphuric Acid : Sulphuric acid is called "King of Chemicals" because it is very useful in preparation of most of the chemicals. Sulphuric acid is manufactured by contact process. Sulphuric acid is used as concentrated sulphuric acid and as dilute sulphuric acid in industries and in laboratory.

Dilute sulphuric acid (H_2SO_4) →

- Metal → Sulphate salt of metal + dihydrogen gas
- Metallic oxide → Sulphate salt of metal + water
- Metal hydroxide → Sulphate salt of metal + water
- Metal carbonate → Sulphate salt of metal + water + carbon dioxide gas
- Metal bicarbonate → Sulphate salt of metal + water + carbon dioxide gas

EXERCISE

1. Select the proper choice from the given multiple choices :

(1) Which non-metallic element is in liquid form ?

(A) Carbon (B) Hydrogen (C) Bromine (D) Phosphorus

(2) With which of the following elements carbon does not give reaction ?

(A) Dichlorine gas (B) Dioxygen gas

(C) Dihydrogen gas (D) Dilute hydrochloric acid

(3) Which of the following oxides is of neutral nature ?

(A) CO_2 (B) SO_2 (C) P_2O_5 (C) N_2O

(4) Which of the following gases is insoluble in water ?

(A) H_2 (B) CO_2 (C) NH_3 (D) SO_2

(5) Which of the following gases is used as preservative in juice of fruits and jams ?

(A) NH_2 (B) SO_2 (C) H_2 (D) CO_2

(6) Which of the following acids is called king of chemicals ?

(A) HNO_3 (B) H_2SO_4 (C) HCl (D) CH_3COOH

(7) Which of the following gases is combustible ?

(A) CO_2 (B) H_2 (C) SO_2 (D) NH_3

(8) Which of the following acts as catalyst in production of ammonia by Haber's porcess ?

(A) Al_2O_3 (B) K_2O (C) V_2O_5 (D) Fe

(9) Make the correct pairs from below mentioned (X) and (Y).

(X)	(Y)
(a) Extraction of sulphur	(1) Contact Process
(b) Production of nitric acid	(2) Frasch method
(c) Production of sulphuric acid	(3) Haber's process
(d) Production of ammonia gas	(4) Ostwald's method

(A) (a-4) (b-3), (c-2), (d-1) (B) (a-2) (b-4), (c-1), (d-3)

(C) (a-3), (b-2), (c-4), (d-1) (D) (a-4), (b-2), (c-3), (d-1)

(10) Make correct pairs from below mentioned (X) and (Y).

(X)	(Y)
(a) Dehydrating agent	(1) Sulphur dioxide gas
(b) In preparation of fire crackers	(2) Concentrated sulphuric acid.
(c) Weak bleaching agent	(3) Dihydrogen gas
(d) Lightest gas	(4) Sulphur

(A) (a-4), (b-3), (c-1), (d-2) (B) (a-3), (b-2), (c-4), (d-1)

(C) (a-3), (b-1), (c-2), (d-4) (D) (a-2), (b-4), (c-1), (d-3)

(11) Make the correct pairs from below mentioned (X) and (Y).

(X)	(Y)
(a) Sulphurous acid	(1) H_3PO_4
(b) Sulphuric acid	(2) $H_2S_2O_7$
(c) Oleum	(3) H_2SO_3
(d) Phosphoric acid	(4) H_2SO_4

(A) (a-2), (b-3), (c-1), (d-4) (B) (a-4) (b-2), (c-1), (d-3)

(C) (a-3), (b-4), (c-2), (d-1) (D) (a-2), (b-3), (c-1), (d-4)

2. Answer the following questions in brief :

(1) Give two examples of non-metallic elements which are in solid form.

(2) Give two examples of non-metallic elements which are in gaseous form.

(3) The mixture of which two gases is known as water gas ?

(4) Which two substances are used as promoters in manufacture of ammonia gas by Haber's process ?

(5) What is meant by liquor ammonia ? Write its chemical formula.

(6) What is meant by allotropy and allotropes. ?

(7) Write two allotropes of sulphur.

(8) Mention the effect of litmus paper on aqueous solution of ammonia.

(9) Mention the formulas of the products, name and physical state of the following reactions :

(i) $P_4(s) + 5O_2(g) \rightarrow$ ....

(ii) $SO_2(g) + H_2O(l) \rightarrow$ ....

(iii) $P_4(s) + 6Cl_2(g) \rightarrow$ ....

(iv) $O_2(g) + 2H_2(g) \rightarrow$ ....

(v) $Mg(s) + H_2O(g) \rightarrow$ ....

(vi) $3Fe(s) + 4H_2O(g) \rightarrow$ ....

(vii) $CO\ (g) + H_2O(g) \rightarrow$ ....

(viii) $3NO_2\ (g) + H_2O(l) \rightarrow$ ....

(ix) $S(s) + 6HNO_3(aq) \rightarrow$ ....

(x) $SO_3(g) + H_2SO_4(aq) \rightarrow$ ....

(xi) $C_{12}H_{22}O_{11}(s) + \text{Con}\ H_2SO_4(l) \rightarrow$ ....

(xii) $CaCO_3(s) + \text{dil}\ H_2SO_4(aq) \rightarrow$ ....

(10) Mention the missing information in $\boxed{\quad}$ in the following chemical reactions :

(i) $\boxed{\quad} + H_2O(l) \rightarrow H_2SO_4(aq)$

(ii) $S(s) + \boxed{\quad} \rightarrow SO_2(g)$

(iii) $\boxed{\quad} + H_2O(l) \rightarrow H_2CO_3(aq)$

(iv) $S(s) + H_2(g) \rightarrow \boxed{\quad}$

(v) $2Na(s) + \boxed{\quad} \rightarrow 2NaOH(aq) + H_2(g)$

(vi) $Zn(s) + H_2O(g) \rightarrow ZnO(s) + \boxed{\quad}$

(vii) $CH_4(g) + H_2O(g) \xrightarrow[1073\,K,\ 30\,bar]{\boxed{\quad}} CO(g) + 3H_2(g)$

(viii) $CuO(s) + \boxed{\quad} \rightarrow Cu(s) + H_2O(g)$

(ix) $H_2(g) + \boxed{\quad} \rightarrow 2KH(s)$

(x) $MgSO_4(aq) + \boxed{\quad} \rightarrow Mg(OH)_2(s) + (NH_4)_2SO_4(aq)$

(xi) $SO_2(g) + 2H_2S(g) \xrightarrow[573\,K]{\boxed{\quad}} 3S(s) + 2H_2O(g)$

(xii) $2SO_2(g) + O_2(g) \xrightarrow[723\,K]{\boxed{\quad}} 2SO_3(g)$

(xiii) $CuSO_4\ 5H_2O(s) + \text{con.}\ H_2SO_4(l) \rightarrow \boxed{\quad}$

3. Write answers of the following questions :

(1) Mention physical properties of non-metallic elements.

(2) Mention physical properties of dihydrogen gas.

(3) Write uses of dihydrogen gas.

(4) Write physical properties of ammonia gas.

(5) Write chemical equations, to obtain nitric acid from ammonia gas by Ostwald's process.

(6) Write uses of ammonia gas.

(7) Mention physical properties of sulphur.

(8) Mention the chemical reactions of sulphur with acids, dihydrogen gas and carbon element.

(9) Mention uses of sulphur.

(10) Write physical properties of sulphur dioxide gas.

(11) Mention uses of sulphur dioxide gas.

(12) Write uses of sulphuric acid.

(13) Give difference between concentrated sulphuric acid and dilute sulphuric acid.

4. Answer the following questions in detail :

(1) Explain with diagram the method for preparation of hydrogen gas in laboratory.

(2) Explain with chemical equations the industrial production of dihydrogen gas.

(3) Discuss Haber's process for industrial manufacture of ammonia.

(4) Write short note : Allotropes of sulphur.

(5) Explain contact process for production of sulphuric acid.

(6) Explain chemical properties of dilute sulphuric acid.

5. Answer the following questions pointwise :

(1) Explain chemical properties of non-metallic elements.

(2) Explain chemical properties of dihydrogen gas.

(3) Describe Frasch's method of extraction of sulphur.

(4) Discuss chemical properties of sulphur dioxide gas.

UNIT

10

MINERAL COAL AND MINERAL OIL

10.1 Introduction

The rocks on the earth are made up of minerals. Metals like silver, copper and gold are available in original form of element in the minerals but most of the minerals are compounds of two or more elements. Some substances like mineral coal and petroleum available from the crust of the earth are formed from the fossils of living elements and residues of vegetation in the prehistoric time. It is the most important and significant mineral wealth given by the nature. Thus, mineral coal and petroleum are the important energy sources available from nature. Mineral coal is like a black rocky substance, which is very useful in industrial field, steel industry, thermal power station, production of steel and extraction of metals. Petroleum or natural mineral oil is a thing known from ancient times. It contains liquids which can be easily evaporated, sticky, black and semisolid substance, soft materials like wax. Petroleum is a viscous oil, black dense liquid having specific smell. Petroleum is the mixture of many hydrocarbons containing hydrogen and carbon elements. In addition, substances having nitrogen, sulphur and oxygen are also present in small proportions. The composition of the mineral oil depends on the place from where it is obtained. Hence, the mineral oil available from different places, is of different types.

The important general useful components like petroleum gases, gasolene, diesel, kerosene, lubricating, oils, asphalt, etc. are available from petroleum. These component substances are used as fuel and at different places viz. Liquefied Petroleum Gas (LPG) and kerosene in the lantern and petromax to obtain light, as fuel for motor cars, diesel engine etc. Asphalt is used in construction of roads. The main basic requirement of modern age is the mineral coal and petroleum. The modern life is not possible without it, because carbon and hydrocarbon compounds (organic compounds) are available in the largest proportion.

10.2 Mineral Coal

Mineral coal is available from the earth's crust by combustion of fossils of plants and animals. Crores of years ago, plants and animals were buried in the earth's crust and remained accumulated there. In the crust of the earth, at high temperature and pressure, the components of plants and animals were converted into large proportion of mineral coal at the end of the chemical reaction. The fuel of this type of mineral coal is called fossil fuel. Mineral coal is a non-renewable source of energy. In the world, mineral coal is mainly available in China, America, U.K. Germany, Poland and India. In India, mineral coal is mainly available from Jharkhand, Madhya Pradesh, Orissa, West Bengal and Andhra Pradesh. In Gujarat, near Thangadh in Saurashtra and sulphur containing lower type of mineral coal is available in Kachchh.

In the mineral coal, mainly carbon and hydrogen and in addition, more or less proportion of nitrogen, sulphur, phosphorus, potassium etc, elements are present as compounds.

The mineral coal also contains inorganic substances.

The main types of mineral coal are as given below :

(1) Peat :

Peat contains about 28% carbon. The primary state of transformation of coal from wood is called peat. It is called rough coal. Wax, acetone (CH_3COCH_3), acetic acid (CH_3COOH), methanol (CH_3OH) as well as cyclic organic compounds are available from destructive distillation of peat.

(2) Lignite :

Lignite contains about 28 to 30% carbon. It contains volatile matter and moisture also. The heat (energy) of lignite is about 27 kJ g^{-1}. It is used as fuel in railway engines, thermal power stations and small and big industries. Lignite is used to obtain coal gas and coal tar is obtained as residue, in which cyclic hydrocarbons, phenol, cresol and other compounds are present.

(3) Bituminous coal :

Bituminous coal contains about 78 to 86% carbon. It also contains volatile matters and moisture in some proportion. Its heat energy is about 30 kJ g^{-1}. It is used as fuel in the production of steel and in production of electricity.

(4) Anthracite :

Anthracite is a matured form of mineral coal. It contains about 94 to 98% carbon. It contains small proportion of volatile matter and moisture. Its heat energy is about 33 kJ g^{-1}. When pure anthracite burns, smoke or smell is not produced and the amount of residue is very less. Hence, anthracite is considered as the best type of coal.

10.3 Destructive Distillation of Mineral Coal

Mineral coal is heated in an iron retort at 1273 K. Volatile substances are separated due to this. The hot gases are passed through the tubes cooled by keeping them in water. Hence, the substances which are soluble in water are dissolved in water and the other insoluble substances settle down in water. Afterwards, these gases come out; they are purified and used for heat and energy. We know it as "coal gas". The coal remained in the retort is known as coke. It is used for burning and in preparing steel from iron.

The black sticky liquid substance which is insoluble in water and settles down is called tar. Earlier it was a problem as how to remove this tar, but later on it was found that many important substances are there in it. At that time its value was appreciated.

Generally, in advanced countries, the coal obtained from the mines is not allowed to burn directly, but the coke resulted after taking out the useful coal gas, ammonia, coal tar and coke from the mineral coal in laboratory.

Activity : 1

Take mineral coal in a hard glass test tube. Take some water in the second test tube. Arrange the apparatus as shown in the Fig. 10.1 Heat the coal on the Bunsen burner and pass the vapour coming out from it through the water in the test tube. After sometime, it will be found that coal tar is collected at the bottom of the test tube filled with water.

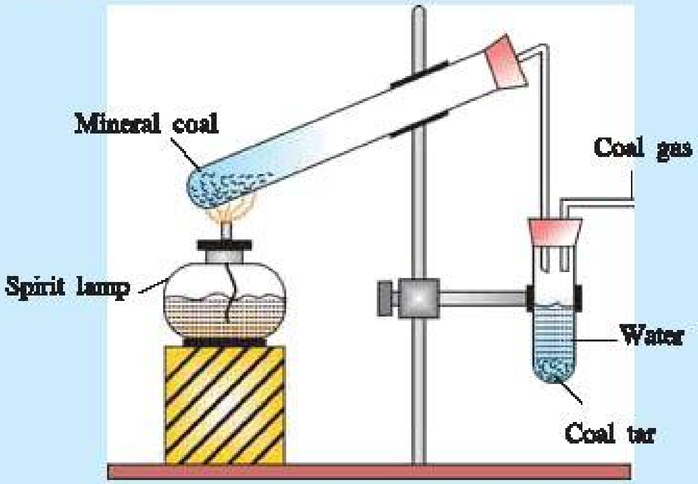


Fig. 10.1 Destructive Distillation of mineral coal

The gas will come out through the tube connected with the upper part of the test tube. The gas starts burning when a lighted match stick is brought near the end of this tube. This gas is coal gas. The portion that is left out in the tube containing mineral coal is called coke. The ammonia produced during the reaction is absorbed in water which can be tested with red litmus paper. It turns red litmus paper blue.

Coke :

Coke is black-brown coloured hard and porous substance. It contains about 80% carbon. It is used as smokeless fuel in the production of water gas. The mixture of carbon monoxide and hydrogen ($CO + H_2$) gas is obtained when water vapour is passed over hot coke. It is called water gas.

$$\underset{\text{Coke}}{C(s)} + \underset{\text{Steam}}{H_2O(g)} \longrightarrow \underbrace{(CO + H_2)(g)}_{\text{Water gas}}$$

Coke is not mainly used as fuel, but its main use as reducing agent is to obtain metal from metal oxide.

Coal Tar :

Coal tar is dark black coloured liquid. Mostly different types of organic compounds are present in it. In the earlier times, it was used in the preparation of organic compounds like explosives, dyes, artificial fibres, drugs, pesticides. In the modern time, organic substances are obtained from petroleum products instead of coal tar.

Coal gas :

Mostly carbon monoxide and some other gaseous hydrocarbon compounds are present in coal gas. This mixture of gases is combustible and so it is used as a fuel.

10.4 Petroleum

Mineral oil is known by one or the other name from ancient times. It had been noted that asphalt obtainable from mineral oil was used in construction work in the year 5000 BC. It is also mentioned that it was used as natural gas for the lamps in China in 1900 BC. The "Lakshagruh" mentioned in 'Mahabharat' must have been prepared from tar like easily combustible substance. At some places where the oil or the gas that was coming out of the cracks in the earth used to burn accidentally and so it was worshipped as holyfire. e.g. Eternal fire of Bookie. In Trinidad, when this type of oil after coming out in large amount, the volatile substances were completely evaporated and now-a-days the pond of tar is left out as residue. In Gujarat, near Ghogha port, gas comes out from the land. Even then, the large scale production of petroleum had started after the earlier half of the nineteenth century. At present, petroleum supplies one third part of the requirement of world's energy. Half the portion of the total production of organic compounds is obtained from petroleum. This way, petroleum is very important in the modern age. The meaning of petroleum is the oil of rock (mineral oil).

Origin and discovery :

The mineral oil has been originated from the fossils of plant and animal kingdoms burried under the surface of sea in prehistoric times. The pressure, heat and microorganisms present at the bottom of the earth must have played very important role for this, the mineral oil mixed with water flows and gets collected in caves as oil pond in the form of oil. It is called crude oil. Generally the rocks above these oil ponds are very hard. A reaction takes place on innumerable small marine living beings and marine vegetation for lacs of years. During this reaction petroleum is formed.

Scientist Berthelot proposed that by the reaction of carbon dioxide in water with alkali metal the gas named acetylene and other oily substances must have been formed. While, Mendeleve suggested that carbides of metals on reaction with acidic water, substance like petroleum would have been formed. Many other scientists have supported these ideas but the formation of mineral oil has not been explained by them.

Sometimes such substances were available during digging of wells. It was used as "medicine for massage" in those time. While digging well for water in Pennsylvania Samuel Killer found mineral oil instead of water. George Beal and Steelman established the company for the search of oil. Their main purpose was to extract natural oil in large proportion to use for other industrial uses. They entrusted this work to Adverd Drac. Drac started the digging work with the tools available for digging the wells in Pennsylvania. He got oil at the depth of 21 meters in the village named. Titusville on 27th of August 1859. This was the first well of petroleum.

Mainly mixture of methane and hydrocarbon containing 1 to 4 carbons is present in natural gases. Generally, petroleum is obtained by drilling in the region of sedimentory rocks.

The possibility of mineral oil in India was found some years after the Drac's well. Oil was obtained at the depth of 34 meters at the place named Makum near Dibrugarh on 26th of August 1867. 1350 litres of oil was drilled from this well each day. This was the first well in Asia. A good proportion of oil was found in the countries like Saudi Arabia, Iraq, Iran, Kuwait, America, Russia, England, Maxico, China, Brahmadesh, Burma (Myanmar), Galacia, Hungary, Trinidad etc. Oil fields are also there in India. At present petroleum is available at Ankaleshwar, Cambay (Khambhat), Navagam, Sanand, Kalol in North and Central Gujarat and also near the end of the South Gujarat known as "Bombay High". The proofs of availability of underground petroleum are there in Gujarat, North Gujarat in Jotana, Santhal, Ambasan etc. Also, proofs have been obtained for the existence of reservoirs of petroleum in Kachchh, Saurashtra, Rajasthan, West Bengal and basins of Godavari and Kaveri rivers. In India, Oil and Natural Gas Commission (ONGC) which is at present known as Oil and Natural Gas Corporation Limited has been formed for the search of oil and the development.

Petroleum is dark brown or black coloured oily liquid. Mainly hydrocarbons, oxygen and sulphur containing certain organic compounds are present in it.

Impure Petroleum and its components :

The petroleum available from the wells is impure. Its colour is from light green to brown and upto black. It contains natural gas, water, clay, sand etc. as impurities.

Chemically, mineral oil is mainly a mixture of hydrocarbons. It contains sulphur, nitrogen and oxygen containing substances in small proportions. The mineral oil available from different countries have different compositions. The following chemicals are mainly present in petroleum.

(1) **Paraffin hydrocarbon :** These substances are aliphatic compounds having long chain. Their general formula is C_nH_{2n+2}. These substances are mixture of straight and branched paraffins. The proportion of substances having simiple chains is more. The petroleum of America and the oil available in Ankaleshwar are of this type.

(2) **Naphthalene hydrocarbon :** These compounds are cyclic and their general formula is C_nH_{2n}. They are saturated hydrocarban six to seven carbon atoms are present in them. e.g. Methyl cyclohexane, cyclopentane and their derivatives.

The oil available in many parts of our country is of this type.

(3) **Aromatic compounds :** This type of compounds are in very less proportion in mineral oil. Their general formula is C_nH_{2n-6}. These compounds are also cyclic but there is specific type of unsaturation e.g. Benzene, toluene, xylene etc. Oil available from Bornio is of this type.

(4) **Asphalt :** Many complex solid substances are available from asphalt type black mud type oil. In these compounds, substances containing oxygen, nitrogen and sulphur with carbon and hydrogen are present. Sulphur containing compounds like thiophene, hydrogen sulphide etc. are available. Alcohol, phenol etc. are also obtained as oxygen containing compounds. While pyridine is present as heterocyclic based nitrogen compounds. The oil from Ankleshwar of Gujarat contains 0.4% sulphur containing compounds, while oil available from Kalol has only 0.03% sulphur. The presence of sulphur compounds in mineral oil is very harmful. Hence, it is most important to refine it before taking mineral oil in use.

10.5 Refining of Petroleum

The impure oil available from the wells is carried by pipes or tankers to refinery for purification. The natural gas is separated from it in the initial stage. The oil is allowed to settle in many large tanks in refinery and the waste and water are separated. Then the fractional distillation of it is carried out.

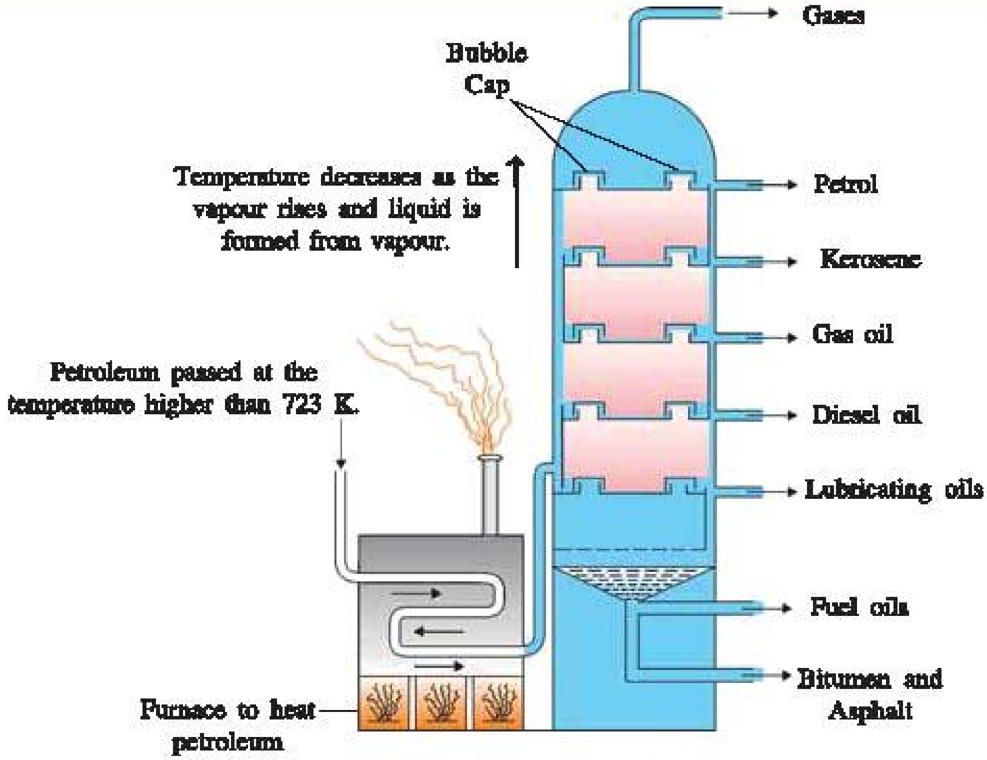


Fig. 10.2 Distillation Tower

Fractional distillation of Petroleum : The purpose of this distillation is not to separate each hydrocarbon individually but are separated in fractions having specific properties useful in industry. Each of these fractions is being distilled in definite range of temperatures, and it is a mixture of certain compounds.

As shown in Fig. 10.2 petroleum is heated in the furnace and then sent to fractionating column, in the form of vapour. This column is of 2 to 4 meter diameter and is 30 to 60 meter high. Perforated shelves are fixed in it, and on each of these shelves there is a cover like a cap. This specific construction is called bubble cap (Fig. 10.2). The substances which do not distil are collected at the lower part of the column. The vapour of petroleum gets cooled while going up in the column and falls down in the form of liquid and the vapour rises up. Thus, a dense contact remains between vapour and liquid. The vapour passed through the liquid is collected on the shelves. Thus, substances having higher boiling points come down in the form of liquid and the substances having lower boiling points go up in the form of vapour. In this way, distillation continues near each shelf. Hence, compounds having nearby boiling points can be separated. Thus, substances having lower boiling points are collected in the shelves of the upper part and the substances having higher boiling points are collected in the shelves of the lower part. The number and the distance of the shelves are so arranged that a certain fraction is collected in the shelves at certain height. This description gives only simple explanation of the principle. In reality many such fractionation columns are used. And the entire process of refining is very complex. The properties and uses of the different fractions obtained by fractional distillation are given below :

(1) **Petroleum Gases :** Hydrocarbons from C_1 to C_4 are present in this fraction. These gases are useful for petrochemicals, foul smell containing sulphide is added to gases

for household uses. Hence, if it comes out accidently, it gives warning by its intense smell. e.g. LPG, PNG (Piped Natural Gas)

(2) **Gasolene :** In this fraction, hydrocarbons from C_5 to C_{12} are present. The boiling range of this fraction is 343 to 473 K. It is used as fuel for aeroplanes and motors. The hydrocarbons with C_5 to C_7 carbons are separated from this fraction and used as solvents.

(3) **Kerosene :** In this fraction the hydrocarbons have C_{12} to C_{15} carbons. Its boiling range is 473 to 548 K. It is used as fuel in kerosene lamps, stoves, jet planes and rockets.

(4) **Gas oil or Diesel oil :** C_{15} to C_{18} carbon containing hydrocarbons are in this fraction. They are available at temperature higher than 523 K. It is used as fuel in diesel engine. Naptha is obtained from this fraction.

(5) **Lubricating oil :** C_{16} to C_{20} carbon containing hydrocarbons are present in this fraction. It is used for lubrication and cracking. This fraction is cooled and the wax is taken out after freezing.

(6) **Asphalt (Tar) :** C_{21} to C_{40} carbon containing hydrocarbons are in this fraction. It is useful for preparation of roads.

(7) **Coke :** It is deposited on the inner side of the furnace used for heating the petroleum. Carbon for electric cells is obtained from this. This carbon is known as petroleum coke. As this carbon is pure, it is used for preparation of electrodes and carbon tiles. This type of tiles resist the corrosion. Hence, it is used in chemical industries for the protection of vessels.

The products obtained by fractional distillation of petroleum and their uses are shown in Table 10.1.

Table : 10.1 The products obtained by fractional distillation of petroleum and their uses

	Fraction	Number of carbon	Temperature range	Uses
1.	Gases	C_1 to C_4	298 K	As fuel.
2.	Petrol	C_5 to C_{10}	303 K to 393 K	As fuel in vehicles
3.	Naphtha	C_8 to C_{10}	393 K to 453 K	As solvent in petrochemicals
4.	Kerosene	C_{12} to C_{15}	473 K to 548 K	As fuel in household and jet planes
5.	Diesel	C_{15} to C_{18}	533 K to 613 K	In trucks, buses, pumps for water, diesel engines, as fuel. Generators for production of electricity
6.	Lubricating oil	C_{16} to C_{20}	above 613 K	As lubrication oil in machine and to prepare grease, vaseline, wax etc.
7.	Fuel oil	–	773 K	As fuel in steamers and electric power houses
8.	Tar	C_{21} to C_{40}	Dense liquid left after fractional distillation.	Preparation of roads, for water proofing
9.	Petroleum coke	–	deposited carbon	In preparation of electrodes of battery and carbon tiles.

Octane Number :

Gasolene which is generally known as petroleum is mainly used as fuel in the internal combustion engines of cars. The mixture of gasolene and air from carburettor is collected in the cylinder of the engine. Here, the mixture is pressed by a piston. When the sparks of the electricity are released, the flame spreads from one end to the other in the cylinder and the gaseous mixture is systematically combusted. The piston moves immediately in cylinder and the combusted gases are going out. This force gives velocity to the car. This reaction occurs repeatedly. In certain circumstances, when electric spark occurs, the nearby gaseous mixture experiences contraction and before the flame reaches there, it burns with explosion. Certain type of sound is created in the cylinder by unsystematic combustion which is known as knocking. More the pressure, more will be the knocking. It is very necessary to obtain more horse power and to decrease the magnitude of use of fuel. Because of the thrust on the piston of cylinder due to knocking, there is more wear and carbon is deposited on the inner part of cylinder.

From the study of composition of hydrocarbons and by knowing, it is found that the knocking of simple chain hydrocarbons is more while knocking of branched chain hydrocarbon is less or negligible. Iso octane is considered standard for the comparison of fuels. Its octane number is taken as 100 because of its negligible knocking. As knocking of n-heptane takes place, its octane number is taken as 0.

$$\begin{array}{ccccccc} & & CH_3 & & H & & H & & \\ & & | & & | & & | & & \\ H_3C & - & C & - & C & - & C & - & CH_3 \\ & & | & & | & & | & & \\ & & CH_3 & & H & & CH_3 & & \end{array} \qquad CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3$$

Isooctane : Octane number 100
(2,2,4, trimethyl pentane)

n-Heptane : Octane number 0

The octane number of any sample of gasolene is equal to the same efficiency of the mixture of isooctane and n-heptane, its octane number is same. e.g. the efficiency of a sample of fuel is equal to that of mixture of 90% isooctane and 10% n-hetane, then its octane number is considered to be 90. The octane number of normal alkane is higher than alkene to cyclic paraffin and simple chain hydrocabons than branched chain hydrocarbons have very high octane number. Octane number of aromatic hydrocarbons is very high.

After a long research work two methods have been discovered to increase octane number of gasolene. (1) Gasolene obtained by straight run from fractional distillation of mineral oil or virgin gasolene undergoes reforming or some similar transformation processes. By this the simple chain hydrocarbons in original gasolene are transformed to branched chain hydrocarbon and its octane number increases. If this reaction is carried out on fractions after gasolene, the proportion of gasolene can be increased. This matter is important because the demand of gasolene obtained from this method is more than that obtained from mineral oil. (2) The quality of gasolene can be improved by addition of substances to gasolene which increases the octane number. In America, Midgal and Boeid discovered in 1922, a substance having such properties called tetraethyl lead – $(C_2H_5)_4Pb$. In the gasolene used in motors, 1 ml tetraethyl lead is added to every 4 litre of gasolene. The octane number of such gasolene is 75-85; some diethylene dichloride of dibromide is added to it so that lead may not deposit on spark plug when gasolene is combusted. Hence, lead is removed with exhaust gases in the form of lead chloride or lead bromide.

Cracking of Hydrocarbons :

Generally about 18% gasolene is obtained from mineral oil. The proportion of kerosene etc. is more in the fraction having higher boiling points after the gasolene fraction. But its demand is less, while demand for gasolene is more. Hence cracking reactions are developed so that proportion of gasolene increases. There are three advantages of these reactions. (1) To obtain more gasolene, (2) The octane number of the gasolene available is high and (3) Unsaturated organic gases that are obtained, can be the important raw material for the petrochemicals.

In this reaction, kerosene naphtha, diesel and wax are also used. These substances are in the form of vapours passed from the layer of the catalysts at above 773 K temperature. Generally Al_2O_3, SiO_2 are used as catalyst. In the modern method small spheres of catalyst are allowed to fall from above in the column and the vapour of kerosene etc. is allowed to go up higher.

In the above reaction, hydrogen, methane and unsaturated hydrocarbons are also obtained. As these substances are the raw materials for preparation of petrochemical cracking units into existence. From such units, mainly cracking of naptha occurs and unsaturated alkene compounds are obtained. Some of the reactions occurring during catalytic cracking are shown below :

Isomerization :

In this reaction, simple chain substances are converted into branched chain substances.

$$\underset{\text{(n-hexane)}}{CH_3-CH_2-CH_2-CH_2-CH_2-CH_3} \longrightarrow \underset{\text{(2,3 dimethyl butane)}}{\begin{array}{c} \quad\;\; CH_3\,CH_3 \\ \quad\;\;\, | \quad\;\; | \\ H_3C - C - C - CH_3 \\ \quad\;\;\, | \quad\;\; | \\ \quad\;\; H \quad H \end{array}}$$

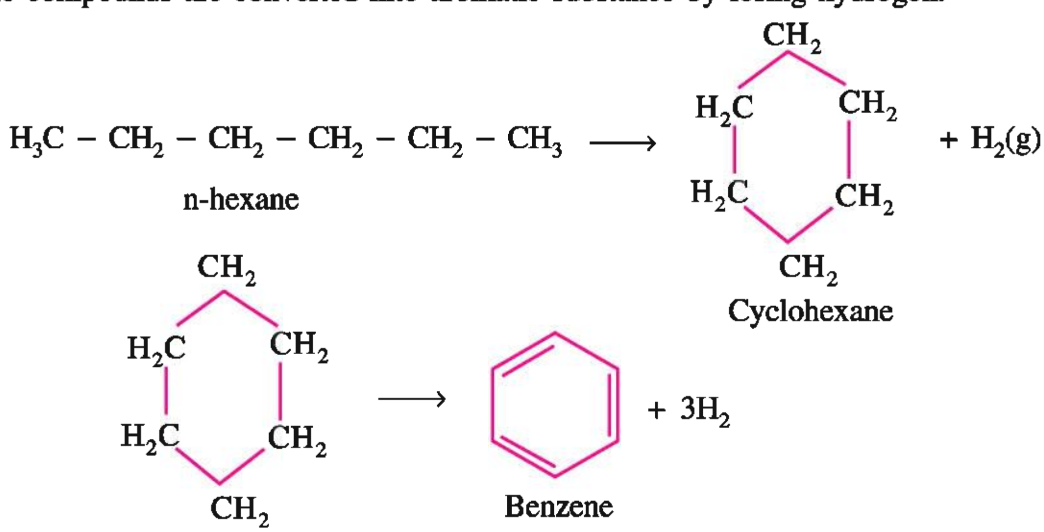
Dehydrogenation :

In this reaction saturated substances are converted into unsaturated substances.

$$\underset{\text{(n-butane)}}{CH_3 - CH_2 - CH_2 - CH_3} \longrightarrow \underset{\text{But-1-ene}}{CH_3 - CH_2 - CH = CH_2} + H_2$$

Aromatization :

In this reaction the various chain containing substances, are converted into cyclic substances and cyclic compounds are converted into aromatic substance by losing hydrogen.



Alkylation :

In this reaction, medium size molecules are obtained by reaction between smaller molecules.

$$\begin{array}{ccccccccccccccccccc}
 & & & & & & & & CH_3 & & & & & & & & CH_3 & & CH_3 \\
 & & & & & & & & | & & & & & & & & | & & | \\
H_3C & - & C & - & CH_3 & + & H_3C & - & C & - & H & \longrightarrow & H_3C & - & CH_2 & - & C & - & CH \\
 & & \| & & & & & & | & & & & & & & & | & & | \\
 & & CH_2 & & & & & & CH_3 & & & & & & & & CH_3 & & CH_3
\end{array}$$

2- Methyl propene (isobutene)   2-2 Dimethyl propane (isobutane)   Isooctane.

Better gasolene can be obtained by carrying out this reaction separately.

Cracking :

In this reaction, big molecules crack (break) into smaller molecules

$$\underset{\text{(n-octane)}}{CH_3 - CH_2 - CH_2 - CH_2 - CH_2 - CH_2 - CH_2 - CH_2}$$

$$\downarrow$$

$$\underset{\text{(n-butane)}}{CH_3 - CH_2 - CH_2 - CH_3} + \underset{\text{(But-1-ene)}}{CH_2 = CH - CH_2 - CH_3}$$

When this reaction takes place in presence of hydrogen, unsaturated substances become saturated.

10.6 Natural Gas

Petroleum has originated from complex chemical reactions continuously occurring in the earth's crust. Natural gas is collected over the petroleum in the rocks. The gas available with petroleum is called natural gas. It is obtained as oily liquid along with petroleum or independently in the gaseous form. During drilling in the earth's crust natural gas is obtained first and then the petroleum comes out and the gas that is obtained is called natural gas.

The main hydrocarbon in natural gas is methane. In addition, gaseous hydrocarbons like ethane, propane and butane are also present. It can be sent easily to proper places through pipelines. By such an arrangement, it is available as fuel for house-hold uses in the cities like Vadodara, Ankleshwar, Surat, Bharuch and now in Ahmedabad in Gujarat. Natural oil fields are found at the places like Tripura, Jaisalmer, Bombay high, Basin area of Krishna and Godavari rivers.

Hydrogen gas can be produced on a larger scale from natural gas and from it, ammonia and urea can be obtained. Natural gas is now used as fuel in the gas-based thermal power stations. As many industries based on natural gas have developed in Gujarat, the gas which was being wasted is found to be very valuable. Natural gas is used as fuel in Dhuvaran thermal power station in Gujarat. LPG and CNG are known natural gases.

LPG and CNG :

LPG (Liquefied Petroleum Gas) means liquefied petroleum gas contains gases mainly butane and in small proportions propane and butene. The gaseous mixture is liquefied under high pressure and filled in cylinders at high pressures. To know the leakage of the gas from the cylinder, methyl mercaptan having very bad smell is mixed. LPG is mostly used as household fuel.

CNG (Compressed Natural Gas) contains mostly methane and in some proportion ethane and propane are present. By reducing its volume at high pressures, it is used as a fuel in place of petrol in automobile engines like trucks, buses, etc. As CNG is completely combusted, the additional poisonous gas does not spread pollution but sometime because of incomplete combustions, it heats up the mechanical machinery of the vehicle which is the disadvantage of CNG.

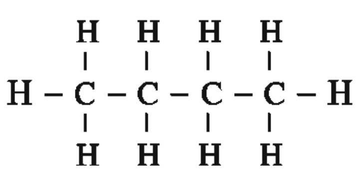
10.7 Tetravalency and Catenation of Carbon

Carbon and its compounds are present in mineral coal and petroleum. The organic compounds which contain carbon and hydrogen are called hydrocarbons. They are generally known as organic compounds. Organic compounds are present in different types of compounds in living viz. carbohydrates, protein etc.

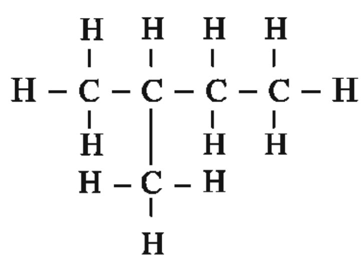
Innumerable useful things like grain, pulse, sugar, tea, coffee, paper, cotton, wool, synthetic resins, kerosene, petrol, diesel, cooking gas, drugs, dyes, rubber, plastic, perfumes etc. contain mainly organic compounds. Really organic compounds are distributed in large proportion in nature. The total number of organic compounds are in larger number as compared to the total compounds available from all the elements except carbon. In addition to this, many organic compounds are obtained by synthesis in laboratory over and above the organic compounds present in nature. Hence, it can be said that carbon is a unique element.

Carbon element is in the 14th group of the periodic table. The atomic number of carbon is six and its electronic configuration is 2, 4. There are four electrons in its valence orbit. Carbon contains four valence electrons in excited state. The atoms of carbon share these four electrons with four electrons of other elements and form four covalent bonds.

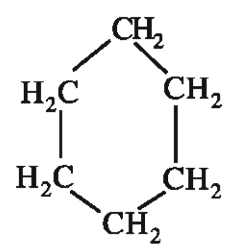
One carbon atom forms covalent bonds with carbon atoms through normal chain, or cyclic chain.



(Normal chain structure)



(Iso chain structure)

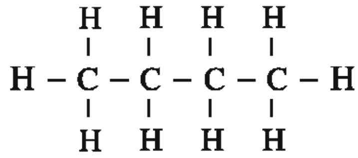


(Cyclic chain structure)

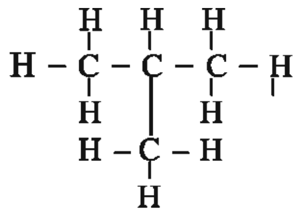
Because of this specific property of combination by valence bond between carbon–carbon atoms and as a result large number of organic compounds of abnormal types have been prepared. This specific property of carbon is called catenation. **The combination of more than one atom of the same element is called catenation.**

Because of this catenation property of carbon, compounds having different structural formula and compounds having different physical properties are observed. Such organic compounds having molecular formula same but different structural formula are called isomers. This type of phenomenon is called isomerism, viz.

(i) Butane (C_4H_{10}) has two isomers



n – Butane



2 – Methyl propane

(Isobutane)

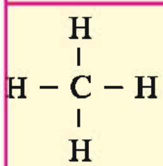
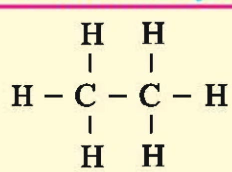
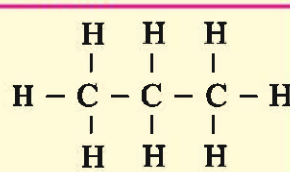
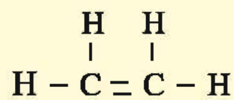
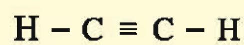
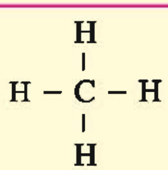
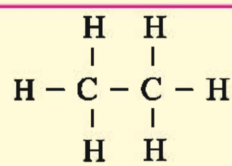
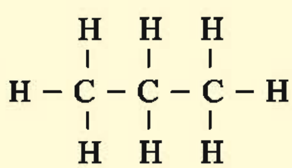
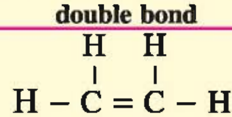
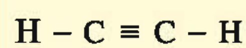
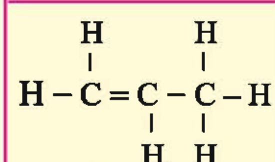
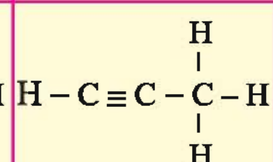
10.8 Hydrocarbons

As seen earlier, compounds containing carbon and hydrogen are called hydrocarbons. In these hydrocarbon compounds, methane (CH_4), ethane (C_2H_6), propane (C_3H_8), ethene (C_2H_4), propene (C_3H_6), ethyne (C_2H_2), propyne (C_3H_4) are included.

Classification of Hydrocarbons : Hydrocarbons are considered to be the simplest organic compounds in organic chemistry. Only carbon and hydrogen elements are present in them. Hence, they are called hydrocarbon compounds.

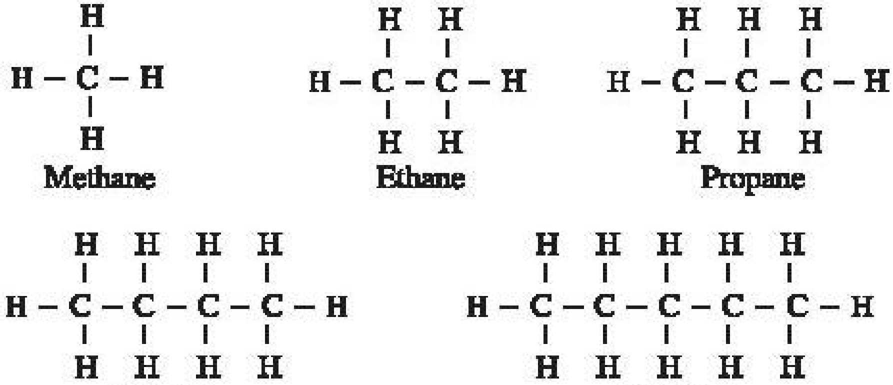
Hydrocarbons are classified by two methods. Their classification is done on the basis of number of covalent bonds between carbon-carbon atoms : (i) Saturated hydrocarbon and (ii) Unsaturated hydrocarbon.

In saturated hydrocarbons, all the four valencies of carbon are completed by covalent single bond with other atoms. While, in unsaturated hydrocarbons, the two carbon atoms are combined by double or triple bond.

<table>
<tr><th colspan="3">Hydrocarbon</th></tr>
<tr><th>Saturated Hydrocarbon</th><th colspan="2">Unsaturated Hydrocarbon</th></tr>
<tr><td> Methane  Ethane  Propane</td><td> Ethene</td><td> Ethyne</td></tr>
<tr><td rowspan="2">Compounds containing single bond.
Alkane
General formula (C_nH_{2n+2})</td><td colspan="2">Compounds containing covalent double bond or triple bond</td></tr>
<tr><td>Alkene
(C_nH_{2n})</td><td>Alkyne
(C_nH_{2n-2})</td></tr>
<tr><td>Compounds containing single bond</td><td>Compounds containing double bond</td><td>Compounds containing triple bond</td></tr>
<tr><td rowspan="2"> Methane  Ethane  Propane</td><td> Ethene</td><td> Ethyne</td></tr>
<tr><td> Propene</td><td> Propyne</td></tr>
</table>

10.9 Saturated Hydrocarbons

In saturated hydrocarbons, each carbon atom is combined with other atoms by only one single covalent bond viz. Methane (CH_4), ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}) pentane (C_5H_{12}) etc..



Methane Ethane Propane

Butane Pentane

When the overlapping of two or more orbitals nearby to each other, having very less difference in energy levels, the same number of orbitals having similar shape, and same energy are formed is called hybridization and the orbitals produced by this method are called hybrid orbitals.

The first simple member of saturated hydrocarbon is methane. As there is C–C single bond in this compound, the sp^3 hybridization taking place in this can be explained as follows :

In the excited state of carbon atom, the electronic configuration of its outermost orbit having unpaired electrons- one of 2s and three of 2p orbitals overlap and four hybrid orbitals having same shape and energy are obtained. This is called sp^3 hybridization. The unpaired electrons have same energy. In methane, four similar orbitals having unpaired electron and formed by sp^3 hybridization at carbon atom, they arrange in tetrahedral shape. Here, the bond angle between any two orbitals is of 109° 28'. Now, the overlapping of each of four hybrid orbitals obtained by sp^3 hybridization with 1s type unpaired electron of four hydrogen atom with opposite spins takes place and four covalent bonds are formed. The bonds formed this way, by sharing of electrons with two unpaired electrons with opposite spins, are called σ bonds.

Thus, four C–H bonds have same bond length and the bond angle is 109° 28'

If any one hydrogen present in methane molecule, is substituted by CH_3 group, ethane is obtained. By substitution of any hydrogen atom of ethane by CH_3 group propane (C_3H_8) is obtained. This way, the series of butane (C_4H_{10}), pentane (C_5H_{12}) etc. are obtained. This series of saturated hydrocarbons is called alkane series. The general formula of alkane series is C_nH_{2n+2} where n = Number of carbon atoms in the molecule.

At the end of the name of the members of this series have suffix – ane.

If each member of the organic compound series differs from its earlier and latter differs by carbon and hydrogen in the number (CH_2) is called Homologous series. Almost all the types of organic compounds have homologous series.

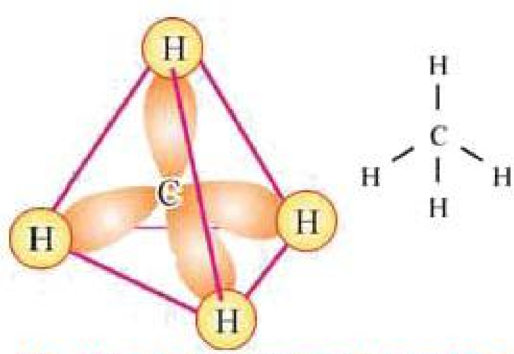


Fig . 10. 3 Three dimensional geometrical structure of molecule of methane.

Characteristics :

(1) Each member of the series can be expressed by general molecular formula viz. each member of alkane series can be expressed by general formula C_nH_{2n+2}

(2) The difference in molecular formula between two successive members of the series is equal to CH_2.

(3) There is difference of 14 u between molecular masses of any two successive members of the series.

(4) Same number of prefix or suffix is applied to each member of the series in their nomenclature.

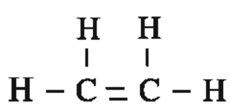
(5) The molecular mass of the member of series increases due to increase in the atoms of carbon and hydrogen. Hence, the physical properties based on the molecular masses of the members, viz boiling point, melting point, density, solubility etc. have gradual change. The homologous series of alkane compounds and their characteristics are given in Table 10.2.

Table : 10.2 Characteristics of homologous series of Alkanes

Sr. No.	Number of carbon	Name of alkane	Molecular formula	Molecular Mass (u)	State
1.	n = 1	Methane	CH_4	16	Gas
2.	n = 2	Ethane	C_2H_6	30	Gas
3.	n = 3	Propane	C_3H_8	44	Gas
4.	n = 4	Butane	C_4H_{10}	58	Gas
5.	n = 5	Pentane	C_5H_{12}	72	Gas/liquid
6.	n = 6	Hexane	C_6H_{14}	86	Gas/liquid

10.10 Unsaturated Hydrocarbons

In unsaturated hydrocarbons, the nearby any two carbon – carbon atoms are combined by a double bond ($-C=C-$) or triple bond ($-C\equiv C-$) i.e. there is double bond or triple bond because of sharing of two-two or three-three electrons of any two nearby carbon atoms viz. Ethene (C_2H_4), ethyne (C_2H_2) etc.

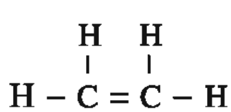


Ethene (Ethylene)

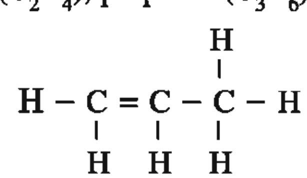
$H-C\equiv C-H$

Ethyne (Acetylene)

The hydrocarbons in which any two nearby carbon atoms are combined by a double bond unsaturated hydrocarbons are called alkenes. viz ethene (C_2H_4), propene (C_3H_6), butene (C_4H_8), pentene (C_5H_{10}).



Ethene (Ethylene)



Propene (Propylene)

The general formula of alkene series is C_nH_{2n} where n = the number of carbon atoms. The first simple member of this series is ethene. The difference of CH_2 is observed between two neighbouring members in the series and the difference of 14 in atomic mass unit is there. This series is called alkene homologous series.

The hydrocarbon in which the nearby two carbon atoms are combined by a triple bond, such unsaturated hydrocarbons are called alkynes. viz. ethyne (C_2H_2), propyne (C_3H_4), butyne (C_4H_6), pentyne (C_5H_8) etc.

$$H - C \equiv C - H$$

Ethyne (Acetylene)

$$\begin{array}{c} \phantom{H - C \equiv C - {}}H\phantom{{} - H} \\ \phantom{H - C \equiv C - {}}|\phantom{{} - H} \\ H - C \equiv C - C - H \\ \phantom{H - C \equiv C - {}}|\phantom{{} - H} \\ \phantom{H - C \equiv C - {}}H\phantom{{} - H} \end{array}$$

Propyne

The general formula of the alkyne series is C_nH_{2n-2}, where n = number of carbon atoms in the compound. The alkene and alkyne homologous series are shown in Table 10.3.

Table 10.3 Homologous series of alkenes and alkynes

	Alkene (C_nH_{2n})			Alkyne (C_nH_{2n-2})		
Number of carbon	Molecular formula	Name of alkene	Molecular mass	Molecular formula	Name of alkyne	Molecular mass
n = 2	C_2H_4	Ethene	28	C_2H_2	Ethyne	26
n = 3	C_3H_6	Propene	42	C_3H_4	Propyne	40
n = 4	C_4H_8	Butene	56	C_4H_6	Butyne	54
n = 5	C_5H_{10}	Pentene	70	C_5H_8	Pentyne	68
n = 6	C_6H_{12}	Hexene	84	C_6H_{10}	Hexyne	82

10.11 Methane

The moleular formula, electronic formula and the structural formula of methane are as follows :

CH_4

Molecular formula

$$\begin{array}{ccccc} & & H & & \\ & & \bullet\times & & \\ H & \overset{\times}{\bullet} & C & \overset{\times}{\bullet} & H \\ & & \bullet\times & & \\ & & H & & \end{array}$$

Electronic formula

$$\begin{array}{ccccc} & & H & & \\ & & | & & \\ H & - & C & - & H \\ & & | & & \\ & & H & & \end{array}$$

Structural formula

Occurrence of methane :

Methane gas is the chief constituent in Marsh gas available from the mines of mineral coal and gas collected over petroleum in the sedimentary rocks in the crust of the earth. In addition, methane is a chief constituent in dung, excretion of animals, and gobar gas, sewage gas and biogas obtained from decomposition of plant and animal waste.

Preparation :

Methane gas is obtained by heating sodium acetate and soda lime (3:1 proportion mixture of sodium hydroxide and calcium oxide)

$$\underset{\text{Sodium acetate}}{CH_3COONa} + \underset{\text{Sodalime}}{\begin{matrix} CaO \\ + \\ NaOH \end{matrix}} \xrightarrow{\Delta} \underset{\text{Methane}}{CH_4} + \underset{\text{Sodium carbonate}}{Na_2CO_3}$$

Methane gas collected by downward displacement of water proves that it is insoluble in water. It is colourless and odourless gas. It is lighter than air. Observe by dropping a burning piece of paper into a test tube filled with methane gas. It is a combustible gas and so it is a combustible substance. It burns with blue flame when burnt in air and gives carbon dioxide and water.

$$\underset{\text{Methane}}{CH_4} + \underset{\text{Di-oxygen}}{2O_2} \rightarrow \underset{\text{Carbon dioxide}}{CO_2} + \underset{\text{water}}{2H_2O} + \text{Heat}$$

10.12 Ethene (Ethylene)

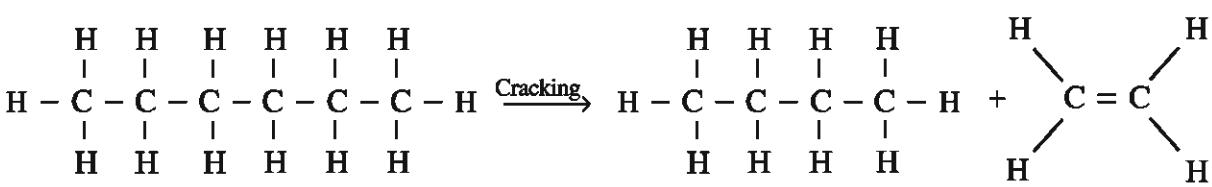
The molecular formula, electronic formula and structural formula of ethene is as follows :

C_2H_4

(Molecular formula) (Electronic formula) (Structural formula)

Cracking Method :

Cracking means to break organic molecules and to prepare small molecules. When alkanes containing more number of carbon atoms is heated at suitable temperature, lower hydrocarbons having less number of carbon atoms are formed by cracking. If it is heated in absence of the catalyst, it is called thermal cracking and if heated in presence of the catalyst, it is called catalytic cracking. By cracking of saturated hydrocarbon hexane, saturated hydrocarbon butane and unsaturated hydrocarbon ethene are obtained.



Hexane Butane Ethene

General methods of preparation of Ethene :

(1) Ethene from alcohol : Ethene is formed by heating ethanol with con. H_2SO_4 or H_3PO_4 at 443 K temperature. During this reaction a molecule of water is removed and so this reaction is known as dehydration of alcohol.

$$\underset{\text{Ethanol}}{CH_3CH_2OH} \xrightarrow[{[H_2SO_4]\ \text{OR}\ [H_3PO_4]}]{443\,K} \underset{\text{Ethene}}{CH_2 = CH_2} + H_2O$$

(2) Ethene from alkyl halide :

Ethene is formed by the reaction of ethyl chloride with alcoholic potassium hydroxide. Halogen of α-carbon of alkyl halide and hydrogen of b - carbon are removed. Hence, it is b - elimination or dehydrohalogenation reaction.

$$\begin{array}{c} \begin{array}{ccccc} & H & & H & \\ & | & & | & \\ H - & C^{\beta} & - & C^{\alpha} & - Cl \\ & | & & | & \\ & H & & H & \end{array} \\ \text{Ethyl chloride} \end{array} + KOH \xrightarrow{\text{Ethanol}} \begin{array}{c} CH_2 = CH_2 \\ \text{Ethene} \\ \text{(Ethylene)} \end{array} + KCl + H_2O$$

Ethene is obtained by cracking reaction of kerosene or wax. Unsaturated hydrocarbon is mostly obtained from petroleum by cracking method.

Preparation of ethene in laboratory : Mix 3 ml kerosene or melted wax and one tea spoon sand in a hard glass test tube. Then insert, some small pieces of China clay or porcelain in the front part of the test tube. Arrange this test tube as shown in Fig. 10.4. Heat the test tube on the spirit lamp till the pieces of porcelain becomes red hot and then immediately heat the sand containing kerosene or wax. Continue heating alternately the pieces of porcelain and the sand. When alkene vapour from wax passes through porcelain piece, ethene gas will be liberated by cracking. Collect the gas in gas jar by downward displacement of water. Collect gas jars with ethene and make the observation as follows for ethene gas.

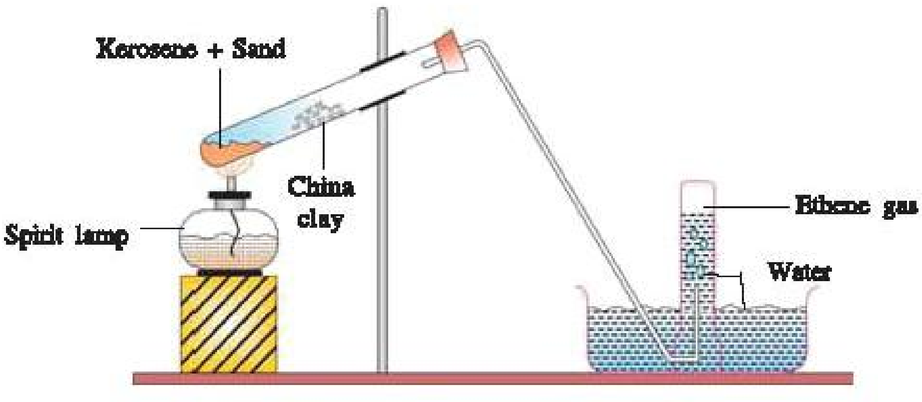


Fig : 10.4 Preparation of ethene

Ethene gas is insoluble in water. It is colourless and odourless gas. It is lighter than water. Drop a burning piece of paper in the test tube and observe whether gas is combustible. When burnt in presence of air, it burns with sooty flame i.e. it is a combustible substance. The soot produced is called carbon black. By taking ethene in one test tube and shaken after adding bromine water to it, the brown colour of bromine water disappears and 1, 2 dibromoethane is obtained. This reaction indicates the property of unsaturation.

$$\begin{array}{c} \begin{array}{ccccc} & H & & H & \\ & | & & | & \\ H - & C & = & C & - H \end{array} \\ \text{Ethene} \end{array} \quad + \quad \begin{array}{c} Br_2 \\ \text{Bromine water} \end{array} \longrightarrow \begin{array}{c} \begin{array}{ccccc} & H & & H & \\ & | & & | & \\ H - & C & - & C & - H \\ & | & & | & \\ & Br & & Br & \end{array} \\ \text{1, 2-dibromoethane} \end{array}$$

Ethene also removes the pink colour of dilute alkaline solution of potassium permanganate ($KMnO_4$) and makes it colourless. This reaction also indicates the property of unsaturation of ethene.

General chemical reactions of Ethene :

As carbon-carbon double bond is present in ethene, and one π bond present in it being weak breaks easily and the molecule of the reactant is added.

(1) Reaction with Hydrogen : Ethane is obtained by heating ethene with hydrogen in presence of catalyst Pd or Pt or Ni. This reaction is called hydrogenation reaction. This reaction is useful for preparing vegetable ghee from vegetable oil.

$$\underset{\text{Ethene}}{H-\overset{\displaystyle H}{\overset{|}{C}}=\overset{\displaystyle H}{\overset{|}{C}}-H} + H_2 \xrightarrow[\text{[Pd/Pt/Ni]}]{473\ K} \underset{\text{Ethane}}{CH_3-CH_3}$$

(2) Reaction with halogen : Dihalogen containing ethene if obtained by reaction of ethene with halogen in which the ethelenic π double bond breaks and halogen molecule is added.

$$\underset{\text{Ethene}}{CH_2=CH_2} + \underset{\text{Dichlorine}}{Cl_2} \rightarrow \underset{\text{1, 2 - Dichloro ethane}}{ClCH_2-CH_2Cl}$$

(3) Reaction with halogen acid : The reaction of ethene with halogen acid is called hydrohalogenation reaction. Reaction with hydrochloric acid is called hydrochlorination.

$$\underset{\text{Ethene}}{CH_2=CH_2} + \underset{\substack{\text{Hydrochloric}\\ \text{acid}}}{HCl} \rightarrow \underset{\substack{\text{Chloroethane}\\ \text{(Ethylchloride)}}}{CH_3CH_2Cl}$$

(4) Polymerization : When number of molecules of ethene under specific conditionas combine polymer named polythene is formed. This reaction is called polymerization. In polythene molecule carbon atoms of number of ethene molecules combine with one another and forms a chain. Ethene is called a monomer.

$$\underset{\text{Ethene}}{nH_2C=CH_2} \rightarrow \underset{\text{Polythene}}{+\!\!\!\!\!\left(CH_2-CH_2\right)\!\!\!\!\!+_n}$$

ICI company of England first of all prepared polythene in 1933. Polythene is used in preparation of buckets, pipes, bags and boxes. In addition, it is very essential for other household products and industrial production.

10.13 Ethyne (Acetylene)

Molecular formula, electronic formula and structural formula of ethyne are as follows :

C_2H_2	$H \overset{\bullet}{\times} C \vdots\vdots\vdots C \overset{\bullet}{\times} H$	$H-C\equiv C-H$
Molecular formula	Electronic formula	Structural formula

Acetylene is one of the chief substances for petrochemical industries. Earlier it was prepared from calcium carbide. But now it is prepared from natural gas because it is cheaper. At present, 30% of total production of acetylene is obtained from methane.

Preparation of Ethyne : Ethyne gas is obtained by the reaction of calcium carbide with water.

In a conical flask, take two to three small pieces of calcium carbide. Arrange the conical flask as shown in Fig. 10.5. Now, on adding water through Thistle funnel, chemical reaction takes place and ethyne is produced. Collect the ethyne gas in gas jars by downward displacement of water.

Chemical Reaction

$$\underset{\text{Calcium carbide}}{CaC_2} + \underset{\text{Water}}{2H_2O} \rightarrow \underset{\text{Ethyne}}{HC \equiv CH} + \underset{\text{Calcium hydroxide}}{Ca(OH)_2}$$

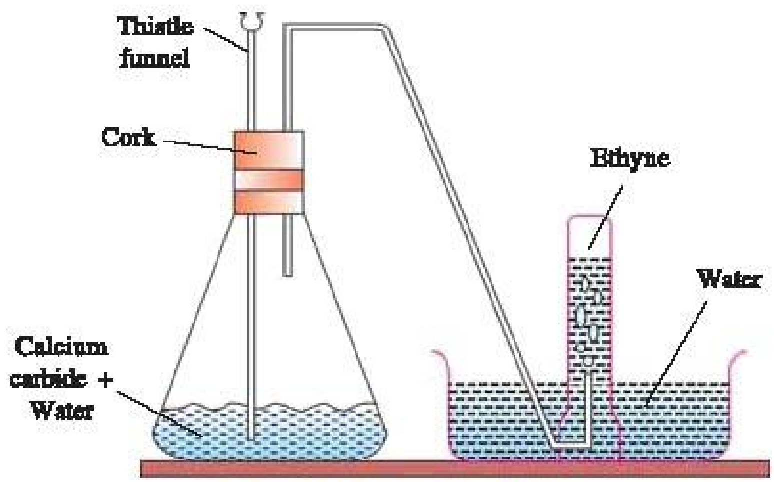


Fig. 10.5 Preparation of Ethyne

Observe the properties of ethyne gas, as follows :

Ethyne obtained by downward displacement of water proves that it is insoluble in water. It is colourless and odourless gas. It is lighter than water. It burns with non-luminous bright, flame when burns in air. If bromine water is added to a test-tube containing ethyne and shaken then the brown colour of bromine water is removed and 1, 1, 2, 2- tetrabromo ethane is formed.

$$\underset{\text{Ethyne}}{HC \equiv CH} + \underset{\text{Bromine water}}{2Br_2} \rightarrow \underset{\text{1,1,2,2, Tetrabromo ethane.}}{\begin{array}{ccccccc} & & Br & & Br & & \\ & & | & & | & & \\ H & - & C & - & C & - & H \\ & & | & & | & & \\ & & Br & & Br & & \end{array}}$$

This is addition reaction of ethyne.

Ethyne and hydrogen react in presence of Raney nickel catalyst; ethane is obtained by addition reaction.

$$\underset{\text{Ethyne}}{HC \equiv CH} + \underset{\text{Dihydrogen}}{2H_2} \xrightarrow[\text{Nickel)}]{\text{(Raney}} \underset{\text{Ethane}}{\begin{array}{ccccccc} & & H & & H & & \\ & & | & & | & & \\ H & - & C & - & C & - & H \\ & & | & & | & & \\ & & H & & H & & \end{array}}$$

Ethyne also undergoes polymerization reaction.

Vinyl chloride and vinyl cyanide or acrylonitrile are formed on reaction of ethyne with HCl and HCN respectively. Polyvinyl chloride (PVC) and Polyacrylonitrile (PAN) polymers can be obtained by their polymerization.

e.g.

(1)
$$\underset{\text{Ethyne}}{HC \equiv CH} + HCl \xrightarrow{HgCl_2} \underset{\text{Vinyl chloride}}{H_2C = CHCl}$$

$$\underset{\text{Vinyl chloride}}{nCH_2 = CHCl} \xrightarrow{\text{Polymerisation}} \left[-CH_2 - \underset{\substack{| \\ Cl}}{CH} - \right]_n$$

Polyvinyl chloride (PVC)

(2)
$$\underset{\text{Ethyne}}{HC \equiv CH} + HCN \longrightarrow \underset{\text{Vinyl cyanide}}{CH_2 = CHCN}$$

$$\underset{\text{Vinyl cyanide}}{nCH_2 = CHCN} \xrightarrow{\text{Polymerisation}} \underset{\text{Polyvinyl cyanide (polyacrylonitrile) (PAN)}}{\left[-CH_2 - \underset{\substack{| \\ CN}}{CH} - \right]_n}$$

The industrial name of ethyne is acetylene. Ethyne is industrially very important. The substances like ethanol, acetic acid, vinyl polymer and plastic like substances can be prepared from it. Ethyne is used in oxyacetylene flame used for welding of metals. On kite flying day, acetylene gas is filled in rubber balloons and are flown high in sky.

What have you learnt ?

- The mineral coal and petroleum available from earth's crust is a very important and useful wealth.
- Mineral coal and petroleum available from nature are important sources of energy.
- Mineral coal is very useful in steel industry, thermal power stations, manufacture of steel and extraction of metals.
- At the high pressure and temperature in the crust of the earth, the vegations and their parts are decomposed and at the end of the chemical reactions, they are converted into mineral coal. This type of fuel of mineral coal is called fossil fuel.
- Types of mineral coal - peat, lignite, bituminous coal and anthracite.
- If mineral oil is heated at high temperatures in absence of air, then coal gas, coaltar, ammonia and coke are formed.
- The oil available naturally from the crust of the earth is called petroleum. The name petroleum is derived from the Greek words 'petro' means rock and 'oleum' means oil.

- The main purpose of refining of petroleum is to obtain pure chemicals in addition to obtain liquid fuels like gasolene, petrol, kerosene and to separate Liquefied Petroleum Gas (LPG), lubrication oil, wax, naptha, tar etc.
- Petroleum in the furnace when heated, carbon is obtained by decomposition of hydrocarbon. This is known as petroleum carbon. It is used in the preparation of electrodes of battery and carbon tiles. Carbon tiles resist corrosion.
- Carbon possesses tetravalency and property of catenation so that it forms innumerable organic compands.
- The compounds which contain carbon and hydrogen are called hydrocarbons.
- In organic compounds like grains, pulses, sugar, tea, coffee, paper, cotton, wool, synthetic fibres, kerosene, petrol diesel, cooking gas, drugs, dyes, soap, detergent, rubber, plastic, perfume etc. which are useful in our everyday life mainly contain organic compounds.
- On classification of hydrocarbons, alkanes are saturated hydrocarbons, alkene and alkyne compounds are unsaturated hydrocarbons - Alkenes contain double bond and alkynes contain triple bond.
- The general molecular formula of alkanes is C_nH_{2n+2} where n is the number of carbon atoms in that molecule. The suffix at the end of members of alkane series is ane viz. methane, ethane, propane etc.
- sp^3 hybridisation is there in methane which possesses tetrahedral structure- the angle between two bonds is 109° 28'
- Methane is the chief component in gobar gas obtained from animal waste, sewage gas and biogas.
- Ethene gas is obtained by cracking reaction of kerosene or wax. Unsaturated hydrocarbons are mostly obtained by cracking of petroleum.
- Ethene forms polymer polythene by polymerisation which is used in large proportion in household uses.
- The molecular formula of ethyne is C_2H_2 which is known by the name acetylene. Ethyne gas can be obtained by reaction of water with calcium carbide, which is industrially very important. In ethanol, acetic acid, vinyl chloride etc. are used in welding by oxyacetylene flame,

EXERCISE

1. Select the proper choice from the given multiple choices :

(1) Which is the primary state in transformation of coal ?

(A) Lignite (B) Bitumen (C) Anthracite (D) Peat

(2) What is the matured form of coal ?

(A) Lignite (B) Bitumen (C) Anthracite (D) Peat

(3) Which type of coal does not produce smoke or odour when burnt ?

(A) Anthracite (B) Lignite (C) Bitumen (D) Peat

(4) Which of the following components is not obtained when destructive distillation of mineral coal is carried out ?

(A) Coal gas (B) Methane (C) Coaltar (D) Coke

(5) Which of the following is used in production of water gas ?

(A) Coke (B) Coaltar (C) Coal gas (D) Ammonia

(6) Water gas is the mixture of which gases ?

(A) Carbon dioxide and hydrogen (B) Carbon and hydrogen

(C) Carbon monoxide and hydrogen (D) Ammonia and hydrogen

(7) Which gas is filled at high pressure in cylinders of household cooking gas ?

(A) Methane (B) Ethane (C) Propane (D) Butane

(8) Which component obtained from refining of petroleum is used as solvent in petrochemicals ?

(A) Naphtha (B) Kerosene (C) Tar (D) Petroleum coke

(9) Which of the following is used in petromax to obtain light ?

(A) Petrol (B) Diesel (C) Kerosene (D) Butane

(10) Which is the chief hydrocarbon in natural gas ?

(A) Methane (B) Ethane (C) Propane (D) Butane

(11) What is the molecular formula of ethene ?

(A) C_2H_6 (B) C_2H_2 (C) C_2H_4 (D) CH_4

(12) What is the general formula of alkyne series ?

(A) C_nH_{2n} (B) C_nH_{2n-2} (C) C_nH_{2n+2} (D) C_nH_n

(13) What is the commercial name of ethyne ?

(A) Acrylic acid (B) Acetylene (C) Ethane (D) Oxyacetylene

(14) C_3H_8 is the molecular formula of which compound ?

(A) Methane (B) Ethane (C) Propane (D) Butane

(15) What is the angle between any two bonds in methane molecule ?

(A) 105°54’ (B) 109°28’ (C) 119°28’ (D) 190°28’

(16) What is called fossil fuel ?

(A) Mineral coal (B) Wood

(C) Cowdung cake (D) All the given

(17) From where mineral coal is obtained in Gujarat ?

(A) Ankleshwar (B) Cambay (Khambhat)

(C) Thangadh (D) Kalol

(18) What is used as fuel in jet planes ?

(A) Gasolene (B) Diesel oil (C) Kerosene (D) All the given

2. Answer the following questions in brief :

(1) What is called fossil fuel and write its use.

(2) How many main types of mineral coal are there and which are they ?

(3) Write a short note on coke.

(4) Explain in brief about coal tar and coal gas.

(5) What is the valency of carbon ? Why ?

(6) What is meant by hydrocarbon ? How are they classified ?

(7) Explain by drawing the shape of methane molecule.

(8) From which methane is obtained ? Write its preparation

(9) Write uses of ethyne by writing its common name and structural formula.

(10) What is isomerism ? Write isomers of butane and pentane.

(11) The everyday life is not possible without mineral coal and petroleum. Why ?

(12) Explain cracking reaction.

3. Answer the following questions :

(1) Explain the destructive distillation of mineral coal in laboratory by drawing its figure.

(2) Write the types of mineral coal, explain that the use of anthracene coal is more than the bitumen coal. Why ?

(3) Explain occurrence of methane and its preparation.

(4) Writing the common molecular formulas of alkanes, alkenes and alkynes, write the names of first compound of each.

4. Answer the following questions in detail :

(1) Explain preparation of ethene in laboratory by drawing figure.

(2) Explain preparation of ethyne in laboratory by drawing figure.

(3) What is meant by hydrocarbons ? Explain its classification in detail.

(4) Explain in detail about natural gas.

5. Answer the following question pointwise.

(1) What is meant by petroleum ? Explain in detail the refining of petroleum.

UNIT

11

ORGANIC COMPOUNDS

11.1 Introduction

The role of substances available through minerals, plants and animals existing in nature from ancient time is important. The substances available from non-living sources are called inorganic substances. The substances available from plants and animals that is substances available from living sources are called organic substances. Organic molecules are very essential for sustaining life on the earth. It was believed in the ancient time that some important force present in the living entities is necessary for the formation of organic compounds.

The basic constituent of organic compounds is carbon. Hydrocarbons are the basic organic compounds in organic chemistry. Many organic compounds are obtained by displacement of one or more than one hydrogen atom by elements like nitrogen, oxygen, sulphur and halogen. Thus, organic compounds contain the elements like nitrogen, oxygen sulphur, halogen in addition to carbon on the displacement of hydrogen. Hence, organic chemistry is made up of the several types of organic compounds obtained by displacement of hydrogen in them.

Organic compounds are very useful in everyday life of human being. The study of functional groups of organic compounds is necessary to understand easily the organic compounds. We shall obtain the preliminary information about organic functional groups.

11.2 Organic Functional Groups

The chemical reactivity of any organic substance is because of its functional group.

The reactivity of alkene or alkyne compounds corresponding to their alkane compounds is more viz. the reaction of ethene or ethyne is faster than that with its corresponding alkane.

Ethanol or ethanoic acid having same number of carbon atoms as in ethane have different physical and chemical properties which is due to the functional group present in them and the intermolecular forces associated with them.

Definition of Functional Group :

The atom or the group of atoms by which the characteristic reactions of organic compounds are determined, that atom or group of atoms is called the functional group.

Alkane hydrocarbon does not possess any functional group for causing the reaction because of its saturation in organic compound. Different organic compounds having same functional group show similar chemical reactions.

In organic compounds functional groups have atoms like oxygen(O), nitrogen(N), or sulphur(S) in addition to carbon. Common and IUPAC names of compounds having functional groups and examples of some common functional groups are given in Table 11.1

Table 11.1 Some Common Functional Groups

Formula of the functional group	Name of the functional group	Molecular Formula	Common name	IUPAC* name
–COOH	Carboxylic acid	CH_3COOH	Acetic acid	Ethanoic acid
>C = O	Ketone	CH_3COCH_3	Acetone	Propanone
–CHO	Aldehyde	HCHO	Formaldehyde	Methanal
–OH	Hydroxyl (alcohol)	CH_3CH_2OH	Ethyl alcohol	Ethanol
–COOR	Ester	CH_3COOCH_3	Methyl acetate	Methyl ethanoate
– X (Halogen)	Halide			
(F,Cl, Br,I)		CH_3Cl	Methyl chloride	Chloromethane

*(IUPAC = International Union of Pure and Applied Chemistry)

11.3 Organic Compounds Possessing Oxygen Containing Functional Group

In this section we shall have the preliminary study of organic compounds having mainly (1) Alcohol (–OH), (2) Aldehyde (–CHO), (3) Ketone (>C = O) (4) Carboxylic acid (–COOH) groups. In addition, organic compounds having ester and ether as functional groups are also included. We shall study them in the next standards.

Alcohol

If one hydrogen atom of an alkane is displaced by hydroxyl (–OH) group, then corresponding alcohol compound is obtained. The general formula of alcohol is C_nH_{2n+1} OH. Hence, it is represented as R-OH where R = alkyl group.

Nomenclature of Alcohols :

The nomenclature of alcohol corresponding to its hydrocarbon is carried out by removing last alphabate 'e' from the hydrocarbon the suffix – ol is added. Viz. After removing e from methane and by adding ol to methan, methan + ol = methanol. Similarly from ethane, ethan + ol = ethanol.

The first five alkane compounds and their corresponding alcohol compounds are given in Table 11.2.

Table : 11.2 Alkanes and their corresponding alcohols (first five members)

Alkane Name	Alkane : Molecular formula C_nH_{2n+2}	Common name	IUPAC name	Alcohol : Molecular formula ($C_nH_{2n+1}OH$)
Methane	CH_4	Methyl alcohol	Methanol	CH_3OH
Ethane	C_2H_6	Ethyl alcohol	Ethanol	CH_3CH_2OH
Propane	C_3H_8	Propyl alcohol	Propanol	$CH_3CH_2CH_2OH$
Butane	C_4H_{10}	Butyl alcohol	Butanol	$CH_3CH_2CH_2CH_2OH$
Pentane	C_5H_{12}	Pentyl alcohol	Pentanol	$CH_3CH_2CH_2CH_2CH_2OH$

Here, we shall study chemistry of well-known alcohol amongst alcohol compounds. Before this we will obtain information about fermentation process.

Process of Fermentation and its Importance :

You must have noted certain phenomena occurring in everyday life viz. formation of curd from milk, the reaction occurring in donaught (Khiru) of idli, 'handva', 'dhokla' which we call as fermentation reaction. It is anaerobic decomposition reaction. It is carried out by biological enzymes. Such biochemical catalysts are called enzymes.

Formation of curd from milk is carried out by lactase enzyme. It converts lactose of milk to lactic acid obtained in the form of curd. The formation of curd from milk by slow decomposition carried out by enzyme lactase, is known as fermentation. **Thus, reaction of formation of simple substances by slow decomposition of organic compounds through enzyme and in absence of oxygen is called fermentation.** In such reactions, presence of oxygen is not necessary, hence it is an anaerobic respiration e.g. as seen above, fermentation in donaught of idli. In the juice of grapes or fruits, ethanol is formed by decomposition in presence of enzyme yeast. During this fermentation reaction, carbon dioxide gas is produced. Hence, bubbles of gas are observed in this fermentation process.

Ethanol (CH_3CH_2OH) :

We know ethanol as alcohol. It is present in some toxic drinks like whiskey, wine, beer, as well as certain syrups. It also exists as component in dense liquid medicines for cough and for digestion. Two methods of industrial production are known.

(I) Industrial production of ethanol by fermentation reaction : First glucose and fructose are formed by fermentation reaction of sugarcane juice, juice of fruits or grapes, molasses (The waste which is without sugar after removal of sugar from sugarcane is called molasses) etc. in presence enzyme invertase.

$$\underset{\text{Sugar or molasses}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{\text{Invertase}} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Fructose}}{C_6H_{12}O_6}$$

Ethanol and carbon dioxide are formed by fermentation of this glucose or fructose in presence of enzyme zymase. Both the enzymes - invertase (sucrase) and zymase are present in yeast. (which is in the skin of the grapes).

$$\underset{\text{Glucose or fructose}}{C_6H_{12}O_6} \xrightarrow{\text{Zymase}} \underset{\text{Ethanol}}{2C_2H_5OH} + 2CO_2(g)$$

Ethanol is obtained as a mixture of 95% ethanol and 5% water which cannot be further concentrated. But pure ethanol is obtained by membrane technology.

(2) Modern Method of Industrial Production of Ethanol : The industrial production of ethanol is carried out by hydration of ethene ($CH_2 = CH_2$) obtained as petrochemical. Ethanol is formed by hydration of ethene with water in presence of concentrated sulphuric acid.

$$\underset{\text{Ethene}}{CH_2 = CH_2} + H_2O \xrightarrow{\text{Conc.}H_2SO_4} \underset{\text{Ethanol}}{CH_3CH_2OH}$$

Properties of Ethanol :

(1) Pure ethanol : Pure ethanol is colourless. Its boiling point is 351 K and it is highly soluble in water.

(2) Combustibility : Ethanol is a very combustible liquid. It burns rapidly with a blue flame when combusted and produces carbon dioxide and water by combustion.

$$\underset{\text{Ethanol}}{C_2H_5OH} + 3O_2 \xrightarrow{\Delta} 2CO_2 + 3H_2O$$

(3) Reaction with sodium (Na) metal : When ethanol reacts with sodium metal sodium ethoxide (which is generally known as alcoxide) and dihydrogen gas are produced.

$$\underset{\text{Ethanol}}{2C_2H_5OH} + \underset{\text{Sodium metal}}{2Na} \rightarrow \underset{\text{Sodium ethoxide}}{2C_2H_5ONa} + H_2(g)$$

(4) Ethanol on reaction with acetic acid in presence of acid gives ethyl acetate which has sweet fruity smell. This reaction is called esterification reaction.

$$\underset{\text{Acetic acid}}{CH_3COOH(l)} + \underset{\text{Ethanol}}{C_2H_5OH(l)} \xrightarrow{[H^+]} \underset{\text{Ethyl acetate}}{CH_3COOC_2H_5(l)} + H_2O(l)$$

(5) Acetic acid is formed by oxidation of ethanol.

$$\underset{\text{Ethanol}}{CH_3CH_2OH} \xrightarrow[KMnO_4]{\text{Alkaline}} \underset{\text{Ethanoic acid or Acetic acid}}{CH_3COOH}$$

Activity : 1

Take small amount of ethanol in a dry test tube. Add a small piece of sodium metal to it. Note the observation. The bubbles of hydrogen gas will be produced around the piece of sodium metal. By bringing a lighted match stick near the open mouth of the test tube it burns with explosion, which will be combustion. The teacher should take utmost care during this activity.

Activity : 2

Take some amount of ethanol in a dry test tube. Add slowly dropwise $KMnO_4$ solution prepared in 5% aqueous solution of NaOH and keep it for some time. Afterwards, on observation, it will be found that the colour of $KMnO_4$ disappears which indicates the formation of ethanoic acid by oxidation of ethanol.

Uses of Ethanol :

(1) It is used as solvent in industry and in lacquers, varnish, and in fragrant materials like perfumes and in medicine also.

(2) As it is antiseptic, it is used for dressing and cleaning of boils.

(3) As ethanol should not be used as toxic drink, harmful substances like methanol, copper sulphate are mixed with it.

(4) Ethanol solution containing 5% water is called rectified spirit which is useful for making the outer surface of the body germ-free. 100% ethanol is called absolute alcohol.

Alcohol - harmful as drink :

Ethanol is known as toxic amongst alcohols. Those who drink ethanol containing adulterant substances like methanol known as "lathha" lose their eyesight and become blind. They lose sensitivity and lose the balance of the body. It affects the liver and causes death due to a diseases called scirrohsis of liver. Hence, the drinking of alcohol is harmful for the health.

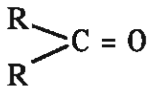
In alcohol containing drinks, ethanol is the main constituent and so it has got toxic effect on the body. If it is taken in small amount, it works as stimulant. If alcohol containing drinks are taken, then ethanol is absorbed through mucosa of stomach and ethanol mixes with the flow of blood through the layers of liver. If an adult drinks alcohol, then it becomes 0.3% in the blood. If more concentration of alcohol is there in the blood, it is harmful and in this condition, he becomes unconscious and the heart fails also.

If alcohol is absorbed in the cells, then 90% of ethanol is slowly converted into acetaldehyde by oxidation. Acetic acid is formed by oxidation of acetaldehyde and finally carbon dioxide and water are formed by oxidation. All the cells are able to carry out this oxidation, even then the oxidation reaction occurs mainly in the liver. The toxic effect of alcohol is due to this acetaldehyde and so the person feels vomiting or loses balance or becomes unconscious.

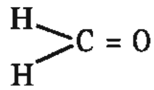
In the liver of the alcohol-drinker (alcohol addict) the amount of enzyme P-450 increases very high and so one who drinks alcohol gets tempted to drink more alcohol. One who is habituated to drinking alcohol, is given medicine called disulfiram. By this medicine alcohol is oxidised only upto acetaldehyde and so by drinking acetaldehyde containing alcohol, one feels vomiting and nautia and as a result the alcohol drinker (alcohol addict) develops hatred towards alcohol.

Aldehyde and Ketone Compounds :

Aldehyde and Ketone are carbonyl $(>C=O)$ group containing organic compounds. The carbon atom of carbonyl compound group is attached with one alkyl (– R) group and one hydrogen atom (H) in which formaldehyde is the exception.



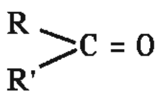
Aldehyde



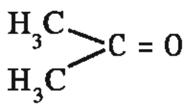
Methanal

(Formaldehyde)

While in ketones carbon of carbonyl group is attached with carbon atoms of two alkyl groups (R and R').



Ketone



Propanone (Acetone)

where R and R' are similar or different alkyl groups.

IUPAC Nomenclature of Aldehydes and Ketones :

For IUPAC nomenclature of aldehyde compounds having longest hydrocarbon carbon chain with aldehyde group (– CHO) corresponding to original carbon is decided and last alphabet 'e' is removed from the name of the hydrocarbon and the suffix 'al' is added.

As an example, the aldehyde corresponding to methane is known as methanal (Common name : formaldehyde) ethane known as ethanal (Common name : acetaldehyde) and propane known as propanal.

From methane, methan + al = methanal. From ethane, ethan + al = ethanal.

While in ketone compounds last alphabet 'e' is removed from the name of the hydrocarbon and the suffix 'one' is added viz. Ketone corresponding to propane is propanone, and ketone corresponding to butane as butanone.

From Propane : Propan + one = Propanone, From Butane : Butan + one = Butanone

Examples of simple aldehydes and ketones corresponding to alkanes are given in Table 11.3.

Table 11.3 Some Common Aldehydes and Ketones

Alkane		Aldehyde			Ketone		
Formula	Name	Formula	Common name	IUPAC name	Formula	Common name	IUPAC name
CH_4	Methane	HCHO	Formaldehyde	Methanal	-	-	-
C_2H_6	Ethane	CH_3CHO	Acetaldehyde	Eathanal	-	-	-
C_3H_8	Propane	CH_3CH_2CHO	Propionaldehyde	Propanal	CH_3COCH_3	Acetone	Propanone
C_4H_{10}	Butane	$CH_3CH_2CH_2CHO$	Butanaldehyde	Butanal	CH_3CH_2-$COCH_3$	Methyl ethyl ketone	Butanone

Methanal (Formaldehyde) (HCHO)

The common name of methanal is formaldehyde. Its aqueous solution containing 4 to 6% concentration is called formalin. It is antiseptic. Its molecular formula is HCHO. It is used as preservative in preserving samples of dead animals in the laboratory.

Preparation of Methanal :

Methanal (HCHO) is formed by oxidation of methanol at 873 K to 973 K temperature in presence of catalyst like oxides of silver or iron.

$$\underset{\text{Methanol}}{2CH_3OH} + O_2 \xrightarrow[\text{[}Ag_2O\text{] 873K-973K}]{\text{Oxidation}} \underset{\text{Methanal (Formaldehyde)}}{2HCHO + 2H_2O}$$

Properties of Methanal :

(1) Methanal is a colourless, poisonous gas. Its boiling point is 253 K. It is soluble in water.

(2) The chemical reactions of aldehyde as analdehyde functional group are as follows :

(1) **Oxidation :** Methanoic acid is formed by oxidation of methanal in presence of oxidising substance.

$$\underset{\substack{\text{Methanal} \\ \text{(Formaldehyde)}}}{HCHO} \xrightarrow{\boxed{O}} \underset{\substack{\text{Methanoic acid} \\ \text{(Formic acid)}}}{HCOOH}$$

In this reaction oxidising agents like ammoniacal silver nitrate (Tollens reagent) and Fehling reagent oxidise aldehyde compound to corresponding carboxylic acid having same number of carbon atoms.

Activity : 3

In a test tube, take solution of silver nitrate. Add solution of NaOH in such a proportion that stable brown black colour precipitates are obtained. Dissolve these precipitates by adding liquor ammonia. The resulting solution is Tollens reagent. In another test tube take aldehyde and add Tollens reagent to it. Place this test tube in a beaker containing hot water. Silver metal is separated by reduction of silver ion (Ag^+) and gets deposited on the inner surface of the test tube which appears as a mirror. This test is known as silver mirror test.

Activity : 4

Glucose is a compound containing aldehyde group. When Fehling solution-A (Solution of copper sulphate) and Fehling solution –B (sodium potassium tartarate and sodium hydroxide mixture) are added to aldehyde. Copper (II) is reduced and red precipitates of copper (I) oxide are formed. This test is known as Fehling test in the laboratory.

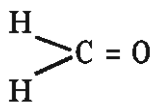
Activity : 5

Glucose is a compound containing aldehyde group. In the urine of a diabetic patient, amount of glucose is present. When it is treated with Benedict's Solution (mixture of $CuSO_4$ + aqueous citric acid + sodium carbonate) copper (II) is converted to precipitates of copper (I) oxide. This test is known as Benedict's test in pathological laboratory.

(ii) **Reduction of methanal :** Methanol is formed by reaction of methanal with dihydrogen (H_2) gas in presence of palladium (Pd) catalyst.

$$\underset{\text{Methanal}}{HCHO} + \underset{\text{Dihydrogen}}{H_2} \xrightarrow{[Pd]} \underset{\text{Methanol}}{CH_3OH}$$

(iii) **Addition reaction of hydrogen cyanide (HCN) with methanal**



A double bond is present between carbon and oxygen atoms in methanal. Organic compounds containing double bond give addition reaction (addition of reagent to the original substance). Methanal reacts with hydrogen cyanide and gives methanal cyanohydrin product by addition reaction.

Methanal   Hydrogen cyanide   Methanal cyanohydrin

Uses of Methanal :

(1) Aqueous solution of methanal (formalin) is antiseptic and so used to preserve residues of dead animals.

(2) Methanal is used as a raw material in plastic industry. Methanal is used as a monomer in preparation of bakelite, melamine plastic etc.

(3) Methanal is used for making dyes phenol and formaldehyde fibres (Polymer).

(4) The resin known as urea formaldehyde (UF) resin is prepared from urea and formaldehyde, which is used as foam.

Propanone (Acetone) (CH_3COCH_3)

The simplest compound of ketone group is propanone. Its common name is acetone which is one of the compounds of the solution to remove nail polish.

Preparation of propanone :

Fisher – Tropsch Process : When a mixture of ethene obtained during cracking of petroleum and water gas is passed over a catalyst cobalt oxide (CoO) at 150 bar pressure and 453 K temperature, acetone is obtained.

$$\underset{\text{Ethene}}{CH_2 = CH_2} + \underbrace{H_2 + CO}_{\text{Water gas}} \xrightarrow[453\,K;\,150\,bar]{[CoO]} \underset{\text{Propanone}}{CH_3COCH_3}$$

Properties of Propanone :

(1) **Propanone (acetone)** is a colourless liquid and possesses fragrant smell. Its boiling point is 329 K and it is very much soluble in water.

(2) **Reduction of propanone :** Propanone gives propan-2-ol on reduction with reducing agent like sodium borohydride ($NaBH_4$) or Lithium aluminium hydride ($LiAlH_4$)

$$\underset{\text{Propanone}}{CH_3COCH_3} \xrightarrow[\text{or } LiAlH_4]{NaBH_4} \underset{\text{Propan-2-ol}}{CH_3\text{-}\underset{\substack{|\\OH}}{CH}\text{-}CH_3}$$

(3) **Oxidation of propanone :** Ethanoic acid is obtained by oxidation of propanone, with alkaline potassium permanganate. ($KMnO_4$)

$$CH_3COCH_3 \xrightarrow[\text{Alkaline}]{[O]KMnO_4} CH_3COOH + CO_2 + H_2O$$

Propanone — Ethanoic acid or Acetic acid

(4) **Addition reaction of propanone :** Like methanal propanone contains $>C = O$ double bond. As a result of this it reacts with hydrogen cyanide (HCN) and gives additive product propanone cyanohydrin.

$$H_3C-\underset{\underset{O}{\|}}{C}-CH_3 + HCN \longrightarrow H_3C-\underset{\underset{OH}{|}}{\overset{\overset{CN}{|}}{C}}-CH_3$$

Propanone — Hydrogen cyanide — Propanone cyanohydrin

Uses of Propanone :

(1) As a solvent in laboratory and in paint industry.

(2) In preparation of artificial leather and synthetic fibres.

(3) It is used as nail paint remover.

Carboxylic Acid Compounds :

Organic compounds containing –COOH functional group are called carboxylic acid compounds. Some of them like methanoic acid and ethanoic acid have well known common name as formic acid and acetic acid respectively.

IUPAC Nomenclature :

For nomenclature of carboxylic acid compounds, the longest hydrocarbon carbon chain with carboxylic group is selected and last alphabate 'e' is removed from the corresponding hydrocarbon and 'oic' suffix is added. e.g. Methane – Methanoic acid, Ethane – Ethanoic acid.

Common and IUPAC names of some carboxylic acids are given in Table 11.4

Table 11.4 Common and IUPAC Names of Carboxylic Acids :

Alkane		Carboxylic acid		
Molecular formula	Common name	Molecular formula	Common name	IUPAC name
CH_4	Methane	$HCOOH$	Formic acid	Methanoic acid
C_2H_6	Ethane	CH_3COOH	Acetic acid	Ethanoic acid or Acetic acid
C_3H_8	Propane	CH_3CH_2COOH	Propanoic acid	Propanoic acid

Carboxylic acids having general formula $\underset{HO}{\overset{R'}{>}}C = O$ obtained by substitution of any one of the R or R' group present in general formula $\underset{R}{\overset{R'}{>}}C = O$ by -OH group.

Ethanoic acid (Acetic acid) CH_3COOH :

The common name of ethanoic acid is acetic acid. Its formula is CH_3COOH.

Preparation of Ethanoic Acid :

(1) Ethanoic acid (vinegar) is formed by oxidation of ethanol in air by fermentation in presence of acetobacter enzyme.

$$C_2H_5OH + O_2 \xrightarrow[\text{Enzyme}]{\text{Acetobacter}} \underset{\text{Ethanoic acid}}{CH_3COOH} + H_2O$$

The proportion of ethanoic acid obtained by this method is very less.

(2) In the modern industrial production of ethanoic acid, methanol is reacted with carbon monoxide in presence of catalyst Iodine-Rhodium (I_2 -Rh)

$$\underset{\text{Methanol}}{CH_3OH} + \underset{\text{Carbon monoxide}}{CO} \xrightarrow{[I_2-Rh]} \underset{\text{Ethanoic acid or Acetic acid}}{CH_3COOH}$$

Properties of Ethanoic Acid :

(1) Ethanoic acid is a colourless, liquid containing highly sour smell and is soluble in water. Its boiling point is 391 K.

(2) **Acidic Property :**

(a) It reacts with metals like sodium (Na) and magnesium (Mg) and forms metal ethanoate (acetate) salt and dihydrogen gas. It is a weak acid.

$$\underset{\text{Ethanoic acid}}{2CH_3COOH} + \underset{\text{Sodium}}{2Na} \longrightarrow \underset{\substack{\text{Sodium ethanoate}\\\text{(Sodium acetate)}}}{2CH_3COONa} + \underset{\text{Dihydrogen}}{H_2(g)}$$

(b) Ethanoic acid forms salt like sodium acetate by reaction with base like sodium hydroxide.

$$\underset{\substack{\text{Ethanoic acid}\\\text{(Acetic acid)}}}{CH_3COOH} + \underset{\substack{\text{Sodium}\\\text{hydroxide}}}{NaOH} \longrightarrow \underset{\substack{\text{Sodium ethanoate}\\\text{(Sodium acetate)}}}{CH_3COONa} + H_2O$$

These reactions indicate that hydrogen present in -COOH group possesses acidic property.

(3) **Reaction with Alcohol :** Ethanoic acid reacts with ethanol in presence of concentrated sulphuric acid and forms ethyl ethanoate (ethyl acetate).

$$\underset{\text{Ethanoic acid}}{CH_3COOH} + \underset{\text{Ethanol}}{C_2H_5OH} \xrightarrow[\Delta]{[\text{Con. } H_2SO_4]} \underset{\substack{\text{Ethyl ethanoate}\\\text{(Ethyl acetate)}}}{CH_3COOC_2H_5} + H_2$$

Here the reaction of formation of ester by the reaction of carboxylic acid with alcohol is called esterification.

Uses of Ethanoic acid :

(1) In preparation of vinegar, to have sour taste in food stuffs and as preservative for foods.

(2) As a solvent and reagent in the laboratory.

(3) In preparation of white lead.

11.4 Polymers

The macromolecules that are formed by combination of one or more than two types of innumerable simple molecules by chemical bond formation are called **polymers.**

One or more than two types of innumerble simple organic molecules that combine with one another and form a polymer are called **monomers.**

The process (reaction) of one or more than two types of innumerable simple organic molecules that combine with each other by chemical bond formation is called **Polymerisation.**

Polythene is formed by addition reaction of innumerable molecules of ethene with one another. In this reaction, two molecules of monomer ethene combines in the first step and form a dimer. Third molecule combines with a dimer and forms a trimer. A trimer combines with fourth monomer and forms a tetramer. In the same way the chain elongates. As a result very long chain is formed which is called macromolecule or polymer.

$$\underset{\text{Ethene monomer}}{CH_2 = CH_2} \xrightarrow{CH_2 = CH_2} \underset{\text{Dimolecular formation (Dimer)}}{CH_3 - CH_2 - CH = CH_2} \xrightarrow{CH_2 = CH_2}$$

$$\underset{\text{Trimolecular formation (Trimer)}}{CH_3 - CH_2 - CH_2 - CH_2 - CH = CH_2} \xrightarrow{CH_2 = CH_2}$$

$$\underset{\text{Tetramolecular formation (Tetramer)}}{CH_3 - CH_2 - CH_2 - CH_2 - CH_2 - CH_2 - CH = CH_2}$$

$$\xrightarrow{n(CH_2 = CH_2)} \underset{\text{Polythene (polymer)}}{\left[CH_2 - CH_2 \right]_n}$$

In every polymer chain, certain part is continuously repeated on the basis of the monomer molecule. This part is called 'repeating unit' viz. In polythene, ethene is the monomer. The number of repeating unit 'n' in a polymer is called degree of **polymerisation.**

(1) Classification of Polymers :

Polymers are classified in different types :

(i) **Naturally occurring Polymer :** Polymers are found in nature, viz, starch, protein, nucleic acid, rubber etc. are very essential for human beings.

(ii) **Semisynthetic Polymer :** Semisynthetic polymers are obtained by chemical reaction with polymers occurring in nature. The rubber with improved properties obtained by vulcanization of natural rubber, is used in the formation of tyres,

(iii) **Synthetic Polymers :** Man-made synthetic polymers are made up of polymers. This is an important big class of polymers, in which fibres, plastic and rubber are included. Synthetic polymers are used in textile industry, electrical appliances, and in lieu of wood and metal.

(2) Classification based on Polymerisation Reaction :

(i) Homopolymer and Co-polymer : When two or more types of innumerable simple organic monomers of the same type combine with one another through chemical bond formation gives polymers. They are called homopolymers viz. Polythene formed from ethene is a homopolymers. When two or more types of innumerable simple organic monomers of same type combine with one another through chemical bond formation gives polymers. They are called co-polymers viz. Styrene Butadiene Rubber (SBR) prepared from styrene and butadiene is a copolymer.

(ii) Addition and Condensation Polymer : The polymers that are formed by combination of chemical bond formation of innumerable simple organic monomers having double bond are called addition polymers viz. Polystyrene formed from styrene is an addition polymers.

Some important addition polymers, their monomers and their uses are given in Table 11.5

Table 11.5 Monomer, Polymer and their uses

Monomer	Polymer	Uses
$CH_2 = CH_2$ Ethene	$-\!\!\![CH_2 - CH_2]\!\!\!-_n$ Polythene	Toys, packing bags
$CH_2 = CH\text{-}Cl$ 1-Chloroethene (Vinyl chloride)	$\left[CH_2 - \underset{\displaystyle Cl}{\underset{\vert}{CH}} \right]_n$ Polyvinylchloride	In preparation of flooring tiles, rain coats, hand bags .
$CF_2 = CF_2$ Tetrafluoroethene	$-\!\!\![CF_2 - CF_2]\!\!\!-_n$ Teflon	Preparation of non-stick cooking vessels and as insulator
$CH_2 = \underset{\displaystyle CH_3}{\underset{\vert}{C}} - CH = CH_2$ 2-Methyl buta-1,3-diene (Isoprene)	$\left[CH_2 - \underset{\displaystyle CH_3}{\underset{\vert}{C}} = CH - CH_2 \right]_n$ Natural rubber	In preparation of water proof clothes, tyres of cars and bikes.
$CH_2 = CH - CH = CH_2$ Buta-1,3-diene (Butadiene)	$-\!\!\![CH_2 - CH = CH - CH_2]\!\!\!-_n$ Polybutadiene	As an alternative for natural rubber
$CH_2 = \underset{\displaystyle Cl}{\underset{\vert}{C}} - CH = CH_2$ 2-Chlorobuta-1,3-diene	$\left[CH_2 - \underset{\displaystyle Cl}{\underset{\vert}{C}} = CH - CH_2 \right]_n$ Neoprene	As an insulator in conveyor belts, rollers of printing

Uses : In preparation of utensils for household purposes, pipes, paints, fibres, nylon, terrylene, etc. spare parts of automobile, furniture and brush, comb, chappal, raincoat etc. Also useful in preparation of fish nets, ropes, and tyres. It is useful in textile industry. With the use of science and technology we have been able to prepare polymers having different characteristics,

Rubber : Rubber is obtained naturally and is also prepared synthetically.

There is notable elasticity in natural rubber. The reversible stress is maintained for a long time even if a small force is applied on it. Because of this characteristic property of elasticity, the natural rubber is notably used in different fields. The rubber latex available from the rubber plant, obtained by a cut in its bark, is a colloidal suspension called rubber latex. Natural rubber is obtained by physical and chemical reactions with rubber latex. The characteristic property of elasticity of natural rubber is maintained between temperatures 283 K to 333 K or higher. At the temperatures below 283 K, it remains brittle while it becomes soft at temperatures 333 K or higher. Its capacity of absorbing water is high. It is resistant to non-polar solvents and gets oxidised easily by the oxidising agent.

Vulcanised Rubber : In 1893, Charles Goodyear found out that if the mixture of rubber and sulphur is heated at 373 K to 413 K temperature, the required change in the required proportion can be carried out. This process is known as vulcanisation. This reaction is slow and so zinc oxide is added as addition substance and so the rate of reaction becomes fast.

Vulcanised rubber has very good elasticity, very low water absorbing property and resists organic solvents and oxidation reaction. By use of 5% of sulphur during vulcanisation, rubber suitable for tyres and by use of 30% of sulphur during vulcanisation, rubber suitable for cases of battery can be prepared.

Uses : The vulcanised rubber is used in rubber bands and preparation of tubes and tyres of vehicles. The high non-inflamable property of neoprene is due to large number of chlorine atoms present in it.

Condensation Polymers :

When two different types of innumerable simple organic monomers combine with one another by condensation polymerisation and gives polymers after removal of molecule like water, ammonia or alcohol, are called condensation polymers viz. Nylon 6,6 polymer obtained from hexamethylene diamine and adipic acid is a condensation polymer.

Uses : Nylon 6,6 is of thermoplastic type polymer. Its fibres are strong, elastic and water resistant. It is used in preparation of fishing nets, ropes and also used in tyre industry.

Polyester :

Polyester molecule possesses innumerable ester functional group containing repeating units. It is formed by combination of two hydroxyl and two carboxylic groups containing substances.

$$nHO-\boxed{\quad\quad}-OH + nHOOC-\boxed{\quad\quad}-COOH \xrightarrow[\Delta]{\text{Polymerisation}}$$

(Compound containing hydroxyl group

(Compound containing carboxylic group)

$$HO \left[\boxed{\quad\quad} - COO - \boxed{\quad\quad} \right]_n COOH + n\ H_2O$$

Polymer

where $\boxed{\quad\quad}$ shows hydrocarbon part.

Uses : Polyester fibres are mixed with cotton fibres and used in textile industry.

Polyamide : Polyamide is a polymer containing amide group. It can be prepared by condensation of diamine and carboxylic acid and is known as nylon :

$$\underset{\text{Diamine}}{H_2N-\boxed{\quad\quad}-NH_2} + n\ \underset{\text{Dicarboxyllic acid}}{HOOC-\boxed{\quad\quad}-COOH} \xrightarrow[\Delta]{\text{Polymerisation}}$$

$$\underset{\text{Nylon}}{H_2N \left[\boxed{\quad\quad} - NHCO - \boxed{\quad\quad} \right]_n COOH} + n\ H_2O$$

where $\boxed{\quad\quad}$ shows hydrocarbon part.

Biopolymers :

Some polymers in nature, viz; polysachharide, protein and nucleic acid are very essential for human beings. They are called biopolymers.

Most of the polymers used in everyday life possess inactivity towards environmental reactions. Hence, decomposition reactions do not occur during use of polymers and substances useful to human being are not produced. Hence, a big and intense problem has emerged out for the disposal of waste collected after use of this type of non-biodegradable polymers.

In the biological systems of human being the degradation of biopolymers is mostly carried out by hydrolysis through enzymes and to some extent by oxidation.

In recent years the development of biodegradable polymers is being carried out with a view that it is suitable to human life system and taking into consideration the disposal of solid waste after use of polymers.

Uses : Biodegradable polymers are used in special types of packing, orthopaedic appliances and in capsules to fill controlled drugs. Only when controlled drug containing PHBV (Polyhydroxy butyrate Co-β hydroxy valerate) capsule is decomposed in the body, then after effect of the drug released from the capsule starts. The dextran used for taking stitches after surgical operation is a biodegradable polymers.

11.5 Soap and Synthetic Detergents

The chemical substance used to remove the dirt sticked to the surface and does not harm the surface of a thing is called detergent.

Detergents have been used for many of years, we will be familiar with the preliminary information of detergents like soap and detergents.

Soap : Soap is a sodium or potassium salt of fatty acid (stearic acid, oleic acid, palmitic acid). Sodium salt is present in washing soaps and potassium salt is present in bathing soaps. Acid gives glycerol and ester compounds which is present in animal fat (mutton tallow) and vegetable oil (fat).

Preparation of Soap : Vegetable oil (groundnut oil, castor oil etc.) or animal fat when heated with sodium hydroxide (NaOH), sodium salt of fatty acid and glycerol are formed. This process of preparing soap is called saponification.

$$\text{Vegetable oil or Animal fat} + \text{Sodium hydroxide} \xrightarrow[\Delta]{\text{Saponification}} \text{Glycerol} + \text{Sodium salt of fatty acid (Soap)}$$

Activity 6

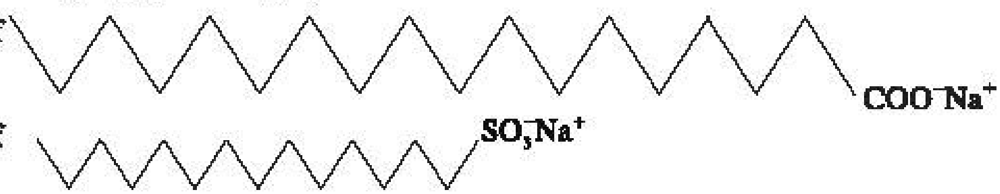
In a beaker, take 20 ml. of vegetable oil and add aqueous solution of 20% NaOH. Heat it for some time and stir it. The oily and aqueous layers will mix with each other and the mixture will be viscous. Add 5 to 10 grams of common salt (NaCl). Cool the mixture so that the insoluble substance will come in the upper part of the mixture. Take it in another vessel and prepare cakes which is soap. In the preparation of this soap, fragrant substances, antiseptic drug, filler etc. are added as per the requirement of the soap.

Detergents : Chemically, detergents are the sodium salts of organic sulphonic acids.

In soap - COONa functional group is attached to hydrocarbon while detergents are sulphonate ($-SO_3Na$) functional group possessing hydrocarbon chains.

Molecule of soap

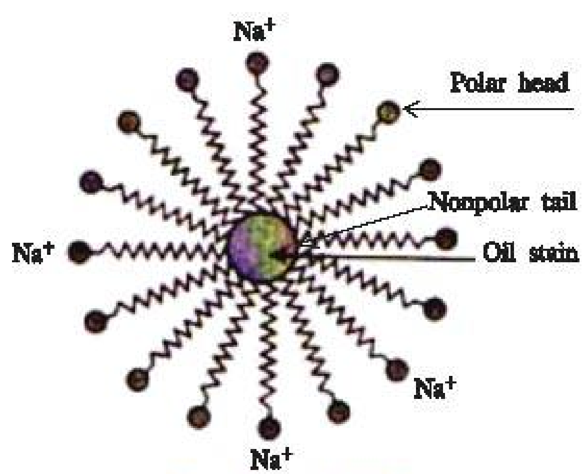
Molecule of detergent



The cleansing effect of the detergent is more effective because Ca^{2+} and Mg^{2+} ions present in hard water do not give precipitates with ions which are in the soluble form. They remain in the solution and so detergent in more quantity is not used. Hence, the use of detergent has increased. The cleansing process of soap and detergent is same. There are two parts in the structure of soap and detergent; one part of a long hydrocarbon chain is known as nonpolar tail. It does not possess attraction towards water but possesses attraction towards dirt or stain.

While the other negatively charged part ($-COONa$ or $-SO_3Na$) is known as head. It possesses attraction towards water molecules. Concentrated solution of soap or detergent is applied on the dirty or oily stained surface. The nonpolar part possessing attraction towards dirt is attracted by oily stain or dirt.

When polar part remains in water, it possesses attraction towards water. The spherical structure formed around the stain is called micelle.



Formation of micelles

The hydrocarbon part remains attached with the surface containing dirt or oil while polar part remains in water.

The part on which detergent is applied, is being dragged by water so that the water gets dirty and the surface becomes clean.

What have you learnt ?

In this unit, we have learnt about information on organic compounds and how organic compounds are very useful in our everyday life. The study of functional group is essential for the study of organic compounds.

The atom or group of atoms which carry out reactions of organic compounds is called functional group.

- Functional groups are like carboxylic acid (–COOH), ketone (> C = O), aldehyde (–CHO), alcohol (–OH), ester (–COOR) and halogen (X)

In this unit, alcohol and ethanol etc., fermentation method of obtaining alcohol, fermentation reaction and its importance are discussed.

Usage of ethanol in toxic beverages such as whisky, wine, beer and certain syrups, in medicines necessary for cough and digestion. Drinking toxic drinks and the harmful effect due to that, necessary medicine for that and properties of ethanol are studied in detail.

You have studied about aldehyde and ketone compounds, their nomenclature, methanal (formaldehyde), ethanal (acetaldehyde), etc. Preparation of methanal, properties and uses, and also studied the silver mirror test and Fehling tests as activity.

Preparation of propanone, properties, uses and study of reduction-oxidation and addition reactions are also carried out.

In carboxylic acid compounds, ethanoic acid (acetic acid), its preparation, properties and acidic properties, esterification reaction and uses - acetic acid as preservative (vinegar) have been discussed.

Also learnt about artificial polymers, classification of polymers, addition and condensation polymer, rubber, vulcanised rubber, polyester, polyamide and their uses as well as biopolymers.

Also learnt in detail about soap and synthetic detergents, preparation of soap. Detergents and their uses, method of removing dirt.

EXERCISE

1. Select the proper choice from the given multiple choices :

(1) What is called the compounds possessing (-CHO) functional group ?

(A) Amide (B) Aldehyde (C) Ketone (D) Alcohol

(2) Which functional group is possessed by carboxylic acid ?

(A) $>C = 0$ (B) -COOH (C) -CHO (D) -OH

(3) 'ol' suffix is attached with which group in nomenclature ?

(A) -CHO (B) $>C = O$ (C) -OH (D) -X

(4) Which functional group is there in methyl ethanoate ?

(A) Alcohol (B) Halide (C) Ketone (D) Ester

(5) Which of the following compounds is obtained by fermentation reaction of molasses ?

(A) Chloromethane (B) Ethanol (C) Acetone (D) All the given

(6) What is called the solution ethanol containing 5% water ?

(A) Beer (B) Varnish (C) Rectified spirit (D) Perfume

(7) What is the moleuclar formula of formalin ?

(A) HCOOH (B) $HCOOCH_3$ (C) HCHO (D) $HCOOC_2H_5$

(8) Which substance is obtained by reduction of methanal ?

(A) Ethanol (B) CO_2 and O_2 (C) Methanol (D) All the given

(9) What is prepared by Fisher-Tropsch method ?

(A) Acetic acid (B) Acetaldehyde (C) Acetone (D) Ethanol.

(10) Which of the following is the use of propanone ?

(A) To remove nail polish (B) Antiseptic

(C) Antibiotic (D) As preservative.

(11) Which of the following is the reaction occurring between alcohol and carboxylic acid in presence of concentrated H_2SO_4 ?

(A) Hydrolysis (B) Beta-elimination (C) Saponification (D) Esterification

(12) Which compound of the following functional groups is having minimum three carbon atoms ?

(A) –COOH (B) –CHO (C) $>C = O$ (D) –C–O–

(13) Which of the following monomers is in polythene ?

(A) $CH_3–CH_3$ (B) $CH_2 + CH = CH_3$

(C) $CH_2 = CH_2$ (D) $CH = CH$

(14) Which of the following is the use of acetic acid ?

(A) Preparation of vinegar (B) White lead

(C) As reactant (reagent) (D) All the given

(15) Which of the following is used in conveyor belts ?

(A) Polythene (C) PVC (C) Teflon (D) Neoprene

2. Answer the following questions in brief :

(1) Mention the functional groups containing oxygen.

(2) Explain the fermentation reaction and its importance.

(3) Write preparation of methanal with equation.

(4) Write properties of methanal.

(5) Write Fisher-Tropsch method with equation.

(6) Write preparation of ethanoic acid.

(7) Write the defintion of functional group and give examples of two functional groups.

(8) Explain homopolymer and co-polymers.

(9) Explain addition and condensation polymers.

(10) Write structures and uses of ethene and vinyl chloride polymer.

(11) Write uses of polymers.

(12) Write the structure and uses of teflon and polyisoprene polymers.

3. Answer the following questions :

(1) Write industrial production of ethanol.

(2) Write properties of ethanol.

(3) What is rubber ? Explain.

(4) Write uses of ethanol.

(5) Give examples of aldehyde and ketone.

(6) Write oxidation, reduction and addition reaction of methanal with hydrogen cyanide.

(7) Write uses of acetone.

(8) Write uses of ethanoic acid.

(9) What is meant by soap ? Write its preparation.

(10) What is called esterification reaction ? Explain giving examples.

4. Answer the following questions in detail :

(1) Write names and molecular formulas of first four members of alkanes and their corresponding alcohols.

(2) Write four chemical properties of ethanol.

(3) "Alcohol is harmful as drink." Explain this statement in detail.

(4) Write uses of methanal (formaldehyde).

(5) Write properties of propanone.

(6) Write properties of ethanoic acid.

(7) What is polymer ? Explain in detail.

(8) Write a short note on detergents.

5. Answer the following questions pointwise :

(1) Write in detail classification of polymers.

(2) Write short notes-polyester and polyamide.

(3) Write about vulcanised rubber and its uses.

UNIT

12

NUTRITION AND RESPIRATION

Every organism performs different types of physiological activities. For these activities organisms required energy. This energy is obtained by organisms through different methods of nutrition. Autotrophic organisms obtained nutrition by performing the process of photosynthesis. While heterotrophic organisms dependent on other organisms for food. In animals, the entire process of ingestion of food conversion into easily absorbable components and transport to the different cells is known as nutrition. The process of getting energy from nutritive substances is carried out by cells. Thus, phenomenon is generally known as cellular respiration. During this process energy is realesed which can be utilised by organisms for physiological activities.

12.1. What are Life Processes ?

All the organisms perform certain main functions to keep themselves alive. The main fundamental functions, performed by living organisms to maintain their life are called life processes. They are nutrition, growth, respiration, circulation, excretion, control and coordination, movement and reproduction. The nutrition means taking of food and converting it into smaller absorbable unit by our body. The process of respiration releases energy from the absorbed food. Transport is the process through which absorbed substance are transported to various parts of the body. Waste materials produced in various cells of the body are removed from the body by process of excretion. Control and coordination keep the living organisms to survive in the changing environment surrounding them. The process of growth involves the change in size of the living organism (small to big). In the process of movement the living organisms move from one place to another or make movement of smaller to larger parts of the body. The process of reproduction involves multiplication of existing organisms, so they can make existence of their species on the earth.

Nutrients

Nutrients mean substances which provide the two basic requirements of organisms, namely organic raw material and energy.

12.2. Nutrition

Nutrition can be defined as the process of intake of nutrients from which organisms derive energy to work. A substance which supply nutrients to the body is called diet or food. The food taken by an organism contains, carbohydrates, proteins, fats, vitamins, water and minerals. In organisms there are different ways for obtaining food. Hence in various organisms different modes of nutrition can be seen.

Modes of Nutrition :

The modes of nutrition means methods of obtaining food by organisms. All the organisms do not obtain their food in the same way. So organisms have following methods for obtaining food.

(A) Autotrophic (Holotrophic) Nutrition

(B) Heterotrophic Nutrition

[A] Autotrophic nutrition :

The word 'auto' means self and 'trophe' means nutrition. Autotrophic means 'self nutrition'. In autotrophic nutrition organisms synthesize their own food, like carbohydrate, from water and carbon dioxide with the help of chlorophyll in presence of sun light. This process is known as photosynthesis. e.g. green plants, Euglena, Volvox and Bacteria. Carbohydrates are used for providing energy to them. The carbohydrates which are not used are stored in the form of starch. We derived energy from the food which is stored in our body in the form of glycogen.

The following events are involved in the process of photosynthesis :

(i) Absorption of light energy by chlorophyll

(ii) Conversion of light energy into chemical energy

(iii) Reduction of carbon dioxide in to carbohydrates.

Let us see how sunlight, chlorophyll and CO_2 are important for photosynthesis. In leaf some cells contain green organelles viz. chloroplasts which contain chlorophyll. Let us do an activity which demonstrates that chlorophyll is important for photosynthesis.

Activity : 1

- Take a potted Croton plant whose leaves are partly green and partly white.
- The green part of the leaf possesses chlorophyll while the white part of the leaf does not have chlorophyll.
- Keep this plant in a dark place for about three days to destarch its leaves.
- Now keep the plant in sunlight for about six hours.

Fig. 12.1 Variegtated leaves

- Pluck the variegated leaf from the plant and remove its "chlorophyll" by boiling it in alcohol. Thus green parts of the leaf get decolourised.
- Now dip the leaf in a dilute solution of iodine for a few minutes.
- Observe the change in colour of leaf.
- The inner part of the leaf which was originally green turns blue on dipping in iodine solution, this shows that starch is present in it.
- The outer part of the leaf which was originally white (without chlorophyll) does not turn blue while dipping in iodine solution, showing that no starch is present.
- From this observation we can conclude that chlorophyll is essential for the process of photosynthesis.

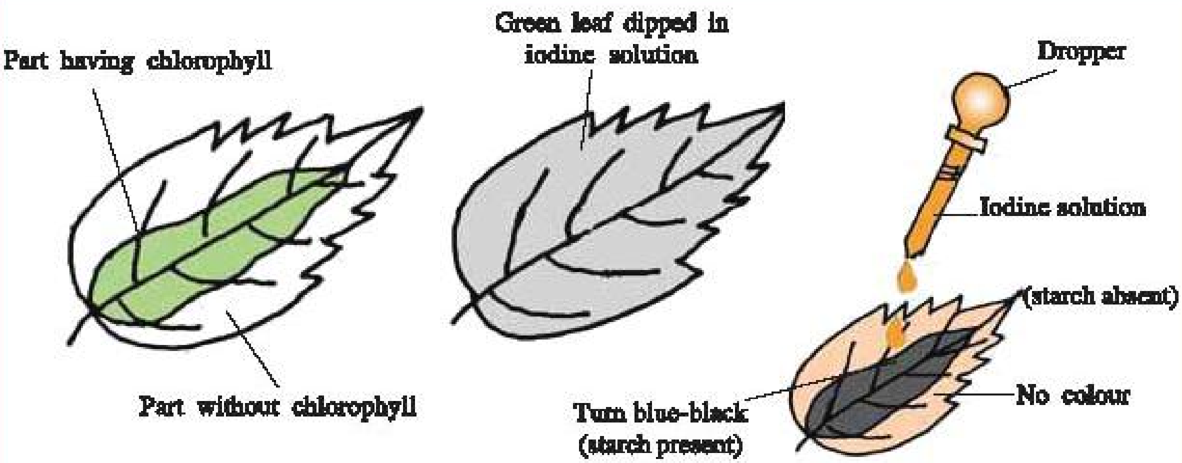


Fig. 12.2 Experiment shows necessity of chlorophyll for photosynthesis

Let us know how the plants obtain carbon dioxide. The plants take carbon dioxide from the atmosphere for photosynthesis. The carbon dioxide enters the leaves of plant through the stomata present on the surface of leaves. The stomata are also present in the green stems of plant.

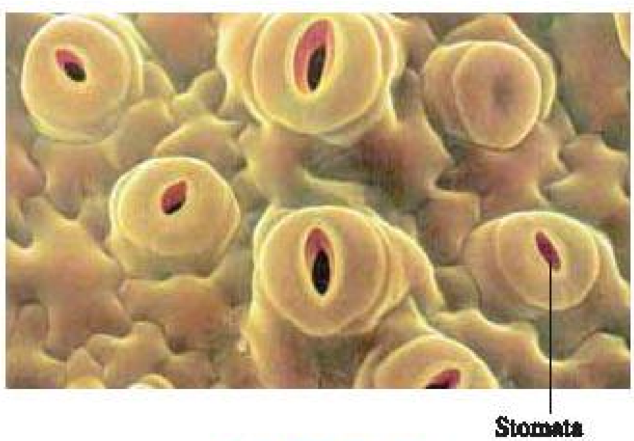


Fig. 12.3 Stomata

Each stomatum consists of minute pore surrounded by a pair of guard cells. The opening and closing of stomata are controlled by the guard cells. When water enters into the guard cells, the cells become turgid and cause the pore to open. When the guard cells lose water, they shrink and cause the pore to close. Aquatic plants obtain the carbon dioxide gas dissolved in water to carry out photosynthesis.

Activity : 2

Let us do an activity which demonstrate that carbon dioxide is necessary for photosynthesis.

- Take two potted plants which are nearly same in size.
- Keep them in a completely dark place for three days to destarch their leaves.
- Now put each potted plant on a separate glass plate.
- Put a watch glass containing potassium hydroxide by the side of one of the plants. The use of potassium hydroxide is to absorb carbon dioxide.
- Cover plants with separate bell – jars.
- Use vaseline to seal the bottom of the jars to the glass plates so that set-up is airtight.
- Keep the plants in sunlight for more than two hours.
- Pluck the leaf from both plants and check the presence of starch as in activity No. 1. This shows that carbon dioxide is necessary for photosynthesis.

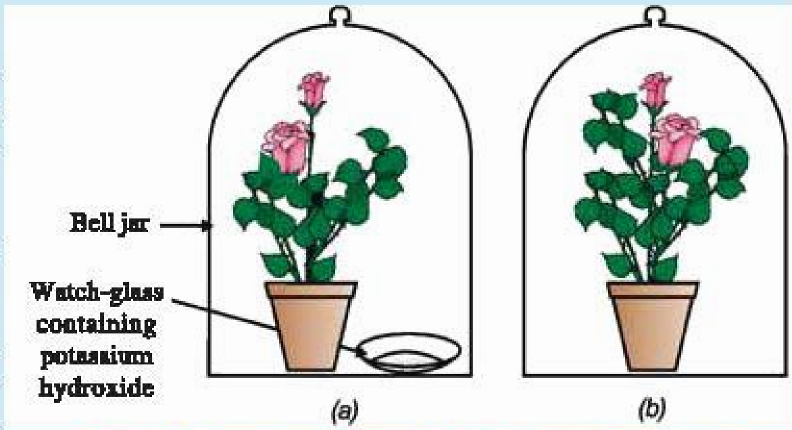


Fig. 12.4 Experimental set-up (a) with potassium hydroxide (b) without potassium hydroxide

Activity : 3

Sunlight is necessary for photosynthesis

- Take the potted plant with green leaves and place it in a dark place for about three days to destrach its leaves.
- Take a thin aluminium foil and wrap it in the centre of one leaf on both the sides, in such way that the remaining part of the leaf remain uncovered and exposed to sunlight. The covered part of leaf does not receive sunlight.
- Keep this potted plant in bright sunlight for three days.
- Pluck the partially covered leaf and remove the aluminium foil.
- This leaf is to be tested for the presence of starch.
- Before testing starch, chlorophyll from the leaf is removed.
- Put the plucked leaf in a beaker containing alcohol
- Put the beaker containing alcohol and leaf, into water bath.
- Heat the water bath, alcohol in the beaker will also get heated and start boiling.

  The boiling alcohol will remove chlorophyll from the green leaf completely.

- Now the leaf becomes almost colorless, remove colorless leaf from alcohol.
- Put the colorless leaf in a perti-dish and with the help of dropper put a drop of iodine solution.
- Observe the change in colour of leaf.
- Part of the leaf which was covered with aluminium foil does not turn blue-black because sunlight could not reach there. Hence this part did not perform photosynthesis to make starch.
- The uncovered part of the leaf, which was exposed to sunlight turns blue-black on adding iodine solution.
- The starch is present in this part of the leaf. This means that the part of the leaf which was exposed to sunlight make starch by the process of photosynthesis. So we can conclude that sunlight is necessary for photosynthesis to make starch.

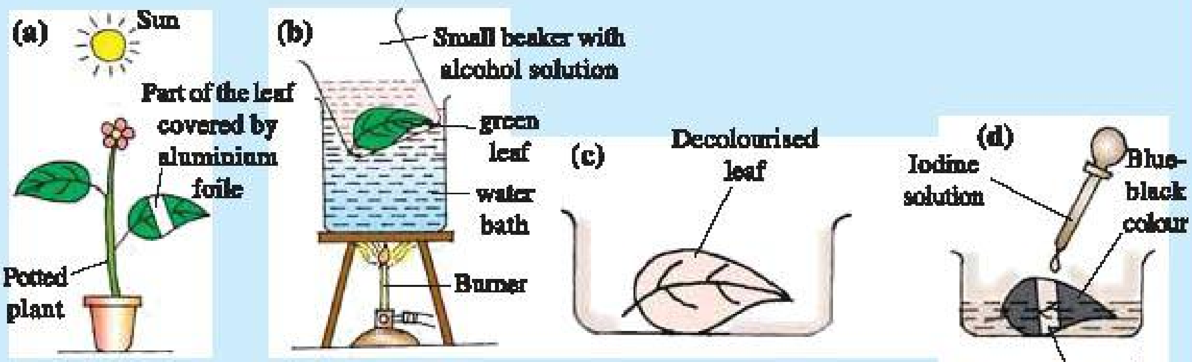


Fig. 12.5 Sunlight is necessary for photosynthesis

Now we have understood how autotrophs meet their energy requirements. We should keep in mind that plants also require other raw materials like water, nitrogen, phosphorus, iron and magnesium for building their body which are taken from soil. For the synthesis of protein, nitrogen and other compounds these are essential elements.

[B] Heterotrophic nutrition

All organisms are adapted to their environment. The heterotrophic nutrition differs depending on the availability and also how it is obtained by the organism. In heterotrophic nutrition the organisms cannot synthesize their own food by using carbon dioxide, sunlight and water. In heterotrophic nutrition energy is derived by digestion of organic substances obtained from plant and animal. In this type of nutrition, after intake, the food is digested in to simple forms and then organisms utilize it. All animals, bacteria and fungi are heterotrophic organisms.

Heterotrophic nutrition is of the following types:

[1] Saprophitic nutrition :

Here the dead and decaying organic materials are absorbed through the body wall of the organisms. The organisms depend entirely on the non-living substances. e.g. Bacteria and Fungi.

Fig. 12.6 Fungi

[2] Parasitic nutrition :

When organisms depend on another living organisms for their nutrition, then this mode of nutrition is called parasitic nutrition and the organism from which they obtain food is called 'host'. The parasite has close association with the host and obtains food from it. The host is not benefited but harmed. Several bacteria, fungi, plant like cuscuta and animal like tapeworm, ascaris etc live as parasites.

[3] Holozoic nutrition :

In this type of nutrition parts of plants or animals or whole organism are taken in as food which is then digested with the help of digestive enzymes into simple substance and then absorbed by body cells of the animals. The undigested food is thrown out of the body of animal through the process of egestion.

12.3 How do organisms obtain their nutrition ?

In different animals, food and the way how they obtained food are different. Animals cannot make their own food and hence, they obtain food either from plants or animals. All the animals can be divided into three groups on the basis of their food eating habits.

(1) Herbivores : Those animals which eat only plants are known as herbivores. eg. Goat, cow etc.

(2) Carnivores : Those animals which eat only animals are known as carnivores. eg. Lion, Tiger.

(3) Omnivores : Those animals which eat both plants and animals are known as omnivores. eg. Man, Rat

Nutrition in Amoeba :

Amoeba is unicellular animal. The mode of nutrition in Amoeba is holozoic. In Amoeba the process of obtaining food is called phagocytosis (means cell feeding). The various processes involved in nutrition are ingestion, digestion, absorption, assimilation and egestion. Amoeba ingests food particles by forming temporary finger like projections known as pseudopodia around them so the food is encaptured along with lysosomes into a bag called food vacuole.

Digestion : In Amoeba food is digested in the food vacuoles by digestive enzymes.

Absorption : The digested food found in food vacuoles is absorbed directly into cytoplasm by diffusion

Assimilation :

A part of the food absorbed in cell is used to obtain energy through respiration. The remaining part is used in the growth of Amoeba.

Egestion :

The undigested food remains in the food vacuole is thrown out of the body by rupturing cell membranes.

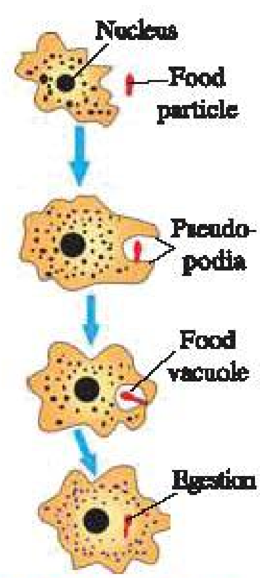


Fig. 12.7 Nutrition in Amoeba

The unicellular animal Paramoecium has thin, hair-like cilia found all over the body. Through sweeping of cilia the food particle found in water enters in the mouth of Paramoecium, this process is known as ingestion. Ingestion is followed by other steps as described in the case of Amoeba.

12.4 Human Digestive System :

The digestive system of human consists of the alimentary canal and its associated glands. The human digestive organs are mouth, oesophagus, stomach, small intestine, large intestine and associated glands like salivary gland, liver and pancreas.

The mouth is the special organ for ingestion of food. With the help of hands the food is put into mouth. The digestion of food starts as we put food in our mouth. The mouth cavity contains teeth, tongue, and salivary glands. The teeth cut the food into small pieces, chew and grind it. The salivary gland secretes the saliva in our mouth. The tongue mixes the food with saliva. Saliva is a watery liquid so it wets the food in mouth. The wetted food is swallowed easily.

The salivary gland secretes an enzyme called amylase, which digests the starch of food into maltose. Thus, the digestion of starch begins from mouth. As the food remains in the mouth for a short time, the digestion of food is incomplete in mouth. The partly digested food in the mouth goes down to oesophagus. Now the food is carried from oesophagus to stomach. The stomach is present on the left side of the abdomen. The food is churned in stomach for nearly three hours. The food breaks into small pieces and converts into semi-solid paste. The wall of stomach contains three tubular glands which secrete gastric juice. The gastric juice contains dilute hydrochloric acid, enzyme pepsinogen and mucus. The mucus protects the stomach wall from its own secretion of hydrochloric acid and pepsin. The hydrochloric acid makes the acidic medium in stomach. It also kills bacteria which enter the stomach with food. In acidic medium, the enzyme pepsin digests protein, present in the food, and converts into small molecules. Thus digestion of protein begins in the stomach. The partly digested food then goes from the stomach into small intestine. The exit of food from stomach is regulated by a sphincter muscle. The small intestine is the largest part of the alimentary canal and in adult person it is about 6.5 meter long. The length of the small intestine differs in various animals depending on the type of food they eat. Herbivorous animals, eating grass, need a longer small intestine to allow the cellulose, present in grass, to be digested completely. The meat is easy to digest, so the carnivorous animals have shorter small intestine.

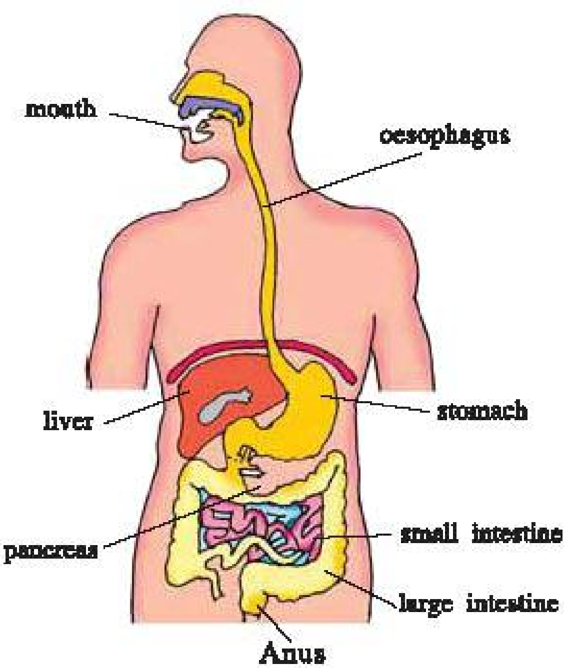


Fig. 12.8 The human digestive systems

The small intestine in man is the site of complete digestion of carbohydrates, proteins and fats. The small intestine receives the secretion from liver and pancreas. The liver secrets bile, which is a greenish yellow liquid and normally stored in the gall bladder. The bile is alkaline in nature and contains salts. It makes the acidic food coming from the stomach alkaline, so that pancreatic enzymes can act on it. The bile salts break the fats present in the food into small globules, making it easy for the enzyme to act and digest them. The pancreas secretes pancreatic juice which contains enzyme like amylase, trypsin and lipase. The enzyme amylase digests starch, the trypsin digests proteins and lipase digests fats.

The glands of the wall of small intestine secrete intestinal juice. The intestinal juice contains various enzymes which complete the digestion of carbohydrates into glucose, proteins into amino acids and fats into fatty acids and glycerol.

After complete digestion, the small intestine becomes the main site for the absorption of digested food. The inner wall or the small intestine has millions of small, finger-like projections called villi. The presence of villi increases the surface of small intestine. This helps in the rapid absorption of digested food. The absorbed digested food passes through the wall of the small intestines, goes into our blood.

The blood carries digested food to all the parts of body where it is assimilated as part of the cells. This assimilated food is used by all the cells, where it is utilized for energy, growth and repair of the body. The undigested food passes from small intestine to large intestine, where most of water from the undigested food is absorbed. Now the undigested food becomes almost solid, and is removed from the body via anus. The exit of this waste material (faeces or stool) is regulated by the muscles of anus.

12.5 Respiration

Cells in order to perform various functions require energy. This energy is derived by the oxidation of food. The process of releasing energy from food is called respiration. The process of respiration involves intake of oxygenated air into the cell (inspiration), using it for releasing energy by burning of food, and then removal of the carbon dioxide and water from the body. During the process of respiration energy is released inside the cells. So it is known as cellular respiration. Respiration is essential for life, because it releases energy to carry out different life processes.

Types of respiration :

Respiration is of two types, aerobic and anaerobic.

Aerobic respiration :

The respiration which takes place in the presence of oxygen is called aerobic respiration. Aerobic respiration takes place in the cell, so it is also called cellular respiration. During this food (Glucose) is broken down into carbon dioxide and water in the presence of oxygen. The energy released in the process is stored in ATP.

The overall equation can be represented as follows :

$$\text{Glucose} \xrightarrow[\text{in cytoplasm}]{\text{Glycolysis}} 2\ \text{Pyruvic acid} \xrightarrow[\text{(in mitochondria)}]{\text{Oxygen(Kreb's cycle)}} 6CO_2 + 6H_2O + 38\ \text{ATP Energy}$$

Anaerobic respiration :

The respiration which takes place without oxygen is called anerobic respiration. It is seen in microorganisms like bacteria, yeast, fungi, end parasites and muscle cells. In anaerobic respiration, the microorganisms break down glucose into ethanol and carbon dioxide and release energy. CO_2

and ethanol are formed as end products in plants, while lactic acid is an end product in muscles of animals. The equations are as follows :

$$\text{Glucose} \xrightarrow[\text{in cytoplasm}]{\text{Glycolysis}} \text{2 Pyruvic acid} \xrightarrow[\text{Yeast}]{\text{In absence of oxygen}} \text{2 Ethanol} + 2CO_2 + \text{2ATP}$$

$$\text{Glucose} \xrightarrow[\text{in cytoplasm}]{\text{Glycolysis}} \text{2 Pyruvic acid} \xrightarrow[\text{In muscles of animals}]{\text{In absence of Oxygen}} \text{2 Lactic acid} + \text{2 ATP}$$

Difference between aerobic and anaerobic respiration :

Aerobic respiration	Anaerobic respiration
(1) It takes place in presence of oxygen.	(1) It takes place in absence of oxygen.
(2) End products are CO_2 and water	(2) End products are ethanol or lactic acid.
(3) It takes place in cytoplasm and mitochondria	(3) It takes place only in cytoplasm.
(4) Aerobic respiration produces a considerable amount of energy.	(4) Much less energy is produced.

Respiration in plants :

Plants also need energy like animal. The plants get this energy by the process of respiration. Plants also use O_2 of air for respiration and release CO_2. The respiration in plants differs from that of animals by the following ways:

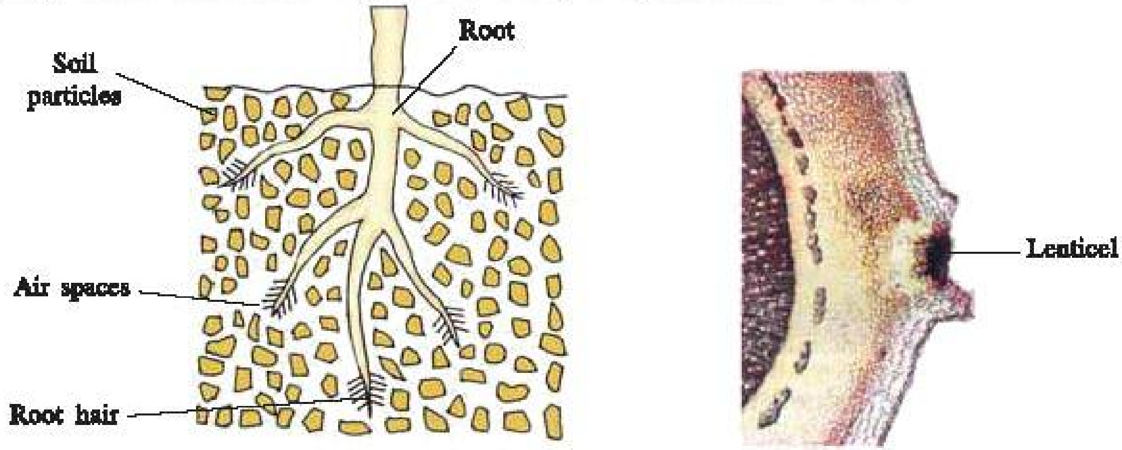
(1) All parts of a plant (like root, stem and leaf) perform respiration independently.

(2) There is a little transport of gases from one part to another in plant.

(3) Respiration in plants occurs at much slower rate than in animal.

Exchange of gases in root and stem :

The roots of a plant take oxygen for respiration from the air present in between the soil particles by the process of diffusion. The extensions of the epidermal cells of a root are known as root hair. These root hairs are in contact with air in the soil hence, oxygen diffuses into root hairs and reaches all the cells of the root for respiration. The CO_2 gas produced in the cells of the root during respiration moves out through root hairs by the process of diffusion.



[A] [B]

Fig. 12.9 [A] Absorption of Oxygen through root [B] Lenticel

The stems of herbs have stomata, so the exchange of gases takes place through stomata. The oxygen from air diffuses into stem through stomata and reaches all the cells of stem for respiration. The CO_2 gas produced during respiration diffuses out into air through stomata. The hard and woody stems of big plants do not have stomata. In woody stems, the bark, has lenticels for respiratory gaseous exchange. The leaves of a plant have small pores called stomata. The exchange of respiratory gases by the process of diffusion takes place through stomata.

Fig. 12.10 Stomata

In leaves during day time when photosynthesis occurs O_2 diffuses out and CO_2 diffuses in, but at night time no photosynthesis occurs so O_2 diffuses in and CO_2 diffuses out.

Respiration in animals :

Various animals have different modes of respiration. In unicellular animals (eg. Amoeba) respiration takes place in cell membrane by diffusion of gases. In earthworm the respiratory organ is skin. In insects tracheae are the respiratory organs. The aquatic animals like fish, prawns, crabs and sepia have gills as respiratory organs which obtain oxygen dissolved in water. In frog, lizard, bird and human beings the lungs are the respiratory organs.

Respiration in human being :

Human respiratory system consists of nostril, nasal passage, pharynx, laropharynx, trachea, bronchi, lungs and diaphragm. Nostrils open into nasal cavities. The air for respiration is drawn into our body through nostril. This air then goes into nasal cavity. The nasal cavity is lined by fine hairs and mucus. The dust particles and microbes in the air get trapped in mucus of the nasal cavity. Nasal cavity ends in internal nostril through which air passes to pharynx. The pharynx leads to trachea, through a slit called glottis. Glottis is protected by a cartilaginous flap like epiglottis. While swallowing food, glottis is covered by the epiglottis so food cannot enter the trachea. Trachea does not collapse even when there is no air because it is supported by 'C' shaped cartilaginous ring. At the upper end trachea has a voice box known as larynx. Trachea runs down the neck and divides into two bronchi which lead into the lungs. Each bronchus divides in the lungs and form many smaller bronchioles. The smallest bronchioles terminate into alveoli. The wall of the alveoli is thin and covered by blood capillaries. In alveoli the gaseous exchange takes places.

Mechanism of breathing :

When the diaphragm pulls down and rib muscles contract, the volume inside the thoracic cavity increases and air pressure inside the chest cavity decreases hence, air from outside (being at higher pressure) rushes into the lungs. So the alveoli get filled with oxygen rich air and exchange of gases takes place. When the diaphragm moves up (relaxes) the volume inside the thoracic cavity decreases and thus pressure increases so air containing CO_2 is pushed out of the lung into atmosphere through nostril.

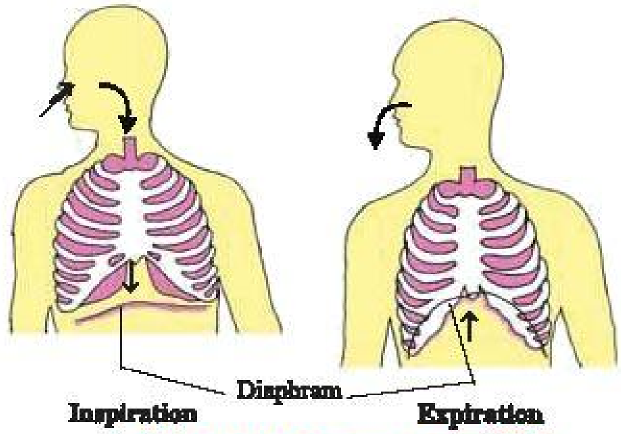


Fig. 12.11 Mechanism of Breathing

What have you learnt ?

- Various types of movements can be taken as an indication of life.
- The processes like nutrition and respiration are required for the maintenance of life.
- In autotrophic nutrition, organism make (synthesize) its own food from carbon dioxide, water and sunlight. Plants are Autotrophs.
- Animals are heterotrophs which depend on plants or other animals for their food.
- Heterotrophic nutrition is of three types, saprotrophic nutrition, parasitic nutrition and holozoic nutrition.
- All the animals can be divided into three groups on the basis of their food habit. These are herbivores, carnivores and omnivores.
- The mode of nutrition in Amoeba is holozoic. The process of obtaining food by Amoeba is called phagocytosis.
- In human beings, the food is broken down by the process of digestion and digested food is absorbed by the small intestine and is sent to all the cells in the body.
- The main purpose of respiration is the release of energy from the oxidation of organic compound like glucose.
- The energy produced during respiration is stored in the form of ATP molecules in the cell of the body.
- Respiration are of two types – aerobic respiration and anaerobic respiration.
- Plants get oxygen by diffusion, diffusion occurs in roots, stems and leaves of plants.
- Various animals have different types of respirations.
- In unicellular animals respiration takes place in cell membrane.
- In insects trachea is a respiratory organ. In prawn, crabs, sepia and fishes, gill is a respiratory organ. Frog, lizard, bird and human beings respire through lungs.

EXERCISE

1. Select the proper choice from the given multiple choices :

(1) Which of the following types has the longest small intestine ?

(a) Carnivores (b) Omnivores (c) Herbivores (d) Autotroph

(2) The process of obtaining food by Amoeba is known as ....

(a) Dialysis (b) Cytokinesis (c) Phagocytosis (d) Amoebiosis

(3) Which organism possesses parasitic mode of nutrition ?

(a) Penicillium (b) Plasmodium (c) Paramoecium (d) Euglena

(4) Which one of the following organisms has a saprophytic mode of nutrition.

(a) Mushroom (b) Malarial parasite (c) Leech (d) Lice

(5) The length of small intestine in an adult human being is about :

(a) 4.5 m (b) 1.5 m (c) 3.5 m (d) 6.5 m

(6) Where the process of digestion of food starts in human being ?

(a) Stomach (b) Food canal (c) Mouth (d) Small intestine

(7) In which organ the process of digestion in human is completed ?

(a) oesophagus (b) small intestine (c) stomach (d) large intestine

(8) By which of the following bile is secreted in human digestive system ?

(a) Pancreas (b) Liver (c) Kidney (d) Stomach

(9) The autotrophic mode of nutrition requires ....

(a) Carbon dioxide and water (b) Chlorophyll

(c) Sunlight (d) All of the above

(10) In human digestive system, the enzymes pepsin and trypsin are secreted respectively by which organs ?

(a) Pancreas and liver (b) Stomach and salivary glands

(c) Pancreas and gall bladder (d) Stomach and pancreas

(11) Which one of the following organisms can live without oxygen of air.

(a) Amoeba (b) Sheep (c) Yeast (d) Leech

(12) During respiration, the exchange of gases takes place in:

(a) Bronchi (b) Alveoli (c) Bronchioles (d) Trachea

(13) In which of the following organisms, the gaseous exchange during respiration does not take place through cell membrane or skin.

(a) Electric ray (b) Leech (c) Earthworm (d) Amoeba

2. Answer the following questions in brief :

(1) Which inorganic sustances are used as food by autotrophic organisms ?

(2) What is the mode of nutrition in fungi ?

(3) Name one organism each having saprophytic, parasitic and holozoic modes of nutrition.

(4) Name the process by which plants make food.

(5) In addition to carbon dioxide and water, state two other conditions necessary for the process of photosynthesis to take place.

(6) Name the pigment which can absorb solar energy.

(7) Where is chlorophyll mainly present in a plant?

(8) Which structure of the food vacuole in Amoeba to break down the food ?

(9) From which part of the body, undigested food is egested in Amoeba ?

(10) Name one organism which can live without oxygen.

(11) In which type of respiration more energy is released?

(12) Which part of root is involved in the exchange of respiratory gases ?

(13) Name the respiratory organ of fish.

3. Write answers of the following questions :

(1) (a) What is autotrophic nutrition ? Give one example of autotrophs.

(b) What are the conditions necessary for autotrophic nutrition ?

(2) (a) What is heterotrophic nutrition ? Give one example of heterotroph.

(b) What is the difference between autotrophic nutrition and heterotrophic nutrition ?

(3) (a) Define nutrition. Name four important nutrients present in food.

(b) What are the various types of heterotrophic nutritions ?

(4) Define (i) saprophytic nutrition (ii) parasitic nutrition, and (iii) holozoic nutrition. Give one example of each type.

Define (i) saprophyte, and (ii) parasite. Name two saprophytes and two parasites.

(5) (a) What is the role of hydrochloric acid in our stomach?

(b) What is the function of enzymes in the human digestive system?

(6) Describe the process of respiration in the following parts of a plant:

(a) Root (b) Stem (c) Leaves

4. Answer the following questions in detail :

(1) (a) Describe the process of nutrition in Amoeba. Draw labelled diagram to show various steps of the nutrition in Amoeba.

(b) What is the mode of nutrition in Amoeba known as?

(2) Draw a labelled diagram of the human digestive system. With the help of this diagram, describe the process of digestion of food in man (human).

(3) (a) Give the main points of difference between respiration in plants and respiration in animals.

(b) Describe the exchange of gases which takes place in the leaves of a plant (i) during daytime, and (ii) at night.

(c) What type of respiration takes place (i) in yeast and (ii) in human being ?

UNIT

13

Transportation, Circulation and Excretion in organisms

The body of multicellular organism possesses complex structure. In order to survive and maintain themselves, the body cells require oxygen, water and food. Different types of substances absorbed or synthesized in one part of the body are transported to another part of the body. This process is known as transportation. In this chapter we will study how plants and animals transport substances from one part of the body to another part.

13.1 Transportation in Plants

We have studied that plants convert solar energy into chemical energy utilizing atmospheric CO_2 and water. Other substances which are also required for the building plant bodies will be taken up separately. These substances are absorbed by the roots of the plants from the soil. If the distances between the roots and leaves are small, energy and raw materials can easily diffuse to all parts of the plant body. But if distances are large, the process of diffusion will not be sufficient to provide raw materials in leaves and energy in roots. Thus a proper transportation system is required in such situation.

As plants do not move, the energy requirement of plants is low as compared to animals which move from one place to another. In plants, energy stored in the leaves, and raw materials absorbed by the roots will be transported to the different parts of the body. Xylem moves water and other substances obtained from the soil and phloem transports products of photosynthesis from leaves to other parts of plants.

Transportation of Water : Higher plants possess xylem which is associated with the transportation of water. Water absorbed by the root from the soil is transported to stem, branches, leaves and flowers. The main structural components of the xylem responsible for the transport of water are tracheids and vessels. We have studied the structure of these components in class IX. Xylem tissue of all the organs of plants are interconnected forming a continuous system for water conduction. As the root cells are directly in contact with soil, they take up ions. Due to this, a difference is created between the concentration of these ions between the root and the soil. Water therefore, moves into the root from the soil to eliminate this difference. This water movement creates a column of water that is steadily pushed upwards. However, in higher plants this pressure is not sufficient to move water over the heights is commonly found in plants.

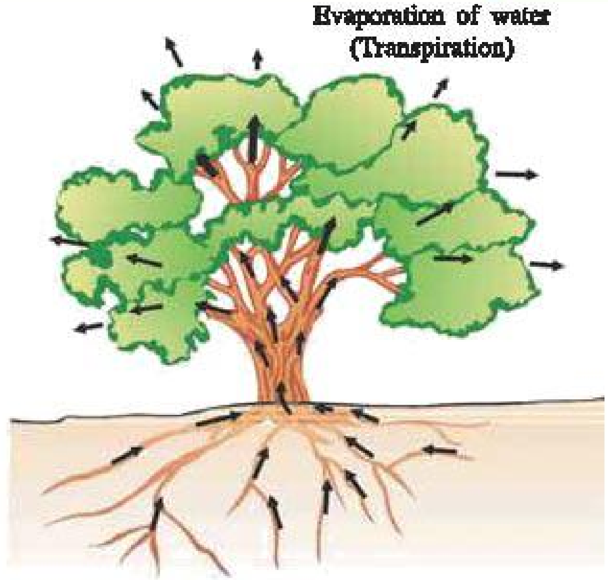


Fig. 13.1 Transport of water

Plants use another strategy to move water in the xylem upwards to the highest points of the plant body. If adequate water is available then the water which lost through the stomata is replaced by the water present in xylem vessel. In fact, evaporation of water molecules from the cells of a leaf creates a suction which pulls the water from the xylem cells of roots.

The loss of water in the form of water vapor from the aerial parts of the plant is known as transpiration. Transpiration also helps in regulation of temperature. As the stomata are open during day time, the transpiration pull becomes the major driving force in the movement of water in the xylem.

Transportation of food and other substances : Carbohydrates are synthesized in the green leaves by the process of photosynthesis. From the green leaves, these photosynthetic products are transported to the various parts of the plant body. Transportation of photosynthetic products is known as translocation and it is performed by sieve tubes and sieve cells of vascular tissue known as phloem. Besides the carbohydrates, the phloem transports amino acids, several plant hormones which are synthesized at the shoot and root tips and other substances. The translocation takes place in both, upward and downward directions. Translocation of substances requires energy which is obtained from ATP. When the material like sucrose is transferred into phloem tissue, the osmotic pressure of tissue increases leading to entry of water into it. This pressure moves the material in the phloem to tissue which have less pressure. This allows the phloem to move material according to the need of plant.

13.2 Transportation in Human Beings

The system which is concerned with the transportation of various substances in animals is called circulatory system. In human being, the transport of nutrients, oxygen, carbon dioxide, hormones, enzymes and excretory substances take place through blood and lymph. As we have studied in class IX that blood is a living red colored liquid connective tissue. The liquid medium of blood is known as plasma in which blood cells are suspended. We will study the various components of circulatory system of human being.

Heart : The human heart is conical in shape and is of the size of a closed fist. It is located in the small space between two lungs and slightly towards the left side. As both carbon dioxide and oxygen are transported by blood, the heart is four chambered in order to prevent the mixing of oxygen rich blood with the blood containing carbon dioxide. The upper two chambers are called atria (singular – atrium). Of these one is left atrium and the other is right atrium. The two lower chambers are known as ventricles, of these one is left ventricle and the other is right ventricle. The walls of atria are thin while the walls of ventricles are thick. All the four chambers are separated from each other by partitions called septa. For the flow of blood from the left atrium to the left ventricle, there is a bicuspid valve. Similarly there is a tricuspid valve between right atrium and right ventricle. These valves prevent backward flow of the blood from ventricles to atria.

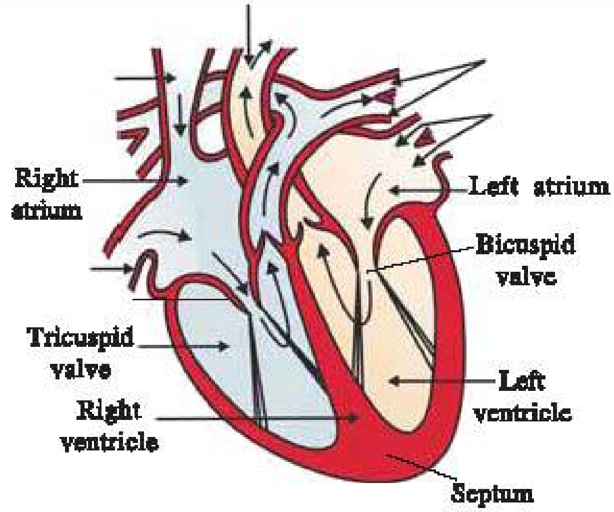


Fig. 13.2 Internal structure of heart

Entry of oxygen in the blood through lungs : Deoxygenated blood from various organs of the body is received by the right atrium through the superior and inferior vena cava. At the same time left atrium receives oxygenated blood from the lung through the pulmonary veins. Now both the atria contract and the deoxygenated blood from right atrium is poured into right ventricle and oxygenated blood from left atrium is poured into left ventricle. Now both the ventricles contract. Due to contraction of right ventricle, the blood enters into lungs through arteries. In lungs CO_2 is released from blood and O_2 diffuses into it. While due to contraction of left ventricle, oxygenated blood is distributed to all the parts of the body through the aorta.

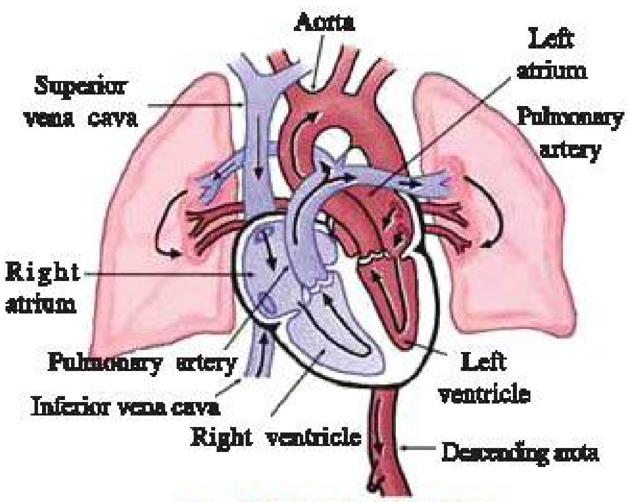


Fig. 13.3 Blood circulation

The separation of both types of the blood in the heart allows a highly efficient supply of oxygen to the body. This is useful in the animals which have high energy need, such as birds and mammals, which constantly use energy to maintain their body temperature.

Blood vessels : Blood circulates throughout the body along definite routes through blood vessels. Arteries and veins are such blood vessels. Arteries carry blood away from heart to different organs. Veins carry blood away from different organs towards heart. Since the blood is pumped in to the arteries by the heart, it is under high pressure and therefore, arteries have thick elastic walls. Veins collect the blood from different parts of the body and bring it back to heart. In the veins, blood is not under pressure and hence, wall of vein is thin. In order to prevent backward flow of blood valves are present in veins.

On reaching to the organs or tissues, the artery divides into many smaller vessels to bring the blood in contact with all the individual cells. These smaller vessels have single cell thick walls and are known as capillaries. Exchange of materials between blood and surrounding takes place through capillaries. Capillaries then join together to form veins.

Lymphatic system : Lymphatic system consists of lymph, lymph vessels, lymphatic capillaries and lymphatic nodes. Lymph is another type of fluid which is also involved in transportation. Some amount of plasma, proteins and blood cells, escape into the intercellular spaces through the pores present in the wall of capillaries, form lymph. Lymph is colorless and contains less proteins as compared to that in the blood.

Lymph drains into lymphatic capillaries form intercellular spaces. Lymphatic capillaries join to form lymph vessels that finally open into large veins. Lymphatic system performs following three important functions :

1. Collect intercellular fluid through the medium of lymph vessels and returns it to blood circulation.
2. In the villi of small intestine, lymph vessels absorb lipids and conduct them to blood circulation
3. Protects against diseases.

13.3 Excretion in Plants

Like animals, plant do not possess any excretory organs or system. In plants O_2 may be considered as waste product generated during photosynthesis and released back to the atmosphere directly. They remove excess water by the process of transpiration. Sometimes they store excretory waste in the leaves that fall off. Many plant waste products are stored in cellular vacuoles. Other waste products are stored as resins and gums.

13.4 Excretion in Human Beings

For sustaining life, body cells perform biochemical processes. During these processes useful as well as harmful toxic substances are produced. Accumulation of toxic substances in the body may harm body and hence, there will be a need to remove these substances from time to time. The harmful substances produced during biochemical reactions are known as excretory substances and a biological process involved in removal of these excretory substances in liquid form is known as excretion. Unicellular organisms remove the excretory substances by simple diffusion from the body surface into the surrounding water. This process is complex in the multicellular organisms and hence, they use special organs to perform the same function.

Excretory system of human being : Excretory system of human being includes a pair of reddish brown bean shaped kidneys located in the abdomen on the dorsal side, a pair of ureters, one from each kidney, a urinary bladder and a muscular tube called urethra. Urethra opens out by a small opening known as urinary opening. Kidney is divided into cortex and medulla. These regions consist of the excretory units called nephrons.

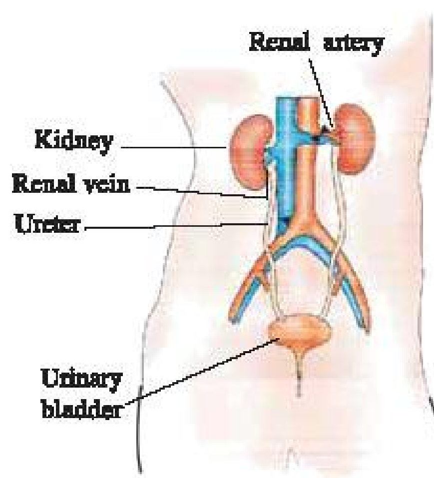


Fig. 13.4 Excretion in Human Beings

Structure of nephron : Each kidney has very minute tubular and convoluted structures known as uriniferous tubules. Nephrons in each kidney has ten lacs such tubules. Each nephron has a double walled cup shaped structure called Bowman's Capsule at its upper end. The Bowman's Capsule possesses a mass of capillaries called glomerulus. The short tubular region after the Bowman's Capsule is called neck. After this the tubule is narrow and coiled. It consists of a proximal convoluted tubule, a Henle's loop and a distal convoluted tubule. The post end of nephron is called collecting tubule. Collecting tubule opens in the renal pelvis, which opens into the ureter.

Fig. 13.5 Nephron

Process of urine formation

The waste material along with blood is brought to kidneys by the renal arteries. As the blood is under pressure in the arteries, it is filtered out from the blood capillaries into Bowman's capsule. This process is known as ultrafiltration. This filtrate passes through the lumen of tubular parts of nephron. During this useful substances like water, amino acids, minerals ions etc. are reabsorbed by blood capillaries surrounding the nephron. The remaining fluid contains excretory substances and is called urine. From the ureter urine passes into urinary bladder where it is stored. When the bladder is filled with the urine, it contracts and urine passes out of the body.

What have you learnt ?

Different types of substances absorbed or synthesized in one part of the body are transported to another part of the body. This process is known as transportation. In plants, vascular tissues like xylem moves water and other substances obtained from the soil and phloem transports product of photosynthesis from leaves to other parts of plant.

In higher plants, evaporation of water molecules from the cells of leaves creates a suction which pulls the water from the xylem cells of roots. The loss of water in the form of water vapor from the aerial parts of the plant is known as transpiration. The system which is concerned with the transportation of various substances in animals is called circulatory system. Heart, blood, lymph and vessels are the components of blood circulatory system. Arteries and veins are the blood vessels. Arteries transport blood from heart to various parts of the body while veins collect the blood from different parts of the body and supply to heart. Lymphatic system consists of lymph, lymph vessels, lymphatic capillaries and lymphatic nodes.

Like animals, plant do not possess any excretory organs or system. But animals possess various structures associated with the process of excretion. In unicellular organisms, the excretory substances are diffused out in the surrounding water. But multicellular organisms have complex mechanism of excretion. They have excretory organs and system. Excretory system of human being includes a pair of reddish brown bean shaped kidneys, located in the abdomen on the dorsal side, a pair of ureters, one from each kidney, a urinary bladder and a muscular tube called urethra. The formation of urine involves the processes like ultrafiltration and reabsorption.

EXERCISE

1. Select the proper choice from the given multiple choices :

(1) Which of the following structures is responsible for transportation of water in higher plants :

(A) Sieve tube (B) Sieve cell (C) Vessel (D) Companion cell

(2) The kidneys in human being are a part of the system for :

(A) Respiration (B) Transportation (C) Excretion (D) Nutrition

(3) How many chambers are present in human heart ?

(A) 2 (B) 3 (C) 4 (D) 6

(4) Where is tricuspid valve found in human heart ?

(A) Between two atria (B) Between two ventricles

(C) Between right atrium and right ventricle (D) Between left atrium and left ventricle.

(5) What is the excretory unit in human being ?

(A) Bowman's capsule (B) Nephron

(C) Urinary bladder (D) Kidney

(6) In which part of the body blood gets purified (Becomes oxygenated) ?

(A) Heart (B) Lungs (C) Atrium (D) Ventricle

(7) In plants, food and other substances are transported through ....

(A) Tracheids (B) Vessels (C) Sieve tubes (D) Companion cell

(8) During which process blood is filtered out in Bowman's capsule ?

(A) Reabsorption (B) Secretion (C) Ultrafiltration (D) None of them

2. Answer the following questions in brief :

(1) Mention the color of blood and lymph.

(2) Define Transpiration.

(3) What is transported through phloem?

(4) Define Ultrafiltration.

(5) Name the organs of excretory system in human being.

(6) Name the components of circulatory system of human being.

(7) Differentiate between arteries and veins.

(8) Why the wall of artery is thick and elastic ?

(9) What is the advantage of four chambered heart ?

(10) Define Excretion.

3. Answer the following questions pointwise :

(1) Explain the excretory system of human being.

(2) Explain the structure of human heart.

(3) Explain the process of urine formation.

(4) Describe the structure of nephron.

(5) Write a note on lymphatic system.

UNIT

14

CONTROL AND CO-ORDINATION IN ORGANISMS

Introduction

Living organisms are stimulated due to less or more changes in their environment. Due to stimulation against these changes organisms give response. As an example, if there is a change in heat, cold or noise, living organism gives response against it. This response to stimulus is generally in the form of movements of their body parts. e.g. If a man touches a very hot vessel he quickly pulls his hand away. Thus reaction to stimuli is a characteristic feature of the living organisms. Plants and animals respond to various stimuli surrounding them. But the method of reacting to stimuli is different in plants and animals. For example plants bends towards the light, but animal do not bends toward light. Thus animal can react to stimuli in different ways, while plant can react to stimuli in a limited way. Since they do not have a nervous system like the animals. From the above discussion we conclude that functioning of the various organs together in a systematic manner to produce a proper response to the stimulus is termed as co-ordination. Now we will study the control and co-ordination. First, start with plants and then with animals.

14.1 Control and Co-ordination in Plant

Like animals, plants do not have nervous system and sense organs like nose, ears and eyes. The plants can sense gravity, light, water, chemicals and touch by the action of hormones present in them. The stimuli like gravity, light, water, chemicals and touch are known as environmental changes. By using hormones the plant co-ordinates their behaviour against environmental changes. The hormones in plants do not act in the same way as in the animals. The response of plants to different stimuli like gravity, light, water, chemicals and touch is due to the effects of hormones. The plants cannot react to respond quickly as compared to animals because they are devoid of nervous system. Animals use both nervous system and hormones for the co-ordination of their activities, while plants use only hormones for co-ordination because they have no nervous system. Thus the response of plant to a stimulus cannot be quick, but it takes a considerable time to know the effect of a stimulus on plant. The plant hormones are called as phytohormones. The auxins, gibberellins and cytokinins are phytohormones which promote growth of plants, while abscisic acid inhibits the growth.

14.2 Response to Stimulus

The sensitive plant moves in response to touch. But in this sensitive plant there is no nervous system and muscle tissue. Then how does plant detect the touch and how do the leaves move to response ? Plants respond to light, touch, water, gravitation force and other stimuli only by means of chemicals i.e. hormones. The animals can react to stimuli in different ways because they have nervous system and endocrine system. In the following section we will study the types of stimuli in plants.

14.3 Types of Stimulus

The plant movements made in response to external stimuli fall into two main categories (i) tropism and (ii) nastism.

(i) Tropism (Tropic movements) : If the movement of curvature in a plant organ is induced by an external and directional stimuli, then it is called tropism. If the growth of plant is towards the stimulus, it is called positive tropism and if it is away from the stimulus then it is called negative tropism. There are five common stimuli such as light, gravity, chemical, water and touch. The movement of the plant in response to light is called phototropism. Stem shows positive phototropism while root shows negative phototropism. The movement of a plant to gravity is called geotropism. Stem shows negative geotropism while root shows positive geotropism. The movement of a plant part in response to a chemical stimulus is called chemotropism eg. The growth of pollen tube towards ovule during the process of fertilization. The movement of a plant part in response to water is known as hydrotropism eg. The root of plant goes towards water. Movement in response to touch is called thigmotropism eg. tendrils of a plant.

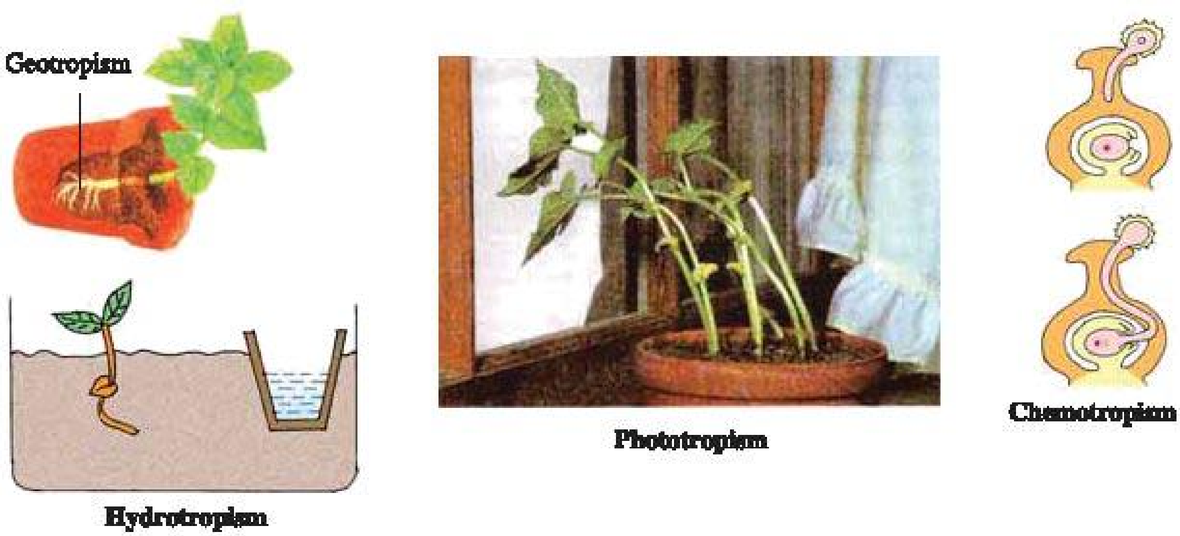


Figure : 14.1 Types of stimulus of plant

ii) Nastism (Nesctic movement) : This kind of movement depends on the presence and intensity of external stimulus. In nastic movement the direction of response is not determined by the direction of stimulus.

Thigmonesty :

The thigmonesty is the nastic movement of a plant part in response to touch, eg. The nastic movement in plants caused by touch is seen in Mimosa plant.

When we touch the leaves of Mimosa with our fingers, the leaves of plant fold up.

In this plant the 'touch' with our fingers is the stimulus and leaves respond by 'folding up'. The sensitive parts which leaves possess is a soft, cushion-like swollen structure known as 'pulvinus'. The cells of pulvini contain a lot of water. When the leaflets having pulvini at their base are touched with a finger, then an electrical impulse is generated which travels through cells. These impulses act on plant hormones which makes the water to migrate from the cells of one half of a pulvinus to the intercellular spaces in the other half of pulvinus. This loss of water from half of pulvinus causes the pulvinus to lose its firmness and leaf folds. Similarly all pulvinus of leaflets lose firmness and collapse and fold up. Like animals in plants there is no specialized nerve tissue for conduction of information. In animals some cells change their shape in order for movement to happen. The plant cells change the shape by changing the amount of water in them.

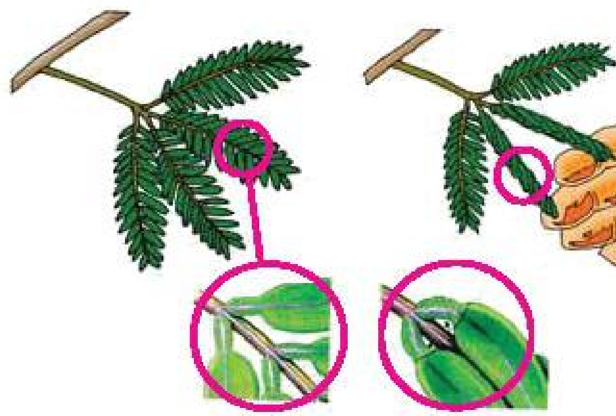


Fig. 14.2 Thigmonesty

Photonesty : – Movement of plant part in response to light. e.g. The flower of lotus and sunflower open in morning.

Thermonesty : – Movement in response to temperature. e.g. Flower of Crocus and Tulip at higher temperature.

14.4 Control and Co-ordination in Humans

There are two following systems for the co-ordination of different activities in humans :

(1) Nervous system, (2) Endocrine system

The nervous system and endocrine system of human beings work together to control and co-ordinate all our activities such as physical, emotional behaviour and thinking processes. The function of nervous system is to control and co-ordinate all the parts of our body. The nervous system co-ordinates muscles so person can do works like writing, reading and dancing. The nervous system also c-oordinates certain involuntary functions like heart beat and breathing. The human nervous system collects all the information from surroundings and interprets them, and then responds accordingly. The nervous system also passes information from one system to other system. The nerve cells are the units of nervous system. Hence nerve cell is the structural and functional unit of nervous system. The nerve cell has three components :

(i) Cell body, (ii) Dendrites and (iii) Axon

Cell body contains cytoplasm and nucleus. A number of short or long fibers are stretching out from the cell body and they are known as nerve fibers. The short fibers on the cell body are known as dendrites, while the longe fiber on the cell body is known as axon. Around the axon a protective and an insulating sheath of myelin is found, which is made up of fat and protein. The dendrites and axon both arise from the cell body of nerve cell. The messages acquired at the dendrite of nerve cell, sets off a chemical reaction that creates an electrical impulse known as nerve impulse. The dendrites pick up messages from receptors. They pass the messages to cell body and then to axon. The axon passes the message to another nerve cell through the junction. A very small gap is present between the two nerve cells. This gap is known as synapse. Thus nervous tissue is made up of organized network of nerve cells, and is very specialized for conducting messages through electrical impulses from one part of the body to another.

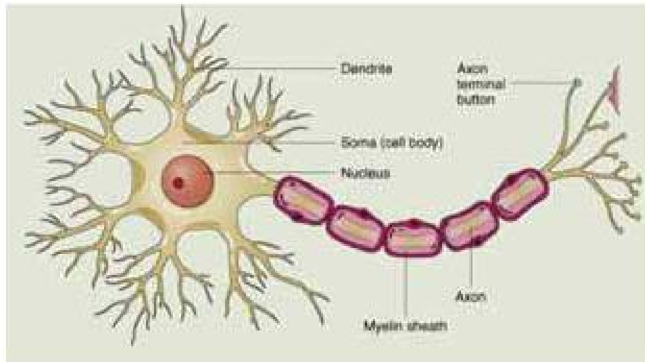


Fig. 14.3 Nerve cell

The nerve cell acquires message, which travels as an electrical impulse, This electrical when impulse is converted into a chemical signal for onward transmission.

Human brain :

The central nervous system (CNS) consists of the brain and the spinal cord. They receive messages from all parts of the body and integrate them. It is protected by the cranium and three membranes known as menings. The brain of an adult weigh about 1350 gms and it is mainly made up of nervous tissues. In the brain, grey matter is present on the outer surface while the white matter forms the inner part. The space between meanings is filled with cerebrospinal fluid which protects the brain from mechanical shock and acts as a cushion. The brain is broadly divided into three regions – Forebrain, midbrain and hind brain.

Human brain	Fore-brain	Cerebrum (with olfactory lobe), Thalamus, Hypothalamus
	Mid-brain	Corpora quadrigemina, Cerebellum
	Hind-brain	Pons

Cerebrum is largest and most complex part of brain. It consists of two cerebral hemispheres, joined together by a band called corpus callosum. Each cerebral hemisphere is divided into 4 lobes. The occipital lobe has specific activities of visual reception, while temporal lobe controls specific activities of auditory reception. The parietal lobe has perception of general sensation like smell, touch and temperature. Frontal lobe controls specific muscular activities, both involuntary and voluntary, which include thought, speech and memory. The outer region of cerebral hemispheres is densely packed with nerve cells called cerebral cortex. Cerebral cortex is highly convoluted which increases its surface area. It does various kinds of activities. The cerebrum has sensory areas where information (impulse) is received from sense organs. Similarly there is a motor from where impulses are sent to muscles or effector organs. Thalamus is present at the centre of forebrain. All sensory informations that reache the cerebral hemispheres pass through thalamus and direct sensory information to the cerebral cortex. Below thalamus lies hypothalamus which controls and regulates blood pressure, hunger, body temperature and thirst. It connects the fore-brain and the hind brain and controls functioning of eyes and ears. Hind-brain consists of three regions. Cerebellum which lies on dorsal side of pons. Pons and medulla oblongata on ventral side.

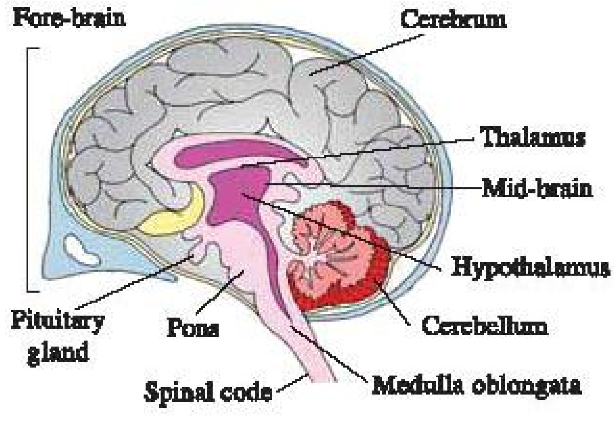


Fig 14.4 Human Brain

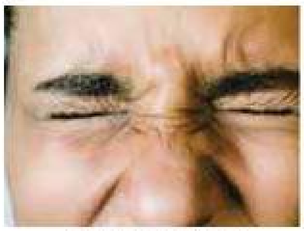
The pons regulates process of respiration. The cerebellum maintains balance of body and posture. The cerebellum co-ordinates body movements like dancing, walking and riding bicycle. The medulla oblongata controls various involuntary activities like breathing, heartbeats, blood pressure, peristaltic movements of alimentary canal etc. Medulla oblongata controls the centre of reflexes like coughing, sneezing, swallowing, secretion of saliva and vomiting.

Spinal Cord :

Spinal Cord is a cylindrical structure which is a posterior extension of medulla oblongata. It is enclosed within the vertebral column. Spinal cord is surrounded by three membranes known as meeninges. Grey matter forms the centre of spinal cord and the white matter is present in the periphery. In the centre canal the cerebrospinal fluid is present 31 pairs of nerves arise from spinal cord. Grey matter is arranged in the "H" shape of the Grey matter contains non-medullated nerve fibres and neurons possessing short processes. White matter contains medullated nerve fibres and neurons possessing long processes. The bundles of nerve fibers run ascending and descending in tracts, and link the spinal cord with the brain. Ascending tracts conduct sensory information from spinal cord to brain while descending tracts conduct motor information from brain to spinal cord.

14.5 Reflex Action

The reflex action is the simplest form of response in nervous system. It is a rapid automatic response without thinking or any thought like pulling our hand away on pricking a pin or unknowingly touching the hot plate. Other examples of reflex action are : a knee jerk, coughing, blinking eye, yawning, movement of diaphragm and sneezing. In bright light the pupils of our eyes get smaller. The reflex action protects the retina from damage because of too much light. Coughing is another example of reflex action which clears our wind pipe. This reflex action can be defined as an unconscious and involuntary response of the muscles or glands to a stimulus. Reflex action is an automatic process.


blinking of eye


Yawing


sneezing

Fig. 14.5 Reflection actions

Reflex arc :

The nerve impulse pathway involved in a reflex action is known as reflex arc. Rapid response allowed by reflex arc. The meaning of a reflex arc can be explained by the following example. Suppose we touch a hot plate, quickly and without thinking about it, we pull our hand away. Here the heat is sensed by thermo receptor in our hand. The thermo receptor triggers an impulse in a sensory neuron, which transmits the information to spinal cord. The impulse passes it to a motor neuron. The motor neuron transmits the impulse to a muscle of hand. Now the muscle then contracts and pulls the hand away from the hot plate. The muscle of hand is effector because it responds to stimulus. This pathway along which the impulse tranamits is known as reflex arc.

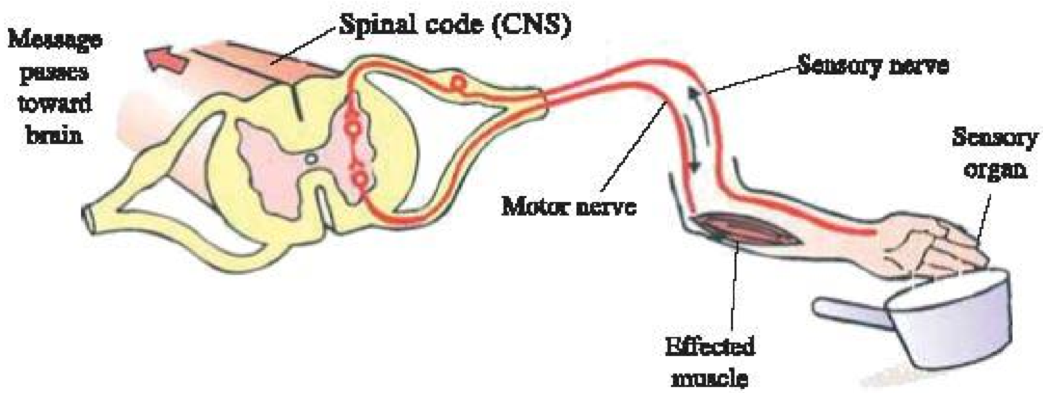


Fig. 14.6 Reflex action

14.6 The Autonomous Nervous System :

The term autonomous is derived from the term 'autos' means 'self' and 'nomos' means 'governing'. Thus 'autonomous nervous system' means 'self governing nervous system'. The system which is responsible for the control of the activities of the organs located in the body automatically even without our thinking involuntarily. This system has a specific network of nerves in the body which controls and regulates the processes like, digestion, sweating, breathing, heart beat etc. The nerves of autonomous nervous system are connected to the smooth muscles of head, heart, blood vessels, lungs, alimentary canal, kidneys, glands and skin. Autonomous nervous system is of two types (i) sympathetic (ii) parasympathetic. By the co-ordination of these two systems, the involuntary functions of the body are controlled and regulated. The effects of sympathetic and parasympathetic nervous systems are complimentary and contradictory to each other. Sympathetic nervous system increases heart beats while parasympathetic system decreases them and brings them back to normal.

14.7 Endocrine Glands

A gland which does not have a duct and secretes its product directly into blood stream is known as endocrine gland. So endocrine glands are ductless glands. A hormone is produced in one part of the body but it acts on other part of the body. Thus hormones are a kind of chemical messengers.

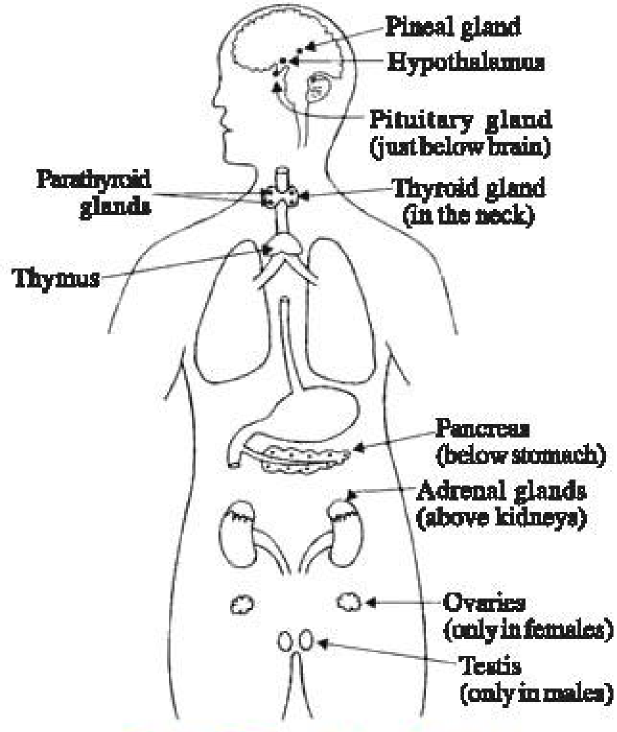


Fig 14.7 The position of endocrine glands in human

The endocrine glands in human : The human endocrine system made up of various endocrine glands, is situated in different parts of the body. The main endocrine glands in the body are hypothalamus, pituitary, thyroid, parathyroid, pancreas, adrenal, testis and ovary.

Hypothalamus is a part of fore brain present below the thalamus and above the pituitary gland. It contains many neurosecretory cells which produce releasing hormone (RH) that stimulates the anterior pituitary gland to secrete specific hormones. Releasing hormones and their effects on anterior pituitary gland are given below:

(1) TSH releasing hormone : Release Thyroid Stimulating Hormones (TSH) from pituitary gland.

(2) GH releasing hormones : Release Growth Hormones (GH) from pituitary.

(3) ACTH releasing hormones : Release Adreno Cortico Tropic Hormone (ACTH)

(4) Ganadotropic releasing hormones : Release Follicle Stimulating Hormones (FSH) and Leutenizing hormone (LH) from pituitary gland.

Two inhibitory hormones are also released from hypothalamus (1) GH inhibitor factor inhibit the release of GH. (2) Prolactin Inhibitor Factor (PIF) inhibits the release of Prolactin from pituitary.

Pituitary gland :

It is known as the master gland. It is located just below the hypothalamus. The pituitary gland is divided into three lobes: anterior lobe, intermediate lobe and posterior lobe. Anterior pituitary lobe secretes TSH, ACTH, FSH, LH, Prolectin and GH hormones.

Intermediate pituitary lobe secrets melanocyte stimulating hormone (MSH). Posterior pituitary lobe secretes two hormones vasopressin and oxytocin. Vasopressin or Anti-diuretic hormone (ADH) stimulates re-absorption of water, and controls the loss of water through urine. It increases the arterial blood pressure by acting as vasoconstrictor. Oxytocin in female causes contraction of uterine muscles during child birth and ejection of milk from mammary gland.

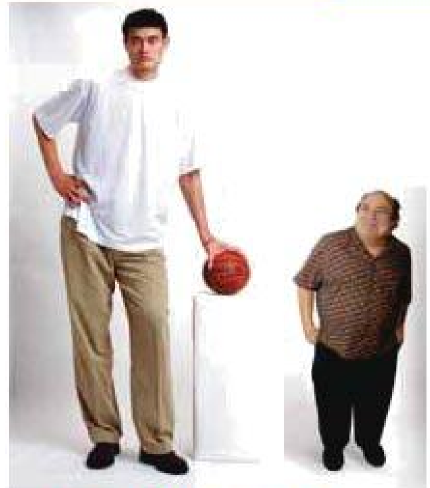


Fig. 14.8 Giantism and Dwarfism

Disorders due to GH :

Dwarfism :

Hypo or under secretion of GH from childhood leads to dwarfism.

Gigantism :

Hyper or over secretion of GH from childhood leads giantism. i.e. giant height of more than 7ft.

Acromegaly :

Too much secretion of growth hormones after adolescence causes the enlargement of certain parts like hand, feet and jaws giving appearance of body like gorilla.

Pancreas :

Fig 14.9 Goiter

The pancreas lies just below the stomach in the body. Pancreas secretes the hormone insulin, which lowers the blood sugar level. Deficiency of insulin in the body causes diabetes. Diabetes causes large amount of sugar in the blood and also in urine. The high sugar level in the blood can cause many harmful effects to a person. Diabetic persons should take less amount of sugar. Diabetes can be controlled by controlling diet, doing physical exercise, reducing body weight taking medicines and injection of insulin regularly.

Thyroid gland :

Thyroid gland is attached to the wind pipe in our body. Thyroid gland secretes thyroxine hormone, which contains iodine. Hormone thyroxine controls the rate of metabolism of carbohydrate, protein and fat. The deficiency of iodine in our diet can cause a deficiency of thyroxine. Thus deficiency of iodine in our diet results in hypothyroidism and enlargement of thyroid gland. It resultes into a disease called goitre. Iodised salt provides appropriate amount of iodine to make sufficient thyroxine by thyroid gland. Condition of hyperthyroidism of thyroid gland is known as exophthalmic goiter. (Bulging of the eyeball)

Parathyroid gland :

Parathyroid glands are four small glands which are embedded in the thyroid gland. This glands secrete a hormone known as parahormone, which regulates calcium and phosphate levels in the blood.

Adrenal gland :

Adrenal glands are two in number. They are small, conical in shape, and composed of two distinct regions: an outer cortex and an inner medulla. The adrenal cortex secretes three types of steroid hormones. Mineral ocorticoids regulate balance of water and ions like Na^+, Cl^- and K^+ in our body. Glucocorticoids stimulate metabolism of carbohydrate, proteins and fat. While sex corticoids are responsible for secondary sexual characters.

Adrenal medulla secretes adrenaline and non-adrenaline. Adrenalin hormone is called fight or flight (run away). Hence adrenal glands are also known as glands of 'emergency'.

Testis :

Testis secretes the male sex hormone testosterone. The main function of testosterone is to control the development of sex organs, secondary sexual characters like deeper voice, beard and moustache. The testes also produce sperms.

Ovary :

Ovaries produce two female sex hormones known as estrogen and progesterone. The main functions of estrogen is to control development of female sex organs. Secondary sexual characters like feminine voice, soft skin and mammary gland are under the control of estrogen. The function of progesterone is to control the changes in uterus during menstrual cycle. It also regulates the production of ova in the ovaries.

14.8 Properties of Hormone

Hormones show the following main properties :

- Each hormone is produced by a specific kind of cells.
- Hormones are not effective at their site of synthesis.
- Hormones are poured directly into blood. They are transported through blood to a specific organ and influence specific processes occurring there. This influence may be stimulatory or inhibitory. Thus, hormones are "regulator chemicals".
- Hormones are used up in producing their regulatory effect.
- Chemically hormones are peptides and steroids. Some are biogenic amines.

What have you learnt ?

- Like animals the plants do not have nervous system and sense organs.
- In our bodies control and co-ordination are the functions of the nervous system and hormones.
- Nervous tissue is made up of a network of nerve cell and is specialized for conducting information through electrical impulses to different parts of body.
- A reflex action can be defined as an unconscious and involuntary response of the body to a stimulus.
- The nerve pathway involved in a reflex action is called a reflex arc.
- Human brain is highly specialized organs. It is the highest co-ordinating centre of the body.

- External stimuli are of two types : tropism and nastism.
- Hormones produced by endocrine glands act as messengers between the nervous system and organs of our body.
- In addition to nervous systems the endocrine system also helps in co-ordinating the activities of our body.

EXERCISE

1. Select the proper choice from the given multiple choices.

1. What is called the movement of plant toward the gravity ?
   (A) hydrotropism (B) geotropism (C) chemotropism (D) phototropism
2. The plant part which exhibits negative geotropism is:
   (A) root (B) stem (C) branch (D) leaves
3. The growth of a pollen tube towards the ovule is caused by......
   (A) phototropism (B) hydrotropism (C) gravitropism (D) chemotropism
4. Bending of the shoot of a plant in response to light is known as......
   (A) geotropism (B) phototropism (C) thigmotropism (D) photonasty
5. The stimulus in the process of thigmotropism is:
   (A) touch (B) gravity (C) light (D) chemical
6. Which of the following helps in maintaining posture and balance of the human body?
   (A) cerebellum (B) cerebrum
   (C) medulla oblongata (D) pons
7. How many pairs of nerves arise from the spinal cord ?
   (A) 21 (B) 31 (C) 41 (D) 51
8. Cerebellum, medulla oblongata and pons are the parts of:
   (A) mid-brain (B) hind-brain (C) fore-brain (D) spinal cord
9. For the synthesis of which of the following hormone iodine is necessary ?
   (A) adrenaline (B) auxin (C) thyroxine (D) insulin
10. Which of the following is a mismatched pair?
    (A) adrenaline : pituitary gland (B) estrogen : ovary
    (C) pancreas : insulin (D) progesterone : ovary
11. The spinal cord originates from:
    (A) cerebrum (B) cerebellum
    (C) medulla oblongata (D) pons

12. Which of the following hormone prepares our body for action in emergency situations ?

    (A) testosterone (B) growth hormone (C) adrenaline (D) insulin

13. Which is male sex hormone ?

    (A) estrogen (B) adrenaline (C) testosterone (D) progesterone

14. Which of the following endocrine gland does not occur as a pair in the human body ?

    (A) adrenal (B) pituitary (C) testis (D) ovary

2. Answer the following questions in brief :

1. Name the plant which shows thigmonesty.
2. Give the scientific terms used to represent the following:
   (A) Bending of a shoot towards light.
   (B) Growing of roots towards the earth.
   (C) Growing of a pollen tube towards ovule.
   (D) Bending of roots towards water.
   (E) Winding of tendril around a support.
3. Give example of the movement of a plant part which is caused by the loss of water.
4. Name the two systems of control and co-ordination in higher animals.
5. Name the three components of a nerve cell.
6. Name the most important part of the human brain.
7. State one function each of cerebellum and pons.
8. Name one hormone secreted by the pituitary gland.
9. Where are hormones synthesised in the human body?
10. Which gland secretes the growth hormone?
11. Name the disease caused by the deficiency of insulin hormone in the body.

3. Write answers of the following questions :

1. (A) What does a root do in response to gravity ? What is this phenomenon known as?
   (B) What does a stem do in response to light? What is this phenomenon known as?
2. (A) What does a stem do in response to gravity? What is this phenomenon known as?
   (B) What does a root do in response to light? What is this phenomenon known as?
3. (A) What is spinal cord ? What is its main function?
   (B) Give the functions of medulla oblongata.
4. (A) Name the hormones secreted by the following endocrine glands :
   (i) Thyroid gland (ii) Parathyroid glands (iii) Pancreas (iv) Adrenal glands
   (B) Write the functions of testosterone and estrogen hormones.
5. (A) Write the names of the regions of hind-brain. Give functions of each region.
   (B) Mention the functions of cerebrum.
6. What does CNS stand for ?

4. Answer the following questions in detail :

1. (A) What is meant by 'tropisms' ? Explain with an example.

   (B) Mention types of tropisms. Define each type of tropism. Write the name of stimulus in each case.

   (C) How do tropism differ from nastism ?

2. (A) Define phototropism and give one example of it.

   (B) How does phototropism occur in a plant stem ? Explain with the help of labelled diagrams.

   (C) What is meant by positive phototropism and negative phototropism? Give one example of each type.

3. (A) Name the structural and functional unit of nervous system.

   (B) What is autonomus nervous system? What is its function?

   (C) What is voluntary nervous system? Explain the working of voluntary nervous system with an example.

4. (A) What is a reflex action ? Explain with the help of an example.

   (B) How involuntary actions and reflex actions differ from each other?

5. (A) Write the names of five endocrine glands found in the human body. Name the hormones secreted by each gland.

   (B) Name the gland which controls the secretion of hormones of pituitary gland.

   (C) How does our body respond when adrenaline is secreted in large amounts into the blood?

   (D) Name the disease which occurs in adults due to the deficiency of iodine in the diet. What is the main symptom of this disease ?

UNIT

15

REPRODUCTION IN ORGANISMS

It is fact that all living organisms grow old with time and ultimately die. Every living organism remains alive on this earth for limited period of time and then dies. So new organisms have to produce in place of those who die. This can be acheived by the process of reproduction in which new organisms are produced from the existing organisms in order to maintain the life of their species on this earth.

15.1 What is Reproduction?

In the previous chapters, we have learnt about the life processes which help animals to keep 'alive'. Every organism remains alive for a certain limited time and then dies. The production of new organisms from the existing organisms of the same species is known as reproduction. Thus reproduction is the production of new living organisms. So reproduction is one of the very important features of living organisms and it is their ability to reproduce more members of the same species. Thus reproduction is indispensable for the survival of the species. The process of reproduction makes thing safe against continuity of life.

15.2 How Organisms Create Exact Copies of Themselves?

Organisms of a species show similarity because their body designs are similar. In order to maintain similarity in body designs the blue print of the design should be similar. Reproduction is a process which makes copies of the blue prints of the design. In class-IX we learnt that the chromosomes in the nucleus of the cell contain information of protein synthesis which is stored in DNA. If the information is changed, there will be a change in protein which eventully leads to an altered body design. The creation of another copy of the cell is the basic event in the reproduction. The cells are duplicated by duplicating DNA, hence, two progeny cells are produced.

Thus two cells formed, are similar but are they absolutely identical ? This depends upon how accurately the sequence information has been copied. Although copy error is rare event, but when happens it brings about change in the characteristic. When the changes are not compatible with the cellular system halting important function, cell cannot survive. The natural process of evolution is the outcome of slow but definite changes that have taken place over a year of evolutionary era. The next topic described how this inbuilt tendency for variation is the basis for evolution.

15.3 The Importance of Variation

The population of organisms in niches or ecosystems is also reproduced. During reproduction the consistency of DNA copying is important for the maintenance of body design feature. Thus reproduction is linked to the stability of populations of species.

The niches can change because the causes for their change are not under the control of the organisms. Such changes are temperature of the earth which can go up or down, variation in water level, or they could be meteorite hits. We will see some examples. Suppose population of reproducing organisms was suited to particular niche and if there was a drastic change in niche, the population can be wiped out. In a few individuals of this population if there were some variations present, then there would be few chances for them to survive. Thus, if there was a population of bacteria living in water with moderate temperature and because of global warming the water temperatures were to be increased, many bacteria would die, but few temperature resistant bacteria would survive and grow further. Thus variation is useful for the survival of species.

15.4 Types of Reproduction in Organisms

Types of asexual reproduction :

(A) Fission : Fission is the simplest method of asexual reproduction in unicellular organisms like protozoa and bacteria. In the process of fission, a unicellular organism divides to form two new organisms. Fission is of two types-binary fission and multiple fission. In binary fission the nucleus lengthens and divides into two parts. After that the cytoplasm divides into two parts, one part around each nucleus. This results into two daughter cells. Each one of them grows into an adult organism. e.g. *Amoeba, Paramoecium.*

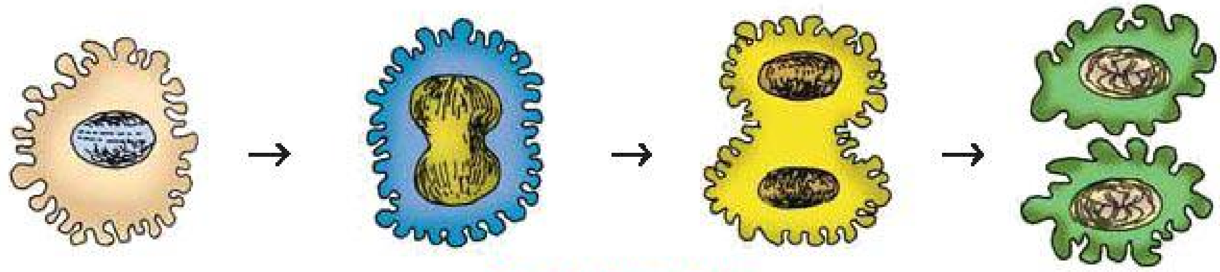


Fig. 15.1 Binary fission

In multiple fission, the parent organism divides to form many new organisms at the same time. Particularly during unfavorable conditions, a cyst is formed around the single cell organisms. Inside the cyst, the nucleus divides several times to form many smaller daughter nuclei, small amount of cytoplasm collects around each daughter nuclei and thin membranes are formed around them. Thus many daughter cells are formed from a single parent cell within cyst. When the favourable condition arrives, the cyst breaks up and many daughter cells are released, each forming a new organisms e.g. *Plasmodium, Amoeba*

Fig. 15.2 Multiple fission

[B] Fragmentation : The breaking up of the body of a multicellular organism into two or many pieces and on maturing, each piece grows to form a complete new organism is known as fragmentation e.g. *Spirogyra*

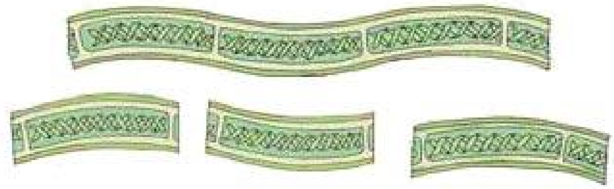


Fig. 15.3 Fragmentation

Fig. 15.4 Regeneration

[C] Regeneration : In some plants and animals small cut parts of their body can regenerate to form a complete new organism. e.g. *Hydra* and *Planaria*

[D] Budding : In budding, a small part of the body of the parent organism grows out as a 'bud' then it detaches from parent and becomes a new organism. e.g. *Hydra* and *Planarian.*

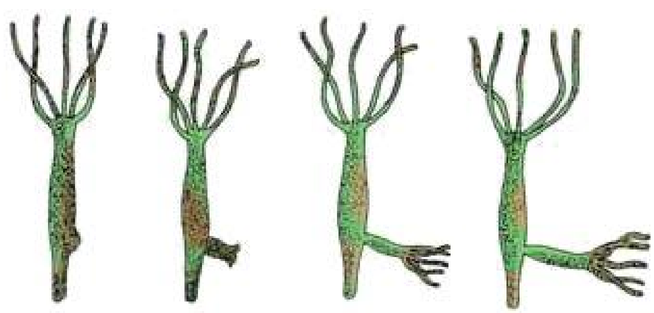


Fig. 15.5 Budding

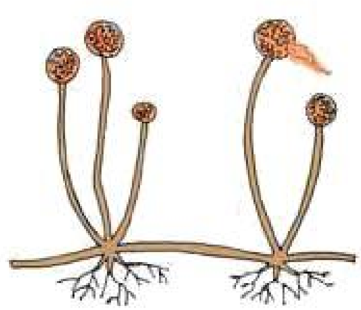
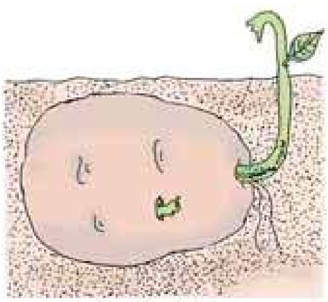


Fig. 15.6 Spore formation in mycor

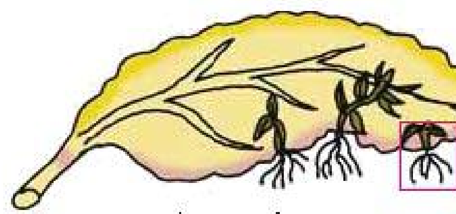
[E] Spore formation : Spores are the microscopic reproductive units of plants which are covered by a protective coat. When the protective coat bursts, the spores spread into air. These air-borne spores settle on food and under favourable condition they germinate to produce new plants, e.g. *Rhizopus, Mucor*

15.5 Vegetative Propagation

Vegetative propagation is an asexual method of reproduction, which occurs only in plants. In vegetative propagation, new plants are obtained from the plant parts like roots, stem and leaves of old plants, without taking help of any reproductive organs. Vegetative propagation involves the development and growth of dormant state of buds present in old part of the plant. When suitable moisture and temperature are provided to dormant state of bud then these buds grow to form new plants. Buds are found on the leaves of Bryophyllum. A potato tuber has a number of buds on its body, which act as organs for vegetative reproduction. When a potato tuber is planted in the ground, then buds start growing and form new plants.



Potato tuber



Leaf buds of Bryophyllum

Fig. 15.7 Vegetative propagation

15.6 Artificial Propagation in Plant :

By using artificial methods to produce many plants from a single plant is known as artificial propagation of plants. The three common methods for artificial propagation of plants are (1) Cutting, (2) Layering and (3) Grafting. A cutting of stem or shoot or leaf having some buds on it is taken and its lower part is buried in the moist soil. After few days, the cutting develops roots and grows into plant exactly similar to that of the parent plant. An advantage of this method is that we can grow many new plants from just one plant quickly, without seeds. e.g. Rose, Bougainvillea.

Fig. 15.8 Cutting

Layering : A part of stem is pulled towards the ground and covered by the soil. Once the covered part develops its own roots, it behaves independently and is detached from the parent plant and develops into matured plant e.g. Lemon, Bougainvillea, Crysenthemum

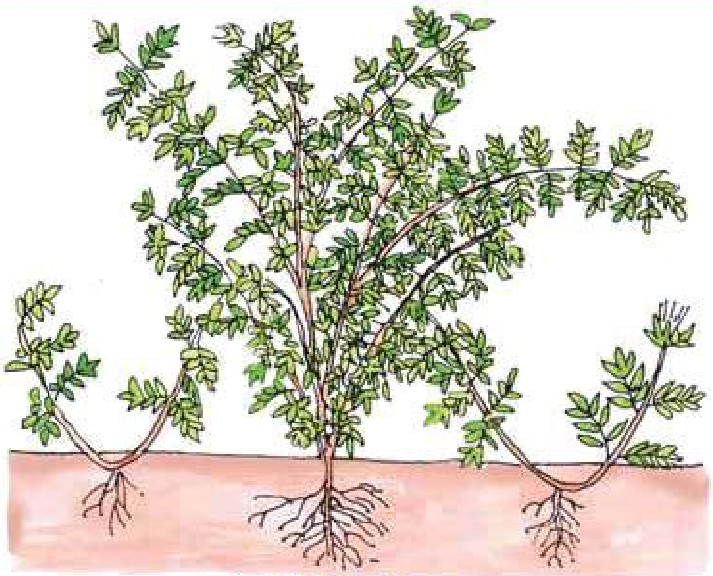


Fig. 15.9 Layering

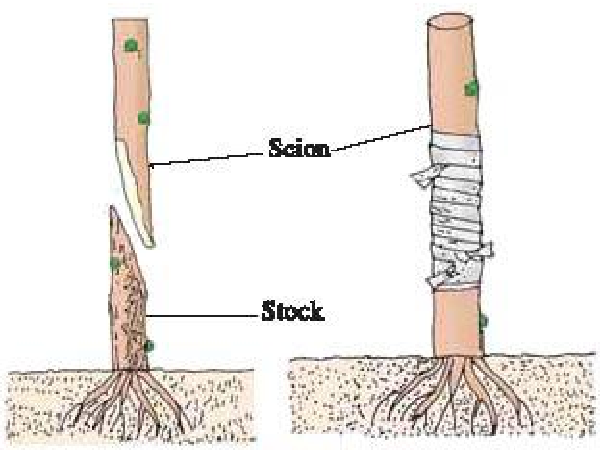


Fig. 15.10 Grafting

Grafting : In this method the cut stems of two different plants, one with roots and other without roots are joined together in such a way that they unite and grow as one plant. The stem having roots is called stock. The stem without root of another plant is called scion. Scion is the upper part which possesses leaves on it but no roots. On stock of citrus, scion of orange or lemon can be grafted. By grafting, most desirable characters of the plants can be brought together. Grafting method is always good in the plants where seeds are having long dormancy period, poor germination capacity and to produce varieties of seedless fruit.

15.7 Sexual Reproduction

Sexual reproduction takes place by union of two types of sex cells, i.e. male sex cells and female sex cells. The sex cells involved in sexual reproduction are known as gametes. In sexual reproduction, a male gamete unite with a female gamete to produce 'zygote'. This zygote then develops into new organism in course of time.

The importance of sexual reproduction:

The sexual reproduction has many advantages. In sexual reproduction the offsprings have genetic variations. In population sexual reproduction leads to greater variety. The species of plants and animals can adapt quickly to the changing environment. Those individuals which are more adapted to changes will survive and reproduce sexually. In the offspring, thus, sexual reproduction shows diversity of characters by providing genetic variations. In origin of new species the sexual reproduction plays an important role. This genetic variation leads to the important role. These genetic variations lead to the evolution in various species to form better organisms. In sexual reproduction, the genetic material DNA from male and female gametes combine to form zygote but the amount of DNA in zygote does not get doubled. The male and female gametes contain only half the number of chromosome as compared to that of in the normal body cells of an organism. During sexual reproduction when male gamete fuses with the female gamete, then zygote achieves normal amount of DNA or normal number of chromosomes in it. e.g. The human ovum has 23 chromosomes and sperm has also 23 chromosomes. Thus when a sperm and an ova combined during fertilization the zygote, formed will have 23 + 23 = 46 chromosomes which is the normal number of chromosomes in human.

15.8 Sexual Reproduction in Flowering Plants :

The sex organs of a plant are located within the flowers. In most of the plants, the same flowers contain both male and female reproductive organs. These plants are known as bisexual. Thus, the reproductive part in higher groups of plant is flower. The function of a flower is to produce male and female gametes and to ensure fertilization which makes new seeds for the plants. The stamen is the male organ in flower which produces male gametes. The carpel is the female organ in flower which produces female gametes. Female gametes are present in ovules, and are known as ova or egg cells. The male gametes present in pollen grains which fertilize the egg cells found in ovules. The fertilized egg cell develops within ovule which later on produces embryo and entire ovule is converted into seed. Under the suitable condition the seeds germinate to produce new plants.

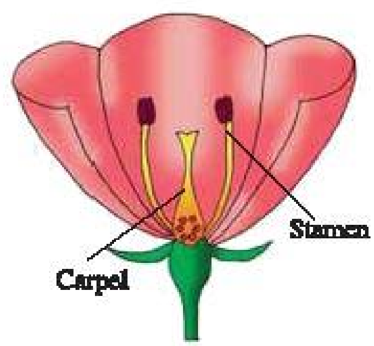


Fig.15.11 Flower of plant

15.9 Reproduction in Human Being

Human have a sexual mode of reproduction. All of us know that our body changes as we become older. Our height and weight also increase as we grow further. First we acquire milk teeth then permanent teeth. Some of these changes are common to girls and boys. In small child, it is difficult to know from the appearance whether he is boy or girl because small girls and boys have same body shape. In the early teenage, rapid growth starts and body changes. Some of these changes are common in both girls and boys. We begin to notice thick hairs growing in armpits and the genital area between the thighs. Hair can also appear on legs, arms and face. The skin some time becomes oily and pimples begin to develop. The ovary in girl and testis in boy produce different hormones, and thus girl and boy become sexually mature.

The age at which gametes start to be produced and girl and boy able to reproduce is known as puberty. Generally girls attain puberty at the age of 12 years, while boys reach puberty at the age of 13 to 14 years. On attaining puberty, testis start producing sperm and ovaries start producing eggs. In addition to these sex hormones also start secreting with the onset of puberty. Thus the time between childhood and adulthood is known as 'adolescence'. Many changes take place during puberty, such as new hair growth, body becomes more muscular, the voice deepens, shoulders and chest broaden. The penis becomes larger and it is capable of becoming erect. In humans, the baby is carried in mother's body for a long period and will be breast fed after birth. The female breast and reproductive organs develop to accommodate these possibilities. Let us look at the reproductive system which is involved in the process of sexual reproduction.

The male reproductive system :

The male reproductive system consists of part which produce the male gametes and other part that transfer the gametes to the site of fertilization. The human male reproductive system consists of the following organs like testis, scrotum, epididymis, vas deference, seminal vesicles, prostate gland and penis. Testis are paired, oval shaped gland which produce the male gametes and secrete sex hormones, the testosterone. The testes are lying in muscular pouch scrotum present outside the abdominal cavity. The temperature of testis remains 2-3°C below the body temperature which is essential for the formation of sperms. The sperms in testis come out and carried into coiled tube known as epididymis. From epididymis the sperms come out into a long tube called vas deference, which joins with urinary duct coming from urinary bladder. Now it is known as urethra. The seminal vesicle and prostate gland join with vasdeference. The secretion of seminal vesicle increases the mobility and viability of sperms, while prostate gland secretion increases mobility of sperms. Urethra transfers the sperms to an organ called penis which opens outside through a male genital pore. From male genital pore sperms pass into vagina in the woman's body during mating.

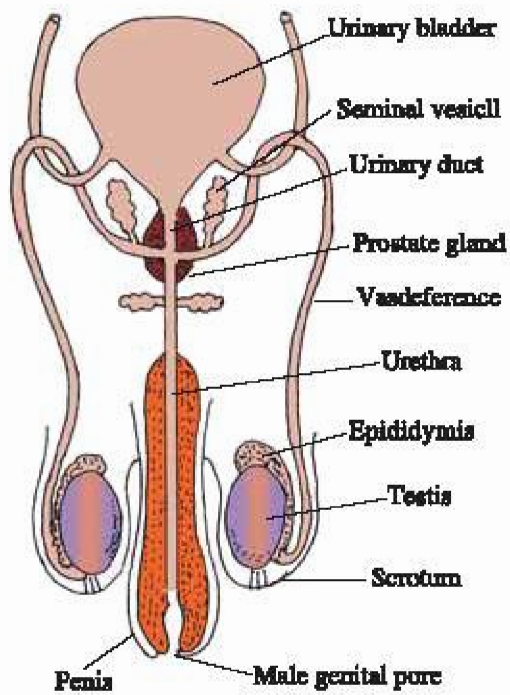


Fig. 15.12 Male reproductive system

Female reproductive system :

Female reproductive system consists of ovaries, oviduct, uterus and vagina. The female reproductive system is more complicated than male, because in it fertilization and the development of embryo till birth, occur.

Two ovaries are oval in shape and lie inside the abdominal cavity. The function of the ovary is to produce ova or eggs, and also to secrete the female sex hormones, estrogen and progesterone. There are two fallopian tubes (oviducts). These are not

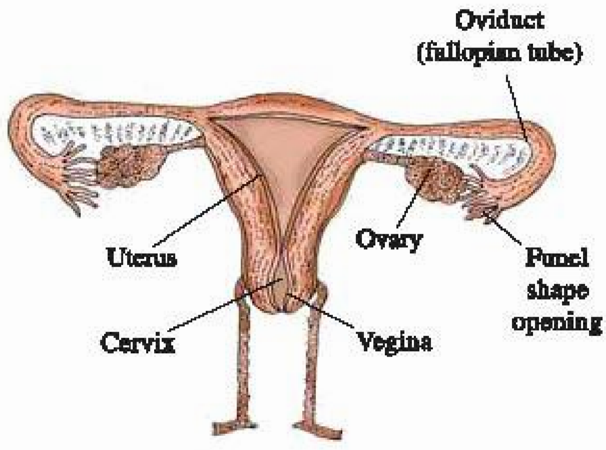


Fig. 15.13 Female reproductive system

attached to ovaries and have a funnel shaped opening to receive mature ova. Oviducts carry the ova from ovary to the uterus. The fertilization of ovum by a sperm takes place in the upper part of the oviduct. The oviduct unites to form a thick walled muscular bag like organ called uterus. Fertilized ovum further develops and grows into the uterus. The lower tip of the uterus is known as cervix. Uterus opens into tubular structure vagina, which receives sperms by the penis.

When a girl is born, the ovaries contain thousands of immature ovarian follicles. When a girl reaching puberty these immature ovarian follicles start maturing. One of the ovaries produces one ovum every month. The mature ovum finally carried to fallopian tube. During sexual inter course the sperms enter vagina. The fertilized ovum, gets implanted in the lining of the uterus and starts dividing and forms a hollow ball of hundreds of cells known as embryo. The embryo gets nutrition from the mother's blood with the help of a disc-like special tissue, develops between embryo and the uterus wall, known as placenta. The exchange of oxygen, nutrients and waste products takes place through the placenta. The development of the child inside uterus takes about nine months. The child is born as a result of rhythmic contractions of the muscles in the uterus.

15.10 Menstrual Cycle in Female

When girl reaches the age of about 10 to 12 year (puberty), the sex hormones cause the ova to become mature. Every 28 day one matured ovum is released from the ovary into the oviduct and this is known as ovulation. Before ovulation, the inner wall of uterus becomes thick, and with full

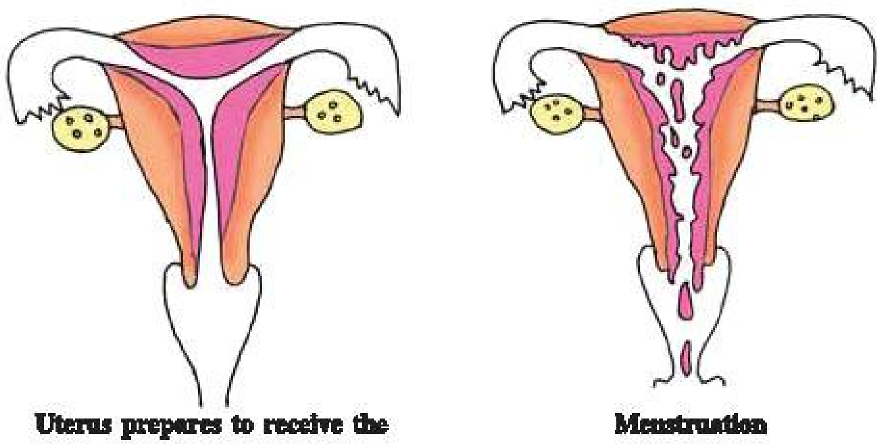


Fig. 15.14 Menstruation

of blood capillaries. Now at this stage uterus prepares to receive the fertilized ovum. If the ovum does not get fertilized, then the thick wall of uterus along with the blood vessels and dead ovum comes out of the vagina in the form of a bleeding known as menstruation. Menstruation lasts for 3 to 5 days. When menstruation is over, the inner wall of uterus starts building up again so that it may receive the next fertilized ovum. If the ovum does not get fertilized even now, then menstruation takes place again. The menstruation cycle is repeated in women every 28 days. Menstruation stops when woman gets pregnant and when woman reaches the age of about 50 years, menstruation stops permanently. This is known as menopause and in this stage woman lose the capacity of carrying embryo.

15.11 Reproductive Health

The process of sexual maturation is slow and gradual, and it continues with general growth of body. How do we decide that for this major responsibility our body or mind is ready? About this issue all of us are under different types of pressures. There can be pressure from the family members to get married and start having children. The pressure can be from government to avoid more children. Making choice becomes very difficult under this situation. We have studied in class IX that disease can be spread from person to person in a various ways. The diseases which are transmitted by sexual intimate contact with an infected person are called sexually transmitted diseases (STD). These include bacterial infections like syphilis and gonorrhea. Syphilis is caused by bacteria *Treponema palidium*. There are lesions in mucus membrane of urinogenital track and ulser in general. Gonorrhea caused by *Neisseria gonorrhea*. It is the inflammation of urinogenital tract. Both are curable diseases. The causative for AIDS is Human Immuno-deficiencey Virus (HIV). AIDS means Acquired Immuno Deficiency Syndrome. AIDS is a fetal disease, because it damages the body's immune system so that the body becomes weak and cannot protect against infection. Using condom during sex helps to prevent spread of many of these diseases to some extent. To find out medicines to cure AIDS, research work is in progress. To protect human from AIDS, the programme under guidance of WHO is in practice. In India also NACO (National AIDS Control Organization) has taken steps to create awareness and provide relevant information about reproductive health.

The continuous sexual act has the potential to lead to pregnancy. During pregnancy women's health will be adversely affected. Therefore, many ways have been devised to avoid pregnancy. These contraceptive methods can be broadly classified into the following three categories. One category is the creation of mechanical barrier that prevent the entry of sperm in the genital track. So fertilization cannot take place. Condoms on the penis or Diaphragm worn in the vagina by female can serve this purpose. In other category of contraceptives chemical methods, the female

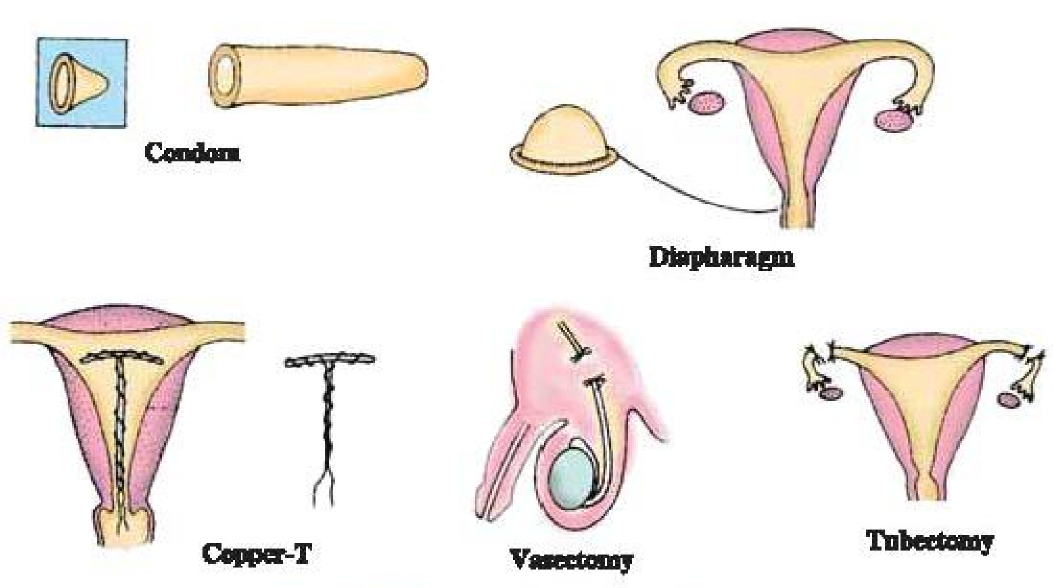


Fig. 15.15 Contraceptive devices and surgery

uses two types of pills. The oral pills contain a combination of hormones which stop the production of ova and fertilization cannot occur. The vaginal pills contain the chemical known as spermicide which kills the sperms. Another Intrauterine Contraceptive Devices (IUCDs) like copper-T are placed in uterus to prevent pregnancy. In surgical methods, in males small portion of vas deference is surgically removed and both the cut ends are tied properly. This prevents the sperms from entering the urethra. This process is known as vasectomy. In female, a small portion of oviduct is removed and tied up. This process is known as tubectomy. This process prevents the ovum from entering the oviduct. Surgical methods can be used to create such blocks. Surgery can be used to remove unwanted pregnancies. People who do not want a female child this facility may misuse. Some people are interested to have a son or to know the sex of their unborn child by ultrasound technique (sonography) illegally. In case of female child, they get it removed by surgery. The killing of the unborn girl child is known as female foeticide. By female foeticide, child sex ratio is reducing at an alarming rate in society. The reproduction is the process by which organisms increase their population. The rates of birth and death in a given population will determine its size. Human population is increasing at an enormous rate.

What have you learnt ?

- The production of new organisms from the existing organisms of the same species is known as reproduction
- Organisms look similar because their body designs are similar
- Variation is useful for the survival of species over time.
- There are two main methods of reproduction in living organisms. (1) asexual reproduction (2) sexual reproduction. Asexual reproduction takes place by six different methods. These are (1) fission (2) fragmentation (3) regeneration (4) budding (5) vegetative propagation (6) spore formation.
- Sexual reproduction has many advantages. The offspring have genetic variations, greater variety, adapt quickly to changes in environment
- The main reproduction parts of flower are stamens and carpels which contain the germ cells.
- Male reproductive system consists of testis, vasdeference, seminal vesicle, prostate gland, urethra, penis.
- Female reproductive system consists of ovary, oviduct, uterus, cervix, and vagina
- The break down and removal of the inner, thick lining of the uterus along with blood vessel gets slashed off and discharged from vagina is called menstruation
- Process of menstruation occurs every 28 day is known as menstruction.
- Birth control methods are

  (1) Barrier method (2) Chemical methods (3) Surgical method
- Gonorrhea, Syphilis and AIDS are common sexually transmitted disease.

EXERCISE

1. Select the proper choice from the given multiple choices.

1. Asexual reproduction is:
   - (A) a fusion of specialized cells
   - (B) a method by which all types of organisms reproduce
   - (C) a method producing genetically identical offsprings.
   - (D) a method in which more than one parent are involved
2. One of the following organisms does not reproduce by binary fission. This is:
   (A) Amoeba (B) Plasmodium (C) Euglena (D) Paramoecium
3. Reproduction is essential for living organisms in order to:
   (A) keep the individual organ alive (B) fulfil their energy requirements
   (C) maintain growth (D) continue the species for ever
4. A multicellular organism which reproduces by budding is:
   (A) Amoeba (B) Yeast (C) Paramoecium (D) Hydra
5. A simple multicellular animal having tentacles and lives in freshwater reproduces by the asexual method of :
   (A) binary fission (B) spore formation (C) budding (D) fragmentation
6. In which of the following living organisms spore formation takes place ?
   (A) Mucor (B) Planaria (C) Spirogyra (D) Potato
7. Method of a sexual reproduction in Spirogyra.
   (A) division of a cell into two cells (B) breaking up of filaments into smaller bits
   (C) division of a cell into many cells (D) formation of a large number of buds
8. An alga which reproduces by the asexual reproduction method called fragmentation is:
   (A) Rhizopus (B) Salmonella (C) Plasmodium (D) Spirogyra
9. The cut part of plant stem (having roots and fixed to ground) which is used in the process of grafting is ......
   (A) stock (B) scion (C) cutting (D) bud
10. In asexual reproduction, two offsprings having the same genetic material and the same body features are called:
   (A) callus (B) twins (C) clones (D) chromosomes

2. Answer the following questions in brief :

1. (A) Name two animals which reproduce sexually.
   (B) Name two animals which reproduce asexually.
2. Name the method by which Paramoecium reproduces. Is this method sexual or asexual?
3. Name the asexual method of reproduction in yeast.

4. Name the asexual method of reproduction in (a) Hydra, and (b) Plasmodium.
5. Name the artificial propagation of the rose plant for reproduction.
6. Which artificial propagation method is used for the production of citrus plants?
7. Name two plants which are propagated by layering method.
8. Name any two plants which are propagated by cutting method.
9. Write down the name of different methods of asexual reproduction.

3. Write answers of the following questions.

1. (a) What is the basic difference between asexual reproduction and sexual reproduction?

   (b) Which of the following organisms reproduce by sexual method and which by asexual method? Amoeba, Cats, Humans, Hydra, Birds
2. What do you mean by regeneration ? Name two animals which can regenerate fully from their cut body parts.
3. Explain vegetative propagation with the help of two examples. List two advantages of vegetative propagation.
4. Describe the layering method for the artificial propagation of plants. Ilustrate your answer with the help of a labelled diagram. Name any two plants which are propagated by the layering method.
5. (a) What is a tuber ? give example.

   (b) Name one commonly used vegetable which is propagated by using tubers.
6. What is meant by vegetative propagation ?
7. Explain how, new Bryophyllum plants can be produced from the leaves of the old plant ? Ilustrate your answer with the help of a labelled diagram.

4. Answer the following questions in detail.

1. Name one organism which reproduces by fission and another by fragmentation. Describe these processes with example.
2. What is the meaning of multiple fission : Describe.
3. Describe the method of reproduction in fungus.

UNIT 16

HEREDITY AND EVOLUTION

We know that the living organisms reproduce either by asexual or sexual method. Due to this capacity every organism reproduces new generation of offsprings that resembles the parental generation. Though the offsprings of a species may resemble very closely to their parents, they never exactly resemble them. In other words, we can say that each species has individuality, i.e. each species is recognizable by certain specific characteristics. By the process of gradual and continuous change, living organisms have evolved to exhibit a wide diversity. In this chapter you will learn about heredity, variation, sex determination and also about evidences of evolution.

16.1 Accumulation of Variation During Reproduction :

The occurrence of differences among the individuals of the same species is known as variation. Very little variations can be seen in the organisms which are reproduced vegetatively or asexually while distinct variations are observed in the organisms which reproduce sexually. We know that sexual reproduction involves the process of meiosis for gamete formation. During meiosis, crossing over takes place between the genes and hence, new combinations are formed, which ultimately results in producing variations among the characteristics of individuals of species. However, all these variations in a species do not have equal chances of surviving in the environment in which they find themselves. Depending on the nature of variations, different individuals would have different kinds of advantages. Selection of variants by environmental factors forms the basis of evolutionary processes.

16.2 Heredity :

Heredity means continuity of features from one generation to another. For example, eggs laid by a sparrow hatch into sparrows only. A dog gives birth to pups only. This is the essence of heredity.

Hereditary information is present in the fertilized egg or zygote. The zygote develops into an organism of a particular type only. Thus heredity can be defined as "the transmission of characters from parents to the offspring" or the tendency of every individual to resemble their parents.

Heredity and variation are important aspects of science, which are studied under Genetics. And so Genetics is also known as the science of heredity and variation.

16.3 Inherited Characters :

How do organisms follow the characters of their own species ? We can say that it is their inheritance. It is through inheritance that each species maintains the structure of characters generation after generation. At the same time, it is also equally true, that offsprings are not exact copies of their parents. This aspect of differing from parents is called variation. Human populations show a great deal of variations. In the following part we will study how characters are transmitted generation to generation.

16.4 Mendel's Contribution :

We know that complete inheritance from mother and father is received by offsprings through a single ovum and a single sperm respectively. It is through their fertilization, that the first cell, called zygote, comes into existence as a new offspring. This means that each character in offspring will be influenced by both the parents. What will, the character then be seen in the offspring ? Mendel performed experiments on *Pisum sativum* (Garden pea) and worked out the main rules of such inheritance. After selecting Garden pea as an experimental material, Mendel performed experiments to study the inheritance of some of the pairs of contrasting characters like tall and short plants, white and violet flowers, round and wrinkled seeds, axial and terminal flower positions and so on.

When Mendel crossed a tall plant (with TT traits on DNA) with a dwarf plant (with tt traits on DNA), the F_1 generation was found to be tall. There were no dwarf or medium height plants in F_1 generation. This means that only one of the parental characters was seen. But when F_1 generation plants were self-fertilized, it was found that some plants were dwarf (25%) some were tall (75%) in F_2 generation. This indicates that both tallness and dwarfness characters were inherited in F_1 generation from the parents, but only the character for tallness was expressed. Thus two copies of each character are inherited in each sexually reproducing organisms which may be either identical or different.

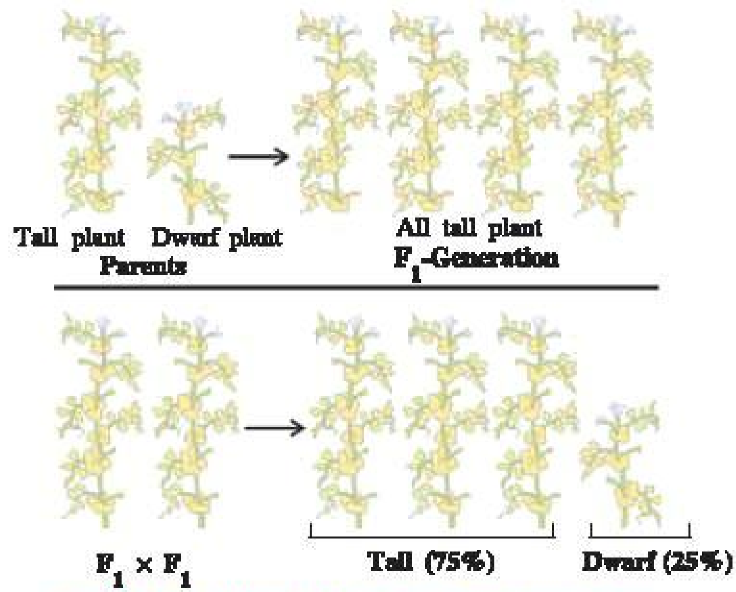


Fig. 16.1 Inheritance of traits over two generations

The experiment indicated that plants having either TT or Tt traits for height were tall while with tt traits were dwarf. In other words we can say that a single trait "T" is enough for making plant tall but for dwarfness traits "tt" are required. Thus "T" is called dominant trait while "t" is a recessive trait.

In other experiment, Mendel selected two different characteristics in a plant. He crossed a plant having yellow and round seeds with a plant having green and wrinkled seeds. In F_1 generation all the plants were with yellow and round seeds indicating that yellow and round seeds are dominated characteristics (Traits). When the plants of F_1 generations are self pollinated, plants along with the parental combinations (i.e. yellow and round seeds, green and wrinkled seeds) new combinations (i.e. yellow and round seeds, green and round seeds) are also formed. This indicates that the yellow seeds/green seeds characteristics (traits) and the round seeds/wrinkled seeds characteristics are independently inherited.

Yellow round YYRR X Green wrinkled yyrr

↓

Yellow round YyRr — F_1 generation

Gemetes of F_1 :

♀ \ ♂	YR	Yr	yR	yr
YR	YYRR	YYRr	YyRR	YyRr
Yr	YYRr	YYrr	YyRr	Yyrr
yR	YyRR	YyRr	yyRR	yyRr
yr	YyRr	Yyrr	yyRr	yyrr

F_2 generation

Yellow round : Yellow wrinkled : Green round : Green wrinkled

9 : 3 : 3 : 1

Fig. 16.2 Independent inheritance of two separate traits, colour and shape of seed

16.5 Expression of Inherited characters

The gene is a unit of heredity. Genes are located on DNA in a linear order. Each gene exercises its function by synthesizing specific protein which is responsible for the expression of characteristic. How do proteins control the characteristics ? Let us consider the height as a characteristic of the plant. We know that plants have hormones that can trigger growth. So height of plants depend upon the amount of particular hormone. The synthesis of hormones is catalysed by particular type of enzymes and the synthesis of enzymes is regulated by genes located on DNA. It means if enzyme is synthesized in required amount and is working efficiently, a lot of hormones will be made and the plant will be tall. However, if the gene has alteration that makes the enzyme less efficient, the amount of the hormone will be less and plant will be dwarf. This clearly indicates that characteristics or traits are under the control of genes.

16.6 Sex Determination in Human

How is the sex of a newborn individual determined ? Different species use different mechanism for this. Some rely on the environmental factor like temperature. The temperature at which fertilized eggs are kept determines whether the animal developing in the eggs will be male or female. In other animals such as snails, individuals can change sex, indicating that sex is not genetically determined. However in human beings, the sex of the individual is genetically determined. Thus, the mechanism to determine the sex of an individual is known as sex determination.

In human beings, the sex will be determined by the genes, located on the chromosomes, which are inherited from parents to offsprings. In humans, 23 pairs of chromosomes occur. Of these, 22 pairs are of autosomes. They are similar in male and female. In female 23^{rd} pair consists of two similar X sex chromosomes. In male one chromosome in 23^{rd} pair is like X chromosome in women. Its homologous chromosome is smaller in size and is called Y chromosome .

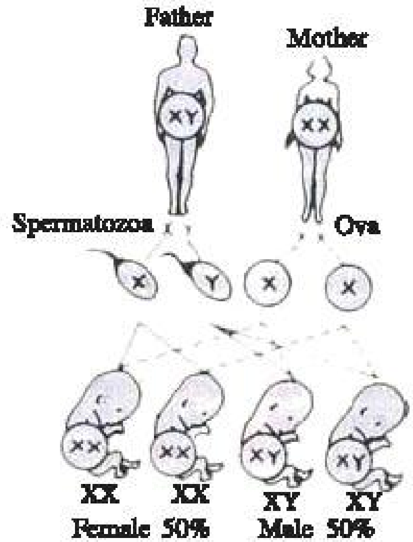


Fig. 16.3 Sex determination in Human

All eggs of a female are similar. Each egg contains 22 autosomes and one X sex chromosome. Male produces two types of sperms. 50% sperms carry X sex chromosome while other 50% carry Y sex chromosome.

When a sperm carrying X chromosome fertilizes an egg, the zygote develops into a female, while a sperm carrying Y chromosome fertilizes an egg, the zygote develops into a male.

In human, presence of Y chromosome is obligatory for maleness. When the zygote is formed and embryo development occurs, the gonads which are formed are undifferentiated. They can develop either into testes or into ovaries. If the zygote contains the Y sex chromosome, the gonads differentiate into testes. Testes produce male sex hormones and stimulate development of a male individual.

16.7 Evolution

On this earth an enormous number of different types of plants and animals are present. Besides these the remnant of the dead organisms which lived in the past are also present which are known as fossils. On this earth a great variety of living plants and animals exist. All these things are studied in the branch of biology known as 'evolution'. The word evolution has been derived from the Latin word 'evolvere' which means to 'unfold' or 'unroll'.

Primary Explanation of Evolution

Evolution is a kind of gradual formation of new organisms from the pre-existing primitive plants or animals by constant and relatively long time changes. Thus evolution is the sequence of gradual changes which have taken place over millions of years in the primitive plants and animals from which new species are formed. The evolution is a constant process which is taking place in the primitive organisms since life is originated. All the enormous varieties of organisms which we see around us have evolved from some ancestors that lived on this earth long time ago.

Acquired and Inherited Traits (Characteristics) :

Acquired trait means a Trait of an organism that is not inherited but developed in response to the environment. For example reduction in weight due to starvation. The reduced weight due to starvation would not change the DNA of germ cells. Thus reduced weight is not a trait that can be inherited by the future generation of starving organisms. Another examples of acquired trait are cut tail of mouse or a man who knows how to swim, or speak German or roller skate, or may have scar on the face due to accident. Thus the man is not born with these acquired traits and he cannot pass on these traits to his progeny. The reason for this because only those traits inherited to their progeny where change has occurred in the genes in gametes of organisms during the process of reproduction. Thus the changes in the non-reproductive body cells of an organism cannot be transmitted to its progeny.

A trait of organisms which is caused by a change in its DNA is known as inherited trait. For example there is a population of red beetles which live in bushes with green leaves. Suppose a color variation arises during reproduction in the gene of reproductive cells, one green color beetle arises instead of red color. Here the green color of this beetle is an inherited trait which can be transmitted to the next generations. This is the essence of the idea of evolution.

16.8 Speciation :

The process by which new species develops from the existing species is known as speciation. Thus speciation means, the formation of new species. When population of same species splits into two groups which then get separated from each other geographically by the certain barriers like rivers, seas or mountain ranges then new species are formed. Thus geographical isolation leads to reproductive isolation due to which there is no gene flow between two separated groups of population. Variation arises in individuals due to natural selection. Due to processes of random change in gene frequency (genetic drift), after thousands of years the individuals become so different that they cannot reproduce with each other. Thus new species are formed. There can be more ways like DNA changes, the change in the number of chromosomes, the green cells of two isolated groups of populations which cannot fuse with each others etc. which can lead to speciation. Thus new species are formed.

16.9 Evolution and Classification :

Among organisms we find similarities that will allow us to classify them in to groups and study in detail. The main characteristic of plants is that they can do photosynthesis while animals cannot do. The cell is the basic fundamental unit of life. The next characteristic of classification is that not all the organisms possess cells. Among various organisms the basic characteristic of cell design is also different. Some organisms like bacterial cell do not have nucleus. Organisms with nucleated cells are of two types, unicellular and multi-cellular. And there is a basic difference in body design, because of specialization of cells and tissues. Among the multicellular organisms the skeleton around the body or inside the body will mark another basic design difference. The more closely related two species have a common ancestor. For example a brother and sister are closely related, and they have a common ancestor.

16.10 Evidences for Evolution :

Some of the very significant sources which provide evidences for evolution are as follows:

Homologous organs :

Those organs which have the same internal structure but different functions are called homologous organs. For example the basic design of bones of forelimbs of a frog, a lizard, a bird, a bat and a man is similar in their internal structures but they perform different types of functions. These indicate that all these forelimbs have evolved from a common ancestral animal which had a same basic internal structure.

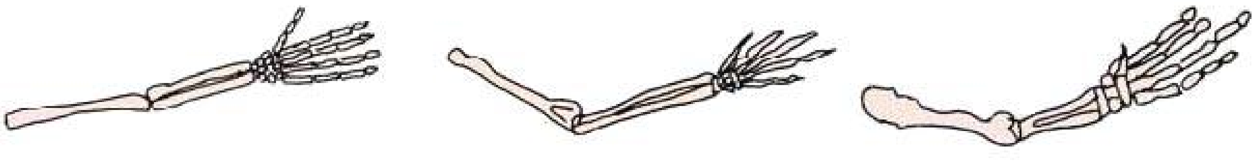


Fig. 16.4 Homologous organs

Analogous Organs :

Organs which have different basic design but have similar appearance and carry out similar functions are called analogous organs. For example the wings of insect and bird have different structures but perform similar functions. Thus the presence of analogous organs in different animals provide evidence that they are not evolved from the common ancestors, but they perform similar functions to survive in prevailing environment.

Fig. 16.5 Birds feathers (Analogous organs)

Fossils Provide Evidence for Evolution :

The impressions of dead plants or animals that lived in the past are known as fossils. When plants or animals die, the micro-organisms in the presence of moisture and oxygen, decompose their bodies but sometime due to environment conditions their bodies do not decompose completely. Such body parts of the plants on animals become fossil and are available on digging the earth. If the dead leaf gets caught in the mud, leaf will not decompose completely. The mud around the leaf will set around it as a mould which slowly harden to form rock and retain the impression of the leaf. Thus fossil of leaf is formed. The age of the fossils can be estimated by carbon dating method. When living organisms changed in to fossil, their ^{14}C radioactivity decrease slowly. Thus the age of fossil is determined with the help of the ^{14}C radioactive. Ammonite, Trilobite and Dinosaur are the examples of fossils which are determined by this process.

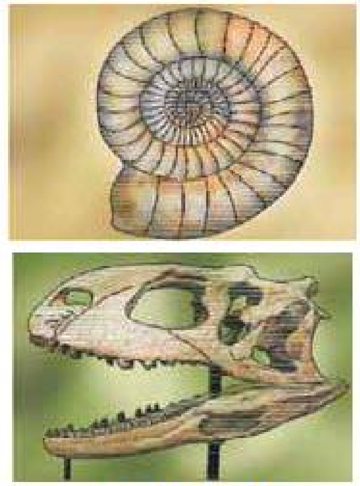


Fig. 16.6 Fossils

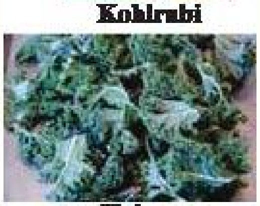
Wild cabbage

Cabbage

Broccoli

Cauliflower

Kohlrabi



Kale

Fig. 16.7 Varieties of wild cabbage

16.11 Evolution by stages

For animals the eye is a very important and it is a complicated organ which cannot be generated by a single DNA change. The eyes of animals have been created in stages after many generations. First of all, eye was formed in Planaria. The eyes of Planaria (flat worm) are very simple and are just like 'eye-spots' which detect light. These simple eyes provide a survival advantage to Planaria. Thus eye seems to be very popular adaptation. Most of the animals like insects, octopus, invertebrates and vertebrates have eyes. The structure of eye in above organisms is different which suggests the evolution of eye and is an example of evolution by stages.

Feathers : For example, in some dinosaurs feathers could not be used for flying but provided insulation in cold weather. But later, they might become useful for flight. Birds, however later adapted to flight. Thus presence of feathers in world tell us that birds are very closely related to reptiles, since dinosaurs which had feathers were reptiles.

Analogus organ

We have learnt that very dissimilar looking structures evolved from common ancestral body design. But those are all guesses about what happened in history long time ago. Are there any present time examples of such a process ? The wild cabbage plant is a good example. It provides evidence that completely dissimilar looking plant can evolve from the wild cabbage by the process of evolution. The only difference here is that we are using artificial selection evolution, rather than natural selection. Over more than two thousand years the farmers cultivated wild cabbage as food plant and have bred the cabbage (very short distance between leaves) which we eat, some farmers obtained for arrested flower development of wild cabbage, and have bred broccoli or some farmers went in for sterile flowers and have developed cauliflowers. Farmers selected swollen parts of wild cabbage, and developed another variety known as 'kohlrabi'. Some farmers have developed slightly large leaves of wild cabbage and their leafy vegetable is called 'kale'. Now wild cabbage is the ancestor of cabbage, broccoli, cauliflower, kohlrabi and kale varieties obtained by artificial selection by farmers and they look different from wild cabbage which is their ancestor.

16.12 Human Evolution:

Human evolution has been studied by using same tools like digging earth, time-dating, studying fossils and determining DNA sequence for tracing evolutionary relationship. Across the earth there is a great diversity of human firms and future. Man thought for a long time about different 'races' of human. The human race was identified on commonest way of their skin colour and named as yellow, black, white or brown. It is now known that the human races have not evolved differently. In the recent years, the evidence has become very clear that all human beings are a single species called *Homo Sapiens*. By research it has been established that we lived for past few thousands years. We all came from Africa. Our genetic foot prints can be traced back to our African roots. A couple of hundred thousand years ago some of our ancestors left Africa while others stayed back. Those who left Africa slowly spread over the planet – from Africa to West Asia to Central Asia, Eurasia, South Asia and East Asia. They migrate down the island of Indonesia and Philippines to Australia and reached to America. They went with groups, sometimes separating from each other and mixing with each other, even moving in and out of Africa. Like all other species on the earth, they had come into being as accident of evolution.

What have you learnt ?

Due to reproduction capacity every organism reproduces new generation of offsprings that resembles the parental generation. However, by the process of gradual and continuous change, living organisms have evolved to exhibit a wide diversity. During meiosis, crossing over takes place between the genes and hence, new combinations are formed, which ultimately result in producing variations among the characteristics of individuals of a species. Heredity means continuity of features from one generation to another. Heredity and variation are important aspects of science, which are studied under Genetics .

Mendel performed experiments on *Pisum sativum* (Garden pea) and worked out the main rules of such inheritance. Mendel performed experiments to study the inheritance of some of the pairs of contrasting characters like tall and short plants, white and violet flowers, round and wrinkled seeds, axial and terminal flower positions and so on. The gene is a unit of heredity. Genes are located on DNA in a linear order. Each gene exercises its function by synthesizing specific protein which is responsible for the expression of characteristic. The mechanism to determine the sex of an individual is known as sex determination. In human beings, the sex will be determined by the genes, located on the chromosomes, which are inherited from parents to offsprings.

Evolution is the sequence of gradual changes which have taken place from primitive organism over millions of years in which new species are produced. A characteristic of an organism which is not inherited but develops in response to the environment is known as acquired trait. The process by which new species develop from the existing species is known as speciation. The important factors which could form new species are (1) Geographical isolation of a population (2) Genetic drift and (3) Variation. Some important sources which provide evidences for evolution are (1) homologous organs (2) analogous organs and (3) fossils. For evolution by stages possible explanations are, Evolution of feathers and Farmers have evolved different looking vegetables like cabbage, broccoli, cauliflower, kohlrabi and kale by evolution by artificial selection.

EXERCISE

1. Select the proper choice from the given multiple choices :

1. The occurrence of differences among the individuals of the same species is due to :
   (A) Transition (B) Variations (C) Development (D) Evolution
2. The continuity of features from one generation to another is known as :
   (A) Evolution (B) Mutation (C) Heredity (D) Generation
3. On which of the following plant species Mendel has worked:
   (A) Zea mays (B) Pisum sativum (C) Cassia tora (D) Phaseolus mungo
4. When Mendel crossed Tall plant with Dwarf plant what was the ratio of dwarf plants in F_2 generation ?
   (A) 75 % (B) 25 % (C) 60 % (D) 40 %
5. In human being sex is determined by ;
   (A) Cell (B) Tissues (C) Genes (D) Organelles
6. The Human Species have genetic roots in:
   (A) India (B) America (C) Africa (D) Australia
7. The organs which perform different functions but have the same basic structure are known as:
   (A) Homologous organs (B) Analogous organs
   (C) Homolytic organ (D) Analytic organs
8. If the fossil of an organism is found in the deeper layers of earth, then we can predict that :
   i. the extinction of organism has occurred recently
   ii. the extinction of organism has occurred thousands of years ago
   iii. the fossil position in the layers of earth is not related to its time of extinction
   iv. time of extinction cannot be determined.
9. New species may be formed if :
   i. DNA undergoes significant changes in germ cells
   ii. there is no change in the genetic material
   iii. mating does not take place
   (A) (i) and (ii) (B) (i) and (iii) (C) (ii) and (iii) (D) (i), (ii) and (iii)

10. The presence of which of the following types of organs in two animals indicates that they are not derived from a common ancestor?

(A) Homologous organs (B) Excretory organs

(C) Analogous organs (D) Reproductive organs

11. Which one of the following is not homologous ?

(A) forelimbs in humans and lizard (B) forelimbs in lizard and frog

(C) wings in butterfly and bat (D) wings in bat and bird

2. Answer the following questions in brief :

1. Define sex determination
2. What are the mechanisms or methods of sex determination in different organisms?
3. Name the ancestor of the following:

   Broccoli, Kohlrabi, Kale
4. Name two organisms which are now extinct and are studied from their fossils.
5. Name five verities of vegetables which have been produced from 'wild cabbage' by the process of artificial selection
6. Choose the one term from the following which includes the other three : broccoli , wild cabbage, cauliflower, cabbage

3. Write answers to the following questions :

1. What are fossils ?
2. In what way homologous organs give evidence for evolution?
3. Will geographical isolation be a major factor in the speciation of an organism that reproduces asexually? Give reason for your answer.
4. Does geographical isolation of individuals of a species lead to the formation of a new species? Provide a suitable explanation for your answer.
5. How characters are inherited ?
6. Write a note on heredity.

4. Answer the following questions in detail :

1. (A) Explain the terms 'analogous organs' and 'homologous organs' with examples.

   (B) In what way analogous organs give evidence for evolution ?
2. (A) Define 'speciation'. Explain how speciation occurs.

   (B) Will geographical isolation be a major factor in the speciation of a self-pollinating plant species? Give reason for your answer.
3. Explain Mendel's contribution.
4. Describe the sex determination in human beings

UNIT

17

OUR ENVIRONMENT

All organisms including plants, animals and human beings and their physical surroundings with which they interact is called environment. All biotic and abiotic components of the environment are dependent on each other for maintaining balance. Therefore, we can say that the different components of the environment are inter-linked and interdependent. The environment varies from place to place due to variation in climate, soil type and topography. All plants and animals adjust to the environment in which they are born and live. A change in any component of environment may cause discomfort and affect normal life of living organisms. In this chapter, we shall be study how various factors in the environment interact with each other and how they impact the environment.

17.1 What Happens When we Add Our Waste to the Environment ?

Wastes are unwanted, unusable items, remains or household garbage. Wastes are generated in our homes on daily basis. These wastes are classified into two major forms namely solids and liquids. The liquid forms are easy to handle and manage as compared to those of solid forms. The solid wastes include kitchen wastes such as vegetables and fruits, peels, scales, bones, etc., metal wastes, glasses, plastics and polythenes. The waste materials which are broken down by biological processes are called biodegradable, for example vegetables and fruits while glass, plastics and polythenes which are not broken down by biological processes are said to be non-biodegradable.

Activity

- Collect waste materials from your homes. This waste include boiled food, vegetable peels, used tea leaves, plastic bags, milk bags, empty bottles, torn clothes, waste papers and empty cartons.
- Bury these materials in a pit in the school garden.

- Keep these materials moist and observe after a month.
- You will find that shape and structure of some of the materials like boiled food, vegetable peels, used tea leaves, torn clothes, waste papers and empty cartons have been changed due to degradation processes.
- No change can be seen in the shape and structure of some of the materials like plastic bags, milk bags and empty bottles since they are non biodegradable.
- The non biodegradable materials may be inert and simply persist in the environment for long time or may harm various members of the ecosystem. These materials take up precious land and may be major sources of diseases. Even a few kilos of putrid garbage or waste can cause a dangerous epidemic disease.

17.2 Ecosystem

In an ecosystem all organisms such as plants, animals, microorganisms and human beings as well as the physical surroundings interact with each other and maintain a balance in nature. In other words, the biotic community, together with the physical environment forms an interacting system which is called the ecosystem. An ecosystem may be of a small or a large size. Based on the kind of habitat, an ecosystem may be aquatic or terrestrial. Terrestrial ecosystems include forests, grasslands and deserts. Aquatic ecosystems include freshwater ecosystems like river, springs, lakes and ponds as well as marine ecosystems of oceans. Every ecosystem gradually merges into another one. Each ecosystem possesses a specific structure and performs definite functions.

Components of Ecosystem : Each ecosystem consists of two main components – a biotic component and an abiotic component. Biotic component includes all living organisms e.g. producers, consumers and decomposers while abiotic component includes all non-living factors such as soil, water, light, temperature, wind, humidity, rain, inorganic nutrients and dead organic matter containing proteins, lipids, carbohydrates etc.

(1) Biotic components : All organisms living in an ecosystem can be divided into two types - producer organisms and consumer organisms.

(i) Producers : These organisms are autotropic. They possess chlorophyll and prepare food through photosynthesis for themselves as well as for other organisms. In terrestrial ecosystem green plants are producers. In aquatic ecosystems various kinds of algae act as producers.

(ii) Consumers : These organisms cannot synthesize their food by themselves and so, they consume other organisms or their products for their food. They are heterotrophic. Consumers can be divided into the following four categories.

(a) Herbivores or first order consumers : They utilize green plants and obtain their food.

(b) Carnivores or secondary and following level consumers : They predate upon herbivores and other carnivorous animals to obtain food. Carnivores which consume herbivores are the second order consumers. Carnivores which consume other carnivorous animals constitute third and higher order consumers.

(c) Omnivorous organisms : They utilize plants as well as animals as their food.

(d) Decomposers : They fulfill their nutritional requirements by decomposing dead bodies of plants and animals. They convert complex organic matter into simple organic constituents and then transform these into inorganic constituents.

(2) Abiotic components :

All the non-living constituents of an ecosystem are included in the abiotic components. The most important abiotic components are divided into two categories : i) Climatic factors and ii) Edaphic factors.

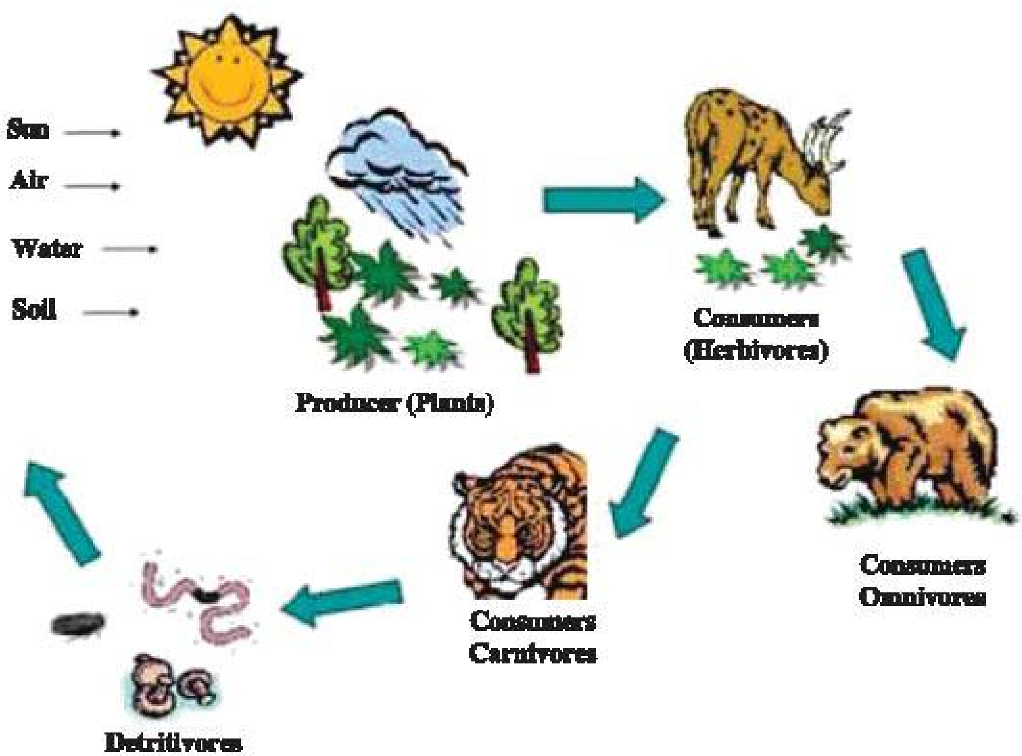


Fig. 17.1 Components of ecosystem

Climatic factors include temperature, water, light, wind, pH, mineral elements, topography and habitat while edaphic factors include soil structure and composition.

Food Chains and Food Webs : Living organisms depend on each other for their food requirement and form a chain. This is termed as food chain. Each step or level of food chain forms a trophic level. Thus, producers form first trophic level, herbivores the second and carnivores the third. As an example, a food chain might consist of grasses, fed upon by grasshoppers which, in turn are fed upon by rats which in turn are fed upon by kites or hawks. Thus food chain usually starts with primary producers and ends with carnivores.

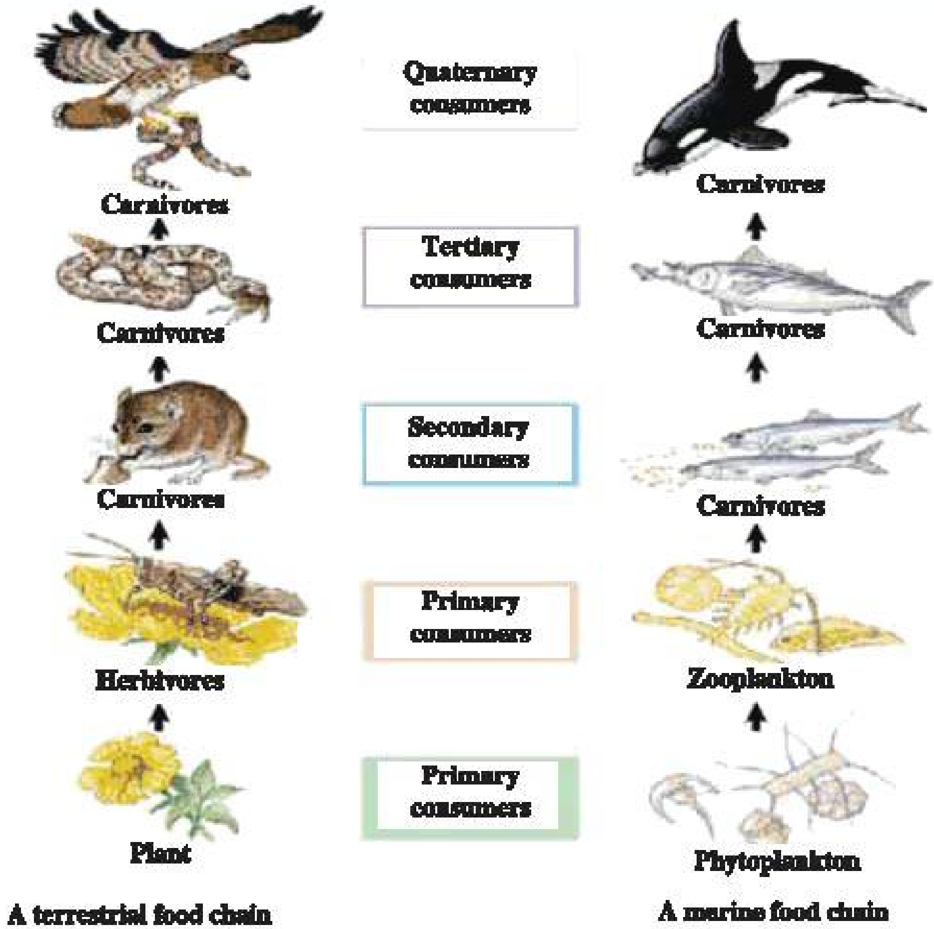


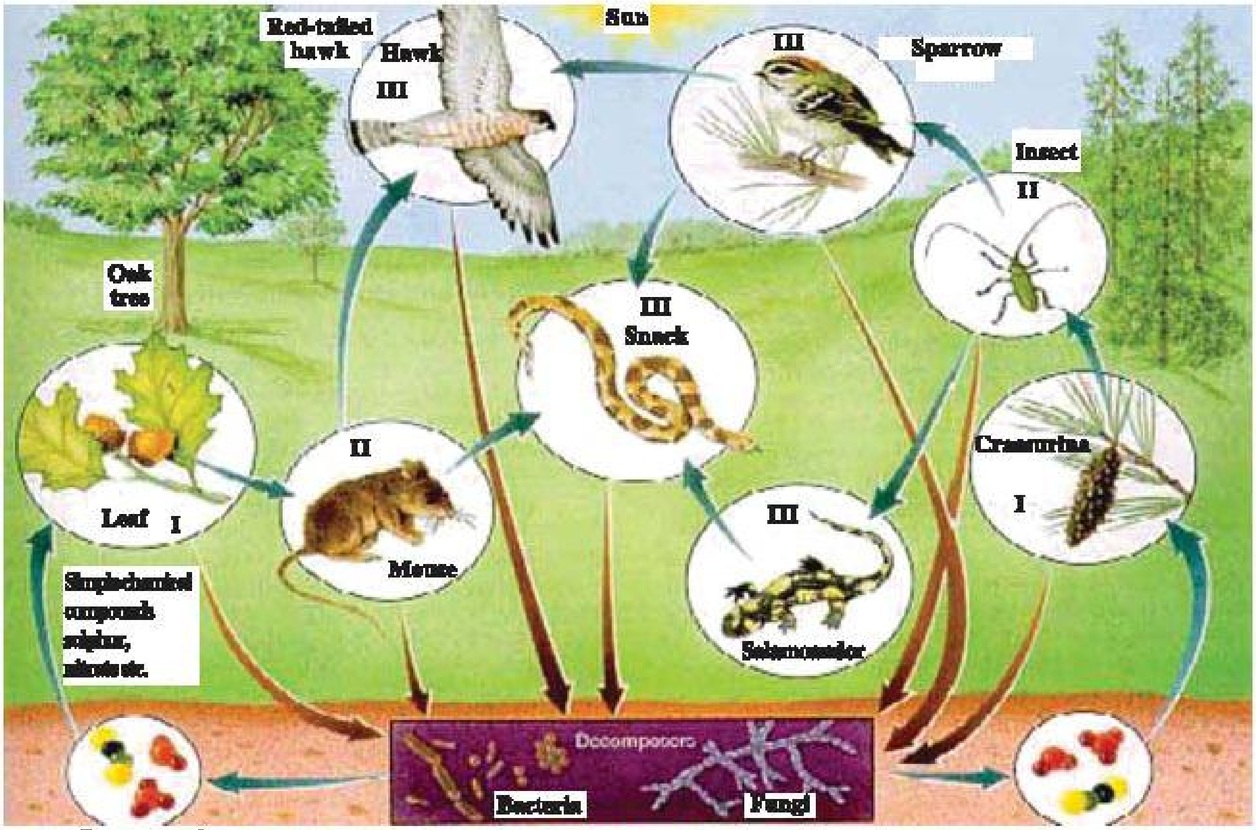
Fig. 17.2 Trophic level of food chain

Food chains : Food chains are of two types – grazing food chain and detritus food chain. A grazing food chain begins with chlorophyllous producers and extends through herbivores, carnivores and decomposers. A detritus food chain begins with decomposers which live on dead organic matter and passes through detritus feeding organisms in soil to organisms feeding on detritus feeders.

A food chain describes how energy and nutrients move through an ecosystem. The autotrophs or the producers are at the first trophic level that produce the energy. The energy then moves up to higher level organisms like herbivores. After that when carnivores eat herbivores, energy is transfered from one to the other. Thus green plants are the only source of energy which capture the energy present in sunlight and convert it into chemical energy. This energy supports all the activities of living world. The flow of energy in an ecosystem is always unidirectional. The energy that is captured by green plants does not revert back to the sun and the energy which passes to the herbivores does not come back to the autotrophs. As it moves progressively through the various trophic levels it is no longer available to the previous level.

Due to uncontrolled use of pesticides and other chemicals in order to protect the crops from diseases or pests, the amount of these chemicals increases in the soil or water bodies. From soil or water they enter in the body of plants and then in the bodies of herbivores and carnivores. As these chemicals are not degradable, they get accumulated progressively at each trophic level. This phenomenon is known as Biological magnification.

The trophic inter-relationship between animals in nature cannot be explained as simple food chains only. Among the various ecosystems, each one is having definite food chain. The individuals involved are also linked with food chains of other ecosystems. In this way, the animals are inter-dependent for food and they form a net which is termed as a food web.



Decomposed Molecules

Fig. 17.3 Food web

Decomposed Molecules

17.3 Global Problems

Global problems are not just important problems that affect directly to individual man, but they are those problems that affect the whole planet and potentially all the people who live on it.

Climate change is one of the best examples. It is a result of human generated change. Some of the global problems faced by the living organisms are : global warming and depletion of the ozone layer, biodiversity and ecosystem losses, fisheries, depletion, deforestation, water deficits, waste disposal and maritime safety and pollution. In this chapter we shall be looking at two of the environmental problems in detail which are depletion of the ozone layer and waste disposal.

17.4 Ozone Layer and Its Depletion

The atmosphere of the earth is stratified. The nearest to our earth is troposphere. At a height of about 50 km in the stratosphere, the ozone layer is located. This layer absorbs UV-radiation from the sunlight and prevent it from reaching the earth.

Ozone is formed when oxygen molecules absorb ultraviolet photons and undergo a chemical reaction known as photodissociation or photolysis, where a single molecule of oxygen breaks down two oxygen atoms. The free oxygen atom (O), then combines with an oxygen molecule and forms a molecule of ozone (O_3).

$$O_2 \longrightarrow O + O$$

$$O + O_2 \longrightarrow \underset{\text{(Ozone)}}{O_3}$$

The ozone molecules, in turn absorb ultraviolet rays between 310 to 200 nm wavelength and thereby, prevent these harmful radiations from entering the Earth's atmosphere.

The depletion of the ozone layer in the stratosphere is turning out to be serious problem. This fact was first noticed in the year 1980. Depletion of ozone layer is noticed all over the earth. It is observed that around 40 to 50% depletion in ozone layer occurs in the south polar region. Such a large reduction is called ozone hole. Such ozone holes were later noticed in North polar region also. The probability of development of ozone holes also exists in other regions where human inhabitation is present. Where this will occur or not depends on the prevalent wind, climatic conditions and suspended particulate matter in the atmosphere.

The main factor responsible for the depletion of ozone layer is the addition of Cl in the atmosphere. The chlorine atom reacts with ozone and removes an atom of O one by one. One atom of chlorine can decompose 100,000 molecules of ozone in this fashion. The most important compound which accounts almost 80% of the total depletion of ozone in the stratosphere is chlorofluorocarbon (CFC). One such substance, Freon, is used in refrigerator and airconditioners.

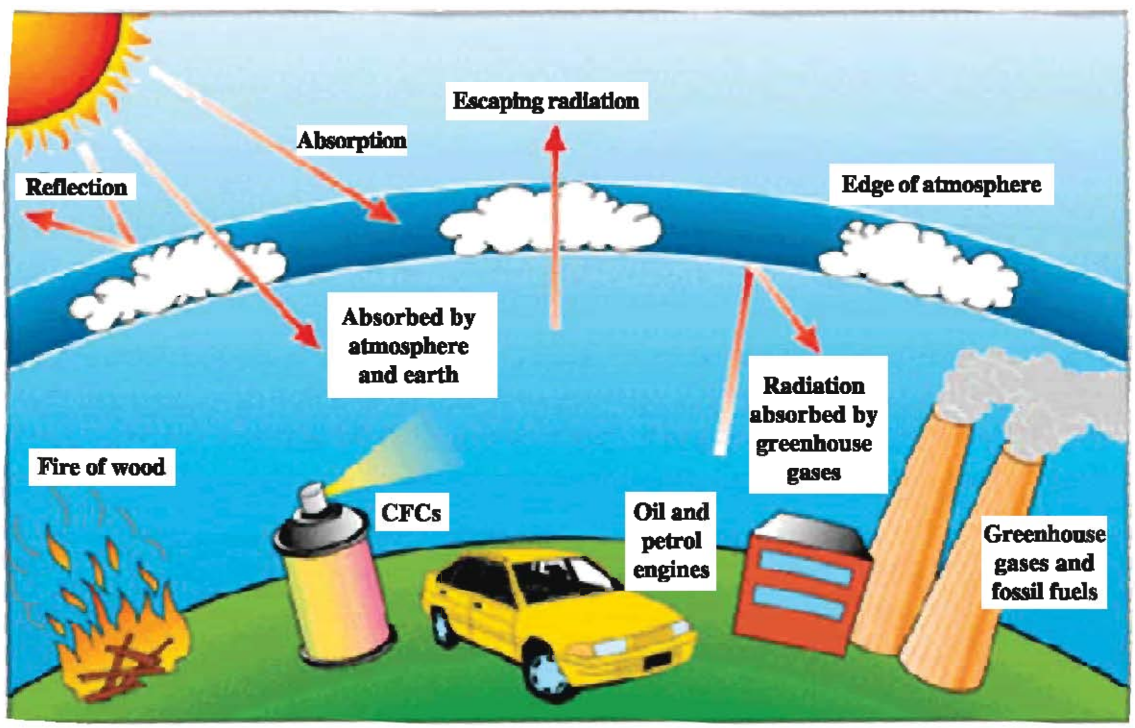


Fig. 17.4 Depletion of ozone layer

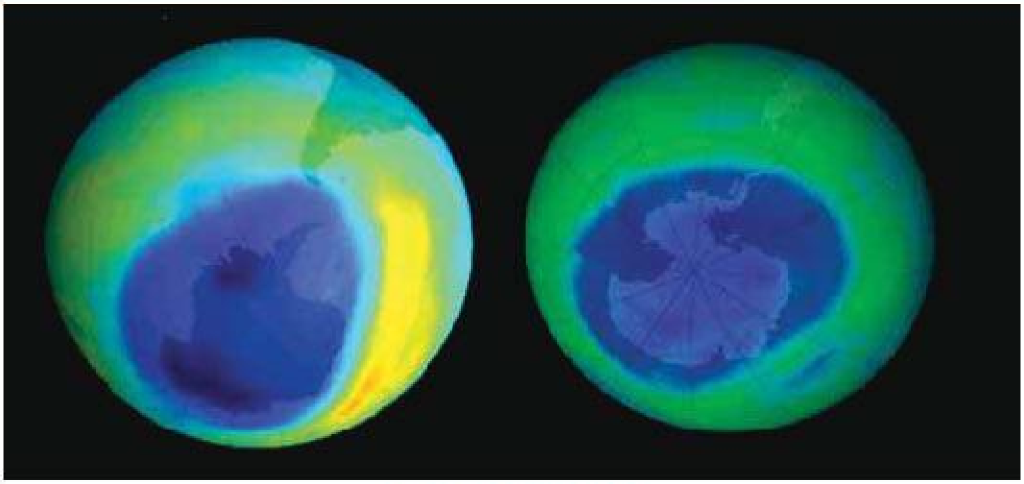


Fig. 17.5 Ozone holes

17.5 Household Waste Management

Wastes are unwanted, unusable items, remains or byproduct of household garbage. The waste generated in our homes are classified into two major forms namely solid and liquid. The liquid forms are easy to handle and manage. They can be connected from their sources to septic and soak away pits. The solid wastes are relatively different in their management.

Studies indicate that on an average, each person in urban areas produces half a kilogram of garbage everyday. This garbage takes up precious land and is a major source of disease. Just a few kilos of putrid garbage can cause a dangerous epidemic disease. If we continue to accumulate garbage at the current rate, our children and grandchildren will have no hope for a quality life in future. Therefore, it is important to reduce the amount of waste we produce. This can be done in the following ways :

- Buy loose fruits and vegetables in order to avoid packaging
- Do not buy disposable items such as razors and pens
- Use reusable nappies
- Buy reusable carry bags from supermarkets
- Use rechargeable batteries
- Do not throw old clothes and shoes but donate them
- Reuse the back of papers as scrap paper
- Put kitchen waste inside the bags or container as soon as they are generated and as soon as they are filled dispose them at the designated place.

Waste in our homes, though unwanted, can be a source of extra income when properly managed.

What have you learnt ?

All organisms including plants, animals and human beings and their physical surroundings with which they interact is called environment. A change in any component of environment may cause discomfort and affect normal life of living organisms.

Unwanted, unusable items, remains and biproduct of household garbage are called waste. Wastes are classified into two forms : solid and liquid. The waste materials which are broken by biological processes are called biodegradable and those which are not broken down by biological processes are called non-biodegradable.

The biotic community, together with physical environment forms an interacting system called as ecosystem. Based on the kind of habitat, an ecosystem may be aquatic and terrestrial. Aquatic ecosystem may be fresh water or marine. Each ecosystem consists of biotic and abiotic components. Biotic components may be producers or consumers while abiotic components include soil, water, light, air, temperature, wind, rain, humidity inorganic nutrients and dead organic matter.

Living organisms depend on each other for their food requirement and form a chain which is termed as food chain. A food chain describes how energy and nutrients move through an ecosystem. However, the trophic inter-relationship between animals in nature cannot be explained as simple food chains only. Among the various ecosystems, each one is having definite food chain. The individuals involved are also linked with food chains of other ecosystem. In this way, the animals are inter-dependent for food and they form a net which is termed as a food web.

Global warming and depletion of ozone layer, biodiversity and ecosystem losses, fisheries' depletion, deforestation, water deficits, waste disposal and pollution are global problems faced by the living organisms.

The ozone layer is located in the stratosphere. This layer absorbs UV radiations from the sunlight and prevents it from reaching the earth. However, the depletion of the ozone layer is reported all over the earth. The main factor responsible for the depletion of ozone layer is the addition of Cl in the atmosphere.

It is essential to reduce the amount of waste we produce. This can be done in the following ways :

Buy loose fruits and vegetables in order to avoid packaging, do not buy disposable items such as razors and pens, use reusable nappies, buy reusable carry bags from supermarkets, use rechargeable batteries, donate old cloths and shoes, reuse the back of papers as a scrap paper and put kitchen waste inside the bags or container as soon as they are generated and as soon as they are filled up dispose them at the designated place.

EXERCISE

1. Select the proper choice from the given multiple choices :

(1) Which of the following is an example of biodegradable waste :

(A) Vegetables (B) Glass (C) Plastic (D) Metal

(2) Which of the following is an example of non-biodegradable waste :

(A) Fruits (B) Vegetables (C) Paper (D) Polythene

(3) Ecosystem is an interacting system made up of :

(A) Organisms and their physical surroundings

(B) Producers and consumers

(C) Producers and their physical surroundings

(D) Consumers and their physical surroundings

(4) The structural and functional unit of the environment is known as :

(A) Food chain (B) Food web (C) Ecosystem (D) None of them

(5) First order consumers are :

(A) Carnivores (B) Herbivores (C) Decomposers (D) Omnivores

(6) Omnivorous organisms consume :

(A) Only plants (B) Only animals

(C) Plants and aminals both (D) Microorganisms

(7) Edaphic factors are included in :

(A) Abiotic components (B) Biotic components

(C) Producers (D) Consumers

(8) How many molecules of ozone can be decomposed by one atom of chlorine ?

(A) 10,000 (B) 1,00,000 (C) 1,000,000 (D) 1000

(9) The most important compound which accounts for almost 80% of the total depletion of ozone layer is :

(A) Chloride ion (B) Sulphur ion

(C) Chlorofluoro carbon (D) Magnesium ion

2. Answer the following questions in brief :

(1) What is an environment.

(2) Define ecosystem.

(3) Define food chain and food web.

(4) Give examples of solid waste.

(5) What do you mean by biodegradable waste ?

(6) Give examples of non-biodegradable waste.

(7) How ozone is formed ?

(8) Name compounds responsible for depletion of ozone layer.

3. Write answers of the following questions :

(1) Describe the types of waste.

(2) Explain the components of an ecosystem.

(3) Explain food chain giving suitable example.

(4) Explain food web giving suitable example.

(5) What are the global problems ?

(6) How amount of household waste can be reduced ?

4. Answer the following questions in detail :

(1) Explain Food Chain (with figure)

(2) Explain Food web (with figure)

UNIT

18

Management of Natural Resources

Man depends on the nature for his requirements. For thousands of years the earth has been fulfilling our basic requirements like air, water, light, habitat, food and clothes. Our increasing demand of energy, as a result of our cultural evolution, development of agriculture and technological advances is also fulfilled by the earth.

The naturally occurring resources, which cannot be created by man, are termed our natural wealth. Those components of the atmosphere, hydrosphere and lithosphere which can be used for the maintenance of life are called natural resources e.g., water, land, forest, minerals, plants and animals.

In Std. IX, we have studied some of the natural resources and how various components are cycled over and over again in nature. In this chapter we shall study some of the natural resources like forest, wild life, coal and petroleum and how these resources are to be managed for sustainable development.

18.1 How We Should Make Use of Natural Resources

On this earth, man is the most developed organism. He is able to speak fluently, can write legibly and has curiosity to know new things. For making life luxurious and comfortable, man started adopting industrialization and started building roads, canals, dams, houses, satellites, cars, motors, ships, aeroplanes, submarines, missiles, rockets etc. To achieve his goal, man has destroyed nature to a great extent, so much so that even the natural products, environment etc, are also destroyed. Man has cut forests and ground plants for agriculture, shelter and factories and developed villages and cities. In natural surroundings, he has built his own social and cultural environment using various instruments, skills and intelligence. All these activities have caused an imbalance in the environment.

It will be a huge error if man continues to believe that all his essential natural resources are unlimited and he can exploit them in any way or in any amount as per his wishes. An indiscriminate and rampant use of natural resources are creating serious danger for existence of humans and their culture.

The amount of water, trees, minerals and other natural resources on the earth is limited while the number of people using these resources is growing rapidly. But the number of people is not the real problem. The problem is how these natural resources are used. Whenever one person or group of people uses more than their fair share of resources, or causes an excess of pollution, this imbalance can lead to environmental health problems for others. Hence there is a need to use natural resources rationally and judiciously.

18.2 Applications to Save Environment

You must have come across three R's to save the environment. These are Reduce, Recycle and Reuse.

(A) Reduce : This indicates minimization of use of natural resources. One can save electricity by switching off unnecessary lights and fans. Water can be saved by avoiding misuse and wastage of water, by repairing the leaking taps or even by developing a proper distribution system of available water. We can reduce the use of LPG by making use of solar cooker for cooking food. If the mineral resources are used sensibly and repeatedly, mining and dredging for their search can be reduced.

(B) Recycle : Plastic, papers, glass, metals and scraps produced by the industries can be melted at appropriate temperature and new materials can be produced. This process is known as recycling. In order to recycle, we first need to segregate our wastes so that the material that can be recycled is not dumped along with other wastes.

(C) Reuse : As the process of recycling uses some energy, the method of reuse is always considered better. Pieces of colored glass, cups and plates made of china clay, ceramic tiles, etc. can be used to make decorative wall pieces. The plastic bottles in which you buy various food items like jam or pickle can be used for storing things like salt, sugar, tea leaves, pulses etc. in the kitchen.

18.3 Why do We Need to Manage Our Resources

All the things like food, clothes, furniture, fuels, vehicles, water etc. which we use are obtained from the resources on this earth. As the resources on the earth are limited while the human population is increasing at a tremendous rate, the demand of resources is also increasing day by day. Hence, proper management is required to ensure that the natural resources are used judiciously.

The proper management can ensure equitable distribution of natural resources so that all the people can benefit from the development of these resources.

The proper management will take into consideration the damage caused to the environment during extraction or use of the natural resources and find ways and means to minimize this damage. For example, if some trees have to be cut for some reason, then the damage to the environment can be minimized by planting new saplings in place of cut out trees.

18.4 Forest and Wild Life

(1) Forests : We all know that forests are our most valuable resources. We get food, fodder, fibres, timber, fuel wood, medicines, gum, resins and bamboo from the forest. Bamboos are mostly used to make slats for huts and baskets for storing things. However, with the increasing population of human being, forests have been cut down. At present forest area and its quality have remarkably decreased. In our country only 768436 sq. km. area is under the forest which covers 23.38 percent of the total land area. In Gujarat total 18999 sq. km. area is covered by the forest which constitutes 9.69 percent of the total land area.

Forest cover of the world is rapidly depleting. It is more rapid in developing countries. The reasons are : rapidly increasing population, industrialization and urbanization. Destruction of the forest is very rapid, particularly in the tropical region. Deforestation has serious effects. Deforestation induces changes in the regional and global climate. Due to the destruction of forests, the rain fall decreases. Loss of forest cover causes increase in soil erosion, decrease in the fertility of land, increase in the amount of CO_2 and temperature in the atmosphere. This leads to green house effects.

In our country the rate of deforestation is very high. If deforestation continues at the same rate, the day is not far off when we may be deprived of all these things which we get from forest. Therefore, we must conserve forest in the following ways:

- Scientific methods should be adopted for harvesting the forests.
- Scientific methods should be adopted to monitor proper rate of forestation and deforestation.
- Forest should be protected from fire.
- Unauthorised felling of trees should be prevented.
- Fast growing tree should be planted.
- Social forestry should be adopted. People should plant fast-growing trees on available land such as boundaries of fields, along the road sides and railway tracts, along canals etc. to get fire wood, fodder, timber, fruits etc.

In our country there are instances where local people working traditionally for conservation of forests. For example, the case of Bishnoi community in Rajasthan, for whom conservation of forest and wild life has been a religious tenet. The Government of India has recently instituted an Amrita Devi Bishnoi National Award for wild life conservation in memory of Amrita Devi Bishnoi who in 1731 sacrificed her life along with 363 others for the protection of Khejri trees in Khejrali village near Jodhpur in Rajasthan.

(2) Wild life : Normally we imagine dangerous animals such as elephant, tiger, lion, python, crocodile as wild life. But when put in the definition of wild life, those animals that are not domestic, those plants that cannot grow by agriculture and microorganisms are also included.

Wild life is not only economically beneficial but it is also an important component of the food web of ecosystem. Therefore, it is helpful in maintaining the balance of the ecosystem. The main importance of wild life is success of the gene bank. Men use them for developing many varieties of plants and animals in agriculture, animal husbandry, fishery etc.

Those plants and animals that are on the threshold of getting destroyed or extinct are called endangered wild species. Bear, elephant, tiger, lion, rhinoceros, snow leopard, gudkhar, dugong, Kashmiri stag, a deer called Baresingha and Deer of Manipur, several birds like Pheasant, Great Indian bustards, Florican, Hornbill etc. are endangered species. While reptiles like Python, Wall lizard, Crocodile, and many types of Tortoise are endangered species. Many plant species are also endangered. Endangered plant species are published in the book called Red Data Book.

The importance of wild life has been recognized by all the countries of the world. In our country several laws are framed for the protection of environment and wild life of which the main act is Wild Life Conservation Act of 1972. Many areas have been declared as sanctuaries and many are declared as national parks in order to protect wild life and to increase their number. In national parks wild lives are allowed to survive without interference with human activities. In sanctuaries also wild life is protected but many necessary human activities are allowed. As per the current report of 2010, in our country a total of 88 national parks and 441 wild life sanctuaries are there. While in Gujarat, there are 4 national parks and 21 wild life sanctuaries.

Lion

Barehsinga

Fig. 18.1 Endangered wild species

18.5 Stalkeholders of Forest

When we consider the conservation of the forest, following are the stalkeholders who take part in the management of forest.

(1) The people who live in or around forests are dependent on forest produce for various aspects of their life. These people get firewood from the forest tree. They cut the branches and pluck leaves but do not cut down the whole tree. They cut bamboo for making their huts and baskets. They make use of wood for making agricultural implements and collect fruits, fodder, medicines from the plants. In fact people living near or in the forest had developed practices to ensure that the forest resources should be used in a sustainable manner.

(2) The forest department of the government which owns the land and control the resources from the forest. The forest is a good source of revenue for the government. Most of the revenue comes from the sale of cut down trees for the timber. In order to plant trees for timber such as pine, teak and eucalyptus, huge area of the forest is cleared of all vegetation. This destroys a large amount of biodiversity in the area which harms the environment. The forests are also damaged by constructing the dams in the forest as well as building the roads through the forest.

(3) The industrialists who use various forest products and consider the forests as merely a source of raw materials for their industry. Timber industry, paper manufacturing industry, lac

industry and sports equipment industry are mostly dependent on forests. For making bidies, tendu leaves are used. The main source of tendu leaves is forest.

(4) The wild life and nature enthusiasts who want to conserve nature in pristine form (original form). These people are not dependent on the forests, but they want that forest and wild life should be conserved to prevent the damage to the environment. The example of the naturalists towards the conservation of forest is Chipko Andolan (Hug the trees movement). The Andolan was originated from an incident in a remote village called "Reni" in Garhwal in the early 1970s. There was a dispute between local villagers and a logging contractor who had been allowed to fell trees in a forest near the village. One day the contractor's workers appeared in the forest to cut the trees but the men folk were absent. However, the women from the village reached the forest quickly and clasped the tree trunks preventing the workers from felling the trees. Thus the forest trees were saved.

Fig. 18.2 Chipko Andolan

18.6 Water

Life is impossible without water. Water plays a key role in a control of climatic conditions. The water in the seas absorbs or releases heat and helps to maintain the atmospheric temperature by keeping it cool or warm. Water is used in agriculture, industries and in the production of electricity. Usually man depends upon fresh water. The earth depends mainly on rain to maintain the quantity of fresh water. Irregularities in rainfall leads to either floods or drought causing disaster. Fresh water is a key factor in the lives of man and other living organisms.

(1) Water for all : Some parts of our country have good resources of water while in other parts there is a shortage of water. The regions having good availability of water are flourishing because they have good crops but the regions having shortage of water are facing poverty because of poor crop growth. It is therefore, necessary to have a proper management system so that there is a uniform distribution of water to all the regions.

There are three sources of fresh water – the rainfall, the riverstreams and the ground water.

Rainwater is available in monsoon only. As monsoon lasts for a few months, most of the rain water lasts for a few months only. This rain water fills lakes and ponds and also flows into rivers. Some rain water also percolates into ground and become available as ground water. Rain water is stored in lakes for use over a long period of time. There are many natural lakes in our country but in order to meet the increasing demand of fresh water many artificial lakes are made.

Rivers are another important sources of water. In our country, rivers flow across diverse regions. Some of these rivers are large and are perennially filled with water. Rivers get their water supply from the melting of snow lying on the peaks of snow mountains.

The water inside the soil is called groundwater. This water which has percolated deep into the ground is clean. We are at present, utilizing nearly 25% ground water. Most of it is used in agriculture. The availability of this water is decreasing due to its overuse and deposition of salts and pollutants in it.

(2) Water related problems : More than 40 % of the world population lives in arid or semi-arid regions. Regions of Saurashtra and North Gujarat in our state are also semi-arid. Arid desert occurs in Kachchh. People living in such regions spent a major part of life in gathering water. A huge amount of wealth and manpower are used in other regions also in obtaining potable water, water for agriculture and water for industries. Due to over-exploitation, water levels are going down in rivers, lakes and ponds. This also affects the surrounding wetlands, which then dry up. Large amount is also sucked out from the ground water to meet the increasing demand. Looking to this, it is obvious that water conservation and water management require immediate attention.

(3) Water Management : Water management means a program to provide an adequate supply of good quality of water for different purposes without causing any harm to the source of water. Some of the approaches to water management are as under :

1. In hilly areas or flood prone areas, big water reservoir, ponds or dams should be constructed so that rain water and used water may be stored. This water percolates gradually and becomes ground water.
2. Canals should be constructed from the areas of excess water to the desert areas.
3. Domestic used water or municipal water should be recycled and should be used for irrigation.
4. By distillation, salt contents of sea water should be removed so that it may become drinkable. This is being adopted in Bhavnagar.
5. Excess use of water and wastage should be prevented as far as possible.

Fig : 18.3 Narmada Canal

(4) Dams : For the storage of water smaller or larger dams can be constructed across the flow of water in rivers. In our country dams have been constructed across many rivers. The large reservoir of a dam stores a huge amount of water. This stored water is then allowed to flow downstream at the desired rate . In Gujarat state such two dams have been constructed.

(1) Dharoi dam has been built across the Sabarmati river in Dharoi village.

(2) Sardar Sarovar dam has been built across the Narmada river in Kevadia village.

Dams are useful to the society in the following ways :

(1) Water from a dam is used for irrigation in fields through a network of canals. Dams ensure round the year water supply to the crop fileds.

(2) Water from a dam is supplied to the people in towns and cities through pipelines after suitable treatment.

(3) The falling water from the dams is used for generating electricity.

Fig : 18.4 Sardar Sarovar Dam

18.7 Coal and Petroleum

Coal and petroleum are fossile fuels. They are important sources of energy for us. Since the industrial revolution, we have been using increasing amounts of energy to meet our basic needs and for the manufacture of a large number of goods upon which our lives depend. These energy needs have been largely met by the reserves of coal and petroleum. The use of coal and petroleum and their products in the world economy is immense. Coal is an important fuel source as its energy is converted into other forms of energy such as electricity, steam and coal gas. It is used as a fuel as such in homes and in industry or it is used to generate electricity at thermal power plants.

Petroleum is often referred to as liquid gold due to its importance as a fuel in transport to run scooter, motorcycles, cars, buses, trucks, trains, ships and aeroplanes. It is used in forms of petrol, diesel, kerosene, gas oil, fuel oil etc. Kerosene and LPG (Liquefied Petroleum Gas) obtained from petroleum are used as domestic fuel for cooking food. Petroleum is a source of over hundred and fifty petrochemicals used in industrial and consumer applications. The prosperity of any country depends upon petroleum reserves.

18.8 Management of Coal and Petroleum

The management of these non-renewable energy sources involves slightly different perspective from those resources discussed earlier in the term of policy and technology issues. One way of conservation and managing of these resources is to substitute existing technology so that hydrocarbon fuels are more efficiently used or used less. For example, the use of vehicles with more efficient mileage and exhaust characteristics is a substitution of fuel. Some technologies in cars now use alternate fuel in combination with petrol (alcohol mixed petroleum) or completely use biofuel. Biogas can replace liquid petroleum fuel for cooking in rural areas.

Finding non conventional and renewable sources can also conserve these resources. Power generation technologies can be developed by using wind energy through windmills, hydro energy and nuclear energy for generating electricity. Steam turbines and solar energy based technologies can be used to reduce the dependence on hydrocarbon fuels. Following steps can be taken to conserve energy resources :

- Switch off the lights, fans, television and other electrical appliances when not needed.
- Make use of stairs instead of lift at least upto two to three floors in a building.
- Pressure cookers should be used to save the fuels.
- Public transport system (local buses and trains) in the cities should be made available so people do not use their own vehicles to commute.
- Bicycles can be used to cover short distances.

What have you learnt ?

Man depends on nature for his requirement. The naturally occurring resources, which cannot be created by man, are termed our natural wealth. e.g., water, land, forest, minerals, plants and animals.

It will be a huge error if man continues to believe that all the essential natural resources are unlimited and he can exploit them in any way or in any amount as per his wishes. An indiscriminate and rampant use of natural resources are creating serious danger for existence of humans and their culture. Three R's namely reduce, recycle and reuse, have been suggested to save the environment.

We all know that forests are our most valuable resources. At present forest area and its quality have remarkably decreased. In our country only 768436 sq. km. area is under the forest which covers 23.38% of the total land area. In Gujarat total 18999 sq. km. area is covered by the forest which constitutes 9.69 % of the total land area. Due to the destruction of forests, the rain fall decreases. Loss of forest cover causes increase in soil erosion, decrease in the fertility of land, increase in the amount of CO_2 and temperature in the atmosphere. This leads to green house effects.

Those animals that are not domestic, those plants that cannot grow by agriculture and microorganisms are considered as wild life. Those plants and animals that are on the threshold of getting destroyed or extinct are called endangered wild species. The importance of wild life has been recognized by all the countries of the world. In our country, several laws are framed for the protection of environment and wild life of which the main act is Wild Life Conservation Act of 1972. Many areas have been declared as sanctuaries and many are declared as national parks in order to protect wild life. The stalkeholders of forest are : (1) The people who live in or around forest, (2) The government Forest Department (3) The industrialists (4) The wild life and nature enthusiasts.

Water plays a key role in control of climatic condition. The earth depends mainly on rain to maintain the quantity of fresh water. Irregularities in rainfall leads to either floods or drought causing disaster. Fresh water is a key factor in the lives of man and other living organisms. There are three sources of fresh water - the rainfall, the riverstreams and the ground water.

More than 40 % of the world population lives in arid or semi-arid regions. A huge amount of wealth and manpower are used in other regions also in obtaining potable water, water for agriculture and water for industries. Due to over-exploitation, water levels are going down in rivers, lakes and ponds. This also affects the surrounding wetlands, which then dry up. Large amount of water is also sucked out from the ground water to meet the increasing demand. Looking to this it is obvious that water conservation and water management require immediate attention.

The use of coal and petroleum and their products in the world economy is immense. Coal is an important fuel source as its energy is converted into other forms of energy such as electricity, steam and coal gas. It is used as a fuel as such in homes and in industry or it is used to generate electricity at thermal power plants. As these resources are limited, there is a need to conserve and manage them properly.

EXERCISE

1. Select the proper choice from the given multiple choices :

(1) To reduce the use of LPG by making use of solar energy is an example of :

(A) Recycle (B) Reduce (C) Reuse (D) none of them

(2) How much area is under the forest cover in our country ?

(A) 758330 sq. km. (B) 768436 sq. km.

(C) 750093 sq. km. (D) 749832 sq.km.

(3) In Gujarat how much area is covered by forest ?

(A) 9.32 % (B) 9. 86 % (C) 9.69 % (D) 9.99 %

(4) In which year Amrita Devi Bisnoi sacrificed her life for the protection of khejri trees ?

(A) 1731 (B) 1763 (C) 1783 (D) 1873

(5) Names of endangered plant species are published in :

(A) Green Data Book (B) Red Data Book

(C) Endangered species book (D) Yellow Data Book

(6) How many National Parks are there in Gujarat ?

(A) 5 (B) 4 (C) 21 (D) 24

(7) Which of the following dams is constructed in Gujarat ?

(A) Narmada Dam (B) Sardar Dam

(C) Sardar Sarovar Dam (D) Tapi River Dam

(8) Which one of the following is considered as liquid gold

(A) Kerosene (B) Diesel (C) Petroleum (D) Fuel oil

2. Answer the following questions in brief :

(1) What creates serious danger for existence of humans and their culture ?

(2) Mention three R's which can save the environment.

(3) Define natural resources.

(4) Define wild life.

(5) What are the reasons for depletion of forests ?

(6) What leads to green house effect ?

(7) What do you mean by social forestry ?

(8) Name bird species which are considered as endangered species.

(9) Name reptiles which are considered as endangered species.

(10) In our country how many sanctuaries and national parks are there ?

(11) Mention the sources of fresh water.

(12) How dams are useful to the society ?

3. Write answers of following questions :

(1) Why we need to manage our resources ?

(2) It will be a huge error if man continues to believe that all natural resources are unlimited : Explain

(3) How recycle can save the environment ?

(4) How can we conserve the forest ?

(5) Give an example indicating local people working traditionally for conservation of forest.

(6) What are the consequences of loss of forest cover ?

(7) What are the differences between sanctuaries and national parks ?

(8) Who are the stakeholders of forest?

(9) Give the importance of Chipko Andolan.

(10) Explain water related problems .

(11) Explain approaches to the water management.

(12) What steps could be taken to conserve energy resources ?