CHAPTER 5

# GENERAL SCIENCE

## PHYSICS

### MECHANICS

**Physics** is the branch of science which deals with the study of matter, energy, and the interaction between them.

### PHYSICAL QUANTITIES – SCALARS & VECTORS

In physics, large number of physical quantities can be broadly classified into two categories– Scalars & Vectors.

- A **scalar** is a physical quantity that has only a magnitude (size) E.g. : Distance, speed, time, power, energy, etc.
- A **vector** is a physical quantity that has both a magnitude and a direction. E.g. Velocity, displacement, acceleration, force etc.

Some physical quantities like moment of **inertia**, **stress**, etc. are neither scalar nor vector. They are **tensor**.

Fundamental quantities and derived quantities are the two types of physical quantities.

The physical quantities which are independent are called **fundamental quantities**. The following seven quantities are fundamental:

### Fundamental and Derived physical Quantities and their units

**Seven Fundamental Physical Quantities and their Units**

| Physical Quantity | SI Unit | Symbol |
|---|---|---|
| Length | meter | *m* |
| Mass | kilogram | *Kg* |
| Time | second | *S* |
| Electric Current | ampere | *A* |
| Temperature | kelvin | *K* |
| Luminous intensity | candela | *Cd* |
| Amount of substance | mole | *mol* |

The physical quantities which depend upon the fundamental quantities are called **derived quantities**. All physical quantities other than fundamental quantities are derived quantities.

**Example :** Area, volume, speed, acceleration, pressure, specific heat, etc.

### Unit of a physical quantity

The **unit** of a physical quantity is the reference standard used to measure it.

### SI SYSTEM

Due to the variability of units, a system of units is worldwide taken in a conference held on 1971 naming general conference on weights and measures. This system is named as SI units. There are seven fundamental units and two supplementary units in this system.

There are two types of units. They are

(i) Fundamental units and (ii) Derived units

Units of fundamental physical quantities are called **fundamental units**.

**Example :** metre, kilogram, second, kelvin, ampere, candela and mole.

### DERIVED UNITS

The units of derived physical quantities are called derived units. All derived units obtained from fundamental units of mass, length and time are called derived units of speed ($ms^{-1}$) is a derived unit.

**Example :** metre per second (unit of speed), metre per second$^2$ (unit of acceleration), kilogram per metre$^3$ (unit of density), etc.

### Types of System of Units

1. **MKS System** In this system, metre, kilogram and second are the fundamental units of length, mass and time respectively.
2. **CGS System** In this system, centimetre, gram and second are the three basic units of length, mass and time respectively.
3. **FPS System** (or British System) In this system, foot, Pound and second are the units of length, mass and time respectively.

### MOTION

**Distance or path length** is the actual length of the path. It is the characteristic property of any path.

**Displacement:** It is the shortest distance between the initial and the final positions of an object. Its direction is taken from the initial position towards the final position.

The displacement may be +ve, –ve or zero, and its SI unit is meter.

**Speed** of an object is defined as the distance travelled in unit time. Mathematically,

$$\text{Speed} = \frac{\text{Distance travelled}}{\text{Time taken}}$$

The **average speed** of an object is defined as the total distance covered to the total time taken to cover that distance. Mathematically,

$$\text{Average speed} = \frac{\text{Total distance}}{\text{Total time}} \quad \text{or } \bar{v} = \frac{s}{t}$$

**Uniform Speed:** An object is said to be moving with a uniform speed if it covers equal distances in equal intervals of time, how so ever small these intervals may be.

**Non-Uniform (or variable) Speed:** An object is said to be moving with a non-uniform speed if it covers equal distances in unequal intervals of time or unequal distances in equal intervals of time, howsoever small these intervals may be.

The rate of change of displacement of a particle with time is called the **velocity** of the particle.

$$\text{i.e. Velocity} = \frac{\text{Displacement}}{\text{Time interval}}$$

The **average velocity** of an object is equal to the ratio of the displacement, to the time interval for which the motion takes place

$$\text{i.e. Average velocity} = \frac{\text{Displacement}}{\text{Time taken}}$$

**Uniform velocity:** A body is said to move with uniform velocity, if it covers equal displacements in equal intervals of time, howsoever, small these intervals may be.

**Non-uniform velocity:** The particle is said to have non-uniform motion if it covers unequal displacements in equal intervals of time, howsoever, small these time intervals may be. In this type of motion, velocity does not remain constant.

**Relative Velocity:** The relative velocity of one body with respect to that of another is the rate of change of displacement of one body relative to that of another and vice-versa.

**Acceleration:** Acceleration is a vector quantity and its S.I. unit is $m/s^2$. Most moving things usually experience variations in their motion. We say they undergo acceleration. It is defined as the rate of change of velocity with time. Mathematically,

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

## FORCE

Everywhere in our nature there are four types of forces :

(i) Gravitational Forces (Weakest)
(ii) Weak nuclear Force
(iii) Electromagnetic Forces
(iv) Nuclear Forces (Strongest)

(i) **Gravitational forces** is the weakest of all existing force and it is negligible for all lighter and smaller bodies. The value of Gravitational constant (G) is measured in Torsion balance by Cavendish was very small and is $6.67 \times 10^{-11}$ $Nm^2\,kg^{-2}$.

(ii) **Weak Force** came into existence firstly in Yukawa Meson theory when explanation of β-decay was propounded.

(iii) **Electromagnetic Force** operates on all charged particles and provides the atomic and molecular binding forces. Thus electromagnetic interactions are charged dependent.

(iv) **Nuclear force** is also called strong force. Among all the forces found in nature, nuclear forces is the strongest force which basically exists within atomic nucleus between proton-proton, proton-neutron and neutron-neutron within the range upto $10^{-15}$ M.

## Centripetal Force

When a body moves on a circular path of radius r with uniform speed v then an acceleration of magnitude $\frac{v^2}{r}$ acts towards the radius and it is called **centripetal acceleration**. This is also called Read force.

**Example :**

(i) The Sun and planets and in the orbital motions of planets and satellites the centripetal forces are counterbalanced by Gravitational forces.

(ii) The orbiting electron experiences a centripetal force about a massive nucleus equal to the electrostatical forces of attraction.

## Centrifugal Force

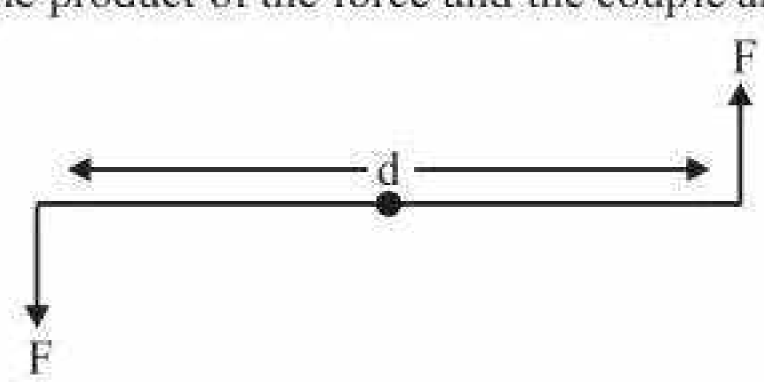
Centrifugal force is a fictitious force appearing in non-inertial frame and where magnitude is equal to that of centrifugal force but oppositely directed to it. This force is not the reactionary force of the centripetal force but a virtual imaginary force appears by the virtue of inertia that's why it is also called **inertial force**.

**Example :** If a man travelling in a car in a straight line path and car suddenly be turned towards right then man realises severe push towards left. A centripetal force around the radius of curvature of the path generated which is counterbalanced by the man so a shock is realised by the man which comes from the virtue of inertia and this is the centrifugal force which act outwardly.

**Conservative Force:** A force is said to be conservative, if the work done by it on any particle that moves between two points depends only upon these two points and not on the path followed.

**Non-Conservative Force:** A force is non-conservative of the work done by the force on a particle that moves between two points depends on the path taken between those points.

**Couple :** Two equal and opposite forces form a couple and it is defined as the product of the force and the couple arm.




Thus, Couple = Force × Couple arm
= F × d

The couple is also a vector quantity which apears like a torque and its SI unit is Nm

## FRICTION

**Friction** is a force that is created whenever two surfaces move or try to move across each other.

- Friction always opposes the motion or attempted motion of one surface across another surface.
- Friction is dependent on the texture of both surfaces.
- Friction is also dependent on the amount of contact force pushing the two surfaces together.

## Instances where friction is important

1. Walking
2. Driving
3. Picking something up
4. Car brakes
5. Erosion in the environment
6. Burning up meteors in the atmosphere before they hit Earth.
7. Striking a match/building a fire.
8. Rubbing your hands together when it's cold.
9. Friction keeps knots from coming undone (like in shoelaces)

# NEWTON'S LAWS OF MOTION

## Newton's first law of motion

The first law of motion is generally called the **Law of Inertia**. It is a restatement of Galileo's idea. It is stated as below : *Every object continues in a state of rest or in a state of uniform motion in a straight line, unless it is compelled to change that state by external forces exerted upon it.*

**Inertia:** The tendency of bodies or objects to remain in the original initial state of rest or uniform motion is called inertia.

**Example of inertia of rest:** The passenger standing in a bus tends to fall backwards when the bus suddenly starts, when a carpet is suddenly jerked the dust fly off etc.

**Example of inertia of motion :** When a running car stops suddenly the passenger is jerked forward, when a person jumps out of a moving train, he falls down, etc.

**Mass and Inertia**

Inertia is directly related to the mass of an object. A heavy body has higher inertia than that of a light body. Mass in this context is called "**inertial mass**".

## Momentum

It is the product of mass and velocity of the moving body.

It is a vector quantity.

**Newton's second law of motion :** It states that the rate of change of momentum of a body is directly proportional to the applied unbalanced force.

It is the product of force and time

i.e. Impulse = Force × time = change in momentum.

If any external force is operative on an object or a body for a very short span of time, then the product of this external force and the time is called impulse and the force is called Impulsive force.

Thus, Impulse is also defined as change in the linear momentum of the body for a short span of time.

## Newton's third law of motion

To every action, there is always an equal and opposite reaction. Forces always occur in pairs.

**Balanced Force:** If on a body various forces act at a time and if the resultant of all these forces is zero then the body is said to be in equilibrium state and at this moment all forces are called a balanced force.

**Unbalanced Force:** If on a body two or more forces operate in such a way that the body starts to move towards any force, then the force acting on a body is called unbalanced force.

**Force of friction/ Friction:** Frictional force opposes relative motion between two surfaces in contact. The force of friction is independent of area of surfaces in contact but it depends on the nature of material of surface in contact. Frictional force is directly proportional to the normal reaction.

**Law of conservation of linear momentum:** It states that in absence of external force, the total linear momentum of a system remains conserved.

## Instances of Newton's Laws of Motion

**First law of Motion**

A magician pulls a tablecloth out from under dishes and glasses on a table without disturbing them.

A person's body is thrown outward as a car rounds a curve on a highway.

**Second law of Motion**

Pushing a child on a swing is easier than pushing an adult on the same swing, because the adult has more inertia.

A soccer player kicks a ball with his foot and the toes are left stinging.

Two students are in a baseball game. The first student hits a ball very hard and it has a greater acceleration than the second student who bunts the ball lightly.

**Third law of Motion**

Rockets are launched into space using jet propulsion where exhaust accelerates out from the rocket and the rocket accelerates in an opposite direction.

# WORK, ENERGY AND POWER

**Work :** If a force acting on a body brings about displacement in it then work is said to be done on the body by the applied force.

**Energy :** It is defined as the capacity to do work. It is a scalar quantity. The SI unit of energy is joule.

**Potential energy:** The energy possessed by a body due to its position, shape, or state is called potential energy (P.E.).

**Gravitational potential energy :** The energy possessed by a body at a certain height from a reference level (generally, the surface of the earth) is called its gravitational potential energy.

**Kinetic energy :** The energy possessed by a body due to motion is called its kinetic energy.

**The law of conservation of mechanical energy:** Energy can neither be created nor be destroyed. Energy can be transformed from one form to another form only. This is called the *law of conservation of energy*.

**Conversion of Energy from one form to another :**

| | |
|---|---|
| **Dynamo-** | Mechanical Energy into Electrical Energy. |
| **Electric Motor-** | Electrical Energy into - Mechanical Energy. |
| **Microphone-** | Sound Energy into Electrical Energy. |
| **Loud Speaker-** | Electrical Energy into Sound Energy. |
| **Electric Bulb-** | Electrical Energy into Light and Heat Energy. |
| **Solar Cell–** | Solar energy into electrical energy. |
| **Candle-** | Chemical Energy into light and heat energy. |
| **Sitar-** | Mechanical Energy into Sound energy. |

**Power :** The rate of doing work is called power. It is given by

$$\text{Power} = \frac{\text{Work done}}{\text{Time taken}}$$

- The **SI** unit of **power** is **joule/second**.
- **One horse** power is equivalent of **746** watt.
  **Board of Trade Unit (B.O.T.U.) : kwh** (Kilo watt hour)

1 kwh = 1 Unit = $3.6 \times 10^6$ joule

This is to measure domestic electric energy consumption.

**Work-energy theorem:** The change in kinetic energy is equal to the work done. This important relationship is called the work-energy theorem.

**Simple machine:** A simple machine is a device used to overcome resistance by applying a smaller force at a convenient point in a convenient direction and the effect of this force is obtained at another point in the same or different direction and with same or different magnitude.

**Collisions :** It is an event in which two or more than two bodies interact with one another for a short time and exchange a momentum and kinetic energy.

**Centre of Mass (COM):** When we consider the motion of a rigid body then a point inside or outside the body which behaves in such a way that the entire mass of the body is supposed to be concentrated at that point. This is called centre of mass of the body.

**Torque :** It is the turning ability of a force about an axis.

It is also defined as the moment of force.

## GRAVITATION

The force of attraction between two objects is called gravitation.

**Newton's Law of Gravitation :** Force of attraction which is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

Mathematically, $F \propto \frac{m_1 m_2}{d^2}$ or, $F = G\frac{m_1 m_2}{d^2}$

The value of $G$ is $6.67 \times 10^{-11}$ Nm²/kg²

**Kepler's Laws of Planetary Motion :**

**1st Law** : All planets move in elliptical orbits with the sun at a focus.

**2nd Law :** The radius vector from the sun to the planet sweeps equal area in equal time.

**3rd Law :** The square of the time period of a planet is proportional to the cube of the semimajor axis of the ellipse.

- The force of gravity depends upon the **object's mass** or the amount of matter in the object.
- The weight (w) of an object is equal to the mass of the object multiplied by the acceleration due to gravity(g).
  W = mg
- $g_{maximum}$ at poles and $g_{minimum}$ at equator.
- $g_{moon} = \frac{1}{6} g_{earth}$
- The value of 'g' decreases with altitude, depth from the earth's surface.
- **g** decreases due to rotation of earth.

**Weight of a body in a lift**

(i) If lift is stationary or moving with uniform speed (either upward or downward), the apparent weight of a body is equal to its true weight.

(ii) If lift is going up with acceleration, the apparent weight of a body is more than the true weight.

(iii) If lift is going down with acceleration, the apparent weight of a body is less than the true weight.

(iv) If the cord of the lift is broken, it falls freely. In this situation the weight of a body in the lift becomes **zero**. This is the situation of weightlessness.

(v) While going down, if the acceleration of lift is more than acceleration due to gravity, a body in the lift goes in contact of the ceiling of lift.

- **Escape speed ($v_e$)** is the minimum speed with which an object just crosses the earth's gravitational field and never comes back.
- The escape velocity of Earth is about 11.2 kilometres per second and on moon it is 2.4 km/sec.

## SATELLITES

- A **satellite** is a smaller object in space which orbits around a larger object Planet in space.
- It can be either artificial, like the communication or weather satellites that orbit the Earth, or they can be natural, like our Moon.
- A **geostationary satellite** is an earth-orbiting satellite, placed at an altitude of approximately 35,800 kilometres (22,300 miles) directly over the equator.
- Geostationary satellite revolves in the same direction the earth rotates (west to east). Its time period is 24 hours.
- It is used for Communication, television broadcasting, weather forecasting , defence and intelligence.
- **Polar orbiting satellites** closely parallel the earth's meridian lines, thus having a highly inclined orbit close to 90°.
- They pass over the North and South poles each revolution.
- They are used for weather forecasting, earth-mapping, earth observation, etc.

**Orbital velocity :** Orbital velocity of a satellite is the velocity required to put the satellite into its orbit so that it rotates around the earth.

## MECHANICAL PROPERTIES OF SOLIDS AND FLUIDS

- **Elasticity and plasticity:** The property by virtue of which the body regains its original shape after the removal of deforming force is called **elasticity**. And if the body retains its deformed shape after the removal of deforming force is called **plasticity.**
- **Rubber** is less elastic than steel.
- **Hooke's law:** Within elastic limit stress is directly proportional to strain, i.e. stress ∝ strain or stress = Y strain

  or, $Y = \frac{\text{stress}}{\text{strain}}$

  where Y = Young's Modulus of elasticity
- **Pressure** is defined as force acting normally on an unit area of the surface.

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

Its unit is **N/m²**. It is a scalar quantity.

- **Atmospheric pressure** is measured by an instrument called the **barometer**.
- **Sudden fall** in barometric reading is the indication of **storm.**
- **Slow fall** in barometric reading is the indication of **rain**.
- Slow rise in the barometric reading is the indication of **clear weather.**
- The pressure exerted by liquid column at the surface given as $p = hdg$, where $d$ is the density of liquid, $h$ is height of liquid column.
- In a static liquid at same horizontal level, pressure is same at all the points.

**Pascal's Law of Pressure :** If gravitational attraction is negligible in equilibrium condition, pressure is same at all points in a liquid.

- The pressure exerted anywhere at a point of confined liquid is transmitted equally and undiminished in all directions throughout the liquid.
- **Hydraulic lift**, hydraulic **press** and hydraulic **breaks** are based on the **Pascal's law of pressure**.

**Atmospheric pressure decreases with altitude. That is why**

- It is difficult to cook on the mountain.
- The **fountain pen** of a passenger leaks in aeroplane.
- **Bleeding** occurs from the nose of the man.
- It is difficult to breath on higher altitude due to less amount of air.
- **Water** starts to boil below **100°C**.

**Archimedes' Principle :** When a body is immersed partly or wholly in a liquid, there is an apparent loss in the weight of the body, which is equal to the weight of liquid displaced by the body.

- All objects placed in a liquid experience an upward force which allows the body to float if it displaces water with weight equal to the weight of the body. This upward force is called the **buoyant force** and the law is called the **law of buoyancy**.
- The weight of water displaced by an iron ball is less than its own weight. Whereas water displaced by the immersed portion of a ship is equal to its weight. So, small ball of iron ball sink in water, but large ship float.
- **Hydrogen** filled ballon float in air because hydrogen is lighter than air.

**Law of Floatation :** A body floats in a liquid if

- The density of material of body is less than or equal to the density of liquid.
- When body floats in neutral equilibrium, the weight of the body is equal to the weight of displaced liquid. The centre of gravity of the body and centre of gravity of the displaced liquid should be in one vertical line for the condition.
- **Density (d) :** It is the mass per unit volume. $d = \frac{M}{V}$
- **Density of water** is maximum at **4°C.**
- **Viscosity :** The property of a fluid by virtue of which an internal frictional force acts between its different layers when it is in motion.
- **Bernoulli's theorem:** For a non-viscous, incompressible fluids flowing streamline from one point to another point, then at every point of its path, pressure, energy, potential energy and kinetic energy per unit volume remains constant.
  **Blowing of roofs** by storms, sprayer action of carburetor, etc. are based on Bernoulli's principle.

**Surface tension:** The evidences of the experiments tell us the surface of the liquid behaves to some extent like a stretched elastic membrane having a natural tendency to contract and occupy a minimum possible surface area as permitted by the circumstances of the liquid mass. This property of the liquid is called surface tension and it is measured by the force per unit lenth of line drawn in the liquid surface acting tending to pull the surface apart along the line.

Thus, surface tension (T) = $\frac{\text{Force(F)}}{\text{Length of line drawn } (l)}$

**Surface Energy :** Every strained body possess potential energy. Thus surface of a liquid is also strained system and hence the surface of the liquid also has potential energy which is equal to the work done in creating the surface. This energy per unit area of the surface is called surface energy.

### Some Incidents and Facts related to surface tensions

(i) The hairs of shaving brush stick to each other due to surface tension on drawing it from water.
(ii) Hot soup is tasty because its surface tension is reduced and spread uniformly on the mouth - toungue.
(iii) In the solution of soap great bubble can be produced as water reduces its surface tension.
(iv) Soaps and detergents reduce the surface tension of the water and cloths and thereby cleaned.
(v) A thin little needle can float in water, due to surface tension.

## CAPILLARY ACTION

When a long glass tube of very fine bore called capillary tube is dipped into a liquid, then liquid riser is in tube. If the angle of contact is acute (less than 90°) then liquid rises and if the angle of contact is obtuse (more than 90°) then the liquid is depressed. It is called capillary action or capillarity.

**Example of Capillarity :**

(i) From the wicks of K-oil lamp K-oil rises into the wick due to capillary action.
(ii) Bloting paper sucks the ink due to small holes of this paper that act like capillary tubes.
(iii) In the branches of plants and in leafs the water and nutritional salts rise due to capillarity.
(iv) Just after the heavy rainfalls the farmers plough their agriculture lands to break the capillaries formed by the soil and by which water doesn't come upto upper surface and soil remains wated.

## HEAT AND THERMODYNAMICS

### Heat

**Heat** is a form of energy which produces the sensation of warmth in us. It is a measure of the total energy content of the molecules in an object. Its S.I. unit is joule and CGS unit is erg. Heat is also measured in thermodynamics, the study of the relationship between heat and energy. The thermal energy due to which the existence of the temperature in the body appears is called heat. In other words, heat is a type of energy by which mechanical work can be done.

**Thermal equilibrium:** Due to different temperatures of two bodies thermal energy transfers from the body having high temperature to the body of lower temperature and at a particular temperature the process of energy transfer stops and now both bodies are said to be in thermal equilibrium.

**Joule's experiment:** According to the experiment, it was observed that heat is a form of energy by which various works can be performed. Joule also asserted that heat and mechanical work are inter-transferable to each other and the ratio of mechanical work and heat energy by which work is done is a fixed ratio called mechanical equivalent of heat. If mechanical work W is produced by amount of heat H then,

**Absolute Zero :** Theoretically there is no limit of maximum temperature but there is a limit or restriction on the minimum temperature. The lower most temperature is –273.15°C and it is called *absolute temperature*.

**Temperature** is defined as the degree of hotness or coldness of a body. Spontaneous transfer of heat takes place from higher temperature to lower temperature.

To measure temperature of a body, we use an instrument called thermometer.

The common temperature scales are *Celsius*, *Fahrenheit* and *Kelvin*. The lower fixed point is ice point and upper fixed point is boiling point of water.

**Relation between Temperature on different scales.**

$$\frac{C-0}{100}=\frac{F-32}{180}=\frac{R-0}{80}=\frac{K-273}{100}=\frac{Ra-492}{180}$$

OR

$$\frac{C}{5}=\frac{F-32}{9}=\frac{R}{4}=\frac{K-273}{5}=\frac{Ra-492}{9}$$

- The normal temperature of a human body is 37°C or 98.6°F.
- At –40° temperature, celsius and fahrenheit thermometers read the same.
- **Thermal expansion :** Increase in length, area or volume on heating

## Thermal Expansion

When heat is added to a solid, a liquid or a gas, it expands. Similarly when heat is subtracted from a substance, it contracts. For a given temperature change gases expand more than liquids and liquids expand more than solids. The thermal expansion of a body in one dimension (lengthwise) is called **linear expansion**.

**Coefficient of linear expansion (α) :** It is in solids only.

Gaps at joints between rails, bridges on rollers, concrete roads have gaps between sections etc. all due to thermal expansion.

Coefficient of linear expansion (α)

**Anomalous Expansion of Water :** Most substances expand when heated, but water as the temperature rises from 0°C to 4°C it contracts and occupies the smallest volume at 4°C. Due to this anomalous behaviour of water fish and other aquatic animals and plants remain alive even when water bodies freeze.

**Thermal Capacity :** It is the amount of heat required to raise the temperature of substance through 1ºC or 1K. Thermal capacity = mass × specific heat. Its unit is cal/ºC, kcal/ºC, J/K.

## Latent Heat

- The amount of heat required to change phase (liquid to gas or liquid to solid etc.) without change in temperature is called **latent heat.** Q = mL where, L = latent heat
- Why are steam burns more severe than hot water burns. It is because latent heat of steam is more than hot water.
- Latent heat of fusion of ice is 80 cal/g
- Latent heat of steam is 538 cal/g.

## Specific Heat

- The amount of heat that is required to raise the temperature of a unit mass of a substance by one degree (14.5°C to 15.5°C) is known as **Specific heat**.

**Specific heat of Different materials**

| Material | Specific heat (J/Kg K) |
|---|---|
| Water | 4200 |
| Ice | 2100 |
| Iron | 460 |
| Kerosene oil | 210 |
| Mercury | 140 |
| Lead | 130 |

(i) Cooking utensils are made of aluminum, brass & steel because of their low specific heat and high conductivity.

(ii) Due to low specific heat of sand, deserts are hot in day and cool in night.

### Different Processes of Phase Change

(i) **Sublimation :** It is the process of conversion of solids to gaseous state on heating. On cooling the vapours get converted back into solids.
**Examples-** Iodine (dark solid) Dry ice (solid $CO^2$)

(ii) **Condensation :** It is the process of conversion of gases/vapors to liquid state on cooling. On heating, these liquids are converted into vapours/gases.

(iii) **Boiling :** It is the process of conversion of liquid to gaseous state.

(iv) **Melting :** It is the process in which solid gets converted into liquid. Melting and boiling occur at definite temperature called melting point and boiling point respectively. The liquid boils at a temperature, at which its **vapour pressure is equal to the atmospheric pressure.**

## Evaporation

It is a process, in which molecules escape slowly from the surface of a liquid. Water can change into the vapour state either by boiling or by evaporation at lower temperature. Small puddle of water formed on the road, soon disappear due to evaporation. Therefore, when evaporation takes place at room temperature, the every required for evaporation is taken from the liquid itself, which cools as a consequence. Thus, evaporation produces cooling. For a given liquid the rate of evaporation depends on the following terms.

- Temperature of the liquid (as the wet cloths) dry more rapidly in a warm day.
- Area of evaporating surface (as a person, who wants to drink hot tea quickly, pours it in the saucer in which evaporation increases due to the increased surface area and tea cools faster.
- Rate of removal of vapour (as wet clothes) dry quicker in a windy day.

## FACTS ABOUT EVAPORATION

- In Summer season, water is stored in pitcher for cooling.
- A little either spilt on the hand produces cooling sensation.
- The evaporation of ether at room temperature leads cooling.
- Water evaporating from the wet cloth produces cooling and brings the temperature down.
- A desert cooler produces cooling by evaporation.

### Heat Transfer

**Conduction** is the process in which heat is transmitted from one point to the other through the substance without the actual motion of the particles.

This process of conduction is prominent in the case of solids.

**Convection** is the process in which heat is transmitted from one place to the other by the actual movement of the vibrating particles i.e. molecules. It is prominent in the case of liquids and gases. Land and sea breezes and trade winds are formed due to convection.

**Radiation** is the process in which heat is transmitted from one place to the other *directly* without the necessity of any intervening medium. We get heat radiations directly from the sun without affecting the intervening medium. Heat radiations can pass through vacuum. Heat radiations are a part of the electromagnetic spectrum.

## Emissive Power, Absorptive Power and Kirchhoff's Law

**Emissive power :** It is the total amount of thermal energy emitted per unit time, per unit area of the body for all wavelength. It is denoted by '*E*' its SI unit is Watt $m^{-2}$ or $Js^{-1}$ $m^{-2}$.

**Absorptive power:** It is defined as the ratio of radiation absorbed by a body to the incident radiation.

$$a = \frac{\text{Energy absorbed}}{\text{Energy incident}}$$

## Black Body

A perfectly black body is one, which absorbs completely all the radiations of whatever wavelength incident upon it. Since it neither reflect nor transmit any radiation, it appears black whatever the colour of the incident radiation may be.

## Greenhouse effect

In a greenhouse, heat radiation from the sun passes through the glass and keeps the plants and the air inside warm. The glass prevents warm air from escaping.

Moreover, radiation emitted by an object in the greenhouse cannot escape through the glass. A car parked in the sun with its windows closed get terribly warm due to the greenhouse effect.

**Kirchhoff's Law:** According to Kirchhoff's law the ratio of emissive power to absorptive power is the same for all bodies at a given temperature and it is equal to the emissive power of a black body at that temperature.

Significance of Kirchhoff's law is that good absorbers are good emitters.

**Newton's Law of Cooling:** The rate of cooling of a body is directly proportional to the temperature difference between the body and surrounding and exposed area.

## Cooling at the night

The earth and other objects on it, receive solar radiation during the day nad become warm but at night they start emitting radiant every and become cool. Cloudy night are warmer than clear night, because clouds reflect the radiations emitted by the earth at night and keep it warm. Thus, clouds acts like a blanket.

**Stefan's Law:** It states that the total radiant energy (E) emitted per second from unit surface area of a black body is proportional to the fourth power of its absolute temperature (T)

Thus $E \propto T^4$ $E = \sigma T^4$

Where $\sigma$ is called Stafan's constant

**Wien's Displacement Law :** According to Wien's displacement law wavelength corresponding to highest intensity ($\lambda_m$) is inversely proportional to the absolute temperature of the body.

## Relative Humidity

It is defined as the degree of wetness of air. It is the ratio of the the mass of water vapour in a given condition volume of air to the mass required for saturating the same volume of air at the same temperature. It is measured with an instrument called **Hygrometer**.

- An AC provides temperature as well as humidity for body comfort.
- On a chilly night, when a spectacled person enters a warm room, moisture is deposited on his pectacle lenses.

## THERMODYNAMICS

**Thermodynamics** : It is that branch of Physics in which we are mainly concerned about the transformation of heat into mechanical work.

## Thermodynamic Processes

In practice, the following types of thermodynamic processes can take place :

(a) **Isothermal process:** A thermodynamic process that takes place at constant temperature is called isothermal process.

(b) **Isobaric process:** A thermodynamic process that takes place at constant pressure is called isobaric process.

(c) **Isochoric process:** A thermodynamic processes that takes place at constant volume is called isochoric process.

(d) **Adiabatic process:** A thermodynamic processes in which no heat enters or leaves the system is called adiabatic process.

(e) **Cyclic process:** A thermodynamic processes in which the system returns to its original state is called a cyclic process.

**Zeroth Law of thermodynamics:** If two independent thermodynamical systems are in thermal equilibrium with a third thermodynamical system, then they must be in thermal equilibrium to each other. This is called zeroth law of thermodynamics and it becomes a base for the definition of temperature.

## First Law of Thermodynamics

This equation is known as the first law of thermodynamics, i.e. if some quantity of heat is supplied to a system capable of doing external work, then the quantity of heat absorbed by the system is equal to the sum of the increase in the internal energy of the system and the external work done by the system. The first law of thermodynamics is essentially a restatement of the law of conservation of energy, i.e. energy can neither be created nor be destroyed but may be converted from one form to another.

**Second Law of Thermodynamics:** First law simply tells that if a process takes place, energy will remain conserved. It doesn't tell us whether the process is possible or not. Similarly, if a hot body and a cold body are brought in contact, the First law is not violated whether the heat flows from hot to cold or cold to hot. But experience has shown that heat never flows from cold to hot body. The second law of thermodynamics explains the possibility of the thrermodynamical process, its direction and its relivance.

**Kelvin-Planck's statement:** It is impossible to construct a device which operates in a cycle that will take heat from a body and convert it completely into work without leaving any change anywhere.

**Clausius's statement:** It is impossible to construct a self acting device which operates in a cycle that will transfer heat from a cold body to hot body without expenditure of work by an external agency source.

**Carnot's Theorem :** The efficiency of Carnot's heat engine depends only on the temperature of source ($T_1$) and temperature of sink($T_2$)

Carnot stated that no heat engine working between two given temperatures of source and sink can be more efficient than a perfectly reversible engine (Carnot engine) working between the same two temperatures.

## Assumptions of Kinetic Theory of Gases

(i) All gases consists of very large number of molecules which are perfectly elastic, spheres & identical in all respects.

(ii) All these molecules are moving randomly in all directions.

(iii) The size of molecules is much small compared to the average separation between molecules.

(iv) The molecules exert no force on each other or on the wall of container except during collision. The time spent during collision is very small.

(v) The molecule obey Newton's laws of motion.

(vi) The collisions between molecules or between a molecules and a wall are perfectly elastic.

(vii) A molecule moves along a straight line path between two successive collisions. The straight distance covered between two successive collisions is called mean free path($\lambda$).

## SOUND

The sensation felt by our ears is called sound. Sound is a form of energy.

## WAVE MOTION

A wave is a vibratory disturbance in a medium which carries energy from one point to another without there being a contact between two points.

A disturbance which communicated from one to another place without transfer of medium is called wave motion.

If a wave is to travel through a medium such as water, air, string, it must cause the particles of medium to oscillate as it passes through the medium.

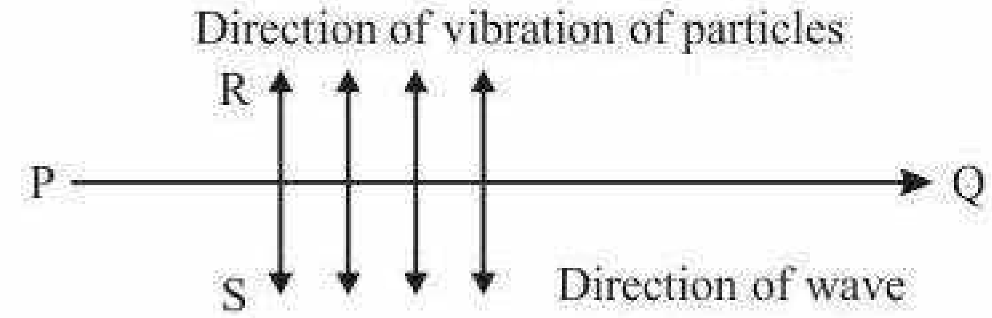
For the propagation of wave, medium must have **inertia** and **elasticity** . These two properties of medium decides the speed of the wave.

## There are Two Type of Waves

1. **Mechanical waves :** These waves require material medium for their propagation. Sound waves, waves in stretched string are the examples of mechanical waves.
   sound waves cannot travel in vacuum.
2. **Non-mechanical or electromagnetic waves:** These waves require no medium for their propagation. Light waves are electromagnetic waves.

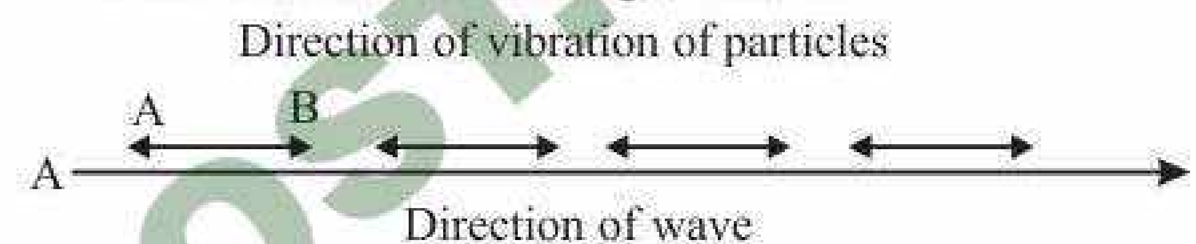
## Transverse and longitudinal mechanical waves

**(i) Transverse waves:** A wave in which the particles of the medium vibrate up and down 'at right angles' to the direction in which the wave is moving is called a transverse wave. A transverse wave is the one in which the particles of medium execute oscillations in a direction perpendicular to the direction of propagation of wave. *Transverse waves can travel only in solids and surface of liquids.*



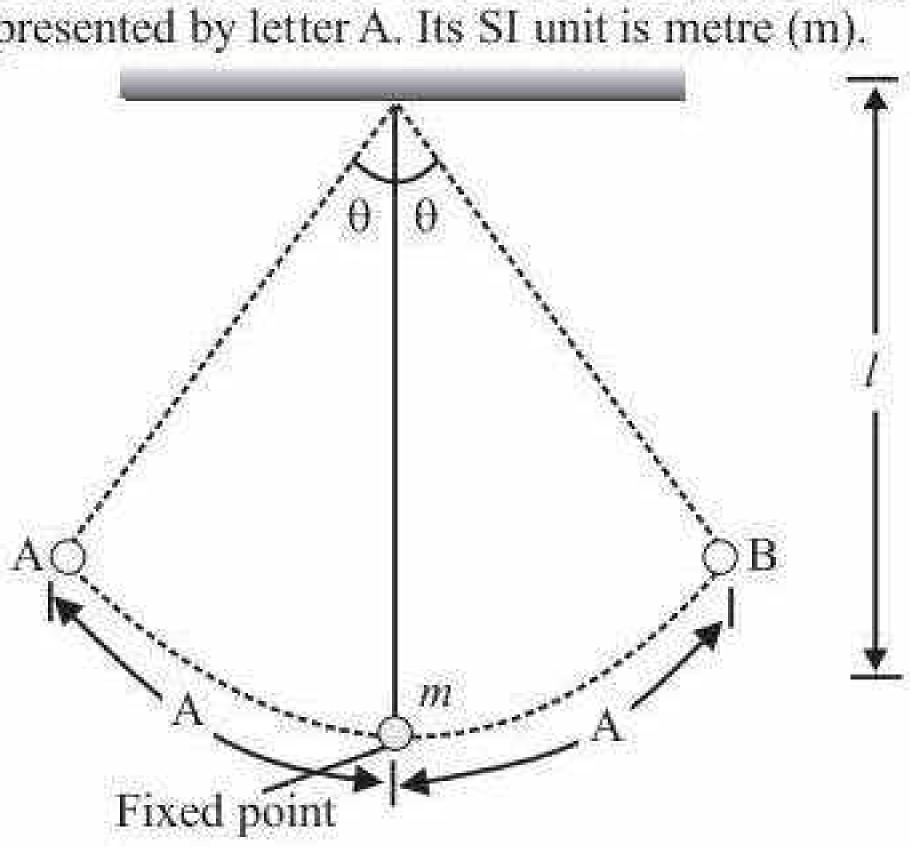

Transverse waves can be produced only in solids and liquids but not in gases.

**(ii) Longitudinal waves:** A wave in which the particles of the medium vibrate back and forth in the 'same direction' in which the wave is moving, is called a longitudinal wave. In a longitudinal wave particles of medium execute oscillations in the direction of propagation of wave. Longitudinal waves can travel in solids, liquids and gases. Sound waves in air are longitudinal.

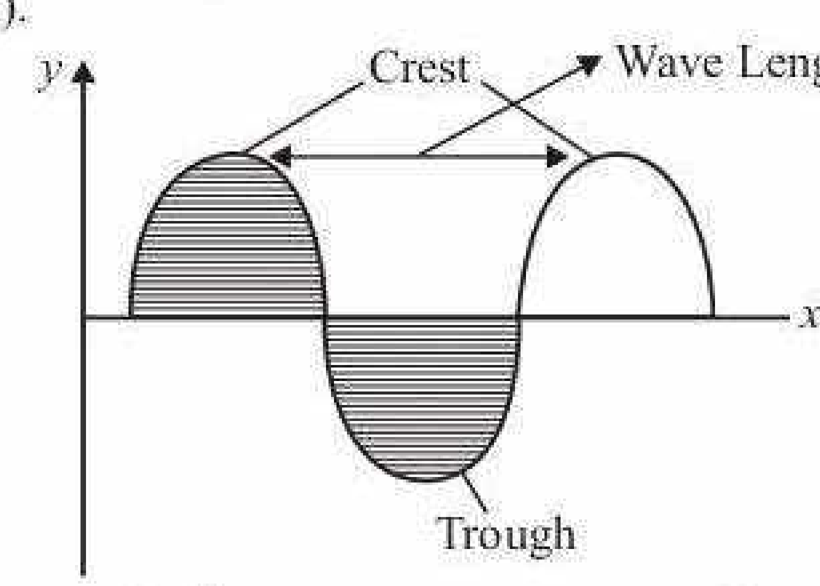



## Characteristics of Mechanical Waves

**(a) Amplitude:** The amplitude of a wave is the magnitude of maximum displacement of the oscillating particles of the medium on either side of their mean position. It is usually represented by letter A. Its SI unit is metre (m).




**(b) Wavelength:** The distance between two consecutive crests or two consecutive troughs is called wavelength. Or the distance between two consecutive compressions or two consecutive rarefactions is called wavelength. It is usually represented by Greek letter lambda,. Its SI unit is metre (m).



(c) **Time period:** The time taken by crest or trough to move a distance equal to one wavelength is called time period. In case of longitudinal wave, the time taken by compression or rarefaction to travel a distance equal to one wavelength is called the time period.

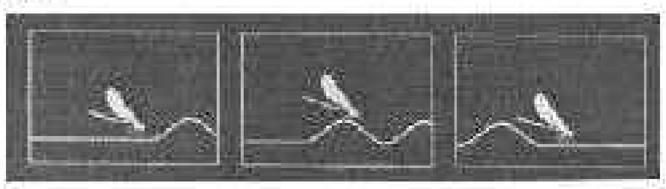
(d) **Frequency:** The frequency of a wave may be regarded as the number of complete wavelength traversed in one second. The SI unit of frequency is hertz (Hz).

(e) **Wave velocity:** It is the distance travelled by the wave in one second. The wave velocity is usually represented by v. Its S.I. unit is metre/ second (m/s).

$$v = f\lambda$$

Wave velocity is the product of frequency and wavelength of wave.

- **Classical waves** transfer energy without transporting matter through the medium. Waves in a pond do not carry the water molecules from place to place; rather the wave's energy travels through the water, leaving the water molecules in place, much like a bug bobbing on top of ripples in water, as shown in figure.

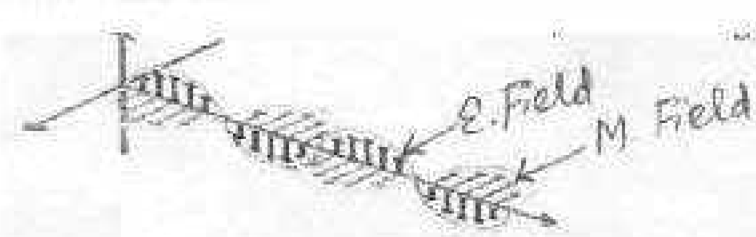


## Electromagnetic Waves

- **Electromagnetic waves** differ from mechanical waves in that they do not require a medium to propagate.
- This means electromagnetic waves can travel not only through air and solid materials, but also through the **vacuum.**
- In the 1860's and 1870's, a Scottish scientist named **James Clerk Maxwell** noticed that electrical fields and magnetic fields can couple together to form electromagnetic waves.


- He summarized this relationship between electricity and magnetism into what are now referred to as **"Maxwell's Equations."**
- **Heinrich Hertz,** a German physicist, applied Maxwell's theories to the production and reception of **radio waves**.
- His experiment with radio wave solved two problems. **First,** the velocity of radio waves was equal to the velocity of light! This proved that radio waves were a form of light!

  **Second**, Hertz found out how to make the electric and magnetic fields detach themselves from wires and go free as Maxwell's waves – electromagnetic waves.
- Electromagnetic waves are formed by the vibrations of electric and magnetic fields. These fields are perpendicular to one another in the direction the wave is traveling. Once formed, this energy travels at the speed of light until further interaction with matter.




**Examples** of electromagnetic waves are light, radio waves, X-rays, X-rays microwave etc.

**Difference between sound waves and electromagnetic waves**

(a) Sound waves are longitudinal and electromagnetic waves are transverse.

(b) Sound waves travel at a speed of 340 m/s whereas electromagnetic waves travel at a speed of $3 \times 10^8$ m/s

(c) Sound waves do not pass through a vacuum but electromagnetic waves (light) do.

**Wave front:** A plane or surface on which particles of the medium are in an identical state of motion at a given instant, i.e., in the same phase, is called a wave front.

In an isotropic medium, the wave front is always perpendicular to the direction of the wave motion and the position of a given wave front shifts outwards with the wave speed.

A point source produces spherical wave front. All wave front at a large distance from the source become plane wave front.

**Phase of a wave:** The phase of a harmonic wave is a quantity that gives complete information regarding wave at any time and at any position. It is equal to the argument of the sine or cosine function representing the wave. In wave equation

**Particle velocity:** In the process of wave motion, the particle velocity changes with time. It can be obtained by differentiating displacement of the particle w.r.t. time.

(i) The particle velocity leads displacement in phase by radian.

(ii) The maximum particle velocity, $v_0 = \omega A$.

**Particle acceleration:** The acceleration of the particle can be obtained by differentiating particle velocity.

(i) The maximum value of particle acceleration $a_0 = \omega^2 A$.

(ii) The particle acceleration leads particle velocity by $\frac{\pi}{2}$ and displacement by $\pi$ radian.

## Speed of Transverse Waves in Solid

The speed of transverse waves in solid medium is determined by modulus of rigidity of the material of the solid and density of the solid (determine the inertia property).

Sound waves we mean the longitudinal waves in air which, when strike the ear, produce the sensation of hearing. The human ear is sensitive to waves in the frequency range from about 20 to 20000 Hz.

The sound waves in an elastic medium can be described by a wave function of displacement

$$y = A\cos(kx - \omega t)$$

# CHARACTERISTICS OF SOUND

## Intensity of Sound

- The distance at which a sound can be heard depends on its intensity.
- Sounds higher than **20000 Hz** are called **ultrasonics**.
- Sounds less than 20 Hz are called **infrasonics**.
- When temperature is increased the speed of sound is increased.
- Speed of sound in air is 330 m/s.

**Speed of Sound in Different Mediums**

| Medium | Speed of sound (In m/s) |
|---|---|
| Air(0°C) | 332 |
| Air (20°C) | 343 |
| Steam (at 100°C) | 405 |

| | |
|---|---|
| Mercury | 1450 |
| Water (20°C) | 1482 |
| Sea water | 1533 |
| Iron | 5130 |
| Glass | 5640 |

**Pitch :** It is the characteristic which distinguishes between shrill and grave sound. The faster the vibration of source, the higher is the frequency and the higher is the pitch.

**Loudness :** It is the sensation produced on the ears. It depends on the amplitude of the sound wave. The sound produced by greater energy has larger amplitude and therefore more loudness.

## Quality or Timbre of Sound

Quality is that characteristic of sound, which enables us to distinguishes between sound produced by two sources having the same intensity and pitch. It depends on harmonics and their relative order and intensity.

According to their frequency range, waves are divided into the following categories.

## 1. Audible or Sound Waves

The longitudinal mechanical waves, which lie in the frequency range 20 Hz to 20000 Hz are called audible or sound waves. These waves are sensitive to human ear.

## 2. Infrasonic Waves

The longitudinal mechanical waves, having frequencies less than 20 Hz are called infrasonic waves. These waves are produced by sources of bigger size such as earthquakes, volcanic erruptions, ocean waves, by elephants and whales.

## 3. Ultrasonic Waves

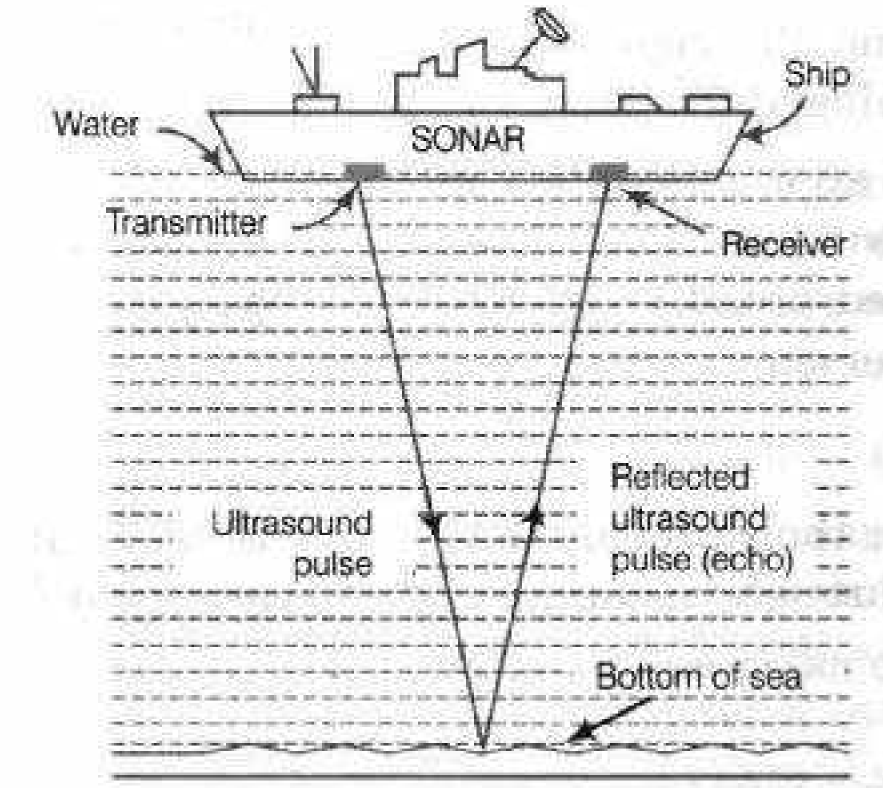
The longitudinal mechanical waves, having frequencies greater than 20000 Hz are called ultrasonic waves. Human ear cannot detect these waves. But certain creatures like dog, cat, bat, mosquito etc can' detect these waves. **Note** Bat not only detect but also produce ultrasonic waves.

## Applications of Ultrasonic Waves

- For sending signals.
- For measuring the depth of sea.
- For cleaning clothes, aeroplanes and machinery parts of clocks.
- For removing lamp-shoot from the chimney of factories.
- In sterilising of a liquid.
- In ultrasonography.
- In SONAR

## SONAR

The acronym SONAR stands for Sound Navigation and Ranging. The SONAR is a device, that uses the ultrasonic waves to measure the distances, directions and speed of objects under water.




The ultrasonic sound pulse to travel from the ship to the bottom of the sea and back to the ship.

In other words, the SONAR measures the time taken by the echo to return to the ship. Half of this time gives the time taken by the ultrasonic sound to travel from the ship to the bottom of the sea.

## Applications of SONAR

- target location for torpedoes.
- resources location for mines.
- submarine navigation.
- in aircraft.
- remotely operated vehicles.
- detecting the vehicle location.

## Shock Waves

A body moving with supersonic speed in air leaves behind it, a conical region of disturbance, which spreads continuously. Such a disturbance is called shock wave. These waves carry huge energy and may even make cracks in window panes or even damage a building.

**Quality** of sound distinguishes one sound from another having the same pitch and loudness. The sound which is more pleasant is said to be a rich quality. The sounds of sitar and violin can be distinguished by their quality.

## Echo

If we clap in front of a large wall or hill, we will hear the same sound again a little later . This repetition of sound after reflection from large obstruction is called echo. The sensation of sound persists in our brain nearly for 0.1s. To hear an echo the time interval between original sound and the reflected sound must be atleast 0.1s.

## Sound level: The decibel scale

The lowest intensity of sound that can be perceived by the human ear is called threshold of hearing .

## Reverberation

The sound created in a big hall will persist by repeated reflections from the walls and roof until it is reduced to a value where it is no longer audible. The persistence of audible sound after the source has ceased to emit sound is called reverberation.

## Doppler Effect

When a source of sound is moving towards us or away from us then we observe different pitches of the sound produced by it.

This change in the frequency (or pitch) of the sound produced by a source due to relative motion between the source and observer is known as **Doppler effect**, after the Austrian physicist and mathematician christian Johann Doppler.

The Doppler effect is evident when you hear the changing pitch of an ambulance or fire-engine siren. When the siren is approaching you, the crests of the sound waves encounter your ear more frequently, and the pitch is higher than normal. And when the siren passes you and moves away, the crests of the waves encounter your ear less frequently and you hear a drop in pitch.

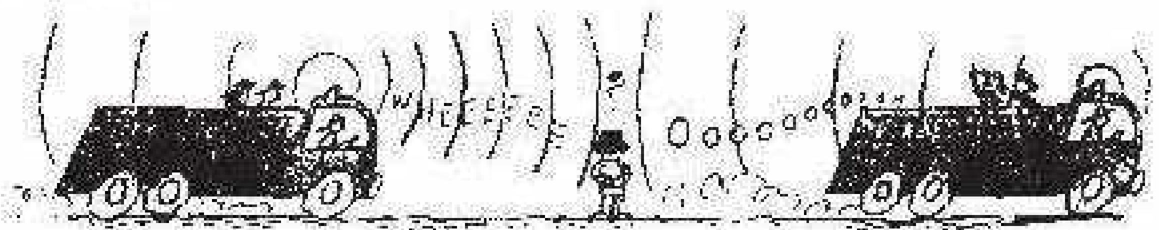


Fig.: The pitch of sound inceases when the source moves towards you, and it decreases when the source moves away

## Applications of Doppler Effect

- be police, to check over speeding of vehicles.
- at airports to guide the aircraft
- to study heart beats and blood flow in different parts of the body.
- by astrophysicist to measure the velocities of planets and stars.

## Range of Hearing

Normal human ears can hear the sound of frequency 20 Hz to 20000 Hz called **audible range**. Sound of frequency less than 20 Hz is called **infrasonic** . Sound of frequency greater than 20000 Hz is called **ultrasound**.

Some animals, such as dolphins can produced ultrasound. Bats can produce and hear ultrasound.

## Applications of Ultrasound

1. Ultrasound can kill bacteria and therefore can be used for water purification.
2. To detect cracks in metal and in thick walls
3. Echocardiography
4. Ultrasound may be used to break stones formed in the kidney. The crushed stone later get flushed out with urine.
5. **Sonography:** Ultrasonography is used for examination of the factor during frequency to detect congenial defects and growth abnormalities.

**Superposition of waves:** The principle states that when a number of waves travel through a medium simultaneously, the resultant displacement of any particle of the medium at any given time is equal to the algebraic sum of the displacements due to the individual waves.

## BEATS

The periodic variations in the intensity of sound due to the superposition of sound waves of slightly different frequencies are called beats. One rise and one fall of the intensity constitute a beat. The number of beat produced per second is called beats frequency. Thus

beat frequency = difference in frequency of the two superposing waves.

## Stationary Waves

When two identical waves of same frequency travel in opposite directions with the same speed along the same path superpose each other give rise to a new wave. The resultant wave does not travel in the either direction and therefore is called **stationary or standing wave.**

**Unison:** If time period is same i.e., two frequencies are equal then vibrating bodies are said to be in unison.

**Resonance :** The phenomenon of making a body vibrate with its natural frequency under the influence of another vibrating body with the same frequency is called resonance. Sonometer is used to produce resonance of tuning fork.

The marching soldiers break, step while crossing a bridge. It is to avoid resonance with the natural frequency of the structure.

**SPECTRUM OF ELECTROMAGNETIC WAVES**

| Electromagnetic waves | Inventors | Utilities |
|---|---|---|
| X-rays | Roentgen | X-rays are vigorously used in the various surgical diagonasis of bone fractures or the occurance of diseases in lungs, kidneys etc. in medical hospitals and for various industrial purpose. |
| $\gamma$-rays | H. Becquerel | Y-rays has maximum penetring power and it is utilized in nuclear reaction and artificial radioactivity. |
| U/V-rays | Ritter | U/V-rays are utilised in producing electric discharge, photoelectric effect. |
| Visible radiation | Newton | By visible radiation objects become visible and by the illumination of the visible radiation objects are made distinct. |
| Infra-red radition | Hurssel | I/R-Radiations are utilized in the photography of the objects behind the mist and fog. It is also used to warm the patients in hospital. In T.V. remote also. |
| Short radio waves | Henric Hertz | Short radio waves are utilised in radio, TV and Telephone etc. |
| Long radio waves | Marconi | Longer radio waves are used in radio and T.V. |

# ELECTRICITY AND MAGNETISM

## Electric Charges

Electric charge is a physical property of matter or substance which causes it to experience a force when placed near other matter or substance. The study of charges is called electricity. The study of charges at rest is called **static electricity** or **electrostatic** while the study of charges in motion is called **current electricity.**

The SI unit of charge is coulomb (c)

Charges are of two types :

(i) Positive charges (ii) Negative charges.

**Properties :**

(1) Similar charges repel and opposite charges attract.

(2) A charged body attracts light uncharged bodies.

(3) Charge is conserved.

(4) Quantum Nature of Charge or Principle of Atomicity of Charge: Just as a substance is formed of atoms, a charge is formed of small units of charges, each unit being known as fundamental or elementary charge, which is equal to $e = 1.6 \times 10^{-19}$ coulomb.

(5) The charge resides on the outer surface of a conductor. In insulators it remains where placed, i.e. may reside inside the body also.
In case irregular conducting bodies charge density is not uniform. It is maximum where the radius of curvature is min. and vice – versa $\Rightarrow \sigma \propto 1/R$.
This is why the charge leaks from sharp points.

(6) Method of charging : Friction, induction or conduction.

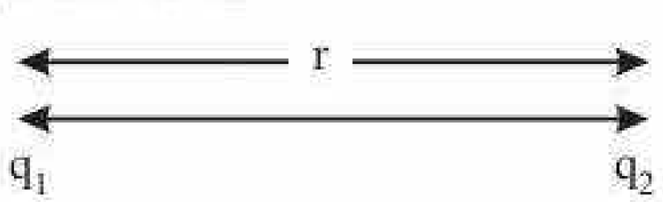
(7) Electrostatic Induction : If a charged body is brought near a neutral body, the charged body will attract opposite charge and repel similar charge present in the neutral body. As a result of this one side of neutral body becomes (+ ve) while the other (–ve). This process is called "electrostatic induction".

(8) Charge can be detected and measured with the help of gold leaf electroscope, electrometer, voltmeter or Ballastic. Galvanometer.

## Coulomb's Law

It states that, the electrostatic force of interaction (repulsion or attraction) between two electric charges $q_1$ and $q_2$ separated by a distance r, is directly proportional to the product of the charges and inversely proportional to the square of distance between them.

$\Rightarrow$ $F \propto q_1 q_2$ and $F \propto 1/r^2$




## Electric Field

The region surrounding an electric charge or a group of charges in which another charge experiences a force of attraction or repulsion is called 'electric field'.

**Electric cell :** It is the device used to convert chemical energy into electrical energy.

**Emf of cell (E) :** It is the potential difference across the terminals of a cell when it is not in use.

**Potentiometer**:

It is used to measure the exact potential difference between two points of an electric circuit or electromotive force (emf) of a cell.

## Properties of Electric Field Lines

- Two lines can never intersect.
- Electric field lines always begin on a positive charge and end on a negative charge.
- These line do not start or stop in mid space.
- Electric field lines are perpendicular to the surface of a charged conductor.

units $\rightarrow$ N/coul or volt/metre.

**Electric Line of Force**

An electric line of force is that imaginary smooth curve drawn in an electric field along which a free isolated unit positive charge moves.

**Properties** :

(1) The lines of force diverge out from a +ve charge and converge at a – ve charge. More correctly the lines of force are always directed from higher to lower potential.

(2) The tangent drawn at any point on line of force gives the direction of force acting on a positive charge placed at that point.

(3) Two lines of force never intersect. If they are assumed to intersect, there will be two directions of electric field at the point of intersection which is impossible.

(4) Electric lines of force differ from magnetic lines of force.
(a) Electric lines of force never form closed loop while magnetic lines are always closed or extended to infinity.
(b) Electric lines of force always emerge or terminate normally on the surface of charged conductor, while magnetic lines emanate from or terminate on the surface of a magnetic material at any angle.
(c) Electric lines of force do not exist inside a conductor but magnetic lines of force may exist inside magnetic material.

## Electric Flux ($\phi$)

The total number of electric line of force through a given area is called the electric flux.

## Gauss's Law

Gauss's law states that electric flux $\phi_\varepsilon$ through any closed surface is equal to $\left(\frac{1}{\varepsilon_0}\right)$ times the net charge q enclosed by the surface.

Law is valid for symmetrical charge distribution and for all vector fields obeying inverse square law.

## Electric Potential (V)

Electric potential at a point in an electric field is defined as the work done in moving a unit positive charge from infinity to that point in the electric field.

Unit is $J\,C^{-1}$ or volt

Potential at a point can be physically interpreted as the work done by the field in displacing a unit +ve charge from some reference point to the given point.

## Equipotential Surfaces (EPS)

For a given charge distribution, locus of all points having same potential is called equipotential surfaces. It is worth noting that.

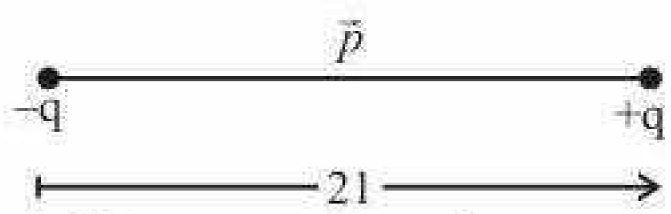
(i) EPS can never cross each other (otherwise potential at a point will have two values which is observed)

(ii) EPS are always ⊥ to ELP (Electric line of force)
(iii) If a charge is moved from one point to other over an EPS work–done will be zero.
(iv) The intensity of electric field along an EPS is always zero.

## Electric Dipole and Dipole Moment

An electric dipole is a system formed by two equal and opposite charges placed at a short distance apart. Product of one of the two charges and the distance between them is called "**electric dipole moment**" $\vec{p}$.

$\vec{p} = q \times 2\vec{\ell}$




It is a vector quantity, directed from – ve to + ve charge.
Dimension → [L T A], unit → Cb × m.

## Electric Current

The time rate of flow of charge through any cross-section is called current. If Δq charge passes through a cross-section in time Δt then

average current $I_{av} = \frac{\Delta q}{\Delta t}$

and instantaneous current $I = \lim_{\Delta t \to 0} \frac{\Delta q}{\Delta t} = \frac{dq}{dt}$

The conventional direction of current is the direction of flow of positive charge or applied field. It is opposite to direction of flow of negatively charged electrons.

**Current Density :** This is defined as current flowing per unit area held normal to direction of flow of current.

## Types of Current :

**(a) Direct Current (DC):** The current whose magnitude and direction does not vary with time is called direct current (dc).

**(b) Alternating Current (AC):** The current whose magnitude continuously changes with time and periodically changes its direction is called alternating current (AC). It has constant amplitude and has alternate positive and negative halves.

## Conductors

Conductors are substances through which electric charges can flow easily. copper, silver, aluminium, etc. are some examples of conductor.

**(a) Behaviour of conductor in absence of applied potential difference :**

The free electrons present in a conductor gain energy from temperature of surrounding and move randomly in a conductor.

**(b) Behaviour of conductor in presence of applied potential difference :**

When two ends of a conductor are joined to a battery then one end is at higher potential and another at lower potential. This produces an electric field inside the conductor from point of higher to lower potential, i.e. $E = \frac{V}{L}$.

## RESISTANCE AND OHM'S LAW

**Resistance (R):** Resistance of a conductor is the property of a conductor to oppose the flow of charge through it. It is given by

$$R = \frac{V}{I}$$

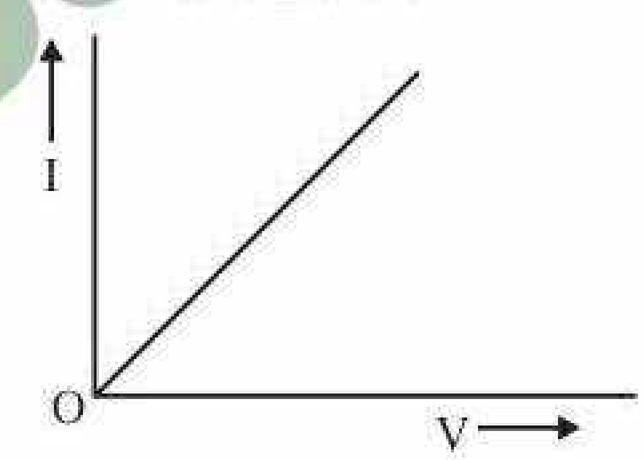
The unit of resistance is ohm (Ω)

The property of a substance due to which it opposes the flow of current through it is called **resistance**. It is a scalar quantity with unit volt/ampere called ohm (Ω)

The reciprocal of resistance is called conductance $G = \frac{1}{R}$.

The SI unit is $ohm^{-1}$ or mho or siemen (s)

**Ohm's Law:** George Simon Ohm (German Physicist) in 1826 studied the relationship between electric current and potential difference across the ends of a conductor. The relation between electric current and potential difference is known as Ohm's law. This law states that "the electric current flowing in a conductor is directly proportional to the potential difference across the ends of a conductor, provided the temperature and other physical conditions of the conductor remains the same".




$V \propto I$ or $V = IR$

Where R is known as resistance of the conductor.

If the physical state i.e. temperature, nature of material and dimensions of a conductor remain unchanged then the ratio of potential difference applied across its ends to current flowing through it remains constant.

**Resistivity (ρ) :** Resistivity of a conductor is defined as the resistance of the conductor of unit length and unit area of cross-section.

Resistivity of a substance does not depend upon its length, shape and area of cross-section.

Resistivity of a substance depends on the nature of the material of which the substance is made up of.

## Combination of Resistances

**(a) Series Combination**

Resistances are said to be connected in series between two points if they provide only a single path between two points.

equivalent resistance $R_s = \frac{V}{I} = R_1 + R_2 + R_3 + ....... + R_n$

**(b) Parallel Combination**

Resistances are said to be connected in parallel between two points if it is possible to proceed from one point to another along different paths.

$$\frac{1}{R_p} = \frac{I}{V} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ......... + \frac{1}{R_n}$$

## Electrical Power

Electric power is defined as the amount of electric energy consumed in a circuit per unit time. Energy liberated per second in a device is called its power. The electrical power P delivered or consumed by an electrical device is given by P = VI, where V = Potential difference across the device and I = current.

Power consumed by a resistor

$$P = I^2R = VI = \frac{V^2}{R}$$

When a current is passed through a resistor energy is wasted in overcoming the resistance of the wire. This energy is converted into heat.

1 unit of electrical energy = 1 kilowatt hour

= 1 kWh = $3.6 \times 10^6$ joule

**Electromotive Force (EMF):** The emf of a cell is defined as work done by cell in moving a unit positive charge in the whole circuit including the cell once.

**Internal Resistance of Cell:** The opposition offered by the electrolyte of the cell to the flow of electric current through it is called the internal resistance of the cell.

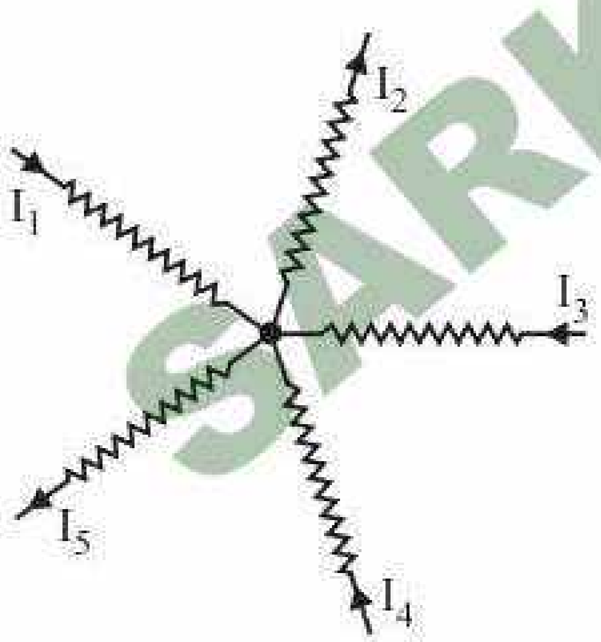
**Terminal Potential Difference:** The potential difference between the two electrodes of a cell in a closed circuit, i.e. when current is being drawn from the cell is called terminal potential difference.

## KIRCHHOFF'S LAW

Kirchoff in 1842 gave two laws which enable us to find out the distribution of current in any electrical network of conductors.

**(a) Kirchhoff's first law or current law or junction rule:**

In any electrical network, the algebraic sum of currents meeting at a junction is always zero i.e. $\Sigma I = 0$




$$I_1 - I_2 + I_3 + I_4 - I_5 = 0 \quad \text{or} \quad I_1 + I_3 + I_4 = I_2 + I_5$$

**(b) Kirchhoff's second law or voltage law or loop rule:**

The algebraic sum of all the potential drops and emf's along any closed path in a network is zero. i.e. $\Sigma V = 0$

The change in potential in covering a resistance in the direction of current is negative (–IR) while in opposite direction it is positive.

## Ammeter

An ammeter is a low resistance galvanometer used to measure strength of current in an electrical circuit.

A galvanometer can be converted to an ammeter by connecting a low resistance shunt in parallel to coil of galvanometer.

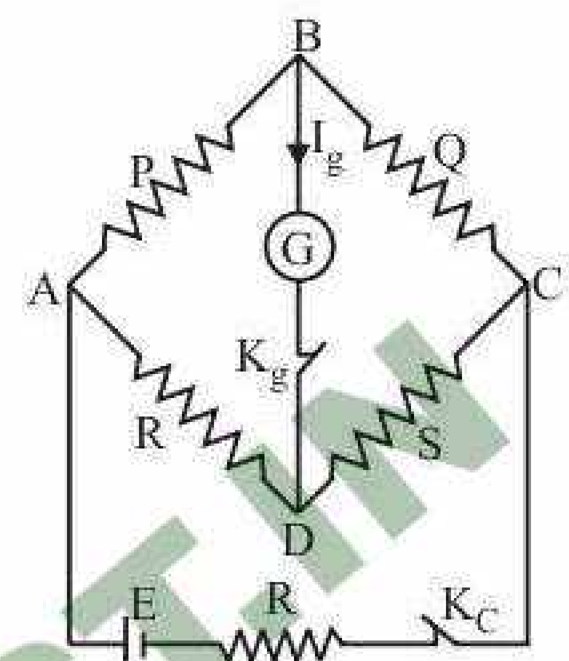
## Voltmeter

A voltmeter is a high resistance galvanometer used to measure potential difference.

A galvanometer is converted to a voltmeter by connecting a high resistance in series with coil of galvanometer.

## Wheatstone Bridge

It is an arrangement of four resistances devised by Charles Wheatstone which is used to measure an unknown resistance.




The wheatstone bridge principle states that if four resistances P, Q, R and S are arranged to form a bridge with a cell and key between A and C, and a galvanometer between B and D then bridge is said to be balanced when galvanometer shows a zero deflection. In balanced condition $I_g = 0$

so $V_B = V_D$ or $\frac{P}{Q} = \frac{R}{S}$.

This is called condition of balance.

## Transformer

- Transformer is a device which converts low voltage AC into high voltage Ac and vice-versa.
- It is based on **electromagnetic induction**.

**Application /uses**: As voltage regulators for –

(i) T.V, refrigerator, computer, air conditioner, etc.

(ii) Induction furnaces.

(iii) for welding purposes.

**AC Generator/Dynamo/Alternator:**

- It is an electric device used to convert mechanical energy into electrical energy.
- It works on the principle of electromagnetic induction.

**D.C. Motor**

- It converts direct current energy from a battery into mechanical energy of rotation.
- **Its uses :**

(i) In D.C. fans, exhaust, ceiling, table fans, etc.

(ii) In pumping water.

(iii) In running tram-cars, trains, etc.

## Post Office Box

It is based on principle of wheatstone bridge. Unknown resistance is $S = \frac{Q}{P}R$ and specific resistance is $\rho = \frac{\pi r^2 S}{L}$, where r is radius and L is length of wire.

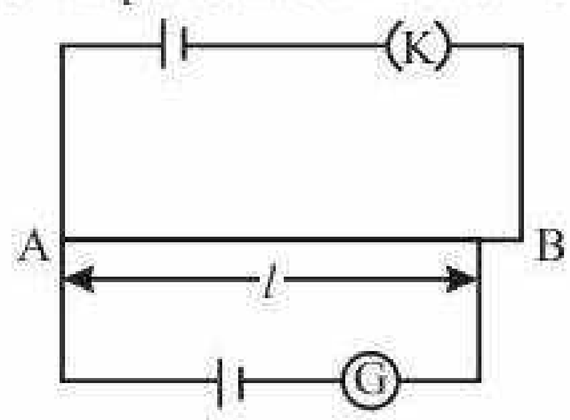
## House Hold Circuit

House hold circuit are provided parallel combination due to following advantages

- If one electrical appliance stop working, then other appliances keep working normally
- Each appliance has its own switch, whenever needed can be turned on or off independently without affecting other appliances. Same voltage at each appliance.
- Due to small equivalent resistance, current from power supply high.

## Potentiometer

Potentiometer is a device to measure the emf of a cell or p.d. between the ends of a cell or p.d between the ends of a current-carrying conductor without drawing any current from the circuit. It operates on the principle that an emf or p.d. can be balanced against another emf or p.d. which produces a zero current. In a potentiometer the emf of a battery D (called driving battery) is distributed over a long uniform wire AB of high resistivity and p.d. between any two points of it (one fixed at the left end A and other is sliding) is applied against emf or p.d. to be measured. The sliding joint J is then moved over the wire, until both are balanced to each other. A sensitive galvanometr indicates whether the current in the circuit is zero or not. When there is no deflection in the galvanometer the p.d. between A and J = emf of the test cell.




It is a device used to measure unknown potential difference accurately.

**Uses of potentiometer :**

1. Determination of unknown emf or potential difference
2. Comparison of emfs of two cells
3. Determination of internal resistance of cell

## Galvanometer

Galvanometers are the electrical devices used for the detection or measurement of the electric currents.

## Shunt

Shunt is an electrical system of configuration of the electric conductor or wire of small resistance. Sometimes it is not desirable to send heavy electric currents through a sensitive Galvanometer and thus in order to protect such Galvanometer a low resistance wire or conductor is attached in parallel to the coil. Shunt decreases the effective resistance of the instrument. It increases the current measuring range but decreases the sensitiviness of the instrument.

## Heating Effect of Current

**Joule's law of heating :** When a current I is made to flow through a resistance R for time t, heat Q is produced such that

$$Q = I^2Rt$$

$$Q = P \times t = VIt = \frac{V^2}{R}t$$

**Fuse Wire**

Electric Fuse is a safety device used to save the electrical appliances from burning when large current flows in the circuit. The fuse wire for an electric circuit is chosen keeping in view the value of safe current through the circuit.

The fuse wire should have high resistance per unit length and low melting point.

## Miniature Circuit Breakers (MCBs)

In present time, the fuses are replaced by MCBs (Miniature Circuit Breakers) which is an automatically operated electrical switch designed to protect an electrical circuit from the damage caused by over load or short-circuit.

The tin-lead alloy is also used as soldering material for joining metals in electronic circuit. Earth pin of the plug is always made thicker and longer.

## Invertor

It is a device which converts DC to AC, used in offices, homes and designed to

- charge the battery.
- convert DC from a battery to AC.

It is fitted in main power line. In case of failure of power, it is automatically switch ON and provide power to the domestic wiring in the homes. When the main supply is restored, the invertor automatically switch to a mode on which it starts charging the battery depleted due to use, during the period of power failure.

## Lighting Devices

The appliances that give the light instead of electricity through it are known as lighting appliances such as

## Incandescent Lamp or Filament Lamp

It has tungsten filament connected between two lead in wires. When there is a current through it, it gets heated and emits light. The melting point of tungsten is about 3400°C. The electric bulb contains argon gas to prevent the evaporation of tungsten.

Air could not be used because it oxidise the tungsten. Lead in wires of lamp are not heated much because they have very low resistance. All the switches in a house are put in the live wires. If they were in the neutral wire, the sockets would remains live even when the switches were in the off position which may cause a danger.

## Fluorescent Tubes

It contains mercury vapours at low pressure which emits invisible ultraviolet rays when tube is switched on. These ultraviolet rays fall on the fluorescent coating inside of the tube and emits visible light. Since, there is a little amount of heat is produced in a tube, i.e. almost electrical energy is converted into light energy. The tubes are more cheaper and efficient.

## Compact Fluorescent Lamps

An incandescent light bulb waste a lot of electricity in the form of heat while, no electric energy is wasted as heat in a fluorescent lamp. A CFL (Compact Fluorescent Lamp) is miniature fluorescent tube and works on the same principle. It is 4 to 6 times more efficient than an incandescent bulb. That's why one can buy a 15 W fluorescent lamp that produces the same amount of light as a 60 W incandescent bulb.

Although, initial cost for CFL is more but its lasting is 15 times longer than that of other bulbs. (Fluorescent lamps contains mercury which is a hazardous substance). In terms of light emission 40 Wincandescentbulb=10WCFL,
60 W incandescent bulb = 15 W CFL
100 W incandescent bulb =26-29W CFL.

## Faraday's Laws of Electrolysis

**First Law:** The mass of a substance deposited or liberated at an electrode is directly proportional to the quantity of charge passed through the electrolyte.
$m \propto q$ or $m = Zq = ZIt$, where Z is electrochemical equivalent (ECE) of the substance.

**Second Law :** When same charge is passed through different electrolytes, the mass of substance deposited or liberated are directly proportional to the chemical equivalents i.e. $\frac{m_1}{m_2} = \frac{E_1}{E_2}$.

### Applications of electrolysis

(i) Extraction of metals
(ii) Electroplating
(iii) Purification of metals

**Seebeck Effect:** When two different metalic wires (conductors) are connected to each other and two junctions are formed by a differential heating or a temperature difference is maintained then an electric current is generated through this couple, which is called Seeback's effect. The phenomenon of generation of an electric current in a thermocouple by keeping its two junctions at different temperatures is called Seebeck or thermoelectric effect.

**Pelteir Effect:** If the junctions of a thermocouple are at same temperature and a current is passed through it then heat is evolved at one junction and absorbed at the other, i.e. one of the junction is heated and the other is cooled.
This is know as Peltier effect.

**Thomson's Effect:** The absorption or evolution of heat in excess of joule heat when current is passed through an unequally heated conductor is known as Thomson's effect.

**Cyclotron:** A compact machine devised by Lawrence and Livingston in 1932 to accelerate the positive ions like protons, deutrons and $\alpha$ - particles is called cyclotron (or cyclic accelerator). But by this machine (device) negatively charged particle (electron) cannot be accelerated because relativistic mass starts to increase abruptly with increase of velocity. A cyclotron is used for accelerating positive ions, so that they acquire energy large enough to carry out nuclear reactions.

## Lightning Conductor

It is a genetic electric discharge occurring between two charged clouds or between a charged cloud and the earth. Lightning conductor are used to protect tall building from lightning-damage. It is a conductor with thick copper strip fIxed to an outside wall of the building.
The upper end of strip is in the form of several sharp spikes reaching above the highest part of the building and lower end is connected to a copper plate buried in the earth. By passing the charged cloud over it, it accepts any discharge which may occur and conducts it harmlessly to the earth.

## MAGNETISM

The phenomenon of attracting magnetic substances like iron, cobalt, nickel, etc. is called magnetism. A body possessing the property of magnetism is called magnet.

- The force of attraction of a magnet is **greater at its poles than in the middle.**
- **Similar** poles of two magnets repel each other.
- Opposite poles of two magnets attract each other.
- If a **bar magnet** is suspended by a thread and free to rotate, its South Pole will move towards the North Pole of the earth and vice versa.

**Uses /Applications**

- Magnets are used in making magnetic compasses which help **sailors** and **navigators** to know the **directions**.

**Faraday's law of magnetic induction**

When a material is placed within a magnetic field, the magnetic forces of the material's electrons will be affected. This effect on electrons is called **Faraday's law** of **electron magnetic induction**.

According to Faraday's law of electromagnetic induction,

**MAGNETIC SUBSTANCES:**

On the basis of magnetic behaviour, substances are divided into three categories:

(i) **Diamagnetic materials**
Those materials which have a **weak, negative** susceptibility to magnetic fields. These are **slightly repelled** by a magnetic field, egs. Bismuth, zinc, copper, silver, gold, diamond, mercury, etc.

(ii) **Paramagnetic materials**
Those materials which have a **small, positive** susceptibility to magnetic fields. These are **slightly attracted** by a magnetic field, egs. Aluminium, platinum, magnesium, sodium, oxygen, molybdenum, lithium, tantalum, etc.

(iii) **Ferromagnetic materials**
Those materials which have a **large, positive** susceptibility to an external magnetic field. They exhibit a strong attraction to magnetic field, egs Iron, cobalt, nickel, ferric chloride, etc.

- **Electromagnets** are used in generators, motors, loud speakers, telephones, TV sets, fans, mixers, electric bells, Maglev etc.

## MODERN PHYSICS

- The nucleus of an atom consists of protons and neutrons together called nucleons. Size of the nucleus Redius of the nucleus $R = R_0 A^{1/3}$
  where $R_0 = 1.1 \times 10^{-15}$m, A = atomic mass.

**Difference between stable and unstable nucleus**

| Stable nucleus | Unstable nucleus |
|---|---|
| Low atomic number | High atomic number |
| Low mass number | High mass number |
| Nucleus of small size | Nucleus of bigger size |
| $\frac{n}{p} = 1$ | $\frac{n}{p} > 1$ |

## Coulomb's Law in Magnetism

If two magnetic poles of strengths $m_1$ and $m_2$ are kept at a distance r apart then force of attraction or repulsion between the two poles is directly proportional to the product of their pole strengths and inversely proportional to the square of the distance between them

**Pole Strength :** The pole strength of north pole is defined as the force experienced by the pole when kept in unit magnetic field.

$$m = \frac{\vec{F}}{\vec{B}}$$

**Magnetic Dipole :** An arrangement of two magnetic poles of equal and opposite strengths separated by a finite distance is called a magnetic dipole.

A small bar magnet is treated like a magnetic dipole.

The product of strength of either pole and the magnetic length of the magnet is called **magnetic dipole moment**.

**Magnetic Field:** The space around a magnet (or a current carrying conductor) in which its magnetic effect can be experienced is called the magnetic field.

The strength of magnetic field is also known as magnetic *induction* or *magnetic flux density*. The SI unit of strength of magnetic field is *Tesla* (T)

## Magnetic Lines of Force and Their Properties

The magnetic field lines is the graphical method of representation of magnetic field. This was introduced by *Michael Faraday*.

**Properties :**

(1) A line of force is an imaginary curve the tangent to which at a point gives the direction of magnetic field at that point.

(2) The magnetic field line is the imaginary path along which an isolated north pole will tend to move if it is free to do so.

(3) The magnetic lines of force are closed curves. They appear to converge or diverge at poles outside the magnet they run from north to south pole and inside from south to north.

## GAUSS'S LAW IN MAGNETISM

The surface integral of magnetic field over a closed surface S is always zero

## SOME DEFINITIONS :

**(1) Geographic Axis:** It is straight line passing through the geographic poles of the earth. It is the axis of rotation of the earth. It is known as polar axis.

**(2) Geographic Meridian:** It is a vertical plane passing through geographic north and south poles of the earth.

**(3) Geographic Equator:** A great circle on the surface of the earth in a plane perpendicular to geographical axis is called geographic equator. All places on geographic equator are at equal distances from geographical poles.

**(4) Magnetic Axis:** It is a straight line passing through the magnetic poles of the earth. It is inclined to geographic axis at nearly 17°.

**(5) Magnetic Meridian:** It is a vertical plane passing through the magnetic north and south poles of the earth.

**(6) Magnetic Equator:** A great circle on the surface of the earth in a plane perpendicular to magnetic axis is called magnetic equator. All places on magnetic euqator are at equal distance from magnetic poles.

## Magnetic Elements

The physical quantities which determine the intensity of earth's total magnetic field completely both in magnitude and direction are called magnetic elements.

**(1) Angle of Declination ($\phi$):** The angle between the magnetic meridian and geographic meridian at a place is called angle of declination.

**(2) Angle of dip or inclination:** At any place of the earth the angle between the direction of the total earth's magnetic field intensity and the horizonal line in the magnetic meridian is called angle of dip or angle of inclination. At the poles of the earth angle of dip is 90°, while at the equator the angle of dip is 0°. The angle through which the N pole dips down with reference to horizontal is called the angle of dip. At magnetic north and south pole angle of dip is 90°. At magnetic equator the angle of dip is zero.

**(3) Horizontal component of earth's magnetic field:** The total intensity of the earth's magnetic field makes an angle θ with horizontal. It has

(i) Component in horizontal plane called horizontal component $B_H$.

(ii) Component in vertical plane called vertical component $B_V$.

**Intensity of Magnetisation:** It is defined as the magnetic dipole moment developed per unit volume when a magnetic material is subjected to magnetising field.

Intensity of magnetisation

$$I = \frac{\text{magnetic dipole moment}}{\text{volume}} = \frac{M}{V}$$

**Magnetic Susceptibility:** It is obseved experimentally that soft iron can be easily magnetised in comparison to steel, then it is said that susceptibility of soft iron is more than that of steel. Thus, susceptibility of a substance (material) is defined in such a way in which a magnetic substance can be magnetised. The magnetic susceptibility of a magnetic substance is defined as the ratio of the intensity of magnetisation to magnetic intensity $\chi_m = \frac{I}{H}$

**Magnetic Permeability:** If a magnetic substance say iron is kept in any magnetic field then more and more magnetic lines of force cross through it in comparison to air. In other words we can say that magnetic substance like iron, cobalt or nickle are good conductors of magnetic lines of force. This characteristic of the magnetic substance is called magnetic permeability. The magnetic permeability of a magnetic substance is defined as the ratio of the magnetic induction to the magnetic intensity so $\mu = \frac{B}{H}$

**Retentivity:** The value of I (or B) of a material when the magnetising field is reduced to zero is called retentivity or residual magnetism of the material.

**Coercivity:** The value of reverse magnetising field required to reduce residual magnetism to zero is called coercivity of the material.

## Curie Temperature

The permeability of a ferromagnetic substance decreases with rise in temperature and becomes practically equal to $\mu_0$ at a certain temperature, called curie temperature. Above curie temperature, the ferromagnetic substance becomes paramagnetic. The curie temperature for iron is about 770°C.

## Magnetic Flux

Physically, magnetic flux represents total lines of induction passing through a given area.

## Faraday's Laws of Electro-Magnetic Induction

Whenever there is change in the magnetic flux associated with a circuit, an e.m.f. is induced in the circuit.

The magnitude of the induced e.m.f. (e) is directly proportional to the time rate of change of the magnetic flux through the circuit.

## Lenz's Law

**The direction of the induced current e.m.f. is given by Lenz's law:** The direction of the induced current is such that it oppose the change in the magnetic flux that causes the induced current or e.m.f. i.e. induced current tries to maintain flux

On combining Lenz's law with Faraday's laws $e = -\frac{d\phi}{dt}$ –ve sign indicating that the induced e.m.f. opposes the change in the magnetic flux. The Lenz's Law is consistent with the law of conservation of energy.

## TRANSFORMER

It is a device for transforming a low alternating voltage of high current into a high alternating voltage of lower current and vice versa, without increasing power or changing frequency.

If a low voltage is to be transformed into a high voltage, then the number of turns in secondary is more than those in primary. The transformer is called a step up transformer.

If a high voltage is to be transformed into a low voltage, then the number of turns in secondary is less than those in primary. The transformer is called step-down transformer.

**Principle:** It works on the phenomenon of mutual induction.

**Eddy Currents:** The induced circulating currents produced in a metal itself due to change in magnetic flux linked with the metal are called eddy currents.

## OPTICS

## Introduction

Optics is a branch of physics deals with the behaviour of light and other electromagnetic waves.

## Light

Light is an external cause due to which any object becomes visible for human eye. For the illumination or visibility of an object light incidents upon it (up to 1/6th second). Then after reflection it comes to the eye and then the object is seen. At present light is defined in the form of an energy which transmits as an electromagnetic wave and whose energy is confined in the form of a small packet called photon.

- **Photons** carry momentum, have no mass, and travel at the speed of light, i.e. **300,000 km/sec**.
- All light has both particle and wave like properties. For example–
  –Particle like; use of detectors in digital camera for the detection and storage of image data.
  –Wave like; use of instrument for diffraction of light into a spectrum for analysis.
- It is a **transverse wave**.
- One of the physical properties of light is that it can be **polarized**.
- Sun's light reaches to earth in 8 **minutes** 19 seconds (i.e. 499 seconds).
- **Roemer** was the person who measured speed of light in AD 1678.
- The light reflected from moon reaches to earth in **1.28** second.

## Luminous and Non-luminous Objects

Luminous objects are those which emit its own light, e.g. sun, glow worm, burning candle, electric lights etc. Non-luminous objects do not give out its own light but are visible only when light from a luminous object falls on it, e,g. moon, earth, table, paper, etc.

## Transparent, Translucent and Opaque Materials

**Transparent** materials are those which allow most of light to pass through them.

**Example:** Glass, water, air.

**Translucent** materials allow only a part of light to pass through it. We cannot see distinctly through them.

**Example:** Greased paper, paraffin wax, etc.

**Opaque** materials do not allow any light to pass through it. They reflect or absorb all the light that falls on them.

**Example:** Books, desk, stone, rubber, trees, etc.

**Speed of light in different mediums**

| Medium | Speed of light |
|---|---|
| Glass | $2 \times 10^8$ m /sec |
| Turpentine oil | $2.04 \times 10^8$ m /sec |
| Water | $2.25 \times 10^8$ m/sec |
| Vacuum | $3 \times 10^8$ m/sec |

- **Ultraviolet radiation** is an electromagnetic radiation that has wavelength from 400 nm to 10 nm, shorter than that of visible light but longer than X-rays. It is used in water purification.
- **Infrared radiation** is emission of energy as electromagnetic waves in the portion of the spectrum just beyond the limit of the red portion of visible radiation.
- Range between $10^{-6}$m and $10^{-3}$m. It is used to treat muscular strain, in green house etc.
- **X-rays** are electromagnetic radiation having a shorter wavelength and produced by bombarding a target made of tungsten, with high speed electrons. Uses in medical diagonosis.

- **Microwaves** are short, high frequency waves lying roughly between very high frequency (infrared) waves and conventional radio waves.
- Their wavelength range - $10^{-3}$ m to $10^{-2}$ m. It is used in microwave oven.
- **Electromagnetic** wave and **Dis-coverers**.

| Waves | Discoverer |
|---|---|
| $\gamma$-Rays | Henry |
| X-Rays | W. Roentgen |
| Ultra-Violet rays | Ritter |
| Visible radiation | Newton |
| Infrared rays | Herschel |
| Short radio waves or (Hertz Hertzian Waves) | Heinrich |
| Long radio waves | Marcony |

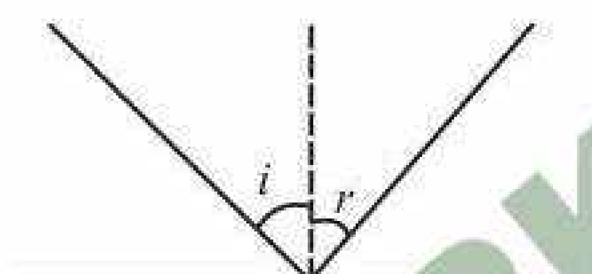
## REFLECTION OF LIGHT

When light hits an opaque material, the light may be absorbed by the material and converted into heat energy. If light is not absorbed, it is bounced back or reflected at the surface of material. This phenomenon of reflecting back of light in the same medium is called reflection of light.

### Laws of Reflection:

There are two laws of reflection.

1. The angle of incidence '$i$' is equal to the angle of reflection '$r$'.




2. At the point of incidence, the incident ray, the normal to the surface and the reflected ray all lie in the same plane.

**Diffuse reflection:** When light is incident on a rough surface, it is reflected in many directions. This is called diffuse reflection.

**Reflection by plane mirrors:** Plane mirror is a looking glass which is highly polished on one surface and is silvered on the other surface. When a light ray strikes the polished surface, it is reflected by the silvered surface.

### Types of Images

**Real image**

1. When the rays of light actually meet, the image so formed is known as real image.
2. A real image can be caught on a screen since it is formed by actual meeting of rays.
3. A real image is always inverted.
4. A real image is formed by a convergent reflected beam.
5. In ray diagrams, for real image, the rays are represented by full lines.

**Virtual image**

1. When the rays of light appear to meet, the image so formed is known as virtual image.
2. A virtual image cannot be caught on a screen since it is formed by meeting of imaginary rays.
3. A virtual image is always erect.
4. A virtual image is formed by a divergent reflected beam.
5. In ray diagrams, for virtual image, the rays are generally represented by dotted lines.

**Characteristics of images formed by a plane mirror**

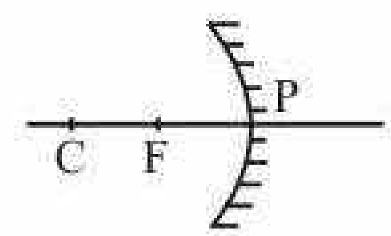
The image formed by a plane mirror is

(a) virtual (the image cannot be taken on a screen)
(b) upright
(c) laterally inverted (the left side of an image is formed by the right side of an object and vice-versa)
(d) the same size as the object
(e) the same distance behind the mirror as the object is in front of the mirror

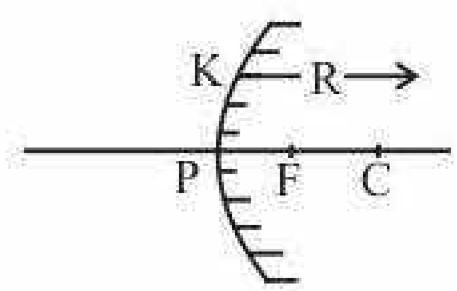
**Images by two inclined plane mirrors:** When two plane mirrors inclined to each other at an angle θ, then number of image (n) formed of an object kept between them $n = \left(\frac{360°}{\theta} - 1\right)$

### Types of curved mirror

**Concave mirror :** If the reflection takes place from the inner surface of a spherical mirror, then the mirror is called concave mirror.




**Convex mirror :** If the outer surface of the spherical mirror acts as a reflector then the mirror is called convex mirror.




### Terms Related to Spherical Mirror

**Centre of curvature (C):** It is the centre of sphere of which the mirror is a part.

**Radius of curvature (R):** It is the radius of the sphere of which the mirror is a part.

**Pole (P):** It is the geometrical centre of the spherical reflecting surface.

**Principal axis:** It is the straight line joining the curvature to the pole.

**Focus (F):** When a narrow beam of rays of light, parallel to the principal axis and close to it (known as paraxial rays), is incident on the surface of a mirror, the reflected beam is found to converge (concave mirror) or appear to diverge (convex mirror) from a point on principal axis. This point is called focus.

**Focal length (F) :** It is the distance between the pole and the principal focus. For spherical mirrors $f = R/2$.

**Magnification** (m) $= \frac{\text{Height of image}}{\text{Height of object}} = \frac{\text{Image distance}}{\text{Object distance}}$

**Position & nature of image formed by a spherical mirror**

| Position of object | Position of image | Size of image in comparison to object | Nature of image |
|---|---|---|---|
| **Concave mirror** | | | |
| At infinity | At focus | Highly diminished | Real, inverted |
| Between infinity and centre of curvature | Between focus and centre of curvature | Diminished | Real, inverted |
| At centre of curvature | At centre of curvature | Of same size | Real, inverted |
| Between focus and centre of curvature | Between centre of curvature and infinity | Enlarged | Real, inverted |
| At focus | At infinity | Highly enlarged | Real, inverted |
| Between focus and pole | Behind the mirror | Enlarged | Virtual, erect |
| **Convex mirror** | | | |
| At infinity | At Focus | Highly diminished | Virtual, erect |
| Infront of mirror | Between pole and focus | Diminished | Virtual, erect |

### Uses of concave mirror

(i) As a shaving mirror.
(ii) As a reflector for the head lights of a vehicle, search light.
(iii) In opthalmoscope to examine eye, ear, nose by doctors.
(iv) In solar cookers,

### Uses of convex mirror

(i) As a rear view mirror in vehicle because it provides the maximum rear field of view and image formed is always erect.
(ii) In sodium reflector lamp.

## REFRACTION OF LIGHT

The bending of the light ray from its path in passing from one medium to the other medium is called refraction of light. Twinkling of stars is due to atmospheric refraction. The refraction of light takes place because speed of light changes when light goes from one medium to another medium.

### Laws of Refraction

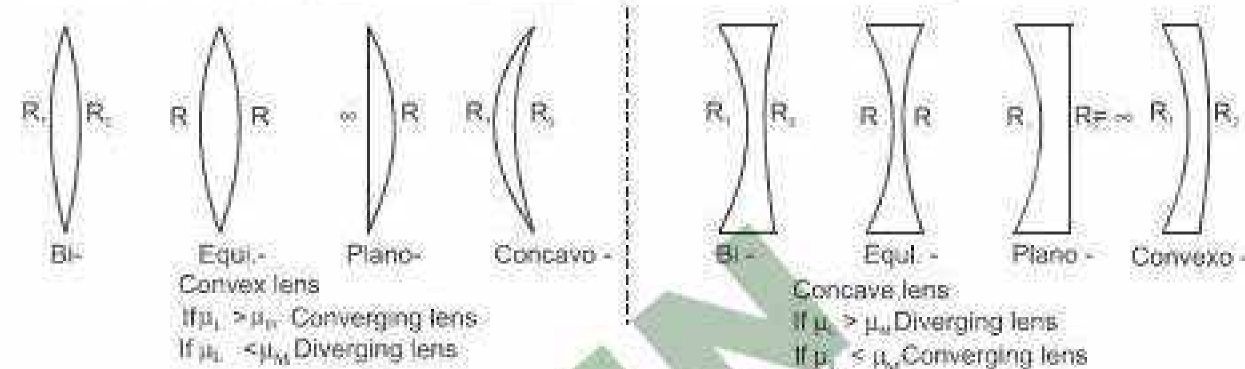
(i) **Snell's Law:** For any two media and for light of a given wavelength, the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant.
(ii) The incident ray, the refracted ray and the normal at the incident point all lie in the same plane.

**Refractive index:** Refractive index of a medium is defined as the ratio of the velocity of light in the vacuum to the velocity of light in the medium. The amount of change in the speed of light in a medium depends upon the property of the medium. This property is known as refractive index of the medium. Refractive index is a measure of how much the speed of light changes when it enters the medium from air.

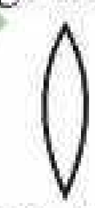
**Factors on which the refractive index of a medium depends**
(i) Nature of the material of the medium.
(ii) Density of the medium.
(iii) Colour or wavelength of light

### Lens

A lens is a piece of transparent material with two refracting surface such that least one is curved and refractive index of used material is different from that of the surroundings.




**Convex lens**: A lens having both spherical surfaces or one spherical surface and other plane surface such that it is thick in the middle and thin at the edges is known as convex lens.



**Concave lens:** A lens having both spherical surfaces or one spherical and other plane surface such that it is thin in the middle and thick at the edges is known as concave lens.

### Refraction Through a Thin Lens (Lens Formula)

If an object is placed at a distance $u$ from the optical centre of a lens and its images is formed at a distance $v$ (from the optical centre) and focal length of this length is $f$ then $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

This is called lens formula.

### Power of a Lens

Power of a lens is the ability of the lens to converge or diverge the rays of light falling on it. Power of a lense is defined as the reciprocal of the focal length of the lens (expressed metres).
The power of a lens is defined as

$P = \frac{1}{f(\text{in } m)}$. The unit of power is diopter (D)

The unit of power is **diopter**.

**Some Phenomena based on Refraction**
(i) **Twinkling** of stars
(ii) **Oval Shape** of sun in the morning and evening.
(iii) Rivers appear **shallow**
(iv) Coins appear **raised** in glass filled with water.
(v) Pencils appear **broken** in the beaker filled with water.
(vi) Sun appears **above horizon** at sunset and sunrise.
(vii) Writing on a paper appears **lifted** on putting glass slab on it.
(viii) An object in a denser medium appears to be **nearer** when seen from a rarer medium, eg. fish in water, a coin at the base of a water filled vessel.

### Total Internal Reflection

When the angle of incidence, for a ray of light passing from a denser medium to a rarer medium, exceeds a particular value (called **critical angle** for which angle of refraction 90°), the ray reflects back in the same medium from the boundary. This phenomena is called **total internal reflection.**

**Critical angle ($\theta_c$) :** In case of propagation of light from denser to rare medium through a plane boundary critical angle is the angle of incidence for which angle of refraction is 90°.

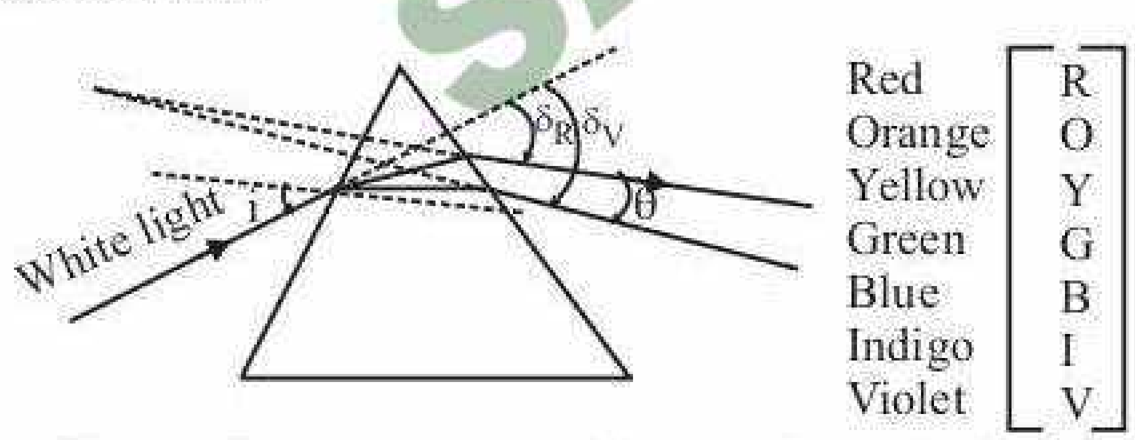
Scattering of Light: Sunlight gets scattered by small particles present in the atmosphere. Red colour scatters least and violet most. According to Rayleigh the intensity of scattered light, i.e. $I \propto \frac{1}{\lambda^4}$. Some phenomena like – **reddish** appearance of the sun at **sunrise** and **sunset**, **blue colour** of sky, white colour of clouds etc. based on scattering of light.

**Some Phenomena of total Internal Reflection**

(i) Endoscopy using optical fibre.
(ii) Sparkling of diamond.
(iii) Mirage in desert
(iv) Increase in duration of sun's visibility.
(v) Appearance of air bubbles in glass paper weight.
(vi) Shining of air bubbles in water.
(vii) Shining of a smoked ball or a metal ball on which lamp soot is deposited when dipped in water.

## DISPERSION OF LIGHT IN PASSING THROUGH A PRISM

When the white light, having the seven colours, passes through a prism, it is split up into its constituent colours. This phenomenon is known as the dispersion of light. It arises due to the fact that the refractive index μ of the prism, material is different for the different colours, characterised by the different wavelengths in the material of prism. The rays of different colours are deviated through the different angles, i.e. the violet colour is deviated the most and the red colour is deviated the least, and hence, go in the different directions after the emergence. The rainbow is the most colourful phenomenon in nature and it arises due to the dispersion of sunlight in passing through the raindrops suspended in air.




(i) The regular arrangements of seven colours in the order of VIBGYOR is known as **spectrum**.
(ii) The spectrum in which all the seven colours are arranged in a regular manner without overlapping is known as **pure spectrum.**
(iii) The spectrum in which different colours overlap one another is known as **impure spectrum**.

## Scattering of Light

When light is incident on tiny particles having dimensions of the order of wavelength of light then it is neither reflected, nor transmitted nor absorbed, instead of it, it is splitted up into a large number of components. This is known as scattering of light.

**Due to scattering of light:**

(a) Setting sun and rising sun appears red
(b) Sky appears blue
(c) Crushed ice appears white, etc.

**Power of accommodation:** The ability of eye to see near objects as well as far objects is called power of accomodation.

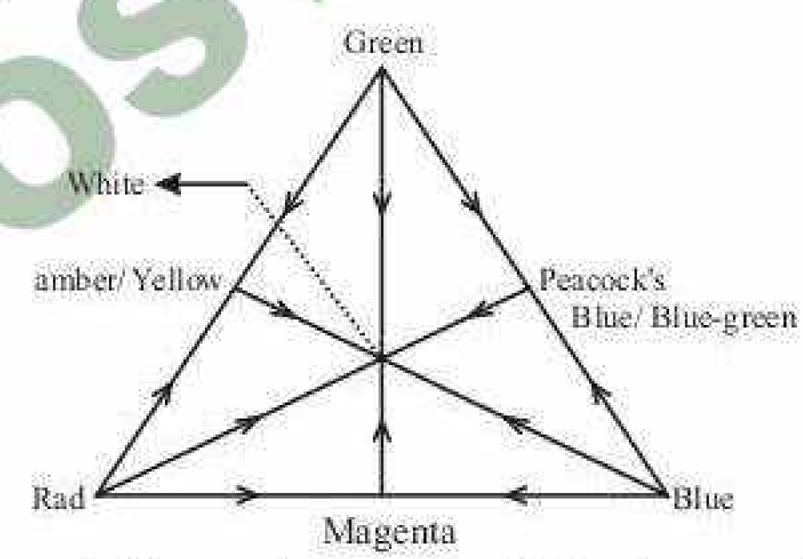
For a normal healthy human eye it is 25 cm (near point) to ∞ (far point).

**Rainbow:** When the phenomenon of refraction, reflection and total interal reflection occur coincidentally and a comprehensive optical disperson takes place then a rainbow is appeared.

The rainbow is of two types –

(i) **Primary rainbow:** Whenever rainfall occurs then after its complete end some rain drop remains suspended and at the meantime if any light ray incidents on a particular drop in such a way that it reflects one time and refracts two times then primary rainbow is formed.
(ii) **Secondary rainbow:** As above if the light ray incidents on a particular drop in such a way that reflects two times and refracts two times then secondary rainbow is formed.

## Primary, Secondary and Complementary Colours




Red, green and blue colours are called primary colours while yellow, magenta and peacock blue colours are called secondary colours.

Red + Blue → Magenta
Green + Blue → Peacock blue (blue-green)
Red + Green → Yellow (amber)

If two colours mutually meet to form a white light then the colours is complementary.

**Example :** Red + Peacock blue = White
Green + Magenta = White
Yellow + Blue = White
Red + Green + Yellow = White

Colour T.V. utilises primary colours Red, Green and Blue.

### Human Eye

The normal range of vision for a healthy human eye is from 25 cm (least distance of distinct vision to infinity (for point).

### Defects of Vision & Remedies

**Myopia or Near(short) sightedness**:

- A person suffering from Myopia can't see the far (distant) object clearly but can see nearby object clearly.

**Causes:**

- The eye ball is too long (i.e. elongated) so image is formed before retina.
- Lens being too curved for the length of the eye ball.
- Combination of above, i.e. elongated eyeball & curved lens.
- Shortening of focal length of eye lens.
- Over stretching of ciliary muscles.

**Remedy:** Concave lens is used to diverge the rays at retina.

**Hyperopia or Hypermetropia (long (far) sightedness)**

- A person suffering from it can't see near object clearly but can see distant object clearly.

**Causes:**

- The eye ball is too short so image is formed beyond the retina.
- Cornea is not curved enough,
- Eye lens is farther back in the eye.
- Increase in the focal length of eye lens.
- Stiffening of ciliary muscles.

**Remedy:**

- Convex lens is used to converge the rays at retina.

**Target group:**

- It can affects both children and adults.
- People whose parents are farsighted,
- It can be confused with presbyopia (i.e. ." after 40" vision).

**Astigmatism:** Astigmatism is the most common refractive problem responsible for **blurry vision**. **Cylindrical** lens is used to correct astigmatism.

**Presbyopia ("after 40" vision) :** After age 40, and most noticeably after age 45, the human eye is affected by presbyopia, which results in greater difficulty maintaining a clear focus at a near distance with an eye which sees clearly at a far away distance.

**Cataract**

- It is the clouding of the lens of the eye that prevent a person to see.
  Because light rays can't pass through the cloudy lens, Vision of a person becomes cloudy, blurry, foggy, or filmy.

**Causes:**

- Protein builds up in the eye lens & make it cloudy.
- Cloudy protein layers prevent rays to pass through eye lens.
- New lens cells form on the outside of the lens, making older cells compacted into the center of the lens to form cataract.

**Remedy:**

- It can be corrected with suitable eye glasses (lenses).
- Cataract surgery is performed when eye glass does not suit.

**Magnifying glass (or simple microscope):** A magnifying glass is, in fact, a convex lens. The lens is usually fixed to a frame with a handle to make it easy to use.

**Microscope:** A Microscope is used to obtain an enlarged image of very small objects that cannot be seen with unaided or naked eyes. A magnifying glass may be considered to be the simplest form of a microscope.

**Telescope:** A telescope is a device that is used to get an enlarged view of distant objects, like the moon and the planets. These are known as **astronomical telescopes.**

## Wave Front

The locus of all particles vibrating in the same phase is called wave-front.

(a) Each point of wavefront is considered as source of secondary wavelets.

(b) The ray of light is considered in the direction of outward normal to the wave front.

## DUAL NATURE OF LIGHT

* According to this light has dual nature, one wave nature (E.M. wave) and second corpuscles nature (Energy particle of planck).
* In microscopic description, when we talk about propagation of light in medium then wave nature of light is considered.
* In microscopic description, when light mutually interacts with matter, then particle nature of light is considered.
* Both particle and wave nature exist together but we can't see both nature in single experiment.
* All phenomenon of light can be explained by this.

**Interference of two waves:** When two waves of same frequency travel in a medium simultaneously in the same direction then, due to their superposition, the resultant intensity at any point of the medium is different from the sum of intensities of the two waves. At some points the intensity of the resultant wave is very large while at some other points it is very small or zero.

**Coherent Source:** The two sources of light, whose frequencies are same and the phase difference between the waves emitted by which remains constant with respect to time are defined as coherent sources.

**Diffraction:** The phenomenon of bending of light waves around the sharp edges of opaque obstacles or aperture and their encroachment in the geometrical shadow of obstacle or aperture is defined as diffraction of light.

**Necessary Conditions of Diffraction of Waves**

The size of the obstacle (a) must be of the order of the wavelength of the waves ($\lambda$).

## Example of Diffraction

* When an intense source of light is viewed with the partially opened eye, colours are observed in the light.
* Sound produced in one room can be heard in the nearby room.
* Appearance of a shining circle around the section of sun just before sun rise.
* Coloured spectrum is observed if a light source at far distance is seen through a thin cloth.

**Polarisation:** The phenomenon of restricting the vibration of light (electric vector) in a particular direction perpendicular to the direction of propagation of wave is called polarisation of light.

## MODERN AND SPACE PHYSICS

## MODERN PHYSICS

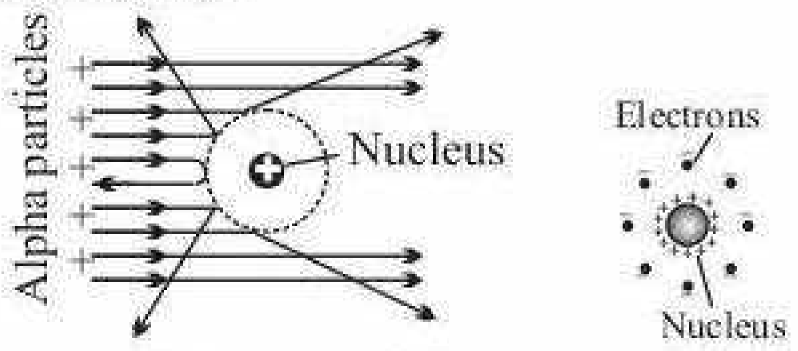
Since the primitive days it was assumed that every matter is the composition of small particles but there was no experimental evidence at that time regarding it. In 1803 Dalton asserted and propounded that every matter around us is made of small particles and these are said to be atoms. Dalton also speculated that the atom is the basic constituent of all matters and cannot be divided by any physical or chemical means. But later atom was also divided into electron, proton and neutron and these are called fundamental (elementary) particles. Of lately these are also assumed to made from quarks. Some more micro particles also appeared along with the research and development activities of Atomic and Nuclear Physics which have been kept in the class of elementary particles and at present there are nearly 30 elementary particles.

## RUTHERFORD'S ATOMIC MODEL

Rutherford suggested that in an atom the entire positive charge and nearly all of its mass are concentrated at the centre of the atom in a small volume known as the nucleus of the atom. The electrons revolve around the nucleus in the planetary orbits at a larger distance compared with the size of the nucleus. The orbital motion was assumed because without it the electrons will fall into the nucleus under the electrostatic attraction and the atom will collapse.

This model was in fact based upon the results of α-particles scattering experiment.

When a beam of α - particles was passed through a thin gold foil, it was found that




- Most of the α - particles went straight through the gold foil and produced flashes on the screen as if there were nothing inside gold foil. Thus the atom is hollow.
- Few particles collided with the atoms of the foil which have scattered or deflected through considerable large angles. Few particles even turned back towards source itself.
- The entire positive charge and almost whole mass of the atom is concentrated in small centre called a nucleus.
- The electrons could not deflected the path of a α - particles i.e. electrons are very light.
- Electrons revolve round the nucleus in circular orbits.

### Atoms and Elementary Particles

Radius of atom = $10^{-10}$ m

Radius of nucleus of an atom = $10^{-14}$ m (approx.)

Mass of electron, $m_e = 9.1 \times 10^{-31}$ kg

Mass of proton, $m_p = 1.0073$ a.m.u $= 1.6726 \times 10^{-27}$ kg

Mass of neutron, $m_n = 1.00866$ a.m.u $= 1.6749 \times 10^{-27}$ kg

Mass number, A = total number of nucleons (neutrons + protons)

Atomic number, Z = number of protons = number of electrons

**Isotopes:** of an element are the atoms of the element which have the same atomic number but different atomic mass numbers.

**Isobars:** are the atoms of different elements which have the same atomic mass number but different atomic numbers.

**Isotones:** are the nuclides which contain the same number of neutrons.

**Isomers:** having same mass number, same atomic number but different radioactive properties.

Rest mass of nucleus is less than sum of rest masses of constituent nucleons, the difference is called **mass defect**.

$$\Delta M = [Zm_P + (A - Z)\, m_n] - m_N$$

**Einstein's mass energy equivalence ($E = m_0c^2$):** In nuclear physics, the mass of the fundamental (elementary) particles is generally expressed in terms of the unified mass unit (u), defined as one twelfth (1/12th) of the mass of the normal carbon atom ($_6C^{12}$)

Also $1\mu = 1.67 \times 10^{-27}$ kg

The energy of a particle/wave is expressed in terms of electron volt (ev) which is energy acquired by an electron falling through a potential difference of one volt.

$$1 \text{ a.m.u} \equiv 931.5 \text{ Me.V, where } 1 \text{ eV} = 1.6 \times 10^{-19} \text{ J.}$$

**Binding energy** of a nucleus is the energy with which nucleons are bound in the nucleus. It is measured by the work required to be done to separate the nucleons an infinite distance apart from the nucleus, so that they may not interact with one another.

Total $BE = \left[Zm_P + (A-Z)m_n - m_N\right] C^2$

where Z = No. of photon, A – Z = No. of neutrons

and $m_N$ = mass of nucleus.

### Nuclear Forces

The force acting inside the nucleus or acting between nucleons i.e. proton and neutron in called nuclear force. The properties of nuclear force are as follows.

- Nuclear forces are the strongest forces in nature.
- It is a very short range attractive force.
- It is non-central, non-conservative force.
- It is neither gravitational nor electrostatic force. It is independent of charge.
- It is 100 times that of electrostatic force and $10^{38}$ times that of gravitational force.

According to Yukawa, the nuclear force acts between the nucleons due to continuous exchange of meson particles.

## NUCLEAR REACTIONS

### Nuclear Fission : (By otto hans and F strassmann)

Nuclear fission is the disintegration of a heavy nucleus (A > 200) upon bombardment by a projectile, such that the heavy nucleus splits up into two or more segments of comparable masses with an enormous release of energy.

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{141}_{53}Ba + ^{92}_{36}Kr + 3\left(^{1}_{0}n\right) + 200\text{MeV}$$

The most of the energy released is by the mode of kinetic energy of fission segment.

### Uncontrolled Chain Reaction

It is the principle of atom bomb (destructive) the number of fission in this case goes on increasing at a tremendous rate leading to the creation of a huge controlled chain reaction (constructive use) amount of energy in a very small time.

The number of fissions in this case is maintained constant. Nuclear reactor has been devised for this purpose. The main parts are

(a) **Nuclear fuel:** ($U^{233}$, $U^{235}$, $Pu^{239}$)

(b) **Moderator:** Graphite, heavy water ($D_2O$). To slow down the neutrons.

(c) **Control rods:** (Cadmium, boron) To absorb excess neutrons

(d) **Coolant:** (water etc) To remove the heat produced in the core to heat exchanger for production of electricity.

The reaction of controlled chain reactor is also called critical reaction.

## Nuclear Fusion

Nuclear fusion is the fusion of two or more light nuclei (A < 20) to form a heavy nuclei with a release of huge amount of energy. For a nuclear fusion to take place very high temperature is required to overcome the coulombic repulsive forces acting between the nuclei.

The nuclear fusion reaction, which is the source of the energy of sun\ are proton -proton cycle

$${}_1^1H + {}_1^1H \longrightarrow {}_1^2H + {}_1^0e + \nu + 0.42Mev$$

$${}_1^2H + {}_1^1H \longrightarrow {}_2^3He + \gamma + 5.5MeV$$

$${}_2^3He + {}_2^3He \longrightarrow {}_2^4He + {}_1^1H + {}_1^1H + 12.8MeV$$

$$4\,{}_1^1H \longrightarrow {}_2^4He + 2\,{}_1^0e + 2\nu + 2\gamma + 24.6\text{ MeV}$$

- Stars with mass 0.4 to 2.5 solar mass produce energy by carbon - nitrogen cycle. Stars with lower masses produce energy by proton-proton cycle.

## RADIATION HAZARDS

The γ-radiation are highly energetic and cause pathological and genetic damage.

## RADIOACTIVITY

It is the spontaneous disintegration of the heavy nucleus of an atom (it occurs without external provocation). There are three main type of radioactive radiation

(i) α-rays (i.e. Helium nuclei)
(ii) β-rays (i.e. electron or positron)
(iii) γ-rays (photons)

It is a process by which a unstable nuclei achieves stability & this process is not affected by

(i) Chemical Combination
(ii) By changing physical environment other than nuclear bombardment.

**Photon** is a packet of energy emitted from a source of radiation. Photons are carrier particle of electromagnetic interaction. Photons travel in straight lines with speed of light.

**Photo electric effect :** The phenomenon of emission of electrons from the surface of metal when light of suitable frequency falls on it is called photo electric effect.

## Einstein's Photoelectric Equation

Some part of incident energy equal to work function is used to remove an electron from metal and remaining is given to electron as its kinetic energy.

**X-rays** are produced by bombarding high speed electrons on a target of high atomic weight and high melting point.

## Properties of X-Ray

- X-ray always travel with the velocity of light in straight line because X-rays are e.m. waves
- X-ray is electromagnetic radiation it show particle and wave both nature.
- In reflection, diffraction, interference, refraction X-ray shows wave nature while in photoelectric effect it shows particle nature.
- There is no charge on X-ray thus these are not deflected by electric and magnetic field
- X-ray are invisible.
- X-ray affect the photographic plate.
- When X-ray incident on the surface of substance it exert force and pressure and transfer energy and momentum

## CT Scan (Computed Tomography Scan)

It is a medical imaging method employing tomography. This technique is used to diagnostic studies of internal bodily structures such as tumours. In this method, a number of X-rays beams and set of X-rays detectors around the patient and take X-rays images are taken around a single axis of rotation of the inside of a body part and then a three-dimensional image is obtained.

## Magnetic Resonance Imaging (MRI)

It is a medical test used by doctors to diagnose and treat diseases that cannot be accurately diagnosed by X-rays, ultrasound or CT scanning.

In MRI, a powerful magnetic field and radio frequency pulses are used and a detailed picture of organs such as heart, kidney, liver, pancreas, etc are obtained on a computer screen. This image can be printed or copied on a Compact Disc (CD).

## De Broglie Hypothesis

De Broglie imagined that as light possess both wave and particle nature, similarly matter must also posses both nature, particle as well as wave.

**De Broglie wavelength associated with moving particles**

The wave length known as de Broglie wavelength associated with the particles is

## CRYSTALLINE AND AMORPHOUS SOLID

All solids are made up of atoms and molecules but due to different internal arrangement of the molecules inside them, they are divided into two classes (a) crystalline and (b) amorphous solids.

**Properties of crystalline solid**

(i) The atoms & molecules are arranged in a definite order.
(ii) Crystalline solids are bounded by flat surfaces.
(iii) They possess uniform chemical composition.
(iv) They have sharp melting point.

**Properties of Amorphous solids**

(i) The atoms & molecules are arranged in an irregular manner.
(ii) These are isotric, i.e. they have same physical properties in all direction.
(iii) These do not have a sharp melting point.

**Crystal lattice:** It is defined as the infinite array of atoms and molecules in space (three dimensions) such that at every point, an atom or the molecule has got the identical surroundings.

A **unit cell** is the smallest geometrical unit in three dimensions, the repetition of which will give the entire crystal. The crystalline solid is said to be consisting of a large number of unit cells, each one in contact with immediate neighbours.

(i) For simple cubic(sc)crystal, the total number of atoms per unit cell = 1

(ii) The total number of atoms in body centered cubic (bcc) crystal = 2

(iii) The total number of atoms in face centered cubic (fcc) cell = 4.

**Coordination Number:** The number of nearest neighbours of a given atom in the crystal is called the coordination number.

(i) Coordination no. of scc = 6

(ii) Coordination no. of bcc = 8

(iii) Coordination no. of fcc = 12

**Energy bands:** The electrons in an isolated atom have well defined energy levels. The collection of very closely spaced energy levels is called an energy band.

**Valence band:** It is the range of energy states/levels which one completely filled with electrons that is equal to number of electrons allowed by Pauli's exclusion principle.

**Conduction band:** This band is lying above the valence band and it corresponds to energy states in which number of electrons is less than the maximum number of electrons (as allowed by Pauli's exclusion principle).

**Forbidden gap:** The minimum energy required by an electrons to jump from valence band to conduction band is equal to the magnitude of the energy of the forbidden energy gap.

## Electronics

It is a branch of engineering & applied physics which deals with the design & application of instruments.

**Conductor:** A conductor such as sodium, has a partially filled band (in sodium, the upper most band 3S is half filled). In these substance, electrons are free to move by applying an electric field, because un-occupied states are available in upper most band half states are empty or un-occupied. Therefore these electrons can contribute to electrical and thermal conductivity.

**Insulators:** In these substance (such as diamond), the upper most level is completely filled i.e., no unoccupied state is available for electron to move. The nearest unoccupied states are in next band (called C.B), but this is separated from filled band (called V.B) by an energy gap of about 6eV. Hence electron in diamond refuses to carry an electric current.

## SEMICONDUCTOR

A semiconductor is a solid material whose electrical resistivity is higher than that of a conductor and lower than that of an insulator. Typical values of the resistivity of a semiconductor lies between $10^{-12}$ to 1 ohm - meter at room temperature.

The electrical resistance of a semiconductor decreases with increase in temperature over a particular temperature - range which is the specific characteristic of a semiconductor.

A semiconductor, has a completely filled valence band i.e., it resembles an insulator at zero temperature. However, the gap between this filled valence band & next band (C.B) is small, about 1eV or less. Hence electrons can easily make the transitions from one band to another at room temperature & then carry an electric current (Silicon, Germanium are semiconductors). There are two types of semiconductor.

(i) **Intrinsic Semiconductor:** These semiconductors are pure materials in which the thermal vibrations of the lattice have liberated charge carries (i.e. electron & holes). In intrinsic semiconductor, the number of electrons are equal to the number of holes.

(ii) **Extrinsic Semiconductor:** They are impure semiconductors in which minutes traces of impurity introduces mobile charge carries [Which may be +ve (holes) or –ve (electrons)]. In addition to those liberated by thermal vibration. Again there are two types of Extrinsic semiconductors.

(a) **N-type semiconductor:** When we add a pentavalent impurity in intrinsic semiconductor, then we obtain N-type semi conductors. The pentavalent impurity substances are P, As & Sb. In N-type semi conductor, the electrons are majority carriers & holes are minority carriers.

(b) **P-type Semi Conductor:** When we add a trivalent impurity in intrinsic semiconductor (such as B, Al, In), we obtain P-type semiconductors. In P-type semiconductor, the holes are majority carriers & electrons are minority carriers.

**Principle of the P-N junction diode:** If we join a piece of N-type to a piece of P-type by appropriate method, then we obtain P-N junction diode. It is clear that P-type has more hole concentration. But less concentration of electron than N-type semiconductor.

**Forward bias:** When P of the PN junction is connected to the +ve terminal of a battery and N to -ve terminal, conduction takes place.

**Reverse bias:** When P of the PN junction is connected to the -ve terminal of a battery terminal and N to the +ve., there is no conduction.

## LASER

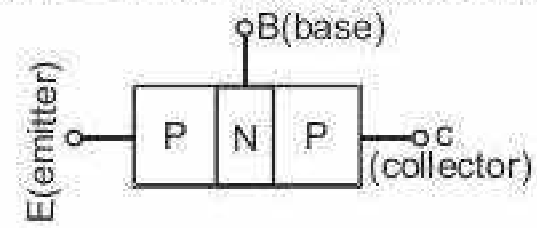
LASER is an acronym of Light Amplification by Stimulated Emission of Radiation. It is an optical device, which produces an intensive beam of highly coherent, monochromatic light. It can travel over great distance without being spread.

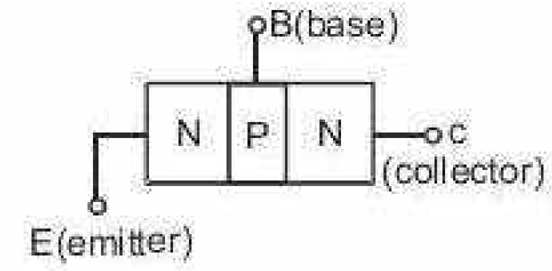
The first working laser was a **Ruby Laser** made from **Ruby**.

**Rectifiers** Junction diode (p-n junction) can be used to convert the a.c. current to d.c. current. The process of conversion from a.c. to d.c. is called rectification.

PN junction diode can be used as a half wave or full wave rectifier.

**Transistors** are three terminal (solid state) devices just like triode. It can be assumed to consist of two back to back P-N junctions. In practice a junction transistor (P-N-P) consists of silicon (or germanium) bar crystal in which a layer of N-type silicon (or Ge) is sandwiched between two layers of P-type silicon & we get P-N-P transistor. Alternatively it may consist of a layer of P-type between two layers of N-type material & we get a N-P-N transistor as shown in fig.



## Transistor as an Amplifier

The process of increasing the amplitude of input signal without distorting its wave shape and without changing its frequency is known as amplification.

A device which increases the amplitude of the input signal is called amplifier.

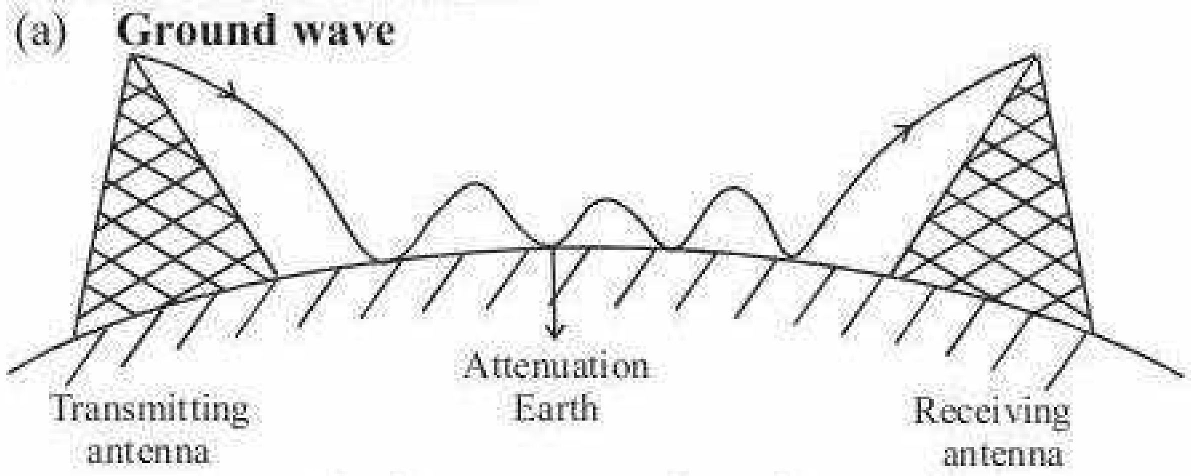
## Transistor as an Oscillator

Oscillator is device which delivers a.c. output wave form of desired frequency from d.c. power even without input signal excitation. A transistor can be used as an oscillator. The frequency of oscillation is given by $f = \frac{1}{2\pi\sqrt{LC}}$

## FACTORS INFLUENCING ELECTROMAGNETIC WAVES

**Propagation of Electromagnetic waves :** Several factors influence their propagation.

(a) **Ground wave**




**Surface propagation of ground wave**

**Antenna size** ~ λ /4.

At longer wavelength (high frequency) antennas have large size and located near ground Surface wave glides over the earths surface and is attenuated due to loss of energy by absorption (by earth). The maximum range of coverage depends on transmitted power and frequency (less than few MHz)

(b) **Sky wave**

**Frequency range :** few MHz to 30 - 40 MHz.

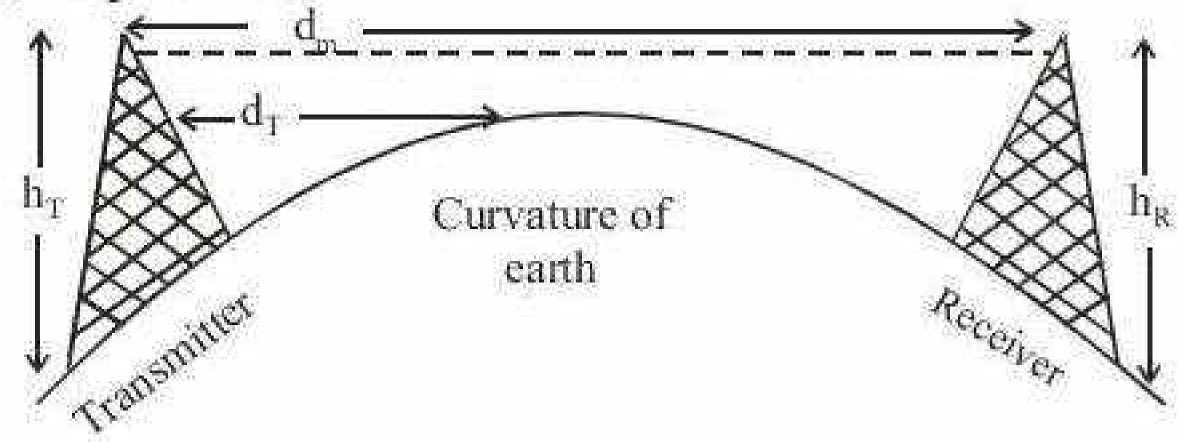
**Used for** - long distance communication of radio waves

**Means** - ionospheric reflection.

**Phenomenon** - similar to total internal reflection.

There are various layers of the ionosphere and their degree of ionisation and densities are different.

(c) **Space Wave**




**Line of sight communication by space waves**

Space waves are used for line of sight communication as well as satellite communication. Frequency > 40 MHz, communication is by space waves. Antennas are smaller, placed at heights. Direct waves get blocked due to curvature of earth, so receiving antenna must be placed high enough to intercept line of sight waves.

If $h_T$ = height of transmitting antenna.

$h_R$ = height of receiving antenna

$d_T$ = distance of horizon

R = radius of earth (6400 km)

$d_M$ = maximum line of sight distance, then

$$d_M = \sqrt{2Rh_T} + \sqrt{2Rh_R}$$

and $d_T = \sqrt{2Rh_T}$

## SATELLITE COMMUNICATION

A communication satellite receives signals from an earth station, amplifies and returns it back to earth at a different frequency to avoid interference.

**Remote sensing :** It is a technique used to collect information about a distant objects, area or phenomenon without going in direct contact with it. It is done through satellites. Its orbits is called Sun-synchronous orbit.

**Uses of remote sensing :**

(i) For ground water survey

(ii) To measure surface temperature

(iii) To prepare waste land maps.

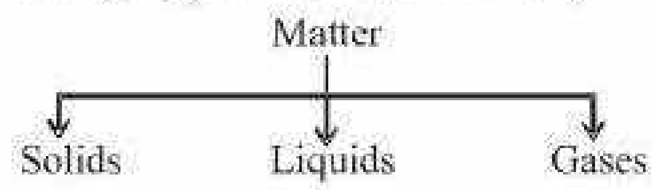
# CHEMISTRY

## MATTER

Anything that occupies space and have mass is known as **'matter'**.

### Classification of Matter

Based on state (Physical Classification)




## STATES OF MATTER

Matter is anything that has mass and occupy space. Matter is also related to light and electromagnetic radiation. Up to 1995 scientists have identified five states of matter. These five main states of matter are solids, liquids, gases, plasmas and Bose-Einstein condensates. These all are different states of matter.

### The Solid State

These are characterized by incompressibility, rigidy and mechanical strength. It has a definite shape and volume. It is rigid and cannot be expressed. It does not diffuse because interamolecular force of attraction is very strong. It usually changes into liquid state by heating

### Classification of Solids

Solids are classified into two groups based on the arrangement of constituent practicles.

(a) **Crystalline solids**

(b) **Amorphous solids**



### Table : Distinction between Crystalline and Amorphous Solids

| | Property | Crystalline solids | Amorphous solids |
|---|---|---|---|
| 1 | Shape | They have a definite and regular geometrical form. | They do not have definite geometrical shape. |
| 2 | M.P. | They have a sharp (definite) melting point. | They melt over a wide range of temperatures. |
| 3 | Compressibility | They are rigid and incompressible. | They too are usually rigid and cannot be compressed to any appreciable extent. However, graphite is soft because of its unusual structure. |
| 4 | Cutting with sharp edged tool | They give clean cleavage, i.e., they break into two pieces with plane surfaces. | They give irregular cleavage, i.e., they break into two pieces with irregular surfaces. |
| 5 | Heat and fusion | They have a definite heat of fusion. | They do not have a definite heat of fusion. |

### The liquid state

The liquid state is characterised as having fluidity, low compressibility and no definite shape. Liquids take the shape of container in which they are stored.

**Properties of liquids**

Liquids have no definite shape, and definite volume. Liquids have much higher density than gases but less than solids. Liquids diffuse like gases but the diffusion is much slower. and are compressible to appropriate extent. Liquids exhibit vapour pressure.

**The gaseous state**

The gaseous state is characterised as having fluidity, high compressibility, no definite boundaries, no definite volume and no definite shape. A gas has no definite volume or shape because its particles are very far apart.

**Properties of gases**

Molecules are sufficiently apart from one another. Force of attraction between gas molecules are almost negligible. Gases possess high compressibility and thermal expansion. Gases neither have definite shapes nor definite volumesand generally have low densities.

**Plasma :** Plasmas are a lot like gases, but the atoms are different because they are made up of free electrons and ions of the element. example of plasma is a neon sign. Just like a fluorescent light, neon signs are glass tubes filled with gas. When the light is turned on, the electricity flows through the tube. The electricity charges the gas, possibly neon, and creates plasma inside of the tube. The plasma glows a special color depending on what kind of gas is present inside the plasma.

### Bose-Einstein Condensates :

Condensation happens when several gas molecules come together and form a liquid. It all happens because of a loss of energy. Gases are really excited atoms. When they lose energy, they slow down and begin to collect. They can collect into one drop. Water condenses on the lid of your pot when you boil water. It cools on the metal and becomes a liquid again. You would then have a condensate.

In 1995, two scientists, Cornell and Weiman, finally created this new state of matter. Two other scientists, Satyendra Bose and Albert Einstein, had predicted it in the 1920.

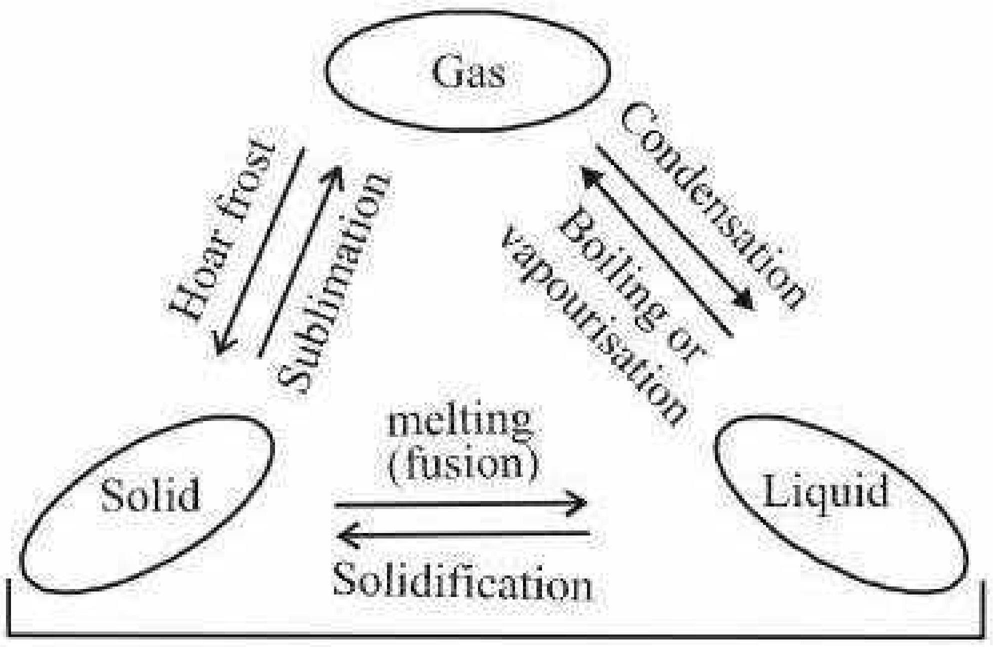
## INTER-CONVERSION BETWEEN STATES OF MATTER

We know from our observation that water can exist in all the three states (i.e. solid, liquid and gas) of matter e.g.

Solid → ice
Liquid → liquid water
Gas → steam or water vapour

The different changes occurring in state of matter by absorption or evolution of heat can be diagrammatically represented as follows :

Melting and melting point




## Evaporation

The phenomenon of change of a liquid into gas at any temperature below its boiling point is called evaporation. Evaporation is a surface phenomenon. The particles of a liquid present on the surface gain energy and leave the surface.

## Condensation

It is the process whereby a gas changes into a liquid. This change in state occurs when a gas is cooled. During the process of condensation heat is evolved.

## 5. Sublimation:

This process is used to separate a mixture containing two components, one of which can form a sublimate i.e., direct change of solid to vapour state on heating, while the other do not.

## 1. Altering the Temperature of Matter

**(a) Interconversion of solid into liquid & vice versa:**

The solids can be converted into liquids by heating them. Similarly, liquids can be cooled to form solids.

For e.g. : Ice at 0°C changes into water at 0°C, when heat energy is supplied to it.

The water at 0°C changes into ice at 0°C on freezing.

**(i) Melting or fusion :**

The process due to which a solid changes into liquid state by absorbing heat energy is called melting or fusion. The constant temperature at which a solid changes into liquid state at atmospheric pressure by absorbing heat energy is called melting point.

**(ii) Freezing or solidification :**

The process due to which a liquid changes into solid state by giving heat energy is called freezing or solidification. The constant temperature at which liquid changes into a solid state by giving out heat energy is called freezing point.

## Latent Heat of Fusion :

The amount of heat energy that is required to change 1 kg of solid into liquid at atmospheric pressure at its melting point is known as the latent heat of fusion. Latent heat of fusion of ice = $3.34 \times 105$ J/kg.

**(b) Interconversion of liquid into gaseous state & vice versa:**

Liquids can be converted into gases by heating them. Similarly, gases can be converted into liquids by cooling them.

**(i) Boiling or vaporisation:**

The process due to which a liquid changes into gaseous state by absorbing heat energy is called boiling. The constant temperature at which a liquid rapidly changes into gaseous state by absorbing heat energy at atmospheric pressure is called boiling point.

**(ii) Condensation or liquefaction**

The process due to which a gas changes into liquid state by giving out heat energy is called condensation. The constant temperature at which a gas changes into liquid state by giving out heat energy at atmospheric pressure.

## Latent heat of vaporisation :

The amount of heat which is required to convert 1 kg of the liquid (at its boiling point) to vapour or gas without any change in temperature. Latent heat of vaporisation of water = $22.5 \times 105$ J/kg.

**(c) Direct Interconversion of solid into gaseous state & vice versa : Sublimation**

Certain substances when heated, pass directly from the solid state to vapour state without being converted into liquid. The vapours when cooled give back the solid substance. This phenomenon is known as sublimation and the substance is called sublimate.

## 2. By Altering Pressure

The difference in various states of matter is due to the difference in intermolecular spaces between their particles. So when a gas is compressed the intermolecular space between its particles get decreases & ultimately it will convert into liquid. So high pressure & low temperature can liquify gases.

For eg : Carbon dioxide (CO2) is gas under normal conditions of temperature and pressure. It can be liquefied by compressing it to a pressure 70 times more than atmospheric pressure.

## PURE SUBSTANCE

A pure substance is one that has a uniform composition and always have the same texture, colour, taste at a given temperature and pressure. A pure substance is homogeneous in nature and it has definite set of properties. It is not possible to change the composition of a pure substance by physical methods.

## Elements

An element is a substance which cannot be split up into two or more simpler substances by the usual chemical methods of applying heat, light or electric energy. There are 115 elements known at present, out of which 92 elements occur in nature, while the remaining 23 elements have been prepared artifically.

## Compounds

"A chemical compound is a pure substance formed from chemical combination of two or more elements."

## Mixtures

Two or more substances (either elements or compounds) can be mixed together in any proportion and the resultant substances so obtained are called mixtures (impure substance).

## Types of mixtures

Depending upon the nature of the components that forms the mixture we can have different types of mixtures.

**(i)** **Homogeneous mixture :** It is a mixture that has the same composition throughout. e.g. a solution of sugar in water.

**(ii)** **Heterogeneous mixture :** In such a mixture the particles of each component of the mixture remain separate and can be observed as individual grains under a microscope. e.g. mixture of grains and sand.

## Classification of Homogeneous Mixtures

Homogeneous mixtures can be further classified as follows:

**(i)** **Solid-solid mixture: Examples of such a mixture are brass, bronze, etc.**
A homogeneous mixture of two or more metals (or non-metals) is called an alloy. Brass and Bronze are alloys. Alloys find a wide range of applications in construction and various other types of industries.

**(ii)** **Solid-liquid mixture:** Examples of such a mixture are
(a) aqueous solution of salt or sugar
(b) solution of iodine (I2) in carbon tetra chloride (CCl4).

**(iii)** **Liquid-liquid mixture:** Examples of this type of mixture are
(a) rectified spirit (a mixture of gasoline and alcohol)
(b) a mixture of toluene and benzene.

## Classification of Heterogenous Mixture :

**(i)** Solid-gas mixture: For example, Hydrogen gas adsorbed on palladium.

**(ii)** Solid-solid mixture: For example
(a) gun powder
(b) mixture of sulphur and iron filling

**(iii)** Solid-liquid mixture:: Suspension of sulphur in water.

**(iv)** Liquid-liquid mixture: : Benzene in water (i.e. immiscible liquids).

## METHODS OF SEPARATION OF THE CONSTITUENTS OF MIXTURES

based upon the particular property (e.g., melting point, boiling point,
solubility, etc,) in which the constituents of the mixture differ, it can be separated into its constituents. Various techniques employed for the separation of mixtures are discussed below:

### 1. Decantation or Sedimentation

Sedimentation is the process by which insoluble heavy particles in a liquid, are allowed to settle down. Decantation is the process by which, a clear liquid obtained after sedimentation, is transferred into another container, without disturbing the settled particles.

### 2. Filteration

Infilteration the mixture is shaken with the solvent and then filtered. The soluble component passes through the filter paper as filtrate and the insoluble solid component is retained on the filter paper called residue.

### 3. Centrifugation

Centrifugation is the process of separation of insoluble materials from a liquid where normal filtration does not work well. The centrifugation is based on the size, shape, and density of the particles. The principle is that the denser particles are forced to the bottom and the lighter particles stay at the top when spun rapidly.

### 4. Gravity separation

This technique is used for the separation of a mixture having components differing in densities. e.g., separation of gold particles from rocky substances.

### 5. Magnetic separation

This method is applied to separate a mixture containing one magnetic component and the other non- magnetic components. When the mixture passes over the rollers, non-magnetic substance falls vertically down whereas the magnetic substance falls a little away. e.g., Separation of iron from sand Iron fillings from sulphur.

### 6. Separating funnel

This method is applicable to recover one of the components from aqueous solution of the mixture by extracting the mixture with a suitable solvent. The solvent should be immiscible with water but should dissolve one of the components of the mixture.

### 7. Crystallisation or Recrystallisation

Crystals are the purest form of a substance having definite geometrical shapes. The process by which an impure compound is converted into its crystals is known as crystallisation.

### 8. Distillation

This technique is commonly applied for the separation of a mixture of liquid components having a large difference in boiling point. The lower boiling point component vapourises first and its vapours are condensed by using water condenser and collected e.g.,
(i) Separation of benzene (B.P. 353 K) and toluene (B.P. 384 K)
(ii) Separation of chloro benzene and bromobenzene.

### 9. Fractional distillation

This method of distillation is applied for the separation of the mixture in which the components have a small difference in boiling points. For example,
(i) Separation of fractions like gasoline, kerosene, diesel, lubricating oil, etc, from crude petroleum.
(ii) Separation of a mixture of methanol (B.P. 338 K) and acetone (B.P. 329 K).

Fractional distillation method is used when b,p's of the two liquids of the mixture are very close to one another i.e. differ by 10 k.

### 10. Vacuum distillation or distillation Under reduced pressure

This technique of distillation is applied to liquids which decompose on heating to their boiling point. At reduced pressure the boiling point of liquid is also reduced and thus liquid distils at low temperature. For example, glycerol is distilled at reduced pressure as it decomposes on heating to its boiling point.

## 11. Steam distillation

This is a convenient method for the separation and purification of organic compounds (solid or liquid) from non-volatile organic or inorganic impurities. This method is applicable to only those compounds which are volatile in steam, insoluble in water, possess a vapour pressure of about 10 – 15 mm of Hg at 373 K and contain non-volatile impurities. Some of the compounds which can be purified by this process are essential oils, nitrobenzene, chlorobenzene, etc.

## 12. Chromatography

Chromatography is based on the difference in adsorption of different substances on the surface of a solid medium. The technique of separating the components of a mixture in which separation is achieved by the differential movement of individual components through a stationary phase under the influence of a mobile phase. The name chromatography means colour writing, since in its original applications by Michael Tswett in 1906 it involved separation of mixtures containing coloured substances which when separated, formed distinct coloured rings.

## Gas Laws

By changing the pressure or temperature of any gas its volume also changes. The nature of the change is almost same for all gases. Therefore many scientists studied them in detail and gave some laws which are known as Gas Laws.

## Boyle's Law

The volume of the definite amount of any gas at constant temperature is inversely proportional to the pressure of the gas. Boyle's law states that, "at constant temperature, the volume of a sample of a gas varies inversely with the pressure".

$\therefore \quad P \propto \frac{1}{V}$ (when temperature and number of moles are kept constant)

or $\quad P = \frac{k}{V}$ or $PV = k$ (constant)

or $\quad P_1V_1 = P_2V_2$

## Gay-Lussac Law

It relates the pressure and absolute temperature of a given mass of a gas at constant volume. P µ T (if volume and number of moles are kept constant)

At constant volume, the pressure of a given amount of a gas is directly proportional to its absolute temperature.

At constant volume $\frac{P}{T}$ = constant or $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

## Avogadro's Law

In 1812, Amadeo Avogadro stated that samples of different gases which contain the same number of molecules (any complexity, size, shape ) occupy the same volume at the same temperature and pressure. It follows from Avogadro's hypothesis that V µ n (T and P are constant).

$$V \propto n \text{ (T, P constant)} \Rightarrow \frac{V_1}{n_1} = \frac{V_2}{n_2}$$

## Graham's Law of Diffusion

Graham in 1883 propounded a comprehensive theory regarding the rate of diffusion of gases and it is called Graham's Law of diffusion stated as below :

According to Graham, the rate of diffusion (or effusion) of a gas at constant pressure and temperature is inversely proportional to the square root of its molecular mass.

$$r \propto \sqrt{\frac{1}{M}}, \text{ or } \quad \therefore \quad \frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}},$$

Since, molecular mass of gas = 2 × vapour density, $\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}}$, at constant P and T

## Dalton's Law of Partial Pressures

The total pressures of a mixture of gases, which do not react with each other, filled in a vessel is equal to the sum of partial pressures of the mixed gases.

$$P = P_1 + P_2 + \ldots\ldots\ldots\ldots + P_n$$

where P1, P2 ... are the partial pressures of individual gases

## ATOMS AND ITS STRUCTURE

Around 400 BC, the greek philosopher Democrilus suggested that all mater is composed of tiny, discrete, indivisible particles. he named it "atoms"

- The smallest unit of element is known as atoms.
- It is composed of electron, proton and neutron.

## The Avogadro's Law

This law states that "equal volumes of all gases under similar conditions of temperature and pressure contain equal number of molecules".

## Dalton's atomic Theory

The first useful theory about atom was put forward by John Dalton in 1808 AD.

The important postulates of Dalton's atomic theory are:

**(i)** Matter is made up of very small particles called atoms.
**(ii)** All atoms of an element are chemically alike
**(iii)** Atoms of one element differ from the atoms of other elements in all respects.
**(iv)** Atoms can not be broken down by ordinary chemical means.
**(v)** Atoms of same or different elements combine in simple whole number ratio.
**(vi)** Atoms are neither created nor destroyed.

## Electromagnetic Wave Theory

This theory was put forward by James Clark Maxwell in 1864. The main points of this theory are following

**(i)** The energy is emitted from any source (like the heated rod or the filament of a bulb through which electric current is passed) continuously in the form of radiations (or waves) and is called the radiant energy.

**(ii)** The radiations consist of electric and magnetic fields oscillating perpendicular to each other and both perpendicular to the direction of propagation of the radiation.

**(iii)** The radiations possess wave character and travel with the velocity of light (i.e., nearly 3 × 108 m/sec).

**(iv)** These waves do not require any material medium for propagation. For example, rays from the sun reach us through space which is a non-material medium.

## Planck's quantum theory

In order to explain the phenomenon of photoelectric effect and black body radiations, Max Planck (1900) postulated quantum theory of radiations, which was further extended by Einstein (1905). The main features of Planck's quantum theory are :

(i) The radiant energy is not emitted or absorbed continuously but discontinuously in the form of small packets of energy called quantum. For light the quantum of energy is termed as photon.

The energy associated with each quantum is directly proportional to the frequency of the radiation

i.e., $E \propto V$ or $E = hv$

# ATOMIC MODELS

## Thomson's Model

According to Thomson's model negatively charged particles are embedded in a positively charged sphere. Thomson named negatively charged particles as electrons. The total positive charge of the sphere is equal to the total negative charge of electrons.

## Rutherford's Model of the Atom

Based on his experiments Earnest Ruther ford gave a model of atom in 1911 which is known as Rutherford's atomic model.

where h is called

**Explanation of Rutherford Model**

- Since most of the alpha particles pass straight through the gold foil without any deflection, it shows, there is a lot of empty space in an atom.
- Some of the alpha particles are deflected through small and large angles, which shows that there is a centre of positive charge' in an atom, which repels the positively charged alpha particles and deflects them from the original path.
- Very few alpha particles rebound on hitting the gold foil, which shows that nucleus is very dense and hard which does not allow alpha particles to pass through it. The whole mass of the atom is centered at its nucleus.

## Bohr's Model

The major drawback of Rutherford's model is that why the moving electron, revolving around positively charged nucleus not loses energy continuously and finally falls down in the nucleus?

Keeping the above drawback in mind Neils Bohr; in 1913, suggested that an atom has a nucleus (positively charge tiny sphere) surrounded by electrons. Nucleus contains protons (positively charged particles). The electron revolve around the nucleus in definite circular path called orbits or shells.

Another sub-atomic particle called neutron was discovered in 1932 by Sir James Chadwick. Neutron is a neutral particle (i.e. it is neither positively charged nor negatively charged) and is present in the nucleus of the atom.

## Discovery of electron

In 1879, William Crookes studied the conduction of electricity through gases at low pressure. Gas at 0.01 mm mercury pressure was filled in 60 cm long glass discharge tube and two electrodes were placed, at both ends of discharge tube. High potential difference of the 10,000 volts to 30,000 volts was applied across the electrodes then rays are emitted from cathode and collide with the opposite, wall. They produce illumination of green colour.

Properties of Cathode Rays

From the various experiments carried out by J.J. Thomson (1897) and others, the cathode rays have been found to possess the following properties.

(i) Cathode rays travel in straight line.
(ii) Cathode rays produce mechanical effect.
(iii) Cathode rays are negatively charged particles.
(iv) Cathode rays travel with high speed approaching that of light.
(v) Cathode rays cause fluorescence.
(vi) Cathode rays heat the object on which they fall due to transfer of kinetic energy to the object.
(vii) When cathode rays fall on solids such as copper, X-rays are produced.
(viii) Cathode rays posses ionizing power i.e. they ionize the gas through which they pass.
(ix) The cathode rays affect the photographic plates.
(x) They penetrate through thin metallic sheets.
(xi) The nature of these rays does not depend upon the nature of gas & the cathode material used in discharge tube.

The negatively charged material particles constituting the cathode rays are called electrons.

## Discovery of proton

In 1886 Eugen Goldstein first observed that a cathode ray tube also generates a stream of positively charged particles that moves towards the cathode. These were called canal rays because they were observed occasionally to pass through a channel, or "canal", drilled in the negative electrode.

These positive rays, or positive ions, are created when cathode rays knock electrons from the gaseous atoms in the tube, forming positive ions by processes such as

$$\text{Atom} \longrightarrow \text{Cation}^{+} + e^{-} \text{ or } X \longrightarrow X^{+} + e^{-}$$

These rays were attracted towards the negative plate in the electric field as shown in figure. This means that these rays consist of positively charged particles and were also named positive rays or anode rays.

**Properties of Anode Rays :**

(i) Anode rays travel in straight lines.
(ii) Anode rays are material particles.
(iii) Anode rays are positively charged.
(iv) Anode rays are affected by electric and magnetic field.
(v) Anode rays affect the photographic plate.

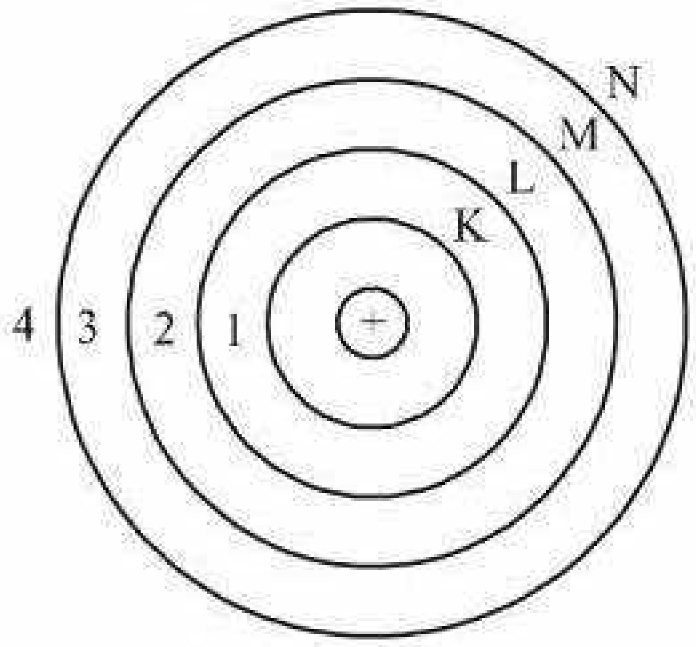
## COMPARISON OF PROPERTIES OF SUBATOMIC PARTICLES

| | Particle | Electron | Proton | Neutron |
|---|---|---|---|---|
| (i) | Symbol | e | p | n |
| (ii) | Nature of charge | negatively charged | positively | neutral (i.e uncharged) |
| (iii) | Charge | $-1.60219\times10^{-19}$C | $1.60219\times10^{-19}$C | no charge |
| (iv) | Charge | –1 | 1 | 0 |
| (v) | mass | | | |
| | (a) amu | (a) 0.0005486 | (a) 1.0073 | (a) 1.00893 |
| | (b) kg | (b) $9.1\times10^{-31}$ | (b) $1.67265\times10^{-27}$ | (b) $1.67493\times10^{-27}$ |

## ARRANGEMENT OF ELECTRONS IN AN ATOM

The orbits are also known as shells or energy levels and are designated as 1,2,3,4 ......or K, L, M, N ..... starting from innermost shell. Fig.

The electrons are arranged in different orbits as follows :




**Orbits in an atom**

**The K-Shell**

The innermost shell was called the K-shell. It can hold, at most, two electrons before it becomes full.

**The L-Shell**

The next shell is referred to as the L-shell, and the electrons in it orbit further away from the nucleus than those in the K-shell. The L-shell (shell 2) can hold a maximum of 8 electrons before it fills up.

**The M-Shell**

Now that the L-shell is full, we have to start filling the next shell out, the M-shell or shell 3, which can hold a maximum of 18 electrons.

**The N-Shell**

The next shell is referred to as the N-shell, and the electrons in its orbit are further away from the nucleus than those in the K-shell. The N-shell can hold a maximum of 32 electrons before it fills up.

In general any shell can accommodate a maximum of 2n2 electrons, where n represents the number of shell (i.e. 1, 2, 3)

The atomic number or Proton number (Z)

It is a number characteristic of a particular element, that represents the number of protons in the nucleus of an atom of that element.

Atomic number (Z) = Number of protons = Number of
of an element esent in an atom electrons present
in an atom

### Mass number (A) or atomic mass

It is the sum of number of protons and neutrons present in the nucleus of an atom. Thus Mass Number (A) = number of protons (p) + number of neutrons (n)

Number of electrons = Number of protons = Z

Number of neutrons = Mass number – Atomic number = A – Z

### Isotopes

Isotopes are atoms of the same element having the same atomic number but different mass number.

Atoms of the same element (i.e. same atomic number and same number of protons) but with different number of neutrons (i.e. different mass number). For example: Two common isotopes of Uranium are Uranium-235 (with 92 protons and 143 neutrons) and Uranium-238 (with 92 protons and 146 neutrons)

### Isobars

Atoms whose atomic numbers are different but mass numbers are same. Such atoms are called isobars. Some important examples of Isobars are Argon 18Ar40, Potassium 19K40 and Calcium 20Ca40 are Isobars.

## QUANTUM NUMBERS

Thus, quantum numbers may be defined as set of numbers which display complete information about size, shape and orientation of the orbital.

### 1. Principal Quantum Number (n)

This is an important quantum number which gives the following information about the electron.

(i) This refer to the average distance of the electron from the nucleus i.e., it relates to the size of the electron cloud.

(ii) It denotes the energy level to which the electron belongs.

### 2. Azimuthal Quantum Number or Angular Momentum Quantum Number (l)

It tells about the number of subshells within a given principal energy shell to which the electrons belong. For a given value of principal quantum number, 'n', the azimuthal quantum number, 'l', may have all integral values from 0 to (n – 1).

### 3. Magnetic Quantum Number (m)

Magnetic quantum number gives the number of permitted orientations of subshells. For example, for a given value of 'l', the possible values of 'm' range from –l through 0 to +l.

### 4. Spin Quantum Number (s)

Spin quantum number accounts for the spinning orientation of the electron. The electron in an orbital can have only two types of spins i.e., in clockwise and anticlockwise direction. Therefore, the spin quantum number can have only two values i.e.,

## PAULI'S EXCLUSION PRINCIPLE

According to this principle "No two electrons in an atom can have the same set of all the four quantum numbers".

## AUFBAU'S PRINCIPLE

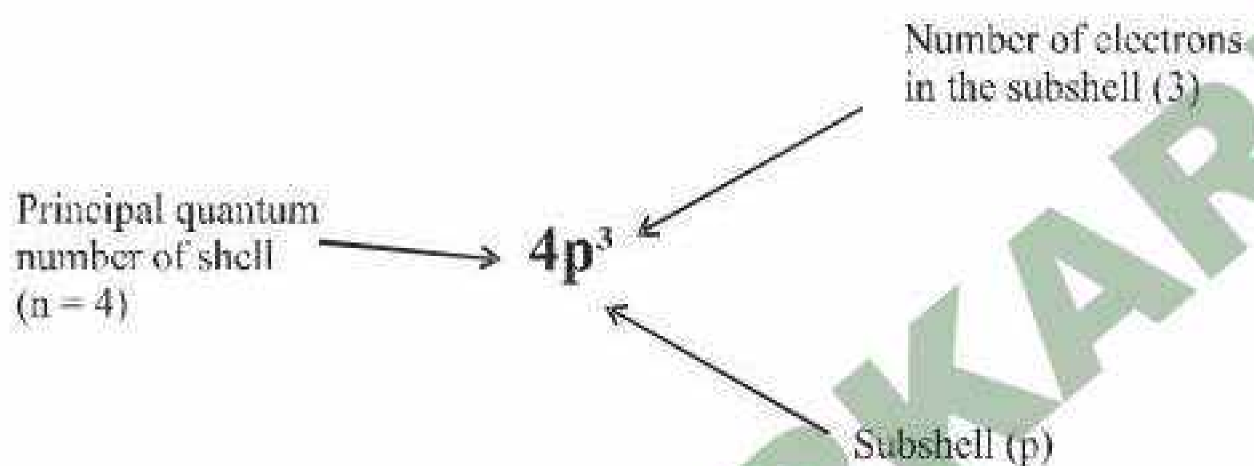
In the ground state of the atoms, the orbitals are filled in order of their increasing energies.

Hund's Rule of Maximum Multiplicity

This rule deals with the filling of electrons into degenerate (equal energy) orbitals of the same sub-shell (p, d and f). According to this rule, Electron pairing in p, d and f orbitals cannot occur until each orbital of a given subshell contains one electron each or is singly occupied.

## ELECTRONIC CONFIGURATION

The assignment of all of the electrons in an atom into specific shells and subshells is known as the element's electronic configuration.




## MOLECULE

The smallest particle of an element or compound which can exist independently in nature is termed as molecule. Molecules are formed by the combination of two or more atoms in a constant ratio. If same type of atoms are present in molecule then it is termed as Homoatomic molecule.

For example : $N_2$ (Nitrogen molecule), $O_2$ (Oxygen molecule), $Cl_2$ (Chlorine molecule). If two or more than two types of atoms are present in any molecule then it is termed as heteroatomic molecule. For example – $H_2O$ (water), $CO_2$ (Carbon dioxide), $H_2O_2$ (Hydrogen peroxide) etc.

Molecular Mass or Molecular Weight

The molecular mass of a substance (element of compound) is the number or times the molecule of the substance is heavier than 1/12th the mass of an atom of carbon-12 isotope. Molecular weight is calculated by adding the atomic weights of all the constituent atoms present in a molecule. For example. Molecular weight of a molecule of hydrogen ($H_2$) = 2 × atomic weight of hydrogen = 2 × 1 = 2 amu

Similarly, molecular weight of some compounds are:

Water ($H_2O$) = 2 × 1 + 1 × 16 = 2 + 16 = 18 amu.

Carbon dioxide ($CO_2$) = 1 × 12 + 2 × 16 = 12 + 32 = 44 amu

Molecular weight is expressed in amu.

Gram Molecular Mass

The molecular mass of a substance when expressed in grams is known as gram-molecular mass or simply gram-mole (g-mole) for the sake of convenience it is expressed simply as mole. Thus one mole (or g-mole) of water weighs 18g (molecular weight of water = 18)

## IONS

The electrically charged particles formed when electrons are added to or removed from a neutral atom are called ions. Neutral atoms are turned into positively charged ions called cations by removing one or more electrons.

Atoms that gain extra electrons become negatively charged ions called anions.

Polyatomic Ions :

Simple ions, such as $Mg^{2+}$ and $N^{3-}$ ions, are formed by adding or subtracting electrons from neutral atoms. Polyatomic ions are electrically charged substances composed of more than one atom. There are only two polyatomic cations that you will commonly encounter. These are $NH^{4+}$ and $H_3O^+$. There are many more polyatomic anions. A few of the more common anions are –

## CHEMICAL FORMULA

The composition of a molecular compound can be represented by a chemical formula. The subscripts in a chemical formula represent the relative numbers of atoms present in the compound. When there is no subscript, as in the case of carbon in $CO_2$, a value of one is assumed. Thus the formula $CO_2$ represents a molecule that contains one carbon atom and two oxygen atoms.

| Compound | Symbol with valencies | Criss-cross | Molecular Formula |
|---|---|---|---|
| Sodium Chloride | $\overset{1}{Na}$ $\overset{1}{Cl}$ | 1 ⤫ 1, Na ↙ ↘ Cl | NaCl |
| Sodium Oxide | $\overset{1}{Na}$ $\overset{2}{O}$ | 1 ⤫ 2, Na ↙ ↘ O | $Na_2O$ |
| Chromium Nitrate | $\overset{3}{Cr}$ $\overset{1}{(NO_3)}$ | 3 ⤫ 1, Cr ↙ ↘ $(NO_3)$ | $Cr(NO_3)_3$ |

## MOLE CONCEPT

In the honour of scientist *Amdio Avogadro* this number is called Avogadro's number. ($6.02 \times 10^{23}$)

In one gram atomic weight of any element 6.02 × 1023 atoms of that element are present. This quantity of the element is known as one mole.

### Mole and Gram Atomic Mass

Since 1 mole of any atomic substance is equal to its gram atomic mass and contains $6.023 \times 10^{23}$ atoms of that element therefore gram atomic mass of an element is defined as the mass of Avogadro number of atoms [i.e., mass of $6.023 \times 10^{23}$ atoms]. For example,

Mass of $6.023 \times 10^{23}$ atoms of hydrogen = 1 g

## Mole and Gram Molecular Mass

One gram molecular mass of any molecular substance is its gram molecular mass and contains $6.023 \times 10^{23}$ molecules of that substance. Therefore, gram molecular mass of any substance is defined as the mass of Avagadro's number of molecules (i.e., mass of $6.023 \times 10^{23}$ molecules) of that substance. For example,

Mass of $6.023 \times 10^{23}$ molecules of oxygen $(O_2) = 32$ g

$$\text{Mass of a single atom} = \frac{\text{Atomic mass (g mole}^{-1})}{6.023 \times 10^{23}\,\text{atom}}$$

$$\text{Mass of a single molecule} = \frac{\text{Molar mass (g mole}^{-1})}{6.023 \times 10^{23}\,\text{molecules}}$$

## Determination of emperical and molecular formulae

**(a) Emperical Formula :**

It expresses the whole number ratio of the atoms of various elements present in one molecule of the compound. For example, the emperical formula of glucose $(C_6H_{12}O_6)$ is $CH_2O$. This shows that C, H and O are present in the simple ratio of 1 : 2 : 1.

$$\text{Atomic ratio} = \frac{\text{Percentage of an element}}{\text{Atomic mass of the same element}}$$

**(b) Molecular Formula :**

It is that formula of the compound which gives the actual number of atoms of various elements in a molecule of that compound. For example, molecular formula of glucose is $C_6H_{12}O_6$.

Molecular formula = $n$ × Emperical formula [where $n$ = 1, 2, 3, ............, etc.]

$$n = \frac{\text{Molecular mass}}{\text{Emperical formula mass}}$$

When n = 1, Molecular Formula = Emperical Formula

The molecular mass of a volatile compound can be determined by Victor Meyer's method (based on the principle that 22. 4L of vapours of a substance at STP have mass equal to gram molecular mass) or by employing the relation

**Molecular mass = 2 × Vapour density.**

## RADIOACTIVITY

The property by virtue of which certain substances spontaneously disintegrate by emitting certain radiations is called radioactivity.

An alpha-particle consists of two protons and two neutrons. Thus it is a positively charged helium nucleus. A Beta -particle is a high speed electron emitted from nucleus of a radioactive atoms. It carries a negative charge. Gamma rays are the high-frequency electromagnetic radiation emitted by radioactive elements. They posses high energy, mass and no electric charge. Gamma rays are able to penetrate through most materials. However, they cannot easily penetrate very dense materials, such as lead.

## Nuclear fission

Nuclear reaction in which a heavy atomic nucleus (such as that of uranium) disintegrates into two nearly equal fragments with release of large amount of energy

## Nuclear fusion

Nuclear reaction in which two light nuclei fuse together to form heavy nucleus with release of large amount of energy, e.g. two deuterium nuclei can fuse together to form a nucleus of helium atom by releasing a large amount of energy. Hydrogen bomb is the result of nuclear fusion.

**Application of Nuclear fission for mankind**

**Nuclear Reactor :** A device or system, in which desired number of neutrons are absorbed and the chain reaction proceeds in a controlled way is called a nuclear reactor. The most common type of fission reactor contains four components nuclear fuel, control rods, a moderator (to slow the neutrons, which are required for fission), and a liquid (usually water) to transfer heat from the reactor to the turbine and generator. The nuclear fuel is primarily U-238, plus about 3 per cent U-235. The control rods are made of a neutron-absorbing material, usually the metal cadmium or boron. One disadvantage of fission power is the generation of radioactive waste products. Radiocarbon dating is used to determine age of dead speciman with $C^{14}$ content.

$$N = N_0\left(\frac{1}{2}\right)$$

where n = total time/t 1/2.

**Uses of radio-active materials**

(i) diagnosis and treatment in field of medicines
(ii) research in laboratories.
(iii) determination of age of materials that were once parts of a living organism. This process is called radio-carbon dating and is used to find age of wood, etc.
(iv) food processing plants where low doses of radioactive radiations are used to kill bacteria on certain food so as to preserve the food.

## METALLURGY, METALS AND THEIR COMPOUNDS

We have already learnt that a pure substance which can neither be broken down into simpler substance nor formed from two or more simpler substances by any known physical or chemical means is called an element. Elements can be roughly divided into metals, non-metals and metalloids.

## Occurrence of metals

The earth crust is a very big source for the metals. Metals occur in nature sometimes free but mostly in combined state. Metals like silver, gold, platinum, etc., occur in free or native state. Most of the metals are found in the form of the compounds in the nature.

**Ores:** Those minerals from which metals can be obtained economically and profitably. Therefore, all ores are minerals, but all minerals are not ores.

Gangue or Matrix: The unwanted rocky, earthy or sandy materials almost always associated with ores as impurities are called gangue or matrix.

The table given here lists some common ores of some metals.

| Sl. No. | Name of the ore | Formula of the ore | Type of ore | Metal obtained from the ore |
|---|---|---|---|---|
| 1 | Bauxite | $Al_2O_3.2H_2O$ | Oxide | Aluminium |
| 2 | Haematite | $Fe_2O_3$ | Oxide | Iron (Fe) |
| 3 | Magnetite | $Fe_3O_4$ | Oxide | Iron (Fe) |
| 4 | Zincite | ZnO | Oxide | Zinc (Zn) |
| 5 | Cuprite | $Cu_2O$ | Oxide | Copper (Cu) |
| 6 | Litharge | PbO | Oxide | Lead (Pb) |
| 7 | Malachite | $CuCO_3.Cu(OH)_2$ | Carbonate | Copper (Cu) |
| 8 | Magnesite | $MgCO_3$ | Carbonate | Magnesium (Mg) |
| 9 | Lime stone | $CaCO_3$ | Carbonate | Calcium (Ca) |
| 10 | Cinnabar | HgS | Sulphide | Mercury (Hg) |
| 11 | Chalcopyrite | $CuFeS_2$ | Sulphide | Copper (Cu) |
| 12 | Zinc blende | ZnS | Sulphide | Zinc (Zn) |
| 13 | Galena | PbS | Sulphide | Lead (Pb) |
| 14 | Common salt | NaCl | Chloride | Sodium (Na) |
| | | | (Halide) | |
| 15 | Fluorspar | $CaF_2$ | Fluoride | Calcium (Ca) |
| | | | (Halide) | |
| 16 | Horn silver | AgCl | Chloride | Silver (Ag) |
| | | | (Halide) | |
| 17 | Chalcocite | $Cu_2S$ | Sulphide | Copper (Cu) |

**Physical Properties of Metals**

(i) They have a metallic lustre (shine).
(ii) They conduct heat and electricity.
(iii) They are ductile (i.e. can be drawn into wires).
(iv) They are malleable (i.e. can be hammered into thin sheets).
(v) They are sonorous (i.e. make a tinkling sound when hit).

Chemical Properties of Metals

(i) Reaction with oxygen : Metals can donate electrons to oxygen molecule, therefore metal form oxides by combining with oxygen.

$$2Mg + O_2 \longrightarrow 2MgO$$

(ii) Reaction with water : On reaction with water metals form their hydroxides with evolution of hydrogen gas. For example

$$2Na + 2H_2O \longrightarrow 2NaOH + H2\uparrow$$

(iii) Reaction with acids : Generally metals react with dilute hydrochloric acid (dil. HCl) to form corresponding chlorides with evolution of hydrogen gas. For example:

$$Mg + 2HCl \longrightarrow MgCl2 + H2\uparrow$$

## METALLURGY

### Concentration

The removal of impurities like soil, sand, stones and useless silicates (Gangue) from the ores is known as concentration.

Physical methods

**(i) Hydraulic washings** (gravity separation) : This process of concentration of ores is based on the fact that ore and gangue particles are having different densities. Heavy ore are separated from lighter gangue particles by washing with a stream (flow) of water. Ores of tin and lead are concentrated by this process.

**(ii) Froth flotation process :** This method is exclusively used for the concentration of sulphide ores like galena (PbS), zinc blende (ZnS) etc. It is based on the different wetting characteristics of the ore and gangue particles with water and oil. The gangue particles are preferentially wetted by water while the ore particles by oil.

**(iii) Magnetic separation :** This process is used for separating magnetic materials from non-magnetic materials. This is used for separating ores like magnetite (Fe3O4), chromite $[Fe(CrO_2)_2]$, etc.

### Chemical methods

**(i) Calcination :** Heating of the carbonate ore to a high temperature in the absence of air is known as calcination. Organic matter and volatile impurities are eliminated and the metal oxide results.

Example : $\underset{\text{(Zinc Carbonate)}}{ZnCO_3} \xrightarrow{\text{heat}} \underset{\text{(Zinc Oxide)}}{ZnO} + CO_2$

**(ii) Roasting:** This process is usually used in case of sulphide ores. The ore is heated in the presence of air at a temperature below its melting point when the metal oxide or metal sulphate is formed.

Example:

$$\underset{\text{(Zinc blende)}}{2\,ZnS} + \underset{\text{(air)}}{3O_2} \xrightarrow{\text{heat}} 2\,ZnO + 2SO_2$$

**(iii) Leaching :** Crude powdered ore is allowed to react with suitable reagent. Ore reacts with added reagent to form soluble complex while impurities remain undissolved. Insoluble impurities are separated by filtration and ore is reprecipated from soluble complex. E.g. → This process is used for concentration of Al, Ag, Au ores etc.

## Reduction to Free Metal

**(i) Smelting :** In this process the metallic oxides are reduced to metals by chemical treatment with reducing agents. The commonly used reducing agents are carbon, and carbon monoxide.

Examples:

$$ZnO + C \longrightarrow Zn + CO$$

(zinc oxide) (carbon monoxide)

$$Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$$

**(ii) Self reduction process :** This process is used for reducing metals having low reactivity. Mercuric oxide (HgO) can be reduced to mercury (Hg) by heating above 300 ºC.

$$2HgO \xrightarrow[300°C]{heat} 2Hg + O2$$

(mercuric oxide)

**(iii) Reduction by aluminium (Gold-schmidt aluminothermic process) :** In this process the metal oxides are thoroughly mixed with Al power and a little $BaO_2$ in a crucible. The reaction is brought about by introducing a lighted Mg ribbon. Since the reaction is exothermic the temperature it reached to about 3000°C. Metals like Cr and Mn can be extracted by this method.

$$Cr_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Cr$$

$$3\,MnO_2 + 4Al \longrightarrow 2Al_2O_3 + 3Mn$$

**(iv) Electrolytic reduction:** Highly electropositive metals (e.g. sodium. potassium, calcium, etc.,) can not be reduced by chemical reducing agents. These are obtained by electrolytic reduction of their fused chlorides.

## Refining

**(i) Liquation :** It is used for metals having low melting point. This method is used to purify readily fusible metal (e.g., Sn, Pb and Bi, etc.,) from infusible impurities.

**(ii) Distillation :** Low boiling point metals like zinc, mercury etc. can be purified by this method. The pure metal distills over while the impurities are left behind.

**(iii) Refining by electrolysis or electrolytic refining :** Large number of metals like copper, silver, gold and zinc are purified by this method. The metal of highest purity are obtained by this method.

Various steps involved in this method are :

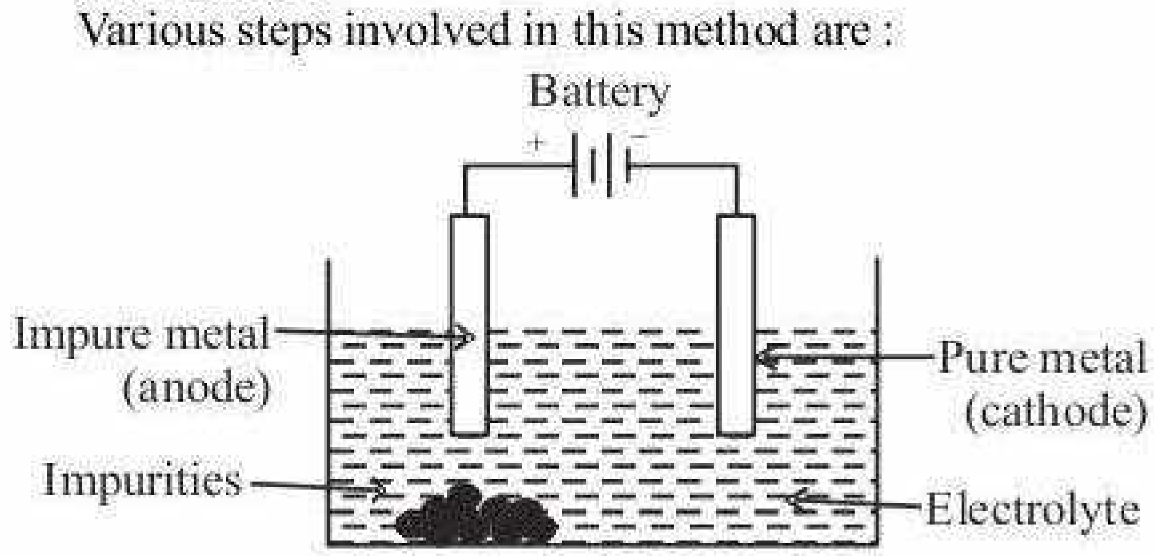



Fig. Electrolytic refining

(1) The block of impure metal is made anode by connecting to the positive terminal of the battery.

(2) A thin strip of pure metal is made cathode by connecting to the negative terminal of the battery.

(3) A water soluble salt of the metal acts as an electrolyte.

The arrangement is shown in figure above. When the battery is switched on, current flows in the circuit. Impure metal from the anode dissolved by the electrolyte and pure metal gets deposited on the cathode.

**(iv) Thermal decomposition method :** This method may be of different type and in this method, the metal is converted into suitable volatile compound which is decomposed at high temperature to give pure metal.

**(v) Zone-refining or fractional crystallization :** This is another method used to obtain metals of very high purity. Metals like Si, Ge, Ga etc., used in semiconducter devices are purified by this method. This method is based on difference in solubilities of impurities in molten and solid state.

| | | | |
|---|---|---|---|
| These metals are more reactive than hydrogen | **Potassium** | **K** | **(Most reactive metal)** |
| | Sodium | Na | |
| | Calcium | Ca | |
| | Magnesium | Mg | |
| | Aluminium | Al | Decreasing Chemical reactivity ↓ |
| | Zinc | Zn | |
| | Iron | Fe | |
| | Tin | Sn | |
| | Lead | Pb | |
| | **[Hydrogen]** | **[H]** | |
| These metals are less reactive than hydrogen | Copper | Cu | |
| | Mercury | Hg | |
| | Silver | Ag | |
| | Gold | Au | **(Least reactive metal)** |

# USES OF METALS

## Uses of Iron

One of the most important use of iron ore is in the manufacture of steel. Iron is combined with various other combinations of elements including carbon, chromium, nickel, silicon, molybdenum, etc., to make different varieties of steel which is an excellent material for various forms of construction work. As steel can withstand high pressure as well as temperature.

## Uses of Aluminum

It is used to make house-hold article and for making aeroplanes (because of its lightness). It is also used in making electrical cables (because it is quite cheaper than copper). Aluminium foils (used for wrapping of food stuffs, medicines, chocolates, cigarettes, etc.)

## Uses of Copper

It is used in electrical gadgets (because it is a very good conductor of electricity). It is also used for making radiators of automobiles.

Noble Metals and their Uses

Gold, silver and platinum are known as noble metals. These metals are not affected by air, water or acids.

## Uses of silver :

(i) Used in jewellery (because it is too soft).

(ii) Used to make coins and medals.

## Uses of gold :

(i) Used in jewellery and ornaments.
(ii) Used to make coins and medals.

## Uses of platinum :

(i) Used to make surgical instruments and chemical equipments.
(ii) Alloys of silver and platinum are used for making electrical parts and bearings.

## Uses of Alloys

(i) Common engineering metals include aluminium, chromium, copper, iron, magnesium, nickel, titanium and zinc. These are most often used as alloys.
(ii) Stainless steel or galvanized steel are used where resistance to corrosion is important. Aluminium alloys and magnesium alloys are used for applications where strength and lightness are required.

| | Alloy | Composition | Uses |
|---|---|---|---|
| 1 | Brass | Cu = 80%, Zn = 20% | For making utensils and cartridges. |
| 2 | Bronze | Cu = 90%, Sn = 10% | For making statues, medals, ships, coins and machines. |
| 3 | Solder | Sn = 50%, Pb = 50% | For joining metals, solding wire and electronic components, etc. |
| 4 | Duralumin | Al = 95.5%, Cu = 3%, | Used in bodies of aircrafts, kitchen ware and automobile. |
| | | Mn = 1.0%, Mg = 0.5% | part, etc. |
| 5 | German Silver | Cu = 60%, Zn = 20%, Ni = 20% | For making utensils and ornaments. |
| 6 | Gun metal | Cu = 90%, Sn = 10% | For Gears and castings, etc. |
| 7 | Bell metal | Cu = 80%, Sn = 20% | For bells, gangs, etc. |
| 8 | Magnalium | Al = 90%, Mg = 10% | For balance beams, light instruments. |
| 9 | Type metal | Pb = 82%, Sb = 15%, Sn = 3% | For casting type |
| 10 | Stainless steel | Fe, Ni, Cr, C | For utensils, cutlery, etc. |

## Uses of non-metals

### Uses of Sulphur

(i) Used in manufacture of dyes, matches, fire work and gun powder.
(ii) Used in many medicines (e.g. skin ointments)
(iii) Used in vulcanization of rubber.

### Uses of Chlorine

(i) Used in manufacture of PVC (poly vinyl chloride) which is a plastic.
(ii) Used as water disinfectant to kill germs.
(iii) Used as a bleaching agent in paper and textile industry.

### Use of Iodine

(i) Used as an antiseptic.
(ii) Used in preparation of "tincture of Iodine".

### Uses of noble gases

(i) Helium is used to fill balloons.
(ii) A mixture of helium and oxygen is used by divers for respiration.

### Uses of phosphorus

(i) Used in manufacture of phosphoric acid and super phosphate fertilizer.
(ii) Used in preparation of fire works, smoke screens and in match stick industry.

### Uses of Silicon

(i) Used for making silicon steel alloy and also in preparation of a polymer called silicone.
(ii) Used in making semi-conductor devices such as transistors.

## Corrosion of Metals

Corrosion is an oxidation reaction with atmospheric oxygen in the presence of water on the surface of a metal. Rusting is the corrosion of iron on exposure to atmosphere

$$2Fe(s)+\frac{3}{2}O_2(g)+xH_2O(l)\longrightarrow Fe_2O_3.xH_2O(s)$$

i.e., rust is hydrated iron (III) oxide
The major problem of corrosion occurs with iron (or steel) as it is used as a structural material in industries like construction, infrastructure, bridges, rail transport power transmission, ship building, automobiles, heavy industries etc.

## PERIODIC CLASSIFICATION OF ELEMENTS AND ITS COMPOUND

## Mendeleev's law

A periodic function is the one which repeats itself after a certain interval. Thus, according to the periodic law (given by Mendeleev) the chemical and physical properties of elements repeat themselves after certain intervals when they are arranged in the increasing order of their atomic mass.

**Main Features of Mendeleev's Periodic Table**

1. The horizontal rows are called series which are further divided into periods. There are seven periods in the periodic table.
2. Properties of elements in a particular period show regular gradation (i.e. increase or decrease) from left to right.
3. The vertical columns are called groups. These are nine numbered from I to VIII and Zero (Roman numerals).
4. Groups I to VII are subdivided into A and B subgroups. Groups Zero and VIII don't have any subgroups. All the elements in a particular group are chemically similar in nature.

**Merits of Mendeleev's Periodic Classification**

1. Classification of all elements: Mendeleev's classification was the first classification which successfully included all the elements.
2. Prediction of new elements : Mendeleev's periodic table had some blank spaces in it. These vacant spaces were for elements that were yet to be discovered.

**Defects in Mendeleev's Periodic Classification**

1. Position of hydrogen : Hydrogen resembles alkali metals (forms H+ ion just like Na+ ions) as well as halogens (forms H– ion similar to Cl– ion).Therefore, it could either be placed with alkali metals (group I) or with halogens (group VII ).
2. Position of isotopes : Different isotopes of same elements have different atomic masses, therefore, each one of them should be given a different position in the periodic table. On the other hand, since they are chemically similar, they had to be given same position.
3. Anomalous pairs of elements : At certain places, an element of higher atomic mass has been placed before an element of lower atomic mass.

## MODERN PERIODIC LAW

It states that "the properties of the elements are periodic functions of their atomic numbers.

## MODERN PERIODIC TABLE

### The Main Features of this Periodic Table:

There are 18 vertical columns in the periodic table. Each column is called a group. Numbered from 1 to 18 from left to right. All elements present in a group have similar electronic configurations and have same number of valence electrons. There are seven rows in the periodic table. Each row is called a period. The periods have been numbered from 1 to 7 (Arabic numerals). In each period a new shell starts filling up.

### Merits of modern periodic table over Mendeleev's periodic table

1. Position of isotopes: Isotopes of same element occupy the same position in the modern periodic table which they should have because all of them are chemically similar.
2. Anomalous pairs of elements: When elements are arranged in the periodic table according to their atomic numbers the anomaly regarding certain pairs of elements in Mendeleev's periodic table disappears.
3. It explains the periodicity of the properties of the elements and relates them to their electronic configurations.

## TRENDS IN THE MODERN PERIODIC TABLE

### Valency

The combining capacity of an atom or radical is known as its valency.

(a) Valency in a period: In normal elements it increases from 1 to 8 in a period from left to right. It reaches 8 in group 18 elements (noble gases) which show practically no chemical activity under ordinary conditions and their valency is taken as zero.

(b) Valency in a group: All the elements of a group have the same number of valence electrons. Therefore, they all have the same valency.

### Atomic Radii

It is defined as one-half of the distance between the nuclei of two atoms when they are linked to each other by a single covalent bond.

(a) Variation of atomic radii in a period: In a period, atomic radius generally decreases from left to right with increase in atomic number.

(b) Variation of atomic radii in a group: Atomic radii increases in a group from top to bottom.

### Ionization Energy

The minimum amount of energy required to remove an electron from a gaseous atom in its ground state to form a gaseous ion is called ionization energy.

(a) Variation of ionization energy in a group : The force of attraction between valence electrons and nucleus decreases in a group from top to bottom. So ionization energy decreases in a group from top to bottom.

(b) Variation of ionization energy in a period : Force of attraction between valence electron and nucleus increases in a period from left to right due to increase in nuclear charge. So, the ionization energy generally increases in a period from left to right.

### Electron Affinity

It is the energy change when an electron is accepted by an atom in the gaseous state. It corresponds to the process :

$$X(g) + e^- \longrightarrow X^-(g) + E$$

(a) Variation of electron affinity in a group: On moving down a group, the size and nuclear charge increases. The effect of increase in atomic size is much more pronounced than the effect of nuclear charge therefore additional electron feels less attraction by nucleus. Hence lower is electron affinity.

(b) Variation of electron affinity along a period: On moving across a period, the size of atom decreases and nuclear charge increases. Thus electron affinity increases in a period from left to right.

### Electronegativity

Electronegativity is relative tendency of a bonded atom to attract the bond-electrons towards itself. Electronegativity generally decreases in a group from top to bottom. Electronegativity generally increases in a period from left to right.

### Metallic and Non-Metallic Character

(a) Variation of metallic character in a group : Metallic character of elements increases from top to bottom.

(b) Variation of metallic character in a period : Metallic character of elements decreases in a period from left to right.

### Elements classified as Metalloids :

The 7 elements classified as "Metalloids" are located in Groups 13, 14, 15, 16 and 17 elements of the Periodic Table. Elements classified as Metalloids have properties of both metals and non-metals. Some are semi-conductors and can carry an electrical charge making them useful for electronic appliances like calculators and computers. The Metalloids in the Periodic Table are: Boron, Silicon, Germanium, Arsenic, Antimony, Tellurium, Polonium,

## Elements classified as Alkali Metals :

The 6 elements classified as "Alkali Metals" are located in Group 1 elements of the Periodic Table. Elements classified as Alkali Metals are very reactive metals that do not occur freely in nature. Alkali metals are soft, malleable, ductile, and are good conductors of heat and electricity. The Alkali Metals are: Lithium, Sodium, Potassium, Rubidium, Cesium, Francium

## Elements classified as Alkaline Earth Metals :

The 6 elements classified as "Alkaline Earth Metals" are located in Group 2 elements of the Periodic Table. Elements classified as Alkaline Earth Metals are all found in the Earth's crust, but not in the elemental form as they are so reactive (Inspite of being so reactive there reactivity is less than alkali metals). Instead, they are widely distributed in rock structures. The Alkaline Earth Metals on the Periodic Table are : Beryllium, Magnesium, Calcium, Strontium, Barium, Radium.

## Elements classified as Transition Metals :

The elements classified as "Transition Metals" are located in Groups 3 - 12 of the Periodic Table. Elements classified as Transition Metals are ductile, malleable, and conduct electricity and heat. The Transition Metals on the Periodic Table are:

Scandium, Titanium, Vanadium, Chromium, Manganese, Iron, Cobalt, Nickel, Copper, Zinc, Yttrium, Zirconium, Platinum,

Gold, Mercury, Rutherfordium, Dubnium, Seaborgium, Bohrium, Hassium, Meitnerium, Ununbium, Niobium, Iridium, Darmstadtium, Molybdenum, Technetium, Ruthenium, Rhodium, Palladium, Silver, Cadmium, Hafnium, Tantalum, Tungsten, Rhenium, Osmium.

## Elements classified as Other Metals :

The 7 elements classified as "other metals" are located in groups 13, 14, and 15 of the Periodic Table. All of these elements are solid, have a relatively high density and are opaque. The "Other Metals" on the Periodic Table are: Aluminum, Gallium, Indium, Tin, Thallium, Lead, Bismuth

## Elements classified as Non-metals

The 7 elements classified as "Non-metals" are located in Groups 14,15 and 16 of the Periodic Table. Non-metals are not easily able to conduct electricity or heat and do not reflect light . Non-metallic elements are very brittle, and cannot be rolled into wires or pounded into sheets. Non-metallic elements exist, at room temperature, in two of the three states of matter : gases (such as oxygen) and solids (such as carbon). The Non-Metal elements on the Periodic Table are : Carbon, Nitrogen, Oxygen, Phosphorus, Sulfur, Selenium etc.

## Elements classified as Noble Gases

The 6 elements classified as "Noble Gases" are located in Group 18 of the Periodic Table. Six Noble Gases on the Periodic Table are: Helium, Neon, Argon, Krypton, Xenon, Radon

## Elements classified as Rare Earth Elements

The elements classified as "Rare Earth Elements" are located in Group 3 of the Periodic Table and in the 6th and 7th periods. The Rare Earth Elements consists of the Lanthanide and Actinide series. Most of the elements in the Actinide series are synthetic or man-made. The Lanthanide and Actinide series of Rare Earth Elements on the Periodic Table are:

## Classification based on differentiating electron :

This classification divides the elements into four types. i.e., s-, p-, d- and f-block elements depending on the type of the atomic shell into which the last electron enters.

### s-block elements

Those elements of the periodic table in which the last electron enters in s–orbital, are called s–block elements.

s-orbital can accommodate a maximum of two electrons. Their general formulae are $ns^1$ and $ns^2$ respectively, where n = (1 to 7).

I A group elements are known as alkali metals because they react with water to form alkali. II A group elements are known as alkaline earth metals because their oxides react with water to form alkali and these are found in the soil or earth. s-block element are soft and have low melting and boiling points. They mostly form ionic compounds. The total number of s block elements are 14. $Fr^{87}$ and $Ra^{88}$ are radioactive elements while H and He are gaseous elements. Cs and Fr are liquid elements belonging to s-block.

### p-block elements :

Those elements of the periodic table in which the last electron gets filled up in the p-orbital, called p-block elements. A p-orbital can accommodate a maximum of six electrons. Therefore, p-block elements are divided into six groups which are III A, IV A, V A, VI A, VII A and VIII A groups. They include both metals and non-metals. They form mostly covalent compounds. The general formula of p block elements is $ns^2np^{1-6}$ (where n = 2 to 6)

The VIIIA group elements having general formula $ns^2np^6$ are inert, because their energy levels are fully filled. The total number of p block elements in the periodic table is 30 (excluding He). There are nine gaseous elements (Ne, Ar, Kr, Xe, Rn, $F_2$, $Cl_2$, $O_2$ and $N_2$) belonging to p-block. Gallium (Ga) and bromine (Br) are liquids.

### d-block elements

Those elements of the periodic table in which the last electron gets filled up in the d orbital, called d block elements. The d block elements are placed in groups named IIIB, IV B, V B, VI B, VII B, VIII, I B and II B. In d block elements the electron gets filled up in the d orbital of the penultimate shell. Though the total number of d block elements is 39 in the periodic table but there are only 36 transition elements. Because only those elements are transition in which d orbital is partially filled. The general formula of these elements is $(n-1)d^{1-10} ns^{1-2}$ where n = 4 to 7. They are metals having high melting and boiling points. Most of them form coloured compounds and exhibit several oxidation states.

## f-block elements

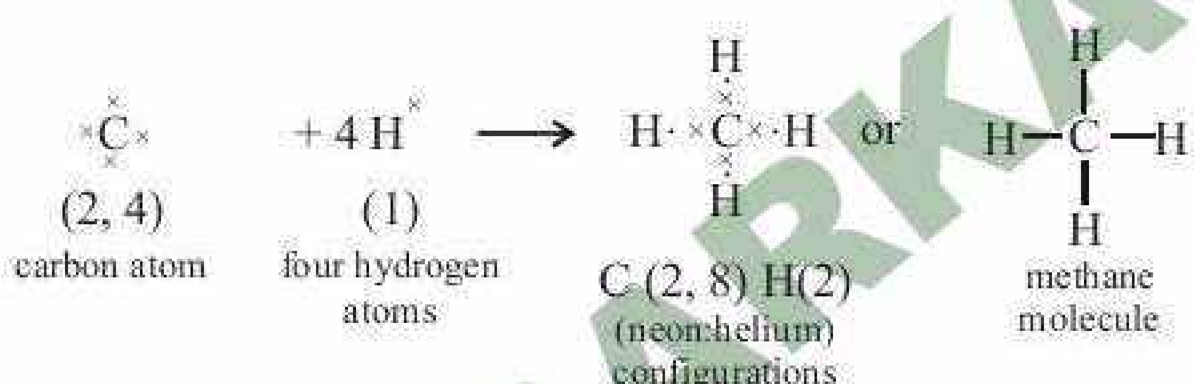
Those elements of the periodic table in which the last electron gets filled up in the f orbital, called f block elements. There are 28 f block elements in the periodic table. The elements from atomic number 58 to 71 are called lanthanides because they come after lanthanum (57). The elements from 90 to 103 are called actinides because they come after actinium (89). They are heavy

## CARBON

In fact more than 90% of all known compounds contain carbon. Carbon is the 15th most abundant element in the earth's crust, and the fourth most abundant element in the universe by mass after hydrogen, helium, and oxygen. Chemistry of carbon compounds is known as organic chemistry. Organic chemistry encompasses study of all carbon-hydrogen compounds. These are also called hydrocarbons. Inorganic carbon chemistry is the study of oxides, nitrides and allotropes of carbon. Carbon has 6 protons, 6 neutrons and 6 electrons. Its chemical symbol is 12C6. Its electronic configuration is 2 electrons in the K-shell, and 4 electrons in the L-shell. Carbon covalent bonds are the strongest in nature.

### Methane Molecule :

Carbon atom has four electrons in its outermost shell. Thus, it requires four more electrons to acquire a stable noble gas configuration. Each of the hydrogen atoms has only one electron in its outermost shell and requires one more electron to complete its outermost shell (to acquire He configuration). This is done as follows.




## ALLOTROPES OF CARBON :

Carbon (in Latin carbo means charcoal) is an element of prehistoric discovery. It is very widely distributed in nature. It is found in abundance in the sun, stars, comets, and atmospheres of most planets.

Carbon can either be in structural crystalline forms or may occur in a structure-less amorphous form. Some elements like carbon, sulphur, tin, oxygen, etc. are found in more than one structural forms. That is some elements can have several different structural forms while in the same physical state. These differing forms are called allotropes and the phenomena is called allotropy. The various allotropic forms of carbon can be broadly classified into two classes.

**Crystalline form :** Diamond, Graphite

**Amorphous form :** Coal, Coke, Charcoal (or wood charcoal), Animal Charcoal (or bone black), Lamp black, Carbon black, Gas carbon and Petroleum coke. For example in crystalline form, pure carbon is found as graphite, diamond, Buckministerfullerene.

**Graphite :** At normal pressures carbon takes the form of graphite, in which each atom is bonded trigonally to three others in a plane composed of fused hexagonal rings. The resulting network is 2-dimensional, and the resulting flat sheets are stacked and loosely bonded .This gives graphite its softness and its cleaving properties (the sheets slip easily past one another). Because of the delocalization of one of the outer electrons of each atom, graphite conducts electricity, but only in the plane of each covalently bonded sheet.

Diamond: At very high pressures carbon forms the more compact allotrope diamond, having nearly twice the density of graphite. Here, each atom is bonded tetrahedrally to four others, thus making a 3-dimensional network of puckered six-membered rings of atoms. Diamond has the same cubic structure as silicon and germanium and because of the strength of the carbon-carbon bonds, it is the hardest naturally occurring substance in terms of resistance to scratching.

**Fullerene:** Fullerene is the newly discovered allotropic form of carbon. It is a crystalline form of carbon. A fullerene is a molecule composed entirely of carbon, in the form of a hollow sphere, ellipsoid, or tube (Fig.). Spherical fullerenes are also called buckyballs, and cylindrical ones are called carbon nanotubes or buckytubes. The first fullerene to be discovered, buckminsterfullerene (C60), was prepared in 1985.

### Uses of Carbon

It can form alloys with iron, of which the most common is carbon steel. Graphite is combined with clays to form the 'lead' used in pencils used for writing and drawing. It is also used as a lubricant and a pigment, as a molding material in glass manufacture, in electrodes for dry batteries and in electroplating and electroforming, in brushes for electric motors and as a neutron moderator in nuclear reactors.

### Oxides of Carbon

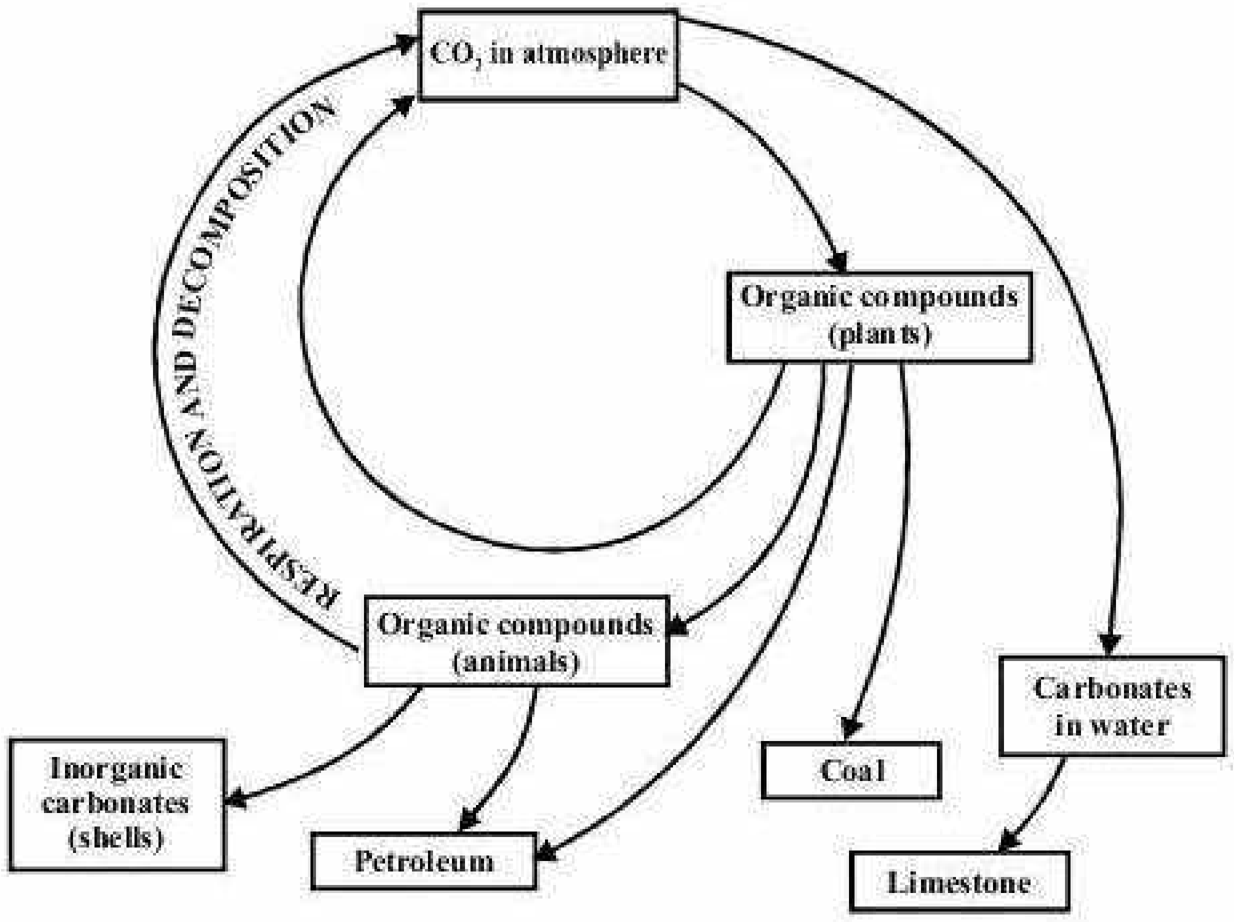
Carbon mainly forms two types of oxides

**Carbon monoxide :** It is not naturally found in atmospheric air. Its small amounts are found in volcanic gases, exhausts of engines and chimney gases. It is mainly produced due to incomplete combustion of fossil fuels like wood, coal, petrol, etc. Carbon monoxide is highly toxic. It combines with haemoglobin to produce carboxyhaemoglobin. When the haemoglobin is combined with carbon monoxide, it cannot combine with oxygen; this destroys the ability of haemoglobin to carry essential oxygen to all parts of the body.

**Carbon dioxide :** It is a gas at standard temperature and pressure and exists in Earth's atmosphere in this state. $CO_2$ is a trace gas comprising 0.039% of the atmosphere. Sources of $CO_2$ in the atmosphere are from decay of vegetable matter, animal breathing, burning of carbon and carbonaceous matter etc. The $CO_2$ absorbs strongly in the infrared region, and its presence in the atmosphere decreases the loss of heat from the earth by radiation which results into increase in temperature of earth (Global warming). This global warming is called the 'green house effect' (other gases, including the oxides of nitrogen from car exhausts, freons from aerosols and refrigerators and methane from bacteria in the soil and in the rumen of cows, also add to the green house effect).

### Carbon Cycle

In nature, carbon is cycled repeatedly through different forms by the various physical and biological activities.




## Organic Compounds :

According to the earlier defination *organic chemistry was defined as the chemistry of substances found in the living matter* (Berzelius in 1808). Further, Berzelius in 1815 also suggested that the organic compounds could be prepared only by living organisms under the influence of a mysterious force known as the **vital force** (*life-force*). The **vital force theory** remain unchallanged until 1828, when Friedrich Wohler, a German chemist, reported the synthesis of a typical organic compound **urea** by heating an inorganic compound, ammonium cyanate.

The synthesis of urea from inorganic compounds gave a blow to the vital force theory Accordingly, **organic chemistry has now been defined as the chemistry of carbon compounds.**

## FUNCTIONAL GROUPS :

In organic chemistry, functional groups (or moieties) are specific groups of atoms within molecules that are responsible for the characteristic chemical reactions of those molecules. The same functional group will undergo the same or similar chemical reaction(s) regardless of the size of the molecule it is a part of.

Combining the names of functional groups with the names of the parent alkanes generates a powerful systematic nomenclature for naming organic compounds.

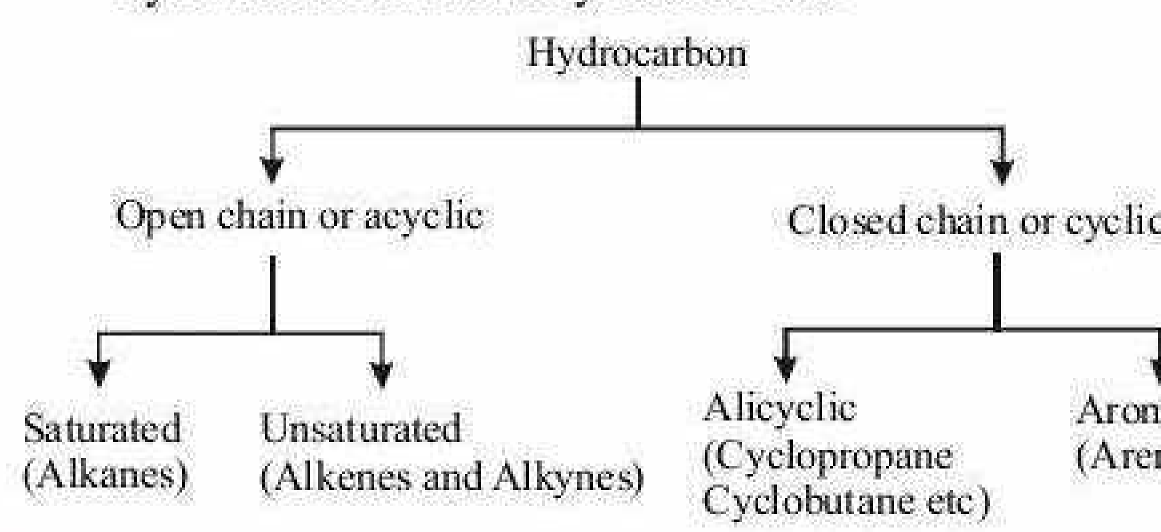
The first carbon atom after the carbon that attaches to the functional group is called the alpha carbon. Functional groups are attached to the carbon backbone of organic molecules. They determine the characteristics and chemical reactivity of molecules. Functional groups are far less stable than the carbon backbone and are likely to participate in chemical reactions. Free valency or valencies of the group are shown by the single line. The functional group is attached to the carbon chain through this valency by replacing one hydrogen atom or atoms.

**Important Functional Groups and the Corresponding Classes of Organic Compounds :**

| S.No. | Functional Group | | Class of compounds |
|---|---|---|---|
| | Formula | Name | |
| 1. | –X (–F, Cl, –Br, –I) | Halo (fluoro, chloro, bromo, iodo) | Alkyl halides or halogen compounds |
| 2. | –OH | Hydroxy | Alcohol |
| 3. | –OR | Alkoxy | Ethers |
| 4. | –SH | Mercapto | Thioalcohols, mercaptans or thiols |
| 5. | –SR | | Thioethers or sulphides |
| 6. | –CHO | Aldehydic | Aldehydes |
| 7. | –CO– | Ketonic | Ketones |
| 8. | –COOH | Carboxyl | Carboxylic acids |
| 9. | –COOR | Ester | Esters |
| 10. | –COX (X = Cl, Br or I) | Acyl halide | Acid halides or Acyl halides |
| 11. | $–CONH_2$ | Amide | Amides or acid amides |
| 12. | –CO.O.CO– | Anhydride | Acid anhydrides |
| 13. | $–NH_2$ | Amino | Amines |
| 14. | –NH– | Imino | Imines |
| 15. | $–C \equiv N$ | Cyano | Cyanides or Nitriles |
| 16. | $–N \overset{\to}{=} C$ | Isocyano | Isocyanides or Isonitriles |
| 17. | $–NO_2$ | Nitro | Nitro compounds |
| 18. | –N = O | Nitroso | Nitroso compounds |
| 19. | –N = N– | Azo | Azo compounds |
| 20. | $–SO_2 – OH$ | Sulphonic acid | Sulphonic acids |

The simplest organic compounds are hydrocarbons. Hydrocarbons are compounds formed by the combination of carbon and hydrogen only. Petrol, diesel, kerosene, liquid petroleum gas (LPG) and condensed natural gas (CNG) etc. are all hydrocarbons or are their mixtures. All organic compounds can be considered as the derivatives of hydrocarbons, obtained by substituting hydrogen with an appropriate functional group.

Hydrocarbon are broadly classified as



## ALKANES :

Alkanes or saturated hydrocarbons are those in which all the four valancies of carbon atom(s) are satisfied by four atoms or groups i.e. the carbon valencies are fully satisfied. These compound contain only C–C and C–H types of covalent bonds. Since they are relatively inert towards most of the chemical reagent under ordinary conditions, they are called Paraffins (latin-parum, little; affinis-affinity). The IUPAC name for these compounds is alkanes. Their general formula is $C_nH_{2n+2}$. Alkanes are quite stable compound and gives substitution reaction while alkenes and alkynes are more reactive and give addition reactions.

## ALKENES :

Alkenes are those unsaturated hydrocarbons which contain at least one carbon-carbon double bond in their molecules. Their general formula is $C_nH_{2n}$ and hence they contain two hydrogen atoms less than the corresponding alkanes and hence designated as unsaturated hydrocarbon. Their general formula is $C_nH_{2n+2}$. These are also known as olefins or olifines (olifiant = oil forming) Their IUPAC name is alkenes.

## ALKYNES :

Alkynes are characterised by the presence of a triple bond between two carbon atoms i.e. $-C \equiv C-$. They contain four hydrogen atoms less than the corresponding alkane and hence correspond to the general formula $C_nH_{2n-2}$. The first and the most important member of this series is acetylene $CH \equiv CH$ and hence these compounds are also called as acetylenes and the triple bond is usually referred to as the acetylenic linkage or acetylenic bond.

**Aromatic hydrocarbons:** Those compounds which contain one or more benzene ring.

## PETROLEUM

Petroleum or crude oil (petra = rock, oleum = oil), is a dark greenish - brown, viscous oil found deep in earth's crust

Petroleum is a mixture of hydrocarbons particularly aliphatic; although alicyclic and aromatic hydrocarbons along with small amounts of nitrogen, oxygen and sulphur containing organic compounds are also found to be present.

## ROCKET PROPELLANTS

Rocket propellant is a combination of a fuel and an oxidiser which when ignited generates a large volume of hot gases at a predetermined rate.

### Solid Propellants

In solid propellants ignition can not be controlled. They are of two types.

(i) Composite propellants: Fuel is a synthetic rubber or resin such as polyurethane or polybutadiene with additives such as Al or Mg. Oxidiser is ammoniumperchlorate, potassiumperchlorate or ammonium nitrate.

(ii) Double base propellant: Mixture of nitroglycerine and nitro cellulose.

### Liquid Propellants

They provide higher thrust than solid propellants which can be controlled.

(i) Biliquid propellants: Fuel is kerosene, alcohol, hydrazine, monomethyl hydrazine (MMH) and unsymmetrical dimethyl hydrazine (UDMH), liquid hydrogen. Oxidiser is liquid oxygen, dinitrogen tetraoxide or nitric acid.

(ii) Monopropellants: Nitromethane, methyl nitrate hydrazine, and hydrogen peroxide. They act as fuel as well as oxidiser.

## NITROGEN

Discovered by Daniel Rutherford. Abundance in air is 78.15% by volume.

### Manufacturing : By Linde's or Claude's process

Atmospheric air is compressed and then released into a bigger area when liquid air is obtained (Joule Thomson effect) which is mainly mixture of $N_2$ and $O_2$. They are separated by fractional distillation.

### Ammonia ($NH_3$)

**Preparation : Lab method :**

$$2NH_4Cl + Ca(OH)_2 \rightarrow CaCl_2 + 2NH_3 + 2H_2O$$

**Manufacturing : Haber's process :**

$$N_2 + 3H_2 \xrightarrow[450^\circ C,\ 245\ Atm.]{Fe/Mo} 2NH_3$$

### Nitric Acid (HNO3) :

### Preparation : Lab method :

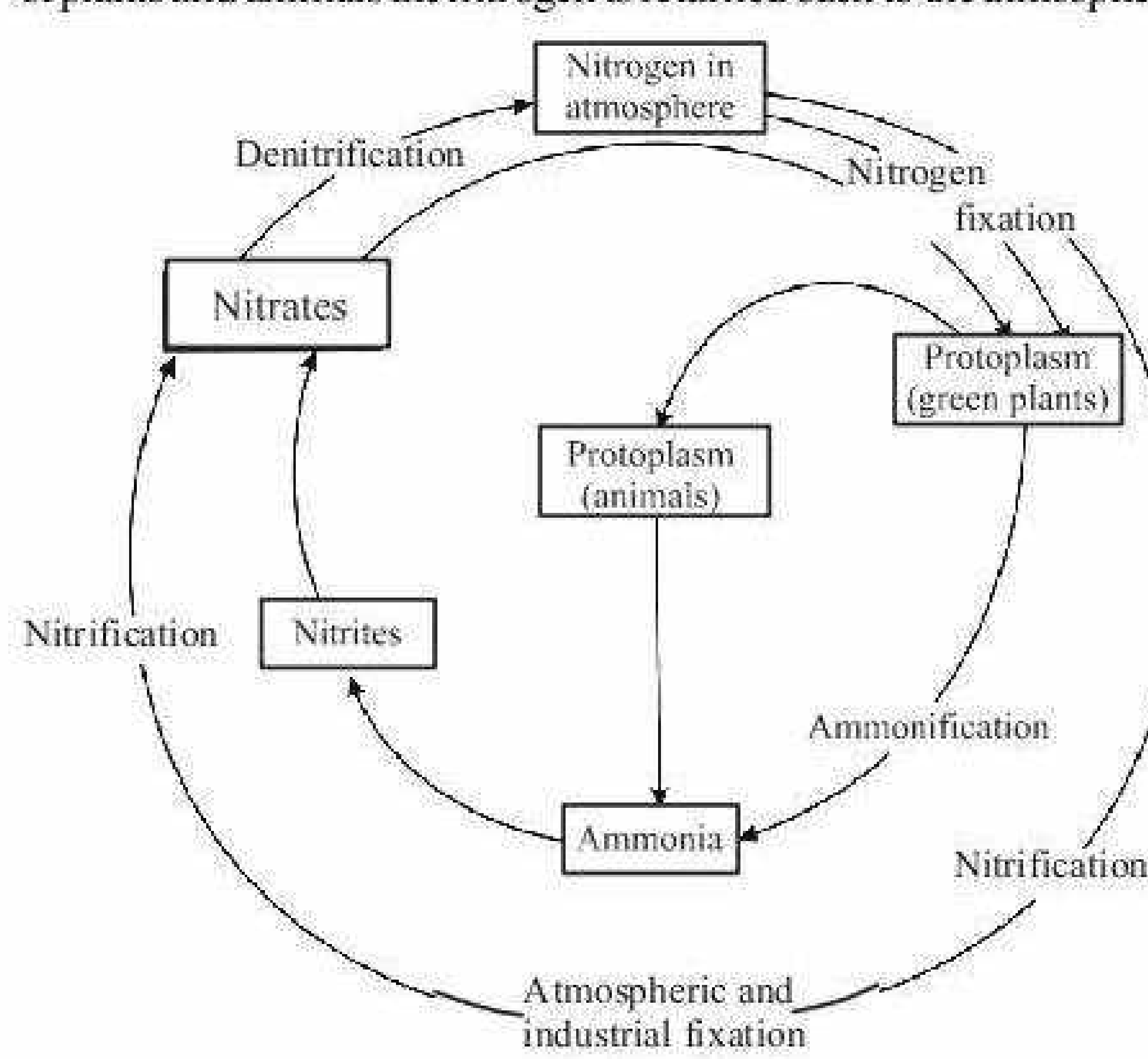
$$2NaNO_3 + H_2SO_4\ (Conc.)\ Na_2SO_4 + 2HNO_3$$

**Manufacturing :**

$$N_2 + O_2 \rightarrow 2NO$$
$$2NO + O_2 \rightarrow 2NO_2$$
$$4NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$$

### Nitrogen cycle

About 78% of nitrogen is present in our atmosphere. It is also present in proteins, nucleic acids and vitamins, alkaloids, urea etc. The free nitrogen is fixed by nitrogen fixing bacteria into nitrates and nitrites. This nitrogen is used by plants and animals. After death and decay of plants and animals the nitrogen is returned back to the atmosphere.




Nitrogen cycle in nature

## PHOSPHOROUS :

Discovered by **Brand**

### Occurence :

It occurs in combination only as phosphates

(i) **Phosphorite** $Ca_3(PO_4)_2$

(ii) **Chlorapatite** $CaCl_2.3Ca_3(PO_4)_2$

(iii) **Fluorapatite** $CaF_2.3Ca_3(PO_4)_2$.

In phosphoproteins of brain, bones, teeth, milk, egg, nervous tissues of animal and plants.

### Manufacturing :

By reduction of calcium phosphate with carbon in presence of $SiO_2$ in an electric furnance

$$2Ca_3(PO_4)_2 + 6SiO_2 \rightarrow 6CaSiO_3 + P_4O_{10}$$

$$P_4O_{10} + 10C \rightarrow P_4 + 10CO$$

**Purification :** By melting under acidified solution of $K_2Cr_2O_7$. The impurities are oxidised and redistilled.

**Properties :** Freshly prepared phosphorous is colourless. On standing acquires pale lemon colour due to formation of red phosphorus on the surface. It is therefore called yellow phosphorous. Due to its poisonous nature the jaw bones decay and disease is known as **"Phossy jaw"**

***Allotropic forms of phosphorous and their preparation :***

*i)* ***Red phosphorous*** *:* It is prepard by carefully heating yellow phosphorous in an inert atmosphere for about 8 days.

*ii)* ***Violet phosphorous*** *:* By crystallisation of white phosphorous from molten lead

*iii)* ***Scarlet*** *:*

1. By exposing the solution of red P in $PBr_3$ to light or by boiling.
2. By heating $PBr_3$ with Hg at 513 K

$$4PBr_3 + 6Hg \rightarrow 6HgBr_2 + P_4$$

*iv)* ***Black*** *:* By heating white P to 473K under 1000kg/sq. cm.. It is the most stable form, good conductor of electricity.

### Phosphine ($PH_3$) :

***Preparation :***

(i) **Any phosphide** $+H_2O \rightarrow PH_3$

$$Ca_3P_2 + H_2O \rightarrow 2PH_3 + Ca(OH)_2$$

$$Na_3P + 3H_2O \rightarrow PH_3 + 3NaOH$$

$$2AlP + 3H_2SO_4 \rightarrow 2PH_3 + Al_2(SO_4)_3$$

*(ii)* ***Decomposition*** **of $H_3PO_3$** :

$$4H_3PO_3 \rightarrow 3H_3PO_4 + PH_3$$

*(iii)* ***Lab. method*** *:*

$$4P + 3NaOH + 3H_2O \rightarrow 3NaH_2PO_2 + PH_3$$

*(iv)* ***Pure*** **$PH_3$** : $PH_4I + NaOH \rightarrow PH_3 + NaI + H_2O$

## SOLUTION

Solution may be defined as a homogeneous mixture of two or more pure substances, the relative ratio of which can be varied within certain limits. Solution of two substances is the most common type of solution and is termed as binary solution. Solvent is that component of the solution.

Based on the size of particles solutions are classified into three main catagories 1. True solution 2. Colloidal solution 3. Suspension

### True Solution

A solution in which the particles of the solute are broken down to such of fine state, that they cannot be seen under powerful microscope is called a true solution. The particles of solute break down to almost molecular size and their diameter is of the order of 1 nm (10–9 metre) or less.

**Types of True Solutions :**

| Solute | Solvent | Solution | Example |
|---|---|---|---|
| solid | solid | solid | certain alloys |
| liquid | solid | solid | Hg in Ag |
| gas | solid | solid | hydrogen gas in palladium |
| solid | liquid | liquid | sugar in water |
| liquid | liquid | liquid | petrol in kerosene |
| gas | liquid | liquid | soft drinks |
| solid | gas | gas | carbon in air (smoke) |
| liquid | gas | gas | fog |
| gas | gas | gas | air |

## SOLUBILITY

Solubility is the ability of the solvent (water) to dissolve the solute (sugar). The solubility of a solute is defined as the maximum amount that dissolves in a given amount of solvent at a specified temperature. When a specific amount of solvent contains the maximum amount of dissolved solute, the solution is said to be saturated. If less than the maximum amount is present, the solution is unsaturated.

Note that $PbSO_4$, $Mg(OH)_2$ and AgCl have very low solubilities and thus are considered insoluble.

$$\text{Solubility} = \frac{\text{Weight of solute in saturated solution}}{\text{Weight of solvent in saturated solution}} \times 100$$

Various facters which affect the solubility are temperature, pressure nature of solvent, nature of solute. size of solute particles and mechanical stirring.

### Concentration of solution

concentration of solution =

$$\frac{\text{Amount of solute}}{\text{Amount of solution}} \text{ or } \frac{\text{Amount of solute}}{\text{Amount of solvent}}$$

**(1) Mass Percentage (% by weight).**

The mass of the solute in gms per 100 g of the solution is termed as the mass percent.

Mathematically,

$$\% \text{ by weight} = \frac{\text{Weight of the solute}}{\text{Weight of the solution}} \times 100$$

**(2) Volume Percentage (% by volume).**

It may be defined as the volume of solute in ml present in 100 ml of the solution.

$$\% \text{ by volume} = \frac{\text{Volume of the solute}}{\text{Volume of the solution}} \times 100$$

**(i) Normality (N) :**
Normality of a solution may be defined as the number of gram equivalent of solute present per litre of the solution. It is denoted by N.

$$N = \frac{\text{Gram equivalents of solute}}{\text{Volume of the solution in litres}}$$

$$N = \frac{\text{Weight of solute in gm}}{\text{Eq. wt. of solute} \times \text{volume of solution in litre}}$$

$$N = \frac{\text{Strength of solution in gm / litre}}{\text{Equivalent weight of solute}}$$

**(ii) Molarity (M) :**
Molarity of a solution is defined as the number of moles of the solute per litre of solution.

$$M = \frac{\text{Number of moles of solute}}{\text{Volume of solution in litres}}$$

$$\text{or } M = \frac{\text{Wt. of solute in gms}}{\text{Molecular wt. of solute} \times \text{Volume of solution in litres}}$$

$$\text{Molarity} = \text{Normality} \times \frac{\text{Eq. wt.}}{\text{Mol. wt.}}$$

**(iii) Molality (m) :**
Molality of a solution may be defined as the number of moles of the solute dissolved per 1000 g of the solvent.

$$\text{Molality (m)} = \frac{\text{Moles of solute}}{\text{Mass of solvent in kilograms}}$$

$$\text{Molality (m)} = \frac{\text{No. of moles of solute}}{\text{Wt. of solvent in gms}} \times 1000$$

**(iv) Mole Fraction (X) :**
It is defined as the ratio of the number of moles of one component (solute or solvent) to the total number of moles of all the components (solute plus solvent) present in the solution. It is denoted by 'X'

$$\text{Thus,} \quad X_{solute} = \frac{\text{Moles of solute}}{\text{Moles of solute} + \text{Moles of solvent}}$$

**(v) Mass Fraction :**
Similar to mole fraction, mass fraction is defined as the ratio of the mass of one component (solute or solvent) to the total mass of the solution (both components). For a binary solution containing two components A and B, the mass fractions are

$$\text{Mass fraction of A} = \frac{w_A}{w_A + w_B}$$

$$\text{Mass fraction of B} = \frac{w_B}{w_A + w_B}$$

## Suspension

A supension may be defined as a heterogeneous mixture in which the solid particles are spread throughout the liquid without dissolving in it. They settle as precipitate if the suspension is left undisturbed for sometime. To form suspensions, particles must have dimensions larger than about 1000nm (1μm). Suspension that don't settle at once, like powdered sand in water, can nearly always be separated by filtration.

## Colloidal solution (Colloids) :

The dispersed particles of a solution are of molecular size. Between these extremes lie dispersed particles that are larger than molecules, but not so large that the components of the mixture separate under the influence of gravity.
These intermediate types of dispersions are called colloidal dispersion, or simply colloids. Colloids form the dividing line between solutions and heterogeneous mixtures. Like solutions, colloids can be gases, liquids,or solids.
A substance is said to be in colloidal state when it is dispersed in another medium in the form of very small particles having size in the range 1-200 nm. ($1 \times 10^{-7}$ to $2 \times 10^{-5}$ cm). The colloidal particle may consist of many atoms, ions, or molecules, or it may even be a single giant molecule. Gas in gas, always form homogeneous mixture and so never form colloids.



## Difference between the solution, colloidal solution and suspension

| Property | True solutions | Colloidal solutions | Suspensions |
|---|---|---|---|
| • Particle size | Less than 10–7 cm. | Between 10–5 and 10–7 cm | Greater than 10–5 cm |
| • Visibility of particles | Invisible to naked eye, not visible under powerful | Invisible to naked eye. Visible under powerful microscope | Easily visible |
| • Sedimentation of particles | Do not settle down | Settle down under high centrifugation | Settle down due to gravity |
| • Filtration through filter paper | No residue is formed | No residue is formed | Residue is formed |
| • Nature | Homogeneous | Heterogeneous | Heterogeneous |
| • Appearance | Transparent | Turbid | Opaque |
| • Diffusion through membranes | Readily | Diffuses slowly | Does not diffuse |

## Special Properties of Colloids

**(1) Brownian movement :**
English Botanish Robert Brown noticed the irregular or chaotic motion of particles suspended in water. This was later on named as Brownian motion.
When a colloidal solution is viewed through a powerful microscope, the colloidal particles can be seen moving in a random zig-zag path. This zig-zag motion of colloidal particles is called Brownian movement. This random motion is due to collisions between the colloidal particles.

**(2) Tyndall effect:**
All colloidal solutions are capable of scattering light or opalescence.
When a beam of converging rays falls in colloidal solution, scattering of light by sol particles in all the directions, gives rise to a bright glowing cone when looked at it sideways. This is known as Tyndall effect.

## PHYSICAL AND CHEMICAL CHANGES

As with the properties of a substance, the changes that substances undergo can be classified as either physical or chemical. During physical changes a substance changes its physical appearance, but not its composition. The evaporation of water is a physical change. When water evaporates, it changes from the liquid state to the gas state, but it is still composed of water molecules. All changes of state (for example, from liquid to gas or from liquid to solid) are physical changes.

### Characteristics of Physical Changes

(i) It is a temporary change.
(ii) No new substances are formed.
(iii) No change in mass takes place.
(iv) Can be reversed by reversing the conditions.
(v) Change in physical state, size and appearance.

### Some Examples Involving Physical Changes

| Physical changes | Observation | Change on physical property |
|---|---|---|
| 1. Switching of an electric bulb. | The bulb glows and gives out heat and light energy. | The physical appearance of the bulb changes. |
| 2. Rubbing a permanent magnet on a steel rod. | The steel rod gets magnetised. If it is brought near iron nails, they get attracted. | The steel rod acquires the property of attracting pieces of iron. |
| 3. Action of heat on iodine | The brownish grey crystals of iodine change to form violet vapours. On cooling the vapours condenses to for form crystals. | Change in state and colour. |
| 4. Dissolving of common salt in water. | The white crystalline salt disappears in water. However, the water tastes exactly like common salt. Moreover, common salt can be recovered by evaporation. | Change of state. |

### Chemical Change

A chemical change is one in which the identity of the original substance is changed and a new substance or new substances are formed. In a chemical change the properties of the substance before and after the change are entirely different. e.g. souring of milk, burning of paper,
buring of candle, etc.

### Characteristics of a Chemical Change

(i) A chemical change is permanent change and cannot be reversed to give back the original substance.
(ii) One or more new substances (called products) are formed.
(iii) Change in mass of a substance takes place.
(iv) The composition of the product is different from that of the starting substance.
(v) A chemical change is always accompanied by the change in energy.

### Comparison Between Physical and Chemical Changes :

| Physical change | Chemical change |
|---|---|
| (i) It is a temporary change and can be reversed by change of conditions | (a) It is a permanent change and is an irreversible change. |
| (ii) No new substance is formed and the composition of the substance remains unaltered. | (b) The composition of the substance changes, resulting in the formation of one or more new substances. |
| (iii) No energy changes occur | (c) It is generally accompanied by energy changes. |

## Types of Chemical Reactions

**(i) Homogeneous reactions**
When all the reactants and products of a chemical reaction are in the same physical state then such a reaction is known as homogeneous reactions.

$$H_2(g) + Cl_2(g) \longrightarrow 2HCl(g)$$

**(ii) Heterogeneous reactions**
If in a chemical reaction, all the products and reactants are not in the same physical state then such a reaction is known as heterogeneous reaction.

$$CaCO_3(s) \xrightarrow{heat} CaO(s) + CO_2(g)$$

**(iii) Exothermic reactions**
A chemical reaction which takes place with evolution of heat is known as an exothermic reaction.

$C(s) + O_2(g)\ \ CO_2(g) + Heat$

**(iv) Endothermic Reactions**
A chemical reaction that is accompanied by absorption of heat energy is known as an endothermic reaction.

N2 (g) + O2 (g) $\longrightarrow$ 2NO (g) – Heat.

**(v) Combination Reactions (or Synthesis Reactions)**
Those reactions in which two or more substances combine to form a single substance are known as combination reactions.

$$2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$$

**(vi) Decomposition Reactions**
Those reactions in which a compound splits up into two or more simpler substances are known as decomposition reactions.

$$CaCO_3(s) \xrightarrow{heat} CaO(s) + CO_2(g)$$

**(vii) Displacement reactions**
Those reactions in which one element takes the place of another element in a compound are known as displacement reactions.

$$Zn(s) + CuSO_4(aq) \longrightarrow ZnSO_4(aq) + Cu(s)$$

In general, a more reactive element displaces a less reactive element from its compound.

**(viii) Double displacement reaction**
Those reactions in which two compounds react by an exchange of ions to produce two new compounds are referred to as double displacement reactions.

$$AgNO_3(aq) + NaCl(aq) \longrightarrow AgCl(s)\downarrow + NaNO_3(aq)$$

**(ix) Isomerisation Reactions**
It is a special type of reaction in which the rearrangements of chemical bonds takes place in such a way that a molecule of one compound is changed into the molecule of another compound.

$$NH_4CNO \xrightarrow{heat} NH_2CONH_2$$

**(x) Precipitation Reactions**
A reaction in which a precipitate is formed is known as precipitation reaction.

$$NaCl(aq) + AgNO_3(aq) \longrightarrow AgCl(s) + NaNO_3(aq)$$

Precipitation is the sudden formation of a solid, either;

- when two solutions are mixed, or
- when a gas is bubbled into a solution.

## REDOX REACTIONS :

Those reactions in which oxidation and reduction takes place simultaneously, are known as redox reactions. Example

$$2\,HgCl_2 + SnCl_2 \longrightarrow Hg_2Cl_2 + SnCl_4$$

Here stannous ion is oxidised into stannic ion and mercuric ion is reduced to mercurous ion.

## OXIDATION-REDUCTION REACTIONS

### Oxidation

The addition of oxygen to a substance or removal of hydrogen from a substance in a chemical reaction is defined as oxidation.
Therefore, the term oxidation is defined as a process which involves the addition of oxygen or any other electronegative element or radical or removal of hydrogen or any other electropositive element or radical or increasing the valency of electropositive part.

$$N_2 + O_2 \longrightarrow 2NO$$
$$2P + 5Cl_2 \longrightarrow 2PCl_5$$
$$Cl_2 + H_2S \longrightarrow 2\,HCl + S$$
$$2\,KI + O_2 + H_2O \longrightarrow 2\,KOH + I_2 + O_2$$

### Reduction

It may be defined as the addition of hydrogen to a substance or removal of oxygen from a substance in a chemical reaction.
The term reduction is defined as a process which involve the removal of oxygen or any other electronegative part or addition of hydrogen or any other electropositive part or radical.

$$CuO + H_2 \longrightarrow Cu + H_2O$$
$H_2 + S \longrightarrow$ H2S
$FeCl_3$ + H $\longrightarrow$ $FeCl_2$ + HCl
Nascent hydrogen
$$2\,HgCl_2 + SnCl_2 \longrightarrow Hg_2Cl_2 + SnCl_4$$

### Oxidising agent or oxidant

Any substance that is capable of giving oxygen to bring about the process of oxidation (or combustion).

### Reducing agent

A substance which gives hydrogen or removes oxygen thus causing reduction is known as reducing agent.
Those reactions in which both oxidation and reduction takes place are known as redox reactions.
Ex:- Upon heating zinc oxide with coke, zinc and carbonmonoxide are formed coke (C) is a reducing agent as it undergoes oxidation. ZnO is an oxidising agent as it undergoes reduction.

Oxidation (C → CO)
$$ZnO + C \longrightarrow Zn + CO$$
Reduction (ZnO → Zn)

### Oxidation-reduction in terms of electronic concept

Oxidation is a loss of electrons. Reduction is a gain of electrons. Oxidizing agent accepts electrons. Some common oxidising agents are KMnO4, K2Cr2O7 etc. Reducing agent lose electrons. Some common reducing agents are LiAlH4, NaBH4 etc.

## CHEMICAL KINETICS AND EQUILLIBRIUM

Chemical kinetics is a branch of physical chemistry which deals with the rates of a chemical reaction, factors influencing the rate of chemical reaction and mechanism of a reaction.

## CLASSIFICATION OF CHEMICAL REACTIONS BASED ON THEIR SPEED :

Depending upon the rate of reaction, by which the reactants are converted into products reactions are classified in three types

**(a) Fast or Instantaneous Reactions :**

Those reactions in which the reactants readily change into products within few seconds.

**Example :**

(i) Acid-base reactions complete in a fraction of second. Example Neutralisation of sodium hydroxide by hydrochloric acid.

(ii) Mostly ionic reactions are fast reactions.

**(b) Moderate Reactions :** Those chemical reactions which take a few minutes or hours to complete. (Neither very slow nor very fast)

## REACTION RATE AND ITS MEASUREMENT

the rate of a reaction may be defined as the decrease in the concentration of reactant per unit time or increase in the concentration of product per unit time. It represents the average rate of reaction. So, mathematically the rate of reaction is expressed as given below.

$$\text{Average rate of reaction} \propto \frac{\text{Decrease in concentration of reactant}}{\text{Time interval}}$$

$$= \frac{\text{Amount of reactant consumed}}{\text{Time interval}}$$

$$= -\frac{\Delta[X]}{\Delta t}$$

Similarly, average rate of reaction

$$\propto \frac{\text{Increase in concentration of product}}{\text{Time interval}}$$

$$= \frac{\text{Amount of product formed}}{\text{Time interval}} = +\frac{\Delta[Y]}{\Delta t}$$

## FACTORS AFFECTING RATE OF A REACTION :

### 1. Effect of Concentration on Reaction Rate

The rate of reaction increases as the concentration of reactant increases and vice versa. i.e

$$\text{Rate} \propto [\text{Concentration}]$$

### 2. Effect of Temperature on Reaction Rate :

Generally reactions take place much faster at a higher temperature. It means on increasing temperature rate of reaction increases.

Rate $\propto$ Temperature

### 3. Effect of catalyst :

A catalyst is a foreign substance which is added to reaction mixture to change the rate of chemical reaction (either increases or decreases the rate of reaction) without itself undergoing any change. A catalyst is recovered unchanged in mass and composition at the end of the reaction.

**Catalysts are of two types :**

**(i) Homogeneous Catalysts :** Those catalysts in which physical states of reactants & catalyst are same.

$$2SO_2(g) + O_2(g) \xrightarrow{NO(g)} \underset{\text{Sulphur trioxide}}{2SO_3(g)}$$

**(ii) Heterogeneous Catalysts :** Those catalysts in which physical states of reactants & catalyst are different.

$$N_2(g) + 3H_2(g) \xrightarrow{Fe(s)} \underset{\text{Ammonia}}{2NH_3(g)}$$

Enzymes are also called biocatalyst as they catalyse the biological reactions (reactions in living beings).

**4. Effect of Light on Reaction rate :**

There are many reactions whose rates are influenced by light. Those chemical reaction which are carried in the presence of light are known as photochemical reactions.

Example

**(i) Photosynthesis :**

$$6CO_2(g) + 12H_2O(\ell) \xrightarrow[\text{Sunlight}]{\text{Chlorophyll}} \underset{\text{Glucose}}{C_6H_{12}O_6(aq)} + 6O_2(g) + 6H_2O$$

**5. Effect of Surface Area :** Rate of reaction is directly proportional to the surface area of the reactants. More will be the surface area, more will be the rate of reaction.

Rate $\propto$ surface area of reactants

## REVERSIBLE & IRREVERSIBLE REACTIONS :

**(a) Reversible Reaction :**

The chemical reaction which can proceed both in the forward and reverse directions are called reversible reactions.

**Characteristics of reversible reaction**

(i) It is indicated by a double half headed arrow.

(ii) The reactants are never get exhausted In these reactions.

(iii) Change in temperature, pressure or concentration changes the direction of reaction.

(iv) Such reactions should be carried out in a closed container.

(v) Such reaction never go to completion.

Eg. $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

**(b) Irreversible Reaction :**

The reactions in which complete conversion of the reactants into products occurs are called irreversible reactions.

Characteristics of irreversible reaction

(i) They are indicated by a single headed arrow. ($\rightarrow$)

(ii) Change in concentration, temperature, pressure doesn't change the direction of reaction.

(iii) They can proceed only in the forward direction.

Example $\underset{\text{Potassium chlorate}}{2KClO_3(s)} \xrightarrow{\text{Heat}} \underset{\text{Potassium chloride}}{2KCl(s)} + 3O_2(g)$

On the basis of bahaviour of equilibrium state of a system towards small changes in external factors, nature of process in which equilibrium has been attained and some other factors, state of equilibrium is classified as follows.

## LAW OF MASS ACTION :

According to the law of mass action at a given temperature the rate at which a substance reacts is directly proportional to its active mass raised with suitable power and the rate of a chemical reaction is proportional to the product of the active masses raised with suitable power of the reactants.

### Active mass

Active mass of a substance is directly proportional to its concentration (i.e. molarity, molality or mole fraction.

Active mass $\alpha$ C where C is molarity, molality or mole fraction.

Consider a reaction $A + B \rightleftharpoons C + D$

Rate of forward reaction $\propto [A][B]$

$r_f = K_f[A][B]$ {$K_f$ = Rate constant for forward reaction}

Similarly, $r_b = K_b[C][D]$ {$K_b$ = Rate constant for backward reaction}

At equilibrium $r_f = r_b$

So, $K_f[A][B] = K_b[C][D]$

$$\frac{K_f}{K_b} = \frac{[C][D]}{[A][B]}$$

$$\therefore \quad K_C = \frac{[C][D]}{[A][B]} \quad \left(K_C = \frac{K_f}{K_b}\right)$$

## RELATION BETWEEN $K_p$ & $K_c$ :

**(a)** If $\Delta n = 0$ then $K_p = K_c$ **(b)** If $\Delta n = +ve$ then $K_p > K_c$
**(c)** If $\Delta n = -ve$ then $K_p < K_c$

**Characteristics Significance of Equilibrium Constant ($K_c$) :**

1. The equilibrium constant ($K_c$) is a constant for any given chemical reaction at equilibrium at a definite temperature.
2. The value of $K_c$ is different for different reaction at equilibrium. It is also different for the same reaction carried out at different temperatures.
3. The equilibrium constant is independent of concentration of the reactants but not independent of temperature, pressure, etc.
4. If the value of $K_c$ of a chemical reaction is known, the equilibrium condition for any concentrations of the reacting substances be determined.
5. The value of $K_c$ indicates the extent to which a chemical reaction can occur.

**Applications of Equilibrium Constant**

1. It helps to predict the extent of reaction on the basis of its magnitude.
2. It predicts the direction of the reaction
3. It helps to calculate equilibrium concentrations.

### Types of Chemical Equilibrium

There are two types of chemical equilibria :

1. **Homogeneous Equilibrium.** The equilibrium reactions in which all the reactants and the products are in the same phase are called homogeneous equilibrium reactions. For example,

$$C_2H_5OH(l) + CH_3COOH(l) \rightleftharpoons CH_3COOC_2H_5(l) + \underset{\text{liquid phase}}{H_2O(l)}$$

2. **Heterogeneous Equilibrium.** The equilibrium reactions in which the reactants and the products are present in different phases are called heterogeneous equilibrium reactions. For example,

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$$

## THERMODYNAMICS, ELECTROCHEMISTRY AND IONIC EQUILLIBRIUM.

## THERMOCHEMISTRY

It is the branch of chemistry which deals with the energy changes taking place during physical and chemical changes.

Terminology used in thermodynamics :-

### System

A system is that part of universe which is under investigation .

### Surroundings

The part of the universe other than the system is known as surroundings.

Thus universe = system + surroundings

In simple case surroundings implies air or water both.

**Types of System**

(i) Open system: A system which can exchange matter as well as energy with surroundings.
(ii) Closed system: A system which can exchange energy and not matter with surroundings.
(iii) Isolated system: A system which can exchange neither matter nor energy with surroundings.
(iv) Homogeneous system: A system consisting of one phase only e.g. pure solid, a liquid or a mixture of gases.
(v) Heterogeneous system: It may consists of two or more phases e.g. a solid in contact with liquid etc.

## THERMODYNAMIC PROCESSES

(i) Isothermal Process ($\Delta T = 0$)
During each stage of process, the temperature remains constant. If the process is exothermic heat is given out to surroundings. If the process is endothermic heat is absorbed from surroundings.

(ii) Adiabatic Process ($dq = 0$)
No heat leaves or enter the system, temperature of a system rises in exothermic process, temperature falls in endothermic process.

(iii) Isobaric Process ($\Delta P = 0$)
Pressure remains constant, only volume changes.
e.g. $O_2 + 2H_2 \rightarrow 2H_2O$ volume decreases
$N_2O_4 \rightarrow 2NO_2$ volume increases

(iv) Isochoric process ($\Delta V = 0$)
Volume remains constant but pressure changes.
$O_2 + 2H_2 \rightarrow 2H_2O$ pressure decreases
$N_2O_4 \rightarrow 2NO_2$ pressure increases

(v) Cyclic process ($\Delta E = 0$)
After undergoing a number of changes, the system returns to its original state. In cyclic process
$\Delta E = 0; \Delta H = 0; \Delta S = 0$

## First Law of Thermodynamics

(i) Law of equivalence of different forms of energies
(ii) Energy can neither be created nor destroyed but can be transformed from one form to another.
(iii) Total energy of universe is conserved (fixed, constant)

**Mathematical Expression of First Law**

If q is the amount of heat absorbed by the system and w is the work done on the system, the change in internal energy,

$E = q + W$

$E = q + P\Delta V$ (work is pressure volume work)

If volume remains constant, no work is done then $\Delta E = q_v$

## ENTHALPY (H) AND ENTHALPY CHANGE ($\Delta$H)

Enthalpy is the heat content of the system and related to internal energy as follows.

$H = E + PV$

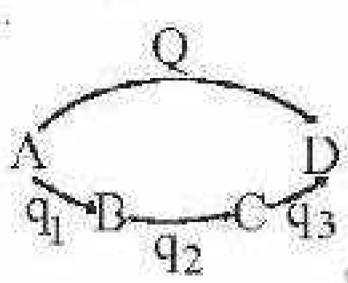
We can measure change in enthalpy and not absolute value of enthalpy. It is a state function.

H = Hproducts – H Reactants= HP – HR

If HP > HR, the change is endothermic. If HR > HP , the change is exothermic.

## Applications of First Law of Thermodynamics

Hess's law of constant heat summation - Law is based upon the first law of thermodynamics and states that if a chemical change can be made to take place in two or more ways involving one or more steps, the net amount of heat change in the complete process is the same regardless of the method employed.




$Q = q_1 + q_2 + q_3$

Applications of Hess's law
(i) Calculation of heats of reactions
(ii) Determination of heat changes of slow reactions
(iii) Calculation of enthalpies of formation
(iv) Calculation of bond energies

## Spontaneous Process

A process which has an urge or a natural tendency to occur either of its own or after proper initiation under a given set of conditions.

## Entropy (S)

It is a measure of degree of disorder or randomness in a system. More the disorder or randomness, the more is entropy.

Units of Entropy

$jmol^{-1}K^{-1}$; It is a state function. The change in entropy is represented by

$\Delta S = (S_{final} - S_{initial}) = q_{rev} / T$

**Second Law of Thermodynamics**

The entropy of the universe increases in every spontaneous (natural) change. The entropy of the universe is continuously increasing.

**Gibb's free energy (G)**

It is the maximum amount of energy which can be converted into the useful work (other than PV work). It is related to enthalpy (H) and entropy (S) as follows.

$G = H - TS$ and change is given by

$\Delta G = \Delta H - T\Delta S$

Criteria for Feasibility or Spontaneity of a Process

Enthalpy and entropy alone can not predict the spontaneity of a change.
(i) If $\Delta G$ is negative, the process is spontaneous
(ii) If $\Delta G$ is Zero, the process is in equilibrium
(iii) If $\Delta G$ is Positive the process does not occur

**Standard Free Energy Change (DG°) and Equilibrium Constant (K):**

They are related as follows $\Delta G^o = -2.303\ RT \log K$

**Free Energy Change and Cell Potential**

$\Delta G^o = -nFE^o$

## Zeroth Law of Thermodynamics

If two bodies have separately equality of temperature with a third body, they also have equality of temperature with each other.

## Third law of thermodynamics

At absolute zero temperature, the entropy of a perfectly crystalline substance is taken as zero. This law was formulated by Nernst in 1906.

## ELECTROCHEMISTRY

Electrochemistry is the area of chemistry dealing with the interconversion of electrical energy and chemical energy. electrochemistry always involves on oxidation-reduction process. Batteries we use in devices like torch, watches, calculator, invertor, automobile etc. depend on electrochemically produced power. Natural processes like corrosion of metals is a electrochemical process.

## electrochemical cells

Cell is a system or arrangement in which two electrodes are fitted in the same electrolyte or in two different electrolytes which are joined by a salt bridge. Cells are of two types.

**(a) Electrolytic Cell**

It is a device in which electrolysis (chemical reaction involving oxidation and reduction) is carried out by using electricity or in which conversion of electrical energy into chemical energy is done.

**Electrolysis**

Electrolysis is the use of electrical energy to produce chemical change. The recharging of a battery is an example of electrolysis. Process of Electrolysis : The process of electrolysis is carried out by taking the solution of an electrolyte in a suitable vessel. The vessel is called electrolytic tank. It is made up of either glass or of a material which is a bad conductor of electricity. Two metallic rods or plates are suspended in the electrolytic solution. These are connected to the terminals of a battery with the help of metallic wires. These metallic rods or plates allow the passage of current and are called electrodes. The electrode connected to the positive terminal of the battery is called anode while the electrode connected to the negative terminal of the battery is called cathode.

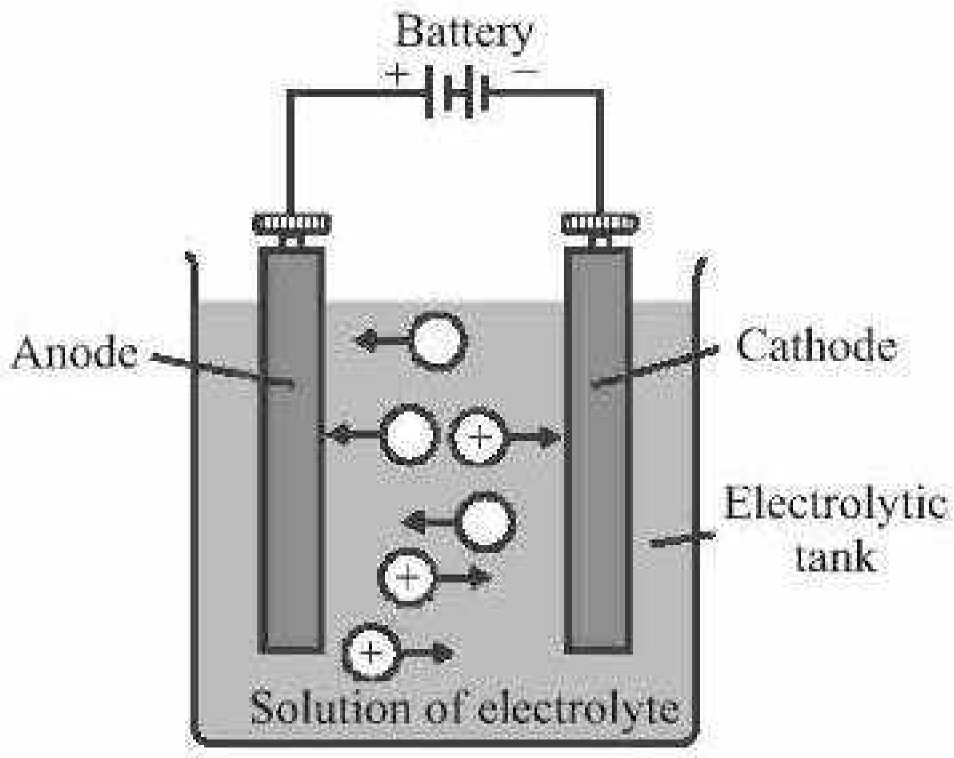



**Fig. Process of electrolysis**

On passing electric current through the solution, the ions are attracted by the oppositely charged electrodes. As a result, cations move towards cathode while anions move towards anode. This movement of ions in solution is known as electrolytic or ionic conduction and constitutes flow of current through the solution.

**Industrial Uses of Electrolysis :**

- Production of aluminium, lithium, sodium, potassium, magnesium
- Coulometric techniques can be used to determine the amount of matter transformed during electrolysis by measuring the amount of electricity required to perform the electrolysis
- Production of chlorine and sodium hydroxide
- Production of sodium chlorate and potassium chlorate
- Production of electrolytic copper as a cathode, from refined copper of lower purity as an anode.

## FARADAY'S LAW OF ELECTROLYSIS

### Faraday's First Law :

When an electric current is passed through an electrolyte, the amount of substance deposited at electrode is proportional to the quantity of electric charge passed through the electrolyte.

If W be the mass of the substance deposited by passing Q coulomb of charge, then according to the law, we have the relation.

$$W \propto Q$$

A coulomb is the quantity of charge when a current of one ampere is passed for one second. Thus, amount of charge in coulombs.

$$Q = \text{current in amperes} \times \text{time in seconds} = I \times t$$

$$W \propto I \times t$$

$$W = Z \times I \times t$$

### Faraday's Second Law

It states that when same quantity of electricity is passed through different electrolytes connected in series then the quantity of electrolytes deposited at electrode is directly proportional to its equivalent weight. (Equivalent wt. of electrolytes).

$$W \propto E$$

$$\frac{W_A}{E_A} = \frac{W_B}{E_B} = \frac{W_C}{E_C}$$

**(b) Galvanic or Voltaic Cell or Electrochemical Cell**

It is a device in which a redox reaction is used to convert chemical energy into electrical energy, i.e., electricity can be obtained with the help of oxidation and reduction reaction. The chemical reaction responsible for production of electricity takes place in two separate compartments.

Each compartment consists of a suitable electrolyte solution and a metallic conductor. The metallic conductor acts as an electrode. One compartment contain 1M solution of zinc sulphate and the other 1M solution of copper sulphate. A zinc rod is dipped into ZnSO4 solution while a copper rod is dipped into CuSO4 solution. The compartments containing the electrode and the solution of the electrolyte are called half-cells. When the two compartments are connected by a salt bridge and electrodes are joined by a wire through galvanometer the electricity begins to flow. This is the simple form of voltaic cell.

**Anode :** $Zn \longrightarrow Zn^{2+} + 2e^-$ **Cathode :** $Cu^{+2} + 2e^- \rightarrow Cu$

(I[st] half cell reaction) (II[nd] half cell reaction)

Total cell reaction :

$$Zn(s) + Cu^{+2}(aq) \longrightarrow Zn^{+2}(aq.) + Cu(s)$$

### Electrode Potential & EMF OF CELL :

The electrical potential difference setup between the metal and its solution is known as electrode potential. Thus, the electrode potential is a measure of tendency of an electrode in a half cell to gain or lose electrons. The potential difference between the two electrodes of a galvanic cell is called the cell potential and is measured in volts. It is called the cell electromotive force (emf) of the cell when no current is drawn through the cell. It is now an accepted convention that we keep the anode on the left and the cathode on the right while representing the galvanic cell.

$$EMF = E_{right}(cathode) - E_{left}(anode)$$

**TABLE**

| Element | Electrode Reduction Reaction | Standard Reduction Potential E° (in Volt) |
|---|---|---|
| Li | $Li^+ + e^- \longrightarrow Li$ | – 3.05 |
| K | $K^+ + e^- \longrightarrow K$ | – 2.93 |
| Ba | $Ba^{2+} + 2e^- \longrightarrow Ba$ | – 2.90 |
| Ca | $Ca^{2+} + 2e^- \longrightarrow Ca$ | – 2.87 |
| Na | $Na^+ + e^- \longrightarrow Na$ | – 2.71 |
| Mg | $Mg^{2+} + 2e^- \longrightarrow Mg$ | – 2.37 |
| Al | $Al^{3+} + 3e^- \longrightarrow Al$ | – 1.66 |
| Mn | $Mn^{2+} + 2e^- \longrightarrow Mn$ | – 1.18 |
| Zn | $Zn^{2+} + 2e^- \longrightarrow Zn$ | – 0.76 |

| | | |
|---|---|---|
| Cr | $Cr^{3+} + 3e^- \longrightarrow Cr$ | – 0.74 |
| Fe | $Fe^{2+} + 2e^- \longrightarrow Fe$ | – 0.44 |
| Cd | $Cd^{2+} + 2e^- \longrightarrow Cd$ | – 0.40 |
| Ni | $Ni^{2+} + 2e^- \longrightarrow Ni$ | – 0.25 |
| Sn | $Sn^{2+} + 2e^- \longrightarrow Sn$ | – 0.14 |
| Pb | $Pb^{2+} + 2e^- \longrightarrow Pb$ | – 0.13 |
| $H_2$ | $2H^+ + 2e^- \longrightarrow H_2$ | 0.00 |
| Cu | $Cu^{2+} + 2e^- \longrightarrow Cu$ | 0.34 |
| $I_2$ | $I_2 + 2e^- \longrightarrow 2I^-$ | 0.53 |
| Hg | $Hg_2^{+2} + 2e^- \longrightarrow 2Hg$ | 0.79 |
| Ag | $Ag^+ + e^- \longrightarrow Ag$ | 0.80 |
| Hg | $Hg^{+2} + 2e^- \longrightarrow Hg$ | 0.85 |
| $Br_2$ | $Br_2 + 2e^- \longrightarrow 2\,Br^-$ | 1.08 |
| $Cl_2$ | $Cl_2 + 2e^- \longrightarrow 2\,Cl^-$ | 1.36 |
| Au | $Au^{3+} + 3e^- \longrightarrow Au$ | 1.50 |
| $F_2$ | $F_2 + 2e^- \longrightarrow 2F^-$ | 2.87 |

Michael Faraday classified the substances into two types. Electrolytes and non-electrolytes. The substance which conduct electricity in their molten states or in the form of their aqueous solutions are called electrolytes.

(1) **Strong electrolytes :** The substances which ionise almost completely into ions in aqueous solution. For example, HCl, $H_2SO_4$, $HNO_3$, NaOH, NaCl, $KNO_3$, etc.

(2) **Weak electrolytes :** The substances which ionise to a small extent in aqueous solution. For example, $CH_3COOH$, $NH_4OH$, HCN etc.

The strong electrolytes gets almost completely ionised.

## Corrosion :

Corrosion can be defined as the deterioration of for is electrochemical corrosion of metals, in which the oxidation process M ® M+ +c is facilitated by the presence of a suitable electron acceptor, sometimes referred to in corrosion science as a depolarizer. In a sense, corrosion can be viewed as the spontoneous return of metal to this ores, the huge quantities of energy that were consumed in mining, refing and manufacturing metals into useful object is dissipated by a variety of different routes.

The unionised molecules are present to such a small extent that it is not of any significance to study the ionisation of strong electrolytes. Where as, the weak electrolytes are only partially ionised and a dynamic equilibrium is established after sometime between the ions and unionised molecules. This is called ionic equilibrium.

## DEGREE OF DISSOCIATION (A)

It is a measure to express the extent of dissociation of an electrolyte in solution and so its strength. Strong electrolytes have high value of degree of dissociation while for weak electrolytes its value is low. It is calculated as

$$\text{Degree of dissociation } (\alpha) = \frac{\text{Moles of electrolyte dissociated at any time}}{\text{Moles of electrolyte added initially}}$$

## THEORIES OF ACIDS AND BASES :

### Arrhenius Concept of Acids and Bases :

Svante Arrhenius in 1887, stated that acid ionizes in aqueous solution to produce hydrogen ions (which are protons), $H^+$, and anions; and a base ionizes in aqueous solution to produce hydroxide ions ($OH^-$) and cations. Later studies of aqueous solutions provided evidence of a small, positively charged hydrogen ion combining with a water molecule to form a hydrated proton, $H^+(H_2O)$ or $H_3O^+$, which is called the hydronium ion.

$$H^+ + H_2O \longrightarrow H_3O^+$$

Often, the hydronium ion or hydrated proton is represented as $H^+$ (aq). Hydrogen chloride (HCl), a gas, is an acid because it dissolves in water to yield hydrogen ions and chloride ions. This water solution of HCl is referred to as hydrochloric acid.

$$HCl + H_2O \longrightarrow H^+(aq) + Cl^-(aq)$$

**Problems with Arrhenius Theory :**

1. The solvent has no role to play in Arrhenius theory. An acid is expected to be an acid in any solvent. This was found not to be the case.
2. All salts in Arrhenius theory should produce solutions that are neither acidic nor basic.
3. The need for hydroxide as the base led Arrhenius to propose the formula $NH_4OH$ as the formula for ammonia in water. This led to the misconception that $NH_4OH$ is the actual base, not $NH_3$.

   The Arrhenius theory of acids and bases will be fully supplanted by the theory proposed independently by Johnnies Bronsted and Thomas Lowry in 1923.

### Bronsted Lowry Theory of Acids and Bases :

By the definition of Thomas Lowry and J.N. Bronsted working independently in 1923, "an acid is a material that donates a proton and a base is a material that can accept a proton".

$$HCl + H_2O \rightleftharpoons H_3O^+ + Cl^-$$

HCl – this is an acid, because it has a proton available to be transferred.

$H_2O$ – this is a base, since it gets the proton that the acid lost.

These pairs are called conjugate pairs.

### Lewis Theory of Acids and Bases :

In 1923, G.N. Lewis introduced another theory of acids and bases which could successfully explain the cases where there is no role for protons.

The G.N. Lewis idea of acids and bases is broader than the Lowry– Bronsted model. The Lewis definitions are: Acids are electron pair acceptors and bases are electron pair donors.

(i) An acid is a substance which can act as an electron pair acceptor. The molecule or ion should be associated with shortage of electrons to act as an acid.
Example $BF_3$, $H^+$ etc.

(ii) A base is a substance which can act as an electron pair donor. The molecule or ion should be associated with one or more lone pairs of electrons to act as a base.
Example $NH_3$, $OH^-$ etc.

(iii) Acid base neutralization can be defined as the transfer of an electron pair from a base to an acid.

$$H^+ + NH_3 \rightarrow [H^+ \leftarrow NH_3]^+$$

**Merits :**

(i) This theory could explain even the acidic nature of those substances which do not contain hydrogens.

(ii) It could explain the neutralization reactions which do not involve any transfer of protons.

**Limitations:**

(i) This theory failed to explain the acidic and basic nature of general acids and bases.

(ii) This theory could not explain the general neutralization reactions involving the formation of salt and water.

(iii) Generally, the acid-base reactions are fast reactions. But the formation of a coordinate bond is a slow process.

(iv) This theory cannot explain the relative strengths of acids and bases.

## Strength of Acids :

The concentration of hydronium ion, $H_3O^+$, accounts for the properties of acids. All acids release hydronium ions in water, as

$$HNO_3 + H_2O \rightarrow H_3O^+ + NO_3^-$$

Acids behave in certain ways because of the hydronium ion concentration. Vinegar and vitamin C form acid solutions that have small amounts of hydronium ion in solution. We say that these solutions are weak. However, the liquid in a car battery has large concentrations of hydronium ion. We say that this acid solution is strong.

Acid solutions with high concentrations of hydronium ion react vigorously with certain metals and can chemically burn your skin. Acids with low concentrations react slowly with these metals and some are even safe enough to eat or drink.

## Strength of Bases :

Just like acids, bases form ions in water:

Sodium hydroxide $\rightarrow$ Sodium ion + Hydroxide ion

Since ions are formed, bases are electrolytes. We can also categorize basic solutions as strong or weak electrolytes depending on how concentrated the ions are. Notice that both bases release hydroxide ions, $OH^-$, when they dissolve. The behaviour of a base depends on its hydroxide ion concentration. Concentrated bases are dangerous whereas dilute bases are not.

## NEUTRALIZATION :

What happens when an acid and base are mixed together? The hydronium ions react with the hydroxide ions to make water:

Hydronium ion + Hydroxide ion $\longrightarrow$ 2 molecules of water

This reaction is called neutralization. After neutralization, the solution no longer has high concentrations of either ion. Thus, it no longer has acidic or basic properties. Such solutions are said to be neutral.

## IONISATION OF WATER

Pure water undergoes self ionisation:

$$H_2O(\ell) + H_2O(\ell) \rightleftharpoons H_3O^+ + OH^-$$

**By Law of Chemical Equilibrium :**

$$K = \frac{[H_3O^+][OH^-]}{[H_2O]^2}$$

(a) For Neutral Solution $[H_3O^+] = 10^{-7}$ M

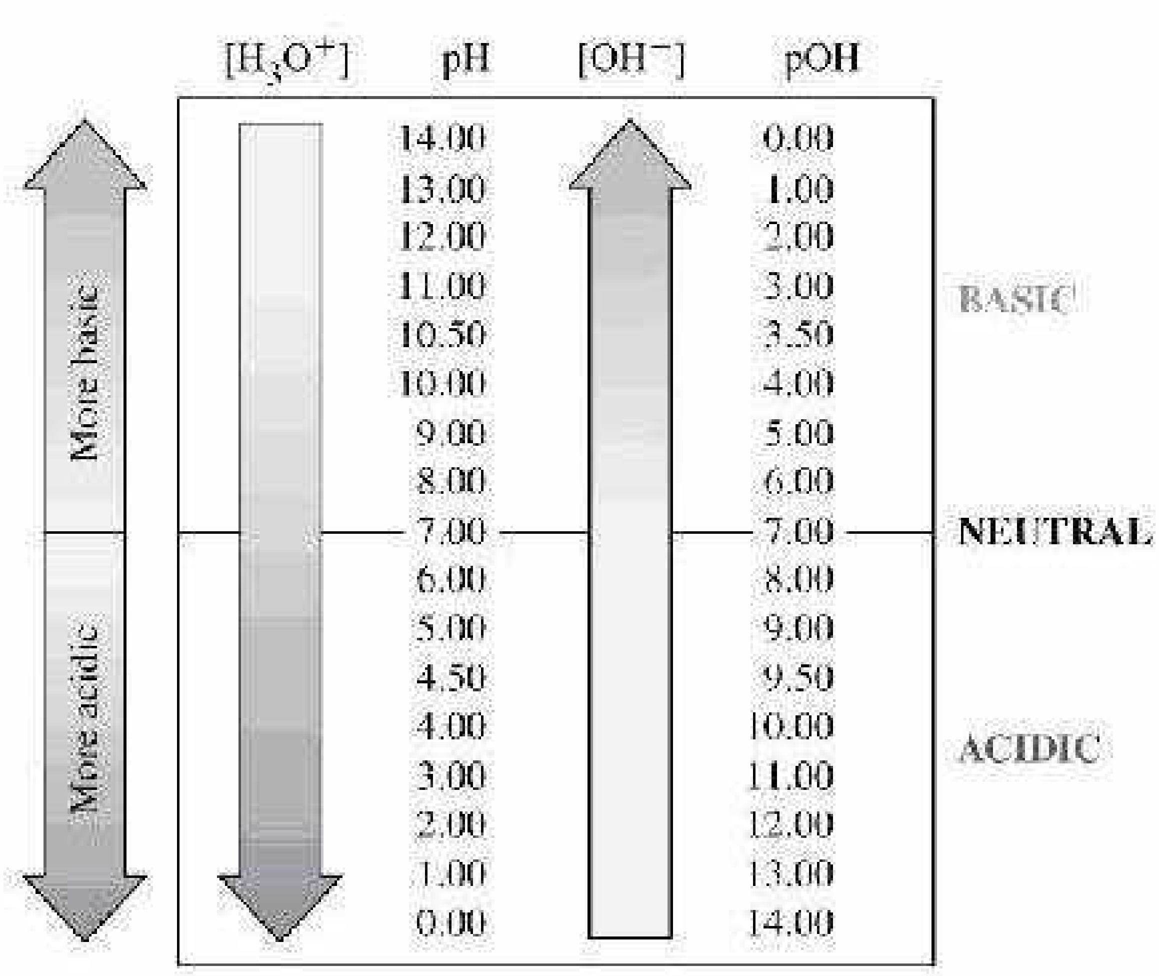
(b) For Acidic Solution $[H_3O^+] > 10^{-7}$ M

(c) For Basic Solution $[H_3O^+] < 10^{-7}$ M

## THE PH SCALE :

The term pH stands for "potential" of "Hydrogen". It is the amount of hydrogen ions in a particular solution. The more ions, the more acid the solution. The fewer ions the more alkaline (base) the solution. Sorenson defined pH as the negative logarithm (to the base 10) of the hydrogen ion concentration expressed in moles per litre pH = – log $[H^+]$, where $[H^+]$ is the hydrogen ion concentration in Moles/Litre

Remember that sometimes $H_3O^+$ is written, so pH = – log $[H_3O^+]$ means the same thing. The pH scale runs from 0 to 14. For acids, pH < 7. For bases, pH > 7. For neutral substances, pH = 7.



**Approximate pH values of some common substance :**

| Substance | pH value | Subatance | pH value |
|---|---|---|---|
| Hydrochloric acid | 1.0 | Bread | 5.5 |
| Sulphuric acid | 1.2 | Potatoes | 5.8 |
| Gastric juice | 2.0 | Rain water | 6.2 |
| Lemon | 2.3 | Milk | 6.6 |
| Vinegar (Acetic acid) | 2.8 | Pure water | 7.0 |
| Soft drink | 3.0 | Egg | 7.8 |
| Apple | 3.1 | Sea water | 8.5 |
| Grape | 3.1 | Ammonium hydroxide | 11.1 |
| Tomato | 4.2 | Sodium hydroxide | 13.0 |
| Banana | 4.6 | | |
| Battery acid, 1M sulphuric acid | 0 | Stomach acid, 0.1 M hydrochloric acid | 1 |
| Baking soda, $NaHCO_3$ | 8 | Washing soda, $Na_2CO_3$ | 9 |
| Milk of magnesia, $Mg(OH)_2$ | 10 | Aqueous household ammonia, $NH_3$ | 11 |
| Limewater, $Ca(OH)_2$ | 12 | Drano, 0.1 M NaOH | 13 |
| Drano, 1.0 M NaOH | 14 | | |

## HYDROLYSIS OF SALTS

The ions produced when salt interact with water molecules and thereby produce either an acidic or an alkaline solution. This process is called salt hydrolysis. Thus hydrolysis is the interaction of anion or cation of the salt with water to produce an acidic or basic solution.

The pH of the solution gets affected by this interaction. The cations of strong bases (such as $Na^+$, $K^+$, $Rb^+$, $Ca^{2+}$, $Ba^{2+}$, etc.) do not hydrolyze and therefore, the solutions of salts formed by strong acids and strong bases are neutral and their pH is 7. On the other hand, the solutions of the salts formed by strong acids and weak bases are acidic *i.e.*, their pH is less than 7. While the solutions of strong bases and weak acids are basic and their pH is greater than 7.

## BUFFER SOLUTIONS :

Generally pH of an aqueous solution decreases on addition of a small amount of HCl because of the increase in the concentration of $H^+$ ions. On the other hand, if a small amount of NaOH is added, the pH of the solution increases. However, there are some solutions which resist the change in pH on addition of small amount of strong acid or alkali. Such solutions are called buffer solutions. For example, solution of ammonium acetate, blood, a equimolar mixture of $NH_4OH + NH_4Cl$, $CH_3COOH + CH_3COONa$, etc. i.e., Buffer solutions

**Types of buffer solution :**

**(a)** **Acidic buffer :** Acidic buffer solution contains equimolar quantities of a weak acid and its salt with strong base. For example, acetic acid ($CH_3COOH$) and sodium acetate ($CH_3COONa$). A solution containing equimolar quantities of acetic acid and sodium acetate maintains its pH value around 4.74.

**(b)** **Basic buffer :** Basic buffer solution contains equimolar quantities of a weak base and its salt with a strong acid. For example, ammonium hydroxide ($NH_4OH$) and ammonium chloride ($NH_4Cl$). A solution containing equimolar quantities of ammonium hydroxide and ammonium chloride maintains its pH value around 9.25.

**Important applications of buffer solution**

Many important industrial processes as well as biological processes make use of buffer solution e.g.,

(a) In electroplating

(b) In dyes, manufacturing of leather and photographic material

(c) Calibration of pH meter

(d) In analytical chemistry

(e) As bacteriological culture medium

(f) pH of human blood is 7.4 which is not altered inspite of various acid and base producing reactions going on in our body due to concumption of different variety of foods and spices.

## ACID, BASES AND SALTS

## ACID

The word "acid" comes from the Latin acidus, meaning "sour" or "tart," since water solutions of acids have a sour or tart taste. Lemon, grapefruit, and limes taste sour because they contain citric acid and ascorbic acid (vitamin C). Another common acid is vinegar, which is the sour liquid produced when apple cider, grape juice, or other plant juices ferment beyond the formation of alcohol. Vinegar is a 5 percent water solution of acetic acid.

**Properties of Acids :**

**(1)** **Taste :** Acids are generally sour in taste. Sour test is a property common to compounds classified as acids.

**(2)** **Change of colours with indicators :**

| Indicator | Change of colour | |
|---|---|---|
| | From | to |
| Litmus | Blue | Red |
| Methyl orange | Orange or yellow | Pink |
| Phenolphthalein | Deep pink | colourless |

(3) **Corrosive action** → The common man i.e. the man in the street connects the term acid with an idea of a corrosive 'burning liquid', This is because two of the commonest acids sulphuric acid and nitric acid are actually corrosive liquids.

**Classification of Acids :**

(1) **Classification based on the Source :**

(i) **Organic acids :** Acids obtained from plants material and animals are called organic acids. e.g citric acid (oranges & lemons), Acetic acid (Vinegar), oleic acid (olive oil) etc.

(ii) **Mineral acids :** Acids obtained from minerals are called mineral or inorganic acids. They do not contain carbon. eg $H_2SO_4$, HCl, $HNO_3$ etc.

(2) **Classification based on the presence of oxygen**

(i) **Oxy-acids :**

Oxy-acids are those, which contain oxygen in their composition.

Example, sulphuric acid ($H_2SO_4$), Oxalic acid ($H_2C_2O_4$), Nitric acid ($HNO_3$), Acetic acid ($CH_3COOH$)

(ii) **Hydracids :**

Acids, which contain hydrogen together with other elements and not any oxygen in their composition, are called Hydracids. Example, Hydrochloric and (HCl), Hydroiodic acid (HI), Hydrobromic acid (HBr)

(3) **Classification Based on the Strength of the acid**

(i) **Strong acid**

An acid, which dissociates completely or almost completely in water, is classified as a strong acid.

$$HCl\,(aq) \rightleftharpoons H^+_{(aq)} + Cl^-_{(aq)}$$

(ii) **Weak acid -** An acid which dissociates negligibly or almost incompletely in water is classified as weak acid.

Examples- acetic acid, formic acid, carbonic acid etc.

$$\underset{\text{Acetic acid}}{CH_3COOH(aq)} \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$$

(4) **Classification Based on the Concentration of the acid.**

(i) **Concentrated acid :** An acid that has a relatively high percentage of the acid dissolved in the aqueous solution is classified as a concentrated acid Example concentrated hydrochloric acid, sulphuric acid, nitric acid, acetic acid etc.

(ii) **Dilute acid :** An acid, which has a relatively low percentage of the acid dissolved in the aqueous solution, is classified as a dilute acid Example dilute hydrochloric acid, sulphuric acid, nitric acid, acetic acid etc.

(5) **Classification based on the basicity of the acid :**

(i) **Monobasic acid :**

monobasic acids have only one hydrogen ion, they form only one kind of salt.

Hydrochloric acid: HCl, Hydroiodic acid: HI, Nitric acid: $HNO_3$, Acetic acid: $CH_3COOH$, Hypochlorous acid: HOCl, Formic acid: HCOOH, Hydrobromic acid: HBr etc.

(ii) **Dibasic acid**

When an acid can combine with 2 hydroxyl groups it known as a dibasic acid. Such acids dissociate in 2 steps in water.

**Example :** Sulphuric acid: $H_2SO_4$, Sulphurous acid: $H_2SO_3$, Carbonic acid: $H_2CO_3$, Oxalic acid: $(COOH)_2$

(iii) **Tribasic acids :**

The tribasic acids can combine with three hydroxyl groups. These acids must have three replaceable hydrogen ions, and as such they can form three types of salts Example, phosphoric acid ($H_3PO_4$).

## BASE

base is a compound, which on dissolving in water yields hydroxyl ions ($OH^-$) as the only negative ions. The characteristic property of a base is due to the presence of these negative hydroxyl ions. A base may be an oxide or a hydroxide of a metal. If a base is soluble in water, it dissociates to form a metal ion and the only negative hydroxyl ion.

## Alkali

All alkalis are bases that dissociate in water to yield hydroxyl ion ($OH^-$) as the only negative ions. Sodium hydroxide, potassium hydroxide, calcium hydroxide and ammonium hydroxide are the common alkalis.

**Properties of Bases:**

(1) **Taste :** Bases are bitter to taste. If you have ever gotten soap in your mouth, you have noted a bitter taste.

(2) **Feel :** They are soapy and slippery to touch.

(3) **Electrical Conductivity :** Some bases are good conductors of electricity. For Example, soluble bases like sodium hydroxide and potassium hydroxide are used as electrolytes.

(4) **Corrosive Action :** Strong alkalis like sodium hydroxide and potassium hydroxide are highly corrosive or caustic in nature. Sodium hydroxide and potassium hydroxide are commonly called caustic soda and caustic potash respectively. Organic tissues like skin, etc. get completely corroded by these two alkalis. However, the other alkalis are only mildly corrosive.

## Classification of Bases

Bases can be classified in various ways, depending on the following factors:

(1) **Classification based on the strength of the Base**

(i) **Strong base :**

A base that dissociates completely or almost completely in water is classified as a strong base. The greater the number of hydroxyl ions the base produces, the stronger is the base.

Example: $NaOH \rightleftharpoons Na^+ + OH^-$

(ii) **Weak base :**

A base that dissociates in water only partially is known as a weak base.

Example: $NH_4OH(aq) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

(2) **Classification based on the concentration of the base**

(i) **Concentrated base :** A base that has a relatively high percentage of the base in the aqueous solution is classified as a concentrated base Example concentrated sodium hydroxide, potassium hydroxide, ammonium hydroxide etc.

**(ii) Dilute base :** A base, which has a relatively low percentage of the base dissolved in the aqueous solution, is classified as a dilute base. Example dilute sodium hydroxide, potassium hydroxide, ammonium hydroxide etc.

**(3) Classification based on the Acidity of Bases :**

Based on the acidity bases can be classified as

**(i) Monoacidic base :**

It is a base that has only one hydroxyl ion. It combines with only one hydrogen ion.

Example : Sodium hydroxide, Potassium hydroxide: KOH, Lithium hydroxide: LiOH, Ammonium hydroxide: $NH_4OH$.

**(ii) Diacidic base**

It is a base that has two hydroxyl groups and combines with two hydrogen ions.

Example : Iron (II) hydroxide: $Fe(OH)_2$, Magnesium hydroxide: $Mg(OH)_2$, Copper hydroxide: $Cu(OH)_2$, Zinc hydroxide : $Zn(OH)_2$, Lead hydroxide: $Pb(OH)_2$.

**(iii) Triacidic base**

A base that has three hydroxyl ions and can combine with three hydrogen ions, is known as a triacidic base. Example: Aluminium hydroxide

## INDICATOR ($H_2$)

A substance which gives different colour in acidic and basic media and helps to differentiate the two types is known as an **Indicator.**

Ä **Litmus** (a natural dye) is one of the most common and naturally available indicator. It is extracted from lichens (combination of alga and tungus). When this litmus is added to an acidic solution, it turns red and when added to a basic solution, it turns blue. It possess a purple colour in distilled water

Ä **Phenolphthalein** is a synthetic indicator. It turns colorless in acidic solutions and pink in basic solutions. If the concentration of indicator is particularly strong, it can appear purple.

Ä **Methyl orange** is also a synthetic indicator used more oftenly because of clear colour change. In a solution becoming less acidic, methyl orange moves from red to orange and finally to yellow with the reverse occuring for a solution

increasing in acidity.

**Universal indicators :** It is a mixture of indicators often sold readymade as solution which can indicate pH values, usually over a range of 3-11, by successive changes of colour

## SALT

A salt is an ionic compound which dissociates to yield a positive ion other than hydrogen ion $[H^+]$ and a negative ion other than hydroxide ion $[OH^-]$ Example : $NaCl \rightarrow Na^+ + Cl^-$ (fused/Aq. soln)

## Classification of Salts

**(i) Acidic Salt :** If a polybasic acid (Example, $H_2SO_4$, $H_3PO_4$, $H_2SO_3$ etc.) is neutralised partly by a base, the salt formed is acidic. In other words such salts are produced by the replacement of only a part of the acidic hydrogen of the polybasic acids by a metal.

$$H_2CO_3 + NaOH \longrightarrow NaHCO_3 + H_2O.$$

**(ii) Normal Salt :** In case the acid and base neutralise completely the salt formed is a normal salt. Normal salts are produced by the replacement of all replaceable hydrogen (s) present in the molecule of an acid by metal or $NH_4^+$ group.

$$\underset{\text{(Carbonic acid)}}{H_2CO_3} + 2NaOH \rightarrow \underset{\text{(Normal salt)}}{Na_2CO_3} + H_2O$$

**Examples of normal salts :**

**Normal Salts :** $KNO_3$ (potassium nitrate)

**Acid involved :** $HNO_3$

KCl (potassium chloride)

HCl

## Other types of salts

**(1) Basic Salts :** This type of salts are formed by incomplete neutralization of a base with an acid or by partial replacement of hydroxy radicals of a diacids or triacidic base with an acid radical.

**Examples :**

$Cu(OH)NO_3$ - Basic copper nitrate.

$$[Cu(OH)_2 + HNO_3 \longrightarrow Cu(OH)NO_3 + H_2O]$$

**(2) Double Salt** - Such a salt is formed by mixing saturated solution of two simple salts followed by crystallisation of the saturated solution.

**Example :**

$FeSO_4 (NH_4)_2 SO_4 6H_2O$ — Mohr's salt – it a is mixture of $FeSO_4$ (Simple salt) and $(NH_4)_2 SO_4$ (Simple salt)

**(3) Mixed Salts -** There is no general method for the formation of this type of salt.

**Examples :** Sodium potassium sulphate $NaKSO_4$ (two basic radicals, $Na^+$, $K^+$)

**(4) Complex salt** - Such a salt is formed by mixing saturated solution of simple salts followed by crystallisation of the solution similar to double salts.

**Example :** Potassium mercuric iodide - $K_2[HgI_4]$

Simple ion - $K^+$

Complex ion - $[HgI_4]^{2-}$

**5. Calcium oxide, Quick lime, CaO**

**Properties**

(i) It is a white amorphous solid.

(ii) Its m.p is 2870 K.

(iii) When exposed to air it absorbs $CO_2$ and moisture.

**Uses :**

(i) It is used in construction industry and is used as a building material

(ii) It is used in manufacture of calcium carbide ($CaC_2$) and bleaching powder ($CaOCl_2$)

(iii) It is used in purification of sugar

(iv) It is used in tanning industry

(v) It is used in drying of gases and alcohol

6. **Calcium hydroxide, $Ca(OH)_2$, slaked lime :**

**Preparation :** Slaked lime is obtained by adding water to calcium oxide, CaO (quick lime)

**Properties :** It is a white amorphous powder and is sparingly soluble in water.

**Uses:**

(i) Its suspension in water is known as *milk of lime* and is used in medicines.

(ii) Lime water is used as a test for carbon dioxide gas

7. **Calcium Carbonate, $CaCO_3$**

**Properties :** It is a white fluffy powder and is insoluble in water.

**Uses :** It is used in extraction of metals (Example iron.)

8. **Calcium Sulphate, $CaSO_4$**

**Properties :** Gypsum when heated to 390 K loses water to give $CaSO_4.\frac{1}{2}H_2O$ or $(CaSO_4)_2, H_2O$. This is known as plaster of Paris. When heated above 437 K, it becomes anhydrous $CaSO_4$. Anhydrous $CaSO_4$ is known as dead burnt plaster because it does not set like plaster of pairs when moistened with water.

9. **Plaster of Paris $(CaSO_4)_2, H_2O$ or $CaSO_4.\frac{1}{2}H_2O$**

**Uses of plaster of paris**

**Uses**

(i) On mixing with water it changes into plastic mass and solidifies due to dehydration. This is called setting of plaster of paris. During this process of setting, it undergoes a slight expansion (about 1%) thus it produces very sharp impressions of mould into which it is put. It is used for producing moulds for industries like pottery, ceramics, etc.

(ii) It is used for setting broken and fractured bones in the body.

(iii) It is used for making statues, models and other decorative material.

(iv) It is mixed with cement and so used in the building industry.

10. **Bleaching powder :** $CaOCl_2$

(i) It is a yellow white solid having a strong smell of chlorine

(ii) It is soluble in water. The lime present is always left behind as an insoluble salt.

(iii) It has greater available chlorine than sodium hypochlorite, NaClO (liquid bleach). It contains about 36% of available chlorine.

(i) It is widely used as a bleaching agent for bleaching clothes.

(ii) It is used for disinfection of drinking water or swimming pool water. For use in outdoor swimming pools, $CaOCl_2$ can be used as a sanitizer in combination, with cyanuric acid stabilizer. Two stabilizer will reduce the loss of chlorine because of u.v. radiation.

(iii) It is also used for bleaching cotton and linen.

(iv) It is used in manufacture of chloroform ($CHCl_3$)

(v) It is used as an oxidising agent

(vi) It is also used in bathroom cleaners, household disinfetant sprays, mass and algae removers, and weed killers.

## CHEMICAL BONDING

Thus, a chemical bond is defined as a force that acts between two or more atoms to hold them together as a stable molecule.

## TYPES OF BONDS

### Ionic Bonds

The atomic bonds which are formed by the transfer of electrons between the constituent atoms of a compound are known as ionic bonds (or electrovalent bonds). The compound thus formed is called an ionic or electrovalent compound. Magnesium Oxide (MgO), Potassium Chloride (KCl), Iron Oxide (FeO) are some of the examples of ionic compounds.

**Properties of Ionic Compounds**

(i) Ionic compounds are usually solid and crystalline in nature.

(ii) Because of availability of ions in aqueous or molten state, such compounds are good conductors of heat and electricity.

(iii) Due to their crystalline nature, such compounds also have high melting points.

(iv) They are non-conductors of electricity when solid no free ions all locked together in a crystal.

### Covalent Bonds

Atomic bond formed by sharing of electrons is called a covalent bond. Compounds that are formed due to covalent bonding of atoms are called covalent compounds. Covalent bonds are generally formed between non-metals. Hydrogen gas (H2), Nitrogen gas ($N_2$), $H_2O$. Oxygen gas ($O_2$), Hydrochloric acid (HCl) are some of the examples of covalent bonded compounds.

**Properties of covalent compounds**

(i) The covalent compounds do not exist as ions but they exist as molecules.

(ii) The melting and boiling points of covalent compounds are generally low.

(iii) Covalent compounds are generally insoluble or less soluble in water and in other polar solvents.

(iv) These are poor conductors of electricity in the fused or dissolved state.

(v) Since the covalent bond is localized in between the nuclei of atoms, it is directional in nature.

## CO-ORDINATE BOND

A covalent bond is formed by two atoms sharing a pair of electrons. The atom are hold together because the electron pair is attached by both of the nuclei. In the formating of a simple covalent bond, each atom supplies one electron to the bond but that doesn't have to be in the case of co-ordinate bond (also called as dative covalent bond) is a covalent bond (a shared pair of electron) in which both electrons come from the same atom.

## Bond order

It is defined as the number of covalent bonds by which the two atoms are joined in the molecule. It is calculated as given below.

$$\text{Bond order} = \frac{1}{2}\begin{bmatrix} \text{Number of electrons} & & \text{Number of electrons} \\ \text{in bonding M.O.} & - & \text{in antibonding M.O.} \\ \text{i.e.} N_b & & \text{i.e.} N_a \end{bmatrix}$$

$$\therefore \quad \text{Bond order} = \frac{1}{2}[N_b - N_a]$$

## CHEMICAL IN EVERYDAY LIFE

### Pesticides

The chemical substances used to kill or stop the growth of unwanted organisms are called pesticides. They are further classified as

(a) **Insecticides :** They are used to kill insects. The most common insecticides are
  (i) D.D.T.
  (ii) BHC, 666, gamexane
  (iii) Baygon
  (iv) Sevin, Carbaryl
  (v) Parathion
  (vi) Methoxychlor
  (vii) Aldrin

(b) **Herbicides :** They are used to kill weeds e.g.
  (i) 2, 4-dichlorophenoxy acetic acid (2, 4 – D)
  (ii) Triazines
  (iii) NaClO3
  Sodium cholrate
  (iv) Na3AsO3
  Sodium arsenite

(c) **Fungicides :** They are used to stop or kill fungus e.g.
  (i) CuSO4
  copper sulphate
  (ii) 2, 4, 6-trichlorophenol

(d) **Rodenticides :** They are used to kill rodents e.g.
  (i) Zn3P2
  Zinc phosphide
  (ii) Tl.SO4
  Thalium sulphate
  (iii) ClCH2COONa
  Sodium monochloroacetate

### Fertilizers

As you know that after repeated cultivation soil become less productive and yield of crop is less and poor. This is due to deficiency of essential primary nutrients like N, P, K required by plants for healthy growth. Thus in order to make up this deficiency certain elements in the form of there compounds are added to soil. Fertilizers are chemical compounds which when added to the soil increase their fertility and directly supply the need of essential elements [N, P, K] of primary importance.

### Classification of Fertilizers

Chemical fertilizers are broadly classified into the following three types :

(i) **Nitrogenous fertilizers :** Ammonium sulphate, urea etc.

(ii) **Phosphatic fertilizers :** Superphosphate, ammonium phosphate.

(iii) **Potash fertilizers :** Potassium chloride, potassium sulphate. Fertilizers are referred to as N.P.K. fertilizers i.e. nitrogenous, phosphatic and potassium fertilizers.
(N = nitrogen, P = phosphorus, K = potassium)
Micro - nutrients are also added to the soil in form of fertilizers. These are called secondary fertilizers.
**Characteristics of fertilizer :**
1. Must possess essential elements required by the plant
2. Should be water soluble
3. Should be less costly
4. Should be easy to transport
5. Should be able to maintain pH of soil between 5 to 10.

### Eutrofication

When excess of fertilizers are added to soil they are carried by water to various water bodies like pond, lake etc. This excess of nutrients in water bodies results into formation of algae on surface of water in large quantities. Now this algae consume large quantity of oxygen dissolved in water result into deficiency of oxygen in water to support aquatic life. This phenomenon is called Eutrophication.

## DRUGS

For the treatment of diseases in Aryuvedic, Unani or the modern allopathic system, the chemical compounds are used in the forms of drugs. Chemical substances used for curing, diagonising and treatment of diseases are called drugs. The branch of chemistry which deals with the treatment of diseases using suitable chemicals is known as chemotherapy. Every drug has a particular therapeutic range below which it is not effective and above which it could be harmful.

Requirements of a Substances to Act Like a Drug

(1) Its target should be localised at the site of action.
(2) It should not make host tissue resistant against the effect of drug after use for some time.
(3) It should not produce any side effects of long term use.
(4) It should be effective with in therapeutic range.

### Designing a Drug

Four important factors which must be taken into consideration while designing a drug are :

(i) **Drug target:** The biomolecules or biological macro-molecules such as carbohydrates, proteins, nucleic acids and lipids are called drug targets. Since drugs usually interact with these drug targets.

(ii) **Drug metabolism:** A drug travels through the body in order to reach its molecular target. Therefore, the design of the drug should be such that it reaches the target without being metabolized in between.

(iii) **Physiological function of the drug target:** A knowledge of the physiological function of the drug target helps us in choosing a compound, which can interact with the target and is likely to be therapeutically active.

(iv) **Mechanism of drug action:** A knowledge of the mechanism of action of the drug and metabolic pathways in the biological systems helps us in improving the quality of the drug and minimising the side effects.