Optional Science

Grade 9

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Government of Nepal
Ministry of Education
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Publisher: Government of Nepal
Ministry of Education
Curriculum Development Centre
Sanothimi, Bhaktapur

First Edition: 2017

Price Rs: 126

PREFACE

The curriculum and curricular materials have been developed and revised on a regular basis with the aim of making the education objective-oriented, practical, relevant and job oriented. It is necessary to instill the feelings of nationalism, national integrity and democratic spirit in the students and equip them with morality, discipline and self reliance, creativity and thoughtfulness. It is essential to develop in them the linguistic and mathematical skills, knowledge of science, information and communication technology, environment, health and population and life skills. It is also necessary to bring in them the feeling of preserving and promoting arts and aesthetics, humanistic norms, values and ideals. It has become the need of the present time to make the students aware of respect for ethnicity, gender, disabilities, languages, religion, cultures, regional diversity, human rights and social values so as to make them capable of playing the role of responsible citizens. This textbook has been developed in line with the Secondary Level Optional Science Curriculum, 2072 by incorporating the recommendations of various education commissions and the feedback obtained from various schools, workshops, seminars and interaction programs attended by the teachers, students and parents.

In bringing out the textbook in this form, the contribution of the Executive Director of the Curriculum Development Centre (CDC) Krishna Prasad Kapri, Dr. Hridhaya Ratna Bajracharya, Umanath Lamsal, Baburam Gautam, Puspa Raj Dhakal, Devraj Gurung, Keshar Khulal, Manumaya Bhattrai. The content of the book was edited by Yubraj Adhikari. Language of the book was edited by Ramesh Prasad Ghimire. The layout and artworks of the book were done by Jayaram Kuikel. CDC extends sincere thanks to all those who have contributed in developing this textbook.

This textbook contains a variety of learning materials and exercises which will help learners to achieve the competency and learning outcomes set in the curriculum. Each unit contains various interesting activities and the content required for meaningful learner engagement and interaction. There is uniformity in the presentation of the activities which will certainly make it convenient for the students. The teachers, students and other stakeholders are expected to make constructive comments and suggestions to make it a more useful learning material.

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Content

Unit 1

Force

Isaac Newton was born in Woolsthorpe near Grantham, England. He is generally regarded as the most original and influential theorist in the history of Science. He made many discoveries in multiple fields of science, including the discoveries of gravitational force and the three universal laws of motion.

Newton (1642-1727)

Learning outcomes

After the completion of this unit, learners will be able to

1. Explain the behavioral application of velocity, acceleration, inertia and force
2. Derive the equation of motion and solve numerical problems
3. Describe the principle of momentum with examples
4. Define simple pendulum and demonstrate its uses.

Introduction

We use force to perform various types of activities in our daily life. For examples, to walk on the ground, to lift objects, to displace a body, to throw something, etc. Newton's three laws of motion are also related to force, which we study in compulsory science. In fact, force helps us to change the position of a body from rest to motion or motion to rest. Simply, force means either push or pull. In other words, a force can produce three effects. They are: a force can either increase or decrease the speed of a moving body, a force can change the direction of motion of a body and a force can change the shape and size of the body.

> Force is defined as an external agency which changes or tends to change the state of rest or motion of a body or the speed and direction of a moving body or the shape and size of a body. Mathematically, $F = m \times a$

Force is a vector quantity as it has both magnitude and direction. Its SI unit is newton and measured by spring balance. Forces are of two types: balanced forces and unbalanced forces.

In this chapter we will deal with the study of force, velocity, inertia, and acceleration including derivation of equations of motion, principle of momentum, simple pendulum and its demonstration too.

Balanced forces

Consider a heavy block is lying on a table. Let us push this block with our hands. But, it does not move though four forces are acting on it. The four forces acting on the block are:

a. The force of push

b. The force of friction

c. The force of gravity

d. Force of reaction of ground

Since the block does not move at all, we conclude that the resultant of all forces acting on it is zero. Here, the block behaves as if no force is acting on it. These forces acting on this stationary block are examples of balanced forces. The force of push on the block is balanced by the force of friction, and the force of gravity is balanced by the force of reaction of the ground. While playing a tug of war, the rope is pulled between two teams. If the resultant of force applied by the two teams is zero, the rope does not move in either direction. In this case, the forces exerted by the two teams are balanced. Now, we come to know from this discussion that a body continues to remain in its state of rest if a number of balanced forces act on a resting body. In the same way, a body continues to be in its state of uniform motion if a number of balanced forces act on a moving body.

Though a balanced force can not produce motion in a stationary body or stop a moving body, they can, however, change the shape of the body. An example of a balanced force changing the shape of a body is in the squeezing of rubber ball or balloon. When we press a rubber ball or a balloon between our two hands, the shape of the rubber ball or balloon changes from spherical to oblong. In this case, we apply two equal and opposite forces (balanced forces) with our hands though the ball or balloon does not move but its shape changes.

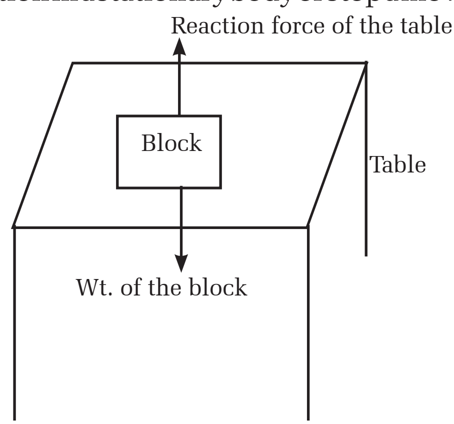


Fig. 1.1 Balanced forces

Therefore, balanced forces are such forces in which the resultant of all the forces acting on a body is zero. In other words, when a number of forces acting simultaneously on a body do not bring about any change in the state of rest or uniform motion in a straight line, the forces acting on the body are said to be balanced forces.

Unbalanced forces

When a toy car lying on the ground is pushed, it starts to move. In this case the above mentioned four forces are acting on the toy car. Here, the force of gravity on the toy car acting downwards and the force of reaction of ground acting upwards are equal and opposite. As a result, they balance each other. But the force of our push is greater than the frictional force. In this case, they cannot balance each other. In doing so, the resultant of all the forces acting on the toy car is not zero. There is net resultant and unbalanced force acting on the toy car which makes the toy car move from its rest position. Thus, pushing force must be greater than the opposing force of friction to move a stationary object.

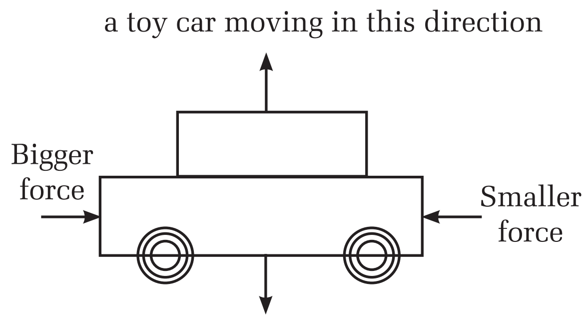


Fig. 1.2 Unbalanced forces

In tug of war, if one of the teams suddenly releases the rope, an unbalanced force acts on the other team due to which the team falls backward. So, in this case, an unbalanced force results in the motion of the weaker team along with the rope they are holding. From the above examples, it is clear that when an unbalanced force acts on a resting body, it produces motion. Unbalanced force can also stop a moving body. For example, a ball rolling on the ground stops after sometimes, due to an unbalanced force of friction acted on it. If the speed or direction of motion of a body changes, it indicates that an unbalanced force is acting on it.

Therefore, unbalanced forces are such forces in which the resultant of all the forces acting on a body is not zero. In another words, when a numbers of forces acting simultaneously on a body bring about a change in its state of rest or uniform motion in a straight line, these forces acting on the body are said to be unbalanced forces.

Differences between balanced and unbalanced forces

Balanced forces	Unbalanced forces
1. Balanced forces do not change the state of rest or state of motion of a body.	1. Unbalanced forces change the state of rest or state of motion of a body.
2. They do not produce acceleration or deceleration.	2. They produce acceleration or deceleration.
3. They can change the shape of the body but not the direction of motion of the body.	3. They can change the shape of the body as well as direction of the moving body.
4. The resultant of all the forces acting on the body is zero.	4. The resultant of all the forces acting on the body is not zero.

Velocity

The speed of a bus (or any body) gives us an idea of how fast the bus is moving but it does not tell us the direction in which the bus is moving. Thus, to know the exact position of a moving bus, we should also know the direction of speed. This gives us another term known as velocity. Velocity tells us how fast a body is moving along a particular direction. It can be defined as the distance travelled by body per unit time in a specified direction. In other words, velocity of a body is its speed in a specified direction. For example, if the velocity of a body is 20 m/s, it means that the body covers 20 m distance in one second in a fixed direction. Depending on the direction of motion, it may be positive or negative or zero. By the definition,

> Do you know?
>
> A car that can accelerate in a short interval of time is considered to be eye candy for anyone with a taste in vehicles. The faster that a car can accelerate to a high velocity is crucial to its performance and handling. A car's acceleration is calculated when the car is not in motion (0 m/s), until the amount of time it takes to reach a velocity of 60 metre per second. This means that the initial velocity is zero and the final velocity is 60 m/s.

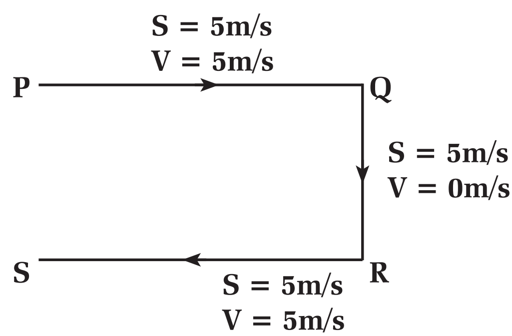
$$\textbf{Velocity} = \frac{\text{Distance travelled in a particular direction}}{\text{Time taken}}$$

$$V = \frac{S}{t}$$

The unit of velocity is metres per second (m/s). It can also be expressed in kilometer per hour and centimeter per second. Velocity has magnitude as well as direction. Therefore, it is a vector quantity.

The statement "Butwal is 114 km far from Narayanghat" means that the road from Narayanghat to Butwal is 114 km long. As we know that this road isn't straight and has innumerable bends in different directions. If a man travels to Butwal from Narayanghat by road, he will cover the distance 114 km. But if we measure the distance in straight line, Butwal is not so far from Narayanghat. It is approximated 50 km south west from Narayanghat. The displacement from Narayanghat to Butwal has both magnitude and direction. So we say that Butwal is about 50 km west from Narayanghat to inform the exact location of Butwal to somebody in Narayanghat.

Suppose a bus is travelling along a straight road PQ, at a constant speed of 5 m/s. Its velocity in the direction PQ will also be 5 m/s. When it turns and takes the route QR, its speed will still be 5 m/s, but its velocity in the original direction PQ will now be zero. When it turns again to travel along RS its speed will still be 5 m/s, but velocity in the original direction QR will be -5 m/s.



Average velocity

When a body is moving along a straight line at a variable speed, the velocity of the body is also variable. In that case, we express the rate of motion of the body in terms of its average velocity. For example, if a body covers a distance of 5 m in the first second, 10 m in the second and 15 m in the third second in a particular direction, the average velocity of the body becomes $= \frac{5+10+15}{3} m/s = \frac{30}{3}$ = 10 m/s in the given direction. Thus, the average velocity of the body is given by the arithmetic mean of the initial velocity and final velocity for a given period of time, i.e.

$$\text{Average velocity } (A_{av}) = \frac{\text{Initial velocity (u) + Final velocity (v)}}{2} = \frac{u+v}{2}$$

On the other hand, if the velocity of a body moving in a specified direction changes in time, the ratio of the displacement to the time taken for the whole journey is known as average velocity. i.e.

$$\text{Average velocity } (A_{av}) = \frac{\text{Total distance travelled in a specified direction}}{\text{Total time taken}}$$

$$= \frac{\mathbf{S}}{\mathbf{t}}$$

Acceleration

In our everyday practice, the moving bodies do not have uniform velocity. It means that the velocity of the body either increases or decreases. The body is said to be accelerating if its velocity is increasing. Similarly, a body is said to be decelerating if its velocity is decelerating. Consider that a car starts to move from rest (initial velocity is zero) and its velocity increases at a steady rate so that after 10 seconds its velocity becomes 20 metres per second. Now, in 10 seconds the velocity has increased by 20 m/s and in one second, the velocity increases is 2 metres per second. The car is said to have an acceleration of 2 metres per second per second. Thus, acceleration of a body is defined as the rate of change of its velocity with time.

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time taken for change}}$$

Now, the change in velocity is the difference between the final velocity and the initial velocity. i.e. Change in velocity = Final velocity- Initial velocity

$$\text{So Acceleration (a)} = \frac{\text{Final velocity(v) - Initial velocity (u)}}{\text{Time taken (t)}}$$

$$\therefore a = \frac{\mathbf{v-u}}{\mathbf{t}}$$

> Do you know?
>
> When a driver inside a moving car presses its accelerator, more fuel passes into the engine and combustion of extra fuel takes place which offers more energy to the car. As a result velocity of the car increases which causes the production of acceleration.

The S.I unit of acceleration is metre per second per second. It can be written as m/s^2. The other units of acceleration which are also sometime used are" centimeters per second square" (cm/s^2) and " kilometers per hour square" (km/h^2). If the motion of the body is in a straight line, acceleration takes place in the direction of velocity; therefore, acceleration is a vector quantity. If a body is moving with uniform velocity, its acceleration will be zero. This is because the difference of two velocities in this case is zero.

Uniform Acceleration

If the change in velocity of a moving object is equal in equal intervals of time, the object is said to be moving with a uniform acceleration. A body has a uniform acceleration if it travels in a straight line and its velocity increases by equal amounts in equal intervals of time. In other words, a body has a uniform acceleration if its velocity changes at a uniform rate. For example; the motion of a freely falling body is an example of uniformly accelerated motion.

Non- Uniform Acceleration

If the change in velocity of the moving object is not equal in equal intervals of time, the object is said to be moving with a non uniform acceleration. In other words, a body has a non-uniform acceleration if its velocity changes at a non-uniform rate. The speed (or velocity) of a bus running on a crowded city road is variable. At one moment the velocity of bus increases whereas at another moment it decreases.

Retardation

Retardation is also known as deceleration or negative acceleration. If the velocity of a body changes, acceleration takes place. The velocity of a body may increase or decrease accordingly. The acceleration is of two types: positive acceleration and negative acceleration. If the velocity of a body increases with respect to time, the acceleration is said to be positive, and if the velocity of a body decreases, the acceleration is said to be negative. A body is said to be retarded if its velocity is decreasing. For example, a train is retarded when it slows down on approaching a station because its velocity decreases. Retardation is measured in the same way as acceleration. Retardation is actually acceleration with the negative sign.

> Do you know?
>
> There are two factors that acceleration depends upon: direction and velocity. If you are in a car moving at a constant speed but it changes direction and it is also accelerating. This also relates to the same car moving around a curve in the road. The speed remains constant but the car is accelerating. This is referred to as 'circular acceleration'.

Equations of motion

When a body moves along a straight line under uniform acceleration, the relation between its velocity, acceleration, distance covered and time taken can be found by using equation which are known as equations of motion. There are three equations for the motion of uniformly accelerating bodies. These equations are illustrated in the following ways:

First equation of motion

Consider a body having initial velocity u. Suppose it is subjected to a uniform acceleration 'a' so that after time 't' its final velocity becomes 'v'. Now from the definition of acceleration, we know that:

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time taken}}$$

$$\text{Acceleration (a)} = \frac{\text{Final velocity(v) - initial velocity (u)}}{\text{Time taken (t)}}$$

$$\text{i.e. } a = \frac{v - u}{t}$$

or, $at = v-u$

or, $at + u = v$

$\therefore$ $v = u + at$ ....(i)

Second equation of motion

Consider a body has an initial velocity 'u' and a uniform acceleration 'a' for time 't' so that its final velocity becomes 'v'. Let the distance travelled by the body in this time be 's'. Since the initial velocity of the body is 'u' and its final velocity is 'v', the average velocity is given by

$$\text{Average velocity (a)} = \frac{\text{Final velocity+ initial velocity}}{2}$$

$$\text{Average velocity} = \frac{u+v}{2}$$

Distance travelled = Average velocity × time taken

or, $s = \frac{u+v}{2} \times t$..(ii)

Putting this value of v in equation (ii),

or, $s = \frac{u+u+at}{2} \times t$

or, $s = \frac{2u+at}{2} \times t$

or, $s = \frac{2u+at^2}{2} \times t$

$s = ut + \frac{1}{2} \times at^2$ ....(iii)

Third equation of motion

The third equation of motion can be obtained by eliminating t in equation no. (i)

We know,

$a = \frac{v-u}{t}$

or $t = \frac{v-u}{a}$

Substituting the value of 't' in equation No. (i), we get

$$s = \frac{u(v-u)}{a} + \frac{1}{2}a\left(\frac{v-u}{a}\right)^2$$

$$or, s = \frac{uv - u^2}{a} + \frac{1}{2}a\frac{(v-u)^2}{a^2}$$

$$or, s = \frac{2uv - 2u^2 + v^2 + 4^2 - 2vu}{2a}$$

$$or, s = \frac{v^2 - u^2}{2a}$$

Do you know?

I f a body starts from rest, its initial velocity u =0
If a body comes to rest, its final velocity, v = 0
If a body moves with uniform velocity, its acceleration, a =0

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

where, v = final velocity   u = Initial
a = acceleration   s = distance travelled

Numerical illustration

A car acquires a velocity of 72 km/hr in 10 seconds just after the start. Calculate its acceleration.

Solution:

Initial velocity (u) = 0 (car starts from rest)

Final velocity (v) = 72km/hr

$$= \frac{72 \times 1000}{60 \times 60} m/s = 20m/s$$

Time taken (t) = 10 s

Acceleration (a) = ?

We know,

$$a = \frac{v - u}{t}$$

$$= \frac{20 - 0}{10}$$

$$= \frac{20}{10}$$

$$= 2 \text{ m/s}^2$$

$\therefore$ The acceleration of the car is 2 m/s^2

b. A bus is running at a constant speed of 90 km/hr. When a driver sees a child 25 m ahead on the road, he applies the brakes. The bus stops in 20m. Calculate the time taken by the bus and its retardation.

Solution:

Initial velocity (u) = 90km/hr

$$= \frac{90 \times 1000}{60 \times 60} \text{ m/s}$$

$$= 25 \text{m/s}$$

Final velocity (v) =0 (bus stops)

Distance travelled (s) =25 m

Time taken (t) = ?

Retardation (-a) = ?

We know,

$V^2 = u^2 + 2as$

or, $0 = (25)^2 + 2 \times a \times 25$

or, $a = \frac{-625}{2 \times 25} = \frac{-25}{2}$

$= -12.5 \text{ m/s}^2$

Again using,

$$t = \frac{v-u}{a}$$

$$t = -\frac{0-25}{12.5}$$

$$t = \frac{25}{12.5}$$

$$t = 2\ s$$

The retardation of the bus is 12.5 m/s^2 and the time taken by the bus to stop is 2 second.

Inertia

Inertia is the property or tendency of a body to resist any change in its state of rest or uniform motion in a straight line. For example, a ball lying on a table will continue to remain there until an external force is applied on it to remove or displace from its original position. The mass of a body is the measure of its inertia. i.e. greater the mass of a body, greater will be its inertia and vice versa. Depending upon the states of motion, there are two types of inertia. They are: inertia of rest and inertia of motion.

Do you know?

Rotational inertia is a property of any object which continues it to rotate. It is a scalar value which tells us how difficult it is to change the rotational velocity of an object around a given rotational axis. Rotational inertia plays a similar role in rotational mechanics to mass in linear mechanics. Indeed, the rotational inertia of an object depends on its mass. It also depends on the distribution of that mass relative to the axis of rotation.

Inertia of rest

The property of a resting body by virtue of which it keeps on resting without application of some external force is called inertia of rest. In other words, the tendency of a body to remain in its state of rest until an external force acts on it is called 'inertia of rest'.

Examples:

a. If a bus starts to move suddenly, the passenger sitting inside it moves backward. When it starts to move suddenly, the lower parts of passenger's body which is in contact with the seat acquires motion along with the bus but the upper part of the body keeps on resting due to the inertia of rest.

b. When a card board over which a coin is placed is flicked, the coin remains in its original position. Initially, both the coin and the card are at rest. When the card is flicked, the card comes into motion. But, the coin remains in its original position due to inertia of rest.

c. We beat a carpet with a stick to separate dust particles. Dust particles are removed from a hanging carpet by beating it with a stick. When the carpet is beaten, it suddenly moves forward while the dust particles tend to remain at rest due to inertia of rest and so fall off.

d. When we shake the branch of a mango tree, mangoes fall. When it is shaken, the branch of the tree comes into motion. Due to inertia of rest, mangoes continue to be at rest and fall from the tree.

Inertia of motion: The property of a moving body by virtue of which it continues to be in a state of motion until an external force acts on it. In other words, the tendency of a moving body to remain in its state of uniform motion in a straight line until an external force acts on it is called 'inertia of motion'.

a. An athlete has to run a long distance before taking a long jump. When an athlete runs before taking a long jump, he acquires velocity due to the inertia of motion. This velocity is added to the velocity at the time of jump which helps him to have a longer jump.

b. When electric current is switched off, the main parts of the fan stop rotating, but the blades attached to it continue to be in the state of rotation. Due to inertia of motion in the blades of the fan, the blades keep on moving for sometime.

c. When a running bus suddenly stops, passengers sitting in it fall forward. Initially, the bus and the passengers are in a state of motion. When it stops suddenly, the lower parts of body of passengers which are in contact with the bus, come to rest, but their upper parts continue to move forward due to inertia of motion.

d. If a horse running fast suddenly stops, the rider is thrown forward if he is not firmly seated. This is due to inertia of motion. When it stops, it comes to rest, but the rider sitting on horse continues to be in a state of motion.

Momentum

Momentum can be defined as "mass in motion." All objects have mass. More effort is needed to stop heavier object than lighter one. Similarly, more force is needed to stop an object moving with a greater speed than another object of the same mass moving with a lesser speed. Therefore, momentum of an object depends upon two variables i.e. mass and velocity. In terms of an equation, the momentum of an object is equal to the product its mass and velocity.

i.e. Momentum = mass $\times$ velocity

In physics, the symbol for the quantity of momentum is p. Thus, the above equation can be rewritten as:
$p = m \times v$

where m is the mass and v is the velocity. From this equation, we conclude that momentum is directly proportional to an object's mass and directly proportional to its velocity.

If a body is at rest, its velocity,
$v = 0$,
$p = 0$

i.e. momentum of a body at rest is zero or the body at rest possesses no momentum. Momentum is a vector quantity, possessing both the magnitude as well as direction. The direction of momentum is as same as the direction of velocity. To get clear idea from this term, let us talk about some common experiences.

In the game of table tennis, if the tennis ball hits a player, he is not hurt but he is hurt with a cricket ball moving with the same speed. This is because the cricket ball is much heavier than the table tennis ball.

A bullet of small mass fired from a gun may kill a person. Though there is small mass but it is with large velocity. Therefore, we observe that impact of motion produced by objects depends on their mass and velocity. Newton identified this quantity and named it as momentum of the body.

Do you know?

There are two kinds of momentum, linear and angular. A spinning object has angular momentum; an object travelling with a velocity along a straight line has linear momentum.

SI unit of momentum

We have learnt that momentum is a product of mass and velocity. The SI unit of mass is kg and the SI unit of velocity is m/s. So, the SI unit of moment is kilogram meter per second($kgms^{-1}$).

Impulse of a force

The momentum change produced by a force is called impulse of that force. It is equal to the product of force and time for which the force acts.

Consider a body of mass 'm' moving with an initial velocity 'u' by applied force F. Its velocity is 'v' after time 't'. Using Newton's second law of motion, Force = rate of change of momentum

Or, $F = \frac{mv-mu}{t}$

Or, $F\times t = mv - mu$

Here, this quantity $F\times t$ is called impulse of force F on the object. Its unit is $kgms^{-1}$.

Principle of conservation of linear momentum

It states that if the resultant external forces acting on a system is zero, the total momentum of the system remains constant i.e. total momentum before collision is equal to total momentum after collision.

Single particle system:

Consider a particle of mass 'm' moving with velocity 'v'. In this case, linear momentum is given by $p = mv$

According to Newton's second law of motion, the force 'F' acting on the particle is equal to the rate of change of momentum. i.e. $F = \frac{dp}{dt}$

Or, $F = \frac{d \times mv}{dt}$ $(p = mv)$

If no external force acts on a system, then $F = 0$

Or, $\frac{d \times mv}{dt} = 0$

Or, mv = constant

$\therefore$ The momentum of a system remains constant.

Two particle system

Let's consider, two objects A and B of masses m_1 and m_2 respectively are moving with velocities u_1 and u_2 in the same direction. These two masses A and B collide for small time t. After collision, they travel with the velocities v_1 and v_2 in original direction.

From Newton's second law of motion,

Force exerted by A on B = Rate of change of momentum of B.

$F_{AB} = \frac{m_2v_2 - m_2u_2}{dt}$

Force exerted by B on A = Rate of change of momentum of A

$F_{BA} = \frac{m_1v_1 - m_1u_1}{dt}$

According to Newton's third law of motion,

$F_{AB} = - F_{BA}$

or, $\frac{m_2v_2 - m_2u_2}{dt} = -\left(\frac{m_1v_1 - m_1u_1}{dt}\right)$

or, $m_2 v_2 - m_2u_2 = -m_1v_1 + m_1u_1$

or, $m_2 v_2 + m_1v_1 = m_1u_1 + m_2u_2$

∴ Total momentum before collision = Total momentum after collision

∴ It clearly proves the principle of conservation of linear momentum.

Numerical Illustration

a. Calculate the momentum of a car weighing 900 kg and moving with a velocity of 25 m/s.

Solution:

Mass of the car (m) = 900 kg

Velocity of the car (v) = 25 m/s

Momentum (p) = ?

We know that,

p = m v

= 900 x 25

=22500 kg m/s

∴ The momentum of a car is 22500 kgm/s

b. Calculate the momentum of a toy car weighting 600 gm and moving with a velocity of 72 km/hr.

Solution:

Mass of the car (m) = 600 gm = 0.6 kg

Velocity of the car (v) = 72 km/hr = 20 m/s

We know that,

$p = m v$

$= 0.6x20$

$= 12.0$ kg m/s

∴ The momentum of a toy is 12 kgm/s

Periodic motion and oscillatory motion

The motion, which repeate itself after equal intervals of time is called a periodic motion. The interval of time is called the time period of the periodic motion. For examples, the motion of the pendulum of a wall clock, oscillations of a mass suspended from a spring, the motion of a planet around the sun, the motion of the hands of a clock, etc.

If a body moves back and forth (to and fro) repeatedly about its mean position, it is said to possess oscillatory or vibratory motion. For example, the motion of the pendulum of a wall clock, oscillations of a mass suspended from a spring, the oscillations of the hands of a walking person, etc.

Simple Pendulum

Let's us discuss about simple pendulum, its picture representation and terms related to it.

A simple pendulum is a heavy point mass suspended by an in extensible, weightless string from a rigid support. The point on a rigid support from where the pendulum is suspended is called point of suspension. The distance between the point of suspension and center of gravity of the bob, is called the length (L) of simple pendulum. The simple pendulum is said to have been suspended. The bob rests in mean position O. The diagram of a simple pendulum is shown alongside.

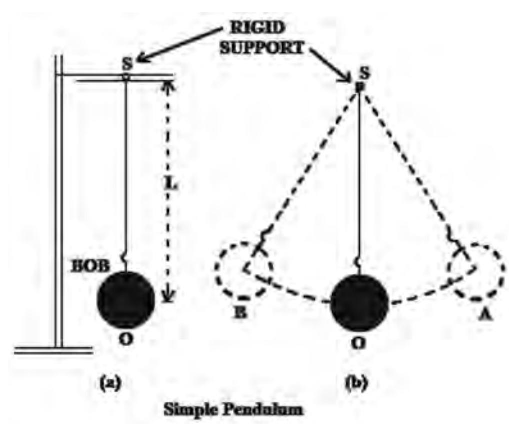


Fig. 1.4 simple pendulum

Simple Harmonic Motion

When an object oscillates with constant time period even if the amplitude varies, we say it is moving with simple harmonic motion. The regular oscillation of a pendulum through a small angle is approximately simple harmonic.

> Do you know?
>
> In 1656, Christiaan Huygens, a Dutch scientist, made the first pendulum clock, regulated by a mechanism with a "natural" period of oscillation. Although Galileo Galilei, sometimes credited with inventing the pendulum, studied its motion as early as 1582, Galileo's design for a clock was not built before his death. Huygens' pendulum clock had an error of less than 1 minute a day.

Let us discuss about the motion of a pendulum. When the bob is slightly moved to one side (right), to extreme position A (above figure), it does not stay there. It moves towards mean position O with increasing speed. Its speed becomes the maximum at mean position. Due to inertia, the bob does not stay at O but over shot to the other side (left) and continues moving ahead with decreasing speed. The speed becomes zero at extreme position B, where the bob comes to rest momentarily. From B, the bob returns back to O and continue moving towards right extreme A.

From A, the motion is repeated as before. In this way, the bob continues its to and fro motion between A and B with O as mean position. The motion of the bob becomes an oscillatory motion. We say that the simple pendulum is oscillating.

Due to friction at rigid support and air resistance for the motion of the bob, the extreme points shift inwardly and the oscillation seem to die out and finally the bob comes to rest at mean position O.

Displacement : At any moment, the distance of a bob from mean position, is called displacement. It is a vector quantity.

Amplitude : Maximum displacement of the bob on either side of the mean position, is called its amplitude. In the above figure OA and OB measure amplitude.

Vibration : The motion of the bob from the mean position to one extreme, then to other extreme and then back to mean position, is called one vibration.

Oscillation : The motion of the bob from one extreme to other extreme, is called one oscillation. Thus, one oscillation is equal to half vibration.

Time Period of a Simple Pendulum

The time taken by the bob to complete one vibration is called the time period of the pendulum. It is represented by the symbol T. The time period of a simple pendulum is expressed by the formula

$$T = 2\pi\sqrt{\frac{l}{g}}$$

Where l is the length of the pendulum and g is the acceleration due to gravity.

Frequency of a Simple Pendulum and its equation

The number of complete oscillations made by the bob in one second is called the frequency of the pendulum. It is given by reciprocal of time period and represented by the symbol f. Its S.I unit is per sec. This has special name hertz (Hz). Hence,

$$\text{frequency} = \frac{1}{\text{Time period (T)}}$$

$$\text{or, } f = \frac{1}{2\pi\sqrt{\frac{l}{g}}}$$

$$\therefore\ f = \frac{1}{2\pi}.\sqrt{\frac{g}{l}}$$

Numerical Illustration

If a pendulum takes 4 sec to swing in each direction, find the length of the pendulum.

Solution:

Given T = 4 sec

g = 9.8 m/s^2

We know that, $T = 2\pi\sqrt{\frac{l}{g}}$

We can obtain the equation for length (l),

$$l = \frac{T^2 g}{4\pi^2}$$

$$= \frac{4 \times 4 \times 9.8}{4 \times 3.17 \times 3.17}$$

$$= 3.9\text{m}$$

∴ The length of the pendulum is 3.9 m

Factors affecting the period of a pendulum

The time period of a simple pendulum:

1. Depends on the length of pendulum, (l)
2. Depends on the acceleration due to gravity, g
3. Does not depend on the mass of bob
4. Does not depend on the nature of material of the bob
5. Does not depend on the amplitude of oscillations

For small displacements, a pendulum is a simple harmonic oscillator. A simple pendulum is defined to have an object that has a small mass, also known as the pendulum bob, which is suspended from a wire or string of negligible mass, such as shown in the illustrating figure. Exploring the simple pendulum a bit further, we can discover the conditions under which it performs simple harmonic motion, and we can derive an interesting expression for its period.

Summary

1. The property of a body by virtue of which it is unable to change its state of rest or of uniform motion in a straight line is called inertia.
2. If the resultant of all the forces acting on a body is zero, the forces are called balanced forces. A body under the action of balanced forces does not change its position of rest (or of uniform motion) and it appears as if no force is acting on it.
3. If the resultant of all the forces acting on a body is not zero, the forces are called unbalanced forces. When unbalanced forces act on a body, they produce a change in their state of rest or of uniform motion.
4. Velocity of a body is the distance travelled by it per unit time in a given direction.

   $$\text{Velocity} = \frac{\text{Distance travelled in a given direction}}{\text{Time taken for change}}$$

5. Acceleration of a body is defined as the rate of change of its velocity with time.

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time taken for change}}$$

6. A body has a non-uniform acceleration if its velocity increases by unequal amounts in equal interval of time.

7. If the velocity of a body increases, the acceleration is positive, and if the velocity of a body decreases, the acceleration is negative.

8. If the velocity of a body is always changing but changing at a uniform rate (the acceleration is uniform), then the average velocity is given by the arithmetic mean of the initial velocity and final velocity for a given period of time.

9. A pendulum is a weight suspended from a pivot so that it can swing freely.

   Factors affecting the period of a pendulum are as follows:

   The time period of a simple pendulum depends:

   i) on the length of pendulum, L

   ii) on the acceleration due to gravity, g

10. Momentum of a body at rest is zero or body at rest possesses no momentum.

11. Momentum is a vector quantity, possessing both the magnitude as well as direction. The direction of momentum is as the same as the direction of velocity.

12. The SI unit of mass kg and the SI unit of velocity is m/s. So, the SI unit of moment is kilogram meter per second. i.e. kgm/s.

13. Momentum is the motion contained in a body. Quantity of motion possessed by a body depends upon both of its mass and velocity. So the product of mass and velocity is the measure of the momentum.

Exercise

A. Tick (✓) the best alternative from the followings.

1. What is called the property of a body by virtue of which it is unable to change its state of rest or of uniform motion in a straight line?

i)	Inertia of rest	ii)	Inertia of motion
iii)	Inertia	iv)	Directional inertia

2. What are called the forces if the resultant of all the forces acting on a body is zero?

i)	Unbalanced forces	ii)	Balanced forces
iii)	Uniform forces	iv)	Non forces

3 The distance travelled by a body per unit time in a given direction is known as

i)	Velocity	ii)	Speed
iii)	Displacement	iv)	Distance

4 Which of the following term is not related to pendulum?

i)	Length of pendulum	ii)	Time period
iii)	Oscillations	iv)	Frequency

5. What are the factors on which momentum of a body depends upon?

i)	Mass and velocity	ii)	Mass and Time
iii)	Mass and speed	iv)	Mass and displacement

B. Answer the following short questions:

1. What is meant by inertia?
2. What is called balance force?
3. What is meant by unbalance force?
4. Define the term velocity.
5. What is meant by the term ‘acceleration’? Give its SI unit.

6. What is the acceleration of a body moving with uniform velocity?
7. When do you say a body is in uniform velocity?
8. At which condition the velocity of a body is zero?
9. Define non uniform acceleration.
10. Give two examples of bodies in non uniform motion.
11. Define the term uniform acceleration.
12. Give one example of uniformly accelerated motion.
13. What term is used to denote the change of velocity with time?
14. What is meant by momentum?
15. What is the unit of momentum?
16. What is simple pendulum?

C. Answer the following long questions:

1. Define the types of inertia with suitable examples.
2. Define balance force and unbalance force with examples.
3. Velocity may be positive, negative or zero. Explain this statement with the help of diagram.
4. Establish the formula $S = ut + \frac{1}{2}at^2$ where the symbols have usual meaning.
5. Establish the formula $v^2 = u^2 + 2as$, where the symbols have usual meaning.
6. Define momentum with its formula.
7. Explain in detail about the linear momentum.
8. Write the working process of simple pendulum.
9. List the factors affecting the period of a pendulum.

D. Solve the given numerical problems:

1. A car of mass 1200 kg is moving with the velocity of 30 m/s. Calculate the force required to stop it in 10 seconds. (Ans: 3600 N)
2. An object undergoes an acceleration of 10 m/s^2 starting from rest. Find the distance travelled in one second. (Ans: 5 m)

3. A body of mass 5 kg is moving with a velocity of 10 m/s. A force is applied to it so that it attained a velocity of 30 m/s in 20 seconds. Find the magnitude of the force applied. (Ans: 5 N)

4. What will be the final velocity of a bus if it starts from rest having acceleration of 0.8 m/s^2 until the distance of 1 km? How much time does it take to cover 1 km distance? (Ans: 40 m/s, 50s)

5. A truck starts from rest and rolls down a hill with constant acceleration. It travels a distance of 450 m in 25 s. Find its acceleration. Also, calculate the force acting on it if its mass is 6 metric tonnes. (Ans: 1.4 m/s^2,8640N)

6. A car is moving with a velocity of 90 km/hr. When a car driver saw a cow on the road about 50 m ahead, then he braked the car, the car came to rest with retardation of 2 m/s^2. Find whether the car crosses out the cow or not. (Ans:156.25m)

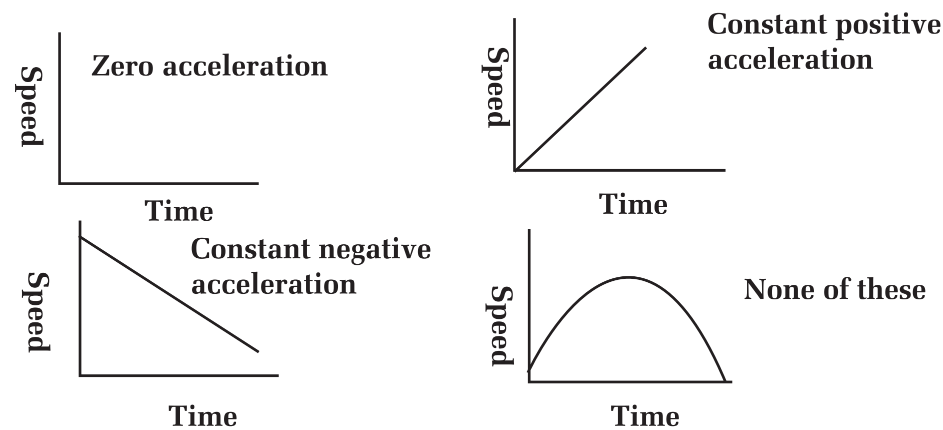
7. What is the period of a simple pendulum whose length is 1m? (Ans:2s)

8. A body of mass 50 g is moving with a velocity of 10 m/s. It is brought to rest by a resistive force of 10N. Find the distance that the body will travel after the resistive force is applied. (Ans: 25 cm)

Project Work

Prepare a report on the basis of the activity given below and present it in the class with the help of your teacher.

Sort out these speed time graphs for: zero acceleration, positive acceleration, uniform negative acceleration or none of these.



Glossary

Density: mass per unit volume of a substance

Retardation: negative acceleration of a body

Momentum: product of mass and velocity

Decelerate: to decrease velocity per unit time

Unit 2

Pressure

Mathematician Blaise Pascal was born on June 19, 1623, in Clermont-Ferrand, France. In the 1640s he invented the Pascaline, an early calculator, and further validated Evangelista Torricelli's theory concerning the cause of barometrical variations. In the 1650s, Pascal laid the foundation of probability theory with Pierre de Fermat He died in Paris on August 19, 1662

Blaise Pascal (1623 -1662

Learning outcomes

After the completion of this unit, learners will be able to

1. Describe and demonstrate the working principle of hydraulic press.
2. Describe the pressure and upthrust and derive the formula of upthrust.
3. Describe the floating, sinking and flying processes.

Introduction

We are much familiar with the word 'pressure' in our daily life. We have experienced so many events cause due to high and low pressure. Similarly we have some common devices in our home which are related to pressure. For example, pressure cooker, vacuum cleaner, etc.

If you stand on foam, your feet sink deeply but when you lie down it, your body does not sink into the foam deeply. In either case, the force exerted on the surface is due to your weight and is same. When you stand, the force is acting on a smaller area but when you lie down the same force acts on a larger area. From these events, it makes clear that there is relation among force, area and pressure. In this chapter we will discuss about the hydraulic press, liquid pressure and upthrust, and sinking, floating and flying in detail.

The total force acting on a surface is called thrust. The term pressure is used to measure and describe the effect of force acting on a surface. The effect of a force depends on the area upon which it acts. The three quantities force, pressure and area are related in a simple way which can be expressed mathematically as follows:

$$\text{Pressure} = \frac{\text{Force or Thrust}}{\text{Area}}$$

The above formula explains why flat footed camels can walk easily in sandy deserts. Heavy tractors can go through marshy land and muddy soil easily because their rear wheels have large area. Similarly, cutting and piercing tools like saws, needles and knives have sharp points or blades so that they exert great pressure even the applied force is of small magnitude.

It is experimentally proved that pressure is directly proportional to the force and inversely proportional to the area of the surface in which force acts perpendicularly.

Thus, pressure is defined as the force or thrust exerted per unit area.

Pressure (P) $\propto$ Force (F) ... (i) (Keeping the area constant)

Pressure (P) $\propto \frac{1}{\text{(Area(A)}}$ ... (ii) (Keeping the force constant)

From equation no (i) and (ii), we have,

$$P \propto \frac{F}{A}$$

Or, $P = K\frac{F}{A}$ (Where K is a constant)

When P = 1 N/m^2, F = 1 N and A= 1 m^2, then K = 1

$$\therefore P = \frac{F}{A}$$

Unit of pressure

In the MKS system, force is measured in newton (N) and area in square metre (m^2). Therefore, in this system, the unit of pressure is newton per square metre (N/m^2). This is also called pascal to honour the French scientist Blaise Pascal. In short, it is represented by Pa.

When a force of 1 N acts perpendicularly on an area of 1 m^2, then the pressure acting on the surface is called 1 pascal.

Some practical consequences of pressure

a. The base of the reservoir tank is made wider than walls.

b. The tyres of buses and trucks have broad and double wheels.

c. The end of the nail is made pointed one.

d. A sharp knife cuts well effectively than a blunt one.

e. The heeled shoes of a lady descend into the ground but the legs of an elephant do not.

f. A camel can walk easily in the desert but a horse can not.

Pascal's law

This law is formulated by the French scientist Blaise Pascal in 1647 AD who was born in 1623 AD in France. This is one of the basic principles of hydrostatics. Pascal's law states that **"when pressure is applied on a liquid enclosed in a vessel, it is transmitted equally in all the directions."** The transmitted pressure acts with equal force on every unit area of the containing vessel (in a direction at right angle to the surface of the vessel) exposed to the liquid.

Experimental verification of Pascal's law

Suppose a vessel filled with water and fitted with pistons A, B, C and D in different positions as shown in the figure. These four pistons A, B, C and D have the same cross sectional area 'A'. If the piston 'A' is pushed inward with a force F, the pressure exerted by the piston P is $\frac{F}{A}$.

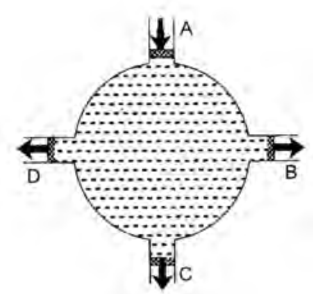


Fig. 2.1 vessel

This pressure is transmitted throughout the liquid and then acts at right angles to the surfaces of the pistons. It causes pistons B, C and D to pull outwards equally, i.e. the outward distance moved by these pistons is the same.

This experiment proves that the liquid pressure is transmitted equally is all the directions by the liquid enclosed in a vessel. Pascal's law is also known as the principle of transmission of fluid pressure.

Hydraulic Press

A hydraulic press is a type of simple machine in which force applied is highly multiplied to overcome heavy loads.

Principle of hydraulic press:

It is based on the Pascal's law of liquid pressure.

Construction of hydraulic press: As shown in figure, it consists of two cylinders C1 and C2 connected by horizontal tube (T). The cylinder C1 has small cross section area (A1) called pump tube. The cylinder C2 has large cross section area (A2) called press tube. The pump tube and press tube are fitted with air tight pistons p1 and p2 respectively. The cylinders and horizontal tube filled with a liquid like water. The load to be lifted is placed on the piston whereas the effort is applied on the piston p1 (pump tube).

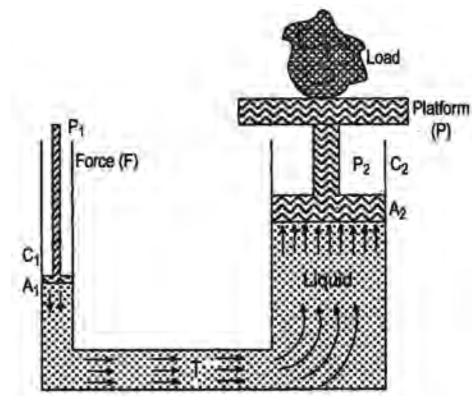


Fig. 2.2 hydraulic press

> Do you know?
>
> $$P = \frac{F}{A}$$
>
> $F = PA$
>
> Force generated is directly proportional to the area on keeping the pressure constant i.e.
>
> $F \propto A$, in this special case only.

Working of Hydraulic press

The heavy load to be lifted is placed on the platform. To lift the load, a force (effort) is applied on the piston (P1). When an effort is applied on the piston (P1), water from the pump tube flows in to the press tube under pressure. When the pressure acts on the press piston (p2) through water, it is raised upward with a large force. Water used in the hydraulic press transmits pressure from one piston (P1) to another piston (P2). From the Pascal's law,

Pressure on C_1 = Pressure on C_2

$$\therefore \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

Hydraulic Brakes

The brakes which are based on the Pascal's law are called hydraulic brakes. Hydraulic brakes are used in motor cars.

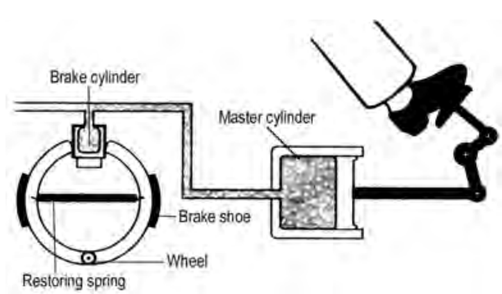


Fig. 2.3 hydraulic brakes

Construction: It consists of a pipe line containing liquid. One end of the pipe is connected to the wheel cylinder having two pistons attached to the brake shoes. The area of cross section of the wheel cylinder is greater than the area of cross section of the master cylinder. When pressure is applied on the brake pedal, the liquid in the master cylinder is under pressure. This pressure is transmitted equally through the liquid to the piston of car wheels. Therefore the piston gets pushed out-wards through rim of the wheel due to which the motion retards.

Application of hydraulic press

1. For pressing cotton goods, books, etc.
2. For extracting the juice of sugarcane, sugar beet, etc.
3. For squeezing the oil out of linseed and cotton seeds.
4. It is used for the punching holes in metals.
5. It is used for servicing automobiles.

Liquid pressure

Liuid does not have fixed shape but it has weight and can occupy space. So liquid can also exert pressure on the bottom and the walls of the container in which it is kept. The pressure exerted by a fluid (liquid or gas) on per unit area of the surface is called liquid pressure. It depends upon height of the liquid column, density of the liquid and acceleration due to gravity.

Let us consider a container with a base area 'A'. It is filled to a depth 'h' with a liquid of density 'ρ'.

The pressure acting on the base of the container is equal to the weight of liquid pressing down on the base.

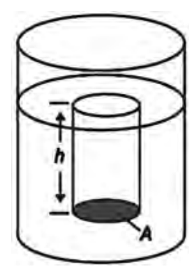


Fig. 2.4 liquid pressure

We know,

$$P = \frac{F}{A}$$

Or, $P = \frac{m \times g}{A}$ ($\therefore$ force = weight of the liquid = m x g)

Or, $P = \frac{\rho \times V \times g}{A}$ ($\therefore$ mass = density x volume)

Or, $P = \frac{\rho \times A \times h \times g}{A}$ $(\therefore V = A \times h)$

$\therefore P = h \rho g$

Therefore, pressure at a point vertically beneath the surface of a liquid of density P = h ρ g i.e. Pressure = Depth x Density of liquid x Acceleration due to gravity.

Thus, $P \propto h \rho$ (Keeping 'g' constant)

$P \propto g$ (Keeping h and ρ constant)

$P \propto \rho$ (Keeping g and h constant)

$P \propto h$ (Keeping g and ρ constant)

Factors affecting the pressure at a point in a liquid

The pressure at a point in a liquid depends on the following three factors:

i. Depth of the point below the free surface (height of the liquid column)

ii. Density of the liquid, and

iii. Acceleration due to gravity

The pressure at a point at a certain depth in a liquid:

i. is same in all directions.

ii. applies force at 90° to any contact surface, and

iii. does not depend on the shape of the container.

Up thrust of a liquid

A piece of wood floats on water. Boats and very big ships also float on water. We have experienced during swimming that it is easier to lift a friend in the water. All the things become lighter in water. This is due to the reason that water pushes every thing up with certain force.

All the liquids exert force on all the surfaces in contact with it. The

> Do you know?
>
> The mean sea level pressure is the atmospheric pressure at sea level. This is the atmospheric pressure normally given in weather reports on radio, television, and newspapers or on the Internet. When barometers in the home are set to match the local weather reports, they measure pressure adjusted to sea level, not the actual local atmospheric pressure.

total force acting on surface is called thrust. The resultant thrust or force with which a liquid pushes every object partially or totally immersed in it towards its surface is called upthrust. In other words, the net upward force exerted by the liquid on wholly or partially immersed body is called upthrust. Upthrust exerted by a liquid is also equal to loss in weight of the object immersed in that liquid.

Suspend a stone in a spring balance and note down the reading shown. Now dip the stone in the water and then record the second reading shown by spring balance. Let,

Weight of the stone in air = W_1

Weight of the stone in the water = W_2

Now, Loss in weight = $W_1 - W_2$

= Upthrust exerted by the water

$\therefore$ Upthrust on a body = Weight of object in air - Weight of object in the liquid

Pressure and Up-thrust of a Liquid:

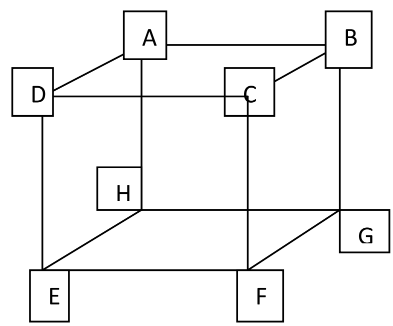


Fig. 2.5 upthrust

Suppose, a cubical box is entirely immersed in the liquid.

Let,

The density of the liquid taken = ρ

Acceleration due to gravity of this place = g

Area of each face of the box = A

Height of liquid column for the face A B C D = h_1

And height of liquid column for the face EFGH = h_2

Now,

Pressure acting on the face ABCD = $P_1 = h_1 \rho g$

Face i.e. thrust acting on the face ABCD = $F_1 = P_1 \times A$ ($P = \frac{F}{A}$)

$= h1 \rho g\ A$ ……………………(i)

Similarly,

Force i.e. thrust acting on the surface EFGH = $F_2 = P_2 \times A$

$= h_2 \rho g A$ ....(ii)

The forces i.e. thrust acting on the faces ADEH and BCFG are equal and opposite. Thus, they do not bring any change in the floatation of the box i.e. their resultant force becomes zero.

Here,

$F_2 > F_1$ because $h_2 > h_1$ (from the figure)

Therefore, the resultant thrust = Up-thrust = $F_2 - F_1$

Or, up-thrust = $h_2 \rho g A - h_1 \rho g A$

$\therefore$ UP thrust = $A \rho g (h_2 - h_1)$

Also, up thrust = $\rho g A h$ (height of the object)

Up thrust = $v \rho g$ ($\therefore A \times h$ = volume of the object)

Thus, it can be concluded that

$\therefore$ Upthrust $\propto$ volume of the object (Keeping g and ρ constant)

$\therefore$ Upthrust $\propto$ density of liquid (Keeping g and v constant)

$\therefore$ Upthrust $\propto$ acceleration due to gravity (Keeping ρ and v constant)

Activity 1

Take two glasses A and B containing fresh water and concentrated solution of salt and water respectively. Put fresh egg in each glass. An egg sinks in fresh water and floats in the concentrated solution of salt. The weight of an egg is greater than the upthrust given by fresh water on it. So the egg sinks in fresh water.

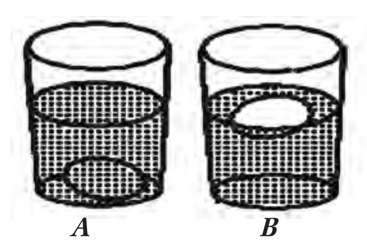


Fig. 2.6 Two glasses with eggs

The density of salt solution is more than fresh water. The up thrust given by salt solution on the egg increases. The weight of an egg (downward force) and the upthrust of water become equal and egg floats. What happen if more salt is dissolved in it?

The density of water increases further. Its upthrust on the egg increases and some portion of an egg comes out of the surface slowly. In this condition also the weight of an egg is equal to the upthrust acting on it.

The upthrust exerted by liquid neither depends upon its depth nor on the weight of an object placed in liquid. But it depends the volume of the object immersed in liquid. An object immersed completely in liquid experiences more upthrust than one which is partially immersed.

Sinking and floating

An object floats when the weight of the object is balanced by the upward push (upthrust) of the liquid on the object. The upwards push of the liquid increases with the volume of the object i.e. under liquid. It is not affected by the depth of the liquid column or the amount of liquid.

If the weight (downward force) is larger than the upward push (upthrust) of the liquid on the object, then the object will sink. If the reverse is true then the object will rise. Rising is the opposite of sinking.

Different objects float at different levels in the liquid. When most regular objects are lowered into the surface of liquid, the upthrust of the liquid steadily increases until it is in balance with the weight of the object and the object then continues floating at this level with the two forces in balance.

Many objects that are hollow containing air may float because the hollow sections increase the volume of the object causes increase in upthrust with very little increase in weight. However, it is not necessary for an object to contain air in order to float.

No object can float without some part of it being below the surface of the liquid.

Flying

While birds have been flying for millions of years, it's something relatively new to humans and we rely on some important scientific principles to achieve it. Beginning with simple kites, humans have moved on to develop gliders, airships, helicopters, commercial planes and even supersonic flight. Supersonic flight is achieved when an object travels at a speed faster than sound. Planes have wings that

> Do you know?
>
> The Wright Brothers, Orville and Wilbur, were American aviation pioneers who created the first successful airplane, thanks in part to their invention of 3-axis control, enabling the pilot to effectively control the plane.

feature an airfoil shape. This is important as it helps to overcome the effect of gravity pulling down on the plane. Airships and blimps are lighter than air and use buoyancy for flight. They are typically filled with gas (such as helium) i.e. less dense than the surrounding atmosphere. The only living things capable of powered flight are insects, birds and bats. While some can glide, bats are the only mammals that can achieve sustained level flight. In fact, the upthrust given by the air on flying objects helps them to fly in the sky.

Summary

1. The force acting on a surface is called thrust. Pressure is defined as the force or thrust exerted per unit area.

   $$\text{Pressure} = \frac{\text{Force or Thrust}}{\text{Area}}$$

2. In the MKS system, the unit of pressure is newton per square metre (N/m^2). This is also called pascal.

3. Pascal's law states that when pressure is applied on a liquid enclosed in a vessel, it is transmitted equally in all the directions.

4. A hydraulic press is a type of simple machine which converts small forces into large forces.

5. The pressure exerted by the liquid due to its weight on the bottom of the vessel is called liquid pressure.

6. The pressure at a point in a liquid depends on the following three factors:

   (a) Depth of the point below the free surface

   (b) Density of the liquid, and

   (c) Acceleration due to gravity

7. At a particular place, the acceleration due to gravity is constant. Therefore, the pressure at a point in a liquid is directly proportional to the depth of the point from the free surface of the liquid, and directly proportional to the density of the liquid.

8. The net upward force exerted by the liquid on wholly or partially immersed liquid is called up thrust.

   Up-thrust on an object = weight of object in air- weight of object in liquid.

9. Objects of density less than that of a liquid float on the liquid. The objects of density greater than that of a liquid sink in the liquid.

Exercise

A. Tick (✓) the best alternative from the followings.

1. What is the SI unit of pressure?

   i) Kg/m^2 ii) N/m

   iii) N/m^2 iv) J/m

2. What is the main function of a hydraulic press?

   i) Converts small forces into large forces

   ii) Converts large forces into small forces

   iii) Does not convert small forces into large forces

   iv) Does not convert large forces into small forces

3. What are the factors on which liquid pressure depend?

   i) Depth, acceleration due to gravity and density

   ii) Depth and density

   iii) acceleration due to gravity and density

   iv) density and volume

4. Which of the following formula is used to calculate an upthrust of liquid?

   i) Up-thrust = weight of object in air- weight of object in liquid

   ii) Up-thrust = weight of object in liquid - weight of object in air

   iii) Up-thrust = weight of object in air + weight of object in liquid

   iv) None of the above

5. An object is put one by one in three liquids having different densities. The object floats with 1/9, 2/11 and 3/7, parts of their volumes outside the liquid surface in liquid of different $\rho 1$, $\rho 2$ and $\rho 3$ densities respectively. Which of the following statement is correct?

   i) $\rho 1 > \rho 2 > \rho 3$ ii) $\rho 1 > \rho 2 < \rho 3$

   iii) $\rho 1 < \rho 2 > \rho 3$ iv) $\rho 1 < \rho 2 < \rho 3$

B. Answer the following short questions.

1. What is meant by thrust?
2. Give the definition of pressure and mention its unit in SI system.
3. State Pascal's law. Give two machines, which are based on Pascal's law.
4. Define a hydraulic press.
5. What is liquid pressure? What factors affect the liquid pressure?
6. If the liquid of density ρ is in a container upto height h, then calculate the pressure exerted by the liquid column.
7. Define an upthrust. List the factors on which upthrust of liquid depend.
8. What is meant by sinking?
9. Define floatation of body with an example.

C. Answer the following long questions.

1. How is applied force multiplied by the hydraulic press? Explain it.
2. A camel can walk easily on sandy desert but a horse cannot, why?
3. It is easier to cut with sharp knife than with a blunt one, why?
4. It takes less time to fill a bucket in the first floor than that at the top floor, why?
5. It is easier to pull a bucket of water from the well until it is inside the water but difficult when it is out of water, why?
6. How does density affect the pressure of a liquid?
7. A ship coming from sea enters the river will its hull sinks more or less in river water and why?
8. The different weights of a piece of stone on weighing in three different me dia: air, pure water and sea water are shown on the table below. Observe the table given below and answer the questions that follow:

Medium	Weight
X	12 N
Y	20 N
Z	15 N

a. Identify the media X, Y and Z.

b. Which one has got more density, why?

c. Calculate the upthrust exerted by the sea water.

d. If the weight of 1 kg mass in air is 10 N, then find out the mass of piece of stone.

e. Calculate the weight of water displaced by the piece of stone.

D. Solve the following numerical problems

1. A force 150 N is applied on blade area whose edge is 0.02 cm^2. Now calcu late the pressure exerted at the edge. (Ans:7.5×10^7 pa)

2. If a woman has mass 50 kg and the area of her one foot is 120 cm^2, what is pressure exerted by her on the ground when she stepped with one foot. (Ans: 4.1×10^4 pa)

3. The height of mercury column of a barometer is 760 mm. Calculate the pres sure exerted on the mercury column, if density of mercury is 13.6 gm/cm^3 and acceleration due to gravity is 9.8 m/s^2. (Ans: 1.013×10^5 pa)

4. The area of large cylinder in a hydraulic press is 5 m^2. A load of 500 N is to overcome. Calculate the force required on the piston of small cylinder to lift it if its area of cross section is 250 cm^2. (Ans: 2.5 N)

5. What will be the mass of an iron block with dimensions of 5cm $\times$10cm $\times$20cm, if the density of iron is 7800 kg /m^3? (Ans: 7.8 kg)

6. If an iron box having length 2m, breadth 1m and height 2m, has mass of 2000 kg. Does it float on water? Show by calculation. (Ans:500 kg/m^3, Yes)

7. What will be the height of water column in the special type of barometer kept at the sea level, if Mercury is replaced by water? (Density of Mercury = 13.6 g/cm^3 and density of water = 1 g/cm^3) (Ans: 10.336 m)

Project Work

Take three identical wooden corks and immerse them in water, salt solution and glycerine solutions separately with the help of your hand. Observe what happen to their floating conditions in these three liquids (upthrust)? Draw the conclu- sions from these activities and present it in the class.

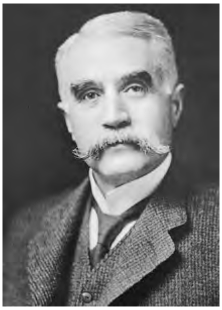
Glossary

Hydrostatics:	the branch of physics which deals with the properties of fluids (liquids and gas) at rest.
Thrust:	the force acting on an object perpendicular to the surface
Density:	mass per unit volume
Supersonic flight:	breaking the sound barrier

Unit 3

Energy

Charles F. Brush, born in Euclid in 1849, was a restless backyard tinkerer and clever entrepreneur. A child prodigy, by age 15 he had built electrical gadgets and microscopes and telescopes for school chums. Brush graduated from the University of Michigan in 1869, with a degree in mining engineering. Brush is best remembered for his dynamo and arc lights.


Charles Brush (1849 – 1929)

Learning outcomes

After the completion of this unit, learners will be able to

1. Describe the process of production of energy in the sun.
2. Explain the solar energy technology and its simple uses.
3. Explain the wind energy technology and its simple uses.

Introduction

The ability of a system to perform its work is known as energy. It is difficult to give single definition of energy because energy has its many forms. There are many other definitions of energy, depending on the context, such as thermal energy, radiant energy, electromagnetic energy, nuclear energy, etc. Some common types of energy are: the kinetic energy of a moving object, the potential energy stored by an object's position in a force field (gravitational, electric or magnetic), the elastic energy stored by stretching solid objects, the chemical energy released when a fuel burns, the radiant energy carried by light, and the thermal energy. Most of the forms of energy are convertible to other kinds of energy. In Newtonian physics, there is a universal law of conservation of energy which states that energy can neither be created nor be destroyed; however, it can be changed from one form to another.

In this unit we will discuss about the process of production of energy in the sun, the solar energy technology and the wind energy technology.

Sources of energy

Energy in nature is manifested in various forms - energy from the sun, wind energy, heat energy, light energy, sound energy, electric energy, water energy and nuclear energy, etc.

The materials which provide the requisite amount of energy are known as the sources of energy.

According to the nature or life span of sources, we have two types of energy sources. These two types are: Non-renewable sources of energy and Renewable sources of energy.

Non-renewable sources

The energy sources such as coal, oil, diesel, kerosene, natural gas and petroleum products are non-renewable or exhaustible. These are so called because they are limited in nature. We must therefore use these resources more judiciously.

The sources of energy which take millions of years to build up and once exhausted are not easily available again are called non renewable sources of energy.

Advantages of non renewable sources

a. Non-renewable sources are cheaper and easy to use.

b. Fewer amounts of fuel can produce large amount of energy.

c. They are considered as cheaper when converting from one form of energy to another.

Disadvantages of non- renewable sources

a. Non-renewable sources are limited in nature and over dependency on such sources casues energy crisis.

b. The speed at which such resources are being utilized can have serious environmental changes.

c. Non-renewable sources release toxic gases in the air when burnt which are the major cause for global warming.

d. Since these sources are going to expire soon, prices of these sources are soaring day by day.

Renewable sources

These sources of energy can be used and reused again and again. The nature has given us a large number of renewable sources of energy such as biomass, solar, wind, tidal, geothermal, etc. These are so called because their reserve can supply energy indefinitely. We must use these sources of energy based on the demand of the day to save the exhaustible sources of energy.

> The sources of energy which are being produced continuously in nature and never exhaust or can be developed again and again are called renewable sources of energy.

Advantages of renewable sources

a. The solar energy, wind energy, geothermal energy, tidal energy are available in the abundant quantity and free to use.

b. Renewable sources have low carbon emissions, therefore they are considered as green and environment friendly.

c. We do not have to rely on any country for the supply of renewable sources as in case of non renewable sources.

d. Renewable sources can cost less than consuming the local electrical supply.

Disadvantages of renewable sources

a. It is not easy to set up a plant as the initial costs are quiet steep.

b. Solar energy can be used during the day time and not during night or rainy season.

c. Geothermal energy can bring toxic chemicals beneath the earth surface onto the top and can create environmental changes.

d. Hydroelectric provides pure form of energy but building dams across rivers which is quite expensive can affect natural flow and condition of wildlife.

e. To use wind energy, we have to rely on strong winds. Therefore, we have to choose suitable sites to operate them.

Solar Energy: The Ultimate Power Source

Every morning the sun rises, providing light and heat to the earth, and every evening it sets. It seems so common place that we rarely spare a thought for that bright object in the sky. Without it, we wouldn't exist. Deep in the core of our local star, hydrogen atoms react by nuclear fusion, producing a massive amount of energy that streams in all directions at the speed of light. In just about eight minutes, that energy travels 93 million miles to earth.

We use different forms of energy here on earth, but here's the thing: almost all of them originate with the sun, not just light and heat (thermal) energy! The law of conservation of energy says that energy can't be created or destroyed, but can change its form. And that's what happens with energy from the sun, it changes into lots of different forms:

a. Plants convert light energy from the sun into chemical energy (food) by the process of photosynthesis. Animals eat plants and use that same chemical energy for all their activities.

b. Heat energy from the sun causes changing weather patterns that produce wind. Wind turbines then convert wind power into electrical energy.

c. Hydroelectricity is electrical energy produced from moving water, and water flows because heat energy from the sun causes evaporation that keeps water moving through the water cycle.

d. Right now, much human activity uses energy from fossil fuels such as coal, oil, and natural gas. These energy sources are created over very long periods of time from decayed and fossilized living matter (animals and plants), and the energy in that living matter originally came from the sun through photosynthesis.

Do you know?

The water cycle is an important result of solar insulation. The earth, oceans and atmosphere absorb solar radiation and their temperature rises. Warm air rises from the oceans causing convection. When this air rises to high altitudes, clouds are created by condensation of water vapor. These clouds cause rains that bring water back to the earth's surface which completes the water cycle.

The sun sends more energy to the earth in one hour than the whole planet needs in a year. Imagine if we could capture that energy directly and convert it to a form that could power our cities, homes, and cars! Many scientists around the world are researching how we can improve our use of the sun's energy. One way is to use solar thermal panels to collect thermal energy to heat air and water. Another way is to use photovoltaic (PV) cells, also called solar cells, to convert sunlight directly into electricity.

PV cells use a material such as silicon to absorb energy from sunlight. The sunlight energy causes some electrons to break free from the silicon atoms in the cell. Because of how the solar cell is made, these free electrons move to one side of the cell, creating a negative charge and leaving a positive charge on the other side. When the cell is hooked up in a circuit with wires, the electrons will flow through the wires from the negative side to the positive side, just like a battery — this electron flow is electricity and it will power a load (light bulb, motor, etc.) you connect to its path.

PV cells today are still only able to capture a small fraction of the sun's energy, so acres of them are necessary to collect enough light to create electricity on a large scale. A lot more scientific work needs to be done to make them more efficient and take up less space. Despite the challenges, solar panels are used to power many things such as emergency signs, school crossing lights, and more. Many people are also able to power their homes by mounting solar panels on the roof, and this will only get easier as the technology continues to advance.

Sources of solar energy

> Do you know?
>
> Positron is known as the antiparticle of electron as it has mass equal to electron but bears the opposite charge as that of electron.

The mass of the sun has been estimated approximately as 2×10^{30} kg. It has been mentioned earlier that the sun is composed of 70% hydrogen and 28% helium. The hydrogen is ionized i.e. they lose their electron on account of very high temperature and pressure existing inside the sun. In other words, hydrogen nuclei are predominantly present in the sun's interior. Four hydrogen nuclei combine together to form a helium and release large amount of energy. A large number of such fusion reactions are occurring in the sun continuously. In this way, the sun is generating huge amount of energy continuously by nuclear fusion.

$$ {}_{1}^{1}H + {}_{1}^{1}H \xrightarrow{\text{Enough temp and pressure}} \underset{\text{(Deuterium)}}{{}_{1}^{2}H} + 1e^{0} + \text{energy} $$

$$ {}_{1}^{2}H + {}_{1}^{1}H \xrightarrow{\text{Enough temp and pressure}} \underset{\text{(Light helium)}}{{}_{2}^{3}He} + \text{energy} $$

$$ {}_{2}^{3}He + {}_{2}^{3}He \xrightarrow{\text{Enough temp and pressure}} \underset{\text{(Helium)}}{{}_{2}^{4}He} + {}_{1}^{1}H + {}_{1}^{1}H + \text{energy} $$

$$ \text{Or, } 4\,{}_{1}^{1}H \longrightarrow {}_{2}^{4}He + 2\,{}_{1}e^{0} + \text{energy} $$

Albert Einstein showed the relation of mass and energy by the equation $E = mc^2$. Where, E is the energy (in joule) released in the conversion of mass "m" (in kilogram) into energy and c is the speed of light in m/s. The quantity "c" equals $3\times10^8\ ms^{-1}$ and occurs as c^2 in the above formula of energy. It means that a small mass of matter results into a huge quantity of energy on complete conversion. Thus, nuclear fusion taking place inside the sun is the real source of sun's energy.

Nuclear Fusion

When two light nuclear particles combine or fuse together, energy is released, because the product nuclei have less mass than the original particles. Such fusion reactions are caused by bombarding targets with charged particles using an accelerator. Nuclear Fusion is thus a process in which two nuclei of light atoms like hydrogen combine to form a heavy and more stable nucleus.

Let us consider the reaction involving the combination of two hydrogen nuclei and neutrons resulting in the formation of helium nuclei.

$$4\,{}^{1}_{1}H + 2\,{}^{1}_{0}n \longrightarrow {}^{4}_{2}He$$

This reaction occurs in the sun and other stars too. In a hydrogen bomb, on the other hand, a high temperature is caused by a fission process which causes fusion to proceed in a rapid and uncontrolled manner.

> The phenomenon in which the nuclei of light atoms combine to form a stable heavy nucleus with the release of large amount of energy is called nuclear fusion.

Conditions and evidences of nuclear fusion reaction in the sun

Some evidences of nuclear reaction going on in the sun are as follows:

a. There is huge amount of hydrogen which participates in nuclear fusion.

b. There is plenty of helium in the sun.

c. There is enough temperature in the sun to split the hydrogen atoms into plasma state.

d. There is extreme pressure on the sun to combine the similar charger nuclei.

Nuclear fission

When uranium is bombarded with neutron, the nucleus of uranium splits into the nuclei of Barium, Krypton and three neutrons with the release of large amount of energy. It is shown in the equation as below.

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \longrightarrow ^{139}_{56}\text{Ba} + ^{94}_{36}\text{Kr} + 3\,^{1}_{0}n + \text{Energy}$$

The large amount of energy thus released can be used for destruction in Atomic Bomb. This can also be used for number of peaceful uses. This is carried out in a nuclear reactor where uranium atoms are bombarded with slow moving neutrons under controlled conditions. The process of fast multiplication of neutrons causing fission of uranium nuclei is called a chain reaction. This can be shown in the figure 3.1.

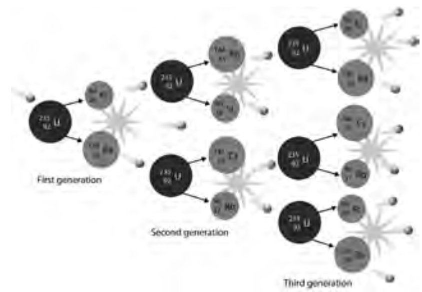


Fig. 3.1 nuclear fission

> The process in which a heavy nucleus splits into two or more radioactive nuclei of nearly equal sizes with the release of large amount of energy is called nuclear fission.

Trapping the Solar energy

The sun is the source of enormous energy. It is a fusion reaction at a distance of 1.5 x 10^8 km from the earth. Its problem age is 4.6 x 10^9 years and is expected to radiate energy for another 5.0 x 10^9 years. The energy from the sun in the form of radiation is called solar energy. It makes the production of solar electricity possible. Electricity can be produced directly from photovoltaic, PV, cells. These cells are made from materials which exhibit the photovoltaic effect. i.e. when sun shine hits the PV cell, the photons of light excite the electrons in the cell and cause them to flow, generating electricity. Solar energy produces electricity when it is in demand during the day particularly hot days when air conditioners drive up electricity demand. In use, solar energy produces no emissions.

PV panels are being used increasingly, both in the city and in remote locations, to produce electricity for households, schools and communities, and to supply power for equipment such as telecommunication and water pumps.

Solar power is energy from the sun and without its presence all life on the earth would end. Solar energy has been looked upon as a serious source of energy for many years because of the vast amounts of energy that are made freely available,

> Do you know?
>
> Horticulture and agriculture seek to make the maximum use of solar energy. These include techniques like timing of planting cycles and mixing of plant varieties. Green houses are also used to convert light into heat to promote year round cultivation of special crops.

if harnessed by modern technology. A simple example of the power of the sun can be seen by using a magnifying glass to focus the sun's rays on a piece of paper. Before long the paper ignites into flames.

Solar Technology

Solar energy is the cleanest, most abundant renewable energy source available. Today's technology allows us to harness this resource in several ways, giving the public and commercial entities flexible ways to employ both the light and heat of the sun.

There are three primary technologies by which solar energy is commonly harnessed: photovoltaics (PV), which directly convert light to electricity; concentrating solar power (CSP), which uses heat from the sun (thermal energy) to drive utility-scale, electric turbines; and heating and cooling systems, which collect thermal energy to provide hot water and air conditioning.

Fig. 3.2 solar energy

Solar energy can be deployed through distributed generation (DG), whereby the equipment is located on rooftops or ground-mounted arrays close to where the energy is used. Some solar technologies can also be built at utility-scale to produce energy as a central power plant.

Photovoltaic (PV)

These solar technologies directly produce electricity which can be used, stored, or converted for long-distance transmission. PV panels can be manufactured using a variety of materials and processes and are widely-used for solar projects around the world.

Solar Heating and Cooling (SHC)

These technologies generate thermal (heat) energy for water & pool heating and space heating. Some people are surprised to learn that SHC technology can also be used for cooling. Solar heating technologies are cost-effective for customers in a variety of climates.

Fig. 3.3 solar heating and cooling

Concentrating Solar Power (CSP)

Fig. 3.4 solar power

Using reflective materials like mirrors and lenses, these systems concentrate sunlight to generate thermal energy, which is in turn used to generate electricity. Similar to traditional power plants, many CSP plants are hundreds of megawatts (MW) in size and some can continue to provide power after sunset.

Applications of solar energy

Solar energy is used in wide range in our everyday practices. The traditional and modern uses of solar energy are as follow:

a. Solar energy is used for drying clothes, obtaining salt from sea water, etc.

b. It can be used for heating and cooking purposes.

c. It provides warmth on the earth surface.

d. It regulates the flow of wind and water cycles on the earth.

e. It is used for transportation.

f. It can be used for the preservation of fruits, vegetables, etc.

g. It helps the plants to grow which in turn provide food to us.

h. Solar cells convert solar energy into electrical energy.

Activity

Converting solar energy into electrical energy

Glue the back of the solar cell onto a cardboard box as support. Connect two pieces of insulated wire of the cell to the ends of the milliameter. Shield the cell from light. Your ammeter will show zero deflection. Now allow the sunlight to fall on the cell. The pointer of the ammeter will show a small deflection. Now, use a concave mirror to reflect the sunrays onto the solar cell. The mirror focuses the sunlight onto the cell. In this case, the ammeter will show greater and greater deflection as the size of the patch of light on solar cell is reduced by moving the mirror back and forth. It indicates that the photoelectric current increases as the amount of light falling on the solar cell increases. In this way, solar energy can be converted into electrical energy.

Wind Energy

Fig. 3.5 wind energy

The fast moving air is called wind. Wind energy is a form of solar energy. Wind energy (or wind power) describes the process by which wind is used to generate electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. A generator can convert mechanical power into electricity. Mechanical power can also be utilized directly for specific tasks such as pumping water.

Wind is caused by the uneven heating of the atmosphere by the sun, variations in the earth's surface, and rotation of the earth. Mountains, bodies of water, and vegetation all influence wind flow patterns. Wind turbines convert the energy in wind to electricity by rotating propeller-like blades around a rotor. The rotor turns the drive shaft, which turns an electric generator. Three key factors affect the amount of energy a turbine can harness from the wind: wind speed, air density, and swept area.

How does a wind turbine generate electricity?

Wind power converts the kinetic energy in wind to generate electricity or mechanical power. This is done by using a large wind turbine usually consisting of propellers; the turbine can be connected to a generator to generate electricity, or the wind used as mechanical power to perform tasks such as pumping water or grinding grain. As the wind passes the turbines it moves the blades, which spins the shaft. There are currently two different kinds of wind turbines in use, the horizontal axis wind turbines (HAWT) or the vertical axis wind turbines (VAWT). HAWT are the most common wind turbines, displaying the propeller or fan style blades, and VAWT are usually in an egg beater style.

Creating electricity from wind

To create electricity from wind the shaft of the turbine must be connected to a generator. The generator uses the turning motion of the shaft to rotate a rotor which has oppositely charge magnets and is surrounded by copper wire loops. Electromagnetic induction is created by the rotor spinning around the inside of the core, generating electricity.

Distribution of electricity

The electricity generated by harnessing the wind's mechanical energy must go through a transformer in order increase its voltage and make it successfully transfer across long distances. Power stations and fuse boxes receive the current and then transform it to a lower voltage that can be safely used by business and homes.

Applications of wind energy

Wind energy can be used for various purposes. The uses of wind energy can be summarized in the given points:

a. Wind energy is used to propel sailboats.

b. It is used to generate electricity, which can be used for various purposes.

c. It is used to run a pump to draw water from the ground.

d. It is used in flour mills to grind wheat and other grains.

> Do you know?
>
> Windmills have been in use since 2000 B.C. and were first developed in Persia and China. Ancient mariners sailed to distant lands by making use of winds. Farmers used wind power to pump water and for grinding grains. Today the most popular use of wind energy is converting it to electrical energy to meet the critical energy needs of the planet.

Existing wind energy data

Hourly wind energy data of 10 different locations according to Alternative Energy Promotion Centre (AEPC) are as follows:

a. Okhaldhunga (Apr 2001-Aug 2005)

b. Nagarkot (Bhaktapur) (Jun 2001-Apr 2006)

c. Butwal (Rupandehi) (Mar 2001-Aug 2003)

d. Kagbeni (Mustang) (Apr 2001-Feb 2006)

e. Thini (Mustang) (Apr 2001-Jun 2007)

f. Batase Danda (Palpa) (Sep 2003-Dec 2006)

g. Ramechhap (Jul 2005-Oct 2007)

h. Phakhel (Makwanpur) (Oct 2007-April 2009)

i. AEPC building (Feb 2009-end of March 2009)

j. Neta (Pyuthan) (Dec 2007-Feb 2011)

Summary

1. The ability of a system to perform its work is known as energy.

2. The materials which provide the requisite amount of energy are known as the sources of energy.

3. The sources of energy which take millions of years to build up and once exhausted are not easily available again are called non renewable sources.

4. The sources of energy which are being produced continuously in nature and never exhaust or can be developed again and again are called renewable sources of energy.

5. Various forms of energy such as water energy, wind energy, energy of fossil fuels and others are obtained from the sun directly or indirectly. Therefore, the Sun is considered as the ultimate source of energy in the universe.

6. The sun emits 5.45 x 10^{33} J/s of energy. Thus sun can be regarded as a big thermonuclear furnace.

7. The essential conditions present in the sun for Nuclear Fusion reaction are

   a. There is huge amount of hydrogen gas in the sun.

   b. There is plenty of helium in the sun.

   c. There is enough temperature and pressure in the sun

8. The process in which a heavy nucleus splits into two or more radioactive nuclei of nearly equal sizes with the release of large amount of energy is called nuclear fission.

9. The process due to which the nuclei of the light atoms combine to form a stable heavy nucleus with the release of large amount of energy is called nu clear fusion.

10. The evidences of nuclear fusion reaction are:
    a. There is huge amount of hydrogen which participates in nuclear fusion.

    b. There is plenty of helium in the sun.

    c. There is enough temperature in the sun to split the hydrogen atoms into plasma state.

    d. There is extreme pressure on the sun to combine the similar charger nuclei.

11. The energy from the sun in the form of radiation is called solar energy.

12. The main applications of solar energy are:

    a. Solar energy is used for drying clothes, obtaining salt from sea water,

    b. It can be used for heating and cooking purposes.

    c. It regulates the flow of wind and water cycles on the earth.

13. The fast moving air is called wind. Wind energy is a form of solar energy. Wind energy is used to generate electricity.

14. The main applications of wind energy are :

    a. Wind energy is used to propel sailboats.

    b. It is used to generate electricity, which can be used for various purposes.

Exercise

A. Tick (✓) the best alternative from the followings.

1. Coal is an example of which of the following source of energy?

   i) Renewable ii) Non renewable

   iii) Both sources iv) None of the sources

2. Why is the Sun considered as the ultimate source of energy?

   i) The sun provides hydro energy

   ii) The sun provides wind energy

   iii) Energy of fossil fuels are obtained from the sun

   iv) All of the above

3. Which of the following material is used by photovoltaic cells to absorb energy from the sun light?

   i. Aluminium

   ii. Silicon

   iii. Germanium

   iv. Copper

4. The process in which a heavy nucleus splits into two or more radioactive nuclei of nearly equal sizes with the release of large amount of energy is called ...

   i) Nuclear fission ii) Nuclear fusion

   iii) Both iv) None of the above

5. What is the evidence of nuclear fusion reaction?

   i. There is huge amount of hydrogen and helium in the sun

   ii. There is enough temperature in the sun

   iii. There is extreme pressure in the sun

   iv. All of the above

B. Answer the following short questions.

1. What is meant by energy?
2. Define sources of energy with examples.
3. What do you mean by non renewable sources of energy?
4. What do you mean by renewable sources of energy?
5. Why is the sun regarded as a big thermonuclear furnace?
6. Who invented the relation $E= mc^2$? Write the meaning of E, m and c in the given relation.
7. What is thermonuclear fusion?
8. What is nuclear fusion reaction?
9. What is nuclear fission reaction?
10. Define solar energy with example.
11. Name any three devices run by solar energy.
12. Define wind energy with example.

C. Answer the following long questions.

1. Write the advantages of renewable sources of energy.
2. Mention the disadvantages of renewable sources of energy.
3. Write the advantages of non renewable sources of energy.
4. Mention the disadvantages of non renewable sources of energy.
5. Write two differences between renewable and non renewable sources of energy.
6. How is the enormous amount of energy produced in the sun? Explain with chemical equations.
7. The ultimate source of energy in the universe is the sun. Explain this statement.
8. Mention the essential conditions essential in the sun for nuclear fusion reaction.
9. What are the evidences present in the sun which supports nuclear fusion reaction?
10. Mention a difference between nuclear fusion reaction and nuclear fission reaction.

11. Point out the use of solar energy in our daily life.
12. How can we generate electricity from wind energy? Explain its process in detail.
13. Write the applications of wind energy in four points.
14. What is the basic cause for winds to blow? Name a part of Nepal where wind energy is commercially harnessed. Compare wind power and power of water flow in respect of generating mechanical and electrical energies. What is the hindrance in developing them?

Project Work

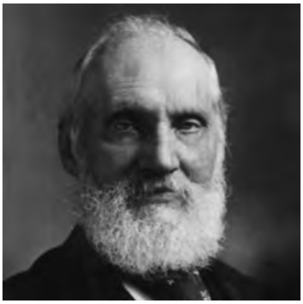
Take a funnel with aluminium foil (concave reflector), test tube containing water, a stand and a clamp. Set these materials in such a way that it makes the water in the test tube warm. Observe the activity and present the conclusion obtained from it.

Glossary

Deuterium	:	a stable isotope of hydrogen with a mass about double of usual isotope
Light helium	:	an isotope of helium atom with two protons and only one neutron in the nucleus
Radioactive elements	:	elements which emit invisible radiations
Nuclear energy	:	energy obtained from nuclear reactions
Solar panel	:	a group of solar cells
Radiation	:	usually refers to the electromagnetic waves such as light, radio, infrared x- rays, ultraviolet, gamma rays
Photovoltaic	:	light and electric

Unit 4 Heat

William Thomson is popularly known as 1st Baron Kelvin, the creator of 'absolute zero' which are low limit temperature units now represented in units of 'Kelvin' in his honour. Lord Kelvin, as he is popularly known, is remembered for his outstanding works and achievements in the field of physics and mechanics.



WilliamThomson(1824– 1907)

Learning outcomes

After the completion of this unit learners will be able to

1. Describe thermometry and mention its uses.
2. Illustrate the effects of heat with examples.
3. Describe the types of thermal expansion and demonstrate their interrelation.

Introduction

When we come out to the sun light, we feel warm. Similarly, we feel cold nearby/now covered mountains. If we touch the piece of ice, we feel further cold. In both cases energy is exchanged with our body. In former case, our body has gained some energy from sun light by the process of radiation as well as convection. In second case, our body has lost some energy by the process of convection as well as conduction. The exchange of energy is due to difference of hotness between our body and sun light or ice i.e the exchange of heat energy is due to temperature difference of two bodies during thermal contact. The measure of hotness is the temperature and exchanged energy is heat. Hence, heat is the energy which is transferred on the account of temperature (hotness) difference from one body to another body by the conduction or convection or radiation.

Let's take a general example; if we put our left hand in hot water and right hand in ice water and then together we put both hands in tap water, our left hand feels cold and right hand feels warm for the same tap water. The feeling of coldness and warmness is because of the heat contained in tap water. Hence, heat is a form of energy which gives sensation of hotness or coldness to us.

In molecular concept, all the substances are composed of up a large number of molecules. These molecules are in random motion except at the absolute zero temperature so that they possess kinetic energy. The sum of kinetic energy to all molecules of a substance is the measure of heat energy contained in that substance.

When two bodies at different hotness are brought in thermal contact, heat is transferred from a body at higher hotness to a body at lower hotness without any support of mechanical work. Hence, the natural transfer of heat is a non mechanical process.

It is not necessary to flow heat from a body with more heat energy to a body having less heat energy. A full bucket of warm water have more heat energy than a red hot iron rod. In this case, heat flows from the metallic iron rod to the warm water of bucket during their thermal contact.

Heat is a form of energy and its SI unit is Joule (J) and CGS unit is calorie (cal). 1 cal = 4.18 J. Heat is measured in term of exchange of energy and is measured by using calorimeter.

In this chapter, we will discuss about the thermometry, effects of heat and thermal expansion in detail.

Heat is a form of energy which produces the sensation of warmth.

Heat and Temperature

Heat is a form of energy which stimulates our sense organs so that we feel hot or cold. If you touch a hot cup of tea, heat energy enters your hand because the cup is often warmer than your hand. When you touch a piece of ice, energy transfers from your hand to ice. The direction of spontaneous energy transfer always takes place from a warmer object to a neighboring cooler object. The energy transferred from one object to another because of the temperature difference between them is called heat.

It is important to note that substance does not contain heat but it contains internal energy. The internal energy of a substance is the sum of molecular kinetic energy (due to random motion of the molecules), molecular potential energy (due to the force that acts between the atoms of a molecule and between molecules) and other types of molecular energies. When heat flows, the internal energy of a hot substance decreases and the internal energy of a cold substance increases. While heat originates in the internal energy of a substance, it is not correct to say that a substance contains heat. So, the substance has internal energy, and the word heat is used only when referring to energy actually in transit from the hot to the cold.

For two objects in thermal contact, heat flows from higher temperature substance to the lower temperature substance. This means quantity of energy contained in the bodies does not determine the direction of heat flow. For example, a full bucket of warm water contains more internal energy than a red hot iron rod but heat will flow from the red hot iron rod to the warm water.

The degree of hotness of a body is called temperature. It is the property which determines whether the body is in thermal equilibrium or not with neighboring systems. If the systems are in thermal equilibrium, this common property of the system can be represented by a single numerical value called the temperature. In other words, temperature is a factor which determines the direction of flow of heat. It means if the two systems are in thermal equilibrium, they are at the same temperature.

Distinguish between Heat and Temperature

The following are the differences between heat and temperature.

Heat	Temperature
1. It is a form of energy which produces the sensation of warmth.	1. It is a degree of hotness or coldness of a body.
2. In SI- unit, it is measured in joule and in CGS- system, its unit is calorie.	2. Its SI-unit is Kelvin and in CGS-system it is ^{0}C.
3. It is a cause of temperature.	3. It is an effect of heat.
4. Two bodies can be in thermal equilibrium without having same amount of heat.	4. Two bodies cannot be in thermal equilibrium if they are at different temperature.
5. It is a measure of total kinetic energy of all molecules of a body.	5. It measure average kinetic energy in all molecules of the body.
6. Flow of heat is independent of amount of heat energy contained in the bodies in thermal contact.	6. Flow of heat depends of temperature of two bodies. It flows from a body at higher temperature to a body at lower temperature.

Thermometry

The science of temperature and its measurement is termed as thermometry. An instrument used to measure temperature is called a thermometer. For example, in a mercury thermometer, the mercury expands with increasing temperature. The pressure of a gas changes with changing temperature in a constant volume gas thermometer.

> Do you know?
>
> Excessive heat is determined by Heat Index Values. The heat index, also known as the apparent temperature, is what the temperature feels like to the human body when relative humidity is combined with the air temperature.

The essential requisites of a thermometer are:

a. **Construction:** The physical property of a substance plays an important role in the construction of thermometer. For examples, Mercury thermometer is based on the principle of change in volume of Mercury with change in temperature. Gas thermometer is based on the principle of change in pressure or volume with change in temperature. The resistance thermometer is based on the principle of change in resistance with change in temperature. The radiation thermometer is based on the quantity of heat radiations emitted by a body. The vapour pressure thermometer is based on the principle of change of vapour pressure with change in temperature.

b. **Calibration:** The process of determining the scale of thermometer is called calibration. When a thermometer is constructed, it should be properly calibrated. First of all, standard fixed points are determined for calibrating a thermometer. Melting point of pure ice and boiling point of pure water are taken as lower and upper fixed points respectively. The temperature at which pure ice melts at standard atmospheric pressure is called lower fixed point. The temperature at which pure water boils at standard atmospheric pressure is called upper fixed point. In centigrade scale lower fixed point and upper fixed point are taken as 0°C and 100°C respectively. The scales are built by dividing the interval between the two fixed points in to equal parts. Centigrade scale is built by dividing the interval between the melting point of ice and the boiling point of water (under normal pressure) into 100 equal parts and each part is called 1°C. Similarly, Fahrenheit scale is built by dividing this interval into 180 equal parts.

c. **Sensitiveness:** The instrument which is once constructed and calibrated should also be sensitive. So,

   a. It reads the temperature of body very quickly.

b. It does not absorb large quantity of heat from the body whose temperature is to be measured.

c. It shows even a small variation in temperature.

Mercury thermometer

One of the most familiar thermometers in use is mercury thermometer. Figure shows mercury thermometer in Celsius scale. At one end, mercury is sealed into a glass bulb that is connected to fine capillary in a glass rod. When temperature is increased, the mercury expands in capillary tube, the rate of expansion of mercury is greater than that of the glass and the mercury is forced to expand in the tube as the temperature increases. In practice, a relatively larger bulb is used with a narrow capillary tube. Two fixed points: the ice point and boiling point of water are fixed near two ends in the thermometer and the distance between these points is divided into 100 equal parts. So, each part represents 1°C.

Fig. 4.1 Mercury thermometer

Advantages of mercury thermometer

Use of mercury in the thermometer as thermometric liquid has following advantages:

a. Its boiling point is 357°C and freezing point is -39°C, therefore, it can be used over a wide range of temperature.

b. Its expansion is nearly uniform over the ordinary range of temperatures. This makes the calibration of the thermometer easier.

c. It can easily be seen through the glass because it is opaque and shining in colour

d. It does not wet the wall of glass tube and can easily be obtained in the pure state.

e. It has low specific heat, so it doesn't take much heat from the body whose temperature is to be measured.

Disadvantages of mercury thermometer

Mercury thermometer cannot, measure temperature below – 39°C and above 357°C. Therefore, in the Arctic and the Antartic region, this thermometer cannot be used.

Alcohol Thermometer

The construction of alcohol thermometer is similar to to the mercury thermometer. In this thermometer alcohol is used as thermometric substance.

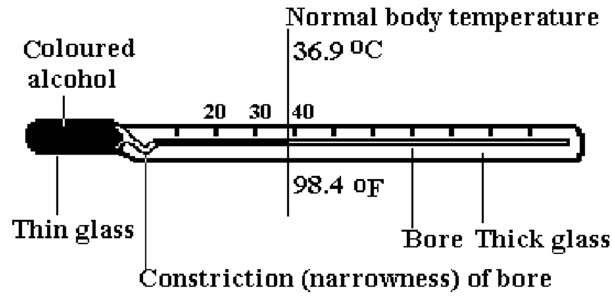


Fig. 4.2 Alcohol thermometer

Advantages of alcohol thermometer

Alcohol thermometer is suitable in very cold places because it freezes at -115°C and boils at 78°C.

It is more sensitive than mercury because its expansion is seven times that of mercury.

Disadvantages of alcohol thermometer

a. Its expansion is not uniform.

b. It cannot be used to measure temperature more than 78°C because its B.P. is 78°C.

c. It is colourless and bad conduction of heat.

d. The specific gravity of alcohol is smaller than that of mercury.

e. It sticks to the wall of the glass tube.

Temperature Scales

Considering the variation in lower point and upper fixed point, different temperature scales are in practice.

a. **Centigrade (or Celsius) scale:** In 1742 Celsius suggested the centigrade system of temperature measurement. He marked zero at lower fixed point and 100 at upper fixed point. The interval between the two fixed points is divided into 100 equal parts. Each part or degree represents 1°C. This scale is known as Celsius scale.

> Do you know?
>
> The earliest thermometer was constructed by Galileo in 1593. Newton suggested the necessity of the fixed points. The temperature of melting of ice is taken as lower fixed point and temperature of steam at atmospheric pressure i.e. at 760 mm of Hg is taken as upper fixed points.

b. **Fahrenheit scale:** In this scale, the lower fixed point is taken as 32°F and upper fixed point is 212°F. The interval between lower and upper fixed point is divided into 180 equal divisions. Each division represents 1°F.

c. **Reaumer scale:** In this scale the lower fixed point is marked as zero and the upper fixed point is marked as 80. The interval is divided into 80 equal parts. Each part or division represents 1°R.

d. **Absolute temperature scale:** In this scale, the lower fixed point is marked as 273K and upper fixed point is marked as 373K. The interval is divided into 100 equal parts. Each parts or division represent 1K.

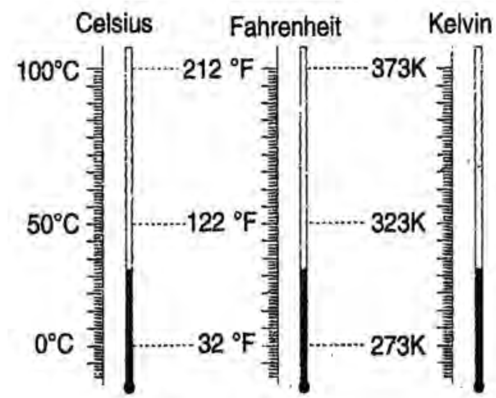


Fig. 4.3 temperature scales

Relation between different Temperature Scales

There are two fixed points in all temperature scales and different intervals between them. If C, F, R and K be the temperature of a body in Celsius, Fahrenheit, Reaumer and Kelvin scale respectively,

$$\frac{C-0}{100-0}=\frac{F-32}{212-32}=\frac{R-0}{80-0}=\frac{K-273}{373-273}$$

or, $$\frac{C}{100}=\frac{F-32}{180}=\frac{R}{80}=\frac{K-273}{100}$$

$$\therefore \frac{C}{5}=\frac{F-32}{9}=\frac{R}{4}=\frac{K-273}{5}$$

Effects of heat in our daily life

We cannot see the vibration of molecules due to heat in an object, but we can see the effect when the vibration increases enough in molecules. The change of state from solid to liquid and liquid to gas when heated enough is due to the increase in

> Do you know?
>
> Urban areas often experience higher temperatures during the summer, referred to as "Urban Heat Island." This is due to buildings, roads, and other infrastructures absorbing solar energy, resulting in higher temperatures.

vibration of molecules of the substance. Some effects of heat are as follows:

a. Expansion of the substances

b. Increase in temperature

c. Change in the state of substances

d. Chemical change

e. Change in the solubility of the substance

A short description of each of the above mentioned points are as follows:

(a) **Expansion of substances:** When heat is added to a solid, the particles gain energy and vibrate more vigorously about their fixed positions, forcing each other further apart. As a result expansion takes place. Similarly, the particles in a liquid or gas gain energy and are forced further apart. The degree of expansion depends on the substances. For a given rise in temperature, a liquid will expand more than a solid. Gases expand enormously on heating, causing a possible explosion if the gas is in a confined space. In a fire, the thermal expansion of steel beams, concrete and glass can cause considerable damage, especially if expansion takes place at different rates, setting up stresses in the material or structure. Liquids in drums and pans may overflow when heated. This is due to the fact that liquids expand at a greater rate than solids.

(b) **Increase in temperature:** As we know that heat is the cause and the temperature is the effect. It means that when heat is given to a substance, its temperature increases. This is due to the increase in the vibration of the molecules of the substances. Instead, when the body is cooled down, the temperature of the body decreases.

(c) **Change in the state of substances:** As we know that matter exists in three states i.e. solid, liquid and gas. Due to heat, the state of the matter may change from one state to another. For example, if heat is given to the solid, it changes into liquid and on further heating of liquid changes into gas. On cooling these substances, the reverse process occurs. As a result, gas changes into liquid and liquid to solid.

(d) **Chemical change:** Heat may be the cause for chemical change of a substance. When heat is supplied to a substance, its molecular structure changes. As a result, new substace is formed. For example, when heat is given to Potassium chlorate, it changes into Potassium chloride and oxygen.

$$2KClO_3 \xrightarrow{\Delta} 2KCl + 3O_2$$

(e) **Change in the solubility of the substances:** Generally, solubility of a substance increases with the rise in temperature. For example, further heating a saturated solution becomes unsaturated and more solute particles can dissolve in it. Some substances have less solubility even if there is increase in temperature, too.

Anomalous expansion of water

Water shows unusual expansion in comparison to other substances. If it is cooled from four degree centigrade to zero degrees centigrade, then its volume increases. The unusual behavior of water, when it expands below 4°celsius to 0° is called anomalous expansion of water.

Do you know?

Anomalous expansion of water takes place because when water is heated to 277K hydrogen bonds are formed. Though ice is supposed to expand when it is converted into water, this gradual formation of hydrogen bonds causes it to contract, i.e. the contraction caused due to the formation of hydrogen bonds is greater than the actual expansion of ice. At 277K water has the maximum density because all the hydrogen bonds are formed by 277K beyond which water obeys the kinetic theory of molecules, an increase in volume when heated and the reverse when cooled. The same thing happens in the reverse when water is cooled beyond 277K .

The anomalous expansion of water helps to preserve aquatic life during very cold weather. When temperature falls, the top layer of the water in a pond contracts, becomes denser and sinks to the bottom. A circulation is thus set up until the entire water in the pond reaches its maximum density at 4° C. If the temperature falls further, the top layer expands and remains on the top till it freezes. Thus even though the upper layer are frozen the water near the bottom is at 4°C and the aquatic animals like fishes can survive in it easily.

At 0°C, we have the lowest density, this means the volume has increased the most crushing containers if water was very tight in the container. Since most containers contract by lowering the temperature and water expands between 4°C and 0°C, often the containers, even metallic ones, will rip open due to this expanding force. Having temperature lower than 0°C, Ice now retracts.

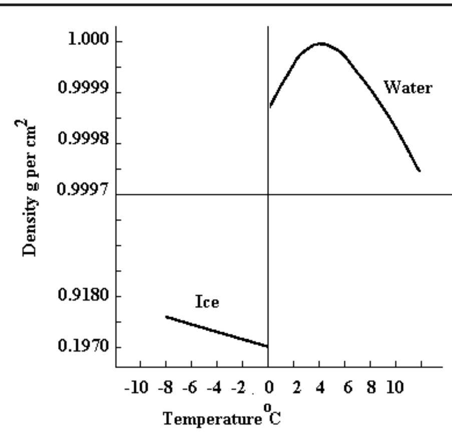


Fig. 4.4: Amomalous expansion of water

Effects of Anomalous expansion of water

Due to anomalous expansion of water, the fishes and other aquatic organisms are able to survive in Himalayan ponds. In winter when atmospheric temperature falls to 0°C or below it, the surface water turns into ice water at different temperature remains as shown in the diagram. The less density of ice than that of water makes it to float on the water and the bad conductivity of ice does not allow exchanging the temperature in and out of it. Due to it the fishes are safe in ponds.

What are the advantages of anomalous expansion of water?

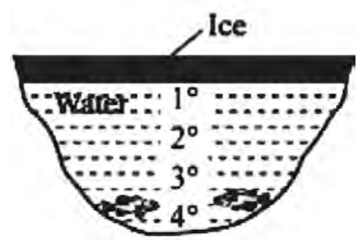


Fig. 4.5: Effects of Anomalous expansion of water

Normally, liquids contract on cooling and become denser. However, water contracts when cooled to a temperature of 4°C and thereafter expands as it is cooled further from 4°C to 0°C. Water attains its maximum density at 4°C. This phenomenon is useful for the preservation of marine life in very cold temperatures. Initially, the surface water in water bodies starts cooling. Upon reaching the temperature of 4°C, the surface water descends to the bottom as it denser. Upon further cooling between 4 degree C, a temperature gradient is set up in depths of the water body whereby, the bottom-most layer is at 4 degree C and the temperature gradually drops as one goes upwards. At 0 degree C, ice is formed. Ice being lighter than water, floats to the upper surface and also because ice has space or kind of holes between its molecules it is able to float in water. Further, water and ice are bad conductors of heat. All this help in the maintenance of temperature of the water at the bottom at 4°C. In this layer, marine life is able to sustain itself.

Thermal Expansion

There are various effects of heat. One of the effects of heat is thermal expansion, which means increase in size on heating. When temperature of a substance is raised, it expands and if it is lowered, then it contracts. In fact, thermal expansion occurs on solids, liquids and gases as well.

Thermal Expansion on solids

Most of the solids expand when they are heated and contract when they are cooled. On heating the materials, the temperature rises and their length, breadth and thickness increase. The expansion in length of an object is called the linear expansion. The expansion in three dimensions, i.e. length, breadth and thickness of an object is called the cubical expansion. So, three types of expansion are obtained in the solid.

Types of expansion in solids

When a solid is heated its length, surface area, and volume may change.

(a) Linear expansion (one dimensional): The thermal expansion in which the length of a solid increase on heating is known as linear expansion.

For example: If a thin wire is heated, its length increases as compared to negligible expansion in breadth, and area of cross section.

The increase in length of rod is directly proportional to

(i) its original length, (ii) increase in temperature.

Consider, the length of the rod be L_1 at temperature t_1. Consider, this length becomes L_2 at temperature t_2.

Now, increase on length = $L_2 - L_1$

increase in temperature = $t_2 - t_1$

So, From above condition,

$L_2 - L_1 \alpha L_1$..........................(i)

$L_2 - L_1 \alpha (t_2 - t_1)$....................(ii)

On combining (i) and (ii), we have

$L_2 - L_1 \alpha L_1 (t_2 - t_1)$

Or $L_2 - L_1 = \alpha L_1 (t_2 - t_1)$

Where α is a constant. It is known as coefficient of linear expansion and different for different materials. Its value depends upon the nature of material and its temperature.

So, $\alpha = \dfrac{L_2 - L_1}{L_1 (t_2 - t_1)}$....................(iii)

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

Therefore, coefficient of linear expansion of a substance is defined as the increase in length per unit original length, per unit change in temperature. Its unit is $0C^{-1}$.

Numerical Illustration

A steel rod of original length 55 cm at temperature 20°C is heated to 80°C. Calculate the total length of that rod at temperature 80°C. Also find the change in length of the rod. Coefficient of linear expansion of steel is $12 \times 10^{-6}\ {}^0C^{-1}$.

Solution:

Initial length $(L_1) = 55$ cm

Initial temperature $(t_1) = 20°C$

Final temperature $(t_2) = 80°C$

Coefficient of linear expansion $(\alpha) = 12 \times 10^{-6}\ {}^0C^{-1}$

Final Length $(L_2) = ?$

Change in length = ?

We know

$L_2 - L_1 = \alpha L_1 (t_2 - t_1)$

Or, $L_2 = L_1 + \alpha L_1 (t_2 - t_1)$

Or, $L_2 = L_1(1 + \alpha(t_2 - t_1))$

Or, $L_2 = 55 (1 + 12 \times 10^{-6} (80 - 20))$

Or, $L_2 = 55 (1 + 12 \times 10^{-6} \times 60)$

Or, $L_2 = 55 (1 + 72 \times 10^{-5})$

Or, $L_2 = 55.04$ cm

$\therefore$ The total length of rod 55.04 cm

$\therefore$ Change in length $= L_2 - L_1 = 55.04 - 55 = 0.04$ cm

(b) Superficial expansion (two dimensional): The thermal expansion of a solid in which its area increases on heating is known as superficial expansion.

The increase in area is directly proportional to

(i) the original area, (ii) the increase in temperature

Consider, the areas be A_1 and A_2 at temperature $t_1{}^0C$ and $t_2{}^0C$ respectively.

Now, increase in area $= A_2 - A_1$

and increase in temperature $= t_2 - t_1$

So, From above condition

$A_2 - A_1 \propto A_1$..........................(i)

$A_2 - A_1 \propto (t_2 - t_1)$....................(ii)

On combining (i) and (ii), we have

$A_2 - A_1 \propto A_1 (t_2 - t_1)$

Or, $A_2 - A_1 = \beta A_1(t_2 - t_1)$

Where β is a constant known as coefficient of superficial expansion

$$\beta = \frac{A_2 - A_1}{A_1 (t_2 - t_1)} \quad \text{....................} \quad \text{(iii)}$$

$$\beta = \frac{\text{increase in area}}{\text{original area} \times \text{rise in temperature}}$$

So, the coefficient of superficial expansion of a solid is defined as increase in area per unit original area per degree rise in temperature. Its unit is $^0C^{-1}$.

Numerical Illustration

A rectangular metal sheet has area 125 cm^2, which is heated from 20^0C to 80^0C. Its area now becomes $125.5 cm^2$. Calculate the value of coefficient of superficial expansion.

Solution:

Area of a metal $(A_1) = 125 cm^2$

and after heating its area $(A_2) = 125.5\ cm^2$

Temperature $(t_1) = 20°C$

And temperature $(t_2) = 80°C$

We have, $A_2 - A_1 = \beta A_1 (t_2 - t_1)$

Or, $125.5 - 125 = \beta \times 125 (80 - 20)$

Or, $0.5 = \beta \times 125 \times 60$

Or, $\beta = 0.5/7500$

$\therefore \beta = 7.0 \times 10^{-5}\ {}^0C^{-1}$

$\therefore$ The value of coefficient of superficial expansion $= 7.0 \times 10^{-5}\ {}^0C^{-1}$

Cubical expansion (three dimensional): The thermal expansion of a material in which its volume increases on heating is known as cubical expansion (or volume expansion). It has been experimentally observed that the change in volume of a body is:

i. directly proportional to the original volume

ii. directly proportional to the change in temperature.

Consider, V_1 and V_2 at temperature $t_1{}^0C$ and $t_2{}^0C$ respectively.

Now, increase in volume = $V_2 - V_1$

and increase in temperature = $t_2 - t_1$

So, From above,

$V2 – V_1 \alpha V1$..........................(i)

$V2 – V1 \alpha (t2 - t1)$....................(ii)

On combining (i) and (ii), we have

$V2 – V1 \alpha V1 (t_2 - t_1)$

Or $V2 – V1 = \gamma V1 (t2 - t1)$

Where ϒ is a constant, known as coefficient of cubical expansion of solid

$$\gamma = \frac{V_2 - V_1}{V_1 (t_2 - t_1)} \text{ ....(iii)}$$

So, coefficient of cubical expansion of a solid is defined as increase in volume per unit original volume per degree rise in temperature. Its unit is 0C-1.

Numerical Illustration

The volume of a small metal ball is 40 cm^3 at 10^0C. When it is heated to 80°C, its volume increases to 40.21 cm^3. Find the coefficient of cubical expansion.

Solution:

Volume of a small metal ball (V_1) = 40 cm^3

After heating its volume (V_2) = 40.21 cm^3

temperature (t_1) = 10^0C

and temperature (t_2) = 80^0C

We know,

$V_2 - V_1 = \gamma V1 (t_2 - t_1)$

Or, 40.21- 40 = γ x 40 (80-10)

Or, 0.21 = γ x 40 x 70

Or, γ = 0.21/2800

$\therefore \gamma = 7.5 \times 10^{-5}\ {}^0C^{-1}$

$\therefore$ The coefficient of cubical expansion $= 7.5 \times 10^{-5}\ {}^0C^{-1}$

Applications of expansion of solids

1. **Fixing of iron tyre to a cart wheel:** You might have seen bullock carts having iron tyres around them. Using thermal expansion process, these iron tyres are fitted to the wooden wheels. While making, the iron tyre is made slightly smaller than the wooden wheel. Its size increases on heating uniformmly. This hot iron tyre is now easily put around the wooden wheel and water is poured over it to cool it. On cooling, the iron tyre contracts and fits tightly to the wheel.

2. **To remove a tight glass stopper from a bottle:** Using thermal expansion process, a tight glass stopper from a bottle can be removed. The neck of the bottle is dipped in warm water. During this process, the neck of bottle expands; the stopper becomes loose and can be removed easily.

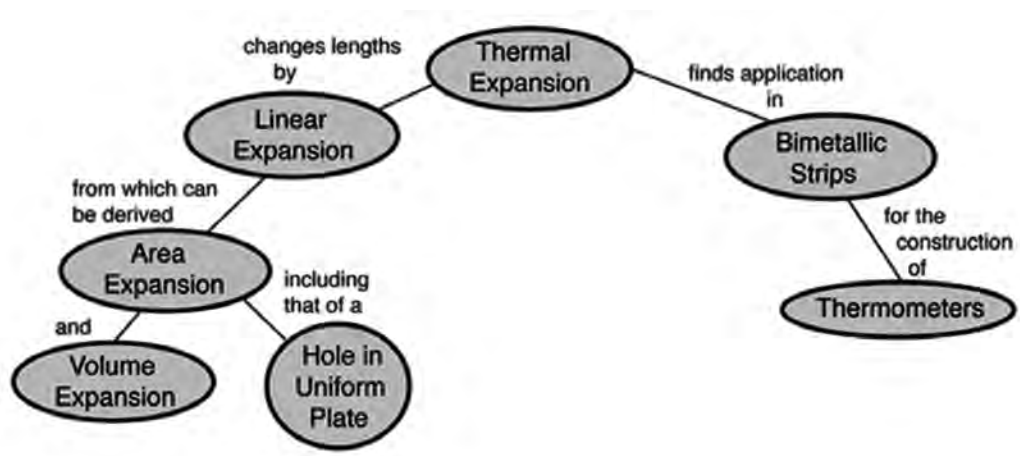
3. **Riveting of metal plates:** Metal plates are riveted with red hot rivets to a tight joint. When the hot rivets are cooled, they contract and hold the two plates very tightly.

4. **To make thermo switches:** The use of thermal expansion of metals is in the bimetallic strips which are used as thermo switches in automatic electrical heating (and cooling) appliances like thermostats, electric ovens, electric irons, fire alarms, bimetallic thermometers.

Thermal expansion on liquids

As we have discussed earlier, solid expands on heating and constract on cooling. In the same way, liquid also expands on heating and contract on cooling. But its expansion is comparatively more than that of solids. It is about 5 to 10 times more than solids for the same rise in temperature. An expansion of liquid does not contain proper length and surface area. So, linear expansion and superficial expansion of liquid can not be considered. But cubical expansion of volume in liquid is considered as it has got a definite volume. Like solid (as discussed earlier), the increase in the volume of liquid is directly proportional to the original volume of the liquid and rise in temperature.

Expansion Concepts



From the diagram given above, it is clear that these are interrelated to each other. The linear expansion of solid causes increase in the surface area which leads to the increment of volume. The increase in the surface of a body causes the increase in the volume. If the volume of a body increases, obviously, its length and surface area increase and vice versa.

Summary

1. Heat is a form of energy which causes in us the sensation of hotness or coldness.
2. The energy transferred from one object to another because of the temperature difference between them is called heat.
3. The science of temperature and its measurement is termed as thermometry.

4. An instrument used to measure temperature is called a thermometer.
5. Construction, Calibration and Sensitiveness are essential requisites of a thermometer.
6. The main advantages of Mercury thermometer are :
   a. Its boiling point is 357°C and freezing point is -39°C, therefore, it can be used over a wide range of temperature.
   b. Its expansion is nearly uniform over the ordinary range of temperatures. This makes the calibration of the thermometer easier.
   c. It does not wet the wall of glass tube and can be easily obtained in the pure state.
7. Mercury thermometer cannot measure temperature below – 39°C and above 357°C.
8. Alcohol thermometer is suitable in very cold places because it freezes at -115°C and boils at 78°C.
9. Liquid thermometers, Gas thermometers, Resistance thermometers, Thermo electric thermometers, Radiation thermometers, Vapour pressure thermometers are different types of thermometer.
10. Centigrade (or Celsius) scale, Fahrenheit scale and Reaumer scale are temperature scales.
11. Expansion of the substances, increase in temperature, and change in the state of substances, chemical change and change in the solubility of the substances are effects of heat in our daily life.
12. Fixing of iron tyre to a cart wheel, to remove a tight glass stopper from a bottle, riveting of metal plates, and to make theorem switches are uses of expansion of substance due to heat.
13. When a solid is heated its length, surface area, and volume may change.

Exercise

A. Tick (✓) the best alternative from the followings.

1. What is the boiling point of Mercury in degree Celsius scale?

   i) 337°C   ii) 357°C
   iii) 375°C   iv) 387°C

2. What is called the instrument used to measure heat?

   i) Thermometer   ii) Calorimeter
   iii) Lactometer   iv) Barometer

3. Which of the following are the essential requisites of a thermometer?

   i) Construction   ii) Calibration
   iii) Sensitiveness   iv) All of the above

4. What is the boiling point of alcohol in degree Celsius scale?

   i) 78°C   ii) 87°C
   iii) 117°C   iv) 357°C

5. What happens when a solid is heated?

   i) Length changes   ii) Surface area changes
   iii) Volume changes   iv) All of the above

B. Answer the following short questions.

1. What is heat?
2. What is meant by thermometry?
3. Define the term thermometer.
4. Mention the essential requisites of a thermometer.
5. What are the boiling and freezing point of mercury thermometer?
6. Mention the boiling and freezing points of alcohol thermometer.
7. What are different types of temperature scales?

8. Mention the effects of heat in our daily life.
9. What is anomalous expansion of water?
10. At what temperature water has maximum density?

C. Answer the following long questions.

1. What are the advantages of mercury thermometer?
2. What are the disadvantages of mercury thermometer?
3. Mention the advantages of alcohol thermometer.
4. Mention the disadvantages of alcohol thermometer.
5. What do you mean by apparent and real expansion of liquid?
6. Water has maximum density at 4° C temperatures, why?
7. How is aquatic life possible in winter season in very cold places? Explain with reason.
8. What is linear expansion of solid? Derive the coefficient of linear expansion of solid.
9. What is meant by superficial expansion of liquid? Derive the coefficient of superficial expansion of solid.
10. What is meant by cubical expansion of liquid? Derive the coefficient of cubi cal expansion of solid.
11. When a beaker filled with water at 4°C is cooled or heated water overflows from the beaker, why?

D. Solve the following numerical problems

1. The coefficient of linear expansion of copper is 17×10^{-6} per ^{0}C. Calculate the increase in length of a copper wire 10 m long when heated from 30^0C to 60^0C. (Ans: 10.0051 m)
2. A rectangular metal sheet has sides of 50 cm and 3 cm. This sheet is heated from 0° to 50° C, and the value of superficial expansion of it is $6.67\times 10^{-5}\ {}^0C^{-1}$. Calculate its area in cm^2. (Ans: $6.67 \times 10^{-5}\ {}^0C^{-1}$)
3. The volume of a small metal ball is 50 cm^3 at 20°C. When they are heated to 50°C, its volume increases to 50.15 cm^3. Find the coefficient of cubical expansion. (Ans: $1.0 \times 10^{-4}\ {}^0C^{-1}$)

Project Work

Bring a clinical thermometer from nearby medical. Measure the body temperature of five friends in your class and convert these readings in other temperature scales too. Prepare a report on the basis of these observations and present it in the class.

Glossary

Bimetallic thermometers	:	A thermo-switch which works by the action of heat
Thermal expansion	:	increase in size on heating
Rip open	:	tear apart in a vigorous manner
Retract	:	be drawn back
Riveting	:	Compelling

Unit 5

Light

Thomas Young (1773 – 1829)

Thomas Young was an English polymath and physician. Young made notable scientific contributions to the fields of vision, light, solid mechanics, energy, physiology, language, musical harmony, and Egyptology. He "made a number of original and insightful innovations" in the decipherment of Egyptian hieroglyphs (specifically the Rosetta Stone) before Jean-François Champollion eventually expanded on his work..

Learning outcomes

After the completion of this unit, learners will be able to

1. Demonstrate and describe the refraction of light.
2. Demonstrate and describe the total internal reflection of light.
3. Calculate the refractive index of water and glass.
4. Solve simple mathematical problems.
5. Explain real and apparent depth with examples.

Introduction

Light is a form of energy which produces sensation of vision in our eyes to see objects from which it comes. In the absence of light, we cannot see the objects. We detect light by our eyes which is an optical instrument provided to us by nature. There are many sources of light energy, some are natural and other are man-made sources of light. Sun is the most important natural source of light. An opaque surface like that of a mirror reflects light according to laws of reflection, whereas a transparent object like a lens refracts light rays according to laws of refraction of light. We have already studied reflection of light and its laws in junior classes.

> Do you know?
>
> In physics, light refers to electromagnetic radiation. The light we normally talk about in everyday life refers to the visible spectrum (the part of the electromagnetic spectrum that the human eye can see).

In this unit, we will discuss about the laws of refraction of light, total internal reflection and its causes, dispersion of light through glass slab, refractive index, real and virtual images.

Refraction of Light

We have learnt that light travels in a straight line in a particular medium. When obstructed by various objects, some part of it is absorbed, reflected back or transmitted through the object. When a beam or a ray of light passes through a transparent material, such as glass or water, it changes its path or it bends at the edges of two media. This is due to variation of speed of light in different media. When a ray of light travels from rarer to denser medium, it travels slower and vice versa.

The bending of light as it passes from one optical medium to another medium is called refraction of light.

Activity 5.1

Refraction of light through a glass block (glass slab)

Place a rectangular glass block ABCD on a white sheet of paper; trace its outline with a pencil. Fix two vertical pins P_1 and P_2 as marked on one side of the block so that the line P_1P_2 becomes a ray incident on the glass block. Remove the glass block; draw line P_1P_2 and a normal NN' at the point O on which the ray is incident. Now replace the glass block properly along the outline.

Look from the other side and fix pins P_3 and P_4 as marked such that they are in line with the images of pins P_1 and P_2 as seen through the block. Now, remove the block, produce P_3P_4 to meet the outline of the block at O' and mark on it as the emergent ray. The ray of light entered the block at O comes out through though point O'. It could be assumed that light travelled from O to O' in a straight line; hence, join points O and O' to obtain a straight line and mark the direction on it. This is called the refracted ray.

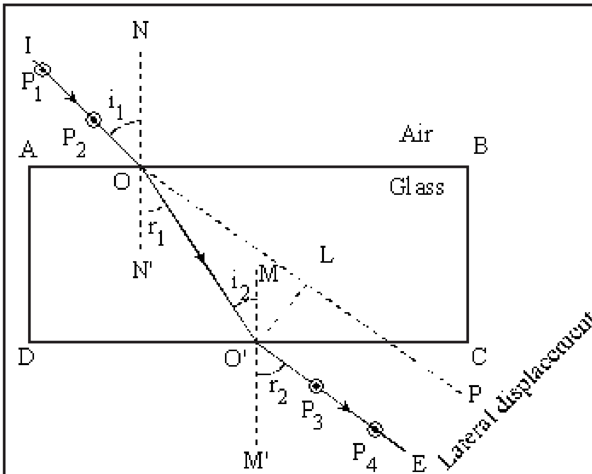


Fig. 5.1: Refraction of light through glass slab

Now, measure the angle of incidence ∠i, and the angle of refraction ∠r. You will notice that ∠r is less than ∠i . This shows that when light enters a denser medium, it bends towards the normal. At O', when the ray OO' emerges out into a rarer medium, the ray P_3P_4 (O'E) is seen to bend away from the normal.

Activity 5.2

Take a penny and an empty plastic cup and place penny in the cup. Put the plastic cup on a table and step back until the penny is just out of your view. The edge of the plastic cup hides it from your sight. Do not move your eyes from this position. Now, ask someone to pour water gradually in the plastic cup. What do you observe? The penny appears in your view and you can clearly see it. The penny and bottom of the plastic cup appear to have lifted a little. This is due to the refraction of light.

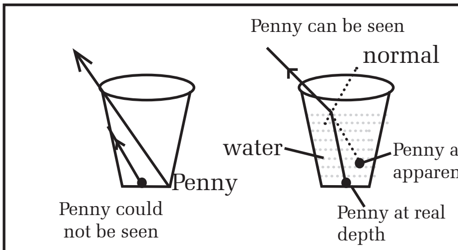


Fig. 5.2: Refraction of light

Laws of refraction of light

a. The incident ray, normal and the refracted ray lie on the point of incidence, and all three lie on the same plane.

b. The refracted ray bends away from the normal when a ray passes from denser to rarer and it bends towards normal when it is passed from rarer to denser medium.

c. The ratio of the sine of the angle of incidence (sin i) to the sine of the angle of refraction (sin r) is constant for any two media. The refraction takes place according to the following laws. These laws were given by Willihrod Snellius and commonly known as Snell's law. i.e.

$$\boxed{\frac{\sin i}{\sin r} = \mu \text{ (constant)}}$$

where μ is a constant and it is also known as the refractive index of the second medium. As the refractive index increases its density of the medium also increase a vice versa.

The refractive index of glass with respect to air is represented by the symbol a μ g.

Do you know?

Isaac Newton observed that a thin beam of sunlight hitting a glass prism on an angle creates a band of visible colors that includes red, orange, yellow, green, blue, indigo and violet (ROYGBIV). This occurrs because different colors travel through glass (and other media) at different speeds, causing them to denote at different angles and separate from each other, producing a gap between any two colours which helps to identify all the colours.

Numerical Illustration

A ray of light is incident on a glass with an angle of incidence 30°. Calculate the angle of refraction if refractive index of glass is 1.5.

Solution:

Refractive index (μ) =1.5

Angle of incidence ($\measuredangle$i) =30°

Angle of refraction ($\measuredangle$ r) =?

We know that,

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

or, $\frac{\sin 30}{\sin r} = \mu$

or, $\frac{\sin 30}{\sin r} = 1.5$

or, $\sin r = \frac{\sin 30}{1.5}$

or, $\sin r = \frac{0.5}{1.5}$

$\measuredangle r = \sin^{-1}(1/3)$

$\therefore \measuredangle r = 19.5^0$

$\therefore$ The angle of refraction is 19.5°.

Reversibility of Light

The principle of reversibility of light simply states that the paths of light ray are reversible. That means if the ray of light is sent in the exact opposite direction it will follow the same path.

When a ray of light passes from glass to air, the refractive index of air with respect to glass is represented by aμ g $= \frac{1}{g\mu a}$

The refractive index of a substance with respective to vacuum is called its absolute refractive index.

The values of absolute refractive index for some substances are given below:

Substance	**Refractive index, μ**
Alcohol	1.30
Ice	1.31
Water	1.33
Paraffin	1.44
Glycerin	1.47
Turpentine	1.47
Glass	1.50
Ruby	1.76
Diamond	2.42

The speed of the light is inversely proportional to the density of the medium. It means that light travels faster in a medium with low density than a medium with high density. In fact, the refraction of light is due to the change in speed when they pass from one medium to other. For a light passing from vacuum into a medium,

$$\text{Refractive index, } \mu = \frac{\text{Speed of light in vacuum (c)}}{\text{Speed of light in the medium (v)}}$$

Numerical Illustration

The velocity of light in air is 3×10^8 m/s and its velocity in water is 2.2×10^8 m/s. Calculate the refractive index of water.

Solution:

Velocity of light in air (c) = 3×10^8 m/s

Velocity of light in water (v) = 2.2×10^8m/s

Refractive index (μ) =?

We know that,

$$\text{Refractive index, } \mu = \frac{\text{Velocity of light in vacuum(c)}}{\text{Velocity of light in the medium(v)}}$$

$$\text{Or, } \mu = \frac{3\times 10^8}{2.2\times 10^8}$$

Or, $\mu = 1.3$

$\therefore$ The refractive index of water is 1.3.

Dispersion of light

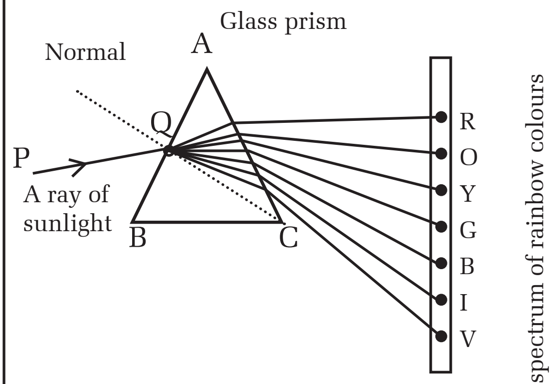


Fig. 5.3: Dispersion of light through prism

In the year 1665, Sir Isaac Newton discovered by his experiment with those glass prisms light that consists of a mixture of seven different colors. Newton found that if a beam of white light is passed through a triangular prism, the white light splits to form a band of seven colors. The seven colors of the spectrum can be denoted by the word VIBGYOR where V stands for Violet, I stands for Indigo, B stands for Blue, G for Green, Y for Yellow and R for Red. The red color is deviated the least while the violet color is deviated the most.

The phenomenon of splitting of a beam of white light into its component colors on passing through a refracting medium such as a glass prism is known as dispersion of light.

In figure 5.3, a beam of white light PQ is passed into a glass prism ABC. This beam of white light splits of entering the glass prism and forms a broad patch of seven colors in a white screen placed on the other side of the prism.

The formation of spectrum of seven colors shows that white light is made up of seven different colors mixed together. That is, white light is the mixture of seven colors. The effect of glass prism is only to separate the seven colors of white light. A similar band of seven colours is produced when a beam of white light from an electric bulb falls on a triangular glass prism. We can explain the dispersion of light by a glass prism as follows.

Do you know?

Humans are bioluminescent from metabolic reactions, but our glow is 1,000 times weaker than the naked eye can register.

A white light is a mixture of seven colours: red, orange, yellow, green, blue, indigo and violet.

The dispersion is seen to be least for red and most for violet. The refractive index of a transparent material is the maximum for violet and the least for red. Thus, the reason of dispersion is the different deviations of different colours produced due to the difference in refractive indices for them. When white light fall on black color, it does not reflect any light, it absorbs all the colours of white light falling on it. A white, red or green object, all appear black during the darkness of night because there is no light to be reflected. Please note that the colours of objects which we see in white light (sunlight or bulb light) are their natural colours.

The natural colours of transparent objects are due to their selective transmission of light. Thus, a piece of glass held before the eye appears to be red, green or yellow, according as it transmits red, green or yellow portion of the white light falling on it. The rest of the colours are absorbed by it.

Activity 5.3

Allow a very narrow beam of light from a light box to fall on one face of a prism. Hold a white screen on the other side so that light emerging out of the other face falls on it. In the given figure, you will see that the light has spread of light into its various components is called dispersion. The spread out patch of light on the screen is called a spectrum.

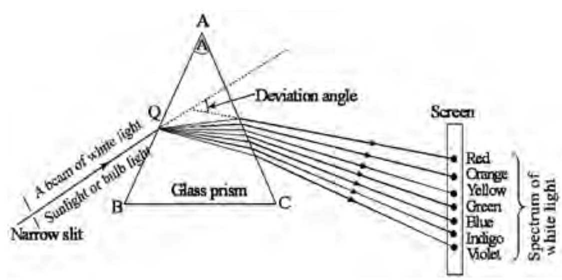


Fig. 5.4: A spectrum of seven colours

The order of colours is the same as that seen in a rainbow, with the red bending least and the violet most. A rainbow, is formed when rays of the sun refract through water particles suspended in air. The major rainbow colours which you may be able to detect are violet, blue, green yellow and red, in that order. Actually the rainbow as well as the spectrum formed by you, has seven colours- violet, indigo, blue, green, yellow, orange and red. For the names and the order of colours you can remember the word VIBGYOR formed by using the first letter of each colour. Thus, when a ray of light is refracted through a prism, it not only suffers deviation but also dispersion. The deviation is least for red and most for violet, in the case of any particular prism.

It is possible to recombine the colours by the following method.

Activity 5.4

Remove the screen and place a second prism with base upwards in the path of light. The white screen is placed in the path of the light transmitted through the second prism. The arrangement will need some adjustment. You will obtain on the screen a single beam of light without dispersion

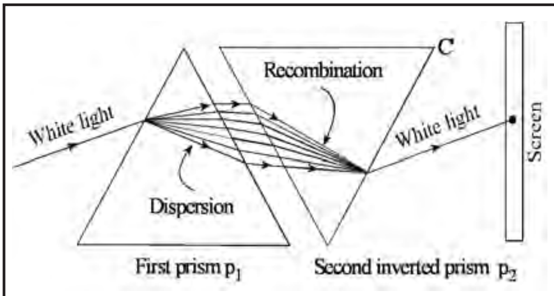


Fig. 5.5: Recombination of seven colours to show a white ray

The emergent light which is a combination of all the rainbow spectrum colors is called white light. (Light it is invisible; yet the term 'white light' is in common usage. You should therefore clearly understand the meaning of this term)

Real depth and Apparent depth

The actual length or depth measure from the free upper surface of water to its bottom is known as real depth. If the level of water in a pond is 6 m in real, then its real depth is 6 m. Similarly, any object in a denser medium when viewed from a rarer medium appears to be in less depth (less than 6m) than its real depth. Such less depth is called apparent depth. This is due to refraction of light.

Suppose O be a point of an object lying at the bottom of a pond. A ray of light OA from the object incident to the surface of water emerges out along AB. Another ray OC strikes normally to the surface, which does not bend and emerges out along CD. When the refracted ray AB is produced in backward direction, it meets OD at I forming the image at I. Here, CO is real depth and IC is the apparent depth (fig 5.6). It is found that

$$\text{Refractive index } (\mu) = \frac{\text{Real depth (D)}}{\text{Apparent depth (d)}}$$

In the given figure, the difference between the real depth and apparent depth of the object under water is shown. Here, the object is seen closer than its real depth to the surface. We see objects only if the rays coming from them reaches to our eyes. In this figure, ray coming from the object reaches the observer's eye after refraction. Thus, observer sees the image of the object closer than it really is which the apparent depth of the object is.

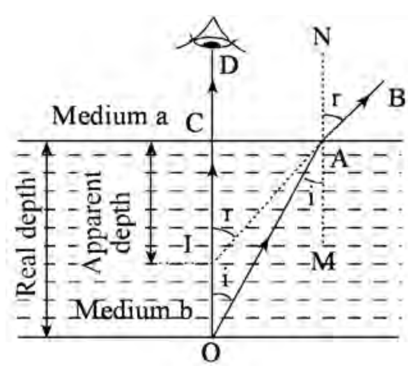


Fig. 5.6: Refraction of light

Critical angle and Total internal reflection

Let's discuss what happens when a ray of light is allowed to pass from optically denser medium (water) to optically rarer medium (air) at different angles of incidence as shown in figure.

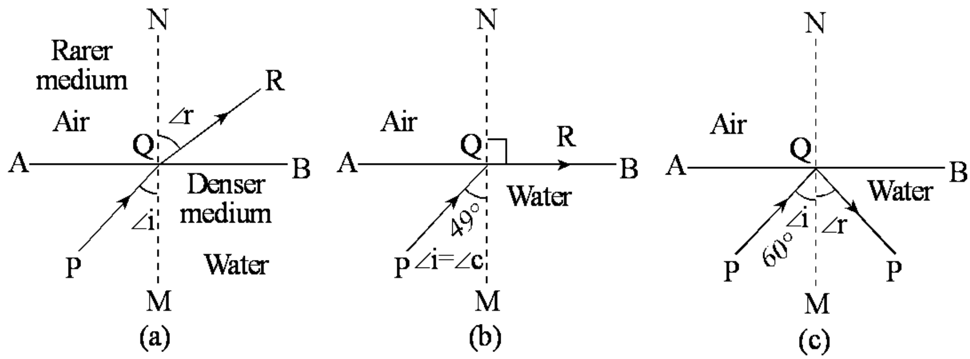


Fig. 5.7: Refraction of light

In the figure given alongside, the angle of incidence (∡PQM = (∡i) is increased, the ray of light refracts into air being far from the normal because water is optically denser medium than air. Here, the angle of incidence (∡PQM) is less than the angle of refraction (∡RQN). If the angle of incidence (∡PQM) is increased steadily, the angle of refraction (∡RQN or (∡r) also increases accordingly. In doing so, a stage will come when the angle of refraction (∡RQN) becomes exactly 90° for a particular value for angle of incidence in the denser medium

The angle of incidence in the denser medium for which the corresponding angle of refraction in the rarer medium is 90° is known as critical angle. It is represented by ∡c.

If the angle of incidence in the denser medium is still increased beyond the critical angle (∡c), the ray of light travelling from denser to rarer medium reflects back to the denser medium instead of being refracted through the rarer medium. The phenomenon is called total internal reflection of light. In the same figure, the ray of light is reflecting back to the previous medium as per the rule of reflection of light.

The phenomenon of reflection of light in the denser medium when light is passed from denser to rarer medium making incident angle greater than the critical angle for the two media is known as total internal reflection of light.

Conditions for total internal reflection of light

1. Light rays must travel from optically denser medium to the rarer medium.
2. The angle of incidence in the denser medium must be greater than the critical angle for given pair of media.

> Do you know?
>
> Greek mathematician Euclid discovered the laws of reflection of light in 300 BC.

Relationship between critical angle and refractive index

Let us consider, a ray of light is passed from water to air. By the use of Snell's law, the refractive index of air with respective to water is given by

$$w\mu a = \frac{\text{Sin } i}{\text{Sin r}} = \frac{\text{Sin } i}{\text{Sin } 90}$$

$$= \text{Sin}\measuredangle c$$

Now, the refractive index of water with respective to air is

$$\mu = a\mu w = \frac{1}{w\mu a} = \frac{1}{\text{Sin}\measuredangle c}$$

$$\therefore \text{ Refractive index } (\mu) = \frac{1}{\text{Sin}\measuredangle c}$$

The critical angles of some of the substances are shown below:

Substance	Critical angle ($\measuredangle$c)
Diamond	24°
Ruby	35°
Glass	42°
Turpentine	43°
Paraffin oil	44°
Alcohol	48°
Water	49°
Ice	50°

Some more illustrations on total internal reflection of light

1. Mirage

It is an optical illusion caused by the total internal reflection of light which can be observed in deserts and coal-tarred roads on a hot day. The object such as a tree is seen inverted and the observer gets the impression of reflection as in a pool of water in front of it. Such type of illusion caused by total internal reflection of light is called mirage.

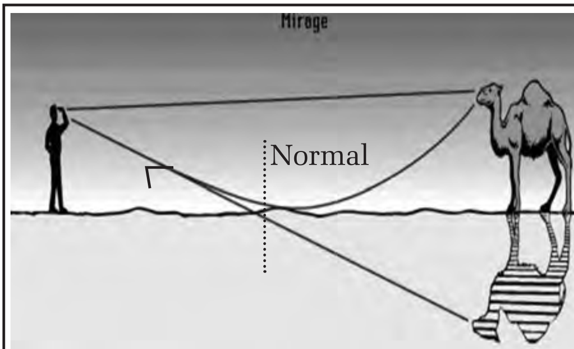


Fig. 5.8 Mirage

Due to the hot surface of earth, the temperature of air near the surface of earth is the maximum. The temperature of the layers of air goes on decreasing as one goes up. Therefore, density and hence refractive index of air increases slightly for higher layers. Thus, a ray of light travelling from point O of a camel passes through air of gradually decreasing refractive index, and is therefore refracted more and more away from the normal as shown in the figure 5.8. At a layer, when the angle of incidence becomes greater than the critical angle, total internal reflection takes place and when the ray reaches the eye of the observer, it appears to come from point I. Hence, the inverted image of the camel produces the impression of reflection from a pool of water.

2. Brilliancy of diamonds

Brilliancy of diamonds is also due to the total internal reflection. The refractive index of diamond-air interface is 24°. Due to the low value of the critical angle, there is maximum chance of occurring total internal reflection. A diamond can be cut into a number of faces so that the angle of incidence becomes greater than the critical angle. A ray of light on entering it from one face undergoes repeated total internal reflection from other faces. The face through which light emerges shine very brightly.

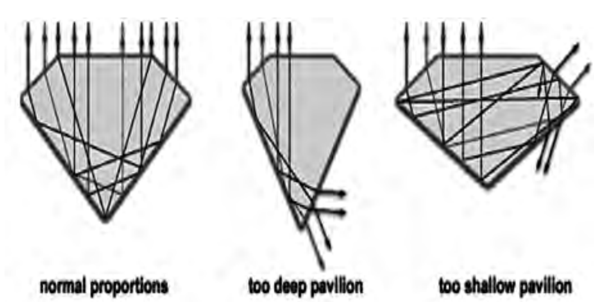


Fig. 5.9: Brilliancy of diamonds

3. Light pipes

A ray of light travels in a

straight line. It can be made to go in a curved path by using the phenomenon of total internal reflection.

A light pipe is a bent rod made up of transparent material like glass or plastic. It works under the principle of total internal reflection. The ray of light enters the pipe through one end and undergoes successive total internal reflections at different inner points and finally comes out of the other end.

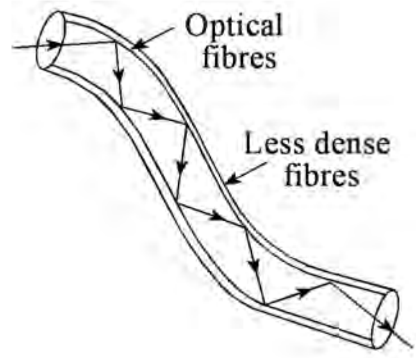


Fig. 5.10: Light pipe

It is used by the doctor to find out the diseased part/s of inaccessible areas.

A light pipe is a bent tube through which light travels in a curved path as per the rule of total internal reflection of light.

Uses of Total Internal Reflection of Light

We have already discussed that a piece of diamond cut at various faces sparkles due to total internal reflection of light.

A fiber optic is a glass "hair" which is so thin that once light enters one end, it can never strike the inside walls at less than the critical angle. The light undergoes total internal reflection and at each time it strikes the wall. After successive reflections, it reaches the other end and allow to exit the fibre. Fiber optic cables are used to carry telephone and computer communications.

Summary

1. Light is a form of energy which produces sensation of vision in our eyes to see objects from which it comes.
2. The bending of light as it passes from one transparent medium to another medium is called refraction of light.
3. The ratio of the sin of the angle of incidence (sin∡i) to the sin of the angle of refraction (sin∡r) is constant for any two media. It is also known as Snell's law. i.e.

   $$\frac{\sin i}{\sin r} = \mu \text{ (constant)}$$
4. The phenomenon of splitting of a white light into its component colors on passing through a refracting medium such as a glass prism is known as dispersion of light.

5. The actual length or depth measure from the free upper surface of water to its bottom is known as real depth.

6. Any object in a denser medium when viewed from a rarer medium appears to be in lesser depth than its real depth. Such lesser depth is called apparent depth.

7. The angle of incidence in the denser medium for which the angle of refraction in the rarer medium is 90° is known as critical angle. It is represented by $\measuredangle c$.

8. The phenomenon of reflection of light in the denser medium when light is incident at an angle greater than the critical angle for the two media is known as total internal reflection of light.

9. Conditions for total internal reflection of light

   (a) Light rays must travel from optically denser medium to the rarer medium.

   (b) The angle of incidence in the denser medium must be greater than the critical angle for given pair of media.

10. Mirage is an optical illusion observed in deserts and coal-tarred roads on a hot day due to total internal reflection.

11. Brilliancy of diamonds is due to the total internal reflection.

12. A light pipe is a bent rod made up of transparent material like glass or plastic, which works under the principle of total internal reflection.

Exercise

Tick (✓) the best alternative from the followings.

1. The bending of light as it passes from one transparent medium to another medium is called

   i) Refraction of light ii) Reflection of light

   iii) Dispersion of light iv) Diffusion of light

2. The ratio of the sine of the angle of incidence (sin<i) to the sine of the an gle of refraction (sin<r) is constant for any two media. What is this law called?

   i) Snell's law ii) Pascal's law

   iii) Archimedes's principle iv) Newton's law

3. The angle of incidence in the denser medium for which the angle of refraction in the rarer medium is 90° is known as

   i) Total internal reflection   ii) Critical angle

   iii) Incident angle   iv) Reflected angle

4. Which one is the condition for total internal reflection of light?

   i) Light rays must travel from optically denser medium to the rarer medium.

   ii) The angle of incidence in the denser medium must be greater than the critical angle for given pair of media.

   iii) Both i) and ii)

   iv) None of the above

5. A light pipe is a bent rod made up of transparent material like glass or plastic, which works under the principle of

   i) Reflection of light   ii) Refraction of light

   iii) Total internal reflection   iv) Critical angle

B. Answer the following short questions.

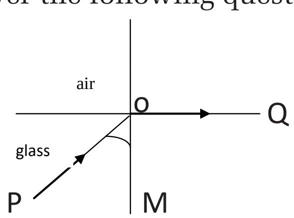
1. What is meant by light?
2. Define the term 'refraction of light'.
3. Give the definition of dispersion of light.
4. What is real depth?
5. Give the definition of apparent depth.
6. What is meant by refractive index?
7. Define critical angle.
8. What is meant by total internal reflection?
9. Mention the conditions for total internal reflection of light.
10. What is mirage?
11. Define light pipe and mention its one use.

C. Answer the following long questions.

1. Describe the process of refraction of light through glass slab.
2. A boy standing by a lake sees a fish in the pond and tries to thrust a spear into it, he will success or not? Explain with reason.
3. Experimentally prove that real depth is more than its apparent depth.
4. Clarify the concept of refractive index with an example.
5. State Snell's law of refraction of light.
6. A diamond sparkles more than a glass cut to similar shapes. Why?
7. A white ray of light is dispersed by prism. Explain with reason.
8. A paper gets burnt when sun light is focused on it. Give reason.
9. Show the process of dispersion of light through prism.
10. Describe the process of total internal reflection of light.
11. Explain how is mirage formed?
12. How does light pipe work? Explain.
13. A pencil appears to be bent away when partly immersed in water. Explain with reason.
14. A pool of water appears shallower than it really is. Why?
15. Observe the diamond given below and answer the following questions.

i. What term is used to denote the angle POM?

ii. What effect is caused to the ray OQ when angle POM is increased?



D. Solve the following numerical problems

1. The refractive index of glass is 1.5. If the velocity of light in air is 3×10^8 m/s, then, calculate the velocity of light when it travels through glass. (Ans: 2.0×10^8 m/s)
2. What is the apparent depth of a lake if its real depth is 8 m? (Ans: 6.01 m)
3. The velocity of light in diamond is 1.24×10^8 m/s and its velocity in air is 3×10^8 m/s. Calculate the refractive index of diamond. (Ans: 2.41)
4. A ray of light is incident on water with an angle of incident 60°. What is the angle of refraction in the water? The refractive index of water is 1.33.

(Ans: 40.54°)

5. The real depth of a pond is 6m and its apparent depth is 4m. Calculate the refractive index of water. (Ans: 1.5)
6. What is the refractive index for ruby if its critical angle is 35°. (Ans: 1.75)
7. The refractive index of glass is 1.5. With what angle should a ray strike the surface of glass to make an angle of refraction 30°? (Ans: 48.59°)

Project Work

1. Take a pencil and a glass of water. Place the pencil in the empty glass and look at it from the side. Pour water in the glass till the glass is about half full. The pencil seems to be bent at the surface of water. Observe this activity and prepare a report and present it in the class.
2. You must have seen a rainbow in the sky with its various colours during the rainy season. How is the rainbow formed? Where do the colours come from? Observe the activity very carefully and prepare a report on the basis of your observation and present it in the class.

Glossary

Incident ray	:	light ray which strikes any surface
Rarer medium	:	a medium with lower density
Apparent depth	:	virtual depth of water as seen from out side
Denser medium	:	a transparent medium having higher density
Lateral displacement	:	a displacement of emergent ray from its original path
Spectrum	:	a band of visible light wave
Refracted ray	:	a ray which passes into other medium after bending at the surface in between two media
Prism	:	a solid glass whose section is triangular
Penny	:	The United States one cent coin

Unit 6

Current Electricity and Magnetism

André-Marie Ampère was a French physicist and mathematician who was one of the founders of the science of classical electromagnetism, which he referred to as "electrodynamics".

Andre Marie Ampere (1775 – 1836)

Learning outcomes

After the completion of this unit, learners will be able to

1. Differentiate between static electricity and current electricity with examples.
2. Explain properties of magnetic lines of force and demonstrate it experimentally.
3. Give the meaning of angle of dip or inclination and angle of declination and describe the method of finding their values.
4. Explain the structure and function of solar cell.

Introduction

The word 'electricity' has been derived from the Greek word electron which means amber (a yellowish fossilized resin). Electricity is of two types i.e. static and current. Electricity has become the main source of energy in our daily life. In our daily life, we use various types of electronic appliances such as TV, Radio, Refrigerator, Mobile, etc. To operate these devices, electricity is consumed. These electrical appliances use electricity to convert other forms of energy like heat, light, sound, magnet, etc.

The word 'magnet' is derived from magnesia (ancient Asia Minor). The property of a magnet due to which it attracts the magnetic substances is called magnetism. Magnet is of two types i.e natural and artificial. Electricity can be generated from magnet. Like electricity, it can also be used for various purposes such as to lift heavy loads, to find the direction, to produce electricity, etc.

Electricity and magnetism is a pair of components. We can convert electricity into magnetism and magnetism into electricity. In this unit we will discuss about the static electricity and current electricity, properties of magnetic lines of force, angle of dip and angle of declination, and the structure and function of solar cell.

Static Electricity

When you take off your nylon cloth in dark room, you will notice electric sparks. What is the reason behind it? To understand the above phenomenon, we have to first understand about the structure of atoms and charges.

Electric charges

Activity 6.1

Take a plastic comb and touch it with small pieces of paper. See whether it attracts pieces of paper or not. Rub a plastic comb several times with silk or hair and keep it closer to the pieces of paper. They get attracted by the comb. If same experiment is performed without rubbing the plastic comb without rubbing the plastic comb with silk clothes or hair it doesn't attract the pieces of paper. Discuss with your friends to find the cause of this event.

Activity 6.2

Take a air filled balloon and rub it with hair several times and placed gently against a wall. You will see the balloon gets stick to the wall. In this case, the balloon is said to be charged on rubbing with hair. When the charged balloon is brought closer to the wall, there is attraction between the balloon and the wall. As a result, the balloon gets stick to the wall.

In the above mentioned examples, the comb and the balloon are said to be charged after rubbing. Something that the comb and the balloon acquired while rubbing is called electric charge. Not only the comb and the balloon acquire electric charge by rubbing but also all bodies acquire this.

Electric charge is represented by the symbol Q. It is a physical quantity and its SI unit is coulomb. It is named after the scientist Charles Augustin de coulomb.

For the detection and testing of small electric charges on a body, an electroscope is used. It is an instrument which gives a rough estimation of the quantity of electricity present in different bodies.

Kinds of charges

6.3 Activity

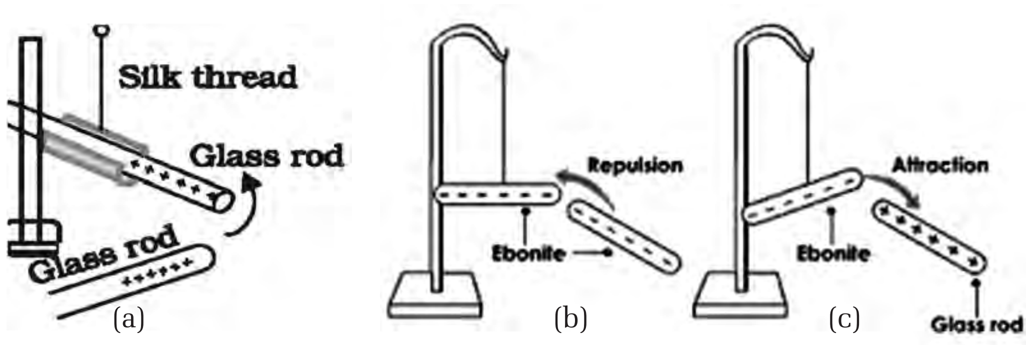


Fig : 6.1 kinds of charges

Take two glass rods. Rub them separately with a silk clothe and bring them closer to each other as in figure 6.1 (a). They will repel each other.

Similar result will be obtained when same type of activity is performed by using two ebonite rods and fur as well in figure 6.1 (b). Now, bring them near to each other as in figure 6.1 (b). There is repulsion between these ebonite rods. On the other hand, if a glass rod rubbed against silk is brought closer to the ebonite rod rubbed against fur, there is attraction between them as shown in figure 6.1 (c).

These activities conclude that the nature of charge developed in the glass rod is different from that developed in the ebonite rod. The charge on the glass rod is said to have positive charge and the charge on the ebonite rod is said to have negative charge. Thus, there are two types of charges: positive charge and negative charge. The charge of protons is called positive charge. Positive charge gets developed occurs in bodies due to loss of electrons in them. The charge of electrons is called negative charge. It is developed in bodies due to gain of electrons is them. Electric charges also repel and attract according to their nature. There is repulsion between like charges and attraction between unlike charges.

Modern theory of production of charges (Electrification)

Atoms are found to be electrically neutral. It is because in an atom there is equal number of electrons and protons. Protons are found inside the nucleus while electrons orbit them. Atoms with more valence electrons tend to acquire electrons while atoms with less valence electrons tend to lose the electrons. On rubbing with other bodies, they acquire or lose electrons in accordance with their valencies. In our previous discussion, nylon cloth acquires electrons from our body. So when we take off the cloth, there is discharge of electrons causing the electric sparks. Due to the disturbance in the number of electrons in a neutral atom, there occurs production of charge and the body is said to be charged.

For example, when a glass rod is rubbed against silk, the glass rod becomes positively charged and the silk becomes negatively charged. In this case, the glass rod loses electrons and the silk gains electrons. Similarly, when an ebonite rod is rubbed against fur, the ebonite rod accepts electrons and becomes negatively charged and at the same time, the fur donates electrons and becomes positively charged. The charge on an electron is equal and opposite to charge on a proton. Therefore, charge on electron is -1.6×10^{-19} coulomb whereas that of proton is $+1.6\times10^{-19}$ coulomb.

Current electricity

The substance which gains electrons becomes negatively charged and the substance which looses electrons becomes positively.

Cell, battery, generator, dynamo etc are the sources of electricity. This electricity can be carried from one place to another through an electric cable. Such type of electricity is called current electricity. If electric charged is in motion or allows to flow through a conductor it is said to be current electricity.

Electric current is defined as the rate of flow of charges i.e. current flowing through a circuit is the amount of charge flowing per unit time. If 'Q' amount of charge flows through a electric circuit in the time 't' then

$$\text{Electric Current (I)} = \frac{\text{Charge (Q)}}{\text{Time (t)}}$$

$\therefore\ I = Q/t$

Unit: The SI unit of charge Q is coulomb and time is sec, so unit of current is coulomb per second (C/S). It is also called ampere & is denoted by A.

i.e. 1 Ampere = 1C/1S

The current is said to be 1 ampere if one coulomb of charge flows through a point in a circuit in one second. Also, from above we have $Q = I \times t$

1 amp = 1000 mA

1 mA = 1000 micro Amp.

Sources of electricity

An instrument or device that changes any forms of energy into electrical energy is called the sources of electricity i.e. the devices which generate electricity are called sources of electricity. E.g. cell, photocell, generator, dynamo, etc. Heat energy, chemical energy, light energy, mechanical energy, atomic energy etc, can be converted into electrical energy by using different types of electric devices. The strength and the type of electrical energy produced by these devices vary.

Distinguish between static and current electricity

	Static electricity		Current electricity
1.	It is caused due to the disturbance in the number of electrons.	1.	It is caused due to the flow of electrons.
2.	It is mainly produced in insulators.	2.	It occurs mainly in good conductors.
3.	It cannot be transported from place to place through conducting wires.	3.	It can be transported from place to place through conducting wires.

Electric circuit

A closed and continuous path along which electric current flows is called electric circuit. Basically, an electric circuit consists of conducting wire, switch, bulb and cell or battery.

An electric circuit, through which electricity flows, is called a close circuit, where the key remains closed and electrical appliances like bulb, radio, tv etc. work. An electric circuit through which electricity does not flow is called open circuit, where the key is open or there is a gap or break and electrical appliances do not work.

Potential difference (pd) and electromotive force (emf)

Let's consider a simple cell in which copper and zinc plates are immersed in dilute sulphuric acid. When the cell is in use, zinc atom of zinc plate loses electrons causing the formation of zinc ions. These ions remain in acid while electrons remain at zinc plate. The zinc plate has negative potential. The electrons released at zinc plate move towards copper plate through external circuit. Hydrogen ion of acid receives these electrons and gets converted into hydrogen atoms which finally changed into hydrogen gas. . The copper plate has positive potential. The difference in potential of these two plates is called potential difference between the plates.

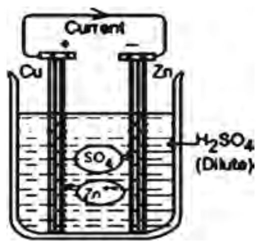


Fig : 6.3 A simple cell

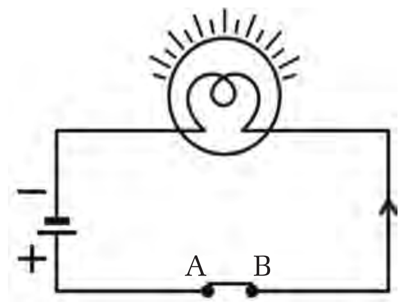


Fig: 6.4 an electric circuit

Similarly, let's consider two points A and B in an electric circuit as shown in figure 6.4. The point A is connected to +ve terminal of the battery and the point B is connected to –ve terminal of the battery. 'A' has +ve potential and B' has negative potential.

The potential difference between A and B is the difference of the potential at point A and at point B. It is also defined as the amount of work done in moving a unit positive charge from one point to another in an electric circuit. It is denoted by 'V'

$$\text{Potential difference (V)} = \frac{\text{Work done (W)}}{\text{Charge (Q)}}$$

Its unit is volt (v).

If 1 Joule of work is done in driving 1 coulomb charge from one point to another of an electric circuit, the p.d between the points is said to be 1V

i.e. 1V= 1 Joule/1 coulomb

Similarly, p.d. between the ends of a conductor is said to be 5V, if 5 J of work is done by moving 1C charge across its ends.

Electric current flows through an electric circuit when p.d is maintained. If two points are at the same potential, no electric current flows through these points.

> Potential difference (pd) is the differential of potential between any two points in a closed circuit. In other words, potential difference between any two points of the circuit is the amount of work done in taking a unit positive charge from one point to another.

The electrical energy supplied by the source of electricity drives the charge from the –ve terminal to the +ve terminal. The amount of energy supplied by a source to drive unit +ve charge from one terminal to another terminal in the absence of electric field is called the electromotive force.(emf) of the source. It is measured in open circuit.

Electromotive force (emf) is the difference of potential between the two terminals of a cell or any source in an open circuit. In other words, it is the amount of work done by the source in taking a unit positive charge once round the circuit.

Numerical Illustration

1. **A cell has capacity of supplying 150J energy to drive 50 coulomb charge from –ve terminal to +ve terminal. When it is connected in an electric circuit, it is found to supply only 100 J energy. Find the p.d and emf of the cell.**

   Solution:

   Energy supplied in open circuit (W)=150J

   Charge driver (Q)= 50C

   emf =?

   We know that,

   emf $= W/Q = (150\ J)/(50\ C) = 3V$

   We have,

   $$p.d. = W/Q = 100J/50C = 2V$$

   ∴ The emf of cell is 3V and p.d. is 2V

2. **How much work is done in moving a charge of 5C across to point having a p.d. 20V?**

   Solution:

   Charge (Q)= 5C

   p.d.(V)=20V

   Work done (W)= ?

   We know that,

   $$W = Q \times V = 5 \times 20 = 100\ J$$

∴ Work done is 100J.

Some instruments used in the electric circuit

The following are the most common instruments use to various things in the electric circuit.

Ammeter: An ammeter is used to measure high current. It has got very low resistance and it is connected in series with a conductor whose current is to be measured. A simple construction of an ammeter is shown in figure 6.5. It has two terminals with red coloured as + (positive) and another black coloured as – (negative). To measure current in a circuit, the +ve terminal of the ammeter is connected to the +ve terminal of the battery and the –ve terminal of the ammeter is connected to the –ve terminal of the battery.

Fig: 6.5 Ammeter

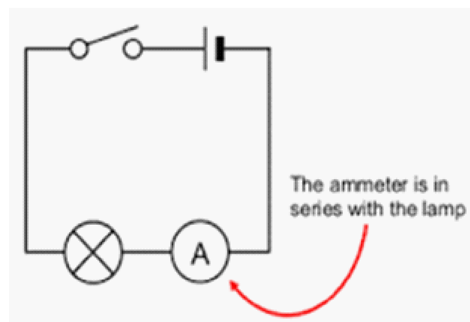


Fig: 6.6 Ammeter in circuit

Voltmeter

A voltmeter is a device to measure potential difference. It has got very high resistance device. Its two terminals having red coloured as + (+ve) and black coloured as –(-ve). The voltmeter is connected in parallel with the load whose potential difference is to be measured. Its simple construction and connection in a circuit is shown in figure:

Fig: 6.7 Voltmeter

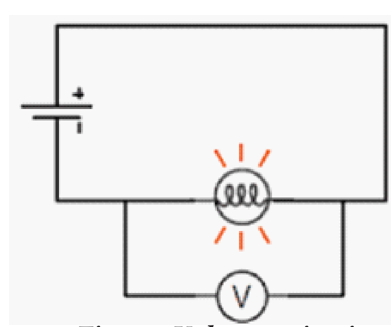


Fig: 6.8 Voltmeter in circuit

Galvanometer

A galvanometer is a device to detect and measure the small magnitude of current in a circuit. It is high sensitive device having very low resistance. It has two terminals marked as '+' and '–'. It is connected in series. If +ve current flows through the galvanometer, the needle of the galvanometer is deflected on the right side of the zero position of the scale. If current is negative, the needle is deflected on the left side of the zero position on the scale. Its simple construction and connection in a circuit is as shown in figures 6.9 and 6.10.

fig : 6.9 Galvanometer

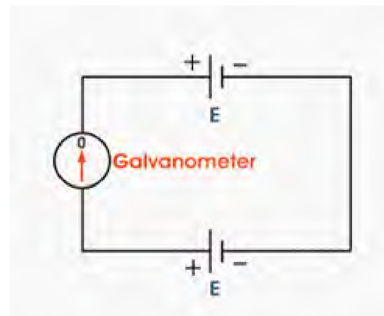


fig : 6.10 Galvanometer in circuit

Activity 6.4

Make an electric circuit as shown in figure 6.11 below. Take some pieces of constantan wires having different length and cross sectional area. Connect them in between points A and B. Observe the current in different cases:-

i. Current through 6cm wire and 3cm wire.

ii. Heat the same wires with candle and measure the current.

iii. Current through the wire with more and less cross sectional area.

iv. Current through the same constantan and copper wires having same length and cross section

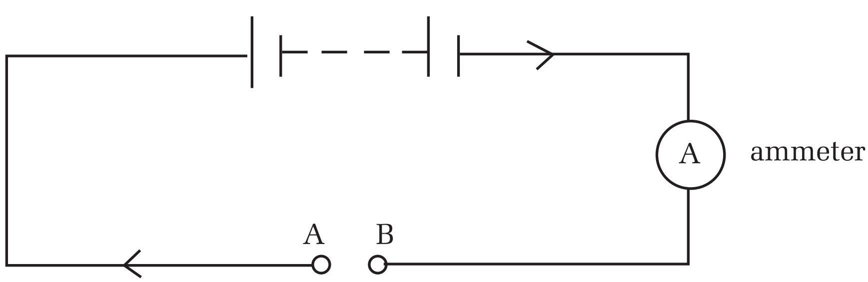


fig : 6.11

Resistance

A conductor opposes the flow of electric current through it. This property of the conductor is called its resistance. The resistance of a conductor is its property that restricts the movement of free electrons through it. It is measured in ohm (Ω) in SI system and is denoted by R.

If a current of 1 A through a conductor maintains a p.d. of 1 V across its ends, the resistance offered by the conductor is called 1 Ω.

Resistance measures the extent to which a conductor conducts electricity. Actually the flow of current in a wire is due to the motion of electrons. The electrons frequently collide with the atoms of the wire as they move through it. The speed of electrons decreases due to collisions. Thus the resistance of a wire depends on the number of collisions between electrons and the atoms of their wire.

Factors affecting resistance

The resistance of a conductor depends on the following factors:

a. **Length of conductor:** Resistance of a conductor is directly proportional to its length, i.e. $R \propto l$.

b. **Cross sectional area (thickness) of a conductor:** Resistance of a conductor is inversely proportional to its cross sectional area, i.e. $R \propto 1/A$

c. **Temperature:** Resistance of a conductor increases with increase in temperature, i.e. $R \propto T$.

d. **Shape of conductor:** Resistance of a conductor changes with its shape. A curved conductor offers more resistance than a straight conductor.

e. **Type of material:** Some materials like copper, gold, silver, aluminum have low resistance. The metals like chromium, manganese, tungsten, nickel and their alloys have high resistance.

Reciprocal of resistance is called conductance i.e. conductance (K) = $\frac{1}{R}$, its unit is Ohm-1

Resistivity and Conductivity

We know that the resistance of a conductor is directly proportional to its length and inversely proportional to its cross-sectional area. If 'l' is the length of a wire 'A' is its cross-sectional area and 'R' is its resistance, then

$R \propto l$................................(i)

Again $R \propto \frac{1}{R}$ ....(ii)

Combining equation, (i) and (ii)

$$R \propto \frac{l}{A}$$

$$\therefore\ R = \frac{\rho \times l}{A}$$

$$\therefore\ \rho = \frac{R \times A}{l}$$

Where ρ is the resistivity or specific resistance of the material. The SI unit of resistivity is Ω m. If, l=1m, A=1m^2, then R= ρ. Thus, the resistivity of a material is numerically equal to the resistance of a conductor of unit area per unit length of the material. The reciprocal of the resistivity (ρ) of a material is called its conductivity. It is denoted by σ.

$$\sigma = 1/\rho$$

∴ The SI unit of conductivity is Ω^{-1} m^{-1} (per ohm per meter)

Numerical Illustration

1. **What is the resistivity of manganin wire of 3.42m length with diameter 0.44 mm to construct a 10 Ω coil?**

   Solution:

   Length of manganin wire(l)=3.42 m

   Diameter (d)=0.44 mm =4.4×10^{-4} m

   Resistance (R)= 10Ω

Resistivity (ρ) =?

We know that,

$$\rho = \frac{R \times A}{l}$$

$$= \frac{\pi d^2}{7 \times 4 \times 3.42} \quad \left(\because \text{ Area (A)} = \frac{\pi d^2}{4}\right)$$

$$= 10 \times \frac{22\left(4.4 \times 10^{-4}\right)^2}{7 \times 4 \times 3.42}$$

$= 4.43 \times 10^{-7}\ \Omega m$

$\therefore$ Resistivity (ρ) of Manganin wire is $4.43 \times 10^{-7}\ \Omega m$.

Magnetism

The word magnetism is derived from the name of an iron ore called magnetite. It was found in Magnesia. It is believed that the Chinese invented the magnetic compass in 1100 A.D. Until 19th century, people treated current electricity and magnetism independently. Later discoveries proved that electricity and magnetism are like two sides of the same coin. In 1820, Oersted discovered magnetic effect of current. The magnetism can be obtained from electric current. Similarly, in 1831, Michel Faraday discovered electromagnetic induction, the production of electricity from magnet. Current electricity and magnetism do not remain as separate aspects of physics but two aspects of as single discipline called electromagnetism. Electromagnetism is explained by the electromagnetic theory of Maxwell.

It is found that some substances attract pieces of iron, cobalt, nickel. The substances which attract pieces of such metals in nature in the form of mineral are called magnetite. A piece of a substance which attracts pieces if iron, cobalt, nickel, steel is called a magnet. The substances which are attracted by magnet are called magnetic substances, e.g. iron, cobalt, nickel, etc. The property of a magnet to attract magnetic substances is called magnetism.

You may be familiar with magnet. It is used in speakers of mobile, radio, TV, loudspeaker etc. When small pin is brought near to the speaker, it is found to be attracted. Similarly, two magnets also get attracted or repulsed from each other. These properties are commonly known as magnetism. The property of a magnet by virtue of which it attracts or repel other magnetic materials is called magnetism.

Do you know?

Magnet was discovered in ancient civilization. It has a story of a shepherd of magnesia in the Asia Minor. Legend imputes the magnetire to the shepherd Magnes, the nails of whose shoes stuck fast in magnetic field while he pastured his flocks of sheep. Later in the middle ages, the magnetire was used to make navigational compasses, since it used painting to the N-S direction when it was allowed to move freely.

Magnetic field

When a magnetic substance is placed near a magnet, it is affected by the magnet. As the distance from the magnet is increased, the magnetic influence goes on decreasing and after certain distance, the magnetic influence is not observed. The space around a magnet up to which the magnetic influence can be felt is called magnetic field. A large magnet has large magnetic field and a small one has small magnetic field. The field can be represented by lines called magnetic lines of force.

> Magnetic field is the space around where magnetic lines of force are found. The region or space around a magnet in which magnetic effect can be experienced is called magnetic field.

Magnetic lines of force

The magnetic lines of force of a magnet are the imaginary curves around the magnet along which a unit north pole would move if it sets free to move. The magnetic lines of force of a magnet can also be defined as the curves around the magnet along which the magnetic compass moves. A number of magnetic lines of force originate from the north pole of a magnet.

The magnetic lines of force are continuous curves having the following properties:

a. The magnetic lines of force are continuous closed curves.

b. Magnetic lines of force appear to start from the north pole and reach to the south pole of a magnet externally and from south pole to north pole internally.

c. The magnetic lines of force do not intersect each other.

d. The tangent at any point on a magnetic line of force gives the direction of the magnetic field at the point.

Activity: To plot the magnetic lines of force

To draw magnetic lines of force, keep a bar magnet on a sheet of paper over a drawing board as shown in the figure. Place a small compass near the north pole of the magnet. When the compass needle comes to rest after the deflection, mark the ends N-S of the needle with a sharp pencil as dots A and B. Now replace the compass so that S- pole rests on the dot B which is previously shown by N- pole. Now, put a dot C against N- pole. This process is continued until the compass reaches the south pole of the magnet. The series of dots obtained thus gives the magnetic lines of force.

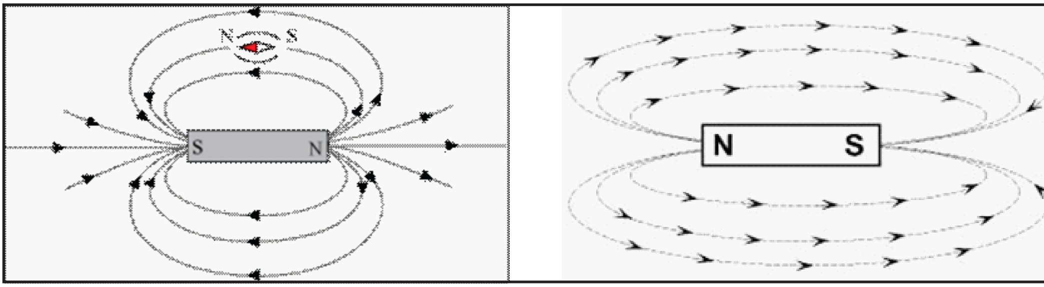


Fig : 6.12 Plotting magnetic lines of forces

Put an arrow on the line to indicate the direction of magnetic lines of force from north to south. Plot the other lines in the same way to obtain the entire magnetic field. Any magnetic field consists of infinite number of magnetic lines of force. Thus, the magnetic lines of force of a bar magnet can be drawn by two ways:

A. By placing the magnet with its N-pole pointing towards geographical south.

Procedure

1. Fix a sheet of paper on a drawing board with the help of fixing pins and place the board on a table.
2. Place a bar magnet in the middle of the paper parallel to the length of the paper and draw its outline with a pencil.
3. Remove magnetic substances around the table. Remove the magnet from its outline.
4. Place the magnetic needle on the outline of the magnet. Rotate the board slowly till the needle and the outline parallel to each other.
5. Place the magnet on the outline with its north pole pointing towards the geographical south.
6. Keeping the position of the board undisturbed, draw the lines of force as:
   a. Mark a dot close to the north pole of the magnet with pencil.
   b. Place one end of the compass needle over this dot point.
   c. Also mark the other end of the compass needle with the pencil.
   d. Now, move the compass needle to the second point and mark the third point as before.

e. Repeat the operations (c) and (d) till the south pole is reached.

f. Join all of these points .The line obtained gives a magnetic lines of force.

g. Similarly, draw other lines of force on the same side and on the other side of the magnet as shown in fig. 6.13 (i)

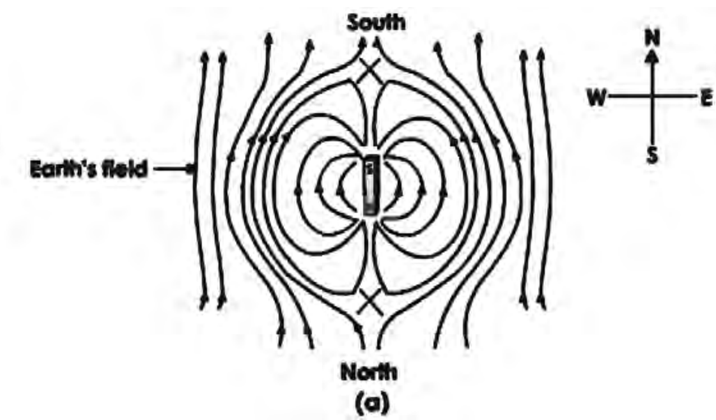


Fig : 6.13 (i) Magnetic lines of forces N-pole pointing towards geographical south

B. By placing the magnet with its N- pole pointing geographical north

Procedure

1. Perform operations from 1 to 4 of above (A) .
2. Place the magnet on its outline so that its north pole points towards the north.
3. Keeping the position of the board undisturbed, draw the lines of force are drawn as:
   a. Mark a point close to the north pole of the magnet with a pencil.
   b. Place one end of the compass needle over this point.
   c. Also mark the other end of the compass with the pencil.
   d. Now,move the compass needle to the second point and mark a third point as before.
   e. Repeat the operation (c) and (d) till the south pole is reached.
   f. Join all of these points. The curve line so obtained gives a magnetic line of force.

g. Similarly, draw other lines of force on the other side of the magnet as shown in fig. 6.14 (ii)

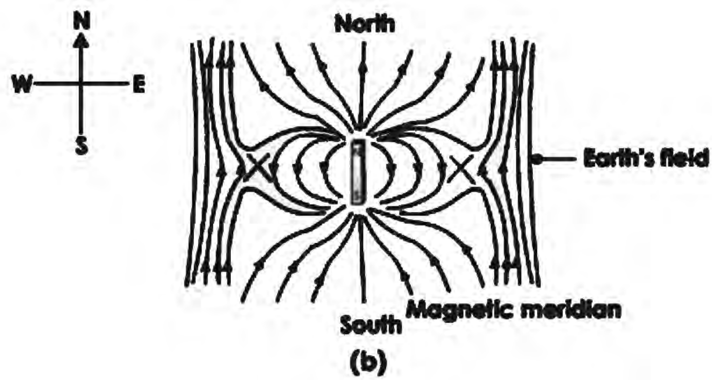


Fig : 6.13 (ii) Magnetic lines of forces N-pole pointing towards geographical north.

Neutral point

When a bar magnet is placed on any surface, the magnetic field around the magnet is not only due to the magnet alone. But, the field is the combination of the magnetic fields of the magnet and the earth. As we move away from the magnet, magnetic field of the magnet is almost zero and the earth's field is dominating. Within this region, there are two points where the magnetic field of the magnet is exactly equal and opposite to that of the earth's magnetic field. These points are called neutral or null points. ***The points inside the magnetic field of a magnet where the resultant magnetic field intensity due to earth's field and magnet is zero are called neutral points.*** No lines of force will pass through the neutral point and the compass needle will not point to any fixed direction at this point. In the above mentioned fig. 6.12 (i) and (ii), magnetic lines of force represent neutral or null point.

Terrestrial magnetism

The earth behaves as a huge magnet. The earth's magnetism is called terrestrial magnet. ***The magnetic property possessed by terrestrial magnet is called terrestrial magnetism.*** Terrestrial magnet has its own magnetic field and magnetic lines of force. Terrestrial magnet has its south pole located at north Canada and north pole located at south Antarctica. Following are the evidences for the existence of terrestrial magnetism:

a. A freely suspended magnet always points North-south direction when it rest by the influence of terrestrial magnetism on it.

b. The ores of iron possess magnetic properties, which may be due to the effect of the earth's magnetism. Magnetic property is developed in iron ores by induction.

c. Neutral points exist in the magnetic field of all permanent magnets. The fields of permanent magnet and terrestrial magnet are equal in strength and opposite in direction at neutral points. There is no influence of magnetic force at neutral points. For this reason, when a compass needle is kept at neutral point, it does not show any particular direction.

d. Angle of declination and angle of dip exist due to terrestrial magnetism.

Causes of terrestrial magnetism

Although there is no any clear cut explanation to support, the possible causes of the earth's magnetic field are as follows:

a. There is a permanent magnet inside the earth. This idea was proposed by Dr. Gilbert. This is rejected because inside the earth's interior surface there is very high temperature and at that temperature nothing is magnetic.

b. The earth's crust contains magnetic substances, which may cause the earth's magnetism. This idea is also rejected. This is because the earth's crust does not contain sufficient magnetic substances to produce its magnetic field.

c. **Dynamo theory:** It is the latest and most convincing theory that explains about the causes of terrestrial magnetism. According to this theory, the flow of liquid state of iron in the outer core of the earth sets of electric currents that produce earth's magnetic field.

Magnetic elements of earth's magnetic fields

The quantities that are required to specify the magnetic field of the earth completely are called the magnetic elements of the earth. They are the angle of declination, angle of dip and horizontal component of the earth's magnetic field. Before explaining these components, following other important terms should be known:

a. **Magnetic poles:** The magnetic poles of the earth magnet are the places where the freely suspended magnetic needle becomes exactly vertical.

b. **Magnetic equator:** The locus of the points on the earth's surface where the freely suspended magnetic needle remains horizontal is called magnetic equator of the earth.

c. **Magnetic axis:** The line passing through the magnetic poles (N-pole and S-pole) of the earth is called magnetic axis of the earth.

d. **Geographical axis:** The line passing through the geographical poles of the earth is called geographical axis of the earth.

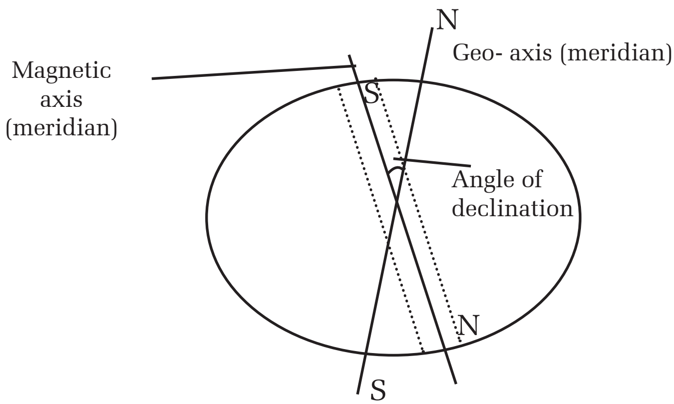


fig: 6.14 Geographical axis and Magnetic axis

e. **Magnetic meridian:** The vertical plane passing through the axis of a freely suspended magnet at a place is called the magnetic meridian at that place. This plane contains the magnetic South and North poles of the earth.

f. **Geographical meridian:** The vertical plane passing through a place and the geographical north and south poles is called the geographical meridian at that place. The magnetic and geographical meridians do not coincide but make a certain angle at a given place. At equator the angle is 170.

g. **Geographical equator:** It is an imaginary line round the earth's surface which is located at equal distances from geographical poles.

Angle of Declination

The magnetic poles and the geographical poles of the earth do not lie at the same point. It is, therefore, at any place, the line joining the magnetic north-south and the line joining the geographical north-south intersect at a point. ***The angle made by the intersection of the line joining the magnetic north-south and the line joining the geographical north-south at a place is called the angle of declination at the place. Or, the angle between the magnetic meridian and geographical meridian at a place is called angle of declination at that place.***

The angle of declination varies from place to place and time to time as the position of magnetic meridian and geographical meridian is different at different places. It is necessary to know the angle of declination to find out the geographical direction of places. Without knowing the exact value of angle of declination of a place, it is impossible to take aeroplane and ship to right place at night. The angle of declination is very useful to the cave searchers, navigators, travelers, pilots and surveyors to find their position on the earth.

Fig: 6.15 magnetic compass

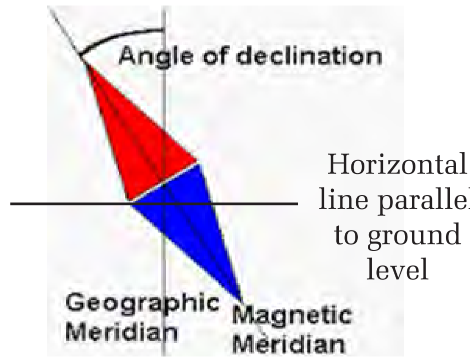


Fig: 6.16 angle of declination

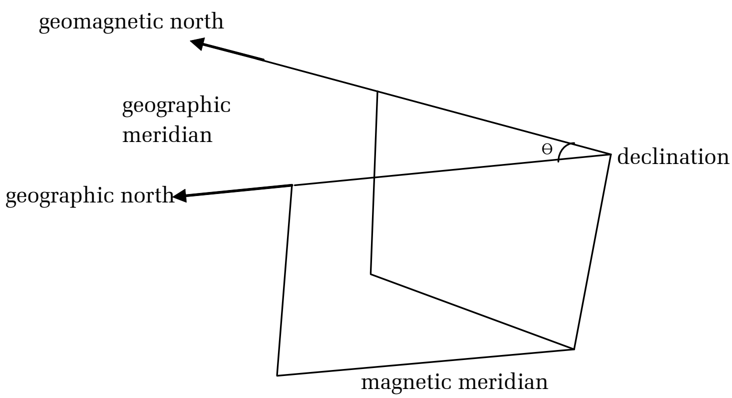


Fig: 6.17 declination at a place

Angle of declination is measured by magnetic compass. A magnetic compass is a simple device having a magnetic needle free to rotate on a pivot at the centre of a round box. A simple construction of the magnetic compass is shown in fig. 6.14. When the magnetic compass is placed on a table, its needle always points in the north-south direction.

In the magnetic compass, the red part of the needle points towards the geographical north direction and the other part points towards the geographical south direction.

Angle of Dip or Inclination

Before we study about the angle of dip, we should know what a dip needle is. Dip needle or a dip circle is a magnetic needle or circle mounted in a frame vertically. The needle is free to rotate about a vertical plane. It is used to determine the angle of dip at a place. At a place, the dip needle always sets itself in a direction. In fact, the dip needle sets itself parallel to the magnetic lines of force at the place.

When a dip needle is placed at a particular place, the needle makes certain angle with its horizontal axis. This angle is called angle of dip. Thus, the angle of dip at a place is defined as the angle made by a dip needle with the horizontal axis. Angle of dip varies from place to place. This is because the direction of the resultant magnetic intensity is different at different places on the earth's surface. The angle of dip is 0° near the equator and 90° at the poles. At other places, its value lies between 0° and 90°. Let's study the variation of angle of dip in different places.

a. **Angle of dip at magnetic north pole:** There is south pole of terrestrial magnet at magnetic north. When a dip needle is placed at magnetic north pole, the north pole of dip needle will be strongly attracted by the south pole of terrestrial magnet. As a result, the dip remains vertical making 90°. Thus, the angle of dip is 90° at magnetic north pole.

b. **Angle of dip at magnetic south pole:** There is north pole of terrestrial magnet at magnetic south. When a dip needle is placed at magnetic south, its south pole will be strongly attracted by the north pole of terrestrial magnet. As a result, the dip needle remains vertical making 90° with its horizontal axis. Thus, the angle of dip is 90° at magnetic south pole.

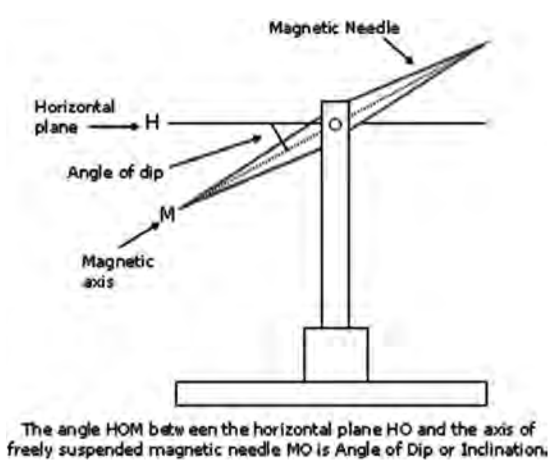


Fig : 6.18 Angle of dip

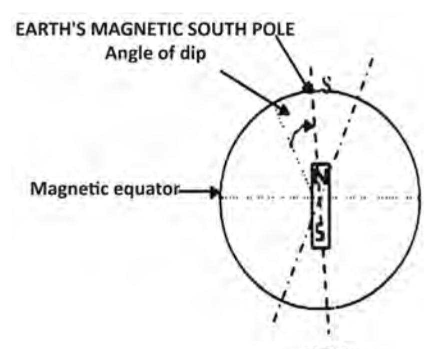


Fig: 6.19 angle of dip and the components of the earth's magnetic field

c. **Angle of dip at magnetic equator:** Magnetic equator is the imaginary plane that divides the magnetic field of terrestrial magnet into two equal halves. The poles of terrestrial magnet has equal and opposite influence at all the parts lying in magnetic equator. When a dip needle is placed at magnetic equator, its poles are equally and oppositely affected by the poles of terrestrial magnet. As a result, dip needle remains parallel to its horizontal axis, i.e. it is parallel to ground making 0° with the horizontal axis. Thus, angle of dip is 0° at magnetic equator but it is not 0° at geographical equator.

Method of finding the value of dip or inclination

Let 'I' be the total intensity of the earth's magnetic field at a place, 'H' and 'V' be its horizontal and vertical components respectively δ be the angle of dip, then in the magnetic meridian, the horizontal component $H=I \cos \delta$

and the vertical component $V=I \sin \delta$

in the right angle triangle,

$H^2 + V^2 = I^2 \cos^2\theta + I^2\sin^2\theta = I^2$

$\tan \delta ==V/H$

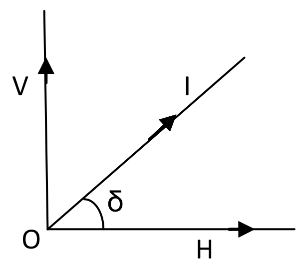


Fig: 6.21 declination at a place.

Photocell

Photocell is a device, which converts light energy into electrical energy; it produces a small amount of electricity. It is used to run radios and television sets. Photocells are also called solar cells. They are also used in heating and cooking at home. When solar cells are arranged side by side, connecting each other in such a way that potential difference and the total capacity to provide electric current is highly increased, the arrangement is called solar cell panel.

Solar panels are fast becoming a very attractive renewable energy option, which could end up being incredibly beneficial to the environment. The process of converting sunlight to electrical energy is one that has improved dramatically over the last few decades, and is now more efficient than ever. The solar energy has been used around for years in small devices such as calculators, but now many are talking this energy as powering houses and businesses.

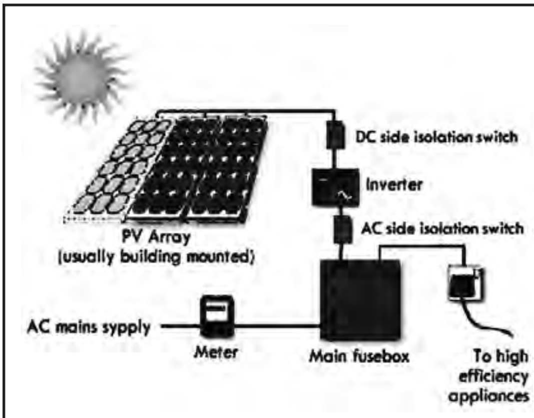


Fig : 6.20 Solar cell panels

Solar is one of the most promising renewable energy sources currently available, due to the fact that solar power is abundant. The rays that are emitted from the sun can produce nearly 1,000 watts of energy for every square meter of the earth's surface. By collecting that energy, we would never have to rely upon damaging fossil fuels again.

Solar energy is created using the energy which has been generated by the sun. A solar power panel is able to function using the solar energy which is derived from the sun. Every solar power panel contains many different silicon cells or solar cells. They are building blocks of solar panels. The energy from the sun is absorbed by these solar cells. The solar energy derived from the sun is converted into electricity with the help of a solar power panel.

Summary

1. The body which acquires the property of attracting light objects like pieces of paper and other lighter bodies is said to be charged or electrified.

2. There are two kinds of charges: positive and negative.

3. If electric charge on a body is in rest or not allow flowing it is known as static electricity. If electricity is in motion then it is called current electricity.

4. A closed conducting path for the charges to flow through it is called an electric circuit.

5. The p.d. between two points in an electrical circuit is the amount of work done in moving a unit charge from one point to another.

6. The e.m.f of a source is the rate at which energy in a non-electrical form is converted into electrical form during the passage of unit positive charge through it.

7. Ammeter is a device having very low resistance used to measure high current. Voltmeter is a device having very high resistance used to measure p.d. A galvanometer is a highly sensitive device having very low resistance used to detect and measure flow of small magnitude of current in the circuit.

8. The property by which a conductor opposes the flow of electric charge through it is its resistance. It is directly proportional to the length of a conductor and inversely proportional to its cross-sectional area. It also increases with increase in temperature of the conductor.

9. The resistivity of a material is numerically equal to the resistance of a conductor of unit area per unit length of the material. The reciprocal of the resistivity of a material is called its conductivity.

10. The space around a magnet where magnetic force of the magnet can be felt is called magnetic field of the magnet.

11. A line of force in a magnet field is a line, straight or curved, tangent to which at any point gives the direction of the magnetic field at that point.

12. A neutral point in a magnetic field is a point at which the horizontal component of the earth's magnetic field and the magnetic field due to a magnet are exactly equal and opposite.

13. The angle between the magnetic meridian and geographical meridian at a place is called angle of declination at the place.

14. The angle of dip is the angle made by a freely suspended magnet with the horizontal.

15. Photo cell is a device which converts light energy into electrical energy. Solar cells are used in heating and cooking at home.

Exercise

A. Tick (✓) the best alternative from the followings.

1. The phenomenon by which the charge is produced in a body is called

   i) Electricity ii. Electrification

   iii. Induction iv. Potential difference

2. Which instrument is used to measure high current?

   i. Ammeter ii. Voltmeter iii. Galvanometer iv. Dynamo

3. What is the unit of electric charge?

   i. Ampere ii. Volt iii. Coulomb iv. Joule

4. What is the value of resultant field at neutral point?

   i. 90 ii. 0 (zero) iii. 5 iv More than 100

5. Which instrument is used to find the right direction while flying aero plane?

   i. Dip circle ii. Voltmeter iii. Magnetic compass iv. Galvanometer

B. Answer the following short questions.

1. What is electric charge? Write the types of electric charges.
2. Define the term ‘electrification’.
3. Distinguish between positive and negative charges.
4. What is meant by an electric circuit?
5. Write the differences between static electricity and current electricity.
6. What is electric current?
7. Write a formula showing the relation between electric current, amount of charge and time
8. What is meant by 1 A current?
9. Define resistivity and conductivity.
10. Write any two differences between ammeter and voltmeter.

11. Why is ammeter always connected in series and voltmeter connected in parallel with a load in the circuit?

12. What is meant by magnetism?

13. What are magnetic lines of force?

14. Give reasons:

    i. The compass needle does not show the actual direction at neutral points.

    ii. The value of angle of dip at earth's geographical poles is less than 900.

    iii. A freely suspended magnet always points in north-south direction when it rests.

    iv. The value of the angle of dip at the magnetic equator of the earth is zero.

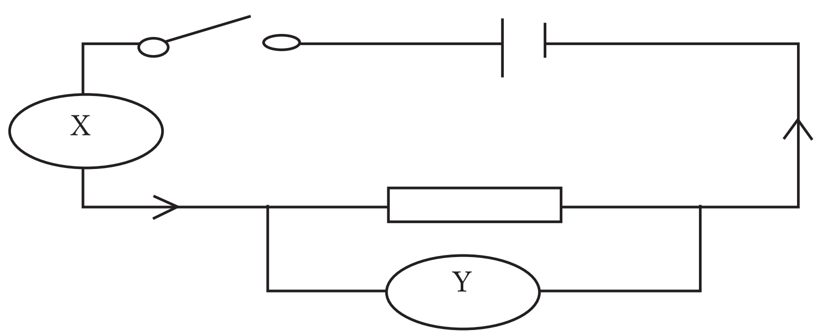
15. Define the following terms:

    i. Neutral point   ii. Magnetic lines of force

    iii. Angle of dip   iv. Angle of declination

C. Answer the following long questions.

1. Study the given diagram and answer the following questions



    i. Name 'x' and 'y'.

    ii. What difference will be observed in the reading when switch is on and off? Why?

2. Draw the labeled diagram of magnetic lines of force of a bar magnet pointing its N-pole towards geographical N-pole and N-pole towards geographical S-pole.

D. Solve the following numerical problems

1. How much charge flows through a wire carrying 1A in 3 minutes. (Ans.180 coulomb)

2. A simple electric circuit has a 24 volt battery and a resistor of 600Ω. What will be the current in the circuit? (Ans. 0.4A)

3. What is the length of a metallic wire of diameter 0.5 mm required to constant a 12Ω coil. Resistivity of the metal is 4.46×10^{-7}Ωm? (Ans. 1.35×10^{4} m)

Project Work

1. Producing electricity from potatoes

Required materials

- Eight medium sized fresh potatoes
- Eight stripes of copper 5cm x 1cm
- Eight stripes of zinc 5cm x 1cm
- Copper wire
- 1 five volt bulb with holder

Procedures

Take 8 potatoes and insert a stripe of zinc on one end of each potato. Similarly, insert one copper on another end of each potato. Arrange these potatoes on a table in two rows, each containing a zinc stripe of one potato to the copper stripe of the other with the copper wire Connect all zinc and copper stripes with the help of the copper wire. Now, take one wire connected to the zinc stripes and connect these two with the 4.5 V bulb. The bulb will glow for a limited time.

Glossary

Charge	:	quantity of imbalanced electricity in a body either positive or negative
Thermocouple	:	thermoelectric device used for measuring temperature having two dissimilar metal wires or rods are joined at both ends
Terrestrial	:	related with earth
Electroscope	:	instrument used to detect the charge of a body
Electric load	:	device which converts electrical energy into other forms of energy
Tangent	:	a straight line or plane that touches a curve or curved surface at a point, but if extended does not cross it at that point.

Unit 7

Atomic Structure

Niels Bohr (1885-1962), born in Copenhagen, Denmark. He received the Nobel Prize in Physics in 1922 AD for his research on structure of an atom. He is also known as the father of atomic physics.

Niels Bohr (1885-1962)

Learning outcomes

After the completion of this unit, learners will be able to

1. Define isotopes, isobar and isotones.
2. Explain the Dalton's atomic theory.
3. Explain the Rutherford's atomic model and its limitations.
4. Describe the atomic structure based on Bohr's concept.

Introduction

In our surrounding we can see various substances. These substances have different shapes, sizes and textures. Everything in this universe is made up of materials which have mass and occupy space. These materials are scientifically called matter. For example; table, pen, pencil, bag, book, exercise book, etc. Thus, anything that occupies space and has mass is called matter. There are mainly three physical states of matter. They are solid state, liquid state, gas state. Recently, two more physical states of matter are introduced. They are plasma state and BEC (Bose Einstein condensate) state. Matters are mainly classified into two groups. They are pure matter and impure matter. Pure matter includes elements and compounds and impure matter includes mixtures.

> Do you know?
>
> Plasma: It consists of super energetic and super excited ionized gaseous particles. BEC (Bose Einstein condensate): The state of matter of dilute gas which is super-cooled and unexcited form of matter near to the absolute zero temperature.

Atom

Take a piece of magnesium ribbon and cut it into as smaller pieces as possible. The smallest pieces which cannot be broken down into further small pieces are called atoms of magnesium.

For example; if gold is divided into very tiny fragments in the atomic level, the single fragment that you get is still gold. An atom of gold is the smallest piece of gold that exists. It has all the properties of gold. So, an atom is the smallest possible unit of an element that has the same properties as the element. All the atoms of one element are the same but different elements have different atoms. For example; all the atoms of silver are the same but atoms of silver are different than the atoms of copper.

Do you know?

The word atom is derived from the Greek language 'atomos'. Its meaning is 'impossible to cut.

Do you know?

There are so many elements which have different forms of atoms called isotopes.

Sub-atomic particles or fundamental particles of an atom

When we look into an atom (which is not possible by naked eyes), several particles are found that are thousands of times smaller than the size of an atom. These particles are called sub-atomic particles or fundamental particles. There are three sub-atomic particles in an atom. They are protons, neutrons and electrons. The summary of characteristics of the fundamental particles is given in the table.

Atomic number

Particle	Charge (e)	Actual Mass (g)	Relative Mass (amu)
Proton (nucleus)	+1	1.67×10^{-24}	1
Neutron (nucleus)	0	1.67×10^{-24}	1
Electron (Orbits)	-1	9.11×10^{-28}	0

Note: 1 atomic mass unit (amu) = 1/12th mass of a carbon atom = 1.67×10^{-27} kg
elementary charge (e) = 1.6×10^{-19} coulomb

The total number of protons present in the nucleus of an atom is called atomic number. It is denoted by the letter Z. For example, atomic number of oxygen (Z) = 8. It suggests that oxygen has 8 protons in its nucleus. In an atom the number of protons and the number of electrons are equal.

Atomic mass or mass number

In the nucleus of an atom, there are protons and neutrons. The total number of protons and neutrons lying in the nucleus of an atom is known as the atomic mass or atomic mass number. It is represented by the letter A.

$$\boxed{\text{Atomic mass (A)} = \text{number of protons} + \text{number of neutrons}}$$

Example:

What is the mass number of calcium as it has 20 electrons, 20 protons and 20 neutrons?

Solution:

Atomic mass of calcium (A) = number of protons (p^+) + number of neutrons (n^0)

= 20 + 20

= 40 amu

It should be noted that 40 is not the actual mass of the calcium atom but it is its mass number. The unit of mass number is atomic mass unit (a.m.u). 1 a.m.u is the mass of a proton or a neutron which is equivalent to 1.67×10^{-27} kg. Therefore, mass number 40 amu of calcium means that the mass of 1 atom of calcium is 40 times greater than the mass of a proton or a neutron. This can be calculated as $40 \times 1.67 \times 10^{-27}$ kg = 6.68×10^{-26} kg.

Do you know?

The electron's mass is extremely small as compared to the mass of a proton or a neutron. So, its mass is neglected as it doesn't contribute much to the total mass of an atom.

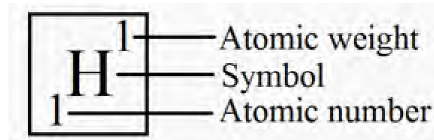
Element

An element is a purest form of a substance that contains only one type of atoms. Consider one kilogram of iron. It has millions of atoms in it. But, all these atoms are identical to each other. They have the same number of protons, electrons and neutrons. We cannot convert any other element to make iron nor can we divide iron to make any other elements by any physical and chemical means. That is why it is called a pure indivisible substance. The same rule applies to every other element in the periodic table.

Do you know?

It is said that atoms are indivisible. Recent discoveries in nuclear physics enable an element to be broken down to other elements by nuclear reaction.

There are altogether 118 discovered elements. These elements are arranged systematically in a table called periodic table. Out of these 118 elements, 92 are natural and rests are obtained artificially in the laboratory. The symbol of the element, atomic weight and atomic number are represented as in figure.



Concept of Isotopes, Isobars and Isotones

Out of 118 discovered elements, some elements resemble each other in atomic mass number, some resemble in the number of neutrons and some in atomic number. These groups of elements are described below:

1. Isotopes

Isotopes are the elements having the same atomic number (number of protons) but different atomic mass. In other words, they are different forms of the same element having different masses. They have the same number of protons and electrons but the numbers of neutrons are different. Isotopes have the same chemical properties but different physical properties. All the isotopes of one element lie in the same group of the modern periodic table. Some of the elements that have isotopes are hydrogen (${}_1H^1$, ${}_1H^2$, ${}_1H^3$), oxygen (${}_8O^{16}$, ${}_8O^{17}$, ${}_8O^{18}$), nitrogen (${}_7N^{14}$, ${}_7N^{15}$) chlorine (${}_{17}Cl^{35}$, ${}_{17}Cl^{37}$), uranium (${}_{92}U^{235}$, ${}_{92}U^{238}$, ${}_{92}U^{239}$) ,etc. The detail information of isotopes of hydrogen and uranium are given in the table.

Isotopes							
Element		Names of isotopes	Symbol	Number of			Atomic mass
				Protons (p^+)	Electrons (e^-)	Neutrons (n^o)	A = p + n
Hydrogen (H) At.no= 1	1.	Protium	${}_1H^1$	1	1	0	1+0 = 1
	2.	Deuterium	${}_1H^2$	1	1	1	1+1 = 2
	3.	Tritium	${}_1H^3$	1	1	2	1+2 = 3
Uranium (U) At.no=92	1.	U-235	${}_{92}U^{235}$	92	92	143	92+143 = 235
	2.	U-238	${}_{92}U^{238}$	92	92	146	92+146 = 238
	3.	U-239	${}_{92}U^{239}$	92	92	147	92+147 = 239

Isotopes are found in the nature in different proportions. Some isotopes are abundant in nature while some are very rare.

2. Isobars

Isobars are the elements having the same atomic mass number but different atomic number. They have different number of protons in their nucleus but the sum of protons and neutrons are the same in isobars. They have different physical as well as chemical properties. For example, argon (18) and calcium (20) are isobars because they have the same atomic mass number, i.e. 40.

Isobars	
Argon	**calcium**
At. No. (Z) or (p) = 18	At. No. (Z) or (p) = 20
No. of neutrons = 22	No. of neutrons = 20
Atomic mass (A) = p+n=40	Atomic mass (A) = p+n = 40

3. Isotones

Those elements that have the same number of neutrons but different atomic numbers and atomic mass number are called isotones. These elements are entirely different from each other. They show different physical and chemical properties. For example; nitrogen ($_7N^{15}$) and oxygen ($_8O^{16}$) are isotones. They have different atomic numbers and mass but the numbers of neutrons are the same.

Isotones	
Nitrogen	**Oxygen**
At. No. (Z) or (p) = 7	At. No. (Z) or (p) = 8
n = 8	n = 8

Atomic theory

When matter is observed upon its atomic level, it becomes quite difficult to study its properties. Till late 1800s, scientists were unknown about the structure of an atom. Different theories were suggested to describe the possible structure of an atom. ***The theory that describes the structure of an atom, its properties and composition is known as atomic theory.*** In this connection, several models or theories have been proposed by the different scientists to explain the structure of an atom. Some of these theories are described below:

A. Dalton's atomic theory

B. Rutherford's atomic model

C. Bohr's atomic model

A. Dalton's atomic theory

John Dalton was an English Chemist, Physicist and meteorologist. He proposed the first modern scientific theory that described atom as the fundamental particle of a matter. He said that all the matters are made up of tiny spherical particles called atoms. He did not have the idea of the sub-atomic particles within an atom. Dalton's atomic theory is simply based on the following two laws:

i. Law of conservation of mass

This law states that the total mass of the matter before a chemical reaction is always equal to the mass of products after the chemical reaction.

For example;

$2H_2 + O_2 \rightarrow 2H_2O$

$2\ (1+1) + (16+16) \rightarrow 2(\ 1+1+\ 16)$

36amu $\rightarrow$ 36 amu

ii. Law of constant composition

Law of constant composition states that "in all compounds elements are combined in their fixed ratio." It is also called the law of definite proportions. For example; in water (H_2O) molecule hydrogen and oxygen are in the ratio 2:1 by atoms and 1:8 by weight.

On the basis of these two laws, Dalton derived some conclusions about the composition of matter. The main postulates of Dalton's atomic theory are given below:

The main postulates of Dalton's atomic theory

1. **All kinds of matters are made up of atoms**

   Each matter is composed of a large number of extremely small particles called atoms. Atoms of each matter are movable, indivisible and indestructible. Atoms of all matter cannot be created, broken down or changed to form the atoms of other matter.

2. **Atoms of the same element are identical in mass and other properties but atoms of the different elements are different.**

   Atoms of the same element are similar in structure and composition. For example; all the atoms of iron are the same no matter how much iron we take. Similarly, atoms of iron are different from the atoms of copper in all respects.

3. **Compounds are formed by the combination of two or more types of atoms.**

   All kinds of chemical compounds are made up of elements. In each compound, elements are combined in a fixed ratio. For example; the compound NaCl (sodium chloride) has one atom of sodium and one atom of chlorine in the ratio 1:1.

4. **A chemical reaction is due to combination, separation and rearrangement of atoms**

When a chemical reaction occurs, substances change their properties. New substances with different properties are formed. But, they still contain the same atoms. For example; hydrogen (H_2) and oxygen (O_2) combine to form water (H_2O). The water so formed has different properties as compared to hydrogen and oxygen but it still has only the atoms of hydrogen and oxygen. Atoms of hydrogen and oxygen just rearranged and combined themselves to form water. $2H_2 + O_2 \rightarrow 2H_2O$

Similarly, $2Na + Cl_2 \rightarrow 2NaCl$,

$NH_4CNO \rightarrow NH_2CONH_2$

Ammonium cyanate $\longrightarrow$ Urea

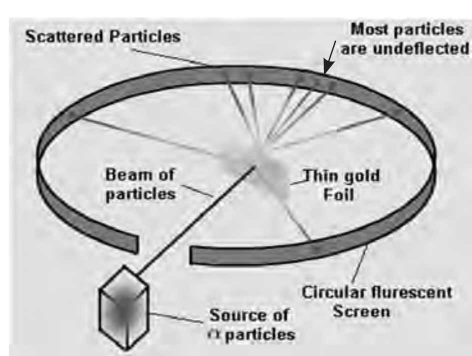
B. Rutherford's atomic model

The sub-atomic particles were not discovered till the early 1900s. During that time structure of an atom was suggested to be a spherical body. After the discovery of protons and electrons, still the location, shape and nature of these sub-atomic particles were not known. Then, in 1911 A.D., an English physicist Ernest Rutherford performed an experiment on gold atoms to understand how the sub-atomic particles are arranged themselves in the atom. This experiment is popularly known as the Rutherford's alpha-particle scattering experiment.

Ernest Rutherford
(1871-1937)

Rutherford's alpha-particle scattering experiment

Rutherford did an experiment to find out the exact structure of an atom. Though he was not successful to prove the existence of all sub-atomic particles, he discovered the nucleus. In this experiment, Rutherford used a radioactive substance to produce the positively charged particles called α-particle. The beam of α-particles were passed on an extremely thin gold foil to hit the atoms of gold. Around the gold foil a zinc sulphide (ZnS) coated surface was carefully placed which acted as a screen for detecting the alpha particles. Finally, the region in which the alpha particles hit the screen was carefully observed with a moving microscope.



When the alpha particles hit the atom of gold, three possibilities might occur. They might pass through the gold foil without any deflection or get deflected slightly or return back to the same direction.

Actual observations of the alpha rays experiment

After the experiment was conducted and the zinc sulphide (ZnS) screen was carefully studied, the following observations and conclusions were drawn by Rutherford.

(a) About 99% of the alpha prticles penetrated through the gold foil without even a small amount of deflection.

Conclusion: The alpha particles found nothing inside the atom to strike. Therefore, Rutherford concluded that 99% of the atom is empty. The sub-atomic particles occupy only a small region of the space inside an atom.

(b) Some of the alpha particles were deflected slightly.

Conclusion: The alpha particles are big positively charged particles. Moving alpha particles bend when something big of the same charge repels them. So, there must be heavy positively charged particles (protons) inside the atom that bends the alpha particles. As the bending of alpha particles is very less, the space occupied by the protons must be less. This observation concludes that there are positively charged particles inside an atom.

(c) About 0.005% of the alpha particles returned back to the same direction.

Conclusion: Heavier alpha particles only return back when they hit something very massive. It made him discover the nucleus of an atom. A nucleus is a heavy region at the centre of an atom where positively charged particles lie.

On the basis of these discoveries, Rutherford proposed an atomic model with the following conclusions:

1. Most of the space (about 99%) of an atom is empty. In this vast space negatively charged particles (electrons) are moving with high speed like planetary motion in the solar system.
2. The effective volume of nucleus is very small as compared to the effective volume of atom.
3. Nucleus is present at the centre of an atom. The positively charged particles (protons) lie in the nucleus. Different types of atoms have different number of protons.

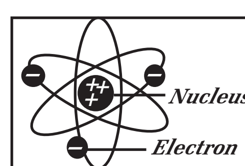


Fig: 7.1: Rutherford atomic model

4. The revolving electrons are strongly held by the protons present inside the nucleus.
5. Since, an atom is electrically neutral; the number of protons is equal to the number of electrons.

Limitations of Rutherford's atomic model

Ernest Rutherford is known as the father of nuclear physics. He received a Nobel Prize in 1908 A.D. for his extensive research and discovery on radioactive substances. He successfully discovered the nucleus of an atom. In spite of that, the Rutherford's atomic model has some drawbacks and limitations.

(a) Rutherford's atomic model could not explain about the stability of an atom.

According to Rutherford's atomic model, electrons continuously revolve around the nucleus. As electrons revolve around the nucleus, they emit radiation and continuously lose energy and become weak. Due to this, velocity of electrons decreases. As a result, they follow the spiral path and ultimately fall into the nucleus. When electrons fall into the nucleus, atom should collapse. But, in real this does not happen and atoms are stable. Rutherford's atomic model could not explain the stability of an atom.

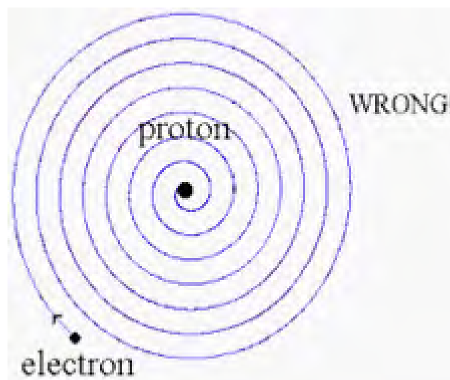


Fig. 7.2: Spiral path followed by electron

(b) Rutherford's atomic model could not explain the atomic spectra.

When electrons change their orbits, they either absorb or emit energy. When they emit energy, they produce the light rays (electromagnetic waves) of different colours. But, these emitted light rays are not produced continuously. They form dark and light bands and thus are discontinuous. Rutherford could not explain the reason for its existence.

(c) Rutherford's atomic model could not explain how electrons are arranged in an atom.

In Rutherford's atomic model, it is said that nucleus of an atom is present at the center and electrons are present outside the nucleus. But he could not explain that how these electrons are arranged in an atom.

C. Bohr's atomic model

Rutherford's atomic model could not explain how and where electrons revolved around the nucleus. To answer these questions, a Danish physicist named Niels Bohr proposed an atomic model. This model explained how electrons revolve around the nucleus. It also answers why Rutherford's model failed. In order to understand the Bohr's atomic model, we need to understand the movement of electrons.

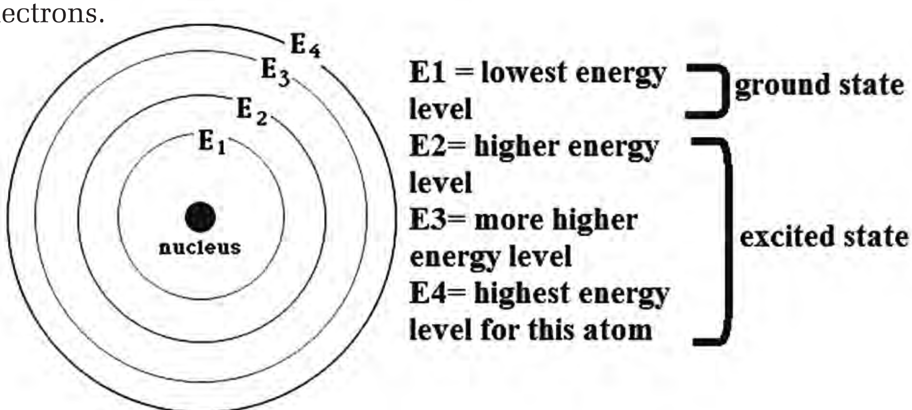


Fig. 7.3: Energy level

Bohr's atomic concept

According to Bohr, electrons of an atom do not move around the nucleus randomly. They revolve around the nucleus in fixed paths called orbits or shells or energy level. Electrons are allowed to revolve only in these fixed orbits. To prevent themselves from falling into the nucleus, they have to revolve around the nucleus continuously with certain energy and velocity. The orbit nearer to the nucleus is called the lowest energy level. It is because the electron requires less energy to revolve around the nucleus as the pull of the nucleus is more in this orbit. Likewise, the orbit farther from the nucleus is called the higher energy level as electrons require higher energy to revolve in them. Electrons have to remain in these designated energy levels strictly. An electron can revolve around the nucleus either in lower energy level or higher but not in between. It can be said that the electrons revolve around these energy levels whose energy can be measured or quantified. This is called the quantization of energy of electron.

Generally, electrons revolve around the nucleus in the orbit with lowest possible energy known as the ground state. But, electrons can jump from one energy level to the other. When electrons jump from lower to higher energy levels, this state is called excited state. Electrons absorb energy when they move into the excited state. Similarly, when they come back to the lower energy levels, they emit energy. When electrons emit energy, they do so in the form of electromagnetic waves of certain specific wavelengths like the visible light, infrared rays etc.

Conclusion of Bohr's atomic model

1. Electrons revolve around the nucleus in fixed paths called orbits or energy levels.
2. The path which is nearer to the nucleus is called the lower energy level and the path which is farther from the nucleus is called the higher energy level.
3. Electrons can jump from one orbit to another. In this process they radiate or absorb a definite amount of energy. This energy is emitted or absorbed in the form of electromagnetic radiation which gives rise to atomic spectra.
4. Electron can move only in that orbit where the angular momentum of the revolving electron is fixed.
5. For a moving electron, the centrifugal force acting on the moving electron is balanced by coulombic force of attraction between the nucleus and the electron.

How Bohr's model solved the problems of Rutherford's model about the stability of an atom?

Niels Bohr presented a better model of the electrons arrangement in an atom. According to Bohr, electrons move around the nucleus in fixed orbits with certain energy. These negatively charged electrons revolving in the orbits are attracted by the positively charged protons in the nucleus. To avoid this attractive force and prevent collision, electrons tend to push themselves away from the nucleus by revolving at a certain speed. Hence, Bohr explained the problem of stability of an atom and also arrangement of electrons.

Limitations of Bohr's atomic model

Niels Bohr received a Nobel Prize in 1922 A.D. for his work in atomic physics. His work on atomic structure is still strongly accepted. But there are some drawbacks in this model.

i. Bohr's atomic model only works for hydrogen-like atoms.

ii. It does not explain the origin of atomic spectra for the atoms which have more than one electron.

iii. It does not explain how electrons react to external electric and magnetic fields during their jump within energy levels.

iv. Bohr suggested that the exact position and speed of the electrons can be measured. But, in reality we can never do so.

v. Bohr's atomic model says that electron moves around the nucleus in planer form. But, modern research tells that electron moves in three dimensional patterns.

vi. Inside a single orbit, there are other smaller orbits called orbitals. Bohr couldn't explain the existence of these orbitals.

Summary

1. An atom is the smallest possible unit of an element that has the same properties as the element.
2. Isotopes are those elements that have the same atomic number but different atomic mass. For example; hydrogen has three isotopes; protium ($_1H^1$), deuterium ($_1H^2$) and tritium ($_1H^3$).
3. Isobars are the elements that have the same atomic mass but different atomic numbers. For example; argon($_{18}Ar^{40}$) and calcium($_{20}Ca^{40}$).
4. Isotones are those elements which have the same number of neutrons but different atomic numbers.
5. Dalton's atomic theory suggests that all matters are made up of the smallest particles called atoms. Atoms are the smallest indivisible and indestructible particles of the matter.
6. Rutherford's atomic model suggests that 99% of the atomic space is empty. Most of the atomic mass is concentrated at the central region called nucleus.
7. Protons are the positively charged particles present in the nucleus of an atom. Around the nucleus negatively charged electrons revolve.
8. Bohr's atomic model suggests that electrons revolve around the nucleus in fixed designated orbits.
9. When electrons jump from lower to higher energy level, they absorb energy and when they return back to the lower energy level, they emit energy. They emit energy in the form of electromagnetic rays of specific wavelengths.

Exercise

A. Tick (√) the best alternative from the followings.

1. What is the name of the smallest particle of an element?

   i. Molecule ii. Atom

   iii. Compound iv. Radical

2. What is symbol of tritium?

   i. $_1H^1$ ii. $_1H^2$

   iii. $_1H^3$ iv. $_2H^3$

3. Isotones have the same number of

   i. Electrons ii. Protons

   iii. Neutrons iv. Atomic mass

4. Which of the following has the same number atomic mass?

   i. Isotopes ii. Isobars

   iii. Isotones iv. Isomers

5. According to Rutherford atomic model

   i. 99 % of an atom is empty ii. 99 % of an atom is filled

   iii. 75 % of an atom is empty iv. 75 % of an atom is filled

B. Give short answers to the following questions.

1. What is an atom?
2. Write down the meaning of atom in Greek language.
3. What are the sub-atomic particles?
4. What is an element? Why is it called a pure matter?
5. Write down about isotopes.
6. List out any three elements which have isotopes.

7. What are isobars? Write with examples.
8. Define isotones with any two examples.
9. Define atomic number and atomic mass number.
10. State the law of conservation of mass.
11. State the law of constant composition.
12. What is nucleus? What are present in the nucleus of an atom?
13. Where is the mass of an atom concentrated?
14. What are lower and higher energy levels?

C. Give long answers to the following questions.

1. Explain the postulates and limitations of Dalton's atomic theory.
2. Describe in brief about the Rutherford's alpha rays scattering experiment.
3. Write down the conclusions of Rutherford's atomic model.
4. List out the conclusions of Bohr's atomic model.
5. How does Bohr's atomic model solve the problem of stability of an atom?
6. Discuss about the limitations of Bohr's atomic model.

Project Work

1. Make a model of isotopes of hydrogen with the help of chart paper, seeds of pea, gram and maize. Also, present it in the classroom.
2. Make a model of atomic structure similar to the Rutherford model with the help of cotton threads, seeds of pea and grams using a card board.

Glossary

Atom : the smallest indivisible particle of an element

Element : the purest form of the substance

Isotopes : the different forms of an element having same atomic number and different mass number

Isobars : elements having the same atomic mass but different atomic number

Isotones : elements having the same number of neutrons

Alpha partifcles: a helium nucleus emitted by radioactive sources

Unit 8

The Gas Laws

Jacques Alexandre César Charles born in 12 November 1746 AD and died in 7 April 1823 AD. He was a French inventor, scientist, mathematician and balloonist. Charles and the Robert brothers launched the world's first (unmanned) hydrogen-filled balloon in August 1783. He described how gases tend to expand when heated.

Alexandre César (1746-1823)

Learning outcomes

After the completion of this unit, learners will be able to

1. Describe the Boyles' law showing the relation between volume and pressure.
2. Explain the Charle's law showing the relation between volume and temperature.
3. Explain the combined gas law using Boyles' law and Charle's law.
4. Describe the Graham's law of diffusion.

Introduction

Matter exists in many physical states. The major states of matter are solid, liquid and gas. Solids have fixed shape and volume; liquids have fixed volume but no fixed shape but gases neither have fixed shape nor fixed volume. If we consider a room full of gas, the amount of the same gas can be filled inside a small box. That is why we say gases do not have fixed volume. Most of the gases are invisible and colourless. Some gases are heavier and others are lighter. The heavier gases do not settle down at the bottom of the lighter gas as they are affected very less by gravity. Some of the properties of gases are listed below:

a. Gases do not have definite shape and volume.

b. Gases are mostly invisible. They occupy the space of all empty places.

c. Gases exert pressure in all directions of the container.

d. When heavier and lighter gases are mixed together, they try to mix themselves uniformly.

e. Gases highly expand on heating and contract on cooling.

f. Gases are highly compressible.

To study the properties of gas, and gas laws, we need to learn about certain physical quantities, They are:

a. Volume of gas: The space occupied by the gas in the vessel is called the volume of gas. When a gas in the vessel is compressed, the space occupied by it (volume) is decreased. When it is heated, the gas expands and will have more volume. Hence, the volume of the same gas can be increased and decreased by different methods. The SI unit of volume of gas is m^3.

b. Pressure exerted by the gas: To understand the pressure exerted by a gas, let us observe the diagram given alongside. In figure (1), the gas is freely moving inside the vessel as no external force is applied. In this condition, the gas molecules collide with each other and also with the walls of the vessel. Because of this collision, gases exert pressure uniformly on all sides of the vessel.The more particles hit the walls of the vessel, the more is the pressure. Now, look at the figure (2). The gas molecules in figure 2(a) are farther from each other. After the gas is pushed by applying the pressure, the gas molecules come closer to each other. In this case, the pressure of gas is greater as molecules collide more when they are near to each other.

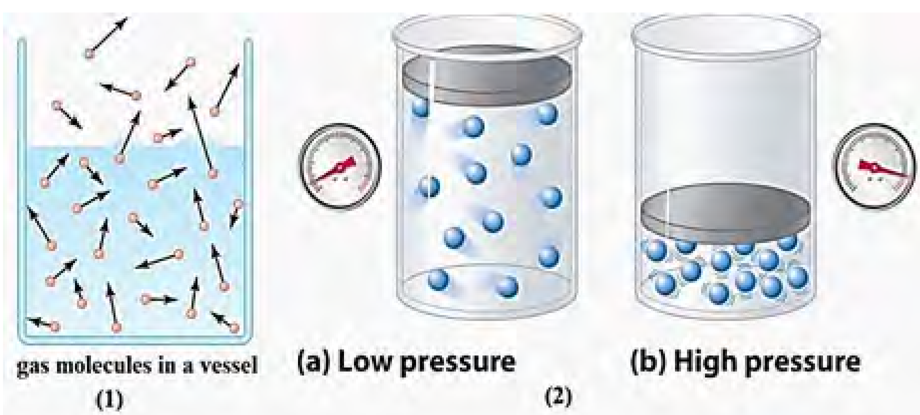


Fig. 8.1: Gas molecules

The SI unit of pressure is N/m^2 or pascal (Pa). Some other units of pressure are atmosphere (atm), torr, bar, millimeter of Mercury (mm of Hg) etc.

c. Temperature of gas: The degree of hotness or coldness of a gas is called its temperature. The SI unit of temperature is kelvin (K) which is also called the absolute scale.

$K = 0^{o}C + 273$

Do you know?

Standard temperature and pressure (STP): Standard temperature and pressure (STP) is the standard condition to measure the different properties of a gas. According to IUPAC, the standard temperature is $0^{o}C$ and standard pressure is 1 atm or 760 mm of Hg.

Kinetic theory of gas

Gases are not compact substances like the solids and liquids. Look at the figure of a gas in a vessel given alongside. The space between the individual molecules A, B, C, D, E and F is about 10 times greater than in solids. So, these molecules can move freely in all directions randomly. The movement of one molecule does not affect the other. As all the molecules of the gas are in random motion, they have some velocity. By using the average velocity of gases, we can calculate the kinetic energy of the gas. Therefore,

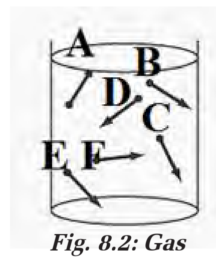


Fig. 8.2: Gas molecules

Kinetic energy (K.E.) of the gas = K.E. of A + K.E. of B + K.E. of C + K.E. of D + K.E. of E + K.E. of F

As all these molecules have different K.E., we can use the average K.E. as:

$$\text{Average K.E. of all molecules} = \frac{\text{sum of total K.E of molecules A,B,C,D,E and F}}{6}$$

Thus, Total K.E. of the gas = Average K.E. of molecules × 6

If there are 'n' number of molecules, then,

Total K.E. of the gas = Average K.E. × number of molecules

This is the basic idea of the kinetic theory of gases which can be illustrated briefly in these points:

(i) Gases can be considered as a group of particles, atoms or molecules that are in random motion.

(ii) As the molecules move randomly, they have some kinetic energy. The total kinetic energy of the gas is the sum of all average kinetic energies of the gas molecules.

Laws of gas

Since 1650 A.D., several chemists have studied the behaviour of gases. They have tried to establish the relationship among the different properties of gases like mass, pressure, volume, temperature, density, diffusion etc. So, the quantitative relationship among mass, pressure, volume, temperature, density, diffusion, etc. of the gas given by the several chemists is called gas law. There are different chemists who have proposed different theories. Some of the gas laws with their description are given below:

(a) Boyle's law (Proposed by Robert boyle)

(b) Charle's law (Proposed by Jacques Charles')

(c) Combined gas law(Combined form of Boyle's law and Charles' law)

(d) Graham's law of diffusion (Proposed by Thomas Graham)

1. Boyle's Law:

In 1662 A.D., a famous Ireland born English chemist called Robert William Boyle proposed a law of gas by studying the relationship between pressure and volume of a gas.This law is called the Boyle's law. It was one of the first scientific laws of gas.

Boyle's law states that, the volume of the gas is inversely proportional to the pressure applied on it if the amount of gas and the temperature are kept constant.

$V \propto 1/P$

An activity to demonstrate Boyle's law

Let us take a sample of a gas in a vessel with a piston over the top. The temperature and amount of gas in the vessel are constant and do not change throughout the process. The piston can be moved up and down as gases are highly compressible. In condition (a), the pressure in vessel is less as the piston is not pushed inside. The gas molecules are also farther from each other and have more volume. Now, when we push the piston inside and increase the pressure, the molecules will be pushed closer to each other and hence the volume (space occupied) will be decreased.

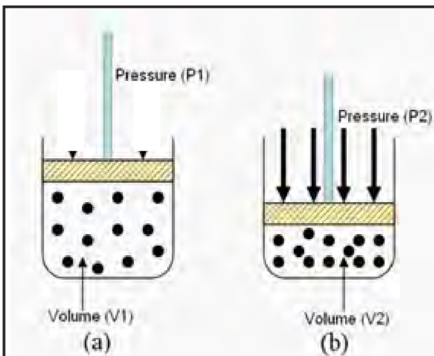


Fig. 8.3: Condition of gas molecules

Again, when the piston is released and allowed to move up, the volume of the gas will increase.

Conclusion: At constant temperature, pressure and volume of a gas are inversely related to each other. When pressure is increased, the volume of a gas gets decreased and when pressure is decreased, the volume of a gas gets increased. For example; if pressure of a gas increases by two times the volume of the gas is decreased by two times.

Mathematical expression of Boyle's law

According to the Boyle's law, the volume of a gas is inversely proportional to the pressure.

i.e. $V \propto \frac{1}{P}$ (when temperature and amount of gas are constant)

or, $V = K.\frac{1}{P}$

$PV = K$

(Here, K is proportionality constant.)

Therefore, the product of pressure and volume of a gas is always constant.The value of proportionality constant depends upon the amount and temperature of the gas.

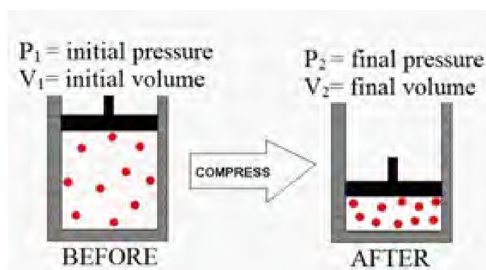


Fig. 8.4: Pressure and volume of gas

Let, the initial volume and pressure of a gas be V_1 and P_1 respectively. After applying pressure, the final volume and pressure of the gas become V_2 and P_2 respectively. As we know that, the product of volume and pressure of a gas is constant.

So, before applying pressure, $P_1V_1 = K$ (constant) ------------ (i)

after applying pressure, $P_2V_2 = K$ (constant) ----------------- (ii)

Equating equations (i) and (ii)

We get,

$$\boxed{P_1V_1 = P_2V_2}$$

It is a required equation to measure the unknown pressure or volume when the initial pressure and volume are given.

Numerical Illustration

If a gas occupies 3 litres volume at 0.6 atm pressure, what will be the volume of the gas when the pressure is 4 atm?

Solution:

Here, we have been given,

Initial volume (V_1) = 3 litres

Initial pressure (P_1) = 0.6 atm

Final pressure (P_2) = 4 atm

Final volume (V_2) = ?

Temperature (T) and amount of gas (n) = constant

Applying the Boyle's law,

$P_1V_1 = P_2V_2$

Or, $0.6 \times 3 = 4 \times V_2$

or, $V_2 = \dfrac{0.6 \times 3}{4}$

or, $V_2 = \dfrac{1.8}{4}$

$\therefore V_2 = 0.45\ l$

Thus, the volume of the gas becomes 0.45 l after applying 4 atmpressure.

2. **A cycle tube contains air of volume 5000 cc with the pressure of 8×10^5 Pa. To make three times volume of air in the cycle tube how much pressure need to be reduced in the cycle tube?**

Solution:

Given,

Initial volume of air in the tube (V_1) = 5000 cc

Initial pressure inside the tube (P_1) = 8×10^5 Pa

Final volume of air in the tube (V_2) = three times of the initial volume = 3×5000 cc
= 15000 cc

Temperature (T) and amount of gas (n) = constant

Final pressure (P_2) = ?

Now, applying the Boyle's law,

$P_1V_1 = P_2V_2$

or, $8 \times 10^5 \times 5000 = P2 \times 15000$

or, $P_2 = \dfrac{8 \text{ x } 10^5 \times 5000}{15000}$

$\therefore P_2 = 2.66 \text{ x } 10^5$Pa

Thus, the reduced pressure of the gas in the tube is 2.66×10^5Pa.

Applications of Boyle's Law

i. Deep sea divers use special suit: The pressure at the bottom of the ocean is very high. Divers cannot reach at the bottom without special swimming suit. This is because the excessive pressure causes to decrease in the volume of the diver's body. According to the Boyle's law diver gets crushed if he does not wear the special suit.

ii. For jet passengers: Jet planes fly at a higher altitude (30,000 feet to 45,000 feet) from the earth's surface. At that altitude, the pressure of the surrounding air is very low. This increases the volume of air causing the oxygen to expand in a larger region, according to Boyle's law. At that condition, it becomes difficult to breathe in natural air. So, passengers may experience altitude sickness. To overcome the altitude sickness, the air pressure is maintained at very high inside the jet plane.

iii. For mountain climbers: Air at higher altitudes and mountains is at low pressure. This causes the air to expand increasing volume. As a result, the oxygen saturation decreases and climbers may feel difficulty in breathing, nausea, dizziness,headache, etc. This condition is known as altitude sickness. To prevent altitude sickness, mountain climbers get long-term training in breathing and also carry oxygen cylinder to breathe in enough oxygen.

Charles' law

It is obvious that gases expand on heating i.e. there is a rise in volume. The extent of expansion of gases is affected by the amount of heat supplied to the gas. The relationship between temperature and the volume of a gas at constant pressure was given by Jacques Charles in 1787 A.D, called charle's law. Charles' law states that, ***"At constant pressure, the volume of a gas is directly proportional to the absolute temperature (kelvin scale)".***

According to the Charle's law, the volume of a gas is directly proportional to the temperature in Kelvin scale (T).

i.e. $V \propto T$(when pressure and amount of gas are constant)

or, $V = K.T$

$$\frac{V}{T} = K$$

(Here, K is proportionality constant.)

An activity to demonstrate Charles' law

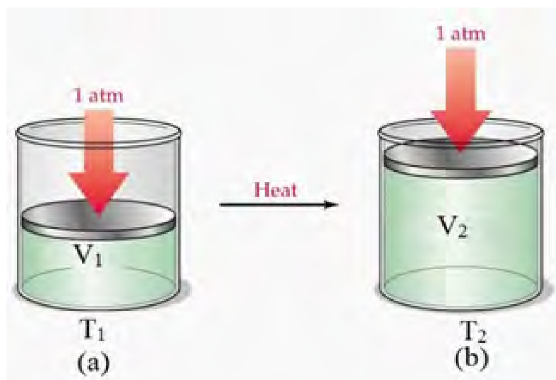


Fig. 8.5: Relation among pressor, volume and temperature of gas

Consider a gas is present in a vessel with a loose piston over its top. The piston applies a constant pressure of 1 atm and is allowed to move up and down due to the change in volume of the gas. Let, the temperature of the gas in the vessel be T_1. An external heat is supplied to the gas. When the gas molecules are heated, their kinetic energy increases and they start to collide aggressively with each other. Due to higher K.E. of the molecules, they hit the vessels harder and also the piston. As a result, they move the piston up and thus expand. The expansion causes the volume to increase.

Conclusion: At constant pressure, volume and temperature are directly proportional to each other. When the temperature of a gas is increased, the volume also increases and similarly when the temperature is decreased, the volume also decreases. This activity proves the statement of Charles' law.

Mathematical expression of Charles' law

Let, initial volume and temperature of a gas at constant mass and pressure are V_1 and T_1 respectively. Similarly, after supplying heat, the final volume and temperature become V_2 and T_2 respectively. Charles' law simply says that if we increase absolute temperature by two times, the volume also increases by two times. So, According to the statement of Charle' law;

$$\frac{V1}{T1} = K \text{ .... (i)}$$

$$\frac{V2}{T2} = K \text{ .... (ii)}$$

Equating equations (i) and (ii)

$$\frac{V1}{T1} = \frac{V2}{T2}$$

This is a mathematical expression of the Charles' law.

Numerical Illustration

1. **A balloon is filled with 450*l* of air at 0°C. If it is heated to 60°C, what will be its new volume?**

   Solution:

   Here given,

   Initial volume (V_1) = 450*l*

   Initial temperature (T_1) = 0^0C = 0 +273 K = 273 K

   Final temperature (T_2) = 60^0C = 60 + 273 K = 333 K

   Final volume (V_2) = ?

   Pressure (P) and amount of gas (n) = constant

   Since, it shows the relation between volume and temperature, applying Charles' law,

   $$\frac{V1}{T1} = \frac{V2}{T2}$$

   or, $\frac{V_2}{333} = \frac{450}{273}$

   or, $V_2 = \frac{450 \times 333}{273}$

   or, $V_2 = 548.90l$

   $\therefore V_2 = 548.90l$

2. **A sample of gas at 20°C temperature and at constant 2 atmpressure occupies a space of 3.56 litres. After raising the temperature, the volume of gas became 5 litres. Calculate the temperature.**

   Solution:

   Here, we have,

   Initial volume (V_1) = 3.56*l*

   Initial temperature (T_1) = 20°C = 20 +273 K = 293 K

   Final volume (V_2) = 5 l

   Pressure (P) = 2 atm (constant)

   Final temperature (T_2) = ?

   At constant pressure, the relation between volume and temperature is given by the Charles' law as,

   $$\frac{V2}{T2} = \frac{V1}{T1}$$

   or, $$\frac{5}{T_2} = \frac{3.56}{293}$$

   or, $$T_2 = \frac{6 \times 293}{3.56}$$

   or, $$T_2 = \frac{1456}{3.56} = 411.51K$$

   $\therefore T_2 = 411.51$ K

Applications of Charles' law

i. **Helium balloon in cold weather expands in warm room:** A helium filled balloon in cold weather decreases in size and after entering into the warm room inside the house, its size increases. This is because air expands in warm temperature and contracts at cold temperature. This is according to the Charles' law.

ii. **Dented tennis ball is resurfaced keeping in hot water:** While playing table tennis, we often experience dimples caused due to contracted air inside the ball. We can remove the dents by putting the ball in hot water vessel or by applying moderate heat.

iii. **Hot air balloons were used in transportation:** Previously hot air balloons were used as a means of transportation. But, nowadays they are used only for sporting events. Inside a hot air balloon, the temperature of air is higher. According to the Charles' law, as we increase temperature, it causes the volume of air to increase. The hot air balloon has more volume and less density. Thus, it rises up.

3. **Combined gas law:**

Volume of a gas is inversely proportional to the pressure and directly proportional to the absolute temperature. These two relations are stated by Boyle's and Charles' law. When we combine these two laws, the combined gas law is obtained. The combined gas law is the unified form of Boyle's law and Charles' law. It gives the relation of volume with pressure and temperature.

According to combined gas law, under constant amount of a gas, the volume is directly proportional to the absolute temperature and inversely proportional to the pressure exerted on it.

Mathematical expression of the combined gas equation

From Boyle's law, when amount of gas and temperature are kept constant,

Volume is inversely proportional to the pressure of the gas,

$V \propto \frac{1}{P}$ .... (i)

Again, From Charles' law, when amount of gas and pressure are kept constant,

Volume is directly proportional to the absolute temperature.

$V \propto T$ .... (ii)

Combining equation (i) and (ii) to obtain the combined gas law,

$V \propto \frac{T}{P}$

or, $V = k.\frac{T}{P}$

or, $PV = k.T$

$\therefore \frac{PV}{T} = k$.................. (iii) Where k is the proportionality constant.

The value of k depends on the amount of gas taken. When one mole of a gas is taken then the value of 'k' remains constant for all gases and it is called universal gas constant (R). So, the above equation becomes

$\frac{PV}{T} = R$ or $PV = RT$

For n molecules of the gases;

$$\boxed{\mathbf{PV = nRT}}$$

Which is called ideal gas equation.

Consider a gas with initial temperature T_1, initial volume V_1 and initial pressure P_1 is converted to another form in which the final temperature is T_2, final volume V_2 and final pressure P_2. Then from the equation (iii) we have;

$$\frac{P_1V_1}{T_1} = k \text{ ----------------- (v)}$$

$$\frac{P_2V_2}{T_2} = k \text{ ------------------ (vi)}$$

Combining equations (v) and (vi) we have;

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

It is called the combined gas equation.

Numerical Illustration

If the volume of a gas at 50^{0}C and 5 atmpressure is 20 litres, find the volume of the gas at 0^{0}C and 1 atm pressure (STP).

Solution:

Here, given that,

Initial volume (V_1) = 20l

Initial temperature (T_1) = 50^{0}C = 50 + 273 K = 323 K

Initial pressure (P_1) = 5 atm

Final temperature (T_2) = 0^{0}C = 0 + 273 K = 273 K

Final pressure (P_2) = 1 atm

Final volume (V_2) = ?

Using the combined gas equation, we get,

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Or, $\frac{5 \times 20}{323} = \frac{1 \times V_2}{273}$

or, $\frac{100}{323} = \frac{1 \times V_2}{273}$

or, $V_2 = \frac{27300}{323}$

$\therefore V_2 = 84.52\ l$

Diffusion of a gas

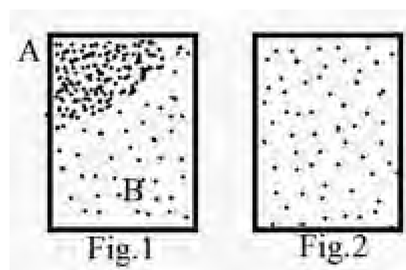


Fig. 8.6: Diffusion of a gas

Have you ever smelled the odour of the LP gas as soon as it accidently leaks out? The strong smell can be felt even in other rooms. How is the smell travel faster? This is related to the process called diffusion of gas. To understand diffusion, look at the figure alongside. In figure (1), the gas at corner A of the room is at higher concentration and gas at corner B is at lower concentration. Rapidly, the gas from higher concentration (corner A) mixes uniformly with gas at lower concentration (corner B) as shown in figure (2) until there has the same concentration. It is because gas particles move very quickly in random directions to mix up completely, called diffusion. Thus, ***the process of mixing one gas with another gas rapidly without external help to form a homogeneous mixture is called diffusion***.

Rate of diffusion

Diffusion is the property of the gases by which they mix with each other quickly and form homogeneous mixture. Diffusion generally occurs from the area of higher concentration to the area of lower concentration. The amount or volume of gas diffused in per unit time is called the rate of diffusion.

$$\text{Rate of diffusion (r)} = \frac{\text{Volume of gas diffused (V)}}{\text{time taken (t)}}$$

Diffusion is affected by how heavy the gas is i.e. the density of the gas. The relation between diffusion of gases and their densities is given by Graham's law of diffusion.

Graham's law of diffusion

Diffusion is the process of mixing of one gas with the other without the help of any external factors. In 1829 A.D., a Scottish chemist named Thomas Graham offered an idea of diffusion of the gases. He postulated a theory popularly known as the Graham's law of diffusion.Graham's law of diffusion shows the relationship between densities of the gases and the rate they diffuse with each other.

Graham's law of diffusion states that,"***Under constant temperature and pressure, the rate of diffusion of gases is inversely proportional to the square root of their densities***".

Mathematical expression of Graham's law of diffusion

Let, r_1 and r_2 be the rates of diffusion of any two gases having densities d_1 and d_2 respectively. Then, according to Graham's law,

$$r_1 \propto \frac{1}{\sqrt{d_1}} \text{ --------------------- (i)}$$

$$r_2 \propto \frac{1}{\sqrt{d_2}} \text{ ---------------------(ii)}$$

Dividing equations (i) by (ii), we get,

$$\frac{r_1}{r_2} = \frac{1}{\sqrt{d_1}} \times \frac{\sqrt{d_2}}{1}$$

$$\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}}$$ ------------------- (iii) is the required equation for Graham's law

Also, Rate of diffusion (r) = $\dfrac{\text{Volume of gas diffused (V)}}{\text{time taken (t)}}$

If equal volume of gases are taken,

$$r_1 = \frac{V}{t_1} \text{ and } r_2 = \frac{V}{t_2}$$

Keeping these values of r_1 and r_2 in equation (iii),

$$\frac{v/t_1}{v/t_2} = \sqrt{\frac{d_2}{d_1}}$$

$$\therefore \frac{t_2}{t_1} = \sqrt{\frac{d_2}{d_1}}$$

It is the Graham's law when times of diffusion and densities are given.

Which gas travels faster: lighter or heavier?

The gas which has less molecular mass has more velocity and moves faster. For example; hydrogen gas has less mass than the mass of oxygen so moves faster.

Numerical Illustration

1. **Arrange the following gases in the decreasing order of their molecular speeds at 30°C.**

   O_2, N_2, NH_3, CO_2

   Solution:

   Here,

   Molar mass of $O_2 = 16 \times 2 = 32$ gm

   Molar mass of $N_2 = 14 \times 2 = 28$ gm

   Molar mass of $NH_3 = 14 + 1 \times 3 = 17$ gm

   Molar mass of $CO_2 = 12 + 16 \times 2 = 44$ gm

   According to the Graham's law of diffusion,

   Lighter gas travels faster than the heavier gas,

   So, speed of $NH_3 >$ speed of $N_2 >$ speed of $O_2 >$ speed of CO_2

2. **If 20 cc of ammonia gas diffuses in 45 seconds, how much volume of carbon dioxide diffuse under similar time and condition? (density of NH_3 = 0.717 kg/m^3 and density of CO_2 = 1.832 kg/m^3)**

   Solution:

   Here, we have

   Volume of NH_3 diffused (V_1) = 20 cc

   Time of diffusion (t_1) = 45 seconds

   Density of NH_3(d_1) = 0.717 kg/m^3

Density of CO_2 (d_2) = 1.832 kg/m^3

Volume of CO_2 diffused (V_2)= ?

Applying the Graham's law of diffusion,

$$\frac{r1}{r2} = \frac{\sqrt{d_2}}{\sqrt{d_1}}$$

or, $$\frac{v1/t1}{v2/t2} = \frac{\sqrt{d_2}}{\sqrt{d_1}}$$

or, $$\frac{20cc/45\,secs}{V2/45\,secs} = \frac{\sqrt{1.832kg/m3}}{\sqrt{0.717kg/m3}}$$

or, $$\frac{20cc}{V2} = \frac{1.35}{0.84}$$

$\therefore V_2$ = 12.44 cc

Ideal gas

Ideal means perfect or that obeys all the laws. An ideal gas is a hypothetical concept of a gas that follows the following conditions:

i. Molecules occupy negligible space

ii. Molecules move randomly

iii. Molecules do not loose energy when they collide

iv. Molecules do not attract each other

In reality, an ideal gas does not exist. All gases are imperfect. They do not obey all the laws of chemistry. So, gases we see around are called real gases.

Summary

1. The quantitative relationship among mass, pressure, volume, temperature, density, diffusion etc. of the gas given by the several chemists is called gas law.

2. The volume of the gas is inversely proportional to the pressure applied on it if the amount of gas and the temperature are kept constant.

3. At constant pressure, the volume of a gas is directly proportional to the absolute temperature (kelvin scale).
4. At constant amount of a gas, the volume is directly proportional to the absolute temperature and inversely proportional to the pressure exerted on it.
5. The process of mixing one gas with another gas rapidly without external help to form a homogeneous mixture is called diffusion.
6. The amount or volume of gas diffused in per unit time is called the rate of diffusion.
7. Under constant temperature and pressure, the rate of diffusion of gases is inversely proportional to the square root of their densities".
8. Lighter gas travels faster than heavier gas.

Exercise

A. Tick (√) the best alternative from the followings.

1. According to IUPAC what is the value of standard pressure?
   i. 100 mm of Hg ii. 760 mm of Hg
   iii. 0 mm of Hg iv. 273 mm of Hg
2. What is the value of average kinetic energy of the molecules which have value of 5J, 4J,5J and 6J?
   i. 20J ii. 10J
   iii. 5J iv. 4J
3. Who gave the formula PV= K?
   i. Boyle ii. Charles
   iii. Graham iv. Dalton
4. Which gas has maximum velocity?
   i. Oxygen ii. Hydrogen
   iii. Nitrogen iv. Carbon dioxide

5. Which one of the followings is an ideal gas equation?

    i. PV= K ii. V/T= K

    iii. PV= nRT iv. $r_1/r_2 = \sqrt{d_2/d_1}$

B. Give short answers to the following questions.

1. What is a gas? Write down any three properties of a gas.
2. Write the relationship between Celsius and Kelvin scale of temperature.
3. Write down the value of temperature and pressure in STP.
4. State Boyle's law. Write the mathematical expression for it.
5. State Charles' law. Write down the equation of Charles' law.
6. Define combined gas law. Mention its mathematical equation.
7. Define diffusion and rate of diffusion.
8. What is Graham's law of diffusion? Write down its mathematical equation.
9. Which gas travels faster between hydrogen and carbon dioxide and why?
10. What is an ideal and real gas?

C. Give long answers to the following questions.

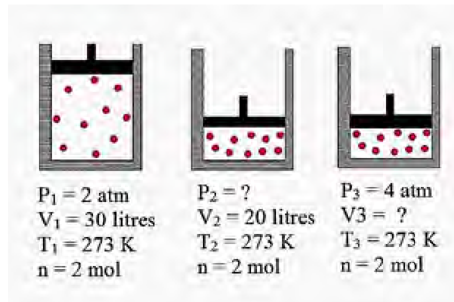
1. How does a gas exert pressure? Show with the help of a diagram.
2. Explain the concept of kinetic theory of gases.
3. Discuss the kinetic theory of gases in short.
4. Write down the applications of Boyle's law.
5. How does Boyle's law apply to mountain climbers carrying oxygen cylinders?
6. How does a hot air balloon rise up? Explain it on the basis of Charles' law.
7. Deduce the combined gas law.
8. Prove that $\frac{r1}{r2} = \frac{\sqrt{d_2}}{\sqrt{d_1}}$

D. Numerical problems

1. Convert 30°C into Kelvin. *(Ans: 303 K)*

2. The pressure of 4.5 litres of gas is 1.2 atm. What will be the pressure if the volume increases to 10 litres? *(Ans: 0.45 atm.)*

3. 40 litres of air at 20°C is filled in a balloon. The balloon moves up and the air expands. The volume of air is increased to 60 litres at about 4000 ft above sea level. Calculate the temperature of air at this altitude. *(Ans: 439.5 K)*



4. Calculate the unknown values from the following figure alongside.
   (Ans: P_1 = 3 atm., V_3 = 15 atm.)

5. Arrange the following gases in the decreasing order of their molecular speed at 50°C.

   CH_4, CO_2, NH_3

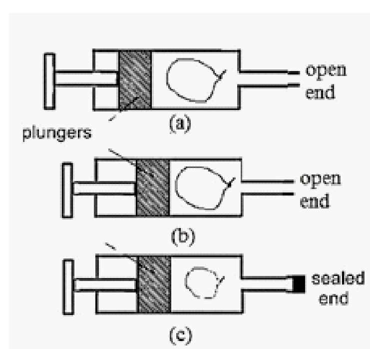
   (Ans: $CH_4 > NH_3 > CO_2$)

6. If 30 cc of ammonia gas diffuses in 55 seconds, how much volume of carbon dioxide diffuse in 40 seconds under the similar condition? (Density of NH_3 = 0.717 kg/m^3 and density of CO_2 = 1.832 kg/m^3 *(Ans: 13.6 atm.)*

Project: 1

To show that volume decreases on increasing pressure.

Materials required: Syringe without needle and a balloon



Procedure: Take a syringe of large volume (say 100 ml). Inflate a small balloon by filling some air and tie its mouth with a short thin thread. Pull the plunger (piston) of the syringe out and insert the balloon inside as in figure (a). Now, push the piston inside slowly as in figure (b) and observe the balloon. Note the change in volume of air inside the balloon. Finally, seal the tip of the syringe with wax or your finger tip so that no air goes out or comes inside the piston. Push the piston inside in the same way towards the balloon. Observe carefully what change occurs in the size of the balloon? Which law does this activity demonstrate? Discuss in your class.

Project: 2

To test the diffusion rates of different deodorants

Materials required: 4 deodorants, 3 stopwatches, paper and pen

Procedure: Take 4 samples of sprays from different brands. Make a group of four students in the class. Ask any three of them to stay at one corner of the class and ask the other at the opposite corner to carry one of the sprays. Tell him/her to spray the deodorant in the air for a second. Ask the other three to note the time after which they first smell the deodorant. Find the average of the three readings from the three students. Do the same for all deodorants sample? Which sample had the highest diffusion rate? Which sample of deodorant is lighter? Discuss in class.

Glossary

Gas	:	the state of matter which does not have definite shape and volume
Universal gas constant (R)	:	the constant whose value is the same all over the universe
Diffusion	:	the process of mixing up
LP gas	:	the liquefied petroleum gas which is used as a domestic fuel
Ideal gas	:	the gas which obeys all the laws of chemistry
Real gas	:	the gas which is present in our surrounding
Dented tennis ball	:	depression in the tennis ball
Atm	:	atmospheric pressure (1Atm=760 mm of Hg)

Unit 9 Chemical Reaction


Fritz Haber (1868-1934)

Fritz Haber born in 9 December 1868 and died in 29 January 1934. He was a German chemist. He received the Nobel Prize in Chemistry in 1918. He invented industrial synthesize ammonia from nitrogen and hydrogen gases.

Learning outcomes

After the completion of this unit, learners will be able to

1. Explain the types of the chemical reactions.
2. Explain the importance and limitation of the chemical reaction.
3. Demonstrate the conditions required to occur the chemical reaction.
4. Explain the reversible and irreversible chemical reactions.
5. Explain the exothermic and endothermic chemical reaction.
6. Introduce the oxidation and reduction reaction.

Chemical Reaction

Take small amount of sugar in a spoon and heat over a flame. After some time you will see red or black coloured substance in the spoon. Take a piece of zinc and insert it into a test tube containing some dilute hydrochloric acid. Observe this mixture for few seconds. What change do you observe in the test tube? Similarly, take some amount of sodium hydroxide and hydrochloric acid. Keep both the chemicals in the test tube and observe the mixture. After some time, you will see some solid substance at the bottom of the test tube. The insoluble solid substance is called salt. Can you say how is this salt formed? All the above activities are called chemical reactions. In these reactions, there may be addition or decomposition or displacement of atoms or molecules of matter take place. Thus, the chemical change which involves addition or decomposition or displacement of atoms or group of atoms is called a chemical reaction.

To express a chemical reaction, we use two methods. They are:

1. Word equation 2. Chemical equation

1. **Word Equation**

The chemical change which is expressed by writing full names of reactant and product molecules is called the word equation. It is a very simple method to express the chemical change. In this method, we use full names of reactant and product molecules.

Hydrogen + Oxygen $\rightarrow$ Water

Calcium carbonate $\rightarrow$ Calcium oxide + Carbon dioxide

2. **Chemical Equation or formula equation**

The chemical change which is expressed by using symbols of reactant and product molecules is called chemical equation. It is an easy and scientific method to express the chemical change. In this method, we use the symbols of reactant and product molecules to write the chemical reaction.

$2H_2 + O_2 \rightarrow 2H_2O$

$CaCO_3 \rightarrow CaO + CO_2 \uparrow$

Types of Chemical Reactions

There are several types of chemical reactions; among them four basic types of chemical reactions are discussed below.

1. **Addition (or Combination or Synthesis) Reaction**

Let us observe the formation of ammonia from nitrogen and hydrogen, formation of carbon dioxide from carbon and oxygen, formation of water from hydrogen and oxygen, etc. In these examples two or more reactant molecules are added to give single product. Such reactions are called addition reactions. Thus, those chemical reactions in which two or more atoms or group of atoms are combined together to give a single product are called addition reactions.

For example:

$N_2 + 3H_2 \rightarrow 2NH_3 \uparrow$

$C + O_2 \rightarrow CO_2 \uparrow$

$2Na + Cl_2 \rightarrow 2NaCl$

$2H_2 + O_2 \rightarrow 2H_2O$

$S + O_2 \rightarrow SO_2 \uparrow$

$4P + 5O_2 \rightarrow 2P_2O_5$

2. Decomposition Reaction

When hydrogen peroxide is kept open, it is decomposed into water and oxygen. Similarly, when calcium carbonate is heated at high temperature; it gives calcium oxide and carbon dioxide. In these reactions, a single reactant molecule (i.e. hydrogen peroxide and calcium carbonate) is converted into two products. Such types of reactions are called decomposition reactions.

The chemical reactions in which a single reactant molecule is decomposed into two or more products are called decomposition reactions.

For example:

$$2H_2O_2 \xrightarrow{MnO_2} 2H_2O + O_2\uparrow$$

$$CaCO_3 \xrightarrow{\Delta} CaO + CO_2\uparrow$$

$$2KClO_3 \xrightarrow{MnO_2/\Delta} 2KCl + 3O_2\uparrow$$

$$2Pb(NO_3)_2 \xrightarrow{\Delta} 2PbO + 4NO_2\uparrow + O_2\uparrow$$

$$CuCO_3 \xrightarrow{\Delta} CuO + CO_2\uparrow$$

3. Displacement Reaction

Let us discuss the formation of zinc sulphate and hydrogen gas in the laboratory. For this reaction, put a piece of zinc in a test tube containing dilute sulphuric acid. It starts to evolve hydrogen gas and makes zinc sulphate. In this reaction, hydrogen is displaced by zinc from the sulphuric acid. Similar type of reaction can be observed when magnesium ribbon is inserted in hydrochloric acid. In these reactions atoms or molecules are displaced by other atom or molecule. These reactions are called displacement reactions.

The chemical reactions in which atoms or group of atoms are displaced by other atoms or group of atoms are called displacement reactions.

There are two types of displacement reactions.

a. Single displacement reaction

b. Double displacement reaction

a. Single Displacement Reaction

When zinc is kept in dilute sulphuric acid, zinc displaces hydrogen from sulphuric acid and makes zinc sulphate and hydrogen gas. In this chemical reaction, one atom or one group of atoms is displaced by another atom or group of atoms. Thus, the type of chemical reaction in which one atom or one group of atoms is displaced by another atom or group of atoms is called single displacement reaction.

For example:

$$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2\uparrow$$

$$Mg + 2HCl \rightarrow MgCl_2 + H_2\uparrow$$

$$Fe + CuSO_4 \rightarrow FeSO_4 + Cu$$

$$2KI + Cl_2 \rightarrow 2KCl + I_2$$

b. Double Displacement Reaction

Let us observe the reaction between NaCl and $AgNO_3$. These two reactants decomposed into opposite ions. After decomposition, they exchange corresponding ions to give new products $NaNO_3$ and AgCl. Thus, the type of chemical reaction in which reactant molecules are decomposed into opposite ions and give the new products after exchanging corresponding opposite ions is called double displacement reaction.

For example:

$$NaCl + AgNO_3 \rightarrow NaNO_3 + AgCl$$

$$CaCl_2 + 2AgNO_3 \rightarrow Ca(NO_3)_2 + 2AgCl$$

$$Na_2CO_3 + MgCl_2 \rightarrow 2NaCl + MgCO_3$$

$$Pb(NO_3)_2 + Na_2SO_4 \rightarrow PbSO_4 + 2NaNO_3$$

4. Acid-base or Neutralization Reaction

Let us discuss the reaction between an acid and a base. Take a test tube and put some amount of hydrochloric acid and sodium hydroxide. After some time, we get salt of sodium chloride and water. Such reaction is called an acid-base reaction. As a result of acid-base reaction, acid and base lose their own properties; hence it is also called a neutralization reaction.

Those chemical reactions in which an acid and a base react together to give salt and water are called acid-base reactions or neutralization reaction.

For example:

Acid + Base	$\rightarrow$	Salt + Water
$HCl + NaOH$	$\rightarrow$	$NaCl + H_2O$
$2HCl + MgO$	$\rightarrow$	$MgCl_2 + H_2O$
$H_2SO_4 + 2KOH$	$\rightarrow$	$K_2SO_4 + 2H_2O$
$2HNO_3 + Ca(OH)_2$	$\rightarrow$	$Ca(NO_3)_2 + 2H_2O$
$H_2SO_4 + 2NH_4OH$	$\rightarrow$	$(NH_4)_2SO_4 + H_2O$

In addition to the major types of chemical reactions, there are also other types of chemical reactions. They are:

Exothermic Reactions

There are many chemical reactions like formation of carbon dioxide, formation of methane, formation of calcium hydroxide, etc. which occur spontaneously without any external energy. Occurrence of these chemical reactions does not require heat. We do not need to supply heat to initiate and to complete these reactions. These reactions are called exothermic reaction. Thus, those chemical reactions which evolve heat during their processing are called exothermic reaction.

$CaO + H_2O$	$\rightarrow$	$Ca(OH)_2$ + Heat
$C + 2H_2$	$\rightarrow$	$CH_4\uparrow$ + Heat
$C + O_2$	$\rightarrow$	$CO_2\uparrow$ + Heat
$CH_4 + 2O_2$	$\rightarrow$	$CO_2\uparrow + 2H_2O$ + Heat

Activity: To show the combination of calcium oxide and water is an exothermic reaction.

Materials required: Quicklime, water and beaker.

Procedure: Take about five grams of calcium oxide in a beaker and add water slowly. Touch the beaker from its outer surface.

Observation: As we touch the beaker, we feel the wall of beaker hotter because calcium oxide reacts with water and gives calcium hydroxide along with heat.

$CaO + H_2O \rightarrow Ca(OH)_2$ + Heat

Conclusion: The above activity proves that reaction between calcium oxide (Quicklime) and water is an exothermic reaction.

Endothermic Reactions

There are so many chemical reactions such as decomposition of potassium chlorate, decomposition of calcium carbonate, etc. which do not initiate, proceed and complete without supplying external heat. They are non-spontaneous chemical reactions. These reactions are called endothermic reactions. Therefore, those chemical reactions which absorb heat during their processing are called endothermic reactions.

$$CaCO_3 \xrightarrow{\Delta} CaO + CO_2\uparrow$$

$$2KClO_3 \xrightarrow{\Delta} 2KCl + 3O_2\uparrow$$

$$Fe + CuSO_4 \xrightarrow{\Delta} FeSO_4 + Cu$$

$$2Pb(NO_3)_2 \xrightarrow{\Delta} 2PbO + 4NO_2\uparrow + O_2\uparrow$$

Reversible Reactions

Let us discuss the formation of ammonia gas from nitrogen and hydrogen gas in necessary conditions. When these gases are mixed in the ratio of 1:3 in presence of necessary conditions of temperature, pressure and catalyst, they give ammonia gas. When some amount of ammonia gas is produced, it undergoes decomposition to give nitrogen and hydrogen gas again. Similar condition can be seen in the formation of hydrogen iodide from hydrogen and iodine. Such types of reactions which occur both in forward and backward directions are called reversible reactions. To express these reactions, we use double headed arrow in between reactant and product molecules.

Those chemical reactions which occur both in forward and backward directions are called reversible reactions.

$$H_2 + I_2 \rightleftharpoons 2HI$$

$$N_2 + 3H_2 \rightleftharpoons 2NH_3\uparrow$$

Irreversible Reactions

Let us discuss the formation of sodium chloride from sodium metal and chlorine non-metal. When sodium chloride is formed from sodium metal and chlorine non-metal, there does not occur again formation of sodium and chlorine in their original state. Similar condition can be observed in the formation of various chemical compounds. These reactions occur only in forward direction. To express these reactions, we use single way arrow in between reactant and product molecules.

Those chemical reactions which occur only in one direction (forward direction) are called irreversible reactions.

$$2KClO_3 \longrightarrow 2KCl + 3O_2\uparrow$$

$$CaCO_3 \longrightarrow CaO + CO_2\uparrow$$

$$2H_2O_2 \longrightarrow 2H_2O + O_2\uparrow$$

$$2Na + Cl_2 \longrightarrow 2NaCl$$

$$CH_4 + 2O_2 \longrightarrow CO_2\uparrow + 2H_2O$$

Catalytic reaction

Let us discuss the decomposition of potassium chlorate in presence of heat. The molecule of potassium chlorate decomposed to give potassium chloride and oxygen gas. This decomposition reaction becomes fast in the presence of manganese dioxide. So, such reaction is called catalytic reaction.

Those chemical reactions which occur in presence of catalyst are called catalytic reactions.

$$2KClO_3 \xrightarrow{MnO_2} 2KCl + 3O_2\uparrow$$

$$2H_2O_2 \xrightarrow{MnO_2} 2H_2O + O_2\uparrow$$

Catalyst not only increases the rate of chemical reaction but there are some chemical reactions where catalysts decrease the rate of reaction. For example, glycerin decreases the rate of decomposition of hydrogen peroxide into water and oxygen.

$$2H_2O_2 \xrightarrow{\text{Glycerin}} 2H_2O + O_2\uparrow$$

Those chemical substances which change the rate of chemical reactions are called catalysts. The catalysts which increase the rate of chemical reaction are called positive catalysts (e.g. manganese dioxide, iron, nickel) and those which decrease the rate of chemical reaction are called negative catalysts (e.g. glycerin, gypsum).

Photochemical reaction

Formation of hydrochloric acid from hydrogen and chlorine, decomposition of silver bromide, etc. occur in presence of the sun light. Not only these, there are also some reactions which are initiated in the presence of sun light only. They include photosynthesis in plants, chlorination in alkanes, decomposition of silver bromide, etc. Thus, those chemical reactions which occur in presence of the sun light are called photochemical reactions.

Examples;

$$2AgCl \xrightarrow{\text{Light}} 2Ag + Cl_2$$

$$2AgBr \xrightarrow{\text{Light}} 2Ag + Br_2$$

$$H_2 + Cl_2 \xrightarrow{\text{Light}} 2HCl$$

$$CH_4 + Cl_2 \xrightarrow{\text{Light}} CH_3Cl + HCl$$

Polymerization reaction

Formation of protein from amino acid molecules, formation of starch from many sugar molecules, formation of polythene from many ethene molecules, etc. are some polymerization reactions. In these reactions, same type of many molecules combine together to give a complex molecule. Thus, those chemical reactions in which the same type many molecules combine together to give a complex molecule are called polymerization reactions.

Examples;

$n(CH_2 = CHCl) \rightarrow (-CH_2 - CHCl-)n$

(Vinyl chloride) (Poly vinyl chloride)

$n(CH_2 = CH_2) \rightarrow (-CH_2 - CH_2-)n$

(Ethene) (Polyethene)

Electrochemical reaction

When we supply electricity in an acidified water, we get hydrogen and oxygen gas in the respective electrodes. Similarly, electrolysis of copper sulphate, electrolysis of sodium chloride, etc. occur in presence of electricity. Such types of many reactions occur in the presence of electricity. Thus, those chemical reactions which occur in presence of electricity are called electrochemical reactions.

$$2H_2O \xrightleftharpoons{\text{electricity}} 2H_2\uparrow + O_2\uparrow$$

Hydrolysis reaction

When we keep common salt in water, the salt molecule break down into opposite ions (sodium ion and chloride ion) and combine with the opposite ions of water to give sodium hydroxide and hydrochloric acid. Such reactions are called hydrolysis reaction. Thus, those chemical reactions which occur in presence of water are called hydrolysis reactions.

$NaCl + H_2O \rightarrow NaOH + HCl$

$KCl + H_2O \rightarrow KOH + HCl$

$CH_3COONa + H_2O \rightarrow NaOH + CH_3COOH$

Oxidation and Reduction reaction

Classical concept of oxidation and reduction reaction

Many elements combine with oxygen to give oxides. For example, sodium combines with oxygen to give sodium oxide, calcium combines with oxygen to give calcium oxide, etc. So, such types of chemical reactions in which elements combine with oxygen to give corresponding oxides are called oxidation reactions.

$4Na + O_2 \longrightarrow 2Na_2O$

$2Ca + O_2 \longrightarrow 2CaO$

$4Fe + 3O_2 \longrightarrow 2Fe_2O_3$

There are many chemical reactions in which compounds lose oxygen. For example; when copper oxide reacts with carbon, it gives carbon monoxide and free copper. Similarly, when water vapour reacts with carbon, it gives carbon monoxide and hydrogen gas. These are called reduction reaction. Thus, those chemical reactions in which compounds lose oxygen are called reduction reactions.

$CuO + C \longrightarrow CO\uparrow + Cu$

$H_2O + C \longrightarrow CO + H_2\uparrow$

Electronic concept of oxidation and reduction reaction

According to electronic concept, during oxidation there occurs a loss of electrons from the atoms or ions or molecules. For example; when sodium loses one electron, it is called oxidation of sodium. Similarly when ferrous ion(Fe^{++}) turns into ferric ion(Fe^{+++}) it is called oxidation of iron. Thus, oxidation is a process in which an atom or ion or molecule loses one or more electrons.

$$Na \longrightarrow Na^{+} + e-$$

$$Mg \longrightarrow Mg^{++} + 2e^{-}$$

$$Fe \longrightarrow Fe^{++} + 2e^{-}$$

$$Fe^{++} \longrightarrow Fe^{+++} + e^{-}$$

According to the electronic concept, during reduction there occurs gain of electrons in the atoms or ions or molecules. For example; when chlorine gains one electron, it is called reduction of chlorine. Similarly when ferric ion (Fe^{+++}) turns into ferrous ion(Fe^{++}) it is called reduction of iron. Thus, reduction is a process in which an atom or ion or molecule gains one or more electrons.

$$Fe^{+++} + e^{-} \longrightarrow Fe^{++}$$

$$Cl_2 + 2e^{-} \longrightarrow 2Cl^{-}$$

Oxidation reduction reaction or redox reaction

It is said that oxidation and reduction are complementary to each other. They occur simultaneously. Oxidation does not take place without reduction and reduction does not take place without oxidation. In a chemical reaction oxidation and reduction occur simultaneously. Such reaction is called a redox reaction. Thus, the chemical reaction in which oxidation and reduction occurs simultaneously is called oxidation reduction reaction or redox reaction.

$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2\uparrow$$

$$Fe + CuSO_4 \longrightarrow FeSO_4 + Cu$$

In the above reactions, zinc and iron get oxidized; similarly hydrogen and copper get reduced. So the above reactions are called redox reactions.

Factors affecting the chemical reaction

Various factors affect the chemical reaction. Among them some important factors are described below.

a. Heat

Heat is a form of energy. It supplies kinetic energy to the reacting molecules. As we supply heat, the vibration of the reacting molecules increases. It also increases the speed of collision of the reactant molecules. So, the more heat the more collisions and the more products. For example;

$$CaCO_3 \longrightarrow CaO + CO_2 \uparrow$$

$$2KClO_3 \longrightarrow 2KCl + 3O_2 \uparrow$$

In the above reactions as we supply heat, the decomposition of calcium carbonate and potassium chloride becomes fast.

b. Light

In presence of the sun light, there occur certain chemical reactions. Not only this, there are also some reactions which are initiated in the presence of sun light only. For example; photosynthesis in plants, chlorination in alkanes, decomposition of silver bromide, etc. initiate only in the presence of the sun light.

$$H_2 + Cl_2 \xrightarrow{\text{Light}} 2HCl$$

$$2Ag\,Br \xrightarrow{\text{Light}} 2Ag + Br_2$$

$$CH_4 + Cl_2 \xrightarrow{\text{Light}} CH_3Cl + HCl$$

c. Pressure

One of the responsible factors for a chemical reaction is pressure. It decreases volume of the reacting molecules. As a result of this, reactant molecules come close to each other and collide speedily. The volume of the reactant molecules should be less for a reaction. If volume of reactants is more than product molecules, we should supply pressure to accelerate the rate of reaction. For example, formation of ammonia from nitrogen and hydrogen takes place in presence of 200 to 500 atmospheric pressure.

$$N_2 + 3H_2 \underset{Fe/Mo}{\overset{200 \text{ to } 500 \text{ atm}, 500°C}{\rightleftharpoons}} 2NH_3\uparrow$$

d. Catalysts

Catalysts are very important factors for the chemical reaction. For example, decomposition of hydrogen peroxide increases in presence of manganese dioxide and decreases in presence of glycerin. Here, manganese dioxide and glycerin are called catalysts. Thus, the chemical substances which either increase or decrease the rate of chemical reactions are called catalysts. There are two types of catalysts.

i) Positive catalysts

ii) Negative catalysts

i) Positive Catalysts

They increase the rate of chemical reactions. For example; manganese dioxide, iron, nickel, copper, etc.

$$2KClO_3 \xrightarrow{MnO_2} 2KCl + 3O_2\uparrow$$

$$N_2 + 3H_2 \xrightarrow{Fe} 2NH_3\uparrow$$

$$2H_2O_2 \xrightarrow{MnO_2} 2H_2O + O_2\uparrow$$

ii) Negative Catalysts

They decrease the rate of chemical reactions. For example; glycerin, gypsum, etc.

$$2H_2O_2 \xrightarrow{Glycerine} 2H_2O + O_2\uparrow$$

e. Electricity

There are many chemical reactions which occur in presence of electricity. For example; in electrolysis of water, we supply electricity in acidified water. As a result, we get hydrogen and oxygen gases at their respective electrodes.

$$2H_2O \overset{electricity}{\rightleftharpoons} 2H_2\uparrow + O_2\uparrow$$

f. Solution

Let us discuss the reaction between silver nitrate and sodium chloride. When solid form silver nitrate and solid form of sodium chloride are mixed together, they do not give any product. But, when they are mixed in solution form, they react together and give silver chloride and sodium nitrate. The given example shows that solution is a factor to initiate, accelerate and complete the chemical reaction.

$$AgNO_3(s) + Nacl(s) \longrightarrow \text{No reaction}$$

$$AgNO_3(aq) + NaCl(aq) \longrightarrow AgCl\,(s) + NaNO_3(aq)$$

g. Contact

Among all factors, contact is a main factor to initiate a chemical reaction. If there is no contact, there is no reaction and there is no product. For example; ammonia gas does not form when nitrogen and hydrogen do not come in contact.

$$N_2 + 3H_2 \longrightarrow 2NH_3 \uparrow$$

Importance of chemical equation

1. Chemical equation is an easy and fast way to represent the chemical change.
2. It shows the name and symbols of reactant and product molecules.
3. A chemical equation gives an idea about the total numbers of atoms of each element in reactant and product molecules.
4. It gives idea about the ratio of molecular weight of reactant and product molecules.
5. It gives an idea about the ratio of reactant and product molecules.
6. It also shows the type of the chemical reaction.

Limitations of chemical Equations

1. A chemical equation does not inform the physical state of reactants and products.
2. It does not inform about the rate of reaction.

3. It does not inform about the concentration of reactants and products.
4. It does not inform the conditions required for the reaction to take place.
5. It does not inform the reversible and irreversible condition of the reactions.
6. It does not inform whether the reaction is exothermic or endothermic.

Modifications in the chemical equation

The above limitations are corrected by using the following modifications.

1. The physical state of reactants and products are symbolized as follows:

   Solid is represented by 's' Liquid is represented by 'l'

   Gas is represented by 'g' or '$\uparrow$' Aqueous 'aq'

   Diluted solution is represented by 'dil'. Concentrated solution is represented by 'conc'.

2. The conditions such as heat, light, catalyst, etc. are writing above or below the arrow.
3. The reversible reactions are represented by a two way arrow ($\rightleftharpoons$) and irreversible reactions are represented by a single way arrow ($\rightarrow$) between the reactants and products.
4. The exothermic reactions are represented by using ($-\ \Delta$) and endothermic reactions are represented by using ($+\ \Delta$) over an arrow.

Summary

1. The chemical change which involves addition or decomposition or displacement of atoms or group of atoms is called a chemical reaction.
2. Those chemical reactions in which two or more atoms or group of atoms are combined together to give a single product are called addition reactions.
3. The chemical reactions in which a single reactant molecule is decomposed into two or more products are called decomposition reactions.
4. The chemical reactions in which atoms or group of atoms are displaced by other atoms or group of atoms are called displacement reactions.
5. The type of chemical reaction in which reactant molecules are decomposed into opposite ions and give the new products after exchanging corresponding opposite ions is called double displacement reaction.

6. Those chemical reactions in which an acid and a base react together to give salt and water are called acid-base reactions or neutralization reaction.
7. Those chemical reactions which evolve heat during their processing are called exothermic reaction.
8. Those chemical reactions which absorb heat during their processing are called endothermic reactions.
9. Those chemical reactions which occur both in forward and backward directions are called reversible reactions.
10. Those chemical reactions which occur only in one direction (forward direction) are called irreversible reactions.
11. Those chemical reactions which occur in presence of catalyst are called catalytic reactions.
12. Those chemical reactions which occur in presence of the sun light are called photochemical reactions.
13. Those chemical reactions in which the same type of many molecules combine together to give a complex molecule are called polymerization reactions.
14. Those chemical reactions which occur in presence of electricity are called electrochemical reactions.
15. Those chemical reactions which occur in presence of water are called hydrolysis reactions.
16. Such types of chemical reactions in which elements combine with oxygen to give corresponding oxides are called oxidation reactions.
17. Those chemical reactions in which compounds lose oxygen are called reduction reactions.
18. Oxidation is a process in which an atom or ion or molecule loses one or more electrons.
19. Reduction is a process in which an atom or ion or molecule gains one or more electrons.
20. The chemical reaction in which oxidation and reduction occur simultaneously is called oxidation reduction reaction or redox reaction.

Exercise

A. Tick (✓) the best alternative from the followings.

1. Name the type of chemical reaction in which an acid reacts with a base.

   i. Addition reaction ii. Decomposition reaction

   iii. Neutralization reaction iv. Displacement reaction

2. Those reaction which occur only one direction are called

   i. Reversible reaction ii. Irreversible reaction

   iii. Decomposition reaction iv. Displacement reaction

3. What type of reaction is given $2KClO_3 \xrightarrow{MnO_2} 2KCl + 3O_2\uparrow$

   i. Addition reaction ii. Decomposition reaction

   iii. Neutralization reaction iv. Displacement reaction

4. Those reaction in which oxygen combines with the reactant are called

   i. Oxidation reaction ii. Reduction reaction

   iii. Acid-base reaction iv. Hydrolysis reaction

5. Which one is a polymer?

   i. Protein ii. Amino acid

   iii. Glucose iv. Sodium chloride

B. Give short answers to the following questions.

1. Define chemical reaction with an example.
2. What is an addition reaction? Give an example.
3. Define decomposition reaction with an example.
4. Write about the single displacement reaction with an example.
5. What is double displacement reaction? Show with an example.
6. Define acid base reaction with an example.
7. Why is acid base reaction called a neutralization reaction?

8. Define the following chemical reactions with one example of each.

   a. Catalytic reaction b. Oxidation reaction c. Reduction reaction

   d. Photochemical reaction e. Polymerization reaction f. Redox reaction

   g. Hydrolysis reaction h. Exothermic reaction i. Endothermic reaction

   j. Reversible reaction k. Irreversible reaction

C. Give long answers to the following questions.

1. Explain the classical and electronic concept of the oxidation reaction with the help of an example.
2. Explain the classical and electronic concept of the reduction reaction with the help of example.
3. Define oxidation reduction reaction (redox reaction) with the help of examples.
4. Oxidation and reduction reaction occur simultaneously. Why? Show with the help of a reaction.
5. Write down the conditions required to occur the chemical reaction.
6. Explain the modifications which have been done in the chemical reaction to make the chemical reaction more informative.

D. Complete and balance the given chemical equations.

i. $\ldots\ldots\ldots + HCl \rightarrow MgCl_2 + H_2\uparrow$

ii. $NaCl + AgNO_3 \rightarrow NaNO_3 + \ldots\ldots\ldots\ldots$

iii. $HCl + \ldots\ldots\ldots\ldots \rightarrow NaCl + H_2O$

iv. $C + O_2 \rightarrow \ldots\ldots\ldots\ldots + \text{Heat}$

v. $KClO_3 \rightarrow KCl + \ldots\ldots\ldots\ldots$

vi. $H_2O_2 \rightarrow H_2O + \ldots\ldots\ldots\ldots$

Project work

1. Take some amount of calcium oxide (CaO) in a beaker and put water in it. After some time, touch the beaker from its outer surface. What do you feel?

Whether it is hot or cold? From this observation explain exothermic and endothermic reaction.

2. Take some amount of sodium nitrite ($NaNO_2$) and ammonium chloride (NH_4Cl) in a beaker and put water in it. After some time, touch the beaker from its outer surface. What do you feel? Whether it is hot or cold? From this observation explain exothermic and endothermic reaction.

3. Take a piece of magnesium ribbon and hold it with the help of a tong. Burn the magnesium ribbon in the flame. What type of chemical reaction is this? Name the chemical compound obtained in this process.

Glossary

Exothermic	:	which releases heat
Endothermic	:	which absorbs heat
Redox	:	the combination of oxidation and reduction
Neutralize	:	to cancel the effect of each other.
Photon	:	the energy of the sun light
Catalyst	:	the chemical which changes the rate of reaction
Synthesis	:	to produce something using two or more raw materials
Limitation	:	the boundary of limit.

Unit 10 Electrochemistry

Svante August Arrhenius born in 19 February 1859 and died in 2 October 1927. He is one of the founders of physical chemistry. The Arrhenius equation, Arrhenius definition of an acid, Arrhenius theory of ionization, etc. are his famous works.

Arrhenius (1859-1927)

Learning outcomes

After the completion of this unit, learners will be able to

1. Distinguish electrolytes and non-electrolytes with examples.
2. Explain strong and weak electrolytes with examples.
3. Explain the Arrhenius theory of ionization.
4. Differentiate between metallic conductors and electrolytic conductors.
5. Explain electroplating, electro refining and electrotyping with their application.

Introduction

There are two ways by which electric energy transfers from one place to another place. One method is by the transfer of electrons and another method is by the transfer of ions. Transfer of electrons occurs in metals and graphite whereas transfer of ions occurs in the solution or molten form of the ionic compounds. The ionic chemical compounds undergo ionization into opposite ions and move to the opposite poles to conduct electricity. They show chemical change while conducting electricity. In chemistry there is a separate branch to study the production of ions and their effects. Thus, the branch of chemistry in which we study about movement and effects of ions is called electrochemistry. Electrochemistry is used in several electrochemical processes like electrolysis, electro refining, electroplating, electrotyping, etc.

Electrolytic conductors

Different electrovalent compounds like NH_4Cl, NaCl, KCl, $CaCl_2$, HNO_3, H_2SO_4, etc. undergo ionization into opposite ions. These ions are cations and anions.

They move towards cathode and anode with conducting electricity respectively. Thus, those chemical compounds which undergo ionization into opposite ions and conduct electricity are called electrolytic conductors or electrolytes. Transfer of electricity through electrolytic conductors is a chemical process. There occurs chemical change in the electrolytic solution.

Similarly, there are so many organic compounds like fat, glucose, protein, oil, petroleum, etc. which do not undergo ionization into opposite ions and also do not conduct electricity. They are called non-electrolytes. They remain in the solution without any change. They do not show any chemical change.

Differences between electrolytes and non-electrolytes

Electrolytes		Non-electrolytes	
1.	Electrolytes undergo ionization to give opposite ions.	1.	Non-electrolytes do not undergo ionization to give opposite ions.
2.	They conduct electricity.	2.	They do not conduct electricity.
3.	They are mostly inorganic compounds. For example, NH_4Cl, $NaCl$, KCl, $AgNO_3$, $CuSO_4$, etc.	3.	They are mostly organic compounds For example; fat, sugar, protein, etc.

Activity

Objective: to classify electrolytes and non-electrolytes from the given substances.

Theory: Those chemical substances which undergo ionization into opposite ions and conduct electricity are called electrolytes and those which do not undergo ionization into opposite ions are called non-electrolytes.

Materials required: Beaker, two graphite rods, switch, electric wire, sugar solution and salt solution.

Procedure: Connect beaker, graphite rods, electric wire and bulb to make a complete circuit as shown in the diagram. Keep salt and sugar solution one by one in the beaker and observe the bulb.

The bulb lights in the salt solution but it does not light in the sugar solution.

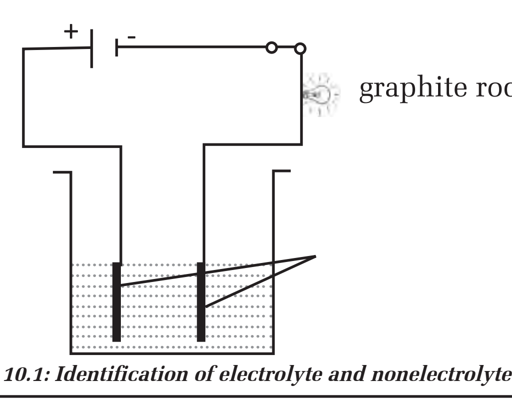


Fig. 10.1: Identification of electrolyte and nonelectrolyte

The above activity proves that salt is an electrolyte and sugar is a non-electrolyte.

Strong and weak electrolytes

In some electrolytic solution the bulb glows brighter because they produce more number of ions. Similarly, in some electrolytic solution the bulb glows fainter because they produce less number of ions. Thus, those chemical compounds which undergo almost complete ionization to give more number of opposite ions are called strong electrolytes. HCl, H_2SO_4, HNO_3, KCl, NaCl, K_2SO_4, etc. are some examples of strong electrolytes. They are good conductor of electricity as they produce more number of ions. In spite of these compounds there are many other compounds like NH_4OH, H_2CO_3, H_3PO_4, CH_3COOH, etc. which undergo very less ionization and produce less numbers of ions. They are also poor conductor of electricity. Thus, those chemical compounds which undergo very less ionization to give opposite ions are called weak electrolytes.

Differences between strong and weak electrolytes

	Strong electrolytes		Weak electrolytes
1.	Strong electrolytes undergo almost complete ionization to give opposite ions.	1.	Weak electrolytes undergo very less ionization to give opposite ions.
2.	They are good conductor of electricity. For example, HCl, KCl, NaCl, H_2SO_4, etc.	2.	They are poor conductor of electricity. For example, H_2CO_3, H_3PO_4, NH_4OH, etc.

Activity

Objective: to compare the strong and weak electrolytes.

Materials required: beaker, graphic rods, switch, electric wire, bulb, solution of sodium chloride and ammonium chloride, etc.

Theory: Strong electrolytes conduct more amount of electricity due to almost complete ionization whereas weak electrolytes conduct less amount of electricity due to less ionization.

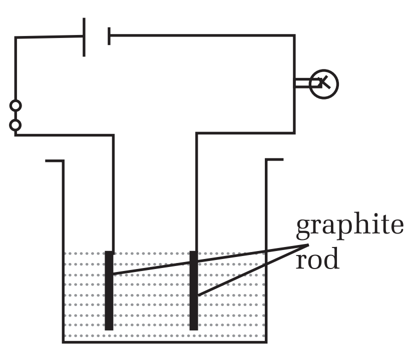


Fig 10.2: Comparison of strong and weak electrolyte

Procedure: Arrange beaker, graphite rods, electric wire and bulb to make a complete circuit as shown in the diagram. Keep the solution of sodium chloride and ammonium chloride one by one in the beaker and observe the brightness of the bulb.

The bulb glows brighter in sodium chloride solution and less bright in the solution of ammonium chloride.

This activity proves that sodium chloride is a strong electrolyte and ammonium chloride is a weak electrolyte.

Metallic conductors

Different kinds of metals like copper, silver, aluminium, mercury etc. have free electrons or loosely bonded electrons in their atomic structures. These metals allow electric current to pass through them whether they are in solid or liquid states. Thus, those substances which allow electric current to pass through them are called conductors. Transfer of electric energy with the help of metallic conductors is a physical process. During this process, metals do not show any chemical change but get heated faintly. This property of metal is widely used to conduct electricity, to make household heating appliances, parts of electronics, parts of engines, etc. The non-metals like phosphorus, sulphur, etc. and other substances like dry wood, paper, plastics, etc. do not have free electrons. They also do not conduct electric energy from one place to another place. Thus, those substances which do not allow electric current to pass through them are called insulators. For example; dry wood, papers, plastics, non-metals, etc.

Differences between conductors and insulators

Conductors		Insulators	
1.	Conductors are those substances which allow electric current to pass through them.	1.	Insulators do not allow electric current to pass through them.
2.	They have free electrons or loosely bonded electrons	2.	They do not have free electrons or loosely bonded electrons.
3.	Usually, metals are conductors of electricity. For example; copper, silver, gold, aluminium, etc.	3.	Usually, non-metals are insulators of electricity. For example, dry wood, paper, plastics, sulphur, phosphorus, etc.

Activity

Objective: to classify the conductors and insulators from the given materials.

Materials required: plastic, iron piece, rubber, wood, magnesium ribbon, bulb, battery, electric wire, etc.

Theory: Conductors allow electric current to pass through them and insulators do not allow electric current to pass through them.

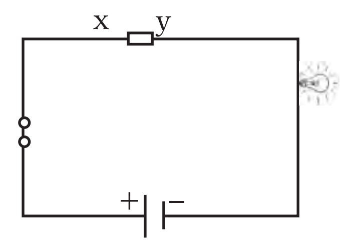


Fig 10.3: Identification of conductor and insulator

Procedure: Connect parts of electric circuit like bulb, wire, switch, battery, etc. as shown in the given diagram. Insert above materials (i.e. wood, plastic, rubber, iron piece, magnesium ribbon) in between the points X and Y and observe the bulb.

As we insert magnesium piece and iron, the bulb lights. But, as we insert rubber, wood, plastic the bulb does not light.

Conclusion: The above activity proves that, iron and magnesium are conductors but wood, plastic and rubber are insulators.

Differences between electrolytic conductors and metallic conductors

	Electrolytic conductors		**Metallic conductors**
1.	Those chemical compounds which undergo ionization into opposite ions and conduct electricity are called electrolytic conductors.	1.	Those metallic substances which allow electric current to pass through them are called metallic conductors.
2.	They produce free ions to conduct electricity.	2.	They have free electrons or loosely bonded electrons to conduct electricity.
3.	Usually, ionic compounds are electrolytic conductors. For example; HCl, KCl, NaCl, H_2SO_4, etc.	3.	Usually, solid metals are metallic conductors. For example, iron, copper, silver, graphite, etc.

Ions

When electrovalent compounds are kept in an aqueous solution, they produce ions. So, atoms or group of atoms which have either positive or negative charge on them are called ions. The ions which have positive charge on them are called cations and ions which have negative charge on them are called anions. Cations move towards cathode and anions move towards anode. The ions which have only one atom, they are called simple ions. For example, Na^+, K^+, H^+, Cl^-, F^-, etc.

Similarly, when ions have two or more atoms, they are called compound ions. For example, NH_4^+, CO_3^{--}, PO_4^{---} etc.

Differences between cations and anions

Cations		Anions	
1.	Cations have positive charge on them.	1.	Anions have negative charge on them.
2.	In cations the numbers of electrons are less than protons.	2.	In anions the numbers of electrons are more than protons.
3.	They are formed by losing of electrons.	3.	They are formed by gaining of electrons.
	For example, Na^+, K^+, Ca^{++}, NH_4^+, etc.		For example, Cl^-, F^-, O^{--}, PO_4^{-3}, etc.

Ionization

Cations and anions combine together to make electrovalent compounds. In these compounds there occurs a force of attraction called electrovalent bond. When these electrovalent compounds are kept in an aqueous solution, they break down into opposite ions called ionization. Thus, ionization is a process in which compounds break down into opposite ions. Ionization is a chemical process. It is carried out by applying heat, light, electricity, solution, etc. If ionization is carried out in presence of electricity, it is called electrolysis. After the process of ionization, the solution becomes conductor of electricity. So the solution is called electrolytic conductor. For example, sodium chloride does not conduct electricity in its solid state but in fused or solution state, it conducts electricity. Some ionic compounds and their opposite ions are given below:

Compounds		Cations		Anions
$CuSO_4$	$\rightleftharpoons$	Cu^{++}	+	SO_4^{--}
NH_4Cl	$\rightleftharpoons$	NH_4^+	+	Cl^-
HCl	$\rightleftharpoons$	H^+	+	Cl^-
$NaCl$	$\rightleftharpoons$	Na^+	+	Cl^-
HNO_3	$\rightleftharpoons$	H^+	+	NO_3^-
$AlCl_3$	$\rightleftharpoons$	Al^{+++}	+	$3Cl^-$
H_2SO_4	$\rightleftharpoons$	$2H^+$	+	SO_4^{--}
NH_4OH	$\rightleftharpoons$	NH_4^+	+	OH^-

Theory of ionization

Arrhenius in 1880 AD proposed the theory of ionization. The theory of ionization explains the formation of cations and anions as well as their behaviour. The main points of this theory are given below.

i. The electrolytes dissociate into opposite ions when they are kept in an aqueous solution.

ii. In an electrolytic solution the numbers of cations and anions are the same.

iii. Strong electrolytes undergo almost complete ionization whereas weak electrolytes do not undergo complete ionization.

iv. Cations being positively charged move toward cathode and anions being negatively charged move towards the anode.

v. In an electrolytic solution the cations and anions reunite together to give a neutral compound. Therefore, there will be a state of equilibrium in between ions and compounds.

   For example,

$$NH_4Cl \rightleftharpoons NH^+_4 + Cl^- \rightleftharpoons NH_4Cl$$

Factors affecting the Ionization

Heat, light, electricity, pressure, concentration, nature of electrolytes, nature of solvent, etc. are some factors which are responsible for the process of ionization.

1. Heat

Heat supplies kinetic energy to the solvent molecules. Due to this reason, the process of ionization increases as we supply heat.

2. Nature of electrolytes

Some electrolytes are strong in nature. They undergo almost complete ionization to give opposite ions. But, there are some electrolytes which are weak in nature. They undergo very less ionization to give opposite ions.

3. Nature of solvent

Generally, two types of solvents are used. They are inorganic solvent and organic solvent. Inorganic solvents have more dielectric constant (more polarity power). So they help to produce more ions whereas organic solvents have less dielectric constant and help to produce fewer ions.

4. **Concentration**

The dilute solution has more ionization power than the concentrated solution. Therefore, ionic compounds kept in dilute solution produce more numbers of ions as compared to the concentrated solution.

5. **Presence of impurities**

The different kinds of impurities increase the speed of ionization.

Electrolysis

Electrovalent compounds like NH_4Cl, NH_4OH, $CuSO_4$, NaCl, etc. are formed by the combination of two opposite ions (i.e. cation and anion). These compounds undergo ionization to give the same ions from where they are made. The ionization process is carried out in presence of heat, light, electricity, solution, etc. If the process of ionization is carried out in presence of electricity, it is called electrolysis.

For example:

H_2O(Water) $\xrightleftharpoons{\text{Electricity}}$ $H^+ + OH^-$

$CuSO_4$(Copper sulphate) $\xrightleftharpoons{\text{Electricity}}$ $Cu^{++} + SO_4^{--}$

Importance of electrolysis (or ionization)

1. The electrolysis process is used to get opposite ions (i.e.cations and anions).
2. During metallurgical process, it is used in electro refining of the impure metals.
3. It is used in the process of electroplating. For example; copper plating, silver plating, gold plating, etc.
4. It is used in the process of electro typing.
5. It is used to protect metals from corrosion (rusting in case of iron).
6. It is used to get hydrogen and oxygen gas from water.

Electrolysis of water

Similar to the other electrovalent compounds, water is formed by the combination of one oxygen and two hydrogen atoms. When a water molecule is ionized, it is separated into hydrogen (H^+) and hydroxyl (OH^-) ions. Thus, the process by which water molecule is broken down into hydrogen (H^+) and hydroxyl (OH^-) ions by the application of electricity is called electrolysis of water.

$$H_2O \xrightleftharpoons{\text{Electricity}} H^+ + OH^-$$

Materials required for the electrolysis of water.

i.	Voltameter	ii.	Test tubes
iii.	Graphite rods	iv.	Battery
v.	Water	vi.	Sulphuric acid

Procedure: Arrange battery, voltameter, test tubes and graphite rods as shown in the given diagram. Keep some amount of water and some drops of sulphuric acid inthe voltameter. Supply electricity with the help of battery. As we supply electricity, water molecules break down into opposite ions and move towards the opposite electrodes. Now, hydrogen and oxygen gases are obtained from the respective electrodes.

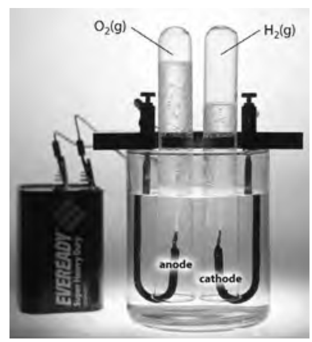


Fig 10.4: Electrolysis of water

Mechanism of hydrogen and oxygen gas formation

a) Reaction at cathode

Hydrogen ion has positive charge. So it moves towards the cathode and gains one electron to make neutral hydrogen atom. This neutral atom is called nascent hydrogen. At cathode, two hydrogen atoms combine together to make hydrogen gas.

$H^+ + 1e^- \rightarrow H$ (Nascent hydrogen)

$H + H \rightarrow H_2\uparrow$ (Hydrogen gas)

b) Reaction at anode

Hydroxyl ion has negative charge. So it moves towards the anode and loses its one extra electron to make neutral species. The neutral OH groups rearrange to make water and oxygen gas.

$OH^- - 1e^- \rightarrow OH$

$4OH \rightarrow 2H_2O + O_2\uparrow$

Electrolysis of copper sulphate ($CuSO_4$)

When we supply electricity in the solution of copper sulphate, the molecules of copper sulphate ($CuSO_4$) ionize into copper ions and sulphate ions. These opposite ions move towards their respective electrodes. Copper ions reach to the cathode and gain electrons. After gaining electrons copper ions become neutral copper atoms. Now, these copper atoms get deposited over the surface of cathode. At the same time sulphate ions reach to the anode and make copper sulphate. In this way the concentration of copper sulphate is maintained in the solution.

$$\underset{\text{Copper sulphate)}}{CuSO_4} \xrightleftharpoons{\text{Electricity}} \underset{\text{(Copper ion)}}{Cu^{++}} + \underset{\text{(Sulphate ion)}}{SO_4^{--}}$$

Reaction at cathode:

$Cu^{++} + 2e^- \rightleftharpoons$ Cu (Deposits over the surface of cathode)

Reaction of anode:

$Cu \rightleftharpoons Cu^{++} + 2e^-$

$Cu^{++} + SO_4^{--} \rightleftharpoons CuSO_4$

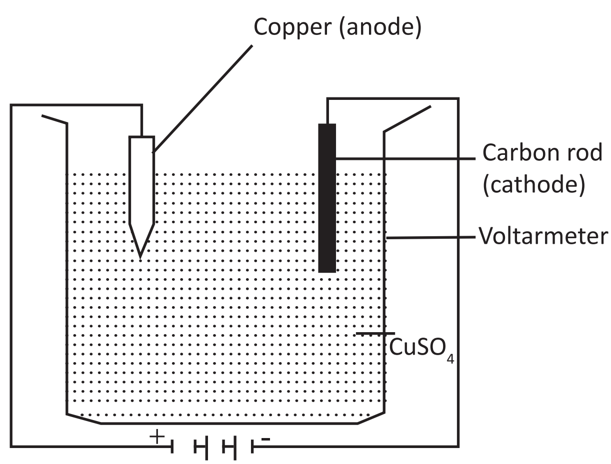


Fig 10.5: Electrolysis of copper sulphate

Electroplating

In the market we can see various fake golden jewelries. They are actually not made by gold but golden coat is deposited over their surface. It is done by using electroplating process. Thus, electroplating is a process in which colour of one metal is deposited over the surface of another metal using electricity. In this process we use two metals, one is anodic metal whose colour is going to be deposited and another is cathodic metal whose surface is going to be coated. To facilitate electroplating,

Do you know?

After the process of electrolysis of copper sulphate; the thickness of cathodic copper increases and anodic copper decreases. At the same time the concentration of copper sulphate remains the same.

we use a salt solution of anodic metal. As we supply electricity, anodic metal deposits over the surface of cathodic metal imparting colour.

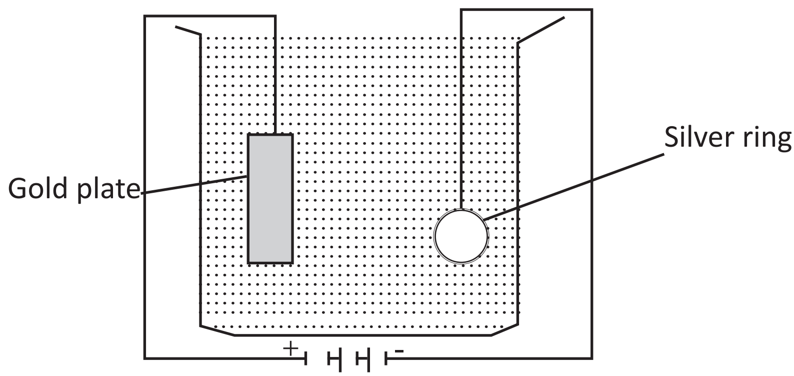


Fig 10.6: Electrolysis of electroplating of Gold

Conditions required for electroplating

i. The metal to be deposited should be made anode.

ii. The metal in which another metal is going to be deposited should be made cathode.

iii. The electrolytic solution should be the salt solution of the metal to be deposited.

iv. Continuous and uniform flow of electricity should be supplied.

Copper plating

The electro plating process in which copper is deposited over the surface of zinc or iron or any other metal by using electricity is called copper plating. During copper plating, copper is connected at anode and zinc or iron or any other metal is connected at cathode. As we supply electricity, copper is deposited over the surface of zinc or another metal imparting copper red colour. For copper plating, an aqueous solution of copper sulphate ($CuSO_4$) is used.

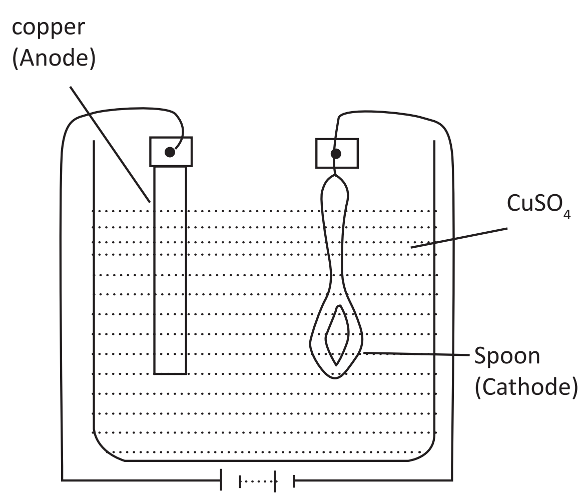


Fig.10.7: Copper plating

Mechanism of copper plating

In an aqueous solution, copper sulphate ($CuSO_4$) undergoes ionization into opposite ions (i.e. copper ion and sulphate ion). Copper being electropositive in nature, it moves towards the cathode and sulphate being electronegative in nature moves towards the anode. At cathode copper ion gains two electrons and becomes neutral. This neutral atom of copper is deposited over the surface of zinc or iron or any other metal imparting copper red colour. At the same time, sulphate ions encircle the anode making negatively charged layer. Now, copper atoms release from anode in form of ions and combine with sulphate ions to continue the concentration of the electrolyte.

In an aqueous solution;

$CuSO_4 \longrightarrow Cu^{++} + SO_4^{--}$

At cathode;

$Cu^{++} + 2e^- \longrightarrow Cu$ (undergoes deposition)

At anode;

$Cu \longrightarrow Cu^{++} + 2e^-$

$Cu^{++} + SO_4^{--} \longrightarrow CuSO_4$

Silver plating

The electro plating process in which silver is deposited over the surface of copper or any other metal by using electricity is called silver plating. In order to do silver plating, silver is connected at anode and copper or any other metal is connected at cathode. As we supply electricity, silver is deposited over the surface of copper or another metal imparting silver white colour. For the silver plating process, an aqueous solution of silver nitrate ($AgNO_3$) is used.

Mechanism of silverplating

In an aqueous solution, silver nitrate ($AgNO_3$) undergoes ionization into opposite ions (i.e. silver ion and nitrate ion). Silver being electropositive in nature, it moves towards the cathode and nitrate being electronegative in nature moves towards the anode. At cathode, silver ion gains one electron and becomes neutral. This neutral atom of silver is

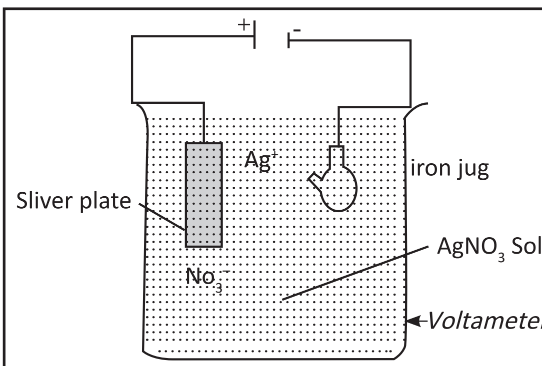


Fig 10.8: Silver Plating

deposited over the surface of copper or any other metal imparting silver white colour. At the same time, nitrate ions surround the anode making negatively charged layer. Now, silver atoms release from anode in the form of ions and combine with nitrate ions to continue the concentration of the electrolyte.

In an aqueous solution;

$$AgNO_3 \rightleftharpoons Ag^+ + NO^-_3$$

At cathode;

$$Ag^+ + e^- \longrightarrow Ag \text{ (undergoes deposition)}$$

At anode;

$$Ag \longrightarrow Ag^+ + e^-$$

$$Ag^+ + NO^-_3 \longrightarrow AgNO_3$$

Application of electroplating

i. Electroplating makes the parts and products coloured, lustrous and attractive.

ii. It makes the surface of the parts harder and more durable.

iii. The products obtained after electroplating have more corrosion resistant properties.

iv. Electroplating makes the protective outer layer. It is shiny and rust-resistant.

v. This process increases the lifespan of metal parts and products.

Electro refining

While taking out metals from the mine, they are completely impure. These metals are purified by using several methods. The overall purification method is called metallurgy. In metallurgy, we try to separate metals by applying several metallurgical processes; even though, it contains little amount of impurities. Finally, to get almost pure metals we use an electro refining process. In this method, impure metal is purified by the application of electricity. Thus, the process in which impure metal is purified by using electricity is called electro refining.

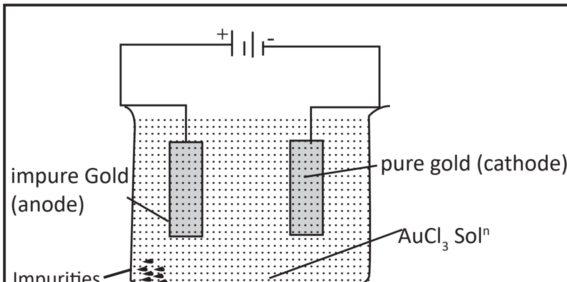


Fig 10.9: Electro refining

In order to refine the impure metal, it is connected at anode and a small piece of the same metal is connected at cathode. To continue the electro refining process we use an aqueous salt solution of the same metal. As we supply electricity, anodic metal slowly dissolves separating metal and impurities. Now, pure metal is deposited at cathode and impurities sediment at the bottom of the voltameter.

Copper refining

The electro refining process in which impure copper is purified by the application of electricity is called copper refining. During copper refining, it is connected at anode and a small piece of pure copper is connected at cathode. For the copper refining process we use an aqueous solution of copper sulphate ($CuSO_4$). As we supply electricity, impure copper slowly dissolves separating pure copper and impurities. Now, pure copper is deposited at cathode and impurities sediment at the bottom of the voltameter.

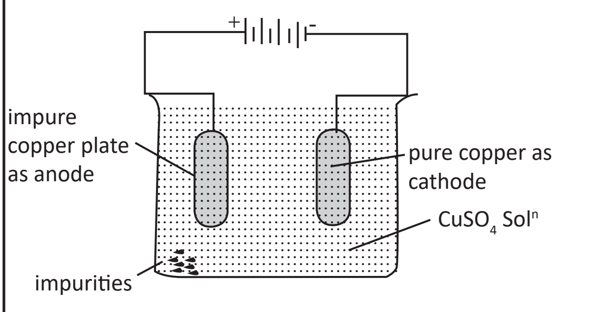


Fig 10.10: Copper refining

Silver refining

The electro refining process in which impure silver is purified by the application of electricity is called silver refining. During silver refining, impure silver is connected at anode and a small piece of pure silver is connected at cathode. To facilitate silver refining process we use an aqueous solution of silver nitrate ($AgNO_3$). When we supply electricity, impure silver slowly dissolves separating pure silver and impurities. As a result of this, pure silver is deposited at cathode and impurities sediment at the bottom of the voltameter.

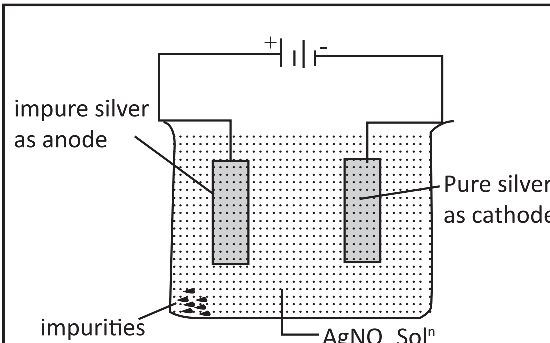


Fig 10.11: Silver refining

Application of electro refining

i. Electro refining is used to purify metals during their extraction.

ii. It is used to separate mixed metals.

Electrotyping

Electrotyping is a chemical method. It is an application of electrolysis and electroplating. It is used for making printing blocks and metallic models having irregular shape. This method was invented by Moritz von Jacobi in Russia in 1838 AD. Electrotyping produces an exact copy of an object having an irregular surface. This method is used for producing plates for letterpress printing . It is also used to make sculptures, models, etc.

Method of electrotyping

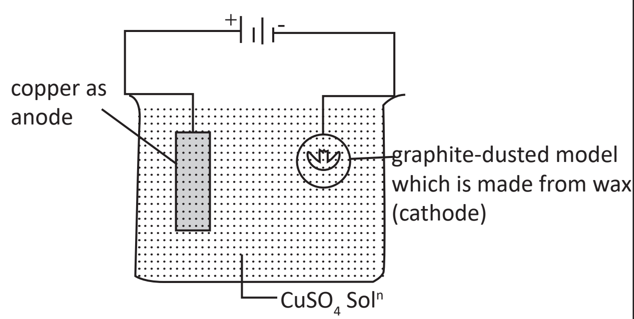


Fig 10.12: Electrotyping

First of all the required designs or impressions are made from the wax. Wax is an insulator of electricity, so it is dusted with graphite powder to make its surface good conductor of electricity. Now, this design is set up for the process of electroplating. The model is connected to the cathode and the metal whose model is going to be made (suppose copper) is connected to the anode. For the electroplating process we use salt solution of the anodic metal (suppose copper sulphate). After the deposition of the required thickness of the anodic metal, the electroplating process is stopped and the model is separated out from the wax.

Application of electrotyping

i. Electrotyping is used to make statues of god, goddess, leaders, writers, scientists, etc.

ii. It is used to make metallic letters like name plates, school's name, name of hospitals, etc.

Summary

1. The branch of chemistry in which we study about the movement and effects of ions is called electrochemistry.
2. Those chemical compounds which undergo ionization into opposite ions and conduct electricity are called electrolytic conductors or electrolytes.
3. Those chemical compounds which undergo almost complete ionization to give more number of opposite ions are called strong electrolytes.
4. Those chemical compounds which undergo very less ionization to give opposite ions are called weak electrolytes.
5. Those chemical substances which conduct electric energy from one place to another place are called conductors.
6. Those chemical substances which do not conduct electric energy from one place to another place are called insulators.
7. Atoms or group of atoms which have either positive or negative charge on them are called ions.
8. Ionization is a process in which compounds break down into opposite ions.
9. If the process of ionization is carried out in presence of electricity, it is called electrolysis.
10. The process in which water molecules are broken down into hydrogen and hydroxyl ions by supplying electricity is called electrolysis of water.
11. Coating of one metal over the surface of another metal by the application of electricity is called electroplating.
12. The process in which impure metal is purified by using electricity is called electro refining.
13. Electrotyping is a process in which letter blocks and required metallic models are made by using electrolysis and electroplating.

Exercise

A. Tick (✓) the best alternative from the followings.

1. Which of the following conducts electricity?

   i. Sodium chloride ii. Fat iii. Sugar iv. Protein

2. Which of the following is a strong electrolyte?

   i. Sulphuric acid ii. Phosphoric acid

   iii. Carbonic acid iv. Acetic acid

3. In copper plating, what should be taken at anode?

   i. Iron ii. Copper iii. Silver iv. Zinc

4. Which electrolyte is used in silver plating?

   i. $CuSO_4$ ii. $AgNO_3$ iii. NaCl iv. $AuCl_3$

5. The theory of ionization was given by

   i. Rutherford ii. Arrhenius

   iii. Neils Bohr iv. Robert Hook

B. Give short answers to the following questions.

1. Define electrolytes with any two examples.
2. What are non-electrolytes? Write down any two examples.
3. What are strong and weak electrolytes? Write down one example of each.
4. Write in very short about the electrolytic conductors.
5. Define conductors and insulators with one example of each.
6. Define ionization with an example.
7. What are cations and anions? Write down with the help of examples.
8. Define electroplating and electro refining.
9. What is electrotyping? Where is it used?

C. Give long answers to the following questions.

1. What is meant by electrolysis? Describe electrolysis of water with diagram.
2. Define copper plating and describe its mechanism with the help of diagram.
3. Describe copper refining with the help of diagram.

4. Explain the Arrhenius theory of ionization.
5. Write down the conditions required for electroplating in points.
6. Write two differences between:

   a) Cations and anions　　b) Electrolytes and non-electrolytes

   c) Conductors and insulators　　d) Weak and strong electrolytes

6. Give reason:

   a) Few drops ofsulphuric acid are added during the electrolysis of water.

   b) Graphite rods are preferred more than metallic rods during electrolysis of water.

   c) Volume of hydrogen is double than the volume of oxygen during the electrolysis of water.

Project work

1. Make a list of five solid substances which are conductor of electricity and five solid substances which are insulator of electricity. Why are they conductors and insulators? Explain in the classroom.
2. Make a list of five chemical compounds which conduct electricity in their solution state and five chemical compounds which do not conduct electricity in solution state. Why do some chemical compounds conduct electricity in the solution state? Explain the reason in the classroom.
3. Take two copper plates, electric wire, beaker, bulb, sodium chloride solution and sugar solution. Arrange them to make like a circuit of a simple cell and observe. Why does the bulb glow in sodium chloride solution and does not in sugar solution? Explain your result in the classroom.

Glossary

Electrolytes : the chemical compound which undergoes ionization into opposite ions

Cathode : the electrode which attracts cations

Anode : the electrode which attracts anions

Cation : atom or group of atoms with positive charge

Anion : atom or group of atoms with negative charge

Nascent : newly born or atomic form of an element

Unit 11 Organic Chemistry

Friedrich Wöhler (1800-1182)

Friedrich Wöhler, born in 31 July 1800 AD and died in 23 September 1882 AD. He was a German chemist. He is best known for his synthesis of urea. He was the first chemist who discarded the vital force theory in organic chemistry.

Learning outcomes

After the completion of this unit, learners will be able to

1. Differentiate organic and inorganic compounds.
2. Classify the organic compounds.
3. Write the IUPAC name of the organic compounds.
4. Explain the tetra valency of carbon with causes.
5. Introduce catenation, functional group, homologous groups and isomerism with examples.
6. Explain the structure and uses of some hydrocarbons like alkanes, alkenes and alkynes.
7. Explain the general method of preparation and uses of some organic compounds like alcohols and carboxylic acids.

Introduction

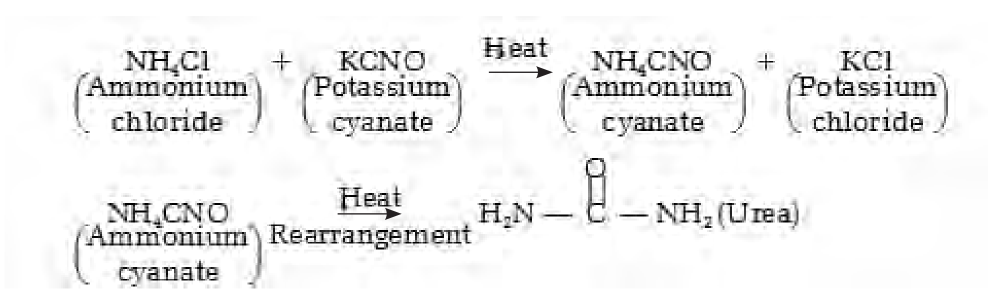
Carbon is a most important and widely distributed useful element. It is an example of non-metallic element. The name carbon has been derived from the Latin word "Carbo". The meaning of carbo is black shoot or charcoal or black rock that can burn. Various carbon containing compounds are found in the bodies of animals and plants. The different kinds of compounds like hydrocarbons, alcohols, protein, vitamin, glucose, soap, detergents, plastics, fibres, drugs, dyes etc. contain carbon. Therefore, these compounds are called organic compounds. To study the structure, composition, preparation and properties of the organic compounds there is a separate branch in chemistry called **organic chemistry.** In this unit we will discuss about the organic and inorganic compounds, naming of some organic compounds, preparation and properties of hydrocarbons, alcohol and carboxylic acids.

Organic and inorganic compounds

Different types of chemical compounds are found in the nature. Formerly, these naturally occurring chemical compounds were divided into three groups; they were compounds obtained from animals, compounds obtained from plants and compounds obtained from minerals. This type of classification of natural compounds was modified in eighteenth century. Now, on the basis of present and absent of carbon, all these natural compounds are divided into two major groups. They are organic compounds and inorganic compounds. The compounds like hydrocarbons, alcohol, carboxylic acid, fat, protein, vitamin, carbohydrates, oil, dyes, petroleum, natural gases, etc. which are obtained directly or indirectly from the living organisms (animals and plants) are called organic compounds. All these organic compounds contain carbon as one of the elements. Thus, **the chemical compounds which are obtained from living organisms and contain carbon as one of the elements are called organic compounds.**

Previously, it was believed that organic compounds cannot be prepared in the laboratory and industry. But it was believed that organic compounds are only isolated from animals and plants. This is called vital force theory. On the basis of this theory, it is said that organic compounds are produced only under the influence of mysterious force.

In 1828 AD., Fried rich Wohler a German chemist had synthesized an organic compound urea in the laboratory by heating an inorganic compound ammonium cyanate. He prepared ammonium cyanate by heating aqueous solution of ammonium chloride and potassium cyanate.



(Inorganic compound) *(Organic compound)*

The synthesis of urea demised the vital force theory and clearly established that no mysterious force is required to synthesize organic compounds in the laboratory and industry. From this time, a separate branch of chemistry is established to study the structure, composition, preparation and properties of the carbon containing compounds called organic chemistry.

The branch of chemistry in which we study about carbon and carbon containing compounds is called organic chemistry or carbonic chemistry.

In organic chemistry we study about various biomolecules like DNA, RNA, amino acids, enzymes, vitamins, fat, protein, carbohydrates, etc. as well as many synthetic compounds like plastics, rubber, soap, dyes, paints, perfume, medicine, synthetic fabric,etc.

In the nature, there are so many compounds which do not contain carbon atom in their molecular structure. These compounds are called inorganic compounds. The separate branch of chemistry in which we study about all other elements except carbon and their compounds is called **inorganic chemistry.**

The branch of chemistry which deals about all other elements except carbon and their compounds is called inorganic chemistry.

Calcium carbonate, calcium bicarbonate, potassium chloride, sodium chloride, copper sulphate, ferric chloride, silver nitrate, gold chloride, calcium sulphate, etc. are some examples of inorganic compounds.

Differences between organic and inorganic compounds

S. N.	Organic compounds	S.N.	Inorganic compounds
1.	Organic compounds contain carbon atom in their molecular structure.	1.	Inorganic compounds do not contain carbon atom in their molecular structure.
2.	They are formed as a result of covalent bonding.	2.	They are formed as a result of electrovalent bonding.
3.	These compounds have a low melting and boiling point.	3.	These compounds have a high melting and boiling point.
4.	They are soluble in organic solvents but insoluble in inorganic solvent.	4.	They are soluble in inorganic solvent but insoluble in organic solvent.
5.	They are generally combustible.	5.	They are generally non-combustible.
6.	They do not give ions in water.	6.	They give opposite ions in water.

Bonding Nature of Carbon

Symbol of carbon – C
Atomic mass - 12
Atomic number - 6
Electronic configuration – 2, 4
Valency – 4
Bonding nature – covalent bonding

From the above data, it is clear that carbon has only two shells in its atomic structure. In the first shell there are 2 electrons and in the second shell or in valence shell there are four electrons. Due to presence of these four electrons, there are three different ways to complete its octet.

a) **By gaining electrons:** According to octet rule, carbon needs four electrons to complete octet. But, carbon cannot gain four electrons to make C^{-4} ion. This is because carbon has six protons in its nucleus. These six protons cannot hold ten electrons easily and there will be a strong inter electronic repulsion.

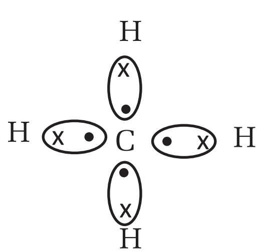
b) **By losing electrons:** To reach duplet condition similar to the electronic configuration of Helium, carbon needs to lose four electrons to make C^{+4} ion. But it is very difficult to lose four electrons of carbon from its outermost shell. This is because there is strong nuclear force of attraction in between protons and valence electrons.

c) **By sharing electrons:** Carbon can share four electrons easily with other atoms of carbon or other elements to acquire stable octet electronic configuration. Therefore the valency of carbon is four which is also called tetra valency.

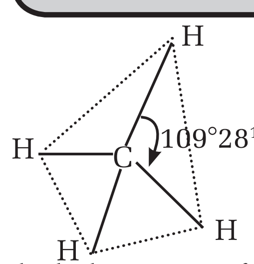
The tetra valency of carbon can be illustrated by explaining the structure of methane. In methane, four electrons of carbon share with four different hydrogen atoms showing the actual tetrahedral structure. The bond angle in this tetrahedral structure is 109°28'.

Do you know?

The chemical bond which is formed by sharing of electrons between or among the atoms is called covalent bond.



(Sharing of carbon with hydrogen)



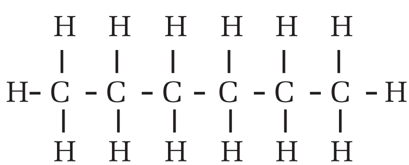
(Tetrahedral structure of Methane)

Catenation property of carbon

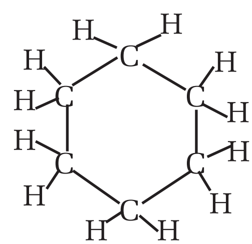
Catenation is the linkage of atoms of the same element into longer chain or a close ring. Some elements like sulphur, silicon, phosphorus, etc. show very less degree of catenation. But, carbon shows high degree of catenation.

In our daily life we can see various carbon containing compounds. For example, hydrocarbons, alcohol, carboxylic acid, carbohydrates, protein, vitamins, etc. In these compounds many carbon atoms are linked together by strong covalent bonding. Thus, t**he property of carbon by which it makes a long chain or a closed ring of organic compounds is called catenation property of carbon.**

Carbon atom has a very small atomic size. Due to small atomic size, it has strong nuclear force of attraction. Therefore, it shows the property of catenation to a maximum extent. Due to catenation property of carbon, there are large numbers of carbon containing compounds in the nature. To study these carbon containing compounds, there is a separate branch of chemistry called organic chemistry.



Structure of hexane



cyclohexane

Functional Group

In nature there are different kinds of organic compounds with different numbers of carbon atoms. For example; hydrocarbons, alcohol, carboxylic acid, amine, aldehyde, ketone, etc. In these organic compounds there are some active atoms or group of atoms or multiple carbon-carbon bonds which determine the actual chemical behaviour of these compounds. These atoms or a group of atoms are called functional groups.

Atom or a group of atoms or carbon-carbon multiple bonds which determine the chemical behaviour of the organic compounds are called functional groups.

For example; in ethanol ($CH_3 - CH_2 - OH$), the hydroxyl group (-OH) is called functional group and hydrocarbon group ($CH_3 - CH_2 -$) is called alkyl group. The chemical properties of ethanol depend upon hydroxyl group (-OH) and physical properties like melting point, boiling point, etc. depend upon alkyl group. Some organic compounds with their functional groups are given in the table.

S.N.	Name of functional group	Symbol	Structure	Organic compounds
1.	Hydroxyl	−OH	−OH	alcohol
2.	Carboxylic acid	−COOH	O || −C−OH	Carboxylic acid
3.	Ether	−O−	−O−	ether
4.	Aldehyde (formyl)	−CHO	O || −C−H	aldehyde
5.	Keto	−CO−	O || −C−	ketone
6.	Amino	$-NH_2$	H | −N−H	amine
7.	Double bond	=C = C=	=C = C=	Alkene
8.	Triple bond	- C ≡C-	- C ≡C-	Alkyne

How are organic compounds formed?

In all organic compounds, hydrocarbon part and functional group combine together to give the final structure of the organic compounds. For example;

Alkyl group	Functional group	Organic compound
$-CH_3$	– OH	CH_3-OH (Methanol)
$-CH_3$	–COOH	CH_3-COOH (Acetic acid)
$-CH_3$	–CHO	CH_3-CHO (Methanal)

Homologous Series

In organic chemistry, within one group there may have many members. These members have the same general formula and the same functional group but these members differ only in the length of alkyl group. The series of these members is called homologous series. To explain homologous series, arrange some continuous members of the same organic compounds. After arranging, observe the series. What similarities and differences do you observe? Obviously, you will see the same general formula and successive members differing by CH_2 group. Now, the series of these organic compounds is called homologous series.

The series of organic compounds which has the same functional group and same general formula but two successive members differ by CH_2 group is called homologous series.

A homologous series of alcohol is given below:

$CH_3 - OH$	Methanol
$CH_3 - CH_2 - OH$	Ethanol
$CH_3 - CH_2 - CH_2 - OH$	Propanol

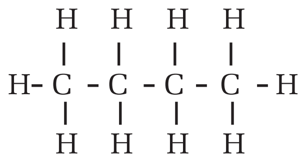
Characteristics of Homologous Series

1. In homologous series, all the members of the same series have the same functional groups. For example, alcohol-OH, acid-COOH, aldehyde-CHO, etc.
2. They have the same general formula. For example; alkene C_nH_{2n}.
3. Two successive members of a homologous series differ by CH_2 group.
4. They can be prepared with the same general methods.
5. They have the same chemical properties.
6. They have different physical properties like melting point, billing point, etc.

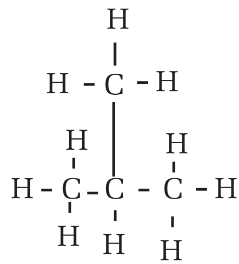
Isomerism

In organic chemistry there are several chemical compounds which have the same molecular formula but different structures. For example; butane is a member of saturated hydrocarbon. It has four carbon atoms. When we draw the molecular structure of butane, we get two possible structures. These two structures have the same molecular formula, but the arrangement of carbon atoms and hydrogen atoms is different. These structures are called isomers and the phenomenon is called isomerism.

Those organic compounds which have the same molecular formula but different in their structures are called isomers and the phenomenon of occurring different structures is called isomerism.



(n-Butane)



(iso-Butane)

Classification of the organic compounds

Previously, very less numbers of organic compounds were known. To study these compounds, there was not any problem then, but now, about five million organic compounds bave been identified. Therefore, it is very difficult to study these compounds individually. To facilitate the study of the organic compounds, they are classified into various groups and sub-groups. On the basis of structure, organic compounds are broadly divided into two groups. They are:

1. **Open chain or acyclic or aliphatic compounds:** These organic compounds have open chain of carbon atoms. There is no limit of the carbon atoms in the open chain but the chain may be straight or branched. There are basically three groups of aliphatic hydrocarbon compounds. They are:

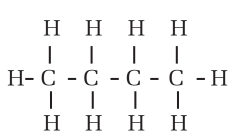
   a. Alkane: They are single bonded saturated hydrocarbons. For example; ethane, propane, butane, etc.

   b. Alkene: They are double bonded unsaturated hydrocarbons. For example; ethane, propene, butane, etc.

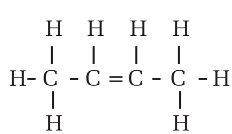
   c. Alkyne: They are triple bonded unsaturated hydrocarbons. For example; ethyne, propyne, butyne, etc.

2. **Closed chain or cyclic compounds:** These organic compounds have closed ring of carbon atoms. There may be only one ring or many rings joined together. There are two groups in cyclic compounds. They are:

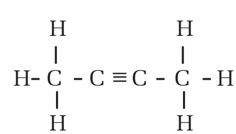
   a. Homocyclic compounds b. Heterocyclic compunds



butane

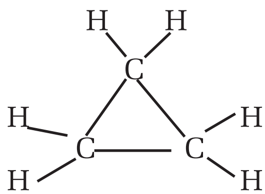


butene

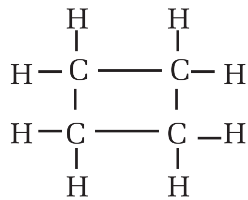


butyne

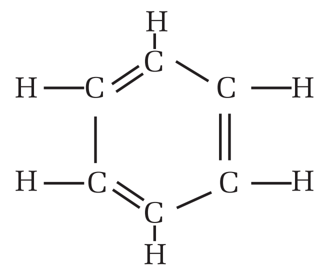
a. **Homocyclic compounds:** These cyclic compounds contain only carbon atoms in their ring. For example cyclopropane, cyclobutane, benzene, etc.



cyclopropane



cyclobutane

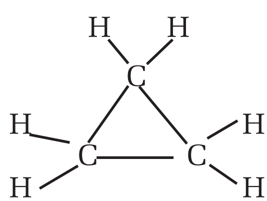


benzene

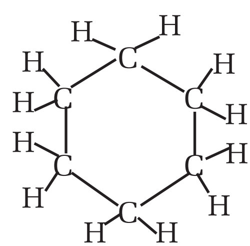
There are two groups in homocyclic compounds. They are:

i. Alicyclic compounds ii. Aromatic compounds

i. **Alicyclic compounds:** When cyclic compounds resemble the behaviour of open chain compounds, they are called alicyclic compounds. For example; cyclopropane, cyclohexane, etc.

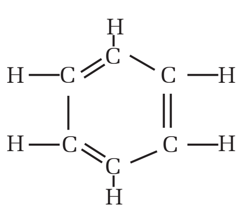


cyclopropane

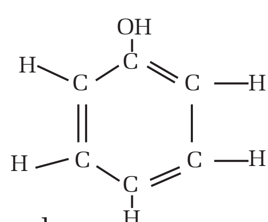


cyclohexane

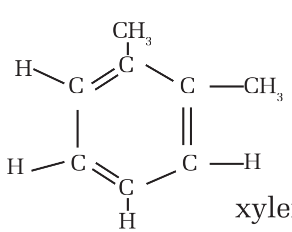
ii. **Aromatic compounds:** These organic compounds contain at least one benzene ring of six carbon atoms with alternate double and single covalent bond. These compounds also have pleasant smell. For example; benzene, phenol, xylene, napthalene, etc.



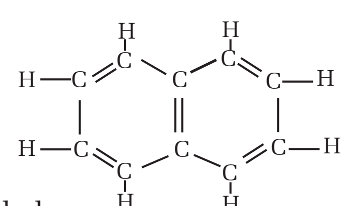
benzene



phenol

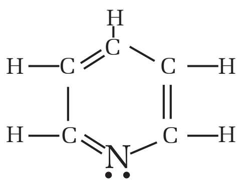


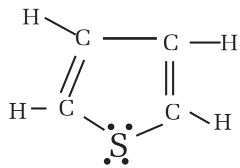
xylene

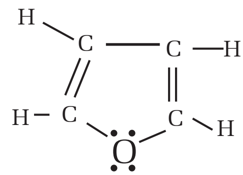


napthalene

b. **Heterocyclic compounds:** These cyclic compounds contain one or more heteroatoms (e.g nitrogen, oxygen and sulphur, etc.) in their ring. For example; pyridine, thiophene, furan, etc.


pyridine


thiophene


furan

IUPAC System of Nomenclature

It has already been mentioned that, more than five million organic compounds are known till date. There are different systems of nomenclature of these organic compounds. All these systems of nomenclature are difficult to understand and memorize. They also have some defects. To eliminate the defects and difficulties in nomenclature, an international system is introduced which is called IPUPAC (International Union of Pure and Applied Chemistry) system. To write the name of the organic compounds based on IUPAC system, the following points should be kept in mind.

1. **Word root:** The longest chain with functional group is called word root. Depending upon the number of carbon atoms in the longest chain the word root is assigned as:

Number of carbon atoms in the longest chain	**Word root**
C_1	Meth
C_2	Eth
C_3	Prop
C_4	But
C_5	Pent
C_6	Hex
C_7	Hept
C_8	Oct
C_9	Non
C_{10}	Dec

2. **Suffix:** Suffix is a word which is written along with the word root. For example; in pentanol, pent is a word root and anol is a suffix. The suffix words of the some functional groups are given in the table.

S.N.	Organic compounds	Functional groups	Suffix
1.	Alkane	C-C (single bond)	ane
2.	Alkene	C=C (double bond)	ene
3.	Alkyne	$C \equiv C$(triple bond)	yne
4.	Alcohol	-OH	anol
5.	Carboxylic acid	- COOH	anoic acid

1. IUPAC Name of alkane

S.N.	Examples of alkane	Word root	Suffix	IUPAC Name
1.	CH_4	Meth	ane	Methane
2.	$CH_3 - CH_3$	Eth	ane	Ethane
3.	$CH_3 - CH_2 - CH_3$	Prop	ane	Propane
4.	$CH_3 - CH_2 - CH_2 - CH_3$	But	ane	Butane
5.	$CH_3 - CH_2 - CH_2 - CH_2 - CH_3$	Pent	ane	Pentane
6.	$CH_3 - CH_2 - CH_2 - CH_2 - CH_2 - CH_3$	Hex	ane	Hexane
7.	$CH_3 - CH_2 - CH_2 - CH_2 - CH_2 - CH_2 - CH_3$	Hept	ane	Heptane

2. IUPAC Name of alkene

S.N.	Examples of alkene	Word root	Suffix	IUPAC Name
1.	$CH_2 = CH_2$	Eth	ene	Ethene
2.	$CH_3 - CH = CH_2$	Prop	ene	Propene
3.	$CH_3 - CH_2 - CH = CH_2$	But	ene	Butene
4.	$CH_3 - CH_2 - CH_2 - CH = CH_2$	Pent	ene	Pentene
5.	$CH_3 - CH_2 - CH_2 - CH_2 - CH = CH_2$	Hex	ene	Hexene
6.	$CH_3 - CH_2 - CH_2 - CH_2 - CH_2 - CH = CH_2$	Hept	ene	Heptene

3. IUPAC Name of alkyne

S.N.	Examples of alkyne	Word root	Suffix	IUPAC Name
1.	$CH \equiv CH$	Eth	yne	Ethyne
2.	$CH_3 - C \equiv CH$	Prop	yne	Propyne
3.	$CH_3 - CH_2 - C \equiv CH$	But	yne	Butyne
4.	$CH_3 - CH_2 - CH_2 - C \equiv CH$	Pent	yne	Pentyne
5.	$CH_3 - CH_2 - CH_2 - CH_2 - C \equiv CH$	Hex	yne	Hexyne
6.	$CH_3 - CH_2 - CH_2 - CH_2 - CH_2 - C \equiv CH$	Hept	yne	Heptyne

4. IUPAC Name of alcohol

S.N.	Examples of alcohol	Word root	Suffix	IUPAC Name
1.	$CH_3 - OH$	Meth	anol	Methanol
2.	$CH_3 - CH_2 - OH$	Eth	anol	Ethanol
3.	$CH_3 - CH_2 - CH_2 - OH$	Prop	anol	Propanol
4.	$CH_3 - CH_2 - CH_2 - CH_2 - OH$	But	anol	Butanol
5.	$CH_3 - CH_2 - CH_2 - CH_2 - CH_2 - OH$	Pent	anol	Pentanol

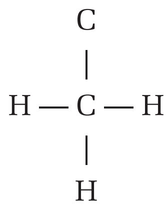
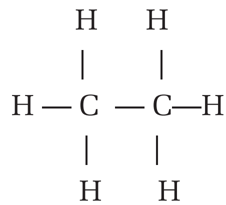
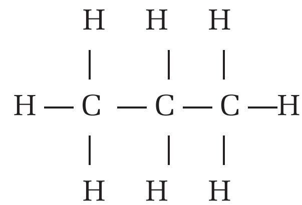
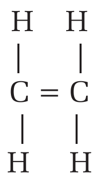
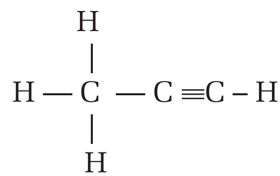
5. IUPAC Name of carboxylic acid

S.N.	Examples of a carboxylic acid	Word root	Suffix	IUPAC Name
1.	$H - COOH$	Meth	anoic acid	Methanoic acid
2.	$CH_3 - COOH$	Eth	anoic acid	Ethanoic acid
3.	$CH_3 - CH_2 - COOH$	Prop	anoic acid	Propanoic acid
4.	$CH_3 - CH_2 - CH_2 - COOH$	But	anoic acid	Butanoic acid
5.	$CH_3 - CH_2 - CH_2 - CH_2 - COOH$	Pent	anoic acid	Pentanoic acid

Note: In carboxylic acid, the carbon of the functional group is also counted in word root.

Hydrocarbons

There are various chemical compounds which are obtained from fossil fuels like coal, natural gas, petroleum, etc. Most of these compounds contain only carbon and hydrogen atoms in their molecular structure. These compounds are called hydrocarbons. Thus, **those organic compounds which contain only carbon and hydrogen are called hydrocarbons.** In hydrocarbons, the tetra valency of carbon is fulfilled by sharing electrons with hydrogen atoms or with other carbon atoms. Some examples of hydrocarbons with their molecular structure are given below.

 Methane (CH_4)	 Ethane (C_2H_6)	 Propane (C_3H_8)
 Ethene (C_2H_4) or, Ethylene	 Ethyne (C_2H_2) or, Acetylene	 Propyne (C_3H_4)

Classification of Hydrocarbons

On the basis of the number of covalent bonds between carbons atoms, hydrocarbons are classified into two groups. They are:

a) Saturated hydrocarbons b) Unsaturated hydrocarbons

a. Saturated Hydrocarbons

Saturated hydrocarbons are also called alkanes. They are the simplest organic compounds present in nature. They contain only carbon and hydrogen atoms. Therefore, in saturated hydrocarbons there are only two types of covalent bonds; they are carbon-hydrogen bond (C – H) and carbon-carbon single bond (C – C). Thus, **those hydrocarbons in which carbon atoms are bonded together by a single covalent bond only are called saturated hydrocarbons.**

Methane (CH_4), ethane (C_2H_6), propane (C_3H_8), etc. are some examples of saturated hydrocarbons. The general formula to represent saturated hydrocarbons is C_nH_{2n+2}, where n is the number of carbon atoms.

b. Unsaturated Hydrocarbons

Unsaturated hydrocarbons contain multiple covalent bonds (either double or triple) between two carbon atoms. Thus, **those hydrocarbons in which carbon atoms are bonded together by multiple (double or triple) covalent bonds are called unsaturated hydrocarbons.**

Ethylene (C_2H_4), acetylene (C_2H_2), propene (C_3H_6), propyne (C_3H_4), etc. are some examples of unsaturated hydrocarbons. Depending upon the number of carbon-carbon covalent bonds, unsaturated hydrocarbons are of two types. They are:

i) Alkene ii) Alkyne

i. Alkene

The unsaturated hydrocarbons in which carbon atoms are bonded together by double covalent bonds are called alkene. Ethene (C_2H_4), propene (C_3H_6), butene (C_4H_8), etc. are some examples of alkene. The general formula to represent alkene is C_nH_{2n} where n is the number of carbon atoms.

> Do you know?
>
> The general formula of alkene (i.e. C_nH_{2n}) is only applicable when there is only one double bond between carbon atoms.

ii. Alkyne

The unsaturated hydrocarbons in which carbon atoms are bonded together by triple covalent bonds are called alkyne. Ethyne (C_2H_2), propyne (C_3H_4), butyne (C_4H_6), etc. are some examples of alkyne. The general formula to represent alkyne is C_nH_{2n-2}, where n is the number of carbon atoms.

Differences between Saturated and Unsaturated Hydrocarbons

	Saturated hydrocarbons		Unsaturated hydrocarbons
i.	In Saturated hydrocarbons, carbon atoms are bonded with single covalent bond.	i.	In unsaturated hydrocarbons, carbon atoms are bonded with multiple bonds.
ii.	Saturated hydrocarbon has only one group which is alkane. Examples; methane ethane, propane, etc.	ii.	Unsaturated hydrocarbons have two groups, which are alkene and alkyne Examples; ethene, ethyne, propene, propyne, etc.

Differences between Alkene Alkyne

Alkene		Alkyne	
i.	In alkene, carbon atoms are bonded with double covalent bonds.	i.	In alkyne, carbon atoms are bonded with triple covalent bonds.
i.	The general formula of alkene is $C_nH_{2n.}$ Examples; ethene, propene, etc.	ii.	The general formula of alkyne is $C_nH_{2n-2.}$ Examples; ethyne, propynetc, etc.

Some examples of alkane with their uses

Methane (CH_4)

The first member of alkane is methane. It is the simplest saturated hydrocarbon. At room temperature, it occurs in a gaseous state. It is called marshy gas as it is obtained from the swamps or marshy places. It is also present in coal mines, gobar gas and biogas.

$$\begin{array}{ccccc} & & H & & \\ & & | & & \\ H & — & C & — & H \\ & & | & & \\ & & H & & \end{array}$$

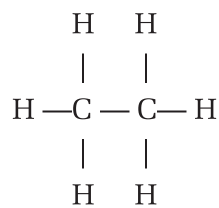
Structural formula of methane.

Uses of methane

1. It is used in the form of LPG for domestic use.
2. It is an important gaseous fuel as it produces a large amount of heat on burning.
3. It is used for manufacturing carbon black, printing ink, water gas, hydrogen gas, etc.
4. Different types of industrial chemicals like methyl chloride (CH_3Cl), chloroform ($CHCl_3$), methanol (CH_3OH), carbon tetrachloride (CCl_4), etc. are manufactured from methane.

Ethane (C_2H_6)

The molecular formula of ethane is C_2H_6. It is a second member of the saturated hydrocarbon. It is slightly heavier than methane as it has more molecular weight than methane. It occurs along with methane in natural gas, petroleum, coal etc.



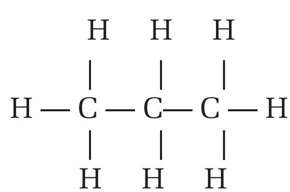
Structural formula of ethane

Uses of ethane

1. Ethane is an important gaseous fuel as it produces large amount of heat on burning along with methane.
2. It is used as a solvent and laboratory reagent.
3. It is used to produce other different types of chemical compounds.

Propane (C_3H_8)

The molecular formula of propane is C_3H_8. It is a third member of the saturated hydrocarbons. It occurs in natural gas, LPG, petroleum mine, etc.



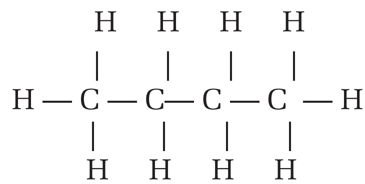
Structural formula of propane

Uses of propane

1. It is used as a fuel.
2. It is used as a cooling agent in the refrigerator.
3. It is used to make other different types of compounds.

Butane (C_4H_{10})

The molecular formula of butane is C_4H_{10}. It is the fourth member of the saturated hydrocarbons. It occurs in petroleum mines, natural gas, etc.



Structural formula of butane

Uses of butane

1. It is an important gaseous fuel.
2. It is used for manufacturing synthetic rubber, gaseous fuel and other compounds.

Alcohol

The organic compounds which contain hydroxyl group (–OH) in their molecular structure are called alcohol.

Methanol (CH_3OH), ethanol (C_2H_5OH), glycol $\{C_2H_4(OH)_2\}$, glycerol $\{C_3H_5(OH)_3\}$, etc. are some examples of alcohol. In all types of alcohols, we can see the functional group –OH. It remains attached with saturated hydrocarbon or hydrocarbon radical. Some alcohols have only one hydroxyl group (–OH) whereas some have more than one.

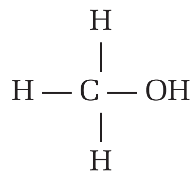
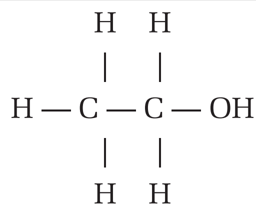
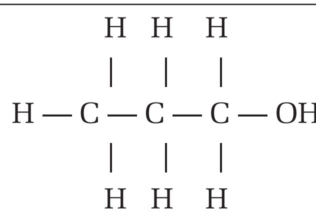
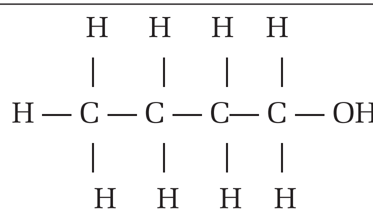
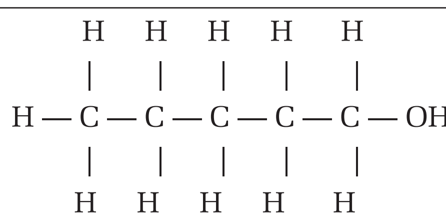
Classification of Alcohol

On the basis of number of hydroxyl groups present, there are three types of alcohol. They are:

a. Monohydric alcohol
b. Dihydric alcohol
c. Trihydric alcohol

a. Monohydric Alcohol

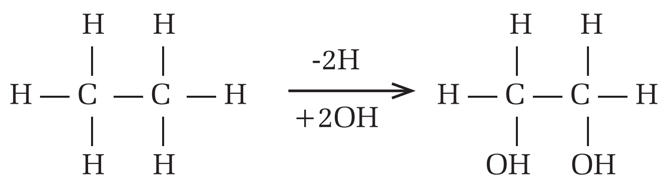
Methanol (CH_3OH), ethanol (C_2H_5OH), propanol (C_3H_7OH), etc. are some examples of monohydric alcohols. They are prepared by replacing one hydrogen atom of alkane by one hydroxyl group. Thus, **those alcohols which have only one hydroxyl group in their molecular structures are called monohydric alcohols**. First five members of monohydric alcohol with their molecular formula, structural formula and IUPAC names are given in the table.

SN	Molecular Formula	Structural Formula	IUPAC Name
1	$CH_3 - OH$		Methanol
2	$C_2H_5 - OH$		Ethanol
3	$C_3H_7 - OH$		Propanol
4	$C_4H_9 - OH$		Butanol
5	$C_5H_{11} - OH$		Pentanol

b. Dihydric Alcohol

Those alcohols which contain two hydroxyl groups (–OH) in their molecular structures are called dihydric alcohol.

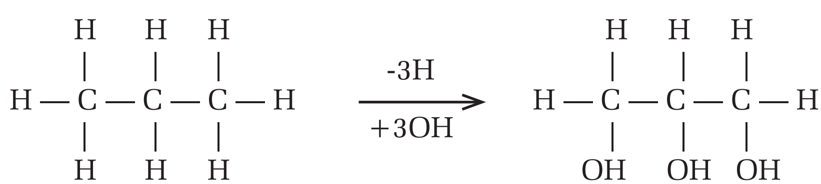
Dihydric alcohols are obtained by replacing two hydrogen atoms of alkane by two hydroxyl groups. For example; glycol.



Ethane   Ethylene glycol/Glycol

c. Trihydric Alcohol

Those alcohols which contain three hydroxyl groups (–OH) in their molecular structures are called trihydric alcohol. Trihydric alcohols are obtained by replacing three hydrogen atoms of alkane by three hydroxyl groups.

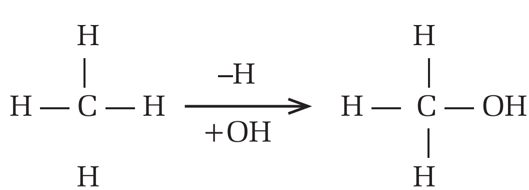


Trihydric alcohol or Glycerol

Some Important alcohols

Methyl alcohol or methanol (CH_3 – OH)

The molecular formula of methanol is CH_3OH. It is the first member of monohydric alcohol. It is obtained by replacing one hydrogen atom of methane by one hydroxyl group (–OH).



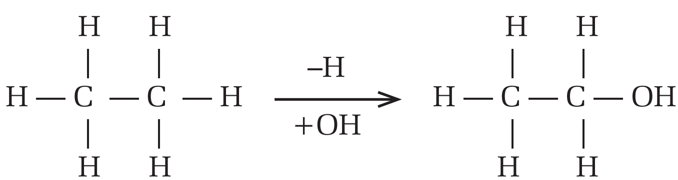
Methane   Methanol

Uses of methanol

1. It is an important source of fuel because it produces a large amount of heat without smoke.
2. It is an important organic solvent to dissolve fat, oil, paint, etc.
3. In the industry, it is used to manufacture dyes, paints, perfume, medicine, synthetic fabric, etc.
4. In the laboratory, it is used as a laboratory reagent to make different types of compounds like methyl chloride (CH_3Cl), formaldehyde (HCHO), etc.
5. It is used for dry cleaning.

Ethyl alcohol or ethanol ($C_2H_5 - OH$)

Ethanol has molecular formula $C_2H_5 - OH$. It is the second member of monohydric alcohol. It is obtained by replacing one hydrogen atom of ethane by one hydroxyl group (–OH).



Ethane Ethanol

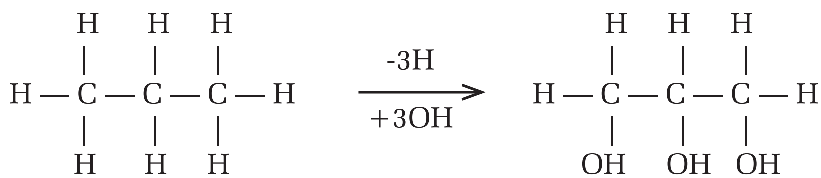
Use of ethanol

1. It is used for drinking purposes as an alcoholic beverage.
2. It is used as a thermometric liquid in an alcoholic thermometer.
3. It is used to dissolve fat, oil, paint, etc.
4. It is used in medicine.
5. It is used as a fuel in sprit lamps and stoves.
6. It is used as a biological preservative liquid to preserve specimens.

Glycerol or Trihydric Alcohol

Glycerol has three hydroxyl groups (–OH) in its molecular structure. It is the first member of trihydric alcohol. It is obtained by replacing three hydrogen atoms from different carbon atoms of propane with three hydroxyl groups (–OH). It is present in animal and plant fats. It is also prepared by the hydrolysis of fat or oil.

> Do you know?
>
> The word glycerol has been derived from glyceros, which means sweet. Glycerol is also known by glycerin.



Propane Glycerol

Uses of glycerol

1. It is used for manufacturing printing ink, stamp pad ink, soap, cosmetics, medicines, explosives, etc.
2. It is an important preservative and sweetening agent for food.
3. It is used as a lubricant.

Organic acids (Carboxylic acid)

Those organic compounds which contain carboxyl radical (–COOH) are called organic acids. It includes formic acid, acetic acid, lactic acid, and all fatty acids. Some organic acids, their structure and IUPAC name are given in the table.

SN	Molecular Formula	Structural Formula	IUPAC Name
1	HCOOH	$H — COOH$	Methanoic acid
2	$CH_3\,COOH$	$\begin{array}{ccccc} & & H & & \\ & & \vert & & \\ H & — & C & — & COOH \\ & & \vert & & \\ & & H & & \end{array}$	Ethanoic acid
3	$C_2H_5\,COOH$	$\begin{array}{ccccccc} & & H & & H & & \\ & & \vert & & \vert & & \\ H & — & C & — & C & — & COOH \\ & & \vert & & \vert & & \\ & & H & & H & & \end{array}$	Propanoic acid

Acetic acid

It is a second member of organic acid. Its molecular formula is $CH_3\,COOH$. It is a colourless liquid with smell. Although, it is a weak acid, concentrated acetic acid may affect skin. This acid is obtained by replacing one hydrogen of methane by one carboxylic radical.

$$\begin{array}{ccccc} & & H & & \\ & & | & & \\ H & — & C & — & H \\ & & | & & \\ & & H & & \end{array} \xrightarrow[+COOH]{-H} \begin{array}{ccccc} & & H & & \\ & & | & & \\ H & — & C & — & COOH \\ & & | & & \\ & & H & & \end{array}$$

Uses of acetic acid

1. It is used to make vinegar as it contains roughly 3 to 9 percentage of acetic acid.
2. It is used as a laboratory reagent to make other different chemical compounds.
3. It is used to make synthetic fibres and fabrics.
4. It is used to make cellulose acetate which is used to make photographic film.

Summary

1. The chemical compounds which are obtained from living organisms and contain carbon as one of the elements are called organic compounds.
2. The branch of chemistry in which we study about carbon and carbon containing compounds is called organic chemistry or carbonic chemistry.
3. The branch of chemistry which deals about all other elements except carbon and their compounds is called inorganic chemistry.
4. Catenation is the linkage of atoms of the same element into longer chain or a close ring.
5. The property of carbon by which it makes a long chain or a closed ring of organic compounds is called catenation property of carbon.
6. Atom or a group of atoms or carbon-carbon multiple bonds which determine the chemical behaviour of the organic compounds are called functional groups.
7. The series of organic compounds which has the same functional group and same general formula but two successive members differ by CH_2 group is called homologous series.
8. Those organic compounds which have the same molecular formula but different in their structures are called isomers and the phenomenon of occurring different structures is called isomerism.
9. Those organic compounds which contain only carbon and hydrogen are called hydrocarbons.
10. Those hydrocarbons in which carbon atoms are bonded together by a single covalent bond only are called saturated hydrocarbons.
11. Those hydrocarbons in which carbon atoms are bonded together by multiple (double or triple) covalent bonds are called unsaturated hydrocarbons.
12. The unsaturated hydrocarbons in which carbon atoms are bonded together by double covalent bonds are called alkene.
13. The unsaturated hydrocarbons in which carbon atoms are bonded together by triple covalent bonds are called alkyne.
14. The organic compounds which contain hydroxyl group (–OH) in their molecular structure are called alcohol.
15. Those organic compounds which contain carboxyl radical (–COOH) are called organic acids.

Exercise

A. Tick (✓) the best alternative from the followings.

1. The chemical compound which is obtained from living organisms and contain carbon atom is called

   i. Inorganic compound ii. Organic compound

   iii. Chemical compound iv. Industrial compound

2. Which element shows catenation property?

   i. Sodium ii. Carbon

   iii. Hydrogen iv. Chlorine

3. What is the IUPAC name of C_4H_{10}?

   i. Propane ii. Butane

   iii. Pentane iv. Hexane

4. What is the molecular formula of glycerol?

   i. $C_3H_5(OH)_3$ ii. $C_3H_6(OH)_3$

   iii. $C_4H_5(OH)_3$ iv. $C_3H_5(OH)_5$

5. Which one is a common drinking alcohol?

   i. Methanol ii. Ethanol

   iii. Propanol iv. Butanol

B. Give short answer to the following questions

1. Define organic and inorganic chemistry.
2. What are organic compounds? Write down any two examples.
3. What are inorganic compounds? Write down any two examples.
4. Define catenation. Write down any two elements which show catenation.
5. What are functional groups? Write down any three examples.
6. Define homologous series with the help of one example.

7. Define isomerism and isomers.
8. Show the isomers of butane.
9. What are hydrocarbons? Write down any three examples
10. Define alkane, alkene and alkyne with their general formula.
11. Write down the full form of IUPAC.

C. Give long answers to the following questions.

1. Write down the differences between organic and inorganic compounds.
2. How can you prove that carbon shows only tetra covalent bond?
3. Write the differences between saturated and unsaturated hydrocarbons.
4. Write the differences between alkene and alkyne.
5. Write down the IUPAC name of first five members of alkane, alkene and alkyne.
6. Write down the IUPAC name of first four members of alcohol.
7. What are carboxylic acids? Write down the IUPAC name of first three members of carboxylic acid.
8. Write down the structural formula and the uses of the following compounds.

i. Ehane	ii. Butane	iii. Methanol
iv. Ehtanol	v. Glycerol	vi. Acetic acid

Project work:

1. Take a lighted candle and put on a table. Adjust a card board just over the flame of the candle. After sometimes observe the card board. Which chemical substance is deposited on it? Discuss with your teachers.
2. Observe in your surrounding and at your home. Collect maximum possible chemical compounds and classify into organic and inorganic groups.
3. Collect coal (stone coal), charcoal (wooden coal) and pencil lead. Observe their hardness as they are forms of carbon. Present it inside the classroom.
4. Make a list of five chemical compounds which contain carbon. Why are they called organic compounds? Explain in the classroom.

Glossary

Vital force	:	a mysterious force
Urea	:	a chemical compound used as a fertilizer
Catenation	:	the property of linking together
Homologous series	:	the series of the organic compounds having same functional group
Functional group	:	group of atoms which determines the characteristics of the compound
Alcohol	:	the hydroxyl derivatives of alkane
Carbon	:	a black coloured substance

Unit 12

Metallurgy

Georgius Agricola was born in 24 March, 1494 and died in 21 November, 1555. He was a German Catholic, scholar and scientist. He is also known as "the father of mineralogy". He is best known for his book De Re Metallica (1556).

Georgius Agricola (1494-1555)

Learning outcomes

After the completion of this unit, learners will be able to

1. Introduce metallurgy and general steps of metallurgy.
2. Differentiate between minerals and ores.
3. Explain step wise general methods of metallurgical process.
4. Describe the extraction process of iron and copper separately.

Introduction

Till today, nearly 118 elements are known to us. To facilitate the study of these elements, we have divided these elements into different classes. Based on metallic properties, elements are classified into metals, non-metals and metalloids. Except silver, gold and platinum, almost all metals are found along with different impurities called minerals and ores. From these minerals and ores we separate pure metals applying several methods. After separating pure metals from their respective ores, they are used for different purposes. In this unit, we will discuss about mineral, ores and general steps of metallurgy in respect of iron and copper.

Metals, non-metals and metalloids

About 80% known elements are metals. They loose electrons to form positive ions and react with oxygen to form basic oxides. They are malleable, ductile and good conductor of heat and electricity. They are very useful for human beings. They are used in our everyday life.

There are 22 non-metals, including 6 inert gases. Non-metals gain electrons and form negative ions. They react with oxygen to form acidic or neutral oxides.

Hydrogen, oxygen, nitrogen, sulphur, chlorine, bromine, etc. are some common non-metals. Among 22 non-metals, 11 elements occur in the form of gases and 10 elements in the form of brittle solids. Bromine is the only non-metal which remains liquid at room temperature.

In the same way, there are certain elements which show properties of both metals and nonmetals. They are called metalloids. They are borderline elements between metals and non-metals. For example, Silicon (Si), Arsenic (As), Antimony (Sb), Germanium (Ge), etc.

Similar to the non-metals, metalloids show allotropy. They are poor conductor of heat and electricity. They are neither malleable nor ductile. They combine with hydrogen to form hydrides like $AsH_{3,}$ SbH_3etc.

Similar to the metals, arsenic possesses metallic luster and forms alloys. It also conducts electricity. Like copper, arsenic also forms arsenic sulphide (As_2S_3). Antimony resembles with arsenic in almost all respects.

Occurrence of Minerals and Metals

Generally, metals occur in the earth's crust in two different states. They are:

1. **Native state or Free State:** Some metals like silver, gold, platinum, etc. occur in native state or Free State in the earth's crust. These metals are not combined with other elements. This is because these metals do not react with air, water, moisture, oxygen, carbondioxide or other gases present in the atmosphere.

2. **Combined state:** Most of the metals react with air,water, moisture, oxygen, carbondioxide or other gases present in the atmosphere. As a result,they are converted into respective compounds. The compounds of the above metals may be oxides, phosphates, sulphides, etc. Thus, many metals exist in the earth's crust in their salts called **minerals**. For example, the minerals of copper are cuprite (Cu_2O), copper glance (Cu_2S), copper pyrite ($CuFeS_2$) and malachite [$CuCO_3.Cu(OH)_2$].

Minerals

It has already been discussed that, very few metals occur in the Free State in the nature. For example, silver, gold, platinum, etc. In general, most of the metals are found in combined state. The compounds of these metals are called minerals. Thus, **minerals are naturally occurring inorganic, solid and crystalline substances which have definite chemical composition.** For example, cuprite (Cu_2O), horn silver (AgCl), hydrated aluminium silicate (Al_2O_3. SiO_2 .$2H_2O$), feldspar, quartz, silica, etc.

There are many minerals which contain large amount of metals. Such minerals are used to extract metals. These minerals are specially called ores. Thus, **ores are those minerals which contain large amount of metals. These minerals are suitable to extract metals for commercial purposes.** For example, bauxite ($Al_2O_3.2H_2O$) is the most important and chief ore of Aluminium. Similarly, cryolite (Na_3AlF_6), Feldspar ($KAlSi_3O_8$) are other ores of Aluminium. This discussion shows that all ores are minerals but all minerals are not ore.

Differences between metals and minerals

Metals	Minerals
1. Metals are elements.	1. Mineral are compounds.
2. Metals have certain chemical properties.	2. Minerals have different set of chemical properties.
3. Metals are more reactive than minerals. For example: Li, Mg, K, Zn, Au, etc.	3. Minerals are less reactive than metals. For example: Cuprite (Cu_2O), horn silver ($AgCl$), hydrated aluminium silicate ($Al_2O_3.SiO_2.2H_2O$), feldspar, quartz, silica, etc.

Metallurgy

The science of extracting metals from their respective ores and utilizing them for useful purpose is called metallurgy. It is a complex and sequential process. The extraction of metals cannot be brought under one method because extraction process depends upon the nature and properties of metals. Different metals have different nature and properties. Thus, only one scheme cannot be applied for all metals. The following are the common and important steps in metallurgical process.

1. Crushing of the ore
2. Grinding or Pulverization of the crushed ore
3. Concentration or dressing of the ore
4. Extraction of metals
   a. Calcinations b. Roasting
   c. Reduction of metal oxide
   d. Extraction of metal from calcinated or roasted ore
5. Purification or refining of impure metal.

1. **Crushing of the ore**

Generally, the ores are found in big lumps. The big lumps of ores are broken down into smaller pieces with the help of hammers or mechanical crushers. Most commonly used crushers are stone breakers or jaw crushers. In these crushers, there are two plates. Out of these two plates, one moves and the other is stationary. The lumps of ores are crushed between these two plates. Thus, **the process, in which the lumps of ores are crushed into smaller pieces with the help of a crusher or a hammer, is called crushing of the ore.**

2. **Grinding or Pulverization of the crushed ore**

The crushed ore is taken into the pulverizing mill. In the pulverization mill, the ore is converted into fine powder. In the stamp mill, a heavy stamp is allowed to fall on a hard plate. In a ball mill, a steel cylinder is used. In this cylinder, 5-6 balls of steel or hard stone are kept. The mixture of coarsely crushed ore and water is fed into the cylinder and it is rotated. The balls rise and fall on the ore. As a result,pulverizing mill converts ore into cream like paste. It is called slurry.

3. **Concentration or dressing of the ore**

The natural ore is always associated with impurities like mud, rocky matter, sand, limestone, etc. The removal of such impurities from the powdered ore is called concentration or dressing of the ore. This is generally done by using suitable method like gravity separation, froth-flotation, electromagnetic separation, chemical separation, etc.

4. **Extraction of metals**

In this step, free metal is obtained by applying several steps. The common steps are calcination, roasting, reduction, etc. The brief discussions about these steps are given below.

a. **Calcinations of the ore**

Calcination is the process of conversion of metallic ores to their respective oxides. This method is applied if ore contains carbonates or hydrated oxides or hydroxide as an impurity. In this method, the ores are heated below their melting point, either in the absence of air or in a limited supply of air. It is usually done in a reverberatory furnace. During this process, the following chemical changes occur.

i. Moisture is removed

ii. Organic matter is destroyed

iii. Water is removed from hydrated and hydroxide ores

iv. Ores become porous

b. Roasting of the ore

Roasting is a process in which ore is heated below its melting point in excess of air. As a result, the ore is converted into metallic oxide. This method is commonly used for sulphide ores. For example, the extraction of lead from galena, zinc from zinc blende, mercury from cinnabar, etc. During this process the following chemical changes occur.

i. Moisture is removed.

ii. Volatile impurities like arsenic, antimony, etc. are removed.

iii. Organic matter is removed after burning.

iv. Impurities like carbonates, sulphides, etc. are decomposed into metallic oxides.

v. Some substances are easily oxidized. For example, ferrous compounds into ferric.

c. Reduction of metal oxides

In this step, free metal is obtained from the metal oxides. To get free metal different types of reducing agents like coke, hydrogen, carbon monoxide, etc. are used. If reduction process is carried out in presence of coke or silica or other reducing materials, it is called smelting. In smelting, the calcinated or the roasted ores are mixed with certain amount of carbon and heated at high temperature. Here, carbon reduces the metallic oxide of the ore into free metal.

5. Purification or refining of metals

The metals obtained by the above methods are not pure. The crude metals may be associated with the following impurities:

i. The metal obtained from the furnace may contain residual slag, flux etc.

ii. The metal obtained from above method may contain unreduced oxides and sulphides of the metals.

iii. The metal obtained from above method may contain non-metallic elements such as silicon, phosphorus, etc.

iv. There may be other metals which might have originally been present in the ore.

Therefore, purification or refining is the process where pure metal is obtained from the impure metals. The actual method applied for the purification of any metal depends upon its nature and the nature of impurities present in it. Some common methods are distillation, liquation, electro-refining, oxidation, etc.

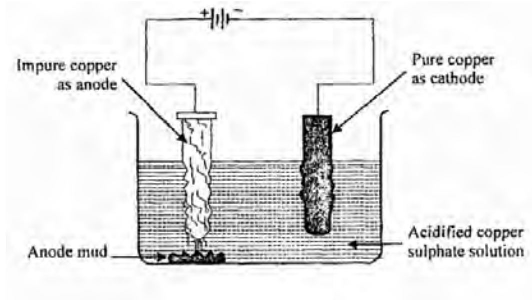


Fig. 12.1: Electro refining

Iron

Introduction

The word iron has its origin from Scandinavia and derived from Latin word 'Ferrum]. It is the second most abundant metal occurring in the earth's crust.

Symbol: Fe	Atomic No: 26

Valency: 2 and 3	Atomic mass: 55.84 (56) amu

Electronic configuration

Shell	K	L	M	N
Electrons	2	8	14	2

Sub-shell configuration: $1s^2$, $2s^2 2p^6$, $3s^2 3p^6 3d^6$, $4s^2$

Position of Iron in periodic Table

Fe is a transition element and known as'd' block element. It belongs to group VIII of the periodic table. It lies the first transition series in the fourth period.

Occurrence

Iron is one of the abundant metals.It is widely distributed in the earth's crust. It is easily attacked by humid atmosphere. Therefore, native or free iron does not occur. Generally, it is associated with other metals like copper, cobalt, nickel, etc. In the blood, it occurs as a part of haemoglobin and in the chlorophyll of plants. The chief ores of iron occur in its oxides and sulphides. In few cases, it occurs in carbonates. The main ores of iron are:

Haematite	Fe_2O_3 (Red oxide)

Magnetite	Fe_3O_4 (Black oxide)

Limonite	$Fe_2O_3 . 3H_2O$	(Red-Brown oxide)
Siderite (spathic ore)	$FeCO_3$	(Iron carbonate)
Iron pyrite	Fe_2S_3	(Iron trisulphide)

Extraction of iron

Haematite (Fe_2O_3) is the main ore of iron. It is used for the extraction of iron. So, the metallurgy of iron involves the following steps.

1. Mining or Digging

The mining is almost similar for all ores. First of all, the ore is dug from the earth by using giant mining machine. As a result, the ore is obtained in the form of mixture. The mined ore is then crushed and concentrated to remove the impurities from it.

Fig 12.2: Iron Ore Mining

2. Crushing or Pulverization of the Ore

The extracted ore along with the unwanted materials is crushed using jaw crusher and then pulverized to form fine powder.

3. Concentration of the Ore (Gravity separation)

The concentration of the ore is done by gravity separation. This method is suitable as the haematite ore is heavier than its impurities. In this process, the ore along with its impurities is agitated with strong blow of water inside a vessel. The agitation causes the heavy ores to settle down at the bottom while the lighter gangue impurities are carried away by the water current which escapes out from another outlet. Thus, the ore is concentrated.

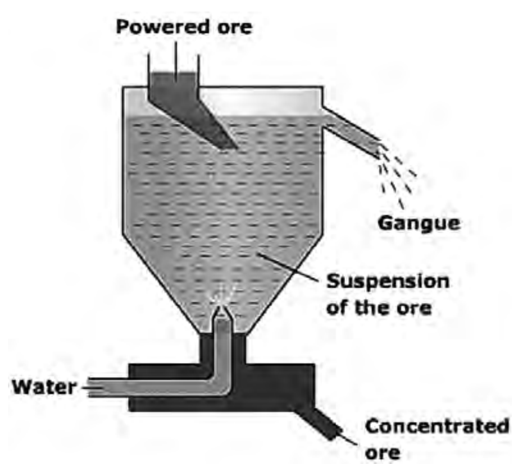


Fig. 12.3: Gravity Separation

4. Calcination

The concentrated ore is then heated strongly in a limited supply of air in a reverberatory furnace, below its melting point. This process is called calcination. The calcination removes the water content in the ore which was present during the concentration. In other words, calcination makes the ore dry. It also converts carbonates, sulphur, phosphorus, hydroxides, etc. into their oxides.

Fig. 12.4: Ore Calcination

5. Smelting

The calcinated ore is smelted in a blast furnace. In this smelting process, the ore, limestone and coke are mixed in the ratio 8:1:4 and is added into the furnace. Then, the blast of hot air is injected. The following changes occur in the blast furnace during the smelting of iron ore.

a. The carbon or coke combines with oxygen to form carbon dioxide and then carbon monoxide. This exothermic process increases the temperature of the blast furnace upto 1700^{0}C.

b. The carbon monoxide (CO) breaks the molten haematite (Fe_2O_3) into molten iron and carbon dioxide.

c. The limestone decomposes to form lime (calcium oxide) and carbon dioxide. The lime combines with the silica of ore to form calcium silicate. This molten form of calcium silicate is called slag.

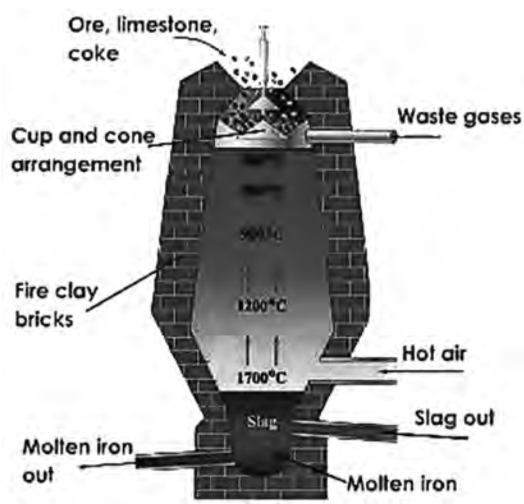


Fig. 12.5: Smelting in a blast furnace

d. The molten iron is heavier than the slag. Hence, the molten iron is collected the bottom of the furnace while the slag stays at its top. The iron is thus collected from the lower outlet. This molten iron is slightly impure and it is called as pig iron. The molten slag is collected from the upper outlet.

6. **Refining**

The molten pig iron which is obtained from the blast furnace contains the impurities like silicon, phosphorus, manganese and sulphur. To obtain pure iron, the pig iron is refined by a process called oxidation. This process is done in a Bessemer converter. In this process, the hot air agitates the molten iron. The impurities convert into their oxides and released out as they are volatile. The molten mass left behind is pure iron.

Physical properties of Iron

i. Pure iron is soft and white solid. But, the ordinary impure iron is grey and crystalline. The hardness of Iron is due to the presence of carbon in it.

ii. The specific gravity of Iron is 7.86.

iii. The melting point of iron is 1539°C and boiling point is 2450°C.

iv. It is malleable and ductile in nature.

v. It is good conductor of heat and electricity.

vi. It becomes strong magnet when placed in a magnetic field.

vii. It becomes non-magnetic substance when its temperature is more than 770°C.

Chemical properties of Iron

1. **Reaction with air**

When iron is strongly heated with excess air (oxygen), it forms ferroso-ferric oxide (Fe_3O_4).

$$3Fe + 2O_2 \longrightarrow Fe_3O_4$$

2. **Reaction with water**

At high temperature, when steam is passed over red hot iron it forms ferroso-ferric oxide (Fe_3O_4) and hydrogen gas(H_2).

$$3Fe + 4H_2O \xrightarrow{\Delta} Fe_3O_4 + 4H_2 \uparrow$$

3. **Rusting**

In the presence of moist air, Iron gets rusted and forms red or brown powder over its surface. It is called rusting. The chemical formula of rust is hydrated ferric oxide ($Fe_2O_3 . nH_2O$).

$$4Fe + 3O_2 + nH_2O \longrightarrow 2Fe_2O_3 . nH_2O$$

4. **Reaction with acids**

(a) ***Reaction with hydrochloric acid (HCl)***

Iron reacts with hydrochloric acid to give ferrous chloride and hydrogen gas.

$$Fe + 2HCl \longrightarrow FeCl_2 + H_2\uparrow$$

(b) ***Reaction with sulphuric acid (H_2SO_4)***

When iron reacts with dilute sulphuric acid, it gives ferrous sulphate and hydrogen gas.

$$Fe + \underset{\text{(dil.)}}{H_2SO_4} \longrightarrow FeSO_4 + H_2\uparrow$$

When iron reacts with hot concentrated sulphuric acid, it gives ferric sulphate, sulphur dioxide and water.

$$2Fe + \underset{\text{(conc.)}}{6H_2SO_4} \longrightarrow Fe_2(SO_4)_3 + 3SO_2\uparrow + 6H_2O$$

(c) ***Reaction with nitric acid (HNO_3)***

When iron reacts with dilute nitric acid, it gives ferrous nitrate, ammonium nitrate and water.

$$4Fe + \underset{\text{(dil.)}}{10HNO_3} \longrightarrow 4Fe(NO_3)_2 + NH_4NO_3 + 3H_2O$$

When iron reacts with concentrated nitric acid, it gives ferric nitrate, nitrogen dioxide and water.

$$Fe + \underset{\text{(conc.)}}{6HNO_3} \longrightarrow Fe(NO_3)_3 + 3NO_2\uparrow + 3H_2O$$

5. **Reaction with sulphur**

Iron gives ferrous sulphide when heated with sulphur.

$$Fe + S \xrightarrow{\Delta} FeS$$

6. **Reaction with chlorine**

Iron gives ferric chloride when reacts with chlorine.

$$2Fe + 3Cl_2 \xrightarrow{\Delta} 2\,FeCl_3$$

7. **Reaction with copper sulphate solution**

Iron displaces copper from copper sulphate solution.

$$Fe + CuSO_4 \longrightarrow FeSO_4 + Cu\downarrow$$

Uses of Iron

1. Iron is used for making rods, wires, buildings, bridges, means of transport, weapons, house-hold utensils, tools, etc.
2. In different types of chemical reactions, it is used as a catalyst.
3. It is used for manufacturing steel.
4. It is present in the haemoglobine of the blood and helps to combine with oxygen during respiration.

Copper

Introduction

The name copper has been derived from the German word 'Kupfer' but its symbol 'Cu' is derived from its Latin name 'Cuprum'.

The metals like copper, silver and gold are called coinage metals or currency metals because they are used for marking coins.

Symbol: Cu	Atomic No: 29
Valency: 1 and 2	Atomic wt: 63.57 (64) amu.

Electronic configuration:

Shell	K	L	M	N
No. of electrons	2	8	18	1

Sub –shell electronic configuration: $1s^2,2s^22p^6,3s^23p^63d^{10},4s^1$

Position in the periodic Table

Copper belongs to fourth period and IB group of the modern periodic table. It is called a d-block element because its last electron is present in 'd' orbital. It is a transition element and called a coinage metal.

Occurrence

Copper occurs in native state mainly in Canada, Mexico, Chile and Russia. Little amount of copper is found many in plants, in the blood of many animals and coloured feathers of certain birds like peacock. The chief ores of copper are:

Copper pyrite:	$CuFeS_2$(Chalcopyrite)
Cuprite:	Cu_2O (Ruby copper)
Copper glance:	Cu_2S (Chalcocite)
Malachite:	$CuCO_3.Cu\ (OH)_2$
Bornite:	Cu_3FeS_2

Extraction of Copper

The chief ore of copper is chalcopyrite ($CuFeS_2$). From chalcopyrite, we get copper by applying following steps.

1. **Mining or Digging of the Ore**

   First of all, the chalcopyrite ore is dug from the earth. After digging, the ore is obtained in the form of mixture. After that, the ore should be separated from the unwanted earthy materials, soil, rock, plastics and other foreign substances.

Fig. 12.6: Copper mining

2. **Crushing or Pulverization of the Ore**

   The extracted ore along with the unwanted materials is crushed using a jaw crusher and converted into tiny pebbles. These pebbles are passed into the stamp mill which converts ore into powdered form. The process of conversion of pebbles into powder is called pulverization. Pulverization makes the separation process easier.

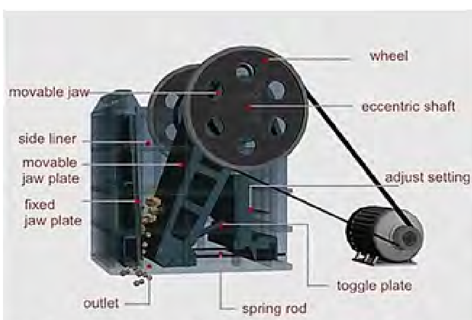


Fig. 12.7: Crushing by jaw crusher

Fig. 12.8: Crushing by jaw crusher

3. **Concentration of the Ore by Froth Floatation**

   The ore is concentrated by froth floatation process. It is the best method for the sulphide ores. **Froth floatation is the method of separating the sulphide ores from its impurities by agitating the mixture of sulphide ore, water and pine oil with a strong blow of**

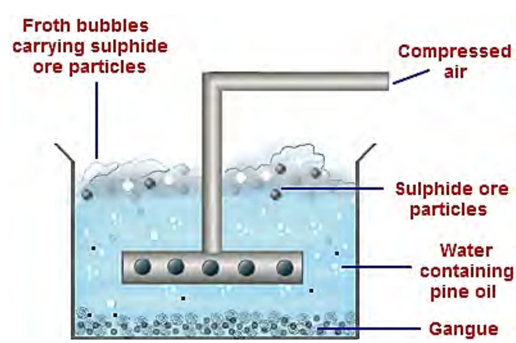


Fig. 12.9: Froth floatation process

air. The agitation causes the formation of froth (small bubbles). The pine oil is added to the mixture because it can wet the sulphide ore but not the impurities. The heavier impurities are actually wetted by water. The pine oil along with the froth and the ore precipitate at the top and the mixture of water and the heavier impurities settle down at the bottom of the vessel. Now, the ore is separated in the form of froth.

4. **Roasting**

The concentrated ore is heated in a reverberatory furnace with excess supply of air below its melting point. In this process, the sulphur, phosphorus and other impurities are converted into their respective oxides. At the same time, copper and iron are converted into copper sulphide (Cu_2S) and Iron sulphide (FeS). On further roasting, small amount of copper sulphide and iron sulphide are converted into copper oxide (CuO) and iron oxide (FeO) respectively.

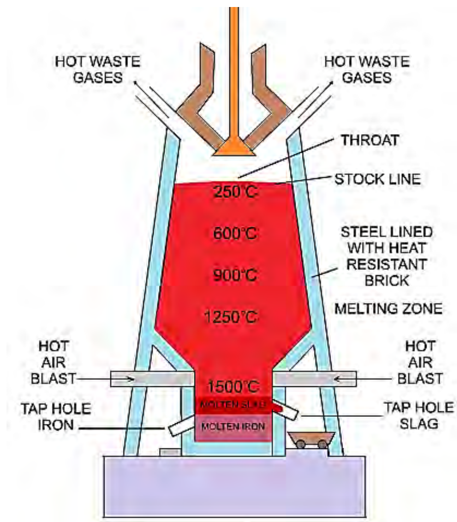


Fig. 12.9: Roasting

5. **Smelting**

The roasted ore is smelted in a blast furnace in presence of coke (carbon powder) and sand particles. During this process, Iron oxide combines with silica and forms ferrous silicate. This molten ferrous silicate is called slag and is removed. The remaining molten mixture of FeO and Cu_2O called matte is left over. The slag and matte are removed separately from the blast furnace.

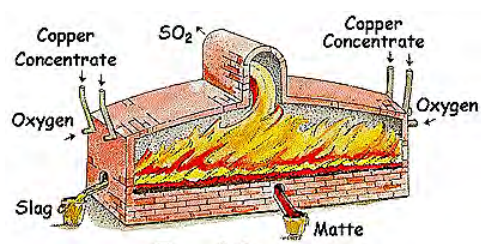


Fig. 12.10: Smelting

6. Bessemerization

Finally, the smelted ore is heated in a Bessemer converter with a blast of hot air and fine sand particles. This process is called Bessemerization. The remaining slag produced from this reaction is removed. Further, the oxides of copper react with the remaining sulphides of copper to produce fizzy copper. From this fizzy copper, impure gases like sulphur dioxide escapes out making blisters on the surface of copper. It is called blister copper. The blister copper is about 98% pure. This copper is further refined to 99.99% copper though electrorefining.

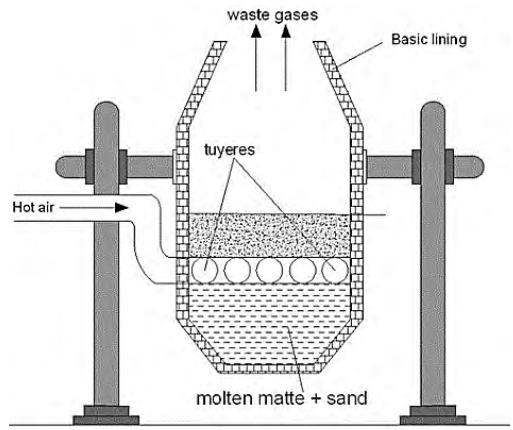


Fig. 12.11: Bessemer converter

7. Electro refining

At the end of copper extraction, the blister copper is further purified by electro refining process. In this process, the impure copper acts as an anode and a small pure copper act as a cathode. The cathode and anode are immersed in an electrolyte of copper sulphate ($CuSO_4$) in the voltameter. As the electricity is passed, the copper particles from the anode get deposited over the pure copper in the cathode. The unwanted impurities of the anode get deposited as residue at the bottom of the vessel.

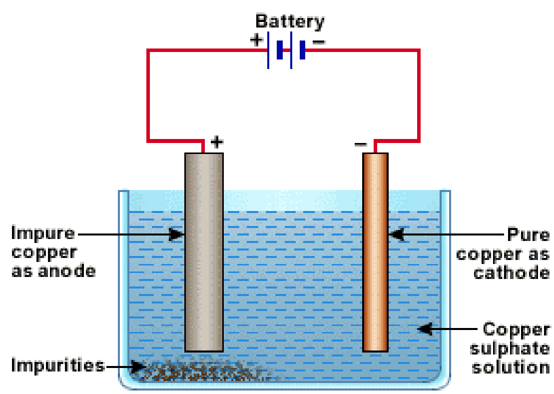


Fig. 12.12: Electro refining

Physical properties of Copper

i. Copper is a reddish brown metal with metallic luster.

ii. It is good conductor of heat and electricity.

iii. It is malleable and ductile in nature.

iv. It's specific gravity is 8.95.

v. It's melting point is 1083^{o}C and boiling point is 2350^{o}C

Chemical Properties of copper

1. **Reaction with air (Oxygen)**

As we heat copper in dry air, it gives black oxide of copper (cupric oxide) first and then red oxide of copper (cuprous oxide).

$$2Cu + O_2 \xrightarrow{\text{below } 1000^\circ C} 2CuO \text{ (black)(cupric oxide)}$$

$$4Cu + O_2 \xrightarrow{\text{above } 1000^\circ C} 2Cu_2O \text{ (red)(cuprous oxide)}$$

2. **Reaction with Acids**

a. Reaction with hydrochloric acid (HCl)

When copper reacts with hot dilute hydrochloric acid in the presence of air, it forms cupric chloride.

$$2Cu + \underset{\text{(dil.)}}{4HCl} + O_2 \longrightarrow 2CuCl_2 \text{ (cupric chloride)} + 2H_2O$$

When copper reacts with hot concentrated hydrochloric acid, it forms cuprous chloride and hydrogen gas.

$$2Cu + \underset{\text{(conc.)}}{2HCl} \longrightarrow 2CuCl \text{ (cuprous chloride)} + H_2\uparrow$$

b. Reaction with sulphuric acid (H_2SO_4)

In the presence of air, copper reacts with hot dilute sulphuric acid to give copper sulphate and water.

$$2Cu + \underset{\text{(dil.)}}{2H_2SO_4} + O_2 \longrightarrow 2CuSO_4 \text{(copper sulphate)} + 2H_2O$$

Copper reacts with hot and concentrated sulphuric acid to give copper sulphate ($CuSO_4$), sulphur dioxide (SO_2) and water (H_2O).

$$Cu + \underset{\text{(conc.)}}{2H_2SO_4} \longrightarrow CuSO_4 + SO_2\uparrow + 2H_2O$$

c. Reaction with nitric acid (HNO_3)

Copper reacts with hot dilute nitric acid to form cupric nitrate, nitric oxide and water.

$$3Cu + 8HNO_3 \longrightarrow Cu(NO_3)_2 \text{(cupric nitrate)} + 2NO + 4H_2O$$

Copper reacts with hot concentrated nitric acid to give copper nitrate

$\{Cu(NO_3)_2\}$, nitrogen dioxide (NO_2) and water (H_2O).

$$Cu + 4HNO_3 \longrightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$$

3. Reaction with halogens

Copper reacts with halogens (Cl_2, Br_2, I_2) to give their halides. For example,

$$Cu + Cl_2 \xrightarrow{\Delta} CuCl_2$$

$$Cu + Br_2 \xrightarrow{\Delta} CuBr_2$$

4. Reaction with sulphur

Copper gives cuprous sulphide (Cu_2S) when it is heated with sulphur.

$$2Cu + S \xrightarrow{\Delta} Cu_2S \text{ (Cuprous sulphide)}$$

5. Reaction with salt solution

Copper displaces silver from its salt solution.

$$Cu + 2Ag\,NO_3 \longrightarrow Cu\,(NO_3)_2 + 2Ag$$

Uses of Copper

1. Copper is used for making electric wires and other electrical appliances.
2. It is used for making coins, utensils, containers, etc.
3. It is used for making different kinds of alloys. For example, brass, bronze, etc.
4. Some copper salts are used as germicides and insecticides.

Summary

1. Metals are electropositive elements (except hydrogen).They are lustrous, malleable and ductile. They are good conductors of heat and electricity.
2. Non-metals are electronegative elements. They gain electrons.
3. Metalloids are border line elements showing some properties of metals and some properties of non-metals.
4. Metals occur either in combined state or in free state in nature.
5. The naturally occurring compounds of metals in the earth's crust are called minerals.
6. The minerals from which the metal can be extracted conveniently and eco

nomically are called ores.

7. The process of extraction of metals from their respective ores is called metal lurgy.

8. Crushing, pulverization, concentration, calcinations and roasting, extraction of metal from calcinated or roasted ore and purification or refining of impure metal are the main steps in metallurgical process.

9. Crushing is the process in which the lumps of ores are crushed into smaller pieces with the help of crusher.

10. Pulverizing means the crushed ore is taken to a pulverizing mill where it is ground to a fine powder.

11. The removal of impurities (gangue particles) from the powdered ore is called concentration or dressing of the ore. It is done by gravity separation, froth-flotation process or electromagnetic separation process.

12. Haematite (Fe_2O_3) is the main ore of iron. It is used for the extraction of iron.

13. Copper pyrite ($CuFeS_2$) is the main ore of cupper. It is used for the extraction of copper.

Exercise

A. Tick (✓) the best alternative from the followings.

1. Which is a metal?

i.	Chlorine	ii.	Arsenic
iii.	Copper	iv.	Oxygen

2. Which is a non-metal?

i.	Chlorine	ii.	Silver
iii.	Copper	iv.	Aluminium

3. Which is a metalloid?

i.	Bromine	ii.	Lithium
iii.	Copper	iv.	Germanium

4. What is the formula of haematite?

i.	Fe_2O_3	ii.	Fe_3O_4
iii.	FeO	iv.	Fe_3O_2

5. Which is the main ore of copper?

i.	Bauxite	ii.	chalcopyrite
iii.	Haematite	iv.	Siderite

B. **Give short answers to the following questions.**

1. Define metallurgy.
2. What is ore and mineral?
3. What is extraction of metal?
4. Write down any two ores of iron.
5. Write down any two ores of copper.
6. What is the main ore of iron?
7. Give the name of one non-metal which remains liquid state at room temperature.
8. For which process of metallurgical operation, reverberatory furnace is used?

C. Give **long answers to the following questions.**

1. Define metals, non- metals and metalloids with examples.
2. What do you mean by native or free state of metals? Explain.
3. What are the differences between metals and minerals?
4. All ores are minerals but all minerals are not ores, why?
5. What are the main steps involved in metallurgical processes?
6. What is calcinations and roasting? Describe in short.
7. Explain the rusting of iron with chemical equation.
8. Write down the balanced chemical equations.
   a. Iron is treated with dil. Sulphuric acid.
   b. Iron is heated with sulphur.
   c. Iron is treated with dil. and conc. Nitric acid.
   d. Iron reacts with copper sulphate solution.
   e. Copper reacts with chlorine.
   f. Copper reacts with conc. Hydrochloric acid.
   g. Copper reacts with dil. and conc. Nitric acid.
9. Write short notes on the followings:
   a. Coining metals   b. Slurry
   c. Smelting   d. Bessemerisation
   e. Electrolytic refining

11. Which metal is extracted from haematite ore? Explain the steps of metallurgy of iron.
12. Which metal is extracted from chacopyrite ore? Explain the steps of metallurgy of copper.

Project Work

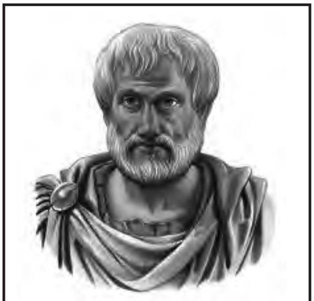
Take some iron pieces or iron nails. Keep some pieces of iron in dry glass and some in the glass with water. Observe them after two to three days. Describe the changes that have occurred in the iron nails.

Glossary

Alloy	:	material containing two or more metals or a metal with non-metals
Gangue	:	useless matter like sand and rocky particles which forms a part of mineral
Amalgam	:	alloy of metal with mercury
Malleable	:	that can be changed into sheet after hammering
Ductile	:	that can be changed into wire
Coinage metals	:	metals used to make coins
Slurry	:	creamy paste powder

Unit 13 Introduction to Biology

Aristotle set the basic standard or the modern scientific method: that all observations must include the composition, the shape or form, the motion or change and the end result of the examination and formed a base in the area of physics for different scientists like Galileo, Newton and Einstein.



Aristotle (384BC-322BC, Greece)

Learning outcomes

After the completion of this unit, learners will be able to

1. Define biology and describe different branches of biology.
2. Describe the importance of biology.
3. Describe the inter-relationship between biology and other sciences.

Introduction

The word Biology is derived from two Greek words: *bios* (life) and *logos* (study). Therefore, biology is the study of all living things found in earth. It is the science which deals with the study of structure, organization, life processes, interactions, origin and evaluation of living organisms. Aristotle is known as the Father of Biology and the term 'biology' was coined by Lamarck and Traveranus. In earth life exists in two forms: plants and animals. Thus, biology is mainly divided into two branches, Botany (study of plants) and Zoology (study of animals). These two branches are further divided into several branches which deal with the different aspects of plants and animal science.

In this chapter we will study about the branches and importance of biology and the relationship of biology to other sciences.

Branches of biology

The study of biology can be divided into several special branches or disciplines which are as follows:

Morphology:	It deals with the study of external features of organisms.
Anatomy:	It deals with the study of internal structures of organisms.
Physiology:	It deals with the study of life processes in animals and plants.
Cytology:	It deals with the study of structure and functions of cells and cell organelles.
Taxonomy:	It deals with the study of classification of organisms and its principle.
Ecology:	It deals with the study of relationship between living organism and environment.
Genetics:	It deals with the study of hereditary characters and their inheritance.
Histology:	It deals with the study of structure and functions of tissues.
Microbiology:	It deals with the structure and functions of microbes or micro-organism.
Biochemistry:	It deals with the study of chemistry of living beings.
Biotechnology:	It deals with the technique of using organisms to modify the organisms and their products for human benefit.
Genetic engineering:	It deals with the study for producing desirable genotype (genetic composition) by synthesis and combination of different genes.

Inter-relation of biology with other disciplines

Nowadays the term biology is also called as life science so as to cover its wide scope. The study of life science involves knowledge of other basic sciences, such as physics and chemistry. The physiology of plants and animals are related with the chemical reactions. The branch of life science which deals with both biology and chemistry is called ***Biochemistry***.

Relation of biology with chemistry

- All the living organisms have organic and inorganic compound which influence the life processes.
- Energy is transferred in the body in the form of organic chemical such as glucose.
- All the metabolic processes such as respiration, metabolism, photosynthesis, etc., involves chemical change.

- The genetic materials such as DNA and RNA are formed by the chemicals.
- The enzyme, hormones, digestive juice secreted etc., in animals are also chemicals.

Relation of biology with physics

It is concerned with the study of physical laws and principles that are used in the study of plants and animals.

- Some life processes like diffusion, movement of minerals, ascent of sap etc. depends upon the physical phenomenon.
- Many biological equipments like microscope, chromatography, X-ray etc., follow the physical application as their working principle.
- Definite pattern of responses in plants and animals induced by light is re lated to the principle of physics.

Besides, chemistry and physics it is also related to biometry and bioinformatics, which involves mathematical and statistical studies in co-relating the various life processes and also with the application of knowledge of information technology in analysing biological data, respectively.

Biology is also concerned with the scientific study of human mind through their behaviour and to solve the problems of people. And the branch of science that deals with the study of human behaviour is called **Psychology.**

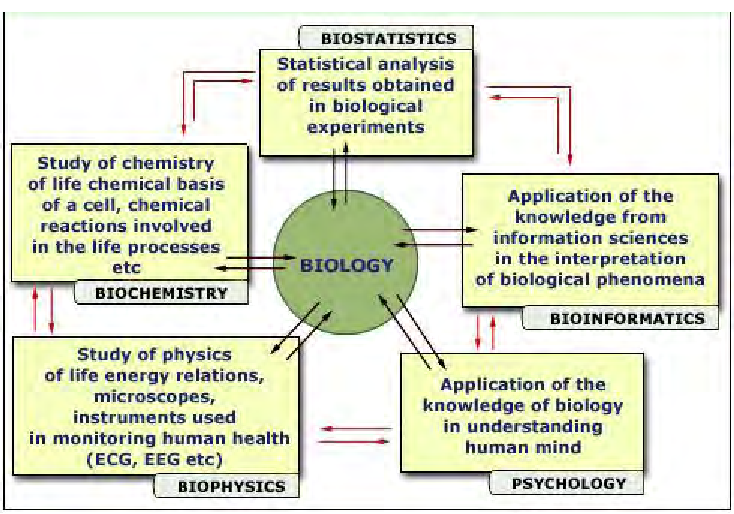


Fig 13.1: Relationship between biology and other branches of science

Scope of biology

The scopes of biology are as follows:

Anthropology: The science that deals with the origins, physical and cultural development, biological characteristics and social customs and beliefs of humankind.

Biomedical engineering: It is the branch of engineering that deals with the production of spare parts like artificial limbs, heart, lungs for human and other machines to help impaired body functions.

Biotechnology: It deals with the technique of using living organisms or of substances obtained from them in industrial process to produce useful products.

Sericulture: It deals with the breeding and treatment of silkworms for producing raw silk.

Food technology: It deals with the science of processing and preservation of healthy foods. The application of science for the manufacture of milk products (dairy technology), the rearing of honey bees, bee keeping especially for commercial purposes (apiculture).The industry of rearing and catching fishes or other products of the sea, lakes, rivers or ponds (Fishery or Pisciculture).

Genetic Engineering: It involves genetic manipulation to produce an organism with a new combination to improve the heredity. The production of improved varieties by selecting mating is called breeding.

Forensic Science: It deals with the application of scientific knowledge and methodology to legal problems, especially scientific analysis of physical evidence.

Veterinary Medicine: It deals with the study of domesticated animals and their health care

Medicine: It deals with the science of treating diseases with drugs or curative substances.

Microbiology: The science dealing with structure, function and use of microscopic organisms is called microbiology.

Pathology: The science dealing with the nature of diseases their causes, symptoms and effects is called pathology.

Surgery: The branch of medicine, involving physical operations to cure diseases or injuries to the body is called Surgery.

Pharmacology: The science of knowledge of drugs and preparation of medicine is called pharmacology.

Physiotherapy: The treatment of diseases, bodily weakness or defects by physical remedies, such as massage and exercise is called physiotherapy.

Importance of biology

The study of living things plays a vital role to understand the nature of living creatures, to meet our needs, to solve our problems and curiosity, to get food and shelter, to maintain ecosystem and to conserve our natural resources.

- Biology explains about the life processes (growth, movement, metabolism) and basic concepts of cell structure and functions.
- Biology deals with the heredity and evolution and solves curiosity.
- Biology gives the knowledge about various types of disease, its symptoms, preventive measures and cure along with the causative agents.
- Biology helps to understand the problems related to pollution of air, water and soil and develop scientific methods for the control of pollution.
- Biology helps us to understand the importance of ecosystem, cause of ecological imbalance like green-house effects, depletion of ozone layer and acid rain and identify measures to overcome these ecological imbalances.
- Biology deals with the care and management (conservation) of the natural environment in order to meet the basic needs of people.
- Biology is concerned with the use of living organisms like bacteria, fungi, yeast, algae and cells of higher plants and animals in the production of useful products such as vitamins, enzymes, medicines (antibiotics), fermented foods, dairy products, alcohols, etc.

Summary

1. The branch of science which deals with the study of structure, organization, life processes, interactions, origin and evaluation of living organisms is called biology. **Aristotle** is known as the Father of Biology.
2. The study of biology can divided into several special branches or disciplines like morphology, anatomy, physiology, zoology, botany, cytology, histology, etc.
3. The branch of biology which deals with the study of external features of or ganisms is called morphology.
4. The branch of biology which deals with the study of internal structures of organisms is called anatomy.
5. The branch of science which deals with the study of structure and functions of cells and cell organelles is called cytology.
6. The branch of science which deals with the study of structure and functions of tissues is called histology.
7. Nowadays the term biology is also called as life science so as to cover its wide scope.

Exercise

A. **Tick (√) the best alternative from the followings.**

1. Who is called the father of biology?

   i) Aristotle ii) Lamarck

   iii) Traveranus iv) Mendel

2. Which one is not a branch of biology?

   i) Bio-technology ii) Microbiology

   iii) Pathology iv) Astronomy

3. The branch of biology which deals with the study of micro-organisms is called

   i) Pathology ii) Microbiology

   iii) Physiotherapy iv) Anatomy

4. Cytology is the branch of biology which deals with the study of

   i) Internal structure of organisms ii) Structure and functions of tissues

   iii) Structure and functions of cells iv) Structure of micro-organisms

B. **Answer the following short questions:**

1. What are the main branches of biology?
2. Define biology and mention the importance of biology.
3. Mention any three relationships of biology with chemistry.
4. Write any two scopes of biology.
5. What is Pharmacology? Write the importance of pharmacology in our life.

C. **Answer the following long questions:**

1. How is biology related to other sciences? Write in brief.
2. Write short notes on the scopes of biology.
3. How is the biological science related with the physical science?

Enzyme : a substance produced by a living organism that acts as a catalyst to bring about a specific biochemical reaction.

Hormones : a substance produced in an organism and transported in tissue fluids such as blood to stimulate specific cells or tissues into action.

Chromatography : the separation of a mixture by passing it in solution or suspension through a medium in which the components move at different rates.

Impaired : weakened or damaged.

Unit 14 Cell Biology

Robert gave the law of elasticity, known as Hooke's law, and in Micrographia (Small Drawings) he first used the word cell to name the microscopic honeycomb cavities in cork.

Robert Hooke (1635 AD – 1703 AD)

Learning outcomes

After the completion of this unit, learners will be able to

1. Define cell, cell biology and different structures of cell.
2. Describe and demonstrate the functions of different cell structures.

Introduction

Cell biology (formerly called **cytology**, Greek word: *kytos*, "vessel" and logos: study) **is a branch of biology that studies the different structures and functions of the cell**. Cell biology explains the structure, organization of the organelles they contain, their physiological properties, metabolic processes, signaling pathways, life cycle, and interactions with their environment.

In this chapter we will study about the structure and functions of cell, different cell organelles and their functions.

Cell

The **cell** is derived from a Latin word *"cella"*, meaning "small room". Cell is defined as the basic, structural, functional, and biological unit of all known living organisms in Earth. A cell is the smallest unit of life that contains the body's hereditary material and can replicate independently. Cells are often called the "building blocks of life". The human body is composed of trillions of cells. They provide structure for the body, take in nutrients from food, convert those nutrients into energy and carry out specialized functions.

Cells consist of cytoplasm enclosed within a membrane, which contains many biomolecules such as proteins and nucleic acids. Organisms can be classified as unicellular (consisting of a single cell; including bacteria) or multicellular (consisting of many cells; including plants and animals).

The cell was discovered by **Robert Hooke** in 1665AD, who named the biological unit for its resemblance to cells inhabited by Christian monks in a monastery.

Cell theory, was first developed in 1839AD by Matthias Jakob Schleiden and Theodor Schwann, state that:

All organisms are composed of one or more cells.

- Cells are the fundamental unit of structure and function in all living organisms.
- All cells come from pre-existing cells.
- Cells contain the hereditary information necessary for regulating cell functions and for transmitting information to the next generation of cells.

> Do you know?
>
> The human egg (ovum) is the largest cell in the body, and can (just) be seen without the aid of a microscope.

Unicellular and Multicellular Organisms

All living organisms are made up of cells; some of them are made up of single cell whereas some are made up of combination of large numbers of cells. The organisms formed by only one cell are called **unicellular** organisms and the organisms formed by numerous numbers of cells are called **multicellular** organisms. Here are the major differences between unicellular and multicellular organisms.

Unicellular animal	Multicellular animal
a) The body of this organism is composed of a single cell.	a) The body of this organism is composed of numerous cell.
b) A single cell carries out all the life processes.	b) Different cells are specialized to perform different function.
c) An injury of cell can cause death of the organism	c) Injury or death of the cell does not affect the organism, as the same can be replace by a new one
d) Unicellular organisms are mostly prokaryotes	d) Multicellular organisms are generally classified as eukaryotes.
e) Unicellular organisms are usually smaller (often always microscopic in nature) and less complex comparatively.	e) Multicellular organism is usually larger and more complex comparatively.

Cells have different shapes and sizes according to their function. A cell may be oval, round, plate-like, tubular, cylindrical, polygonal, irregular or branched. Like for example, the cells of muscle are long and cylindrical in shape while, nerve cells are very long. As the size of the cell is very small, we need an ultra-microscope to observe them.

> Do you know?
>
> The smallest cell is bacterial cell and the largest cell is an ostrich egg.

Cells are of two types, eukaryotic, which contain a well-developed nucleus, and prokaryotic, which lacks a defined nucleus. Prokaryotes are single-celled organisms, while eukaryotes can be either single-celled or multicellular.

Prokaryotic cell (pro: primitive; karyon: nucleus**)**:

Prokaryotic cells are known to be the first form of life on Earth. They are simpler and smaller than eukaryotic cells, and lack membrane-bound organelles such as mitochondria, endoplasmic reticulum, golgi bodies, centrosomes,etc in its cytoplasm. True nucleus is absent, i.e. the nucleus is not enclosed by a membrane and lacks nucleolus. Most prokaryotes are the smallest of all organisms ranging from 0.5 to 2.0 μm in diameter. The genetic material of a prokaryotic cell consists of a single chromosome and lies freely in the cytoplasm in the form of naked DNA without histones. The type of ribosome present in prokaryotic cell is 70S type. Bacteria and archae bacteria are the examples of prokaryotes. Simple flagella are present as locomotory organ in some prokaryotes.

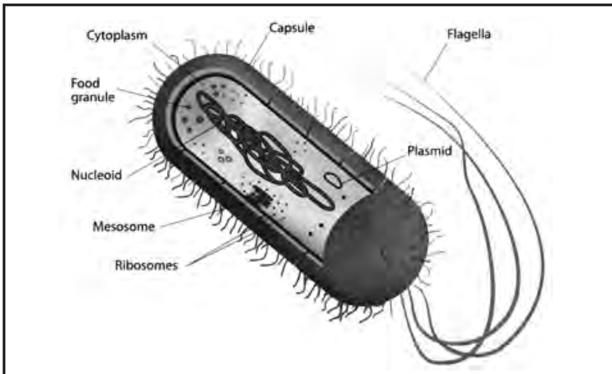
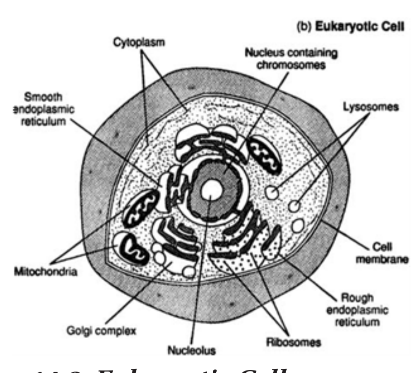


Fig 14.1: Prokaryotic cell

Eukaryotic cells (Eu: true; Karyon):

Eukaryotic cells are about fifteen times wider than a typical prokaryote and can be as much as a thousand times greater in volume. Plants, animals, fungi, slime moulds, protozoa, and algae are the examples of eukaryotic cell. These cells are more advance as compared to prokaryotes due to the presence of membrane-bound organelles in which specific metabolic activities take place.



14.2: Eukaryotic Cell

Cellular structure

Eukaryotic cells have many parts, each with a different function. Some of these parts, called organelles, are specialized structures that perform certain tasks within the cell. These cells generally have three main components: A cell wall and cell membrane, cytoplasm and a nucleus.

A) Cell wall

Cell wall is present in both eukaryotic and prokaryotic cell. It is the outermost, rigid, protective and supportive layer found in all the plant cells, bacteria, fungi and some protists. The cell wall is absent in animal cell and some lower plants. Cell wall of plant cells are primarily made up of cellulose, cell wall of fungi are made up of chitin and bacteria cell walls are made up of peptidoglycan. Plant cell walls are of two types:

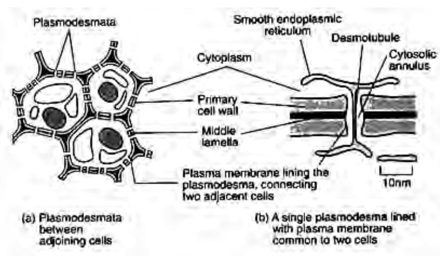


Fig 14.3: Plasmodesmata/cell wall

a) Primary (cellulose) cell wall - While a plant cell is being formed, a middle lamella made of pectin, is formed and the cellulose cell wall develops between the middle lamella and the cell membrane which is primary cell wall.

b) Secondary (lignified) cell wall - The secondary cell wall is formed only in woody tissue (mainly xylem). The secondary cell wall is stronger and water proof and once a secondary cell wall forms, a cell can grow no more – it is dead.

Function of cell wall

a) The cell wall acts to protect the cell mechanically and chemically from its environment.

b) It also protects the inner contents of cell from mechanical injuries.

c) It maintains fixed shape of the cells.

d) It acts as a site for many enzymatic activities.

B) Cell membrane

The cell membrane (plasma membrane), is a biological membrane that surrounds the cytoplasm of a cell. In animals, the plasma membrane is the outer boundary of the cell, while in plants and prokaryotes it is usually covered by a cell wall. This membrane serves to separate and protect a cell from its surrounding environment and is made mostly from a double layer of phospholipids, which are amphiphilic (partly hydrophobic and partly hydrophilic). Hence, the layer is called a phospholipid bilayer, or sometimes a fluid mosaic membrane. The membrane is said to be 'semi-permeable', in that it controls which molecules can enter and leave the cell. It plays an important role in the process of diffusion, osmosis, active transport, endocytosis, exocytosis and cellular locomotion of some unicellular organism

Fluid mosaic model of cell membrane

1. Membranes are fluid and are rather viscous – like vegetable oil.
2. The molecules of the cell membrane are always in motion, so the phospholipids are able to drift across the membrane, changing places with their neighbour.
3. Proteins, both in and on the membrane, form a mosaic, floating in amongst the phospholipids.

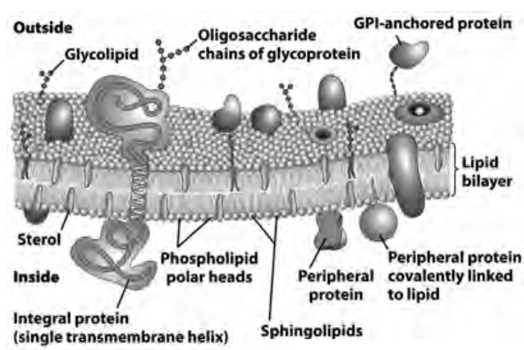


Fig 14.4: Fluid mosaic model of cell membrane

4. Because of this, scientists call the modern view of membrane structure the 'Fluid Mosaic Model'.
5. The mosaic of proteins in the cell membrane is constantly changing.

C) Cytoplasm (cytosol + organelles = cytoplasm**)**

Cytoplasm is made up of a jelly like fluid called cytosol and other cell organelles that surround the nucleus. Organelles carry out specific functions within the cell. In Eukaryotic cells, most organelles are surrounded by a membrane, but in Prokaryotic cells there are no membrane-bound organelles. It is differentiated into two parts: cytoplasmic matrix and cytoplasmic organelles.

Cytoplasmic inclusions (cytosol)

These are non-living substances formed by different metabolic activities in cell. It consists of various organic molecules (carbohydrates, proteins, lipids, nucleoprotein, enzymes etc.,) and inorganic molecules (water, salts of sodium, potassium, and other metals). The outer portion (ectoplasm or cortex) of cytosol is viscous, clear, rigid and non-granular while its inner portion (endoplasm or medulla) is less viscous and granular.

Cell inclusions can be divided into three categories:

Reserve materials: proteins, cellulose, sugar, fat and oil

Secretory materials: plant pigments, enzymes and nectar

Excretory materials: gums, resins, tannin, essential oils, latex

Function

- It provides raw materials to various cell organelles to perform their function.
- It is the site for many catabolic pathways like glycolysis, kreb's cycle, etc.
- It is also the site for the biosynthesis of organic molecules like lipids, proteins, etc.
- It helps in exchange and distribution of various materials inside the cell.

Cytoplasmic organelles

Organelles are parts of the cell which are adapted and/or specialized for carrying out one or more vital functions. These are living sub-cellular structures of the cytoplasm. Both eukaryotic and prokaryotic cells have organelles, but prokaryotic organelles are generally simpler and are not membrane-bound. There are several types of organelles in a cell. Some (such as the nucleus and golgi apparatus) are typically single, while others (such as mitochondria, chloroplasts, peroxisomes and lysosomes) can be numerous in number.

Mitochondria (Greek: mito: thread; chondrion: granule)

Mitochondria are complex granular or filamentous cell organelles that convert energy from food into a form of ATP (Adenosine triphosphate),that can be used for the important activities of cell. Therefore these are also known as "the power house of the cell". They are found scattered throughout the cytosol, and are relatively large organelles. These are absent in prokaryotic cell. Almost all the eukaryotic cell have mitochondria. These are the largest organelles in animal cell. These are distributed throughout the

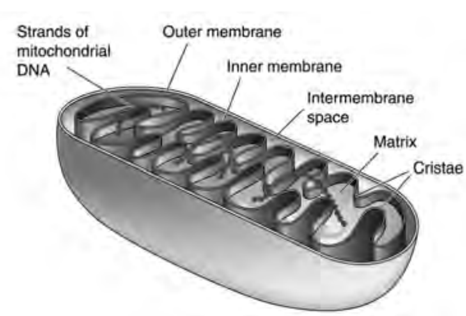


Fig 14.5: Mitochondria

cytoplasm and are located at the sites of more energy requirement. Respiration occurs in the cell mitochondria, which generate the cell's energy.

Mitochondria are surrounded by two membranes:

a) The smooth outer membrane, that serves as a boundary between the mitochondria and the cytosol.

b) The inner membrane having many long folds, known as cristae, which greatly increase the surface area of the inner membrane, providing more space for ATP synthesis to occur.

Endoplasmic reticulum (ER)

The endoplasmic reticulum(ER) is a system of membranous tubules and sacs. The ER has two forms: the rough ER, which has ribosomes on its surface that secrete proteins into the ER, and the smooth ER, which lacks ribosomes. The smooth ER plays a role in calcium sequestration and release.

Function: The primary function of the ER is to act as an internal transport system, allowing molecules to move from one part of the cell to another.

Ribosomes

Ribosomes are most common dense, rounded, granular structures attached either on rough endoplasmic reticulum (rough ER) or floating freely in the cytoplasm. Unlike most other organelles, ribosomes are not surrounded by a membrane. Ribosomes are the site of protein synthesis in a cell. Ribosomes are of two basic types: 70s (50s + 30s) and 80s (60s +40s). 70s ribosome are free floating, smaller in size and are found in all prokaryotic cells, mitochondria and chloroplast of eukaryotic cell. 80s ribosomes are found attached in the cytoplasm of eukaryotic cells of plants and animals attached to the rough- ER. Ribosomes are chemically called ribonucleoprotein.

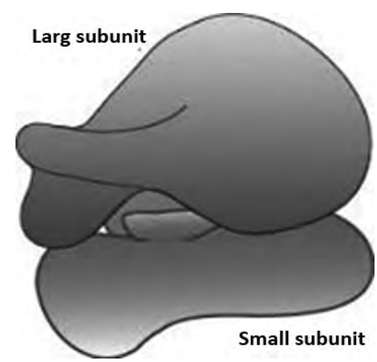


Fig 14.6: Ribosome

Function

- It is the site of protein synthesis, therefore also known as ‘protein-factory’.
- It controls cellular functions.
- Free ribosomes synthesize enzymes for intracellular use and bound ribosomes synthesize for extracellular use.

Golgi apparatus

The Golgi apparatus is the processing, packaging and secreting organelle of the cell, so it is much more common in glandular cells. The Golgi apparatus is a system of membranes, made of flattened sac-like structures called cisternae.

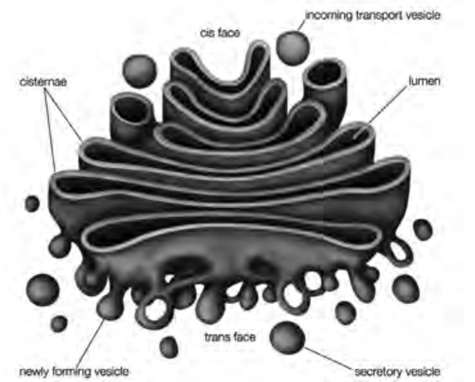


Fig 14.7: Golgi apparatus

Function:

- The primary function of the Golgi apparatus is to process, package and store the macromolecules such as proteins and lipids that are synthesized by the cell.
- These are involved in a cell secretion and helps in absorption of lipids.
- During cell division in plants, these take part in the formation of cell plate.
- It helps in the synthesis of lysosome, hormones, glycoproteins and pectic substance of the cell wall.

Lysosome

Lysosomes are small spherical sac-like organelles, within a single lipo-proteinaceous membrane that contains digestive or hydrolytic enzymes. Lysosomes are the site of protein digestion – thus allowing enzymes to be re-cycled when they are no longer required. They are also the site of food digestion in the cell, and of bacterial digestion (lysis) in phagocytes. Therefore, these are also known as '**suicidal bag**.' Lysosomes are formed from pieces of the Golgi bodies that break off. Lysosomes are common in the cells of animals, protista and even fungi, but rare in plants.

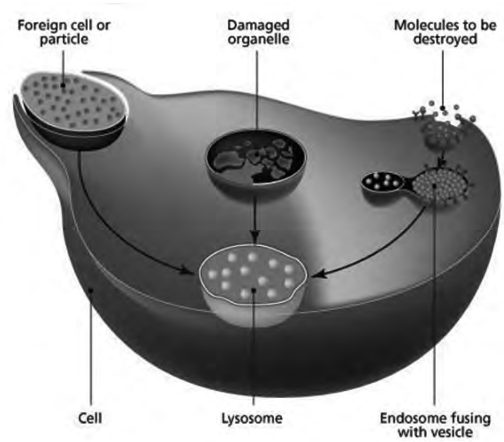


Fig 14.8: lysosome

Centrosome

Centrosomes are composed of two centrioles, which separates during cell division and help in the formation of the mitotic spindle. It is surrounded by a transparent cytoplasmic lipoproteinaceous membrane. A single centrosome is present in the animal cells. They are also found in some fungi and algae cells.

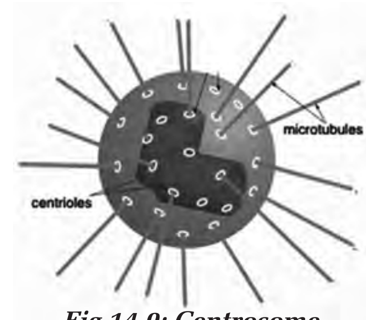


Fig 14.9: Centrosome

Function:

- It forms mitotic spindle during cell division of animal cells.
- In unicellular organisms, it is found at the base of cilia and flagella as a basal body which controls their movement.

Plastids

These are round, oval double membrane bounded organelles found only in plant cell and some protozoans like *Euglena*. They may be colourless or may be coloured.

Plant Cell Chloroplast Structure

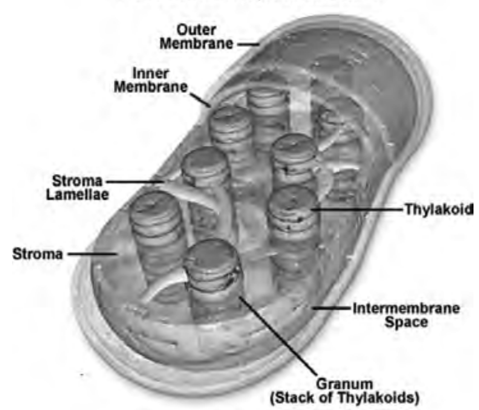


Fig 14.10: Microscopic structure of chloroplast

On the basis of pigments found in them, there are three types of plastid:

1. **Chloroplast** (GK. Chloros: green; plastos: formed)

   It is the most common type of plastid and contains green pigment called chlorophyll. As it helps in the preparation of food by the process of photosynthesis, it is known as the '**kitchen of cells**.' Chloroplasts can only be found in the green parts of plants and algae, and they capture the sun's energy to make carbohydrates through photosynthesis.

2. **Chromoplast** (GK: chroma: colour; plastos: formed)

   These are coloured plastids found in coloured parts of the plants such as flowers, fruits which contain different types of pigment other than green. Some of the examples of these plastids are lycopin (red pigment) in tomatoes and chillies; carotenes in carrot's root; anthocyanin (violet, purple, brown and often red in flower). These colours help in poliination and dispersion of fruits and seeds.

3. **Leucoplast** (GK. Leukos: white; plastos: formed)

   These are non –pigmented plastids usually found in storage parts like roots, underground stem where light is not available. They may be rod like, spherical or oval in shape and are concerned with storage of protein, starch, oil, etc in plant bodies.

Vacuoles

These are the fluid-filled sacs bounded by a single membrane called tonoplast. Vacuoles are present both in plant and animal cells. The vacuoles of plant cells and fungal cells are usually larger than those of animal cells. The cell sap contains water, mineral, salt, glucose, etc inside them.

Fig 14.11: Vacuoles

Function

- It stores water, minerals, sugars, amino acids, pigments, etc.
- It stores waste products or plant metabolites like tannin and latex.
- It also helps in growth and elongation of cells.

The nucleus (pl. nuclei)

The Nucleus is normally the largest organelle within a eukaryotic cell. It is very important part of cell, usually spherical or oval in shape and consist of four major components: Nuclear membrane, nucleoplasm, chromatin fibres and nucleolus.

Nuclear membrane:

It is a double layered lipo-proteinaceous membrane that surrounds nucleus and separates it from the surrounding cytoplasm. It acts as a selective membrane and helps to regulate the interactions between nucleus and cytoplasm.

Nucleoplasm:

It is a transparent, homogenous, semifluid gel like substance found inside a nucleus which provides the site of enzyme activities.

Nucleolus:

It is a small dense rounded body that remains attached to the chromatin. It takes part in synthesis of RNA and nuclear protein which are utilized in the formation of ribosomes. It also forms spindle fibres during cell division.

Chromatin fibres

Chromatin fibres are the network of fibrous structures, which are actually elongated chromosomes. They are the sites of main genetic material, which controls all the activities of cell.

Function

- Nucleus direct and controls all the activities, metabolism and heredity of the cell and hence called as '**The master of cell**.'
- It contains the genetic information for reproduction, development and behavior.
- The nucleolus forms spindle fibres during cell division.
- It takes part in the synthesis of ribosomes.

Chromosome:

The term chromosome was introduced by Waldayer in 1888AD. They are filamentous bodies present in the nucleus. They become visible and active during cell division. They are the carriers of gene.

Chromosomes are composed of DNA and histone proteins. Each chromosome include chromonema, centromere, secondary constriction, nuclear organizers, telomers and satellites. On the basis of position of centromere chromosome is of 4 different types viz; metacentric, sub metacentric, acrocentric and telocentric.

Activity

Draw the diagram of animal cell and plant cell in a chart paper. Compare the similarities and dissimilarities between them and discuss among your friends in a classroom.

ORGANELLE	LOCATION	DESCRIPTION	FUNCTION
Cell wall	Plant, not inanimal	Outer layer rigid, strong, stiff made of cellulose	Support (grow tall) protection allows H_2O, O_2, CO_2 to pass into and out of cell
Cell membrane	Both plant/ animal	Plant - inside cell wall animal - outer layer; selectively permeable	Support protection controls movement of materials in/out of cell barrier between cell and its environment maintains homeostasis
Nucleus	Both plant/ animal	Large, oval	Controls cell activities
Nuclear membrane	Both plant/ animal	Surrounds nucleus selectively permeable	Controls movement of materials in/out of nucleus
Cytoplasm	Both plant/ animal	Clear, thick, jellylike material and organelles found inside cell membrane	Supports /protects cell organelles
Endoplasmic reticulum (E.R.)	Both plant/ animal	Network of tubes or membranes	Carries materials through cell
Ribosome	Both plant/ animal	Small bodies free or attached to E.R.	Produces proteins
Mitochondrion	Both plant/ animal	Bean-shaped with inner membranes	Breaks down sugar molecules into energy
Vacuole	Plant - few/large animal - small	Fluid-filled sacs	Store food, water, waste (plants need to store large amounts of food)
Lysosome	Plant - uncommon animal - common	Small, round, with a membrane	Breaks down larger food molecules into smaller molecules digests old cell parts
Chloroplast	Plant, not in animal	Green, oval usually containing chlorophyll (green pigment)	Uses energy from sun to make food for the plant (photosynthesis)

Comparison of features of prokaryotic and eukaryotic cells		
	Prokaryotes	**Eukaryotes**
Typical organisms	bacteria, archaea	protists, fungi, plants, animals
Type of nucleus	no true nucleus is present	true nucleus with double membrane is present
DNA	circular (usually); naked	linear chromosomes covered with histone proteins
RNA/protein synthesis	coupled in the cytoplasm	RNA synthesis in the nucleus protein synthesis in the cytoplasm
Ribosomes	70S type (50S + 30S)	80S (60S + 40S)
Cytoplasmic structure	Membrane bound organelles are absent	highly structured membrane bound organelles are present
Cell movement	flagella made of flagellin	flagella and cilia containing microtubules; lamellipodia and filopodia containing actin
Mitochondria	none	one to several thousand
Chloroplasts	none	in algae and plants
Organization	usually single cells	single cells, colonies, higher multicellular organisms with specialized cells
Cell division	binary fission (simple division)	mitosis (fission or budding)
Chromosomes	single chromosome	more than one chromosome
Membranes	cell membrane	Cell membrane and membrane-bound organelles

Summary

1. Cell is defined as the basic structural, functional, and biological unit of all known living organisms found in Earth.
2. Cell biology is the branch of biology which deals with the study of structure and function of cell.
3. The cell was discovered by **Robert Hooke** in 1665 AD.
4. Cell theory, was first developed in 1839AD by Matthias Jakob Schleiden and Theodor Schwann.

5. A cell may be oval, round, plate-like, tubular, cylindrical, polygonal, irregular or branched.
6. On the basis of type of nucleus, cells are of two types, eukaryotic, which contain a nucleus, and prokaryotic, which lacks a defined nucleus.
7. The living structures present inside the cytoplasm are called cell organelles and the non-living structures present inside the cytoplasm are called cell inclusions.
8. Plant cell walls are primary made up of cellulose, fungal cell walls are made up of chitin and bacteria cell walls are made up of peptidoglycan.
9. Mitochondria are also known as "the power house of the cell".
10. The endoplasmic reticulum (ER) has two forms: the rough ER, which has ribosomes on its surface that secrete proteins into the ER, and the smooth ER, which lacks ribosomes.
11. Lysosomes are also known as '**suicidal bag**.'
12. Chloroplast is known as the '**kitchen of cells**.' as it helps in the preparation of food by the process of photosynthesis.
13. Chromosomes are composed of DNA and histone proteins.
14. Nucleus direct and controls all the activities, metabolism and heredity of the cell and hence called as '**The master of cell**.'

Exercise

A. Tick (√) the best alternative from the followings.

1. The branch of biology which deals with the study of structure and functions of cells is called:

   i) Bio technology ii) Histology

   iii) Cytology iv) Biology

2. Which cell organelle controls all the activities of the cell?

   i) Mitochondria ii) Nucleus

   iii) Lysosome iv) Plastid

3. Lysosome is also called

i) Power house of the cell ii) Suicidal bag

iii) Kitchen of the cell iv) Brain of the cell

4. 70S ribosome is made up of two following sub units:

   i) 50S and 20S ii) 50S and 30S

   iii) 40S and 30S iv) none

5. Cell theory was given by:

   i) Matthias Jakob Schleiden ii) Theodor Schwann

   iii) None iv) Schleiden and Schwann both

6. Which one is not the statement of cell theory?

   i) All organisms are composed of only one cell.

   ii) Cells are the fundamental unit of structure and function in all living organisms.

   iii) All cells come from preexisting cells.

   iv) Cells contain the hereditary information necessary for regulating cell functions and for transmitting information to the next generation of cells.

B. Answer the following short questions:

1. Define cell. Who discovered cell?
2. Why is the cell considered as, basic, structural and functional unit of life?
3. Define cell biology. Why is nucleus known as master of cell?
4. Prokaryotic organisms are primitive to eukaryotic organisms, justify.
5. Give functions of golgi apparatus.
6. Which cell organelle is called the power house of the cell? Why?
7. Which organelle is called 'suicidal bag', why?
8. Distinguish between:

   a) Prokaryotic cell and Eukaryotic cell

   b) Smooth endoplasmic reticulum and Rough endoplasmic reticulum

   c) Cell organelles and Cell inclusions

   d) Cell wall and Cell membrane

   e) 80S and 70S units of ribosomes

f) Unicellular organisms and multicellular organisms

C. Answer the following long questions:

1. Describe the cell theory.
2. Write short note on the structure and function of plasma membrane.
3. Write the brief about the structure and function of nucleus.
4. Explain Fluid mosaic model of cell membrane in brief.
5. Describe about the prokaryotic and eukaryotic cells in brief.

Project work

1. Make a model of either plant cell or animal cell with the help of waste materials like cotton, pulses, wires etc taking the help of your senior/teacher.

Glossary

Organelles	:	number of organized or specialized structures within a living cell.
Biomolecules	:	a molecule produced by living cells, e.g., a protein, carbohydrate, lipid, or nucleic acid.
Endocytosis	:	the transport of solid matter or liquid into a cell
Exocytosis	:	the transport of material out of a cell
Plasmolysed	:	contraction of the protoplasm in a living cell when water is removed by exosmosis.
Hydrophobic	:	lacking affinity for water (not absorb water)
Hydrophilic	:	having strong affinity for water (tending to dissolve or mixed in water
Amphiphilic	:	having both hydrophobic and hydrophilic
Lignify	:	Converting into wood, to become woody
Phagocyte	:	Scavenger cell (a cell that engulfs and digests debris and invading microorganisms)
Homeostasis	:	Stable state of equilibrium

Unit 15 Organism and Life Cycle

Antonie was the first who observe bacteria and protozoa, who proved that the doctrine of spontaneous generation is wrong on the basis of his researches on lower animals.

Antonie Van Leeuwenhoek (1632-1723AD)

Learning outcomes

After the completion of this unit, learners will be able to

1. Define and explain the importance of microbiology.
2. Describe the structure and a disease caused by bacteria, virus, fungi and protozoa along with their preventions.
3. Define and explain the importance of immunity and vaccination.
4. Describe the structure and life cycle of *Spirogyra* and *Paramecium.*
5. Demonstrate different plant physiologies (osmosis, transpiration and respiration) and to describe the importance of above mentioned plant physiologies.

Introduction

The term Microbiology, is derived from three greek words - *mikros* (small), *bios* (life) and *logos* (study). Therefore, Microbiology is the study of microorganisms, that cannot be seen with our naked eyes and can be unicellular (single cell), multicellular (cell colony), or acellular (lacking cells). Microbiology deals with the numerous sub-disciplines like virology, mycology, parasitology, immunology, biotechnology, bacteriology etc. Microbiologists are people who specialize in the field of microbiology.

Do you know?

Antonie Van Leeuwenhoek is the father of microbiology who first discovered bacteria and named it as animalcules

Microorganisms are almost everywhere in our environment such as air, water, soil, food, on and inside of living organisms, where the conditions are favourable for their growth and metabolisms. Microorganism may be harmful as well as useful to us. Useful in terms, that they play a vital role to keep the biosphere running. For example, they have important roles in the cycles of carbon, oxygen, nitrogen and sulphur gases that take place in terrestrial and aquatic environment, decomposition of dead plants and animals has helped plants to get nutrients and soil to increase their fertility, their role in fermentation has eased many food and pharmaceutical industries. Moreover, they are also responsible for many diseases, among which most are even life threatening. **Microbiology is concerned with form, structure, reproduction, physiology, metabolism classification and most importantly economic importance of microscopic organisms.**

In this chapter we will study about the definition, scope, importance of microbiology, about virus, bacteria, fungi, protozoa and the disease caused by those microorganisms, about immunity and vaccination, life cycle of *Paramecium* and *Spirogyra*, about plant physiologies (osmosis, transpiration and respiration) and demonstration on the plant physiologies.

Scope and importance of microbiology

There is a vast scope in the field of microbiology due to the advancement in the field of science and technology. The scope in this field is immense due to the involvement of microbiology in many fields like medicine, pharmacy, dairy, industry, clinical research, water industry, agriculture, chemical technology and nanotechnology. A microbiologist can innovates new diagnostic kits, discover new drugs, teach, research, etc. Here are some scopes of microbiology:

1. **Medical microbiology:** In the field of medicine and health care, the work is usually associated with diagnosis, prevention and treatment of illnesses associated with microbes.

2. **Pharmaceutical microbiology:** The study of microorganisms that are related to the production of antibiotics, enzymes, vitamins, vaccines, and other pharmaceutical products and that cause pharmaceutical contamination and spoil.

3. **Industrial microbiology:** The exploitation of microbes for use in industrial processes. Examples include industrial fermentation and waste water treatment. This field also includes brewing, an important application of microbiology.

4. **Microbial biotechnology**: The manipulation of microorganisms at the genetic and molecular level to generate useful products.

5. **Genetic engineering**: the microorganisms are engineered to make hormones, antibiotic, vaccines and other products.

6. **Food microbiology:** The study of microorganisms causing food spoilage and foodborne illness. Microorganisms are being used to produce foods such as cheese, yoghurt, pickles, beer, alcohol and other fermented food.
7. **Agricultural microbiology:** It helps to study the role of microbes in plant disease, pest control, nutrition and soil fertility.
   - **Plant microbiology:** The study of the interactions between microorganisms and plants and plant pathogens.
   - **Soil microbiology:** The study of those microorganisms that are found in soil.
8. **Environmental microbiology:** The study of the function and diversity of microbes in their natural environments. This involves bacterial habitats such as the rhizosphere and phyllosphere, soil and groundwater ecosystems, open oceans or extreme environments.
   - **Water microbiology:** The study of those microorganisms that are found in water.
   - **Air microbiology:** The study of airborne microorganisms.
9. **Biotechnology:** This is the most significant branch which may even change the course of life as we know today. New, genetically engineered microbes can produce drugs (human insulin) or in agriculture Nitrogen fixing ability may be transferred to all the plants. The potentialities of bio-technology are immense.
10. **Immunology:** This branch deals with the immune responses in organisms. How toxins are produced? How the antigens influence the formation of antibodies? How protective vaccination helps in combating the diseases? How immune system collapses (as in AIDS) are some of the questions for which immunology as a branch of microbiology is trying to find out answers.

Virus

Virus is acellular infectious agent of small size, which is made up of genetic material and protein that can multiply only in living cells of animals, plants, or bacteria. They are considered both as living and non-living things. In the year 1897AD, a scientist named Beijerinck discovered and coined the term virus. The term virus is derived from Latin word- "*venom*" which means **poison**. Later

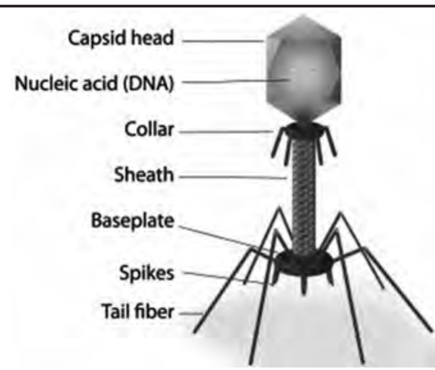


Fig 15.1: Bacteriophage virus

in the year 1935AD, a scientist named Wendell Stanley discovered that these viruses are composed of nucleic acids, protein and lipids. When virus is not inside a living cell, it exists in the form of independent particles. These **viral particles** are known as **virions. The branch of microbiology which deals with the study of viruses is known as virology.**

Structure of Viruses

Viruses can be seen only under electron microscope as they are very small measured in nanometers (20-250nm; where 1nm=10^{-9} m). They are composed of a core of DNA or RNA surrounded by a protein coat called capsid.

Do you know?

Non-enveloped or naked viruses are protected by their capsid.

Virions are complete, fully developed viral particles composed of two or three parts:

a) **Nucleic acid:** The genetic material is made from either DNA or RNA (not both) which carry genetic information.

b) **Capsid:** A protein coat, which surrounds and protects the genetic material.

c) **An envelope of lipids:** It is the outer covering of some viruses that surrounds the protein coat when they are outside a cell.

Shape of the virus

Viruses have three distinct shapes:

a) Helical (cylindrical or rod): tobacco mosaic virus (TMV), influenza virus, mumps virus

b) Polyhedral (cubical or spherical): herpes virus, polio virus

c) Complex structure (tadpole shape): bacteriophage.

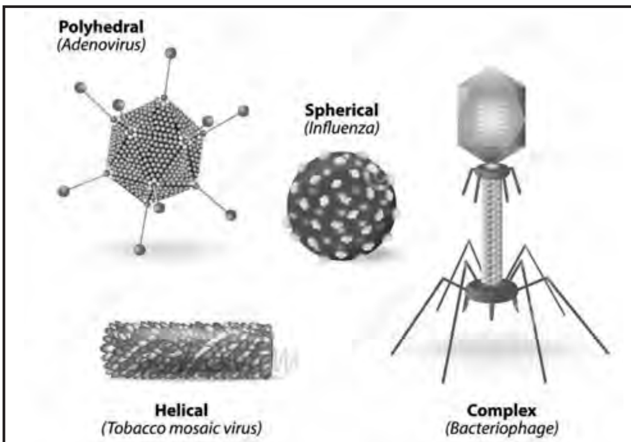


Fig 15.2: Structure of different shape of virus

Diseases caused by virus

Viruses can infect human beings, animals as well as plants. In humans, smallpox, common cold, chickenpox, influenza, herpes, hepatitis, polio, rabies, ebola and AIDS are examples of viral diseases. Even some types of cancer are caused by virus. In plant they cause tobacco mosaic, potato mosaic, cucumber mosaic, yellow vein mosaic of ladies finger, little leaf of brinjal, etc.

HIV/AIDS

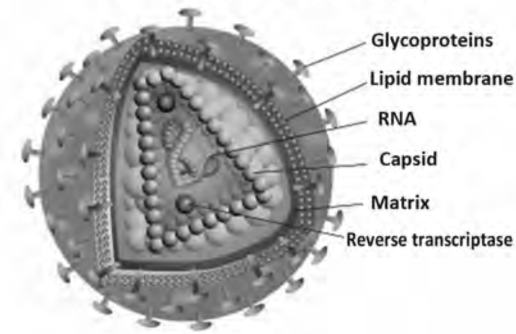


Fig 15.3: Structure of HIV

One of the dangerous and fatal disorder caused by virus is AIDS which was first identified in USA in 1981AD. AIDS (**A**cquired **I**mmune **D**eficiency **S**yndrome) is a viral infection caused by HIV (**H**uman **I**mmuno deficiency **V**irus). HIV infects white blood cells and weakens the immune system of the patient. Therefore, their ability to fight against different infections very low and the patient is prone to different diseases. The victim of AIDS usually dies due to the collection of several diseases.

Modes of transmission:

1. By unprotected sexual intercourse with infected partner through semen, vaginal fluid.
2. Contact with an infected blood (through contaminated syringe, blade, needle, transfusion of contaminated blood).
3. Transplacental (from infected mother to her unborn child through placenta)
4. Breast feeding.

Symptoms:

1. Diarrhoea, fatigue, fever, loss of appetite, weight loss, dry cough, shortness of breath, night sweats, difficulty in concentrating, numbness, etc.
2. Development of multiple infections and cancers and finally the death of the patient.

Preventions and control measures

1. Avoid sharing personal items, such as tooth-brush, intravenous needles, syringes, cotton, drugs, razors, etc.
2. By having safe sex (use condom).
3. By avoiding pregnancy if the mother is HIV positive.
4. Blood should be tested for HIV before transfusion.

Note: HIV/AIDS does not transmit by kissing, hugging, sharing foods, etc.

Bacteria (Singular: Bacterium)

Bacteria are single celled microscopic organisms which can be found almost everywhere in earth's surface. They are present in soil, water, food, acidic hot springs, radioactive waste, different objects and even on and inside the body of living or dead organism. Bacteria usually live in symbiotic (e.g.: nitrogen fixing bacteria like *Rhizobium*) and parasitic relationships with plants and animals. The study of bacteria is known as bacteriology. Since the cell of bacteria lacks nucleus it has grouped into prokaryotic. They move around by using their locomotoy organs such as cilia and flagella.

Bacterium was first discovered in 1675AD by a Dutch man **Antonie Van Leeuwenhoek**, which he called as **animalcules**. In 1864 AD and 1876 AD Louis Pasteur and Robert Koch reported the **disease causing ability** of this organism respectively. But the term becterium was introduced only in 1928 AD by Ehrenberg.

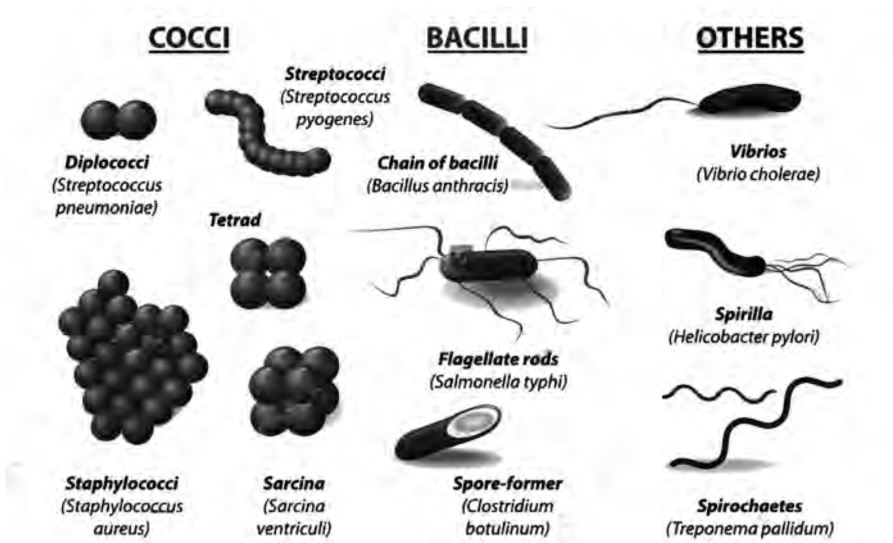


Fig 15.4: Different shapes of Bacteria

Shapes of Bacteria

Bacteria are very small in size. They can be only seen with the help of microscope and their size varies from 0.1 – 1micron in length and 0.3 – 2 micron in diameter where 1micron = 10^{-6}m). There are four basic shapes of bacteria**:**

a) Rod shaped bacteria (bacilli): *Streptobacillus*

b) Spherical shaped bacteria (cocci): *Staphylococcus*

c) Curved shaped bacteria (spirilla): *Vibrio*

d) Thread shaped bacteria (filamentous bacteria): *Streptomyces cholerae*

Bacteria can be **Anaerobic bacteria** (does not require oxygen for respiration) and **Aerobic bacteria** (require oxygen for respiration).

Structure of bacteria

Bacteria are simple unicellular microscopic organism. Under electron microscope it shows the following structures.

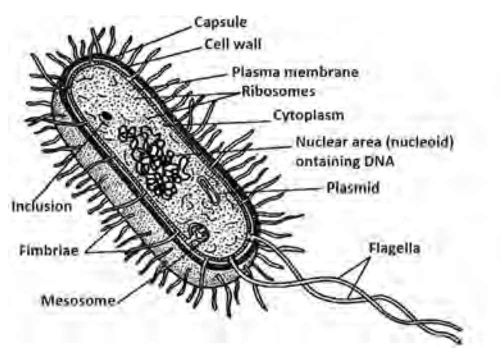


Fig 15.5: Structure of Bacteria

Cell wall:

Cell walls of bacteria are made up of glycoprotein, murein or peptidoglycan. Cell wall helps in providing support, mechanical strength and rigidity to cell and it also protects cell from bursting in a hypotonic medium.

Protoplasm: It is differentiated into cytoplasmic membrane, cytoplasm and nuclear body.

Plasma Membrane: It is also known as cytoplasmic membrane or cell membrane composed of phospholipids, proteins and carbohydrates, forming a fluid-mosaic.

It helps, in transportation of substances including removal of wastes from the body, in providing a mechanical barrier to the cell and acts as a semi permeable membrane, which allows only selected material to move inside and outside of the cell.

Cytoplasm: It is a colourless viscous substance between cytoplasmic membrane and nuclear body. It includes ribosome, granules, gas vacuoles, glycogen, lipid, protein, etc. It helps cellular growth, metabolism and replication. It is the store house of all the chemicals and components that are used to sustain the life of a bacterium.

Nuclear body: Bacterial cell lack a well-developed nucleus which lacks nuclear membrane and nucleolus and this type of nucleus is called as incipient nucleus or nucleoid. It contains naked circular DNA containing all genetic information.

Flagella: Flagella is long, rigid protoplasmic thread like structure. It helps the cell to move in clockwise and anticlockwise, forward and also helps the cell to spin.

Pilli: It is a short protein appendage, smaller than flagella that fixes bacteria to surfaces. It also helps in reproduction during conjugation.

Capsule: Capsule is a kind of slime layer, which covers the outside of the cell wall, composed of a thick polysaccharide. It is used to stick cells together and works as a food reserve. It also protects the cell from dryness and from chemicals.

Importance of bacteria

1. Nitrogen fixing bacteria fertilizes field.
2. They act as decomposers and break down dead organism and waste into nutreints.
3. They are used in producing foods (cheese, pickles, yogurt, vinegar, etc) and medicines such as antibiotics (streptomycin, erythromycin, bacitracin, etc)
4. They are also responsible for causing many diseases in living organisms such as diarrhoea, typhoid fever, food poisoning, urinary tract infection, etc.

Disease caused by Bacteria

Bacteria cause various serious diseases like pneumonia, sore throat, boils, cholera, tuberculosis, diphtheria, typhoid, whooping cough, urinary tract infections, etc in human beings. We will learn about tuberculosis in this chapter.

Tuberculosis

Tuberculosis (TB) is a disease caused by bacteria (*Mycobacterium tuberculosis*) that are spread through the air from person to person. If not treated properly, TB disease can be fatal. There are two types of TB conditions: latent TB infection and TB disease.

TB bacteria can live in the body without making you sick. This is called latent TB infection. People with latent TB infection do not feel sick, do not have any symptoms, and cannot spread TB bacteria to others.

If TB bacteria become active in the body and multiply, the person will go from having latent TB infection to being sick with TB disease.

Causes

Tuberculosis (TB) is caused by a bacterium called ***Mycobacterium tuberculosis***. The bacteria usually attack the lungs, but TB bacteria can attack any part of the body such as the kidney, spinal cord, brain etc. If not treated properly, TB disease can be fatal. Tuberculosis is spread from person to person through microscopic droplets released into the air, when someone with the untreated, active form of tuberculosis coughs, speaks, sneezes, spits, laughs or sings. People nearby may breathe in these bacteria and become infected.

People with latent TB infection do not have symptoms, but may still need treatment.

TB bacteria most commonly grow in the lungs, and can cause symptoms such as:

- A bad cough that lasts 3 weeks or longer
- Chest pain, or pain with breathing or coughing
- Coughing up blood or sputum (mucus from deep inside the lungs)

Other symptoms of TB disease may include: weakness or fatigue, weight loss, loss of appetite, chills, fever, sweating at night etc.

Prevention

In order to reduce exposure in households where someone has infectious TB, the following actions should be taken whenever possible:

- Houses should be adequately ventilated;
- Anyone who coughs should be educated on cough etiquette and respiratory hygiene, and should follow such practice at all times;
- If possible, sleep alone in a separate, adequately ventilated room
- Spend as little time as possible on public transport;
- Spend as little time as possible in places where large numbers of people gather together.

Protozoa

The term protozoa is derived from two Greek words: protos meaning first and zoon meaning animal. **Antonie van Leeuwenhoek** was the first person to see protozoa, using microscopes he constructed with simple lenses. They are single celled eukaryotes often group in the kingdom protista. More than 50,000 species have been described, most of which are free-living organisms. Protozoa are found in almost every possible habitat. They are generally present in moist habitats; free living species are found in fresh or marine water, damp soil while terrestrial species are found in decaying organic matter. Some species are parasitic and some are commensal on plants and animals. Protozoa vary substantially in size and shape. Protozoan cells have no cell walls and therefore can assume an infinite variety of shapes.

Most protozoa have a single nucleus, but some have both a macronucleus and one or more micronuclei (eg *Paramecium*). Contractile vacuoles may be present in protozoa to remove excess water, and food vacuoles are often observed for storing food.

Many protozoan species move independently by one of three types of locomotory organ: flagella, cilia, and pseudopodia.

Protozoa are classified into four classes on the basis of locomotory organs as:

1. **Rhizopodea :** locomotory organ is pseudopodia i.e. false feet (*Entamoeba*),
2. **Ciliate:** locomotory organ is cilia (*Paramecium*),
3. **Flagellate:** locomotory organ is flagella (*Euglena, Trypanosoma*), and
4. **Sporozoa:** no locomotory organ (*Plasmodium, Monocystis*).

Structure of protozoa

Protozoa are microscopic unicellular organinsms which are usually in the size range of 1-100 μm. Perhaps the most famous protozoa, the amoeba, can be up to 1 mm in size.

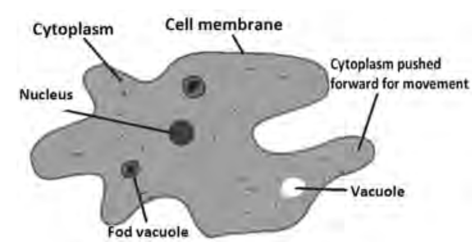


Fig 15.6: An amoeba – a simple protozoan

There are many different types of protozoa and some of them have very complex structures. But all of the protozoa have some structures in common. These include:

- **Cell membrane** that surrounds the cytoplasm and controls the movement of substances into and out of the cell
- **Nucleus** that contains the genetic material which controls the cell activities and reproduction
- **Cytoplasm** consist of liquid gel in which many of the chemical reactions of the cell take place
- **Vacuole** is membrane lined, fluid filled space in the cytoplasm which may be used for water balance or feeding

Many protozoa cause diseases in animals and humans. Some, like *Plasmodium*, which causes malaria, *Trichomonas*, which cause sexually transmitted diseases, *Amoeba*, which causes dysentery, etc

Malaria

Malaria is a life-threatening disease caused by a parasite called ***Plasmodium***. It is typically transmitted through the bite of an infected female ***Anopheles*** mosquito. Infected mosquitoes carry the ***Plasmodium*** parasite. When this mosquito bites, the parasite is released into the bloodstream. Once the parasites are inside your body, they travel to the liver, where they mature. After several days, the mature parasites enter the bloodstream and begin to infect red blood cells. Within 48 to 72 hours, the parasites inside the red blood cells multiply, causing the infected cells to burst open.

The parasites continue to infect red blood cells, resulting in symptoms that occur in cycles that last two to three days at a time.

The symptoms of malaria typically develop within 10 days to four weeks following the infection. In some people, symptoms may not develop for several months. Some malarial parasites can enter the body but will be dormant for long periods of time.

Common symptoms of malaria include: shaking chills that can range from moderate to severe, high fever, profuse sweating, headache, nausea, vomiting, cough, diarrhoea, bloody stools, loss of appetite, anaemia, muscle and joint pain, abdominal pain.

Malaria can cause a number of life-threatening complications such as; swelling of the blood vessels of the brain or cerebral malaria, an accumulation of fluid in the lungs that causes breathing problems, or pulmonary edema, organ failure of the kidneys, liver, or spleen, anaemia due to the destruction of red blood cells, low blood sugar etc.

Prevention

- Avoid being bitten by mosquitoes.
- Travellers to areas with malaria are usually advised to take preventive anti-malarial drugs.
- Personal protection and the environmental management of mosquitoes are important in preventing illness.
- Isolation of infected patients.
- Controlling mosquitoes by avoiding their breeding sites and by killing them

FUNGI

Fig 15.7: Structure of Fungi

Fungi are eukaryotic organisms which constitute large and diverse groups of organisms. Fungi are heterotrophic and have cell walls made of chitin rather than cellulose. Most of the fungi are multicellular (except **yeast)** and structurally, the body of fungi are composed of filaments called hyphae; some have hyphae that are segmented by divisions called septa, while others have a continuous cytoplasm with many nuclei in each hyphae. Many fungi exist as a tangle of hyphae, called a mycelium. Most fungi can also exist in the form of a spore, a microscopic reproductive structure that is much more resistant to lack of food or water. Fungi secrete enzymes to digest their food externally and then absorb the nutrients.

Some fungi are edible and some are poisonous. They are found in aquatic environment, soil, mud and decaying plant and animals where organic matter is in abundant. They include bread mold, yeast, mushrooms, etc.

They usually live as decomposers, which absorbs their food from dead or decaying organic matter, called saprophytic fungi or as parasites (growing on or in other living organism and obtaining food from the other living host). Some fungi grow in a mutually beneficial relationship with a photosynthetic algae or plant, which are called as symbiotic fungi. Lichen is an example of such a partnership between a fungus and an algae.

ACTIVITY

Take bread, moist it and leave it for 3/4 days in safe place. Observe the bread after 3/4 days. What do you observe? Have you observed hair like growth/fungal growth on the surface? If not, then again leave the piece for 3/4 days more at the similar condition and observe. Explain and discuss the observation among friends in classroom.

Structure of cell of fungi

Like plant cells, they have a cell wall; however, unlike plant cells, the cell wall lacks cellulose (in true fungi) and there are no chloroplasts.

Cellwall: Cell wall of fungi is of all composed of chitin; complex carbohydrate for strength and flexibility.

Hyphae: Hyphae is a thread like filament, the basic unit of structure of multicellular fungi.

Mycelium: It is the network of hyphae

Fungi also cause a number of plant and animal diseases: in humans, ringworm, athlete's foot, and several more serious diseases are caused by fungi. Fungi are more chemically and genetically similar to animals than other organisms, which make fungal diseases very difficult to treat. Plant diseases caused by fungi include rusts, smuts, and leaf, root, and stem rots, and may cause severe damage to crops.

Diseases caused by fungi	Organs affected
Beriberi	Foot
Ringworm of the nails	Nail
Fungal meningitis	Brain
Aspergillis	Airtract, lungs
Onchomycosis	Skin

Ring worm

Ringworm is a common skin infection that is caused by a fungus. It’s called “ringworm” because it can cause a circular rash (shaped like a ring) that is usually red and itchy.

Ringworm can affect skin on almost any part of the body as well as fingernails and toenails. The symptoms of ringworm often depend on which part of the body is infected. The common symptoms are: itchy skin, ring-shaped rashes, red, scaly, cracked skin, hair loss, etc.

Symptoms typically appear between 4 to 14 days after the skin comes in contact with the fungi that cause ringworm.

Symptoms of ringworm by location on the body:

- **Feet (tinea pedis or “athlete’s foot”):** The symptoms of ringworm on the feet include red, swollen, peeling, itchy skin between the toes (especially between the pinky toe and the one next to it). The sole and heel of the foot may also be affected. In severe cases, the skin on the feet can blister.
- **Scalp (tinea capitis):** Ringworm on the scalp usually looks like a scaly, itchy, red, circular bald spot. The bald spot can grow in size and multiple spots might develop if the infection spreads. Ringworm on the scalp is more common in children than it is in adults.
- **Groin (tinea cruris or “jock itch”):** Ringworm on the groin looks like scaly, itchy, red spots, usually on the inner sides of the skin folds of the thigh.

- **Beard (tinea barbae):** Symptoms of ringworm on the beard include scaly, itchy, red spots on the cheeks, chin, and upper neck. The spots might become crusted over or filled with pus, and the affected hair might fall out.

Prevention

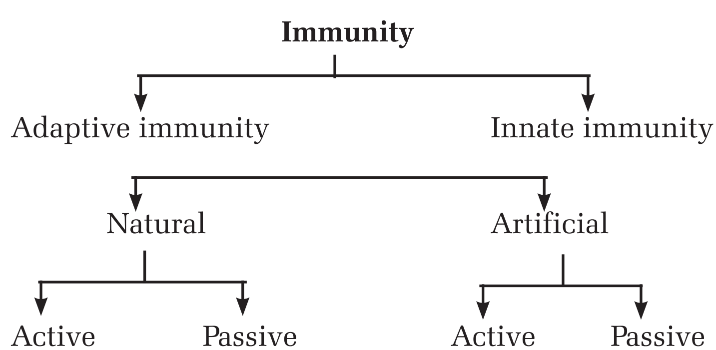
- Keep your skin clean and dry.
- Wear shoes that allow air to circulate freely around your feet.
- Don't walk barefoot in areas like locker rooms or public showers.
- Clip your fingernails and toenails short and keep them clean.
- Change your socks and underwear at least once a day.
- Don't share clothing, towels, sheets, or other personal items with someone who has ringworm.
- Wash your hands with soap and running water after playing with pets. If you suspect that your pet has ringworm, take it to see a veterinarian.
- If you're an athlete involved in close contact sports, shower immediately after your practice session or match, and keep all of your sports gear and uniform clean. Don't share sports gear (helmet, etc.) with other player

Immunity and Vaccination

Introduction

The term immunity refers to the body's ability to defense itself or to fight infection, disease or other unwanted biological invasion. Generally, it is the ability of a body to resist disease. **Immunology is the branch of science that deals with the study of immune system in all organisms.**

Types of immunity



The immunity system is of two types:

1. Innate immune system

2. Adaptive immune system

1. Innate immune system

Innate immune system is responsible for natural immunity. Innate immunity consists of the defenses against infection that are ready for immediate activation prior to attack by a pathogen. It includes physical barrier (eg. Skin and mucous membranes), chemical barrier (eg. Lysozyme, gastric juice, etc) and cellular barrier against infections.

The response to invasion by a microbial agent of infection that overcomes the initial barriers (physical barriers) is rapid, typically initiating within minutes of invasion and recognition by the innate immune system sets the stage for an effective adaptive immune system.

2. Adaptive immune system

Despite the multi-layer innate immunity, some pathogens may evade the innate defense which activates the second defense system, called adaptive immunity or acquired immunity. It is induced by the range of organisms, toxins, transplacental tissues and tumour cells.

The responses of the adaptive immune system are provided chiefly by two types of cells called B-cells and T-cells.

Types of adaptive immune system

Adaptive immune system can be studied into two types:

a) Active immunity b) Passive immunity

a) Active immunity

It is the immunity acquired by immune system

i) **Natural active immunity:** In this type, antibodies are produced during an infection in response to antigen naturally.

ii) **Artificial active immunity:** Artificial active immunity is acquired by vaccines.

Note*: Vaccines produce immunity because it prompts the body to act like it is infected.*

b) Passive immunity

It depends upon the antibodies transported from another person or even from an animal.

i) **Natural passive immunity:** Natural passive immunity is acquired by the transfer of antibodies from mother to a child. It transfers through the placenta before birth and through milk after birth.

ii) **Artificial passive immunity:** It is acquired by injecting antibodies from other animals, humans which are already immune to disease.

Immunization

The process of introducing immunity as a preventive measure against certain infectious diseases is called immunization. There are two basic approaches to immunization; active and passive. With active immunization, modified antigens from pathogenic micro organisms are introduced into the body and cause an immune response. Alternatively, with passive immunization antibodies against a particular pathogen have been produced in one host and are transferred to a second host where they provide temporary protection.

Antigen (Ag) and Antibody (Ab)

Antigen is defined as any substance which when introduced into a body, leads to development of an antibody with which it reacts specifically.

Antibody is defined as a specific protein produced by our body as a result of interaction with an antigen.

Vaccine

Introduction

The word 'vaccine' originates from the latin, *Variolae vaccinae* (Cowpox), which was demonstrated by Edward Jenner in 1798 AD that could prevent small pox in human.

Edward Jenner (1749-1823)

Today the term 'vaccine' applies to all biological preparations, produced from the living organisms, which enhances immunity against diseases and either prevent or in some cases, treat diseases. Vaccines are administered in liquid form either by injection, by oral or by intranasal route and **the process of introducing of vaccine inside the body of a healthy man to develop passive immunity in their body is termed as vaccination (a type of immunization).**

Vaccines are preventive but they usually need to be given before exposure to a disease through some can be effective to post exposure. Example: rabies and small pox vaccine

For the production of vaccines, usually attenuated antigen is collected from any pathogen. This is then injected into the body of horse or sheep where huge quantity of antibodies are produced due to induction of the antigen. These antibodies are applied in the body of a human being where it acts as antitoxin.

> Do you know?
>
> Vaccines usually contain either live or killed germs or components of germs.

> Vaccines prepared from viruses, bacteria and other micro organisms are known as first generation vaccines. Vaccines prepared by recombinant DNA technique/genetic engineering as second generation vaccines and synthetic vaccines as third generation vaccines.

How do vaccines work?

The vaccine is administered in advance so as to give time to the body to set active immunity before invasion of pathogen. When a pathogen enters the human body, it releases a toxic chemical (antigen) to destroy the human defense system. Human body defends itself and destroys that antigen by releasing a very specific chemical called antibody.

Importance of Vaccines

Vaccines are used to develop immunity against specific infections and to destroy or kill the infectious agent.

Some important vaccines

Types of vaccine	Vaccine	Disease
Live attenuated	BCG (Bacillae Calmette Guerin)	Tuberculosis
	Oral polio (sabin)	Polio
	Measles	Measles
	Rubella	Rubella
	Mumps	Mumps
Killed/Inactivated	Injectable polio (Salk)	Polio
	Pertusis (P)	Whooping cough
	Typhoid	Typhoid
	Cholera	Cholera
	Rabies	Rabies

Types of vaccine	Vaccine	Disease
Toxoid	Diptheria (D) Tetanus (T)	Diptheria Tetanus
Sub unit	Hepatitis B	Hepatitis B

National Immunization schedule

Time/Age	Vaccine to be given
At birth	BCG, oral polio-1
6 weeks	Oral polio-2, DPT-1
10 weeks	Oral polio-3, DPT-2
14 weeks	Oral polio-4, DPT-3
9 months	Measles
All pregnant women	Tetanus two doses. Month a part
0.1 and 6 months	Hepatitis B

Note: *A single dose of vaccine may not be sufficient and many doses may be needed initial dose is called primary dose and subsequent doses are known as booster dose.*

SPIROGYRA

Introduction

Spirogyra is common fresh water green algae, widely distributed throughout the world. It is a genus comprising of about 300 species and grows abundantly in spring season in ponds, pools, ditches, springs, lake and slow running rivers and streams. They are usually, free floating filamentous algae but some species of spirogyra such as *S. rhizopus, S. dubia, S. affinis,* **e**tc. remain attached to the substratum with the help of rhizoids. **Since, it is free floating, slimy to touch and looks like a mass of shining long filaments, it is known as "pond silk" or "pond scum."** The filaments are slimy in nature because of the presence of mucilaginous substance around them.

Structure:

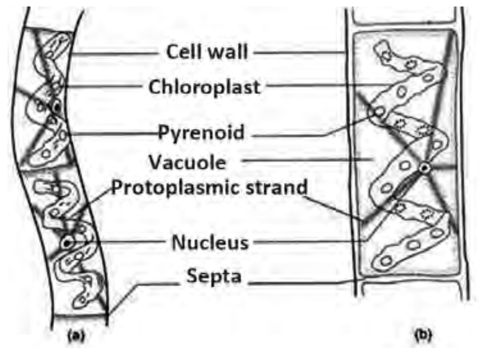


Fig 15.8: Spirogyra

The plant body of spirogyra is gametophytic thallus. The thallus is multicellular, unbranched or unattached silky thread like structure, which is called filament. The young filament is attached to some substratum by the help of basal cells, which is called **hapteron** or **hold fast**. Each filament consists of many cylindrical cells. The cell is surrounded by gelatinous sheath. Cell wall is outermost layer, which is rigid and consists of two layers, the outer layer made up of pectose and inner layer made up of cellulose. Two cells in the filament are separated by a common wall, which is called septum. The cytoplasm contains cell inclusions and cell organelles. There is a central vacuole in the centre of cell which is surrounded by a layer called tonoplast. The vacuole is filled by a liquid called cell sap. There is a nucleus at the centre of cell. In each cell, spirally coiled chloroplast is present in the cytoplasm. In chloroplast, round and spherical bodies are found which are called pyrenoid.

ACTIVITY

Take some green water in a bottle from nearby pond or natural source of water. Take a drop of water along with green object on a slide under microscope. Explain your observation in a classroom with diagram that you observe.

Reproduction

Spirogyra reproduces by vegetative, asexual and sexual methods.

A) Vegetative reproduction

Fragmentation: It is a common method of vegetative reproduction when the conditions are favorable. In this method, the filament may breaks up into small fragments and each such fragment grows into new filament by repeated cell division and growth.

B) Asexual reproduction

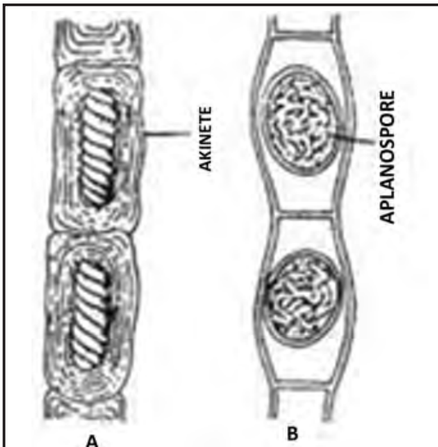


Fig 15.9: Spirogyra – Asexual reproduction
A. Akinete B. Aplanospore

Asexual reproduction in spirogyra is very rarely occurred under unfavorable conditions. In some spirogyra it takes place by akinetes and aplanospores formation.

Akinetes: Under unfavorable condition, some cells of the filament become considerably thick by the addition of thick wall layers around them, which are called akinetes (resting spores containing abundant reserve food materials). With the return of favorable condition, these akinetes germinate into new filaments spirogyra.

Aplanospores: The aplanospores are thin walled spores, which develop singly inside the vegetative cells. The protoplast of the cell loses water and contracts. It rounds off and secretes thin wall around it to become an aplanospore. They are released after the parent cells decay and germinate into new filaments of spirogyra.

C) Sexual reproduction

Under favorable environmental conditions, sexual reproduction takes place by conjugation method. When cells of two filaments of opposite (+ve and -ve) strains conjugate then it is called as conjugation. There are two methods of conjugation:

a) Scalariform conjugation

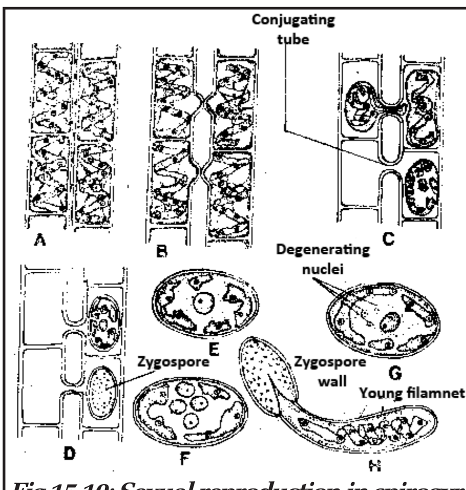


Fig 15.10: Sexual reproduction in spirogyra

Scalariform conjugation is the most common method of sexual reproduction in spirogyra. In this method, two filaments of different strains of spirogyra come close and lie parallel to each other in opposite direction and are surrounded by mucilage sheath, which holds the filaments. Then the cells of the filaments produce small outgrowths towards each other and get attached and forms forming tube like structures, which is called conjugation tube. At this stage, it appears ladder like structure, which is called scalariform. During fusion, the gametes of one filament move towards the gametes of another filament through conjugation tube. The gametes that migrate from the cell are male gametes and the other stationary gametes are female gametes. These two gametes fuse together to from zygote in one filament. The zygote secretes thick spherical wall around it, which is called as zygospore, whereas the cells of another filament, remain empty.

b) Lateral conjugation

The conjugation taking place between adjacent cells of the same filament is called lateral conjugation. The zygospores are usually formed in alternate cells and hence, the lateral conjugation is also called **chain conjugation**. There are two types of lateral conjugation

Direct lateral conjugation

In this method, male gamete penetrates the common septum in between male and female gametes and moves downward and fuses with female gamete to form zygote which later develops into a resting spore called zygospore.

Indirect lateral conjugation

In this method, the male gamete starts to move to lower female cell through conjugation tube and fuse together to form zygote. The zygote secrets wall around it to form zygospore.

Zygospore germination

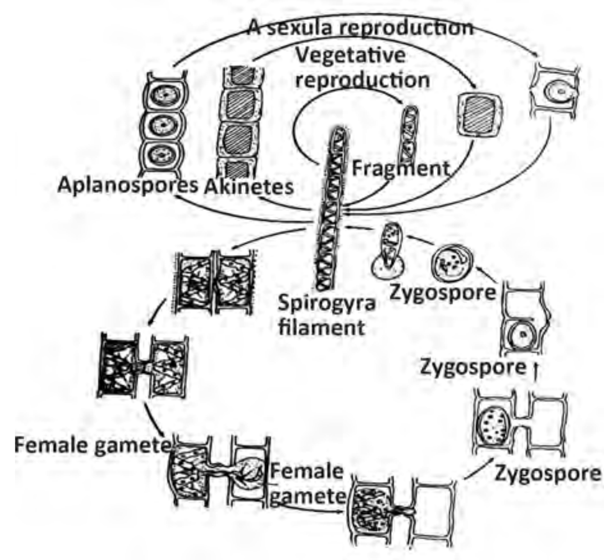


Fig. 15.11: Life cycle of Spirogyra

The zygospore of spirogyra is circular cylindrical and dark brown in colour. The filament of the zygospore decays and zygospore becomes thick walled and sinks at the bottom of water. The diploid nucleus of zygospore undergoes meiosis division and produces four nuclei. Out of four nuclei three degenerate and one remains functional. During favorable condition, the outer wall of zygospore ruptures and inner wall produce small tube called germ tube. Now the germ tube divides transversely with nucleus and septa are formed with the formation of a green new filament of spirogyra.

PARAMECIUM

Introduction

Paramecium is a microscopic, unicellular elongated organism visible to the naked eye as a whitish or greyish spot. Species of *Paramecium* range in size, in length from 80 μm to 350 μm and diameter 170 μm to 290 μm . Cells are typically ovoid, elongate, foot- or cigar-shaped. The anterior end is blunt and semicircular while the posterior end is thick and pointed. The ventral surface is flattened and dorsal surface is concave. The body of the animal is asymmetrical in form showing a well-defined oral and aboral surface. It moves here and there with the help of cilia.

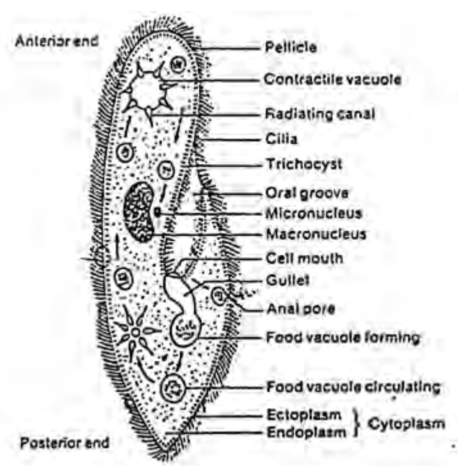


Fig 15.12: Paramecium

*[Note: **the shape of paramecium is lengthy and just like sole of a shoe. So it is named as "slipper animalcule"]***

Habit and Habitat

Paramecium is the most common protozoan having worldwide distribution. They are widespread in freshwater (ponds, pools, streams, rivers, lakes, reservoirs etc), brackish, and marine environments and are often very abundant in stagnant basins and ponds, where organic matter is plenty.

It is a fresh water free living ciliate, feeding upon the bacteria and tiny protozoans. The individuals frequently gather of the surface, especially in contact with floating objects thus forming a white scum. It shows two types of locomotion swimming and creeping with the help of cilia. It is heterotrophic and holozoic.

Structure (Morphology)

External Structure

The external structure of paramecium is complex and consists of pellicle, oral groove, cilia and cytophage.

1. **Pellicle**: The body of *Paramecium* is externally covered by thin, clear, firm and elastic colourless membrane known as pellicle. It gives a definite body form (body shape) to the organism.
2. **Oral groove**: The ventral surface of body bears a prominent, oblique and shallow depression called oral groove, it arises from the middle of body and extends to the left side of anterior end. The cytosome extends into a tubular wide passage known as cytopharynx which terminates into the endoplasm forming a food vacuole. The oral groove, vestibule, cytosome and cytopharynx together are known as feeding apparatus of *Paramecium*.
3. **Cilia**: The entire body surface is covered by a uniform covering of numerous, hair like protoplasmic fine threads called cilia. These are arranged in regular longitudinal rows. The functions of cilia are locomotion and capturing the food particles. They also act as sensory receptors and detect the stimuli of the external environment.
4. **Cytophage:** It is situated on the ventral surface of the oral groove through which undigested food is egested out.

Internal Structure

The cytoplasm, beneath the pellicle, is clearly differentiated into two regions, an outer ectoplasm and an inner endoplasm.

Ectoplasm: The ectoplasm, surrounding the inner mass of endoplasm, forms a clear, dense, thin outer layer which is tough, elastic, supporting and protective. It is also called as cortex. It contains the trichocyst, cilia and bounded externally by a pellicle.

Trichocysts: Beneath the pellicle, numerous peculiar, tiny, spindle-shaped or bottle shaped organelles, arranged perpendicular to the body surface are present, which are called trichocysts. Each trichocyst consists of an elongated shaft and a terminal pointed tip, called the spike or barb, covered by a cap. The trichocyst helps in defense as well as offence and also helps in sticking.

Endoplasm

Below the ectoplasm the large, central, granular and semi-fluid zone is the endoplasm. It includes the usual cell components like food vacuoles, reserve food granules of starch, glycogen and fat, mitochondria, golgi bodies, ribosomes and various crystals and other cytoplasm inclusions of varying size, shape and character.

(1) **Nuclear apparatus**: *Paramecium* is binucleated having two types of nuclei:

(a) **Macronucleus**: The macronucleus is roughly kidney shaped and without nuclear membrane, possess many nucleus and much more chromatin material (DNA). It is derived from micronucleus during reproductive processes and divides asexually during reproduction. It is situated near the cytosome and controls the metabolic activities of the cell.

(b) **Micronucleus**: A small rounded micronucleus is lodged in a depression on the surface of the macronucleus. It has a nuclear membrane and with diploid number of chromosomes. It controls the reproductive activities of the organism and always divides mitotically.

(2) **Contractile Vacuoles**: In *Paramecium*, there are two large liquid filled contractile vacuoles situated on the dorsal surface of anterior and posterior ends. It is of fixed shape. The contractile vacuole opens to the outside through a distinct discharge canal in the pellicle of dorsal side. Each contractile vacuole is surrounded by six to ten elongated radiating canals, which are also known as feeding canals or radiating canals. Main functions of contractile vacuoles are: maintaining osmoregulation, excreting excess water and removal of carbondioxide

(3) **Food Vacuoles**

Numerous non-contractile food vacuoles are found inside the endoplasm is term as gastrides. The food vacuoles move by its streaming movement (like that of needles of watch) in that endoplasm which is known as cyclosis.

(4) **Oral Apparatus**

In *Paramecium*, there is a broad shallow oral groove leads ventrally and posteriorly. The oral groove extends obliquely backwards into a bucccal funnel shaped depression called vestibule. The vestibule leads into a wide tubular passage, the buccal cavity. It leads into a wide cytopharynx through a fixed, oval shaped opening called cytosome. The cytopharynx forms a food vacuole at its proximal end.

Life cycle of *Paramecium*

Paramecium, the most common ciliate of fresh water, reproduces asexually by transverse binary fission as well as sexually by conjugation.

(I) Asexual reproduction (Transverse Binary Fission)

During favourable conditions, *Paramecium* commonly reproduces by transverse binary fission, where single individual divides into two daughter individual.

The daughter *Paramecium* formed from anterior is called proter and as opisthe formed from posterior.

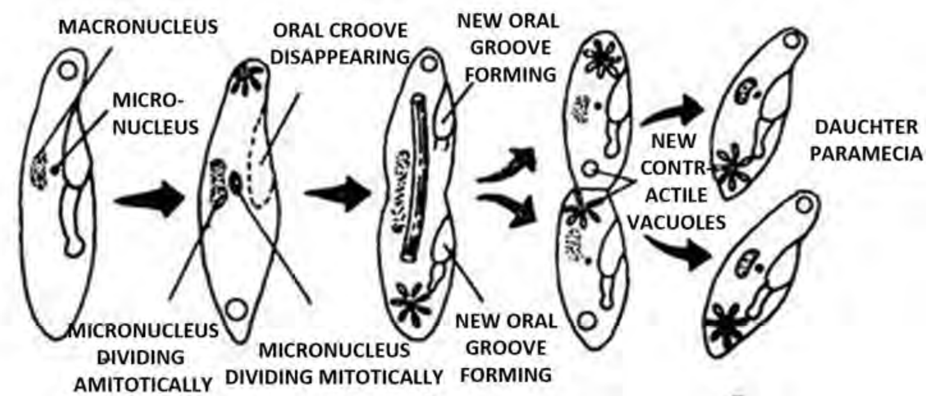


Fig 15.13: Transverse binary fission in Paramecium

(II) Sexual reproduction (Conjugation)

Temporary pairing of two individuals of the same species but from two different mating types for *Paramecium* undergoes a sexual phenomenon, which is called conjugation. During the process, two paramecia come closer and get attached together from side of oral groove by some sticky substances where pellicle degenerates to form cytoplasmic bridge. The micronucleus undergoes meiosis division in each conjugant to give four nuclei among which three nuclei degenerate and only one remain functional. The remaining one nucleus of each conjugant undergoes mitosis division to produce two nuclei. Out of two nuclei, one is larger (stationary/female nucleus) and other is smaller (migratory/male nucleus).

The migrated nucleus fuses with stationary nucleus in each conjugant to form zygote nucleus. The zygote undergoes mitosis division 3 times to produce 8 nuclei (4 macronculeus and 4 micro nucleus). Out of 4 micronucleus 3 degenerate and one remains functional.

The functional micronucleus divides into two and the conjugant divide by binary fission into two daughter paramecia, each containing two macronuclei and one micronucleus.

The micronucleus again divides with the division of each daughter paramecium, forming two individuals, each containing one macronucleus and one micronucleus. Thus each conjugant produces four daughter individuals of the end of conjugation.

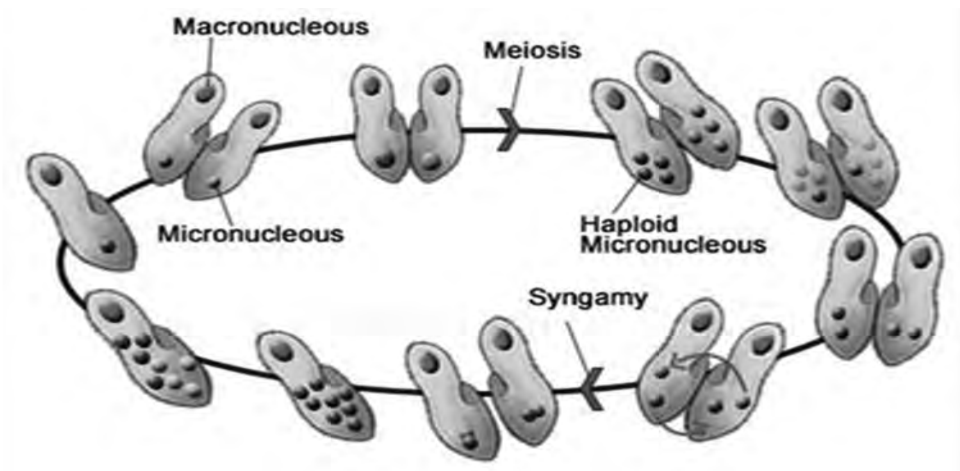


Fig 15.14: Stages of Conjugation in Paramecium

ACTIVITY

Bring a cardboard paper and draw the various stages of life cycle of *Paramecium*. Put suitable colours in these diagrams. Explain the process in the classroom.

PLANT PHYSIOLOGY

The study of life processes is called physiology and the study of life processes of plants is called plant physiology.

OSMOSIS

If two solutions of different concentration are separated by a semi-permeable membrane, only water diffuses from one side to another side of the membrane because semi-permeable membrane only allows solvent to pass through it. The process involved in this event is termed as osmosis. **Hence osmosis can be defined as the movement of water from a region of its higher concentration (dilute**

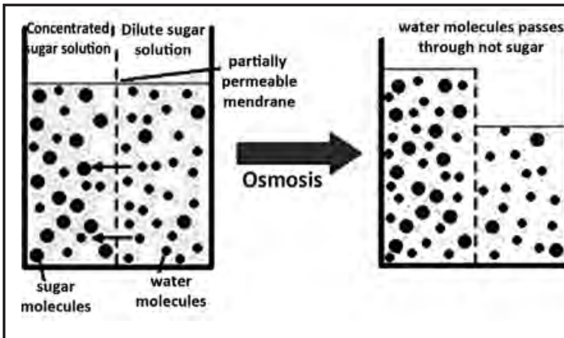


Fig 15.15: Osmosis

solution) to the region of its lower concentration (stronger solution) through semi-permeable membrane until the equilibrium is reached.

ACTIVITY:

Take a large sized potato tuber. Cut one side of it so as it becomes flat. Bore a cavity from the other side in such a way that very thin base is left. Pour sugar solution in the cavity of the potato tuber upto 2/3 level. Mark the level of the sugar solution with the help of pin. Place the tuber in a beaker containing water added with safranin (colouring agent) upto half of tuber. What do you observe?

Discuss your observation among your friends in a classroom.

Osmosis in plant cell

Plant cell behaves as an osmotic system. The cell wall is usually freely permeable to substance in solution, so as cell membrane is semi-permeable in nature, it is only involved in osmosis. If plant cell is subjected to the hypertonic solution (solution having more concentration than cell sap) then water comes out of the cell. This process is termed as exosmosis. When it is placed in hypotonic solution (solution having less concentration than cell sap), the water enters into the cell. This process is called endosmosis. The solutions having the same concentration as cell sap as shown in figure is called isotonic solution, there will be no water movement.

ACTIVITY:

Take some water in bowl. Add some raisins in it. Leave it for 2/3 hours. Record what you observe. Now take some sugar solution in a bowl and add that swollen raisin in it. Leave it for 2/3 hours. What do you observe? Record it. Discuss in a classroom.

The raisin swells up due to endosmosis and when we keep the swollen raisin in sugar solution it shrinks due to exosmosis.

Importance of osmosis

a) Plant root absorbs water by the process of osmosis.

b) Osmosis is utilized for cell to cell movement of water.

c) Osmosis helps in growth of the tissue.

TRASPIRATION

After water is absorbed and transported to leaves it is utilized in small (less than 1%) amount. The excess water normally leaves the plant in the form of vapour. **Hence, throwing out of excess water from plant in the form of vapour is called transpiration.**

Types of Transpiration

a) **Stomatal:** This type of transpiration occurs through stomata. About 90% of total transpiration takes place by stomata.

b) **Cuticular transpiration:** In this type, water lost from cuticle or epidermal cells of leaves and other exposed parts of the plant. About 3-10% of transpiration takes place by this method.

c) **Lenticular:** The transpiration occurring through lenticels found on the epidermal layer of woody branches of the trees is termed as lenticular transpiration. Only 0.5% of the total transpiration takes place by this method.

d) **Bark transpiration:** This types of transpiration occurs through corky covering of the stem. This occurs very little but due to being occurred in very large area, the total loss of water may be more than lenticular transpiration.

Significances of transpiration

1. Transpiration helps to remove excess water that enables plants to absorb extra water and minerals.
2. It lowers down the temperature of plant which is increased by sun light or other factors.
3. It helps in the development of mechanical tissue.
4. The ash and sugar content of the fruit increases due to transpiration.

RESPIRATION

Respiration is a biological oxidation of organic food into simple inorganic forms with release of energy. It is a vital process which occurs in all living cells of plants and animals. The energy released during respiration is used in almost all the life activities (Adenosine triphosphate). Whenever energy is necessary, ATP is broken down into ADP (Adenosine diphosphate) and inorganic phosphate. So, ATP is also called currency of cell.

The overall respiration process may be represented as:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 686 \text{ Kcal}$$

This reaction occurs within cells so it is called cellular respiration.

Types of respiration

There are two types of respiration:

a) Aerobic respiration b) Anaerobic respiration

a) Aerobic respiration

In aerobic respiration, there is complete oxidation of stored food and formation of CO_2 and H_2O, in the presence of oxygen. Energy is released in large amounts (686Kcal). Some of this energy is trapped as energy rich compounds (ATP and $NADPH_2$) and the remaining is lost in the form of heat.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 686Kcal$$

b) Anaerobic respiration

In anaerobic respiration, there is incomplete oxidation of food in the absence of O_2. Ethyl alcohol or lactic acid and CO_2 are produced in this respiration. It takes place when there is deficiency of oxygen in cell. It releases small amount of energy.

$$C_6H_{12}O_6 \longrightarrow 2CO_2 + 2\,C_2H_5OH + 50\text{ Kcal}$$

$$C_6H_{12}O_6 \longrightarrow 2C_3H_6O_3 + 36\text{ Kcal}$$

Differences between aerobic respiration and anaerobic respiration

Aerobic respiration	Anaerobic respiration
1. Oxygen is utilized for breaking the respiratory substrate into simple substrate.	1. Oxygen is not utilized for breaking the respiratory substrate into simple substrate.
2. End products are inorganic.	2. End products are organic; inorganic may or may not be produced.
3. Complete oxidation of food takes place.	3. Incomplete oxidation of food takes place.
4. Large amount of energy is released.	4. Less amount of energy is released.
5. Takes place in cytoplasm and mitochondria.	5. Takes place in cytoplasm
6. Occurs in most animals and higher organisms.	6. Common in lower organism like yeast and bacteria, and occurs temporarily in higher organisms.

Importance of respiration

1. Energy is necessary for all living organism. It needs continuous supply of energy, without energy cell cannot live.
2. Besides energy, respiration yields many biochemical intermediates that take part in growth, repair and metabolism.
3. About 50% of the energy released during cellular respiration is used for active transport of substance in and out of the cell against nerve conduction, osmotic work, development, cell division, muscular contraction, etc.
4. Heat energy released during respiration is used to maintain a constant body temperature in birds and animals.

Summary

1. Microbiology is the study of microorganisms, that cannot be seen with our naked eyes and can be unicellular (single cell), multicellular (cell colony), or acellular (lacking cells).
2. Microorganisms are almost everywhere in our environment such as air, water, soil, food, on and inside of living organisms, where the conditions are favourable for their growth and metabolisms.
3. Virus is acellular infectious agent of small size, which is made up of genetic material and protein that can multiply only in living cells of animals, plants, or bacteria.
4. Virus is considered both as living and non living things.
5. In humans, smallpox, common cold, chickenpox, influenza, herpes, hepatitis, polio, rabies, ebola and AIDS are examples of viral diseases.
6. AIDS (Acquired immune deficiency syndrome) is a viral infection caused by HIV (Human immuno deficiency virus). HIV infects white blood cells and weakens the immune system of the patient.
7. Bacteria are single cellular microscopic organisms which can be found in soil, water, food, hot springs, radioactive waste, different objects and even on and inside the body of living or dead organism.
8. Bacteria can cause many diseases like typhoid fever, tuberculosis, cholera, dysentery, food poisoning, sore throat, urinary tract infection and other many type of infections like blood, wound, meninges, etc.

9. Protozoa are free living eukaryotes found in fresh or marine water, damp soil while terrestrial species inhabitat decaying oraganic matter. Some species are parasitic and commensal on plants and animals.

10. Many protozoa cause diseases in animals and humans like *Plasmodium*, which causes malaria, *Trichomonas*, which cause sexually transmitted diseases, Entamoeba (*Amoeba)*, which causes dysentery, etc.

11. Fungi are heterotrophic and have cell walls made of chitin rather than cellulose.

12. Immunity refers to the body's ability to defense itself or to fight against infection, disease or other unwanted biological invasion.

13. The process of introducing immunity as a preventive measure against certain infectious diseases is called immunization.

14. The immunity system is of two types: Innate immune system and Adaptive immune system.

15. 'Vaccine' applies to all biological preparations, produced from the living organisms, that enhance immunity against disease and either prevent or in some cases, treat diseases.

16. Spirogyra is a common free floating green algae, slimy to touch and looks like a mass of shining long filaments. It is known as "pond silk" or "pond scum."

17. Paramecium is a microscopic, unicellular elongated organism visible to the naked eye as a whitish or greyish spot, its shape is lengthy and just like sole of a shoe. So it is named as "slipper animalcule"

18. The study of life processes is called physiology and the study of life processes of plants is called plant physiology.

19. Osmosis can be defined as the movement of water from a region of its higher concentration (dilute solution) to the region of its lower concentration (stronger solution) through semi-permeable membrane until the equilibrium is reached.

20. The throwing out of excess water from plant in the form of vapour is called transpiration.

21. Respiration is a biological oxidation of organic food into simple inorganic forms with release of energy in the form of ATP.

Exercise

A. Tick (√) the best alternative from the followings.

1. Which one is not the scope of microbiology?

   i) Bio-technology ii) Genetics

   iii) Genetic engineering iv) Immunology

2. The term virus was discovered and coined by:

   i) Beijerinc ii)Stanley

   iii) Hooke iv) Leeuwenhoek

3. HIV/AIDS is not transmitted by:

   i) Kissing ii) Using contaminated syringe

   iii) From infected mother iv) By transfusing contaminated blood

4. Bacteria was named as animalcules by:

   i) Robert Koch ii) Antonie Van Leeuwenhoek

   iii) Ehrenberg iv) Louis Pasteur

5. Which type of disease is a tuberculosis?

   i) Viral ii) Fungal

   iii) Bacterial iv) Protozoal

6. Which one is the type of vaccine?

   i) Live attenuated ii) Killed/Inactivated

   iii) Toxoid iv) All of the above

7. The basal cells which help young filament to attach to the substratum is called

   i) Hapteron ii) Thallus

   iii) Filament iv) Pyrenoid

8. The locomotory organ of *Paramecium* is

i) Flagella ii) Pellicle

iii) Cilia iv) Pseudopodia

9. Which one is true about osmosis?

i) Osmosis can be defined as the movement of water from its higher concentration to its lower concentration through semi-permeable membrane.

ii) Osmosis can be defined as the movement of solute from its higher concentration to its lower concentration through semi-permeable mrmntsnr.

iii) Osmosis can be defined as the movement of water from concentrated solution to the dilute solution through semi-permeable membrane.

iv) none

10. Ethyl alcohol is the product of:

i) Anaerobic respiration ii) Aerobic respiration

ii) Both i) and ii) iv) None

B. Answer the following short questions:

1. Define microbiology. What are its importance?
2. 'Viruses are considered both as living and non living things,' Justify.
3. What is bacteriophage? Draw its well labeled diagram.
4. List the importance of bacteria.
5. Why is fungi known as saprophytes?
6. What do you mean by immunity and vaccination?
7. *Spirogyra* is known as "pond silk", why?
8. Define osmosis. List its importance.
9. What do you mean by transpiration? Write its significances.

10. What is respiration? What are its importance?

11. Write the difference between:

    a. Innate and adaptive immunity

    b. Exosmosis and endosmosis

    c. Scalariform conjugation and lateral conjugation

    d. Aerobic and anaerobic respiration

    e. Autotrophic and heterotrophic organisms.

12. Give two examples of plant and animal viruses respectively.

13. Write the shape of bacteria with one example of each.

14. Make a list of some common fungal diseases.

C. Answer the following long questions:

1. Describe the structure of virus.

2. Who discovered bacteria first? Describe the structure of bacteria with a well labelled diagram.

3. What are the characteristics of protozoa? Describe the structure of protozoa.

4. Describe the structure of fungi in brief. Draw a well labeled diagram of mushroom.

5. What is vaccine? What are it types? Explain with examples of each.

6. Explain the structure of *Spirogyra* with a well labeled diagram.

7. Describe the structure of *Paramecium* with a well labelled diagram.

8. Write short notes on:

    (a) AIDS (b) Tuberculosis

    (c) Malaria (d) Ringworm

Project Work

1. Collect different types of mushrooms available in your surroundings. Study different parts of those collected mushrooms and prepare a report on it.
2. With the help of your seniors or teachers, collect the data on the vaccination and immunization schedule in Nepal. Prepare a report and present in your classroom.
3. Make a report on different viral, fungal, protozoal diseases common in your surroundings. Write in detail about the causative agent, mode of transmission, symptoms, preventive and control measures of those diseases. Also write your opinion that how a person can be protected from such diseases.

Glossary

Fermentation : the chemical breakdown of an organic substance by bacteria, yeasts, or other microorganisms into simpler substances in absence of oxygen.

Brewing : To make (ale or beer) from malt and hops by grinding, boiling, and fermentation

Pathogens : a bacterium, virus, or other microorganism that can cause disease

Glycoprotein : any of a group of complex proteins, as mucin, containing a carbohydrate combined with a simple **protein**.

Hispanic **:** Solution having lesser construction of salt.

Viscous : having a thick, sticky consistency between solid and liquid

Granules : a small piece like a grain of something

Latent : present and capable of emerging or developing but not visible, active, or symptomatic

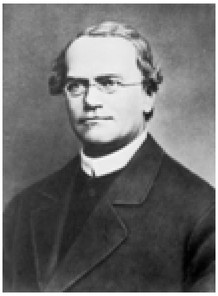
Chills : A sensation of coldness, often accompanied by shivering and pallor of the skin

Mucilage sheath : moist and sticky sheath

Septum	:	a partition separating two chambers
Aboral	:	the side or end that is furthest from the mouth, especially in animals
Egest	:	the act or process of discharging undigested or waste
Brackish	:	slightly salty
Symbiotic bacteria	:	These bacteria have a mutual benefit from other organisms.
Parasitic bacteria	:	These bacteria are present in plants, animals and human beings. These bacteria feeds on host cells and causes harm to the host.
Etiquette	:	Socially acceptable behavior, rules governing
Commensal	:	living together in close association
Osmoregulaiton	:	The maintenance of sonstant osmotic pressure in the fluts of an organism by the control of water and salt concentrations.

Unit 16 Heredity and Evolution

Gregor was the first who gave the mathematical foundation of the science of genetics. He gave different laws of inheritance.



Gregor Johann Mendel (1822-1884AD)

Learning outcomes

After the completion of this unit, learners will be able to

1. Introduce to genetics and define terminologies related with genetics.
2. Differentiate between DNA and RNA with their respective diagrams.
3. Describe Darwin's theory of evolution.

Introduction

An organism produces an organism of its own kind. Dog gives birth to puppy, woman gives birth to a human baby, mango seeds grow into mango plants, etc. Puppy always grows and appears like the dog never as the cat. Why does human give birth to human baby who has the characteristics like his/her own parents have? It seems to be simple but interesting. Similarly a seed from a mango will always grow into a mango tree not into another plant, why? This **phenomenon of transmitting parental characteristics to their offspring is called heredity and the characteristics which are transmitted to their offspring are called hereditary characteristics.**

Every organism possesses its own characteristics and each characteristic is coded in 'gene'. The term gene was coined by **Johannsen** in 1909 AD. The gene transmits the parental characteristics to the offspring. Whereas during the life, organism develops some characteristics for its survival which is called acquired characteristics. The hereditary characteristics and acquired characteristics bring up to variation and the altered hereditary material is again transmitted to ovum and sperm and the process continues.

The heredity and variation lead to the organic evolution and formation of a new species. **The branch of biological science which studies about the heredity and variation is called genetics.** The term genetic was introduced by **W. Bateson** in 1905 AD. But, **Gregor Johann Mendel** (1822-1884 AD) was the first person who studied about the transmission of hereditary characteristics and variations with his experiments on pea plant and introduced the concept of genes as the basic unit of heredity. On the basis of his experiments, he published his result in the "Proceeding of the natural, historical society of Brunn" which was remained unnoticed until 19^{th} century, when three scientists **Hugo de Vries, Tsechermak** and **Correns** enlighten the significances of Mendel's experiment. For his work, Mendel is also called 'Father of Genetics'.

In this chapter we will study about genetics, chromosome, DNA and RNA, Darwin's theory and variation and mutation.

Some terminologies commonly used in molecular biology

1) **Gene:** A gene is a sequence of nucleotides in the deoxyribonucleic acid (DNA) which codes for a particular character. Simply, it is a segment of DNA which has information for synthesis of a protein, responsible for a particular character.

   Functions of gene

   a) It determines the character of the organism.

   b) It is responsible to transmit parental character to the offspring.

   c) It codes for protein to control the metabolism.

   d) The change in gene brings evolution.

2) **Allele/Allelomorphs:** Allele is one of the other forms of the same gene responsible for determining contrasting characters. For example: allelomorphs R(red) and r(white) are the alleles of gene for petal colour.

3) **Homozygous:** An individual having two identical alleles is called homozygous. It is also called pure breed. For example: organisms having TT and tt are homozygous.

4) **Heterozygous:** An individual having two non identical alleles is called heterozygous. It is formed when two pure parents having contrasting characters are crossed. It is also called hybrids. For example: organism having Tt, Rr, etc.

5) **Hybridization:** The process of cross between dissimilar parents to form hybrid is called hybridization.

Chromosome

The term 'chromosome' was given by Waldayer (1888AD). Chromosomes are thread like molecules that carry hereditary information for everything. They are made up of protein and molecules of DNA, which contains genetic information of organisms, transmitted from parents. Most of the chromosomes are arranged in pairs called homologous chromosomes within the nucleus of a cell. Humans have 23 pairs of chromosomes.

Structure of chromosome

A chromatid is a condensed DNA subunit of a chromosome. The two chromatids of a duplicated chromosome are held together at a region of DNA called centromere (as shown in figure). Centromeres are the points which are responsible for the guiding the movement of chromosomes during cell-division.

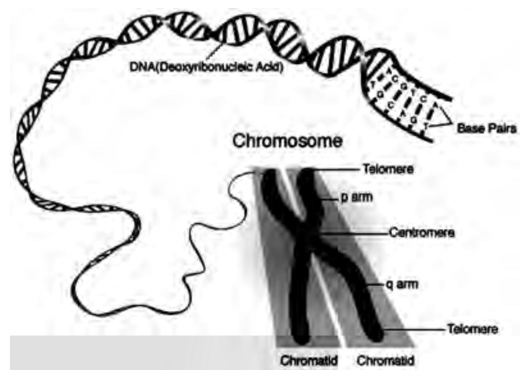


Fig 16.1: Prokaryotic cell

Most eukaryotic cells contain two sets of chromosomes, where one set is originated from paternal origin and remaining from maternal origin. For example, every human cell has 23 pairs of chromosomes: one chromosome of each pair is inherited from the father (through sperm) and the other is inherited from mother (through the egg).

Genetic materials

Genetic materials are those materials which have following characteristics;

a) It should express itself from chemical, metabolic and morphological characteristics to its carrier.

b) It should be able to transmit the information regarding all the biochemical activities from parents to offspring.

c) It should be able to replicate and inherit to offspring, etc.

Nucleic acid

The nucleic acids are the most important molecules produced in the nucleus of cells. They are composed of carbon, oxygen, hydrogen, nitrogen and phosphorous. They are a long chain of nucleotides. Each nucleotide is composed of pentose sugar, nitrogenous base and phosphoric acid. On the basis of type of pentose sugar, nucleic acid can be studied into two types: Deoxyribo nucleic acid (DNA) and ribonucleic acid (RNA). They are responsible for all characteristics of a species and also for biosynthetic activities in the cell.

A) Deoxyribonucleic acid (DNA)

It is a double stranded helically coiled macromolecule present in the nucleus, however, it is also found in mitochondria and plastids in a small amount. DNA can be defined as the genetic material which transmits parental characteristics to the offspring.

> Do you know?
>
> Double stranded helix structure of DNA was proposed by James Watson and Francis Crick in 1953 AD. And for that model they were awarded with Nobel prize in 1962 AD.

Structure 0f DNA

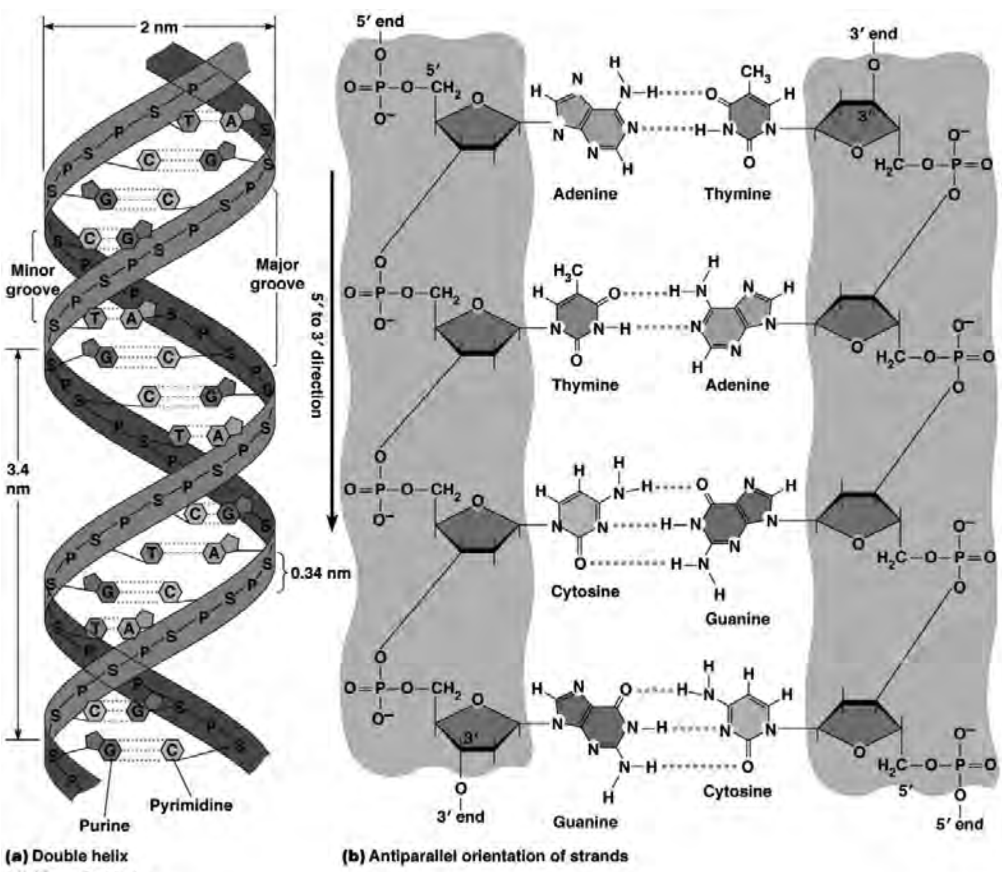


Fig 16.2: Structure of DNA

DNA is helically twisted double stranded polymer of deoxyribonucleotides. Each DNA approximately contains 10^{10} deoxyribonucleotides.

A DNA molecule contains two complementary strands which are spirally coiled around central axis. Two strands are antiparallel and connected by phosphodiester bond.

There are two types of nitrogenous bases in DNA; Purine (includes Adenine and Guanine) and pyrimidine (includes Cytosine and Thymine). In which adenine always pairs with thymine and guanine always pairs with cytosine (hence A=T and C ≡ G are called complementary base pairs).

Do you know?

Thymine and thiamine are different. Thymine is nitrogenous base whereas thiamine is vitamin B1.

On the basis of X-ray diffraction studies of DNA, Watson and Crick put forwarded some findings about DNA in 1953 AD. Some of them are mentioned below:

a) DNA is a double stranded molecule in which two complementary strands are anti-parallel.

b) The distance between two opposite strands is 20A°. [1 A° = 10^{-10}m]

c) The distance of one complete spiral turn is 34 A° which includes 10 base pairs. So, the distance between two consecutive base pairs is 3.4 A°.

d) Adenine and thymine always bonded with double hydrogen bond and cytosine and guanine always bonded with triple hydrogen bond.

Activity

Take a card board paper and draw a well labeled diagram of DNA, colour it with suitable colours and explain about the information of DNA among your friends.

Functions of DNA

a) It acts as a carrier of genetic information from generation to generations.

b) It synthesizes RNA through the process of transcription.

c) It acts as a prime molecule during protein synthesis.

d) It controls biological activities of cells through RNA.

B] Ribonucleic acid (RNA)

Ribonucleic acid (RNA) is a single stranded polymer of ribonucleotides of adenine (A), uracil (U), cytosine (C) and guanine (G) joined together by phosphodiester bond. It is found in nucleolus, ribosomes, mitochondria, chloroplast and cytoplasm. It consists of ribose sugar, nitrogenous bases (A, U, G and C) and phosphoric acid.

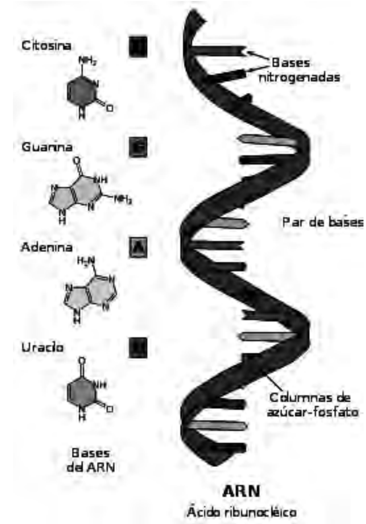


Fig 16.3: Structure of RNA

On the basis of molecular size and functions, there are three major types of RNA;

a) Ribosomal RNA (rRNA): It is the most abundant and stable type of RNA comprising 70-80% of total cellular RNA. It helps to form complete functional ribosome and play a key role in the binding of mRNA.

b) Messenger RNA (mRNA): It carries the genetic information specifying sequence of amino acids in a protein from DNA to ribosome. It comprises 5-10% of total RNA and it helps in protein synthesis.

c) Transfer RNA (tRNA): It comprises 10-15% of total RNA and the second most stable type. It carries amino acid molecule to the ribosome for protein synthesis.

Funcitons of RNA

a) It plays major role in protein synthesis.

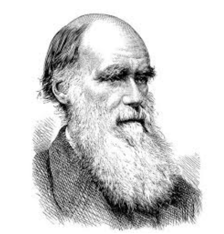
b) In some RNA viruses like HIV, rhino virus, tobacco mosaic virus etc, it acts as a hereditary/genetic material.

Differences between DNA and RNA

Deoxyribonucleic acid (DNA)	Ribonucleic acid (RNA)
a) It is double stranded and helical structure.	a) It is single stranded and non helical.
b) It is a long chain of deoxyribonucleotides.	b) It is a long chain of ribonucleotides.
c) Pentose sugar is deoxyribose sugar.	c) Pentose sugar is ribose sugar.

Deoxyribonucleic acid (DNA)	Ribonucleic acid (RNA)
d) It contains adenine, cytosine, guanine and thymine as nitrogenous bases.	d) It contains adenine, cytosine, guanine and uracil as nitrogenous bases.
e) It is found in nucleus.	e) It is found in cytoplasm.
f) It is the genetic material in all organisms except RNA viruses.	f) It is not a genetic material except in RNA viruses.
g) It carries genetic information to offspring.	g) It plays major role in protein synthesis.

Darwin's theory of evolution


Charles Robert Darwin

Many theories were put forward to explain the mechanism of organic evolution but the most acceptable theory, theory of natural selection was given by **Charles Robert Darwin (1809-1882AD).** Darwin was an English naturalist. He published his famous book "**The origin of species through Natural Selelction"** in 1859, to explain the theory of evolution and how new species could have arisen. Darwin's theory is based on the following three observations and two conclusions.

Observation 1

The individuals in a population of animals and plants produce more offspring than needed to replace the parents.

For example, suppose that a pair of dogs have four offspring and these form 2 pairs which again produce 4 offspring. If this continued unchecked in the fourth generation there will be 32 dogs of the original pair (that is 2----4----8----16----32)

Observation 2

Despite this tendency to increase, the numbers of individuals in any population remain approximately constant. The population of the dogs in the above example remain or less constant generation after generation.

Conclusion 1

From the above two observations the following conclusion is made. Many individuals fail to survive or reproduce. There must be a 'struggle for existence' in a population.

The 'struggle for existence' is in operation in nature because the individuals compete for food and shelter. In any organism the competition may be at any stage.

Observation 3

Individuals of a species vary from each other by small differences. The variations or differences which can be inherited only are of significance in evolution.

Conclusion 2

Those individuals that possesses suitable variations have the advantage to survive or there is 'the survival of the fittest". Here the nature or environment selects the adaptable individual and the stronger members survive and continue its generation.

The main features of Darwin's theory are as follow:

1. **Over production/enormous fertility**

   All the organisms continue their race by producing large number of offspring of their own kind, that can hardly be supported by a particular environment and can possibly survive. If all the offspring survive and reproduce, then soon the earth be overcrowded. Imagine what if all seeds of a plant, or eggs of an animal were developed into adults? The earth will be occupied by the single type of plant or animal. This capacity of organisms to reproduce in large number is called overproduction. This overproduction is checked by great destruction so that the total number of organisms remains constant.

2. **Struggle for existence**

   Due to the availability of limited amount of food and space, organisms have to compete among themselves for food and shelter. The competition may be intra-specific (between same species) or inter-specific (between different species). Organisms also have to struggle against the environmental conditions such as cold, heat, flood, light, etc. This struggle for primary necessities of life is called struggle for existence. As a result of this struggle among the organisms, only few of them survive and reach the reproductive stages and reproduce. So, it helps to check the over production of organisms.

3. **Natural selection/survival of the fittest**

   In the course of struggle for the existence, only the successful variants survive and reproduce further while others who cannot struggle are eliminated. Nature is the super power that selects best fitted individuals and weak and poorly developed individuals are eliminated and usually die. In simple words those organisms who can change their characteristics according to the changing environment can survive long lasting. This process is known as the survival of the fittest or the natural selection.

4. **Variations and heredity**

   Environment is changing continuously and organisms are also changing according to the environment for their survival. This change in organisms is called variation. Darwin noticed two types of variation: useful variation and harmful/useless variation. Useful variation helps organisms to be fit in the nature whereas useless or harmful variation makes them unfit and extinct. Such variations are transmitted from generation to generation so that progenies are more suited. Darwin noticed that no two organisms are alike. Even two individuals of the same species are different.

5. **Origin of new species**

   Due to the continuous variation and due to the transmission of useful variations to the progenies, the progenies become more suited for the environment. After successive generation of this process, the organisms became different from its parents. As a result, new species is raised.

Criticism in Darwinism

1. Natural selection is not only the sole cause of evolution. New species may also arise due to mutation.
2. He did not explain the presence and the effects of use and disuse of vestigial organs.
3. He did not differentiate between somatic and germinal variations.
4. Darwinism explained the survival of fittest but not arrival of the fittest.
5. Darwinism is unable to explain the origin of highly specialized particular structures like tusks of elephants, electric organ of Torpedo, etc.

Due to the presence of these critics, Darwin's theory of origin of new species was modified and elaborated under the heading of 'Neo-Darwinism' or 'Modern Synthetic Theory'.

Variation and mutation

While saying all the organisms are similar with their parents, it is also true that the offsprings are not exact copy of their parents. They also have some different characteristics with their parents. It simply means that though, offspring resemble most of the characteristics from their parents, they are not exactly similar. For example; human mother gives birth to a human child but never resembles to either of the parents in all aspects. Even twins have some different features in the shape, movement or behaviours. No two trees of same species are exactly similar. And, this difference between parents and offsprings or among the offsprings of the same parents is called variation which provides individuality to the organism. It is caused by a combination of genetic and environmental factors like food, light, temperature, humidity, etc. It is of two types on the basis of degree of differences viz; continuous variation and discontinuous variation.

A] Continuous variation

It is an unstable variation and fluctuate according to the change in environment. It occurs gradually but is non inheritable so it is not considered as important from evolutionary point of view. Change in height, weight, size, colour of the organism, etc are the examples of continuous variation.

B] Discontinuous variation

The variation that occurs suddenly is called discontinuous variation. It is stable and inheritable. Mutation is the cause of discontinuous variation. Hairless variety of dogs, cats, a newly born child having additional digits in finger and toes, fused finger, etc are the examples of discontinuous variation.

The main factors that bring out genetic variation are as follows:

A] Genetic recombination

New combination of genetic material appears in offspring produced as a result of crossing of heterozygous parents. And, the process of formation of new combination of genetic material is called genetic recombination which brings out variation.

B] Mutation

Mutation is defined as sudden, stable, discontinuous and heritable change in gene or chromosome of an offspring. The product of mutation is called mutant and the cause of mutation is called mutagen. It is a permanent change.

Darwin's theory of evolution was based on slow variation shown by individual of the same race. According to the Darwin, variation is a gradual and slow process. But Hugo de Vries in 1901 AD found that heritable variations are not slow or gradual or continuous but sudden and discontinuous for what he introduced a term mutation.

Broadly, mutations are divided into following types:

a) Gene or Point mutation or micro mutation

A change in chemicals of DNA of a cell is called a gene mutations or point mutations or micro mutation. This mutation alters the sequence of the nucleotides within a part of the DNA molecule and results in differences in the proteins being produced. For example, in sickle cell anaemia, the mutation of a single gene causes a slight change in the structure of the protein molecule of hemoglobin, and because of that slight change, the blood cell that carries the hemoglobin takes a sickle shape.

b) Chromosomal mutation or macro mutation.

A structural change in chromosome or a part of chromosome is called chromosomal mutation or macro mutation. Chromosomal mutations are changes in the DNA molecule, which result in mistakes in producing proteins as compared to most people. These types of changes in chromosomes are caused by radiation, chemicals, and even by some viral infections. The conditions caused by chromosomal mutations are called genetic disorders. Chromosomal mutations can be inherited from parents to their offsprings. Chromosomal mutations happen when the building blocks of a DNA double-helix molecule switch places, get inserted or deleted or shift places.

Some chromosomal mutations are common and harmless, such as different eye colors in humans but some result a chronic condition like Down's syndrome. Sometimes chromosomal mutations are beneficial and can produce proteins that fight a particular disease.

Significances of variation

1. Variation provides distinct individuality.
2. It increases the chance of survival of an organism according to the changing environment.
3. It forms the basis of heredity.
4. It makes the organism better suited for the struggle for existence.
5. It leads to evolution.

Variation	Mutation
1. The structural difference between parents and offspring and within species which provides individuality to an organism is called variation.	1. A sudden heritable change in the genetic material of an organism is called variation
2. Environmental factors like food, light, temperature, etc, are responsible for bringing out variation.	2. Various factors like UV rays, X-rays, gamma rays and different chemicals are responsible for mutation.
3. It may or may not be heritable.	3. It is heritable.

Summary

1. Heredity/inheritance is the phenomenon by which living organisms transmit parental characteristics to their offspring.
2. Variation is the structural difference between parents and the offspring which provides individuality to the organism.
3. The sudden change in the genetic make up which can be transmitted to the offspring is called mutation.
4. The characteristics transmitted from parents to the offspring are called hereditary characteristics whereas the characteristics developed by an individual for their better survival are called acquired characteristics. The combination of hereditary and acquired characteristics brings out variation.
5. Genetics is the branch of biology which deals with the heredity and variation. Gregor Johann Mendel is the father of genetics.
6. Genes are tiny unit of heredity located in chromosomes.
7. Charles Darwin propounded a theory called 'Theory of natural selection'.
8. DNA is a double stranded helically coiled macromolecule present in the chromosome and is considered as genetic material as it transmits hereditary characteristics from one generation to another.
9. RNA is a single stranded macromolecule present in the nucleus and cytoplasm and is responsible for protein synthesis. In some viruses (RNA virus), it acts as genetic material.

Exercise

A. Tick (√) the best alternative from the followings.

1. Who is the father of genetics?

   i) Gregor Mendel ii) Hugo de Vries

   iii) Bateson iv) Johannsen

2. Which is not a nitrogenous base present in DNA?

   i) Adenine ii) Guanine

   iii) Uracil iv) Thymine

3. Which one is not a feature of Darwin's theory?

   i) Enormous fertility ii) Survival for the fittest

   iii) Variation and heredity iv) Mutation

4. Which one controls protein synthesis?

   i) DNA ii) mRNA

   iii) tRNA iv) rRNA

5. Which one is not a significance of the variation?

   i) It provides distinct individuality.

   ii) It decreases the chance of survival of an organism according to the changing environment.

   iii) It makes the organism better suited for the struggle for existence.

   iv) It leads to evolution.

B. Answer the following short questions:

1. Define genetics. Gregor Mendel is considered as the father of genetics, why?
2. What do you mean by heredity? What are the hereditary characteristics? Give any two examples of hereditary characteristics that you posses.
3. Define the following terms:

   a) homozygous b) allele c) gene

   d) variation e) mutation f) struggle for existence

4. Differentiate between:

   a) DNA and RNA (On the basis of structure)

   b) DNA and RNA (On the basis of function)

   c) DNA and RNA (On the basis of location)

   d) Continuous variation and Discontinuous variation

   e) Variation and Mutation

5. What is organic evolution?
6. Write short note on 'struggle for existence'.

7. Write any three criticisms of Darwin's theory of evolution.

C. Answer the following long questions:

1. What is hybrid? Explain, how is hybrid produced?
2. Explain about the structure of chromosome in brief.
3. Draw double helical structure of DNA. Describe the structure and chemical composition of DNA. Write any two functions of DNA.
4. What is RNA? Explain the structure of RNA and the types of RNA along with their functions.
5. Describe Darwin's theory of natural selection.
6. Discuss on Darwinism. Focus on advantages and critics of Darwinism.

Project work

1. Make a family chart of at least three generations of your family by taking any one or two characters like colour of skin, eyes, hairs,etc (by asking your parents).
2. With the help of teacher and other possible sources, make a DNA model with the help of paper, wire, clay or any material available in your surrounding.

Glossary

Allele : one of two or more alternative forms of a gene that arise by mutation and are found at the same place on a chromosome.

Homologous (of organs) : similar in position, structure, and evolutionary origin but not necessarily in function.

Phosphodiester bond : a covalent bond in RNA or DNA that holds a polynucleotide chain together by joining a phosphate group in the pentose sugar

Heterozygous : having dissimilar pairs of genes for any hereditary characteristic

Unit 17

Ecology

Tansley founded the botany journal New Phytologist in 1902 to serve as "a medium of easy communication and discussion between British botanists on all matters including methods of teaching and research".

Arthur George Tansley (1871-1955)

Learning outcomes

After the completion of this unit, learners will be able to

1. Expalin ecology and ecosystem.
2. Explain the internal and inter-relationship between biotic community and its population.
3. Describe hilly ecosystem and prepare a report about the ecosystem of their own place.
4. Describe adaptational characteristics of aquatic and terrestrial animals and plants.

Introduction

The entire space occupied by living organisms is termed biosphere. The geographical distribution of living organisms is known as bio-geography (which reveals the living creatures found in different places under different sets of environmental conditions). The place where an organism lives is known as its habitat. It offers food, shelter and suitable conditions to the organism to survive, breed and flourish. Organisms live in a variety of habitats. It is the natural abode or locality of organism. The appearance and structure of organisms make it well suited in a particular habitat. Adaptation is the structural and functional features of living beings which are developed over a period of time. It enables them to survive and reproduce within the limits of a particular environment. An organism which copes well with a particular environment leads a better life and reproduces more successfully than the one which does not do so. For example 'An elephant is able to survive and reproduce in the terai region better than the yak which is found in Himalayan region. Similarly, the plants which are found in the terai region have flat leaves to adapt the particular environment however;

the plants which are found in Himalayan region have needle shaped leaves.

Animals and plants are fitted to live where they do live. According to Merrell (1962), "one common feature of the great variety of living things is that they are adapted for life in the environment in which they are found. If they are not adapted to that environment, they will not survive there. Each species is adapted to a somewhat different set of environmental conditions from every other species. Adaptation is a biological fact. Each living organism show adaptation in following ways:

- **By losing and gaining of organs:** Yaks in Himalayan region have thick fur for the protection from extreme cold but buffaloes found in hot regions do not have fur.
- **By changing the colour of body according to the habitat:** Frogs and some type of lizards do so. A type of bird called ptargmigans found in cold climate adapts themselves by changing colour through growing and falling white feathers.
- **By the modification in organs:** Body structures of living beings are modified according to their habitat and their feeding habit. e.g. beaks and legs of ducks are modified for the aquatic environment.

Adaptations are suited to the needs of the organism and its environment. The development of certain features in response to the particular environment which may improve the chances of survival is called adaptation. The process of adjustment of living organism with their surroundings is called adaptation. **The shape, size, colour, structure, and habit that enable the organism to live successfully its environment are adaptation.**

Types of adaptation

There are two general types of adaptations.

A) **Individual adaptation:** It is the adaptation by which organism, due to suitable modifications in physiology, adjusts itself to environmental need.

B) **Population adaptation:** It exists for the whole population.

Both these adaptations are different although they are under hereditary control. Each species is unique in its adaptation to its own special physical and biological environments.

According to time taken by the organism to adjust their body in the environment. Adaptations are of 2 basic types:

A) Short-term adaptation: e.g. change in colour of the skin due to exposure to the sun and dust.

B) Long-term adaptation: e.g. Sunken stomata of xerophytes leaves, characteristic of camel which make it well suited to the desert condition. It is a permanent type of adaptation.

On the basis of habit of living organism adaptations are of main 2 types:

- Aquatic adaptation
- Terrestrial adaptation

A. Aquatic adaptation

Water is the major constituent of the hydrosphere and it covers three-fourth of the earth's total surface. In water, variety of living organisms like fish, whale, hydrilla, pistia etc. survive. They have ability to take water, oxygen, light and food materials from water.

1. Aquatic plants and their adaptation characteristics

The word *aqua* in latin means water. The plants which grow, derive food, multiply and adjust themselves in or on the water are called aquatic plants or hydrophytes. On the basis of the mode of life, hydrophytes are of the following types:

i) **Free floating plants:** Those plants which are floating freely on the surface of water are called Ffree-floating plants. They are not attached to the bottom soil. eg. pistia, lemna, wolfia, water hyacinth etc.

ii) **Submerged plants:** Those plants which are fully merged under water are called submerged plants. e.g. hydrilla, vallisneria etc.

iii) **Amphibious or emergent plants:** Those plants whose lower part of the body (root system) remains under water, fixed in the soil but upper portion (shoot system) remains partly or completely out of water are called amphibious or emergent plants. eg. Lotus, water lily, typha, sagittaria, etc

Adaptational characteristics of hydrophytes:

The following are the adaptational characteristics of hydrophytes:

- The root system of aquatic plants is poorly developed. Root cap and root hairs are absent in them.
- The stem of aquatic plants is long, slender, spongy and flexible.
- Submerged plants have thin, long ribbon-shaped and small leaves; while

floating plants have large and flat leaves.

- Hydrophytes have a waterproof and protective waxy coat on its surface which prevents them from rotting and decaying. e.g. lotus, pistia, water hyacinth etc.
- Hydrophytes have air storage tissues called aerenchyma which help them to float e.g. water hyacinth, pistia etc.
- Conducting tissues (xylem and phloem) are less developed in them.
- The aquatic plants like jussiaea have two kinds of roots. They are fibrous roots for fixation and sponge like floating roots. The floating roots help the plants to breathe inside water.
- The minute flowering floating plants like wolfia have no roots but floating plants like lemna and pistia have very weak roots. Their roots are enclosed inside the root pocket.

2. Aquatic animals and their adaptation characteristics:

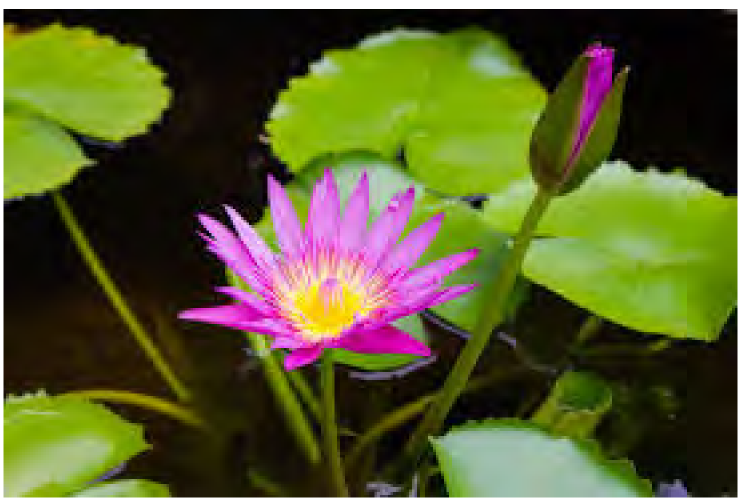


Fig: 17.1 Hydrophytes

Those animals which grow, multiply and adjust themselves inside water are called aquatic animals. The following are the adaptational characteristics of aquatic animals;

- They have streamlined body which is boat shaped. They have a laterally compressed head, a body, a powerful tail and fins.

- The entire body is covered with water proof scales. There is a mucous coating on the scale which reduces water tension.
- The body is provided with air-sacs or air-bladder, so that they do not sink when they stop swimming.
- They have paired and unpaired fins e.g. fish, flippers and paddles e.g. whale and webbed legs e.g. duck, frog, tortoise etc. for swimming.
- Gills are present on the lateral sides, which are respiratory organs capable of inhaling oxygen from water.
- The body is provided with lateral line as sense organ which helps in pressure and temperature detection.
- They are poikilothermic animals i.e. their body temperature charge with changing surrounding temperature. So, they easily live in the water during all seasons.
- Aquatic birds e.g. duck have flat beaks and webbed legs. Flat beak helps them to catch their prey and webbed legs help them to swim.

Fig: 17.2 Aquatic Animals

B. Terrestrial adaptation

The organisms, which adapt themselves on land and continue their generation, are called terrestrial animals.

1. Terrestrial plants and their adaptation characteristics.

Those plants which live on land and do their biological activities are called terrestrial plants. On the basis of physical conditions, terrestrial plants are divided into 2 types. They are mesophytes and xerophytes. The habitat in moist and cool places like mountains is called mesic habitat and the plants which grow in moist and cool places are called mesophytes. e.g. mango, wheat, mustard etc. Similarly, the habitat in dry and hot places like desert is called xeric habitat and the plants which grow in dry habitat with less water are called xerophytes. e.g. opuntia, cactus, aloe etc.

Adaptational characteristics of mesophytes:

- They have well-developed root and shoot system.
- They have well-developed mechanical tissues and vascular system.
- They can remove excess of water from their body during transpiration.
- The growth of the plant body is normal and trees have no any special water conserving mechanisms.
- The leaves and stems are well-developed in mesophytes.

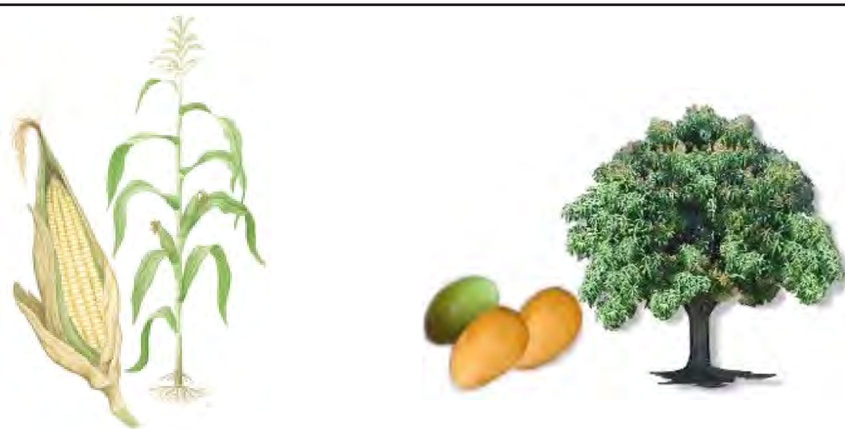


Fig: 17.3 Mesophytes

Adaptational characteristics of xerophytes:

- Xerophytes are bushy, very much branched and are covered with thick wax.
- The roots of xerophytes system fix the plant very deeply in the soil. The root has numerous root hairs to absorb the water from the soil.
- Usually, they have small leaves to reduce transpiration. In some cases, leaves are modified into thorns or spines.
- The stem is flattened, fleshy, thick and green. It helps to store water.
- The leaves and stem have thick cuticle at their surface and have deep seated stomata; that avoids the loss of water.

Fig: 17.4 Xerophytes

2. Terrestrial animals and their adaptational characteristics:

The animals which live on land and do their biological activities on land are called terrestrial animals. e.g. cow, lion, camel etc. Some animals like yak, snow-leopard etc. are found in mountain regions. Some animals are found in Terai regions e.g. elephant, rhino etc.

On the basis of their mode of life, Lull (1952) classified terrestrial animals into following types:

- Cursorial animals
- Fossorial animals
- Arboreal animals
- Aerial animals
- Desert adaptation
- Cave adaptation

a) Cursorial animals and adaptational characteristics

Cursorial animals are those animals, which live in open places and are adapted to run on hard ground. Reptiles, birds and mammals are the vertebrate forms, which exhibit cursorial adaptations. These adaptations are found in the bodies of the organisms. Following are the adaptational characteristics of cursorial animals.

- The body is streamlined which helps them for swift movement.
- The limbs are long and strong with reduction of digit for fast running. In some cases the hoof divides into two parts. e.g. cow, sheep, etc, while in others, it is a single e.g. horse, ass, etc.
- Locomotion is digitigrade. e.g. Hyaena, plantigrade e.g. bear, unguligrade e.g. pig.

b) Fossorial animals and adaptational characteristics

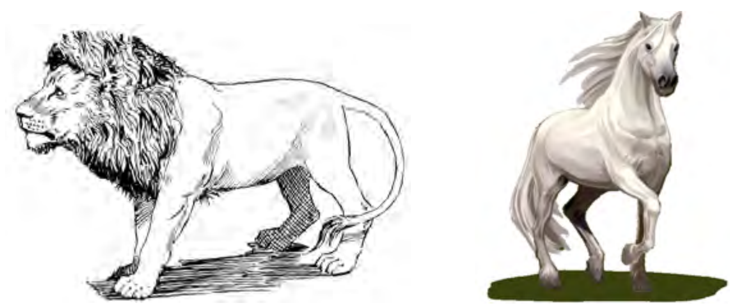


Fig: 17.5 Cursorial animals

Fossorial animals are those animals which are adapted for burrowing mode of life. This adaptation is found in the animals for subterranean life. Some animals are those that live above the ground but which dig for their food and show little fossorial adaptation rabbit, rat, mole etc. show fossorial adaptation. The adaptational characteristics are as follows:

- The head is small and tapers anteriorly to form a snout for digging.
- The forelimbs are short with powerful claws.
- The eyes and the ears are small or tend to reduce.
- Incisors and canine teeth are well-developed which helps them for digging.

c. Arboreal animals and their adaptational characteristics.

Fig: 17.6 Fossorial animals

Arboreal animals are those animals which are adapted for climbing. Climbers can be of 3 types; (i) wall and rock climbers (ii) Terrestrio-arboreal forms and (iii) Arboreal forms.

Wall and Rock climbers are well-suited for climbing on the walls of buildings as well as on similar surfaces in nature. e.g. gecko-lizards, flying squirrels. Terrestrio-arboreals are capable of climbing but they feel at home beneath the grounds. e.g. a number of carnivores, rodents and insectivores.

Arboreal forms make the trees their home and some occasionally descend to the ground. These forms include some primates and on the basis of locomotion they are: branch runners e.g. squirrels, chameleons etc. suspenders, that suspends beneath the branches. e.g. sloths, flying lemurs etc. Another forms are swinging by the forelimbs. e.g. apes etc.

Following are the adaptational characteristics of arboreal animals:

- Body is stout, ribs are very much curved, thus thorax becomes semi-circular.
- Locomotion is plantigrade.
- The legs of some animals like lizards are provided with adhesive pads that help to hold the wall or other surfaces.
- The clavicle and the scapula of the pectoral girdle are well developed for muscle attachment i.e. muscles of chest are strong.

Fig: 17.7 Arboreal animals

d. Aerial or volant animals and their adaptational characteristics:

The animals that are adapted for aerial mode of life are called aerial animals. The aerial creatures never exclusively spend their life in the air but return to the trees or earth or sea. Therefore, adaptation in aerial creatures is always double and cannot reach the extreme of specialization of aquatic types.

The following modifications are found for volant adaptations:

- Body is streamlined, which reduces air resistance during flying.
- Forelimbs are modified into wings. In birds, forelimbs have a large surface area provided with feathers. In bats, wing is a fold of skin called patagium. In insects, wings are thin membranous folds of exoskeleton.
- The bones are hollow, spongy and pneumatic.
- Sternum or breast bone is well-developed in animals with true flight.
- The eyes are very sharp and well-developed.

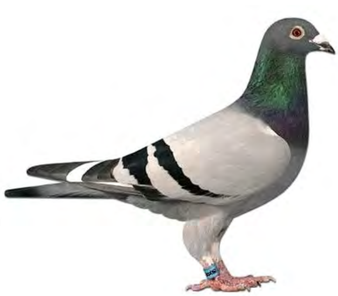
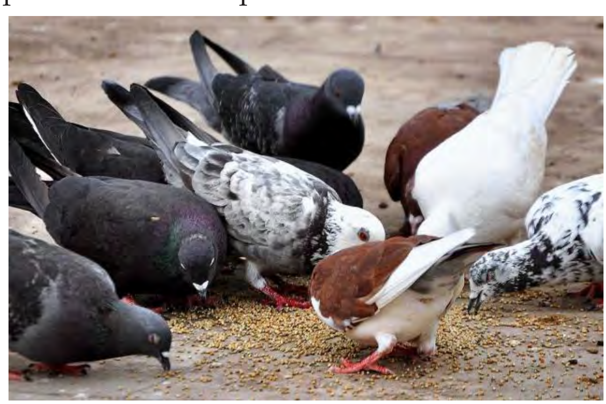
 

Fig: 17.8 Aerial or volant animals

e. Desert animals and their adaptational characteristics

Desert animals are adapted for dry land and hot habitat, e.g. camel, lizard rodents, etc. The adaptational characteristics of desert animals are as follows:

- They are provided with very keen senses of sight, hearing and smell.
- They have thick skin to avoid loss of water.
- They have developed ways of defense against the extreme physical conditions. They seek shadow of a rock or burrow and thus are able to save themselves from extreme heat and cold.
- Eyes, ear and nostrils are well-protected. They are also provided with valves or are reduced.
- Desert lizards have hygroscopic skin that absorbs water from the atmosphere just like a blotting paper.
- Most of them have warning coloration or dull color which blends them with the surrounding environment.
- The limbs of camels are provided with a pad on the flat hoofs which help them to run on hot sand. They also have thick eyelashes that avoid sand entering eyes.
- The body of camel is provided with a hump on the back which stores fat.
- Desert animals have hard and spinous surface.

Fig: 17.9 Desert animals

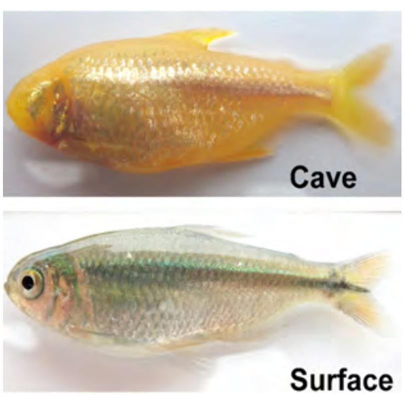
f. Cave adaptations

The abandoned channels of under-ground rivers found in limestone regions are the caves forming animal-habitat. As for the nature of the environment, there is absence of light and nearly uniform temperature. Caves can be divided into 3 regions.

- **Twilight (Transitional region):** It is the region lying within the mouth of the cave between the outer world and the real cave. Therefore, in this region, conditions vary.
- **Region of fluctuating temperature:** In this region, the diurnal or seasonal variations of heat and cold can be felt.
- **Inner cave region:** In this region, light is absent and temperature remains constant.

Adaptational characteristics:

- Cave animals or cave dwellers have slender body.
- They have reduced eyes.
- They have loss of pigmentation.



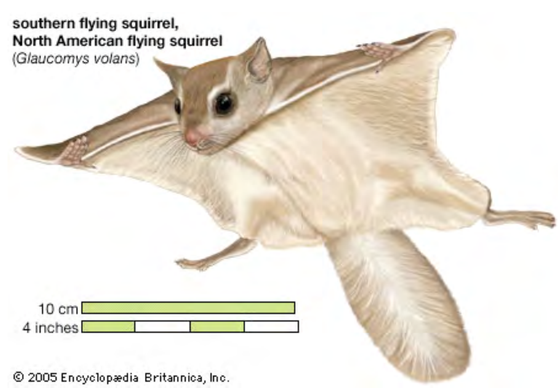


Fig: 17.10 Cave animals

Ecology

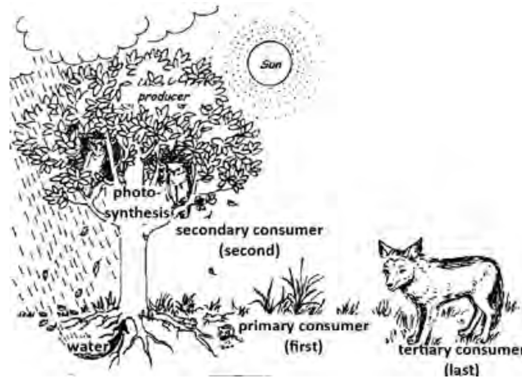


Fig: 17.11 Ecology

Ernst Haeckel (1869) coined the word ecology (oekologie) derived from the Greek word oikos, house and logos, study. He defined ecology "as the total relations of the animal to both its organic and inorganic environments." **Odum (1963) defined ecology as the study of the structure and function of nature.** "Ecology is the study of relationship between organisms and their environment". General ecology deals with biota and its environment. Main sub-divisions are: animal ecology which deals with Components of ecosystem animals. Plant ecology deals with plants.

The earth is inhabited by innumerable living organisms which are found in variety of habitats like water, air, land etc. A set of natural conditions which surround an organism and influence its life is known as environment and the place where an organism lives is called habitat. Plants and animals are simply inhabitants. Environment consists of biotic or living plants and animals and abiotic or non-living or physical and chemical (air, soil, water, light, temperature) factors. So, every organism makes a community by giving and taking materials in the environment. The study of the interrelations of organisms to each other and also to their physical environment either individually or in group of individuals is called populations or in groups of populations, called communities. These different levels of interactions result in the establishment of relatively stable and more or less self sustained system called ecosystem. **Thus, the ecosystem is defined as a functional and self sustaining unit comprising of living and non-living components in which there is constant interaction between them.** A.G. Tansley (1935), a British ecologist was the first person to advise the term ecosystem.

Ecological Factors

No living organism can exist in vacuum. Every living organism, either it be the simplest or a highly developed animal, has a distinct mode of life depending upon its structure and physiology and also upon the influence of the environment which it occupies. Each part of the environment which affects in a specific way, the structure of functioning of the organism is called an ecological factor. These factors control the distribution, reproduction, abundance and growth of the organism. These factors are grouped in 2 classes:

A. Abiotic factors

B. Biotic factors

A. Abiotic factors

These include air, soil, water, temperature, light, humidity and atmospheric pressure etc. These are also called climatic factors. The type of living organism found in any area depend upon the abiotic factors, the nature of soil and the availability of water. The important abiotic factors are as follows:

a) Air

It is one of the most influencing factors which affects the life of living beings. Atmospheric air contains 78% nitrogen, 21% oxygen, 0.03% carbon dioxide. It also contains neon, helium, water vapor, dust particles etc. During photosynthesis, plants take carbon dioxide and give out oxygen. Animals as well as plants utilize the oxygen for respiration. Oxygen is necessary for cellular metabolism, that releases energy for the organisms. Animals take oxygen during respiration and give off carbon dioxide. Air also helps in pollination and dispersal of seeds.

b) Water

Water is the most important ecological factor. It covers more than 71% of the total earth surface. Without water, no vital activity is possible in organisms. It is the raw material for photosynthesis. It affects the inner and outer morphology of the plants. It also plays an important role in pollination, fertilization and dispersal of seed. Human beings, animals, birds, other creatures etc. use water from different sources such as, from river, lake, pond, ocean, well etc. to sustain their life.

c) Soil

Soil is an important abiotic factor which forms the chief substratum for plants and animals and land. It is a natural habitat and storehouse for different organisms. It contains minerals, organic matter, water, air, micro-organisms, and chemical substances such as nitrogen, phosphorous and potassium which are necessary for plants for their growth and development. The organic matter continuously added to the soil indeed comes from plants and animals. These organic matters get mixed up and intermingled with the particles to make the soil suitable for growth of plants and animals. Plants get water and mineral from soil.

d) Solar energy

The energy provided by the sun in the form of heat and light is called solar energy. The sun is the main source of light which supplies radiant energy to plant. By using this radiant energy, green plants make their own food with the help of water and carbon dioxide. Temperature is the degree of hotness and coldness, which varies from place to place. It depends upon a number of factors like height, distance, season and other climatic factors. Both light and temperature affect the distribution of plants and animals. They are essential for productivity, growth, pigmentation, flowering, breeding, etc, for organisms.

B. Biotic factors

The living organisms in an ecosystem constitute the biotic components or factors. There is inter-relationship between the different organisms in a habitat. Different biotic components are connected through food and a number of other relations. It is of the following 3 types.

a) Producers

Those organisms which can prepare their food from simple inorganic substances like water and carbon dioxide in the presence of sunlight are called producers. Green plants are the ultimate producer organisms in any ecosystem. In grassland ecosystem, herbs and shrubs act as producers; in ponds and lakes, algae and free floating plants act as producers; and in oceans, the microscopic phytoplankton act as producers. Thus, phytoplankton, herbs, shrubs and trees and chemosynthetic bacteria form primary basis of life and provide food, shelter and oxygen to the animals. The producers also maintain the balance of oxygen and carbon dioxide in nature.

b) Consumers

The organisms which consume food prepared by producers are called consumers. All animals including human beings, directly or indirectly depend on producers for their food. Consumers are heterotrophs. They are divided into three classes:

- **Primary Consumers:** All the herbivores animals which obtain their food directly from green plants are called primary consumers. Animals like goats, deer, rabbits, beetles, cows, grasshoppers etc. are some common herbivores or primary consumers of terrestrial ecosystem. Similarly, crustaceans, tadpoles, molluscs, protozoans, etc. are herbivores of aquatic ecosystem.

- **Secondary consumers:** Carnivores ingest or prey upon other animals. The carnivores which eat the herbivores or primary consumers are called secondary consumers or primary carnivores. e.g. owl, peacock, fish, jackal, fox etc.

- **Tertiary consumers:** Some animals like snake, tiger, lion, vulture, etc. are secondary carnivores and eat the secondary consumers. Since their food consists of secondary consumers, they are called tertiary consumers. Lion, tiger etc. are also called top carnivores or top consumers because they cannot be preyed upon further and they lie at the top of food chain.

c) Decomposers

Those micro-organisms which break down the complex organic compounds present in dead bodies of plants and animals into simple substances are called decomposers. These are saprophytic micro-organisms. They absorb some of the product while they release most of the inorganic compounds into the environment. In this process, they obtain energy for their growth and reproduction. The chemical substances which pass from organism to organism ultimately go back to the non-living environment and are once again made available to the producers. So, they help to maintain the ecosystem stable and dynamic.

Internal and inter-relationship between biotic Community and its population:

When we go anywhere and look around us, we cannot see only one species. There occur varieties of species. This is because in the natural world, there is interdependence of one form of life upon another. The relationship between one species and another within a community has evolved through their interactions. These relationships are based on the requirement and the mode of obtaining food and shelter and also on the habits of the species.

A community will not be able to survive unless the other non-living components are available to it. Plants use the simple inorganic matter by converting it into complex organic matter likewise, animals derive their food particles from plants. On the basis of their nutritional relationship, living things are divided into two categories. They are autotrophs and heterotrophs.

Autotrophs: Those organisms that can make their own food are called autotrophs. All the green plants and chemosynthetic micro-organisms are autotrophs. They are capable of synthesizing their food materials which is in complex form from simple inorganic substances. Autotrophs are also known as the producers in ecosystem. So in the process of photosynthesis, autotrophic nutrition occurs and this type of auto-tropism is called photoautotrophic nutrition. If sunlight and chlorophyll are not used in the preparation of food. It is called auto chemotropic nutrition. It occurs in some bacteria.

Heterotrophs: Those organisms which cannot prepare their own food but depend on autotrophs for their food are called hetero-trophs. The process of obtaining food by organisms is called heterotrophic nutrition. Such type of nutrition occurs in all the animals, fungi, and most of the bacteria and a few flowering plants -insectivores. These come under consumers and decomposers. On the basis of the nature of food heterotrophs are categorized into 3 types:

Holozoic:

This includes those organisms which feed on solid organic substances obtained from other organisms. On the basis of food habits, holozoic animals can be of 3 types:

a) **Herbivores:** Which mainly feed on green plants eg: cow, goat, deer, elephant etc.

b) C**arnivores:** Which feed on flesh e.g. tiger lion, fox, leopard, frog, reptiles, insectivores (e.g., venues fly trap, pitcher plant, sundew etc.)

c) **Omnivores:** Which feed on both herbivores and carnivores e.g. man, dog, crow etc.

Saprophytes:

These type of organisms feed on dissolved organic and inorganic substances produced as a result of decomposition of plants and animals. They are also called micro consumers or decomposers e.g. bacteria and fungi.

Parasites:

These organisms obtain their food directly from other living beings called hosts. e.g. *Plasmodium*, mosquitoes, liver fluke, tapeworm, roundworm etc.

Biotic or living factors can be considered under 2 heads on the basis of interactions.

I) Intraspecific interactions

II) Interspecific interactions

I) Intraspecific interactions: Intraspecific interactions are within a population i.e. interactions between individuals of the same species. Among the intraspecific interactions are competition, social organization and territorial segregation.

a) I**ntraspecific competition:** There is intraspecific competition for food, minerals, sunlight, water, territory and mates. When population increases competition among the individuals of the same species also increases and it continues to increase till the carrying capacity of environment is reached.

The carrying capacity of environment is defined as the maximum number of individuals of a given kind which can be supported by the ecosystem. Additional increase is responsible for a mechanism by which there is limit to any further increase in the population e.g. in Alaskan Seal, males come to the shore before the herd to have territories for breeding purposes. Each male fights to maintain a harem of 5-20 females and defends his territory during the breeding season. In this competition, only the strongest males of the species can maintain their territories and can reproduce. Intraspecific condition also exerts a selective influence within the population. Those individuals which are successful in the struggle of existence can produce offspring and pass on their specific characteristics to the next generation.

b) Social organization: All the plants and majority of the animals live as independent individuals within the population except during periods of reproduction. Competition takes place without any consciousness. The survival of species within the ecosystem is due to adaptations which ensure continued individual existence. Some animals form a social organization in which there is direct interaction. e.g. bees, ants, birds, deer, wolves. The social organization among insects is due to structural specialization, they show polymorphism e.g. in bees.

Among vertebrates, the social organization is based on functions. Specialization is based upon physical strength, skills and mental acuity, fishes, wolves, birds, deer have mainly protective interaction.

c) Territoriality: This phenomenon is closely associated with social organization. In a population, each family or mating unit possesses its own physical territory. Generally, these territories are protected against invasion by other members of the same species. E.g. in birds and other vertebrates. The territory provides sufficient space for resting and ensures and adequate food for young ones. It also provides the needs of reproduction and survival and reduces intraspecific competition when territories and established, there is a great intraspecific competition for suitable territories which is responsible for natural selection. This also helps to keep the size of the population within the limits of the carrying capacity of ecosystem.

II. Interspecific interactions: Interspecific interactions are between different populations in the community. This includes interspecific competition, symbiotic interactions and predation.

a) Interspecific Competition: Competition between species is a continuous process which maintains differences in population. It is also the important factors in the formation of ecological niches. In animals, the objects of competition may be territory, weather or nesting site. However, in animals, most common object of competition is food.

Thus, interspecific competition is responsible for limiting the number of species within an ecosystem and similar to intraspecific competition, limit the number of individuals within a population.

b) **Symbiotic interactions:** Symbiosis means living together and refers to the interactions between two or more different species. When there is no interaction or no effect between two populations or individuals of two populations, they exhibit neutralism. When two species are called mutualisms i.e. both benefit from each other. E.g. tick bird and rhinoceros, termites and protozoans etc. Another type of interaction is commensalism, in which one gets benefit while the other is neither helped nor harmed. Another is parasitism, in which one organism lives in or on its host and harmful for host parasites may be endo and ecto-parasites. When a parasite is dependent upon specific hosts it is called obligatory parasite.

C) **Predation:** Expect a few insectivore's plants, majoring of the predator are animals. Predators include herbs as well as carnivores.

Ecosystem of Hilly region of Nepal

Have you ever visited terai region or mountainous region or wetland area? You can see different types of plants and animals according to geographical distribution, their habit and habitat. If you observe closely them, you can identify and know various relationships among them. There are different varieties and species of animals and plants seen in different area. The animals and plants that can be seen wetland areas cannot be seen in dry mountainous region and those which are in this region can not be found in wetland or aquatic region. The cause of this is ecological factors and its influences.

Thousands of habitats with innumerable ecological niches are founded in the land or hilly ecosystem which includes biomes and bio-geographical regions. There are hills of different heights, valleys, benshi etc. This region covers about 42 percent area of our country.

In hilly region, terrestrial (land ecosystem) and aquatic ecosystem are found. Components of ecosystem of hilly region:

A. Abiotic factors

Abiotic factors of this region include variations in light intensity, temperature, wind velocity, moisture, climate and organic and inorganic nutrients in soil.

B. Biotic factors

1. Producers

Producers of hilly region ecosystem majorly includes Sal, Kattus, Khayar, Lapsi, Chilaune, Bamboo, Rhododendron etc. Potato, maize, wheat, paddy, millet, oilseeds, soybeans, barley are the main agricultural products of this region. In some area medicinal herbs like serpentine, panch aule, spikenard and Himalayan yew are also found.

2. Consumers

Consumers for aquatic ecosystem and terrestrial ecosystem of hilly region are different. In rivers, streams, ponds and lakes, fish and other aquatic animals like crab, frog etc, are found whereas domestic animals like cow, buffalo, sheep etc., wild animals like leopard, bear, deer, hare, fox, tiger, rabbit, snake, lion, etc and the birds like Black Pheasant, crow, sparrow, cuckoo, dove, pegion, eagle, etc. are found in this region.

3. Decomposers

Various microbial organisms such as fungi, bacteria acts as decomposers for the cause of decay of organic materials to provide nutrients for the producers. When the producers and consumers die, a large number of fungi and bacteria attack their dead bodies and convert the complex organic substance into simpler inorganic substance and return them to the soil and atmosphere. The grass, herbs or shrubs of trees utilize the nutrients produced ecosystem produced by decomposer.

Thus in the hilly ecosystem producer can be crops or other trees, fruits etc. and consumers are wild animal or birds, plant eating insects and domestic animals which are kept only in hilly area balances the ecosystem. These all depend upon each other.

Summary

1. Ecology is defined as science which investigates organism in relation to their environment.
2. An ecosystem is defined as functional unit consisting of living and nonliving components which is capable of independent existence.
3. Air, water. soil solar energy are abiotic or nonliving factors and producers, consumers and decomposers are biotic or living factors.
4. All green plants are producers which are autotrophs.
5. Consumer obtains their food from producers.
6. Decomposers take their food by decomposing dead and decaying matters.

7. The ability of an organism to adjust according to a particular habitat is called adaption.
8. Adaptation increases the chance of survival of organism by helping them to obtain food and protect from their enemies.
9. Aquatic plants have weak root system, large air spaces, flexible stems and coat of waxy substances which protect them in their aquatic environment.
10. Aquatic animals have gills for respiration streamlined body, air sacs, scaly body, fins for locomotion etc.
11. The plants which live in water are known as hydrophytes and the animal found in water are called aquatic animals.
12. Cursorial animal has long and strong lets for running.
13. Fossorial animal has strong spout to push soil and sharp claws for digging holes.
14. Arboreal animals have plantigrade movement and stout body.
15. Aerial animal (birds) have sharp eyes, pneumatic and light bones, wings and special shape of their beaks according to their food.

Exercise

A. **Tick (√) the best alternative from the followings.**

1. Which of the followings are decomposers?

a) Insects b) Bacteria only

c) Bacteria and fungi d) Birds

2. If there is both benefits from each other in two individuals, it is called

a) Mutualism b) Neutralism

c) Commensalism d) Parasitism

3. Pitcher plant is......

a) Omnivores b) Insectivores

c) Carnivores d) Herbivores

4. Those plants whose root system remains under water and shoot system remains out of water are called.....

a) Submerged plant b) Free ploating plant

c) Amphibious d) Xerophytes

5. For what purpose the leaves of xerophytes modified into thorns?

a) Reduce respiration b) Reduce transpiration

c) Absorb water d) Absorb moisture

6. Type of adaptation found in rabbit is..........

a) Cursorial b) Arboreal

c) Fossorial d) Aerial

B. Answer the following short questions:

1. What is ecology? Define the term autotrophs and heterotrophs.
2. Write one difference between intraspecific and interspecific interactions of living beings.
3. What is auto-chemotrophic nutrition?

4. Define the followings:

   a. Decomposers b. Producers

   c. Saprophytes d. Mutualism

5. What are the abiotic components that are found in mountainous ecosystem?
6. What is adaption? Write any two adaptational characteristics of aquatic animals.
7. Write any two characteristics of terrestrial plants.
8. What do you mean by hydrophytes and xerophytes?
9. Write one important adaptational characteristics of aerial animal.
10. Distinguish between cursorial and fossorial animals.
11. Write any two features developed in the cactus plants in order to adapt in the environment of desert.
12. What are the two special features by which free floating plants can float on the surface of water?
13. Camels have flat hoofs with pads. Why?
14. How are birds adapted? Mention any two adptational characters of them.

C. Answer the following long questions:

1. How do decomposers help to make soil fertile? Explain in brief.
2. Describe the internal and inter-relationship between biotic community and its population with example.
3. Sketch a diagrammatic representation of hilly ecosystem.
4. How do living organisms show adaptation? Describe in details.

Project Work:

Visit any place near to your locality and observe the ecosystem, then prepare a report about the ecosystem of that place.

Glossary

Atmosphere	:	The layers of the gases which surround the earth
Biosphere	:	Part of the earth where living things exist.
Chemosynthetic	:	Those who prepare their food in their body in the lack of sunlight and chlorophyll
Photosynthetic	:	Those who prepare their food in the presence of sunlight and chlorophyll
Community	:	Group of populations or plants and animals in a given place
Population	:	Group of individuals which are of a single species
Predatory	:	Predacious, living by killing and eating other animals
Components	:	Constituents parts
Habitat	:	Shelter
Niche	:	The status of an organism within its environment and community (affecting its survival as a species)
Phytoplankton	:	Photosynthetic or plant constituent of plankton; mainly unicellular algae

Unit 18

Behavioral Biology

Learning outcomes

After the completion of this unit, learners will be able to

1. Define livestock farming and explain the importance of livestock farming in Nepal.
2. Make a list of birds found in the forest of Nepal
3. Define eco-tourism and explain the importance of eco-tourism

Livestock farming

Livestock are domesticated animals raised to produce milk, meat, eggs, wool, labor etc. It encourages and pulls people into cultivation as it enhances the cash income of farmers. Even the dung of animals can be used to enrich the fertility of soil. Different animals like yak, donkey, mule, sheep, buffalo, etc are used to transport different goods. Livestock farming is an important source of protein from milk, meat, egg, etc.

The animals are worshiped as a god/goddess in majorities of hindu and buddhist communities. The livestock are used as emergency capital and live cash, provide nutrition (milk, meat and eggs), soil nutrients (manure, urine and decaying carcases), energy (draught power, transportation and fuel), animal fibre (wool and hair), carcass by products (bone and skin). As the larger proportion of the livestock by products is consumed in urban cities; the livestock sector is considered as a major way to drain cash in rural areas and to the poorer households.

Nepal is an agricultural country and livestock farming is an important sector of agriculture. Here we will learn about some important livestock farming of Nepal and concept of ecotourism in Nepal.

1. Cow farming

Cow is just used for the production of milk in Nepal. As cow is our national animal, it is not used as meat production livestock in Nepal. The ancient cow farming system is still practicing traditionally in all over

Fig 18.1: Cow farming

Nepal but commercial cow farming in Nepal has recently been introduced and becoming popular among farmers.

Cow is primarily raised to provide draught power for agricultural work and for manures. The major native breeds of cow in Nepal are lulu, achhami, siri, khaila, terai and hilly. These native cows have short lactation period, long calving interval and low milk yield capabilities and hence to overcome these weaknesses government of Nepal has been given priority to develop the cross breed cow and has established different cattle development farm viz;

a) Livestock development farm, Jiri: Brown swiss cattle

b) Livestock development farm, Khumaltar: Holstein and jersey

c) Livestock development farm, Pokhara: Achhami

a) Lulu cattle: Lulu cattle are found in Mustang, Dolpa and Manang district. The average body weight is 125 kg.

b) Achhami cattle: It is found in Achham, Bajhang, Bajura and Doti districts. These animals are the smallest breeds of cow in the world. The average body weight is 124 kg.

c) Siri cattle: Siri cattle are found in eastern hills like Ilam, Panchthar and are considered as extinct from Nepal. The average body weight is 286 kg.

d) Hill catlle (Kirko): Hill cattle are small in body size and weigh about 165 kg. This cattle is used for agricultural work such as ploughing as a source of manure.

e) Terai cattle (Zebu): The terai cattle are found at southern belt and are developed from crossing between Indian cattle with Hill cattle. The average body weight is 210kg.

Major breeds in Nepal

a) Holstein-Feirsian: It is one of the highest yielding breeds in the world. This breed was found suitable for southern and middle hills.

b) Jersey: It is a famous dairy breed of cattle, noted for small body size low feed intake with high milk yield or rich fat content. This breed is found suitable for southern and middle hills.

c) Brown swiss: Presently this breed is raised at livestock development farm, Jiri. It is found suitable for high mountains.

Precautions in cow farming

The field should be properly managed during cattle farming:

a) Preservation of graziery area

b) Identification of the disease and its treatment: Some of the major diseases occur in cattles are **vyagute rog, khoret rog, namle rog and thunelo.**

Compared to the native cattle, the cross breed cattles are more susceptible to most of the tropical diseases. Hence they should be grown in intensive management conditions.

c) Quality control of the products and proper storage

d) Protection of the products, proper packaging and transportation

e) Market management

Importance of Cow farming

a) Cow farming is used for the production of milk.

b) Milk produced from the commercial cow farming can be used to manufacture different types of milk products like ghee, butter, cheese etc.

c) Milk products can be sold to enhance the economic status of farmers, industrialist as well as of nation.

Goat farming

Fig 18.2: Goat farming

The goat is the most popular species among the domesticated animals. Even non-agricultural households are rearing goats as a source of meat. The goat farming is widely practiced as a means to enhance the economic status of rural sectors which is widely adopted by government as well as non-governmental agencies. Goats are used for meat, pack, manure and milk. Goat farming in Nepal started years ago but commercial goat farming in Nepal has recently been introduced among farmers. It is a profitable business with a low investment because of its multi-functional utility like meat and milk that are very nutritious. Most of the goat farms in Nepal are established to produce goat meat. There is no any dairy goat farms in Nepal. Goat farming is the main source for generating income in rural areas of Nepal peoples are uses to maximize their benefits and survive their lives.

The major native breeds of goats are chyangra, sinhal, khari and terai goats whereas cross breeds are saanen, jamunapari, barberi and beetal. Government of Nepal has been given priority on goat production. Dhangadi goat development farm, Dhangadi, Goat research centre, Bandipur and Tanahu, Agriculture research centre Pakhribas and Lumle have been established to do researches on goat and development of goat under **NARC** (Nepal Agricultural Research Centre).

The goats are much preferred than large ruminant in Nepal because of the following reasons:

- Low capital investment, relatively small body size, higher prolificacy, high demand for meat, low risk of animal casualty, lower feed requirement, easy to handle, goats are multipurpose animals

Native Goat Breeds of Nepal

a) Chyangra: Chyangra goats are found in trans Himalayan region of Nepal. They have coarse but silky long hair reaching up to the knees, beneath which a fine under coat of Pashmina or Cashmere is present. Most of them are white or black with white stripes. The average adult body weight is 35-40kg and 27-30kg for male and female respectively.

b) Sinhal: Sinhal goats are the high hill goats found on the southern flank of the high Himalayan maountain region. The sinhal is the heaviest among the native goat breeds of Nepal. The average adult body weight of male and female goats is 42 kg and 35 kg respectively.Generally, they are black, light brown and white in colour.

c) Khari/Aule: Khari goats are widespread and are found in mid hills. The average body weight of this goat ranging from 20-40kg.

d) Terai Goats: Terai goats are found in the southern plain area (terai) of Nepal. This breed appears to be Jamunapari. The average adult body weight of male and female is 30-35kg and 18-32kg respectively.

To improve the productivity of the native breeds found in Nepal, research and development agencies of Nepal crosses different native breeds mostly with Jamunapari, Barber, Kiko and Saanen.

a) Saanen: Saanen is a famous milk producing breed among goats. It is raised at Panchsayakhola Sheep development farm, Nuwakot and Chitlang Sheep development farm, Makwanpur.

b) Jamunapari: It is a duel purpose Indian breed for meat and milk production. It is raised at goad research centre, Bandipur, Tanahu and Goat development farm, Budhitola, Dhangadi.

c) **Barberi:** It is a meat producing breed. It is raised at goat development farm, Budhitola, Dhangadi.

d) **Beetal:** It is raised at livestock development farm, Gaughat, Banke.

Precautions in goat farming

These field should be properly managed during cattle farming:

a) Preservation of graziery area

b) Identification of the disease and its treatment: Some of the major diseases occur in cattles are **P.P.R, Cherrauti, Pneumonia, Thunelo, Pet fulne wa dhadine rog.**

Compared to the native cattle, the cross breed cattles are more susceptible to most of the tropical diseases. Hence they should be grown in intensive management conditions.

c) Quality control of the products and proper storage

d) Protection of the products, proper packaging and transportation

e) Market management

Importance of goat farming

a) Goat farming is used for the production of milk but specially for the meat.

b) Economic status of the farmers can be increased by selling goat or goat meat.

Poultry

The word 'poultry' means chickens or the domestic fowl but nowadays it also includes some other types of birds such as ducks, turkeys, pigeons, etc. Traditionally, poultry farming is considered as a lower caste business; however, in the recent years the commercial poultry farming is emerging as viable economical enterprises.

The poultry farming or poultry keeping is a branch of agriculture that deals with the raising, growing, breeding under intensive management in order to get meat products and eggs for consumption and marketing.

Fig 18.3: Poultry

Generally three types of poultry breeds are raised in Nepal:

a) Local breed

b) Pure breed

c) Synthetic breed

Local Breeds

a) Shakini: It is a small in body size. It is raised for egg production. The average adult body weight is 1.5-2kg.

b) Ghanti khuile: This breed is a typical bird with few feathers in neck, different feather colour and raised for meat. The average body weight of male and female is 1.6 and 1.3kg respectively.

c) Puwankh Ulte: This breed is a bird with outward growth of the feathers. The average adult body weight of male and female is 1 and 0.9 kg respectively.

Pure Breeds

Pure breeds of poultry birds are raised to government farms. Three major pure breeds raised in Nepal are New Hampshire, Austrolorp and Giri Raja.

a) New Hamsphire: It is an American breed raised for the eggs. The average body weight of adult male and female is 3.8kg and 2.9kg respectively. It is raised at Brooder farm, Banke, Livestock development farm, Pokhara, Agriculture centre, Khumaltar.

b) Austrolop: It is developed in Australia. The average adult body weight of male and female is 3.8kg and 2.9kg respectively. It is raised for eggs and raised at NARC research centre, khumalthar, tarahara and parwanipur.

c) Giri Raja: It is raised for meat. It was introduced and tested in Pakhribas agriculture centre and raised recently at NARC research centre, pakhribas.

Synthetic Breeds

Synthetic breeds are commercial breed for egg (hybrid/layers) and meat (broiler). The synthetic breeds are raised at private sector for eggs and broiler production. Some of the synthetic breeds raised in Nepal are shaver, babcob, key stone, etc.

Method of poultry farming

The steps for establishing and conducting a good poultry farm in scientific way are given below:

1. **Selection of Breed**
   a) Egg laying types or layers
   b) Broiler type of meat producing type
2. **Housing of Birds**
   a) Semi-intensive method
   b) Intensive method

   It is also two types:

   i) The deep litter system

   ii) Individual cage system
3. **Food and Feeding**
4. **Culling**
5. **Medical Care**
6. **Marketing**

Advantages of poultry farming

1. It is the source of regular, supply of meat and eggs.
2. The chicken manure can be used in the field to increase the fertility of the soil.
3. Poultry farming can be started with very less investment of money.
4. It solves the problem of unemployment to some extent.
5. It provides regular source of income.

> **Activity**
>
> What livestock farming is popular among farmers in your area? What may be the reason of its popularity? Discuss among your friends and make a report on it.

Forest in Nepal

About one third of the world's land surface is covered with forest. Forests are the vast natural resources for man for fuel, timber, paper, fodder, water yield and animal products. Forests also check the floods and soil erosion and are important for wild life, human recreation, air and water.

"Green forests are the wealth of Nepal"

Nepal has a sharp climatic variation from subtropical to alpine. Nepal is rich in biodiversity and forest resources. The forest of Nepal is classified on the basis of geographical location and climatic characteristics into four types which are as follows:

1. **Tropical/Deciduous Monsoon Forest (upto 1000m)**:

   This includes the Terai plains and the broad flat valleys found between hill ranges. Because of the adequate rainfall and sun, these forests mostly remain evergreen. Valuable trees for commercial and industrial puposes like Sal, sometimes associated with Semal, Asna, Sissoo, Jasmine, Mimosas, Accecia reeds and bamboo are common in this region. This tropical zone is Nepal's richest area for wildlife, with Gaurs, Wild Buffalo Four species of Deer, Tiger, Leopard, Elephant and other animals, Rhinoceros, Swamp Deer and Hog Deer are found on the grasslands and two species of Crocodile and the Gangetic Dolphin inhabit the rivers. Peacocks, Jungle Fowl and Black Partridge also richly populate in the forests.

2. **Subtropical/Mixed Evergreen Forest: (1000- 1700m)**

   The forest found in sub tropical zone (1000-1700m) is called sub tropical forest. The rainfall is very high and the temperature is also very high in this region: Mahabharat Lekh, **the Terai and the Chure hills.** So, the evergreen and massively tall trees are found here, which can be used for construction and building purpose. Among the tree species characteristic of this region are *Castenopsis indicia* in association with Chilaune, Katush and other species such as *Alnus nepalensis*, *Acer oblongum* and various species of oak and rhododendron.

   This zone is generally poor in wildlife. The only mammals which are at all widely distributed are Wild Boar, Barking Deer, Serow, Ghoral and Bear. Different birds like Sparrow, Crow, Peacock. Kalij, Water Duck are also found in this zone.

3. **Temperate/Evergreen Forest: (2000m-3100m):**

   It can further be studied under two headings:

   a) Lower temperate forest (2000-2700m):

Northward on the lower slopes and spurs of the Great Himalaya, Oaks and Pines are the dominant species up to an altitude of about 2,400 meters.

b) Upper temperate forest (2700-3100):

In this zone conifer forest of Picea, Tsuga, Larix and Betula spp. Abies and Betula are dense.

The wildlife of this region includes the Himalayan Bear, Serow, Ghoral, Barking Deer and Wild Boar, with the Himalayan Tahr sometimes being seen on steep rocky faces above 2,400 meters. The Red Panda is among the more interesting of the smaller mammals found in this zone. This region includes several spectacular and beautiful pheasants, including the *Damphe Pheasant,* Nepal's national bird.

4. Subalpine and Alpine Zone (3000m-4500m):

Above the tree line, Rhododendron, Juniper Scrub and other procumbent woody vegetation may extend to about 4,200 meters where they are then succeeded by a tundra In former times, the Wild Yak and Great Tibetan Sheep could also be sighted in this region and it is possible that a few may still be surviving in areas such as Dolpa and Humla. The bird life at these altitudes includes several interesting species such as the Lammergeyer, Snowcock, Snowpartridge, chough and bunting, with redstarts and dippers often seen along the streams and rivulet. The birds like Danphe, Munal, Koklas, Pheasant, Cheer Pheasant, Blood Pheasant, Kalij, Luinche, Chilme are found.

The climatic condition is very dun, dry and extremely cold and snowy. Therefore, no tall trees except short grass and shrubs are found in this region.

Birds of Nepal

Nepal is rich in biodiversity. Along with the different types of forest different types of animals and birds are also found in Nepal. Here in Nepal, one can see birds and mammals found nowhere else, Although animal habitat has been somewhat depleted as a result of agriculture, deforestation and other causes, through Nepal's extensive and effective park and reserve system, the country still has more varied flora and fauna than any other area in Asia.

Some protected birds in Nepal

a) **Sarus Crane (*Grus antigone)***

It is found in freshwater marshes and plains. It is a very large crane, measuring 156 cm (5 ft) in length in average. The sexes do not differ in color, but the male is larger than the female. Young birds are duller and browner. Adults are grey with a bare red head and white crown and a long dark pointed bill. The average weight is 7.3 kg. In Nepal, mostly found in Lumbini and Western terai regions.

Fig 18.4: Sarus Crane

b) **Impeyan Pheasant/Himalayan Monal/Danfe (***Lophophorus impejanus)*

Danfe is the National bird of Nepal, found mostly in the Himalayas. It is a relatively large sized bird. It is about 70 cm in length, the weight of males and females range between 1980-2380g and 1800-2150g respectively. Notable features in males are a long crest that is metallic green, changeable reddish copper on the back and sides of the neck and, a prominent white back and rump while in flight.

Fig 18.5: Danfe

c) **Great Hornbill/Thulo dhanesh (***Buceros bicornis)*

The great hornbill is a large bird with a very large bill, which bears a sizable, brightly colored, horny growth- the casque. The body is mostly black with a white neck, wing coverts and flight feathers. Its size is 100-120 cm (40-48 in.) and 150 cm (5 ft) with wingspan. This is a resident bird, found in Himalayas.

Fig 18.6: Thulo dhanesh

d) **Satyr Tragopan/Munal (***Tragopan* spp*)*

Male has red under parts with black- bordered white spots and olive brown coloration to upperparts. Facial skin is blue. Female is rufous-brown with white streaking and spotting. This is a resident bird found in Himalayas. It is found in temperate and sub-alpine forest in Nepal.

***Fig 18.7:* Munal**

e) **Black Stork/Kalo saras (*Ciconia nigra)***

This is a large bird, nearly 1 m tall with a 1.8 m wingspan, weighing around 3 kilograms. It is all black except for the white belly and axillaries, and its red bill and legs. It walks slowly and steadily on the ground. The Black Stork, feeds mainly on fish and also amphibians and insects. It is a widespread, but rare, species that breeds in the warmer parts like Makalu Barun National Park, Koshi and Chitwan of Nepal.

Fig 18.8: Kalo Saras

e) **White Stork/Seto saras (***Ciconia ciconia)*

It is a huge bird, flying with its neck outstretched. It is 100-125 cm (40-50 in.) tall, with a 155-200 cm (61-79 in) wingspan and a weight of 2.3-4.5 kg (5-10 lbs). It is completely white except for the black wing flight feathers, and its red bill and legs, which are black on juveniles. It walks slowly and steadily on the ground.

Fig 18.9: Seto Saras

f) **Lesser Florican/Sano Khar majur**
(*Sypheotides indica***)**

It is Small, slim, long necked bustard. Breeding male has spatulate tipped head plumes, black head/neck and under- parts and white wing coverts show as patch on closed wing, but have less white on wing than Bengal Florican. It can be separated from female or immature Bengal florican by smaller size and slimmer appearance, heavily marked wing- coverts and rufuos rather than buff background coloration to barred flight feathers. The Lesser Florican is a large bird that breeds in Pakistan, and is a rare summer visitor in Nepal.

Fig 18.10: Sano Khar majur

g) **Bengal Florican/Khar majur**
(*Houbaropsis bengalensis***)**

The male has black from head to neck and underparts. Upperparts are buff with fine black vermiculations and black arrowhead markings, and it has a conspicuous white patch on the wing coverts. Females are larger than the male and have a buff brown colour, with a dark brown crown and narrow dark streak down the side of the neck. They are found in the terai of Nepal.

Fig 18.11: Khar majur

> **Activity**
>
> Which types of Birds are found in your surrounding? Collect names and make a list.

Ecotourism

Ecotourism is the tourism that is designed to contribute to the protection of the environment or at least minimize damage to it, often involving travel to areas of natural interest in developing countries or participation in environmental projects. It typically involves travel to destinations where flora, fauna, and cultural heritage are the primary attractions.

The International Ecotourism Society defines Ecotourism as: "responsible travel to natural areas that conserves the environment and improves the welfare of local people".

Ecotourism is a growing segment of the global tourism industry that is making significant positive contributions to the environmental, social, cultural and economic well-being of destinations and local communities around the world. Its purpose may be to educate the traveler, to provide funds for ecological conservation, to directly benefit the economic development and political empowerment of local communities. Here are some types of eco-tourism:

- Agro-tourism (rural communities and agriculture)
- Local tourism (local culture and heritage)
- Pro-poor tourism (improving developing countries)

Concept of ecotourism in Nepal

Nepal is known as the green country for its large forests, green valleys and farming. Massive mountains, rolling hills, abundant vegetations and diverse wildlife has made Nepal a popular tourist destination and the ideal location for ecotourism. Ecotourism in Nepal is the main form of tourism in the country aside from the attractions of Kathmandu and other historical cities. From wildlife viewing, to wilderness camps, hiking vacations and white-water rafting, Nepal's ecotourism industry is flourishing.

Nepal’s national economy mainly depends on the natural resources and ecosystems services. The mountains here are the most famous adventure destinations in the world and locals are taking an important role in ecotourism planning and management as well as local and international social organizations have projects in rural areas cover a wide range of ecosystems found in Nepal

The goal of ecotourism in Nepal:

- To enable people to enjoy and learn about the natural, historical and cultural characteristics of unique environments while preserving the integrity of those sites and stimulating the economic development opportunities in local communities.
- To promote the preservation of entire local ecosystems.
- To provide awareness to the local community about sanitation, hazards of deforestation, preservation of eco system; maintain cleanliness and hygiene and so on.

Activity

Search for the places where tourists are attracted in. Make a list. Why those places attract tourist the most? Discuss among friends.

Importance of ecotourism

a) Ecotourism minimizes the physical, social behavioral and psychological impacts and adverse effects of hotels and other infrastructures.

b) Ecotourism provides education for both tourists and residents of nearby communities about minimizing the negative impacts of visiting sensitive environments and cultures.

c) Ecotourism helps to raise funds for environmental protection, research and education through park entrance fees, tour companies, hotels, airlines and airport taxes and voluntary contributions.

d) Ecotourism provides financial benefits and empowerment for local people.

e) Ecotourism maintains relationship between the visitor and the host. A responsible eco-tourist learns about the local customs, respecting dress codes and other social norms.

f) Ecotourism demands to travel, one in which participants strive to respect, learn about and benefit both the local environment and local communities.

Summary

1. Livestock are domesticated animals raised to produce milk, meat, eggs, wool, labor etc.
2. Nepal is an agricultural country and livestock farming is an important sector of agriculture especially in Nepal.
3. The major native breeds of cow in Nepal are lulu, achhami, siri, khaila, terai and hily.
4. The major native breeds of goats are chyangra, sinhal, khari and terai goats whereas cross breeds are sanan, jamunapari, barberi and beetal.
5. The poultry farming or poultry keeping is a branch of agriculture that deals with the raising, growing, breeding under intensive management in order to get meat products and eggs for consumption and marketing.
6. The forest of Nepal is classified on the basis of geographical location and climatic characteristics into four types as Tropical/Deciduous Monsoon Forest, Subtropical/Mixed Evergreen Forest, Temperate/Evergreen Forest and Subalpine and Alpine Forest.
7. Some birds like Sarus Crane, Danfe, Great Hornbill, Kalo saras, Munal, Seto saras, Sano Khar and Bengal Florican are protected in Nepal.
8. Ecotourism is the tourism that is designed to contribute to the protection of the environment or at least minimize damage to it.
9. The purpose of ecotourism may be to educate the traveler, to provide funds for ecological conservation, to directly benefit the economic development and political empowerment of local communities.
10. Agro-tourism (rural communities and agriculture), Local tourism (local culture and heritage) and Pro-poor tourism (improving developing countries) are the types of ecotourism.
11. Massive mountains, rolling hills, abundant vegetations and diverse wildlife has made Nepal a popular tourist destination and the ideal location for ecotourism.

Exercise

A. Tick (√) the best alternative from the followings.

1. Which goat is not a native breed of Nepal?

   i) Sinhal   ii) Jamunapari   iii) Khari   iv) Chyangra

2. The following birds are protected in Nepal:

   i) Sarus Crane   ii) Munal/Danfe

   iii) Great Hornbill   iv) All of the above

3. Which one is not an advantage of poultry?

   i) It is the source of regular, supply of meat and eggs.

   ii) The chicken manure can be used in the field to increase the fertility of the soil.

   iii) Poultry farming needs very large investment of money.

   iv) It solves the problem of unemployment to some extent.

4. Livestock farming is important because:

   i) It enhances the income of farmers

   ii) It increases the production of meat, milk, wool, eggs, etc.

   iii) It also can be used to increase the fertility of the soil indirectly.

   iv) All of the above

B. Answer the following short questions:

1. What do you understand by livestock farming? Mention its two importance.
2. List the significances of livestock farming.
3. What are the steps that are followed in poultry farming?
4. Make a list of birds protected in Nepal.
5. Define Ecotourism. What are its types?
6. Why is ecotourism important?

7. Write difference between:
    a) Synthetic breeds and pure breeds
    b) Tropical/Deciduous Monsoon Forest and Subalpine and Alpine Forest
    c) Black stork and white stork
    d) Ecotourism and tourism

C. Answer the following long questions:

1. Describe in short the types of livestock farming common in Nepal.
2. '*Green forests are the wealth of Nepal*,' Explain.
3. What are the types of forest found in Nepal? Describe in brief.
4. Explain the concept of ecotourism in Nepal.
5. Write short notes on:
    a) Himalayan Monal/Danfe b) White Stork c) Sarus Crane
    d) Advantage of Cow farming e) Advantages of poultry

Project work

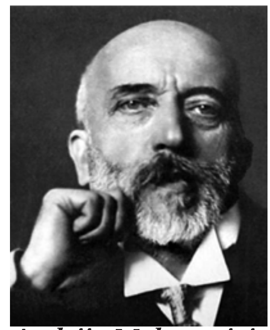
List the names of the places popular for tourism in Nepal. Why those places are popular? Elaborate the reason, form a report on it and present among the friends.

Glossary

Domesticated	:	make fit for cultivation, domestic life, and service to humans
Dung	:	feacal matter of animal
Draught power	:	energy adapted for drawing heavy loads
Carcass	:	the dead body of an animal especially one slaughtered and dressed for food
Native	:	indigenous
Culling	:	remove something that have been rejected
Plumage	:	the feathers on a bird's body
Rufous	:	yellowish red or brownish red colour
Rump	:	the part of an animal that corresponds to the human but tocks
Prolificacy	:	Property of producing abundantly
Flank	:	Location

Unit 19 The Earth

Andrija Mohorovicic, (born Jan. 23, 1857, Volosko, Croatia, Austrian Empire [now in Croatia]—died Dec. 18, 1936, Zagreb, Yugos. Croatian meteorologist and geophysicist who discovered the boundary between the Earth's crust and mantle—a boundary subsequently named the Mohorovicic discontinuity..



Andrija Mohorovicic (1857- 1936)

Learning outcomes

After the completion of this unit, learners will be able to

1. Give the introduction and importance of the geology.
2. Describe the types of fossils and its importance.
3. Describe the types and process of formation of rocks.
4. Identify the rocks found in locality and explain their uses.
5. Describe the process of formation of the mountains.
6. Give the introduction of Geochronology.

Introduction

We know that scientists have never studied any materials from a depth below 11 km. Then how can we say what is in the center of the earth or what the core of the earth is made up of. The answer is actually quite simple. It is true that we cannot study the Earth's core using visible light, but we can study it using other senses. The most important thing we use to sense the Earth's core is seismic waves. Seismic waves are waves of energy caused either by earthquakes or by fabricated explosions.

Geologists are able to measure these waves as they pass through the earth. When these waves encounter different materials, they change themselves in different ways, like becoming longer, shorter, faster, or slower. Geologists study these changes in the form of wave patterns drawn by seismographs and are able to draw conclusions about what the core of the earth must look like.

Scientists also can learn a lot about the core of the planet by looking at earth's magnetic field. The magnetic field is created by massive circulations of hot liquid mantle beneath the earth's surface. Earth is made by different constitutents, i.e. its constituent materials are separated and segregated into layers according to its density. The denser materials are concentrated near the centre and less dense materials are near the surface. The internal layers of the Earth are recognized on the basis of composition and physical properties. On the basis of composition, earth is found to be divided into 3 layers: Crust (SiAl), mantle (SiMg) and core (NiFe). But on the basis of physical property, it is divided into four layers: Lithosphere, Asthenosphere, Mesophere and core. These clues lead geologists to believe that the earth is made of four distinct layers. These layers are: the crust, the mantle, the outer core, and the inner core.

The Earth's Crust

The uppermost layer of the earth is called crust which is made up of rock and loose materials. Besides Oxygen (which is the most abundant element of the crust), crust constitutes mainly Silicon and Aluminium element (SiAl) It is in averageabout 45 km thick. Underneath the continents, the crust is almost three times as thick as it is under the oceans. Its temperature ranges from 0°C to 870ºC. The boundary between the crust and mantle is called the Mohorovicic discontinuity (or Moho). It is named in honour of the person who discovered it, the Croatian scientist Andrija Mohorovicic. Moho is a non continuous, irregular and molten border line between crust and mantle.

The Earth's Mantle

Under the crust, there is the rocky mantle, which is composed of silicon, oxygen, magnesium, iron, aluminium, and calcium. The upper mantle is rigid and is the part of the **lithosphere** (together with the crust). The lower mantle flows slowly, at a rate of a few centimeters per year. The **asthenosphere** is a part of the upper mantle that exhibits plastic properties. It is located below the lithosphere (the crust and upper mantle), between about 100 and 250 kilometers deep. Heat currents carry heat from the hot inner mantle to the cooler outer mantle. The mantle is about 2,900 km thick that represents about 85% of the total weight and mass of the earth. The mantle gets warmer with the depth; the top of

> Do you know?
>
> Massive earthquake hit Nepal on 12 Baisakh 2072 and thereafter. The magnitude was 7.8 Mw (moment magnitude scale) or, 8.1 Ms (Surface wave magnitude) with a maximum Mercalli intensity of IX (Violent). Its epicenter was east of Gorkha at Barpark and hypocenter was at a depth of 8.2 km from it. It was the worst natural disaster to strike Nepal after 1990 B.S., Nepal - Bihar earthquak e. The earthquake killed nearly 10,000 people (8800 as per the government record) and nearly 3.5 million people were left homeless.

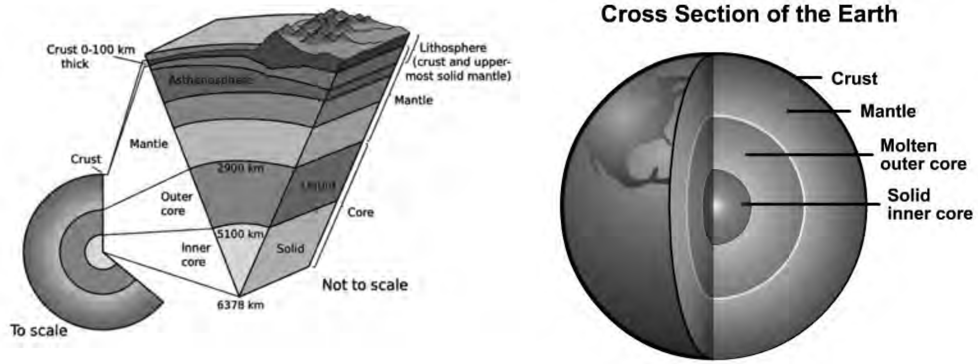


Fig: 19.1 layers of earth

the mantle is about 870° C; towards the bottom of the mantle, the temperature is about 2,200° C - 3,700° C. The main constituents of mantle besides oxygen are silicon and magnesium (SiMg).

The Earth's Outer Core

Below the mantle, there is another layer called Earth's outer core, which extends from about 2,900 km to 5,100 km beneath the earth. The non-continuous & irregular border between mantle & outer core is called Gutenberg discontinuity is believed that this outer core is made up of super-heated liquid i.e. molten lava. This lava is believed to be mostly iron and nickel (NiFe). The outer core may have a temperature up to about 4300°C.

The Earth's Inner Core

The inner core extends another 1,300 km towards the center of the Earth. It is believed that this inner core is a solid ball of mostly iron and nickel (NiFe). The inner core may have a temperature up to about 7,200°C, which is hotter than the surface of the Sun.

Importance

The inner part of the earth contains many daily useful substances. Mostly metals, rocks and other precious gems are found inside the earth. Some pints of importance of the interior part of the earth is given here as follows:

a. It acts as the source of geothermal energy as it contains higher temperature.

b. The huge ball of liquid and solid iron inside the Earth's core protects us from the dangerous radiation of space by causing strong magnetic field which extends up to thermosphere (at the height of 720 km from surface.)

c. We can obtain precious minerals, ores and rocks from the Earth's crust.

d. The seismic and volcanic activities in the Earth's interior create different landforms in the Earth's surface.

Fossils

When most people think of fossils they think of dinosaurs skeletons and large bones, but there are many different types of fossils to be found. Fossils are the remains of once living animals or plants. People have been finding fossils in rocks for thousands of years, but until quite recently they didn't understand what they were.Today we recognize that the fossils we find in rocks represent the ancestors of the animals and plants that are alive today.

Types of fossils

A fossil is any remains or trace of an ancient organism. Fossils include body fossils, left behind when the soft parts have decayed away, as well as trace fossils, such as burrows, tracks or fossilized waste (feces).

Depending upon the modes of fossil preservation, fossils are of following types:

a. Actual remains: The fossils are said to be actual remain if there is no change in the original composition of organism e.g. Wooly Mammoth (25,000 years old) found preserved in frozen ice of Siberia, remains of many mammals and birds found at the one million years old Tar Pits of California.

b. **Petrification:** They are fossils in which organic materials are replaced by mineral matter. In some petrified fossils, even cellular details are found.

> Do you know?
>
> It's important to note that most fossils are preserved by more than one mode. For example, the fossil leaves are carbonized, but also leave a cast and mold. Fossil ammonites are casts, however, they also are mineralized. Fossil trilobites are often found as casts and molds, but their exoskeletons are mineralized (usually replaced by calcite).

c. **Compressions:** Internal structure is absent but a thin carbon film indicates the outline of external features.

d. **Incrustation:** They are external moulds formed around organic remains which later degenerate.

e. **Moulds:** They are hardened encasements formed in the outer parts of extinct organic remains which later decay leaving cavities.

f. **Casts:** They are hardened pieces of minerals matter deposited in the cavities of moulds.

g. **Impressions imprint:** They are external features of organism or their parts left in hardening matter before complete decay.

h. **Polynofossils/Microfossils:** They are fossils of spores, pollen and microscopic organisms. Some of these help to locate fossil fuel.

i. **Coprolites:** They are fossilized fecial remains of the animals.

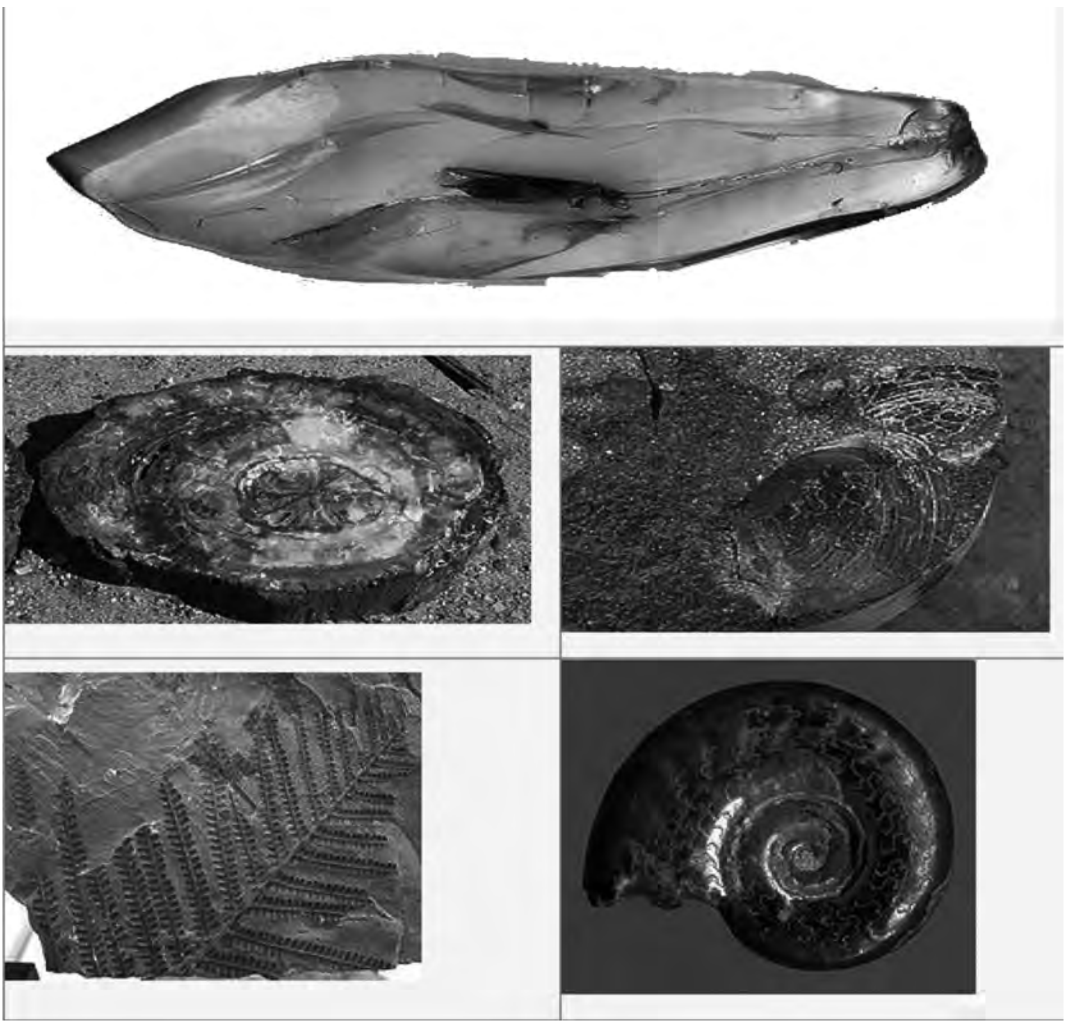


Fig:19.2 Types of fossils: insect preserved in amber, petrified wood, cast and mold of a clam shell, carbonized fossil of a fern and pyritized ammonite.

Activity 1

Take a box of paper. Put some solution of plaster of Paris ($2CaSO_4 H_2O$) into it. Take a leaf or some other small part of a plant and place gently over the layer of plaster of Paris. Again pour the solution of plaster of Paris over the leaf. Leave it for sometime while it becomes hard. Break the solid mass and see what happens inside it.

Activity 2

Collect some old and hard part of soils or rocks that are found in your surroundings. Look at their porous parts. There may be some shapes or impression of different parts of organisms. Then discuss with your teacher and friends.

Importance of fossils

Fossils are traces of ancient life. Scientists use fossils to gather information about the lives and evolutionary relationship of organisms, for understanding geological change and even for locating fossil fuel reserves.

a. Peeking into the Past

Fossil remains can give us insight into how prehistoric plants and animals obtained food, reproduced and even how they behaved. At times fossils can also provide evidence for how or why the fossil organism died.

b. Dating Layers of the Earth

Geologists also use fossils for what's called bio stratigraphic correlation, which allows researchers to match layers of rock in different locations by age based on how similar the fossils in each rock layer are.

c. Documenting Changes

Environmental interpretation, or understanding how the earth has changed over time, is another area where fossils supply invaluable evidence. The type of fossil found in a particular location tells us what kind of environment existed when the fossil was formed.

d. Fossils and Oil

Fossils also have practical and commercial applications. The fossil fuel extractors in our energy and plastic industries collects raw materials from specific types of rock layers.

e. Evolution

Perhaps one of the most important functions of fossils from a scientific perspective is that they constitute one line of evidence for understanding evolution. Using information pieced together from fossil evidence, scientists can reconstruct body types of animals that no longer exist and put together a "Tree of Life" to describe the evolutionary relationship among organisms.

f. The Fossil Record

Fossilization is a relatively rare process. Most organisms are not preserved in the fossil record. Because soft-bodied organisms, for example, usually don't form fossils, there can be "gaps" in the fossil record. Many exceptional deposits of fossils nevertheless provide a surprisingly detailed glimpse into the past and allow scientists to piece together a more complete picture of the history of life on earth

Formation of Rocks

You have seen different types of rocks on your surroundings. Some are hard; however, some are relatively soft. We can see rocks with different colors, shapes, and sizes. These are the important aspects in our daily life. We use rocks mainly in constructions, decorations, security purposes etc.

Minerals:

Minerals are naturally occurring substances formed by geological processes. They are usually solid and appear in a crystal structure with specific physical properties and chemical composition. A mineral is sometimes made up of just one element but more often it is a compound (mixture) of two or more. For example, diamond is made up of just carbon, while fluorite is made up of a compound of calcium and fluorine.

There are over 4000 different types of minerals. Only around 30 of these are commonly found in the earth's crust. Examples of minerals include calcite, gypsum, feldspar, pyrite, gold, quartz and diamond. The precious gems ruby and sapphire are varieties of the mineral corundum.

Ores

A mineral occurring in sufficient quantity and containing enough metal to permit its recovery and extraction at a profit is called an ore. Alternatively, **a mineral or an aggregate of minerals from which a valuable constituent, especially a metal, can be profitably mined or extracted is an ore**. Examples of ore are Haematite and Magnetite of Iron, Bauxite and Felspar of Aluminium, Copper pyrite or Chalcopyrite and Chalcocite or Copper glance of Copper, etc.

Differences between Minerals and Ores

Minerals	Ores
i) These are naturally occurring metals present in the earth's crust.	i) These are minerals which can be used to obtain the metal profitably.
ii) All minerals are not ores.	ii) All ores are essentially minerals too.
iii) Eg: clay is the mineral of Aluminium.	iii) Eg: Bauxite and cryolite are the main ores of Aluminium.

Rocks

Rocks and stones are naturally occurring solids made up of minerals. Rocks have been used by humans for millions of years, from early tools and weapons through to various construction materials. The crust and upper mantle are collectively known as the lithosphere, from which the tectonic plates are composed.

It is the lithosphere that rocks are formed and reformed. There are three different types of rocks based on the way they form; **igneous, sedimentary and metamorphic**. Each type of rock has a different origin. Therefore, there are three different views regarding the formation of the rocks, which are also called the types of rocks.

Formation of Igneous Rocks

Igneous rocks are formed when melted rock cools and solidifies. Melted rock may come in the form of magma, when it is found underneath the earth's surface. It can also come in the form of lava, when it is released unto the Earth's surface during a volcanic eruption. Some examples of igneous rocks are granite, basalt, pumice, obsidian etc.

Formation of Sedimentary Rocks

Sedimentary rocks start forming when soil and other materials on the Earth's surface are eroded and finally settle down, forming one layer of sediments. As time passes, more and more materials get eroded and settle on the older layers. Thus, layer upon layer is formed. The lower layers undergo intense pressure due to the weight of the upper layers, eventually evolving into rocks. Some examples of sedimentary rocks are sandstone, limestone, shale, conglomerate, and gypsum.

Formation of Metamorphic Rocks

Metamorphic rocks are actually products of rocks that have undergone changes. Thus, a metamorphic rock may have originally been an igneous, sedimentary, or even another metamorphic rock. The changes occur when the original rocks are subjected to extreme heat and pressure beneath the earth's surface.

They may also occur when the original rocks are caught in the middle of two colliding tectonic boundaries. Some examples of metamorphic rocks are marble, slate, schist and gneiss. Marble is the result of the metamorphism of limestone and dolostone.

Identification and uses of different types of Rocks

Identifying rocks is easier than identifying minerals. If you have difficulties and cannot decide whether a rock is sedimentary, igneous or metamorphic, then some clues are given below.

Fig: 19.3 different types of rocks

Formation of Mountains

Mountains are formed by slow but gigantic movements of the earth's crust (the outer layer of the earth). The earth's crust is made up of 6-8 huge slabs called tectonic/continental plates, which fit together like a jigsaw puzzle. When two slabs of the earth's crust smash into each other the land can be pushed upwards forming mountains. Many of the greatest mountain ranges of the world have formed because of enormous collisions between continental plates.

Sometimes the crust has folded and buckled, sometimes it breaks into huge blocks. In both cases, great areas of land are lifted upwards to form mountains. Other mountains are formed by the earth's crust rising into a dome or by volcanic activity when the crust cracks open.

Do you know?

Earthquakes occur when two plates pushing past each other, cause of a facture in the earth's crust. The Himalayan Mountains were developed at about 32 - 50 million years ago. The Himalayan range was created from earth's powerful tectonic movements that occurred as the Indian plate, pressed against the Eurasian continental plate. The earth's movement raised the deposits laid down in the ancient, shallow, Tethys (on the present side of mountains) to form the Himalayan ranges from Pakistan eastward across India and from Nepal and Bhutan to the Myanmar (Burmese border). The mountains continue to develop and change, even today. The earthquake and tremors occur frequently in the areas.

Types of mountains

There are five basic types of mountains:

1. Fold Mountains (Folded Mountains)
2. Fault-block Mountains (Block Mountains)
3. Dome Mountains
4. Volcanic Mountains
5. Plateau Mountains

Do you know?

Two tectonic plates meet along the Southern Alps. This is called a fault line. The Southern Alps are constantly changing because the Pacific Plate is being pushed down under the Australian Plate and that causes the Alps to rise up.

These different types of mountain names not only distinguish the physical characteristics of the mountains, but also how they were formed.

Fold Mountains

As the name suggests, Fold Mountains occur when two tectonic plates collide at a convergent plate boundary, causing the crust to uplift. These are the most common types of mountains. The world's largest mountain ranges are Fold Mountains. These ranges were formed over millions of years.

Fig: 19.4 Fold Mountain

Fold Mountains are formed when two plates collide head on, and their edges crumble, much the same way as a piece of paper folds when pushed together. The upward folds are known as anticlines, and the downward folds are synclines.

Some fold mountains are: Himalayan Mountains in Asia, the Alps in Europe, the Andes in South America, the Rockies in North America, the Urals in Russia etc.

The Himalayan mountain chain lies between Tibet and Nepal. This chain formed as a result of the collision between the Indian subcontinent and Asia some 25 million years ago, and has given rise to the tallest mountain in the world – Mt. Everest. In South America, the Andes Mountains were formed by the collision of the South American continental plate and the oceanic Pacific plate.

Fault-block Mountain

These mountains form when faults or cracks in the earth's crust force some materials or blocks of rock up and others down. It is also known as rifting, this process occurs when rocks on one side of a fault rise relative to the other. The uplifted blocks become Block Mountains (also known as horsts) while the intervening dropped blocks are known as graben (i.e. depressed regions). Often fault-block Mountains have a steep front side and a sloping back side. Some fault-block mountains are the Sierra Nevada Mountains in North America, the Harz Mountains in Germany, Satpura horsts in India etc.

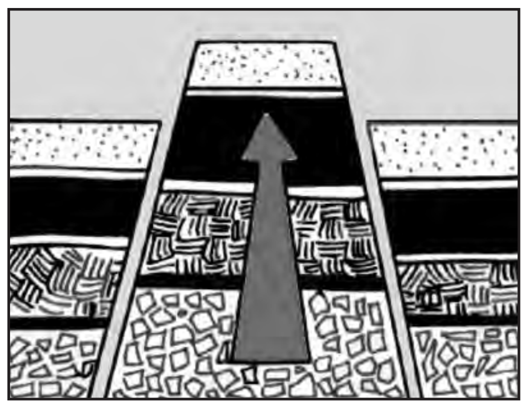


Fig: 19.5 Fault-block Mountain

Geo-chronology

Geochronology is the science of dating and determining the time sequence of events in the history of the Earth. Geologic research and mapping requires the determinations of the ages and composition of rocks. A geologic map or report typically is only a summary of investigations that frequently involve the collecting and processing of hundreds of rock samples, followed by the evaluation and interpretation of data from a variety of analytical techniques.

"Geochronology is the process of determining numerical ages and dates of the earth's materials and events. This is the fundamental way to understand geological time and geological history."

Relative Dating Methods

The majority of the time fossils are dated using relative dating techniques. Using relative dating the fossil is compared to something for which an age is already known. Scientists can use certain types of fossils referred to as index fossils to assist in relative dating via correlation. Index fossils are fossils that are known to only occur within a very specific age range. If the fossil you are trying to date occurs alongside one of these index fossils, then the fossil you are dating must fall into the age range of the index fossil. Sometimes multiple index fossils can be used. In a hypothetical example, a rock formation contains fossils of a type of brachiopod known to occur between 410 and 420 million years. The same rock formation also contains a type of trilobite that was known to live 415 to 425 million years ago. Since the rock formation contains both types of fossils the age of the rock formation must be in the overlapping date range of 415 to 420 million years.

Absolute or Numeric Dating Methods

Absolute dating is used to determine a precise age of a rock or fossil. Absolute dating methods are carried out in a laboratory. Absolute dates must agree with dates from other relative methods in order to be valid. The most widely used and accepted form of absolute dating is radioactive decay dating. This uses radioactive minerals that occur in rocks and fossils almost like a geological clock.

Radioactive decay dating

The atoms in some chemical elements have different forms, called isotopes. These isotopes break down at a constant rate over time through radioactive decay. By measuring the ratio of the amount of the original (parent) isotope to the amount of the final (daughter) isotopes, an age of the sample can be determined. We can express radioactive decay in half-lives. If a radioactive isotope is said to have a half-life of 5,000 years that means after 5,000 years exactly half of it will have decayed from the parent isotope into the daughter isotopes. Then after another 5,000 years half of the remaining parent isotope will have decayed. While people are most familiar with carbon dating, carbon dating is rarely applicable to fossils. Carbon-14, the radioactive isotope of carbon used in carbon dating has a half-life of 5730 years, so it decays too fast. It can only be used to date fossils younger than about 62,000 years. Potassium-40 on the other hand has a half life of 1.25 billion years and is common in rocks and minerals. This makes it ideal for dating much older rocks and fossils.

Summary

1. The earth is made of four distinct layers- the crust, mantle, outer core and inner core.
2. The boundary between the crust and mantle is called the Mohorovicic discontinuity (or Moho) while the Gutenberg discontinuity separates the outer core and the mantle.
3. The inner core may have a temperature up to about 7200^0c, which is hotter than the surface of the sun.
4. Fossils are the remains of once living animals and plants.
5. Depend upon the mode of fossil preservation fossils are of different types.
6. Minerals are naturally occurring substances formed by geological processes. Minerals may contain one or more than one types of chemicals.
7. Minerals with sufficient amount of metal that can be used for its recovery are called ores.
8. Rocks and stones are naturally occurring solids made up of minerals. Mainly, rocks are of three types igneous, sedimentary and metamorphic.
9. Mountains are formed due to tectonic or volcanic activities.
10. Folds mountains are formed by the collision of two tectonic plates at a convergent plate boundary, causing the crust to uplift.
11. Fault block mountains are formed when faults (or crack) on the earth's crust force some parts of the rocks up and others down.
12. Geochronology is the science of dating and determining the time sequence of events in the history of the earth.
13. Carbon-14, radioactive isotope of carbon is used in dating of younger fossils of organisms while potassium-40 is used for dating much older rocks and fossils.

Exercise

A. Tick (√) the best alternative from the followings.

1. The boundary between the crust and mantle is called ....

   i. Lithosphere   ii. Asthenosphere

   iii. Moho   iv. Gutenberg discontinuity

2. Fossil of plants are example of ....

   i. Coprolites   ii. Carbonization

   iii. Per mineralization   iv. Petrification

3. What type of rock is sandstone?

   i. Igneous   ii. Sedimentary   iii. Metamorphic

4. Which layer plays an important role in formation of mountains?

   i. Crust   ii. Mantle

   iii. Outer core   iv. Inner core

5. The science that helps to find the age and history of the earth is called ....

   i. Astronomy   ii. Geology

   iii. Geochronology   iv. Chronology

B. Answer the following short questions:

1. What is the thickness of the earth's crust?
2. How are the crust and mantle differentiated into two layers?
3. Define lithosphere and asthenosphere.
4. What is the temperature of Earth's inner core?
5. Define fossils. How are they formed?
6. Why are fossils important for us?
7. What are index fossils? Give any two examples of index fossils.
8. Define rocks, minerals and stones.
9. What are Moulds and Casts?
10. What do you mean by coprolites? Give any one example of actual remains.
11. Show the differences between minerals and ores?

12. What is the source of igneous rocks? Give any two examples of igneous rocks?
13. Define metamorphic rocks. Where can we find sedimentary rocks?
14. Fossils are generally found in Sedimentary rocks, why?
15. What are the differences between igneous plutonic and igneous volcanic rocks?
16. How are the mountains formed?
17. Himalayan mountains are fold mountains instead of fault-block Mountains, why?
18. Define geochronology. Why is geochronology important for us?
19. Why is Carbon -14 radioactive isotope used mainly for?
20. Give the significance of potassium-40 isotope.
21. Distinguish between relative and absolute dating methods?
22. How is radioactive decay dating carried out? Give examples.

C. Answer the following long questions:

1. Describe the different types of fossils and write the importance of fossils?
2. How are sedimentary, Igneous-Plutonic, Igneous-volcanic and Metamorphic rocks identified?
3. A fossil contains c^{14} and c^{12} – isotopes of carbon in equal ratio i.e. amount of C^{14} isotopes is found to reduce by half. Then find the age of fossil. [Half-life of C^{14} =5730yrs]

Project work

Visit nearby river in your locality. Collect the different samples of rocks and fossils. Sketch rough figure of each and try to differentiate them according to their types. Prepare a report and present it in your class.

Glossary

Amber : Fossilized tree sap that appears yellow shiny stone.

Body fossil : The remains of an ancient organism. Examples include shells, bones, teeth, and leaves.

Cast : A structure that forms when sediments fill a mold and harden, forming a replica of the original structure.

Fossil : Any remains or trace of an ancient organism.

Fossil fuel : A fuel that was formed from the remains of ancient organisms. Examples include coal, oil, and natural gas.

Mass extinction	:	A period of time when an unusually high number of species became extinct.
Microfossil	:	A fossil that must be studied with the aid of a microscope.
Mould	:	An impression made in sediments by the hard parts of an organism.
Seismic waves	:	The waves generated on earth due to earthquake or other types of vibration.
Fabricated	:	False in the sense of made-up, constructed
Peeking	:	To retrieve the information from memory or past.
Bio stratigraphy	:	The study of the stratigraphic (in different layers) distribution of fossils.
Sapphire	:	A clear deep blue variety of corundum, valued as a precious stone.
Corundum	:	An extremely hard mineral, a form of aluminum oxide with the chemical formulas Al_2O_3, that occurs in the form of the gemstones, sapphire and ruby; it is used as abrasive.
Abrasive	:	Being rough and coarse in manner or disposition; rough enough to wear away the outer surface.
Delta	:	A landform at the mouth of a river where it empties into a body of water.
Interlock	:	To pit together securely.
Petrochemical	:	Any compound derived from petroleum or natural gas.
Linoleum	:	An inexpensive waterproof covering used especially for floors, a form polyvinyl chloride.
Rhyolite	:	An igneous, volcanic extrusive rock, of felsic, composition.
Crudely	:	Being naturally.
Varicolored	:	Having a variety of colours.
Emery	:	An impure type of corundum.
Foliation	:	The property, possessed by some crystalline rocks, of being divided into plates of layers.
Streaks or clumps	:	An irregular line left from smearing or motion.
Gigantic	:	Very large
Crumbled	:	Fell apart or disintegrated.

Unit 20

The Universe

Galileo was interested in optics and astronomy, and in 1609 he built his first telescope and began making observations. The following year he published his first results, where he described the highlands and "seas" of the Moon, four of Jupiter's largest moons, and many newly discovered stars. He also discovered the phases of Venus and sunspots, thereby confirming that the Sun rotates, and that the planets orbit around the Sun, not around the Earth. So, he is known for-kinematics, dynamics, telescopic observational astronomy, heliocentrism.

Galileo Galilei
(1564 - 1642)

Learning outcomes

After the completion of this unit, learners will be able to

1. Explain the evolution history of astronomy
2. Describe the origin of the sun and the earth
3. Explain the process of the formation of the solar system
4. Explain the evolution process of star
5. Describe the process of formation of black hole and neutron star

Introduction

Origin of Astronomy comes through religious, mythological, and astrological practices. In some cultures, astronomical data was used for astrological prognostication. Early astronomy involved observing the regular patterns of the motions of visible celestial objects, especially the Sun, Moon, stars and naked eye planets. Ancient astronomers were able to differentiate between stars and planets, as stars remain relatively fixed over the centuries while planets will move an appreciable amount during a comparatively short time. Previously excellent astronomical practices were carried out in Mesopotamia, Egypt, Greece and Hellenistic world, India, China, Mesoamerica, Islamic astronomy, and Medieval Western Europe. The revolution in the Astronomy was occurred in Renaissance Period.

1. **Historical Development of Astronomy**

The historical development of astronomy can be divided into three different periods. They are:

a. Ancient Period b. Renaissance Period c. Modern Period

a. Ancient Period:

Ancient astronomy was mainly involved in religious, mythological and astrological thoughts. Specially, astronomy was used in astrological foreboding. Although in this period some astrologers have great contribution in evolution history of astronomy. Some of these are as follows:

i. In about 500 B.C, in Hellenistic Culture: the ancient Greeks inherited astronomical records from the Babylonians and applied the data to construct a cosmological framework. Data was not just used for practical goals, such as navigation, but also to think of new experiments like natural philosophers. Thales in about 480 B.C, used this data to predict eclipes. After that Heraclites in 330 B.C. developed the first Solar System model, beginning of the geocentric versus heliocentric debate. In 270 B.C, Aristarchus developed the heliocentric theory.

The orbits he considered are perfect circles because the philosophical reasons that all things in the Heavens are "perfect".

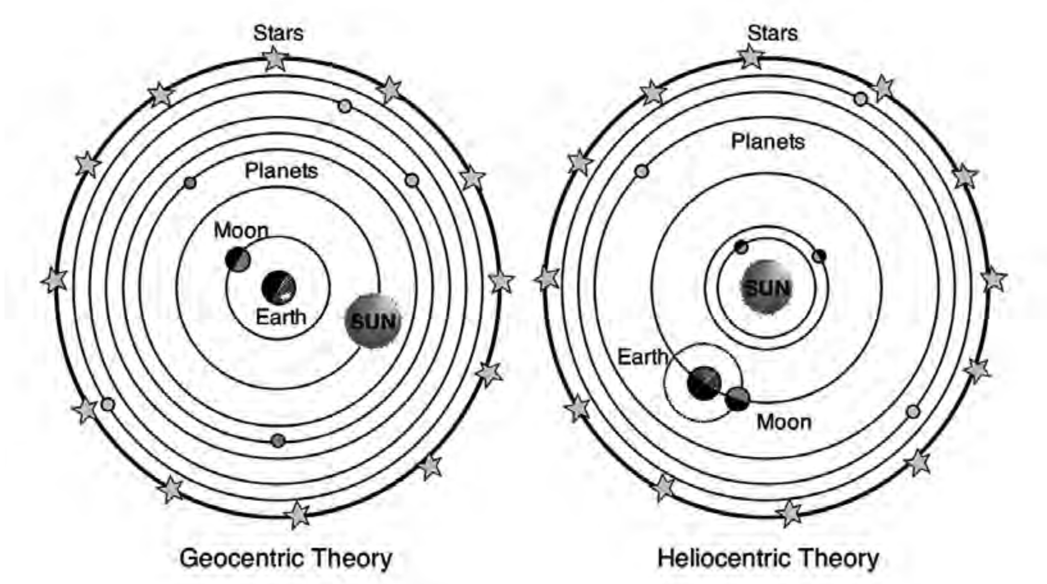


Fig. 20.1: Geocentric and Heliocentric Model of Solar system

b. Renaissance Period:

After Alexandria burned and Roman cultures were collapsed then dark ages in astronomy was started. However, the Roman Catholic Church took Aristotle's scientific methods and Ptolemy's model into its own doctrine. Thus, preserving the scientific method and Ptolemy's Solar System until the Renaissance period started where new ideas were more important than dogma.

1. In 1543, Nicolaus Copernicus published his book in which he became the first person in history to create a complete and general scientific cosmological system. He combined mathematics, physics, and observational astronomy to produce a mostly-accurate working model of planetary motion in which the Sun is at the center. He was the first person to introduce heliocentric theory of the Universe.

2. Brahe (1580's) was the greatest scientist of his time. His observational work creates the foundation of Kepler and Newton's astronomical works. His works profoundly influenced the development of astronomy in the following centuries.

3. Kepler (1600's) a student of Tycho who used Brahe's database to formulate the Laws of Planetary Motion. He had corrected the problems in the heliocentric theory by using ellipses instead of circles for orbits of the planets.

4. Galileo (1620's) developed laws of motion (natural versus forced motion, rest versus uniform motion). Then, with a small refracting telescope (3-inches), destroyed the idea of a perfect geocentric Universe with the following 5 discoveries: spots on the Sun, mountains on the Moon, Milky Way are made up of lots of stars, Venus has phases, and Jupiter has five moons.

5. Newton (1680's) developed the law of Universal Gravitation, laws of accelerated motion, and invented calculus- a mathematical tool. He also formulated the 1st reflecting telescope and theory of light.

c. Modern period of Astronomy:

The modern era on astronomy begins with the discoveries of powerful optical telescopes as well as radio telescopes. In the 18-20th century, with discovery of the outer planets and other heavenly objects leads astronomy towards the discoveries of different stars and galaxies.

Activity 1

Take nine small sized table tennis balls, one big sized ball and some pieces of wires with about 1 mm and 3mm diameter. Place big ball at the center to form the sun and bend big sized wires to form orbit of the planets and moon. Tie the elliptically bent wires with small sized wires. Make the model of geocentric and heliocentric solar system as shown in figure 20.1 and 20.2. Write the name of sun, moon and other planets on their respective position to understand it clearly.

Activity 2

Look at the evolution history of the evolution given in the text. Make a table with different columns including dates, name of scientists and their contributions. From the table, summarize the hierarchy of discoveries in astronomy.

Origin of the Earth

There are different theories and hypotheses regarding the formation of the Earth. The mostly accepted fact is that all the planets including earth were made in the same way. Accretion is the process by which the planets were formed. As lumps of material smashed and became welded together, the planets grew until they were large enough to develop a magnetic force or gravity. This force attracted more materials until the area around each planet was free of debris.

We know principle of energy conservation that tells us that energy neither can be created nor be destroyed. When two objects slam together, their energy is often turned into heat. This happened when the planets were made and it happens when meteors hit the earth. One reason for high temperature inside the earth core is due to this fact.

After the earth was formed, it began to cool. The top layers become a hard, brittle crust. However, the interior of the Earth is kept hot due to presence of radioactive materials. This nuclear energy causes the forces that create volcanoes and earthquakes.

Early in our universe's history, the earth and other planets were formed from dust, pieces of rock and gas orbiting the Sun. This material smashed together and began to heat up until the entire mass melted. Some of the materials in this mass were heavier than others. The heavier metals fell to the center to become the earth's core. The rest of the materials became the mantle, crust and atmosphere.

Origin of the Earth and the Solar System - Theories and Hypotheses

There are various scientific theories of origin and evolution of the earth and Solar system which are:

1. Nebular Hypothesis
2. Planetesimal Hypothesis
3. Gaseous Tidal Hypothesis
4. Binary Star Hypothesis
5. Gas Dust Cloud Hypothesis

1. Nebular Hypothesis

German philosopher, Kant and French mathematician, Laplace gave this hypothesis. This theory tells us that the earth, planets and the sun were originated from nebula. According to this hypothesis, there was large cloud of gas and dust which is called nebula. It rotates slowly and gradually cooled down so that its rotating speed increased very rapidly. Later on, the outer ring was separated from the nebula and cooled down to form the planets. On repetition of this process, all the other planets and satellites were formed and the central region of nebula became the sun.

Objections:

i. Sun should have the greatest angular momentum because of its mass and situated in the center, however, it has only two percent of momentum of the solar system

ii. How the hot gaseous material condensed in to rings

2. Planetesimal Hypothesis

Chamberlin and Moulton proposed this theory in 1904. According to this hypothesis the Sun was existed before the formation of planets. A star came close to the sun and the gravitation pull of the star caused to separate small gaseous bodies from the sun. These bodies on cooing became small planets and started to rotate the Sun. During rotation, the small planets collided and form other planets and satellites.

Objections:

i. The angular momentum could not be produced by the passing star.

ii. The theory failed to explain how the planetesimals had become one planet

3. Gaseous Tidal Theory

Jeans and Jeffrey proposed this theory in 1925. According to this hypothesis, a large star came near to the sun. Due to gravitation pull, gaseous tide was raised on the surface of the sun. As the star came nearer, size of the tide started to increase and it detached from the sun when the star moved away. The shape of the tide was like a spindle. It broke into pieces forming 9 planets and other satellites of the solar system.

> Do you know?
>
> Depending on the star mass, the star will place itself on a specific point of the main sequence of the H-R diagram. It will rest there for a period of millions (for the biggest and hottest starts) to billions (for mid-sized stars like the Sun) to tens of billions (for red dwarf stars) of years, using most of the hydrogen in its core.

4. The double star hypothesis

R.A. Lyttleton presented this hypothesis in 1930 the violence of the explosion of the suns companion caused the larger body to move rapidly away from the sun and to escape altogether into space. Materials ejected at high velocities from the exploding star also largely escaped, but a very small fraction of one percent of the exploded matter remained behind, captured by the gravitational field of the sun, to form the planets.

5. Gas dust cloud hypothesis (condensation hypothesis)

In recent years, scholarly thought about the origin of the solar system has returned in one respect to the basic concept of Kant and Laplace, that solar system developed in and orderly series of stages beginning with a primeval cloud of gas and dust, the solar nebula, which contracted to a rotating disk like body with the sun occupying a central position. Through a condensation process the substance of the nebula ultimately formed into the existing solid bodies of the solar system.

Origin of the Sun

The sun was born about 4.6 billion years ago. Many scientists think the sun and the rest of the solar system formed from a giant, rotating cloud of gas and dust known as the solar nebula. As the nebula collapsed because of its gravity, it spun faster and flattened into a disk. Most of the material was pulled towards the center to form the sun. The sun has enough nuclear fuel to stay much as it is now for another 5 billion years.

Our sun is not unique in the universe. It is a common middle-sized yellow star which scientists have named Sol, after the ancient Roman name. This is why our system of planets is called the solar System. There are trillions of other stars in the universe just like it. Many of these stars have their own systems of planets, moons, asteroids, and comets.

The Sun was born in a vast cloud of gas and dust around 5 billion years ago. Indeed, these vast nebulae are the birth places of all stars. Over a period of many millions of years, this gas and dust began to fall into a common center under the force of its own gravity.

At the center, an ever growing body of mass was forming. As the matter fell inward, it generated a tremendous amount of heat and pressure. As it grew, the baby Sun became hotter and hotter. Eventually, when it reached a temperature of around 1 million degrees, its core ignited, causing it to begin nuclear fusion. When this happened, the Sun began producing its own light, heat, and energy.

What is Thermonuclear Fusion?

Thermonuclear fusion is the process in which a star produces its light, heat, and energy. This happens at the core of the star. The core is superheated to millions of degrees. This heat travels towards the surface and radiates out into the universe. Through this thermonuclear process, stars "burn" a fuel known as hydrogen. The result is that they create another type of fuel known as helium. However, stars do not burn in the same way that a fire does, because stars are not on fire.

Evolution of Star

A star starts out as an enormous cloud of gas and dust many light-years across. Star formation begins when the cloud begins to condense under its own gravity.

The processes that initiate this contraction are not fully understood. The cloud fragments fuse into stellar mass clouds known as protostars. Protostars do not emit visible light, but glow weakly in the infra-red region of the spectrum and can be detected in Bok Globules. If the mass of a protostar is too small, nothing interesting happens, and it dies away as a brown dwarf. If it is massive enough, however, enough gas and dust eventually collects into a giant ball that, at the center of the ball, the temperature (from all the gas and dust bumping into each other under the great pressure of the surrounding material) reaches about 15 million kelvins (or 15 million degrees Celsius). At this point, nuclear fusion begins and the ball of gas and dust starts to glow. A new star has begun its life in our Universe

As the contraction of the gas and dust progresses and the temperature reaches 15 million degrees or so, the pressure at the center of the ball becomes enormous. The electrons are stripped off of their parent atoms, creating a plasma. The contraction continues and the nuclei in the plasma start moving faster and faster. Eventually, they approach each other so fast that they overcome the electrical repulsion that exists between their protons. Hydrogen nuclei are fused to form helium in the proton-proton chain or by the CNO cycle. In doing so, they give off a great deal of energy. This energy from fusion pours out from the core, setting up an outward pressure in the gas around it that balances the inward pull of gravity. When the released energy reaches the outer layers of the ball of gas and dust, it moves off into space in the form of electromagnetic radiation. The ball, now a star, begins to shine. which we call a Main sequence.

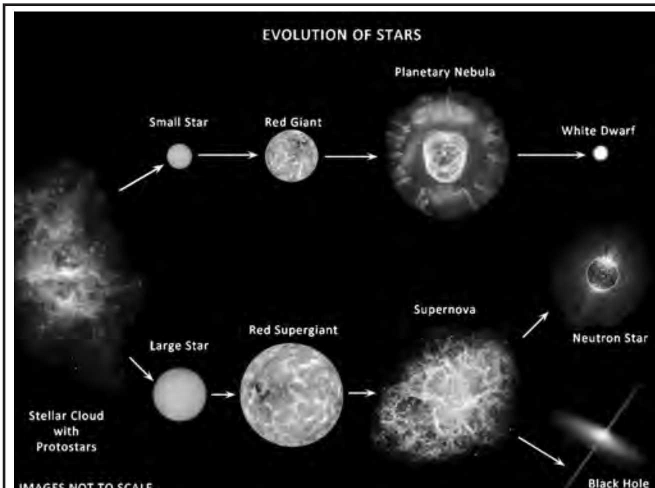


Fig: 20.2 evolution of star

New stars or the main sequence come in a variety of sizes and colors. They range from blue to red, from less than half the size of our Sun to over 20 times the Sun's size. It all depends on how much gas and dust is collected during the star's formation. The color of the star depends on the surface temperature of the star. And its temperature depends, again, on how much gas and dust were accumulated during formation. The more mass a star starts out with, the brighter and hotter it will be. For a star, everything depends on its mass.

Throughout their lives, stars fight the inward pull of the force of gravity. It is only the outward pressure created by the nuclear reactions pushing away from the star's core that keeps the star "intact". But these nuclear reactions require fuel, in particular hydrogen. Eventually the supply of hydrogen runs out and the star begins its demise.

Death of a Star

When a star is born, its hydrogen goes on being used in fusion. When the hydrogen fuel (for fusion) is exhausted in the star, the core of star further contracts and the temperature further rises which causes the expansion of the outer layers of the star. The expansion causes cooling effect. The result is that the size of the star grows and temperature falls, till the size becomes very large and appears red in color which is called red giant. Red giant sustains for millions of years and radiates tremendous amount of energy. At the last, it explodes and explosion is called supernova. This ends existence of star and the star is said to be dead.

Death of star leads to

i) White dwarf

ii) Neutron star

iii) Black hole.

i) White dwarf: The star dies as white dwarf, if original mass of the star is 1.4 times the mass of the sun (Chandershekhar limit). White dwarf cools steadily becomes red dwarf and ultimately become invisible. It is called black dwarf.

Note: Nova (new start) is an extremely bright star that is visible even at daytime. It is formed when a white dwarf attracts dust and gas malesials from its binary red giant star with a tremendous acceleration. Such stars brighten for few month and collapse all of a sudden.

Fig: 20.3 White dwarf

ii) Neutron star: If the mass of the star is between 1.4 to 5 times of the sun, it ends up as neutron star having density of the order of nucleus (= 10^{17} kg/m^3). Due to high gravitational compression, electrons are forced into the nuclei and the combination of electron and protons forms neutrons. Thus, a neutron star is formed. The radius of the neutron star may be around 10km and mass less than 5 solar masses. It produces high magnetic field of the order of 10^8 T.

Fig: 20.4 Neutron star

iii) Black Hole: If the original mass of the star is more than 5 solar masses it ends up as a black hole. Mass of the black hole is greater than that of the sun but it's size is very small. It has infinite gravitational pulls, even photons cannot escape from it and it becomes invisible. So, any particles or light approaching it is attracted and swallowed by it. Since, the radiations are neither reflected nor emitted by it, it appears completely black. For this reason, it is called a Black Hole. Although it cannot be seen, its presence can be ascertained by the gravitational pull. It exerts on the nearby objects.

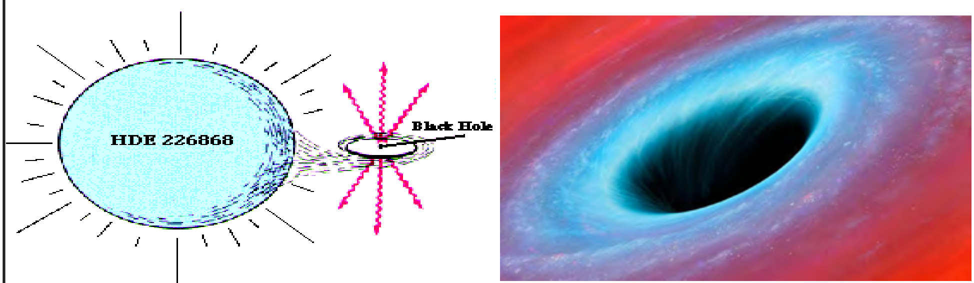


Fig: 20.5 Black Hole

Summary

1. Ancient astronomy was mainly focused in religious, mythological and astrological prognostication.
2. Hericlides (330 B.C.) developed the first solar system model and debate of geocentric versus heliocentric model of solar system started.
3. Aristarchus (2070 B.C.) developed the heliocentric theory of universe.
4. In renaissance period, revolution in the systematic study of astronomy began.
5. Nicholas Copernicus strengthened the heliocentric theory through his systematic study.
6. Kepler, a student of Tycho Brahe, used data observed by Brahe to formulate three laws of planetary motions and coined elliptical orbits of planets instead of circular one.
7. In the modern age of astronomy, there are uses of many scientific technologies for astronomical observations.
8. Solar system was formed from a giant, rotating cloud of gas and dust known as the solar nebular.

9. Sun is radiating enormous amount of energy due to thermonuclear fusion reaction of hydrogen present on it.

10. There are many theories and hypotheses about the origin of earth and solar system. However, mostly accepted scientific theories are nebular hypothesis, planetisimal hypothesis and gaseous tidal theory.

11. The stars are made up of hydrogen, helium, gas and dust particles. Their properties like colour, brightness, temperature motion and size depends on the mass and materials present on them.

12. Like humans, stars have their own ages and they collapse after some time period.

13. Evolution of stars includes birth of a star with high temperature and shining to its end with the formation of white dwarf, neutron star or black hole.

Exercise

A. Tick (√) the best alternative from the followings.

1. A star is formed by ……..

   i. Water ii. Solid iii. Gases iv. Gases and dusts

2. Who proposed gaseous tidal theory?

   i. Kant ii. Chamberlin iii. Jeans and Jeffrey

3. Radio telescopes were discovered in ………

   i. Ancient period ii. Modern age of astronomy iii. Renaissance period

4. Formation of supernova leads ………

   i. Origin of star ii. Development of star iii. Death of star

5. At what temperature, the nuclear fusion begins in the sun?

   i. 5 billion ^{0}C ii. 1 million ^{0}C

   iii. 5000 ^{0}C iv. 2500 ^{0}C

B. Answer the following short questions:

1. What are the dogmas on which astronomy mainly focused?
2. Who proposed the heliocentric model of solar system?
3. Describe the contributions of Aristarchus and Ptolemy in the evolution history of the astronomy.

4. Why is Copernican model of Solar System become popular?
5. When did Renaissance period in astronomy begin?
6. What is the source of energy in the sun?
7. Mention the temperature of the sun inside the core and on the surface.
8. What is nebula? Write the short coming of Nebular hypothesis.
9. Who proposed planetisimal hypothesis of origin of earth.
10. What parameter affects the characteristics of sun?
11. What do you mean by protostar?
12. What are the major events in the evolution history of a star?
13. What do you mean by thermonuclear fusion and where does it take place?
14. Define plasma.
15. What do you mean by Chandershekhar limit?
16. Write the condition of formation of redgiant.
17. How are Newton stars and black holes formed?

C. Answer the following longquestions:

1. Distinguish between geocentric and heliocentric model of universe with figures.
2. Write planetisimal hypothesis of origin of Earth and solar system. Also mention its shortcomings. Write the process of star formation.
3. Describe the evolutionary history of a star from its birth to its end and its consequences.
4. Distinguish between Nova and Supernova.

Project Work

Construct a simple telescope with the help of given materials and observe the heavenly objects in the sky and prepare a report based on this observation.

Materials

- Two biconvex lenses of about 20cm and 50cm focal lengths.
- Paper towel roll
- Piece of cardboard paper
- Tape

Hint for construction of Telescope

Roll up the sheet of cardboard paper by the long way to form a tube that is about the diameter of the lens with the shortest focal length. This will be the eyepiece. Tape the lens to one end of the tube as nearly as possible. Tape the second lens nearly to the end of the paper towel tube fix two tubes so that one inner to the other. Now the telescope is ready.

Glossary

Mythological	:	Legendary of imaginary belief.
Astrological	:	Relating to the phenomena or characteristics from the relative positions of the heavenly bodies.
Prognostication	:	statement about the future or, future-telling
Renaissance	:	the transmission period between middle ages and modern times.
Parallax	:	the apparent shift of an object against a background due to a change in observer position.
Nebula	:	a cloud in outer space consisting of gas or dust (eg: a cloud formed after a star explodes)
Smash	:	the sound of a violent impact or, a violent striking together.
Spindle	:	A rotary axis of a machine tool or power tool
Enormous	:	extremely large or, greatly exceeding the common size, extent, etc..
Bok Globules	:	isolated and relatively small dark nebulae..
Bumping	:	A light blowing or jolting collision.
Stripped off	:	Removed
Plasma	:	a state of matter consisting of a partially ionized gas.
Intact	:	untouched, especially by anything that harms or, not damaged
Orbit	:	A small object path around a larger object which is maintained by the gravity.
Accretion	:	the process of gathering materials through gravity's force
Meteor	:	falling space of rocks or debris
Brittle	:	hard, crisp
Scholarly	:	researcher, educational
Primeval	:	primitive, prehistoric
Bok Globules	:	Relatively small and dark nebula condensed enough to initiate formation of a new star.
Dogma	:	A religious doctrine that is believed true without any proof.