REVISE NEET IN 9 HOURS

Supriya Kadam

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PHYSICS

Units & Measurements

If Q is the quantity, n is the numerical value and u is the unit then;

$Q = nu$

$n_1u_1 = n_2u_2$ (bigger the unit, smaller is the value)

Systems of Measurement

(a) **C.G.S** (Centimeter-Gram-Second) system.

(b**)** **F.P.S.** (Foot-Pound-Second) system.

(c) **M.K.S.** (Meter-Kilogram--Second) system.

(d) **M.K.S.A.** (Meter-Kilogram-Second-Ampere) unit.

Fundamental Units

These units are independent of other units, thus called as fundamental units.

PHYSICAL QUANTITY	SYMBOL	DIMENSION	MEASUREMENT UNIT
Length	S	L	Meter – m
Mass	M	M	Kilogram – kg
Time	T	T	Second – s
Electric charge	I	A	Current – A
luminous intensity	I	C	Candela – Cd
Temperature	T	K	Kelvin - K
Angle **Solid Angle**	Θ ω	None None	Radian - rad Steradian

- **Dimensional Formula:-**

Dimensional formula of a physical quantity is the formula which tells us how and which of the fundamental units have been used for the measurement of that quantity.

- **How to write dimensions of physical quantities:-**

(a) Write the formula for that quantity, with the quantity on L.H.S. of the equation.

(b) Convert all the quantities on R.H.S. into the fundamental quantities mass, length and time.

(c) Substitute M, L and T for mass, length and time respectively.

(d) Collect terms of M,L and T and find their resultant powers (a,b,c) which give the dimensions of the quantity in mass, length and time respectively.

Uses of Dimensional Analysis :

1. To check the correctness of an equation
2. To find the conversion factor
3. To find the dimensions by comparison method

Significant Figures

There are three rules on determining how many significant figures are in a number:

1. Non-zero digits are always significant.
2. Any zeros between two significant digits are significant.
3. A final zero or trailing zeros in the decimal portion ONLY are significant.
4. If the last digit to be rounded off is 5 or greater than 5 , then the last significant digit is increased by 1 .

Order of Magnitude

Order of Magnitude is the power to which 10 is raised to ; to indicate the size of the quantity .

To find out order of magnitude :

1. The number should be in units place . e.g. 2.15×10^4has the order 4 .
2. If the number in units place is 5 or greater than 5 , then increase the order by 1 .
   e.g. 7.4×10^6 has the order 7 .

Types of Errors

Personal Error

Error occurring due to human errors.

Random Error

Error occurring due to random changes in the environment of the experiment.

Systematic Error

Error occurring due to a constant error in the readings of instrument. This is caused due to the faulty calibration of instrument.

Instrumental Error

Error occurring due to faulty construction of instrument.

Error Analysis

Mean Value: Average of All readings

Absolute Error : Individual Reading - Mean Value

Mean Absolute Error : Average of all Absolute values

Relative Error : Mean Absolute Error / Mean Value

Percentage Error : Relative Error x 100

Rules for Error Analysis :

1) If dx is the error in x , then Error in x^n is n dx.

2) If dx is the error in x and dy is the error in y , then the Error in x + y , x – y , xy , x/y , is dx + dy

Scalars & Vectors

Scalars and Vectors

Scalar Quantities can be denoted by a number and a unit, i.e. Magnitude. Vector Quantities are denoted by magnitude and direction.

Tensor Quantities

Tensor Quantities are those quantities whose magnitude changes based upon the direction in which you measure it. (e.g. Moment of Inertia)

Types of Vectors

Equal Vectors: Vectors having same direction and magnitude.

Parallel Vectors: Vectors having same direction.

Anti-Parallel Vectors: Vectors having opposite directions.

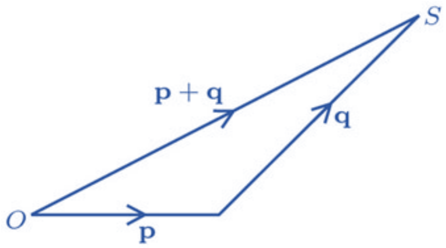
Position Vector: Vector drawn from the origin to a point.

Zero Vector: Vector of magnitude zero.

Free Vector: Vector which can be moved through space, without changing its direction.

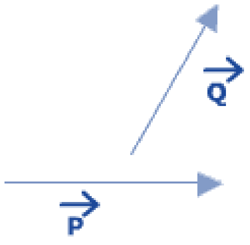
Triangle Law

If two vectors exist such that their directions are taken in order, then their resultant is equal to the third of the triangle formed; & the direction is from head of first to tail of second.

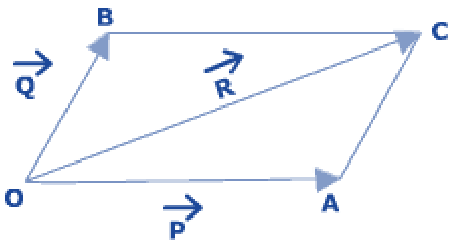


Parallelogram Law

The parallelogram law of Vectors states that if two vectors originate or meet at a common point, then their resultant is given by the diagonal of parallelogram formed.



(a)



(b)

Magnitude: $\bar{R} = \sqrt{\bar{P}^2 + \bar{Q}^2 + 2\bar{P}\bar{Q}cos\theta}$

Direction: $\theta = tan^{-1}\frac{Qsin\theta}{P+Qcos\theta}$

Scalar Multiplication

Scalar multiplication refers to the multiplication of a vector with a number.

In Scalar Multiplication, the number is multiplied to all components of the vector. Thus, scalar multiplication does not change the direction of the vector, it only affects the magnitude.

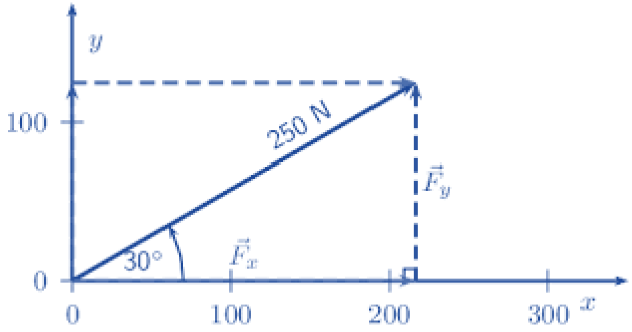
Resolution of Vectors

for co-ordinate system, we know that:

x = rcosθ y = rsinθ

for 3-d coordinate system, we resolve using direction cosines :

r = acosα + acosβ + acosγ



Scalar Product

a.b = abcosθ

Scalar Product gives us a Scalar result.

Vector Product

axb = absinθ

Vector product gives us a vector result.

Unit Vector

A unit vector has unit magnitude and any direction. If we divide a vector by its magnitude, we get an unit vector.

Kinematics & Projectile Motion

- The average speed v_{av} and average velocity $\vec{V}_{av}$ of a body during a time interval is defined as,

  V_{avg} = *Total Distance / Total Time*

  $$\vec{V}_{av} = \text{average velocity}$$
  $$= \frac{\Delta\vec{r}}{\Delta t}$$

- Instantaneous speed and velocity are defined at a particular instant and are given by

  $$v = \lim_{\Delta t \to 0} \frac{\Delta s}{\Delta t} = \frac{ds}{dt} \text{ and } \vec{V} = \lim_{\Delta t \to 0} \frac{\Delta\vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}$$

Note:

(a) A change in either speed or direction of motion results in a change in velocity

(b) A particle which completes one revolution, along a circular path, with uniform speed is said to possess zero velocity and non-zero speed.

(c) It is not possible for a particle to possess zero speed with a non-zero velocity.

- Average acceleration is defined as the change in velocity $\Delta\vec{V}$ over a time interval *t*.

  $$\vec{a}_{av} = \frac{\Delta\vec{V}}{\Delta t}$$

The instantaneous acceleration of a particle is the rate at which its velocity is changing at that instant.

$$\vec{a}_{ins} = \lim_{\Delta t \to 0} \frac{\Delta\vec{V}}{\Delta t} = \frac{d\vec{V}}{dt}$$

Kinematical Equations:

- The three equations of motion for an object with constant acceleration are given below.

  (a) $v = u + at$

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

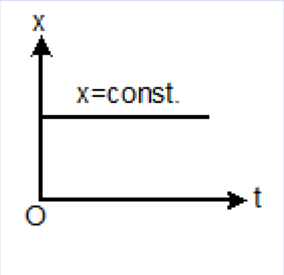
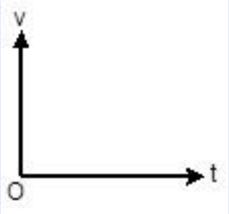
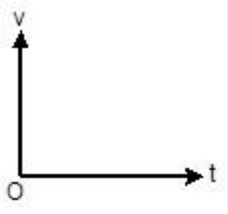
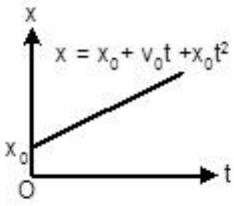
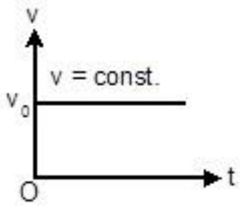
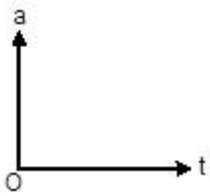
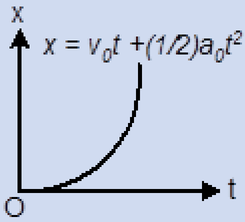
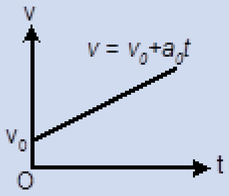
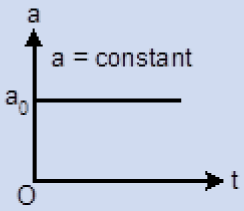
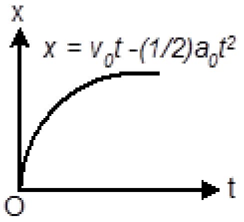
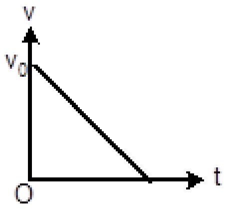
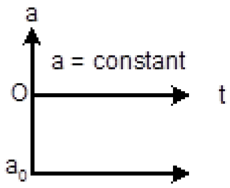
  (c) $v^2 = u^2 + 2as$

Here *u* is the initial velocity, *v* is the final velocity, *a* is the acceleration, *s* is the displacement travelled by the body and *t* is the time.

Note: Take '+ve' sign for a when the body accelerates and takes '–ve' sign when the body decelerates.

- The displacement by the body in n^{th} second is given by, $s_n = u + \frac{a}{2}(2n - 1)$

All Graphs from Kinematics

	Displacement(x)	Velocity (v)	Acceleration (a)
(a) At rest			
(b) Motion with constant velocity			
(c) Motion with constant acceleration			
(d) Motion with constant deceleration			

Relative Velocity

Relative Velocity is the velocity of a moving body with respect to another moving body

1) Bodies moving in the same direction; a - b
2) Bodies moving in opposite directions; a + b
3) Bodies moving and inclined at an angle θ to each other, then:

$$Relative\ Velocity = \sqrt{a^2 + b^2 - 2abcos\theta}$$

Motion in Straight Line: Moves along one co-ordinate axis

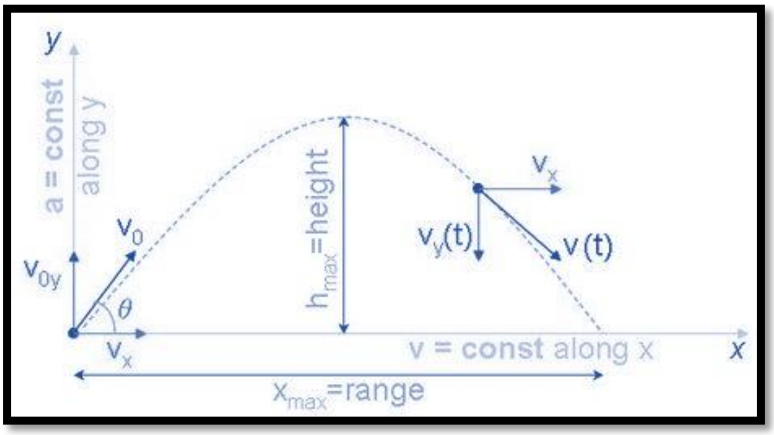
Motion in a Plane: Moves in a plane with 2 d co-ordinate axis.

Motion in Space: Moves in Space with 3 d co-ordinate axis.

Projectile Motion, Motion in 2 Dimensions / Motion in a Plane

Projectile motion in a plane:

If a particle having initial speed u is projected at an angle θ (angle of projection) with x-axis, then,



Equation of trajectory, $y = xtan\alpha - (\frac{gx^2}{2u^2cos2\alpha})$

Time of Flight, $T = \frac{2u\ sin\alpha}{g}$

Horizontal Range,$R = \frac{u^2 sin2\alpha}{g}$

Maximum Height, $H = \frac{u^2 sin2\alpha}{2g}$

Motion on an inclined plane:

(i) Perpendicular vector: At the top of the inclined plane ($t = 0$, $u = 0$ and $a = g \sin \theta$), the equation of motion will be,

(a) $v = (g \sin\theta)t$

(b) $s = ½ (g \sin\theta)\, t^2$

(c) $v^2 = 2(g \sin\theta)\, s$

(ii) If time taken by the body to reach the bottom is t, then $s = ½ (g \sin\vartheta)\, t^2$

$t = \surd(2s/g \sin\vartheta)$

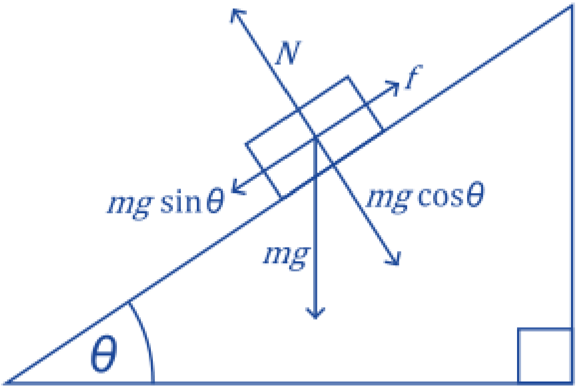
But $\sin\vartheta = h/s$ or $s = h/\sin\vartheta$

So, $t = (1/\sin\vartheta)\, \surd(2h/g)$

(iii) The velocity of the body at the bottom

$v = g(\sin\vartheta)t$

$= \surd 2gh$



Force

Newton's Laws of Motion

First Law of Motion

An object continues to be in its state of rest or uniform motion, until and unless an external unbalanced force acts on it.

Second Law of Motion

Force acting on an object is directly proportional to the rate of change of Momentum with respect to time.

Third Law of Motion

For every action, there is an equal and opposite reaction. This reaction is limiting and acts in opposite direction as long as it is capable of withstanding the force.

Force

Force = Mass x Acceleration

Forces in Nature

Gravitational Force

Force of attraction between two bodies having mass.

Electromagnetic Force

Forces involved in electric and magnetic fields.

Strong Nuclear Force:

A nucleus contains protons and neutrons. Protons being positively charged exert repulsive force on each other. But, this force is not enough to break the nucleus. This is because there exists a strong interaction inside the nucleus. This is called as strong nuclear force.

Weak Nuclear Force:

Forces associated with radioactive reactions are called as Weak Nuclear Forces.

Law of Conservation of Momentum

The law of conservation of momentum states that the total momentum of a system of objects is always conserved.

Impulse is the amount of force acting on a body in given time. Impulse and Momentum have the same dimensions.

$$Impulse = J = F.t$$

Frame of Reference

A Frame of reference is a fixed co-ordinate system, with respect to which the position and motion of an object is determined.

Inertial

Inertial frame of reference is a frame of reference in which Newton's First Law of Motion holds good. i.e. it is an unaccelerated frame of reference.

Non-Inertial

Non-Inertial Frame of reference is a frame of reference in which Newton's First Law of Motion does not hold good. i.e. It is an accelerated frame of reference. Since it is an accelerated frame of reference, even if no force is acting on the object, the object will be set in motion . e.g. A person sitting in train.

Conservative and Non Conservative Force

The Forces that conserve Total Energy, Kinetic Energy and Momentum are called as **Conservative Forces.**

The Forces that conserve Total Energy and Momentum but not Kinetic Energy are called **Non Conservative Forces**.

Moment of Force

Moment of Force = Force x Moment arm

Moment Arm is the distance through which the Force is acting.

Couple & Torque

Torque = Force x Distance between the two forces.

Centre of Mass

The fixed point of an object at which the entire mass of the object is supposed to be concentrated is called Centre of Mass.

$$Centre\ of\ Mass\ = \frac{m_1r_1\ +\ m_2r_2\ +\ m_3r_3 + \ldots + m_nr_n}{m_1 + m_2 + m_3 + \cdots + m_n}$$

Centre of Gravity

The fixed point through which the entire weight of the object is supposed to act in the downward direction is called as Centre of Gravity.

Conditions of Equilibrium of Forces

The resultant force should be 0; i.e. it should not produce acceleration. Thus, the vector sum of all forces acting on the body should be 0.

If the Forces in Equilibrium prevent rectilinear motion, it is called as translational equilibrium. If the forces in equilibrium prevent rotational motion, it is called rotational equilibrium.

Important for solving Problems:

Apparent weight of a man inside a lift:

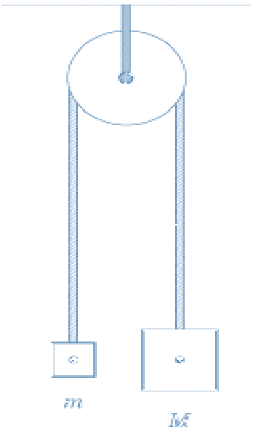
(a) The lift possesses zero acceleration: **W = mg**

(b) The lift moving upward with an acceleration a: **W = mg + ma**

(c) The lift moving downward with an acceleration a: **W = mg – ma**

Connected motion (Pulley problem):

(a) Driven body moving vertically:

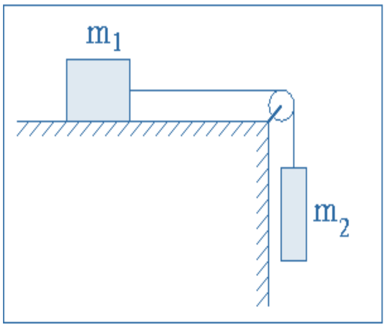


Acceleration of the system, $a\ =\ (M - m/M + m)\ g$

Tension in the string, $T\ =\ (2Mm/M + m)\ g$

The force on the pulley, $F\ =\ (4Mm/M + m)\ g$

(b) Driven body moving horizontally:



Acceleration of the system, $a = \left(\frac{Mm}{M+m}\right) g$

Tension in the string, $T = \left(\frac{Mm}{M+m}\right) g$

The force on the pulley, $F = \sqrt{\left[\frac{2(Mm)}{M+m}\right]} g$

Work, Energy & Power

Work: Work done W is defined as the dot product of force F and displacement s.

Work = F.s = Fs cos θ

Here θ is the angle between Force and displacement.

Work done by a variable force:

If applied force F is not a constant force, then work done by this force in moving the body from position A to B will be,

$$W = \int_a^b F \, . ds$$

Here ds is the small displacement.

Units: The unit of work done in S.I is joule (J) and in C.G.S system is erg.

1J = 1 Nm | 1 erg = 1 dyn.cm

1J = 10^7 erg

Power:

The rate at which work is done is called power and is defined as,

P = W/t = F.s/v = F.v

Here s is the distance and v is the speed.

Instantaneous power in terms of mechanical energy: $P = \frac{dE}{dt}$

Units: The unit of power in S.I system is J/s (watt) and in C.G.S system is erg/s.

Energy

Energy is the ability of the body to do some work. The unit of energy is same as that of work.

Kinetic Energy (KE): It is defined as,

$$KE = \frac{1}{2} mv^2$$

Here m is the mass of the body and v is the speed of the body.

Potential Energy (U): Potential energy of a body is defined as,

$$U = mgh$$

Relation between Kinetic Energy (K) and momentum (p):

$$K = \frac{p^2}{2m}$$

Work-Energy Theorem:

It states that work done on the body or by the body is equal to the net change in its Kinetic Energy.

For constant force,

$$W = \frac{1}{2}mv^2 - \frac{1}{2} mu^2$$

$$= Final\ K.E - Initial\ K.E$$

Law of conservation of Energy:

It states that, “Energy can neither be created nor destroyed. It can be converted from one form to another. The sum of total energy, in this universe, is always same”.

The sum of the kinetic and potential energies of an object is called mechanical energy. So, E = K+U

In accordance to law of conservation of energy, the total mechanical energy of the system always remains constant.

Coefficient of restitution (e):

It is defined as the ratio between magnitude of impulse during period of restitution to that during period of deformation.

$$e = \frac{relative\ velocity\ after\ collision}{relative\ velocity\ before\ collision}$$

$$e = \frac{v_2 - v_1}{u_1 - u_2}$$

Case (i) For **perfectly elastic collision**, e = 1. Thus, v2 – v1 = u1 – u2. This signifies the relative velocities of two bodies before and after collision are same.

Case (ii) For **inelastic collision**, e<1. Thus, v2 – v1 < u1 – u2. This signifies, the value of e shall depend upon the extent of loss of kinetic energy during collision.

Case (iii) For **perfectly inelastic collision**, e = 0. Thus, v2 – v1 =0, or v2 = v1. This signifies the two bodies shall move together with same velocity. Therefore, there shall be no separation between them.

Elastic collision: In an elastic collision, both the momentum and kinetic energy conserved.

Elastic collision in One Dimension:

After collision, the velocity of two body will be,

$$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) u_1 + \left(\frac{2m_2}{m_1 + m_2}\right) u_2$$

and

$$v_2 = \left(\frac{m_2 - m_1}{m_1 + m_2}\right) u_2 + \left(\frac{2m_1}{m_1 + m_2}\right) u_1$$

Friction in Solids

Types of Friction

Static Friction: Friction acting on an object so as to keep it static.

Kinetic Friction: Friction acting on a moving object so as to reduce its velocity. The direction of Kinetic Frictional Force is in opposite direction to its motion.

Rolling Friction: Friction acting on Rolling objects.

Law of Static Friction

$F_s \leq \mu_s N$

Law of kinetic Friction

$F_k \leq \mu_k N$

Law of Rolling Friction

$F_R \leq \mu_R N$

Angle of Friction:-

The angle made by the resultant reaction force with the vertical (normal reaction) is known as the angle of the friction.

Now, in the triangle OAB

$AB/OB = \cot\theta$

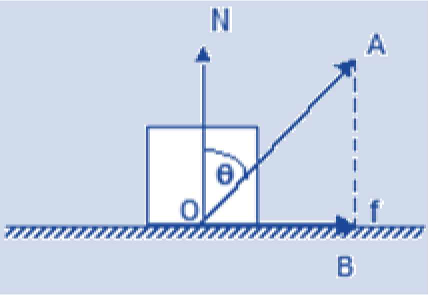
So, $OB = AB/\cot\vartheta$

$= AB \tan\vartheta$

Or, $\tan\vartheta = OB/AB$

$= f / N$

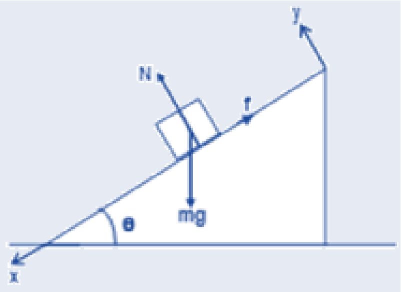
So, $\tan\vartheta = f / N = \mu_s$



Angle of Repose:

It is the angle which an inclined plane makes with the horizontal so that a body placed over it just begins to slide of its own accord.

Consider a body of mass m resting on an inclined plane of inclination$q$. The forces acting on the body are shown – F_f being the force of friction. If friction is large enough, the body will not slide down.



along x: $mg \sin\theta - f = 0$ …(1)

Along y: $N - mg \cos\theta = 0$ …(2)

i.e. $N = mg \cos\theta$ and $f = mg \sin\theta$

Thus, $f \leqslant \mu_S N$ gives,

$mg \sin\theta \leq \mu_S \, mg \cos\theta$

So, $\tan\theta \leq \mu_S$. This signifies, the coefficient of static friction between the two surfaces, in order that the body doesn't slide down.

When q is increased, then $\tan\theta > \mu$. Thus sliding begins, and the angle $\theta_r = \tan^{-1}\mu$. This angle is known as the angle of repose.

Fluid Mechanics

- Stream line flow:- Flow of a liquid fluid is said to be streamlined if the velocity of a molecule, at any point, coincides with that of the preceding one.
- Laminar flow:- It is a special case of streamline flow in which velocities of all the molecules on one streamline is same throughout its motion.
- Turbulent flow:- Whenever the velocity of a fluid is very high or it rushes past an obstacle so that there is a sudden change in its direction of motion, the motion of fluid becomes irregular, forming eddies or whirlpools. This type of motion of fluid is called turbulent flow.

Rate of flow (Equation of continuity):-

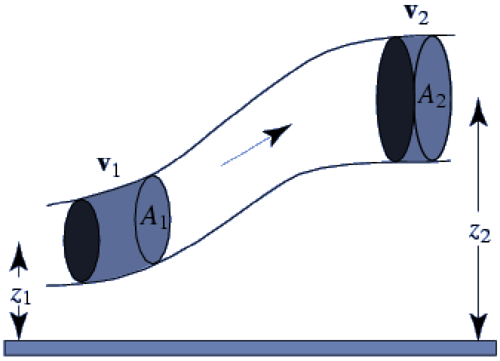
AV = Constant , A – Area , V - velocity

$A_1V_1=A_2V_2$

Equation of continuity can be considered to be a statement of conservation of mass.

So, $V \propto 1/A$

Velocity of flow of liquid varies inversely as the area of cross-section of the opening from where the liquid comes out.



- Total energy of a liquid:-

(a) Kinetic energy:- It is the energy possessed by a liquid by virtue of its velocity.

$$K.E = \frac{1}{2} mv^2$$

$$K.E \ per \ unit \ mass = \frac{1}{2} v^2$$

$$K.E \ per \ unit \ volume = \frac{1}{2}\left[\frac{mv^2}{V}\right] = \frac{1}{2} \rho v^2$$

Here, ρ is the density of liquid.

(b) Potential energy:- It is the energy possessed by a liquid by virtue of its position.

$$Potential \ energy = mgh$$

$$P.E \ per \ unit \ mass = \frac{mgh}{m} = gh$$

$$P.E \ per \ unit \ volume = \frac{mgh}{V} = \rho gh$$

(c) Pressure energy:- It is the energy possessed by a liquid by virtue of its pressure.

$Pressure\ energy\ =\ P \times V\ =\ m\,(\frac{P}{\rho})$

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

$Pressure\ energy\ per\ unit\ volume\ =\ \frac{P \times V}{V} =\ p$

- **Total energy:-** Total energy of a liquid is the sum total of kinetic energy, potential energy and pressure energy.

  $E = \frac{1}{2}\ mv^2\ + mgh + \frac{mP}{\rho}$

  $Total\ energy\ per\ unit\ mass\ = \frac{1}{2}v^2\ + gh + \frac{P}{\rho}$

  $Total\ energy\ per\ unit\ volume\ = \frac{1}{2}\ \rho v^2\ + \rho gh + P$

- **Bernoulli's Equation:-**

  It states that the total energy of a small amount of an incompressible non-viscous liquid flowing without friction from one point to another, in a streamlined flow, remains constant throughout the displacement.

  (a) $\frac{1}{2}\ mv^2\ + mgh + \frac{mP}{\rho} =\ Constant$

  (b) $\frac{1}{2}v^2\ + gh + \frac{P}{\rho} =\ Constant$

  (c) $\frac{1}{2}\ \rho v^2\ + \rho gh + P\ =\ Constant\ \ or\ \frac{v^2}{2g}\ +\ h\ + \frac{P}{\rho g}\ =\ Constant$

  The term $\frac{v2}{2g}$ is called **velocity head**, h is called gravitational head and $\frac{p}{\rho g}$ is called **pressure head**.

Therefore Bernoulli's theorem states that in case of an incompressible, non-viscous fluid, flowing from one point to another in a streamlined flow, the sum total of velocity head, gravitational head and the pressure head is a constant quantity.

Torricelli’s theorem (velocity of efflux)

It states that the velocity of efflux of a liquid (V), from an orifice, is equal to the velocity acquired by a body, falling freely (v), from the surface of liquid to the orifice.

So, $v = \sqrt{2gh}$

- **Viscosity**:- Viscosity is the property of fluids by virtue of which they tend to destroy any relative motion between their layers.
- **Velocity gradient:**- Velocity gradient is defined as the rate of change of velocity with respect to distance.

  Velocity gradient = dv/dr

Newton’s law of Viscosity

In accordance to Newton’s law of viscosity, the viscous drag force depends upon the nature of fluid along with following factors:-

(a) $F \propto A$ (common area of two layers)

(b) $F \propto \frac{dv}{dr}$ (velocity gradient)

(c) So, $F = \eta A \left(\frac{dv}{dr}\right)$

Unit of η:-

S.I:- η = 1 deca poise = 1 N sec/m^2

C.G.S:- η = 1 poise = 1 dyne sec/cm^2

1 deca-poise = 10 poise

Fluidity:- Reciprocal of coefficient of viscosity of a fluid is called its fluidity.

$$Fluidity = \frac{1}{\eta}$$

Unit of fluidity: $poise^{-1}$

Kinematic viscosity:- Kinematic viscosity of a fluid is defined as the ration between its coefficient of viscosity to the density of fluid.

$$Kinematic\ viscosity = \frac{\eta}{\rho}$$

Units of kinematic viscosity:- C.G.S : 1 stoke = $cm^2\ s^{-1}$

Kinetic viscosity of a fluid having its dynamic viscosity one poise and density one g cm^{-3} is said to be 1 stoke.

Critical velocity (Reynold's Number)

Critical velocity (v_c) is the maximum velocity of the flow of liquid flowing in a streamlined flow.

$$v_c = \frac{N_R \, \eta}{\rho D}$$

Here η is the coefficient of viscosity of liquid, ρ is the density of liquid and D is the diameter of the tube.

Reynold's Number, $N_R = \frac{\rho v_c D}{\eta}$

Stokes Law:- In accordance to Stokes' law, force of viscosity F depend upon, force of viscosity, $F = 6\pi \, \eta \, r \, v$

- Terminal velocity:- $v = \frac{2}{9} \, [\frac{r^2 \, (\rho - \sigma)}{\eta}]$
- $\eta = \frac{2}{9} [\frac{r^2 \, (\rho - \sigma) g}{v}]$

(a) Effect of temperature on η:- $\eta = A / (1 + Bt)^c$

Here A, B and C are constants.

Again, $\eta v^{\frac{1}{2}} = A e^{\frac{c}{vt}}$

Here, A and C are constants and v is the relative velocity.

(b) Effect of pressure on η:

Co-efficient of viscosity of liquids increases due to an increase in pressure but there is no relation, so far, to explain the effect.

Change in viscosity of gases:-

(a) Effect of temperature:- Co-efficient of viscosity of a gas at a given temperature is given by,

$$\eta = \eta_0 A T^{\frac{1}{2}}$$

Here T is the absolute temperature of gas.

Modified formula, $\eta = [\eta_0 A T^{\frac{1}{2}}] / [1 + \left(\frac{S}{T}\right)]$

(b) Effect of pressure:- At low pressure, co-efficient of viscosity of a gas varies directly with pressure.

- Rate of flow of liquid through a liquid through a capillary tube of radius r and length l,

$$V = \frac{\pi P r^4}{8\eta l} = \frac{P}{\frac{8\eta l}{\pi r^4}} = \frac{P}{R}$$

Pressure exerted by a column of liquid of height h:- $P = h\rho g$

Here, ρ is the density of liquid.

- Pressure at a point within the liquid:-

$$P = P_0 + h\rho g$$

Here, P_0 is the atmospheric pressure and *h* is the depth of point with respect to free surface of liquid.

Circular Motion

Uniform Circular Motion:-Circular motion is said to the uniform if the speed of the particle (along the circular path) remains constant.

Angular Displacement:-

$$\theta = \frac{s}{r}$$

Angular Velocity:-

$$\boldsymbol{\omega} = \frac{\boldsymbol{\theta}}{\boldsymbol{t}}$$

Relation between linear velocity (v) and angular velocity (ω):-

$$v = r\omega$$

Angular Acceleration:-

$$\alpha = \frac{\omega}{t}$$

Relation between linear velocity (v) and angular velocity (ω):-

$$a = r\alpha$$

- **Centripetal force:-** The force, acting along the radius towards the centre, which is essential to keep the body moving in a circle with uniform speed is called centripetal force. It acts always along the radius towards the centre. A centripetal force does no work.

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

- **Centrifugal force:-** Centrifugal force is the fictitious force which acts on a body, rotating with uniform velocity in a circle, along the radius away from the centre. Magnitude of centrifugal force is,

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

- Centripetal and centrifugal forces are equal in magnitude and opposite in direction. They cannot be termed as action and reaction since action and reaction never act on same body.

- **Banking of Roads:-**

  Road offering no frictional resistance, $\theta = \tan^{-1}\left(\frac{v^2}{rg}\right)$

  Road offering frictional resistance, $v_{max} = \sqrt{rg\left(\frac{\text{⍰}+tan\theta}{1-\text{⍰}tan\theta}\right)}$

- **Bending of Cyclist:-** $\theta = \tan^{-1}\left(\frac{v^2}{rg}\right)$

  (a) Velocity of the cyclist:- Greater the velocity, greater is his angle of inclination with the vertical.

  (b) Radius of curvature:- Smaller the radius, greater is the angle with the vertical.

- **Time period of conical pendulum:-**$T = 2\pi\sqrt{\frac{l\cos\theta}{g}}$

Motion in a vertical circle

	Tension	Velocity	Total Energy
Highest Point	$\frac{mv^2}{r} - mg$	$\sqrt{gr}$	$\frac{5}{2}\,mgr$
Mid Point	$\frac{mv^2}{r}$	$\sqrt{3gr}$	$\frac{5}{2}\,mgr$
Lowest Point	$\frac{mv^2}{r} + mg$	$\sqrt{5gr}$	$\frac{5}{2}\,mgr$

(a) For lowest point A and highest point B, $T_A - T_B = 6\,mg$

(b) Condition for oscillation:- $VA < \sqrt{2gl}$

(c) Condition for leaving circular path:- $\sqrt{2gl} < V_A < \sqrt{5gl}$

- **Non-uniform circular motion:-**

  (a) The velocity changes both in magnitude as well as in direction.

  (b) The velocity vector is always tangential to the path.

  (c) The acceleration vector is not perpendicular to the velocity vector.

  (d) The acceleration vector has two components.

(i) **Tangential acceleration** a_t changes the magnitude of velocity vector and is defined as, $a_t = dv/dt$

(ii) **Normal acceleration** or centripetal acceleration a_c changes the direction of the velocity vector and is defined as,$a_c = \frac{v^2}{r}$

(iii) The total acceleration is the vector sum of the tangential and centripetal acceleration.

So, $a = \sqrt{a_t^2 + a_c^2}$

Gravitation

Universal Law of Gravitation

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

Gravitational Force is independent of the medium . The gravitational force inside a body is zero .

Gravitational Constant

G = 6.67 x 10^{-11} Nm^2/kg^2

Acceleration due to Gravity

Variation with Height

$$g = G\frac{M}{(R+h)^2}\bigg|g_h = g\left(\frac{R}{(R+h)^2}\right)\bigg|g_h = g\left(1-\frac{2h}{R}\right)$$

Variation with Depth

$$g = g_h\left(1-\frac{d}{R}\right)$$

for every percentage decrease in radius , with mass constant ; there is 2 % increase in acceleration due to gravity

Variation with Latitude

$$g' = g - R\omega_2 \cos_2 \Phi$$

Relation between Variation of height and depth

If acceleration due to gravity is same at a certain height and depth ;

then d = 2h

Gravitational Field Intensity

Gravitational field is the field of attraction around a mass . Gravitational Field Intensity is the amount of Force experienced by an object of unit mass in a gravitational Field .

$$\therefore \; Intensity = \frac{Force}{mass}$$

Gravitational Potential Energy

Gravitational Potential Energy is the work done in bringing a charge of unit mass from infinity to a point against the gravitational field .

$$Potential\ Energy\ (U) = \ Force\ x\ Displacement$$

$$= -\frac{GMm}{r}$$

$$\therefore U = Vm$$

Gravitational Potential

Gravitational potential is the amount of work done per unit mass in a gravitational field .

$$Potential(V) = -\frac{GM}{r}$$

$$\therefore V = \frac{U}{m}$$

Gravitational Potential is always directed opposite to Gravitational Field .

Cases of Potential :

1. **Due to point mass :**$V = -\frac{GM}{r}$ ∴ at r = 0 , Z is negative infinite . The graph will be negative , curved and parallel to V and r axes .
2. **Inside a Solid Sphere :** $V = -GM\frac{\left(\frac{3}{2}R^2 - \frac{1}{2}r^2\right)}{R^3}$. At r=R ,V = - GM/R . At r = 0 ,V = $-\frac{1}{2}\frac{GM}{R}$ The graph is negative , parabolic .
3. **Outside a Solid Sphere :** $V = -\frac{GM}{r}$, at r = infinity , V = 0 ; On surface , V = -GM/R
4. **Due to a Spherical Shell :** Outside $V = -\frac{GM}{r}$. Inside V = - GM/r
5. **On the Axis of a Ring :** $V = -\frac{GM}{\sqrt{R^2+x^2}}$

Kepler's Laws

Law of Orbits

Kepler's Law of Orbits states that all planets revolve around the sun in elliptical orbits with sun as the focus .

Law of Areas

Kepler's Law of Areas states that a planet sweeps equal Areas in equal intervals of time around the sun .

Law of Periods

Kepler's Law of Periods states that the square of Time Period is directly proportional to the cube of Distance .

$\therefore T^2 \alpha\, r^3$

Critical Velocity

$$v_c = \sqrt{\frac{GM}{r}}$$

$$v_c = \sqrt{g_h r}$$

Time Period

$$T = 2\pi\sqrt{\frac{r^3}{GM}}$$

Binding Energy

$$B.E. = -T.E.$$

$$B.E. = G\frac{Mm}{r} \text{ \{At rest\}}$$

$$B.E. = G\frac{Mm}{2r} \text{ \{in orbit\}}$$

Escape Velocity

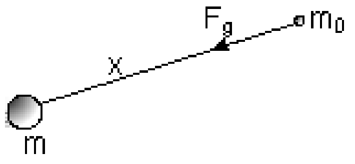
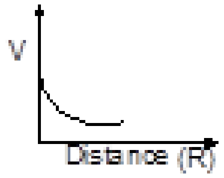
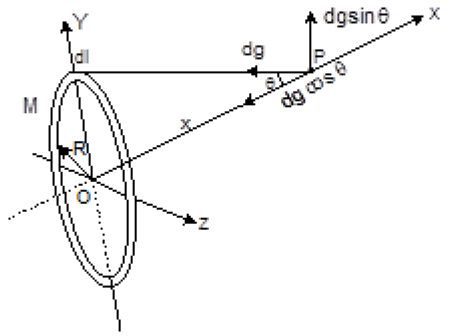
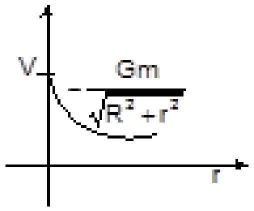
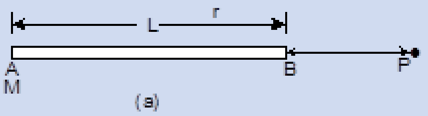
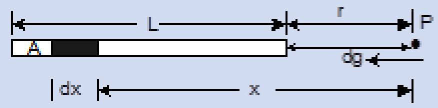
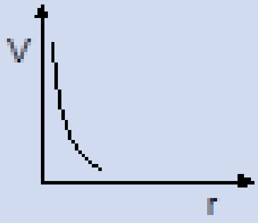
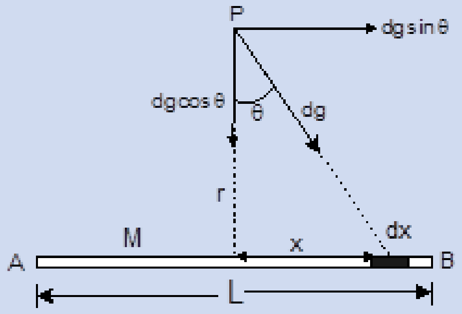
$$v_e = \sqrt{2g_h r}$$

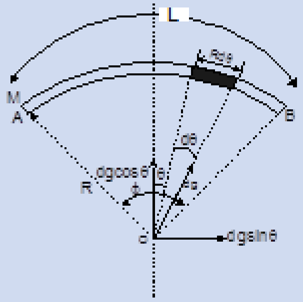
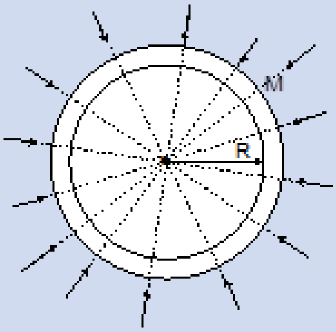
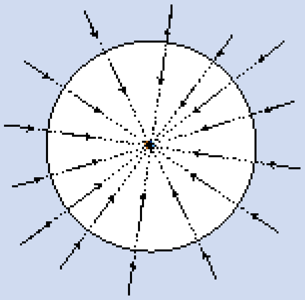
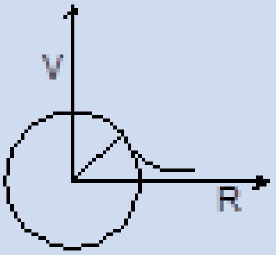
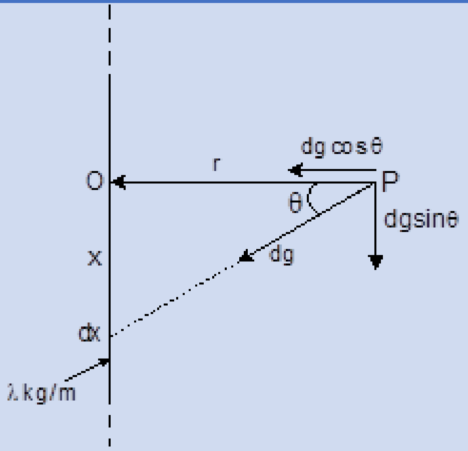
$$v_e = \sqrt{\frac{2GM}{r}}$$

The escape velocity remains independent of angle of projection.

Escape Velocity for an object on earth is 11.2 km/s

GRAVITATIONAL POTENTIAL & FIELD DUE TO VARIOUS OBJECTS

Causing Shape	Gravitational Potential (V)	Gravitational Field (I or E)	Graph V vs R
POINT MASS			
	$V=\frac{-GM}{R}$	$I \text{ or } E=\frac{GM}{R^2}$	
AT A POINT ON THE AXIS OF RING			
	$V=\frac{-GMr}{\sqrt{R^2+r^2}}$ $0 \le r \le \infty$	$E(r)=\frac{-GMr}{(R^2+r^2)^{3/2}}$	
ROD			
1. AT AN AXIAL POINT			
 (a)  (b)	$V=-\frac{GM}{L}\ln\left(1+\frac{L}{r}\right)$	$E=\frac{GM}{r^2}\left(\frac{1}{1+\frac{L}{r}}\right)$	
2. AT AN EQUATORIAL POINT			
	$V=\frac{2GM}{r\sqrt{l^2+4r^2}}$	$E=-\frac{dv}{dr}$	

CIRCULAR ARC			
	$V = \frac{2\pi GM}{L}$	$E = \frac{2\pi GM}{L^2}$	
HOLLOW SPHERE			
	$V(r) = \frac{-GM}{r}$ $(r \geq R)$ $V(r) = \frac{-GM}{R}$ $(r = R)$	$E(r) = \frac{GM}{r^2}$ $(r \geq R)$ $E(r) = \frac{GM}{R^2}$ $(r = R)$	
SOLID SPHERE			
	$V(r) = \frac{-GM}{r}$ $(r \geq R)$ $V(r) = \frac{-GM}{R^3}(1.5R^3 - 1.5R^2)$ $(r \leq R)$	$E(r) = \frac{GM}{r^2}$ $E(r) = \frac{GMr}{R^3}$ $(r \leq R)$	
LONG THREAD			
	$V = \infty$	$E = \frac{2Gl}{r}$	

Rotational Motion

Rigid Body: A rigid body consists of a number of particles such that the distance between any pair of particles always remains constant.

- **Moment of Inertia (Rotational Inertia) *I*:-**

$$I = MR^2$$

  (i) Mass of body

  (ii) Distribution of mass about the axis of rotation

  (iii) Moment of inertia of a body should always be referred to as about a given axis, since it depends upon distribution of mass about that axis.

  (iv) It does not depend upon the state of motion of rotating body. It is same whether the body is at rest, rotating slowly or rotating fast about the given axis.

  $I = \sum mr^2$

- **Rotational Kinetic Energy:-** $K_r = \frac{1}{2}I\omega^2 = \frac{1}{2}\, mr^2\omega^2$

  So, $I = 2K_r/\omega^2$

- **Radius Gyration:-** Radius of gyration of a body about a given axis is that distance, at which if whole of the mass of the body were concentrated, it would have same moment of inertia as that of body.

  $I = MK2$

  So, $K = \sqrt{\frac{I}{M}}$

  Again, Radius of gyration of a body about a given axis is defined as the square root of the mean of the squares of distances of various particles of the body from the axis of rotation.

  So, $K = \sqrt{}[r12 + r22 + r32 + \cdots./n]$

  (a) $x_{CM} = \frac{m_1x_1+m_2x_2}{m_1+m_2}$

  (b) $v_{CM} = \frac{m_1v_1+m_2v_2}{m_1+m_2}$

  (c) $a_{CM} = \frac{m_1a_1+m_2a_2}{m_1+m_2}$

  (d) $v_{CM} = \frac{dx_{CM}}{dt}$

  (e) $a_{CM} = \frac{dv_{CM}}{dt} = \frac{d_2x_{CM}}{dt^2}$

System of mass for many particle system:-

$$xCM = \sum mixi \,/\, \sum mi$$

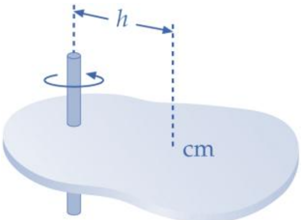
- **Perpendicular axes theorem:-**

$$I_z = Ix + Iy$$

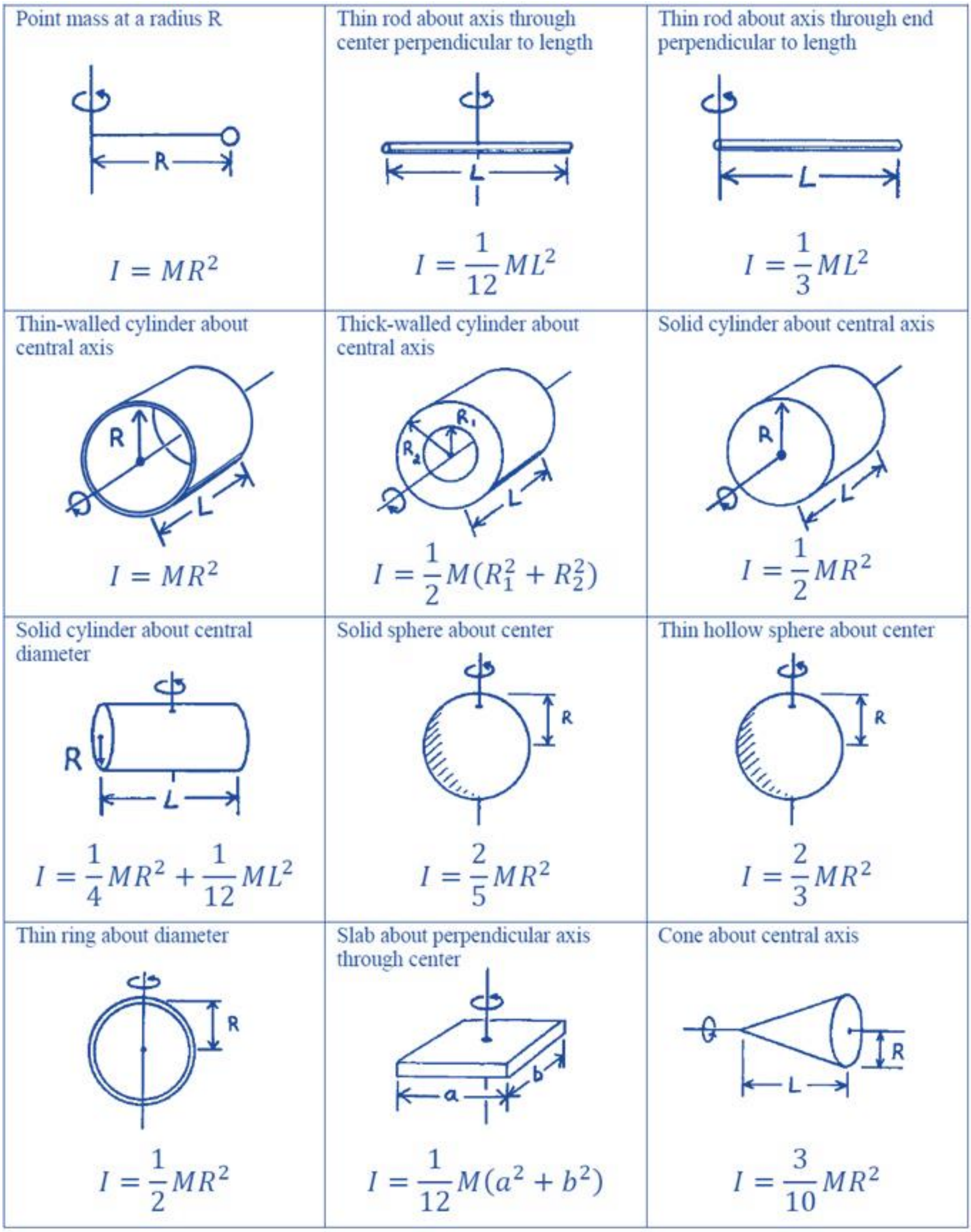
- **Parallel axes theorem:-**

  $I = I_g + Mh^2$

  Here, I_g is the moment of inertia of the body about an axis through its center of gravity G.



Moments of Inertia of Various Objects:-



Point mass at a radius R $I = MR^2$	Thin rod about axis through center perpendicular to length $I = \frac{1}{12}ML^2$	Thin rod about axis through end perpendicular to length $I = \frac{1}{3}ML^2$
Thin-walled cylinder about central axis $I = MR^2$	Thick-walled cylinder about central axis $I = \frac{1}{2}M(R_1^2 + R_2^2)$	Solid cylinder about central axis $I = \frac{1}{2}MR^2$
Solid cylinder about central diameter $I = \frac{1}{4}MR^2 + \frac{1}{12}ML^2$	Solid sphere about center $I = \frac{2}{5}MR^2$	Thin hollow sphere about center $I = \frac{2}{3}MR^2$
Thin ring about diameter $I = \frac{1}{2}MR^2$	Slab about perpendicular axis through center $I = \frac{1}{12}M(a^2 + b^2)$	Cone about central axis $I = \frac{3}{10}MR^2$

- **Moment of inertia of a ring about an axis passing through its center and perpendicular to its plane:-**
  - (a) About one of its diameters:- $I_d = ½ (MR^2)$
  - (b) About a tangent
    - (i) Tangent lying in the plane of ring:-$I = 3/2 (MR^2)$
    - (ii) Tangent perpendicular to the plane of ring:-$I = 2MR^2$

- **Moment of inertia of a solid disc:-**
  - (a) About an axis passing through its center and perpendicular to its plane:- $I = ½ MR^2$
  - (b) About one of its diameters:- $I_d = ¼ (MR^2)$
  - (c) About a tangent:-
    - (i) Tangent lying in the plane of disc:-$I = 5/4 (MR^2)$
    - (ii) Tangent perpendicular to the plane of disc:- $I = 3/2 (MR^2)$

- **Moment of inertia of an annular disc:-**
  - **(a) About an axis passing through the center and perpendicular to the plane:-**
    - (i) For a solid disc:- $I = ½ MR^2$
    - (ii) For ring:- $I = MR^2$
  - **(b) About any of its diameter:-**
    - (i) For a solid disc:- $I_d = ¼ (MR^2)$
    - (ii) For ring:- $I_d = ½ MR^2$
  - **(c) About a tangent:-**
    - **(i) Tangent lying in the plane of disc:-**
      - (1) For a solid disc:-$I = 5/4 MR^2$
      - (2) For a ring:-$I = 3/2 MR^2$
    - **(ii) Tangent perpendicular to the plane of the disc:-**
      - (1) For a solid disc:- $I = 3/2 MR^2$
      - (2) For a Ring:- $I = 2MR^2$

- **Torque (τ) in vector form:-**

$$\vec{\tau} = \vec{r} \times \vec{F}$$
$$= rFsin\theta$$

- **Moment of inertia (*I*) and Torque :-**$\tau = I\alpha$

  Here α is the angular acceleration.

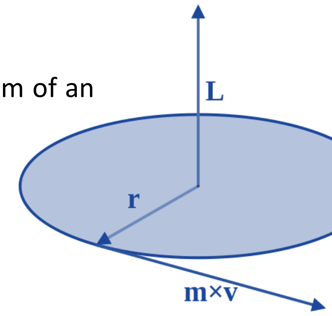
- **Angular Momentum (*L*):-**

$$\vec{L} = \vec{r} \times \vec{p}$$
$$= rp\sin\theta$$

- **Moment of Inertia (*I*) and Angular momentum (*L*):-**

  $$\vec{L} = I\vec{\omega}$$

- **Law of conservation of angular momentum:-** The net angular momentum of an isolated system (no external torque), always remains constant.



  $$\frac{d\vec{L}}{dt} = 0$$

  $$\text{So, } \vec{L} = I\vec{\omega} = \text{constant}$$

  $$I_1\omega_1 = I_2\omega_2$$

- **Motion of a point mass attached to a string would over a cylinder capable of rotating about its axis of symmetry:-**

  $$Tension, T = \frac{mg}{\left[1 + \left(\frac{mR^2}{I}\right)\right]}$$

- **Motion of a body rolling down an inclined plane without slipping:-**

  The maximum allowed angle for rolling without slipping.

  (a) A cylinder rolling down the plane,

  $\vartheta_{max} = \tan^{-1}(3\mu)$

  (b) A sphere rolling down the inclined plane,

  $\vartheta_{max} = \tan^{-1}[7/2\ (\mu)]$

  (c) A ring rolling down the inclined plane,

  $\vartheta_{max} = \tan^{-1}(2\mu)$

  Here μ is the coefficient of sliding friction.

- **Angular impulse:-** $\Delta\vec{L} = \vec{\tau}\,\Delta t$

- **Rotational work done:-** $W = \tau_{av}\vartheta$

- **Rotational power:-** $P = \vec{\tau} \cdot \vec{\omega}$

Oscillations

(a) **Simple harmonic motion (SHM):-** Simple harmonic motion is the motion in which the restoring force is proportional to displacement from the mean position and opposes its increase.

- **Simple harmonic motion (SHM):-** A particle is said to move in SHM, if its acceleration is proportional to the displacement and is always directed towards the mean position.

- **Conditions of Simple Harmonic Motion**

  For SHM is to occur, three conditions must be satisfied.

  (a) There must be a position of **stable equilibrium**
  At the stable equilibrium potential energy is minimum.
  So, $dU/dy = 0$ and $d^2U/dy^2 > 0$

  (b) There must be no dissipation of energy

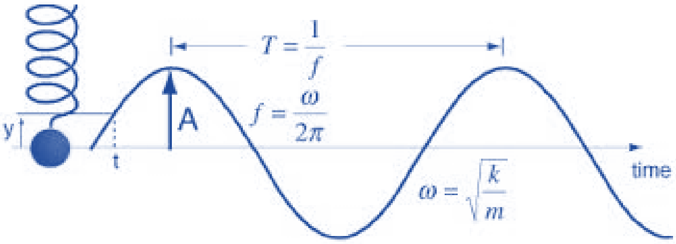
  (c) The acceleration is proportional to the displacement and opposite in direction.
  That is, $a = -\omega^2 y$

- **Equation of SHM**

  (a) $F = -kx$

  (b) $\frac{d_2 y}{dt^2} + \omega^2 x = 0$

  Here $\omega = \sqrt{k/m}$ (k is force constant)



- **Displacement (*y*)**

  Displacement of a particle vibrating in SHM, at any instant , is defined as its distance from the mean position at that instant.

  $y = r\, sin\,(\omega t + \delta\,)$

  Here δ is the phase and *r* is the radius of the circle.

- **Amplitude (*r*):-**

  Amplitude of a particle, vibrating in SHM, is defined as its maximum displacement on either side of mean position.

  As the extreme value of value of $\omega t = \pm 1$, thus, $y = \pm r$

- **Velocity (*V*):-** $V = \frac{dx}{dt} = r\omega cos(\omega t + \delta) = vcos(\omega t + \delta) = \omega\sqrt{r^2 - y^2}$

- **Acceleration (*a*):** $a = \frac{dV}{dt} = -\frac{v^2}{r}\, sin\omega t = -\omega^2 x$

- **Time period (*T*):** It is the time taken by the particle to complete one vibration.

  (a) $T = 2\pi/\omega$

  (b) $T = 2\pi\sqrt{(\text{displacement/acceleration})}$

  (c) $xT = 2\pi\sqrt{\frac{m}{k}}$

- **Frequency (*f*):** It is the number of vibrations made by the body in one second.
  (a) $f = \frac{1}{T}$
  (b) $f = \frac{1}{2}\pi\sqrt{\frac{k}{m}}$

- **Angular frequency (*ω*)**
  (a) $\omega = \frac{2\pi}{T}$
  (b) $\omega = \sqrt{\frac{acceleration}{displacement}}$

- **Relation between Angular frequency (*ω*) and Frequency (*f*):-** $\omega = 2\pi f = \sqrt{\frac{k}{m}}$

- **Phase:**
  (a) Phase of a particle is defined as its state as regards its position and direction of motion.
  (b) It is measured by the fraction of time period that has elapsed since the particle crossed its mean position, last, in the positive direction.
  (c) Phase can also be measured in terms of the angle, expressed as a fraction of 2π radian, traversed by the radius vector of the circle of reference while the initial position of the radius vector is taken to be that which corresponds to the instant when the particle in SHM is about to cross mean position in positive direction.

- **Energy in SHM:**
  (a) Kinetic Energy (E_k): $Ek = \frac{1}{2} m\omega^2(r^2 - y^2) = \frac{1}{2}m\omega^2r^2\cos^2\omega t$
  (b) Potential Energy (E_p): $Ep = \frac{1}{2} m\omega^2r^2 = \frac{1}{2} m\omega^2r^2\sin^2\omega t$
  (c) Total Energy (*E*): $E = Ek + Ep = \frac{1}{2} m\omega^2r^2 = conserevend$

  $$E = (Ek)max = (Ep)max$$

- **Average Kinetic Energy**:-**<E_k> =** $\frac{1}{4} m\omega^2r^2$

- **Average Potential Energy**:-**<E_p> =** $\frac{1}{4} m\omega^2r^2$

- **Spring-mass system:**

  (a) $mg = kx$

  (b) Time period, $T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{x_0}{g}}$

Cutting a spring:

(a) Time period, $T' = T_0/\sqrt{n}$

(b) Frequency, $f' = \sqrt{(n)}\, f_0$

(c) Spring constant, $k' = nk$

(d) If spring is cut into two pieces of length l_1 and l_2 such that, $l_1 = nl_2$, then,

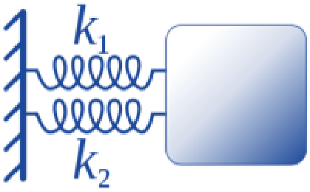
$k_1 = (n+1/n)k$,

$k_2 = (n+1)k$

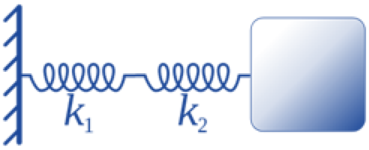
and

$k_1 l_1 = k_2 l_2$

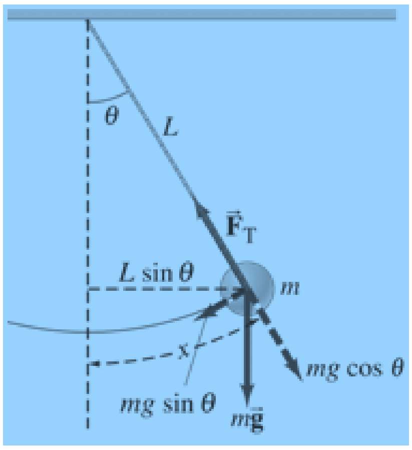
- **Spring in parallel connection:**
  - *(a)* Total spring constant, $k = k_1+k_2$
  - *(b)* Time period, $T = 2\pi\sqrt{[m/(k_1+k_2)]}$
  - *(c)* If $T_1 = 2\pi\sqrt{m/k_1}$ and $T_2 = 2\pi\sqrt{m/k_2}$, then,
    $T = T_1T_2/\sqrt{T_1^2 + T_1^2}$ and $\omega^2 = \omega_1^2 + \omega_2^2$



- **Spring in series connection:**
  - *(a)* Total spring constant, $1/k = 1/k_1 + 1/k_2$ or, $k = k_1k_2/\ k_1+k_2$
  - *(b)* Time period, $T^2 = T_1^2 + T_2^2$
  - *(c)* $T = 2\pi\sqrt{[m(k_1+k_2)/k_1k_2]}$
  - *(d)* $1/\omega^2 = 1/\omega_1^2 + 1/\omega_2^2$
  - *(e)* $f = 1/2\pi\ \sqrt{[k_1k_2/m(k_1+k_2)]}$
  - *(h)* **Equation of motion:-**$d^2\vartheta/dt^2 + (g/l)\vartheta = 0$
  - *(i)* **Frequency,** $f = 1/2\pi\ \sqrt{(g/l)}$
  - *(j)* **Angular frequency,** $\omega = \sqrt{(g/l)}$



- **Second Pendulum:-**A seconds pendulumis that pendulum whose time period is two second.
  - *(a)* $T = 2$ sec
  - *(b)* $l = 0.9925$ m



- **Mass-less loaded spring in the horizontal alignment:-**

  Force, $F = -kx$

  Acceleration, $a = -kx/m$

  Time period, $T = 2\pi\sqrt{m/k}$

  Frequency, $f = 1/2\pi\sqrt{k/m}$

- **Time period of mass-less loaded spring in the vertical alignment:-**

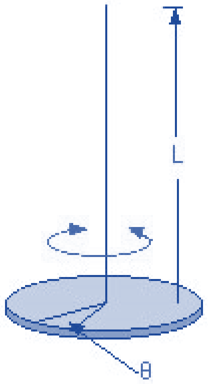
  $T = 2\pi\sqrt{m/k}$ and $T = 2\pi\sqrt{l/g}$

- **Time period of bar pendulum:-**

  $T = 2\pi\sqrt{I/mgl}$

  Here I is the rotational inertia of the pendulum.
  and
  $T = 2\pi\sqrt{L/g}$
  Here, $L = (k^2/l)+l$

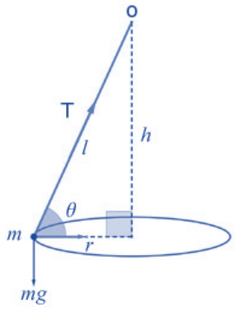
- **Time period of torsion pendulum:-**
  (a) $T=2\pi\sqrt{I/C}$
  Here I is the rotational inertia of the pendulum and C is the restoring couple per unit angular twist.
  (b) Equation of motion:$-d^2\vartheta/dt^2+(C/I)\vartheta = 0$
  Here, $\vartheta = \vartheta_0 \sin(\omega t+\delta)$
  (c) Angular frequency, $\omega = \sqrt{C/I}$
  (d) Frequency, $f = 1/2\pi\sqrt{C/I}$



- **Conical Pendulum:-**

  Time period, $T = 2\pi\sqrt{(L\cos\vartheta/g)}$

  Velocity, $v = \sqrt{(gR\tan\vartheta)}$



- **Restoring couple (τ):-**

  $\tau = C\vartheta$

  Here C is the restoring couple per unit angular twist and ϑ is the twist produced in the wire.

- **Free vibrations:-** Vibrations of a body are termed as free vibrations if it vibrates in the absence of any constraint.
- **Damped Vibrations:-**

  Equation:$d^2y/dt^2 + 2\mu dy/dt+\omega^2 y = 0$

  Here amplitude, $R = Ae^{-\mu t}$
  And
  $\omega' = \sqrt{\omega^2-\mu^2}$
  (a) $\mu<<\omega$ signifies the body will show oscillatory behavior with gradually decreasing amplitude.
  (b) $\mu>>\omega$ signifies the amplitude may decrease from maximum to zero without showing the oscillatory behavior.
  (c) In between the above two cases, the body is in the state of critically damped.
  (d) Time period of oscillation, $T' = 2\pi/\omega' = 2\pi/\sqrt{\omega^2-\mu^2}$. Thus, presence of damping factor μ in the denominator indicates an increase of time period due to damping.

- **Forced vibrations:-** Forced vibrations is the phenomenon of setting a body into vibrations by a strong periodic force whose frequency is different from natural frequency of body.

  Equation: $d^2y/dt^2+2\mu dy/dt+\omega^2 y = (F_0/m)\cos\omega\, t$

  Here, $\mu = r/2m$ and $\omega=\sqrt{k/m}$

  Amplitude:- $A = F_0/m\sqrt{4\mu^2p^2+(p^2-\omega^2)^2}$ and $A_{max} = F_0/2\mu m\sqrt{\omega^2-\mu^2}$

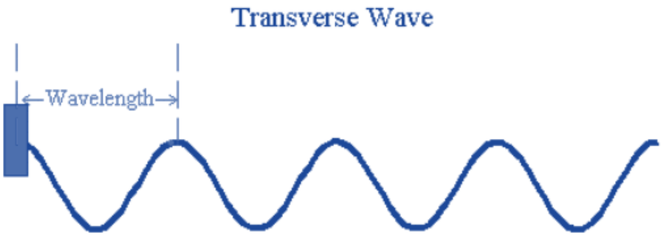
  This state of forced vibrations in which the amplitude reaches a maximum value is known as amplitude resonance.

  Amplitude vibration depends upon value of $\omega = \sqrt{k/m}$. Greater the value of stiffness (k), smaller is the amplitude.

- **Resonance:-** Resonance is the phenomenon of setting a body into vibrations by a strong periodic force whose frequency coincides with the natural frequency of the body.

Waves
Progressive & Stationary

- **Wave motion:-**



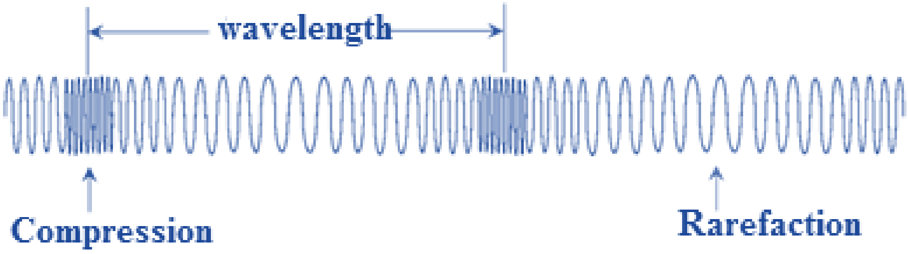
- **Wave Equation:-** $d^2y/dt^2 = v^2\ (d^2y/dx^2)$

- **Transverse wave motion:-**It is the type of wave motion in which the particles of the medium are vibrating in a direction at right angles to the direction of propagation of wave.

  (a) Velocity of transverse wave, $V_t = \sqrt{T/m} = \sqrt{T/\pi r^2 \rho}$

  (b) Vibrations of the particles of medium are normal to the direction of wave propagation.

- **Longitudinal wave motion:-**It is the type of wave motion in which the particles of the medium vibrate in the direction of propagation of wave.



  (a) Velocity of longitudinal wave**,** $V_l = \sqrt{E/\rho}$

  (b) Vibrations of the particles are parallel to the direction of wave propagation.

- **Relation between phase difference (?) and path difference (λ):-**

  Phase Difference = $(2\pi/\lambda) \times$(path difference)

- **Simple Harmonic Motion:-**A wave which originates from a source, undergoing simple harmonic motion, is called a simple harmonic wave.
  Equation:-$y = r\sin\omega t$

  $= r \sin 2\pi f t$

  $= r\sin 2\pi(v/\lambda)t$

  $= r \sin 2\pi x/\lambda$

- **Equation of progressive wave:-** A relation between the instantaneous displacement of a particle executing SHM and time is called equation of progressive wave.
  $y = r \sin 2\pi (\omega t \pm \delta)$
  $y = r \sin [(\omega t \pm (2\pi/\lambda)x]$
  $y = r \sin (\omega t \pm kx)$
  $y = r \sin 2\pi (t/T \pm x/\lambda)$
  $y = r \sin 2\pi/\lambda (vt \pm x)$

- **Angular wave number (*k*):** $k = 2\pi/\lambda$

- **Relation between particle velocity (*V*) and wave velocity (*v*):-**

  $V = (2\pi r/\lambda)\, v\cos[(2\pi/\lambda)(vt \pm x)]$

  $V_{\max} = (2\pi r/\lambda)\, v$

- **Energy transmission in a progressive wave:-**$E = ½\, m\omega^2 r^2$

- **Energy per unit volume:-** $E = ½\, \rho r^2\omega^2$ Here ρ is the density of medium.

- **Intensity of a wave:-**
  $I = 2\pi^2\rho v f^2 r^2$

  Intensity of a wave varies directly as the square of its amplitude.

  So, $I \propto r^2$

- **Velocity of transverse wave in stretched string:-**$v = \surd(T/m)$, Here,T is the tension in the string.

- **Interference:-** Interference is the phenomenon by virtue of which there is a modification in the distribution of energy due to super position of two or more waves.

  $y_1 = a_1\sin\omega t$, $y_2 = a_2\sin(\omega t+\delta)$

  $y = y_1+y_2$

  Amplitude, $A = \surd[a_1^2+a_2^2+2\, a_1\, a_2\cos wt])$
  Intensity, $I = kA^2$ and $I = I_1+I_2+2(\surd\, I_1 I_2)\cos wt$
  Here, $I_1 = ka_1^2$ and $I_2 = ka_2^2$

Angle, ϑ = $\tan^{-1}[a_2\sin wt/(a_1+a_2\cos wt)]$

- **Constructive interference:-**
  Phase difference = $2n\pi$, $n = 0,1,2,3\ldots$

  $\boldsymbol{A} = a_1+a_2$

  $\boldsymbol{I}_{\mathbf{max}} = [\sqrt{I_1}+\sqrt{I_2}]^2$

  Path difference, $\boldsymbol{x}$ = $2n(\lambda/2)$

- **Destructive interference:-**
  Phase difference = $(2n+1)\pi$, $n = 0,1,2,3\ldots$

  $A = 2a\cos wt/2$

  $I = 4a^2k\cos^2 wt/2$

  $\boldsymbol{I}_{\mathbf{max}} = 4a^2k$

  $\boldsymbol{I}_{\mathbf{min}} = 0$

  Path difference, $\boldsymbol{x}$ = $(2n+1)(\lambda/2)$

- **Stationary Wave:-**
  Wave equation, $\boldsymbol{y}$ = $2a\cos(2\pi/\lambda)x\sin(2\pi/\lambda)vt$
  Amplitude, $\boldsymbol{A}$ = $2a\cos(2\pi/\lambda)x$
  Condition for maxima (anti-nodes), $\boldsymbol{x}$ = $k(\lambda/2)$
  Condition for minima (nodes), $\boldsymbol{x}$ = $(2k+1)(\lambda/4)$

- **Frequency of transverse vibrations in stretched string:-**

  $f = (1/2l)\sqrt{(T/m)}$, Here l is the length, T is the tension and m is the mass.

  $f = (1/lD)\sqrt{(T/\pi\rho)}$, Here l is the length, T is the tension, D is the diameter and ρ is the density.

- **Harmonics in stretched strings:-**
  (a) First harmonic (fundamental frequency), $f_0=(1/2l)\sqrt{(T/m)}$

  (b) Second harmonic (first overtone), $f_1 = 2f_0=(2/2l)\sqrt{(T/m)}$

  (c) Third harmonic (second overtone), $f_2 = 3f_0=(3/2l)\sqrt{(T/m)}$

  (d) p^{th} harmonic (p-1 overtone), $f_{p-1} = pf_0=(p/2l)\sqrt{(T/m)}$

  Here, p=1,2,3…

- **Frequency of tuning fork:-**

  $f\propto(t/l)\sqrt{(E/\rho)}$

  Here, t is the thickness, l is the length, E is the elastic constant and ρ is the density.

- **Phenomenon of Beats:-** Periodic variations of amplitude resulting from the superposition of two waves of slightly different frequencies is known as phenomenon of beats.

  If m is the number of beats per second, then, $m = f_1\text{-}f_2$. Here f_1 and f_2 are the frequencies of the two waves.

  $y_1 = a\sin 2\pi f_1 t$, $y_2 = a\sin 2\pi f_2 t$

  $y = y_1 + y_2 = \mathrm{A}\sin 2\pi f t$

  Amplitude, $A = 2a\cos 2\pi(f_1\text{-}f_2/2)t$, Frequency, $\mathrm{F} = f_1\text{-}f_2/2$

  (a) **Maxima**:- $t = f/f_1\text{-}f_2$
  (b) **Minima**:- $t = 2f\text{+}1/2(f_1\text{-}f_2)$

- **Beat period (t_b):-** It is defined as the time interval between consecutive beats or it is the time between two consecutive maxima or minima of intensity of sound.

  $t_{\mathrm{b}} = 1/f_1\text{-}f_2$

  If m is the number of beats per second, then,

  $m = 1/\text{beat period} = f_1\text{-}f_2$

  This signifies, the number of beats per second is equal to the difference in frequencies of two waves.

Elasticity

The property of a body , by the virtue of which material bodies regain their original dimensions (size, shape or both) after removal of deforming forces is called elasticity .

Plasticity

Plasticity is the property of a body to undergo permanent deformation even after the removal of deforming forces .

Rigidity

Deformation α Deforming Force

Strain α Stress

Stress / Strain = Constant

Stress And Strain

1) **Longitudinal Stress & Strain (along length)**

   Longitudinal Stress = Applied Force / Cross Section Area

   Longitudinal Strain = $(l - l_0) / l_0 = \Delta L / L$

2) **Volume Stress & Strain (with Volume)**

   Volume Stress = Applied Force / Volume

   Volume Strain = $\Delta V / V$

3) **Shearing Stress & Strain (with shape)**

   Shearing Stress = Tangential Applied Force / Area

   Shearing Strain = θ

Elasticity Modulus (Hooke's Law)

(Young's Modulus and Hooke's Law for JEE)

Deformation α Deforming Force

Strain α Stress

Stress / Strain = M; where M is a constant , called as Modulus of Elasticity .

Young's Modulus

(for longitudinal strain and stress)

Y = Longitudinal Stress / Longitudinal Strain

Bulk Modulus

(for Volume Strain and Strain)

K = Volume Stress / Volume Strain

Compressibility = 1 / Bulk Modulus

Modulus of Rigidity

(for Shearing Strain and Stress)

η = Shearing Stress / Shearing Strain

Poisson's Ratio

σ = lateral strain / longitudinal strain

Determination of Elasticity Modulus

Elastic Energy

Strain Energy = 1/2 load x extension

Strain Energy per unit volume = 1/2 x $(\text{Strain})^2$

Strain Energy is defined as an elastic potential energy gained by a wire during elongation by stretching force

Surface Tension

- **Force of cohesion:-** It is force between two molecules of similar nature.
- **Force of adhesion:**- It is the force between two molecules of different nature.
- **Molecular range:**- The maximum distance between two molecules so that the force of attraction between them remains effective is called molecular range.
- **Sphere of influence:**- Sphere of influence of any molecule is the sphere with molecule as its center and having a radius equal to molecular range (=10^{-7} cm).
- **Surface film:**- Surface film of a liquid is defined as the portion of liquid lying on the surface and caught between two parallel planes situated molecular range apart.
- **Surface tension:**-

  Surface tension is the property of a liquid by virtue of which its free surface behaves like a stretched membrane and supports, comparatively heavier objects placed over it. It is measured in terms of force of surface tension.
- **Force of surface tension:**- It is defined as the amount of force acting per unit length on either side of an imaginary line drawn over the liquid surface.

  (a) T = Force/length = F/l

  (b) T = Surface energy/Surface area = W/A

  Units:- S.I – Nm^{-1}

  C.G.S- dyne cm^{-1}

- **Additional force:-**

  (a) For a cylindrical rod:- $F = T\times2\pi r$ (Here r is the radius of cylindrical rod)

  (b) For a rectangular block:- $F = T\times2(l+d)$ (Here l is the length and d is the thickness of the rectangular block)

  (c) For a ring:- $F = T\times2\times2\pi r$ (Here r is the radius of cylindrical rod)

- **Surface energy:-**

  Potential energy per unit area of the surface is called surface energy.

  (a) Expansion under isothermal condition:-

  To do work against forces of surface tension:-

  W= $T\times A$ (Here A is the total increase in surface area)

  To supply energy for maintaining the temperature of the film:-

  $E = T+H$

  (b) Expansion under adiabatic conditions:-

  $E = T$

  Force of surface tension is numerically equal to the surface energy under adiabatic conditions.

- **Drops and Bubbles:-**

  (a) Drop:- Area of surface film of a spherical drop of radius R is given by, $A = 4\pi R^2$

  (b) Bubble:- The surface area of the surface films of a bubble of radius R is, $A = 2\times 4\pi R^2$

- **Combination of *n* drops into one big drop:-**

  (a) $R = n^{1/3}r$

  (b) $E_i = n\,(4\pi r^2 T)$, $E_f = 4\pi R^2 T$

  (c) $E_f / E_i = n^{-1/3}$

  (d) $\Delta E/E_i = [1-(1/n^{1/3})]$

  (e) $\Delta E = 4\pi R^2 T\,(n^{1/3}-1) = 4\pi R^3 T\,(1/r - 1/R)$

- **Angle of contact:-** Angle of contact, for a pair of solid and liquid, is defined as the angle between tangent to the liquid surface drawn at the point of contact and the solid surface inside the liquid.

  (a) When $\vartheta < 90^\circ$ (acute):-

  $F_a > F_c/\sqrt{2}$

  (i) Force of cohesion between two molecules of liquid is less than the force of adhesion between molecules of solid and liquid.

  (ii) Liquid molecules will stick with the solid, thus making solid wet.

  (iii) Such liquid is put in the solid tube; it will have meniscus concave upwards.

(b) When θ > 90º (obtuse):-$F_a<F_c/\sqrt{2}$

(i) Force of cohesion between two molecules of liquid is less than the force of adhesion between molecules of solid and liquid.

(ii) In this case, liquids do not wet the solids.

(iii) Such liquids when put in the solid tube will have a meniscus convex upwards.

(c) When ϑ = 90º:-?

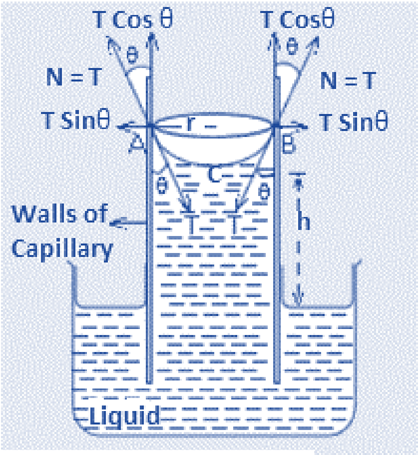
$F_a=F_c/\sqrt{2}$

The surface of liquid at the point of contact is plane. In this case force of cohesion and adhesion are comparable to each other.

(d) $\cos\vartheta_c = T_{sa} - T_{sl}/T_{la}$

Here, T_{sa},T_{sl} and T_{la} represent solid-air, solid-liquid and liquid-air surface tension respectively). Here ϑ_c is acute if $T_{sl} < T_{sa}$ while ϑ_c is obtuse if $T_{sl} > T_{sa}$.

- **Capillarity:-**



Capillarity is the phenomenon, by virtue of which the level of liquid in a capillary tube is different from that outside it, is called capillarity.

Weight of liquid, $W = V\rho g = \pi r^2[h+(r/3)]\rho g$ (Here r is the radius meniscus)

If weight of meniscus is taken into account, the force of surface tension will be,

$T = [r(h+(r/3))\,\rho g]/2\cos\vartheta$

For fine capillary, force of surface tension, $T = rh\rho g/2\cos\vartheta$

So height, $h = 2T\cos\vartheta/ r\rho g$

This signifies, height of liquid risen (or depressed) in a capillary tube varies inversely as the radius of tube. Smaller the diameter of capillary tube, greater is the rise of liquid in it.

- **Tube of insufficient length:**

$Rh = 2T/\rho g$

As, T, ρ and g are all constant, Rh = Constant

Smaller the value of h, greater will be the value of R. But liquid will never flow.

- **Effect of temperature affecting surface tension of liquids:-**

  Surface tension of a liquid decreases with an increase in its temperature.

  $T_\theta = K(\vartheta_c - \vartheta)$

  Here T_θ is the surface tension at a particular temperature ϑ while ϑ_c is the critical temperature of the liquid and K is constant.

- **General formula for excess pressure:-**

  $P_{excess} = T[1/R_1 + 1/R_2]$

- **Excess pressure in liquid drop:-**

  $P_{excess} = 2T/R$, Here R is the radius of liquid drop.

- **Excess pressure for an air bubble in liquid drop:-**

  $P_{excess} = 2T/R$

- **Excess pressure in soap bubble:-**

  $P_{excess} = 4T/R$, Here R is the radius of soap bubble.

- **Pressure inside an air bubble at a depth h in a liquid:-** $P_{in} = P_{atm} + hdg + (2T/R)$

- **Forces between two plates with thin water film separating them:-**

  (a) $\Delta P = T(1/r - 1/R)$

  (b) $F = AT(1/r - 1/R)$

  (c) If separation between plate is d, then $\Delta P = 2T/d$ and $F = 2AT/d$

- **Radius of curvature of common film:-** $R_{comon} = rR/R\text{-}r$

- **Capillary depression,** $h = 2T\cos(\pi\text{-}\theta)/rdg$

- **Shape of liquid surface:-**

  (a) Plane surface (as for water – silver) if $F_{adhesive} > F_{cohesive}/\sqrt{2}$

  (b) Concave surface (as for water – glass) if $F_{adhesive} > F_{cohesive}/\sqrt{2}$

  (c) Convex surface (as for mercury-glass) if $F_{adhesive} < F_{cohesive}/\sqrt{2}$

- **Increase in temperature:-**

  $\Delta\theta = 3T/\rho s\,(1/r - 1/R)$ or $\Delta\theta = 3T/\rho sJ\,(1/r - 1/R)$

Heat Transfer

Heat Energy , Thermal Expansion , thermodynamics , Radiation

- **Conduction:-** Conduction is that mode of transmission of heat by which heat travels, through an unequally heated body, from the hot end to the cold end, from particle to particle, the particles themselves remaining at their mean positions.

- **Convection:**- It is defined as that mode of transmission of heat by which heat travels from one part of a body to another by the actual motion of the heated particles of the body.

- **Radiation:**- It is defined as that mode of transmission of heat in which heat travels from hot body to cold body in straight lines without heating the intervening medium.

  Power, $P = eA\sigma T^4$

  Here, σ is the Stefan's constant.

  $$\sigma = 5.67 \times 10^{-8} \frac{W}{m^2K^4}$$

- **Temperature Gradient:**- It is defined as the rate of change of temperature of different cross-section with distance.

- **Coefficient of thermal conductivity:**-

  Rate of flow of heat = dQ/dt

  Heat current, through a conducting rod, is defined as the amount of heat conducted across any cross-section of the rod in one second.

  H= dQ/dt

  H depends upon following factors:

  (a) Area of cross-section of rod: $H \propto A$

  (b) Temperature Gradient: $H \propto -d\vartheta/dx$

  (c) Nature of the material

  So, $H = -KA\,(d\vartheta/dx)$

  Here K is called the coefficient of thermal conductivity of the material of rod. It depends upon the nature of material of rod.

  (d) The total heat Q crossing from one cross section to the other in time t:-

  $Q = KA(\vartheta_1-\vartheta_2)t/l$

  Or $K = Ql/A(\vartheta_1-\vartheta_2)t$

Coefficient of thermal conductivity of the material of a rod is defined as the heat current (amount of heat flowing per second) flowing per unit area between two cross-section of the rod each of area 1 m^2 and separated 1 m apart.

Dimension of *K*:- $[K] = [M^1L^1T^{-3}K^{-1}]$

Unit:- C.G.S- $cal\ cm^{-1}s^{-1}\ ^{\circ}C^{-1}$

S.I – $Wm^{-1}K^{-1}$

- **Thermal Conductance (σ_h):-** It is defined as heat current per unit temperature difference.

  $\sigma_h = KA/l$

  $\sigma_h = H/d\vartheta$

  Unit- S.I- WK^{-1}

- **Thermal Resistance (R_h):-** Thermal resistance, of a conductor is defined as the temperature difference between its two cross-sections when a unit heat current flows through it. Reciprocal of thermal conductance is known as thermal resistance of the substance.

  $R_h = 1/\sigma_H = l/KA = d\vartheta/H$

  Units of R_h:- S.I – $W^{-1}K$

- **Analogy between electricity and heat:-**

  $H = (\vartheta_1 - \vartheta_2)/(l/KA) = (\vartheta_1 - \vartheta_2)/R_h$

- **Searle's Method for *K*:-**

  $K = m(\vartheta_4 - \vartheta_3)d/A(\vartheta_1 - \vartheta)t$

- The ratio of thermal and electrical conductivities is the same for the metals at a particular temperature and is proportional to the absolute temperature of the metal. If T is the absolute temperature, then

  $K/\sigma \propto T$ or $K/\sigma T$ = constant

- **Ingen Hausz Experiment:-** $K_1/K_2 = l_1^2/l_2^2$

- **Thermal resistance of a conductor of length *d*:-** $R_{TH} = d/KA$

- **Flow of a heat through a composite slab:-**
  - **(a) Thermal resistance in series:-** Thermal resistance of the composite slab is equal to the sum of their individual thermal resistances.

    $(l_1 + l_2)/KA = (l_1/K_1A) + (l_2/K_2A)$

    $R_{comb} = R_h + R_h'$

    If $l_1 = l_2 = l$, then, $K = 2K_1K_2/K_1+K_2$

    Temperature of the interface:-

    $\vartheta_0 = [\vartheta_1 R_h' + \vartheta_2 R_h]/ [R_h + R_h']$ **or** $\vartheta_0 = [\vartheta_1 K_1 l_2 + \vartheta_2 K_2 l_1]/ [K_1 l_2 + K_2 l_1]$
  - **(b) Thermal resistance in parallel:-** Reciprocal of the combination thermal resistance is equal to the sum of the reciprocals of individual thermal resistances.

    $1/R_{comb} = 1/R_h + 1/R_{h'}$

- **Convection:-** It is the mode of transmission of heat, through fluids, in which the particle of fluids acquire heat from one region and deliver the same to the other regions by leaving their mean positions and moving from one point to another.

- **Radiation:**- Radiation is that process of transmission of heat in which heat travels from one point to another in straight lines, with velocity of light, without heating the intervening medium.

- **Bolometer:**- If R_t and R_0 are the resistances of the conductor at 0ºC and tºC, then, $R_t = R_0(1+\alpha t)$, Here α is the temperature coefficient of change of resistance with temperature.

- **Absorptive power (*a*):-** Absorptive power (*a*) of the substance is defined as the ratio between amounts of heat absorbed by it to the total amount of heat incident upon it.

  $a = Q_1/Q$

- **Reflecting Power (*r*):-** Reflecting power (*r*) of a substance is defined as the ratio between amount of heat reflected by the substance to the total amount of heat incident upon it.

  $r = Q_2/Q$

- **Transmitting power (*t*):-** Transmitting power (*t*) of a substance is defined as the ratio between amount of heat transmitted by the body to the total amount of heat incident upon it.

  $t = Q_3/Q$

- $a + r + t = Q_1/Q + Q_2/Q + Q_3/Q = [Q_1 + Q_2 + Q_3]/Q = Q/Q = 1$

- **Radiant emittance (*E*):-** Radiant emittance of a body at a temperature *T* is defined as the total amount of energy (for all wavelengths) radiated per unit time, per unit area by the body.

  $$E = \int_0^\infty e_\lambda \cdot d\lambda$$

  Unit:- S.I-$Jm^{-2}s^{-1}$

  C.G.S- erg $cm^{-2}s^{-1}$

- **Energy Density:-** Total energy density (*U*) at any point is defined as the radiant energy per unit volume, around that point, for wave-lengths taken together.

  $$U = \int_0^\infty u_\lambda \cdot d\lambda$$

- **Kirchhoff's law of heat radiation:-**
  It states that at any temperature, the ratio of emissive power e_λ of a body to its absorptive power a_λ, for a particular wave-length, is always constant and is equal to the emissive power of perfect black body for that wavelength.
  e_λ/a_λ = Constant = E_λ
  This implies the ratio between e_λ and a_λ for any body is a constant quantity (=E_λ).

- **Wein's Displacement Law:-**
  It states that wavelength of radiation which is emitted with maximum intensity varies inversely as the absolute temperature of the body.
  $\lambda_m \times T$ = Constant

- **Stefan's Law:-**
  Radiant emittance or the energy radiated per second per unit area by a perfect black body varies directly as the fourth power of its absolute temperature.

  $E = \sigma T^4$

  Here σ is the Stefan's constant and its value is 5.735×10^{-8} $Wm^{-2}K^{-4}$

- **Spectral emissive power:-**

  $e_\lambda = Q/At(d\lambda)$

- **Emissivity:-** $\varepsilon = e/E$, $0 \le \varepsilon \le 1$

- **Rate of loss of heat:-** $-dQ/dT = \varepsilon A\sigma(\vartheta^4 - \vartheta_0^4)$

- **For spherical objects:-** $(dQ/dT)_1/(dQ/dT)_2 = r_1^2/r_2^2$

- **The emissivity of a body is numerically equal to its absorptive power.**

  $e = a_\lambda$

  (a) Emissivity of body determines the radiant emittance of a body.

  (b) Emissivity of a perfect body is always one.

  (c) Emissivity of any body other than a perfect black body is less than one.

  (d) Emissivity of any body is numerically equal to its absorbing power.

- **Newton's Law of Cooling:-** It states that the rate of loss of heat of a body is directly proportional to the temperature difference between the body and surroundings.

  $dQ/dt = -K(T-T_0)$ or $(T-T_0) \propto e^{-KT}$

- **Wein's Radiation Law:-** $E_\lambda d\lambda = (A/\lambda^5)\, f(\lambda T)\, d\lambda = (A/\lambda^5)\, e^{-a/\lambda T}\, d\lambda$

- **Solar Constant:-** $S = (R_S/R_{ES})^2\, \sigma T^4$

- **Heat:-** Heat is the agent which produces in us the sensation of warmth and makes bodies hot. It is form of energy. The part of thermal energy which flows from one body to the other due to temperature difference is called heat.

- **Thermal Energy:-** In accordance to dynamical theory of heat the sum total of translational, vibrational and rotational energies of the molecules of a system is called the thermal energy of the system .

- **Unit of Heat:-**

  (a) Calorie (cal):- It is the amount of heat required to raise the temperature of 1 gram of water through 1ºC.

  (b) Kilocalorie (kcal):- It is the amount of heat required to raise the temperature of 1 kilo gram of water through 1ºC.

- **Temperature:-** It is defined as the degree of hotness of a body.

- **Zeroth Law of Thermodynamics:-**

  It states that the two systems (*A* and *B*) which are separately in equilibrium with a third system (C) must also be in equilibrium with each other.

- **Absoluter Zero of Temperature:-**
  - (a) Charle’s law:- $V_t = V_0(1+ t/273)$
  - (b) Gay Lussac’s law:- $P_t = P_0(1+ t/273)$
  - (c) Absolute zero of temperature is defined as the temperature at which a gas has zero volume and exerts zero pressure. It is that temperature at which molecular motion ceases.
  - (d) $C \propto \sqrt{T}$, $C = \sqrt{[c_1^2 + c_2^2 + ... + c_n^2]/n}$

- **Absolute gas scale or absolute scale of temperature:-** It is that scale of temperature whose zero (i.e. 0ºK) = -273ºC

  A centigrade degree is exactly equal to the absolute or Kelvin’s degree.

- **Conversion of temperature from one scale to another:-**
  $C/100 = (K-273)/100 = (F-32)/180 = R_e/80 = (R_\alpha-492)/180$
  Here C, K, F, R_e and R_α are respectively, the temperatures of same both on centigrade, Kelvin, Fahrenheit, Reaumer and Rankin scale, respectively.

- $F = [(9/5)C]+32$

- $K = C+273$

- **Linear Expansion (longitudinal expansion):-**
  When the expansion due to heating takes place only along one direction, the expansion is said to be one dimensional and linear.

- **Coefficient of linear expansion (*α*):-** Coefficient of linear expansion of the material of a rod is defined as the change in length per unit length, at 0°C, per degree centigrade rise of temperature.

  $\alpha = l_t-l_0/l_0t$

- **Expansion in two dimensions (Superficial expansion):-**
  When the thermal expansion of a body is confined to a plane, it is to be two dimensional expansion or superficial expansion.

- **Coefficient of superficial expansion (*β*):-** It is defined as the change in area of the surface per unit area at 0ºC, per degree centigrade rise of temperature.

  $\beta = S_t-S_0/S_0t$

- **Expansion in three dimensions (Cubical expansion/volume expansion):-** When thermal expansion of the body takes place in space, it is said to be three dimensional expansion or cubical expansion.

- **Coefficient of cubical expansion (γ):-** Coefficient of cubical expansion is defined as the change in volume per unit volume, at 0ºC, per degree celsius rise of temperature .

  $\gamma = V_t - V_0 / V_0 t$

- **Relation between expansion coefficients:-**
  (a) Relation between α and β:- $\beta = 2\alpha$
  (b) Relation between α and γ:- $\gamma = 3\alpha$
  (c) Relation between β and γ:- $\gamma = 3/2\ \beta$
  (d) $\alpha : \beta : \gamma = 1 : 2 : 3$

- **Thermal expansion of liquids:-**
  (a) Co-efficient of apparent expansion (γ_a):- The coefficient of apparent expansion of a liquid is defined as the apparent (or observed) increase in volume, per unit volume of the liquid at 0ºC per degree celcius rise of temperature.

  γ_a = apparent increase in volume/(original volume at 0ºC) × (rise of temperature)

  (b) Co-efficient of real expansion (γ_r):- The coefficient of real expansion of a liquid is defined as the real increase in volume, per unit volume of the liquid at 0ºC per degree centigrade rise of temperature.

  γ_a= real increase in volume/(original volume at 0ºC) × (rise of temperature)

- **Work and Heat:-**

  Whenever heat is conserved into work or work into heat, the quantity of energy disappearing in one form is equivalent to the quantity of energy appearing in the order.

  $W \propto H$ or $W = JH$

  Joule's mechanical equivalent of heat is defined as the amount of work required to produce a unit quantity of heat.

  $J = W/H$

  Value of J:- $J = 4.2\times10^7$ erg cal^{-1} = 4.2 J cal^{-1}

- **Specific heat capacity or specific heat (*c*):-**

  Specific heat capacity of a material is defined as the amount of heat required to raise the temperature of a unit mass of material through 1ºC.

  $c = Q/m\Delta T$

  Unit:- $kcal\ kg^{-1}K^{-1}$ or $J\ kg^{-1}K^{-1}$

  Dimension:- $M^0L^2T^{-2}K^{-1}$

- **Molar specific heat capacity(*C*):-**

  Molar specific heat capacity of a substance is defined as the amount of heat required to raise the temperature of one gram molecule of the substance through one degree centigrade.

  (a) $C = Mc$ (Here M is the molecular weight of the substance)

  (b) $C = 1/n\ (dQ/dT)$

- **Heat Capacity or Thermal Capacity:-**

  It is defined as the amount of heat required to raise the temperature of body through 1ºC.

  $Q = mc\Delta T$

  If ΔT = 1ºC, Q = heat capacity = mc

  Unit:- $kcal\ K^{-1}$ or JK^{-1}

- **Water Equivalent:-**

  Water equivalent of a body is defined as the mass of water which gets heated through certain range of temperature by the amount of heat required to raise the temperature of body through same range of temperature.

  $w = mc$

  Water equivalent of a body is equal to the product of its mass and its specific heat.

- **Latent Heat:-** When the state of matter changes, the heat absorbed or evolved is given by: $Q = mL$. Here L is called the latent heat.

  (a) Specific latent heat of fusion (L_f):-

  Specific latent heat of fusion of a substance is defined as the amount of heat required to convert 1 gram of substance from solid to liquid state, at the melting point, without any change of temperature.

(b) Specific latent heat of vaporization (L_v):-

Specific latent heat of vaporization of a substance is defined as the amount of heat required to convert 1 gram of liquid into its vapours at its boiling point without any rise of temperature.

Dimensional formula:- $M^0L^2T^{-2}$

Unit:- $kg\ cal\ kg^{-1}$ or $J\ kg^{-1}$

- Triple point of water = 273.16 K
- Absolute zero = 0 K = -273.15ºC
- For a gas thermometer, $T = (273.15)\ P/P_{\text{triple}}$ (Kelvin)
- For a resistance thermometer, $R_e = R_0[1+\alpha\vartheta]$
- **Thermodynamics:-** It is the branch of physics which deals with process involving heat, work and internal energy. Thermodynamics is concerned with macroscopic behavior rather than microscopic behavior of the system.
- **Basic Terminology:-**
- **Kinetic Energy:-** Energy possessed by the atoms or molecules by virtue of their motion is called kinetic energy.
- **Internal Energy (ΔU):-** Sum total of kinetic and potential energies of atoms/molecules constituting a system is called the internal energy of the system.
  (a) ΔU is taken as positive if the internal energy of the system increases.
  (b) ΔU is taken as negative if the internal energy of the system decreases.
- **Heat:-** Heat is the part of internal energy which is transferred from one body to another an account of the temperature difference.
- **Work:-** Work is said to be done when a force acting on a system displaces the body in its own direction.

  $dW = Fdx = PdV$

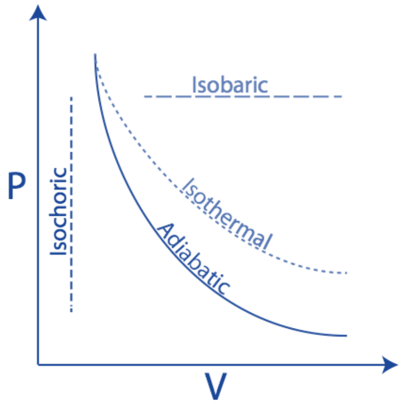
  $W = P(V_f - V_i)$

  (a) If the gas expands, work is said to be done by the system. In this case $V_f > V_i$, therefore, W will be positive.
  (b) If the gas is compressed, work is said to be done on the system. In this case $V_f < V_i$, therefore, work done is negative.
- **Thermodynamic variables or parameters:-** The thermodynamic state of system can be determined by quantities like temperature (T), volume (V), pressure (P), internal energy (U) etc. These quantities are known as thermodynamic variables, or the parameters of the system.
- **Equation of state:-** A relation between the values of any of the three thermodynamic variables for the system, is called its equation of state.

  Equation of state for an ideal gas is $PV = RT$
- **Equilibrium of a system:-** A system is said to be in equilibrium if its macroscopic quantities do not change with time.

- **Relation between joule and calorie:-** 1 joule = 4.186 cal
- **First law of thermodynamics:-** If the quantity of heat supplied to a system is capable of doing 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 it.

  dQ = dU+dW
- **Thermodynamic Process:-** A process by which one or more parameters of thermodynamic system undergo a change is called a thermodynamic process or a thermodynamic change.



(a) Isothermal process:- The process in which change in pressure and volume takes place at a constant temperature

(b) Isobaric process:- The process in which change in volume and temperature of a gas take place at a constant pressure

(c) Isochoric process:- The process in which changes in pressure and temperature take place in such a way that the volume of the system remains constant

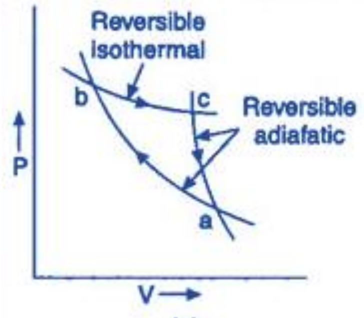
(d) Adiabatic process:- The process in which change in pressure and volume and temperature takes place without any heat entering or leaving the system

(e) Quasi-static process:- The process in which change in any of the parameters take place at such a slow speed that the values of P,V, and T can be taken to be, practically, constant

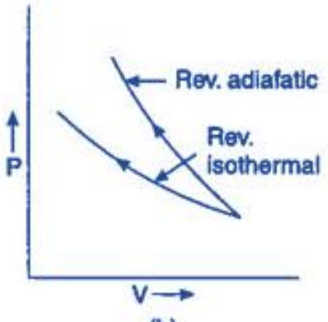
(f) Cyclic process:- In a system in which the parameters acquire the original values, the process is called a cyclic process.

(g) Free expansion:- Such an expansion in which no external work is done and the total internal energy of the system remains constant is called free expansion.

- **Reversible isothermal and adiabatic curve:-**



(a)



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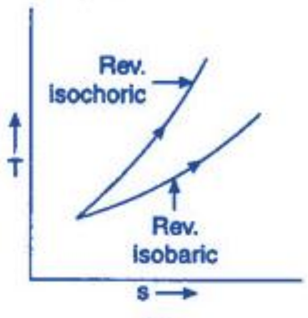


(c)

- **Application of first law of thermodynamics:-**
  - **(a) Cooling caused in adiabatic process:-** $dT = PdV/C_v$
  - **(b) Melting:-** $dU = mL_f$
  - **(c) Boiling:-** $dU = mL_v - P(V_f - V_i)$
  - **(d) Mayer's formula:-** $C_p - C_v = R$

- **Specific heat capacity of gases:-** Specific heat capacity of a substance is defined as the amount of heat required to raise the temperature of a unit mass of substance through 1ºC.
  - **(a) Specific heat capacity at constant volume (c_v):-** Specific heat capacity at constant volume is defined as the amount of heat required to raise the temperature of 1 *g* of the gas through 1º*C* keeping volume of the gas constant.

    Molar specific heat capacity, at constant volume (C_v), is defined as the amount of heat required to raise the temperature of 1 mole of gas through 1º*C* keeping its volume constant.

    $C_v = Mc_v$
  - **(b) Specific heat capacity at constant pressure (c_p):-** Specific heat capacity, at constant pressure, is defined as the amount of heat required to raise the temperature of 1 g of gas through 1º*C* keeping its pressure constant.

    Gram molecular specific heat capacity of a gas (C_p), at constant pressure, is defined as the amount of heat required to raise the temperature of 1 mole of the gas through 1º*C* keeping its pressure constant.

    $C_p = Mc_p$

- **Difference between two specific heat capacities – (Mayer's formula):-**
  - (a) $C_p - C_v = R/J$
  - (b) For 1 *g* of gas, $c_p - c_v = r/J$
  - (c) Adiabatic gas constant, $\gamma = C_p/C_v = c_p/c_v$

- **Relation of C_v with energy:-**

  $C_v = 1/m\,(dU/dT)$
  - **(a) Mono-atomic gas (3 degree of freedom):-**

    Total energy, $U = mN\,3\,[(1/2)\,KT]$, Here m is the number of moles of the gas and N is the Avogadro's number.

    $C_v = (3/2)\,R$

    $C_p = (5/2)\,R$

    $\gamma = C_p/C_v = 5/3 = 1.67$

  - **(b) Diatomic gas:-**

    At very low temperature, Degree of Freedom (DOF) = 3

    $U = (3/2)\,mRT$

    $C_v = (3/2)\,R$, $C_p = (5/2)\,R$

    $\gamma = C_p/C_v = 5/3 = 1.67$

    At medium temperature, DOF = 5

    $U = (5/2)\,mRT$

$C_v = (5/2) R$, $C_p = (7/2) R$
$\gamma = C_p/ C_v = 7/5 = 1.4$
At high temperature, DOF = 7
$U = (7/2) mRT$
$C_v = (7/2) R$, $C_p = (9/2) R$
$\gamma = C_p/ C_v = 9/7 = 1.29$

- **Adiabatic gas equation:-** PV^{γ} = Constant
  - (a) Equation of adiabatic change in terms of T and V:- $TV^{\gamma-1}$ = Constant
  - (b) Equation of adiabatic change in terms of P and T:- $T^{\gamma} P^{1-\gamma}$ = Constant

- **Comparison of slopes of an isothermal and adiabatic:-**
  - (a) Slope of isothermal:- $dP/dV = -P/V$
  - (b) Slope of adiabatic:- $dP/dV = -\gamma P/V$
  - (c) Adiabatic gas constant:- $\gamma = C_p/C_v$
    As, $C_p > C_v$, So, $\gamma > 1$
    This signifies that, slope of adiabatic curve is greater than that of isothermal.

- **Slope on *PV* diagram:-**
  - (a) For isobaric process: zero
  - (b) For isochoric process: infinite

- **Work done for isobaric process:-** $W = P(V_2-V_1)$

- **Work done for isochoric process:-** $W = 0$

- **Work done in isothermal expansion and compression:-**
  ?$W = 2.3026\, RT \log_{10} V_f/V_i$ (isothermal expansion)
  $W = -\, 2.3026\, RT \log_{10} V_f/V_i$ (isothermal compression)

- **Work done during an adiabatic expansion:-**
  $W = K/1-\gamma\, [V_f^{1-\gamma} - V_i^{1-\gamma}] = 1/1-\gamma\, [P_2V_2-P_1V_1] = R/1-\gamma\, [T_2-T_1]$
- **Adiabatic constant (*γ*):-** $\gamma = C_p/C_v = 1+2/f$, Here f is the degrees of freedom.

- **Work done in expansion from same initial state to same final volume:-**
  $W_{adiabatic} < W_{isothermal} < W_{isobaric}$

- **Work done in compression from same initial state to same final volume:-**
  $W_{adiabatic} < W_{isothermal} < W_{isobaric}$

- **Reversible process:-** It is a process which can be made to proceed in the reverse direction by a very slight change in its conditions so that the system passes through the same states as in direct process, and at the conclusion of which the system and its surroundings acquire the initial conditions.

- Irreversible process:- A process which cannot be made to be reversed in opposite direction by reversing the controlling factor is called an irreversible process.

- **Heat engine:-** It is a device used to convert heat into mechanical energy
  - (a) **Work done**, $W = Q_1 - Q_2$
  - (b) **Efficiency:-** Efficiency η of an engine is defined as the fraction of total heat, supplied to the engine which is converted into work.
    $\eta = W / Q_1 = [Q_1 - Q_2] / Q_1 = 1 - [Q_2/Q_1]$

- **Carnot engine – Carnot's reverse cycle:-**
  - (a) **First stroke (isothermal expansion):-** $W_1 = RT_1 \log_e[V_2/V_1]$
  - (b) **Second stroke (adiabatic expansion):-** $W_2 = R/\gamma\text{-}1\ [T_1 - T_2]$
  - (c) **Third stroke (isothermal compression):-** $W_3 = RT_2 \log_e V_3/V_4$
  - (d) **Fourth stroke (adiabatic compression):-** $W_4 = R/\gamma\text{-}1\ [T_1 - T_2]$
  - (e) **Total work done in one cycle,** $W = W_1 + W_2 + W_3 + W_4 = R\,(T_1 - T_2) \log_e (V_2/V_1)$

- **Efficiency of Carnot engine:-** Efficiency η of an engine is defined as the ratio between useful heat (heat converted into work) to the total heat supplied to the engine.
  $\eta = W / Q_1 = [Q_1 - Q_2] / Q_1 = 1 - [Q_2/Q_1] = 1 - T_2/T_1$

- **Second law of thermodynamics:-**
  - **(a) Clausius statement:-** Heat cannot flow from a cold body to a hot body without the performance of work by some external agency.
  - **(b) Kelvin's statement:-** It is impossible to obtain a continuous supply of energy by cooling a body below the coldest of its surroundings.
  - **(c) Planck's statement:-** It is impossible to extract heat from a single body and convert the whole of it into work.

- **Refrigerator:-** It is a device which is used to keep bodies at a temperature lower than that of surroundings.

- **Coefficient of performance (*β*):-** Coefficient of performance of a refrigerator is defined as the amount of heat removed per unit work done on the machine.
  β = Heat removed/work done $= Q_2/W = Q_2/[Q_1 - Q_2] = T_2/[T_1 - T_2]$
  Coefficient of performance of a refrigerator is not a constant quantity since it depends upon the temperature of body from which the heat is removed.
  For a perfect refrigerator, $W = 0$ or $Q_1 = Q_2$ or $\beta = \infty$

- **Mean free path:-** $\lambda = 1/\sqrt{2}\pi d^2\rho_n$

  Here $\rho_n = (N/V)$ = number of gas molecules per unit volume

  d = diameter of molecules of the gas.

- **Heat added or removed:-**
  - (a) For isobaric process:- $Q = n\ C_p\Delta T$
  - (b) For isochoric process:- $Q = n\ C_v\Delta T$
  - (c) For isothermal process:- $Q = nRT\ \log_e (V_2/V_1)$
  - (d) For adiabatic process: $Q = 0$

- **Change in internal energy:-**
  - (a) For isobaric process, $\Delta U = n\ C_p\Delta T$
  - (b) For isobaric process, $\Delta U = n\ C_v\Delta T$
  - (c) For isothermal process, $\Delta U = 0$
  - (d) For adiabatic process, $\Delta U = -W = [nR\ (T_2 - T_1)]/(\gamma - 1)$

- **Mixture of gases:-** $n = n_1 + n_2$

  $M = n_1M_1 + n_2M_2/\ n_1 + n_2 = N_1m_1 + N_2m_2/N_1 + N_2$

  $$C_v = \frac{n_1C_{v_1} + n_2C_{v_2}}{n_1 + n_2} \quad \text{and} \quad C_p = \frac{n_1C_{p_1} + n_2C_{p_2}}{n_1 + n_2}$$

- **Enthalpy (H):-**
  - (a) $H = U + PV$
  - (b) **At constant pressure:-**

    $dH = dU + pdV$
  - (c) **For system involving mechanical work only:-**

    $dH = Q_P$ (At constant pressure)
  - (d) **For exothermic reactions:-**

    dH is negative
  - (e) **For endothermic reactions:-**

    dH is positive

- **Relation between dH and dU:-**

  $\mathbf{dH = dU + dn_g\ RT}$

Kinetic Theory of Gases & Radiation

- **Kinetic Theory of Matter:-**
  (a) Solids:- It is the type of matter which has got fixed shape and volume. The force of attraction between any two molecules of a solid is very large.
  (b) Liquids:- It is the type of matter which has got fixed volume but no fixed shape. Force of attraction between any two molecules is not that large as in case of solids.
  (c) Gases:- It is the type of matter does not have any fixed shape or any fixed volume.

- **Ideal Gas:-** A ideal gas is one which has a zero size of molecule and zero force of interaction between its molecules.

- **Ideal Gas Equation:-** A relation between the pressure, volume and temperature of an ideal gas is called ideal gas equation.

  $PV/T = \text{Constant}$ or $PV = nRT$

  Here, n is the number of moles and R is the universal gas constant.
- **Gas Constant:-**
  (a) Universal gas constant (R):-
  $R = P_0 V_0/T_0$
  $= 8.311\ J\ mol^{-1}K^{-1}$
  (b) Specific gas constant (r):-
  $PV = (R/M)\ T = rT$,
  Here, $r = R/M$
- **Real Gas:**-The gases which show deviation from the ideal gas behavior are called real gas.
- **Vander wall's equation of state for a real gas:-**

  $[P + (na/V)^2?][V - nb] = nRT$

  Here n is the number of moles of gas.
- **Avogadro's number (N):-** Avogadro's number (N), is the number of carbon atoms contained in 12 gram of carbon-12.
  $N = 6.023\times10^{23}$
  (a) To calculate the mass of an atom/molecule:-
  Mass of one atom = atomic weight (in gram)/N
  Mass of one molecule = molecular weight (in gram)/N
  (b) To calculate the number of atoms/molecules in a certain amount of substance:-
  Number of atoms in m *gram* = (N/atomic weight) × m
  Number of molecules in m *gram* = (N/molecular weight) × m

(c) Size of an atom:-

Volume of the atom, $V = (4/3)\pi r^3$

Mass of the atom, $m = A/N$

Here, A is the atomic weight and N is the Avogadro's number.

Radius, $r = [3A/4\pi N\rho]^{1/3\backslash}$

Here ρ is the density.

- **Gas laws:-**

(a) Boyle's law:- It states that the volume of a given amount of gas varies inversely as its pressure, provided its temperature is kept constant.

PV = Constant

(b) Charlers law or Gey Lussac's law:- It states that volume of a given mass of a gas varies directly as its absolute temperature, provided its pressure is kept constant.

V/T**=** Constant

$V - V_0/V_0 t = 1/273 = \gamma_p$

Here γ_p (=1/273) is called volume coefficient of gas at constant pressure.

Volume coefficient of a gas, at constant pressure, is defined as the change in volume per unit volume per degree centigrade rise of temperature.

(c) Gay Lussac's law of pressure:- It states that pressure of a given mass of a gas varies directly as its absolute temperature provided the volume of the gas is kept constant.

$P/T = P_0/T_0$ or $P - P_0/P_0 t = 1/273 = \gamma_p$

Here γ_p (=1/273) is called pressure coefficient of the gas at constant volume.

Pressure coefficient of a gas, at constant volume, is defined as the change in pressure per unit pressure per degree centigrade rise of temperature.

(d) Dalton's law of partial pressures:-

Partial pressure of a gas or of saturated vapors is the pressure which it would exert if contained alone in the entire confined given space.

$P = p_1 + p_2 + p_3 + \ldots\ldots$

$nRT/V = p_1 + p_2 + p_3 + \ldots\ldots$

(e) Grahm's law of diffusion:- Grahm's law of diffusion states that the rate of diffusion of gases varies inversely as the square root of the density of gases.

$R \propto 1/\sqrt{\rho}$ or $R_1/R_2 = \sqrt{\rho_2/\rho_1}$

So, a lighter gas gets diffused quickly.

(f) Avogadro's law:- It states that under similar conditions of pressure and temperature, equal volume of all gases contain equal number of molecules.

For m gram of gas, $PV/T = nR = (m/M)\, R$

- **Pressure of a gas (P):-** $P = 1/3\ (M/V)\ C^2 = 1/3\ (\rho)\ C^2$

- **Root mean square (r.m.s) velocity of the gas:-** Root mean square velocity of a gas is the square root of the mean of the squares of the velocities of individual molecules.

$C = \sqrt{[c_1^2 + c_2^2 + c_3^2 + \ldots.. + c_n^2]/n} = \sqrt{3P/\rho}$

- **Pressure in terms of kinetic energy per unit volume:-** The pressure of a gas is equal to two-third of kinetic energy per unit volume of the gas.

  P= 2/3 *E*

- **Kinetic interpretation of temperature:-** Root mean square velocity of the molecules of a gas is proportional to the square root of its absolute temperature.

  C= **√***3RT/M*

  Root mean square velocity of the molecules of a gas is proportional to the square root of its absolute temperature.

  At, T=0, C=0

  Thus, absolute zero is the temperature at which all molecular motion ceases.

- **Kinetic energy per mole of gas:-**

  K.E. per *gram mol* of gas = ½ MC^2 = 3/2 *RT*

- **Kinetic energy per gram of gas:-**

  ½ C^2 = 3/2 *rt*

  Here, ½ C^2 = kinetic energy per gram of the gas and r = gas constant for one gram of gas.

- **Kinetic energy per molecule of the gas:-**

  Kinetic energy per molecule = ½ mC^2 = 3/2 *kT*

  Here, *k* (Boltzmann constant) = *R/N*

  Thus, K.E per molecule is independent of the mass of molecule. It only depends upon the absolute temperature of the gas.

- **Regnault's law:-** P∝T
- **Graham's law of diffusion:-**

  $R_1/R_2 = C_1/C_2 = \sqrt{\rho_2/\rho_1}$

- **Distribution of molecular speeds:-**

  (a) Number of molecules of gas possessing velocities between *v* and *v+dv* :-

$$n_v dv = \frac{\sqrt{2}\pi n m^{3/2} v^2}{(\pi k\mathrm{T})^{3/2}} e^{-mv^2/2kT} dv$$

  (b) Number of molecules of gas possessing energy between u and u+dv:-

$$n_u du = \frac{2\pi n}{(\pi k\mathrm{T})^{3/2}} \sqrt{u}\, e^{\frac{-u}{k\mathrm{T}}} du$$

  (c) Number of molecules of gas possessing momentum between *p* and *p+dp* :-

$$n_p dp = \frac{\sqrt{2}\pi n}{(\pi mk\mathrm{T})^{3/2}} p^2 e^{\frac{-p}{2mk\mathrm{T}}} dp$$

(d) **Most probable speed:-** It is the speed, possessed by the maximum number of molecules of a gas contained in an enclosure.
$V_m = \sqrt{[2kT/m]}$

(e) **Average speed (V_{av}):-** Average speed of the molecules of a gas is the arithmetic mean so the speeds of all the molecules.
$V_{av} = \sqrt{[8kT/\pi m]}$

(f) **Root mean square speed (V_{rms}):-** It is the square root of the mean of the squares of the individual speeds of the molecules of a gas.
$V_{rms} = \sqrt{[3kT/m]}$

- $\mathbf{V_{rms} > V_{av} > V_m}$
- **Degree of Freedom (n):-** Degree of freedom, of a mechanical system, is defined as the number of possible independent ways, in which the position and configuration of the system may change.
  In general, if N is the number of particles, not connected to each other, the degrees of freedom n of such a system will be, $n = 3N$
  If K is the number of constraints (restrictions), degree of freedom n of the system will be, $n=3N-K$
- **Degree of freedom of a gas molecule:-**
  (a) **Mono-atomic gas:- Degree of freedom of monoatomic molecule, $n = 3$**
  (b) **Di-atomic gas:-**
  At very low temperature (0-250 K):- Degree of freedom, $n = 3$
  At medium temperature (250 K – 750 K):- Degree of freedom, $n = 5$ (Translational = 3, Rotational = 2)
  At high temperature (Beyond 750 K):- Degree of freedom, $n = 6$ (Translational = 3, Rotational = 2, Vibratory =1), For calculation purposes, $n = 7$
- **Law of equipartition of energy:-** In any dynamical system, in thermal equilibrium, the total energy is divided equally among all the degrees of freedom and energy per molecule per degree of freedom is ½ kT.

  $E = ½ kT$

- **Mean Energy:-** K.E of one mole of gas is known as mean energy or internal energy of the gas and is denoted by U.

  $U = n/2\ RT$ (Here n is the degree of freedom of the gas.)

  (a) Mono-atomic gas($n = 3$):- $U = 3/2\ RT$
  (b) Diatomic gas:-
  At low temperature ($n=3$):- $U = 3/2\ RT$
  At medium temperature ($n=5$):- $U = 5/2\ RT$
  At high temperature ($n=7$):- $U = 7/2\ RT$
- **Relation between ratio of specific heat capacities (γ) and degree of freedom (n):-**

  $\gamma = C_p/C_v = [1+(2/n)]$

  (a) For mono-atomic gas ($n=3$):- $\gamma = [1+(2/n)] = 1+(2/3) = 5/3=1.67$
  (b) For diatomic gas (at medium temperatures ($n=5$)):- $\gamma = [1+(2/5)] = 1+(2/5) = 7/5=1.4$
  (c) For diatomic gas (at high temperatures ($n=7$)):- $\gamma = [1+(2/7)] = 9/7 = 1.29$

Sound & Light Waves

Sound Waves:-

It is the form of energy which produces, in us, the sensation of hearing.

- **Properties:-**
  - (a) Longitudinal in nature.
  - (b) It requires a material medium for its propagation.
  - (c) Sound waves can be reflected.
  - (d) Sound waves suffer refraction.
  - (e) Sound waves show the phenomenon of interference
  - (f) Sound waves shows diffraction
  - (g) Sound propagates with a velocity much smaller than that of light.
  - (h) Sound gets absorbed in the medium through which it passes.
- **Loudness (L)or Intensity (I):-**

  $L \propto \log I$

  So, $L = K \log_{10}(I_1/I_0)$

  Unit of intensity of sound is **bel**.
- **Intensity (I) and Amplitude (A):-** $I \propto A^2$
- **Intensity(I) and distance from the source (r):-** $I \propto 1/r^2$
- **Pitch or Shrillness:-**Pitch is a sensation which determines the shrillness of sound. It is subjective and cannot be measured quantitatively. It depends up on frequency and relative motion between the sources and the listener.
- **Quality or Timber:-** It is that characteristic of a musical sound which enables us to distinguish between two notes of the same pitch and loudness produced by two different sources.
- **Velocity u of longitudinal wave (sound) [Newton's Formula]:-**

  $u = \sqrt{E/\rho}$

  Here E is the coefficient of elasticity and ρ is the density of medium.
- **Velocity of sound in solids:-**

  $u = \sqrt{Y/\rho}$

  Here Y is the young's modulus of elasticity and ρ is the density.
- **Velocity of sound in liquids:-**

  $u = \sqrt{B/\rho}$

  Here B is the Bulk modulus of elasticity and ρ is the density.

- **Velocity of sound in gases:-**

  $u = \sqrt{\gamma P/\rho}$

  Here, γ (=c_P/c_V) is the adiabatic ratio, P is the pressure and ρ is the density.

- **Various factors affecting velocity of sound:-**
  - **(a) Effect of density:-** The velocity of sound in a gas varies inversely as the square root of its density. $u_1/u_2 = \sqrt{[\rho_2/\rho_1]}$
  - **(b) Effect of moisture:-**$u_m/u_d = \sqrt{[\rho_d/\rho_m]}$

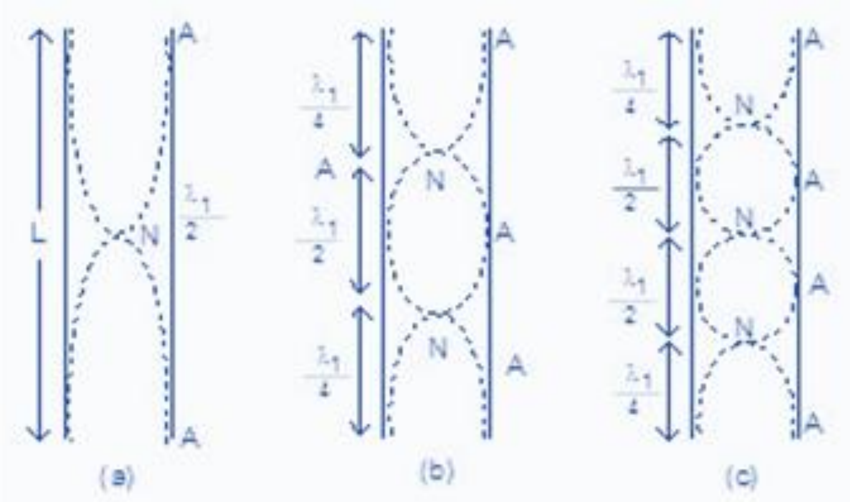
    Since, $\rho_m < \rho_d$, then, $u_m > u_d$

    This signifies sound travels faster in moist air.
  - **(c) Effect of pressure:-** $u = \sqrt{\gamma P/\rho} = \sqrt{\gamma k}$ = constant

    This signifies, change of pressure has no effect on the velocity of sound.
  - **(d) Effect of temperature:-** $u_t/u_0 = \sqrt{\rho_0/\rho_t} = \sqrt{T/T_0}$

    Thus, velocity of sound varies directly as the square root temperature on Kelvin's scale.
  - **(e) Temperature coefficient of velocity of sound (α):-** $\alpha = u_0/546 = (u_t - u_0)/t$

- **Overtones in open pipe:-**An open pipeis open at both ends. Since air is free to vibrate at an open end, we must get an antinode at the open end.



  - (a) **Fundamental frequency:-**

    Wavelength, $\lambda = 2l$

    Frequency, $f = u/2l = (1/2l)\sqrt{(\gamma P/\rho)}$

    Here l is the length of the pipe and u is the velocity of sound.
  - (b) **First overtone (Second Harmonic):-**

    Wavelength, $\lambda_1 = l$

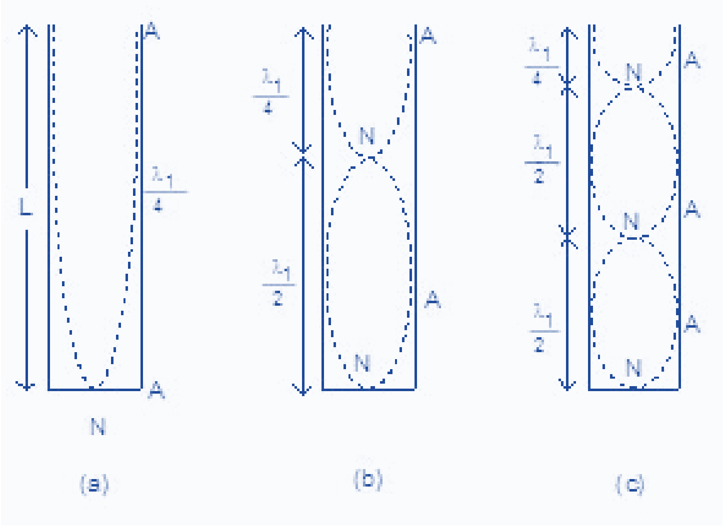
    Frequency, $f_1 = 2f$

(c) **Second overtone (Third Harmonic):-**

Wavelength, λ_2=2l/3

Wavelength, f_2=3f

- **Overtones in closed pipe:-**Since air, at a closed end, is not free to vibrate, there must be a node at a closed end always.



(a) Fundamental frequency:-

Wavelength, λ=4l

Frequency, $F=u/4l = (1/4l)\sqrt{(\gamma P/\rho)}$

Here l is the length of the pipe and u is the velocity of sound.

(b) First overtone (Third Harmonic):-

Wavelength, λ_1=(4/3)l

Frequency, F_1=3F

(c) Second overtone (Fifth Harmonic):-

$\lambda_2 = 4l/5$

$F_2 = 5F$

- **Comparison of fundamental frequencies of a closed end of an open pipe:-** $f = 2F$
- **Doppler's Effect:-**Theapparent change in pitch of a note, due to the relative motion between the source and the listener is called Doppler's effect.

(a) Source in motion, listener at rest:-

(i) Source approaching the listener:-

Modifying wave length, $\lambda' = V-a/f$

Apparent frequency, $f' = [V/V-a]f$

Change in frequency, ?f = (a/V-a)f

Here V is the velocity of sound in air and a is the velocity of source when it moves towards the listener.

(ii) Source going away from the listener:-

Apparent frequency, f' = [V/V+a]f

Change in frequency, ?f = -(a/V+a)f

(iii) Source crossing the listener:-

Apparent frequency of the source before crossing = (V/V-a) f

Apparent frequency of the source after crossing = (V/V+a) f

Change in frequency, ?f = -(2aV/V^2-a^2)f

(b) Source at rest, listener in motion:-

(i) Listener moving away from source:-

Apparent frequency, f'= [V-b/V]f

Change in frequency, ?f = (-b/V)f

Here b is the velocity of listener.

(ii) Listener moving towards the source:-

Apparent frequency:-f'= [V+b/V]f

Change in frequency, ?f = (+b/V)f

(iii) Listener crossing the source:-

Apparent frequency of the source before crossing = (V+b/V) f

Apparent frequency of the source after crossing = (V-b/V) f

Change in frequency, ?f =-2fb/V

(c) **Source and listener both in the medium:-** Change in frequency due to relative motion of source and listener.

Source *(S)*#	**Listener (*L*) (*X*)**	**Nature of velocities**	**Expression for *f* '**
# $\xrightarrow{a}$	X $\xrightarrow{b}$	+ve, +ve	*f* ' = (*V-b/V-a*) *f*
# $\xrightarrow{a}$	$\xleftarrow{-b}$ X	+ve, -ve	*f* ' = (*V+b/V-a*) *f*
$\xleftarrow{-a}$ #	$\xleftarrow{-b}$ X	-ve, -ve	*f* ' = (*V+b/V+a*) *f*
$\xleftarrow{-a}$ #	X $\xrightarrow{b}$	-ve, +ve	*f* ' = (*V-b/V+a*) *f*

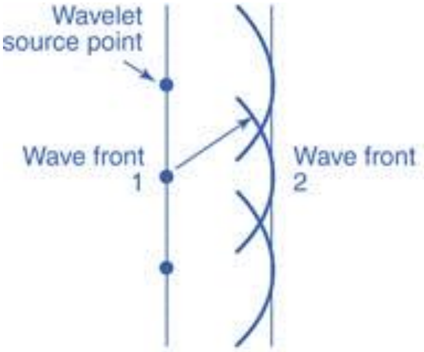
(d) Effect of motion of medium:-

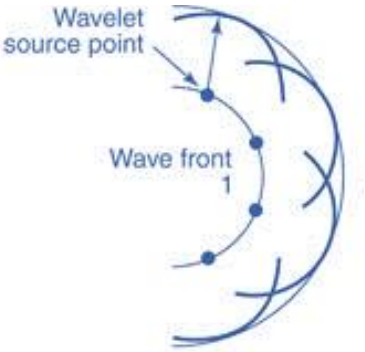
Apparent frequency:-$f' = [(R-b)/(R-a)]\,f$

Here, $R = V + \omega\cos\theta$, ω is the velocity of wind, θ is the angle between direction of propagation of sound and that of wind.

Huygens Principle:- Wave-front of a wave, at any instant , is defined as the locus of all the particles in the medium which are being disturbed at the same instant of time and are in the same phase of vibration.

(a) Each point on a wave front acts as a source of new disturbance and emits its own set of spherical waves called secondary wavelets. The secondary wavelets travel in all directions with the velocity of light so long as they move in the same medium.





(d) The envelope or the locus of these wavelets in the forward direction gives the position of new wave front at any subsequent time.

- **Determination of Phase Difference:-**

  The phase difference between two waves at a point will depend upon

  (a) The difference in path lengths of the two waves from their respective sources.

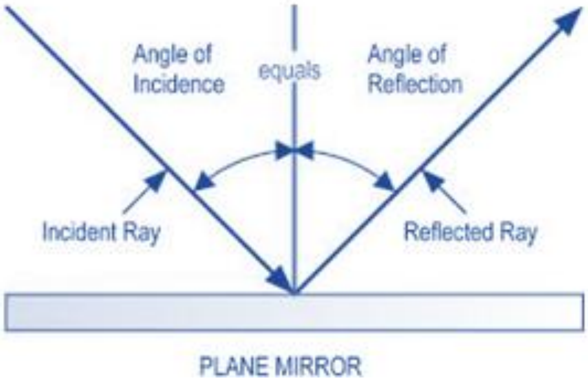
  (b) The refractive index of the medium

  (c) Initial phase difference between the source if any.

  (d) Reflections, if any, in the path followed by waves.

- **Reflection of plane wave at plane surface (Laws of reflection):-**

  (a) The incident ray, the reflected ray and normal to the reflecting surface at the point of incidence, all lie in one plane and that plane is perpendicular to the reflecting surface.



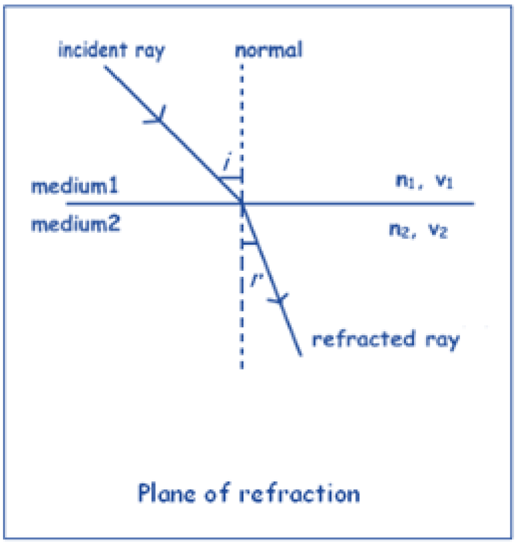
(b) The angle of incidence is equal to the angle of reflection.

So, $\angle i = \angle r$

This signifies angle of incidence is equal to the angle of reflection.

- **Refraction of light:-**

  Refraction is the phenomena by virtue of which a wave going from one medium to another undergoes a change in velocity.



(a) The sine of the angle between the incident ray and the normal bears a constant ratio to the sine of the angle between refracted ray and the normal.

$\sin i/\sin r = v_1/v_2 = {}^1\mu_2$ = constant

Here, v_1 and v_2 are the velocities of sound in first and second medium respectively. ${}^1\mu_2$ is the refractive index of the second medium with respect to first.

(b) The incident ray, the refracted ray and the normal to the refracting surface lie in the same plane.

- **Interference:-** The modification in the distribution of light energy obtained by the superposition of two or more waves is called interference.
- **Principle of superposition:-** It states that a number of waves travelling, simultaneously, in a medium behave independent of each other and the net displacement of the particle, at any instant, is equal to the sum of the individual displacements due to all the waves.
- **Displacement equation:**- $y = R \sin 2\pi/\lambda\,(vt+x/2)$
- **Amplitude:-** $R = 2a \cos \pi x/\lambda$
- **Intensity:-** $I = K4a^2 \cos^2 (\pi x/\lambda)$ $[I = KR^2]$
- **Maxima:-** A point having maximum intensity is called maxima.

  $x = 2n\,(\lambda/2)$

  A point will be a maxima if the two waves reaching there have a path difference of even multiple of $\lambda/2$.

  $I_{max} = 4Ka^2 = 4i$ (Here, $i = Ka^2$)

- **Minima:-** A point having minimum intensity is called a minima.

  $x = (2n+1)(\lambda/2)$

  A point will be a minima if the two waves reaching there have a path difference of odd multiple of $\lambda/2$.

  $I_{min} = K.\ 4a^2\times 0 = 0$
- **Condition for constructive interference:-**

  Path difference = $(2n)\lambda/2$

  Phase difference = $(2n)\pi$
- **Condition for destructive interference:-**

  Path difference = $(2n+1)\lambda/2$

  Phase difference = $(2n+1)\pi$
- **Coherent Sources:-** Coherent sources are the sources which either have no phase difference or have a constant difference of phase between them.
- **Conditions for interference:-**

  (a) The two sources should emit, continuously, waves of same wavelength or frequency.
  (b) The amplitudes of the two waves should be either or nearly equal
  (c) The two sources should be narrow.
  (d) The sources should be close to each other.
  (e) The two sources should be coherent one.
- **Young's double slit experiment:-**

  Path difference, $x = yd/D$

  Maxima, $y = n\lambda D/d$

  Here, $n = 0,1,2,3….$

  Minima, $y = (2n+1)\lambda D/d$

  Here, $n = 0,1,2,3….$
- **Fringe Width:-** It is the distance between two consecutive bright and dark fringes.

  $\beta = \lambda D/d$
- **Displacement of fringes due to the introduction of a thin transparent medium:-**

  (a) Shift for a particular order of fringes:-

  ?y = $(\beta/\lambda)(\mu-1)t$

  (b) Shift across a particular point of observation:-

  $\mu = (m\lambda/t) + 1$
- **Lloyd's single mirror:-**

  ?$\lambda = \beta\ .2a/D$
- **Power of lens:-** $P = 100/f$
- **Magnifying power or magnification of a simple microscope:-** $M = 1+(D/f)$
- **Magnifying power or magnification of a compound microscope:-**

  $M = L/f_0\ (1+D/f_e)$

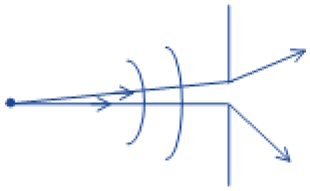
  Here, f_0 is the focal length of the objective, f_e is the focal length of the eyepiece and L is the length of the microscope tube.
- **Magnification of astronomical telescope in normal adjustment:-**

  $M = f_0/f_e$

- **Magnification of astronomical telescope, when the final image is formed at the distance of distinct vision:-**

  $M = (f_0/f_e)\,[(f_e+D)/D]$
- **Magnifying power *M* of Galileo's telescope:-**

  M = focal length of objective/focal length of eye lens = F/f
- **Diffraction:-** Diffraction is the bending or spreading of waves that encounter an object (a barrier or an opening) in their path.



(a) In Fresnel class of diffraction, the source and/or screen are at a finite distance from the aperture.

(b) In Fraunhofer class of diffraction, the source and screen are at infinite distance from the diffracting aperture. Fraunhofer is a special case of Fresnel diffraction.

If I_m represents the intensity at O, its value at P is

$I_\theta = I_m (\sin\alpha/\alpha)^2$

Here, α = ?/2 = $\pi a \sin\vartheta/\lambda$

A minimum occurs when, $\sin\alpha = 0$ and α is not equal to zero.

so $\alpha = n\pi$, $n = 1, 2, 3...$

So, $\pi a \sin\vartheta/\lambda = n\pi$

Or, $a \sin\vartheta = n\lambda$

Angular width of central maxima of diffraction pattern = $2\vartheta_1 = 2\sin^{-1}(\lambda/a)$

[ϑ_1 gives the angular position of first minima]

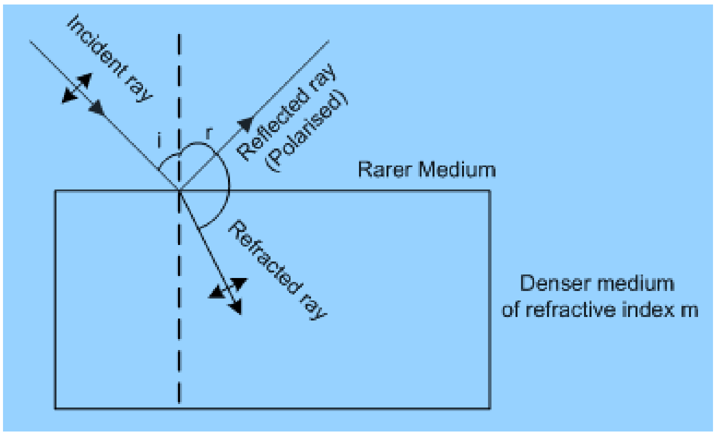
- **Polarization: -** Polarization of two interfering wave must be same state of polarization or two source of light should be un polarized.

- **Brewster Law:-**

  ?According to this law when un polarized light is incident at polarizing angle (i) on an interface separating a rarer medium from a denser medium, of refractive index m as shown in Fig., below such that,

  $\mu = \tan i$

  Then light reflected in the rarer medium is completely polarized. Reflected and refractive rays are perpendicular to each other.



- **Reduction in Intensity:-** Intensity of polarized light is 50% of that of the un polarized light, i.e.,

  $I_p = I_u/2$

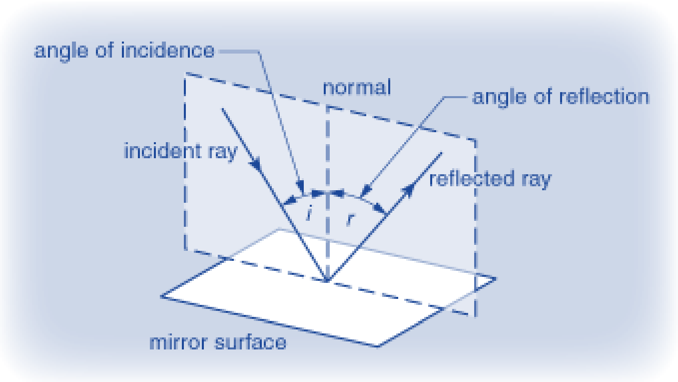
  Here, I_p = Intensity of polarized light.

  I_u = Intensity of un polarized light.

Ray Optics

Reflection:-

- **Light:-** it is an agent which produces in us the sensation of sight. It is a form of energy.
- **Transparent medium:-** It is a medium through which light can be propagated easily.(e.g., sun, candle, electric arc)
- **Translucent medium:**- It is a medium through which light is propagated partially.(e.g., paper, ground, glass)
- **Opaque:**- It is a medium through which light can be propagated. (e.g., wood, iron)
- **Reflection:**- It is the property of light by virtue of which, light is sent back into the same medium from which it is coming after being obstructed by a surface.
- **Laws of reflection:**-



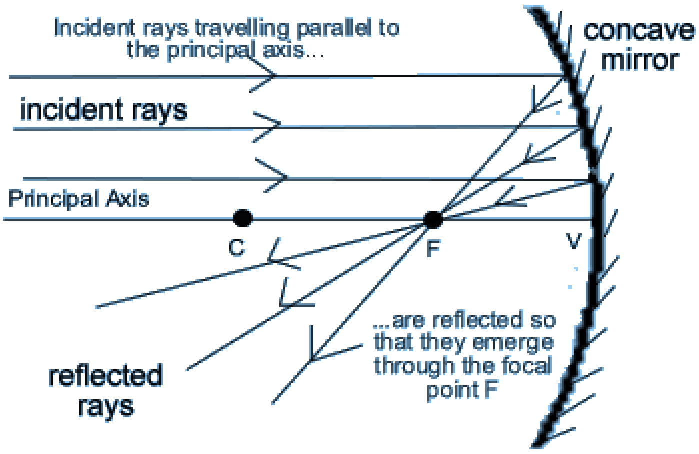
?

(a) The incident ray, the reflected ray and normal to the reflecting surface at the point of incidence, all lie in one plane and that plane is perpendicular to the reflecting surface.

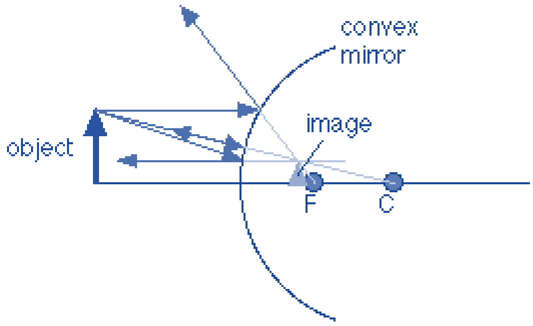
(b) The angle of incidence is equal to the angle of reflection.

So, $\angle i = \angle r$

- **Concave Mirror:-** It is a spherical mirror which when looked from the reflecting side is depressed at the center and bulging at the edges.



- **Convex mirror:-**



?It is a spherical mirror which when looked from the reflecting side bulges at the center and is depressed at the edges.

- **Radius of curvature(*R*):-**

Radius curvature of a mirror is defined as the radius of that sphere of which the mirror forms a part.

- **Principal focus:-**

Principal focus is a point, situated on the principal axis, at which a beam coming parallel to principal axis meets or appears to meet after reflection from the mirror.

- **Focal plane:-**

It is a vertical plane passing through the principal focus and perpendicular to the principal axis.

- **Focal length (*f*):-**

Focal length, of a spherical mirror is the distance of its principal focus from its pole.

- **Relation between focal length and radius of curvature:-**

$f = R/2$

This signifies, the focal length of a spherical mirror is half of its radius of curvature.

- **Mirror formula:-**

?$1/f = 1/v + 1/u = 2/r$

- **Relative positions, size and nature of image as object is brought from infinity to the pole of a concave mirror:-**

(a) If the object is at infinity, $u = \infty$

$v = -f$, $m = 0$

Thus, image is obtained at the focus of a focal plane and very small in dimensions.

(b) If object lies beyond center of curvature,

$2f > v > f$

(c) If object is at center of curvature,

$v = -2f$, $m = 1$

Thus, a real and inverted image of same size as that of object is formed at center of curvature.

(e) Object is in between a distance f and $2f$, i.e., in between focus and center of curvature ($f < u < 2f$):-

$v < \infty$ and $m = (v/u) > 1$

Thus, a real, inverted and magnified image is formed in between center of curvature and infinity.

(e) Object is kept at focus ($u = -f$):-

$v = -\infty$

The rays after reflection are rendered into a parallel beam meeting in infinity.

(f) Object is kept within focus ($u < -f$):-

v is positive.

Thus, a virtual, erect and magnified image is formed on the other side of mirror.

- **Some important points:-**
  (a) In case of spherical mirrors, focal length is half its radius of curvature image.

  (b) In case of concave mirror areal object produces a real and inverted if its distance from pole is greater than the focal length while its virtual and erect if its distance from pole is less than focal length.

  (c) In case of convex mirror a real object always produces a virtual and erect image.

  (d) All real images are inverted and virtual images are erect.

Refraction:-

- **Refraction:-** Refraction is the phenomenon by virtue of which a ray of light going from one medium to the other undergoes a change in its velocity.
- **Incident ray:-**The ray which approaches the interface is called incident ray.
- **Refracted ray:-** Ray which goes into the second medium is called angle of incidence.
- **Laws of refraction:-**

(a) Snell's law:- The sine of the angle of incidence bears a constant ratio with the sine of the angle of refraction.

$\sin i/\sin r = \text{constant}$

(b) The incident ray, the refracted ray and the normal to the interface at the point of incidence all lie in one plane and that plane is perpendicular to the interface separating the two media.

- **Refractive Index:-**

? (a) Refractive index of a medium with respect to another is defined as the ratio between sine of the angle of incidence to the sine of angle of refraction.

sin i/sin r = constant = $^1\mu_2$

(b) Refractive index of medium 2 with respect to1 is also defind as the ratio between velocity of light in medium 1 to the velocity of light in medium 2.

(c) $^1\mu_2 = v_1/v_2$

(d) $\mu = c/v$

(e) Refractive index of a second medium with respect to first is defined as the ratio between absolute refractive index of second medium to the abdsolute refractive index of first medium.

(f) $^1\mu_2 = \mu_2/\mu_1$?

- **Total internal reflection:-**

(a) Critical angle:- Critical angle is the angle of incidence of a ray of light in denser medium such that its angle of refraction in the rarer medium is 90º.

(b) Total internal reflection:- It is the phenomenon by virtue of which, a ray of light travelling from a denser to a rarer medium is sent back in the same medium provided, it is incident on the interface at an angle greater than critical angle.

(c) $\mu = 1/\sin C$

- **Refraction at a single spherical surface when light travelling from medium of refractive index μ_1 (rarer) to that of refractive index μ_2 (denser):-**

(a) Refraction at a convex surface producing real image:-

$\mu_2/v - \mu_1/u = \mu_2 - \mu_1/R$

(b) Refraction at a convex surface producing virtual image:-

$\mu_2/v - \mu_1/u = \mu_2 - \mu_1/R$

(c) Refraction at a concave surface:-

$\mu_2/v - \mu_1/u = \mu_2 - \mu_1/R$

- **Refraction at a single spherical surface when light travelling from medium of refractive index μ_2 (denser) to that of refractive index μ_1(rarer) :-**

Convex surface producing a real image of a real object:-

$\mu_2/u - \mu_1/v = \mu_2 - \mu_1/R$

- **Light travelling from air to glass:-**

  $\mu/v - 1/u = \mu\text{-}1/R$

- **Light travelling from glass to air:-**

  $\mu/u - 1/v = \mu\text{-}1/R$

- **Principal focal length:-**

  (a) Second principal focal length:- Second principal focal length of a surface is the distance of that point from the pole of the surface at which a beam coming parallel to principal axis meets or appears to meet after refraction through the surface.

  $f_2 = \mu_2 R/ [\mu_2 - \mu_2]$

  (b) First principal length:- First principal focal length of a surface is defined as the distance of that point from the pole of surface from where if a beam diverges or to which a beam converges, the rays after refraction through the surface become parallel to principal axis.

  $f_1 = -\mu_1 R/ [\mu_2 - \mu_1]$

  (c) Relation between f_1 and f_2:-

  $f_2/v + f_1/u = 1$

- **Lens:-**
  A portion of refracting material bound between two spherical surfaces is called a lens.

- **Converging lens:-**
  A lens is said to be converging if the width of the beam decreases after refraction through it.

- **Diverging lens:-**
  A lens is said to be diverge if the width of the beam increases after refraction through it.

- **Center of curvature:-**
  Center of curvature of a surface of a lens is defined as the center of that sphere of which that surface forms a part.

- **Radius of curvature:-**
  Radius of curvature of a surface of a lens is defined as the radius of that sphere of which the surface forms a part.

- **Lens formula:-**
  $1/f = 1/v - 1/u$

- **Linear magnification:-**
  It is the ratio between the size of the image to the size of the object.
  $m = I/O$

- **Expression for m in terms of u, v and f :-**
  (a) In terms of v and f:- $m = [f-v] / f$
  (b) In terms of u and f:- $m = f / [f + u]$

- **Position of the image as the object is gradually moved from infinity to the pole of the lens:-**
  (a) Object being at infinity:- $v = f$, Magnification in this case is extremely small and the image is said to be real and inverted.

  (b) Object lying beyond $2f$:- $2f > v > -f$, $m(= v/u)$ always is less than one.

  (c) Object at $2f$:- $v = 2f$, $m = -1$

  (d) Object lying between f and $2f$:- $v > 2f$, $m(= v/u)$ always is greater than one.

  (e) Object at f:- $v = \infty$, $m(= v/u)$ is infinite.

  (f) Object lying between f and optical center C:-

  At f, $u = -f$. So, $v = \infty$

  At C, $u = 0$, So, $v = 0$

- **Refraction through a thin double convex lens when the medium on the two sides of the lens is same (Lens maker's formula):-**

  $1/f = (\mu - 1)(1/R_1 - 1/R_2)$

- **Refraction through a thin double convex lens when the medium situated on the two sides of the lens is different:-**

  $1/f = [[\mu_3 - \mu_1]/\mu_3 R_1] + [[\mu_3 - \mu_2]/\mu_3 R_2]$

- **Double concave lens:-**
  (a) When the medium situated on the two sides of the lens is same:-

  $1/f = (\mu - 1)(1/R_1 - 1/R_2)$

  (b) When the medium situated on the two sides of the lens is different:-

  $1/f = [[\mu_3 - \mu_1]/\mu_3 R_1] + [[\mu_3 - \mu_2]/\mu_3 R_2]$

- **Combination of two convex lenses in contact:-**

  $F = f_1 f_2 / f_1 + f_2$

- **Power of a lens:-**
  The reciprocal of the focal length of a lens, expressed in meter, is called its power.
  $P = 1/f$

- **Refraction through a prism:-**

  $\mu = \sin[(A+d_m)/2] / \sin[A/2]$

  Here, d_m is the minimum angle of deviation.

- **Refraction through a prism for small angle of incidence:-**

  $d = A(\mu-1)$

  This signifies that the angle of deviation d is independent of the angle of incidence, provided it is small.

Dispersion:-

- **Dispersion:-** The splitting of light into its constituent colors is called dispersion.

- **Cauchy's formula:-** $\mu = A+(B/\lambda^2)+\ldots$

  Here A and B are constants and λ is the wavelength of light.

- **Refraction through a prism:-**

  (a) Deviation:- A ray of monochromatic light (light possessing one wave-length only), while passing through a prism suffers a change in its path, the phenomenon is known as deviation.

  $d = (\mu-1)A$

  Here A is the refractive angle of prism and μ is the refractive index of the material of prism for that particular wave length of light.

  (b) Dispersion:- A ray of light (containing more than one wavelengths), while passing through the prism splits up into a number of rays. The phenomenon is called dispersion.

  $d_v = (\mu_v-1)A$

  $d_r = (\mu_r-1)A$

  Here d_v is deviation for violet and d_r is the deviation for red color. μ_v and μ_r be the refractive indices of the material of prism for violet and red colors.

  Since, $\mu_v > \mu_r$, therefore d_v is greater than d_r.

- **Dispersive power (ω):-** Dispersive power of a prism is defined as the ratio between angular dispersion to mean deviation produced by the prism.

  $\omega = (d_v - d_r)/d = (\mu_v - \mu_r)/(\mu-1) = d\mu/(\mu-1)$

- **Spectrum:-** The band of colors lying side-by-side is called spectrum.
  - **(a) Impure spectrum:-** Impure spectrum is a spectrum in which the constituent colors overlap each other.
  - **(b) Pure spectrum:-** Pure spectrum is a spectrum in which all the constituent colors occupy different and distinct positions.

Optical Instruments:-

- **Power of a concave lens (P):-**
  P = (100/x) dioptre, Here 'x' is the distance of far point of the defective eye, in 'cm'.

- **Magnifying power or magnification of a simple microscope:-**
  ? $M = 1+ (D/f)$,

  Here, 'D' is the distance of distinct vision and 'f' is the focal length.

- **Magnifying power or magnification of a compound microscope:-**
  ? $M = L/f_0[1+(D/f_e)]$

  f_0 is the focal length of object, f_e is the focal lengthy of eyepeice and L is the length of microscope tube.

- **Magnifying power or magnification of astronomical telescope (Normal Adjustment):-**

  $M = f_0/f_e$

- **Magnifying power or magnification of astronomical telescope (When the final image is formed at the distance of distinct vision):-**

  $M = (f_0/f_e)\ [(f_e+D)/D]$

- **Magnifying power or magnification of Galileo's telescope:-**

  $M = F/f$

Electrostatics

Electrostatic Force and Electrostatic field:-

- **Electrostatic:-** It is a branch of physics that deals with the phenomena and properties of stationary or slow-moving electric charges with no acceleration**.**

- **Coulomb's Law:-** It states that the electro-static force of attraction or repulsion between two charged bodies is directly proportional to the product of their charges and varies inversely as the square of the distance between the two bodies.

  $F = Kq_1q_2/r^2$

  Here, $K = 1/4\pi\varepsilon_0 = 9\times10^9\ Nm^2C^{-2}$ (in free space)

- **Relative Permittivity (ε_r):-** The relative permittivity (ε_r) of a medium is defined as the ratio between its permittivity of the medium (ε) and the permittivity (ε_0) of the free space.

  $\varepsilon_r = \varepsilon/\varepsilon_0$

- **Coulomb force in vector form:-** The force on charge q_1 due to q_2 is,

  $$\vec{F_{12}} = [q_1q_2/r^2]\hat{r_{21}}$$

  If $q_1q_2>0$, R.H.S is positive.

If $q_1q_2<0$, a negative sign from q_1q_2 will change $\hat{r_{21}}$ and $\hat{r_{12}}$. The relation will again be true, since, in that case have same directions.

- **Unit of Charge:-**

  C.G.S, $q = \pm1$ stat-coulomb

  S.I, $q = \pm1$ Coulomb

- **Relation between coulomb and stat-coulomb:-**

  1 coulomb = 3×10^9 stat-coulomb

  1 coulomb =(1/10) ab-coulomb (e.m.u of charge)

- **Dielectric constant:-** The dielectric constant (ε_r) of a medium can be defined as the ratio of the force between two charges separated by some distance apart in free space to the force between the same two charges separated by the same distance apart in that medium.

  So, $\varepsilon_r = \varepsilon/\varepsilon_0 = F_1/F_2$

Here, F_1 and F_2 are the magnitudes of the force between them in free space and in a medium respectively.

- **Charges:-**

  ? Line charge, $\lambda = q/L$

  Surface chage, $\sigma = q/A$

  Volume charge, $\rho = q/V$

- **Electric field ($\vec{E}$) :-** The strength of an electric field is measured by the force experienced by a unit positive charge placed at that point. The direction of field is given by the direction of motion of a unit positive charge if it were free to move.

  $$\vec{E} = \vec{F}/q = Kq/r^2$$

- **Unit of Electric field:-**

  E = [Newton/Coulomb] or [Joule/(Coulomb) (meter)]

- **Electric lines of force:-** An electric line of force is defined as the path**,** straight or curved**,** along which a unit positive charge is urged to move when free to do so in an electric field. The direction of motion of unit positive charge gives the direction of line of force.

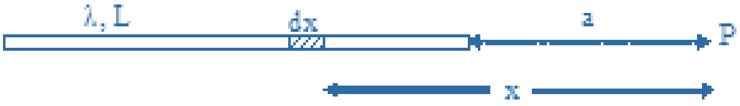
  Properties:-

  (a) The lines of force are directed away from a positively charged conductor and are directed towards a negatively charged conductor.

  (b) A line of force starts from a positive charge and ends on a negative charge. This signifies line of force starts from higher potential and ends on lower potential.

- **Electric field intensity due to a point charge:-** $E = (1/4\pi\varepsilon_0)\,(q/r^2)$

- **Electric field Intensity due to a linear distribution of charge:-**



? (a) At point on its axis.

$$E = (\lambda/4\pi\varepsilon_0)\,[1/a - 1/a+L]$$

Here, λ is the linear charge density.

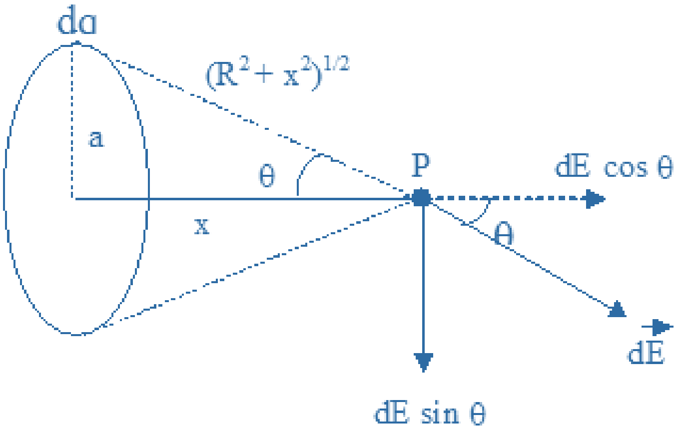
(b) At a point on the line perpendicular to one end.

$$E_X = \frac{\lambda}{4\pi\in_0}\left[\frac{1}{y} - \frac{1}{\sqrt{L^2+y^2}}\right]$$

$$E_Y = \frac{\lambda}{4\pi\in_0}\left[\frac{1}{y\sqrt{L^2+y^2}}\right]$$

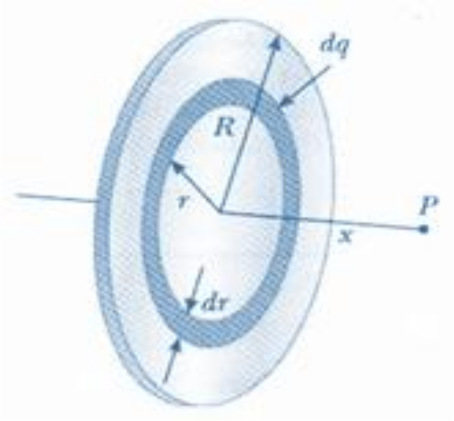
? Here λ is the line charge.

- **Electric field due to ring of uniform charge distribution:-**



At a point on its axis, $E = (1/4\pi\varepsilon_0)\,[qx/(a^2+x^2)^{3/2}]$

- **Electric field due to uniformly charged disc:-**

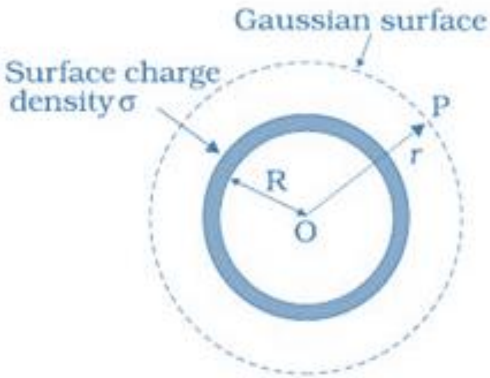


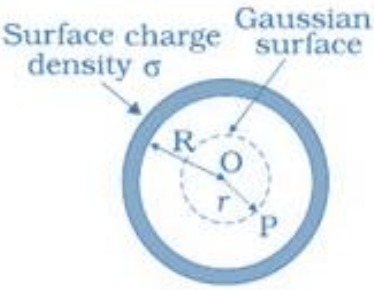
Here σ is the surface charge.

- **Electric field due to thin spherical shell:-**

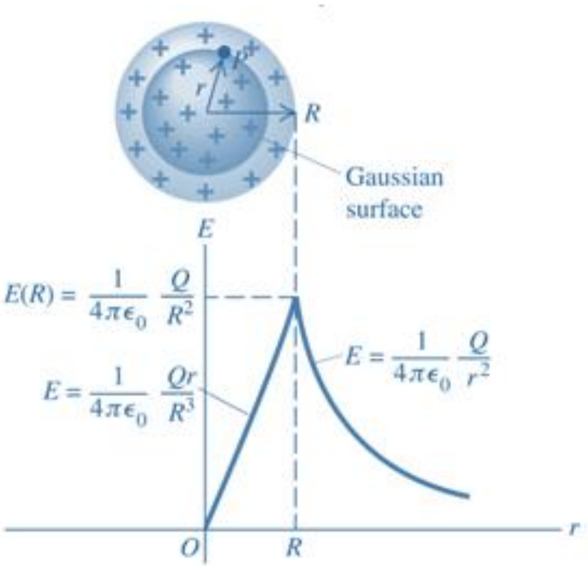
(a) $E_{out} = (1/4\pi\varepsilon_0)\,(q/r^2)$

(b) $E_{in} = 0$





- **Electric field of a non-conducting solid sphere having uniform volume distribution of charge:-**



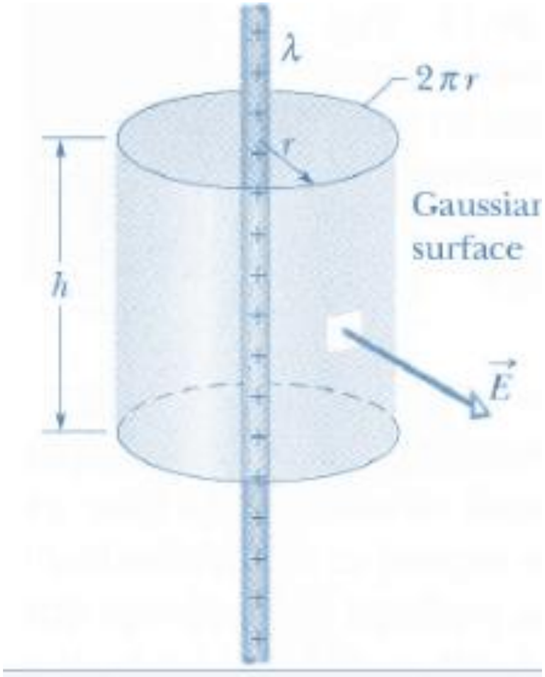
(a) Outside Point:- $E_{out} = (1/4\pi\varepsilon_0)(Q/r^2)$

(b) Inside Point:- $E_{in} = (1/4\pi\varepsilon_0)(Qr/R^3)$

(c) On the Surface:- $E_{surface} = (1/4\pi\varepsilon_0)(Q/R^2)$

Here, Q is the total charge

- **Electric field of a cylindrical conductor of infinite length having line charge *λ*:-**



(a) Outside the cylinder:- E = λ/2πε0r

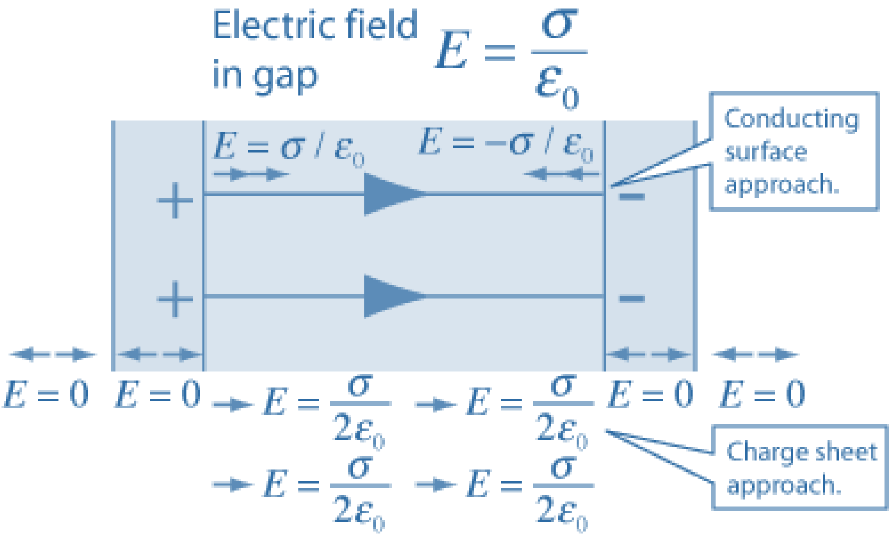
(b) Inside the cylinder:- $E = 0$

- **Electric field of a non-conducting cylinder having uniform volume density of charge:-**

  (a) Outside the cylinder:- $E = \lambda/2\pi\varepsilon_0 r$

  (b) Inside a point:- $E = \rho r/2\varepsilon_0$

- **Electric field of an infinite plane sheet of charge surface charge (σ) :-** $E = \sigma/2\varepsilon_0$



- **Electric field due to two oppositely infinite charged sheets:-**
  (a) Electric field at points outside the charged sheets:-
  $E_P = E_R = 0$
  (b) Electric field at point in between the charged sheets:-
  $E_Q = \sigma/\varepsilon_0$

- **Electric Dipole:-** An electric dipole consists of two equal and opposite charges situated very close to each other.

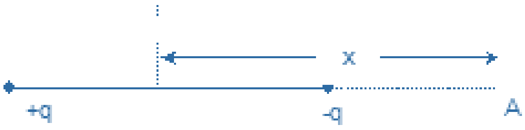
- **Dipole Moment:-** Dipole moment ($\vec{P}$) of an electric dipole is defined as the product of the magnitude of one of the charges and the vector distance from negative to positive charge.

$$\vec{P} = q\vec{a}$$

- **Unit of Dipole Moment:-** coulomb meter (S.I), stat coulomb cm (non S.I)

- **Electric field due to an electric dipole:-**

  (a) At any point on the axial line:-

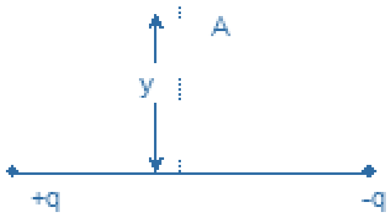


Alt Tag: Electric field due to an electric dipole on the axial line.

$$E = \frac{1}{4\pi\varepsilon_0} \frac{2px}{\left[x^2 - a^2\right]^2}$$

$$\text{For } x \gg a, \vec{E} = \frac{1}{4\pi\varepsilon_0} \frac{2\vec{p}}{x^3}$$

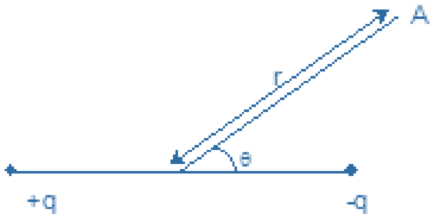
(b) At a point on the equatorial line (perpendicular bisector):-



$$E = \frac{1}{4\pi\,\varepsilon_0} \frac{p}{[a^2 + y^2]^{3/2}}$$

$$\text{For } y \;>>\; a, \vec{E} = -\frac{1}{4\pi\,\epsilon_0} \frac{\vec{p}}{y^3}$$

(c) At any point:-



$$E_r = \frac{1}{4\pi\,\varepsilon_0} \frac{2p\cos\theta}{r^3}$$

$$E_\theta = \frac{1}{4\pi\varepsilon_0} \frac{p\sin\theta}{r^3}$$

$$E = \frac{1}{4\pi\varepsilon_0} \frac{p}{r^3} \sqrt{3\cos^2\theta + 1}$$

$$\text{Angle, } \alpha = \tan^{-1}\left(\frac{1}{2}\tan\theta\right)$$

- **Torque (τ) acting on a electric dipole in a uniform electric field (E):-**

  $\tau = pE \sin\vartheta$

  Here, p is the dipole moment and ϑ is the angle between direction of dipole moment and electric field E.

- **Electric Flux:-** Electric flux ?$_E$ for a surface placed in an electric field is the sum of dot product of $\vec{E}$ and $d\vec{a}$ for all the elementary areas constituting the surface.

$$\Phi_E = \int_s \vec{E}.d\vec{a}$$

- **Gauss Theorem:-** It states that, for any distribution of charges, the total electric flux linked with a closed surface is $1/\varepsilon_0$ times the total charge within the surface.

$$\int_S \vec{\mathrm{E}} \cdot d\vec{\mathrm{S}} = \frac{q_{in}}{\varepsilon_0}, \text{ for free space}$$

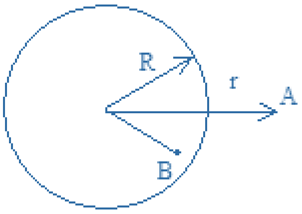
$$\int_S \vec{\mathrm{E}} \cdot d\vec{\mathrm{S}} = \frac{q_{in}}{\varepsilon_0 \varepsilon_r}$$

- **Electric field (E) of an infinite rod at a distance (r) from the line having linear charge density (λ):-**

  $E = \lambda/2\pi\varepsilon_0 r$

  The direction of electric field E is radically outward for a line of positive charge.

- **Electric field of a spherically symmetric distribution of charge of Radius R:-**

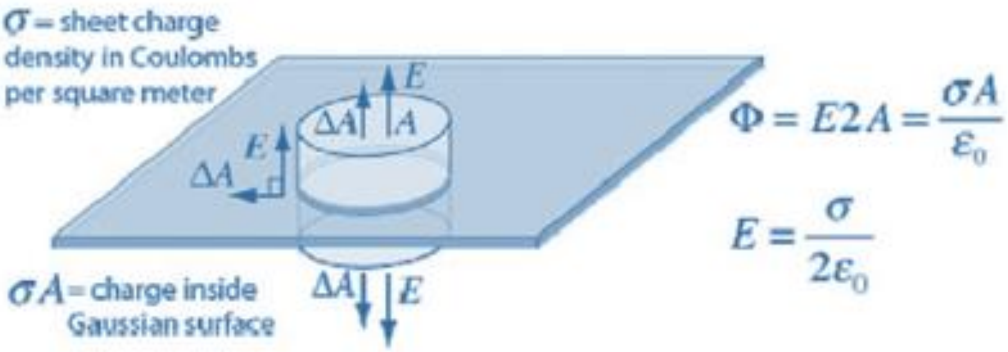


(a) Point at outside ($r > R$):- $E = (1/4\pi\varepsilon_0)\ (q/r^2)$, Here q is the total charge.

(b) Point at inside ($r < R$):- $E = (1/4\pi\varepsilon_0)\ (qr/R^3)$, Here q is the total charge.

- **Electric field due to an infinite non-conducting flat sheet having charge σ:-**

  $E = \sigma/2\varepsilon_0$



This signifies, the electric field near a charged sheet is independent of the distance of the point from the sheet and depends only upon its charge density and is directed normally to the sheet.

- **Electric field due to an infinite flat conductor carrying charge:-**

  ?E= σ/ε_0

- **Electric pressure (P_{elec}) on a charged conductor:-**

  $P_{elec} = (½\varepsilon_0)\ \sigma^2$

Electro-Static Potential and Capacitance:-

- **Electric Potential:-**

  (a) Electric potential, at any point, is defined as the negative line integral of electric field from infinity to that point along any path.

  $$V(\vec{r}) = -\int_{\infty}^{r} \vec{E}.d\vec{r}$$

  (b) $V(r) = kq/r$

  (c) Potential difference, between any two points, in an electric field is defined as the work done in taking a unit positive charge from one point to the other against the electric field.

  $W_{AB} = q\ [V_A\text{-}V_B]$

  So, $V = [V_A\text{-}V_B] = W/q$

  Units:- volt (S.I), stat-volt (C.G.S)

  Dimension:- $[V] = [ML^2T^{-3}A^{-1}]$

  Relation between volt and stat-volt:- 1 volt = (1/300) stat-volt

- **Relation between electric field (E) and electric potential (V):-**

  $E = -dV/dx = --dV/dr$

- **Potential due to a point charge:-**

  $V = (1/4\pi\ \varepsilon_0)\ (q/r)$

- **Potential at point due to several charges:-**

  $V = (1/4\pi\ \varepsilon_0)\ [q_1/r_1 + q_2/r_2 + q_3/r_3]$

  $= V_1+V_2+ V_2+\ldots.$

- **Potential due to charged spherical shell:-**

  (a) Outside, $V_{out} = (1/4\pi\ \varepsilon_0)\ (q/r)$

  (b) Inside, $V_{in} = -\ (1/4\pi\ \varepsilon_0)\ (q/\mathrm{R})$

  (c) On the surface, $V_{surface} = (1/4\pi\ \varepsilon_0)\ (q/R)$

- **Potential due to a uniformly charged non-conducting sphere:-**
  - (a) Outside, $V_{\text{out}} = (1/4\pi\varepsilon_0)(q/r)$
  - (b) Inside, $V_{\text{in}} = (1/4\pi\varepsilon_0)[q(3R^2-r^2)/2R^3]$
  - (c) On the surface, $V_{\text{surface}} = (1/4\pi\varepsilon_0)(q/R)$
  - (d) In center, $V_{\text{center}} = (3/2)[(1/4\pi\varepsilon_0)(q/R)] = 3/2\,[V_{\text{surface}}]$

- **Common potential (two spheres joined by thin wire):-**
  - (a) Common potential, $V = (1/4\pi\varepsilon_0)[(Q_1+Q_2)/(r_1+r_2)]$
  - (b) $q_1 = r_1(Q_1+Q_2)/(r_1+r_2) = r_1Q/\ r_1+r_2$; $q_2 = r_2Q/\ r_1+r_2$
  - (c) $q_1/q_2 = r_1/r_2$ or $\sigma_1/\ \sigma_2 = r_1/r_2$

- **Potential at any point due to an electric dipole:-**

  $$V(r,\vartheta) = qa\cos\vartheta/4\pi\varepsilon_0 r^2 = p\cos\vartheta/4\pi\varepsilon_0 r^2$$

  - (a) Point lying on the axial line:- $V = p/4\pi\varepsilon_0 r^2$
  - (b) Point situated on equatorial lines:- $V = 0$

- **If *n* drops coalesce to form one drop, then,**
  - (a) $R = n^{1/3}r$
  - (b) $Q = nq$
  - (c) $V = n^{2/3}V_{\text{small}}$
  - (d) $\sigma = n^{1/3}\,\sigma_{\text{small}}$
  - (e) $E = n^{1/3}\,E_{\text{small}}$

- **Electric potential energy *U* or work done of the system *W* having charge q_1 and q_2**:-

  $$W = U = (1/4\pi\varepsilon_0)(q_1q_2/r_{12}) = q_1\text{V}_1$$

- **Electric potential energy *U* or work done of the system *W* of a three particle system having charge q_1,q_2 and q_3**:-

  $$W = U = (1/4\pi\varepsilon_0)(q_1q_2/r_{12} + q_1q_3/r_{13} + q_2q_3/r_{23})$$

- **Electric potential energy of an electric dipole in an electric field:-** Potential energy of an electric dipole, in an electrostatic field, is defined as the work done in rotating the dipole from zero energy position to the desired position in the electric field.

  $$W = -\vec{p}.\vec{E} = -pEcos\theta$$

  (a) If $\vartheta = 90º$, then $W = 0$

  (b) If $\vartheta = 0º$, then $W = -pE$

  (c) If $\vartheta = 180º$, then $W = pE$

- **Kinetic energy of a charged particle moving through a potential difference:-**

  K. E = $½\ mv^2 = eV$

- **Conductors:-** Conductors are those substance through which electric charge easily.

- **Insulators:-** Insulators (also called dielectrics) are those substances through which electric charge cannot pass easily.

- **Capacity:-** The capacity of a conductor is defined as the ratio between the charge of the conductor to its potential

  $C = Q/V$

  Units:-
  S.I – farad (coulomb/volt)

  C.G.S – stat farad (stat-coulomb/stat-volt)

  Dimension of *C*:- $[M^{-1}L^{-2}T^4A^2]$

- **Capacity of an isolated spherical conductor:-**

  $C = 4\pi\varepsilon_0 r$

- **Capacitor:-** A capacitor or a condenser is an arrangement which provides a larger capacity in a smaller space.

-
- **Capacity of a parallel plate capacitor:-**

  $C_{air} = \varepsilon_0 A/d$

  $C_{med} = K\varepsilon_0 A/d$

  Here, *A* is the common area of the two plates and *d* is the distance between the plates.

- **Effect of dielectric on the capacitance of a capacitor:-**

  $C = \varepsilon_0 A/[d-t+(t/K)]$

  Here d is the separation between the plates, t is the thickness of the dielectric slab A is the area and K is the dielectric constant of the material of the slab.
  If the space is completely filled with dielectric medium ($t=d$), then,

  $C = \varepsilon_0 KA/ d$

- **Capacitance of a sphere:-**

  (a) $C_{air} = 4\pi\varepsilon_0 R$

  (b) $C_{med} = K\,(4\pi\varepsilon_0 R)$

- **Capacity of a spherical condenser:-**

  (a) When outer sphere is earthed:-

  $C_{air} = 4\pi\varepsilon_0\,[ab/(b-a)]$

  $C_{med} = 4\pi\varepsilon_0\,[Kab/(b-a)]$

  (b) When the inner sphere is earthed:-

  $C_1 = 4\pi\varepsilon_0\,[ab/(b-a)]$

  $C_2 = 4\pi\varepsilon_0 b?$

  Net Capacity, $C' = 4\pi\varepsilon_0[b^2/b-a]$

  Increase in capacity, $\Delta C = 4\pi\,\varepsilon_0 b$

  It signifies, by connecting the inner sphere to earth and charging the outer one we get an additional capacity equal to the capacity of outer sphere.

Current Electricity

- **Current:-** Current strength, in a conductor, is defined as the rate of flow of charge across any cross section of the conductor.

  $I = q/t = ne/t$

  For non-uniform flow,

  $I = dq/dt$

  Or, $q = \ I\, dt$

- **Units of electric current**:-

  (a) C.G.S. electro-static unit (esu):- 1 esu of current (stat-ampere) = 1 esu of charge/1 second

  (b) C.G.S. electro-static unit (emu):- 1 emu of current (ab-ampere) = 1 emu of charge/1 second

  (c) S. I unit (ampere):- 1 ampere = 1 coulomb/1 second

  (d) $1\ A = 3\times10^9$ esu of current or stat-ampere

  (e) 1 A = 1/10 emu of current or abampere

- **Drift velocity**:-The velocity with which the free electrons are drifted towards the positive terminal, under the action of the applied field, is called the drift velocity of the free electrons.

  $V = (eV/ml)\tau$

  Here, e is the charge of electron, V is the potential difference, m is the mass and τ is the relaxation time.

- **Electric current and Drift velocity**:- $I = q/t = nAve$

- **Ohm's Law for conductors**:- At constant temperature current flowing through a conductor of uniform area of cross-section, is proportional to the difference of potential across its terminals.

  (a) $V = IR$, Here, $R = (ml/nAe^2)\ (1/\tau)$

  (b) $R = \rho l/A$

  (c) $\rho = 1/\sigma$

  (d) $v_d = (qE\tau/m)$

  (e) $I = neAv_d$

  (f) $\rho = m/ne^2\tau$

  (g) $\sigma = ne^2\tau/m$

- **Resistance (R)**:- Resistance of a conductor is defined as the ratio between potential differences between the two ends of the conductor to the current flowing through it.

  $R= V/I$

- **Units of R**:-
  (a) In S.I:- 1 ohm = 1 volt/1 ampere
  (b) In C.G.S system:-

  1 statohm = 1 statvolt/1 statamp

  1 abohm = 1 abvolt/1 abampere

  (c) Relation between ohm and statohm:- 1 ohm = $(1/9\times10^{11})$ statohm
  (d) Relation between ohm and abohm:- 1 ohm = 10^9abohm

- **Variation of resistance with temperature**:-

  Temperature coefficient of resistance (α) is defined as change in resistance of the conductor per unit resistance per degree centigrade rise of temperature.

  $R_t=R_0[1+\alpha(T-T_0)]$

  $\alpha = R_t - R_0/R_0(T-T_0)$

  Here, R_t,R_0 is the resistance of the conductor at tº C and 0º C respectively.

- **Resistivity of material (ρ)**:- $\rho = RA/l$,

  Here R is the resisteance of the conductor, A is cross sectional area of conductor and l is the length of the conductor

- **Relation between resistivity(ρ) and relaxation time (τ)**:-

  $\rho = m /ne^2\tau$

- **Variation of resistivity with temperature**:-

  (a) Conductors:-

  $\rho_t = \rho_0 [1+\alpha(T-T_0)]$

  Here c is called the temperature coefficient of the resistivity.

  $= (\rho_t - \rho_0) /\rho_0 (T--T_0)$

  Temperature coefficient of resistivity of a conductor is defined as the change in resistivity per unit resistivity per degree Celsius rise of temperature.

  $\alpha = \rho_t - \rho_0$

(b) Insulators:-

$$\rho_t = \rho_0 e^{\frac{-E_g}{kT}}$$

- **Conductivity (σ):- Conductivity of a material is defined as the reciprocal of the resistivity.**

  $\sigma = 1/\rho$

  Unit:- $ohm^{-1}m^{-1}$

- **Conductance:-**Conductanceof a conductor is defined as the reciprocal of its resistance.
  Conductance = $1/R = (1/\rho)(A/l)$
  Unit:- mho or $ohm^{-1}m^{-1}$

- **Current Density:-**

  $$I = \int_S \vec{J} \cdot d\vec{A}$$

  (a) $J = I/A$

  (b) $J = nev_d$

  (c) $J = \sigma E$

  (d) $\mu = v_d/E$

  (e) $\sigma = ne\mu$

- **Relation between current density and electrified:-**

  $\vec{J} = \sigma\vec{E}$ **?**

  Thus, electrical conductivity can also be defined as electric current density per unit electric field strength.

- **Resistance in series:-** If a number of resistances are connected in series with each other, the net resistance of the combination is equal to the sum of their individual resistances.

  (a) $R = R_1 + R_2 + R_3$

  (b) $V = V_1 + V_2 + V_3$

  (c) $I = I_1 = I_2 = I_3 =$ Constant

  (d) $V_1 = IR_1$, $V_2 = IR_2$, $V_3 = IR_3$

- **Resistance in parallel:-** If a number of resistances are connected in parallel, the reciprocal of the resistance of the combination is equal to the sum of the reciprocals of their individual resistances.
  - (a) $1/R = 1/R_1 + 1/R_2 + 1/R_3$
  - (b) $I = I_1+I_2+I_3$
  - (c) $V = V_1 = V_2 = V_3 =$ Constant
  - (d) $I_1 = V/R_1$, $I_2 = V/R_2$, $I_3 = V/R_3$

- **Distribution of current in a parallel combination of resistances**:-
  - (a) $I_1 = I (R_2/R_1+R_2)$
  - (b) $I_2 = I (R_1/R_1+R_2)$

  In general,

  Current in one branch = total current × (resistance of second branch / sum of resistances in the two branches)

- **Grouping of cells:-**
  - **(a) Cells in series:-**

    $I= (nE)/(R+nr)$

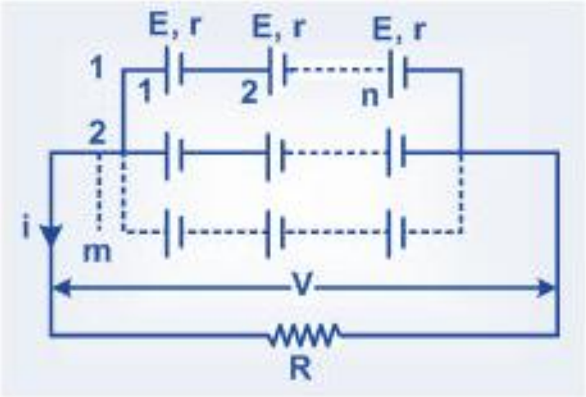
    If $R<<nr$, then $I = E/R$

    If $R>>nr$, then $I = nE/R$
  - **(b) Cells in parallel:-**

    I= $E/[R+(r/m)]$

    If $R>>r/m$, then $I = E/R$

    If $R>>r/m$, then $I = m(E/R)$
  - **(c) Mixed grouping**:-
    - (a) $I = mnE/(mR+nr)$
    - (b) I is maximum when $nR = mR$
    - (c) $I_{max} = mnE/(2\sqrt{mnrR})$



- **Electromotive force and potential difference:-**

  The electromotive force E of a cell is defined as the difference of potential between its terminals when there is no current in the external circuit, i.e., when the cell is in open circuit.

  The potential difference of a cell is the difference of potential between two terminals when it is in closed circuit.

  $E = V+IR$

- **Internal resistance (r) of a cell:-** The resistance offered by the electrolyte of the cell when the electric current passes through it is known as the internal resistance of the cell.

  $r = R (E-V/V)$

- **Electric Power:-**

  (a) $P = VI$

  (b) $P = I^2R = V^2/R$

  Unit of power:-1 watt = 1 volt × 1 amp

- **Electric energy:-**

  $W = Vq = V(It)$

  Unit of electric energy:-

  1 joule = 1 watt sec

  1 kilowatt hour = 1000 watt hour

- **Faraday's Laws of Electrolysis:-**

  (a) The mass of ion deposited on an electrode in the process of electrolysis, is proportional to the quantity of charge that has passed through the electrolyte.

  $m = Zq = ZIt$

  (b) When same current passes through several electrolytes for the same time, the masses of various ions deposited at each of the electrodes are proportional to their chemical equivalents (equivalent weights).

  $m/W = \text{constant}$

  Or, $Z_1/Z_2 = W_1/W_2$

  So, $W/Z = \text{constant} = F$

- **Heating effect of current:-**

  $I = I^2Rt$ Joule $= I^2Rt/J$ Calorie

- **Electric Bulb:-**

  (a) Resistance of filament, $R = V^2/P$

  (b) Maximum current that can be allowed to pass through bulb, $I_{max} = P/V$

- **Total power consumed in parallel combination**:-

  $P = P_1+P_2+P_3$

- **Total power consumed in series combination:-**

  $1/P= 1/P_1+1/P_2+1/P_3$

- **Effect of stretching a resistance wire:-**

  $R_2/R_1 = (l_1/l_2)(A_1/A_2) = (l_2/l_1)^2 = (A_1/A_2)^2 = (r_1/r_2)^4$ [Since, $l_1 A_1 = l_2 A_2$]

- **Thermo e.m.f:-** $e = \alpha\theta + (\beta\theta^2/2)$ (Here, $\theta = \theta_H = \theta_C$)

- **Neutral temperature:** $\theta_N = -(\alpha/\beta)$

- **Temperature of inversion:-** $\theta_N = (\theta_1 + \theta_C)/2$ [Since, $\theta_1 - \theta_N = \theta_N - \theta_C$]

- **Thermoelectric power or Seebeck Coefficient:-** $S = de/d\theta = \alpha + \beta\theta$

- **Peltier effect:**-

  Heat absorbed per second at a junction when a current I flows $= \pi I$

  Here π is Peltier coefficient and is given by, $\pi = S\theta_H$

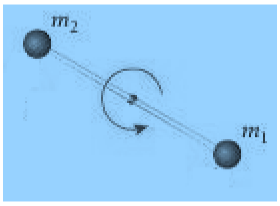
- **Thomson coefficient:-**

  $\sigma = (\Delta Q/\text{time})/I\Delta\theta$

Magnetism

- **Magneto-static:-** It is the study of magnetic fields in systems where the currents are steady (not changing with time). It is the magnetic analogue of electrostatics, where the charges are stationary.

- **Magnitude of magnetic force between two poles (Coulomb's law in magnetism):-**



  $F = (\mu_0/4\pi)\,(m_1m_2/r^2)$

  Here μ_0 is called the absolute magnetic permeability of free space.

  $\mu_0 = 4\pi\times10^{-7}\ Wb\ A^{-1}\ m^{-1}$

- **Magnetic field**:- Magnetic field, of any magnetic pole, is the region (space) around it in which its magnetic influence can be realized.

- **Lines of Force (Flux Lines)**:- Line of force is the path along which a unit north pole would move if it were free to do so.

- **Magnetic Dipole:-** A combination of two isolated , equal and opposite magnetic poles separated by a small distance constitutes a magnetic dipole.

- **Magnetic Moment:-** Magnetic moment *M* of a magnetic dipole is defined as the product of its pole strength and the magnetic length. $M = m\times2l$

- **Torque in Magnetic field:- ?** $\vec{\tau} = \vec{M} \times \vec{B}$ **?**

- **Work done in rotating a magnetic dipole in a magnetic field:-** $W = MB\,(\cos\vartheta_1 - \cos\vartheta_2)$

- **Potential Energy of a magnetic dipole in a magnetic field:-** $\vec{W} = -\vec{M} \times \vec{B}$

- **Magnetic moment (*M*):-** $M = I\times A$

- **Other formulae of *M*:-**
  - (a) $M = nI\pi r^2$
  - (b) $M = eVr/2 = er^2\omega/2 = er^2\,2\pi f/2 = er^2\,\pi/T$
  - (c) $M = n\mu_B$

- **Resultant magnetic moment :-**
  (a) When two bar magnets are lying mutually perpendicular to each other, then,
  $M = \sqrt{[M_1^2+M_2^2]} = \sqrt{2}\ mpl$
  (b) When two coils, each of radius r and carrying current i, are lying concentrically with their planes at right angles to each other, then $M = \sqrt{[M_1^2+M_2^2]} = [\sqrt{2}I]\pi r^2$ If $M_1 = M_2$

- **Atoms as a magnetic dipole:-**
  (a) $I = e\omega/2\pi$
  (b) $M = e\omega r^2/2$
  (c) $M = n\ (eh/4\pi m)$
  The term $eh/4\pi m$ is called Bohr's magneton. It is the smallest value of magnetic moment which an electron can possess.

- **Magnetic flux density at a distance from a magnetic dipole in free space:- B= $(\mu_0/4\pi)\ (m_1/r^2)$**

- **Force:-** $F = (\mu_0/4\pi)\ (m_1 m_2/r^2)$

- **Magnetic intensity at any point due to a magnetic pole in free space:- F = $(\mu_0/4\pi)\ (m/r^2)$**

- **Magnetic intensity due to a bar magnet in free space:-**
  (a) Point situated on the axial line (End-on position):-
  $F = (\mu_0/4\pi)\ [2Mr/(r^2-l^2)^2]$
  In case of a magnetic-dipole, $F = (\mu_0/4\pi)\ [2M/r^3]$
  (b) Point situated on equatorial line (Broad side-on position):-
  $F = (\mu_0/4\pi)\ [M/(r^2+l^2)^{3/2}]$
  In case of a magnetic-dipole, $F = (\mu_0/4\pi)\ [M/r^3]$
  (c) Point situated anywhere:-
  $F= (\mu_0/4\pi)\ [M/r^3]\ \sqrt{1+3\cos^2\vartheta}$
  Direction, $\tan \beta = \frac{1}{2} \tan \vartheta$

- **Combined magnetic field due to bar magnet and earth – "Neutral Points":-**
  Bar magnet placed in a magnetic meridian:-
  (a) North pole facing north of earth:-
  $B = (\mu_0/4\pi)\ [M/(r^2+l^2)^{3/2}]$
  At neutral points, $B=H$
  So, $H = (\mu_0/4\pi)\ [M/(r^2+l^2)^{3/2}]$
  (b) North pole facing south of earth:-
  $B = (\mu_0/4\pi)\ [2Mr/(r^2-l^2)^2]$
  At neutral points, $B=H$
  So, $H = (\mu_0/4\pi)\ [2Mr/(r^2-l^2)^2]$

- **Intensity of magnetization (I):-**
  Intensity of magnetization (I), is defined as the magnetic moment (M) developed per unit volume (V) of the specimen, when subjected to a uniform magnetic field.
  $I = M/V = m/a$
  Here m is the pole strength and a is the area of the specimen.

- **Relation between magnetic field (B) and field intensity (H):- $B = H+4\pi I$**

- **Permeability (μ):-** It is defined as the ratio between magnetic induction to the strength of magnetic field. **$\mu = B/H$**
  (a) For paramagnetic and ferromagnetic substances, $B > H$. So, $\mu > 1$
  (b) For diamagnetic substances, $B < H$. So, $\mu < 1$

- **Susceptibility (k):-** Susceptibility of a magnetic substance is defined as the ratio between intensity of magnetization (I) to the strength of magnetic field (H). **$k = I/H$**

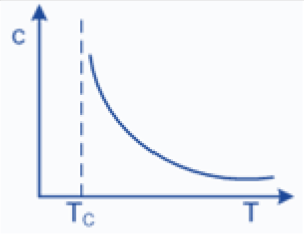
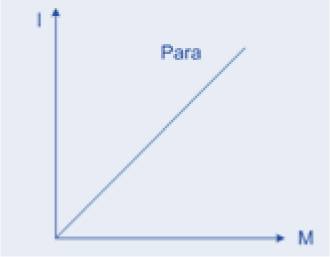
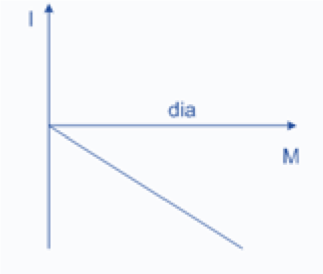
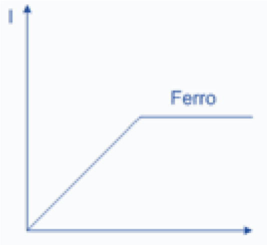
- **Relation between μ and k:- $\mu = 1+4\pi k$**

- **For substances which get magnetized in the direction of magnetic field,**
  (a) I is positive
  (b) k is positive
  (c) $B > H$
  (d) $\mu > 1$

- **For substances which get magnetized in the direction opposite to that of magnetic field,**
  (a) I is negative
  (b) k is negative
  (c) $B < H$
  (d) $\mu < 1$

- **Magnetic Substance:-** A substance which is affected by a magnetic field is called a magnetic substance.
  (a) Diamagnetic substances:- Diamagnetic substances are those substances which are repelled by the magnets.
  Example- antimony, bismuth, lead, tin, zinc, mercury, gold, phosphorus
  (b) Paramagnetic substances:- Paramagnetic substances are those substances which are weakly attracted by the magnets.
  Example-aluminium, platinum, oxygen, manganese, chromium
  (c) Ferromagnetic substances:- Ferromagnetic substances are those substances which are strongly attracted by the magnets.
  Example- iron, cobalt, nickel

- **Curie-Weiss Law:-**

 ***$\chi - T$* Curve**	 ***I-M* curve for paramagnetic material**
 ***I-M* curve for diamagnetic material**	 ***I-M* curve for ferromagnetic materials**

Magnetic Effect of Electric Current

- **Magnetic flux:-**

  Magnetic flux lined with the surface is defined as the product of area and component of B perpendicular that area.

  $$\phi_B = \vec{B}\cdot\vec{A} = BA\cos\theta$$

  and

  $?_B = \mu nAH$

  Here, μ is the permeability of the medium, n is the number of turns, A is the area and H is the magnetic field intensity.

  (a) When $\vartheta = 90º$, $\cos\vartheta = 0$. So, $?_B = 0$

  This signifies, no magnetic flux is linked with surface when the field is parallel to the surface.

  (b) When $\vartheta = 0º$, $\cos\vartheta = 1$. So,$(?_B)_{max} = 1$

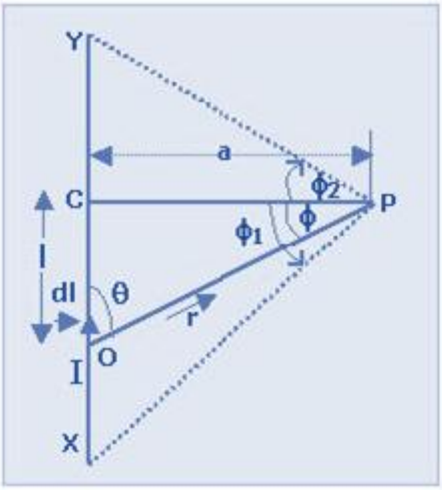
  This signifies, magnetic flux linked with a surface is maximum when area is held perpendicular to the direction of field.

- **Biot-Savart Law or Ampere's Theorem:-**

  $$d\vec{B} = \frac{\mu_0 I}{4\pi}\frac{d\vec{l}\times\vec{r}}{r^3} = \frac{\mu_0 I}{4\pi}\frac{d\vec{l}\times\hat{r}}{r^2}$$

  Or, $dB = (\mu_0/4\pi)\,(I\,dl\sin\vartheta/r^2)$

- **Field due to straight current carrying conductor of finite length at a point *P*, perpendicular distance *a* from the linear conductor *XY*:-**



$B = (\mu_0 I/4\pi a)\times(\sin ?_1 + \sin ?_2)$

Direction:-

(a) For current in the conductor from X to Y, the direction of B is normal to the plane of conductor downwards.

(b) For current in the conductor from Y to X, the direction of B is normal to the plane of conductor downwards.

- **Field due to straight carrying conductor of infinite length at a point *P*, perpendicular distance R from the linear conductor *XY*:-**

  $B = (\mu_0 I/2\pi a)$ (Direction is same as given above)

- **Field due to two concentric coils of radii r_1 and r_2 having turns N_1 and N_2 in which same current I is flowing in anticlockwise direction at their common center *O*:-**

  $B = \mu_0 I/2\ [N_1/r_1 + N_2/r_2]$

  If the number of turns in them is same, $B = \mu_0 NI/2\ [1/r_1 + 1/r_2]$

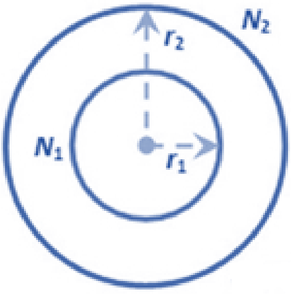
  Direction:- Direction of B will be normal to the plane of paper upwards.

- **Field due to two concentric coils of radii r_1 and r_2 having turns N_1 and N_2 in which same current I is flowing in mutually opposite direction at their common center *O*:-**

  $B = \mu_0 I/2\ [N_1/r_1 - N_2/r_2]$

  If the number of turns in them is same, $B = \mu_0 NI/2\ [1/r_1 - 1/r_2]$

  Direction:- Direction of B will be normal to the plane of paper upwards.



- **Field due to circular coil at the center *O* :-**

  $B = \mu_0 I/2R$

- **Field due to two parallel very long linear conductors carrying current in same direction:-**

  (a) At point P i.e. at a distance $r/2$ from both conductors, $\boldsymbol{B=0}$

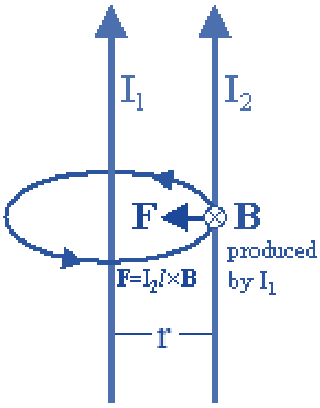
  (b) At a point Q i.e. at a distance x from first and $r+x$ from second conductor, $\mathbf{B = \mu_0 2I/4\pi\ [(1/x) + (1/r+x)]}$

  Direction:- B is normal to the plane of paper downwards.

  (c) At a point P i.e. at a distance x from first and $r-x$ from second conductor, $B = \mu_0 2I/4\pi\ [(1/x) - (1/r-x)]$

  If B is positive, then its direction will be normal to the plane of paper upwards.

  If B is negative, then its direction will be normal to the plane of paper downwards.

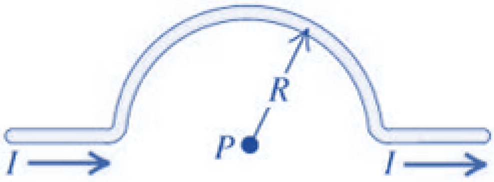


- **Field due to two parallel very long linear conductors carrying current in opposite direction (refer above figure):-**

  (a) At point P distance x from first conductor,

  $B = \mu_0 2I/4\pi\ [(1/x) + (1/r-x)]$

  Direction:- of B will be normal to the plane of paper downwards.



  (b) At point Q distance x from first conductor, $B = \mu_0 2I/4\pi\ [(1/x) - (1/r-x)]$

  Direction:- of B will be normal to the plane of paper upwards.

- **Field due to semicircular arc of wire at the center *O* of the arc:- B = $(\mu_0/4\pi)\ (\pi I/R)$**

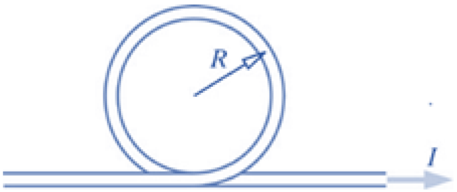
  Direction:- Direction of B will be at right angle to the plane of circular arc downwards. If the direction current is in anticlockwise, then the direction of field B will be a right angle to the plane of circular arc upwards.

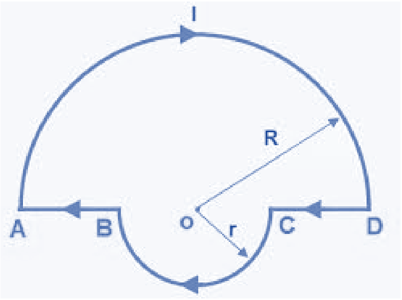
- **Field due to straight wire and loop at the center *O* of the loop (If the current in the looop in anticlockwise direction):-** $B = (\mu_0/4\pi)\ [2\pi I/R + 2I/R]$

  Direction:- Normal to the plane of paper upwards.

- **Field due to straight wire and loop at the center *O* of the loop(If the current in the loop in clockwise direction)**:- $B = (\mu_0/4\pi)\ [2\pi I/R - 2I/R]$

  Direction:- Normal to the plane of paper downwards





- **Field due to two semicircular arc of wire:-**

  ?B = $\mu_0 I/4\ [1/a-1/b]$

  B = $\mu_0 I/4\ [1/R+1/r]$

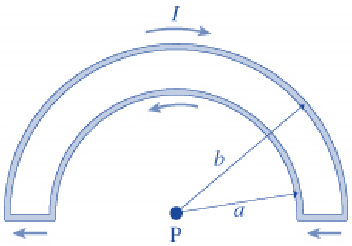
  Direction:- Normal to the plane of paper downward.

- **Field due to two concentric circular arcs at *O*:-**

  $B = (\mu_0/4\pi)\ I\vartheta\ [1/r_1-1/r_2]$

  Here r_1 is the radius of inner circle and r_2 is the radius of outer circle.

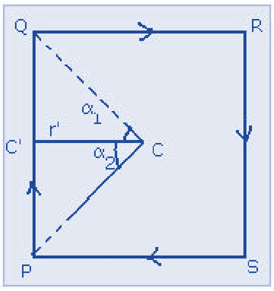
  Direction:- Normal to the plane of paper upwards



- **Field due to semicircular arc and straight conductor at point *P*:-**
  $B = (\mu_0 I/4\pi r)\ [\pi+2]$
  Direction:- Normal to the plane upward.

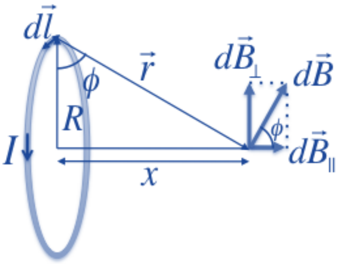
- **Field due to semicircular arc and straight conductor at point *O*:- $B = (\mu_0 I/4\pi r)\ [\pi+1]$**

  Direction: Normal to the plane upward.



- **Field due to square loop having length of side *a* at center *C*:-**
  $B = 2\sqrt{2}(\mu_0 I/\ \pi a)$
  Direction:- Normal to the plane of paper downwards.

- **Magnetic field at any point on the axis of a circular coil carrying current *I*:-**
  $B = (\mu_0/2)\ [NIa^2/(a^2+x^2)^{3/2}]$
  (a) Magnetic field at the center of the coil:-
  $B = (\mu_0/2)\ [NI/a]$
  (b) Magnetic field at a point situated large distance away on the axis:-
  $B = (\mu_0/2\pi)\ [NIA/x^3]$
  (c) Current loop as a magnetic dipole:- $B = (\mu_0/4\pi)\ [2M/x^3]$
  Here, *M* (=*IA*) is the magnetic moment of the magnetic dipole.



- **Magnetic field at any point on the axis of a solenoid carrying current:-**
  $B = (\mu_0 NI/2l)\ [\cos ?_1 - \cos ?_2]$
  For an infinitely long solenoid, $?_1 = 0$ and $?_2 = \pi$. So, $B=\mu_0 NI$
  At one end, $B = \mu_0 NI/2$

- **Field due to a current in cylindrical rod:-**
  ? (a) Outside:- $B = \mu_0 I/2\pi R$
  (b) Surface:- $B = \mu_0 I/2\pi R$
  (c) Inside:- $B = \mu_0 IR/2\pi R^2$

- **Field due to a toroid:-**
  (a) Inside:- $B = \mu_0 NI - \mu_0 NI/2\pi R$
  (b) Outside:- $B = 0$

- **Force on electric current:-** $\vec{F} = \vec{H} \times \vec{B}$

- **Force on a moving charge in a magnetic field:-**

$$\vec{F} = q\left(\vec{v} \times \vec{B}\right)$$
$$= qvB\sin\theta\,\hat{n}$$

- **Lorentz Force:-**

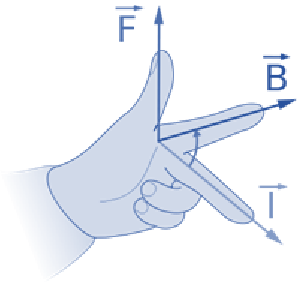
$$\vec{F} = q\left[\vec{E} + \left(\vec{v} \times \vec{B}\right)\right]$$

- **Motion of a charged particle at right angles to a magnetic field:-**
  Radius, r = mv/Qb

- **Force on a conductor carrying current and placed in a magnetic field:-**

$$\vec{F} = I\left(\vec{l} \times \vec{B}\right)$$
$$= IlB\sin\theta\,\hat{n}$$

- **Fleming's left hand rule:-**



- **Force between two parallel conductors carrying currents:-**
  $F = \mu_0 I_1 I_2 / 2\pi d$

- **Torque on a current loop:-** $\tau = NIBA \cos\vartheta = NMB \cos\vartheta$ **(Since,** $M = IA$**)**

- **Moving Coil Galvanometer:-** $I = (C/nBA)\vartheta = K\vartheta$
  Here $K = C/nBA$ is known as the reduction factor of the moving coil galvanometer.

- **Sensitivity of a Galvanometer:-**
  (a) Current Sensitivity:- $S_i = C/nAH$
  Smaller the value of S_i, more sensitive is the galvanometer.
  (b) Voltage Sensitivity:- $S_v = V/G = CG/nAH$
  Smaller the value of S_v, more sensitive is the galvanometer

- **Conversion of a galvanometer into an ammeter:-**
  (a) $I_s/I_g = G/S$
  (b) $S = GI_g/I_s = GI_g/I-I_g$

- **Conversion of a galvanometer into a voltmeter:-** $R = (V/I_g) - G$

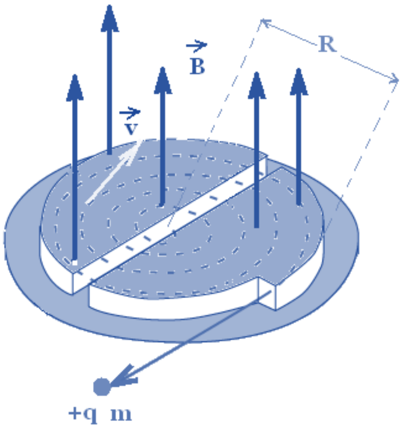
- **Ampere's current law:-**

$$\oint \vec{B}.d\vec{l} = \mu_0 I$$

Or

$$\oint \vec{H}.d\vec{l} = I$$

- **Cyclotron:-**
  - (a) $T = 2\pi m/qB$
  - (b) $v = qB/2\pi m$
  - (c) $\omega = \vartheta B/m$
  - (d) radius of particle acquiring energy E, $r = (\sqrt{2mE})/qB$
  - (e) velocity of particle at radius r, $v = qBr/m$
  - (f) the maximum kinetic energy (with upper limit of radius = R) $K_{max} = \frac{1}{2}\,[q^2B^2R^2/m]$



- **Magnetic field produced by a moving charge:-**

$$(a)\ \ \vec{B} = \frac{\mu_0}{4\pi}\frac{q\left(\vec{v}\times\vec{r}\right)}{r^3}$$

$$(b)\ \ B = \frac{\mu_0}{4\pi}\frac{qv\sin\theta}{r^2}$$

Electromagnetic Induction

- **Magnetic flux:-**

  Magnetic flux lined with the surface is defined as the product of area and component of *B* perpendicular that area.

  $$\phi_B = \vec{B}.\vec{A} = BAcos\theta$$

  and

  $?_B = \mu nAH$

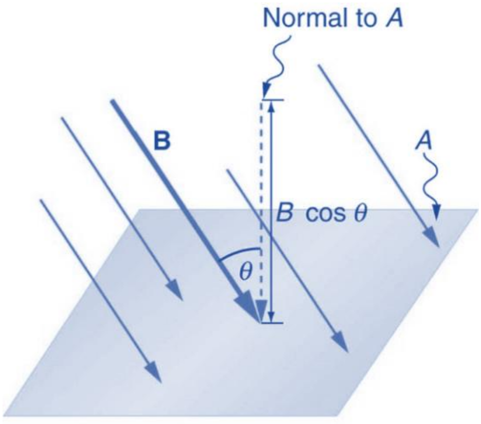
  Here, μ is the permeability of the medium, *n* is the number of turns, *A* is the area and *H* is the magnetic field intensity.

  (a) When ϑ = 90º, cosϑ = 0. So, $?_B = 0$

  This signifies, no magnetic flux is linked with surface when the field is parallel to the surface.

  (b) When ϑ = 0º, cosϑ = 1. So,$(?_B)_{max} = 1$

This signifies, magnetic flux linked with a surface is maximum when area is held perpendicular to the direction of field.



$\Phi = BA\cos\theta = B_{\perp}A$

- **Faraday's law of electromagnetic induction:-**

  (a) Whenever magnetic flux linked with a circuit changes, an *e.m.f* is induced in it.

  (b) The induced *e.m.f* exists in the circuit so long as the change in magntic flux linked with it continues.

  (c) The induced *e.m.f* is directly proportional to the negative rate of change of magnetic flux linked with the circuit.

  So, $E = -d?_B/dt$

  Negative sign is due to the direction of induced *e.m.f*.

- **Induced electric field:-**

  $$e.m.f = \int \vec{E} d\vec{l}$$

- **Lenz's Law:-**

  ?It states that direction of induced *e.m.f.* is such that it tends to oppose the very csause which produces it.

  The induced *e.m.f.* always tends to oppose the cause of its production.

- **Motion of a straight conductor in a uniform magnetic field:-**

  (a) W = Bevl

  (b) Motional *e.m.f*, $E = Bvl$

  (c) Induced current, $I = E/R = Blv/R$

  (d) $F = IlB = B^2l^2v/R$

  (e) $P = Fv = IlBv = B^2l^2v^2/R$

  (f) $H = I^2R = B^2l^2v^2/R$

- **Motion of a loop in a magnetic field when whole of the coil is in the magnetic field:**

  (a) Motional *e.m.f* , $E = 0$

  (b) Resultant Current, $I = 0$

  (c) Force, $F = 0$

  (d) Power, $P = 0$

- **Motion of a loop in a magnetic field when a part of the loop is out of the magnetic field:-**

  (a) $?_B = Blx$

  (b) Induced *e.m.f* , $E = Blv$

- **Power:-**

  P = $I^2R = E^2/R$

  P = $B^2l^2v^2/R$ (Since, $E = Blv$)

  (a) Coil out of field:- $?_B = 0$, $E = 0$, $P = 0$

(b) Coil entering the magnetic field:-

$?_B$ increases gradually

E = a negative constant

P = a positive constant

(c) Coil moving in the magnetic field:-

$?_B$ = Constant

$E = 0$

P = 0

(d) Coil leaving the magnetic field:-

$?_B$ decreases gradually

E = a positive constant

P = a positive constant

(e) Coil out of magnetic field:-

$?_B$?= 0

$E = 0$

P = 0

- **Self-Induction:-** Self Induction of a circuit is defined as the property of the circuit by virtue of which it tends to oppose a change in the strength of current, through it, by inducing an e.m.f. in itself.

  (a) Magnetic flux, $?_B = LI$

  Here L is the coefficient of self -induction.

  (b) *e.m.f.*, $E = -L\,[dI/dt]$

  (c) $L = \mu_0\, \mu_r nNA$

  Here, n is the number of turns per unit length

- **Series and parallel combination:-**

  (a) $L = L_1+L_2$ (If inductors are kept far apart and joined in series)

  (b) $L = L_1+L_2\pm 2M$ (If inductors are connected in series and they have mutual inductance M)

(c) $1/L = 1/L_1 + 1/L_2$ (If two conductors are connected in parallel and are kept for apart)

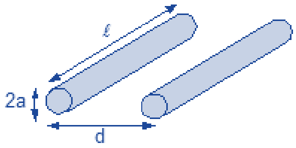
(d) $M = K\sqrt{L_1 L_2}$ (If two coils of self-inductances, L_1 and L_2 are over each other)

- **Inductance of wire:-**

  $L = \mu_0 l/8\pi$

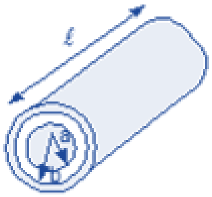
- ?**Inductance of hollow cylinder:-**

  $L = \mu_0 l/2\pi\ [\ln 2l/a - 1], \ l >> a$



- **Inductance of parallel wires:-**

  $L = \mu_0 l/\pi\ [\ln d/a - 1], \ l >> d, \ d >> a$



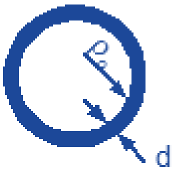
- **Inductance of Coaxial conductor:-**

  $L = \mu_0 l/\pi\ [\ln b/a]$

- **Inductance of Circular loop:-**

  ?$L = \mu_0 l/2\pi\ [\ln 4l/d - 2.45]$

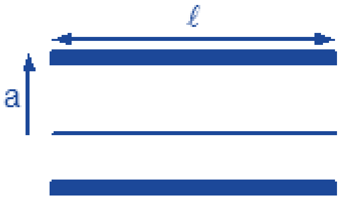
  $l = -2\pi\rho_0, \ \rho_0 >> d$



- **Inductance of Solenoid:-**

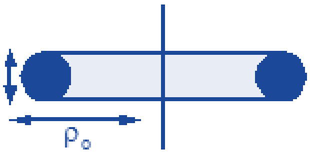
  $L = \mu_0 N^2 S/l$

  $L >> a$



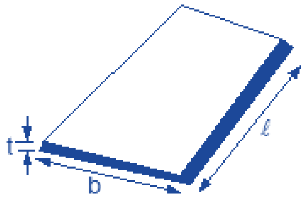
- **Inductance of Torus (of circular cross section):-**

  $L = \mu_0 N^2 [\rho_0 - \sqrt{\rho_0^2 - a^2}]$



- **Inductance of Sheet:-**

  $L = \mu_0 2l\ [\ln(2l/b+t) + 0.5]$



- **Energy stored in an conductor:-**

  (a) $W = ½\ LI^2$

  Here L is the coefficient of self -induction.

  (b) $U_B = B^2/2\mu_0$

- **Mutual Induction:-**

  Mutual induction of two circuits is the phenomenon where a current changing in the first coil results in the induction of an *e.m.f.* in the second.

- **Coefficient of Mutual Induction:-**

  $?_B = MI$ and $E = -M[dI/dt]$

  Here M is called the coefficient of mutual induction of two circuits.

  The value of M, $M = \mu_0\ \mu_r n_1\ N_2\ A$

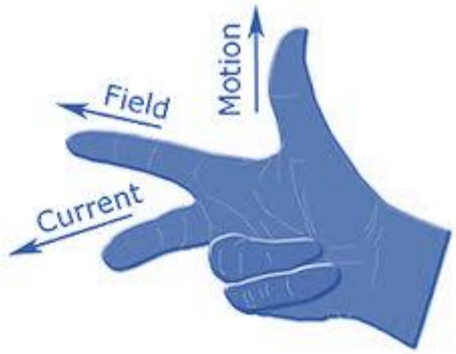
  M depends upon,

  (a) Area of cross-section of the two coils

  (b) Number of turn of each coil

  (c) Distance between the two coils

  (d) Nature of material used as core



- **Fleming's right hand rule:-**

  Stretch first finger, central finger and the thumb of your right hand in three mutually perpendicular directions. If the first finger points towards the magnetic field, thumb points towards the direction of motion of conductor, the direction of central finger gives the direction of induced current set up in the conductor.

- **Coil rotating in a uniform magnetic field:-**

  (a) Magnetic flux, $?_B = \mu naH\,[\cos \omega t]$

  (b) Electromagnetic Induction, $E = \mu na\omega H\,[\sin \omega t]$

  (c) Current, $I = [\mu na\omega H[\sin \omega t]]/R$

- **Growth and decay of current in LR circuit:-**

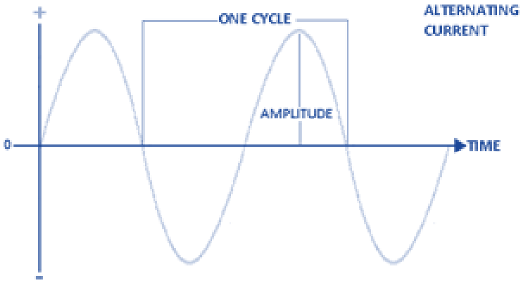
  (a) $I = I_0(1\text{-}e^{-t/\tau})$ (for growth), Here $\tau = L/R$

  (b) $I = I_0e^{-t/\tau}$ (for decay), Here $\tau = L/R$

Alternating Current

Alternating Current:

An alternating current (a.c.) is a current which continuously, changes in magnitude and periodically reverse in direction'.



$i = I_0 \sin \omega t = I_0 \sin (2\pi/T)\, t$

Here I_0 is the peak value of *a.c*.

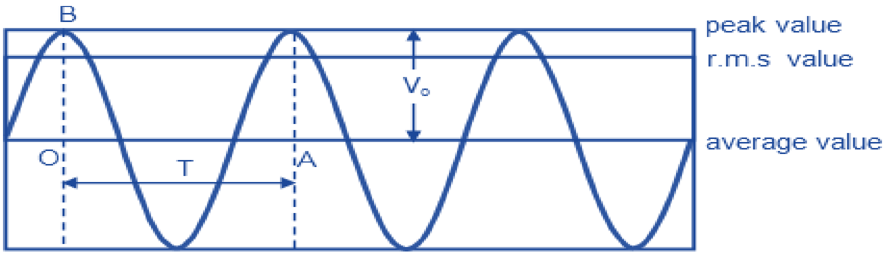
(a) Current, $I = I_0 \sin \omega t$

(b) Angular frequency, $\omega = 2\pi n$ (*n* is the frequency of a.c.)

(c) $I = I_0 \sin 2\pi nt$

- **Mean value of A.C or D.C. value of A.C.:-**

  Mean value of *a.c*. is that value of steady current which sends the same amount of charge, through a circuit, in same time as is done by *a.c*. in one half-cycle.



$(I_{av})_{\text{half cycle}} = (2/\pi) I_0$

Thus, mean value of alternating current is 2/π times (0.637 times) its peak value.

$(V_{av})_{\text{half cycle}} = (2/\pi)\, V_0$

- **Average value of A.C. over a complete cycle:-**

  $I_{av} = 0$

  The average value of *a.c.* taken over the complete cycle of *a.c.*is zero.

- **Root mean square value of a.c. or virtual value of a.c.:-**

  Root mean square value of alternating current is defined as that value of steady current which produces same heating effect, in a resistance, in a certain time as is produced by the alternating current in same resistance in same time. The *r.m.s* value of *a.c.*is also called its virtual value.

  $I_{rms} = I_0/\sqrt{2}$

Root mean square value of alternating current is $I/\surd 2$ times (or 0.707 times) the peak value of current.

Similarly, $V_{rms} = V_0/\surd 2$

Here V_0 is the peak value of *e.m.f.*

- **Form Factor:-**

Form Factor = rms value/average value = $(V_0/\surd 2)/\ (2\ V_0/\pi) = \pi/2\surd 2$

- **Current elements:-**

(a) Inductive reactance:- $X_L = \omega L$

Here, $\omega = 2\pi n$, n being frequency of *a.c.*
L is the coefficient of self-inductance of coil.

(b) Capacitative reactance:- $X_c = 1/\omega C$

Here C is the capacity of the condenser

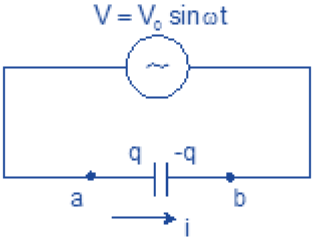
- **Capacitor in AC circuit:-**

$q = CV_0 \sin\omega t$

$I = I_0 \sin(\omega t + \pi/2)$

$V_0 = I_0/\omega C$

$X_c = 1/\omega C$



- **Inductor in AC circuit:-**

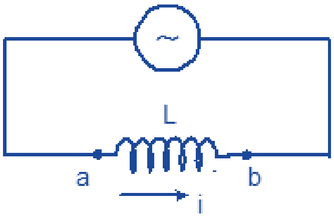
$V_L = L(dI/dt) = LI_0\omega \cos\omega t$

$I = (V_0/\ \omega L) \sin\omega t$

Here, $I_0 = V_0/\ \omega L$

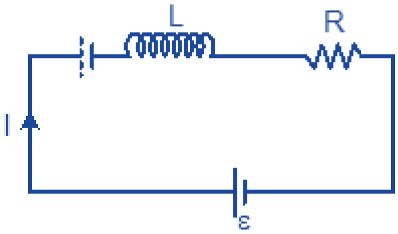
$X_L = \omega L$

And the maximum current, $I_0 = V_0/XL$

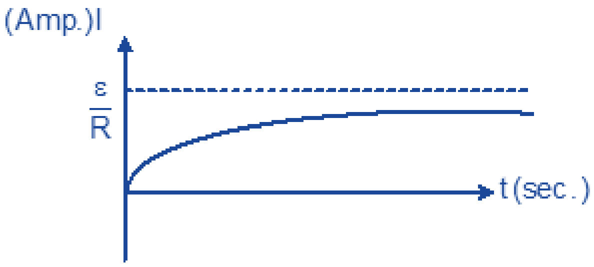


- **R-L circuit:-**

$?I = \varepsilon/R\ [1-e^{-Rt/L}]$
$V = \varepsilon\ e^{-Rt/L}$

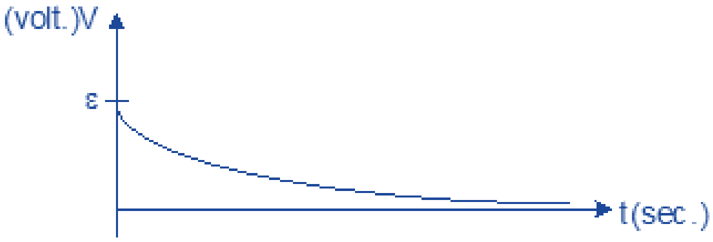


- **Graph between I (amp) and t (sec):-**



?

- **Graph between potential difference across inductor and time:-**



?

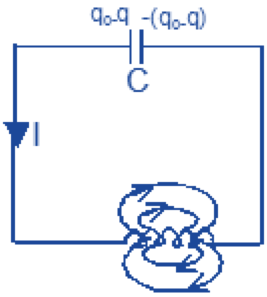
- **L-C Circuit:-**

?$f = 1/2\pi\sqrt{LC}$

q = q_0 sin (ωt+?)

I = $q_0 \omega$sin (ωt+?)

$\omega = 1/\sqrt{LC}$



- **The total energy of the system remains conserved,**

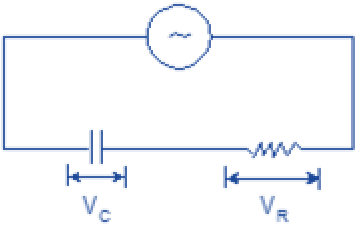
$\frac{1}{2} CV^2 + \frac{1}{2} Li^2$ = constant = $\frac{1}{2} CV_0^2 = \frac{1}{2} Li_0^2$

- **Series in C-R circuit:-**

$V = IZ$

The modulus of impedance, $|Z| = \sqrt{R^2+(1/\omega C)^2}$

The potential difference lags the current by an angle, ? = $\tan^{-1}(1/\omega CR)$

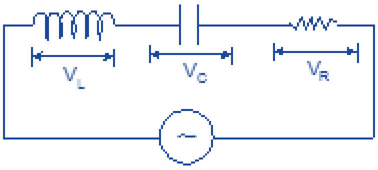


- **Series in L-C-R Circuit:**

$V = IZ$

The modulus of impedance, $|Z| = \sqrt{[R^2+(\omega L-1/\omega C)^2]}$

The potential difference lags the current by an angle, ? = $\tan^{-1}[\omega L - 1/\omega C)/R]$



- **Circuit elements with A.C:-**

Circuit elements	Amplitude relation	Circuit quantity	Phase of V
Resistor	$V_0 = i_0R$	R	In phase with i
Capacitor	$V_0 = i_0X_C$	C	Lags i by 90°
Inductor	$V_0 = i_0X_L$	$X_L = wL$	Leads i by 90°

- **Resonance:-**

(a) Resonance frequency:- $f_r = 1/2\pi\sqrt{LC}$

(b) At resonance, $X_L = X_C$, ? = 0, Z = R(minimum), cos? = 1, sin? = 0 and current is maximum (=E_0/R)

- **Half power frequencies:-**

(a) Lower, $f_1 = f_r - R/4\pi L$ or $\omega_1 = \omega_r - R/2L$

(b) Upper, $f_2 = f_r + R/4\pi L$ or $\omega_2 = \omega_r + R/2L$

- **Band width:-** $\Delta f = R/2\pi L$ or $\Delta f = R/L$
- **Quality Factor:-**

(a) $Q = \omega_r/\Delta\omega = \omega_r L/R$

(b) As $\omega = 1/\sqrt{LC}$, So $Q \propto \sqrt{L}$, $Q \propto 1/R$ and $Q \propto 1/\sqrt{C}$

(c) $Q = 1/\omega_r CR$

(d) $Q = X_L/R$ or $Q = X_C/R$

(e) $Q = f_r/\Delta f$

- **At resonance, peak voltages are:-**

(a) $(V_L)_{res} = e_0Q$

(b) $(V_C)_{res} = e_0Q$

(c) $(V_R)_{res} = e_0$

- **Conductance, susceptance and admittance:-**

(a) Conductance, $G = 1/R$

(b) Susceptance, $S = 1/X$

(c) $S_L = 1/X_L$ and $S_C = 1/X_C = \omega C$

(d) Admittance, $Y = 1/Z$

(e) Impedance add in series while add in parallel

- **Power in AC circuits:-**

  Circuit containing pure resistance:- $P_{av} = (E_0/\surd 2)\times(I_0/\surd 2) = E_v\times I_v$

  Here E_v and I_v are the virtual values of *e.m.f* and the current respectively.

  Circuit containing impedance (a combination of *R*,*L* and *C*):-

  $P_{av} = (E_0/\surd 2)\times(I_0/\surd 2) \cos ? = (E_v\times I_v) \cos ?$

  Here $\cos ?$ is the power factor.

  (a) Circuit containing pure resistance, $P_{av} = E_v I_v$

  (b) Circuit containing pure inductance, $P_{av} = 0$

  (c) Circuit containing pure capacitance, $P_{av} = 0$

  (d) Circuit containing resistance and inductance,

  $Z = \surd R^2+(\omega L)$

  $\cos ? == R/Z = R/[\surd\{R^2+(\omega L)^2\}]$

  (e) Circuit containing resistance and capacitance:-

  $Z = \surd R^2+(1/\omega C)^2$

  $\cos ? == R/Z = R/[\surd\{R^2+(1/\omega C)^2\}]$

  (f) Power factor, $\cos ?$ = Real power/Virtual power = $P_{av}/E_{rms}I_{rms}$

- **Transformer:-**

  (a) $C_p = N_p\ (d?/dt)$ and $e_s = N_s\ (d?/dt)$

  (b) $e_p/e_s = N_p/N_s$

  (c) As, $e_p I_p = e_s I_s$, Thus, $I_s/I_p = e_p/e_s = N_p/N_s$

  (d) Step down:- $e_s < e_p$, $N_s < N_p$ and $I_s > I_p$

  (e) Step up:- $e_s > e_p$, $N_s > N_p$ and $I_s < I_p$

  (f) Efficiency, $\eta = e_s I_s / e_p I_p$

- **AC Generator:-**

  $e = e_0 \sin (2\pi f t)$

  Here, $e_0 = NBA\omega$

Physics of Atom& Nuclei

e/m of an electron (Thomson Method):-

(a) e/m of a particle is called the specific charge of the particle.

e/m = v/rB

Here, r is the radius of curvature, B is the strength of magnetic field, v is the velocity, e is the charge on cathode ray particle and m is the mass.

(b) v = E/B

- **Electric field:-** E = V/d
- **Photo electric effect:-** Photo-electric effect is the phenomenon of emission of electrons from the surfaces of certain substances, mainly metals, when light of shorter wavelength is incident upon them.
- **Effect of collector's potential on photoelectric current:-**

(a) Presence of current for zero value potential indicates that the electrons are ejected from the surface of emitter with some energy.

(b) A gradual change in the number of electrons reaching the collector due to change in its potential indicates that the electrons are ejected with a variety of velocities.

(c) Current is reduced to zero for some negative potential of collector indicating that there is some upper limit to the energy of electrons emitted.

(d) Current depends upon the intensity of incident light.

(e) Stopping potential is independent of the intensity of light.

- **Effect of intensity of light:-** The photoelectric currentis directly proportional to the intensity of incident radiation.
- **Effect of frequency of light:-**

(a) Stopping potential depends upon the frequency of light. Greater the frequency of light greater is the stopping potential.

(b) Saturation current is independent of frequency.

(c) Threshold frequency is the minimum frequency, that capable of producing photoelectric effect.

- **Laws of Photo electricity:-**

(a) Photoelectric effect is an instantaneous process.

(b) Photoelectric current is directly proportional to the intensity of incident light and is independent of its frequency.

(c) The stopping potential and hence the maximum velocity of the electrons depends upon the frequency of incident light and is independent of its frequency.

(d) The emission of electrons stops below a certain minimum frequency known as threshold frequency.

- **Energy contained in bundle or packet:-**
  $E = hf = hc/\lambda$
  Here h is the Planck's constant and f is the frequency.
- **Work function:-** It is defined as the minimum energy required to pull an electron out from the surface of metal. It is denoted by W_0.
- **Einstein's equation of photoelectric effect:-**
  (a) $\frac{1}{2} mv_{max}^2 = hf - W_0$
  (b) $\frac{1}{2} mv_{max}^2 = hf - hf_0 = h(f- f_0) = h [c/\lambda - c/\lambda_0]$
  (c) $eV_0 = hf - W_0$
  (d) $V_0 = [(h/e)f] - [W_0/e]$
  Here f_0 is threshold frequency.
- **Threshold frequency (f_0):-** f_0 = work function/h = W/h
- **Maximum kinetic energy of emitted photo electrons:-** ?$K_{max} = \frac{1}{2} mv_{max}^2 = eV_0$
- **Threshold wavelength:-** $\lambda_0 = c/f_0 = hc/hf_0 = hc/W$
- **Slope of $V_0^{\sim}$ v graph:-** Slope= h/e
- **Rest mass of photon = 0, Charge = 0**
- **Energy of photon:-** $E = hf = hc/\lambda$
- **Momentum of photon:-** $p = E/c = h/\lambda = hf/c$
- **Mass od photon:-** $m = E/c^2 = h/c\lambda = hf/c^2$
- **For electron,** $\lambda_e = [12.27/\sqrt{V}]$Å
- **For proton,** $\lambda_p = [0.286/\sqrt{V}]$Å
- **For alpha particle,** $\lambda_\alpha = [0.286/\sqrt{V}]$Å
- **For particle at temperature** T, $\lambda = h/\sqrt{3mKT}$ (E = 3/2 KT)
- **The wavelength of electron accelerated by potential difference of V volts is:-** $\lambda_e = [12.27/\sqrt{V}]$Å
- **Number of photons:-**
  (a) Number of photons per sec per m^2, n_p = Intensity/hf
  (b) Number of photons incident per second, n_p = Power/hf
  (c) Number of electrons emitted per second = (efficiency per surface)× (number of photons incident per second)
- **Compton wave length:-**
  (a) $\lambda_c = h/m_0c$
  Here h is the Planck's constant, m_0 is the rest mass of electron and c is the speed of light.
  (b) Change in wavelength:- $\lambda' - \lambda = \lambda_c$ (1-cos?)
- **de Broglie wavelength (λ):-** $\lambda = h/mv = h/\sqrt{(2mE)} = h/\sqrt{(2meV)}$
- **In accordance to Bohr's postulate of atomic structure, the angular momentum of an electron is an integral multiple of h/2π.**

  So, $mvr = nh/2\pi$
- **Bragg's diffraction law:-** $2d\sin\theta = n\lambda$

  Here λ is the wavelength of electron and d is distance between the planes.

- **Rutherford's atomic model (α-particle scattering):-**

  (a) $N(\theta) \propto \text{cosec}^4(\theta/2)$

  (b) Impact parameter, $b = [(Ze^2)(\cot \theta/2)]/[(4\pi\varepsilon_0)E]$
  Here, $E = \frac{1}{2} mv^2$ = KE of theα particle.

  (c) Distance of closest approach, $r_0 = 2Ze^2/(4\pi\varepsilon_0)E$
  Here $E = \frac{1}{2} mv^2$ = KE of the α particle.

- **Bohr's atomic model:-**

  (a) The central part of the atom called nucleus, contains whole of positive charge and almost whole of the mass of atom. Electrons revolve round the nucleus in fixed circular orbits.

  (b) Electrons are capable of revolving only in certain fixed orbits, called stationary orbits or permitted orbits. In such orbits they do not radiate any energy.

  (c) While revolving permitted orbit an electron possesses angular momentum L (= mvr) which is an integral multiple of $h/2\pi$.
  $L = mvr = n(h/2\pi)$
  Here n is an integer and h is the Planck's constant.

  (d) Electrons are capable of changing the orbits. On absorbing energy they move to a higher orbit while emission of energy takes place when electrons move to a lower orbit. If f is the frequency of radiant energy,
  $hf = W_2 - W_1$
  Here W_2 is the energy of electron in lower orbit and W_1 is the energy of electron in higher orbit.

  (e) All the laws of mechanics can be applied to electron revolving in a stable orbit while they are not applicable to an electron in transition.

- **Bohr's Theory of Atom:-**

  (a) Orbital velocity of electron:- $v_n = 2\pi kZe^2/nh$

  For a particular orbit (n= constant), orbital velocity of electron varies directly as the atomic number of the substance.
  $v_n \propto Z$

  (b) For a particular element (Z= constant), orbital velocity of the electron varies inversely as the order of the orbit.
  $v_n \propto 1/n$

  (c) $v = nh/2\pi mr$

- **Relation between v_n and v_1:-**$v_n = v_1/n$
- **Radius of electron:-**

  ?$r = n^2h^2/4\pi^2kmZe^2$

  So, $r \propto n^2$
  For, C.G.S system (k = 1), $r = n^2h^2/4\pi^2mZe^2$
  S.I ($k = 1/4\pi\varepsilon_0$), $r = (\varepsilon_0/\pi)(n^2h^2/mZe^2)$

- **Kinetic energy of the electron:-** It is the energy possessed by the electron by virtue of its motion in the orbit.

  $K.E = \frac{1}{2} mv^2 = \frac{1}{2} k (Ze^2/r)$

- **Potential energy:-** It is the energypossessed by the electronby virtue of its position near the nucleus.

  $P.E = -k (Ze^2/r)$

- **Total energy:-**

  $W = K.E + P.E$

  $W = -\frac{1}{2} k (Ze^2/r) = -k^2\, 2\pi^2 Z^2 me^4/n^2h^2$
  For, C.G.S ($k = 1$), $W = -[2\pi^2 Z^2 me^4/n^2h^2]$
  For, S.I. ($k = 1/4\pi\varepsilon_0$), $W = -(1/8\varepsilon_0^2)[Z^2 me^4/n^2h^2]$
  Since, $W \propto 1/n^2$, a higher orbit electron possesses a lesser negative energy (greater energy) than that of a lower orbit electron.
- **Frequency, wavelength and wave number of radiation:-**

  Frequency, $f = k^2[2\pi^2 Z^2 me^4/h^3]\,[1/n_1^2 - 1/n_2^2]$

  Wave number of radiation,

  $$\bar{f} = \frac{1}{\lambda} = \mathrm{R}\left[\frac{1}{n_1^2 - n_2^2}\right]$$

  Here R is the Rydberg's constant and its value is,
  $R = k^2\,[2\pi^2 Z^2 me^4/ch^3]$
- **Bohr's theory of hydrogen atom (Z=1):-**

  (a) Radius of orbit:-

  $r = n^2h^4/4\pi^2 me^2$ (C.G.S)
  $r = (\varepsilon_0/\pi)(n^2h^2/me^2)$ (S.I)

  (b) Energy of electron:-
  $W = 2\pi^2 me^4/n^2h^2$ (C.G.S)
  $W = (1/8\varepsilon_0)[me^4/n^2h^2]$

  (c) Frequency, wavelength and wave number of radiation:-

  C.G.S:- k =1 and Z=1

  Frequency= $f = 2\pi^2 me^4/h^3\,[1/n_1^2 - 1/n_2^2]$
  Wave number = $1/\lambda = 2\pi^2 me^4/ch^3\,[1/n_1^2 - 1/n_2^2]$

  S.I:- k =1/4πε$_0$ and Z=1

  Frequency= $f = (1/8\varepsilon_0)(me^4/h^3)[1/n_1^2 - 1/n_2^2]$
  Wave number = $1/\lambda = (1/8\varepsilon_0^2)(me^4/ch^3)[1/n_1^2 - 1/n_2^2]$
- **Rydberg's constant:-**

  $R = k^2 = 2\pi^2 z^2\, me^4/ch^3$

- **Nuclear Physics:-** Branch of physics dealing with the study of nucleus is called nuclear Physics.
- **Constituents of nucleus (Nucleons) :-**

  (a) Protons:-

  Mass of proton, $m_p = 1.6726\times10^{-27}$ kg
  Charge of proton = 1.602×10^{-19} C

  (b) Neutron:-
  Mass of neutron, $m_n = 1.6749\times10^{-27}$ kg

  (c) 1 atomic mass unit (1 amu) = 1.66×10^{-27} kg

  (d) 1 amu = 1 u = 931.5 MeV
- **Properties of nucleus:-**

  (a) Charge on nucleus = 1.602×10^{-19} Z coulomb

  (b) Size of nucleus:-
  The radius r of the nucleus depends upon the atomic mass A of the element.
  $r = R_0A^{1/3}$
  Here $R_0 = 1.2\times10^{-13}$ cm (1 Fermi $=10^{-13}$ cm)
  Volume of the nucleus:-
  $V = 4/3\ \pi r^3 = 4/3\ \pi\ (R_0A^{1/3})^3$

  (c) Density of nucleus:-
  Density of nucleus = mass/volume = $A/(4/3\ \pi R_0^3A) = [3/(4\pi R_0^3)]$
- **Isotopes:-** Nuclei having same atomic number Z but different mass number A are called isotopes.
- **Isobars:-** Nuclei having same mass number A but different atomic number Z are called isobars.
- **Isotones:- Nuclei having the same number of neutrons (N) but different atomic number (Z) are called isotones.**
- **Nature of nuclear force:-**

  (a) Nuclear forces are attractive in nature.

  (b) Nuclear forces are charge independent.

  (c) These are short range forces.

  (d) Nuclear forces decrease very quickly with distance between two nucleons.

  (e) Nuclear forces are spin dependent.
- **Mas defect:-** If the mass of the nucleus H_Z^A is M, then the mass defect,

  $\Delta M = [Zm_p + (A\text{-}Z)m_n – M]$?

  Here, m_p and m_n are the masses of the proton and neutron respectively.
- **Binding Energy:-**

  Binding Energy = $(\Delta M)\ c^2 = [Zm_p + (A\text{-}Z)m_n – M]\ c^2$

  If we use atomic mass instead of nuclear masses, then,
  Binding Energy, $B = [Zm_H + (A\text{-}Z)m_n – M_{at}]\ c^2$
  Here M_{at} is the mass of the atom and m_H is the mass of the hydrogen atom.

- **Binding energy per nucleon:-**

  $B/A = [Zm_p + (A-Z)m_n - M]\, c^2 /A$

  If we use atomic mass instead of nuclear masses, then,
  $B/A = [Zm_H + (A-Z)m_n - M_{at}]\, c^2/A$
- **Radioactivity:-** The phenomenon by virtue of which substance, spontaneously, disintegrate by emitting certain radiations is called radioactivity**.**
- **Radioactive radiations:-**

  ?

  $$(a)\ \alpha-\text{rays:-}\ X_Z^A\ (\text{mother nucleus}) \rightarrow Y_{Z-2}^{A-4}\ (\text{daughter nucleus}) + He_2^4\ (\alpha-\text{particle})$$
  $$(b)\ \beta-\text{rays:-}\ X_Z^A\ (\text{mother nucleus}) \rightarrow Y_{Z+1}^{A}\ (\text{daughter nucleus}) + e_{-1}^0\ (\text{radiation})$$
  $$(c)\ \gamma-\text{rays :-}\ X_Z^{*A}\ (\text{mother nucleus}) \rightarrow Y_{Z}^{A}\ (\text{daughter nucleus}) + hf\ (\gamma-\text{ray})$$
- **Alpha decay:-** It is the process in which a parent nucleus decays into the daughter nucleus by ejecting an alpha particle.

  ? $P_Z^A \rightarrow D_{Z-2}^{A-4} + He_2^4 + Q_\alpha$
- **Beta decay:-** It is the process in which a parent nucleus decays into the daughter nucleus by ejecting an electron.

  $P_Z^A \rightarrow D_{Z-1}^{A} + e_{-1}^0 + \bar{\nu} + Q_\beta$

  ? Here $\bar{\nu}$ is the anti-neutron and Q_β is the beta disintegration energy.
- **Gama decay:-** Sometimes the daughter nucleus is left in the excited state. It decays in to any other lower state or ground state by emitting γ-rays.

  ? $X_{Z^*}^{A} \rightarrow X_Z^A + hf$
- **Laws of radioactivity:-**

  (a) Radioactivity is due to the disintegration of a nucleus.

  (b) Rate of disintegration is not affected by the external conditions like temperature and pressure etc.

  (c) Law of conservation of charge holds good in radioactivity.

  (d) The disintegration is accompanied by the emission of energy in terms of α, β and γ-rays either single or all at a time.

  Emission of α- particle results in a decrease in its atomic number by 2 and a decrease in its atomic weight by 4.

Emission of β- particle results in an increase in its atomic number by 1 while its atomic weight remains unaffected.

Emission of γ- rays results neither in a change of atomic number nor in a change of atomic weight.

(e) Each of the product disintegration is a new element having physical and chemical properties different from those of the parent atom.

(f) Rate of disintegration of the radioactive substance, at any instant, is directly proportional to the number of atoms present at that instant.

$N = N_0e^{-\lambda t}$

If, $t = 1/\lambda$, then, $N = N_0/e$

Therefore, radioactive decay constant is defined as the reciprocal of time in which the number of atoms of radioactive sample is reduced to N_0/e.

- **Half-life ($T_{1/2}$):-** Half-life of a radioactive substance is defined as the time during which the number of atoms of the substance are reduced to half their original value.

  $T_{1/2} = 0.693/\lambda$

  Thus, half-life of a radioactive substance is inversely proportional to its radioactive decay constant.
- **Average life (T_{av}):-** Arithmetic mean of the lives of all the atoms is known as mean life or average life of the radioactive substance.

  T_{av} = sum of lives of all atoms / total number of atoms

  Average life of a radioactive substance is equal to the reciprocal of its radioactive decay constant.
- **Relation between $T_{1/2}$ and T_{av}:-**

  $T_{1/2} = 0.693\times T_{av}$

  Half-life = 0.693×average life
- **Units of radioactivity:-**

  (a) Curie (Ci):- Radioactivity of a substance is said to be one curie if its atoms disintegrate at the rate of 3.7×10^{10} disintegrations per second.

  (b) Rutherford (rd):- Radioactivity of a substance is said to be 1 Rutherford if its atoms disintegrate at the rate of 10^6 disintegrations per second.
- **Relation between Curie and Rutherford:-**

  1 C = 3.7×10^4 rd
- **Nuclear fission:-** Nuclear fission is the process by which a nucleus breaks up in such a way that the two products obtained are of comparable sizes.

  Fission of U_{92}^{235} by fast moving neutrons is represented as,

  $$n_0^1 + \mathrm{U}_{92}^{235} \rightarrow \mathrm{Ba}_{56}^{141} + \mathrm{Kr}_{36}^{92} + \mathrm{N}_0^1 + \mathrm{Q}$$

  Value of Q in this reaction is 200.4443 MeV.
- **Chain reaction:-**The above quoted fission reaction proceeding in an uncontrolled manner is known as chain reaction and forms the basis of atom bomb.

Semiconductors

- **Thermoionic emission:-** Thermionic emission is the phenomenon in which electrons are emitted by a metal contains free electrons which behave like the molecules of a perfect gas.
- **Richardson Equation:-**

  $I = AT^{1/2}e^{-b/T}$

  Here I is the thermionic current density in amp per sq meter. T is the temperature on kelvin scale, A and b being constants.

  $A = ne\sqrt{k/2\pi m}$, $b = e?/k$

  Here, n is the number of electrons per unit volume, e is the charge on electron, m is the mass of electron, k is the Boltzmann's constant and ? is the potential barrier of the metal.
- **There are three types of energy bands in a solid viz.**

  (a) Valence energy band

  (b) Conduction energy band

  (c) Forbidden energy gap.
- **Energy gap or Band gap (E_g):-**

  (a) The minimum energy which is necessary for shifting electrons from valence band to conduction band is defined as band gap (E_g)

  (b) The forbidden energy gap between the valence band and the conduction band is known as band gap (E_g). i.e. $E_g = E_c - E_v$

  (c) As there are energy levels f electrons in an atom, similarly there are three specific energy bands for the electrons in the crystal formed by these atoms as shown in the figure,

  (d) Completely filled energy bands: The energy band, in which maximum possible numbers of electrons are present according to capacity is known as completely filled bank.

  (e) Partially filled energy bands: The energy band, in which number of electrons present is less than the capacity of the band, is known as partially filled energy band.

  (f) Electric conduction is possible only in those solids which have empty energy band or partially filled energy band.
- **Various types of solids:-**

  On the basis of band structure of crystals, solids are divided in three categories.

  (a) Insulators

  (b) Semi-conductors

  (c) Conductors.

- **Difference between Conductors, Semi-conductors and Insulators:-**
- **The number of electrons or cotters is given by**

  $$n_i = p_i = AT^{3/2}e^{-E_g/2KT}$$

  i.e. on increasing temperature, the number of current carriers increases.

- **The semiconductors are of two types.**

  (a) Intrinsic or pure semiconductors

  (b) Extrinsic or dopes semiconductors

- **Difference between Intrinsic and Extrinsic semiconductors:-**
- **Child's law:-**

  $I_p = KV_p^{3/2}$, K is the proportionality constant.

- **Work function:-**

  Work function of a metal is the amount of energy required to pull an electron from the surface of metal to a distant position.

- **Diode:**-

  It is a vacuum tube containing two electrodes, an emitter and a collector.

- **Diode as a rectifier:**-

  Rectification is the process of converting the alternating current into a unidirectional current.

  Rectification can be done by making use of a diode. A diode affecting rectification is said to be acting

  as a rectifier.

- **Diode Resistance:-**

  (a) Static plate resistance:- *(i)* $R_p = V_p/I_p$ (ii) $R_p \propto (V_p)^{-1/2}$ (iii) $R_p \propto (I_p)^{-1/3}$

  (b) Dynamic plate resistance:- *(i)* $r_p = (\Delta V_p/\Delta I_p)$ (ii) $r_p \propto V_p^{-1/2}$ (iii) $r_p \propto I_p^{-1/2}$

- **Half-wave rectifier:-** It is the type of rectification in which only one half of the input *a.c.* is translated into the output.
- **Full-wave rectifier:-** A rectifier in which current flows through the load for both the halves of input *a.c.* is called half-wave rectifier.
- **Triode:**- It is a vacuum tube containing three elements namely plate, filament and grid.
- **Triode constants:**-

  (a) Plate resistance (r_p):- It is defined as the ratio between changes in plate potential keeping grid potential constant to the corresponding change in plate current.

  $$r_p = \left(\frac{\Delta V_p}{\Delta I_p}\right)_{V_g=constant}$$

  (b) Mutual Inductance (g_m):- (Trans-conductance):- It is defined as the ratio between change in plate current to the change in grid potential keeping plate potential constant required to bring about that change in current.

$$g_m = \left(\frac{\Delta I_p}{\Delta V_g}\right)_{V_p=constant}$$

(c) Amplification factor (μ):- it is defined as the ratio between change in plate potential keeping grid potential constant to the change in grid potential keeping plate potential constant, in order to bring about same change in plate current.

$$\mu = \left(\frac{\Delta V_p}{\Delta V_g}\right)_{I_p=constant}$$

(d) Relation between μ, r_p and g_m:-

$$\mu = r_p \times g_m$$

(e) $r_p \propto I_p^{-1/3}$

(f) $g_m \propto I_p^{1/3}$

- **Triode as an amplifier:-** Process of increasing the amplitude of the input signal is called amplification. A triode affecting an increase in the amplitude of a signal is said to be acting as an amplifier.
  Voltage gain:- It is the ratio between the output voltage (voltage across the load resistance R_L) to the signal voltage.
  Voltage gain = $V_0/e_g = \mu R_L/R_L+r_p = \mu/[1+(r_p/R_L)]$
  This indicates that the voltage gain depend upon the load resistance. For $R_L=\infty$, voltage gain is equal to the amplification factor.

(a) $I_p = (\mu V_g/R_L+r_p)$

(b) $A = \mu R_L/R_L+r_p$

(c) $A_{max} = \mu$

(d) $\mu = A\,[1+(r_p/R_L)]$

(e) $A = \mu/2$ if $R_L = r_p$

- **Cut off voltage:-** $V_g = -(V_p/\mu)$
- **Plate current equation:-** $I_p = K[V_g+(V_p/\mu)]^{3/2}$

- **Triode as an oscillator:-** A triode producing high frequency oscillating waves, of constant amplitude, is said to be acting as an oscillator.
  Frequency of oscillation waves (*f*):- $f = 1/2\pi\sqrt{LC}$

  Here L is the inductance and *C* is the capacitance.

- **Majority charge carrier:-**

(a) For *N*-type semiconductor:- electron

(b) For *P*-type semiconductor:- hole

- **Electrical conductivity of semiconductors:-**

  Intrinsic semiconductors:-

  (a) $\sigma = e(n_e\mu_e + n_h\mu_h)$

  Here, n_e is the electron density, n_h is the hole density, μ_e is the electric mobilities and μ_h is the hole mobilities.

  (b) $\sigma = \sigma_0 e^{-E_g/2KT}$

Extrinsic semiconductor:-

(a) n-type:- $\sigma = en_e\mu_e$

(b) p-type:- $\sigma = en_n\mu_n$

- **Transistor:-**

  (a) $\mathbf{I_E = I_C + I_B}$ $(I_B << I_E,\ I_B << I_C)$

  (b) Current gains:-

  $\alpha = I_C/I_E$, $\alpha_{ac} = \Delta I_C/\Delta I_E$

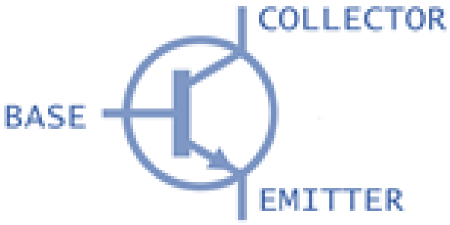
  $\beta = I_C/I_B$, $\beta_{ac} = \Delta I_C/\Delta I_B$

  (c) Relation between α and β:-

  $\alpha = \beta/[1+\beta]$

  or

  $\beta = \alpha/[1-\alpha]$



Communication Technology

- **Transmitter**

  (a) It process and encode the information and make it suitable for transmission.

  (b) The message signal for communication can be analog signals or digital signals.

  (c) An analog signal can be converted suitably into a digital signal and vice-versa.

  (d) An analog signal is that in which current or voltage value varies continuously with time.

- **Communication channel**

  The medium through which information propagate from transmitter to receiver is called communication channel.

- **Receiver**

  It receives and decode the signal.

- **Analog signal**

  A signal in which current or voltage changes its magnitude continuously with time, is called an analog signal.

- **Digital signal**

  A signal in which current or voltage have only two values, is called a digital signal. An analog signal can be converted suitable into a digital signal and vice-versa.

- **Modulation**

  The process of superimposing the audio signal over a high frequency carrier wave is called modulation.

- **Need of modulation**

  ?(a) Energy carried by low frequency audio waves (20 Hz to 20000 Hz) is very small.

  (b) For efficient radiation and reception of signal, the transmitting and receiving antennas should be very high approximately 5000 m.

  (c) The frequency range of audio signal is so small that overlapping of signals create a confusion.

- **Amplitude Modulation**

  In this type of modulation in which the amplitude of a high frequency carrier wave is varied in accordance with some characteristic of the modulating signal.

  Band width required for amplitude modulation = twice the frequency of the modulating signal.

- **Frequency modulation**

  In this type of modulation, the frequency of high frequency carrier wave is varied in accordance to instantaneous frequency of modulating signal.

- **Pulse modulation**

  In this type of modulation, the continuous waveforms are sampled at regular intervals. Information is transmitted only at the sampling times.

- **Demodulation**

  The process of separating of audio signal from modulated signal is called demodulation.

- **Antenna**

  An antenna converts electrical energy into electromagnetic waves at transmitting end and pick up transmitted signal at receiving end and converts electromagnetic waves into electrical signal.

- **Modem**

  The term modem is contraction of the term modulator and demodulator. Modem is a device which can modulate as well as demodulate the signal. It connect one computer to another through ordinary telephone lines.

- **Fax (Facsimile telegraph)**

  The electronic reproduction of a document at a distant place is called FAX.

- **Radio waves**

  ??The radio waves are the electromagnetic waves of frequency ranging from 500 kHz to about 1000 MHz. These waves are used in the field of radio communication.

- **Ground wave or surface wave propagation**

  It is suitable for low and medium frequency upto 2 MHz. It is used for local broad casting.

- **Sky wave propagation**

  It is suitable for radiowaves of frequency between 2 MHz to 30 MHz. It is used for long distance radio communication.

  (a) Critical frequency

  The highest frequency of radio wave that can be reflected back by the ionosphere is called critical frequency.

  Critical frequency, $f_c = 9\,(N_{max})^{1/2}$

  Here, N_{max} = number density of electrons/meter^3

  (b) Skip distance

  The minimum distance from the transmitter at which a sky wave of a frequency but not more than critical frequency, is sent back to the earth.

  Skip distance (D_{skip}) = $2h\,(f_{max}/f_c)^2 - 1$

  Here h is height of reflecting layer of atmosphere.

  f_{max} is maximum frequency of electromagnetic waves and f_c is critical frequency.

  (c) Fading

  The variation in the strength of a signal at receiver due to interference of waves, is called fading.

- **Space wave propagation**

  It is suitable for 30 MHz to 300 Mhz. It is used in television communication and radar communication. It is also called line of sight communication.

Range is limited due to curvature of earth. If h be the height of the transmitting antenna, then signal can be received up to a maximum distance

$d = \sqrt{2Rh}$

If the height of transmitting and receiving antennas be h_T and h_R respectively. The effective range will

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

Microwaves are electromagnetic wave of frequency 1 to 300 GHz, greater than those of TV signals. The wavelength of microwaves is of the order of a few mm.

Microwave communication is used in radar to locate the flying objects in space.

These waves can be transmitted as beam signals in a particular direction, much better than radio wave.

There is no diffraction of microwave around corners of an obstacle which happens to lie along its passage.

- **Satellite communication**

  It is carried out between a transmitter and a receiver through a satellite. A geostationary satellite is utilized for this purpose, whose time period is 24 hours.

- **Geo-synchronous orbit**

  The orbit in which the geo-satellite above revolves around the earth is known as geo-synchronous orbit.

- **Remote sensing**

  It is a technique of observing or measuring the characteristics of the object at a distance. A polar satellite is utilized for this purpose.

  Distance upto which a signal can be obtained from an antenna is given by

  $d = \sqrt{2hR}$

  Here, h is height of antenna and R is radius of earth.

- **LED and Diode laser**

  (a) Light emitting diode (LED) and diode laser are preferred sources for optical communication.

  (b) Each produces light of suitable power required in optical communication. Diode laser provides light which is monochromatic and coherent

  (c) LED provides almost monochromatic light. This suitable for small distance transmission.

- **Line communication**

  Transmission lines are used to interconnect points separated from each other. Line communication may be in the form of electrical signal or optical signal.

- **Optical fibers**

  An optical fiber is a long thread consisting of a central core of glass or plastic of uniform refractive index.

- **Types of optical fiber**

  Single mode step index fiber

  Multi mode step index fiber

  Multi mode graded index fiber

Electromagnetic Waves

- **Electromagnetic wave**

  Electric and magnetic fields fluctuating together can form a propagating wave, appropriately called an electromagnetic wave.

- **Equation of plane progressive electromagnetic wave**

  $E = E_0 \sin \omega (t - x/c)$

  $B = B_0 \sin \omega (t - x/c)$

  Here, $\omega = 2\pi f$

- **Properties of electromagnetic wave**

  (a) These waves are transverse in nature and it does not require a medium for propagation.

  (b) These waves propagate through space with speed of light, i.e., 3×10^8 m/s.

  (c) It carries energy as it propagates. The higher the frequency, the higher the energy associated with the wave.

  (d) It can transfer its energy to the matter on which it impinges.

  (e) Its propagation obeys the inverse square law.

  (f) It can be used to carry information.

  (g) It can be reflected or refracted.

  (h) It can be split and recombined to form diffraction patterns.

  (i) It can travel great distances. The radiation resulting from a simple100 volt, 1 MHz sine wave fed into a suitable antenna can be detected as far away as the next planet.

  (j) It travels in straight lines.

  (k) It can be bent around the Earth's circumference by reflection from the ionosphere.

  (l) It can pass through walls.

  (m) It can be captured by placing a metal rod, a loop, parabolic metal dish or horn in its path and it can be launched into the atmosphere with the same tools.

  (n) The E and B fields are perpendicular to each other.

  (o) The E and B fields are in phase (both reach a maximum and minimum at the same time).

  (p) The E and B fields are perpendicular to the direction of travel (transverse waves).

- **Speed of electromagnetic wave**

  $c = 1/\sqrt{\mu_0 \varepsilon_0}$

  Here, μ_0 is permeability of free space and ε_0 is the permittivity `of free space.

  $c = E_0/B_0$

  Here E_0 and B_0 are maximum values of electric and magnetic field vector.

- **Total radiant flux (Power)**

  $P = q^2a^2/6\pi\varepsilon_0c^2$

- **Poynting vector**

  The rate of flow of energy in an electromagnetic wave is described by the vector S called the poynting vector.

  $S = (1/\mu_0)\ [E \times B]$

  SI unit of S is watt/m^2

  The energy in electromagnetic waves is divided equally between electric field and magnetic field vectors.

- **Average electric energy density**

  $U_E = ½\ \varepsilon_0E^2 = ¼\ \varepsilon_0E_0^2\ S$

- **Average magnetic energy density**

  $U_B = ½\ (B^2/\mu_0) = ¼\ (B_0^2/\mu_0)$

- **Intensity of electromagnetic Wave**

  ?It is defined as energy crossing per unit area per unit time perpendicular to the directions of propagation of electromagnetic wave.

  $I = \langle\mu\rangle\ c = ½\ (\varepsilon_0E_0^2c)$

- **Displacement current**

  ?It is a current which produces in the region in which the electric field and hence the electric flux changes with time.

  Displacement current, $I_D = \varepsilon_0\ (d\phi_E/dt)$

  Here, ϕ_E is the electric flux.

- **Ampere- Maxwell law**

  $?B.dl = \mu_0\ (I + I_D)$

  Where, μ_0 = Permeability = $4\pi \times 10^{-7}$ V/Am

- **Maxwell's Equations**

  (a) $?E.dS = q/\varepsilon_0$

  This equation is Gauss's law in electrostatics.

  (b) $?E.dS = 0$

  This equation is Gauss's law in magnetostatics.

  (c) $?E.dl = (-\ d/dt)\ ?B.dS$

  This equation is Faraday's law of electromagnetic Induction.

  (d) $?B.dl = \mu_0\ [I + \varepsilon_0\ (d\phi_E/dt)]$

  This equation is Ampere – Maxwell law.

- **Electromagnetic spectrum (consists of EM waves of all frequencies)**
  - (a) radio waves (biggest wavelength, smallest frequency)
  - (b) microwaves
  - (c) infrared waves
  - (d) visible light (ROY G BIV)
  - (e) ultraviolet light
  - (f) x-rays
  - (g) gamma rays (smallest wavelength, highest frequency)

- **Speed of waves:**
  - (a) $v = f\lambda$
  - (b) Speed of EM waves through a material is less than in a vacuum
  - (c) Index of refraction: $n = c/v$, where *v* is the speed of light in the material
  - (d) When a waves passes from one material to another, the frequency remains constant but the wavelength changes:
  - (e) $\lambda = \lambda_0/n$, where λ_0 is the wavelength in vacuum

- **Polarization**
  - (a) for an EM wave, the direction of polarization is taken to be the direction of the electric field
  - (b) when an EM wave passes through a polarizing filter, the intensity of the transmitted light decreases:

    $I = \frac{1}{2} I_0$ initially unpolarized light

    $I = I_0 \cos^2\theta$ initially polarized light

    After light passes through a filter, it is polarized in the direction of the filter.

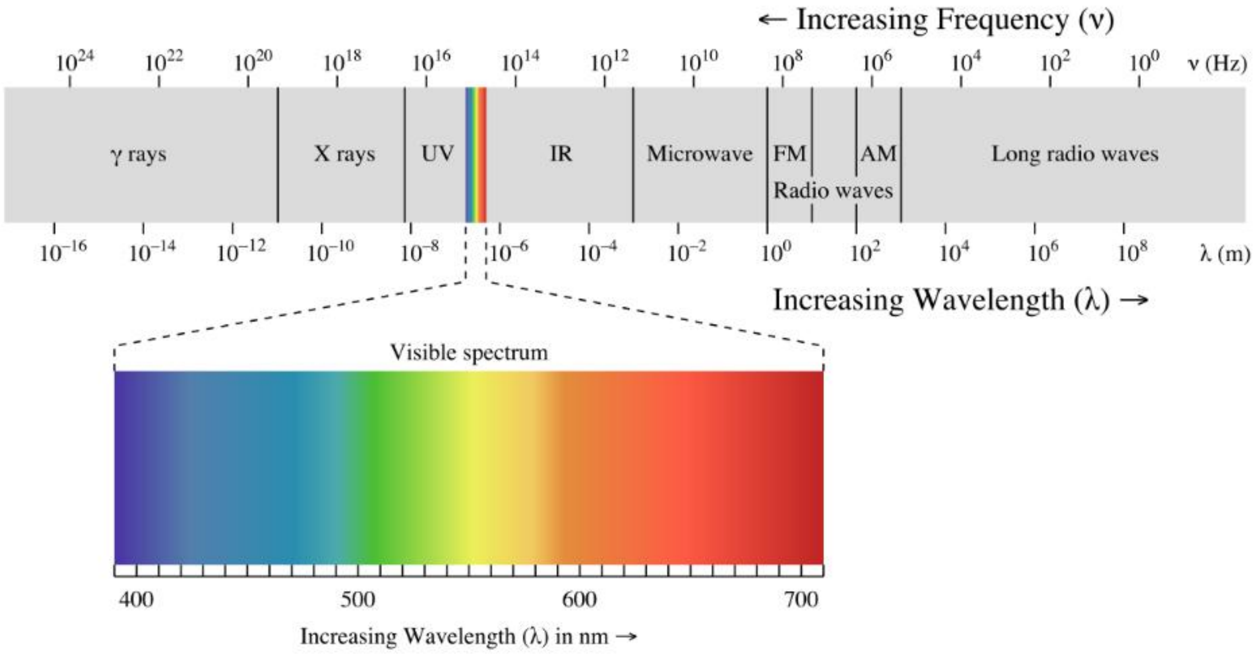
- **Right Hand Rule:**

  An electromagnetic wave propagating in the positive x direction: E and B are perpendicular to each other and in phase. The direction of propagation is given by the thumb of the right hand, after pointing the fingers in the direction of E and curling them toward B (palm towards B).

- **Propagation of Electromagnetic Spectrum**

  In radio wave communication between two places, the electromagnetic waves are radiated out by the transmitter antenna at one place which travel through the space and reach the receiving antenna at the other place.

- **Electromagnetic Spectrum**



The arranged array of electromagnetic radiations in the sequence of their wavelength or frequency is called electromagnetic spectrum.

- **Radio and microwaves** are used in radio and TV communication.
- **Infrared rays are used to**
  - (a) Treat muscular strain
  - (b) For taking photographs in fog or smoke
  - (c) In green house to keep plants warm
  - (d) In weather forecasting through infrared photography
- **Ultraviolet rays are used**
  - (a) In the study of molecular structure.
  - (b) In sterilizing the surgical instruments.
  - (c) In the detection of forged documents, finger prints.
- **X-rays are used**
  - (a) In detecting faults, cracks, flaws and holes in metal products.
  - (b) In the study of crystal structure.
  - (c) For the detection of pearls in oysters.
- **γ-rays** are used for the study of nuclear structure.

- **Thermosphere**

The thermosphere is a thermal classification of the atmosphere. In the thermosphere, temperature increases with altitude. The thermosphere includes the exosphere and part of the ionosphere.

- **Exosphere**

  The exosphere is the outermost layer of the Earth's atmosphere. The exosphere goes from about 400 miles (640 km) high to about 800 miles (1,280 km). The lower boundary of the exosphere is called the critical level of escape, where atmospheric pressure is very low (the gas atoms are very widely spaced) and the temperature is very low.

- **Mesosphere**

  The mesosphere is characterized by temperatures that quickly decrease as height increases. The mesosphere extends from between 31 and 50 miles (17 to 80 kilometers) above the earth's surface.

- **Stratosphere**

  The stratosphere is characterized by a slight temperature increase with altitude and the absence of clouds. The stratosphere extends between 11 and 31 miles (17 to 50 kilometers) above the earth's surface. The earth's ozone layer is located in the stratosphere. Ozone, a form of oxygen, is crucial to our survival; this layer absorbs a lot of ultraviolet solar energy. Only the highest clouds (cirrus, cirrostratus, and cirrocumulus) are in the lower stratosphere.

- **Troposphere**

  The troposphere is the lowest region in the Earth's (or any planet's) atmosphere. On the Earth, it goes from ground (or water) level up to about 11 miles (17 kilometers) high. The weather and clouds occur in the troposphere. In the troposphere, the temperature generally decreases as altitude increases.

- **Ionosphere**

  The ionosphere starts at about 43-50 miles (70-80 km) high and continues for hundreds of miles (about 400 miles = 640 km). It contains many ions and free electrons (plasma). The ions are created when sunlight hits atoms and tears off some electrons. Auroras occur in the ionosphere.

  (a) D-layer is at a virtual height of 65 km from surface of earth and having electron density $\approx 10^9$ m^{-3}.

  (b) E-layer is at a virtual height of 100 km, from the surface of earth, having electron density $\approx 2\times10^{11} m^{-3}$.

  (c) F_1-layer is at a virtual height of 180 km from the surface of earth, having electron density $\approx 3\times10^{11} m^{-3}$.

  (d) F_2-layer is at a vertical height of about 300 km in night time and about 250 to 400 km in day time. The electron density of this layer is $\approx 8\times10^{11} m^{-3}$.

CHEMISTRY

Mole Concept

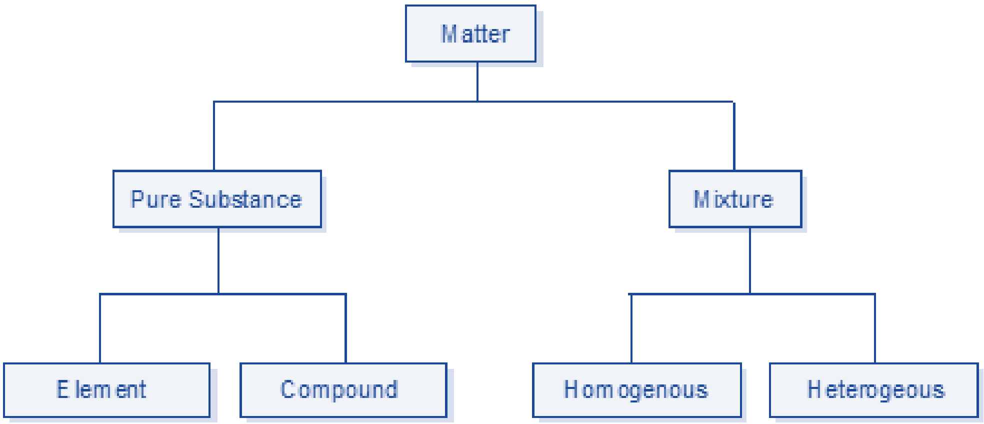
Matter:

Anything that exhibits inertia is called matter.

The quantity of matter is its mass.

Classification of Matter:-

Based on chemical composition of various substances..



Measurement of Temperature

Three scales of temperature

- Kelvin scale (K)
- Degree Celsius scale (°C)
- Degree Fahrenheit scale (°F)

Relations between the scales:

- $^{\circ}F = 9/5(^{\circ}C) + 32$
- $K = {}^{\circ}C + 273$

0 K temperatures is called absolute zero.

Dalton's Atomic Theory:

- Every matter consists of indivisible atoms.
- Atoms can neither be created nor destroyed.
- Atoms of a given element are identical in properties
- Atoms of different elements differ in properties.
- Atoms of different elements combine in a fixed ratio to form molecule of a compound.

Laws of Chemical Combination:

Law of conservation of mass:

"For any chemical change total mass of active reactants are always equal to the mass of the product formed"

Law of constant proportions:

"A chemical compound always contains same elements in definite proportion by mass and it does not depend on the source of compound".

Law of multiple proportions:

"When two elements combine to form two or more than two different compounds then the different masses of one element B which combine with fixed mass of the other element bear a simple ratio to one another"

Law of reciprocal proportion:

" If two elements B and C react with the same mass of a third element (A), the ratio in which they do so will be the same or simple multiple if B and C reacts with each other".

Gay Lussac's law of combining volumes:

"At given temperature and pressure the volumes of all gaseous reactants and products bear a simple whole number ratio to each other".

Atomic and Molecular Masses:

Atomic Mass:

- Mass of an atom.
- Reported in atomic mass unit "amu" or unified mass "u"
- One atomic mass unit i.e. amu, is the mass exactly equal to one-twelfth the mass of one carbon-12 atom.

Molecular Mass:

- Mass of a molecule of covalent compound.
- It is equal to the sum of atomic masses of all the elements present in the molecule.

Formula Unit Mass

- Mass of a molecule of an ionic compound
- It is also equal to the sum of atomic masses of all the elements present in the molecule

Mole Concept:

Mole:

- Unit of amount of substance.
- One mole amount of substance that contains as many particles or entities as there are atoms in exactly 12 g of the ^{12}C isotope.

Molar mass:

- Mass of one mole of a substance in gram
- Molar mass in gram in numerically equal to atomic/molecular/formula mass in amu or u.

?Percentage composition:

Mass percentage of an element in a compound = (Mass of that element in the compound / Molecular mass of the compound)×100

Percentage yield:

- It is the ratio of actual yield of the reaction to the theoretical yield multiplied by 100.
- % yield = (Actual yield /Theoretical yield) ×100

Empirical formula and molecular formula:

Molecular Formula:-

Represents the actual number of each individual atom in any molecule is known as molecular formula.

Empirical Formula:-

Expresses the smallest whole number ratio of the constituent atom within the molecule.

Molecular formula = $(\text{Empirical formula})_n$

Molecular weight = n × Empirical weight

also,

Molecular weight = 2 × Vapour density

Limiting Reagent:

The reactant which is totally consumed during the course of reaction and when it is consumed reaction stops.

For a balanced reaction reaction:

$A + B \rightarrow C + D$

B would be a limiting reagent if $n_A / n_B > n_B / n_A$

Similarly, A is a limiting reagent if $n_A / n_B < n_B / n_A$

Concentration of the solutions:

Mass by Mass Percentage:-

Amount of solute in gram present per 100 gm of the solution.

Mass percentage of solute = [(Mass of solute)/(Mass of solution)] x100

Mass by Volume Percentage:-

Amount solute in gram present per 100 mL of the solution.

Volume by Volume Percentage:-

Volume of solute per 100 mL of the solution

Volume by volume percentage of solute = [(Volume of solute)/(volume of solution)] x100

Parts per million (ppm) :-

The amount of solute in gram per million (106) gram of the solution.

ppm = [(mass of solute/mass of solution)]x 106

Mole fraction:-

Ratio of the moles of one component of the solution to the total number of moles of solution

Total mole fraction of all the components of a solution is equal to 1.

For binary solutions having two components A and B

Mole fraction of A

$X_A = (n_A)/(n_A+n_B)]$

Mole fraction of B

$X_B = (n_B)/(n_A+n_B)]$

or $X_B = 1- X_A$

Molarity(M):-

Number of moles of solute per 1000 mL of the solution.

M = (Number of moles of solute)/(Volume of solution in L)

Molality(m):-

number of moles of solute per 1000 gram of the solvent.

m = (Number of moles of solute)/(Weight of solvent in kg)

Gaseous & Liquid State

Revision Notes on States of Matter

Thus matter is classified mainly into three categories depending upon its physical state namely solid, liquid and gaseous states.

Distinction between three states of matter:

Sr. No	Property	Solid	Liquid	Gas
1	Shape	Definite shape	Indefinite shape	Indefinite shape
2	Volume	Definite Volume	Definite Volume	Indefinite Volume
3	Inter particular Forces	Strong Inter particular Forces	Comparatively weaker Inter particular Forces	Interparticular forces are negligible
4	Inter particular Space	Negligible inter particular space	Comparatively large inter particular space	Very large Inter particular space
5	Particular Motion	Particle motion is restricted to vibratory motion.	Particle motion is very slow	Particle motion is very rapid and also random.
6	Packing of Particles	Particles are very Closely packed	Particles are loosely packed	Particles are very loosely packed
7	Compressibility	Incompressible	Compressible	Highly Compressible
8	Density	Very High Density	Low Density	Very low density

Parameters of Gases

The characteristics of gases are described in terms of following four parameters

- Mass
- Volume
- Pressure
- Temperature

1. **Mass (m):**

The mass of the gas is related to the number of moles as

n = w/M

Where n = number of moles

w = mass of gas in grams

M = molecular mass of the gas

2. **Volume (V):**

   Since gases occupy the entire space available to them, therefore the gas volume means the volume of the container in which the gas is enclosed.

   Units of Volume: Volume is generally expressed in **litre (L), cm^3** & **dm^3**
   1m^3 = 10^3 litre = 10^3 dm^3 = 10^6 cm^3.

3. Pressure:

Pressure of the gas is due to its collisions with walls of its container *i.e.* the force exerted by the gas per unit area on the walls of the container is equal to its pressure.

$$P(pressure) = \frac{F(Force)}{A(Area)} = \frac{Mass \times Accelaration}{Area}$$

Pressure is exerted by a gas due to kinetic energy of its molecules.

As temperature increases, the kinetic energy of molecules increases, which results in increase in pressure of the gas. So, pressure of any gas is directly proportional to its temperature.

Units of Pressure:

The pressure of a gas is expressed in **atm, Pa, Nm^{-2}, bar** and **lb/In^2 (psi).**
760 mm = 1 atm = 10132.5 KPa = 101325 Pa = 101325 Nm^{-2}
760 mm of Hg = 1.01325 bar = 1013.25 milli bar = 14.7 lb/2n^2 (psi)

3. **Temperature (T):**

   Temperature is defined as the degree of hotness. The SI unit of temperature is Kelvin. ^{o}C and ^{o}F are the two other units used for measuring temperature. On the Celsius scale water freezes at 0°C and boils at 100°C where as in the Kelvin scale water freezes at 273 K and boils at 373 K.

   K = ^{o}C + 273.5

   F = (9/5) ^{o}C + 32

Gas Laws:

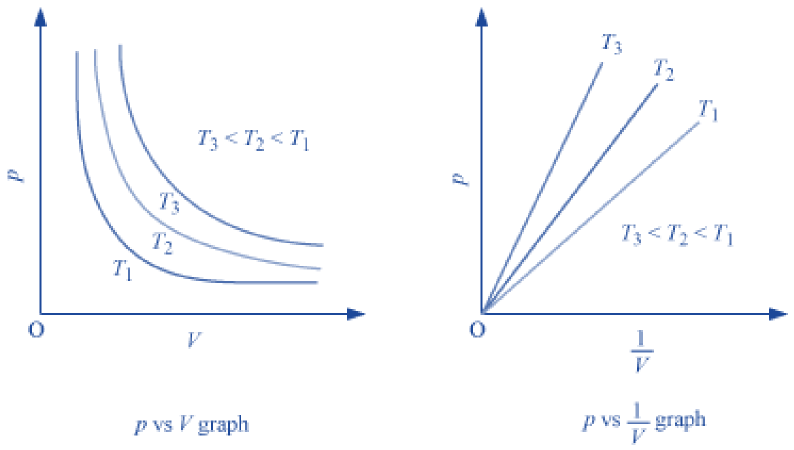
1. Boyle's Law:-

"At constant temperature, the pressure of a fixed amount (i.e., number of moles n) of gas varies inversely with its volume".

$$P_1V_1 = P_2V_2 = Constant \Rightarrow \frac{P_1}{P_2} = \frac{V_1}{V_2}$$

Graphical Representation of Boyle's Law :

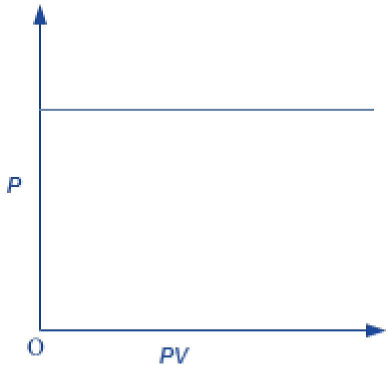
- A plot of P versus $1/V$ at constant temperature for a fixed mass of gas would be a straight line passing through the origin.
- A plot of P versus V at constant temperature for a fixed mass of a gas would be a rectangular hyperbola.



p vs V graph

p vs $\frac{1}{V}$ graph

- A plot of P (or V) versus PV at constant temperature for a fixed mass of a gas is a straight line parallel to the *PV axis.*



P vs PV graph

2. Charles' Law:-

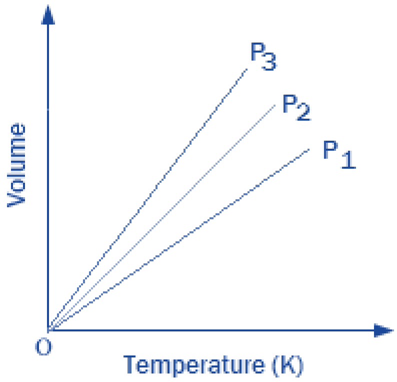
"At constant pressure, the volume of a given mass of a gas is directly proportional to its absolute temperature"

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} = constant$$

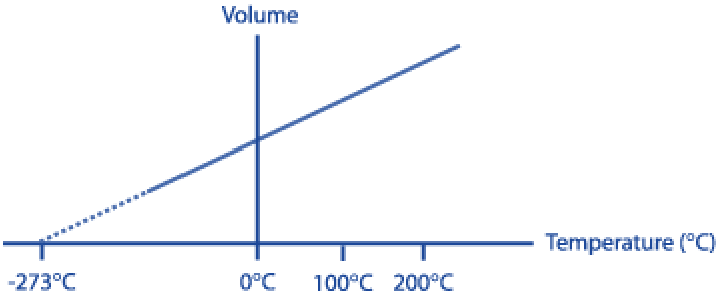
Or log V – log T = Constant

Graphical Representation of Charles's Law :

1. For a definite mass of the gas a plot of *V* vs *T* (^oK) at constant pressure is a straight line passing through the origin.



2. A plot of *V* vs *t* (^oC) at constant pressure is a straight line cutting the temperature axis at -273 ^oC



3. **Combined Gas Law:-**

This law states that *"at constant volume, the pressure of a given mass of a gas is directly proportional to its absolute temperature".*

The combination of Boyle's Law and Charles' Law:

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

4. **Gay Lussac's Law:**

$$P \alpha T \text{ (at constant volume)}$$

$$\Rightarrow P = kT \Rightarrow \frac{P}{T} = k = constant$$

Where,

***P* = Pressure of Gas**

***T* = Absolute Temperature**

If the pressure and temperature of a gas changes from P_1 & T_1 to P_2 & T_2, volume remaining constant, we have

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} = constant$$

$$\text{or } \log P - \log T = \text{constant}$$

$$P_t = P_0(1 + \frac{t}{273.15})$$

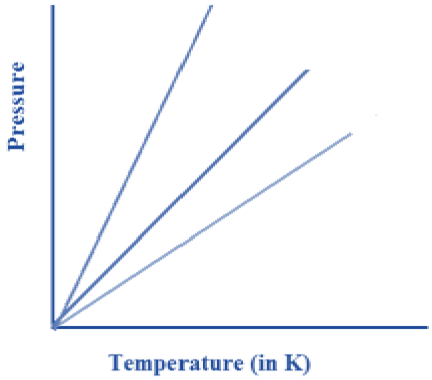
where,

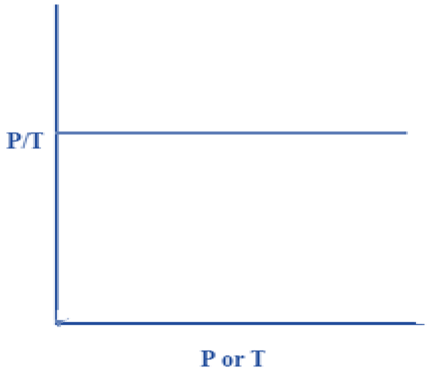
P_t = Pressure of gas at t °C

Po = Pressure of gas at 0 °C

t = Temperature in °C.

Graphical Representation of Gay-Lussac's Law





5. **Avogadro Law:**

   "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 $V \alpha n$ (when T and P are constant).

   Mathematically

$$V \alpha n \Rightarrow V = kn$$
$$\Rightarrow \frac{V}{n} = k = Constant$$

6. **Ideal Gas Equation:**

   Ideal gas obey all the three laws i.e. Boyle's, Charles's, and Avogadro's law strictly.

   pv = nRT

   Where,

   where R is the constant of proportionality or universal gas constant

   The value of R was found out to be

   R = 8.314 J mol^{-1} K^{-1}

$R = 0.0821$ litre atm K^{-1} mol^{-1}

$R = 2$ cal K^{-1} mol^{-1}

Ideal gas equation is also known as equation of state.

7. **Dalton's law of partial pressures:**

The total pressure of mixture of non-reactive gases at constant temperature and pressure is equal to the sum of the individual partial pressures of the gases.

$p_{total} = p_1 + p_2 + p_3 + p_4 \ldots$

$p_1 = x_1 \, p_{total}$

$p_2 = x_2 \, p_{total}$

$p_3 = x_3 \, p_{total}$

Aqueous tension:-

Pressure exerted by saturated water vapour.

$p_{dry\ gas} = p_{Total}$ –Aqueous Tension

Gas Eudiometry:

Gas	Absorbing Reagent used:
O_3	Turpentine oil
O_2	Alkaline pyrogallol
NO	$FeSO_4$ solution
CO_2,SO_2	Alkali solution (NaOH, KOH, $Ca(OH)_2$, $HOCH_2CH_2NH_2$, etc.)
NH_3	Acid solution or $CuSO_4$ solution

Equation for combustion of hydrocarbons:

$C_xH_y + (x + y/4)\, O_2 \longrightarrow xCO_2 + y/2\ H_2O$

Kinetic molecular theory of gases:

- Gases are made of large number of identical particles (atoms or molecules), which are very small and perfectly hard spheres.
- The actual volume of the molecules is negligible as compare to the space between them and hence they are considered as the point masses.
- Interaction between the particles is negligible.
- Particles of a gas are always in constant and random motion and the collision between them is perfectly elastic.
- The average kinetic energy of the particles of a gas is directly proportional to the absolute temperature.
- Pressure of the gas is due to the collision between gas molecules and walls of the container.

The Kinetic Equation

$$pV = \frac{1}{3}mnu^2$$

$$\Rightarrow u^2 = \sqrt{\frac{3PV}{M}} = \sqrt{\frac{3RT}{M}}$$

Velocities of gas molecules

- **Average Velocity**

Average velocity =

$$\frac{u_1 + u_2 + u_3 + u_4 + u_n}{n} = \frac{n_1u_1 + n_2u_2 + n_3u_3 + . + n_nu_n}{n_1 + n_2 + n_3 + . + n_4}$$

$$U_{av} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8pV}{\pi M}}$$

- **Root Mean Square Velocity:-**

Maxwell proposed the term U_{rms} as the square root of means of square of all such velocities.

$$U_{rms}^2 \frac{u_1^2 + u_2^2 + u_3^2 + u_4^2 + u_n^2}{n} = \frac{n_1u_1^2 + n_2u_2^2 + n_3u_3^2 + . + n_nu_n^2}{n_1 + n_2 + n_3 + . + n_4}$$

also

$$U_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3pV}{M}}$$

- **Most probable velocity:-**

It is the velocity which is possessed by maximum no. of molecules.

$$U_{mp} = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2pV}{M}}$$

Furthermore

$$u_{mp} : u_{av} : u_{rms} ::: \sqrt{\frac{2RT}{M}} : \sqrt{\frac{8RT}{\pi M}} : \sqrt{\frac{3RT}{M}} = \sqrt{2} : \sqrt{\frac{8}{\pi}} : 1.224$$

$$\Rightarrow u_{mp} : u_{av} : u_{rms} ::: 1 : 1.128 : 1.224$$

Kinetic Energy of Gas

As per kinetic equation

$$pV = \frac{1}{3}mnu^2$$

For 1 mole m × n = Molecular Mass (M)

$$pV = \frac{1}{3}Mu^2 = \frac{2}{3} \times \frac{1}{2}Mu^2 = \frac{2}{3} \times \frac{2}{3} \times K.E./mole = \frac{3}{2}RT$$

Also

$$\frac{K.E.}{Molecule} = \frac{3}{2}\frac{RT}{N} = \frac{3}{2}kT$$

Where k is the Boltzmann constant (k = R / N)

Graham's Law of Diffusion/Effusion:

1. **Diffusion:** ability of a gas to spread and occupy the whole available volume irrespective of other gases present in the container
2. **Effusion:** process by which a gas escapes from one chamber of a vessel through a small opening or an orifice

$$R = \frac{Volume\ Diffused}{Time\ Taken} = \frac{V}{T}$$

$r \propto 1 / \sqrt{d}$

where r is the rate of diffusion and d is the density of the gas.

Now, if there are two gases A and B having r_1 and r_2 as their rates of diffusion and d_1 and d_2 their densities respectively. Then

$r_1 \propto \frac{1}{\sqrt{d_1}}_1$

and

$r_2 \propto \frac{1}{\sqrt{d_2}}$

or

$$,\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}}\ (at\ same\ T\ and\ P)$$

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$$

The rate of diffusion (r) of a gas at constant temperature is directly preoperational to its pressure

$$\frac{r_1}{r_2} = \frac{P_2}{P_1} = \sqrt{\frac{M_2}{M_1}}$$

Deviation from ideal gas behavior:

For ideal gas,

Compressibility factor i.e. $Z = PV/nRT = 1$

For non-Ideal gas, $Z \neq 1$

Thus for non-ideal gas,Z can be < 1 or > 1

When Z < 1, it is a negative deviation. It shows that the gas is more compressible than expected from ideal behaviour.

When Z > 1, it is a positive deviation. It shows that the gas is less compressible than expected from ideal behaviour.

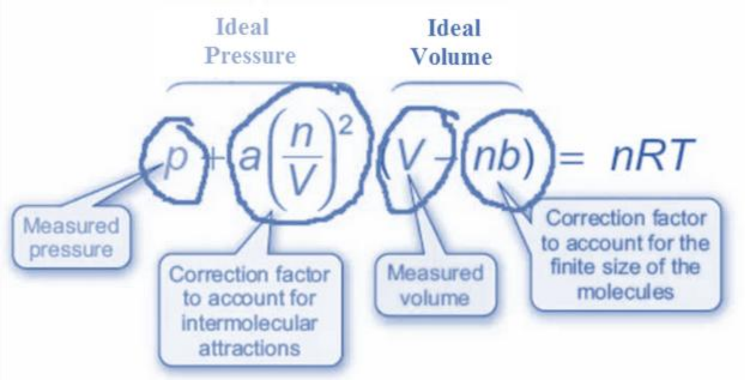
1. **Causes of deviation from ideal behaviour:**

The volume occupied by gas molecules is negligibly small as compared to the volume occupied by the gas.
The forces of attraction between gas molecules are negligible.

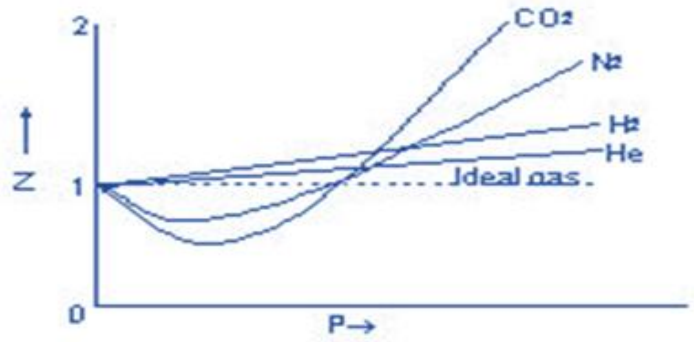
2. **Van der waals Equation:**

$$(P + \frac{an^2}{V^2})(V - nb) = nRT$$

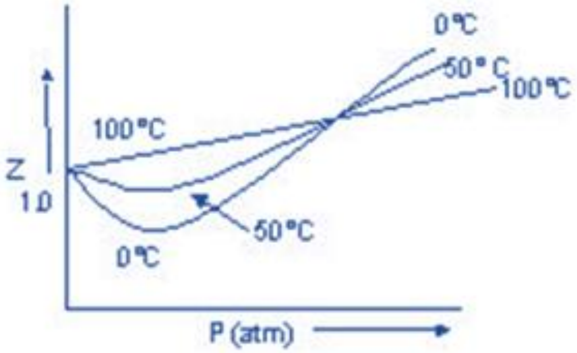
Where,
a and b are van der waals constants.
At low pressures:
$PV = RT - a/V$
or
$PV < RT$
This accounts for the dip in PV vs P isotherm at low pressure



At fairly high pressures



a/V^2 may be neglected in comparison with P. The Vander Waals equation becomes
$PV = RT + Pb$
or
$PV > RT$
This accounts for the rising parts of the PV vs P isotherm at high pressures



Boyle's Temperature (T_b) :- Temperature at which real gas obeys the gas laws over a wide range of pressure.

$T_b = a / Rb = 1/2\ T_1$

Liquefaction of gases:

- **Critical temperature (Tc):-** temperature at which a gas liquefies. $T_c = 8a / 27Rb$
- **Critical Volume: (V_c) :-** volume of one mole of a gas at critical temperature.$V_c = 3b$
- **Critical pressure (pc):-** pressure of A gas at its critical temperature. $P_c = a/27b^2$
- **Molar heat capacity of ideal gases:-**the amount of heat required to raise the temperature of 1 mole of a gas trough 1^0C.

  $C_P - C_V = R$ &

  Poisson's ratio (γ) = C_P/C_V

  For monatomic gas $C_p = 5$ cal and $C_v = 3$ cal

  $\gamma = 5/3 = 1.67$

  For diatomic gas $C_p = 7$ cal and $C_v = 5$ cal

  $\gamma = 7/5 = 1.4$

  For polyatomic gas $C_p = 8$ cal and $C_v =$ cal

  $\gamma = 8/6 = 1.33$

  Also $C_p = C_p m$,

  Where, C_p and C_v are specific heat and m, is molecular weight.

Liquid State:

1) **Surface Tension (γ):-** It is the force acting at right angles to the surface along one centimeter length of the surface.
   Surface tension (γ) = Work done / Change in area
   Units: **CGS:** dcm^{-1}
   SI: Nm^{-1}
   The surface of the liquid tends to contract to the smallest possible area for a given volume of the liquid i.e. spherical shape.
   Surface Tension of liquid decreases with increase of temperature and becomes zero at its critical temperature.

Surface Tension in everyday life:

- Cleansing action of soap and detergents.
- Efficacy of tooth pastes, mouth washes and nasal jellies.

Viscosity:

It is the force of friction which one part of the liquid offers to another part of the liquid.

Coefficient of viscosity: is the force per unit area required to maintain unit difference of velocity between two parallel layers in the liquid one unit apart.

Units: CGS: dscm^{-1}

S.I: Nsm^{-1}

Viscosity of liquid decreases with increase in temperature.

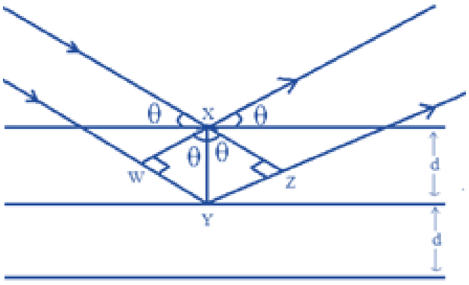
Solid State

Revision Notes on Solid State

Classification of solids:

Crystalline and Amorphous solids:

Based on binding forces:



Bragg Equation:

$n\lambda = 2d\sin\theta$,

Where

- d= distance between the planes
- n = order of refraction
- θ= angel of refraction
- λ = wavelength

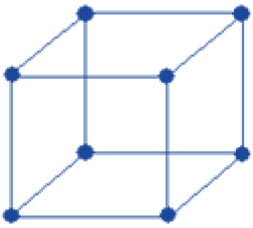
Crystal Systems:

- Total number of crystal systems: 7
- Total number of Bravais Lattices: 14

Crystal Systems	Bravais Lattices	Intercepts	Crystal angle	Example
Cubic	Primitive, Face Centered, Body Centered	a = b = c	a = b = g = 90°	Pb,Hg,Ag,Au Diamond, NaCl, ZnS
Orthorhombic	Primitive, Face Centered, Body Centered, End Centered	a ≠ b ≠ c	a = b = g = 90°	KNO_2, K_2SO_4
Tetragonal	Primitive, Body Centered	a = b ≠ c	a = b = g = 90°	TiO_2,SnO_2
Monoclinic	Primitive, End Centered	a ≠ b ≠ c	a = g = 90°, b≠ 90°	$CaSO_4$,$2H_2O$
Triclinic	Primitive	a ≠ b ≠ c	a≠b≠g≠90°	$K_2Cr_2O_7$, $CaSO_4 5H_2O$
Hexagonal	Primitive	a = b ≠ c	a = b = 90°, g = 120°	Mg, SiO_2, Zn, Cd
Rhombohedra	Primitive	a = b = c	a = g = 90°, b≠ 90°	As, Sb, Bi, $CaCO_3$

Number of atoms in unit cells.

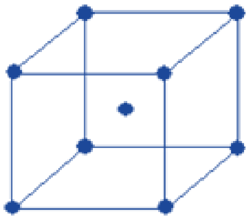
Primitive cubic unit cell:



- Number of atoms at corners = 8×1/8 =1
- Number of atoms in faces = 0
- Number of atoms at body-centre: = 0
- Total number of atoms = 1

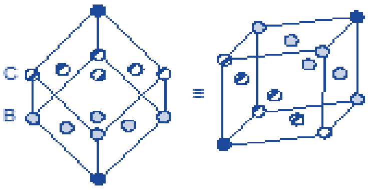
Body-centred cubic unit cell:

- Number of atoms at corners = 8×1/8 =1
- Number of atoms in faces = 0
- Number of atoms at body-centre: =1
- Total number of atoms = 2



Face-centred cubic or cubic-close packed unit cell:

- Number of atoms at corners = 8×1/8 =1
- Number of atoms in faces = 6×1/2 = 3
- Number of atoms at body-centre: = 0
- Total number of atoms = 4



Packing Efficiency

Packing Efficiency = (Volume occupied by all the atoms present in unit cell / Total volume of unit cell)×100

Close structure	Number of atoms per unit cell ‘*z*’.	Relation between edge length ‘*a*’ and radius of atom ‘*r*’	Packing Efficiency
hcp* and *ccp* or *fcc	4	r = a/(2√2)	74%
bcc	2	r = (√3/4)a	68%
Simple cubic lattice	1	r = a/2	52.4%

Density of crystal lattice:

r = (Number of atoms per unit cell × Mass number)/(Volume of unit cell × N_A)

$$r = \frac{Number\ of\ unit\ cells \times Mass\ number}{Volume\ of\ Unit\ Cells \times N_A}$$

or

$$r = \frac{z \times M}{V \times N_A}$$

Octahedral and Tetrahedral Voids:

Number of octahedral voids = Number of effective atoms present in unit cell

Number of tetrahedral voids = 2×Number of effective atoms present in unit cell

So, Number of tetrahedral voids = 2× Number of octahedral voids.

Coordination numbers and radius ratio:

Coordination numbers	Geometry	Radius ratio (x)	Example
2	Linear	$x < 0.155$	BeF_2
3	Planar Triangle	$0.155 \leq x < 0.225$	$AlCl_3$
4	Tetrahedron	$0.225 \leq x < 0.414$	ZnS
4	Square planar	$0.414 \leq x < 0.732$	$PtCl_4^{2-}$
6	Octahedron	$0.414 \leq x < 0.732$	NaCl
8	Body centered cubic	$0.732 \leq x < 0.999$	CsCl

Classification of Ionic Structures:

Structures	Descriptions	Examples
Rock Salt Structure	Anion(Cl^-) forms fcc units and cation(Na^+) occupy octahedral voids. Z=4 Coordination number =6	NaCl, KCl, LiCl, RbCl
Zinc Blende Structure	Anion (S^{2-}) forms fcc units and cation (Zn^{2+}) occupy alternate tetrahedral voids Z=4 Coordination number =4	ZnS , BeO
Fluorite Structures	Cation (Ca^{2+}) forms fcc units and anions (F^-) occupy tetrahedral voids Z= 4 Coordination number of anion = 4 Coordination number of cation = 8	CaF_2, UO_2, and ThO_2
Anti- Fluorite Structures	Oxide ions are face centered and metal ions occupy all the tetrahedral voids.	Na_2O, K_2O and Rb_2O.
Cesium Halide Structure	Halide ions are primitive cubic while the metal ion occupies the center of the unit cell. Z=2 Coordination number of = 8	All Halides of Cesium.
Pervoskite Structure	One of the cation is bivalent and the other is tetravalent. The bivalent ions are present in primitive cubic lattice with oxide ions on the centers of all the six square faces. The tetravalent cation is in the center of the unit cell occupying octahedral void.	$CaTiO_3$, $BaTiO_3$
Spinel and Inverse Spinel Structure	Spinel :$M^{2+}M_2^{3+}O_4$, where M^{2+} is present in one-eighth of tetrahedral voids in a FCC lattice of oxide ions and M^{3+}ions are present in half of the octahedral voids. M^{2+} is usually Mg, Fe, Co, Ni, Zn and Mn; M^{3+} is generally Al, Fe, Mn, Cr and Rh.	$MgAl_2O_4$, $ZnAl_2O_4$, Fe_3O_4,$FeCr_2O_4$ etc.

Defects in crystal:

Stoichiometric Defects

1. **Schottky Defects**
   - Some of the lattice points in a crystal are unoccupied.
   - Appears in ionic compounds in which anions and cations are of nearly same size.
   - Decreases the density of lattice
   - Examples: NaCl and KCl

2. **Frenkel Defects**
   - Ion dislocate from its position and occupies an interstitial position between the lattice points
   - Appears in crystals in which the negative ions are much larger than the positive ion.
   - Does not affect density of the crystal.
   - Examples: AgBr, ZnS

Non-Stoichiometric Defects

1. **Metal Excess defect:**
   - Metal excess defect occurs due to
   - anionic vacancies or
   - presence of extra cation.
   - F-Centres: hole produced due to absence of anion which is occupied by an electron.

2. **Metal deficiency defect:**
   - Metal deficiency defect occurs
   - Due to variable valency of metals
   - When one of the positive ions is missing from its lattice site and the extra negative charge is balanced by some nearby metal ion acquiring two charges instead of one

Structure of Atom

Structure of Atom

Subatomic Particles:

Name	Electron	Proton	Neutron
Symbol	e-	p	n
Approximate relative mass	1/1836	1	1
Mass in kg	9.109×10^{-31}	1.673×10^{-27}	1.675×10^{-27}
Mass in amu	5.485×10^{-4}	1.007	1.008
Charge (coulomb)	1.602×10^{-19}	1.602×10^{-19}	0
Actual Charge (e.s.u)	4.8×10^{-10}	4.8×10^{-10}	0

Atomic Models:

Thomson's Atomic Model (Plum – pudding model):-

Postulate: -Atom is a sphere of positive charge in which number of electrons are embedded.

Limitations: - Could not satisfactorily explain the results of scattering experiment carried out by Rutherford.

Rutherford's Model:

Postulates:-

- Almost all the positive charge and mass of atom is present in its nucleus.
- Electrons revolve around the nucleus in circular orbits.
- There is strong electrostatic attraction between nucleus and electrons

Limitations: - Could not explain stability and electronic structure of atom.

Atomic Terms

Terms	Definition / Explanation
Atomic Number (Z)	Number of protons or electrons of neutral atom.
Mass Number (A)	Total number of protons and neutrons in an atom
Nucleons	Protons and neutrons are present in a nucleus. So, these fundamental particles are collectively known as nucleons
Isotopes	Atoms of the element with same atomic number but different mass number e.g. ${}_1H^1$, ${}_1H^2$, ${}_1H^3$.

Isobars	Atoms having the same mass number but different atomic numbers, e.g. $_{15}P^{32}$ and $_{16}S^{32}$
Isotones	Atoms having the same number of neutrons but different number of protons or mass number, e.g. $_{6}C^{14}$, $_{8}O^{16}$, $_{7}N^{15}$
Isoelectronic	Atoms, molecules or ions having same number of electrons e.g. N_2,CO, CN^-
Nuclear isomers	atoms with the same atomic number and same mass number but with different radioactive properties. Example of nuclear isomers is Uranium –X (half life 1.4 min) and Uranium –Z (half life 6.7 hours
Isosters	Molecules having same number of atoms and also same number of electrons are called isosters. E.g., N_2 and CO

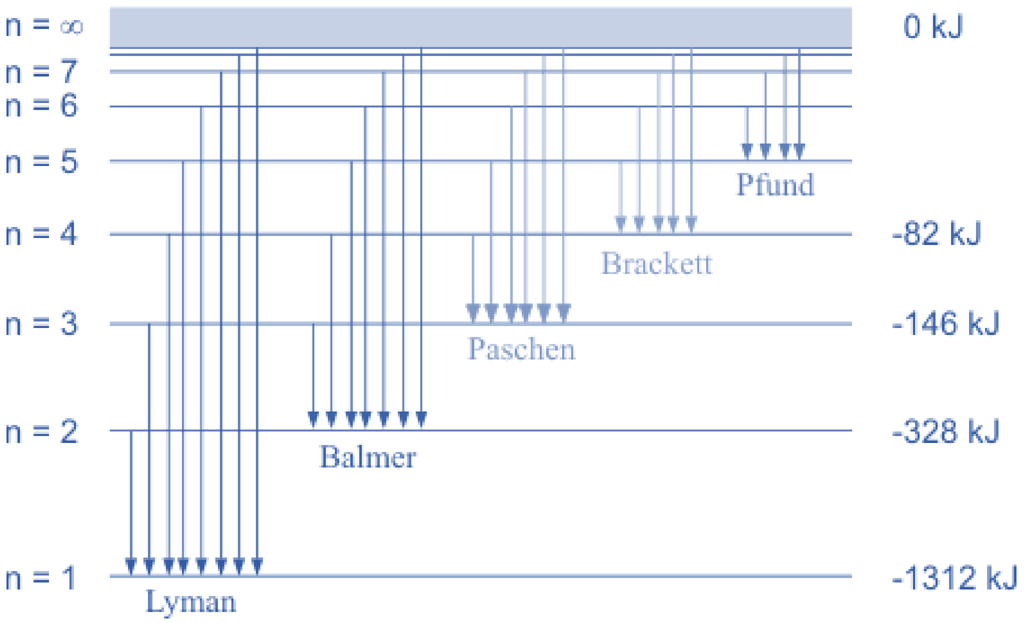
Electromagnetic Waves

Atomic spectrum of hydrogen atom:

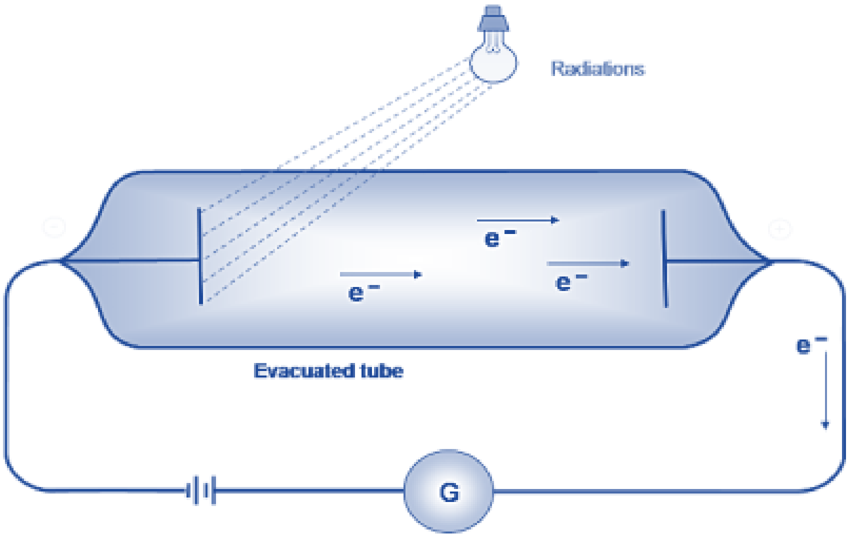
$$\frac{1}{\lambda} = \bar{\nu} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Where, R_H = Rydberg constant (108978 cm^{-1})
n_1 and n_2 have integral values as follows

n_1	n_2	Spectral Series	Spectral region
1	2,3,4…	Lyman	UV
2	3,4,5…	Balmer	Visible
3	4,5,6…	Pascher	IR
4	5,6,7…	Brackett	IR
5	6,7,8…	Pfund	IR



Photoelectric effect:



- Ejection of electrons takes place from the surface of metal when light of suitable frequency fall on it.
- Minimum frequency required for ejection of electron is called threshold frequency (v_o).
- Energy of the ejected electrons is directly proportional to the frequency of radiation.
- Number of electrons ejected per second depends on the intensity of radiation.
- $hv - hv_o = 1/2 m_e v^2$

Planck’s quantum theory:

Substances radiate or absorb energy discontinuously in the form of energy packets

The smallest packet of energy is called quantum. In case of light the quantum is known as photon.

The energy of a quantum is directly proportional to the frequency of the radiation.

E = hv were v is the frequency of radiation and h is Planck’s constant having the value 6.626×10^{-27} erg sec or 6.626×10^{-34} J sec.

A body can radiate or absorb energy in whole number multiples of quantum hn, 2hv,3hv………..nhv, where n is the positive integer.

Bohr’s atomic model:

Electrons revolve around the nucleus in circular orbits of fixed energy.

Electron revolve only in those orbits whose angular momentum (mvr) is an integral multiple of h/2Π.

Electron absorbs energy in the form of EMR, when it jumps from lower energy level (ground state) to higher energy level (excited state) and vice-versa.

Energy absorbed or released in an electron jump, (dE) is given by $dE = E_2 - E_1 = hv$
Energy of stationary state oh hydrogen atom (E_n) = $-R_H (1/n^2)$
For an hydrogen like species i.e. He^+, Li^{2+} with atomic number Z
Radius of n^{th} orbit (r_n) = $52.9 \times n^2/z$ pm
Energy of n^{th} orbit (E_n) = $-2.18\times10^{-18}(Z^2/n^2) = -13.6 \times(Z^2/n^2)$ eV = $313.6 \times(Z^2/n^2)$ kcal /mole
Velocity of electron (v) = (2.18×10^8) z/n cms^{-1}

Where n = 1,2,3,4…

Limitations of Bohr’s theory:

- Failed to explain the spectra of atoms having more than one electron.
- Failed to account for the splitting of spectral line source of a spectrum is placed in a strong magnetic or electric field.
- Dual nature of particle and the uncertainty principle was ignored in the Bohr’s atomic model.

de- Broglie equation:

λ = h/mv = h/p

Heisenberg’s uncertainty principle:

$$\Lambda x \times \Delta v \geqslant \frac{h}{4\pi m}$$

It is impossible to determine simultaneously, the exact position and exact momentum of an electron.

Quantum Numbers:

Principal quantum number (n):

- It tells the main shell in which the electron resides and the approximate distance of the electron from the nucleus.
- Maximum number of electrons a shell can accommodate is $2n^2$.

Azimuthal or angular momentum quantum number (l):

- It represents the number of subshells present in the main shell.
- These subsidiary orbits within a shell will be denoted as s,p,d,f…
- This tells the shape of the subshells.
- For a given value of n, there are n possible values of l starting from 0 to (n-1)

Value of l	0	1	2	3	4
Notation of sub shell	s	p	d	f	g

The magnetic quantum number (m):

- It determines the number of preferred orientations of the electron present in a subshell.
- For a given value of l, there are (2l+1) possible values of m starting from –l to +l.

Value of l	0	1	2	3
Notation of sub shell	s	p	d	f
Values of m	0	-1,0,1	-2,-2,0,1,2	-3,-2,-1,0,1,2,3

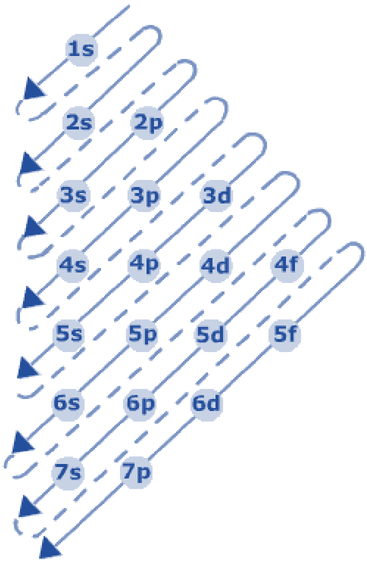
The spin quantum number (s)

- It determines the direction of spin of electron in an orbit.
- There are only two possible values for spin quantum number i.e. -1/2 ,+1/2.

Rules for filling of electrons in various orbitals :

Aufbau Principle:

- Electrons are added one by one to the various orbitals in order of their increasing energy starting with the orbital of lowest energy.
- In neutral isolated atom, the lower the value of (n+ l) for an orbital, lower is its energy
- The increasing order of energy of various orbital is : 1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d < 5p < 6s < 4f < 5d ..



Pauli’s Exclusion principle :-

An orbital can contain a maximum number of two electrons and these two electrons must be of opposite spin.

Hund’s rule of maximum multiplicity :-

Electron pairing in p, d and f orbital cannot occur until each orbital of a given subshell contains one electron each or is singly occupied”.

Exceptional Configurations

Stability of half filled and completely filled orbitals

Cu has 29 electrons. Its expected electronic configuration is

$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^9$

But a shift of one electron from lower energy 4s orbital to higher energy 3d orbital will make the distribution of electron symmetrical and hence will impart more stability.

Thus the electronic configuration of Cu is

$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^1, 3d^{10}$

Fully filled and half filled orbitals are more stable

Chemical Bonding

Revision Notes on Chemical Bonding

Chemical bond:-

Chemical bond is the attractive force which holds various constituents together in a molecule.

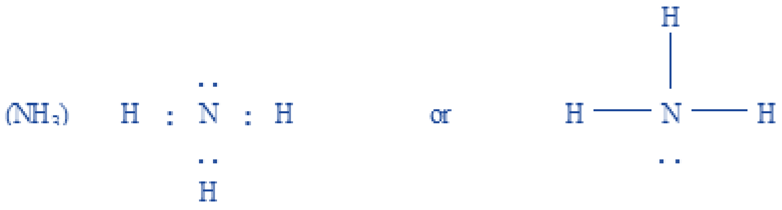
There are three types of chemical bonds: Ionic Bond, Covalent Bond, Co-ordinate Bond.

Octet Rule:

Atoms form chemical bonds in order to complete their octet i.e. eight electrons in their valence shell.

Lewis Structures:

- Pair of bonded electrons is by means of a 'dash' (-) usually called a 'bond'.
- Lone pairs or 'non-bonded' electrons are represented by 'dots'.
- Electrons present in the last shell of atoms are called valence electrons.



Exceptions to the Octet Rule:

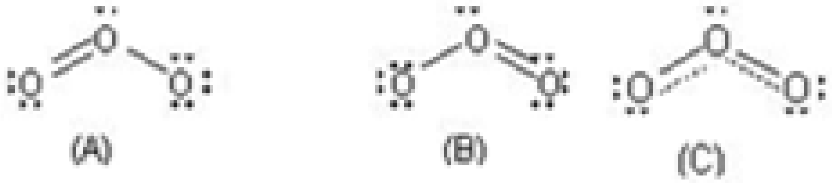
- Species with odd number of electrons**:** NO, NO_2,
- Incomplete octet for the central atom: LiCl, BeH_2 and BCl_3
- Expanded octet for the central atom: PF_5, SF_6 and H_2SO_4

Formal Charge:

- Formal charge is the difference between the number of valence electrons in an isolated atom and number of electrons assigned to that atoms in Lewis structure.
- Formal charge = [Total number of valence electrons in the free atom) - (Total number of lone pairs of electrons) -1/2(Total number of shared electrons i.e. bonding electrons)]

Resonance:

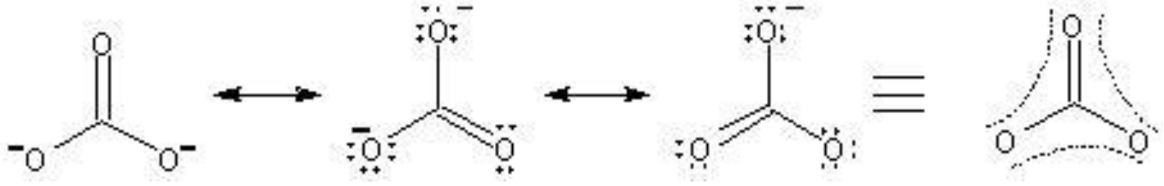
- For molecules and ions showing resonance it is not possible to draw a single Lewis structure.
- All the properties of such species can only be explained by two or more Lewis structures. Example: Resonance of O_3



A and B are resonating or canonical structures and C is the resonance hybrid

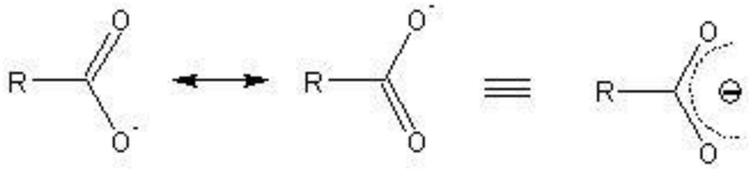
Some other examples

(i) CO_3^{2-} ion

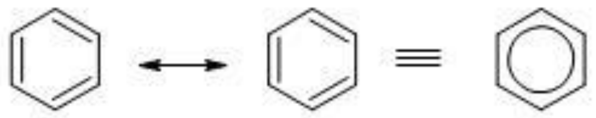


Example

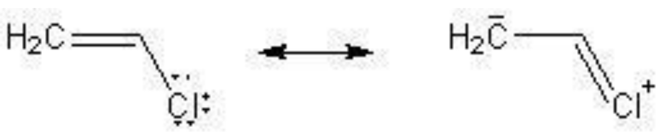
(ii) Carbon-oxygen bond lengths in carboxylate ion are equal due to resonance.



(iii) Benzene



(iv) Vinyl Chloride



Ionic Bonding:

Formation of Ionic Bond:

- Formation of ionic bond takes place between a metal and a non-metal by transfer of electron.
- Steps involved in formation of an ionic bond:

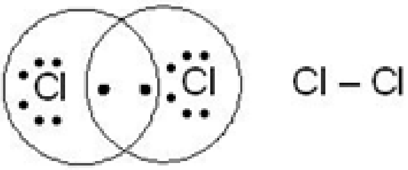
Steps	Equation	Energy involved
Formation of gaseous cations	$A(g) + I.E. \rightarrow A^+ (g) + e$	Ionization Energy
Formation of gaseous anions	$X(g) + e \rightarrow X^- (g) + E.A$	Electron Affinity
Packing of ions of opposite charges to form ionic solids	$A^+ (g) + X^- (g) \rightarrow AX (s) + Energy$	Lattice energy

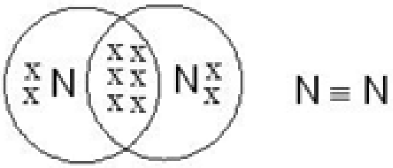
Conditions required of formation of ionic bonds:

- Low I.E of cation.
- High E.A of anion.
- High lattice energy.

Covalent Bonding:

- Covalent bond is formed between two non-metals by sharing of electrons.
- Electron pairs which participate in bonding are called bond pairs.
- Electron pairs which do not participate in bonding are called lone pairs.
- There could be single, double or triple covalent bonds between two elements depending on the number of electrons being shared.





VSEPR (Valence Shell Electron Pair Repulsion) Theory:

X	Shape	Examples
2	Linear	$HgCl_2$/$BeCl_2$
3	Triangular planar	BF_3
3	Angular	$SnCl_2$, NO_2
4	Tetrahedral	CH_4, BF_4^-
4	Trigonal Pyramidal	NH_3, PCl_3
4	Angular	H_2O
5	Trigonal bipyramidal	PCl_5, PF_5
5	Irregular tetrahedral	SF_4, IF_4^+
5	T-shaped	ClF_3, BrF_3
5	Linear	XeF_2, I_3^-
6	Octahedral	SF_6, PF_6^-
6	Square Pyramidal	IF_5
6	Square planar	XeF_4, ICl_4

- The shape of the molecule is determined by repulsions between all of the electron pairs present in the valence shell.
- Order of the repulsion: Lone pair↔ Lone pair > Lone pair↔ Bond pair > Bond pair↔ Bond pair.
- Repulsion among the bond pairs is directly proportional to the bond order and electro negativity difference between the central atom and the other atoms.

Determination of shape of molecules using VSEPR theory:

- Calculate X using following method.

X = (No. of valence electrons of central atom) + (No. of other atoms) + (Negative charge on the molecule) – (Positive charge on the molecule)

Use the following chart to find the shape.

Rule:

It accounts for the covalent character in ionic compounds.

Covalency is favoured by

- Smaller cation .
- Larger anion and
- Large charge on either ion.

Dipole Moment:

- Dipole moment of any bond is the product of the net positive or negative charge and distance between the two charged ends, i.e., the bond length. i.e.

  Dipole moment (m) = electronic charge (e) × Distance (d) Dipole moment is measured in debye unit (D);
- Dipole moment of a molecule is vector addition of all the individual bond moments.

Percentage Ionic Character:

The percent ionic character =

$$\frac{Observed\ dipole\ moment}{Expected\ dipole\ moment} \times 100$$

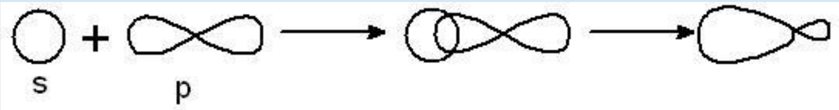
Hydrogen Bonding:

- Hydrogen bond is an electrostatic attractive force between covalently bonded hydrogen atom of one molecule or a part of a molecule and an electronegative atom (such as F,O, N) of another molecule (Inter-molecular hydrogen bonding) or another part of the same molecule (intramolecular hydrogen bonding).
- Intermolecular hydrogen bonding increases boiling point of the compound and also its water solubility
- Intramolecular hydrogen bonding decreases the boiling point of the compound and also its water solubility

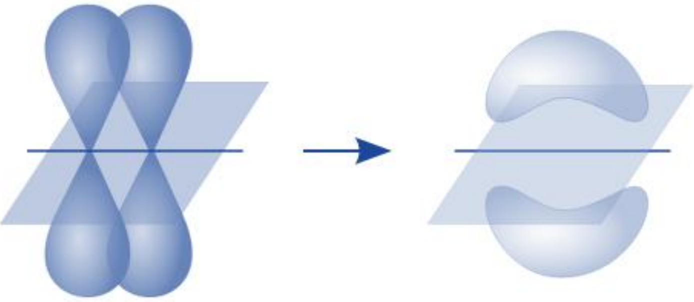
Valence bond theory (VBT):

- A covalent bond is formed by overlapping of valence shell atomic orbital of the two atoms having unpaired electron.
- There is maximum electron density between the bonding atoms.
- Greater the overlapping of atomic orbital higher is the strength of chemical bond.

- The bond formed by lateral overlap of two atomic orbitals having maximum overlapping on both sides of the line connecting the centres of the atoms is called a **π-bond**. A π-bond possess a plane of symmetry, often referred to as the nodal plane.
- **σ-Bond :** When covalent bond is formed by overlapping of atomic orbitals along the same axis it is called s - bond. Such type of bond is symmetrical about the line joining the two nuclei e.g.

(a) s-s overlapping	
(b) s-p overlapping	
(c) p-p overlapping	

- **π - Bond:** This type of bond is formed by the sidewise or lateral overlapping of two half filled atomic orbitals.



- |The strength of a bond depends upon the extent of overlapping of half-filled atomic orbitals. The extent of overlapping is between two atoms is always greater when there is end to end overlapping of orbitals than, when there is sidewise overlapping of orbitals. Hence s-bond is always stronger than p-bond.

- The average distance between the nuclei of the two bonded atoms in a molecule is called bond length and the energy required to break one mole of bonds of particular type in gaseous state is called Bond energy or Bond strength. The same amount of energy is released in formation of one mole of particular bond.

Hybridization:

- The mixing of dissimilar orbital of similar energies to form new set of hybrid orbital.
- Number of hybrid orbital formed is equal to the no. of orbital taking part in hybridization.
- Depending upon the different combination of s and p orbitals, these types of hybridization are known.

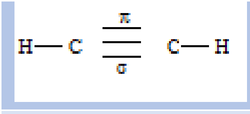
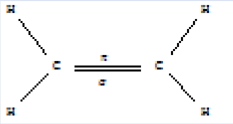
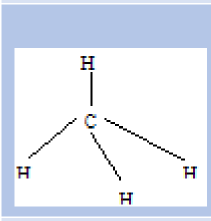
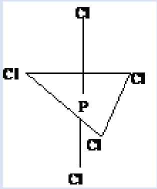
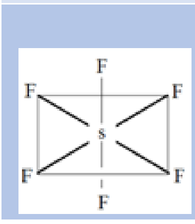
sp^3 hybridization: In this case, one s and three p orbitals hybridize to form four sp^3 hybrid orbitals. These four sp^3 hybrid orbitals are oriented in a tetrahedral arrangement.

sp^2 hybridization: In this case one s and two p orbitals mix together to form three sp^2 hybrid orbitals and are oriented in a trigonal planar geometry.

The remaining p orbital if required form side ways overlapping with the other unhybridized p orbital of other C atom and leads to formation of $p_2C = CH_2$ bond as in H

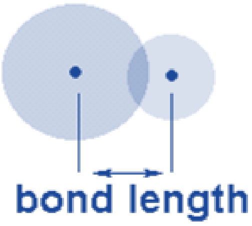
sp hybridization: In this case, one s and one p orbital mix together to form two sp hybrid orbitals and are oriented in a linear shape.

The remaining two unhybridised p orbitals overlap with another unhybridised p orbital leading to the formation of triple bond as in $HC\equiv CH$.

Hybridization	Total Number of orbitals taking part	Shape	Examples
sp	2 (one s and one p)	Linear	
sp^2	3 (one s and two p)	Trigonal planar	
sp^3	4 (one s and three p)	Tetrahedral	
sp^3d	5 (one s ,three p and one d)	Trigonal bipyramidal	
sp^3d^2	6 (one s ,three p and two d)	Octahedral	

Bond Characteristics:

Bond Length:



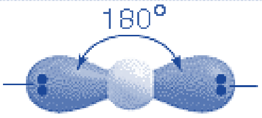
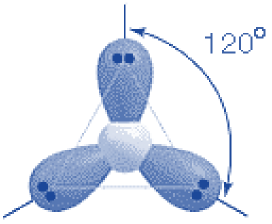
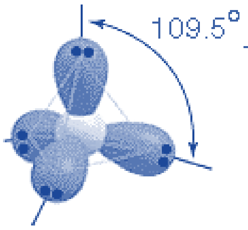
- The distance between the nuclei of two atoms bonded together is called bond length.
- It is expressed in angstrom (Å) units or picometer (pm).
- Bond length in ionic compound = $r_c^+ + r_a^-$
- Bond length in covalent compound (AB) = $r_A + r_B$

Important features of bond length

1. The bond length of the homonuclear diatomic molecules are twice the covalent radii.
2. The lengths of double bonds are less than the lengths of single bonds between the same two atoms, and triple bonds are even shorter than double bonds.Single bond > Double bond > Triple bond (decreasing bond length)
3. Bond length decreases with increase in s-character since s-orbital is smaller than a p – orbital.
   sp^3 C – H = 1.112Å: sp^2 C – H = 1.103Å; sp C – H = 1.08Å;
   (25% s-character as in alkanes) (33.3% s-character as in alkenes) (50% s-character as in alkynes)
4. Bond length of polar bond is smaller than the theoretical non-polar bond length.

Bond Angle:

Bond angel is the angle between two adjacent bonds at an atom in a molecule made up of three or more atoms.

Arrangement of Electron Pairs	Electron-Pair Geometry	Predicted Bond Angles
	Linear	180°
	Trigonal planar	120°
	Tetrahedral	109.5°

Bond angles mainly depend on the following three factors:

- **Hybridization:** Bond angle depends on the state of hybridization of the central atom

Hybridization	Bond angle	Example
sp^3	$109^\circ 28'$	CH_4
sp^2	120°	BCl_3
sp	180°	$BeCl_2$

Generally s- character increase in the hybrid bond, the bond angle increases.

- **Lone pair repulsion:** Bond angle is affected by the presence of lone pair of electrons at the central atom. A lone pair of electrons at the central atom always tries to repel the shared pair (bonded pair) of electrons. Due to this, the bonds are displaced slightly inside resulting in a decrease of bond angle.
- **Electronegativity:** If the electronegativity of the central atom decreases, bond angle decreases.

Bond Energy or Bond Strength:

- The amount of energy required to break a bond in molecule is called bond energy.
- Bond energy of sigma bond is more than that of a π-bond.
- Bond energy increases with decrease in bond length

  $C \equiv C > C = C > C - C$ (decreasing bond length)

  $s < p < sp < sp^2 < sp^3$
- The bond energy decreases with increase in number of lone pairs on the bonded atom.

Molecular Orbital Theory:

- Molecular orbital are formed by linear combination of atomic orbital (LCAO)
- Atomic orbital of all the atoms are assumed to interfere with each other in the form of waves.
- Bonding molecular orbital are formed by constructive interference of atomic orbital.
- Anti-bonding orbital are formed by destructive interference of atomic orbital.
- Anti-bonding MO is of higher energy than Bonding MO.
- In simple homonuclear diatomic molecules the order of MO's based on increasing energy is

$$\sigma 1s, \sigma^* 1s, \sigma 2s, \sigma^* 2s \left| \begin{matrix} \pi\, 2p_y \\ \pi\, 2p_z \end{matrix} \right|, \sigma 2p_x, \left| \begin{matrix} \pi^*\, 2p_y \\ \pi^*\, 2p_z \end{matrix} \right|, \sigma^* 2p_x, - - - - -$$

- For molecules including O_2 and above, the order is
-

$$\sigma 1s,\ \sigma^*1s,\ \sigma 2s, \sigma^*2s,\ \sigma 2p_x \left|\begin{matrix}\pi\ 2p_y \\ \pi\ 2p_z\end{matrix}\right| , \left|\begin{matrix}\pi^*\ 2p_y \\ \pi^*\ 2p_z\end{matrix}\right| ,\ \sigma^*2p_x, - - - - -$$

- **Bond Order:** Bond-order = 1/2 (no. of bonding electrons - No. of anti-bonding electrons).

Application of MOT to Homonuclear Diatomic Molecules

Species	Total number of electrons	Electronic configuration	Bond order	Magnetic Behaviour
H_2^+	1	$s\ 1s^1$	(1-0)/2 =1/2	Paramagnetic
H_2	2	$s\ 1s^2$	(2-0)/2 = 1	Diamagnetic
He_2^+	3	$s1s^2$, $s^*\ 1s^1$	(2-1)/2 = 1/2	Paramagnetic
He_2	4	$s1s^2$, $s^*\ 1s^2$	(2-2)/2 = 0	Molecule does not exist
O_2	16	$s1s^2$, $s^*\ 1s^2$, $s2s^2$, s^*2s^2, $s2p^2_x$, $p2p_y^2$, $p2p_z^2$, $p^*2p_y^1$, $p2p_z^1$	(10-6)/2 =2	Paramagnetic

Application of MOT to Heteronuclear Diatomic Molecules

Molecules/Ions	Total No. of electrons	Magnetic behaviour
CO	14	Diamagnetic
NO	15	Paramagnetic
NO^+	14	Diamagnetic
NO^-	16	Diamagnetic
CN	13	Paramagnetic
CN^-	14	Diamagnetic

Chemical Thermodynamics

Revision Notes on Chemical Thermodynamics:

Basic Terminology:

Terms	Explanation
System	Part of the universe under investigation.
Open System	A system which can exchange both energy and matter with its surroundings.
Closed System	A system which permits passage of energy but not mass, across its boundary.
Isolated system	A system which can neither exchange energy nor matter with its surrounding.
Surroundings	Part of the universe other than system, which can interact with it.
Boundary	Anything which separates system from surrounding.
State variables	The variables which are required to be defined in order to define state of any system *i.e.* pressure, volume, mass, temperature, surface area, etc.
State Functions	Property of system which depend only on the state of the system and not on the path. Example: Pressure, volume, temperature, internal energy, enthalpy, entropy etc.
Intensive properties	Properties of a system which do not depend on mass of the system *i.e.* temperature, pressure, density, concentration,
Extensive properties	Properties of a system which depend on mass of the system*i.e.* volume, energy, enthalpy, entropy etc.
Process	Path along which state of a system changes.
Isothermal process	Process which takes place at constant temperature
Isobaric process	Process which takes place at constant pressure
Isochoric process	Process which takes place at constant volume.
Adiabatic process	Process during which transfer of heat cannot take place between system and surrounding.
Cyclic process	Process in which system comes back to its initial state after undergoing series of changes.
Reversible process	Process during which the system always departs infinitesimally from the state of equilibrium *i.e.* its direction can be reversed at any moment.
Irriversible Process	This type of process is fast and gets completed in a single step. This process cannot be reversed. All the natural processes are of this type

Heat, energy and work:

Heat (Q):

- Energy is exchanged between system and surround in the form of heat when they are at different temperatures.
- Heat added to a system is given by a positive sign, whereas heat extracted from a system is given negative sign.
- It is an extensive property.
- It is not a state function.

Energy:

- It is the capacity for doing work.
- Energy is an extensive property.
- Unit : Joule.

Work (W):

- Work = Force × Displacement *i.e.* dW = Fdx
- Work done on the system is given by positive sigh while work done by the system is given negative sign.
- Mechanical Work or Pressure-Volume Work: work associated with change in volume of a system against an external pressure.
- Work done in reversible process: W=

$$\int_{V_1}^{V_2} PdV$$

W = – 2.303 nRT log v_2/v_1 = –2.303 nRT log p_1/p_2

- Wok done in isothermal reversible contraction of an ideal gas: ?W = – 2.303 nRT log v_2/v_1 = –2.303 nRT log p_1/p_2
- Unit : Joule.

Internal Energy (E or U):

- Sum of all the possible types of energy present in the system.
- ΔE = heat change for a reaction taking place at constant temperature and volume.
- ΔE is a state function.
- It is an extensive property.
- Value of ΔE is -ve for exothermic reactions while it is +ve for endothermic reactions.

First Law of Thermodynamics:

Energy can neither be created nor destroyed although it can be converted from one form to another.

or

Energy of an isolated system is constant**.**

Mathematical Expression

Heat observed by the system = its internal energy + work done by the system. *i.e.* $q = dE + w$

For an infinitesimal process

$dq = dE + dw$

Where, q is the heat supplied to the system and w is the work done on the system.

For an ideal gas undergoing isothermal change $\Delta E = 0$.

so $q = -w$.

- **For an isolated system,** $dq=0$

so, $dE = - dw$

- **For system involving mechanical work only**

$\Delta E = q - pdV$

- **At constant volume i.e. isochoric process**

$\Delta E = q_v$

- **For Isothermal Process**

$\Delta E = 0$
or
$q = - pdV = -W$

- **For adiabatic process**

?q = 0

or

$\Delta E = W$

Enthalpy (H):

$H = E+PV$

At constant pressure:

$dH = dE + pdV$

For system involving mechanical work only

$dH = Q_P$ (At constant pressure)

For exothermic reactions:

$dH = -ve$

For endothermic reactions:

$dH = +ve$

Relation between dH and dE:

$dH = dE + dn_g RT$

Where,

dn_g = (Number of moles of gaseous products - Number of moles of gaseous reactants)

Heat capacity:

- Amount of heat required to rise temperature of the system by one degree.

$C = q / dT$

- **Specific heat capacity:** Heat required to raise the temperature of 1 g of a substance by one dgree.

C_s = Heat capacity / Mass in grams

- **Molar heat capacity**: Heat required to raise the temperature of 1 g of a substance by one dgree.

C_m = Heat capacity / Molar mass.

- **Heat capacity of system at constant volume:**

$C_v = (dE/dT)_v$

- **Heat capacity of system at constant pressure:**

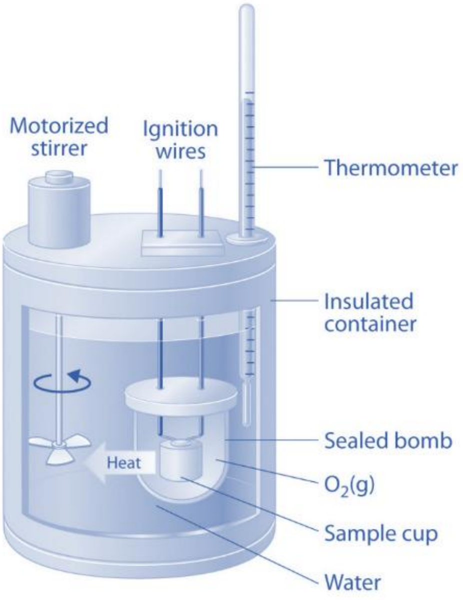
$C_p = (dE/dT)_p$

$C_p – C_v = R$

- **Variation Of Heat Of Reaction With Temperature:**

$dC_P = (dH_2 - dH_1)/(T_2-T_1)$ & $dC_V = (dE_2 - dE_1)/(T_2-T_1$

- **Bomb Calorimeter:**



?

Heat exchange = Z × ΔT

Z–Heat capacity of calorimeter system

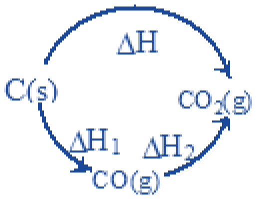
ΔT– Rise in temp.

Heat changes at constant volumes are expressed in ΔE and Heat changes at constant

pressure are expressed in dH.

Enthalpies of Reactions:

Hess's Law of constant heat summation:



?The total enthalpy change of a reaction is the same, regardless of whether the reaction is completed in one step or in several steps.

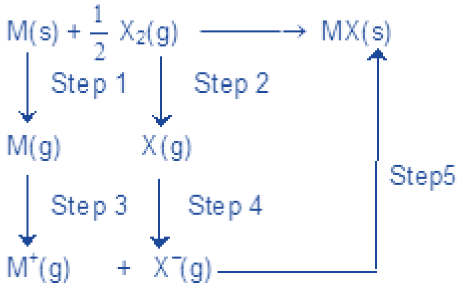
According to Hess's law: $ΔH = ΔH_1 + ΔH_2$

Born–Haber Cycle:

Applying Hess’s law we get

$\Delta H_1 + 1/2\ \Delta H_2 + \Delta H_3 + \Delta H_4 + \Delta H_5 = \Delta H_f$ (MX) (Lattice energy)

Lattice energy: The change in enthalpy that occurs when 1 mole of a solid crystalline substance is formed from its gaseous ions.



Born – Haber cycle

Second law of thermodynamics

Statement:

It is impossible to take heat from a hot reservoir and convert it completely into work by a cyclic process without transferring a part of it to a cold reservoirs.

Mathematically:

- $\Delta S = q_{rev}/T$

Where,

ΔS is entropy change.

- Entropy is the degree of randomness thus it increases with increase in randomness of particles of the system*i.e.* ΔS is positive for melting of ice.
- At equilibrium, $\Delta S = 0$
- For a spontaneous process, $\Delta S > 0$
- Entropy change in an isothermal reversible expansion of a gas $\Delta S = 2.303\ nR\ log\frac{V_2}{V_1} = 2.303\ nR\ log\frac{P_1}{P_2}$
- **Spontaneous Processes:** These type of physical and chemical changes occur of its own under specific circumstances or on proper initiations. For example: Flow of liquids from higher to lower level.
- $\Delta S_{total} = \Delta S_{system} + \Delta S_{surrounding} gt; 0 = \Delta S_{universe} gt; 0$

Gibbs free energy(ΔG):

- $\Delta G = \Delta H - T\Delta S$
- $\Delta G = nRT \ln K_{eq}$
- $\Delta G = nFE_{cell}$
- At equilibrium, $\Delta G = 0$
- For spontaneous process, $\Delta G < 0$

Bond Energies:

Average amount of energy required to break one mole bonds of that type in gaseous molecules.

$H–OH(g) \rightarrow 2H(g) + ½O(g)$ $\Delta H = 498$ kJ

$O–H(g) \rightarrow H_2(g) + ½O_2 (g)$ $\Delta H = 430$ Kj

$\Delta H_{O–H} = (498 + 430)/2 = 464$ kJ mol$^{–1}$

- **Efficiency of a heat engine (carnot cycle):**

$W = R (T_2 – T_1) \ln v_2/v_1$

$q_2 = RT_2 \ln v_2/v_1$

$W = q_2$

$$\frac{T_2 - T_1}{T_2}$$

Efficiency (h). h =

$$\frac{W}{q_2} = \frac{T_2 - T_1}{T_2}$$

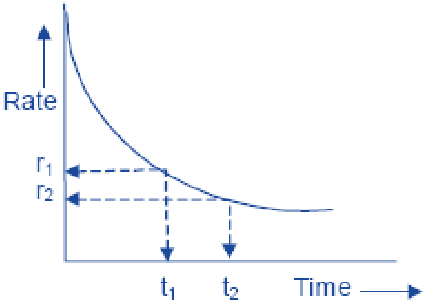
Chemical Kinetics

Revision Notes on Chemical Kinetics:

Rate of Reaction:

- Rate of change of extent of reaction is the rate of reaction.
- Rate of reaction is positive for product and negative for reactant.
- For reaction aA →bB

  Rate =1/b(Δ[B]/ Δ t) = -1/a (Δ [A]/ Δt)
- It goes on decreasing as the reaction progress due to decrease in the concentration(s) of the reactant(s).



- Unit of rate of reaction : mol L^{-1} s^{-1}
- The rate measured over a long time interval is called average rate and the rate measured for an infinitesimally small time interval is called instantaneous rate.
- In a chemical change, reactants and products are involved. As the chemical reaction proceeds, the concentration of the reactants decreases, i.e., products are produced.
- The rate of reaction (average rate) is defined as the change of concentration of any one of its reactants (or products) per unit time.

Order of Reaction

<u>For reaction</u> aA + bB + ….. → cC+ ….

R $\propto [A]^m[B]^n$ or R = $k[A]^m[B]^n$….

Where m and n may or may not be equal to a & b.

m is order of reaction with respect to A and n is the order of reaction with respect to B.

m + n +… is the overall order of the reaction.

Elementary Reaction:

- It is the reaction which completes in a single step.
- A reaction may involve more than one elementary reactions or steps also.
- Overall rate of reaction depends on the slowest elementary step and thus it is known as rate determining step.

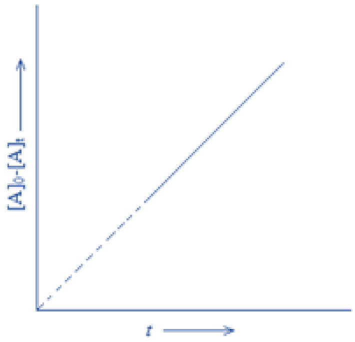
Molecularity of Reaction:

- Number of molecules taking part in an elementary step is known as its molecularity.
- Order of an elementary reaction is always equal to its molecularity.
- Elementary reactions with molecularity greater than three are not known because collisions in which more than three particles come together simultaneously are rare.

Differential and Integrated Rate Laws:

Zero Order Reactions:

For Reaction: A → Product



$[A]_0-[A]_t = k_0t$

Where,

$[A]_0$ = Initial concentration of A

$[A]_t$ = Concentration of A at time t.

k_0 = Rate constant for zero order reaction.

Half Life:

$t_{1/2} = [A]_0/2k$

Unit of rate constant = mol $dm^{-3}s^{-1}$

Examples:

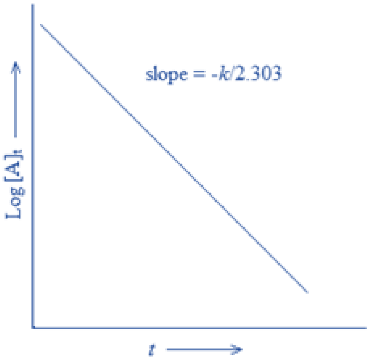
- Enzyme catalyzed reactions are zero order with respect to substrate concentration.
- Decomposition of gases on the surface of metallic catalysts like decomposition of HI on gold surface.

First Order Reactions:

A → Product

$(\Delta [A] /A) = -k_1\Delta t$

or $k_1=(2.303/ t)\log ([A]_0 / [A]_t)$



Half Life:

$t_{1/2} = 0.693/k_1$

Half life is independent of the initial concentration of the reactant for a first order reaction.

Units of k_1 = s^{-1}

Examples:

$N_2O_5 \rightarrow 2NO_2 + 1/2O_2$

$Br_2 \rightarrow 2Br$

$2HNO_3 \rightarrow 2NO + H_2O$

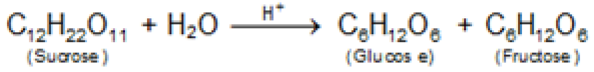
$H_2O_2 \rightarrow H_2O + 1/2O_2$

Pseudo First Order Reactions:

These are the reactions in which more than one species is involved in the rate determining step but still the order of reaction is one.

Examples:

- **Acid hydrolysis of ester:** $CH_3COOEt + H_3O^+ \rightarrow CH_3COOH + EtOH$
- **Inversion of cane sugar:**



$$\underset{\text{(Sucrose)}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{H^+} \underset{\text{(Glucos e)}}{C_6H_{12}O_6} + \underset{\text{(Fructose)}}{C_6H_{12}O_6}$$

- Decomposition of benzenediazonium halides $C_6H_5N{=}NCl + H_2O \rightarrow C_6H_5OH + N_2 + HCl$

Half – Life of a nth Order Reaction:

$kt_{1/2} = (2^{n-1}-1)/(n-1)[A_0]^{n-1}$

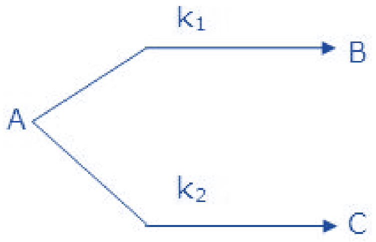
Where, n = order of reaction ≠1

Parallel Reactions:

The reactions in which a substance reacts or decomposes in more than one way are called parallel or side reactions.

If we assume that both of them are first order, we get.

$$-\frac{d[A]}{dt} = (k_1 + k_2)[A] = k_{av}[A]$$



k_1 = fractional yield of B × k_{av}

k_2 = fractional yield of C × k_{av}

If $k_1 > k_2$ then

A → B main and

A → C is side reaction

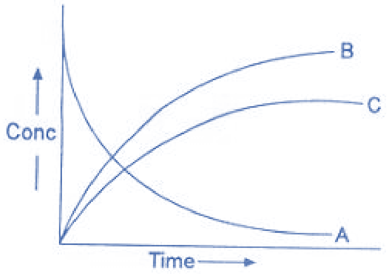
Let after a definite interval x mol/litre of B and y mol/litre of C are formed.

$$\frac{x}{y} = \frac{k_1}{k_2}$$

i.e

$$\frac{\frac{d[B]}{dt}}{\frac{d[C]}{dt}} = \frac{k_1}{k_2}$$

This means that irrespective of how much time is elapsed, the ratio of concentration of B to that of C from the start (assuming no B and C in the beginning) is a constant equal to k_1/k_2.



Sequential Reactions:

This reaction is defined as that reaction which proceeds from reactants to final products through one or more intermediate stages. The overall reaction is a result of several successive or consecutive steps.

A → B → C and so on

$$A \xrightarrow{k_1} B \xrightarrow{K_2} C$$

$$-\frac{d[A]}{dt} = k_1[A] \text{.......(i)}$$

$$\frac{d[B]}{dt} = k_1[A] - K_2[B] \text{.........(ii)}$$

$$\frac{d[C]}{dt} = k_2[B] \text{..........(iii)}$$

Integrating equation (i), we get

$$[A] - [A]_o e^{-k_1 t}$$

$$[B] = \frac{k_1[A]_0}{k_2 - k_1}\left[e^{-k_1 t} - e^{-k_2 t}\right]$$

$$[C] = \frac{[A]_0}{k_2 - k_1}\left[k_2\left(1 - e^{-k_1 t}\right) - k_1\left(1 - e^{-k_2 t}\right)\right]$$

$$t_{max} = \frac{1}{k_1 - k_2} \ln\frac{k_1}{k_2}$$

$$B_{max} = [A]_o\left[\frac{k_2}{k_1}\right]^{k_2/k_1 - k_2}$$

Arrhenius Equation:

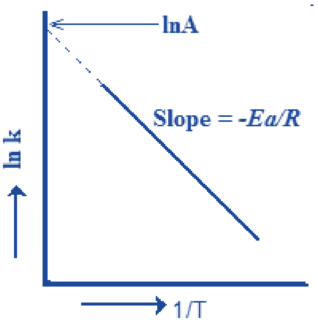
$k = A\ \exp(-E_a/RT)$

Where, k = Rate constant

A = pre-exponential factor

E_a = Activation energy

Temperature Coefficient:



The temperature coefficient of a chemical reaction is defined as the ratio of the specific reaction rates of a reaction at two temperature differing by 10°C.

μ = Temperature coefficient= $k_{(r+10)}/k_t$

Let temperature coefficient of a reaction be ' μ ' when temperature is raised from $T_1$to T_2; then the ratio of rate constants or rate may be calculated as

$$\frac{k_{T2}}{k_{T1}} = \mu^{\frac{T_2 - T_1}{10}} = \mu^{\frac{\Delta T}{10}}$$

$$log\frac{k_{T2}}{k_{T1}} = \mu^{\frac{T_2 - T_1}{10}} = \Delta T log\mu$$

$$\frac{k_{T2}}{k_{T1}} = antilog[\frac{\Delta T}{10}]log\mu$$

Its value lies generally between 2 and 3.

Collision Theory of Reaction Rate

- A chemical reaction takes place due to collision among reactant molecules.
- The number of collisions taking place per second per unit volume of the reaction mixture is known as collision frequency (Z).
- The value of collision frequency is very high, of the order of 10^{25} to 10^{28} in case of binary collisions.
- Every collision does not bring a chemical change.
- The collisions that actually produce the products are effective collisions.
- The effective collisions which bring chemical change are few in comparison to the form a product are ineffective elastic collisions, i.e., molecules just collide and
- disperse in different directions with different velocities.
- For a collision to be effective, the following two barriers are to be cleared.

1. Energy Barrier
2. Orientation Barrier

Radioactivity:

All radioactive decay follow 1st order kinetics

For radioactive decay A ->B

$-(dN_A/dt) = l\ N_A$

Where, l = decay constant of reaction

N_A = number of nuclei of the radioactive substance at the time when rate is calculated.

Arrhenius equation is not valid for radioactive decay.

Integrated Rate Law: $N_t = N_o e^{-lt}$

Half Life: $t_{1/2} = 0.693/\lambda$

Average life time: Life time of a single isolated nucleus, $t_{av} = 1/\lambda$

Activity: Rate of decay

A = dN_A/dt, Also, $A_t = A_o e^{-lt}$

Specific Activity**:** activity per unit mass of the sample.

$$\text{Specific activity} = \frac{\left(\lambda \times \frac{\text{w}}{\text{M}} \times \text{Av}\right)}{\text{w}} = \frac{\lambda \times \text{Av}}{\text{M}}$$

Units: dps or Becquerrel

Chemical Equilibrium

Revision Notes on Chemical and Ionic Equilibrium

Equilibrium

- Equilibrium is the state of a process in which the properties like temperature, pressure, and concentration etc of the system do not show any change with passage of time.
- In all processes which attain equilibrium, two opposing processes are involved.
- Equilibrium is attained when the rates of the two opposing processes become equal.
- If the opposing processes involve only physical changes, the equilibrium is called **Physical Equilibrium.**
- If the opposing processes are chemical reactions, the equilibrium is called **Chemical Equilibrium**.

Physical Equilibrium

- **Solid – liquid Equilibrium:** $H_2O(s) \rightleftharpoons H_2O(l)$
- **Liquid – Gas Equilibrium:** $H_2O(l) \rightleftharpoons H_2O(g)$
- **Solid – Solution Equilibrium:** Salt(Solid) $\rightleftharpoons$ Salt(in solution)
- **Gas –Solution equilibrium:** $CO_2(g) \rightleftharpoons CO_2$(in solution)

Equilibrium in Chemical Process

- **Reversible reaction:** A reaction in which not only the reactants react to form the products under certain conditions but also the products react to form reactants under the same conditions Examples: $3Fe(s) + 4H_2O(g) \rightleftharpoons Fe_3O_4(s) + 4H_2(g)$
- **Irreversible reaction:** A reaction cannot take place in the reverse direction, i.e. the products formed do not react to give back the reactants under the same condition. Example: $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(g)$
- Generally, a chemical equilibrium is represented as $a\,A + b\,B \rightleftharpoons c\,C + b\,D$

  Where A, B are reactants and C, D are products.

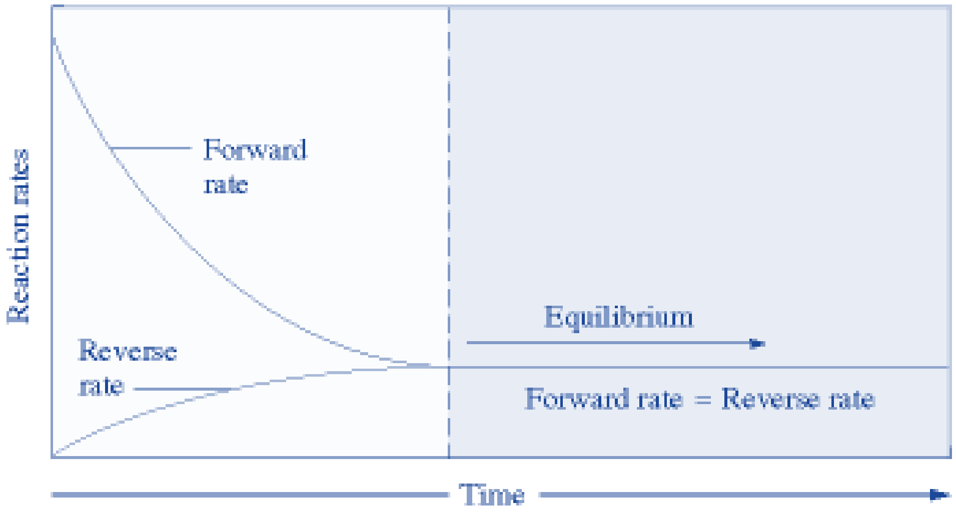
Note:

The double arrow between the left hand part and right hand part shows that changes are taking place in both the directions.

On the basis of extent of reaction, before equilibrium is attained chemical reactions may be classified into three categories.

- **Those reactions which proceed to almost completion.**
- **Those reactions which proceed to almost only upto little extent.**
- **Those reactions which proceed to such an extent, that the concentrations of reactants and products at equilibrium are comparable.**

- The equilibrium state is dynamic and not static in nature. A reaction is said to have attained equilibrium when the rate of forward reaction equals that of backward reaction



?

- **Homogeneous Equilibrium: A**ll the reactants and products of any reaction under equilibrium are in same physical state. Example: $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$
- **Heterogeneous Equilibrium** :Physical state of one or more of the reacting species may differ i.e. all the reactants and products are not in same physical state.
  Example
  $2NaHCO_3(s) \rightleftharpoons Na_2CO_3(s) + CO_2(g) + H_2O(l)$?

Characteristics of Equilibrium State

- It can be attained only if the reversible reaction is carried out in closed vessel.
- It can be attained from either side of the reaction.
- A catalyst can hasten the approach of equilibrium but does not alter the state of equilibrium.
- It is dynamic in nature i.e. reaction does not stop but both forward and backward reactions take place at equal rate.
- Change of pressure, concentration or temperature favours one of the reactions (forward or backward) resulting in shift of equilibrium point in one direction.

Law of Mass Action & Equilibrium Constant

"The rate at which a substance reacts is directly proportional to its active mass and rate of a chemical reaction is directly proportional to product of active masses of reactants each raised to a power equal to corresponding stoichiometric coefficient appearing in the balanced chemical equation".

Fore reaction $aA + bB \rightleftharpoons cC + dD$

Rate of reaction $\propto [A]^a.[B]^b$

or rate of reaction $= K[A]^a[B]^b$

where K is rate constant or velocity constant of the reaction at that temperature.

Unit of rate constant (K)

$$K = \frac{Rate\ of\ reaction}{[A]^a[B]^b} = \frac{molL^{-1}s^{-1}}{(molL^{1)a+b}} = (molL^{-1})^{1\ to\ n}\ s^{-1}$$

(where n is order of reaction.)

For unit concentration of reactants rate of the reaction is equal to rate constant or specific reaction rate.

Applying Law of mass action for general reversible reaction

aA + bB $\rightleftharpoons$ cC + dD

Rate of forward reaction α $[A]^a[B]^b$

or $R_f = K_f\ [A]^b\ [B]^b$

Similarly for backward reaction

$R_b = K_b[C]^c\ [D]^d$

At equilibrium $K_f[A]^a[B]^b = K_b[C]^c[D]^d$

$$\Rightarrow \frac{K_f}{K_b} = \frac{[C]^c[D]^d}{[A]^a[B]^b} = K_c$$

The above equation is known as equilibrium equation and Kc is known as equilibrium constant.

Equilibrium constant for the reverse reaction is the inverse of the equilibrium constant for the reaction in the forward direction.

$$\Rightarrow K_f = \frac{1}{K_b}$$

Expression of K_C

Let"a" moles of PCl_5 be taken in a closed vessel of volume 'V' litre. Suppose "*x*" mole is dissociated at equilibrium.

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

Initial Conc:	**a**	**0**	**0**
At. eqbm	***a-x***	**x**	**x**
Active mass	**(a-x)/V**	**x/V**	**x/V**

According to law of mass action

$$K_c = \frac{[Product]}{[Reactant]} = \frac{[PCl_3][Cl_2]}{[PCl_5]}$$

$$K_c = \frac{\frac{x}{v} \times \frac{x}{v}}{\frac{a-x}{v}} = \frac{x^2}{(a-x)V}$$

Equilibrium Quotient or Mass Action Ratio:

Consider the equilibrium

aA +bB $\rightleftharpoons$ cC +dD

At equilibrium

$$K_c = \frac{[D]^d[C]^c}{[A]^a[B]^b}$$

When the reaction is not at equilibrium this ratio is called 'Q_C' i.e., Q_C is the general term used for the above given ratio at any instant of time. And at equilibrium Q_C becomes K_C.

- If the reaction is at equilibrium, $Q = K_c$
- A net reaction proceeds from left to right (forward direction) if $Q < K_C$.
- A net reaction proceeds from right to left (the reverse direction) if $Q > K_c$

The Le–Chatelier's Principle:
Statement:

"When a chemical reaction at equilibrium is subjected to any stress, then the equilibrium shifts in that direction in which the effect of the stress is reduced."

Effect of Addition of Inert Gases:

- Addition of inert gas at constant volume: No effect on equilibrium.
- Addition of inert gas at constant pressure: Equilibrium shifts in a direction where there is increase in number of moles of gases.

Effect of Change in Temperature:

- In a system at equilibrium, both exothermic and endothermic reactions take place simultaneously.
- Increase in temperature would shift the equilibrium in the direction of endothermic reaction.
- Decrease in temperature would shift the equilibrium in the direction of exothermic reaction.

Effect of Change in Concentration:

- When the concentration of reactants increased, equilibrium shifts in forward direction.
- When the concentration of the products is increases, equilibrium shifts in backward direction.\

Effect of Change in Pressure:

- Increase in pressure shifts the equilibrium in the direction of lesser number of gaseous molecules.
- Decrease in pressure shifts the equilibrium in the direction of larger number of gaseous molecules.

Effect of Catalyst:

Catalyst does not change the equilibrium.

Thermodynamics of chemical equilibrium:

$\Delta G = \Delta G^0 + 2.303\ RT \log Q$

At equilibrium:

$\Delta G = \Delta G^0 + 2.303\ RT \log K = 0$

or

$\Delta G^0 = - 2.303\ RT \log K$

Also

$$\log K = \frac{-\Delta H^0}{2.303RT} + \frac{\Delta S^0}{2.303RT}$$

Assuming ΔH^0 to be constant in temperature range T_1 and T_2

$$\frac{d \log K}{dT} = \frac{\Delta H^0}{2.303RT^2}$$

Acids and Bases:

1. Arrhenius Definition:

a. Acids give H^+ ions aqueous solutions.

b. Bases give OH^- ions in aqueous solution.

2. Bronsted – Lowry Definition:

a. Acid is a proton donor .

b. Base is a proton acceptor.

3. Strong and Weak Acids:

a. Strong acid dissociate completely in aqueous solution.

Example: HCl

b. Weak acid dissociates partially in aqueous solution.

Examples: CH_3COOH

Degree of dissociation (a) =$(Ka/C)^{1/2}$

Where,

$K_a = [CH_3COO^-][H^+]/[CH_3COOH]$

And

C = Initial concentration of acid.

Also

$[H^+] = Ca = (Ka \times C)^{1/2}$

c. Ionic Product of Water:

H_2O $H^+ + OH^-$

$K[H_2O] = [H^+]\ [OH^-] = 10^{-14}$

Common Ion effect:

The addition of an ion to equilibrium, having the same ion makes the equilibrium `reaction move in a direction to consume that ion.

$$HCl \rightleftharpoons H+ + Cl^-$$

$$H_2O \rightleftharpoons H^+ + OH^-$$

This implies that water would dissociate less in the presence of HCl.

Hydrolysis of salts:

1. Salt of a Weak Acid and Strong Base:

   $[H^+] = (K_w K_a / C)^{1/2}$

2. Salt of a Weak Base and Strong Acid

   $[H^+] = (K_w / K_b C)^{1/2}$

3. Salt of a Weak Acid and Weak Base

   $[H^+] = (K_w K_a / K_b)^{1/2}$

- **Buffer Solutions:** Resists change in its pH when such a change is caused by the addition of a small amount of acid or base.

1. **Weak acid–Salt buffer:**

   Formed by combination of a weak acid and a salt of the acid with a strong base. Example, CH_3COOH & CH_3COONa

   pH = pK_a + log [Conjugated base]/ [Acid]

   For weak dibasic acid

   pH = $(pK_{a1} + pK_{a2})/2$

   Where pK_{a1} and pK_{a2} are 1st and 2nd dissociation constant of the acid.

2. **Weak base–salt buffer:** Formed by combination of a weak base and a salt of the base with a strong acid. Example, NH_4OH and NH_4Cl

   pH = pK_b + log [Conjugated acid]/ [Base]

Solubility and Solubility Product :

1. Amount (moles) of the salt that has made the solution saturated per liter of solution is called the solubility of the salt.
2. For salt AB.

   AB ↔ $A^+ + B^-$

   $K_{sp} = [A^+][B^-]$
3. Solution cannot have the product of the concentration of the ions more than K_{SP} of the salt in solution.

Ionic Product:

a) Product of ionic concentration due to ions already present in water or from a salt.

b) I.P. may be and may not be equal to K_{sp}.

c) If ionic Product (IP) > K_{sp} ; precipitation takes place till I.P. equals K_{sp}

d) If Ionic Product < K_{sp} ; a precipitate will not be formed and the solution will be unsaturated.

e) If Ionic Product = K_{sp} ; a precipitate will not form an the solution is saturated in that salt.

Solution & Colligative Properties

Type of Solutions

Vapour Pressure:

S.No.	Solute	Solvent	Example
1	Gas	Gas	Air
2	Gas	Liquid	Aerated water ($CO_2 + H_2O$)
3	Gas	Solid	Hydrogen in palladium
4	Liquid	Liquid	Alcohol in water, benzene in toluene
5	Liquid	Solid	Mercury in zinc amalgam
6	Liquid	Gas	CO_2 dissolved in water
7	Solid	Liquid	Sugar in water, common salt in water
8	Solid	Gas	Smoke
9	Solid	Solid	Various alloys

Raoult's Law:

***"The partial vapour pressure of any component in the solution is directly proportional to its mole fraction"*.**

For a binary solution of two components A and B,

$P_A = X_A$

$P_B = X_B$

Where

P^0_A = vapour pressure of component A in pure state.

P_A = vapour pressure of component A in the solution.

P^0_B = vapour pressure of component B in pure state.

P_B = vapour pressure of component B in the solution

Limitations of Raoult's Law

- Raoult's law is applicable only to very dilute solutions.
- It is applicable to solutions containing non-volatile solute only.
- It is not applicable to solutes which dissociate or associate in a particular solution

Raoult's Law in Combination with Dalton's Law of Partial Pressure:

$P_T = X_A P^0_A + X_B P^0_B = P^0_B + (P^0_A - P^0_B) X_A$

Where

P_T = Total Vapour Pressure of the Solution.

Ideal and Non-Ideal Solutions:

- **Ideal Solution:**

  For Ideal Solution:

  1. $dH_{mixing} = 0$, i.e. no heat should be absorbed or evolved during mixing
  2. $dV_{mixing} = 0$, i.e. no expansion or contraction on mixing

Examples , Ethyl chloride and ethyl bromide, n–hexane and n–heptane , CCl_4 and $SiCl_4$

- **Non-Ideal Solution:**

  ?These solutions deviate from ideal behaviour and do not obey Raoult's law over entire range of composition.

  For non ideal solutions,

  1. $dH_{mixing} \neq 0$
  2. $dH_{mixing} \neq 0$

  Here we may have two cases

  A) Positive Deviation*:*

  1. $P_A > X_A$ **&** $P_B > X_B$
  2. $dH_{mix} > 0$
  3. $dV_{mix} > 0$

  Example: Cyclohexane and Ethanol

  B) Negative Deviation:

  1. $P_A > X_A$ **&** $P_B > X_B$
  2. $dH_{mix} < 0$
  3. $dV_{mix} < 0$

Colligative Properties

Lowering of Vapour Pressure by a Non-Volatile Solute

Elevation of Boiling Point by a Non-Volatile Solute :

Depression of Freezing Point by a Non-Volatile Solute:

Osmosis and Osmotic Pressure:

- **Osmosis:** The phenomenon of the passage of pure solvent from a region of lower concentration (of the solution) to a region of its higher concentration through a semi-permeable membrane.
- **Osmotic Pressure:** Excess pressure which must be applied to a solution in order to prevent flow of solvent into the solution through the semi-permeable membrane.

$$V = nRT$$

where

= Osmotic pressure

V = volume of solution

n = no. of moles of solute that is dissolved

R = Gas constant

T = Absolute temperature

Isotonic Solutions: A pair of solutions having same osomotic pressure is called isotonic solutions.

Abnormal Molecular Weight and Van't Hoff Factor:

Van't Hoff Factor:

Van't Hoff, in order to account for all abnormal cases introduced a factor **i** known as the Van't Hoff factor, such that

Degree of Association:

Let a be the degree of association, then,

The number of unassociated moles = $1-\alpha$

The number of associated moles = α/n

Total number of effective moles = $1-\alpha+\alpha/n$

Obviously, $i < 1$

Degree of Dissociation

The fraction of the total number of molecules which dissociates in the solution, that is, breaks into simpler molecules or ions.

$KCl \leftrightarrow K^+ + Cl^-$

$1-\alpha \quad \alpha \quad \alpha$

Thus, the total number of moles after dissociation $= 1-\alpha+\alpha+\alpha = 1+\alpha$

Hence, $i = (1+\alpha)/1$

$i = 1+ \alpha = 1+ (2–1)\alpha$

In general, **$i = 1+ (n–1) \alpha$,**

Where, n = number of particles (ions) formed after dissociation

From the above formula, it is clear that **$i > 1$**

Redox Reactions and Electrochemistry

Conductors and Non Conductors

- **Non-Conductors:** Those substances which do not allow electric current to pass through them are called non-conductors or insulators. Example: - wood, plastic glass, rubber etc.
- **Conductors:** Those substances which allow electric current to flow through tem are called conductors. Examples: Copper, Iron, Gold, Silver, Graphite, salt solution etc.

  Conductors can further be divided into two groups

- **Metallic Conductors:** These conductors conduct electricity or electric current by movement of electrons without undergoing any chemical change during the process. These conduct electricity in both solid as well as molten state. Example: All the metals and Graphite
- **Electrolytes:** Those substances which conduct electricity only when they are present in aqueous solution and not in solid form are called electrolytes. These conduct electricity by movement of ions in solutions.

S.No	Metallic Conduction	Electrolytic Conduction
1	Electric current flows by movement of electrons.	Electric current flows by movement of ions.
2	No chemical change occurs.	Ions are oxidized or reduced at the electrodes.
3	It does not involve the transfer of any matter.	It involves transfer of matter in the form of ions.
4	Ohm's law is followed.	Ohm's low is followed.
5	Resistance increases with increase of temperature.	Resistance decreases with increase of temperature.
6	Faraday law is not followed.	6Faraday law is followed.

Comparison of Electrolytic and Metallic Conduction

Electrolytic Conductance:

Specific Resistance or resistivity (ρ):

$R = \rho \times l / A$

Where,

R = Resistance

A=Area of cross sections of electrodes

l = Distance between the electrodes.

Specific Conductance or Conductivity (κ):

$\kappa = 1/\rho$

Units: W^{-1} cm^{-1} or Sm^{-1}

Equivalent Conductance (Λ):

Conducting power of all the ions produced by one g-equivalent i.e. one equivalent of an electrolyte in a given solution

$\Lambda = 1000\,\kappa / C$

Where, C be the normality of solution i.e. concentration of electrolytic solution in equivalent/L.

Units: $W^{-1}cm^{2}$

Molar Conductance (Λ_m):

Conductance of solution due to all the ions produced by one mole of the dissolved electrolyte in a given solution.

$\Lambda_m = \kappa/c$

Where, c = concentration of solution in mol m^{-3}.

$\Lambda_m = \kappa \times 1000/M$

Where, M is molarity of solution.

Units: S cm^2 mol^{-1}

Relation between Λ and Λ_m

$\Lambda_m = n\,\Lambda$

Where n = n-factor of the electrolyte = total charge carried by either ion = M/E

Variation of Conductance with Dilution:

Specific conductance: Decrease with dilution due to decrease in number of ions per c.c. of the solution.

Molar and Equivalent Conductance: Increases with increase in dilution.

- Weak electrolyte: Increase is due to increase in extent of ionization.
- Strong electrolyte: Increase is due to increase in mobility of ions because of decreased inter-ionic attraction.

Debye-Hückel-Onsager Equation

$\Lambda_m = \Lambda^0_m - (A + B\,\Lambda^0_m)\sqrt{C}$

Where,

A & B = Debye-Hückel constants.

C = Molar concentration

Λ^0_m = Limiting molar conductivity i.e. molar conductivity at infinite dilution.

At 298 K,

$\Lambda_m = \Lambda^0_m - (60.2 - 0.299\ \Lambda^0_m)\sqrt{C}$

Kohlransch's Law of Independent Migration of Ions:

"At infinite dilution, when dissociation is complete, each ion makes a definite contribution towards equivalent conductance of the electrolyte irrespective of the nature of the ion with which it Is associated and the value of equivalent conductance at infinite dilution for any electrolyte is the sum of contribution of its constituent ions", i.e., anions and cations. Thus,

$$\lambda^{\infty}_{eq} = \lambda^{\infty}_{c} + \lambda^{\infty}_{a}$$

where,

$\lambda^{\infty}_{eq} = Equivalence\ Conductivity\ at\ Infinite\ Dilution$

$\lambda^{\infty}_{c} = Conductivity\ of\ Cation$

$\lambda^{\infty}_{a} = Equivalence\ Conductivity\ of Anion$

According to Kohlrausch'slaw. "conductivity of ions is constant at infinite dilution and it does not depend on nature of co-ions."

For A_xB_y type electrolyte,

$$A_xB_y \overset{H_2O}{\rightarrow} xA^{+y} + YB^{-x}$$

$$\lambda^{\infty}_{eq} = \frac{1}{z}\lambda^{\infty}_{B} + \frac{1}{z^-}\lambda^{\infty}_{A}$$

Here $Z^+$and Z^- are the charges present on cation and anion.

$$\lambda^{\infty}_{m} = m\lambda^{\infty}_{c} + n\lambda^{\infty}_{a}$$

Here m and n are the number of moles of cations and anions.

$$\lambda^{\infty}_{BaCl_2} = \frac{1}{2}\lambda^{\infty}_{Ba^{2+}} + \frac{1}{1}\lambda^{\infty}_{Cl^-}$$

$$\lambda^{\infty}_{AlCl_3} = \frac{1}{3}\lambda^{\infty}_{Al^{3+}} + \frac{1}{1}\lambda^{\infty}_{Cl^-}$$

$$\lambda^{\infty}_{Al_2(SO_4)_3} = \frac{1}{3}\lambda^{\infty}_{Al^{3+}} + \frac{1}{2}\lambda^{\infty}_{SO_4^{2-}}$$

Faraday's Laws of Electrolysis:

First Law: "The mass of a substance deposited or liberated at any electrode is directly proportional to the amount of charge passed."

w = zQ

Where z = electrochemical equivalent i.e. the mass of the substance in grams deposited or liberated by passing one coulomb of charge,

Second Law: "Mass of a substance deposited or liberated at any electrode on passing a certain amount of charge is directly proportional to its chemical equivalent weight".

Charge on one mole electrons = 1 F = 96487 C

That is w a E where w is the mass of the substance in grams while E is its chemical equivalent weight in gms per equivalent=

$$\frac{W_1}{W_2} = \frac{E_1}{E_2}.$$

The charge possessed by 1 mole of electrons = $1.6 \times 10^{-19} \times 6.023 \times 10^{23} \approx 96500$ C

This charge is called as **1 Faraday.**

If we pass one Faraday of charge, it means that we are passing one mole of electron and by passing 1 Faraday of charge 1gm equivalent weight of the substance will be deposited or liberated.

$$W = \frac{q}{96500} \times E$$

By combining the first and second law, we get

$$Z = \frac{E}{96500}$$

Electrochemical Cells:

Difference in Electrolytic Cell and Galvanic Cell:

Electrolytic Cell	Galvanic cell
Electrical energy is converted into chemical energy.	Chemical energy is converted into electrical energy.
Anode positive electrode. Cathode negative electrode	Anode negative electrode. Cathode positive electrode.
Ions are discharged on both the electrodes.	Ions are discharged only on the cathode
If the electrodes are inert, concentration of the electrolyte decreases when the electric current is circulated	Concentration of the anodic half-cell increases while that of cathodic half-cell decreases when the two electrodes are joined by a wire
Both the electrodes can be fitted in the same compartment	The electrodes are fitted in different compartment

Standard electrode potential: The potential difference developed between metal electrode and the solution of its ions of unit molarity (1M) at 25°C (298 K)

IUPAC Cell Representation: Anode (Molarity of electrolyte at anode) || Cathode (Molarity of electrolyte at cathode)

$E^0_{cell} = E^0_{cathode} - E^0_{anode}$

Example:

$$\underbrace{Zn / \underset{(C_1)}{ZnSO_4}}_{Anode} \| \underbrace{\underset{(C_2)}{CuSO_4} / Cu}_{Cathode}$$

The Nernst Equation:

For a general reaction such as

$M_1A + m_2B$ ..... $n_1X + n_2Y$ + ...(i)

Occurring in the cell, the Gibbs free energy change is given by the equation

$$G = \triangle G^0 + 2.303RTlog_{10}\frac{(a_x^{n1} \times a_y^{n2})}{(a_A^{m1} a_B^{m2})}.(ii)$$

where

'a' represents the activities of reactants and products under a given set of conditions and

?G^o refers to free energy change for the reaction when the various reactants and products are present at standard conditions.

The free energy change of a cell reaction is related to the electrical work that can be obtained from the cell, i.e.,

?G^o = -nFE$_{cell}$ and ?G^o = -nFE^o.

On substituting these values in Eq. (ii) we get

$$nFE_{cell} = -nFE^o + 2.303RTlog_{10}\frac{(a_x^{n1} \times a_y^{n2})}{(a_A^{m1} a_B^{m2})}.(iii)$$

$$\Rightarrow E_{cell} = E^o - 2.303RTlog_{10}\frac{(a_x^{n1} \times a_y^{n2})}{(a_A^{m1} a_B^{m2})}.(iv)$$

This equation is known as **Nearnst equation**.

Some other important relations:

- $K_{eq} = e^{nE/FRT}$
- $\Delta H = nF\,[T(dE/dT)-E]$
- $\Delta S = nF(dE/dT)_P$

Some Important Half Cells:

Hydrogen Electrode:

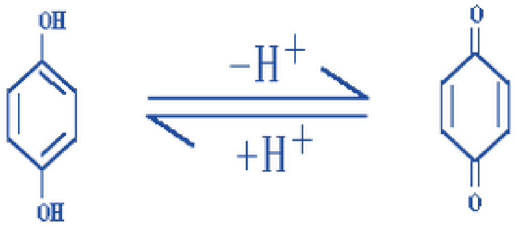
- **<u>The electrode reaction</u> :** $H_2 \rightarrow 2H^+ + 2e^-$
- **<u>Electrode representation</u>:** Pt | H_2 (1 atm) | H^+ (1M).

Ferrous – Ferric Electrode:

- **<u>Electrode reaction</u>:** $Fe^{3+} + e^- \rightarrow Fe^{2+}$
- **<u>Electrode representation</u>:** Pt | Fe^{2+} (C_1), Fe^{3+} (C_2).

Quin – Hydrone Electrode:

- **Electrode reaction:**



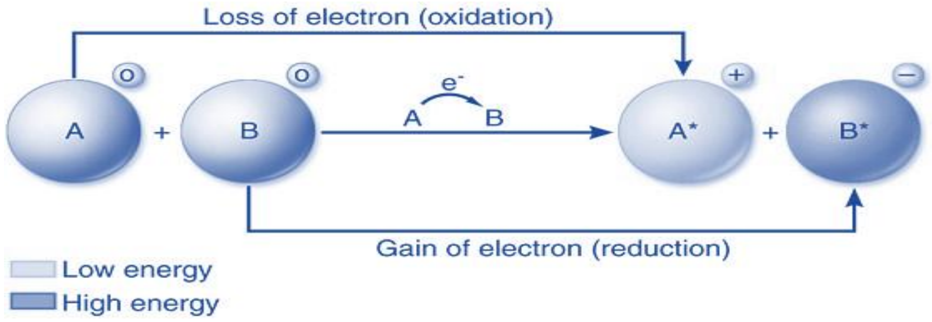
- **Electrode representation**: Pt.|QH_2,Q,H^+ (C)

Calomel electrode :

- **Electrode reaction :** ½ $Hg_2Cl_2 + e^- \leftrightarrow Hg + Cl^-$
- **Electrode is representation:** Cl^- (1M) | Hg_2Cl_2, Hg?

?Oxidation and Reduction

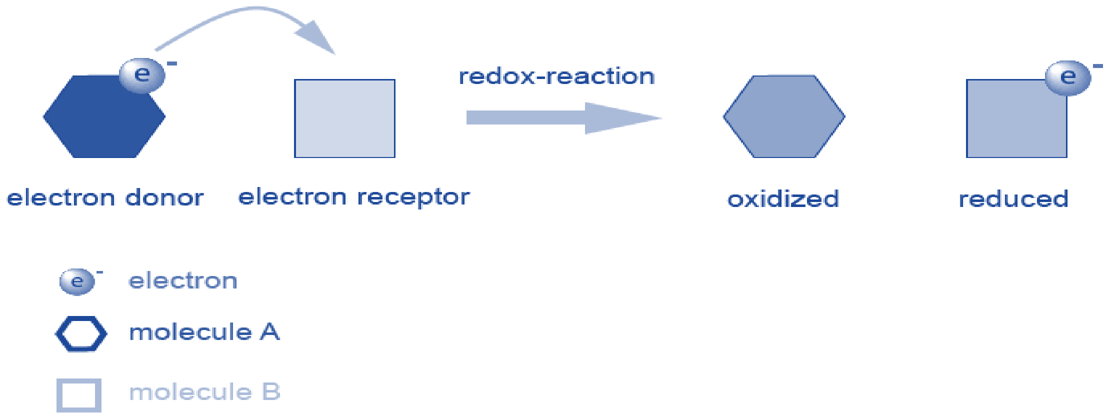
- Oxidation is defined as the loss of electrons by a chemical species (atom, ion or molecule).
- Reduction is the gain of electrons by a chemical species (atom, ion or molecule).
- An oxidising agent that chemical species which takes electrons thus it is an electron acceptor.
- A reducing agent is the chemical species that gives electrons and thus acts as an electron donor.



- When Fe^{2+}(aq) ions are being oxidised they are acting as reducing agents, and when Fe^{3+}(aq) ions are being reduced they are acting as oxidising agents. In general ;

$$\text{O.A.} + \text{electrons} \underset{\text{Oxidation}}{\overset{\text{Reduction}}{\rightleftharpoons}} \text{R.A.}$$

- $\underset{\text{(R.A.)}}{Fe^{2+}_{(aq)}} \xrightarrow{\text{Oxidation}} \underset{\text{(O.A.)}}{Fe^{3+}_{(aq)}} + e^-$ $\quad Fe^{3+}_{(aq)} + e^- \xrightarrow{\text{reduction}} Fe^{2+}_{(aq)}$



- Neither reduction nor oxidation occurs alone. Both of them occur simultaneously. Since both these reactions must occur at the same time they are often termed as "redox reactions". The oxidation or reduction portion of a redox reaction, including the electrons gained or lost can be determined by means of a Half-Reaction ?Oxidation Number
- The oxidation number for an element in a covalent compound is by taking the oxidation number to be equal to the charge that the element would carry, if all the bonds in the compound were regarded as ionic instead of covalent.
- The sum of the oxidation numbers of all the atoms in an uncharged compound is zero. In case of an ion, the algebraic sum of the oxidation numbers of all the atoms is equal to the charge on the ion.
- Oxidation number of any element in its elementary state is zero.
- Fluorine is the most electronegative element. Its oxidation number is always -1 .
- Oxygen after fluorine is the second most electronegative element. It shows an oxidation state of -2 in almost all the compounds excepts peroxides and superoxides,
- In all compounds, except ionic metallic hydrides, the oxidation number of hydrogen is +1.
- In any compounds has more than two elements, the oxidation number of any one of them may have to be obtained by first assigning reasonable oxidation numbers to the other elements.

Oxidation Number / State Method For Balancing Redox Reactions:

This method is based on the principle that the number of electrons lost in oxidation must be equal to the number of electrons gained in reduction. The steps to be followed are :

- Write the equation (if it is not complete, then complete it) representing the chemical changes.
- By knowing oxidation numbers of elements, identify which atom(s) is(are) undergoing oxidation and reduction. Write down separate equations for oxidation and reduction.
- Add respective electrons on the right of oxidation reaction and on the left of reduction reaction. Care must be taken to ensure that the net charge on both the sides of the equation is same.
- Multiply the oxidation and reduction reactions by suitable numbers to make the number of electrons lost in oxidation reactions equal to the number of electrons gained in reduction reactions.
- Transfer the coefficient of the oxidizing and reducing agents and their products to the main equation.

- By inspection, arrive at the co-efficients of the species not undergoing oxidation or reduction.
- Some elements like manganese, chromium, nitrogen and chlorine show variable oxidation states.
- When an element is oxidised its oxidation number gets increased while reduction on any element decreases its oxidation number. Change in oxidation number can be used to decide whether an oxidation or a reduction has taken place. In the change from chloromethane to dichloromethane, for example,

  $C\ H_3\ Cl \quad C\ H_2\ Cl_2$

  $-2\ +1\ -1 \quad 0\ +1\ -1$

  The oxidation number of carbon is increased from -2 to 0. The carbon is therefore being oxidised.

Half-Reaction or Ion-Electron Method For Balancing Redox Reactions

This method involves the following steps :

- Divide the complete equation into two half reactions, one representing oxidation and the other reduction.
- Balance the atoms in each half reaction separately according to the following steps:
  - First of all balance the atoms other than H and O.
  - In a reaction taking place in acidic or neutral medium, oxygen atoms are balanced by adding molecules of water to the side deficient in oxygen atoms while hydrogen atoms are balanced by adding H^+ ions to the other side deficient in hydrogen atoms. On the other hand, in alkaline medium (OH^-), every excess of oxygen atom on one side is balanced by adding one H_2O to the same side and $2OH^-$ to the other side. In case hydrogen is still unbalanced, then balance by adding one OH^-, for every excess of H atom on the same side as the excess and one H_2O on the other side.
  - Equalize the charge on both sides by adding a suitable number of electrons to the side deficient in negative charge.
  - Multiply the two half reactions by suitable integers so that the total number of electrons gained in one half reaction is equal to the number of electrons lost in the other half reaction.

Common Oxidising and Reducing Agents

Oxidising agent	Effective Change	Decrease in Oxidation Number
$KMnO_4$ in acid solution	$MnO_4^- \rightarrow Mn^{2+}$	5
$KMnO_4$ in alkaline solution	$MnO_4^- \rightarrow MnO_2$	3
$K_2Cr_2O_7$ in acid solution	$Cr_2O_7^{2-} \rightarrow Cr^{3+}$	3
dilute HNO_3	$NO_3^- \rightarrow NO$	3
concentrated HNO_3	$NO_3^- \rightarrow NO_2$	1
concentrated H_2SO_4	$SO_4^{2-} \rightarrow SO_2$	2
manganese (IV) oxide	$MnO_2 \rightarrow Mn^{2+}$	2
chlorine	$Cl \rightarrow Cl^-$	1
chloric (I) acid	$ClO^- \rightarrow Cl^-$	2
KIO_3 in dilute acid	$IO_3^- \rightarrow I$	5
KIO_3 in concentrated acid	$IO_3^- \rightarrow I^-$	4
Reducing agent	**Effective Change**	**Increase in Oxidation Number**
iron (II) salts (acid)	$Fe^{2+} \rightarrow Fe^{3+}$	1
tin (II) salts (acid)`	$Sn^{2+} \rightarrow Sn^{4+}$	2
ethanedioates (acid)	$C_2O_4^{2-} \rightarrow CO_2$	1
sulphites (acid)	$SO_3^{2-} \rightarrow SO_4^{2-}$	2
hydrogen sulphide	$S^{2-} \rightarrow S$	2
iodides (dilute acid)	$I^- \rightarrow I$	1
iodides (concentrated acid)	$I^- \rightarrow I^+$	2
metals, e.g. Zn	$Zn \rightarrow Zn^{2+}$	2
hydrogen		

Surface Chemistry

Revision Notes on Surface Chemistry:

Adsorption

Reversible and irreversible adsorption

The adsorption is **reversible,** if the adsorbent can be easily removed from the surface of the adsorbent by physical methods. It is called **irreversible adsorption**, if the adsorbate cannot be removed from the surface of the adsorbent.

A gas adsorbed on a solid surface can be completely removed in vacuum. It is, therefore, reversible adsorption. Examples of irreversible adsorption are adsorption of oxygen on tungsten adsorbate and adsorption of CO on tungsten surface

Adsorbent, Adsorbate and Interface

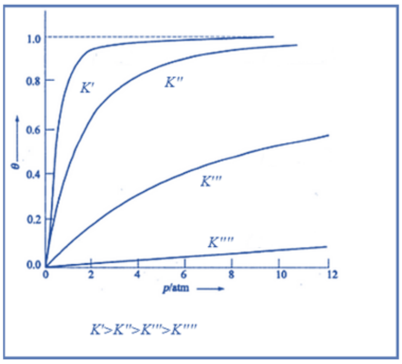
- The substances upon whose surface the change of concentration occurs, is called ***absorbent***.
- The substance taken up on the surface is call ***adsorbate***.
- The common surface between the two phases where the adsorbed molecules concentrate is called the ***interface.***

Physisorption and Chemosorption:

Physisorption	Chemisorption
Only van der Waals force are present between adsorbate and surface of adsorbent	Chemical bonds are formed between adsorbate and surface of adsorbent
Low enthalpy of adsorption ie, in the order of 20 kjmol-1.	High enthalpy of adsorption i.e, order of 200 kjmol-1.
Reversible	Irreversible
It is usually takes place at low temperature and does not require any activation energy.	It takes place at **high temperature** and require activation energy..
Multi molecular layer of adsorbate are formed on the surface	Only **monomolecular layers** are formed.
Not specific.	Highly specific.

Langmular Isotherm:

If A, B & AB represents the adsorbed, absorbent and the absorbed – adsorbent complex then,



$A + B \leftrightarrow AB$

k_a = Equilibrium constant for adsorption = [AB]/[A][B]

k_d = Equilibrium constant for desorption = [A][B]/[AB]

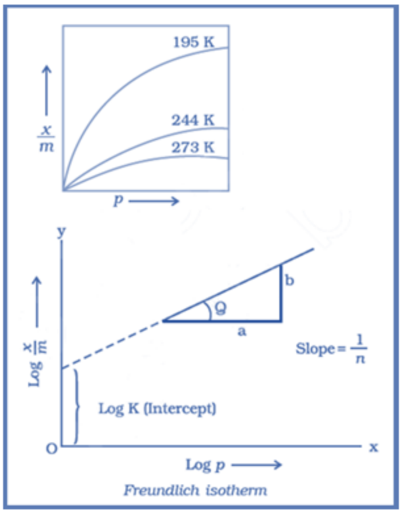
K = Distribution coefficient = k_a/k_b

Θ = Fraction of the surface of adsorbent available for adsorption.

P = pressure

So,

$\Theta = KP/(1+KP)$ (Langmular Equation)



Freundlich Isotherm:

x= Mass of the gas adsorbed

m = Mass of absorbent

p = Pressure

K and n = constants

$x/m = k.p^{(1/n)}$ [n >1]

or

$\log x/m = \log k + 1/n \log P$

Factors Affecting Adsorption:

- **Temperature:** An increase of temperature leads to a decrease in amount adsorbed and vice – versa.
- **Pressure or concentration:** It has been found that in most cases, the adsorption is reversible and an increased pressure of a gases vapour or an increase in concentration of a solute causes increased adsorption.
- **Nature of Adsorbate and Adsorbent:** The amount of the gas adsorbed depends upon the nature of adsorbent and the gas (adsorbate), which is to be adsorbed. It has been found that easily liquifiable gases such as NH_3, HCl, Cl_2, SO_2 CO_2 etc. are more readily adsorbed than so the called permanent gases such as O_2,N_2, H_2 etc. This is because that molecules of the former type of gases have greater Vander waal's or molecular force of attraction.

Colloids

Dispersed Phase:

The phase which is dispersed or scattered through the dispersion medium is called Dispersed phase or discontinuous phase.

Dispersion Medium:

The phase in which the scattering is done is called the dispersion medium or continuous medium.

Dispersed Phase	Dispersion Medium	Name	Typical example
Solid	Liquid	Sol	Gold sol, Mud, $Fe(OH)_3$ sol,
Solid	Solid	Solid sol	Gems, Ruby glass, Minerals
Solid	Gas	Aero sols	Smoke (Carbon in air) Volcanic dust
Liquid	Solid	Gel	Curd, Cheese, Jellies
Liquid	Liquid	Emulsion	Milk, water in benzene, cream
Liquid	Gas	Liquid aero sol	Clouds, fog (water in air) mist
Gas	Solid	Solid foam	Lava, Pumica
Gas	Liquid	Foam	Froth on beer , whipped cream

Lyophobic and Lyophilic Colloids:

Those substance whose colloidal solution cannot be prepared by bringing them in contact with a solvent are called *Lyophobic* (disliking, fearing or hating a liquid). On the other hand those substances whose colloidal solutions can be prepared by bringing them in contact with a liquid solvent are called *lyophilic colloids* (loving a solvent).

Emulsions:

- **Emulsion of oil in water:** Those emulsions in which the dispersed phase is oil and water is the dispersion medium. These emulsion are generally represented as O in W emulsions. Examples are milk, vanishing cream etc.
- **Emulsions of water in oil:** Those emulsion in which the dispersed phase is water while oil is the dispersion medium. These emulsion are generally represented as W in O emulsions. Examples are butter, ice cream etc.

Difference between True Solutions, Suspension & Colloids

True solution	Suspension	Colloid
Homogenous	Heterogeneous	Heterogeneous
Particle size less than 1nm	Particle size more than 1000nm	Particle size between 1-1000nm
Don't settle down	Settle down under the influence of gravity	Don't settle down
Complements cannot be separated out by filtration	Can be filtered	Can be filtered using special filter papers
Don't show tyndrall effect	Show tyndrall effect	Show tyndrall effect

Methods of preparation of colloids

Chemical Methods:

$$As_2O_3 + 3H_2S \xrightarrow{\text{Double decompostion}} As_2S_3(sol) + 3H_2O$$

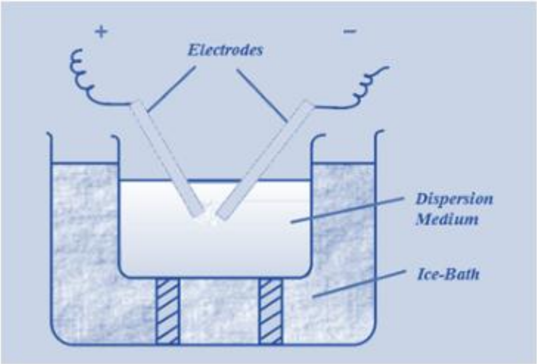
$$SO_2 + 2H_2S \xrightarrow{\text{Oxidation}} 3S(sol) + 2H_2O$$

$$2\,AuCl_3 + 3\,HCHO + 3H_2O \xrightarrow{\text{Reduction}} 2Au(sol) + 3HCOOH + 6HCl$$

$$FeCl_3 + 3H_2O \xrightarrow{\text{Hydrolysis}} Fe(OH)_3\ (sol) + 3HCl$$

Bredig's method:

An electric arc is struck between two metallic electrodes immersed in dispersion medium. The arc produced vapourises the metal which on further condensation produces particles of colloidal size.



- **Peptization:**

Process of converting a precipitate into colloidal sol by shaking it with electrolyte in dispersion medium.

Hardy Schulze Rule:

- Ion carrying charge opposite to the colloidal particle has capacity to coagulate the colloid.
- Greater the valency of ion, greater will be the coagulating power.
- Gold Number: The minimum amount of lyophilic colloid in milligrams which can prevent the coagulation of 10 ml gold sol against 1 ml of 10% NaCl solution.

Surfactants

substances which gets preferentially adsorbed at the air – water and solid – water interfaces forming an oriented monolayer where the hydrophilic groups point towards the aqueous phase and the hydrocarbon chain point towards the air or towards the oil phase.

- Anionic surfactants : NSodium salts of higher fatty acids such as sodium palmitate ($C_{15}H_{31}COONa$), sodium stereate ($C_{17}H_{35}COONa$) and sodium Oleate ($C_{17}H_{33}COONa$).
- Catiuonic Surfactants: Those which dissociates in water to yield positively charged ions ***examples:*** $C_{18}H_{37}$, $C_{16}H_{33}(CH_3)_3$ etc.
- Non ionogenic: Those whose molecules cannot undergo dissociation when an alcohol having a higher molecular weight reacts with several molecules of ethylene oxide, a non – ionogenic surfactant is produced.

Periodic Table

Modern Periodic Law:

- Properties of elements are the periodic function to their atomic numbers.
- The periodicity in properties is due to repetition of similar outer shell electronic configuration at a certain regular intervals.
- In modern periodic table is based on modern periodic law in which elements are arranged in increasing order of their atomic numbers.
- In the modern periodic table, the elements are arranged in rows and columns. These rows and columns are known as periods and groups respectively.
- The table consists of 7 periods and 18 groups
- Period indicates the value of 'n' (principal quantum number) for the outermost or valence shell.
- Same number of electrons is present in the outer orbitals (that is, similar valence shell electronic configuration

IUPAC Nomenclature for Elements with Atomic Number ? 100

Digit	Name	Abbreviation
0	nil	n
1	un	u
2	bi	b
3	tri	t
4	quad	q
5	pent	p
6	hex	h
7	sept	s
8	oct	o
9	enn	e

Classification of Elements:

Elements:	Valence Shell Electronic Configuration	Nature	Position in Modern Periodic Table
s-block elements	ns^{1-2} (n = 1 to 7).	Metals	1 and 2 group elements
p – block elements	ns^2np^{1-6} (n = 2 to 7).	Metalloids & non metals but some of them are metals also.	groups 13 to 18
d-Block Elements	$(n-1)d^{1-10}$ ns^{1-2} (n = 4 to 7).	Metals	3 to 12 groups 3d series – Sc(21) to Zn (30) 4d series – Y (39) to Cd (48) 5d series – La (57), Hf (72) to Hg (80
f-Block Elements	$(n-2)f^{1-14}$ $(n-1)s^2$ $(n-1)p^6$ $(n-1)d^{0-1}ns^2$ (n = 6 and 7).	Radioactive	group 3 4f series – Lanthanides – 14 Elements Ce (58) to Lu (71) 5f series – Actinides – 14 Elements Th (90) to Lw (103)

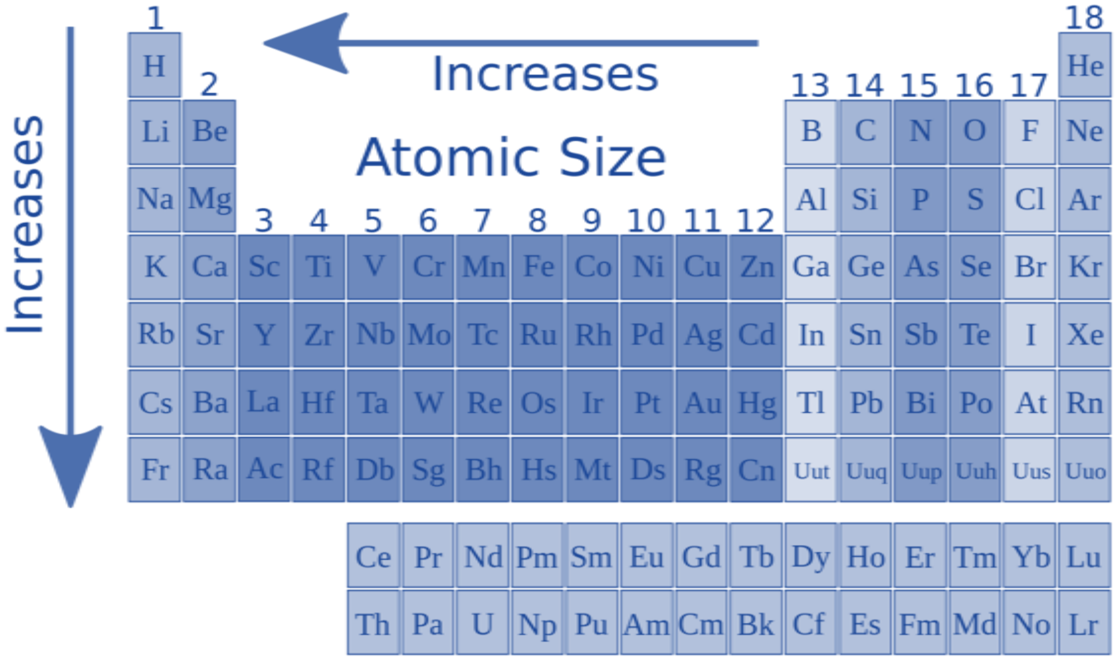
Periodicity in Atomic Properties:

1. Atomic Radius:

- Within a given period atomic radius **decreases from left to right**. This is due to the effect of increase in nuclear charge while the electrons are being added to the same shell.
- Within a given group atomic radius increases down the group. This is due to the increase in number of shells.

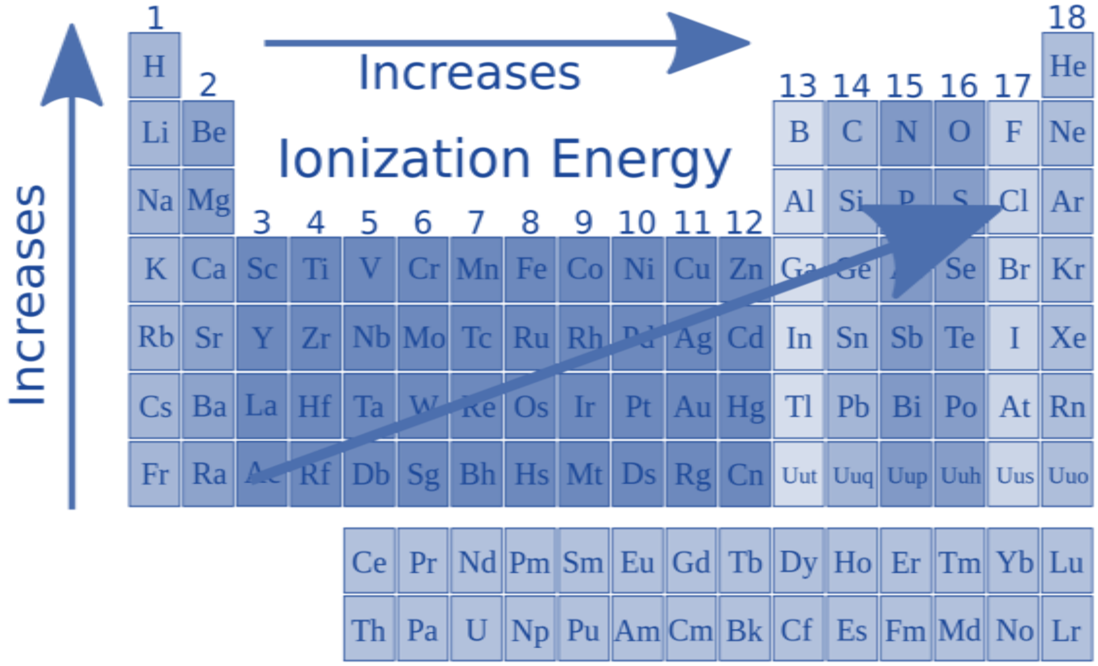
Period	Group							
	IA	**IIA**	**IIIA**	**IVA**	**VA**	**VIA**	**VIIA**	**Zero**
1.	H 0.37							He 0.93
2.	Li 1.34	Be 0.90	B 0.82	C 0.77	N 0.73	O 0.74	F 0.72	Ne 1.31
3.	Na 1.54	Mg 1.30	Al 1.18	Si 1.11	P 1.06	S 1.02	Cl 0.99	Ar 1.74

- In the first transition series the atomic size slightly decreases from Sc to Mn because effect of effective nuclear charge is stronger than the shielding effect. The atomic size from Fe to Ni remains almost the same because both the effects balance each other.
- The atomic size from Cu to Zn slightly increases because shielding effect is more than effective nuclear charge due to d^{10} structure of Cu and Zn.
- Inner transition elements – As we move along the lanthanide series, there is a decrease in atomic as well as ionic radius. The decrease in size is regular in ions but not so regular in atoms. This is called lanthanide contraction.



2) Ionisation potential or Ionisation Energy:

Ionization energy increases along the period while decreases down the group.



Factors which influence I.E.

- Atomic size: the larger the size of the atom, the smaller the I.E. i.e., I.E. µ
- Effective nuclear charge: The greater the effective charge on the nucleus of an atom, the more difficult it would be to remove an electron from the atom because electrostatic force of attraction between the nucleus and the outermost electron increases. So greater energy will be required to remove the electron.
- Penetration effect of orbitals: The order of energy required to remove electron from s,p,d-and¦-orbitals of a shell is s>p>d>¦.
- Shielding or screening effect: Screening effect results in decrease of force of attraction between the nucleus and the outermost electron and lesser energy is required to separate the electron. Thus the value of I.P. decreases.
- Stability of half-filled and fully-filled orbitals: According to Hund's rule the stability of half filled or completely filled degenerate orbitals is comparatively high. So comparatively more energy is required to separate the electron from such atoms.

Successive Ionisation Energies

Element	IE_1	IE_2	IE_3	IE_4
Li	520.1	7297	11813	—
C	1086.2	2352	4620	6221
N	1402.1	2856	4577	7474

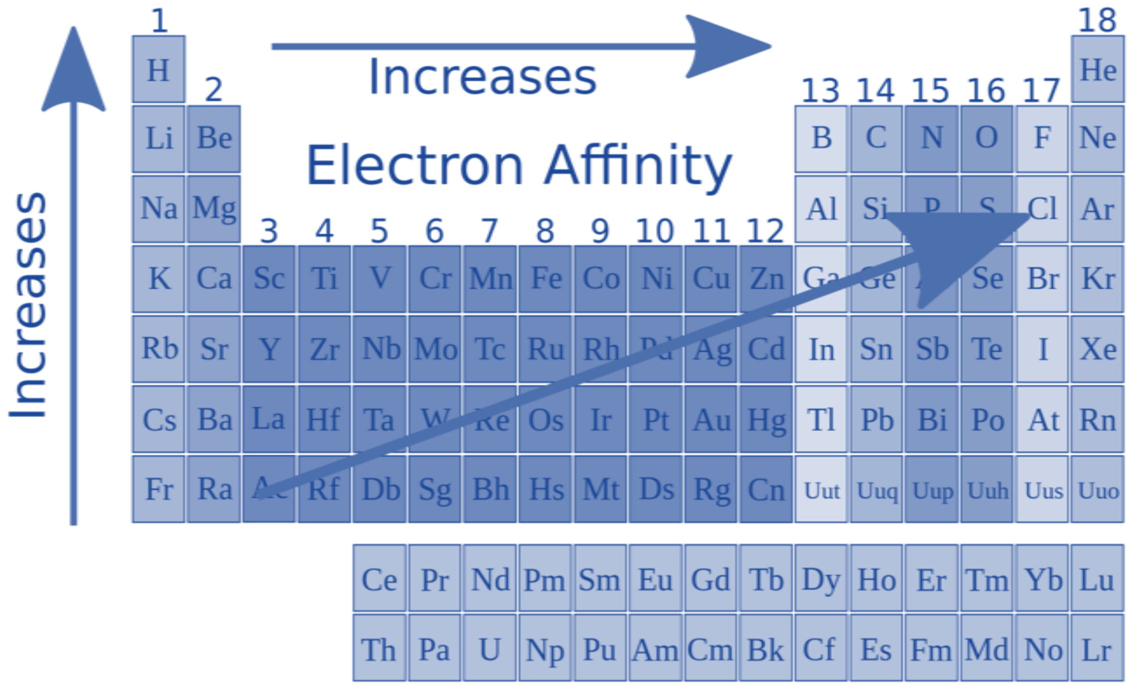
3) Electron Affinity:

Electron affinity increases along the period while decreases down the group.

Factors affecting the magnitude of electron affinity

- Atomic size – In general electron affinity value decreases with the increasing atomic radius because electrostatic force of attraction decreases between the electron being added and the atomic nucleus due to increase of distance between them.
- Effective nuclear charge – Electron affinity value of the element increase as the effective nuclear charge on the atomic nucleus increases because electrostatic force of attraction between the electron being added and the nucleus increases. As the electrostatic force of attraction increases, amount of energy released is more.
- Screening or Shielding effect – Electron affinity value of the elements decreases with the increasing shielding or screening effect. The shielding effect between the outer electrons and the nucleus increases as the number of electrons increases in the inner shells.

Stability of half filled and completely filled orbitals – The stability of half filled and completely filled degenerate orbitals of a sub shell is comparatively more, so it is difficult to add electron in such orbitals and lesser energy is released on addition of electron hence the electron affinity value will decrease.



? Electron Affinities (kJ mol^{-1}), $M_{(g)}$ + e^{-} ® $M_{(g)}^{-}$ + energy

Group 1	2	13	14	15	16	17	18
H							He
72							< 0
Li	Be	B	C	N	0	F	
57	< 0	27	122	< 0	142	333	
Na	Mg	Al	Si	P	S	Cl	Ne
53	< 0	44	134	72	200	349	< 0
K	Ca	Ga	Ge	As	Se	Br	Ar
48	< 0	29	116	77	195	324	< 0
Cs				Bi	Te	1	Xe
43							

Isolation of Metals

General Principles & Processes of Isolation of Metals

Types of Ores:

Ores may be divided into four groups

- **Native Ores:** These ores contain the metal in free state eg. Silver gold etc. These are usually formed in the company of rock or alluvial impurities like clay, sand etc.
- **Oxidised Ores**: These ores consist of oxides or oxysalts (eg. carbonates, phosphate) and silicate of metal. Important oxide ore includes, Fe_2O_3, $Al_2O_3.2H_2O$ etc. and important cabonate ores are limestone ($CaCO_3$), Calamine ($ZnCO_3$) etc.
- **Sulphurised Ores**: These ores consist of sulfides of metals like iron, lead, mercury etc. Examples are iron pyrites (FeS2). galena (PbS), Cinnabar (HgS)
- **Halide ores**: Metallic halides are very few in nature. Chlorides are most common examples include horn silver (AgCl) carnallite KCl. $MgCl_2.6H_2O$ and fluorspar (CaF_2) etc.

Metallurgy:

It is the process of extracting a metal from its ores. The following operations are carried out for obtaining the metal in the pure form.

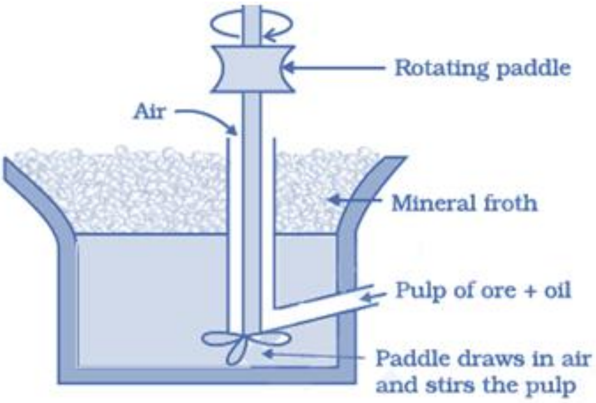
- Crushing of the ore
- Dressing or concentration of the ore.
- Reduction of metal.
- Purification or refining of the metal

Concentration

Physical Method

Gravity separation: The powdered ores is agitated with water or washed with a running stream of water. The heavy ore particles of sand, clay etc. are washed away.

Froth Floatation Process: The finely divided ore is introduced into water containing small quantity of oil (e.g. Pine Oil). The mixture is agitated violently with air a froth is formed which carries away along with it the metallic particles on account of the surface tension forces. The froth is transferred to another bath where gangue-free ore settles down.



Electro Magnetic Separator:. A magnetic separator consists of a belt moving over two rollers, one of which is magnetic. The powdered ore is dropped on the belt at the other end. Magnetic portion of the ore is attracted by the magnetic roller and falls near to the roller while the non-magnetic impurity falls farther off

Chemical Methods

Calcination: Carbonate or hydrated oxide ores are subjected to the action of heat in order of expel water from hydrated oxide and carbon dioxide from a carbonate.

Examples:

$ZnCO_3$ --> $ZnO + CO_2$
$CaCO_3$ --> $CaO + CO_2$
$Al_2O_3 \times 2H_2O$ --> $Al_2O_3 + 2H_2O$
$2Fe_2O_3 \times 3H_2O$ --> $2Fe_2O_3 + 3H_2O$

Roasting: Sulphide ores either are subjected to the action of heat and air at temperatures below their melting points in order to bring about chemical changes in them.

Examples:

$2PbS + 3O_2$ --> $2PbO + 2SO_2$
$PbS + 2O_2$ --> $PbSO_4$
$2ZnS + 3O_2$ --> $2ZnO + 2SO_2$
$ZnS + 2O_2$ --> $ZnSO_4$
$CuS + 2O_2$ --> $CuSO_4$
$2Cu_2S + 3O_2$ --> $2Cu_2O + 2SO_2$

Leaching: It involves the treatment of the ore with a suitable reagent as to make it soluble while impurities remain insoluble. The ore is recovered from the solution by suitable chemical method.
$Al_2O_3 + 2NaOH$ -->2 $NaAlO_2 + H_2O$

Reduction of Free Metal:

Smelting:

Reduction of a metal from its ore by a process involving melting
Several reducing agents such as sodium, magnesium and aluminium are used for reduction.
The calcinated or roasted ore is mixed with carbon (coal or coke) and heated in a reverberatory or a blast furnace.
Carbon and carbon monoxide produced by incomplete combustion of carbon reduce the oxide to the metal.

$$\left.\begin{array}{l} PbO + C \rightarrow Pb + CO \\ PbO + CO \rightarrow Pb + CO_2 \\ SnO_2 + 2C \rightarrow Sn + 2CO \end{array}\right\} \text{Carbon reductionprocess}$$

$$\left.\begin{array}{l} Cr_2O_3 + 2Al \rightarrow 2Cr + Al_2O_3 \\ 3Mn_3O_4 + 8Al \rightarrow 9Mn + 4Al_2O_3 \end{array}\right\} \text{Alumin iumreduction process (Gold - Schimidt alumino thermic process)}$$

Flux:

The ores even after concentration contain some earthy matter called gangue which is heated combine with this earthy matter to form an easily fusible material. Such a substance is known as flux and the fusible material formed during reduction process is called slag.

- **Acidic fluxes** like silica, borax etc are used when the gangue is basic such as lime or other metallic oxides like MnO, FeO, etc
- **Basic fluxes** like CaO, lime stone ($CaCO_3$), magnesite ($MgCO_3$), hematite (Fe_2O_3) etc are used when the gangue is acidic like silica, P_4O_{10} etc.

Refining

The metals obtained by the application of above reduction methods from the concentration ores are usually impure. The impure metal is thus subjected to some purifying process known as refining in order to remove undesired impurities. Various process for this are

a) Liquation process b) Distillation process

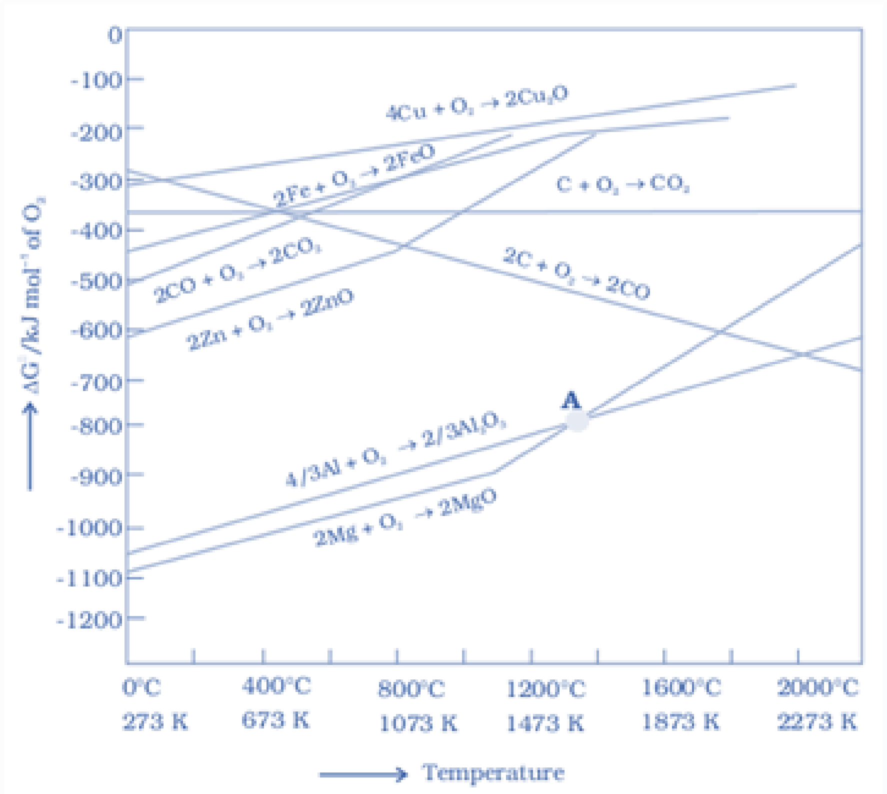
c) Cupellation d) Poling

e) Electrolytic refining f) Bessemerisation

Thermodynamic Principles of Metallurgy:

$\Delta G = \Delta H - TS$

or $\Delta G^0 = -RT \ln K$



An element A can reduce element B if ΔG value for oxidation of A to AO is lower than the ΔG value for oxidation of B to BO.

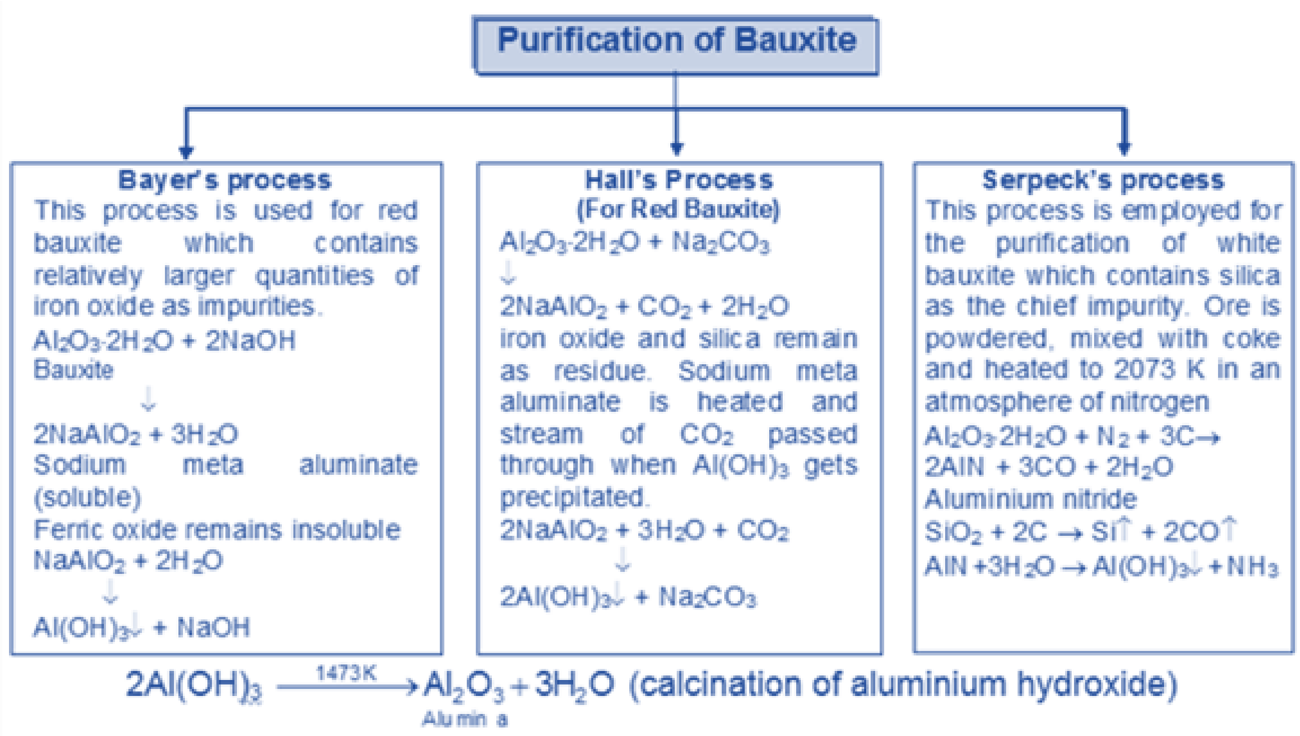
i.e. $\Delta G_{(A \rightarrow AO)} < \Delta G_{(B \rightarrow BO)}$

Extraction of Aluminium:

Important Ores of Aluminium:

- Bauxite : $Al_2O_3\times2H_2O$Cryolite: Na_3AlF_6
- Feldspar: $K_2OAl_2O_3\times6SiO_2$ or $KAlSi_3O8$
- Mica: $K2O\times3Al_2O_3\times6SiO_2\times2H_2O$
- Corundum: Al_2O_3
- Alumstone or Alunite: $K_2SO_4\times Al_2(SO_4)_3\times4Al(OH)_3$

Purification of Bauxite



Purification of Bauxite

Bayer's process

This process is used for red bauxite which contains relatively larger quantities of iron oxide as impurities.

$\underset{\text{Bauxite}}{Al_2O_3{\cdot}2H_2O} + 2NaOH$

$\downarrow$

$2NaAlO_2 + 3H_2O$

Sodium meta aluminate (soluble)

Ferric oxide remains insoluble

$NaAlO_2 + 2H_2O$

$\downarrow$

$Al(OH)_3\downarrow + NaOH$

Hall's Process

(For Red Bauxite)

$Al_2O_3{\cdot}2H_2O + Na_2CO_3$

$\downarrow$

$2NaAlO_2 + CO_2 + 2H_2O$

iron oxide and silica remain as residue. Sodium meta aluminate is heated and stream of CO_2 passed through when $Al(OH)_3$ gets precipitated.

$2NaAlO_2 + 3H_2O + CO_2$

$\downarrow$

$2Al(OH)_3\downarrow + Na_2CO_3$

Serpeck's process

This process is employed for the purification of white bauxite which contains silica as the chief impurity. Ore is powdered, mixed with coke and heated to 2073 K in an atmosphere of nitrogen

$Al_2O_3{\cdot}2H_2O + N_2 + 3C\rightarrow$
$2AlN + 3CO + 2H_2O$

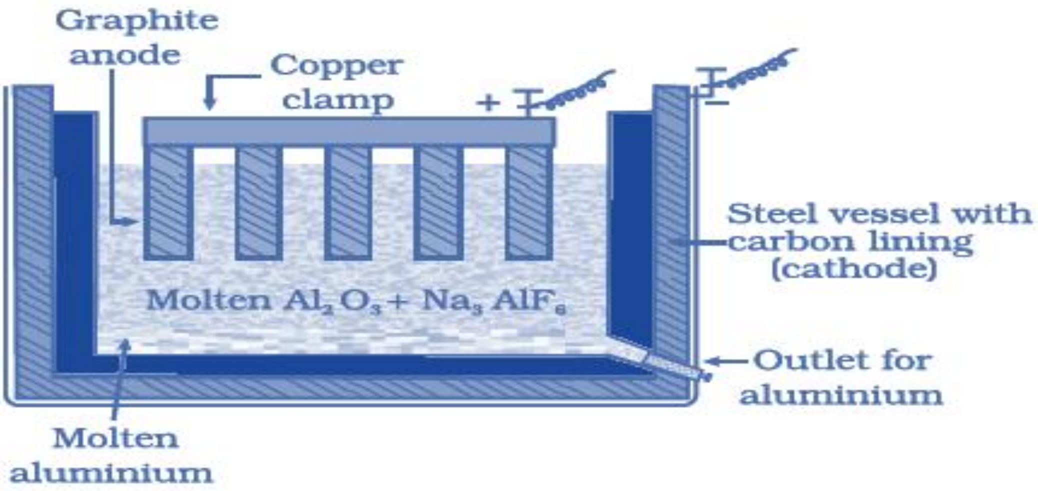
Aluminium nitride

$SiO_2 + 2C \rightarrow Si\uparrow + 2CO\uparrow$

$AlN + 3H_2O \rightarrow Al(OH)_3\downarrow + NH_3$

$$2Al(OH)_3 \xrightarrow{1473K} \underset{\text{Alu min a}}{Al_2O_3} + 3H_2O \text{ (calcination of aluminium hydroxide)}$$

Electrolysis of fused pure alumina (Hall & Herwlt Method)



The addition of cryolite (Na_3AlF_6) and fluorspar (CaF_2) makes alumina a good conductor of electricity and lowers its Fusion temperature from 2323 to 1140 K. the reaction taking place during electrolysis.

$Na_3AlF_6 \rightleftharpoons 3NaF + AlF_3$

$AlF_3 \rightleftharpoons Al^{3+} + 3F^-$

At cathode

$Al^{3+} + 3e^- \longrightarrow Al$

At anode

$F^- \longrightarrow F + e^-$

$2Al_2O_3 + 12\,F \longrightarrow 4AlF_3 + 3O_2$

$2C + O_2 \longrightarrow 2CO$

$2CO + O_2 \longrightarrow 2CO_2$

Refining of Aluminium:

The graphite rods dipped in pure aluminium and Cu–Al alloy rod at the bottom in the impure aluminium work as conductors. On electrolysis, aluminium is deposited at cathode from the middle layer and equivalent amount of aluminium is taken up by the middle layer from the bottom layer (impure aluminium). Therefore, aluminium is transferred from bottom to the top layer through middle layer while the impurities are left behind. Aluminium thus obtained is 99.98% pure.

Hydrometallurgy (solvent extraction)

Solvent extraction is the latest separation technique and has become popular because of its elegance, simplicity and speed. The method is based on preferential solubility principles.

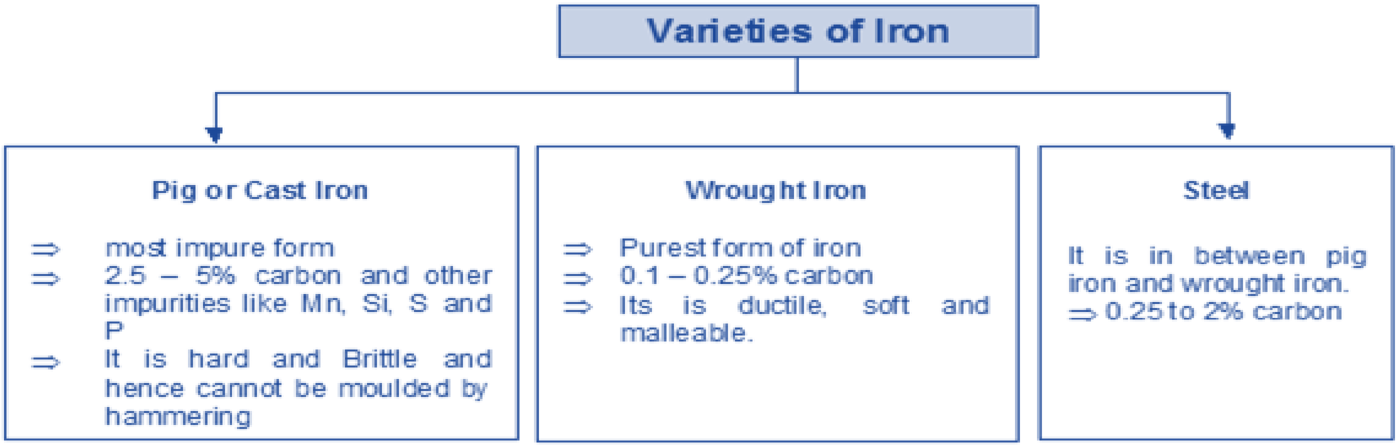
Solvent or liquid-liquid extraction is based on the principle that a solute can distribute itself in a certain ratio between two immiscible solvents, one of which is usually water and the other an organic solvent such as benzene, carbon tetrachloride or chloroform. In certain cases, the solute can be more or less completely transferred into the organic phase.

Extraction of Iron:

a) Important Ores of Iron:

Hematite Fe_2O_3 (red oxide of iron)

Limonite $Fe_2O_3 \times 3H_2O$ (hydrated oxide of iron)



Varieties of Iron

Pig or Cast Iron

⇒ most impure form

⇒ 2.5 – 5% carbon and other impurities like Mn, Si, S and P

⇒ It is hard and Brittle and hence cannot be moulded by hammering

Wrought Iron

⇒ Purest form of iron

⇒ 0.1 – 0.25% carbon

⇒ Its is ductile, soft and malleable.

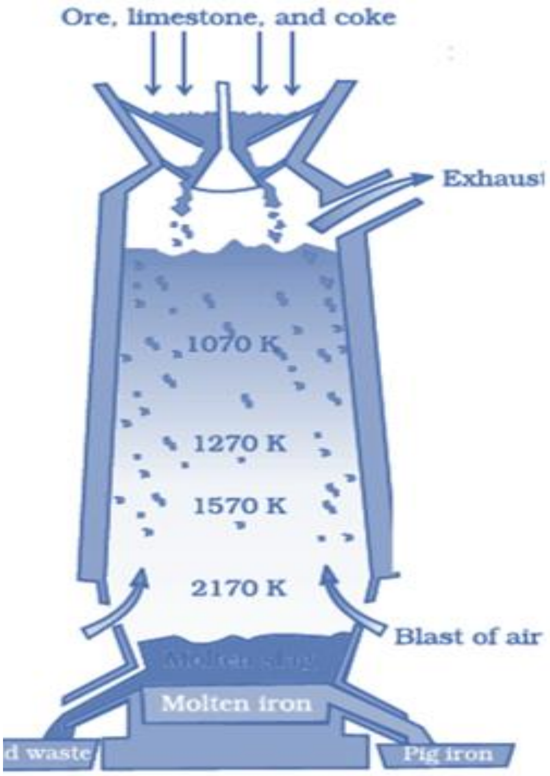
Steel

It is in between pig iron and wrought iron.

⇒ 0.25 to 2% carbon

Magnetite Fe_3O_4 (magnetic oxide of iron)

Extraction of Cast Iron:



Reactions taking place in the blast furnace

Zone of combustion

$$\underset{\text{(Coke)}}{C} + O_2 \longrightarrow CO_2$$

Zone of reduction

$$Fe_2O_3 + 3CO \longrightarrow Fe + CO_2$$

Zone of reduction

$$Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$$

$$FeO + CO \longrightarrow Fe + CO_2$$

Zone of slag formation

$$\underset{\text{(lim e stone)}}{CaCO_3} \longrightarrow CaO + CO_2$$

$$CaO + SiO_2 \longrightarrow \underset{\text{Fusible slag}}{CaSiO_3};$$

Zone of fusion

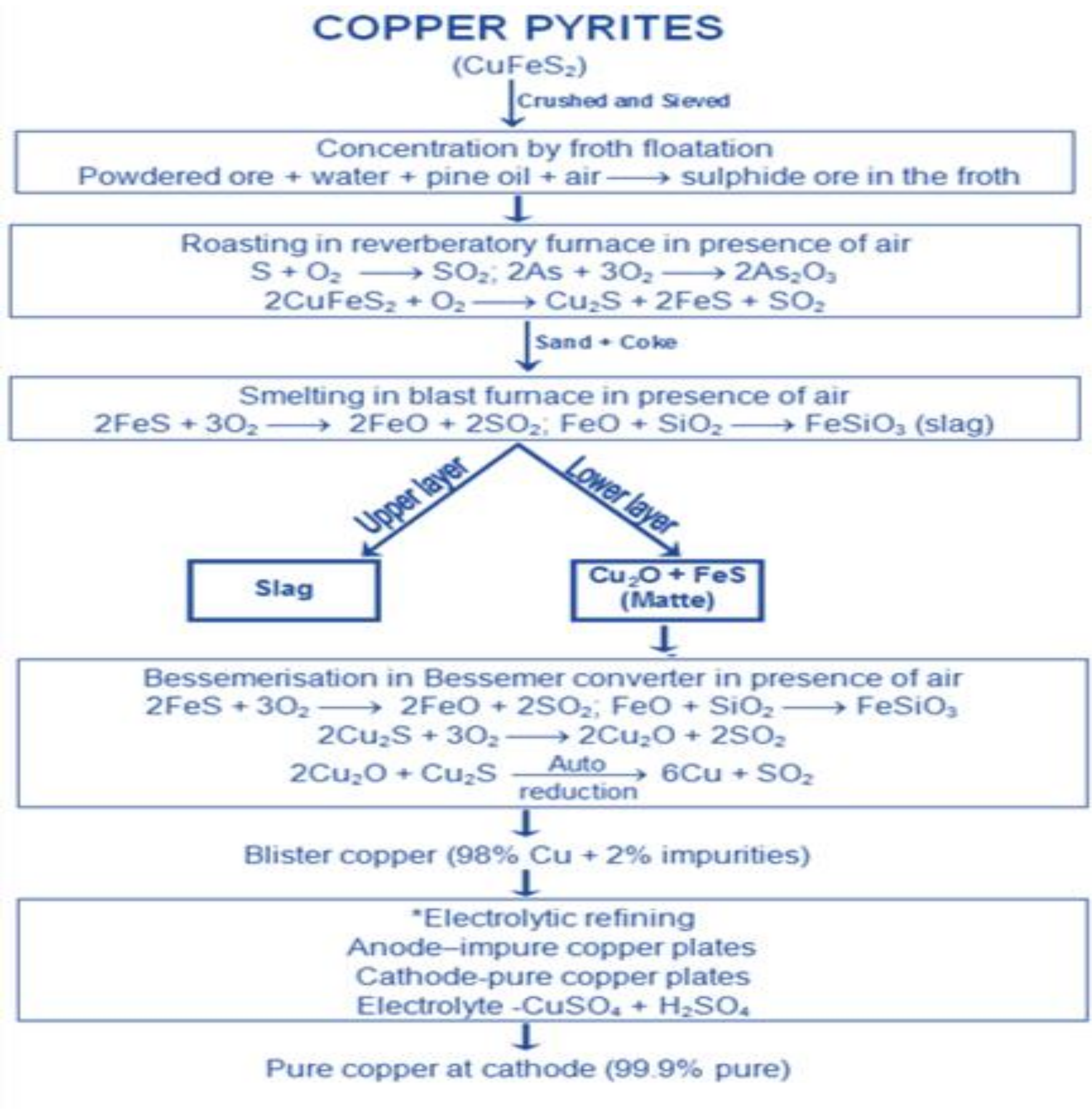
lower part of furnace

Molten iron is heavier than from molten slag. The two liquids are periodically tapped off. The molten iron tapped off from the furnace is solidifed into blocks called 'pigs'.

Extraction of Copper:

Ores of Copper:

- Copper glance (chalcocite) : Cu_2S
- Copper pyrites (Chalopyrites): $CuFeS_2$
- Malachite : $Cu(OH)_2 \times CuCO_3$
- Cuprite or Ruby copper: Cu_2O
- Azurite : $Cu(OH)_2 \times 2CuCO_3$



Refining of Metals:

Zone refining (Fractional crystallization): This method is employed for preparing extremely pure metals. This method is based upon the principle that when a molten solution of the impure metal is allowed to cool, the pure metal crystalises out while the impurities remain in the melt.

Electro-refining: In this method, the impure metal is converted into a block which forms the anode while cathode is a rod or plate of pure metal. These electrodes are suspended in an electrolyte which is the solution of a soluble salt of the metal usually a double salt of the metal. When electric current is passed, metal ions from the electrolyte are deposited at the cathode in the form of pure metal while an equivalent amount of metal dissolves from the anode and goes into the electrolyte solution as metal ion. The soluble impurities present in the crude metal anode go into the solution while the insoluble impurities settle down below the anode as anode mud.

Van-Arkel Method: In this method, the metal is converted into it volatile unstable compound such as iodide leaving behind the impurities. The unstable compound thus formed is decomposed to get the pure metal.

$$Ti(s) + 2I_2(s) + \xrightarrow[540K]{} TiI_4(g) \xrightarrow[Ti(s)]{1700K} Ti + 2I_2(g)$$

Cupellation and Poling are used for refining of metals, cupellation is contain impurities of other metals with traces of lead are removed from silver by heating impure silver with a blast of air in a cupel (an oval shaped pan made up of bone ash) in which lead is oxidised to lead oxide (PbO) which being volatile escapes leaving behind pure silver.Poling is used for refining of such metals which contain impurities of its own oxide.

Study of Representative Elements (spdf blocks)

Revision Notes on s-Block Elements:

Alkali Metals (Group I elements of modern periodic table):

Poperty		**Elements**					
		Li	**Na**	**K**	**Rb**	**Cs**	**Fr (Radioactive)**
Atomic Number		3	11	19	37	55	87
Electronic Configuration		2s’	3s’	4s’	5s’	6s’	7s’
Atomic Mass		6.94	22.99	39.10	85.47	13.91	223
Metallic radius (pm)		152	186	227	248	265	375
Ionic radius (M^+/pm)		76	102	138	152	167	180
Ionization enthalpy (kJ mol^{-1})	I	520	496	419	403	376	–
	II	7298	3562	3051	2633	2230	–
Electro negativity (Pauling Scale)		0.98	0.93	0.82	0.82	0.79	
Density/g cm^{-3} (at 298K)		0.53	0.97	0.86	1.53	1.90	
Melting point/K		454	371	336	312	302	
Boiling point/K		1615	1156	1032	961	944	
E°(V) at 298K for $M^+(aq) + e^- \rightarrow M(s)$		–3.04	–2.714	–2.925	–2.930	–2.927	
Occurrence in Atmosphere		18*	227**	1.84**	78.12*	2.6*	

*ppm (parts per million)

** percentage by weight

Physical Properties of Alkali Metals:

- These are soft in nature and can be cut with the help of knife except the lithium.
- The atoms of alkali metals have the largest size in their respective periods.
- The first ionization energy of the alkali metals are the lowest as compared to the elements in the other group.
- The alkali metals show +1 oxidation state.
- The alkali metals have low values of reduction potential (as shown in table-I) and therefore have a strong tendency to lose electrons and act as good reducing agents.
- The melting and boiling points of alkali metals are very low because the intermetallic bonds in them are quite weak.
- ll the alkali metals form ionic (electrovalent) compounds.
- The alkali metals are good conductors of heat and electricity.
- Alkali metals (except Li) exhibit photoelectric effect
- The alkali metals and their salts impart a characteristic colour to flame

	Li	Na	K	Rb	Cs
Color	Crimson Red	Golden Yellow	Pale Violet	Violet	Sky Blue
l/nm	670.8	589.2	766.5	780.0	455.5

Hydroxides of Alkali Metals:

a) All the alkali metals, their oxides, peroxides and superoxides readily dissolve in water to produce corresponding hydroxides which are strong alkalies.

- $2Na + 2H_2O \rightarrow 2NaOH + H_2$
- $Na_2O + 2H_2O\ 2NaOH$
- $Na2O_2 + 2H_2O \rightarrow 2NaOH + H_2O_2$
- $2KO_2 + 2H_2O \rightarrow 2KOH + H_2O_2 + O_2$

b) The basic strength of these hydroxides increases as we move down the group Li to Cs.

c) All these hydroxides are highly soluble in water and thermally stable except lithium hydroxide.

d) Alkali metals hydroxides being strongly basic react with all acids forming salts.

- $NaOH + HCl \rightarrow NacI + H_2O$
- $2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$

Halides of Alkali metals:

$M_2O + 2HX \rightarrow 2MX + H_2O$

$MOH + HX \rightarrow MX + H_2O$

$M_2CO_3 + 2HX \rightarrow 2MX + CO_2 + H_2O$ (M = Li, Na, K, Rb or Cs)

(X = F, Cl, Br or I)

a) Standard enthalpies of formation in (kJ/mol^{-1})

Element	MF	MCl	MBr	MI
Li	-612	-398	-350	-271
Na	-569	-400	-360	-288
K	-563	-428	-392	-328
Rb	-549	-423	-389	-329
Cs	-531	-424	-395	-

b) Covalent Character:

- Small cation and large anion favors covalency.
- Order: LiCl > NaCl > KCl > RbCl > CsCl & . LiI > LiBr > LiCl > LiF
- Greater the charge on the cation greater is its polarizing power and hence larger is the covalent character: $Na^+Cl^- < Mg^{+2}Cl_2 < Al^{+3}\,Cl_3$
- Greater the charge on the anion, more easily it gets polarized thereby imparting more covalent character to the compound formed eg covalent character increase in the order. $NaCl < Na_2SO_4 < Na_3PO_4$

c) Lattice Energies: Amount of energy required to separate one mole of solid ionic compound into its gaseous ions.

Greater the lattice energy, higher is the melting point of the alkali metals halide and lower is its solubility in water

d) Hydration Energy: Amount of energy released when one mole of gaseous ions combine with water to form hydrated ions.

- M^+ (g) + aq → M^+ (aq) + hydration energy
- X^- (g) + aq → X^- (aq) + hydration energy

Higher the hydration energy of the ions greater is the solubility of the compound in water.

The solubility of the most of alkali metal halides except those of fluorides decreases on descending the group since the decrease in hydration energy is more than the corresponding decrease in the lattice energy.

Due to high hydration energy of Li^+ ion, Lithium halides are soluble in water except LiF which is sparingly soluble due to its high lattice energy.

For the same alkali metal the melting point decreases in the order

fluoride > chloride > bromide > iodide

For the same halide ion, the melting point of lithium halides are lower than those of the corresponding sodium halides and thereafter they decrease as we move down the group from Na to Cs.

The low melting point of LiCl (887 K) as compared to NaCl is probably because LiCl is covalent in nature and NaCl is ionic.

Anomalous Behavior of Lithium and diagonal relationship with Magnesium:

Li has anomalous properties due to

- Very small size
- High polarizing Power

Lithium show diagonal relationship with magnesium because both elements have almost same polarizing power.

- The melting point and boiling point of lithium are comparatively high.
- Lithium is much harder than the other alkali metals. Magnesium is also hard metal.
- Lithium reacts with oxygen least readily to form normal oxide whereas other alkali metals form peroxides and superoxides.
- LiOH like $Mg(OH)_2$ is weak base. Hydroxides of other alkali metals are strong bases.
- Due to their appreciable covalent nature, the halides and alkyls of lithum and magnesium are soluble in organic solvents.
- Unlike elements of group 1 but like magnesium. Lithium forms nitride with nitrogen.$6Li + N_2 \rightarrow 2Li_3N$
- LiCl is deliquescent and crystallizes as a hydrate, $LiCl2H_2O$. Other alkali metals do not form hydrates. also forms hydrate, $MgCl_2.8H_2O$.
- Unlike other alkali metals lithium reacts directly with carbon to form an ionic carbide. Magnesium also forms a similar carbide.

- The carbonates, hydroxides and nitrates of lithium as well as magnesium decompose on heating.
    - $Li_2CO_3 \rightarrow Li_2O + CO_2$
    - $MgCO_3 \rightarrow MgO + CO_2$
    - $2LiOH \rightarrow Li_2O + H_2O$
    - $Mg(OH)_2 \rightarrow MgO + H_2O$
    - $4LiNO_3 \rightarrow 2Li_2O + 4NO_2 + O_2$
    - $2Mg(NO_3)_2 \rightarrow 2Mg + 4NO_2 + O_2$
- The corresponding salts of other alkali metals are stable towards heat.

Lithium nitrate, on heating, decomposes to give lithium oxide, Li_2O whereas other alkali metals nitrate decomposes to give the corresponding nitrite.

- $4LiNO_3 \rightarrow 2Li_2O + 4NO_2 + O_2$
- $2NaNO_3 \rightarrow 2NaNO_2 + O_2$
- $2KNO_3 \rightarrow 2KNO_2 + O_2$
- Li_2CO_3, LiOH, LiF and Li_3PO_4 are the only alkali metal salts which are insoluble in water. The corresponding magnesium compounds are also insoluble in water.
- Hydrogen carbonates of both lithium and magnesium can not be isolated in solid state. Hydrogen carbonates of other alkali metals can be isolated in solid state.

Sodium Hydroxide (NaOH):

a. Properties

- NaOH is stable towards heat but is reduced to metal when heated with carbon

  $2NaOH + 2C \rightarrow 2Na + 2CO + H_2$
- $FeCl_3 + 3NaOH \rightarrow Fe(OH)_3 + 3NaCl$
- $NH_4Cl + NaOH \rightarrow NaCl + NH_3$ (pungent smell) $+ H_2O$
- $HgCl_2 + 2NaOH \rightarrow HgO$ (yellow powder) $+ 2NaCl + H_2O$
- $Zn(OH)_2 \uparrow + 2NaOH \rightarrow Na_2ZnO_2 + 2H_2Oh$
- $Al_2O_3 \uparrow + 2NaOH \rightarrow 2NaAlO_2 + H_2O$
- $SiO_2 + 2NaOH \rightarrow Na_2SiO_3 + H_2O$
- $3P + 3NaOH + 3H_2O \rightarrow PH_3 + 3NaH_2PO_2$
- $2Al + 2NaOH + 2H_2O \rightarrow 3H_2 + 2NaAlO_2$

b. Uses

- It is used in the manufacture of paper, soap and artificial silk.
- It is used in petroleum refining.
- It is used for mercerizing cotton.
- It is used for the preparation of sodium metal and many salts of sodium.

Sodium Carbonate (Washing soda) (Na_2CO_3):

a. Preparation:

Solvay process:

Carbon dioxide gas is bubbled through a brine solution saturated with ammonia and it results in the formation of sodium hydrogen carbonate.

- $NH_3 + H_2O + CO_2 \rightarrow NH_4HCO_3$
- $NaCl + NH_4HCO_3 \rightarrow NaHCO_3 + NH_4Cl$

Sodium hydrogen carbonate so formed precipitates out because of the common ion effect caused due to the presence of excess of NaCl. The precipitated $NaHCO_3$ is filtered off and then ignited to get Na_2CO_3.

$2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$

b. Properties

1. The aqueous solution absorbs CO_2 yielding sparingly soluble sodium bicarbonate.
    - $Na_2CO_3 + H_2O + CO_2 \rightarrow 2NaHCO_3$
2. Dissolves in acids with an effervescence of carbon dioxide and is causticised by lime to give caustic soda.
    - $Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$
    - $Na_2CO_3 + Ca(OH)_2 \rightarrow 2NaOH + CaCO_3$
3. Fusion with silica, sodium carbonate yields sodium silicate.
    - $Na_2CO_3 + SiO_2 \rightarrow Na_2SiO_3 + CO_2$
4. Hydrolysis – being a salt of a strong base (NaOH) and weak acid (H_2CO_3), when dissolved in water sodium carbonate. Undergoes hydrolysis to form an alkaline solution
    - $Na_2CO_3 + 2H_2O \rightarrow H_2CO_3 + 2NaOH$

c. Uses

- It is used for softening hard water.
- A mixture of sodium carbonate & potassium carbonate is used as fusion mixture.
- As an important laboratory reagent both in qualitative and quantitative analysis.
- It is used in paper, paints and textile industries.
- It is used for washing purposes in laundry.
- It is used in the manufacture of glass, borax, soap and caustic soda.

Alkali Earth Metals (Group II elements of modern periodic table):

Beryllium (Be), Magnesium (Mg), Calcium (Ca), Strontium (Sr), Barium (Ba) and Radium (Ra).

- **Physical Properties of Alkali Earth Metals:**

1. **Alkali earth metals are almost similar in properties to the corresponding alkali metals.**
   - Higher melting points than alkali metals
   - Higher boiling points alkali metals
   - Higher densities alkali metals
   - Harder than the corresponding alkali metals

2. **Atomic and ionic radii**

   The atomic radii as well as ionic radii of the members of the family are smaller than the corresponding members of alkali metals.

3. **Ionization energy:** The alkaline earth metals owing to their large size of atoms have fairly low values of ionization energies as compared to the p – block elements. However with in the group, the ionization energy decreases as the atomic number increases. It is because of increase in atomic size due to addition of new shells and increase in the magnitude of screening effect of the electrons in inner shells. Because their $(IE)_1$ is larger than that of their alkali metal neighbours, the group IIA metals trend to the some what less reactive than alkali metals. The general reactivity trend is Ba > Sr > Ca > Mg > Be.

4. **Oxidation state:** The alkaline earth metal have two electrons in their valence shell and by losing these electrons, these atoms acquire the stable noble gas configuration. Thus, unlike alkali metals, the alkaline earth metals exhibit +2 oxidation state in their compounds.

   $M \rightarrow M^{+2} + 2e^-$

   [noble gas]

5. **Characteristic flame colouration:**

Ion	Colour
Ca^{2+}	Brick-red
Sr^{2+}	Crimson
Ba^{2+}	Apple green
Ra^{2+}	Carmine – red

Difference between alkali metals and alkali earth metals:

	Properties	Alkaline earth metals	Alkali metals
1.	Electronic configuration	Two electrons are present in the valency shall. The configuration is ns^2 (bivalent)	One electron is present in the valency shell. The configuration is ns^1 (monovalent) more electropositive
2.	Valency	Bivalent	Monovalent
3.	Electropositive nature	Less electropositive	More electropositive
4.	Hydroxides	Weak bases, less soluble and decompose on heating.	Strong bases, highly soluble and stable towards heat.
5.	Bicarbonates	These are not known in free state. Exist only in solution.	These are known in solid state.
6.	Carbonates	Insoluble in water. Decompose on heating.	Soluble in water. Do not decompose on heating ($LiCO_3$ is an exception)
7.	Action of nitrogen	Directly combine with nitrogen and form nitrides	Do not directly combine with nitrogen except lithium
8.	Action of carbon	Directly combine with carbon and form carbides	Do not directly combine with carbon
9.	Nitrates	Decompose on heating evolving a mixture of NO_2 and oxygen	Decompose on heating evolving only oxygen
10.	Solubility of salts	Sulphates, phosphates fluorides, chromates, oxalates etc are insoluble in water	Sulphates, phosphates, fluorides, chromates, oxides etc are soluble in water.
11.	Physical properties	Comparatively harder. High melting points. Diamagnetic.	Soft, low melting points paramagnetic.
12.	Hydration of compounds	The compounds are extensively hydrated. $MgCl_2.6H_2O$, $CaCl_2.6H_2O$, $BaCl_2.2H_2O$ are hydrated chlorides.	The compounds are less hydrated. NaCl, KCl, RbCl form non – hydrated chlorides
13.	Reducing power	Weaker as ionization potential values are high and oxidation potential values are low.	Stronger as ionization potential values are low and oxidation potential values are high.

Chemical Properties of Alkali Earth Metals:

1. **Reaction with water :**
   - $Mg + H_2O \rightarrow MgO + H_2$
   - or, $Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2$
   - $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$

2. Formation of oxides and nitrides

- Be + O_2 (air) +Δ→ 2BeO
- 3Be + N2 (air) +Δ → Be_3N_2
- Mg + air + Δ → MgO + Ng_3N_2

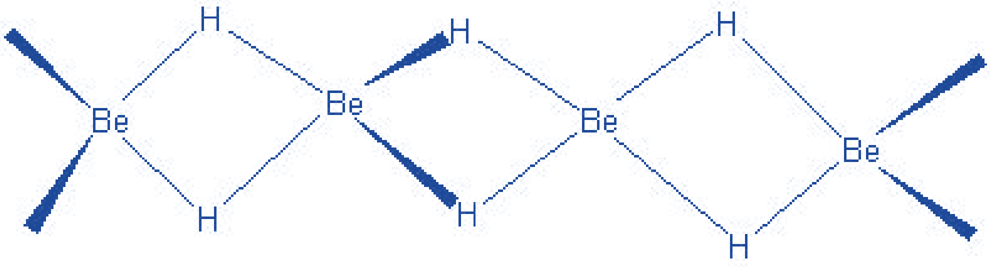
3. Formation of Nitrides

- $3M + N_2 + \Delta \rightarrow M_3N_2$
- $Be_3N_2 + \Delta \rightarrow 3Be + N_2$
- $Ba_3N_2 + 6H_2O + \Delta \rightarrow 3Ba(OH)_2 + 2NH_3$
- $Ca_3N_2 + 6H_2O + \Delta \rightarrow 3Ca(OH)_2 + 2NH_3$

4. Reaction with hydrogen:

$M + H_2 + \Delta \rightarrow MH_2$

Both BeH_2 and MgH_2 are covalent compounds having polymeric structures in which H – atoms between beryllium atoms are held together by three centre – two electron (3C - 2e) bonds as shown below:



5. Reaction with carbon – (Formation of carbides)

When BeO is heated with carbon at 2175 – 2275 K a brick red coloured carbide of the formula Be_2C is formed

$$2BeO + 2C \xrightarrow{2175-2275K} Be_2C + 2CO$$

It is a covalent compound and react water forming methane.

$Be_2C + 4H_2O \rightarrow 2Be(OH)_2 + CH_4$

6. Reaction with Ammonia:

Like alkali metal, the alkaline earth metals dissolve in liquid ammonia to give deep blue black solution from which ammoniates $[M(NH_3)_6]^{2+}$ can be recovered.

Anamolous Behaviour of Beryllium:

- Be is harder than other members of its group.
- Be is lighter than Mg.
- Its melting and boiling points are higher than those of Mg & other members.
- Be does not react with water while Mg reacts with boiling water.
- BeO is amphoteric while MgO is weakly basic.
- Be forms covalent compounds whereas other members form ionic compounds.
- Beryllium carbide reacts with water to give methane whereas carbides of other alkaline earth metals gives acetylene gas.
    - $Be_2C + 4H_2O \rightarrow 2Be(OH)_2 + CH_4$
    - $Mg_2C_2 + 2H_2O \rightarrow Mg(OH)_2 + C_2H_2$
    - $CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2$
- Beryllium does not exhibit coordination number more than four as it has four orbitals in the valence shell. The other members of this group has coordination number

Diagonal relationship of Be with Al:

- Unlike groups – 2 elements but like aluminium, beryllium forms covalent compounds.
- The hydroxides of Be, [$Be(OH)_2$] and aluminium [$Al(OH)_3$] are amphoteric in nature, whereas those of other elements of group – 2 are basic in nature.
- The oxides of both Be and Al i.e. BeO and Al_2O_3 are high melting insoluble solids.
- $BeCl_2$ and $AlCl_3$ have bridged chloride polymeric structure.
- The salts of beryllium as well as aluminium are extensively hydrolysed.
- Carbides of both the metal reacts with water liberating methane gas.
    - $Be_2C + 4H_2O \rightarrow 2Be(OH)_2 + CH_4$
    - $Al_4C_3 + 12H_2O \rightarrow 4Al(OH)_3 + 3CH_4$
- The oxides and hydroxides of both Be and Al are amphoteric and dissolve in sodium hydroxide as well as in hydrochloric acid.
    - $BeO + 2HCl \rightarrow BeCl_2 + H_2O$
    - $BeO + 2NaOH \rightarrow Na_2BeO_2 + H_2O$
    - $Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + H_2O$
    - $Al_2O_3 + 2NaOH \rightarrow 2NaAlO_2 + H_2O$
- Like Al, Be is not readily attacked by acids because of the presence of an oxide film.

Calcium Carbonate ($CaCO_3$):

It occurs in nature as marble, limestone, chalk, coral, calcite, etc. It is prepared as a white powder, known as precipitated chalk, by dissolving marble or limestone in hydrochloric acid and removing iron and aluminium present by precipitating with NH_3, and then adding ammonium carbonate to the solution; the precipitate is filtered, washed and dried.

$CaCl_2 + (NH_4)_2CO_3 \rightarrow CaCO_3 + 2NH_4Cl$
It dissolves in water containing CO_2, forming $Ca(HCO_3)_2$ but is precipitated from solution by boiling.

$CaCO_3 + H_2O + CO_2 \leftrightarrow Ca(HCO_3)_2$

Plaster of Paris, $CaSO_4.1/2\ H_2O$ or $(CaSO_4)_2.H_2O$:

It occurs in nature as gypsum and the anhydrous salt as anhydride. It is prepared by precipitating a solution of calcium chloride or nitrate with dilute sulphuric acid.

The effect of heat on gypsum or the dihydrate presents a review of interesting changes. On heating the monoclinic gypsum is first converted into orthorhombic form without loss of water. When the temperature reaches 120°C, the hemihydrate or plaster of paris is the product. The latter losses water, becomes anhydrous above 200°C and finally above 400°C, it decomposes into calcium oxide.

$2CaSO_4 \rightarrow 2CaO + 2SO_2\uparrow + O_2\uparrow$

The addition of common salt accelerates the rate of setting, while a little borax or alum reduces it. The setting of plaster of paris is believed to be due to rehydration and its reconversion into gypsum.

$2CaSO_4.\ 1/2\ H_2O + 3H_2O \rightarrow 2CaSO_4.\ 2H_2O$
Plaster of Paris Gypsum

Uses

- Plaster of pairs is used for producing moulds for pottery and ceramics & casts of statues & busts.
- It is used in surgical bandages used for plastering broken or fractured bones.
- It is also used in dentistry

Industrial uses of lime and Limestone

Uses of lime

- Calcium oxide is called lime or quick lime. It main industrial uses are
- It is used in steel industry to remove phosphates and silicates as slag.
- It is used to make cement by mixing it with silica, alumina or clay.(iii) It is used in making glass.
- It is used in lime soda process for the conversion of Na_2CO_3 to NaOH & vice versa.
- It is used for softening water, for making slaked lime $Ca(OH)_2$ by treatment with water and calcium carbide CaC_2.

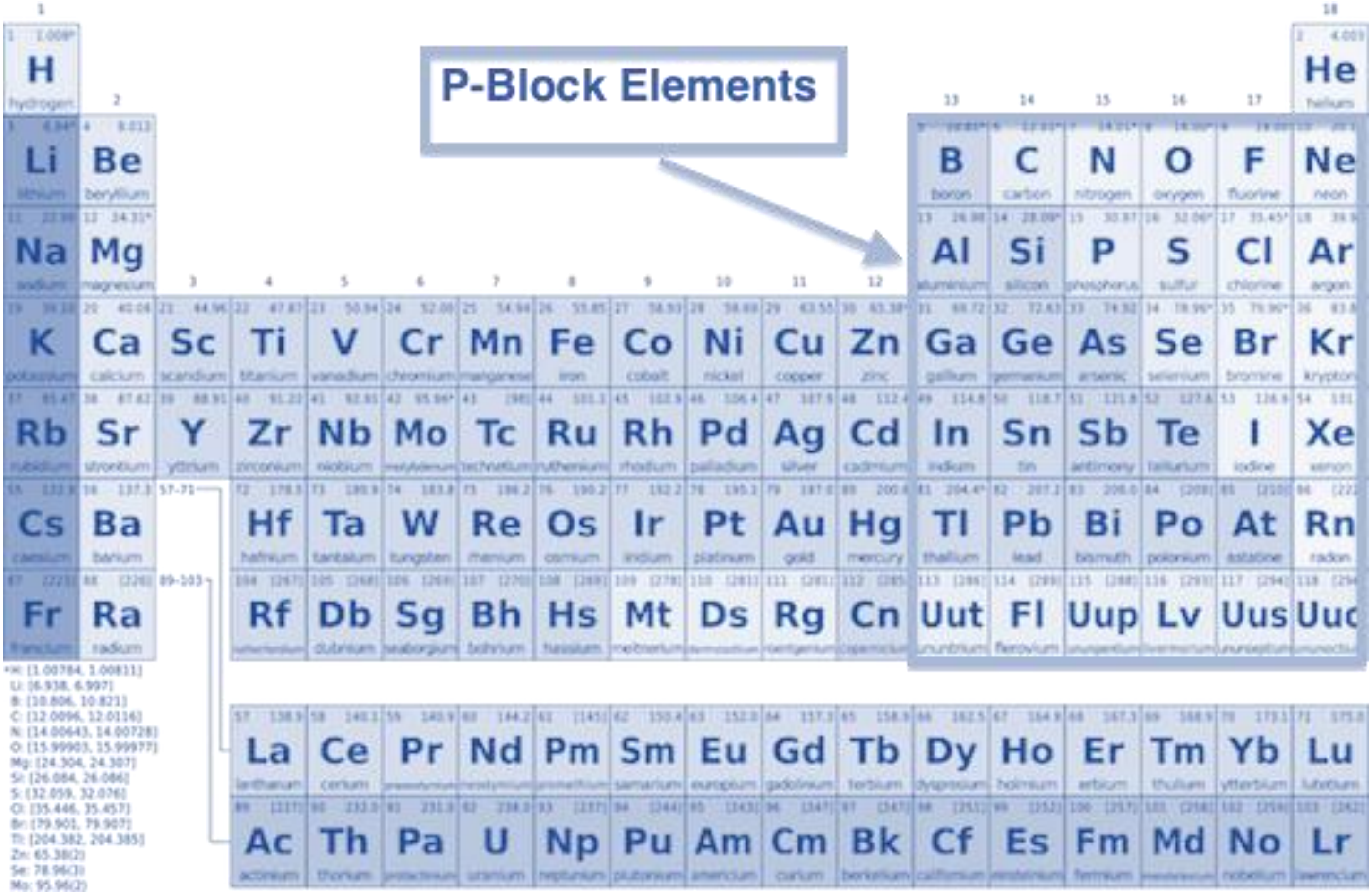
Uses of Slaked lime [$Ca(OH)_2$]

- Slaked lime is used as a building material in form of mortar. It is prepared by mixing 3 – 4 times its weight of sand and by gradual addition of water. Its sets into a hard mass by loss of H_2O and gradual absorption of CO_2 from air.
- In manufacture of bleaching powder by passing Cl_2 gas.
- In making glass and in the purification of sugar and coal gas.
- It is used in softening of hard water.

Uses of lime stone ($CaCO_3$)

- It is used as building material in form of marble.
- In manufacture of quick lime.
- It is used as a raw material for the manufacture of Na_2Co_3 in solvay – ammonia process.
- Commercial limestone contains iron oxide, alumina, magnesia, silica & sulphur with a CaO content of 22 – 56% MgO content upto 21%. It is used as such as a fertilizer.

Revision Notes on p-Block Elements:



Boron Family (Group 13 Elements)

- **Members:** B, Al, Ga, In & Tl
- **Melting Point**: Decreases from B to Ga and then increases up to Tl.
- **Ionization Energies:** $1^{st} <<< 2^{nd} < 3^{rd}$
- **Metallic Character:** Increases from B to Tl. B is non-metal

Boron

Preparation of Boron:

- From Boric Acid: $B_2O_3(s) + 3Mg(s) \rightarrow 2B(s) + 3MgO(s)$
- From Boron Trichloride
  - (at 1270 k): $2BCl_3 + 3H_2(g) \rightarrow 2B(s) + 6HCl(g)$
  - (at 900 ^{0}C): $2BCl_3(g) + 3Zn(s) \rightarrow 2B(s) + 3ZnCl_2(s)$
- By electrolysis of fused mixture of boric anhydride (B_2O_3) and magnesium oxide (MgO) & Magnesium fluoride at 1100 ^{0}C
  - $2MgO- \rightarrow 2Mg + O_2(g)$
  - $B_2O_3 + 3Mg \rightarrow 2B + 3MgO$

- By thermal decomposition of Boron hydrides & halides:
  $B_2H_6\,(g) + \Delta \rightarrow 2B(s) + 3H_2\,(g)$

Compounds of Boron:

Orthoboric acid (H_3BO_3)

Preparation of Orthoboric acid

- **From borax** : $Na_2B_4O_7 + H_2SO_4 + 5H_2O \rightarrow Na_2SO_4 + 4H_3BO_3$
- **From colemanite** : $Ca_2B_6O_{11} + 2SO_2 + 11H_2O \rightarrow 2Ca(HSO_3)_2 + 6H_3BO_3$

Properties of Orthoboric acid

- **Action of Heat**:

$$4H_3BO_3 \xrightarrow[-4H_2O]{373\,k} 4HBO_2 \xrightarrow[-H_2O]{413\,k} H_2B_4O_7 \xrightarrow[-H_2O]{\text{Read heat}} 2B_2O_3$$

Metaboric acid Tetraboric acid Boron trioxide

- **Weak monobasic acidic behavior:**
  $B(OH)_3 \leftrightarrow H_3BO_3 \leftrightarrow H^+ + H_2O +$
  Thus on titration with NaOH, it gives sodium metaborate salt
  $H_3BO_3 + NaOH \leftrightarrow NaBO_2 + 2H_2O$

- **Reaction with Metaloxide:**

$$B(OH)_3 + MO \xrightarrow{\text{Fusion}} M - \text{borates}$$

Where M stands for a bivalent metal

- **Reaction with Ammonium boro fluoride:**

$$B(OH)_3 \xrightarrow[\text{Fusion}]{NH_4HF_2} NH_4BF_4 \xrightarrow[\text{heat}]{B_2O_3} BF_3$$

Ammonium boro fluoride

Borax (sodium tetraborate) $Na_2B_4O_7.\ 10H_2O$

Preparation from Boric Acid

$4H_3BO_3 + Na_2CO_3 \dashrightarrow Na_2B_4O_7 + 6H_2O + CO_2$

Properties of Borax

- **Basic Nature**:-
  Aqueous solution of borax is alkaline in nature due to its hydrolysis
  $Na_2B_4O_7 + 3H_2O \rightarrow NaBO_2 + 3H_3BO_3$
  $NaBO_2 + 2H_2O \rightarrow NaOH + H_3BO_3$

- **Action of heat:**

$$Na_2B_4O_7.10H_2O \xrightarrow[-10H_2O]{heat} Na_2B_4O_7 \xrightarrow{740^\circ C} 2NaBO_2 + B_2O_3$$

Diborabe(B_2H_6)

Preparation of Diborane:

Reduction of Boron Trifluoride:

$BF_3 + 3LiAlH_4 \rightarrow 2B_2H_6 + 3 LiAl F_4$

From $NaBH_4$:

$2NaBH_4 + H_2SO_4 \rightarrow B_2H_6 + 2H_2 + Na_2SO_4$

$2NaBH_4 + H_3PO_4 \rightarrow B_2H_6 + 2H_2 + NaH_2PO_4$

Properties of Diborane:

- **Reaction with water**: $B_2H_6 + H_2O$ -->$2H_3BO_3 + 6H_2$
- **Combustion:** $B_2H_6 + 2O_2$ --? $B_2O_3 + 3H_2O$ $\Delta H = -2615$ kJ/mol

Compounds of Aluminium:

Aluminium Oxide or Alumina (Al_2O_3)

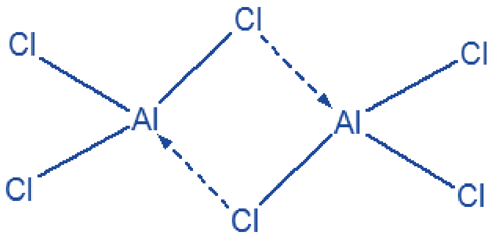
$2Al(OH)_3$ +Heat $\rightarrow$ $Al_2O_3 + 2H_2O$

$2Al(SO_4)_3$ +Heat $\rightarrow$ $Al_2O_3 + 2SO_3$

$(NH_4)_2Al_2(SO_4)_3{\cdot}24H_2O$ --> $2NH_3 + Al_2O_3 + 4SO_3 + 25 H_2O$

Aluminum Chloride $AlCl_3$:

Structure of Aluminium Chloride:



Properties of Aluminium Chloride

- White, hygroscopic solid
- Sublimes at 183 ^{0}C
- Forms addition compounds with NH_3, PH_3, $COCl_2$ etc**.**
- Hydrolysis: $AlCl_3 + 3H_2O$ --> $Al(OH)_3 + 3HCl + 3H_2O$
- Action of Heat: **2**$AlCl_3 .6H_2O$ --> $2Al(OH)_3$ à Al_2O_3+ $6HCl + 3H_2O$

Carbon Family (Group 14 Elements):

- **Members:** C, Si, Ge, Sn, & Pb
- **Ionization Energies:** Decreases from C to Sn and then increases up to Pb.
- **Metallic Character:** C and Si are non metals, Ge is metalloid and Sn and Pb are metals
- **Catenation:** C and Si show a tendency to combine with its own atoms to form long chain polymers

Compounds of Carbon:

Carbon Monoxide

Preparation of Carbon Monoxide

- By heating carbon in limited supply of oxygen: $C + 1/2O_2$ --> CO.
- By heating oxides of heavy metals e.g. iron, zinc etc with carbon.
  - $Fe_2O_3 + 3C \rightarrow 2Fe + 3CO$
  - $ZnO + C \rightarrow Zn + CO$
- By passing steam over hot coke: $C + H_2O \rightarrow CO + H_2$ (water gas)
- By passing air over hot coke: $2C + O_2 + 4N_2 \rightarrow 2CO + 4N_2$ (Producer gas)

?Properties of Carbon Monoxide:

- A powerful reducing agent : $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$
  $CuO + CO \rightarrow Cu + CO_2$
- Burns in air to give heat and carbon dioxide: $CO + 1/2O_2 \rightarrow CO_2$ + heat.

Tests For Carbon Monoxide:

- Burns with blue flame
- Turns the filter paper soaked in platinum or palladium chloride to *pink or green*.

Carbon di-oxide

Preparation of Carbon di-oxide

- By action of acids on carbonates: $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$
- By combustion of carbon: $C + O_2 \rightarrow CO_2$

Properties of Carbon di-oxide

- It turns lime water milky $Ca(OH)_2 + CO_2 \rightarrow CaCO_3{}^{-} + H_2O$,
- Milkiness disappears when CO_2 is passed in excess
  $CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2$
- Solid carbon dioxide or *dry ice* is obtained by cooling CO2 under pressure. It passes from the soild state straight to gaseous state without liquefying (hence dry ice).

Carbides:

- **Salt like Carbides :** These are the ionic salts containing either C_2^{2-} (acetylide ion) or C^{4-} (methanide ion)e.g. CaC_2, Al_4C_3, Be_2C.
- **Covalent Carbides :** These are the carbides of non-metals such as silicon and boron. In such carbides, the atoms of two elements are bonded to each other through covalent bonds. SiC also known as *Carborundum*.
- **Interstitial Carbides :** They are formed by transition elements and consist of metallic lattices with carbon atoms in the interstices. e.g. tungsten carbide WC, vanadium carbide VC.

Compounds of Silicon:

Sodium Silicate (Na_2SiO_3):

?Prepared by fusing soda ash with pure sand at high temperature:

$Na_2CO_3 + SiO_3 \rightarrow Na_2SiO_3 + CO_2$

Silicones:

Silicon polymers containing Si – O – Si linkages formed by the hydrolysis of alkyl or aryl substituted chlorosilanes and their subsequent polymerisation.

Silicates:

Salts of silicic acid, H_4SiO_4 comprised of SiO_4^{4-} units having tetrahedral structure formed as result of sp^3hybridization.

Nitrogen Family (Group 15 Elements)

- **Members:** N, P, As, Sb & Bi
- **Atomic Radii:** Increases down the group. Only a small increases from As to Bi.
- **Oxidation state:** +3, +4 & +5.Stability of +3 oxidation state increases down the group.
- **Ionization energy:** Increases from N to Bi.

Nitrogen

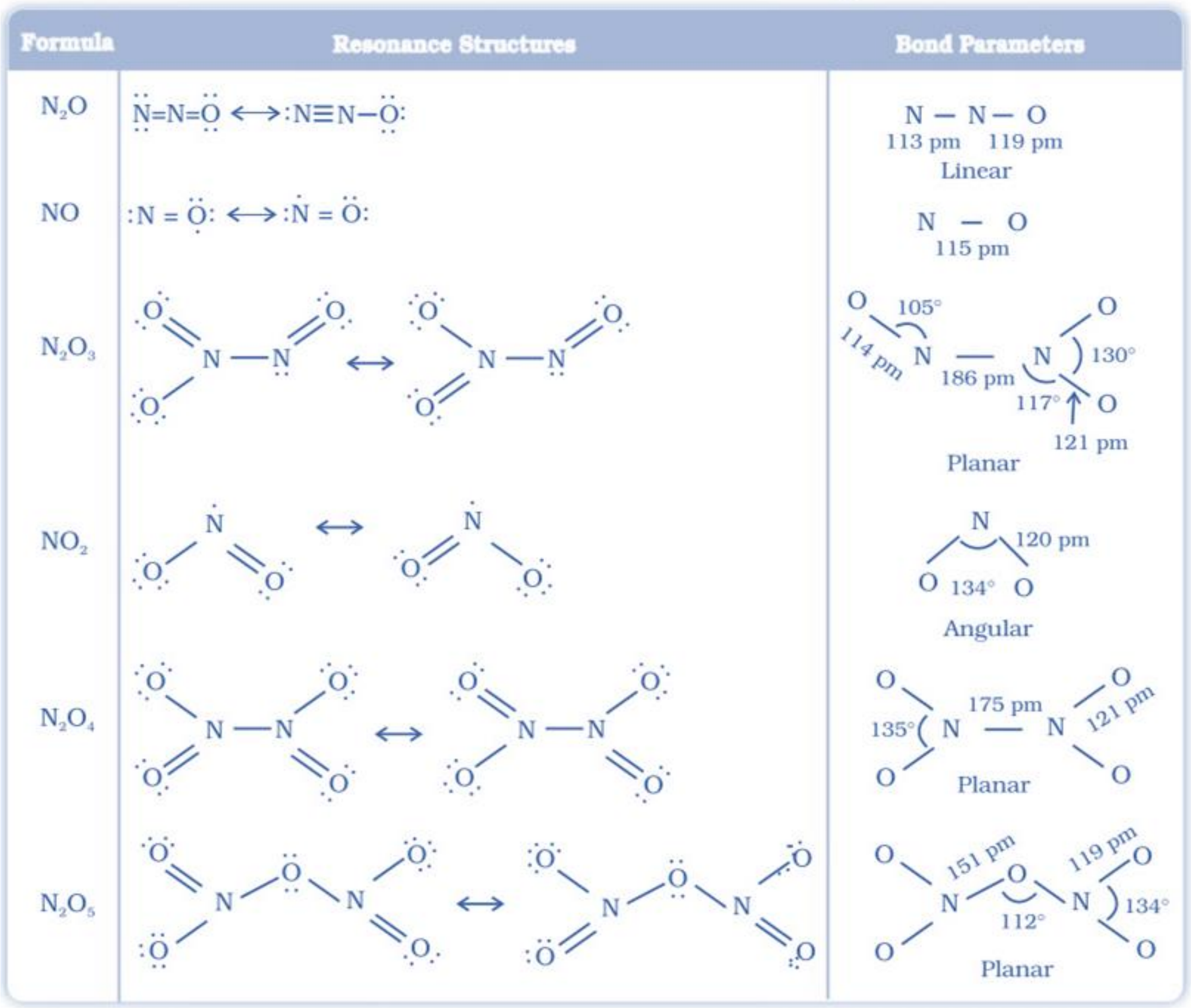
Preparation of Nitrogen:

- $3CuO + 2NH_3 + \text{Heat} \dashrightarrow N_2 + Cu + 3H_2O$
- $CaOCl_2 + 2NH_3 + \text{Heat} \dashrightarrow CaCl_2 + 3H_2O + N_2$
- $NH_4NO_2 + \text{Heat} \dashrightarrow 3H_2O + N_2 + Cr_2O_3$

Properties of Dinitrogen:

- Formation of Nitrides (with Li, Mg, Ca & Al): $Ca + N_2 + \text{Heat} \rightarrow Ca_3N_2$
- Oxidation: $N_2 + O_2 \rightarrow 2NO$
- Reaction with carbide (at 1273 K): $CaC_2 + N_2 \rightarrow CaCN_2 + C$

Oxides of Nitrogen



Formula	Resonance Structures	Bond Parameters
N_2O	$\ddot{N}=N=\ddot{O} \longleftrightarrow :N\equiv N-\ddot{O}:$	N — N — O 113 pm 119 pm Linear
NO	$:N=\ddot{O}: \longleftrightarrow :\dot{N}=\ddot{O}:$	N — O 115 pm
N_2O_3		105° 114 pm 186 pm 130° 117° 121 pm Planar
NO_2		120 pm 134° Angular
N_2O_4		135° 175 pm 121 pm Planar
N_2O_5		151 pm 119 pm 112° 134° Planar

Oxy -Acids of Nitrogen :

Oxy Acids	Name of oxy – acid
1. $H_2N_2O_2$	Hyponitrous acid
2. $H_2\,NO_2$	Hydronitrous acid
3. HNO_2	Nitrous acid
4. HNO_3	Nitric acid
5. HNO_4	Per nitric acid

Ammonia (NH_3):

Preparation of Ammonia:

- By heating an ammonium salt with a strong alkali ;$NH_4Cl + NaOH \dashrightarrow NH_3 + NaCl + H_2O$
- By the hydrolysis of magnesium nitride: $Mg_3N_2 + 6H_2O \dashrightarrow 3Mg(OH)_2 + 2NH_3$.
- Haber's process : $N_2(g) + 3H_2(g) \dashrightarrow 2NH_3(g)$.

Properties of Ammonia:

- **Basic nature :** Its aq. solution is basic in nature and turns red litmus blue. $NH_3 + H_2O \leftrightarrow NH_4^+ + OH^-$

- **Reaction with halogens :**
  - $8NH_3 + 3Cl_2 \dashrightarrow 6NH_4Cl + N_2$
  - $NH3 + 3Cl_2$ (in excess) $\rightarrow NCl_3 + 3HCl$
  - $8NH3 + 3Br_2 \rightarrow 6NH4Br + N_2$
  - $NH_3 + 3Br_2$ (in excess) $\rightarrow NBr_3 + 3HBr$
  - $2NH_3 + 3I_2 \rightarrow NH_3.NI_3 + 3HI$
  - $8NH_3.NI_3 \rightarrow 6NH_4I + 9I_2 + 6N_2$

- **Complex formation :**
  - $Ag^+ + NH_3 \rightarrow [Ag(NH_3)_2]^+$
  - $Cu^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4]^{2+}$
  - $Cd^{2+} + 4NH_3 \rightarrow [Cd(NH_3)_4]^{2+}$

Precipitation of heavy metal ions from the aq. solution of their salts :

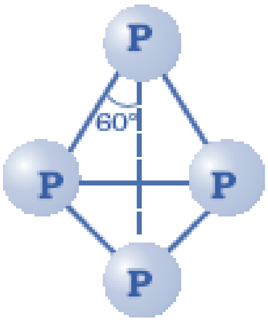
- $FeCl_3 + 3NH_4OH \rightarrow \underset{\text{Brown ppt.}}{Fe(OH)_3} + 3NH_4Cl$
- $AlCl_3 + 3NH_4OH \rightarrow \underset{\text{White ppt.}}{Al(OH)_3} + 3NH_4Cl$
- $CrCl_3 + 3NH_4OH \rightarrow \underset{\text{Green ppt.}}{Cr(OH)_3} + 3NH_4Cl$

Phosphorus:

Allotropy of Phosphorus:

a) White phosphorus:

- Translucent white waxy solid
- Extremely reactive
- Poisonous and insoluble in water



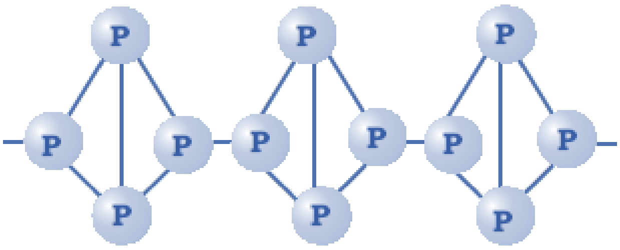
b) Red Phosphorus:

- Formed by heating white phosphorus in absence of air.
- Does not burn spontaneously at room temperature.

c) Black Phosphorus: Formed by further heating of red phosphorus.

Compounds of Phosphorus:

a) Phosphine, PH_3:



<u>Preparation of Phosphine</u>

- $Ca_3P_2 + 6H_2O \rightarrow 2\ PH_3 + 3\ Ca(OH)_2$
- $4H_3PO_3$ +Heat $\rightarrow PH_3 + 3\ H_3PO_4$
- $PH_4I + KOH \rightarrow PH_3 + KI + H_2O$
- $P_4 + 3KOH + 3H_2O \rightarrow PH_3 + 3KH_3PO_2$

Properties of Phosphine:

- Formation of Phosphonic Iodide: $PH_3 + HI$ à PH_4I
- Combustion: $PH_3 + 2O_2$ à H_3PO_4

b) Phosphorous Halides:

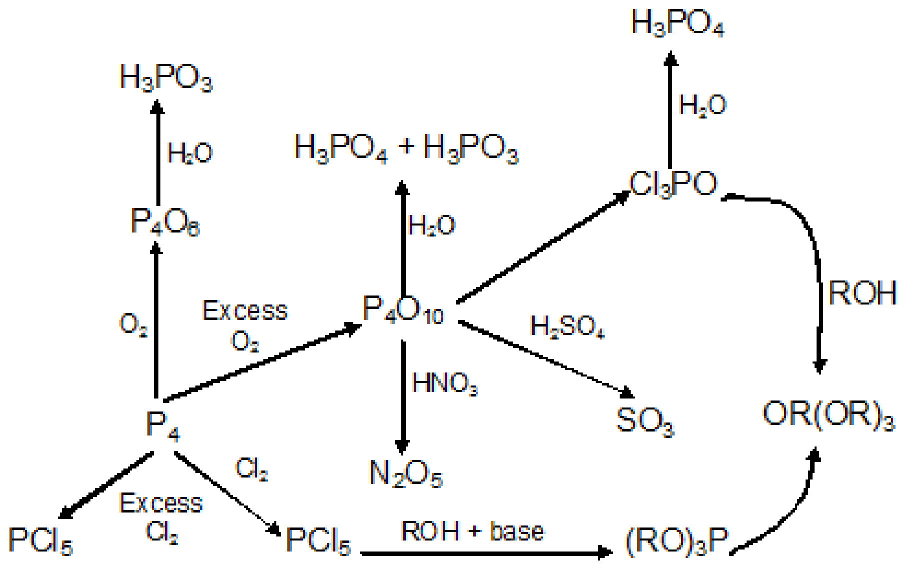
Preparation:

- $P_4 + 6Cl_2 \rightarrow 4PCl_3$
- $P_4 + 10Cl_2 \rightarrow 4PCl_5$
- $P_4 + 8SOCl_2 \rightarrow 4PCl_3 + 4SO_2 + 2S_2Cl_2$
- $P_4 + 10SOCl_2 \rightarrow 4PCl_5 + 10SO_2$

Properties:

- $PCl_3 + 3H_2O \rightarrow H_3PO_3 + 3HCl$
- $PCl_5 + 4H_2O \rightarrow POCl_3$ à $H_3PO_4 + 5HCl$
- $PCl_3 + 3CH_3COOH \rightarrow 3\ CH_3COCl + H_3PO_3$
- $PCl_5 + CH_3COOH \rightarrow CH_3COCl + POCl_3 + HCl$
- $2Ag + PCl_5 \rightarrow 2AgCl + PCl_3$
- $2Sn + PCl_5 \rightarrow SnCl_4 + 2PCl_3$
- PCl_5 + Heat $\rightarrow PCl_3 + Cl_2$

?C) Oxides of Phosphorus:



d) Oxy – Acids of Phosphorus:

Oxo acid	Name
H_3PO_2	Hypophosphorus acid
H_3PO_3	Phosphorus acid
$H_4P_2O_6$	Hypophosphoric acid
H_3PO_4	Orthophosphoric acid
$H_4P_2O_7$	Pyrophosphoric acid
HPO_3	Metaphosphoric acid

Oxygen Family (Group 16 Elements) :

Sr. No.	Property	Oxygen	Sulfur	Selenium	Tellurium	Polonium
1.	Configuration	$[He]2s^22p^4$	$[Ne]3s^23p^4$	$[Ar]4s^24p^4$	$[Kr]5s^25p^4$	$[Xe]6s^26p^4$
2.	Common oxidation state	-2	-2, +4, +6	+4, +6	+4, +6	
3.	Atomic radius (pm)	66	104	116	143	167
4.	First ionization energy (KJ/mol)	1314	1000	941	869	812
5.	Electronegativity	3.5	2.5	2.4	2.1	2.0

Chemical Properties of Group 16:

Formation of volatile Hydrides:

$$Na_2S + H_2SO_4 \longrightarrow Na_2SO_4 + H_2S$$

$$Na_2Se + 2HCl \longrightarrow 2NaCl + H_2Se$$

Formation of Halides:

$$\frac{1}{8}S_8(s) + 3F_2(g) \longrightarrow SF_6(g)$$

$$\frac{1}{4}S_8(\ell) + Cl_2(g) \longrightarrow S_2Cl_2(\ell)$$

$$Te(s) + 2Cl_2(g) \longrightarrow TeCl_4(s)$$

$$Te(s) + 2I_2(g) \longrightarrow TeI_4(s)$$

Formation of Oxide:

a) All elements (except Se) forms monoxide.

b) All elements form dioxide with formula MO_2, SO_2 is a gas, SeO_2 is volatile solid. While TeO_2 and PoO_2 are non – volatile crystalline solids.

c) **Ozone:** It is unstable and easily decomposes into oxygen. It acts as a strong oxidising agent due to the case with which it can liberate nascent oxygen.

Oxyacids:

Sulphur	**Selenium**	**Tellurium**
Sulphurous acid H_2SO_3.	Selenious acid H_2SeO_3	Tellurous acid H_2TeO_3.
Sulphuric acid H_2SO_4	Selnenic acid H_2SeO_4	Telluric acid H_2TeO_4.
Peroxomonosulphuric acid H_2SO_5(Caro's acid)		
Peroxodisulphuric acid		
$H_2S_2O_8$ (Marshell's acid)		
Thio sulphuric acid $H_2S_2O_3$		
Dithiconic acid $H_2S_2O_6$		
Pyrosulphuric acid $H_2S_2O_7$		

Allotropes of Sulphur :

Rhombic sulphur:

- It has bright yellow colour.
- It is insoluble in water and carbon disulphide. Its density is 2.07 gm cm^{-3} and exists as S_8 molecules. The 8 sulphur atoms in S_8 molecule forms a puckered ring.

Monoclinic Sulphur :

- Stable only above 369 K. It is dull yellow coloured solid, also called *b - sulphur*. It is soluble in CS_2 but insoluble in H_2O.
- It slowly changes into rhombic sulphur. It also exist as S_8 molecules which have puckered ring structure. It however, differs from the rhombic sulphur in the symmetry of the crystals

Plastic Sulphur:

- It is obtained by pouring molten sulphur to cold water.
- It is amorphous form of sulphur.
- It is insoluble in water as well as CS_2.

Sulphuric Acid:

- Due to strong affinity for water, H_2SO_4 acts as a powerful dehydrating agent.
- Concentrated H_2SO_4 reacts with sugar, wood, paper etc to form black mass of carbon. This phenomenon is called charring.
- It is moderately strong oxidizing agent.

$$C + 2H_2SO_4 \longrightarrow 2H_2O + 2SO_2 + CO_2$$

$$\frac{1}{8}S_8 + 2H_2SO_4 \longrightarrow 2H_2O + 3SO_2$$

$$P_4 + 10H_2SO_4 \longrightarrow 4H_3PO_4 + 10SO_2 + 4H_2O$$

$$2HBr + H_2SO_4 \longrightarrow 2H_2O + SO_2 + Br_2$$

$$H_2S + H_2SO_4 \longrightarrow 2H_2O + S + SO_2$$

$$Cu + 2H_2SO_4 \longrightarrow CuSO_4 + SO_2 + 2H_2O$$

$$Pb + 2H_2SO_4 \longrightarrow PbSO_4 + SO_2 + 2H_2O$$

- Decomposes carbonates, bicarbonates, sulphides, sulphites, thiosulphates and nitrites at room temperatures.

$$H_2SO_4 + Na_2CO_3 \longrightarrow Na_2SO_4 + H_2O + CO_2 \uparrow$$

$$H_2SO_4 + 2NaHCO_3 \longrightarrow Na_2SO_4 + 2H_2O + 2CO_2 \uparrow$$

$$H_2SO_4 + Na_2S \longrightarrow Na_2SO_4 + H_2S \uparrow$$

- Salts like chlorides, fluorides, nitrates, acetates, oxalates are decomposed by hot conc. H_2SO_4 liberating their corresponding acids.

$$H_2SO_4 + CaCl_2 \longrightarrow CaSO_4 + 2HCl\uparrow$$

$$H_2SO_4 + CaF_2 \longrightarrow CaSO_4 + 2HF$$

?

$$H_2SO_4 + 2KNO_3 \longrightarrow K_2SO_4 + 2HNO_3$$

Halogen Family (Group 17 Elements)

Inter halogen compounds:

Type XX'$_1$ (n = 1) (with linear shape)	Type XX'$_3$ (n = 3) (with T-shape)	XX'$_5$ (n = 5) (with square pyramidal shape)	XX'$_7$ (n = 7) with pentagonal bipyramidal shape)
ClF	ClF_3	ClF_5	
BrF BrCl	BrF_3	BrF_5	
ICl, IBr, IF	ICl_3, IF_3	IF_5	IF_7

Hydrogen Halides:

Properties of Hydrogen Halides:

- All the three acids are reducing agents HCl is not attacked by H_2SO_4.
    - ♦ $2HBr + H_2SO_4 \rightarrow 2H_2O + SO_2 + Br_2$
    - ♦ $2HI + H_2SO_4 \rightarrow 2H_2O + SO_2 + I_2$
- All the three react with $KMnO_4$ and $K_2Cr_2O_7$
    - ♦ $2KMnO_4 + 16HCl \rightarrow 2KCl + 2MnCl2 + 8H_2O + 5Cl_2$
    - ♦ $K_2Cr_2O_7 + 14HBr \rightarrow 2KBr + 2CrBr_3 + 7H_2O + 3Br_2$
- Other reactions are similar.
    - ♦ Dipole moment : HI < HBr < HCl < HF
    - ♦ Bond length: HF < HCl < HBr < HI
    - ♦ Bond strength: HI < HBr < HCl < HF
    - ♦ Thermal stability: HI < HBr < HCl < HF
    - ♦ Acid strength: HF < HCl < HBr < BI
    - ♦ Reducing power: HF < HCl < HBr < HI

Pseudohalide ions and pseudohalogens:

Ions which consist of two or more atoms of which at least one is nitrogen and have properties similar to those of halide ions are called pseudohalide ions. Some of these pseudohalide ions can be oxidised to form covalent dimers comparable to halogens (X_2). Such covalent dimers of pseudohalide ions are called pseudohalogens.

The best known psuedohalide ion is CN^{-}\

Pseudohalide ions	**Name**
CN^{-}	Cyanide ion
OCN^{-}	Cyanate ion
SCN^{-}	Thiocyante ion
$SeCN^{-}$	Selenocyanate ion
NCN^{2-}	Cyanamide ion
N_3^{-}	Azide ion
OMC^{-}	Fulminate ion

Pseudohalogen

- $(CN)_2$ cyanogen
- $(SCM)_2$ thiocyanogen

Some important stable compound of Xenon

- XeO_3 Pyramidal
- XeO_4 Tetrahedral
- $XeOF_4$ Square pyramidal
- XeO_2F_2 Distorted octahedral

First rare gas compound discovered was $Xe^{+} (PtF_6]^{-}$ by Bartlett.

Oxyacids of Chlorine

Formula	Name	Corresponding Salt
HOCl	Hypochlorous acid	Hypochlorites
$HClO_2$	Chlorous acid	Chlorites
$HClO_3$	Chloric acid	Chlorates
$HClO_4$	Perchloric acid	Perchlorates

Acidic Character: Acidic character of the same halogen increases with the increase in oxidation number of the halogen: $HClO_4 > HClO_3 > HClO_2 > HOCl$

Preparation

HOCl :

- $Ca(OCl)_2 + 2HNO_3 \rightarrow Ca(NO_3)_2 + 2HOCl$

$HClO_2$:

- $BaO_2 + 2ClO_2 \rightarrow Ba(ClO_2)_2$ (liquid) $+ O_2$
- $Ba(ClO_2)_2 + H_2SO_4$(dil.) $\rightarrow BaSO_4{}^{-} + 2HClO_2$

$HClO_3$:

- $6Ba(OH)_2 + 6Cl_2 \rightarrow 5BaCl_2 + Ba(ClO_3)_2 + 6H_2O$
- $Ba(ClO_3)_2 + H_2SO_4$(dil.) $\rightarrow BaSO_4{}^{-} + 2HClO_3$

$HClO_4$:

- $KClO_4 + H_2SO_4 \rightarrow KHSO_4 + HClO_4$
- $3HClO_3 \rightarrow HClO_4 + 2ClO_2 + H_2O$

The Noble Gases (Group 18 Elements):

The noble gases are inert in nature. They do not participate in the reactions easily because they have

- stable electronic configuration i.e. complete octet.
- high ionization energies.
- low electron affinity.

Compounds of Xenon

$$Xe + F_2 \xrightarrow[673\,K]{\text{Nickel tube}} XeF_2$$
$$(1:2)$$

$$Xe + 2F_2 \xrightarrow[5-6\text{ atm}]{\text{Nickel tube, }673\,K} XeF_4$$
$$(1:5)$$

$$Xe + 3F_2 \xrightarrow[50-60\text{ atm}]{\text{Nickel tube, }575\,K} XeF_6$$
$$(1:20)$$

Molecule	Total electron pairs (BP + LP)	Hybridisation	Shape
XeF_2	5s	Sp^3d	Linear
XeF_4	6	Sp^3d^2	Square planar
XeF_6	7	sp^3d^3	Distorted octahedral

Uses of Nobles gas

The noble gases are used in following ways:

(A) Helium

- It is used to fill airships and observation balloons.
- In the oxygen mixture of deep sea divers.
- In treatment of asthma.
- Used in inflating aeroplane tyres.
- Used to provide inert atmosphere in melting and welding of easily oxidizable metals.

(B) Neon

- It is used for filling discharge tubes, which have different characteristic colours and are used in advertising purposes.
- Also used in beacon lights for safety of air navigators as the light possesses fog and stram perpetrating power.

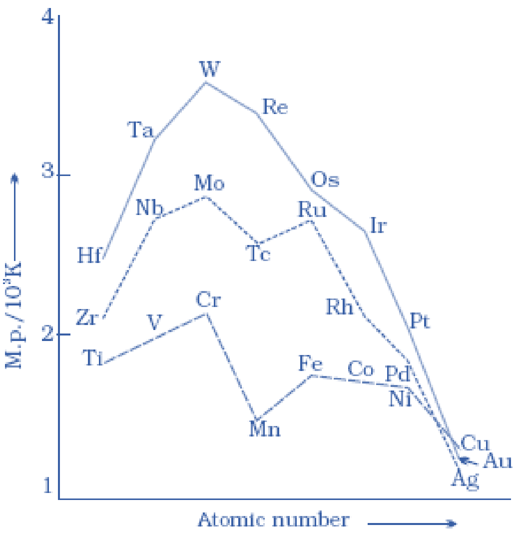
(C) Argon

Along with nitrogen it is used in gas – filled electric lamps because argon is more inert than nitrogen.

Revision Notes on Transition Elements:

Physicochemical Properties

a. Melting and Boiling Points:

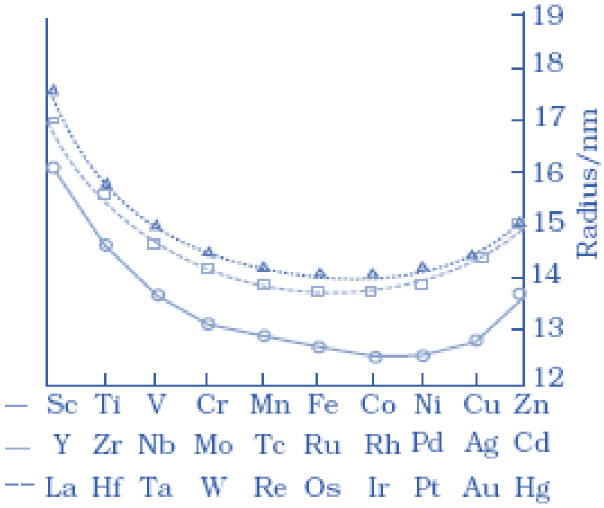


Melting and boiling points show no definite trends in the three transition series.

The metals having the highest melting and boiling points are towards the middle of each transition series.

b. Atomic (Covalent) and Ionic Radii:

Atomic and ionic radii values decrease generally, on moving from left to right in the period.



The atomic radii for the elements from Cr to Cu are very close to one another.

Radii of 5d series elements are virtually the same as those of corresponding members of 4d series due to lanthanoid contraction.

c. Ionisation Potentials:

- **First Ionization Potentials:** I_1 values for the first four 3d block elements (Sc, Ti, V and Cr) differ only slightly from one another. The value of I_I for Zn is considerably higher. This is due to the extra-stability of $3d^{10}$ level which is completely filled in Zn-atom.
- **Second ionisation potentials:** The value of I_{II} for Cr and Cu are higher than those of their neighbours. This is due to the fact that the electronic configurations of Cr^+ and Cu^+ ions have extra stable $3d^5$ and $3d^{10}$levels.There is a sudden fall in the values of ionisation potentials in going from II B (Zn-group elements) to IIIA sub-group.

d. Oxidation States:

- The higher oxidation state of 4d and 5d series elements are generally more stable than those of the elements of 3d series,
- In short it may be said that in going down a sub-group the stability of the higher oxidation states increases while that of lower oxidation states decreases.
- Transition elements cannot form ionic compounds in higher oxidation states because the loss of more than three electrons is prevented by the higher attractive force exerted (on the electrons) by the nucleus

e. Colour: Transition elements with partially filled d orbitals form coloured compounds.

f. Complex Formation: Transition elements show tendency to form complex compounds due to. Small size and high effective nuclear charge.

- Availability of low lying vacant d–orbitals which can accept lone pair of electrons donated by a ligand.

g. Catalytic properties:

Transition metals and their compounds are known to act as good catalyst due to

1. variable oxidation state, they form unstable intermediate compounds and provide a new path with lower activation energy for the reaction (Intermediate compound formation theory)
2. In some cases the finely divided metals or their compounds provide a large surface area for adsorption and the adsorbed reactants react faster due to the closer contact(Adsorption theory)

h. Magnetic Properties:

Magnetic moment is which is related to the number of unpaired electrons as follows

$$\mu = \sqrt{n(n+2)} \text{ B.M.}$$

n = number of unpaired electrons

B.M. = Bohr Magneton, unit of magnetic moment

More the magnetic moment more is the paramagnetic behavior

i. Formation of Alloys:

As the transition elements have similar atomic sizes hence in the crystal lattice, one metal can be readily replaced by another metal giving solid solution and smooth alloys. The alloys so formed are hard and have often high melting point.

j. Interstitial Compounds:

Transition metals form no. of interstitial compounds, in which they take up atoms of small size e.g. H, C and N in the vacant spaces in the their lattices. The presence of these atoms results in decrease in malleability and ductility of the metals but increases their tensile strength.

Potassium Dichromate ($K_2Cr_2O_7$)

a. Preparation

It is prepared from the ore called chromate or ferrochrome or chrome iron, $FeO.Cr_2O_3$.

Steps: 1, Preparation of sodium chromate

$4FeO.Cr_2O_3 + O_2 \rightarrow Fe_2O_3 + 4Cr_2O_3$

$4Na_2CO_3 + 2Cr_2O_3 + 3O_2 \rightarrow 4Na_2CrO_4 + 4CO_2$

Step: 2, Conversion of sodium chromate into sodium dichromate.

$2Na_2CrO_4 + H_2SO_4 \rightarrow Na_2Cr_2O_7 + Na_2SO_4 + H_2O$

Step: 3, Conversion of sodium dichromate into potassium dichromate.

$Na_2Cr2O_7 + 2KCl \rightarrow K_2Cr_2O_7 + 2NaCl$

b. Properties

1. Action of heat: When heated, it decomposed to its chromate

$4K_2Cr_2O_7 + \Delta \rightarrow 4K_2CrO_4 + 2Cr_2O_3 + 3O_2$

2. Action of alkalis

$K_2Cr_2O_7 + 2KOH \rightarrow 2K_2CrO_4 + H_2O$

$2K_2Cr_2O_7 + H_2SO_4 \rightarrow K_2Cr_2O_7 + K_2SO_4 + H_2O$

3. Action of conc. H_2SO_4 solution

(a) In cold conditions

$K_2Cr_2O_7 + 2H_2SO_4 \rightarrow 2CrO_3 + 2KHSO_4 + H_2O$

(b) In hot conditions

$2K_2Cr_2O_7 + 8H_2SO_4 \rightarrow 2K_2SO_4 + 2Cr_2(SO_4)_3 + 8H_2O + 3O_2$

4. Oxidising propertiesIt is a powerful oxidising agent.

In the presence of dil. H_2SO_4 it furnishes 3 atoms of available oxygen.

$K_2Cr_2O_7 + 4H_2SO_4 \rightarrow K_2SO_4 + Cr_2(SO_4)_3 + 4H_2O + 3O$

Some of the oxidizing properties of $K_2Cr_2O_7$ are

It liberates I_2 from KI

$K_2Cr_2O_7 + 7H_2SO_4 + 6Kl \rightarrow 4K_2SO_4 + Cr_2(SO_4)_3 + 3I_2 + 7H_2O$

It oxidises ferrous salts to ferric salts

$K_2Cr_2O_7 + 7H_2SO_4 + 6FeSO_4 \rightarrow K_2SO_4 + Cr_2(SO_4)_3 + 3Fe_2(SO_4)_3 + 2H_2O$

It oxidises S^{-2} to S

$K_2Cr_2O_7 + 4H_2SO_4 + 3H_2S \rightarrow K_2SO_4 + Cr_2(SO_4)_3 + 7H_2O + 3S$

It oxidises nitrites to nitrates

$K_2Cr_2O_7 + 4H_2SO_4 + 3NaNO_2 \rightarrow K_2SO_4 + Cr_2(SO_4)_3 + 3NaNO_3 + 4H_2O$

It oxidises SO_2 to SO_4^{2-}

$K_2Cr_2O_7 + H_2SO_4 + 3SO_2 \rightarrow K_2SO_4 + Cr_2(SO_4)_3 + 3H_2O$

It oxidises ethyl alcohol to acetaldehyde and acetic acid.

5. Chromyl chloride test

When heated with conc. HCl or with a chloride in the presence of sulphuric acid, reddish brown vapours of chromyl chloride are obtained.

$K_2Cr_2O_7 + 4KCl + 6H_2SO_4 \rightarrow 2CrO_2Cl_2 + 6KHSO_4 + 3H_2O$

Thus reaction is used in the detection of chloride ions in qualitative analysis.

c. Uses

In volumetric analysis for the estimation of Fe^{2+} and I^-.

In chrome tanning in leather industry.

In photography and in hardening gelatin film.

Potassium Permanganate

a. Preparation:

It is prepared from the mineral pyrolusite, MnO_2.

Step:1, Conversion of MnO_2 into potassium manganate.

$2MnO_2 + 4KOH + O_2 \rightarrow 2K_2MnO_4 + 2H_2O$

Step:2, Oxidation of potassium manganate into permanganate

Chemical oxidation

K_2MnO_4 is oxidised to $KMnO_4$ by bubbling CO_2 or Cl_2 or ozone into the former.

$3K_2MnO_4 + 2CO_2 \rightarrow 2KMnO_4 + MnO_2 + 2K_2CO_3$

Electrolytic oxidation

$2K_2MnO_2 + H_2O + O \rightarrow 2K_2MnO_4 + 2KOH$

b. Properties

$KMnO_4$ exists as deep purple prisms. It is moderately soluble in water at room temperature and its solubility in water increases with temperature.

(i) Action of heat

When heated it decomposes to K_2MnO_4.

$2KMnO_4 \rightarrow K_2MnO_4 + MnO_2 + O_2$

(ii) Action of conc. H_2SO_4

With cold conc. H_2SO_4 it gives Mn_2O_7 which on warming decomposes to MnO_2.

$2MnO_2 + 2H_2SO_4 \rightarrow Mn_2O_7 + 2KHSO_4 + 2H_2O$

$2Mn_2O_7 + \Delta \rightarrow 4MnO_2 + 3O_2$

With hot Conc. H_2SO_4 O_2 is evolved

$4KMnO_4 + 6H_2SO_4 \rightarrow 2K_2SO_4 + 4MnSO_4 + 6H_2O + 5O_{21}$

(iii) Oxidising properties

$KMnO_4$ is a powerful oxidizing agent. The actual oxidizing action depends upon themedium i.e. acidic, basic or neutral.

(a) In neutral solution, it acts as moderate oxidizing agent.

$2KMnO_4 + H_2O \rightarrow 2KOH + 2MnO_2 + 3O$

Some oxidizing properties of $KMnO_4$ in neutral medium are

$2KMnO_4 + 3Na_2S_2O_3 + H_2O \rightarrow 3K_2SO_4 + 8MnO_2 + 3Na_2SO_4 + 2KOH$
$2KMnO_4 + 4H_2S \rightarrow 2MnS + S + K_2SO_4 + 4H_2O$

(b) In strong alkaline solution, it is converted into

$2KMnO_4 + 2KOH \rightarrow 2K_2MnO_4 + H_2O + O$

Some reaction in alkaline medium are

$2KMnO_4 + H_2O + KI \rightarrow 2MnO_2 + 2KOH + KIO_3$

(c) In acidic medium, Mn^{+7} is converted into Mn^{+2}

$2KMnO_4 + 3H_2SO_4 \rightarrow K_2SO_4 + 2MnSO_4 + 3H_2O + 5O$

Some other reactions are

(i) $2KMnO_4 + 3H_2SO_4 + 5H_2S \rightarrow K_2SO_4 + 2MnSO_4 + 3H_2O + 5S$

(ii) $2KMnO_4 + 5SO_2 + 2H_2O \rightarrow K_2SO_4 + 2MnSO_4 + 2H_2SO_4$

(iii) $2KMnO_4 + 3H_2SO_4 + 5KNO_2 \rightarrow K_2SO_4 + 2MnSO_4 + 3H_2O + 5KNO_3$

(iv) $2KMnO_4 + 3H_2SO_4 + 5C_2H_2O_4 \rightarrow K_2SO_4 + 2MnSO_4 + 8H_2O + 10CO_2$

(v) $2KMnO_4 + 8H_2SO_4 + 10FeSO_4 \rightarrow K_2SO_4 + 2MnSO_4 + 5Fe_2(SO_4)_3 + 8H_2O$

(vi) $2KMnO_4 + 3H_2SO_4 + 10KI \rightarrow K_2SO_4 + 2MnSO_4 + 8H_2O + 5I_2$

c. Uses

(i) Used in volumetric analysis for estimation of ferrous salts, oxalates, iodides & H_2O_2.

(ii) Used as oxidizing agent in the laboratory as well as in industry.

Inner Transition Elements

The f-block elements are known as inner transition elements because they involve the filling for inner sub-shells (4f or 5f)

a. Lanthanides:

It consists of elements that follows lanthanum and involve the filling of 4 subshell

Electronic Configuration : [Xe] $4f^{n+1}$ $5d^{\circ}$ $6s^2$ or [Xe] $4f^n$ $5d^1$ $6s^2$

Oxidation State: +3, +2 and +4.

Colouration: Many of the lanthanides ions are coloured in solid state as well as in solutions. The colour is due to the f-f transition since they have partly filled f-orbitals.

Lanthanide Contraction: The steady decrease in the size of lanthanide ions (M^{3+}) with the increase in atomic no. is called lanthanide contraction.

Causes: As we move down the group from left to right in a lanthanide series, the atomic no. increases and for every proton in the nucleus the extra electron goes to 4f orbital. The 4f orbital is too diffused to shield the nucleus effectively, thus there is a gradual increase in the effective nuclear charge experienced by the outer electrons. Consequently , the attraction of the nucleus for the electrons in the outermost shell increases with the increase of atomic number, thus size decreases.

Consequence of Lanthanide Contraction:

Separation of Lanthanides: Due to the similar sizes of the lanthanides, it is difficult to separate them but due to lanthanide contraction their properties slightly vary (such as ability to form complexes). The variation in the properties is utilized to separate them.

Basic Strength of Hydroxide: Due to the lanthanide contraction, size of M^{3+} ions decreases and there is increase in covalent character in M–OH and hence basic character decreases.

Similarity of second and third transition series: The atomic radii of second row transition elements are almost similar to those of the third row transition elements because the increase in size on moving down the group from second to third transition elements is cancelled by the decrease in size due to the lanthanide contraction.

b. Actinides:

It consists of elements that follow Actinium and involve the filling of 5f subshell.

These are radioactive substances.

$7s^2$ is stable configuration for actinides.

Show +3,+4,+5,+6 & +7 oxidation state.

Co-ordination Compounds

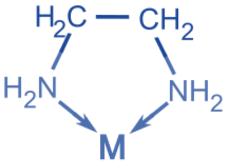
Revision Notes on Coordination Compounds

Ligands: an ion or molecule capable of donating a pair of electrons to the central atom via a donor atom.

- Unidentate ligands: Ligands with only one donor atom, e.g. NH_3, Cl^-, F^- etc.
- Bidentate ligands: Ligands with two donor atoms, e.g. ethylenediamine, $C_2O_4^{2-}$(oxalate ion) etc.
- Tridentate ligands: Ligands which have three donor atoms per ligand, e.g. (dien) diethyl triamine.
- Hexadentate ligands: Ligands which have six donor atoms per ligand, e.g. EDTA.

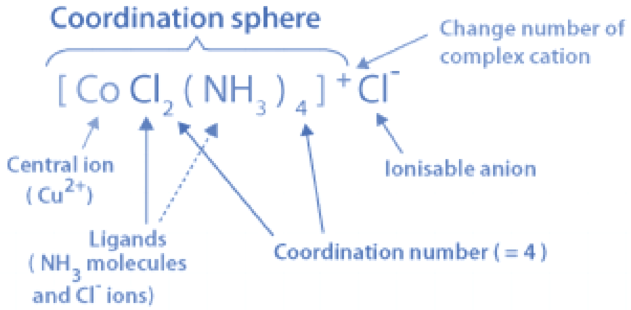
Chelating Ligands:

- Multidentate ligand simultaneously coordinating to a metal ion through more than one site is called chelating ligand. Example: Ethylenediamine ($NH_2CH_2CH_2NH_2$)
- These ligands produce a ring like structure called chelate.
- Chelation increases the stability of complex.



Werner's Theory:

- Metals possess two types of valencies i.e. primary (ionizable) valency and secondary (nonionizable) valency.
- Secondary valency of a metal is equal to the number of ligands attached to it i.e. coordination number.
- Primary valencies are satisfied by negative ions, while secondary valencies may be satisfied by neutral, negative or positive ions.



- Secondary valencies have a fixed orientation around the metal in space.

  $[Co(NH_3)_6]Cl_3$

  Primary Valencies = 3 Cl^-

  Secondary Valencies = 6 NH_3

  Coordination Sphere = $[Co(NH_3)_6]^{3-}$

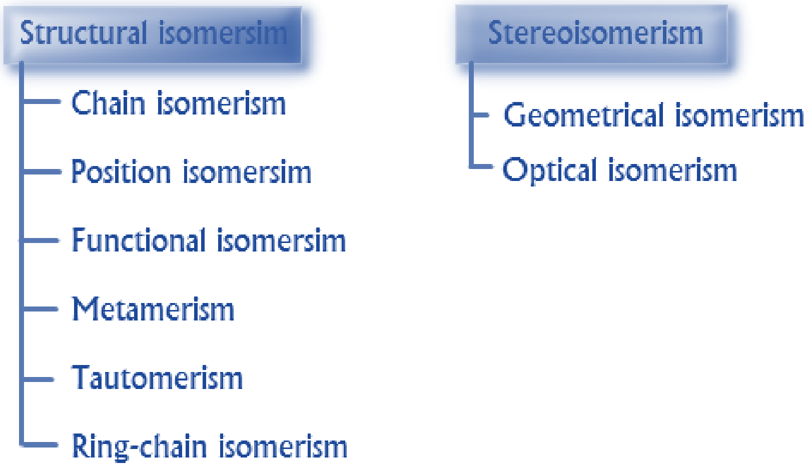
Nomenclature of Complexes:

- Positive ion is named first followed by negative ion.
- Negative ligands are named by adding suffix - o.
- Positive ligands are named by adding prefix – ium.
- Neutral ligands are named as such without adding any suffix or prefix.
- Ligands are named in alphabetical order.
- Name of the ligands is written first followed by name of metal with its oxidation number mentioned in roman numbers in simple parenthesis.
- Number of the polysyllabic ligands i.e. ligands which have numbers in their name, is indicated by prefixes bis, tris etc,
- Number and name of solvent of crystallization if any, present in the complex is written in the end of the name of complex.
- When both cation and anion are complex ions, the metal in negative complex is named by adding suffix-ate.
- In case of bridging ligands:
  [Name of the groups to the left of bridging ligand (Oxidation state)] –μ – [Name of the groups to the right of bridging ligand (Oxidation state)] – [Name of negative ion]

Ligands	Name
Negative	
CH_3COO^-	Acetato
CN^-	Cyano
Br^-	Bromo
Cl^-	Chloro
F^-	Fluoro
OH^-	Hydrido
N^{3-}	Nitrido
$C_2O_4^{2-}$	Oxalato
SO_3^{2-}	Sulfito
O_2^-	Superoxo
O_2^{2-}	Peroxo
O^{2-}	Oxo
NH^{2-}	Imido
SO_4^{2-}	Sulphato
$S_2O_3^{2-}$	Thiosulfato
HS^-	Mercapto

Positive	
NO^+	Nitrosonium
$NH_2NH_3^+$	Hydrazinium
Neutral	
H_2O	Aqua
NH_3	Ammine
CO	Carbonyl
CH_3NH_2	Methylamine
NO	Nitrosyl
C_5H_5N	Pyridine

Isomerism in coordination compounds



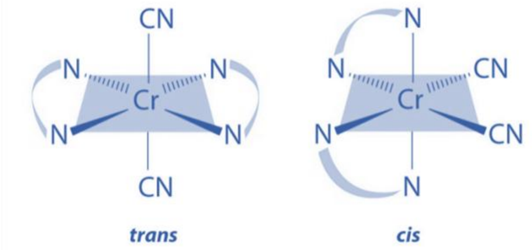
Structural Isomerism

- Ionization Isomerism: Exchange of ligands between coordinate sphere and ionization sphere $[Pt(NH_3)_4Cl_2]Br_2$ & $[Pt(NH_3)_4Br_2]Cl_2$
- Hydrate Isomerism: Exchange of water molecules between coordinate sphere and ionization sphere
  $[Cr(NH_3)_3(H_2O)_3]Br_3$ & $[Cr(NH_{32})_3(H_2O)_2 Br]Br_2 H_2O$
- Linkage Isomerism: Ambient legend binds from the different binding sites to the metal atom. $K_2[Cu(CNS)_4]$ & $K_2[Cu(SCN)_4]$
- Coordination Isomerism: Exchange of the metal atom between coordinate sphere and ionization sphere when both are complex ions.
  $[Cr(NH_3)_6][CoF_6]$ & $[Co(NH_3)_6][CrF_6]$.

- Ligand Isomerism: Different isomers of the same ligands attached to the metal.
  $[Co(pn)_2Br]Cl_2$ & $[Co(tn)_2Br]Cl_2$ Where,
  pn = 1,2- Diaminopropane
  tn = 1,3-Diaminopropane.

Stereoisomerism:

a. Geometrical Isomerism: When two similar ligands are on adjacent position the isomer is called cis isomer while hen they are on opposite positions, the isomer is called trans isomer.



b. Optical Isomerism: In order to show optical isomerism, the complex should form a non superimposible mirror image which rotates the place of polarized light in opposite direction.

Valence Bond Theory:

Hybridization:

Find out the hybridization of central metal ion using following steps:

- Write down the electronic configuration of metal atom.
- Find out oxidation state of metal atom.
- Write down the electronic configuration of metal ion.
- Write down the configuration of complex to find out hybridization.
- Strong field ligands cause the pairing of electrons.
  Strong Field Ligands: CO, CN^-, NO_2^-, en, py, $NH_{3.}$
  Weak Filed Ligands: H_2O, OH^-, F^-, Cl^-, Br^-,I^-

When the d orbital taking part in hybridization is inside the s and p orbital taking part in hybridization with respect to the nucleus, it is called an inner orbital complex.

Example: d^2sp^3 hybridization of $[Co(NH_3)_6]^{3+}$ involves 3d, 4s and 4p orbital, hence it is an inner orbital complex.

When the d orbital taking part in hybridization outside the s and p orbital taking part in hybridization with respect to the nucleus, it is called an outer orbital complex.

Example: sp^3d^2 hybridization of $[CoF_6]^{3-}$ involves 4*d*, 4*s* and 4*p* orbital, hence it is an inner orbital complex.

Coordination Number	Hybridization	Geometry
4	sp^3	Tetrahedral
	dsp^2	Square Planar
6	d^2sp^3 & sp^3d^2	Oct

Geometry:

Magnetic Properties:

- Diamagnetic: All the electrons paired.
- Paramagnetic: Contains unpaired electrons.

Spin:

- Spin paired: All electrons paired.
- Spin free: Contains unpaired electrons.

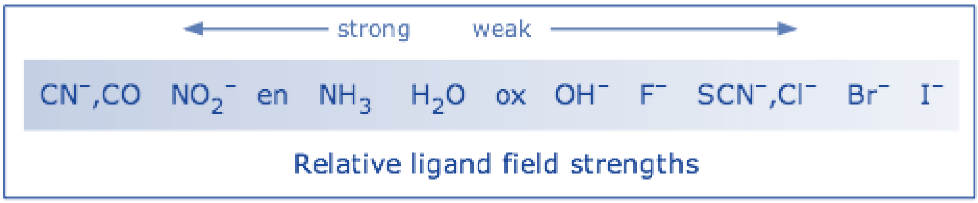
Colour:

Compound must contain free electrons in order to show colour.

Crystal Field Theory:

Strong field ligand causes greater repulsion and thus results in the formation of low spin complexes by pairing of electrons.

- Weak field ligands result in the formation of high spin complexes
- Order of strength of ligands: CO > CN^- > NO_2^- > en > py = NH_3 > H_2O > OH^- > F^- > Cl^- > Br^- >I^-



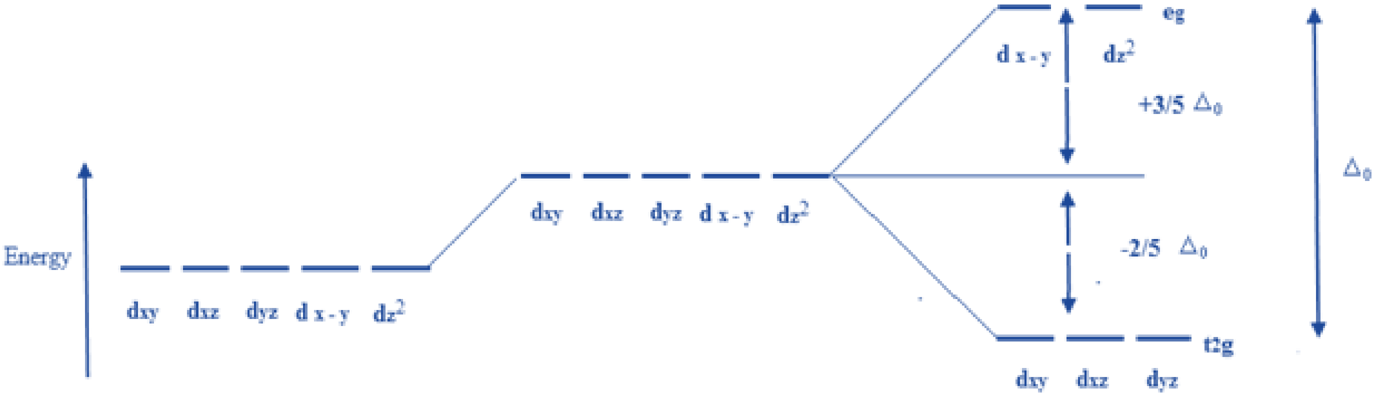
strong ← → weak

CN^-,CO NO_2^- en NH_3 H_2O ox OH^- F^- SCN^-,Cl^- Br^- I^-

Relative ligand field strengths

?

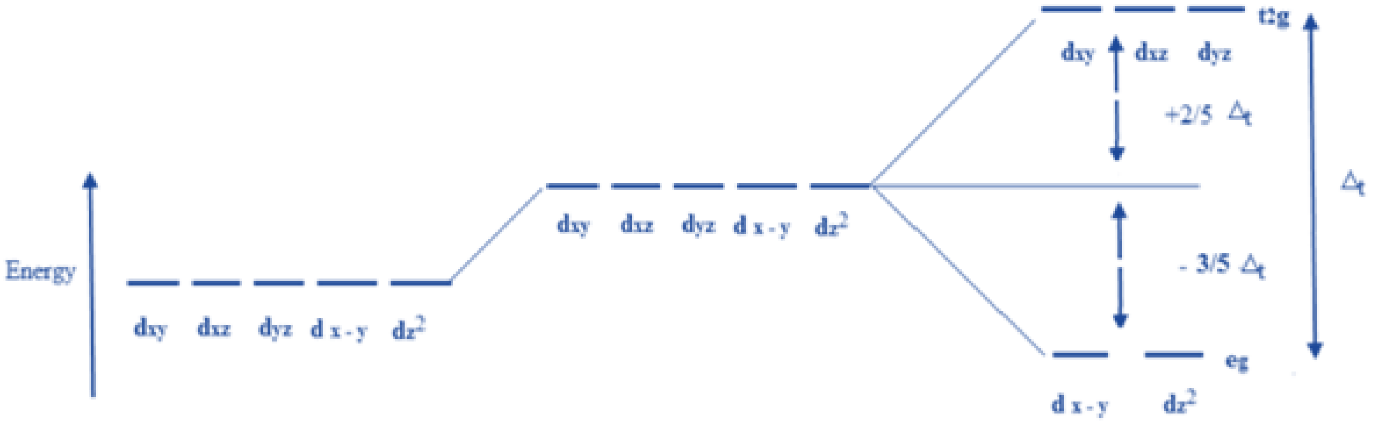
- Octahedral Complexes: e_g orbital are of higher energy than t_{2g} orbital.



Metal Ion in Octhedral Crvstal Field

- Tetrahedral Complexes: e_g orbitals are of lower energy than t_{2g} orbitals.

  $\Delta_t = (4/9)\ \Delta_o$



Metal Ion in Tetrahedral Crystal Field

Crystal Field Stabilization Energy:

System	High Spin		Low Spin	
	Electronic Configuration	**CFSE**	**Electronic Configuration**	**CFSE**
Octahedral Complex				
d^4	$t_{2g}{}^3\ e_g{}^1$	$-(3/5)\Delta_0$	$t_{2g}{}^4\ e_g{}^0$	$-(8/5)\Delta_0+P$
d^5	$t_{2g}{}^3\ e_g{}^2$	0	$t_{2g}{}^5\ e_g{}^0$	$-(10/5)\Delta_0+2P$
d^6	$t_{2g}{}^4\ e_g{}^2$	$-(2/5)\Delta_0+P$	$t_{2g}{}^6\ e_g{}^0$	$-(12/5)\Delta_0+3P$
d^7	$t_{2g}{}^5\ e_g{}^2$	$-(4/5)\Delta_0+2P$	$t_{2g}{}^6\ e_g{}^1$	$-(9/5)\Delta_0+3P$
Tetrahedral Complexes				
d^4	$e_g{}^2\ t_{2g}{}^2$	$-(2/5)\Delta_t$	$e_g{}^4\ t_{2g}{}^0$	$-(12/5)\Delta_t+2P$
d^5	$e_g{}^2\ t_{2g}{}^3$	0	$e_g{}^4\ t_{2g}{}^1$	$-2\ \Delta_t+2P$
d^6	$e_g{}^3\ t_{2g}{}^3$	$-(3/5)\Delta_t+P$	$e_g{}^4\ t_{2g}{}^2$	$-(8/5)\Delta_t+2P$

Magnetic Properties: Complexes with unpaired electrons are paramagnetic while with no unpaired electron are diamagnetic.

Basic Concepts of Organic Chemistry

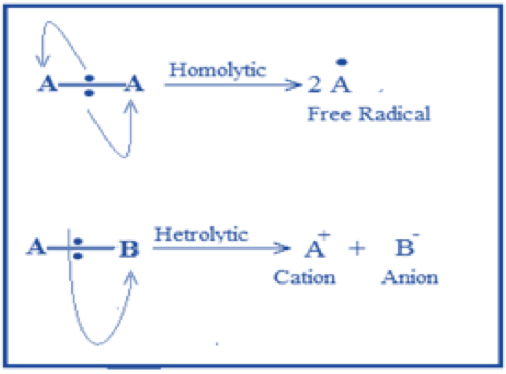
General Organic Chemistry:

Bond Fission:

a) **Homolytic fission:** Each atom separates with one electron, leading to the formation of highly reactive entities called radicals, owing their reactivity to their unpaired electron.

b) **Heterolytic fission:** One atom holds on to electrons, leaving none for the other, the result in the above case being a negative and positive ion, respectively, the result being the formation of an *ion pair*.

Reactions involving radicals tend to occur in the gas phase and in solution in non-polar solvents, and to be catalyzed by light and by the addition of other radicals. Reactions involving ionic intermediates take place more readily in solution in polar solvents, because of the greater ease of separation of charges therein and very often because of the stabilization of the resultant ion pairs through solvation.



Electronic Displacement in Covalent Bonds

The following four types of electronic effects operates in covalent bonds

a) Inductive effect

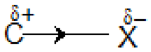
b) Mesomeric and Resonance effect

c) Electromeric effects

d) Hyperconjugation

Inductive Effect:

a) Negative inductive Effect: (–I Effect): This is due to electron - attracting groups (X); it develops positive charge on the chain and is said to exert a negative inductive denoted by (– I)



1) It decreases as one goes away from group X (electron attracting): $X\text{-}C_1\text{-}C_2\text{-}C_3$

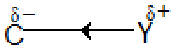
   $C_1(d+) > C_2(dd+) > C_3(ddd+)$ and after third carbon charge is negligible

D and L configuration:

a) The configuration of an enantiomer is related to a standard, glyceraldehydes.

Order: $^{+}NH_3NO_2 > F > COOH > Cl > Br > I > OH > C_6H_5$

a) Positive Inductive Effect (+I): This is due to electron-releasing group (Y). It develops an negative charge on the chain and is said to exert a positive inductive effect denoted by (+I)



1) It also decreases as we go away group Y (electron - releasing):$Y\text{-}C_1\text{-}C_2\text{-}C_3$

   $C_1(d–) > C_2(dd–) > C_3(ddd–)$

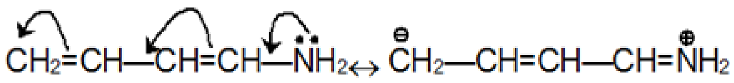
2) Order: $(CH_3)_3C\text{-}R > (CH_3)_2CH\text{-}R > CH_3CH_2\text{-}R > CH_3\text{-}R$

	(–I) effect	**(+I) Effect**
Acidic nature –	Increases	Decreases
Basic nature–	Decreases	Increases

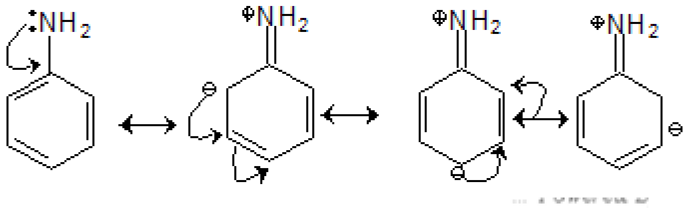
Mesomeric Effect or Resonance Effect:

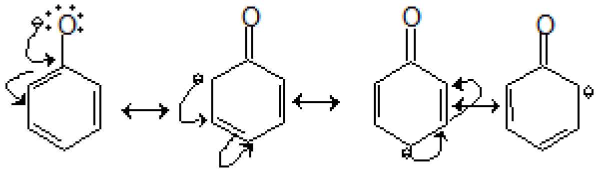
In conjugated systems, p-electrons shifting takes place consecutively giving permanent polarity on the chain.

a) Positive Mesomeric Effect (+M): A group or atom is said to have +M effect when the direction of electron -displacement is away from it.

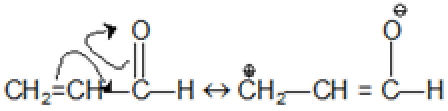


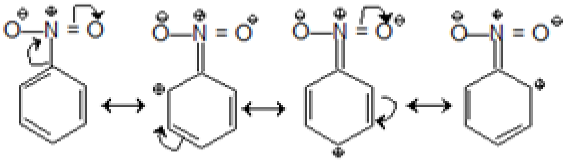
This effect extends the degree of delocalization and imparts stability to the molecule

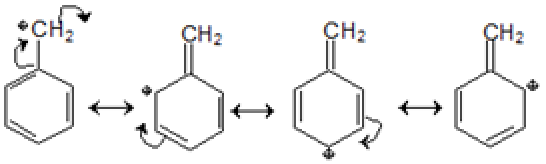




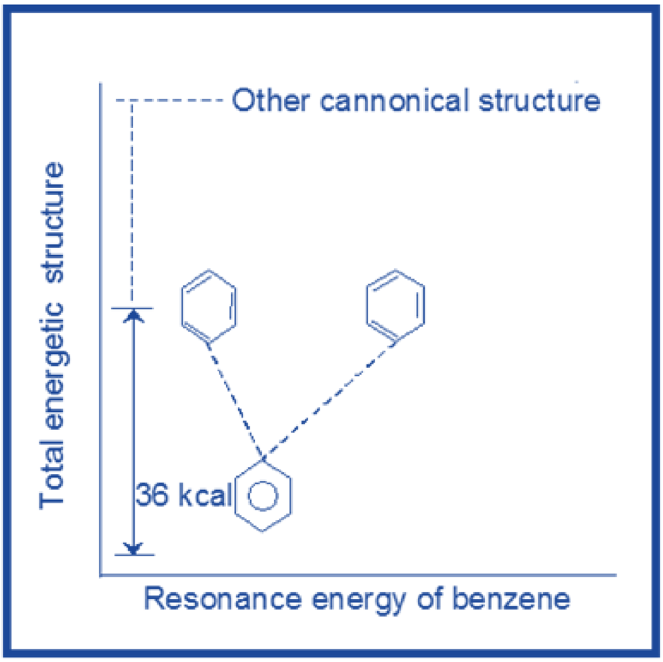
a) **Negative Mesomeric Effect (–M):** A group or atom is said to have +M effect when the direction of electron -displacement is toward it.







a) **Resonance Energy:** The difference in energy between the hybrid and the most stable canonical structure is called as Resonance energy

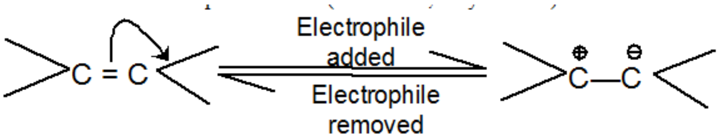


Electromeric Effect:

Complete transfer of p-electrons from one atom to other to produce temporary polarity on atoms joined by multiple bonds, in the presence of an electrophile is known as electromeric effect. Effect is reversible and temporary.

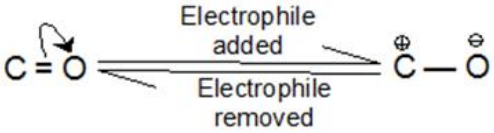
a) Positive Electromeric Effect:

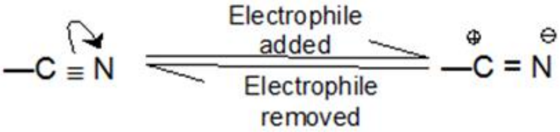
p-electrons transfer takes place C to C (as alkenes, alkynes etc.)



a) Negative Electromeric Effect:

p-electrons transfer takes place to more electronegative atom (O,N,S) joined by multiple bonds.





Hyperconjugation:

Delocalization of sigma electrons also known as sigma-pi – conjugation or no bond resonance. It is a permanent effect.

a) Occurrence

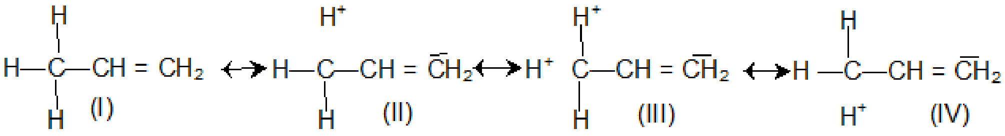
Alkene, alkynes

Free radicals (saturated type) carbonium ions (saturated type)

b) Condition

Presence of a–H with respect to double bond, triple bond carbon containing positive charge (in carbonium ion) or unpaired electron (in free radicals)

Example



Note: Number of hyperconjugative structures = number of a-Hydrogen. Hence, in above examples structures I,ii,iii,iv are hyperconjugate structures (H-structures).

a) Effects of Hyperconjugation:

Bond Length: Hyperconjugation also affects bond lengths because during the process the single bond in compound acquires some double bond character and vice-versa

Dipole moment: Since hyperconjugation causes this development of charges, it also affects the dipole moment of the molecule.

Stability of carbonium Ions: Tertiary > Secondary > Primary

Stability of Free radicals:

$$(CH_3)_3\dot{C} > (CH_3)_2\dot{C}H > CH_3\dot{C}H_2 > \dot{C}H_3$$

Reactive Intermediates:

Species	Geometry	Stability
Carbocation	sp^2 hybridized with a planar structure and bond angles are of about 120°. There is a vacant unhybridized p orbital which (e.g. in the case of CH_3^+) lies perpendicular to the plane of C—H bonds	Any structural feature which tends to reduce the electron deficiency at the tricoordinate carbon stabilizes the carbocation Order: 3°> 2° > 1° > CH_3^+
Carbanions	sp^3 hybridized with the unshared pair occupying one apex of the tetrahedron. Pyramidal structures similar to those of amines.	Any structural feature which tends to reduce the electron deficiency at the tricoordinate carbon stabilizes the carbocation Order: 3°< 2° < 1° < CH_3^-
Free Radicals	sp^2 hybridized with planar (trigonal) structure.. and sp^3 hybridized with pyramidal structure.	Hyperconjugation increases the stability of free radical. Order: : 3°> 2° > 1°

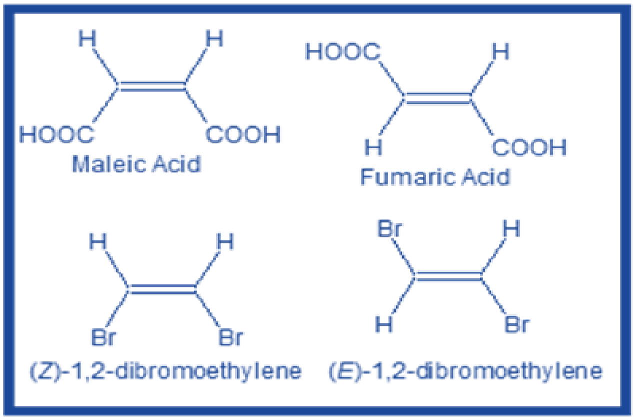
Isomerism :

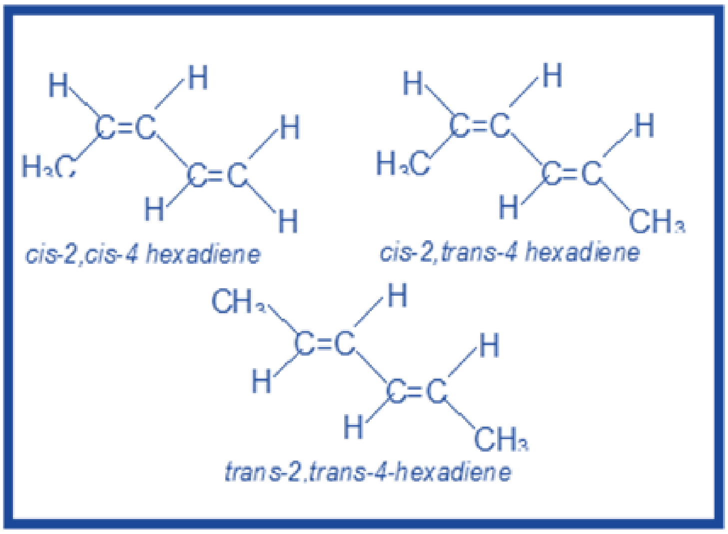
Geometrical Isomerism:

The isomers possess the same structural formula containing a double bond and differ only in respect of the arrangement of atoms or groups about the double bond.

This isomerism is shown by alkenes or their derivatives in which two different atoms or groups are attached to each carbon containing the double bond.

Thus the compounds having the formula abC = Cxy or the simple structure *abC = Cab* occur in two forms and exhibit geometrical isomerism.





a) The *trans* isomers of alkenes are usually more stable than their corresponding *cis* isomers.

b) The *trans* isomers have normally less dipole moments than their corresponding *cis* isomers.

c) The *trans* isomer has greater symmetry than the corresponding *cis* isomer. Thus it packs more easily in the crystal lattice and hence has higher melting points.

Optical Isomerism:

a) Optical Activity: The property of a substance of rotating the plane of polarized light.

b) Specific Rotation: The number of degrees of rotation observed when light is passed through 1 decimeter (10 centimeters) of its solution having concentration 1 gram per milliliter.

$$[\alpha]_D^{t^\circ} = \frac{a_{obs}}{l \times c}$$

a) **Laevorotatory or (-) - form:** rotates the plane of polarized light to the left.

b) **Dextrorotatory or (+)- form :** rotates the plane of polarized light to the right.

c) **Racimic Mixture or (±)– mixture :** An inactive from which does not rotate the plane of polarized light at all. This is a mixture of equal amounts of (+)– and (–)– forms and hence its optical inactivity

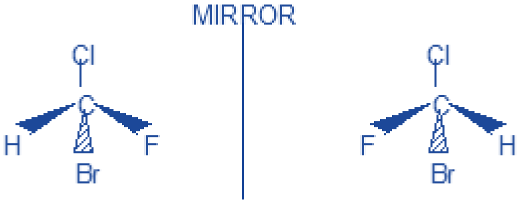
Asymmetric Carbon atom: A carbon atom which is attached to four different atoms

Chirality:

a) All organic compounds which contain an asymmetric carbon (C* *abde*) atom are *chiral* and exist in two tetrahedral forms.

b) A molecule must have chirality in order to show optical activity.

Enantiomers: Two optical isomers which are non superimposable mirror images of each other.



a) **Meso compounds**: Compound containing two or more chiral carbon which do not show optical activity due to presence of centre of symmetry (indicated by thick dot).

b) **Compounds which have unsymmetrical molecule with one or more chiral centres:** In such compounds if 'n' is the number of chiral carbons, then

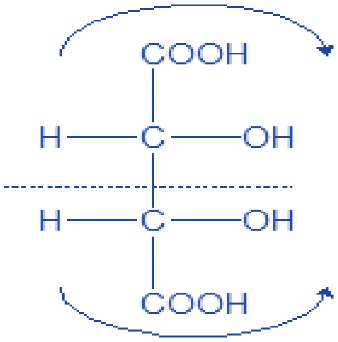
No. of optically active isomers (a) = 2^n

No. of racemic forms (r) = a/2

No. of meso forms (m) = 0

c) **compounds having a symmetrical molecule (compounds having chiral carbons but molecule as a whole is achiral):** (a) compounds with even number of carbons atoms: In such compounds if number of chiral carbons in n, we have a = 2^{n-1}, r = a/2, and m=$2^{(n/2-1)}$

d) Compounds with odd number of carbon atoms: In such compounds if n is the number of asymmetric carbons then total optical isomers are given by 2^{n-1} whereas m = $2^{(n-2)/2)}$. Thus, a = $2^{n-1} - 2^{(n-1)/2)}$.



Inactivity of Meso Tartaric acid by Internal Compesnation

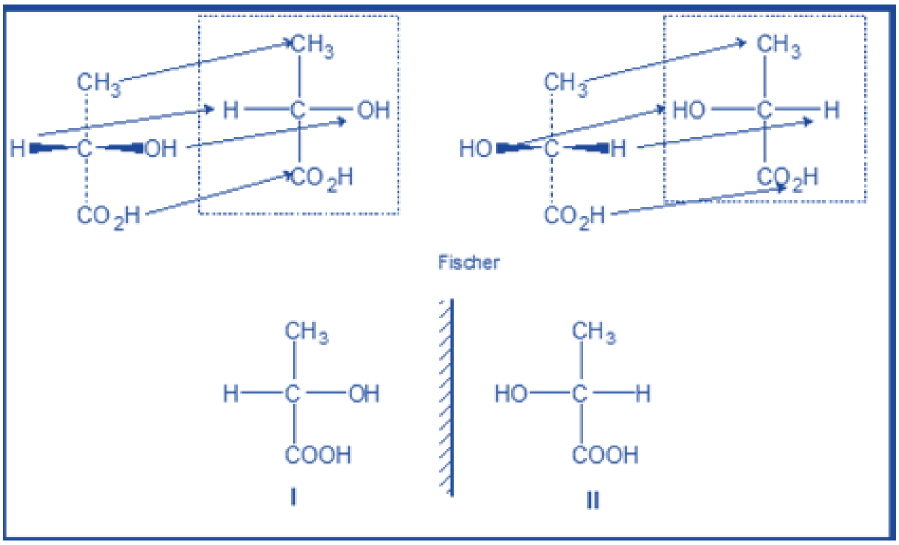
The force of rotation due to one half of the molecule is balanced by the opposite and equal force due to the other half. The optical inactivity so produced is said to be due to **internal compensation.** It occurs whenever a compound containing two or more

Fischer Projections:

a) Representing three dimensional structures on a two dimensional surface.

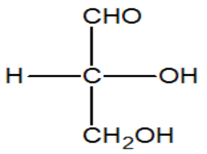
b) Asymmetric carbon atom drawn in a prescribed orientation and then projected into a planar surface.

c) Planar formulas of the asymmetric carbon are obtained by placing it so that the two substituents are horizontal and project out towards the viewer (shown by thick wedge-like bonds), while the two other substituents are vertical and project away from the viewer (shown by dotted bonds).

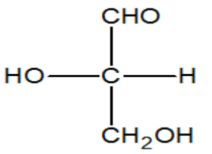


D and L configuration:

a) The configuration of an enantiomer is related to a standard, glyceraldehydes.


(+)-glyceraldehyde

D configuration


(-)-glyceraldehyde

L configuration

b) If the configuration at the asymmetric carbon atom of a compound can be related to D (+)-glyceraldehyde, it belongs to D-series.

c) By convention for sugars, the configuration of the highest numbered asymmetric carbon is referred to glyceraldehyde to determine the overall configuration of the molecule.

R and S System:

The **sequence rules** to determine the order of priorities of groups are :

The atoms or groups directly bonded to the asymmetric carbon are arranged in order of decreasing atomic number and assigned priority 1, 2, 3, 4, accordingly

a) Thus in chlorobromofluoromethane (CHClBrF), the substituents Br (at no = 35), Cl (at no = 17), F (at no = 9) and H (at no = 1) give the order of priorities.

Br	>	Cl	>	F	>	H
(1)		(2)		(3)		(4)

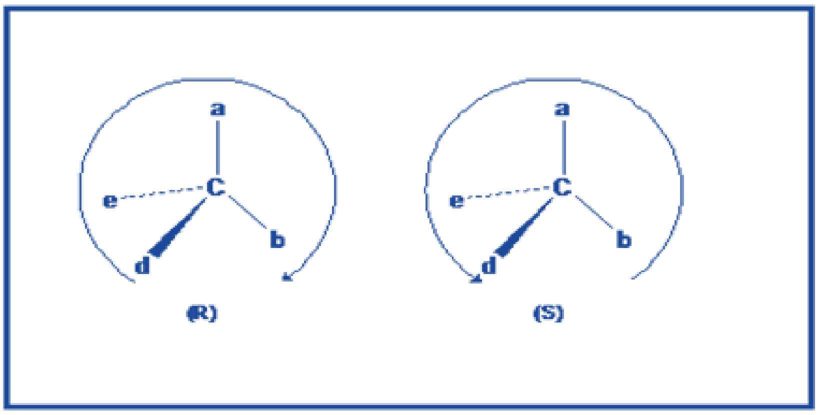
b) When two or more groups have identical first atoms attached to asymmetric carbon, the priority order is determined by considering the atomic numbers of the second atoms; and if the second atoms are also identical the third atoms along the chain are examined.

c) If the first atoms of the two groups have same substituents of higher atomic number, the one with more substituents takes priority.

Thus —$CHCl_2$ has a higher priority than —CH_2Cl.

d) A doubly or triply bonded atom 'A' present in a group appended to asymmetric carbon, is considered equivalent to two or three singly bonded 'A's, respectively. Thus, R= A equals A-R-A.

If in a molecule, order of priority for groups a,b,c,d, & e is $a > b > d > e$



Diastereomers :

- Stereoisomers which are optically active isomers but not mirror images, are called diasteriomers.
- Diastereoisomers have different physical properties. Thus they have different melting points, boiling points, solubilities in a given solvent, densities, and refractive indices.
- They also differ in specific rotations; they may have the same or opposite signs of rotations.
- Like geometrical isomers, the diastereoisomers may be separated from each other :–
  - by fractional distillation due to their difference in boiling points;
  - by fractional crystallisation due to their difference in solubility;
  - by chromatography due to their different molecular shapes and polarity.

Alkanes, Alkenes, Alkynes & Aromatic Compounds

Hydrocarbons

Compounds of carbon and hydrogen.

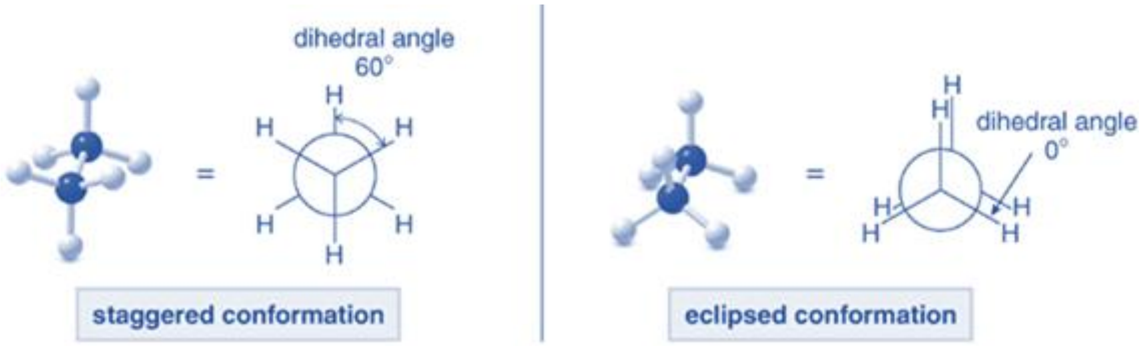
Classification of Hydrocarbons:

Alkane

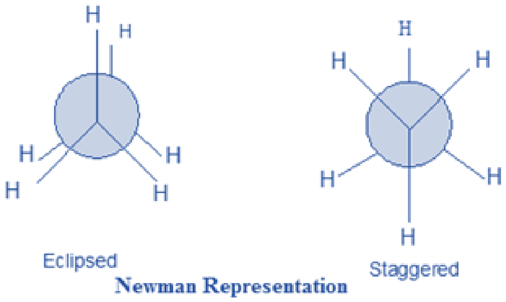
- Open chain saturated hydrocarbon with general formula (C_nH_{2n+2}).
- All the C atoms are single bonded i.e. sp^3 hybridised.

Conformations of Alkane

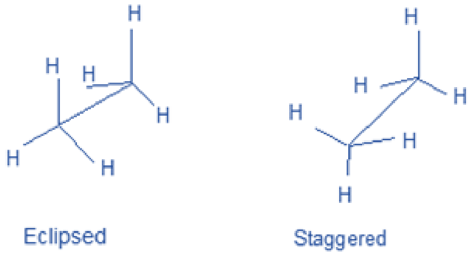
- Conformations are the different arrangement of atoms that can be converted into one another by rotation about single bonds.
- Eclipsed Conformation: H atoms on two adjacent carbon atoms are closest to each other i.e. dihedral angle is 0.



- Staggered Conformation: H atoms on two adjacent carbon atoms are farthest to each other i.e. dihedral angle is 60.



Newman Representation



Sawhorse Representation

Preparation of Alkanes:

- Reduction of Alkyl Halides:

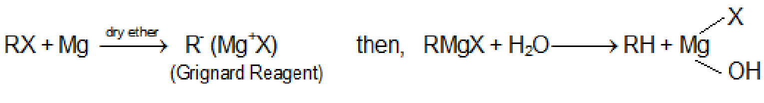
  $RX + Zn: + H^+ \rightarrow RH + Zn^{2+} + X^-$

  $4RX + LiAlH_4 \rightarrow 4RH + LiX + AlX_3$ ($X \neq F$)

  $RX + (n-C_4H_9)_3SnH \rightarrow R\text{-}H + (n-C_4H_9)_3SnX$

- Grignard Reagent:

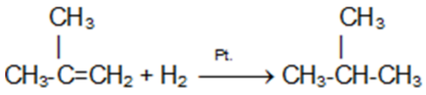
  $RX + 2Li \xrightarrow{\text{dry ether}} R^- Li^+ + LiX$ then $R^- Li^+ + H_2O \longrightarrow RH + LiOH$



  $RX + Mg \xrightarrow{\text{dry ether}} R^-(Mg^+X)$ (Grignard Reagent) then, $RMgX + H_2O \longrightarrow RH + Mg\begin{smallmatrix}X\\OH\end{smallmatrix}$

  ?

- Hydrogenation of Alkenes:



$$CH_3\text{-}\overset{\overset{CH_3}{|}}{C}{=}CH_2 + H_2 \xrightarrow{Pt.} CH_3\text{-}\overset{\overset{CH_3}{|}}{CH}\text{-}CH_3$$

- Wurtz Reaction:

  $2RX + 2Na \rightarrow R\text{-}R + 2NaX$

  $2Na + 2CH_3CH_2CH_2Cl \rightarrow CH_3CH_2CH_2CH_2\text{-}CH_2CH_3 + 2NaCl$

- Corey House Reaction:

  $R\,MgX \text{ or } RLi \xrightarrow[RX]{CuX} R\text{-}R'$ ($R = 1°, 2°$ or $3°$; $R' = 1°$)

- Decarboxylation of a mixture of the sodium salt of a carboxylic acid:

  $RCOONa + NaOH(CaO) \rightarrow RH + Na_2CO_3$

- Kolbe's electrolytic method:

  $2\,RCOOK + 2H_2O \rightarrow R\text{-}R + 2CO_2 + H_2 + 2KOH$

Chemical Properties of Alkane

- Direct Halogenation

  $RH + X_2 \rightarrow RX + HX$

  Order of Reactivity of X_2: $F_2 > Cl_2 > Br_2$; I_2 does not react

  ?a. Initiation Step

  $Cl\text{-}Cl \xrightarrow{uv} 2Cl^{\cdot}$

b. Propagation Step

$H_3C\text{-}H + Cl^{\cdot} \rightarrow H_3C^{\cdot} + H\text{-}Cl$
$H_3C^{\cdot} + Cl\text{-}Cl \rightarrow H_3C\text{-}Cl + Cl^{\cdot}$

c. Termination Step

$Cl^{\cdot} + Cl^{\cdot} \rightarrow Cl\text{-}Cl$
$H_3C^{\cdot} + H_3C^{\cdot} \rightarrow H_3C\text{-}CH_3$
$Cl^{\cdot} + H_3C^{\cdot} \rightarrow Cl\text{-}CH_3$

- Nitration
  Nitration of alkane is made by heating vapours of alkanes and HNO_3 at about 400oC to give nitroalkanes.
  ¨This is also known as vapour phase nitration.

  $CH_{4(g)} + HNO_{3(g)} \xrightarrow{400^{o}C} CH_3NO_2 + H_2O$

- Combustion:
  ?Alkanes burn readily with non luminous flame in presence of air or oxygen to give CO_2 & water along with evolution of heat.

  $C_2H_6 + 7O_2 \rightarrow CO_2 + 6H_2O$ + heat

- Aromatization
  ?¨Alkanes having six to 10 carbon atoms are converted into benzene and its homologues at high pressure and temperature in presence of catalyst.

  $C_6H_4 \xrightarrow[773K\ \&\ 20\ atm]{V_2O_5/Cr_2O_3/Mo_2O_3} C_6H_6$
  Hexane Benzene

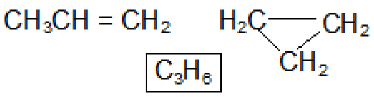
- Oxidization of 3^0 alkane:?

  Tertiary alkanes are oxidized to tertiary alcoholsby KMnO4

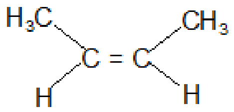
  $R_3CH + KMnO_4 \rightarrow R_3COH$

Alkene (olefins)

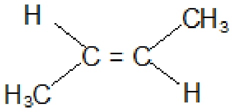
- Open chain, Unsaturated hydrocarbons with general formula (CnH_2n).
- At least one >c=c< (double bond) group i.e. sp2 hybridisation, is present throughout the chain.
- Allene: alkene molecule in which at least one C has double bonds with each of the adjacent carbon i.e. -c=c=c- group.
- Isomeric with saturated cycloalkanes.



Geometric Isomers:

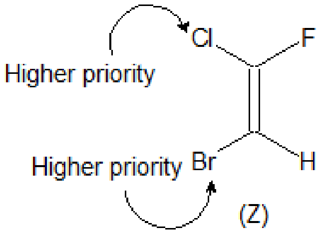


CH_3's on same side called *cis-*

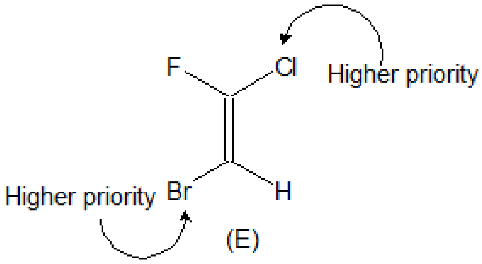


CH_3's on opposite sides : called trans-

Z is used if the higher - priority substituents on each C are on the same side of the double bond.letter E is used if they are on opposite sides

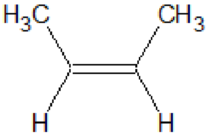


(Z)



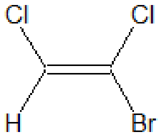
(E)

CH > H

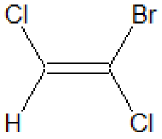


(2*Z*)-but-2-ene

CH > H
Br > Cl



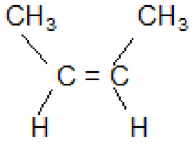
(*E*)-1-bromo-1,2-dichloroethylene



(*Z*)-1-bromo-1,2-dichloroethylene

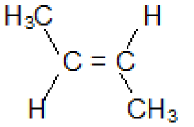
Heats of Hydrogenation: Heat of hydrogenation increases with increase in stability of alkene.

$$\underset{\text{1 - Butene}}{CH_3CH_2CH=CH_2} + H_2 \xrightarrow{Pt} CH_3CH_2CH_2CH_3 \quad \Delta H° = -30.3 \text{ Kcal mol}^{-1}$$



$$+ H_2 \xrightarrow{Pt} CH_3CH_2CH_2CH_3 \quad \Delta H° = -28.6 \text{ Kcal mol}^{-1}$$

cis –2 - Butene



$$+ H_2 \xrightarrow{Pt} CH_3CH_2CH_2CH_3 \quad \Delta H° = -27.6 \text{ Kcal mol}^{-1}$$

trans –2 - Butene

Order of heat of hydrogenation: 1-Butene> cis-2-Butene > trans-2-Butene

Order of stability: 1-Butene> cis-2-Butene > trans-2-Butene

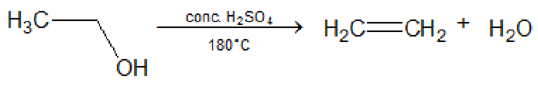
Preparation of Alkenes:

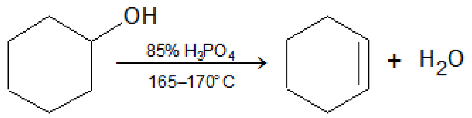
1. Cracking of petroleum: $R-CH_2-CH_3 \xrightarrow{\text{Pt or Pd}} R-CH=CH_2+H_2$

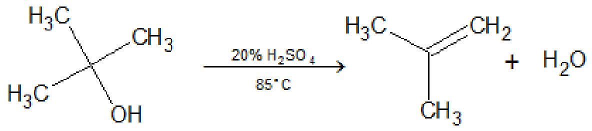
2. Dehydrohalogenation of alkyl halides: RCH_2CH_2X + alc.KOH → $RCH=CH_2$

3. Dehydration of Alcohols :

Saytzeff Rule: In dehydration and dehydrohalogenation the preferential order for removal ofan H is 3° > 2° > 1°

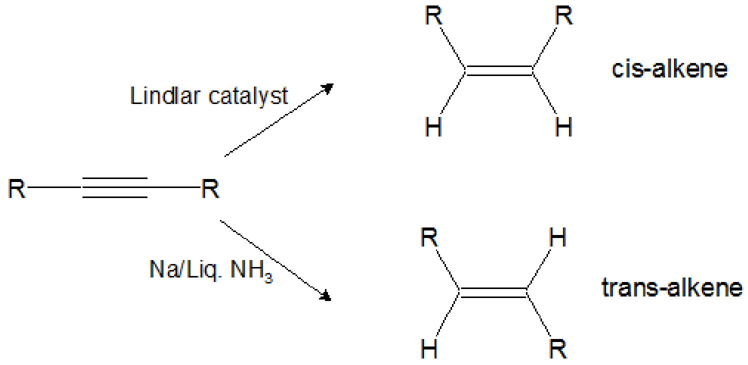






Order of reactivity of alcohols: 1° >2° > 3°

4. Reduction of alkynes:



Chemical Properties:

1. Electrophilic Polar Addition Reactions

Reagent		Product	
Name	**Structure**	**Name**	**Structure**
Halogens (Cl_2, Br_2 only)	X:X	Ethylene dihalide	CH_2XCH_2X
Hydrohalic acids	H:X	Ethyl halide	CH_3CH_2X
Hypohalous acids	X:OH	Ethylene halohydrin	CH_2XCH_2OH
Sulfuric acid (cold)	$H:OSO_2OH$	Ethyl bisulfate	$CH_3CH_2OSO_3H$
Water (dil. H_3O^+)	H:OH	Ethyl alcohol	CH_3CH_2OH
Borane	$H_2B:H$	Ethyl borane	$(CH_3CH_2BH_2) \rightarrow (CH_3CH_2)_3B$
Peroxyformic acid	H:O-OCH=O (HCO_3H)	Ethylene glycol	CH_2OHCH_2OH

2. Addition of Hydrogen Halides to Alkenes: Markovnikov's Addition:

$R - CH = CH_2 + HBr \rightarrow R - CHBr - CH_3$

Mechanism:

$R - CH = CH_2 + HBr \rightarrow R - CH^+ - CH_3 + Br^-$
$R - CH^+ - CH_3 + Br^- \rightarrow R - CHBr - CH_3$

Anit- Markovnikov's Addition (Peroxide Effect):

$R - CH = CH_2 + HBr + (C_6H_5CO)_2O_2 \rightarrow R - CHBr - CH_3$

Mechanism

Initiation:

$R - O - O - R \rightarrow 2RO^{\cdot}$

$RO^{\cdot} + HBr \rightarrow Br^{\cdot} + ROH$

Propagation

$CH_3CH = CH_2 + Br^{\cdot} \rightarrow CH_3{\cdot}CH - CH_2Br$

$CH_3{\cdot}CHCH_2Br + HBr \rightarrow CH_3CH_2CH_2Br + Br^{\cdot}$

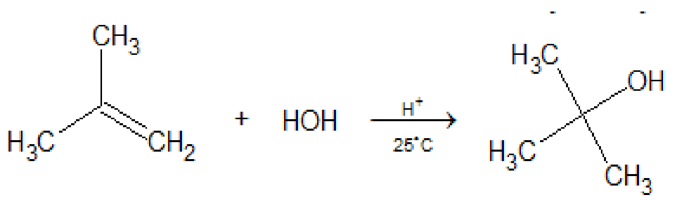
Termination:

$2RO^{\cdot} \rightarrow R - O - O - R$

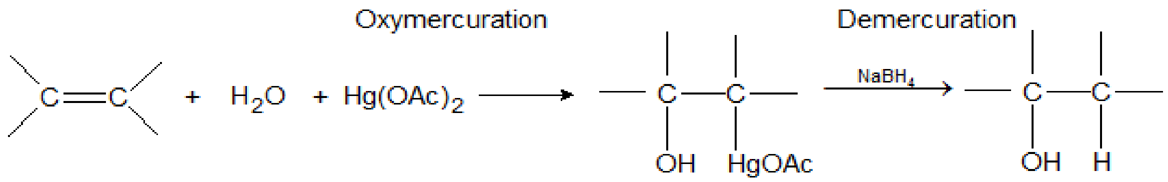
$Br^{\cdot} + Br^{\cdot} \rightarrow Br_2$

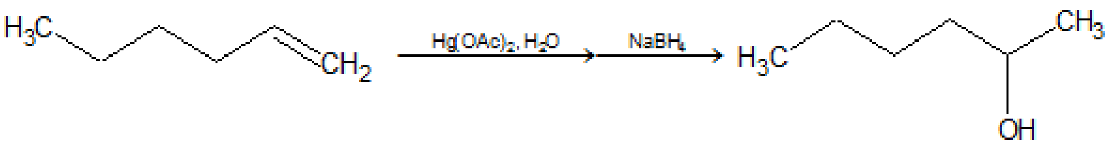
3. Addition of Water to Alkenes: Acid Catalyzed Hydration:

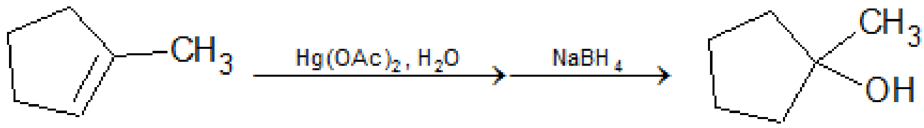
Reagent		**Product**	
Name	**Structure**	**Name**	**Structure**
Halogens (Cl_2, Br_2 only)	X:X	Ethylene dihalide	CH_2XCH_2X
Hydrohalic acids	H:X	Ethyl halide	CH_3CH_2X
Hypohalous acids	X:OH	Ethylene halohydrin	CH_2XCH_2OH
Sulfuric acid (cold)	$H{:}OSO_2OH$	Ethyl bisulfate	$CH_3CH_2OSO_3H$
Water (dil. H_3O^+)	H:OH	Ethyl alcohol	CH_3CH_2OH
Borane	$H_2B{:}H$	Ethyl borane	$(CH_3CH_2BH_2)$®$(CH_3CH_2)_3B$
Peroxyformic acid	$H{:}O - OCH = O$ (HCO_3H)	Ethylene glycol	CH_2OHCH_2OH

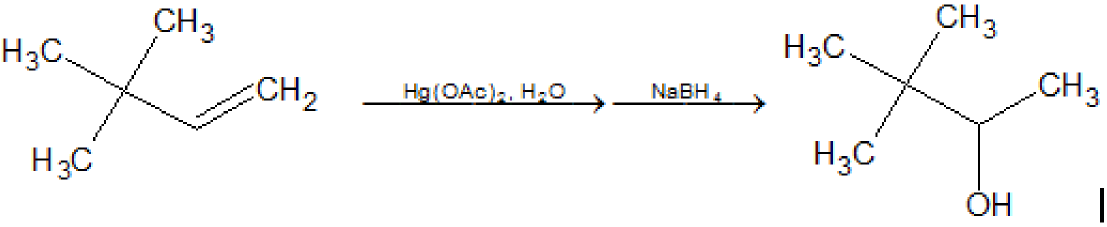


1. Oxymercuration-Demercuration:









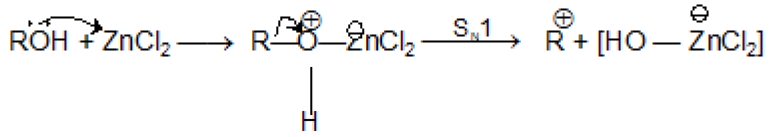
Halogen Derivatives of Organic Compounds

Organic Compounds Containing Halogens can be divided into two groups:

- **Alkyl Halides:** Aliphatic carbon chain with halogen atom(s) as substitution. Example: Chlorobutane.
- **Aryl Halides:** Aromatic carbon ring with halogen atom(s) as substitution on ring. Example: Chlorobenzene.

Methods of Preparation of Alkyl Halides:

Grove's process: Replacement of "OH" group in primary and secondary alcohols with an "X' atom in presence of Zinc chloride.



$$ROH + ZnCl_2 \longrightarrow R-\underset{H}{\overset{\oplus}{O}}-\overset{\ominus}{Z}nCl_2 \xrightarrow{S_N1} \overset{\oplus}{R} + [HO-\overset{\ominus}{Z}nCl_2]$$

The reaction follows S_N2 mechanism when the concentration of zinc chloride is low.

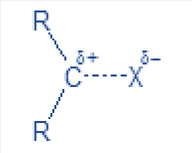
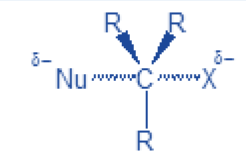
Darzen Process: Reaction of thionyl chloride with straight-chain primary alcohols without presence or absence of pyridine.
In presence of pyridine:
$ROH + SOCl_2 \rightarrow HCl + ROSOCl$
$HCl+C_5H_5N \rightarrow C5H5NH^+ + Cl^-$
$ROSOCl + Cl^- \rightarrow RCl + SO_2$ (S_N2)

- **Action of a phosphorus halide on the alcohol:** $ROH + PCl_5 \rightarrow RCl + HCl + POCl_3$.
- **By addition of Halogen to an alefins:** $R\text{-}CH{=}CH_2 + Br_2 + CCl_4 \rightarrow R\text{-}CH(Br)CH_2Br$
- **Photohalogenation:** $CH_4 + Cl_2 + hv \rightarrow CH_3Cl + HCl$
- **Displacement of one halogen atom by another:** $RCl + NaI \rightarrow RI + NaCl$
- **Bonodine – Hünsdiecker Reaction:** $RCO_2Ag + Br_2 \rightarrow RBr + CO_2 + AgBr$
- **Hydrohalogenation of unsaturated hydrocarbons:**
  - In absence of peroxide: $RCH{=}CH_2 + HBr \rightarrow RCH(Br)CH_3$
  - In presence of peroxide: $RCH{=}CH_2 + HBr + \text{Peroxide} \rightarrow RCH_2CH_{2Br}$

Methods of Preparation of aryl halides

- **Halogenation:** Ar-H + X_2 +Lewis Base → Ar-x + HX
- **From diazonium salts:**
  - $C_6H_5N_2Cl + HBF_4 \rightarrow C_6H_5F$ (Schiemann Reaction)
  - $C_6H_5N_2Cl + CuCl \rightarrow C_6H_5Cl$ (Sandmeyer Reaction)
  - $C_6H_5N_2Cl$ + Cu powder $\rightarrow C_6H_5Cl$ (Gatterman Reaction)
  -

S_N1 and S_N2 mechanism:

	S_N1	**S_N2**
Steps	Two : (1) $R{:}X| \rightarrow R^+ + X^-$ (2) $R^+ + Nu^-| \rightarrow RNu$	One : $R{:}X + Nu^-| \rightarrow RNu + X^-$
Rate	=K [RX] (1st order)	=K[RX] [:Nu^-] (2nd order)
TS of slow step		
Stereochemistry	Inversion and racemization	Inversion (backside attack)
Molecularity	Unimolecular	Bimolecular
Reactivity structure of R Determining Factor **Nature of X** **Solvent effect on rate**	$3^o > 2^o > 1^o > CH_3$ Stability of R^+ RI> RBr> RCl> RF Rate increases in polar solvent	$CH_3 > 1^o > 2^o > 3^o$ Steric hindrance in R group RI> RBr> RCl> RF with Nu^- there is a large rate increase in polar aprotic solvents.
Effect of nucleophile	No effect as it does not appear in the rate expression.	Rate depends on nucleophilicity $I^- > Br^- > Cl^-$; $RS^- > RO^-$
Catalysis	Lewis acid, eg. Ag^+, $AlCl_3$, $ZnCl_2$	None
Competitive reaction	Elimination, rearrangement	Elimination

Reactions of Alkyl Halides:

- **Hydrolysis: :** $RX + OH^{-} \rightarrow ROH + X^{-}$
- **Williamson Synthasis:** R-ONa +R'X → R-R' + NaX
- **Reaction with dry silver oxide:** $2R\text{-}X + Ag_2O \rightarrow R\text{-}O\text{-}R$
- **Reaction with sodio-Alkynides:** R-C≡C-Na +X-R→ R-C=C-R +NaX
- **Reaction with potassium-cyanide:** KCN+X-R→ RCN +KX
- **Reaction with silver-cyanide:** AgCN+X-R→ RNC +AgX
- **Reaction with silver-nitrite:** $AgNO_2 + X\text{-}R \rightarrow RNO_2 + AgX$
- **Reaction with potassium-nitrite:** $KNO_2 + X\text{-}R \rightarrow R\text{-}O\text{-}N{=}O + KX$
- **Fridal Craft Reaction:** $R\text{-}X + C_6H_6 + AlCl_3 \rightarrow C_6H_5\text{-}R$
- **Malonic Ester Synthasis:** $R\text{-}X + {}^{-}CH(CO_2C_2H_5)_2 \rightarrow R\text{-}CH(CO_2C_2H_5)_2 + HX$
- **Acetoacetic Ester Synthasis:** $R\text{-}X + {}^{-}CH(CO_2CH_3)_2 \rightarrow R\text{-}CH(CO_2CH_3)_2 + HX$
- **Reaction with Ammonia:** $R\text{-}X + NH_3 \rightarrow R\text{-}NH_2 + HX$
- **Wurtz Reaction:** 2R-I+ 2Na →R—R + 2NaI
- **Dehydrohalogenation:** $CH_3.CH_2.CH_2Br$ + alco.KOH → $CH_3\text{–}CH = CH_2 + KBr + H_2O$
- **Reaction with alcoholic $AgNO_3$:** $R\text{-}X + AgNO_3 \rightarrow R^{+} + AgX\downarrow + HNO_3$

Substitution Versus Elimination:

CH_3X	RCH_2X	R_2CHX	R_3CX
Methyl	1°	2°	3°
Bimolecular reactions only			$S_N1/E1$ or E_2
Gives S_N2 reactions	Gives mainly S_N2 except with a hindered strong base [e.g., $(CH_3)_3CO^{-}$] and then gives mainly E2.	Gives mainly S_N2 with weak bases (e.g., I^{-}, CN^{-}, RCO_2^{-}) and mainly E2 with strong bases (e.g., RO^{-})	No S_N2 reaction. In solvolysis gives $S_N1/E1$, and at lower temperature S_N1 is favoured. When a strong base (e.g., RO^{-}) is used. E2 predominates.

Haloform(Tri halide):

- **Preparation:** It can be prepared from any alcohol having $\text{–}CH(OH)CH_3$ group or from the aldehydes and ketones formed from above type of alcohols i.e, from a carbonyl compound having three a - hydrogen atoms by the action of $X_2$and an alkali or Na_2CO_3.
- **Laboratory Preparation of $CHCl_3$:**

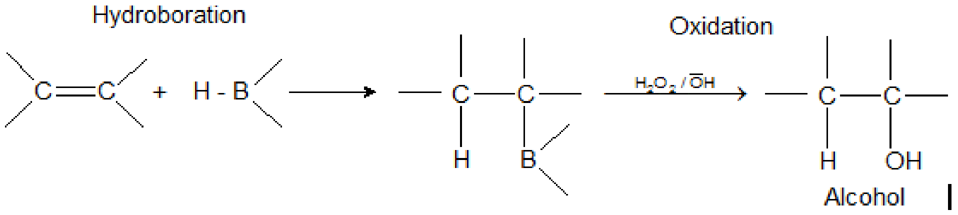
$$CH_3CH_2OH \xrightarrow{\text{oxidation by } Cl_2} CH_3CHO \xrightarrow{\text{chlorination}} CCl_3CHO \xrightarrow[\text{hydrolysis}]{Ca(OH)_2} CHCl_3$$

- **Physical properties of $CHCl_3$:** colourless liquid with sweet smell and test. It is heavier than water and insoluble in it but soluble in alcohol and ether.

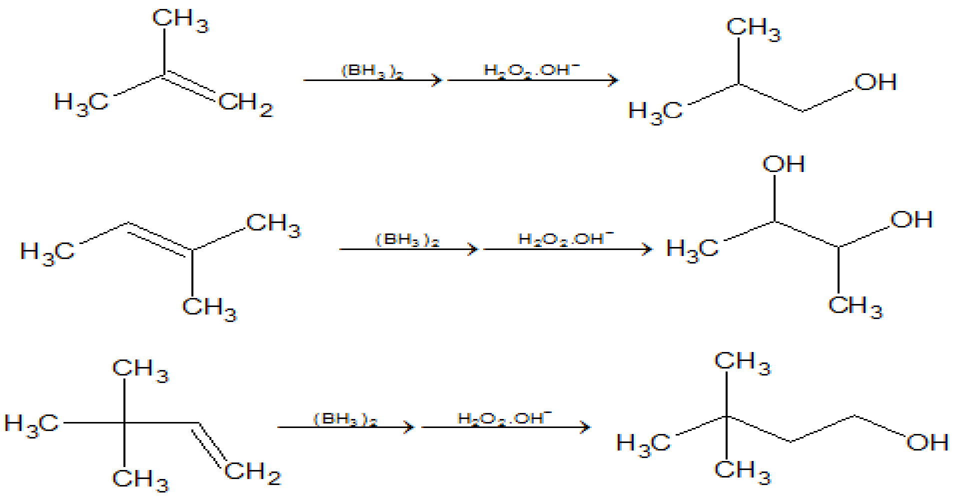
Chemical Reactions of $CHCl_3$:

- **Oxidation:** $CHCl_3 + 1/2\ O_2 \rightarrow HCl + COCl_2$ (phosgene)
- **Hydrolysis:** $CHCl_3 + 4NaOH \rightarrow HCOONa + 3NaCl + 2H_2O$
- **Carbyl amine reactions:** $CHCl_3 + CH_3NH_2 + 3NaOH \rightarrow CH_3N{\equiv}C + 3NaCl + 3H$

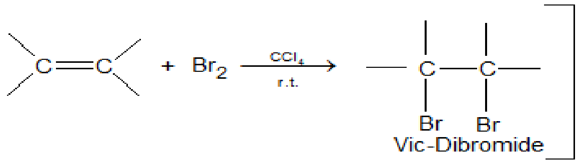
5. Hydroboration-Oxidation:



Examples:

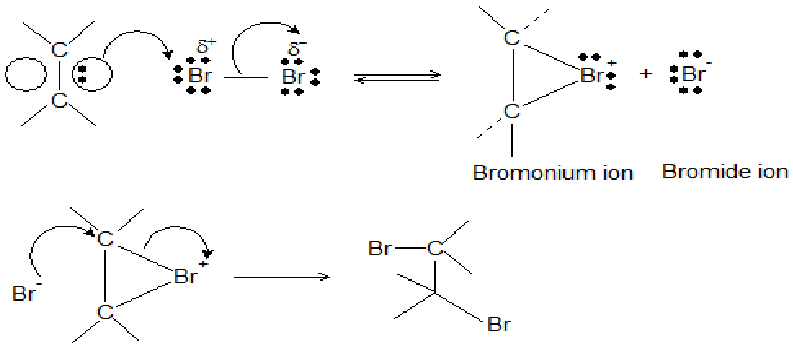


6. Halogen Addition in Non-polar Solvent:

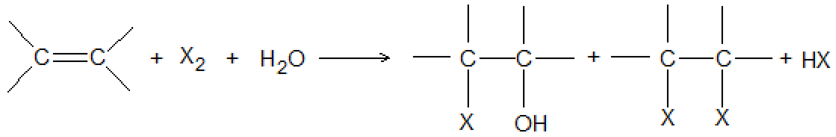


rapid decolourization of Br_2/CC is a test for alkenes and alkynes

Mechanism:

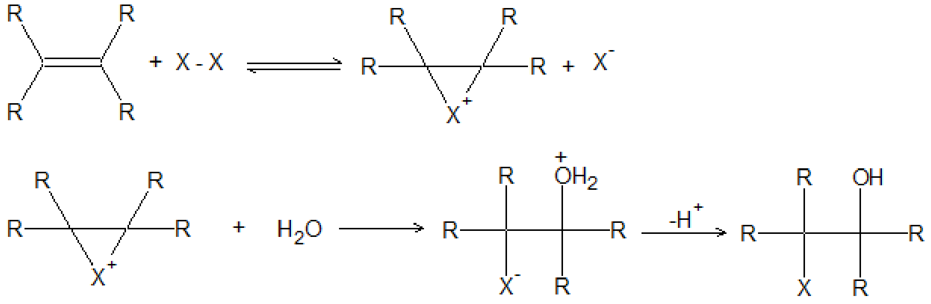


7. Halogen Addition in Aqueous Medium:

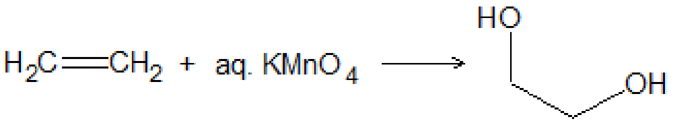


X = Cl_2 or Br_2

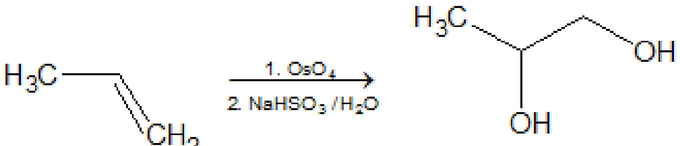
Mechanism:



8. Syn – Hydroxylation: Formation of di-oles.

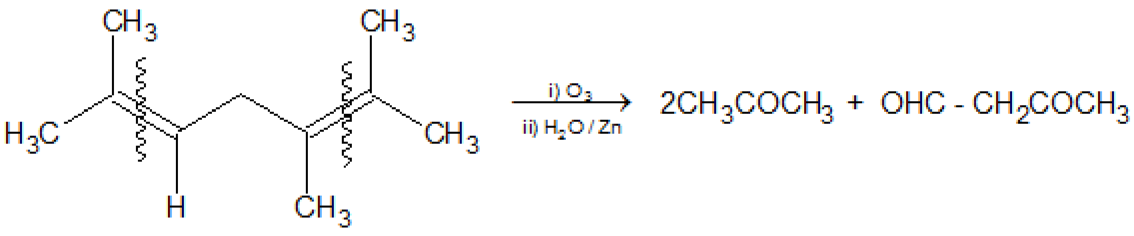


ethylene glycol



propylene glycol

9. Ozonolysis of Alkenes:

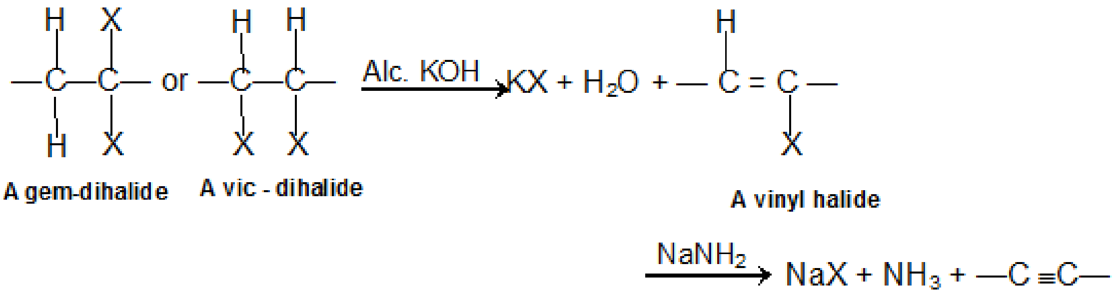


Alkyne

- Saturated open chain hydrocarbon with general formula (C_nH_{2n-2}).
- At least one -c≡c- (triple bond) group i.e. sp hybridisation, is present throughout the chain.
- Physical properties of alkynes are similar to those of the corresponding alkenes

Preparation

1. Dehydrohalogenation of vic-Dihalides or gem-Dihalides



$$-\overset{H}{\underset{H}{C}}-\overset{X}{\underset{X}{C}}- \text{ or } -\overset{H}{\underset{X}{C}}-\overset{H}{\underset{X}{C}}- \xrightarrow{Alc.\ KOH} KX + H_2O + -\overset{H}{C}=\underset{X}{C}- \xrightarrow{NaNH_2} NaX + NH_3 + -C\equiv C-$$

2. Dehalogenation of vic-Tetrahalogen Compounds

$$\underset{\text{2,2,3,3-Tetrabromobutane}}{CH_3—CBr_2—CBr_2—CH_3} + 2Zn \xrightarrow[heat]{EtOH} \underset{\text{2-butyne}}{CH_3—C\equiv C—CH_3} + 2ZnBr_2$$

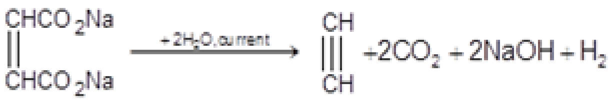
3. Alkyl Substitution in Acetylene; Acidity of º C-H

$$HC\equiv CH + NaNH_2 \xrightarrow[-33°C]{liq.\ NH_3} HC\equiv CNa^+ \xrightarrow{n\text{-}C_4H_9Br} \underset{\text{1-hexyne}}{CH_3(CH_2)_3C\equiv CH}$$

4. From Calcium Carbide:

$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2$

5. Kolbe's Electrolysis:



$$\begin{matrix}CHCO_2Na\\ \|\\ CHCO_2Na\end{matrix} \xrightarrow{+2H_2O,\ current} \begin{matrix}CH\\ |||\\ CH\end{matrix} + 2CO_2 + 2NaOH + H_2$$

Chemical Properties

1. **Hydrogenation: $RC\equiv CCH_2CH_3 + 2H_2 \rightarrow CH_3CH_2CH_2CH_2CH_3$**
2. **Hydro-halogenation:**

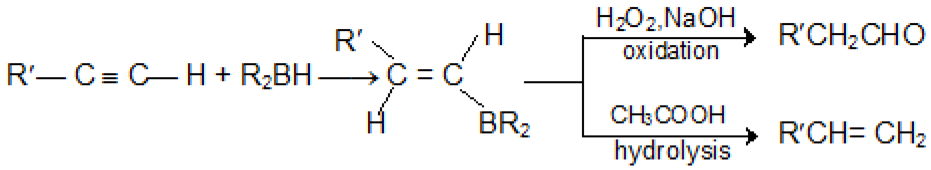
Markovnikov addition: $RC\equiv CH + HBr \rightarrow RCBr{=}CH_2 + HBr \rightarrow RCBr_2\text{-}CH_3$

Anti-markovnikov addition: $RC\equiv CH + HBr + \text{peroxide} \rightarrow RCH{=}CHBr$

3. Hydration:

$$CH \equiv CH + H_2O \xrightarrow[Hg^{2+}]{H_2SO_4} [CH_2 = CHOH] \longrightarrow CH_3CHO$$

4. Addition of boron hydride:



$$R'-C \equiv C-H + R_2BH \longrightarrow R'(H)C = C(H)(BR_2) \begin{cases} \xrightarrow[\text{oxidation}]{H_2O_2,\,NaOH} R'CH_2CHO \\ \xrightarrow[\text{hydrolysis}]{CH_3COOH} R'CH=CH_2 \end{cases}$$

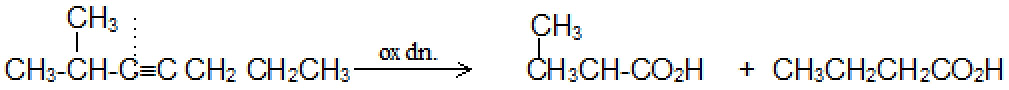
5. Dimerization:

$$2\,H-C \equiv C-H \xrightarrow[H_2O]{Cu(NH_3)_2^+Cl^-} H_2C=CH-C \equiv CH$$

Vinylacetylene

6. Oxidation:

$$CH_3CH_2C \equiv C\text{-}CH_3 + 2KMnO_4 \rightarrow CH_3CH_2COOK + CH_3COOK + 2MnO_2 + 2H_2O$$



$$CH_3\text{-}\underset{}{\overset{CH_3}{CH}}\text{-}C \equiv C\,CH_2\,CH_2CH_3 \xrightarrow{\text{ox dn.}} CH_3\overset{CH_3}{CH}\text{-}CO_2H + CH_3CH_2CH_2CO_2H$$

(Two isomeric acids each having M.F. $C_4H_8O_2$)

7. Ozonolysis-Hydrolysis:

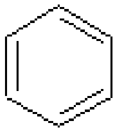
$$\underset{\text{2-Pentyne}}{CH_3C \equiv CCH_2CH_3} \xrightarrow[\text{2. hydrolysis}]{\text{1. } O_3} \underset{\text{Acetic acid}}{CH_3COOH} + \underset{\text{Propanoic acid}}{HOOCCH_2CH_3}$$

8. Cyclic polymerization:

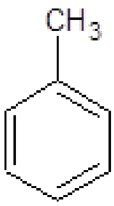
Aromatic Hydrocarbons:

For being aromatic a hydrocarbon should

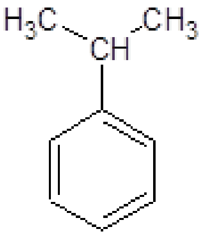
- be a cyclic compounds.
- have planarity in geometry.
- have complete delocalization of electrons over ring.
- follow Huckel Rule i.e. number of ?? electrons in ring = (4n+2). :



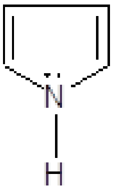
Benzene



Toluene



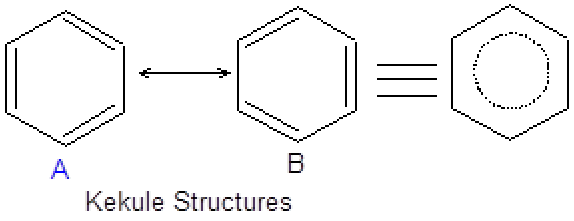
Isopropyl benzene
(Cumene)



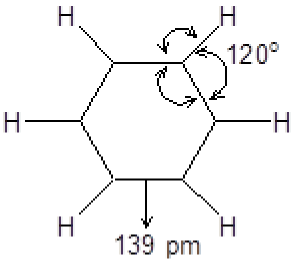
Pyrrole

Benzene (C_6H_6)

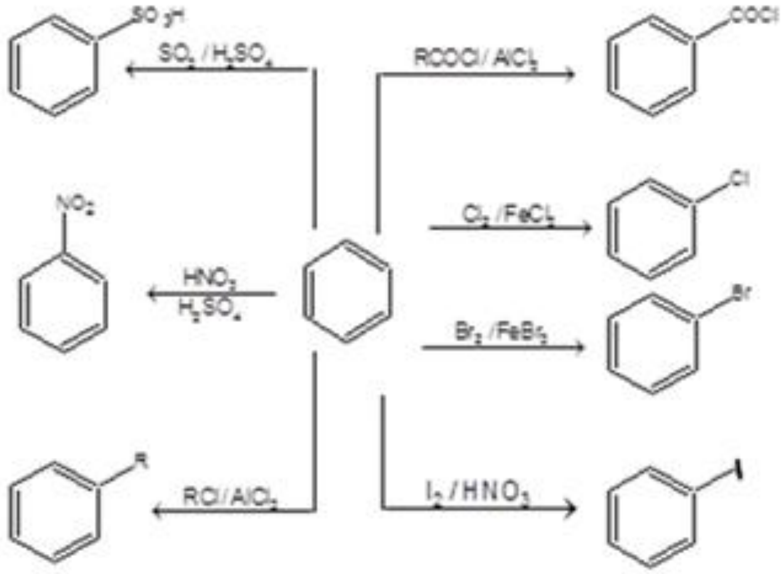
1. Structure:

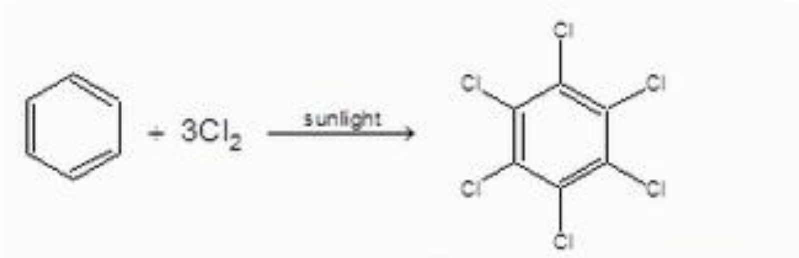


Kekule Structures



2. Chemical Reactions of Benzene:





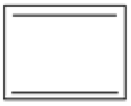
Benzene hexachloride

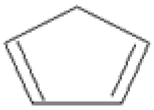
Anti-aromatic Hydrocarbons:

Highly unstable compounds.

Number of π electrons in ring = 4n.

Example:





Alcohols, Phenols & Ethers

Revision Notes on Alcohols, Phenols and Ether:

Alcohols

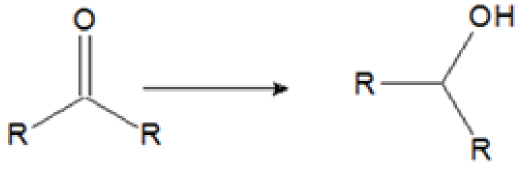
Preparation of Alcohols:

- **By hydrolysis of haloalkanes** : R-X + aq. KOH →ROH +KX
- **By reduction of Carbonyl compounds**

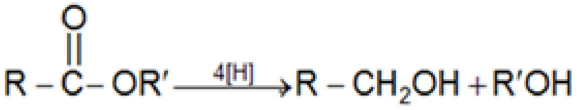
$$4RCOOH + 3LiAlH_4 \rightarrow 4RCH_2OH \ (1^o alcohol)$$

$$CH_3(CH_2)_{14}COOC_2H_5 \xrightarrow{LiAlH_4} CH_3(CH_2)_{14}CH_2OH$$

$$R-CHO \longrightarrow RCH_2OH(1^O \text{ alcohol})$$



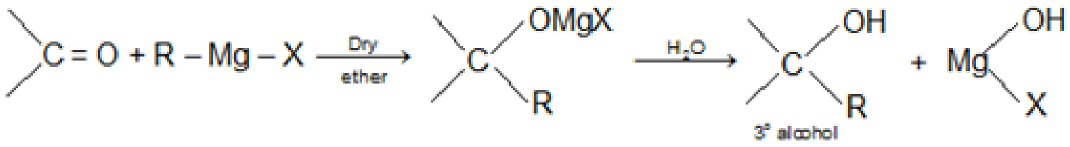
(2^0 alcohol)



$$R-\overset{\overset{O}{||}}{C}-OR' \xrightarrow{4[H]} R-CH_2OH + R'OH$$

$$CH_3CH_2COOCH_3 \xrightarrow{Cr_2O_4} CH_3CH_2CH_2OH + CH_3OH$$

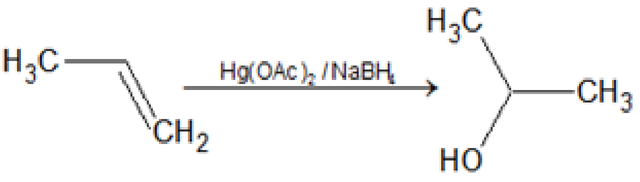
- **By the action of Grignard's Reagent on aldehydes, ketones and esters**



- **By Aliphatic Primary Amines: $RCH_2NH_2 + HNO_2 \rightarrow RCH_2OH + N_2 + H_2O$**
- **Hydration of alkenes:**

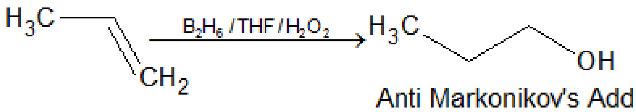
$$CH_2 = CHR + \underset{\text{Concentrated}}{H_2SO_4} \xrightarrow[H_2O]{\text{Boil}} CH_3 - CH(R)OH$$

- **Oxymercuration-demercuration:**



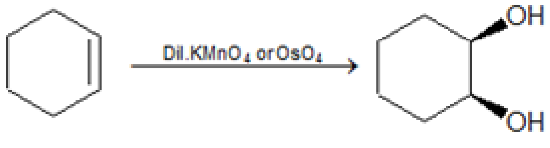
Markonikov's Addition

- **Hydroboration-oxidation:**

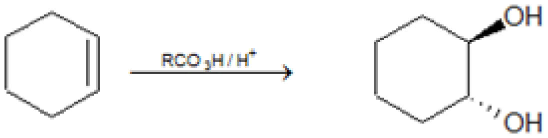


Anti Markonikov's Addition

- **Hydroxylation of alkenes:**



syn-Hydroxylation



anti-Hydroxylation

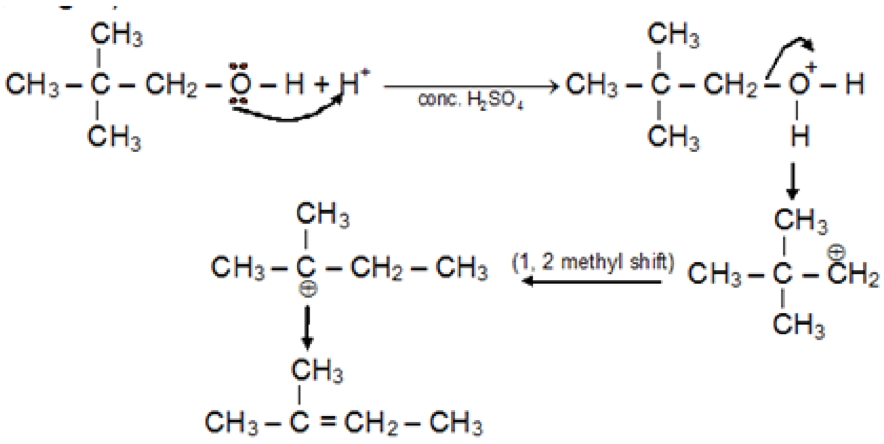
Physical Properties of Alcohol:

- Lower alcohols are liquid at room temperature while higher ones are solid.
- High boiling point due to presence of intermolecular hydrogen bonding. Order of Boiling Point: primary > secondary > tertiary
- Solubility in water decreases with increase in molecular mass due to decrease in extent of intermolecular hydrogen bonding.

Chemical Properties of Alcohol:

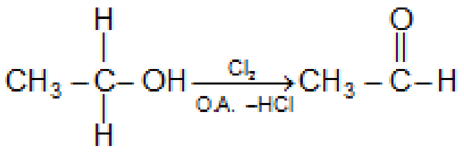
- **Alcohol's reaction with metal:** $ROH + Na \rightarrow 2RO^+Na^- + H_2$
- **Formation of Halides:**
  - $3ROH + P{+}I_2 \rightarrow 3RI + H_3PO_3$
  - $ROH + SOCl_2/PCl_3/PCl_5 \rightarrow RCl$
  - $ROH{+}HX \rightarrow RX$
  - $ROH + NaBr, H_2SO_4 \rightarrow R\text{-}Br$
  - $ROH + Zn{+}HCl \rightarrow R\text{-}Cl$
  - $R_2C\text{-}OH$ alcohol + $HCl \rightarrow R_2CCl$
- **Reaction with HNO_3:** $R\text{-}OH + HO\text{-}NO_2 \rightarrow R\text{-}O\text{-}NO_2$
- **Reaction with carboxylic acid (Esterification) :** $R\text{-}OH + R'\text{-}COOH + H^+ \leftrightarrow R'\text{-}COOR$
- **Reaction with Grignard reagent:** $R'OH + RMgX \rightarrow RH + R'OMgX$
- **Reduction of alcohol :** $ROH + 2HI + \text{Red } P \rightarrow RH + I_2 + H_2O$
- **Dehydration of Alcohol:** Dehydration of alcohols takes place in acidic medium. Intra-molecular dehydration leads to the formation of alkene while inter molecular dehydration which forms ether. Ease of dehydration: 3° > 2° > 1

- **Satyzeff's Rule :** Elimination through b carbon containing minimum b hydrogen



- **Oxidation of Alcohol**:
  RCH_2-OH + [O] → RCHO → RCOOH
  RCH_2-OH + [O] +PCC → RCHO

- **Haloform Reaction:** Compound containing CH_3CO- group (or compound on oxidation gives CH_3CO – group) which is attached with a C or H, in presence of halogen and mild alkali gives haloform.CH_3-CH_2-$COCH_2$-CH_3, CH_3-CO-Cl, CH_3COOH will not respond to haloform reaction wile CH_3CH_2OH will respond to haloform Reaction.



$$CH_3-\underset{H}{\overset{H}{C}}-OH \xrightarrow[\text{O.A. } -HCl]{Cl_2} CH_3-\overset{O}{\overset{\|}{C}}-H$$

$$CH_3CH_2OH \xrightarrow{Cl_2+NaOH} CHCl_3$$

?

Test for Alcohols:

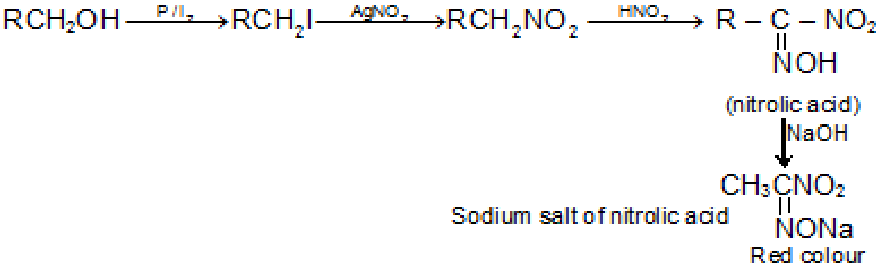
1. **Lucas Test:**

   Alcohols + $ZnCl_2$ + HCl

- 1^o Alcohol: RCH_2OH + $ZnCl_2$ +HCl → No reaction at room temperature
- 2^0 Alcohol: R_2CHOH + $ZnCl_2$ +HCl → R_2CHCl White turbidity after 5-10 min.
- 3^0 Alcohol: R_3CHOH + $ZnCl_2$ +HCl → R_3CHCl white turbidity instantaneously.

2. Victor Meyer Test

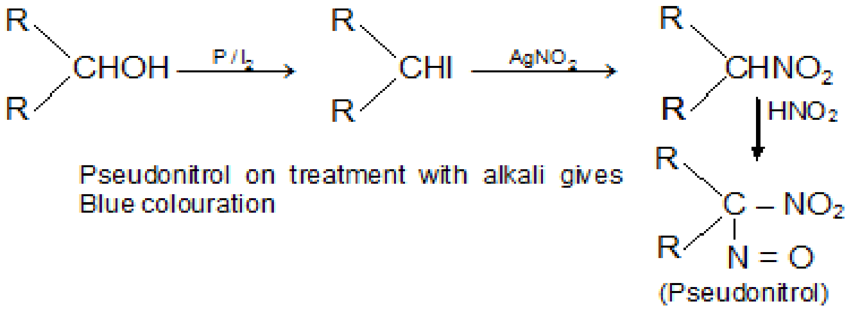
1° alcohol:



$$RCH_2OH \xrightarrow{P/I_2} RCH_2I \xrightarrow{AgNO_2} RCH_2NO_2 \xrightarrow{HNO_2} R-\underset{\underset{NOH}{\|}}{C}-NO_2 \xrightarrow{NaOH} CH_3\underset{\underset{NONa}{\|}}{C}NO_2$$

Nitrolic acid on treatment with alkali gives colouration

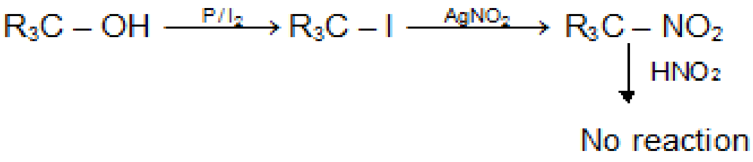
2° alcohol:



$$\begin{matrix}R\\R\end{matrix}\!\!>CHOH \xrightarrow{P/I_2} \begin{matrix}R\\R\end{matrix}\!\!>CHI \xrightarrow{AgNO_2} \begin{matrix}R\\R\end{matrix}\!\!>CHNO_2 \xrightarrow{HNO_2} \begin{matrix}R\\R\end{matrix}\!\!>\underset{\underset{N=O}{|}}{C}-NO_2$$

Pseudonitrol on treatment with alkali gives Blue colouration

3° alcohol:



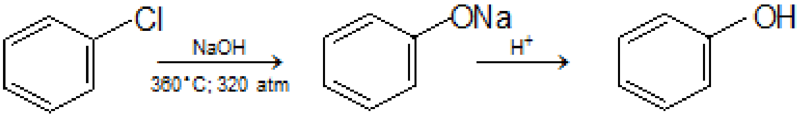
$$R_3C-OH \xrightarrow{P/I_2} R_3C-I \xrightarrow{AgNO_2} R_3C-NO_2 \xrightarrow{HNO_2} \text{No reaction}$$

(colour less)

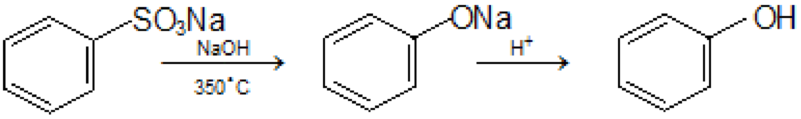
Phenols:

Preparation:

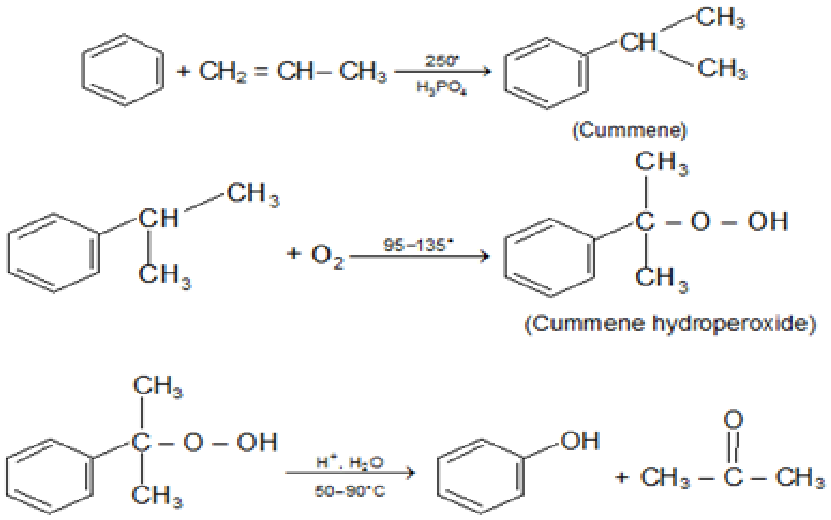
a. Hydrolysis of chlorobenzene: (Dow's process)



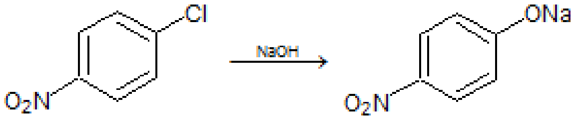
b. Alkali fusion of Sodium benzene sulfonate



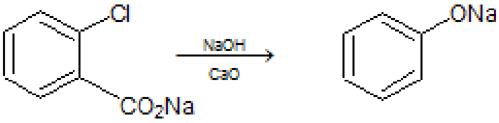
c. From Cummene Hydroperoxide



d. Aromatic Nucleophilic Substitution of Nitro Aryl Halides



e. Distillation of phenolic acids with soda-lime produces phenols, e.g. sodium salicylate gives phenol.



Physical Properties of Phenols

- Phenol is a colorless, toxic, corrosive, needle shaped solid.
- Phenol soon liquifies due to high hygroscopic nature.
- Phenol is less soluble in water, but readily soluble in organic solvents.
- Simplest phenols, because of hydrogen bonding have quite high boiling points.
- o-nitrophenol is, steam volatile and also is less soluble in water because of intramolecular hydrogen bonding

Chemical Properties of Phenols

a) Formation of Esters

Phenyl esters (RCOOAr) are not formed directly from RCOOH. Instead, acid chlorides or anhydrides are reacted with ArOH in the presence of strong base

$(CH_3CO)_2O + C_6H_5OH + NaOH \rightarrow CH_3COOC_6H_5 + CH_3COONa + H_2O$

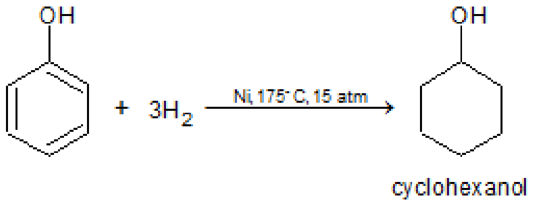
Phenyl acetate

$C_6H_5COCl + C_6H_5OH + NaOH \rightarrow C_6H_5COOC_6H_5 + Na^+Cl^- + H_2O$

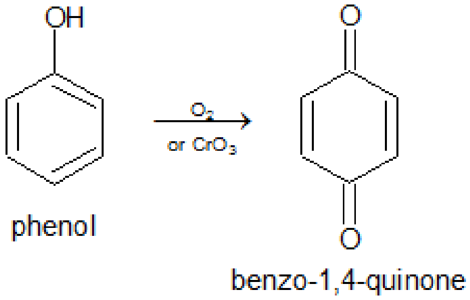
Phenyl benzoate

b) Displacement of OH group: $ArOH + Zn \xrightarrow{\Delta} ArH + ZnO$ (poor yields)

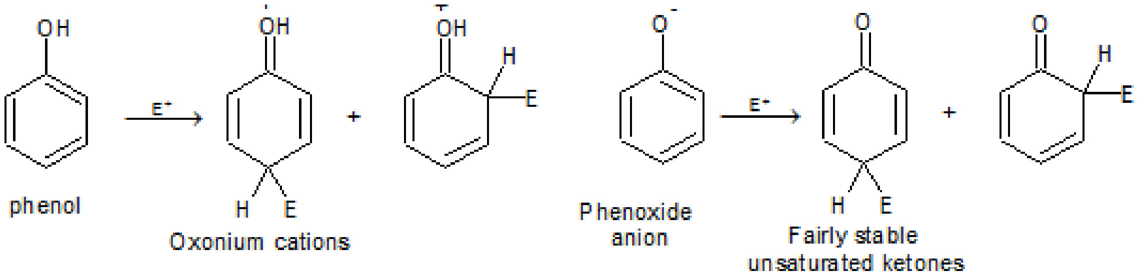
c) Hydrogenation



d) Oxidation to Quionones

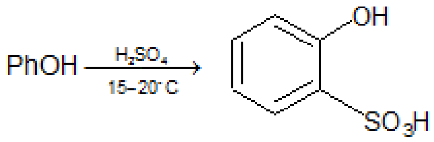


e) Electrophilic Substitution The —OH and even more so the —O(phenoxide) are strongly activating ortho ,para - directing

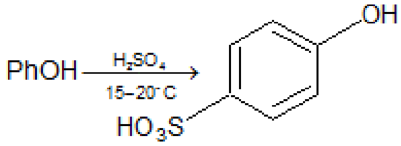


Special mild conditions are needed to achieve electrophilic monosubstituion in phenols because their high reactivity favors both polysubstitution and oxidation.

j) Sulfonation



(rate-controlled)



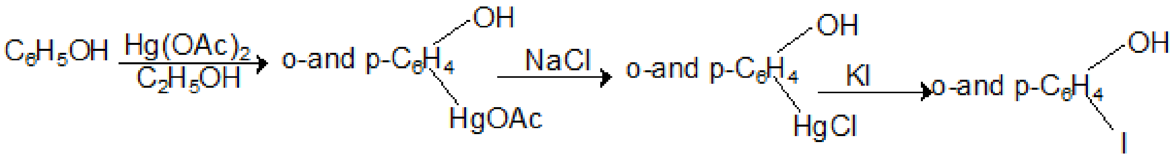
(eqbm-controlled)

k) Diazonium salt coupling to form azophenols

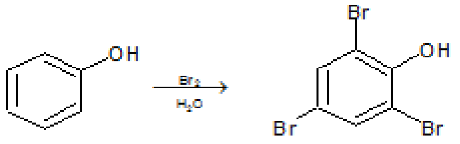
Coupling (G in ArG is an electron – releasing group)

$ArN_2^+ + C_6H_5G \longrightarrow p\text{-}G—C_6H_4—N=N—Ar$ ($G = OH, NR_2, NHR, NH_2$)

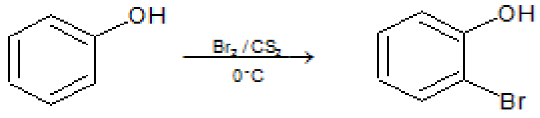
l) Mercuration



f) Halogenation

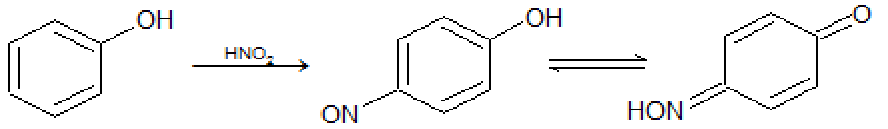


(goes via ArO; no monobromophenols)



2-bromophenol

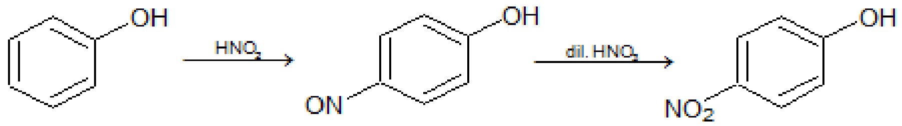
h) Nitrosation



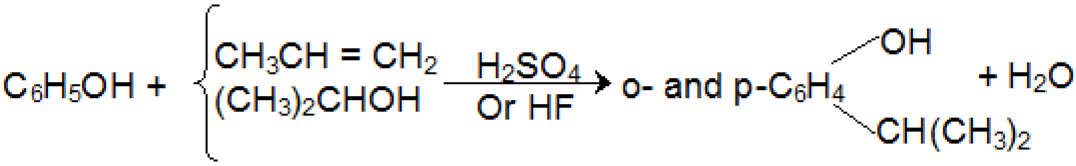
p-nitrosophenol

Quinone monoxime

i) Nitration



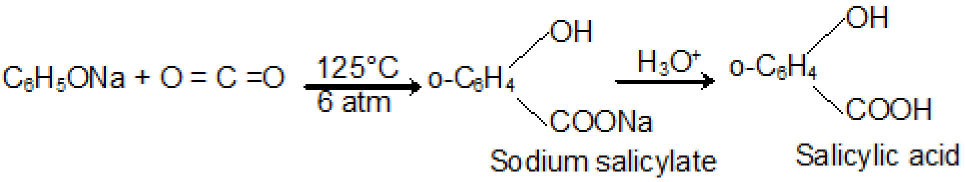
m) Ring alkylation



$$C_6H_5OH + \left\{\begin{matrix} CH_3CH = CH_2 \\ (CH_3)_2CHOH \end{matrix}\right. \xrightarrow[\text{Or HF}]{H_2SO_4} \text{o- and p-}C_6H_4\begin{matrix} OH \\ CH(CH_3)_2 \end{matrix} + H_2O$$

RX and $AlCl_3$ give poor yields because $AlCl_3$ coordinates with O.

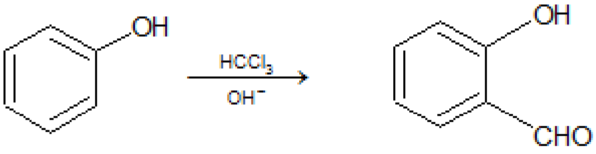
n) Kolbe synthesis of phenolic carboxylic acids



$$C_6H_5ONa + O = C = O \xrightarrow[\text{6 atm}]{125°C} \text{o-}C_6H_4\begin{matrix} OH \\ COONa \end{matrix} \xrightarrow{H_3O^+} \text{o-}C_6H_4\begin{matrix} OH \\ COOH \end{matrix}$$

Phenoxide carbanion adds at the electrophilic carbon of CO_2, para product is also possible.

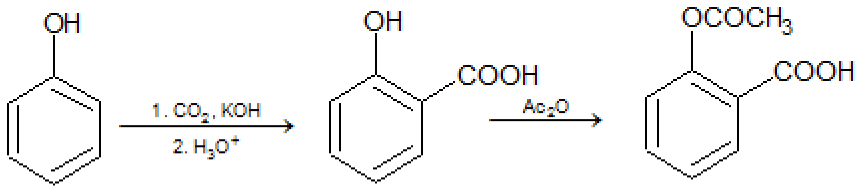
o) Reimer – Tiemann synthesis of phenolic aldehydes



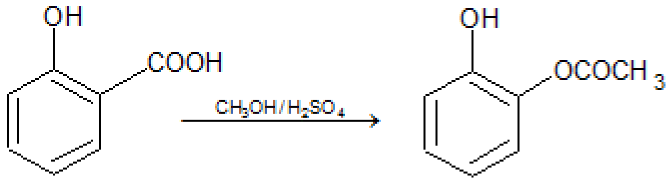
The electrophile is the dichlorocarbene :CCl_2, formation of carbene is an example of α-elimination. $\overline{O}H + HCCl_3 \xrightarrow{-HCl} \ddot{C}Cl_2$

p) Synthesis of (a) aspirin (acetylsalicylic acid) (b) oil of wintergreen (methyl salicylate)

a)



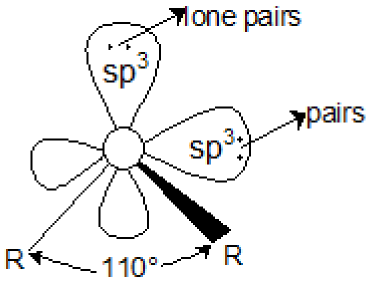
b)

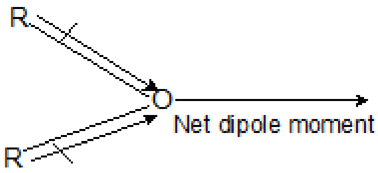


Ethers:

Physical Properties of Ethers

- **Physical state, colour and odour**: Dimethyl ether and ethyl methyl ether is gas at ordinary temperature while the other lower homologues of ethers are colourless liquid with characteristic 'ether smell'.
- **Dipole nature**: Ethers have a tetrahedral geometry i.e., oxygen is sp^3 hybridized. The C— O—C angle in ethers is 110°. Because of the greater electronegativity of oxygen than carbon, the C—O bonds are slightly polar and are inclined to each other at an angle of 110°, resulting in a net dipole moment.



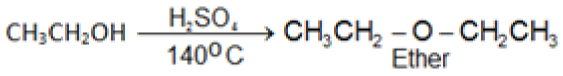


Bond angle of ether is greater than that of tetrahedral bond angle of 109°28'.

- **Solubility and boiling point:** Due to the formation of less degree of hydrogen bonding, ethers have lower boiling point than their corresponding isomeric alcohols and are slightly soluble in water.

Preparation of Ethers:

a) **From alcohols:**



$$CH_3CH_2OH \xrightarrow[140^{o}C]{H_2SO_4} \underset{\text{Ether}}{CH_3CH_2-O-CH_2CH_3}$$

Order of dehydration of alcohol leading to formation of ethers: 1° > 2° > 3°

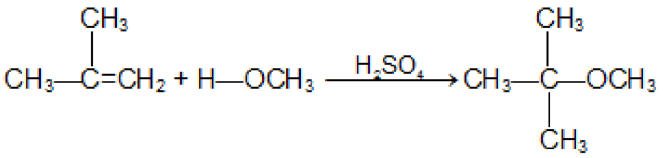
$$CH_3CH_2OH + CH_2N_2 \xrightarrow{HBF_4} CH_3CH_2—O—CH_3 + N_2$$

b) **Williamson's synthesis:**

$R\text{-}X + Na^{+}\,{}^{-}O\text{-}R' \rightarrow R\text{-}O\text{-}R' + Na^{+}X^{-}$

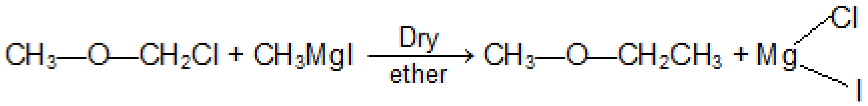
In case of tertiary substrate elimination occurs giving alkenes.

From alkenes:.



$$CH_3—\overset{\overset{\displaystyle CH_3}{|}}{C}=CH_2 + H—OCH_3 \xrightarrow{H_2SO_4} CH_3—\underset{\underset{\displaystyle CH_3}{|}}{\overset{\overset{\displaystyle CH_3}{|}}{C}}—OCH_3$$

From Grignard reagent: Treating a - halo ethers with suitable Grignard reagents.

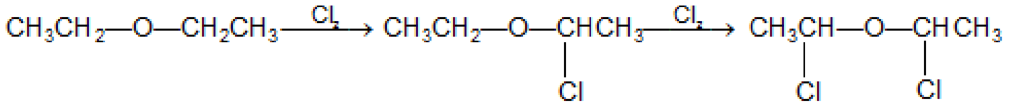


$$CH_3—O—CH_2Cl + CH_3MgI \xrightarrow[\text{ether}]{\text{Dry}} CH_3—O—CH_2CH_3 + Mg\begin{smallmatrix}Cl\\I\end{smallmatrix}$$

On standing in contact with air, most aliphatic ethers are converted slowly into unstable peroxides. The presence of peroxides is indicated by formation of a red colour when the ether is shaken with an aqueous solution of ferrous ammonium sulfate and potassium thiocyanate

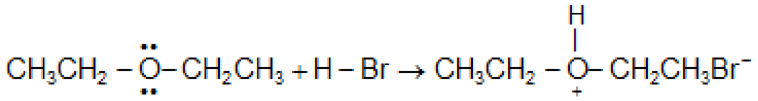
? $$\text{Peroxide} + Fe^{2+} \rightarrow Fe^{3+} \xrightarrow{SCN^-} \underset{\text{Red}}{Fe(SCN)_n^{(3-n)-}} (n = 1 \text{ to } 6)$$

f) Halogenation of ethers:



$$CH_3CH_2—O—CH_2CH_3 \xrightarrow{Cl_2} CH_3CH_2—O—\underset{\displaystyle Cl}{\underset{|}{C}}HCH_3 \xrightarrow{Cl_2} CH_3\underset{\displaystyle Cl}{\underset{|}{C}}H—O—\underset{\displaystyle Cl}{\underset{|}{C}}HCH_3$$

g) Ethers as base:



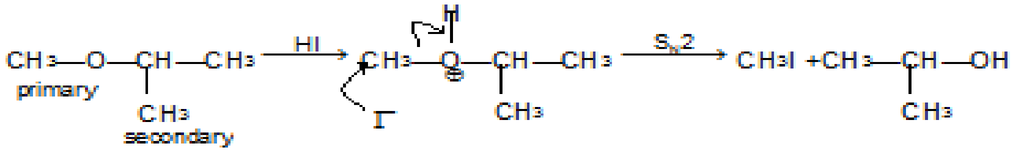
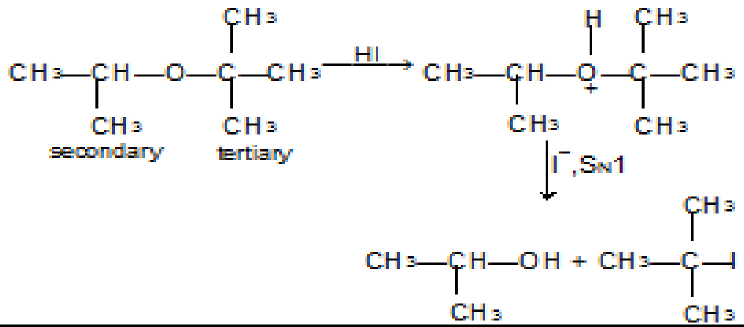
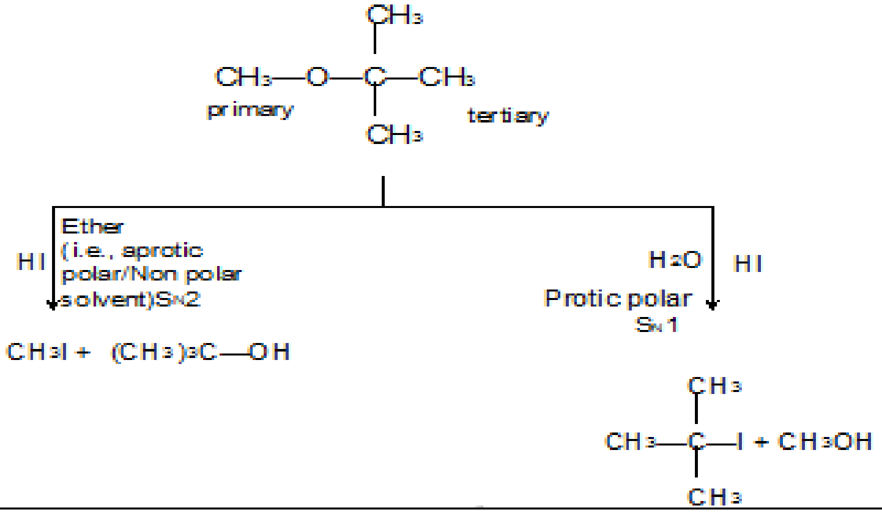
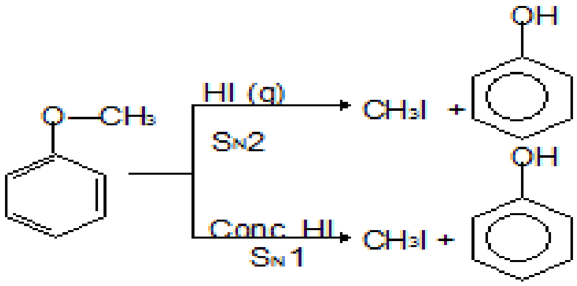
$$CH_3CH_2 - \ddot{\underset{..}{O}} - CH_2CH_3 + H - Br \rightarrow CH_3CH_2 - \overset{\overset{\displaystyle H}{|}}{\underset{+}{O}} - CH_2CH_3 Br^-$$

h) Reaction With Cold conc. HI/HBr:

$$R—O—R' + \text{Cold HI} \longrightarrow R\text{-}OH + R'I \ (R' < R)$$

i) Hot conc. HI/HBr:

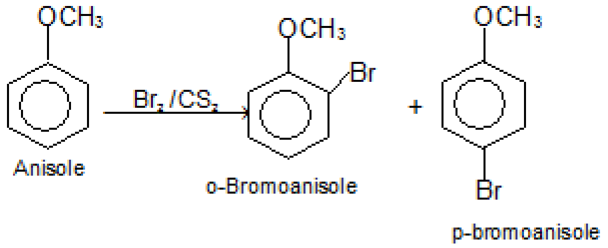
$$R—O—R' + \text{Hot HI} \longrightarrow RI + R'I + H_2O$$

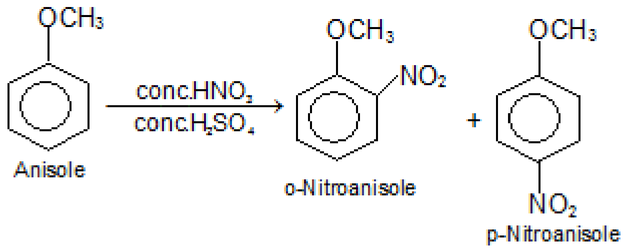
Case I:	
Case II:	
Case III:	
Case IV:	

$$C_2H_5-O-C_2H_5 + CH_3COCl \xrightarrow[Anhy\ ZnCl_2]{\Delta} C_2H_5Cl + CH_3COOC_2H_5$$

i) Reaction with acid chlorides and anhydrides:

j) Electrophilic substitution reactions

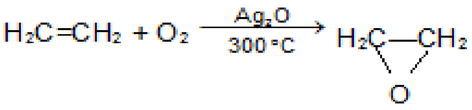




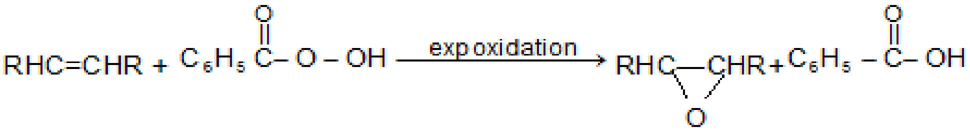
Epoxides or Oxiranes:

Preparation

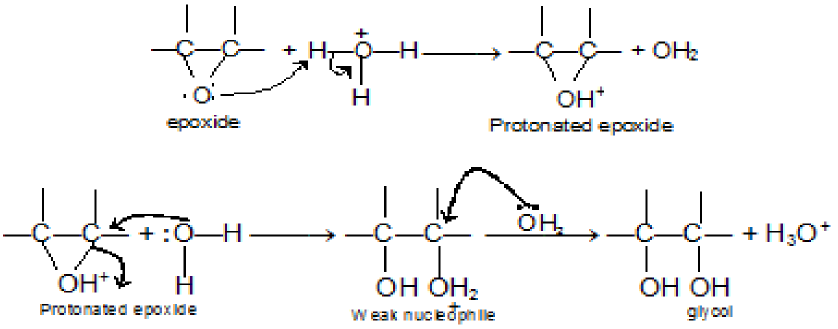
a) Oxidation of ethylene :



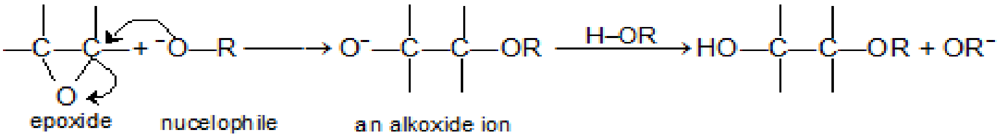
b) Expoxidation :



Acid catalysed ring opening



Base catalysed ring opening:



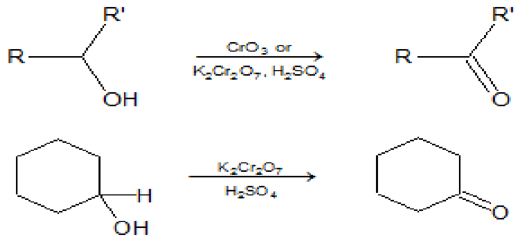
Aldehydes, Ketones & Carboxylic Acid

Aldehyde, Ketones and Carboxylic Acids

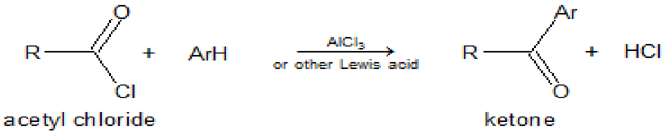
Aldehyde and Ketones

Preparation of Ketones:

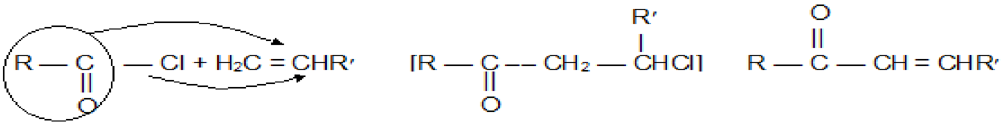
a) Oxidation of Secondary alcohols:



b) Friedel – Crafts acylation



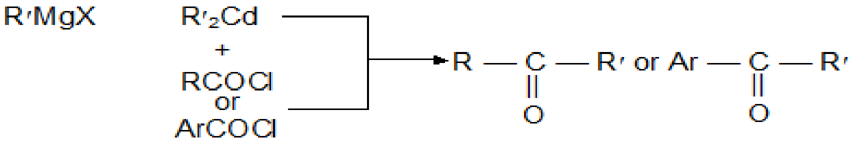
c) Acylation of Alkenes



$$R-\underset{\underset{O}{\|}}{C}-Cl + H_2C=CHR' \qquad [R-\underset{\underset{O}{\|}}{C}-CH_2-\overset{\overset{R'}{|}}{C}HCl] \qquad R-\overset{\overset{O}{\|}}{C}-CH=CHR'$$

This is Markovnikov addition initiated by $R-\overset{+}{C}=\ddot{O}:$, an acylium cation.

d) With Organometallics



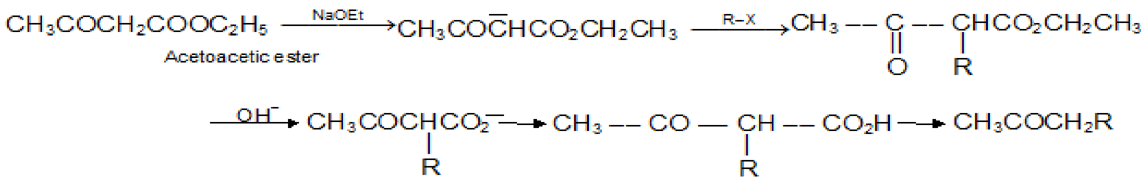
$$R'MgX \qquad R'_2Cd + RCOCl \text{ or } ArCOCl \longrightarrow R-\underset{\underset{O}{\|}}{C}-R' \text{ or } Ar-\underset{\underset{O}{\|}}{C}-R'$$

R′ must by aryl or primary alkyl

e) By heating the calcium salt of any monocarboxylic acid other than formic acid

$$(RCO_2)_2Ca + \Delta \rightarrow R_2CO + CaCO_3$$

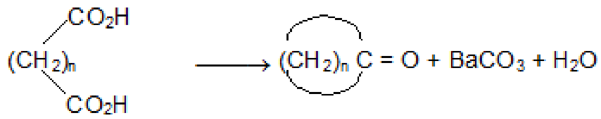
f) Acetoacetic ester synthesis of ketones



$$CH_3COCH_2COOC_2H_5 \xrightarrow{NaOEt} CH_3CO\bar{C}HCO_2CH_2CH_3 \xrightarrow{R-X} CH_3-\underset{\underset{O}{\|}}{C}-\underset{\underset{R}{|}}{C}HCO_2CH_2CH_3$$

$$\xrightarrow{OH^-} CH_3COCHCO_2^- \underset{\underset{R}{|}}{} \longrightarrow CH_3-CO-\underset{\underset{R}{|}}{CH}-CO_2H \longrightarrow CH_3COCH_2R$$

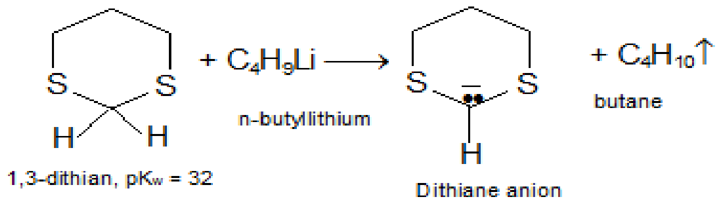
g) Ring Ketones from Dicarboxylic acids and their Derivaties:

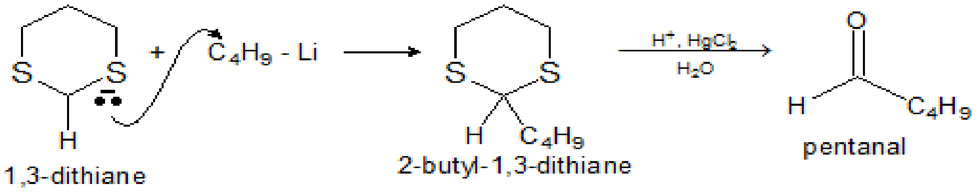


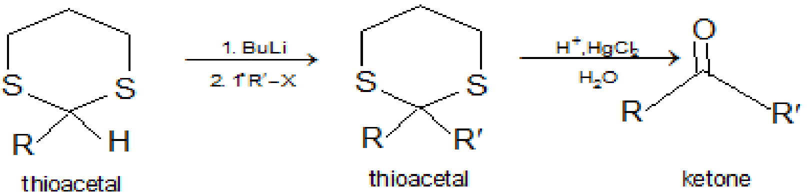
n = 4 and 5

Cyclopentanone or cyclohexanone

h) Synthesis of Ketones and Aldehydes Using 1,3-Dithianes:

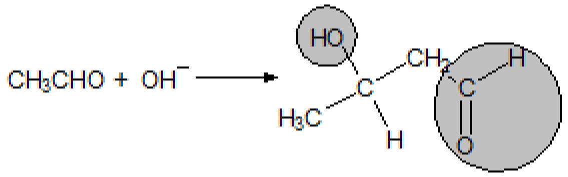






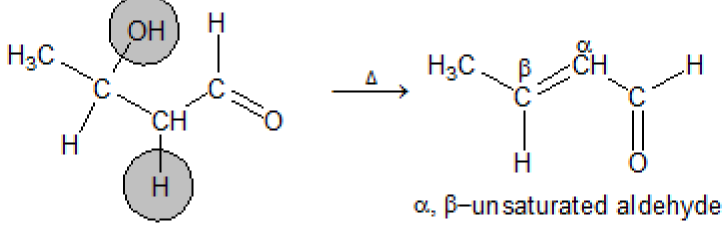
Reactions of Aldehydes and Ketones:

a) Aldol condensation



(Since it contains two functional groups aldehydes and alcohol)

Aldol easily undergoes dehydration

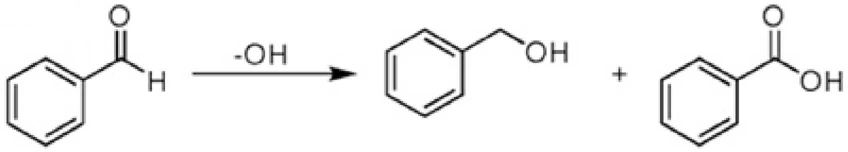


α, β–unsaturated aldehyde

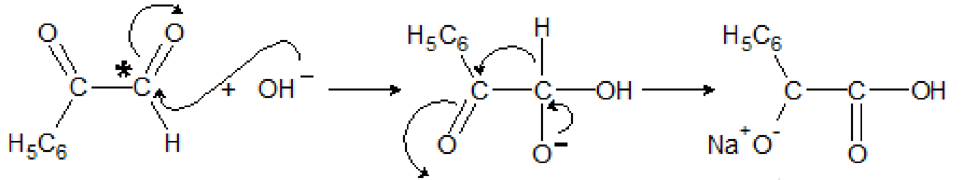
Aldehydes and ketones having alpha hydrogen atom:

b) Cannizzaro reaction:

Aldehydes and ketones having no alpha hydrogen atom:



When two carbonyl groups are present within a molecule, think of intramolecular reaction. OH⁻ will attack more positively charged carbon. In this case, it is right >c=0 group.



Sodium salt of Mandelic acid

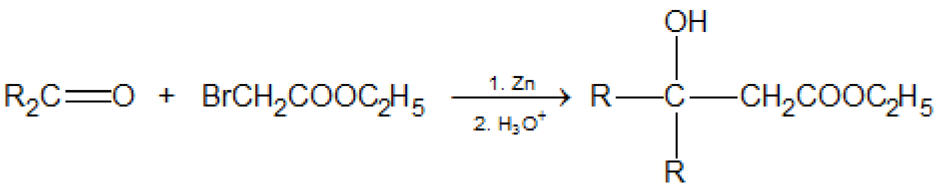
c) Formation of Keto Esters

Esters having a-hydrogen on treatment with a strong base e.g. C_2H_5ONa. Undergo self condensation to produce b-keto esters. This reaction is Claisen Condensation.

$$2CH_3COOC_2H_5 \xrightarrow[2.\ H^+]{1.\ C_2H_5ONa} CH_3COCH_2COOC_2H_5$$

d) Reformatsky Reaction

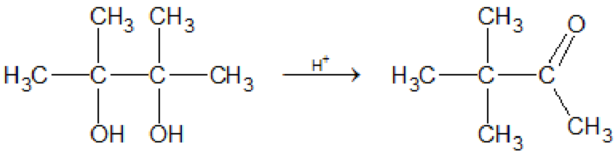
This is the reaction of a-haloester, usually an a-bromoester with an aldehyde or ketone in the presence of Zinc metal to produce b-hydroxyester.



$$R_2C{=}O + BrCH_2COOC_2H_5 \xrightarrow[2.\ H_3O^+]{1.\ Zn} R-\overset{\overset{\large OH}{|}}{\underset{\underset{\large R}{|}}{C}}-CH_2COOC_2H_5$$

e) Pinacol-pinacolone Rearrangement

The acid catalysed rearrangement of 1,2 diols (Vicinal diols) to aldehydes or ketones with the elimination of water is known as pinacol pinacolone rearrangement.



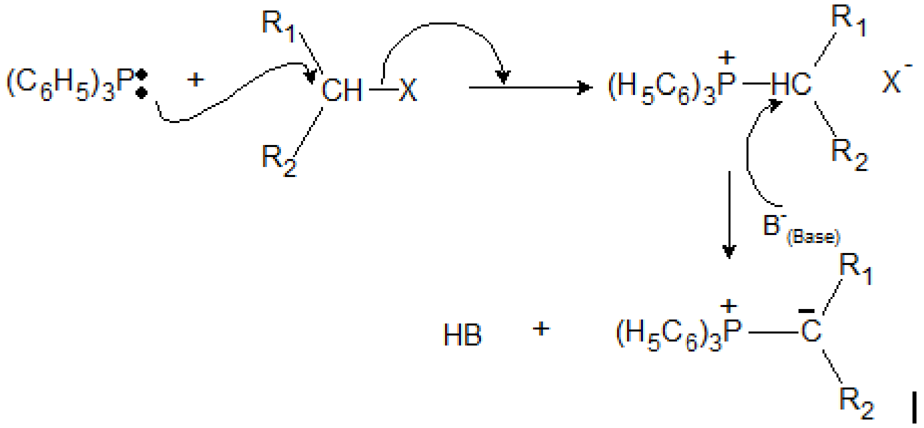
pinacol

Pinacolone
(Methyl t-butylketone)

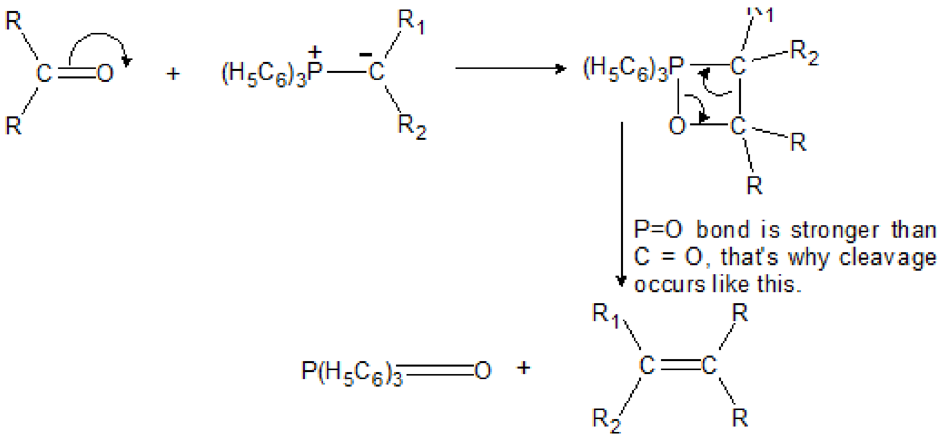
a) Wittig-Ylide Reaction

Aldehydes and Ketones react with phosphorus Ylides to yield alkenes and triphenyl phosphine oxide. An Ylide is a neutral molecule having a negative carbon adjacent to a positive hetero atom. Phosphorus ylides are also called phosphoranes.

Preparation of Ylides

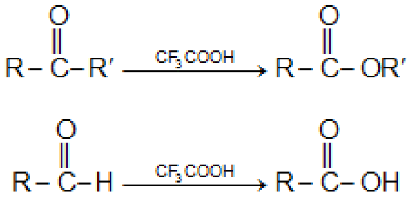


Reaction of Ylide with >C=O



P=O bond is stronger than C = O, that's why cleavage occurs like this.

d) Baeyer-Villiger Oxidation

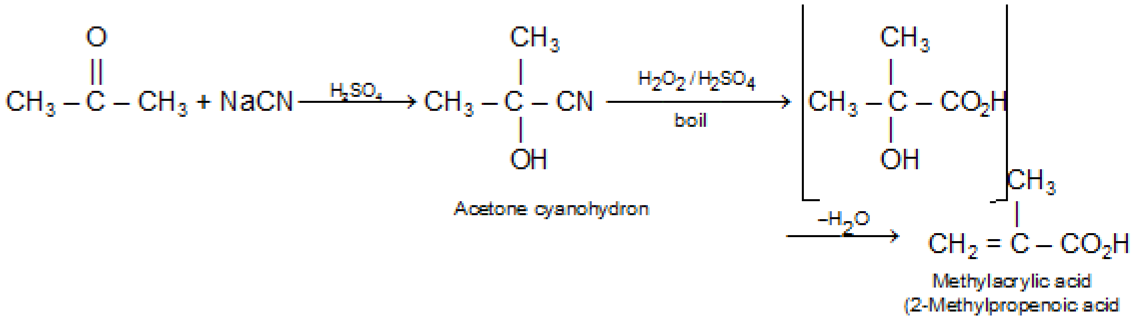


$$R-\overset{O}{\overset{\|}{C}}-R' \xrightarrow{CF_3COOH} R-\overset{O}{\overset{\|}{C}}-OR'$$

$$R-\overset{O}{\overset{\|}{C}}-H \xrightarrow{CF_3COOH} R-\overset{O}{\overset{\|}{C}}-OH$$

Above things happens in BVO (Bayer Villiger oxidation). Reagents are either per acetic acid or perbenzoic acid or pertrifluoroacetic acid or permonosulphuric acid.

e) Addition of cyanide

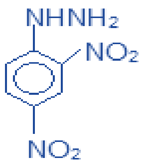
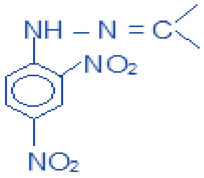


$$CH_3-\overset{O}{\overset{\|}{C}}-CH_3 + NaCN \xrightarrow{H_2SO_4} CH_3-\underset{OH}{\underset{|}{\overset{CH_3}{\overset{|}{C}}}}-CN \xrightarrow[boil]{H_2O_2/H_2SO_4} \left[CH_3-\underset{OH}{\underset{|}{\overset{CH_3}{\overset{|}{C}}}}-CO_2H\right] \xrightarrow{-H_2O} CH_2=\overset{CH_3}{\overset{|}{C}}-CO_2H$$

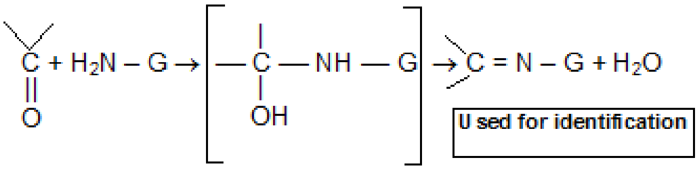
Acetone cyanohydron

Methylacrylic acid
(2-Methylpropenoic acid

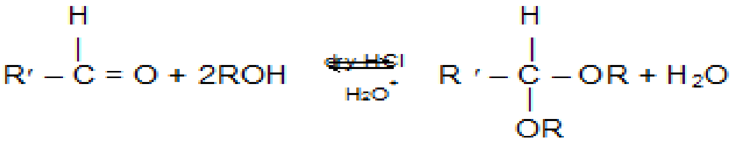
f) Addition of bisulfite:

	$H_2N - G$	Product	
H_2NOH	Hydroxylamine	$> C = N - OH$	Oxime
$H_2N - NH_2$	Hydrazine	$> C = N - NH_2$	Hydrazone
$H_2N - NH - C_6H_5$	Phenylhydrazine	$> C = N - NHC_6H_5$	Phenylhydrazone
$H_2N - NH - CO - NH_2$	Semicarbazide	$> C = N - NHCONH_2$	Semicarbazone
	2, 4-Dinitrophenyl hydrazine		2, 4-dinitrophenylhydrazone (bright orange or yellow precipitate used for identifying aldehydes and ketones

g) Addition of derivative of ammonia



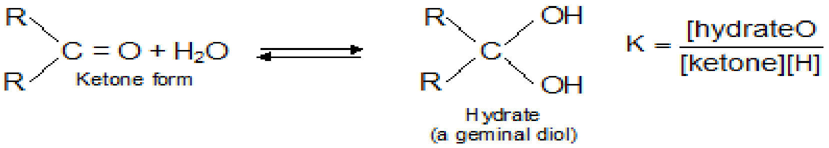
h) Addition of Alcohols; Acetal Formation



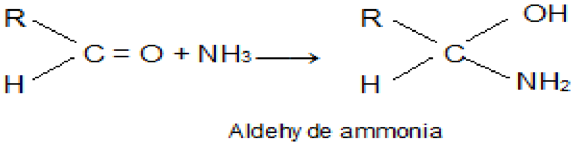
An acetal (gem-diether)

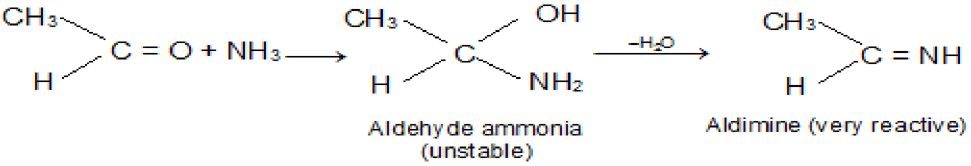
In H_3O^+, RCHO is regenerated because acetals undergo acid catalyzed cleavage much more easily than do ethers. Since acetals are stable in neutral or basic media, they are used to protect the – CH = O group.

i) Addition of Water



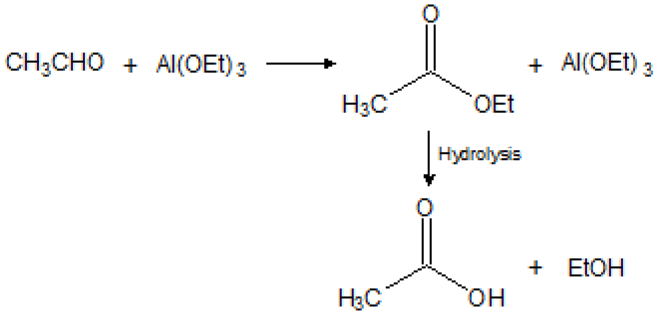
j) Addition of Ammonia:





k) Tischenko reaction:

All aldehydes can be made to undergo the Cannizzaro reaction by treatment with *aluminium ethoxide.* Under these conditions the acids and alcohols are combined as the ester, and the reaction is then known as the Tischenko reaction; eg, acetaldehyde gives ethyl acetate, and propionaldehyde gives propyl propionate.



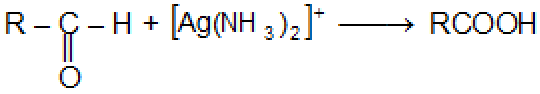
Oxidation of Aldehydes and Ketones

a)

$$\mathrm{R\,CH=O/\,Ar\,CH=O \xrightarrow{KMnO_4\ or\,K_2Cr_2O_7/H^+} R - CO_2H/\,ArCO_2H}$$

b) Tollen's Reagent

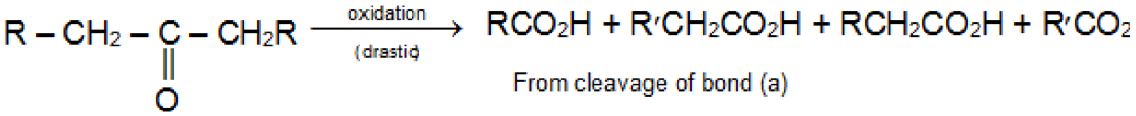
A specific oxidant for RCHO is $[\mathrm{Ag(NH_3)_2}]^+$



$$\mathrm{R-\underset{\displaystyle O}{\underset{\|}{C}}-H + [Ag(NH_3)_2]^+ \longrightarrow RCOOH}$$

Tollen's test chiefly used for the detection of aldehydes.
Tollen's reagent doesnot attack carbon-carbon double bonds.

c) Strong Oxidants: Ketones resist mild oxidation, but with strong oxidants at high temperature they undergo cleavage of C – C bonds on either sides of the carbonyl group.



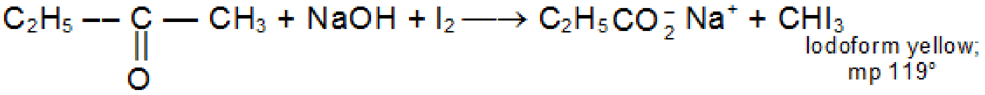
$$\mathrm{R-CH_2-\underset{\displaystyle O}{\underset{\|}{C}}-CH_2R \xrightarrow[(drastic)]{oxidation} RCO_2H + R'CH_2CO_2H + RCH_2CO_2H + R'CO_2}$$

From cleavage of bond (a)

d) Haloform Reaction

CH_3COR are readily oxidised by NaOI (NaOH + I_2) to iodoform, CHI_3, and RCO_2Na

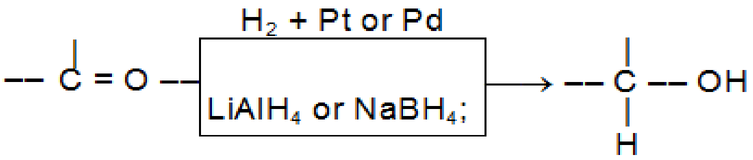
Example:



$$\mathrm{C_2H_5 - \underset{\displaystyle O}{\underset{\|}{C}} - CH_3 + NaOH + I_2 \longrightarrow C_2H_5CO_2^-\,Na^+ + \underset{\text{Iodoform yellow; mp 119°}}{CHI_3}}$$

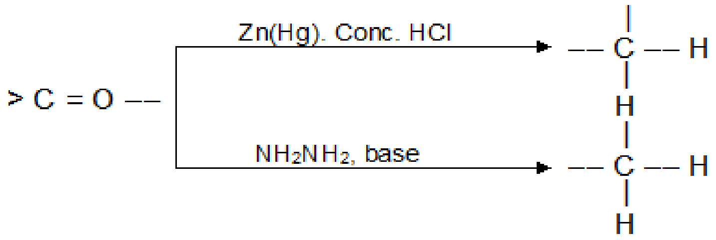
- **Reduction:**

a) Reduction to alcohols



Aldehydes → 1° alcohols; Ketones → 2°alcohols

b) Reduction to hydrocarbons



Clemmensen reduction for compounds sensitive to base

Wolff-Kishner reduction for compounds sensitive to acids

Carboxylic Acids:

Physical Properties of Carboxylic Acids

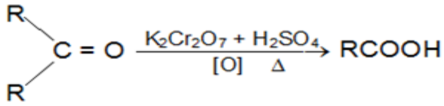
- The first three acids are colourless, pungent smelling liquids.
- First four members are miscible in water due the intermolecular hydrogen bonding whereas higher members are miscible in non – polar solvents like ether.
- Benzene or ethanol but immiscible in water due to the increase in the size of lyophobic alkyl chain.
- The b.p. of carboxylic acids are higher than alcohols because carboxylic acids exist as dimers due to the presence of intermolecular H-bonding
- Increase in the number of Halogen atoms on a-position increases the acidity, eg. $CCl_3COOH > CHCl_2COOH > ClCH_2COOH > CH_3COOH$
- Increase in the distance of Halogen from COOH decreases the acidity e.g $CH_3 – CH_2 – CH(Cl) – COOH > CH_3 – CH(Cl) – CH_2 – COOH > CH_2 – CH_2 – CH_2 – COOH$
- Increase in the electro negativity of halogen increases the acidity. $FCH_2COOH > BrCH_2COOH > ICH_2COOH$

Methods of Preparations of Carboxylic Acids

a. Oxidation of Aldehydes & Ketones

$$R-CH_2OH \xrightarrow[{[O]}]{K_2Cr_2O_7 + H_2SO_4} RCHO \xrightarrow[{[O]}]{K_2Cr_2O_7 + H_2SO_4} RCOOH$$

$$R-CHO \xrightarrow[2.\ H_3O^+]{1.\ Ag_2O \text{ or } Ag(NH_3)_2^+} RCO_2H$$



b. Oxidation of Alkanes:

$$RCH=CHR' \xrightarrow[2.\ \text{Heat},\ H_2O]{1.\ KMnO_4,\ OH^-} RCO_2H + R'CO_2H$$

c. Hydrolysis of Nitriles (Cyanides)

$$R-C\equiv N \xrightarrow[H^+,\ HOH]{\text{Acid hydrolysis}} R.COOH + NH_3$$

d. Carbonation of Grignard Reagents

$$R-X + Mg \xrightarrow{\text{Diethyl ether}} RMgX \xrightarrow{CO_2} RCO_2MgX \xrightarrow{H_3O^+} RCO_2H$$

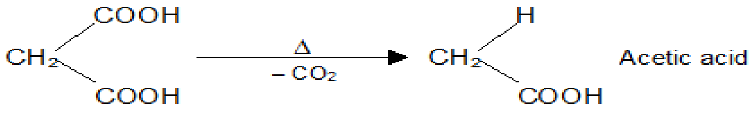
$$\text{or } Ar-Br + Mg \xrightarrow{\text{Diethyl ether}} ArMgBr \xrightarrow{CO_2} ArCO_2MgBr \xrightarrow{H_3O^+} ArCO_2H$$

e. Koch Reaction:

An olefin is heated with carbon monoxide and steam under pressure at 300-400° in the presence of a catalyst, e.g. phosphoric acid.

$$CH_2=CH_2 + CO + H_2O \xrightarrow[\text{steam } 300-400^\circ C]{H_3PO_4} CH_3-CH_2-COOH$$

f. Heating Gem Dicarboxylic Acids:



Chemical Reactions of Carboxylic Acids

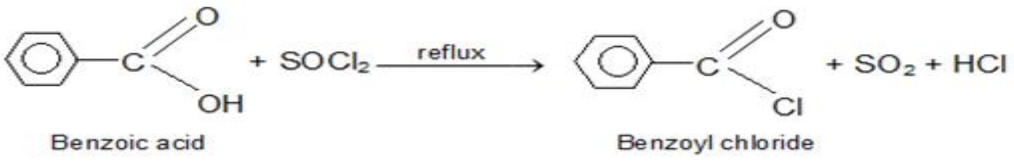
a. Salt formation:

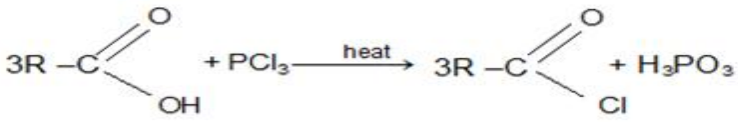
$2CH_3COOH + 2Na \rightarrow 2CH3COO{-}Na^+ + H_2$

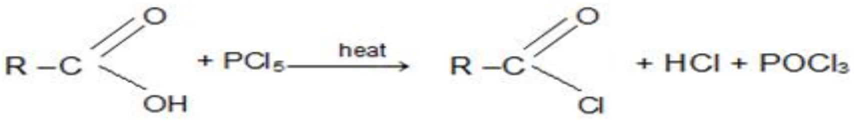
$CH_3COOH + NaOH \rightarrow CH3COO{-}Na^+ + H_2O$

$CH_3COOH + NaHCO_3 \rightarrow CH3COO{-}Na^+ + H_2O + CO_2$

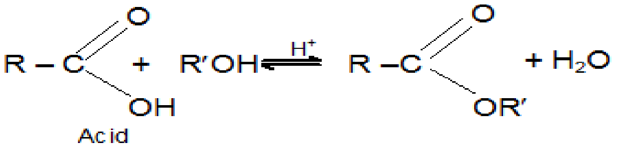
b. Conversion into Acid Chlorides:



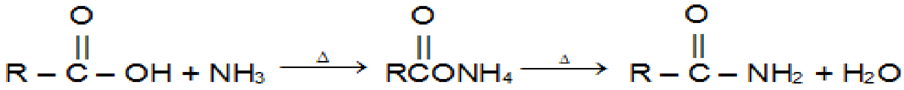




c. Conversion into Esters (Esterification)



d. Conversion into Amides



$$R-\overset{\overset{\Large O}{||}}{C}-OH + NH_3 \xrightarrow{\Delta} R\overset{\overset{\Large O}{||}}{C}ONH_4 \xrightarrow{\Delta} R-\overset{\overset{\Large O}{||}}{C}-NH_2 + H_2O$$

e. Conversion into Anhydrides

$$2CH_3COOH \xrightarrow[\Delta]{P_2O_5} (CH_3CO)_2O + H_2O$$

f. Reduction:

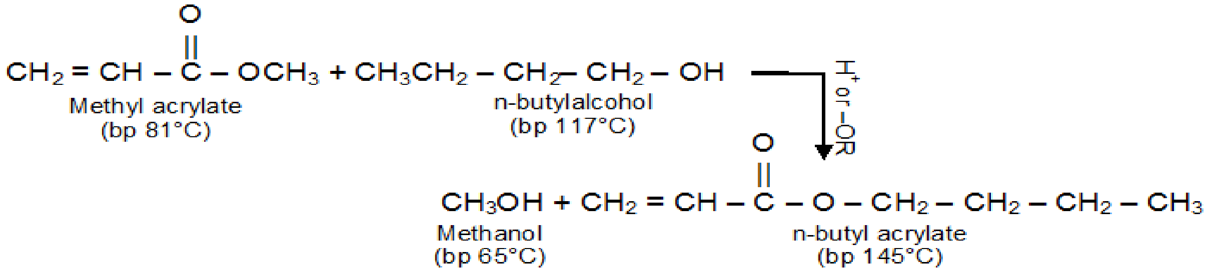
$$4R\text{–}COOH + 3LiAlH_4 \longrightarrow 4H_2 + 2LiAlO_2 + (RCH_2O)_4\,AlLi \xrightarrow{H_2O} RCH_2OH$$

g. Halogenation:

$$CH_3 - COOH \xrightarrow{Cl_2,P} Cl - CH_2 - COOH \xrightarrow{Cl_2,P} Cl_2CH - COOH \xrightarrow{Cl_2,\ P} Cl_3CCOOH$$

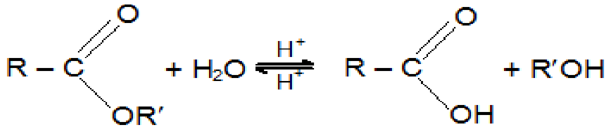
Esters

a) Transesterification :



$$\underset{\substack{\text{Methyl acrylate}\\(\text{bp } 81°C)}}{CH_2 = CH - \overset{\overset{\Large O}{||}}{C} - OCH_3} + \underset{\substack{\text{n-butylalcohol}\\(\text{bp } 117°C)}}{CH_3CH_2 - CH_2 - CH_2 - OH} \xrightarrow{H^+ \text{ or } {}^-OR} \underset{\substack{\text{Methanol}\\(\text{bp } 65°C)}}{CH_3OH} + \underset{\substack{\text{n-butyl acrylate}\\(\text{bp } 145°C)}}{CH_2 = CH - \overset{\overset{\Large O}{||}}{C} - O - CH_2 - CH_2 - CH_2 - CH_3}$$

b) Hydrolysis:



c) Reduction:

$$\underset{\text{Methyl laurate}}{CH_3-(CH_2)_{10}-COOCH_3} \xrightarrow[150°\ \text{High pressure}]{H_2,\ CuO,\ CuCr_2O_4} \underset{\text{Lauryl alcohol}}{CH_3(CH_2)_{10}CH_2OH} + CH_3OH$$

$$\underset{\text{Ethyl palmitate}}{CH_3-(CH_2)_{14}-COOC_2H_5} \xrightarrow{LiAlH_4} \xrightarrow{H^+} \underset{\text{1–Hexadodecanol}}{CH_3-(CH_2)_{14}-CH_2-OH}$$

Acid Chlorides:

a) Acetylation

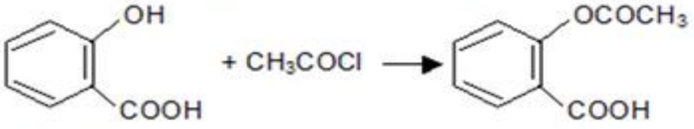
$CH_3COCl + HOH \longrightarrow CH_3COOH + HCl$

$CH_3COCl + HOC_2H_5 \longrightarrow CH_3COOC_2H_5 + HCl$

Acetyl chloride Ethyl acetate

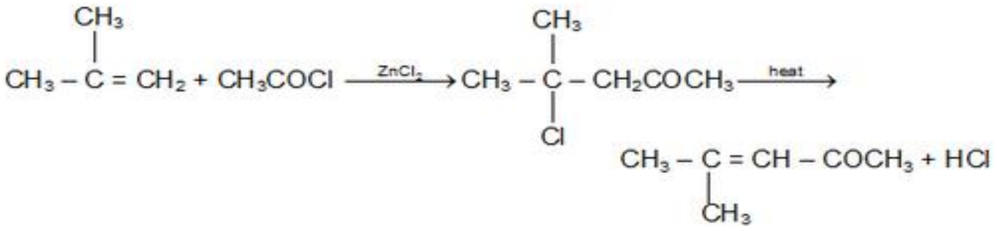
$CH_3COCl + H_2NC_6H_5 \longrightarrow C_6H_5NHCOCH_3 + HCl$

Aniline Acetanilide



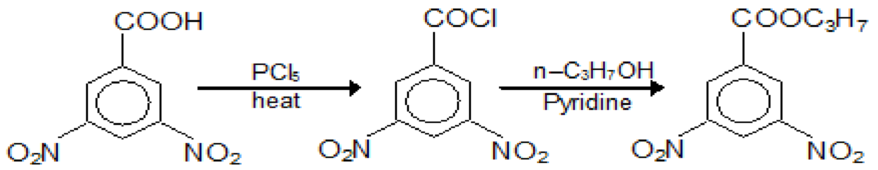
Salicylic acid Acetyl Salicylic acid (Aspirin)

b) Reaction with Olefins:

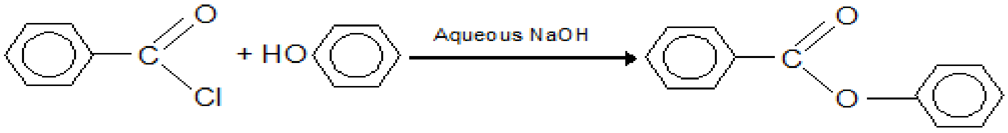


$$CH_3-\overset{\overset{\large CH_3}{|}}{C}=CH_2 + CH_3COCl \xrightarrow{ZnCl_2} CH_3-\underset{\underset{\large Cl}{|}}{\overset{\overset{\large CH_3}{|}}{C}}-CH_2COCH_3 \xrightarrow{heat} CH_3-\underset{\underset{\large CH_3}{|}}{C}=CH-COCH_3 + HCl$$

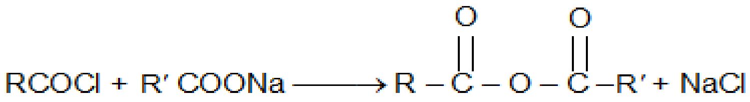
c) Conversion of Acid Chlorides into Acid Derivatives:



3-5, Dinitrobenzoic acid 3-5, Dinitrobenzoyl chloride n-propyl 3, 5 – dinitrobenzoate



Benzoyl chloride Phenol Phenyl benzoate

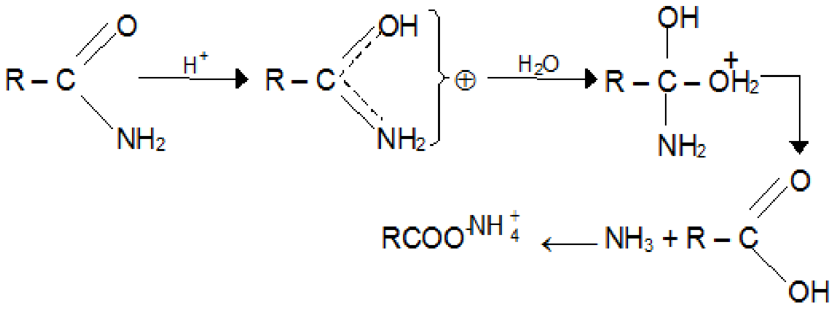


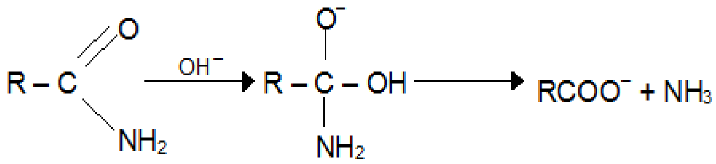
$$RCOCl + R'COONa \longrightarrow R-\overset{\overset{\large O}{||}}{C}-O-\overset{\overset{\large O}{||}}{C}-R' + NaCl$$

Acid anhydride

Amides

a. Hydrolysis:



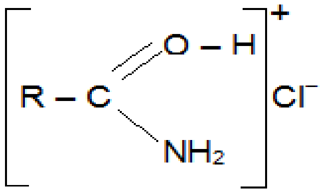


b. Acidic Character of Amides:

$2RCONH_2 + HgO \rightarrow (RCONH)_2Hg + H_2O$

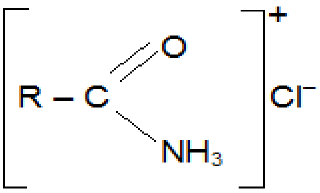
c. Basic Character of Amides:

Amides are very feebly basic and form unstable salts with strong inorganic acids. e.g. $RCONH_2HCl$. The structure of these salts may be I or II



I

or



II

d. Reduction:

$$RCONH_2 + 4H \xrightarrow{Na/C_2H_5OH} R-CH_2-NH_2 + H_2O$$

e. Reaction with Phosphorus Pentaoxide:

$$R\text{-}CONH2 + P_2O_5 \rightarrow R\text{-}CN$$

f. Reaction with Nitrous Acid:

$$RCONH_2 + HNO_2 \rightarrow RCO_2H + N_2 + H_2O$$

Nitroalkanes, Amines & Diazonium Salts

Amines

Structure of amines: Trigonal Pyramidal

Basicity of Amines

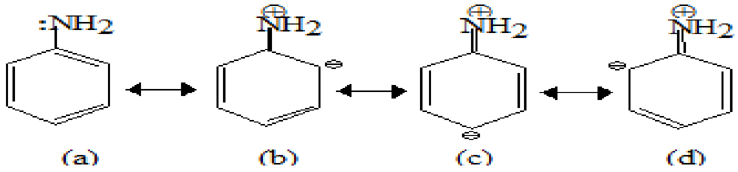
a) **Aliphatic Amine:**

Basic Strength: $NH_3 < RNH_2 < R_2NH < R_3N$,

b) **Aromatic Amine**:

Basic Strength: $NH_3 > Ar\text{-}NH_2 > Ar_2\text{-}NH_2$

Benzene ring decreases the electron density over N atom due to resonance effect.

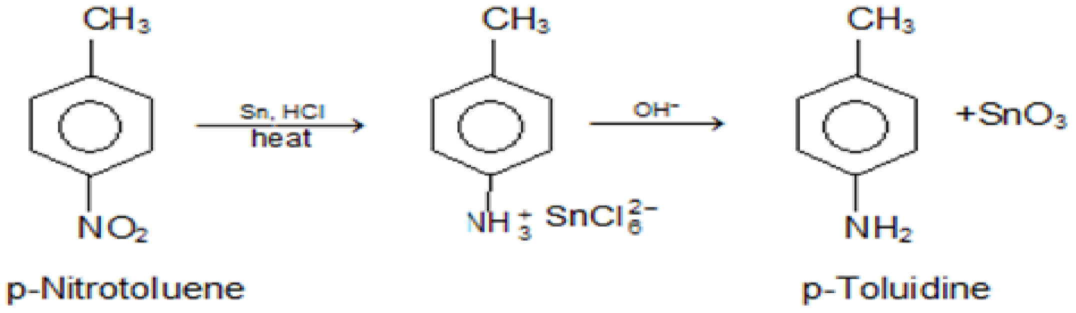


Preparation of Amines

a) From Alkyl halides:

$$RX \xrightarrow{NH_3} \underset{(1^\circ)}{RNH_2} \xrightarrow{RX} \underset{(2^\circ)}{R_2NH} \xrightarrow{RX} \underset{(3^\circ)}{R_3NH} \xrightarrow{RX} \underset{(4^\circ)}{R_4\overset{\ominus}{N}HX^-}$$

b) From Nitro Compounds:



c) From Nitriles :

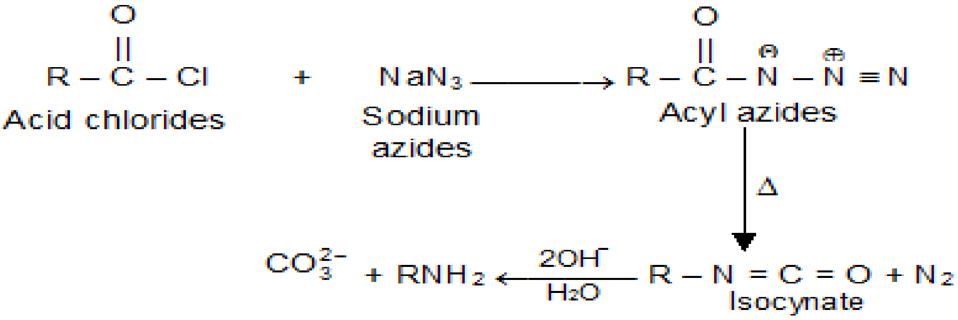
d) Hofmann Bromamide or Hofmann degradation:

$$RCONH_2 + Br_2 + 4KOH \longrightarrow RNH_2 + K_2CO_3 + 2KBr$$

e) From carbonyl compounds (Reductive Amination)

$$CH_3CH=O + NH_3 \longrightarrow \underset{\text{(an imine)}}{CH_3CH=NH} \xrightarrow{H_2/Ni} \underset{\text{(an ami}}{CH_3CH}$$

f) Curtius reaction:



$$\underset{\text{Acid chlorides}}{R-\overset{\overset{O}{\|}}{C}-Cl} + \underset{\text{Sodium azides}}{NaN_3} \longrightarrow \underset{\text{Acyl azides}}{R-\overset{\overset{O}{\|}}{C}-\overset{\ominus}{N}-\overset{\oplus}{N}\equiv N}$$

$$\underset{\text{Isocynate}}{R-N=C=O} + N_2 \xrightarrow[H_2O]{2OH^-} CO_3^{2-} + RNH_2$$

g) Schmidt reaction :

$$RCO_2H + HN_3 \xrightarrow{conc\ H_2SO_4} RNH_2 + CO_2$$

h) Reduction of Alkyl isocyanide:

$$RNC + 4[H] \rightarrow R-NH-CH_3$$

i) Preparation of tertiary amine:

$$3RX + NH_3\ (\text{In excess}) \xrightarrow{\text{Ethanolic solution}} R_3N + 2HX$$

Chemical Reactions

a) Acylation:

$RNH_2 + R'COCl \rightarrow R'CO\ NHR$ an N-substituted amide

$R_2NH + R'COCl \rightarrow R'CO.NR_2$ an N,N disubstituted amide

b) Benzoylation (Schotten Baumann Reaction)

Primary amine reacts with benzoyl chloride to give the acylated product

c) Carbylamine Reaction (Given Only by Primary Amines):

$C_2H_5NH_2 + CHCl_3 + 3KOH \rightarrow C_2H_5NC + 3KCl + 3H_2O$

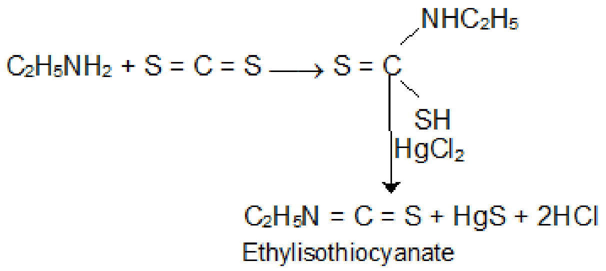
$C_6H_5\ NH_2 + CHCl_3 + 3KOH \rightarrow C_6H_5NC + 3KCl + 3H_2O$

d) Action with Aldehyde and Ketone:

$$C_2H_5NH_2 + CH_3CHO \longrightarrow C_2H_5N = CHCH_3 + H_2O$$

Ethylamine Acetaldehyde Ethylidene ethylamine (Schiff's base)

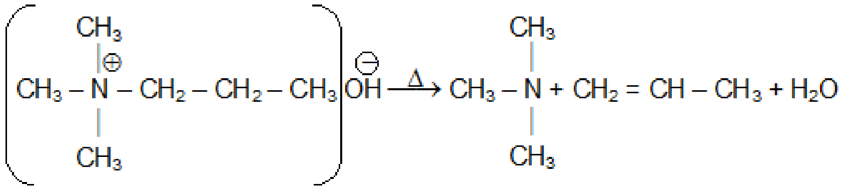
e) Hofmann Mustard Oil Reaction:



f) Reaction with Carbonyl Chloride: $C_2H_5 - NH_2 + COCl_2 \rightarrow C_2H_5NCO + 2HCl$

g) Hofmann Elimination:

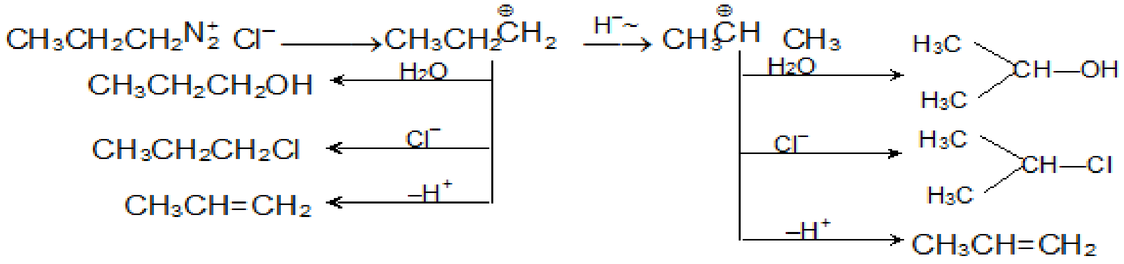
When a quaternary ammonium hydroxide is heated strongly (125° or higher) it decomposes to yield water, a tertiary amine and an alkene

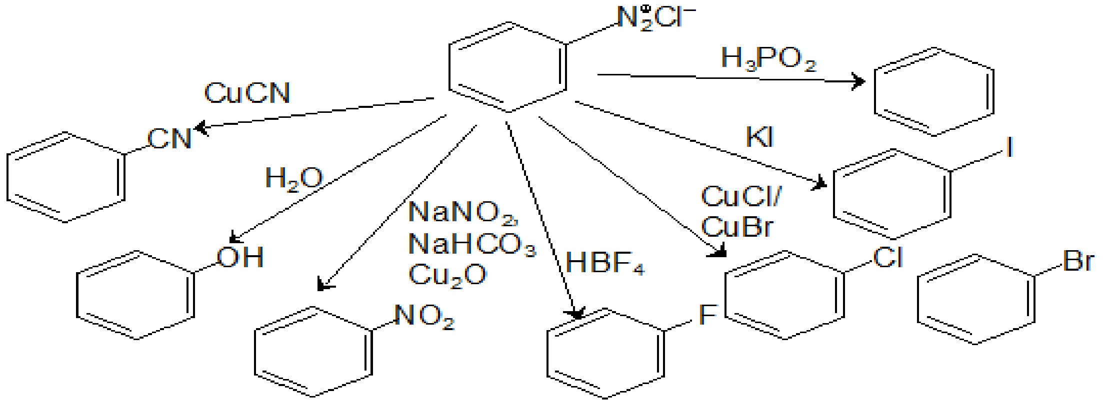


$$\left[CH_3 - \overset{\overset{CH_3}{|}}{\underset{\underset{CH_3}{|}}{N^{\oplus}}} - CH_2 - CH_2 - CH_3\right]\overset{\ominus}{O}H \xrightarrow{\Delta} CH_3 - \overset{\overset{CH_3}{|}}{\underset{\underset{CH_3}{|}}{N}} + CH_2 = CH - CH_3 + H_2O$$

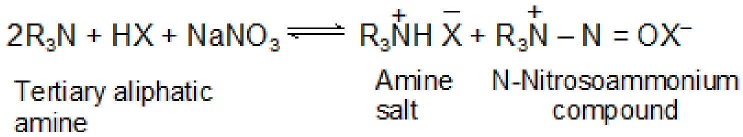
h) The diazonium salts of amines:

$$RNH_2/Ar\text{-}NH_2 \xrightarrow[HCl,0^\circ C]{HONO} RN_2^+Cl^-$$

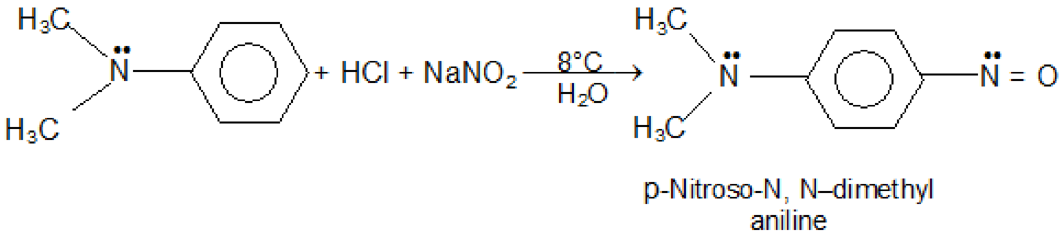




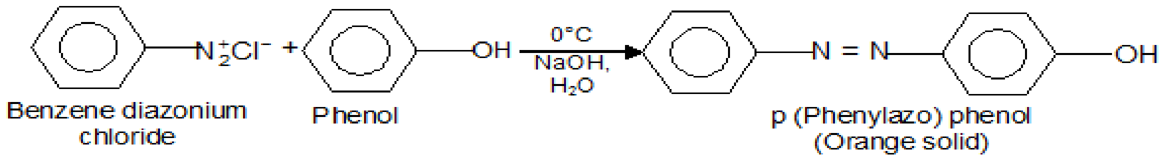
i) Reaction of Tertiary amines with Nitrous acid: When a tertiary aliphatic amine is mixed with nitrous acid, an equilibrium is established among the tertiary amine, its salt, and an N-Nitrosoammonium compound.

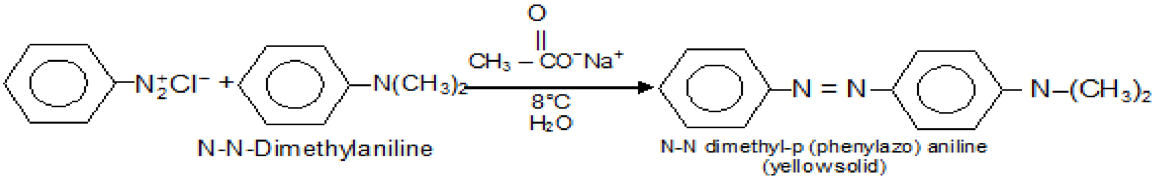


$$2R_3N + HX + NaNO_2 \rightleftharpoons R_3\overset{+}{N}H\,\overset{-}{X} + R_3\overset{+}{N} - N = OX^-$$

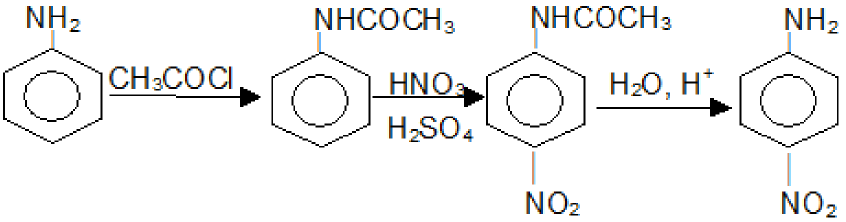


j) Coupling Reactions of Arene Diazonium Salts:

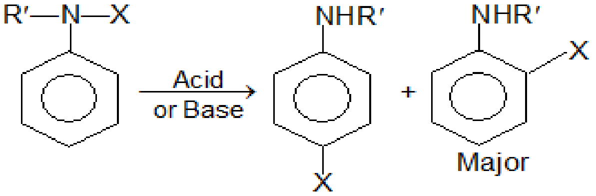




k) Ring Substitution in Aromatic Amines:

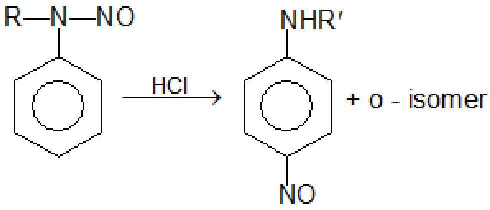


i) Aniline -X rearrangement:



Such compounds are not much stable so the group X migrates mainly at p-position.

1. Fisher-Hepp rearrangement



(Major product)

2. Phenylhydroxylamine - p-aminophenol rearrangement.

Separation of a Mixture of Amines:

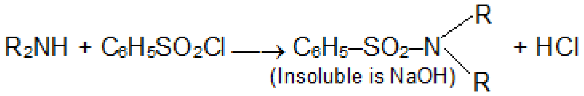
a) Hinsberg's Method

Primary amine: $RNH_2 + C_6H_5SO_2Cl$ ¾® $C_6H_5-SO_2-NH-R + HCl$

$C_6H_5-SO_2-NH-R$: N-alkyl benzene sulfonamides

Dissolves in NaOH due to acidic H-attached to Nitrogen)

Secondary Amine

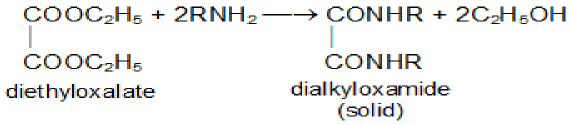


$$R_2NH + C_6H_5SO_2Cl \longrightarrow \underset{\text{(Insoluble is NaOH)}}{C_6H_5-SO_2-N\begin{smallmatrix}R\\R\end{smallmatrix}} + HCl$$

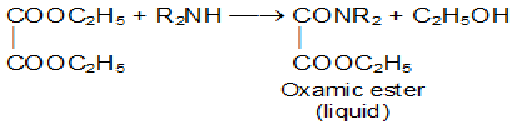
Tertiary amine : Tertiary amines do not react with Hinsberg's reagent.

a) Hofmann's Method:

The mixture of amines is treated with diethyloxalate, which forms a solid oxamide with primary amine, a liquid oxime ester with secondary amine. The tertiary amine does not react.



$$\underset{\text{diethyloxalate}}{\begin{matrix}COOC_2H_5\\|\\COOC_2H_5\end{matrix}} + 2RNH_2 \longrightarrow \underset{\substack{\text{dialkyloxamide}\\\text{(solid)}}}{\begin{matrix}CONHR\\|\\CONHR\end{matrix}} + 2C_2H_5OH$$



$$\begin{matrix}COOC_2H_5\\|\\COOC_2H_5\end{matrix} + R_2NH \longrightarrow \underset{\substack{\text{Oxamic ester}\\\text{(liquid)}}}{\begin{matrix}CONR_2\\|\\COOC_2H_5\end{matrix}} + C_2H_5OH$$

Test for Amines

Primary amine is treated with a strong base in presence in chloroform, an isocyanide is formed and this isocyanide thus formed has a very foul smell.

$$RNH_2 + CHCl_3 + 3KOH \longrightarrow \underset{\substack{\text{an isocyanide}\\\text{(foul smelling)}}}{R-\overset{+}{N}\equiv \overset{-}{C}:} + 3KCl + H_2O$$

Secondary amine is converted into nitrosoamine by treating the amine with nitrous acid. The resultant solutions warmed with phenol and concentrated H_2SO_4, a brown or red colour is formed at first soon it changes to blue and then to green. The colour changes to red on dilution and further changes to greenish blue on treating with alkali.

Tertiary arylamines react with nitrous acid to form o-nitroso aromatic compound.

Polymers

Some Important Terms

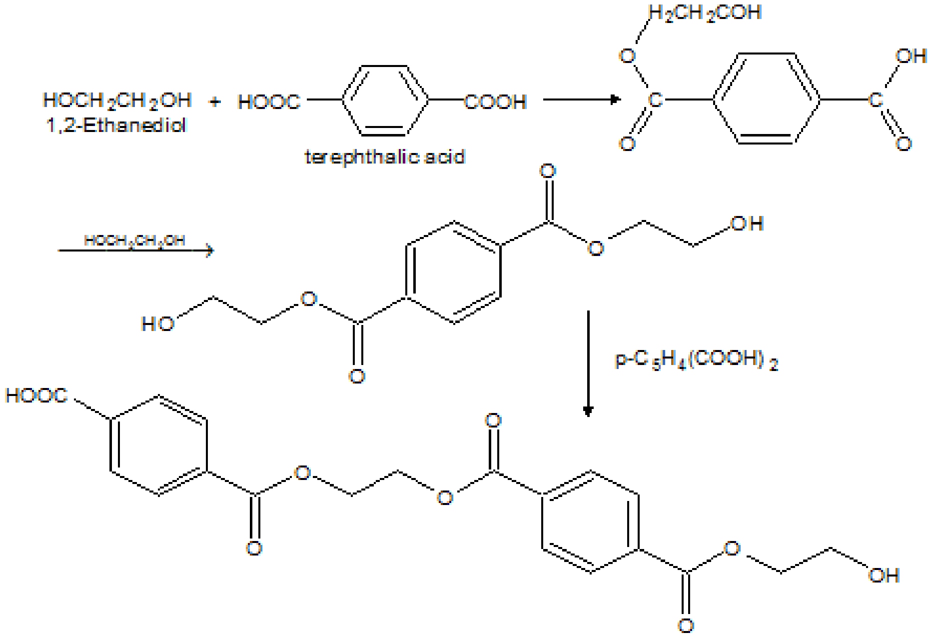
Polymer	Large molecules having high molecular mass formed by combination of number of small units called monomers.
Polymerisation	The process of formation of polymers from respective monomers.
Natural polymers	Found in plants and animals. Examples: proteins, cellulose, starch.
Synthetic polymers:	Synthesised in laboratory from natural material. Example, nylon 6, 6 , Buna-S
Addition Polymers	Formed by repeated addition of monomers having multiple bonds.
Homopolymers	Addition polymers polymers formed from single monomeric species.
Copolymers	Addition polymers formed from two different monomeric species
Condensation polymers	Formed by repeated condensation of different bi or tri-functional monomer units.
Fibres	Long thin, threadlike bits of material that are characterized by great tensile (pulling) strength in the direction of the fiber. The natural fibres – cotton, wool, silk – are typical. The lining-up is brought about by drawing – stretching — the return to random looping and coiling is overcome by strong intermolecular attractions.
Elastomers	Possesses the high degree of elasticity that is characteristic of rubber: it can be greatly deformed — stretched to eight times its original length e.g., buna N and buna S, When the stretching force is removed, the molecular chains of an elastomer do not remain extended and aligned but return to their original random conformations
Thermoplastic polymers	Soften on heating and stiffen on Cooling. e.g polythene, polystyrene, PVC
Thermosetting polymers	Do not soften on heating and cannot be remoulded. Example, bakelite

Polymers are formed in two general ways.

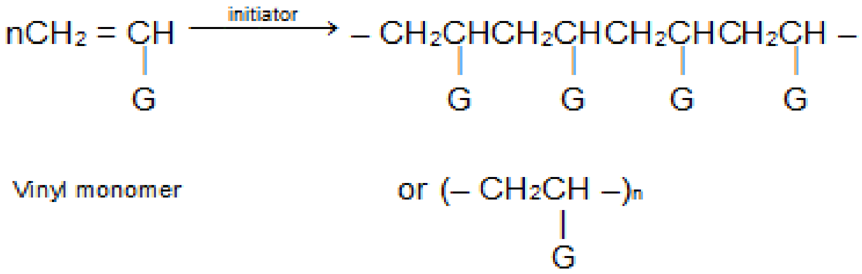
a) In chain-reaction polymerization

$\text{Rad.} + CH_2 = CH_2 \rightarrow RadCH_{2C}H_2 \rightarrow RadCH_{2C}H_{2C}H_{2C}H_{2x} \rightarrow$ etc.

b) In step reaction polymerization,



c) Free-radical vinyl polymerization:



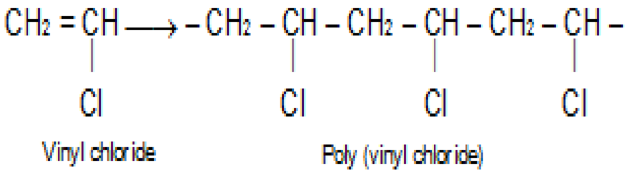
$$nCH_2 = \underset{\displaystyle G}{\underset{|}{CH}} \xrightarrow{\text{initiator}} -CH_2\underset{\displaystyle G}{\underset{|}{C}}HCH_2\underset{\displaystyle G}{\underset{|}{C}}HCH_2\underset{\displaystyle G}{\underset{|}{C}}HCH_2\underset{\displaystyle G}{\underset{|}{C}}H-$$

Vinyl monomer

$$\text{or } (-CH_2\underset{\displaystyle G}{\underset{|}{C}}H-)_n$$

Polymer

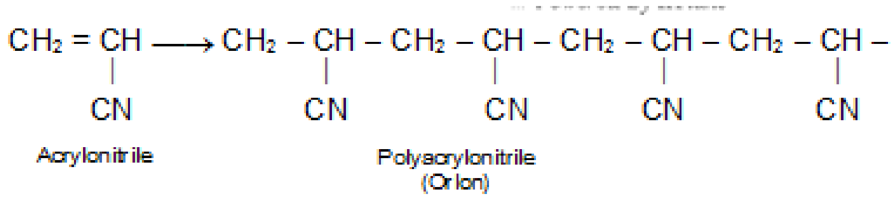
At the doubly bonded carbons — the vinyl groups — and is called *vinyl polymerization*. A wide variety of unsaturated monomers may be used, to yield polymers with different *pendant groups* (G) attached to the polymer backbone. For example.



$$CH_2 = \underset{\displaystyle Cl}{\underset{|}{CH}} \longrightarrow -CH_2-\underset{\displaystyle Cl}{\underset{|}{CH}}-CH_2-\underset{\displaystyle Cl}{\underset{|}{CH}}-CH_2-\underset{\displaystyle Cl}{\underset{|}{CH}}-$$

Vinyl chloride

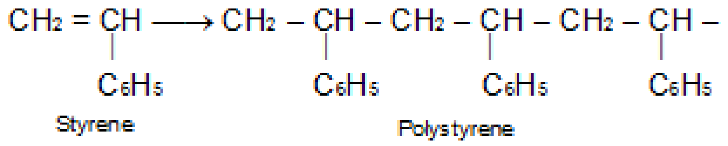
Poly (vinyl chloride)
(PVC)



$$CH_2=\underset{\displaystyle CN}{\underset{|}{CH}} \longrightarrow CH_2-\underset{\displaystyle CN}{\underset{|}{CH}}-CH_2-\underset{\displaystyle CN}{\underset{|}{CH}}-CH_2-\underset{\displaystyle CN}{\underset{|}{CH}}-CH_2-\underset{\displaystyle CN}{\underset{|}{CH}}-$$

Acrylonitrile

Polyacrylonitrile
(Orlon)

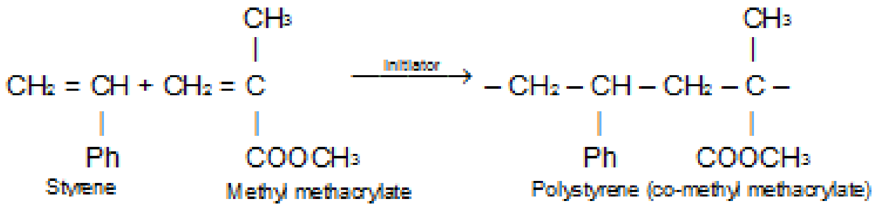


$$CH_2=\underset{\displaystyle C_6H_5}{\underset{|}{CH}} \longrightarrow CH_2-\underset{\displaystyle C_6H_5}{\underset{|}{CH}}-CH_2-\underset{\displaystyle C_6H_5}{\underset{|}{CH}}-CH_2-\underset{\displaystyle C_6H_5}{\underset{|}{CH}}-$$

Styrene

Polystyrene

d) Copolymerization:



$$\underset{\displaystyle Ph}{\underset{|}{CH_2=CH}}+CH_2=\overset{\displaystyle CH_3}{\overset{|}{\underset{\displaystyle COOCH_3}{\underset{|}{C}}}} \xrightarrow{\text{Initiator}} -CH_2-\underset{\displaystyle Ph}{\underset{|}{CH}}-CH_2-\overset{\displaystyle CH_3}{\overset{|}{\underset{\displaystyle COOCH_3}{\underset{|}{C}}}}-$$

Styrene

Methyl methacrylate

Polystyrene (co-methyl methacrylate)

Some Important Polymers:

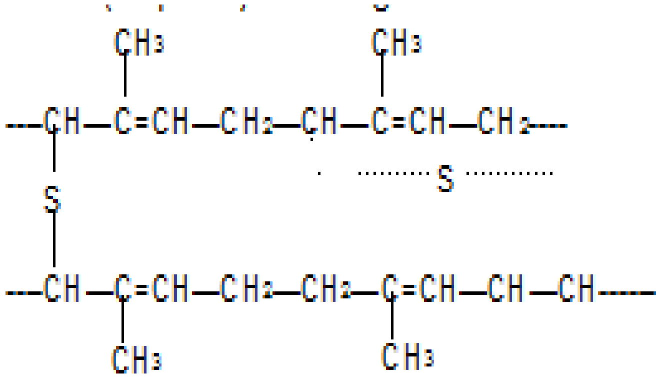
a) Natural Rubber*:*

Addition polymer of isoprene (2-methyl-1,3-butadiene)

An average chain length of 5000 monomer units of isoprene.

The rubber in which the arrangement of carbon chain is trans with respect to the double bond is known as ***Gutta Percha*** and this is the natural rubber obtained from bark of various trees.

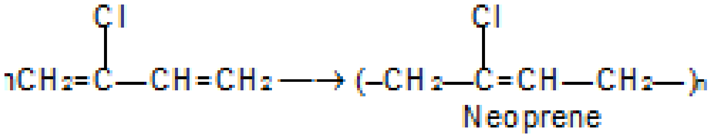
'Vulcanisation of rubber involves addition of sulphur to rubber and heating the mixture to increase the strength of natural rubber. sulphur forms short chains of sulphur atoms that link two hydrocarbon (isoprene) units together.



Vulcanised rubber is thus stronger and less sticky than the natural rubber.

b) Synthetic rubber:(Polychloroprene) or Neoprene)

It is obtained by free radical polymerisation of chloroprene in



$$nCH_2=\overset{\displaystyle Cl}{\overset{|}{C}}-CH=CH_2 \longrightarrow (-CH_2-\overset{\displaystyle Cl}{\overset{|}{C}}=CH-CH_2-)_n$$

Neoprene

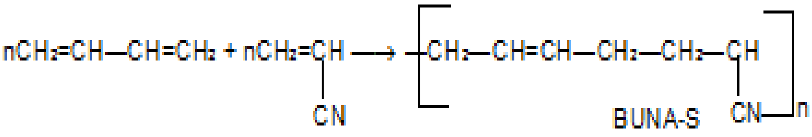
A thermoplastic and need not to be vulcanised.

It is a good general purpose rubber and superior to natural rubber as it is resistant to the reaction of aire, heat, light chemicals, alkalis and acids below 50% strength.

It is used for making transmission belts, printing rolls and flexible tubing employed for conveyence of oil and petrol.

c) **Buna rubbers**:

i) **Buna - N or GRA:** it is synthetic rubber obtained by copolymerisation of one part of acryl nitrile and two parts of butadiene.

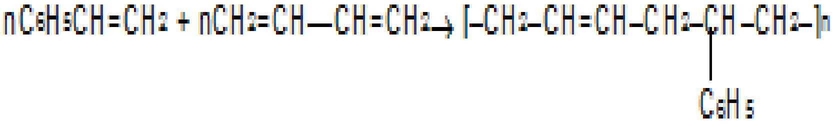


$$nCH_2{=}CH{-}CH{=}CH_2 + nCH_2{=}\underset{CN}{CH} \longrightarrow \left[CH_2{-}CH{=}CH{-}CH_2{-}CH_2{-}\underset{CN}{CH}\right]_n$$

BUNA-S

It is more rigid responds less to heat and very resistant to swelling action of petorol, oils and other organic solvents.

ii) **Buna -S or GRS** (General purpose Styrene rubber): It is a copolymer of three moles of butadiene and one mole of styrene and is an elastomer. It is obtained as a result of free radical copolymerisation of its monomers.



$$nC_6H_5CH{=}CH_2 + nCH_2{=}CH{-}CH{=}CH_2 \rightarrow \left[-CH_2{-}CH{=}CH{-}CH_2{-}\underset{C_6H_5}{CH}{-}CH_2{-}\right]_n$$

BUNA-S

It is generally compounded with carbon black and vulcanised with sulphur. It is extremely resistant to wear and tear and finds use in manufacture of tyres and other mechanical rubber goods.

d) **Teflon**: It is polymer of tetrafluorethylene ($F_2C{=}CF_2$) which on polymerisation gives Telfon.

$$nCF_2{=}CF_2 \xrightarrow{(NH_4)_2S_2O_8\ \ 870-1020K} (-CF_2{-}CF_2{-})_n$$

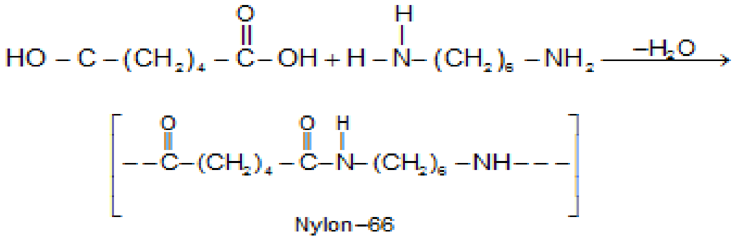
It is thermoplastic polymer with a high softening point (600K).

It is very tough and difficult to work. It is inert to most chemicals except fluorine and molten alkali metals.

It withstands high temperatures. Its electrical properties make it an ideal insulating material for high frequency installation.

e) Nylon -66:

A condensation polymer formed by reaction between adipic acid and hexamethylene diamine. It is a thermoplastic polymer.

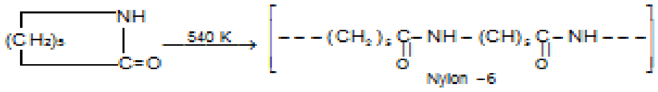


$$HO-C-(CH_2)_4-\overset{O}{\overset{\|}{C}}-OH+H-\overset{H}{\overset{|}{N}}-(CH_2)_6-NH_2\xrightarrow{-H_2O}$$

$$\left[--\overset{O}{\overset{\|}{C}}-(CH_2)_4-\overset{O}{\overset{\|}{C}}-\overset{H}{\overset{|}{N}}-(CH_2)_6-NH---\right]$$

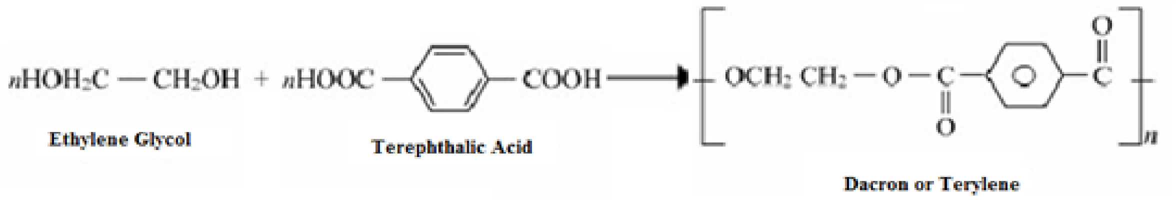
Nylon–66
(A condensation copolymer)

f) Nylon 6 or Perolon - L: A polyamide is prepared by prolonged heating of caprolactam at 530 - 540 K.

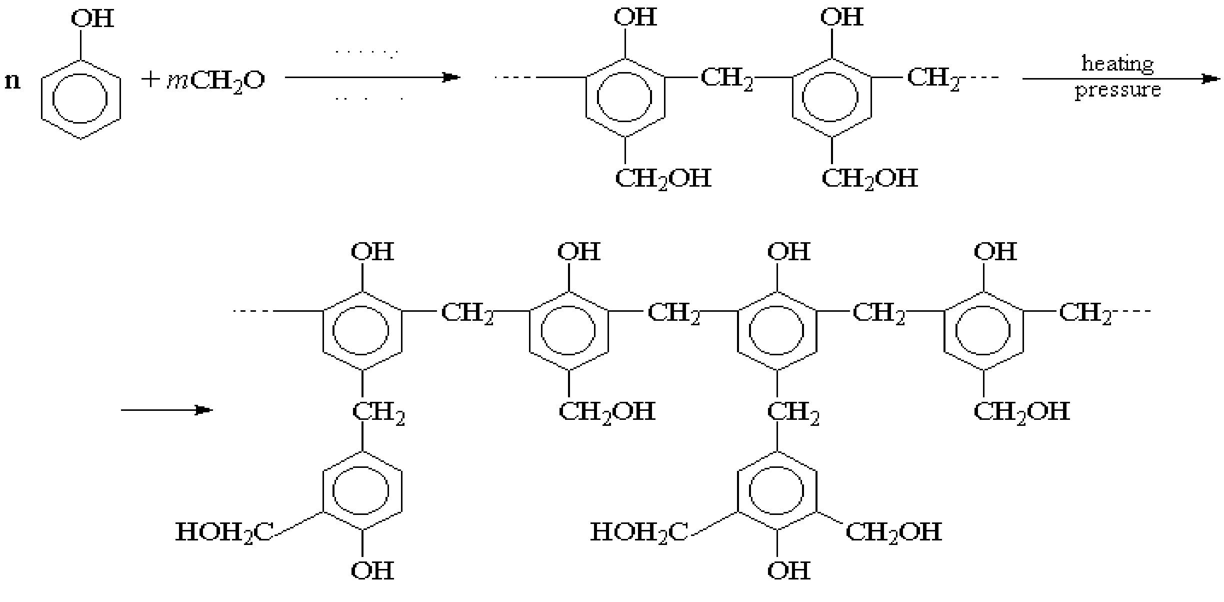


The fiber is practically identical to Nylon in properties

g) Dacron:



h) Phenol-formaldehyde polymer: E.g., Bakelite Novolac



Biomolecules

Revision Notes on Biomolecules

Carbohydrates

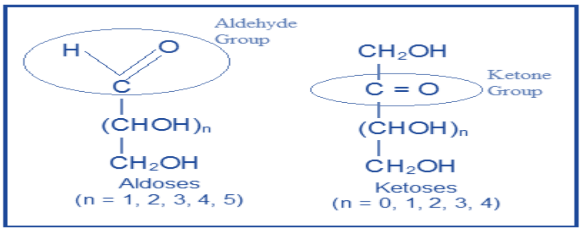
Classification of carbohydrates:

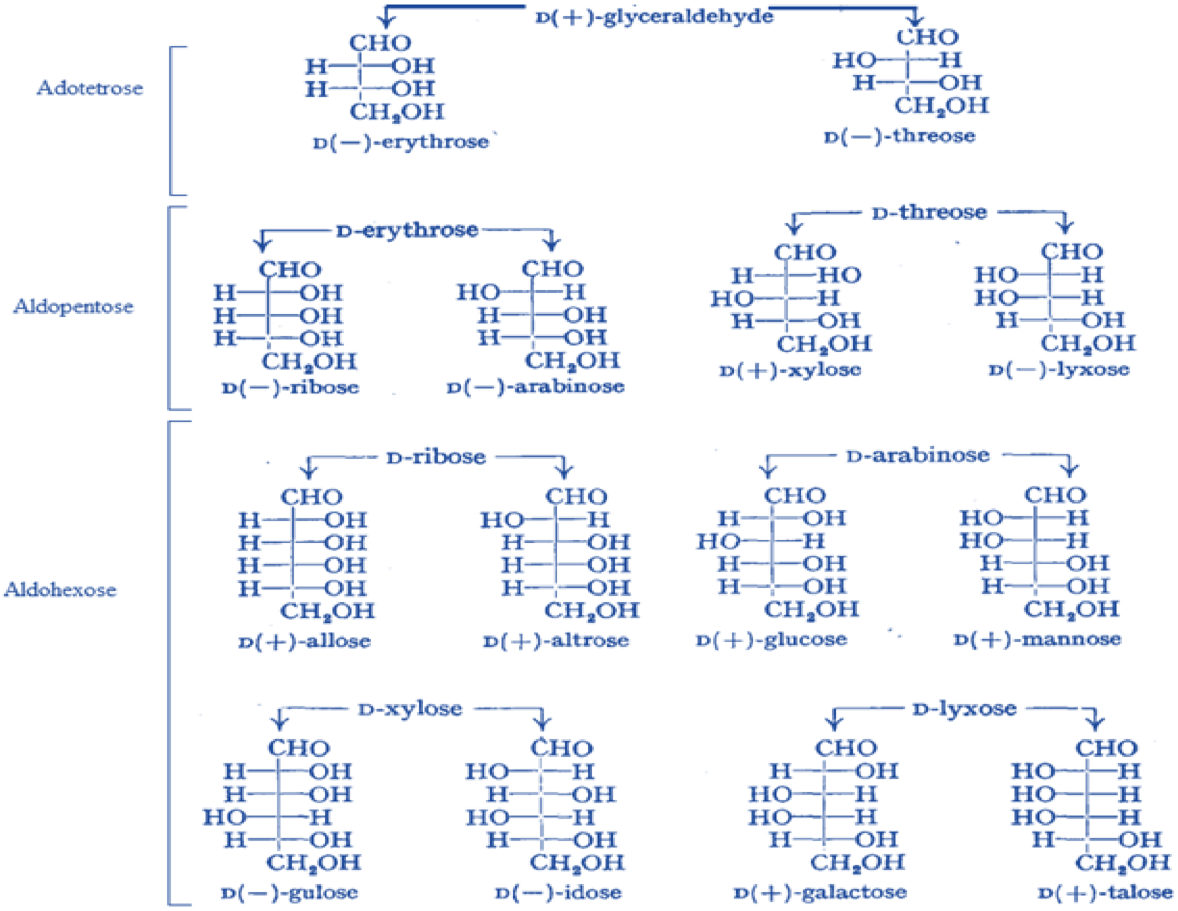
- **Monosaccharides**
- **Trisaccharides**
- **Oligosaccharides**
- **Polysaccharides**

- **Monosaccharides**

The Aldoses, which contain an aldehyde group (-CHO).

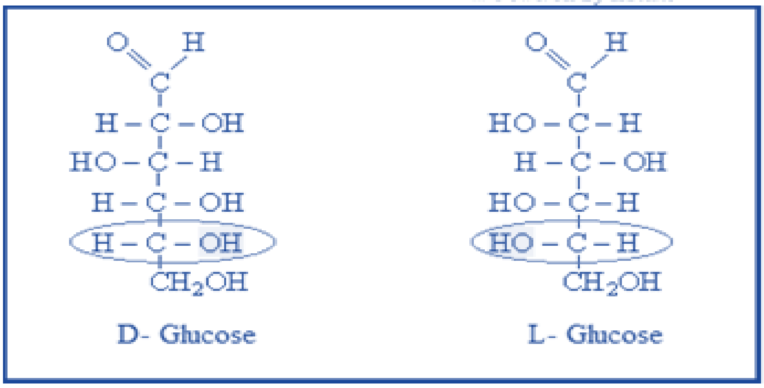
The Ketoses, which contain a ketone group (>C=O).

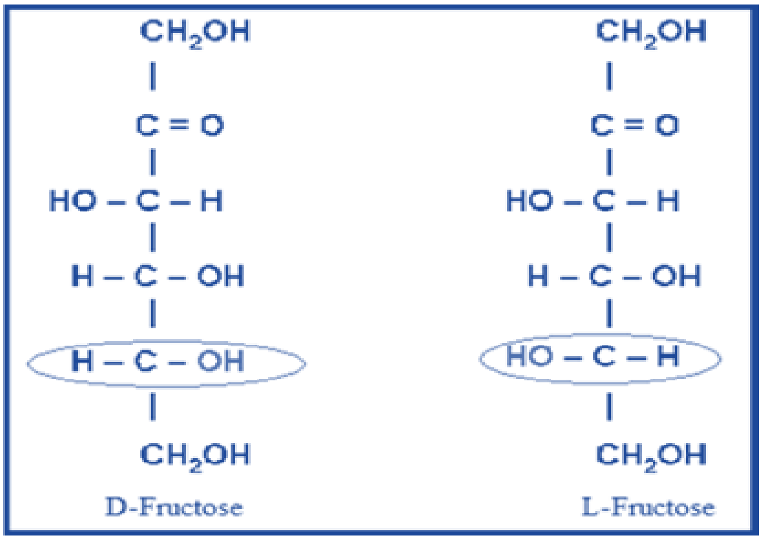




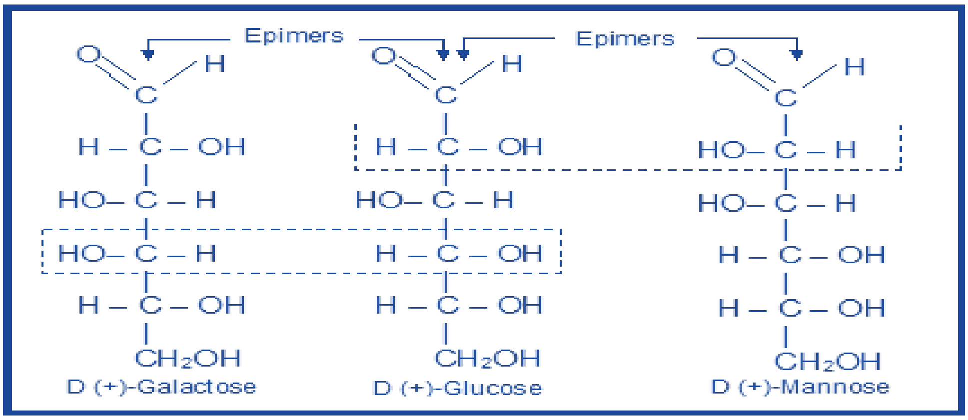
Stereo Isomerism in Carbohydrates:

- If the hydroxyl group on the asymmetric carbon atom farthest from aldehyde or ketone group projects to the right, the compound is a member of the **D-family**.
- If the hydroxyl group on the farthest asymmetric carbon projects to the left, the compound is a member of the**L-family**.



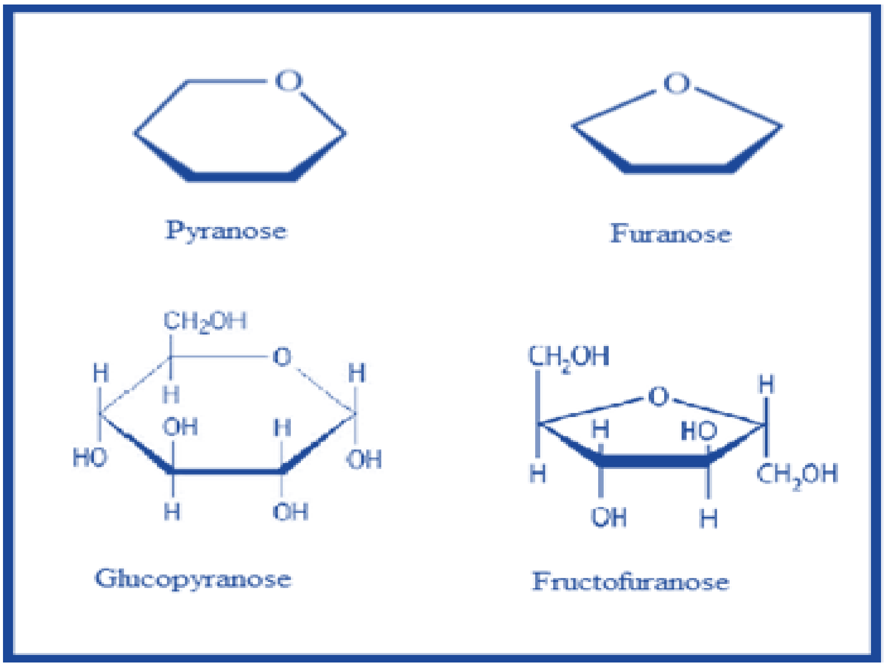


- **Maximum Number of Optical Isomers =** 2^{n}, where n = the number of asymmetric carbon atoms.
- **Epimer:** A pair of diastereomers that differ only in the configuration about of a single carbon atom are said to be epimers.



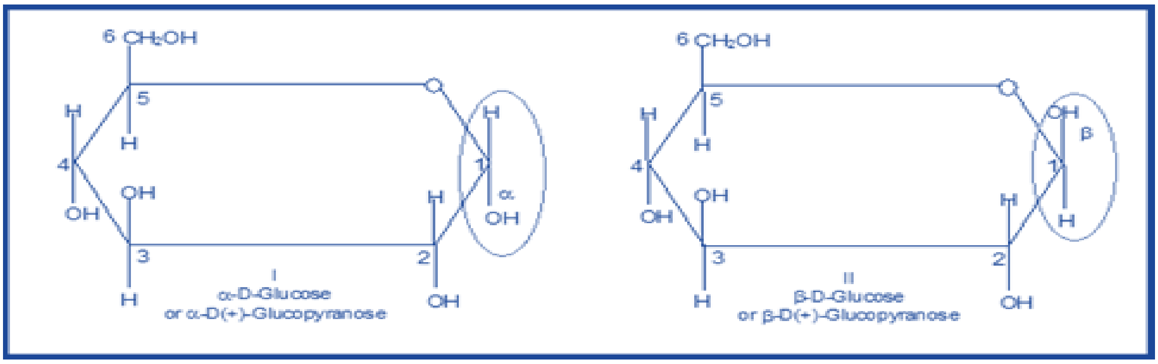
Cyclic Form of Monosaccharide:

- **Pyranose and Furanose Forms:**



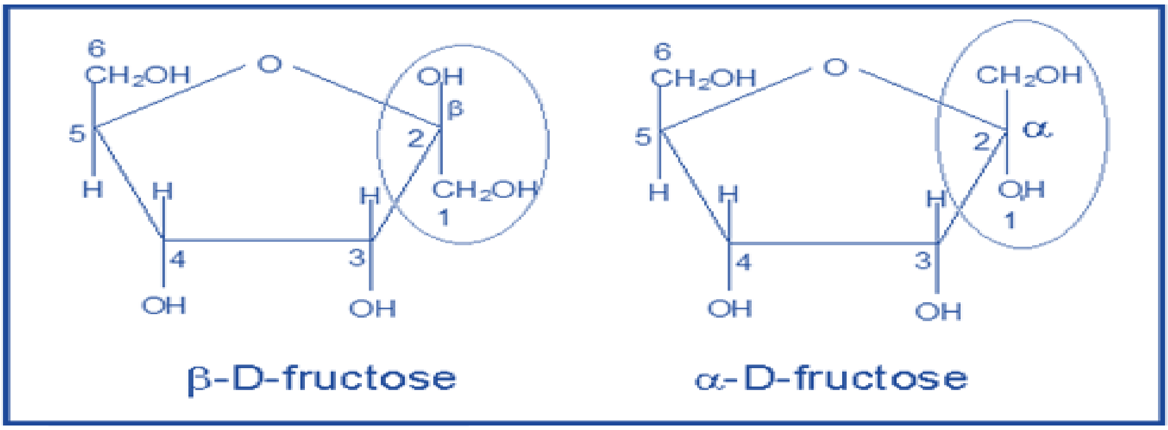
Pyranose
Furanose
Glucopyranose
Fructofuranose

- **Anomers:** Pair of stereoisomers which differ in configuration only around C_1 are called **anomers** and the C_1carbon is called Anomeric carbon.In a- anomer-, the OH group at C_1 is towards right while in b-anomer, the OH group at C_1 is toward



I
α-D-Glucose
or α-D(+)-Glucopyranose

II
β-D-Glucose
or β-D(+)-Glucopyranose



β-D-fructose
α-D-fructose

Mutarotation:

Change in rotation of an optically active sugar in solution with time, to an equilibrium value, is called**mutarotation**. During mutarotation, the ring opens and then recloses either in the inverted position or in the original position giving a mixture of a-and-b-forms.

Reactions of Glucose:

a) **With HI/P:** It undergoes reduction to form n-hexane while with sodium amalgam it forms orbitol.

$$\text{Glucose} \xrightarrow{HI/P} CH_3-(CH_2)_4-CH_3$$

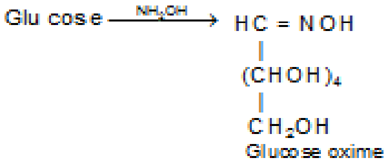
n-hexane

$$\text{Glucose} \xrightarrow{Na/Hg} CH_2OH-(CHOH)_4-CH_2OH$$

sorbitol

b) With H_2O: It forms neutral solution

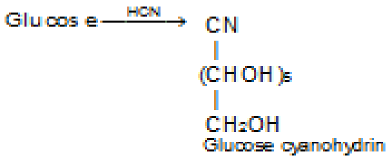
c) With Hydroxylamine (NH_2OH)



$$\text{Glucose} \xrightarrow{NH_2OH} \begin{array}{l} HC=NOH \\ | \\ (CHOH)_4 \\ | \\ CH_2OH \end{array}$$

Glucose oxime

d) With HCN: It form addition product cyanohydrin



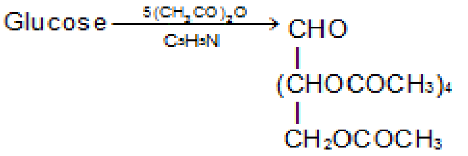
$$\text{Glucose} \xrightarrow{HCN} \begin{array}{l} CN \\ | \\ (CHOH)_5 \\ | \\ CH_2OH \end{array}$$

Glucose cyanohydrin

e) Oxidation: Glucose on oxidation with Br_2 gives gluconic acid which on further oxidation with HNO_3 gives glucaric acid

f) With Tollen reagent and Fehling solution. Glucose forms silver mirror and red ppt. of Cu_2O respectively.

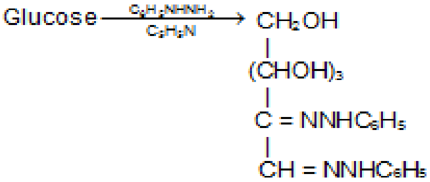
g) With acetic anhydride. In presence of pyridine glucose forms pentaacetate.



$$\text{Glucose} \xrightarrow[C_5H_5N]{5(CH_3CO)_2O} CHO-(CHOCOCH_3)_4-CH_2OCOCH_3$$

Glucose pentaacetate

h) With phenylhydrazine: it forms glucosazone



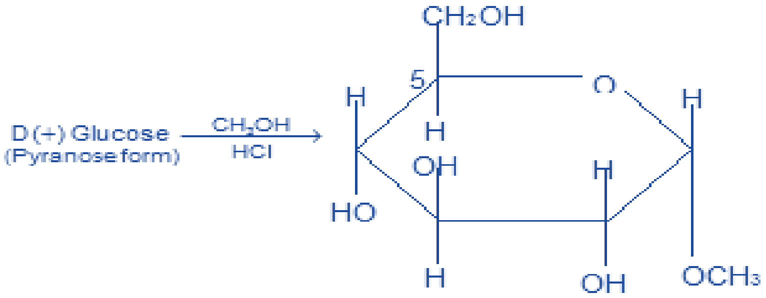
$$\text{Glucose} \xrightarrow[C_5H_5N]{C_6H_5NHNH_2} CH_2OH-(CHOH)_3-C{=}NNHC_6H_5-CH{=}NNHC_6H_5$$

(Glucosazone)

i) With conc. HCl acid: Glucose gives laevulinic acid

$$\text{Glucose} \xrightarrow{\text{Conc. HCl}} \underset{\text{Laevulinic acid}}{CH_3CO\cdot CH_2CH_2\cdot COOH} + HCOOH + H_2O$$

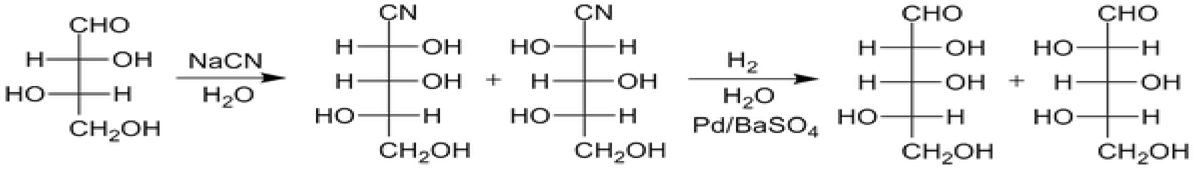
j) Glycoside formation: When a small amount of gaseous HCl is passed into a solution of D (+) glucose in methanol , a reaction takes place that results in the formation of amomeric methyl acetals.



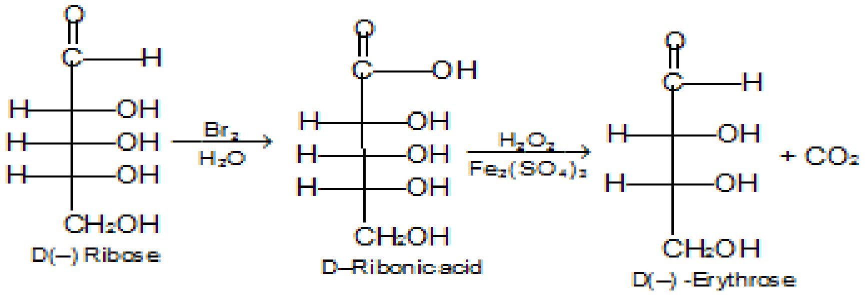
Methyl α-D-glucopyranoside
+
Methyl β-D-glucopyranoside

Carbohydrate acetals, genrally are called glycosides and an acetal of glucose is called glucoside.

k) **Kiliani - Fischer Synthesis:** - This is a method of lengthening the carbon chain of an aldose.



i) **Ruff Degradation***:* It is opposite to Kiliani Fischer synthesis that can be used to shorten the chain by a similar unit.



- **Disaccharides:**

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow[\text{or Invertase}]{H^+} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Fructose}}{C_6H_{12}O_6}$$

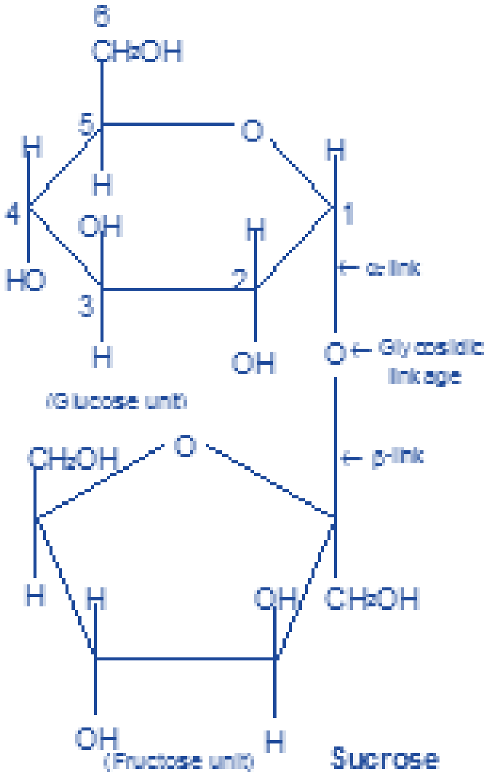
$$\underset{\text{Maltose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow[\text{or Maltase}]{H^+} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Glucose}}{C_6H_{12}O_6}$$

$$\underset{\text{Lactose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow[\text{or Lactase}]{H^+} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Galactose}}{C_6H_{12}O_6}$$

a) Sucrose:

Non-reducing sugar.

Formed by condensation of one molecule of glucose and one molecule of fructose.



Hydrolysis: (Invert Sugar or Invertose). Hydrolysis of sucrose with hot dilute acid yields D-glucose and D-fructose.

Polysaccharides

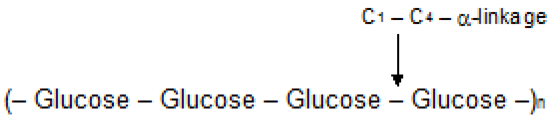
a. Starch:

i. A polymer of glucose.

ii. Mixture of two components – a water soluble component called amylose (20%) and a water insoluble component called amylopectin (80%).

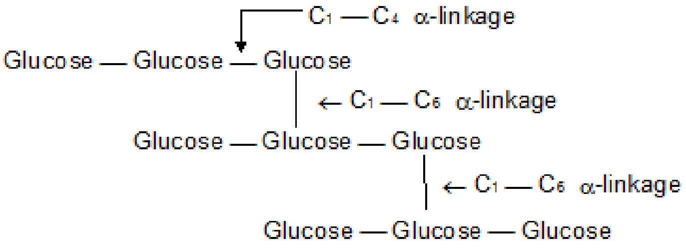
iii. Both amylose and amylopectin are polymers of a-D-glucose.

iv. Amylose is a linear polymer of a-D-glucose



Linear Polymer

vi Amylopectin, is a highly branched polymer



Amino Acids,

Amino acids are molecules, which contain two functional groups, one is carboxylic group and another is amino group

$H_2N\ CH_2\ COOH$: Amino acetic acid, or Glycine

$CH_3\ CH\ (NH_2)\ COOH$: a - Amino propionic acid or Alanine

$H_2N\ CH_2\ CH_2COOH$: b - Amino propionic acid

Acidic Amino Acid*:* These amino acids contain a second carboxyl group or a potential carboxyl group in the form of carboxamide.

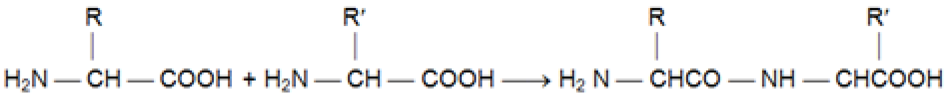
Basic Amino Acids: These contain a second basic group which may be an amino group

Iso Electric Point:

The hydrogen ion concentration of the solution in which a particular amino acid does not migrate under the influence of an electric field is called the ***isoelectric point*** of that amino acid.

Peptides

A peptides as the amides formed by interaction between amino groups and carboxyl groups of amino acids**.**



$$H_2N - \overset{\overset{R}{|}}{CH} - COOH + H_2N - \overset{\overset{R'}{|}}{CH} - COOH \longrightarrow H_2N - \overset{\overset{R}{|}}{C}HCO - NH - \overset{\overset{R'}{|}}{C}HCOOH$$

Depending upon the number of amino acid residues per molecule, they are known as dipeptides, tripeptides and so on and finally polypeptides.

Every two amino acids are linked by means of a –CO-NH group, which is commonly referred as **peptide bond**.

$$H_3^+N—CH_2—COOH \rightleftharpoons H_3N^+—CH_2—COO^- + H^+ \qquad \text{...(1)}$$

Conjugated acid (CA) Dipolar Ion (DI)

$$\text{At equilibrium } K_1 = \frac{[DI][H^+]}{[CA]}$$

$$H_3N^+—CH_2—COO^- \rightleftharpoons H_2N—CH_2—COO^- + H^+ \qquad \text{...(2)}$$

DI Conjugated Base (CB)

$$\text{At equilibrium } K_2 = \frac{[CB][H^+]}{[DI]}$$

$$[CA] = \frac{[DI][H^+]}{K_1}$$

$$[CB] = \frac{K_2[DI]}{[H^+]}$$

At isoelectric point [CA] = [CB]

$$\frac{[DI][H_i^+]}{K_1} = \frac{K_2[DI]}{[H_i^+]}$$ Where $[H_i^+]$ = conc. of $[H^+]$ at isoelectric point.

$$\text{or, } [H_i^+]^2 = K_1 K_2$$

$$\text{or, } 2\log[H_i^+] = \log K_1 + \log K_2$$

$$\text{or } -2\log(H_i^+] = -\log k_1 - \log K_2$$

$$\text{or } 2pH_i = pK_1 + pK_2$$

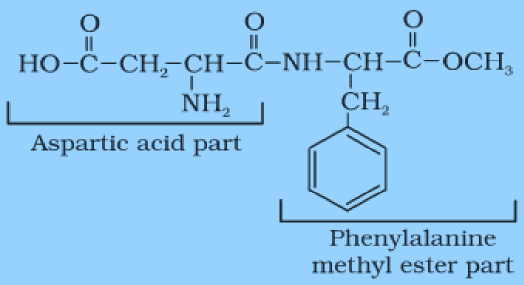
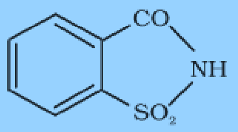
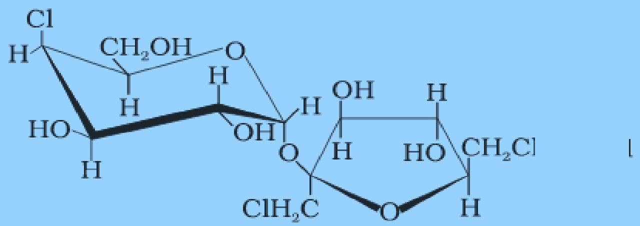
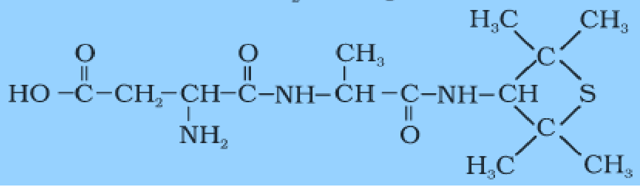
$$\text{or } pH_i = \frac{pK_1 + pK_2}{2}$$

Chemistry in Action

Drugs:

Drugs	Description	Examples
Analgesics	Relieve or decreases the pain without causing unconsciousness. These are also known as "Pain Killers".	Asprin, Analgin, seridon etc.
Tranquizers/ Antidepressants	These are used for treatment of mental diseases.	Equanil, Calmpose, Tofranil, Barbituric Acid, Cocaine and Iproniazids etc..
Antiseptics	They are applied on living tissues to kill or prevent the growth of micro-organisms.	Dettol, Savlon and Acriflavin etc.
Disinfectants	These are applied on floor, instruments or wall etc. to kill microorganisms but are not safe for application on living tissues.	Phenol
Antimicrobial	These are use to either kill (bactericidal) or stop the growth of diseases causing microorganisms. (bacteriostatic).	Salvarsan, Prontosil, Sulphanilamide, Bacteriostatic Drugs: Erythromycin, Tetracycline, Chloramphenicol Bactericidal Drugs: Ofloxacin, Aminoglycosides.
Antipyretics	These drugs bring down the body temperature during fever.	Paracetamol, Analgin and Novalgin.
Antifertility Drugs	Prevent pregnancy in women by controlling menstrual cycle and ovulation.	Norethindrone & Mestranol
Antacids	Used for the treatment of acidity. Metal hydroxides are generally used as antacids.	Eno, & Milk of magnesia [$Mg(OH)_2$]
Antibiotics	These are the chemical substances which are produced by micro –organisms like bacteria and fungi and are able to kill or stop the growth of pathogenic microorganisms.	Penicillin, Amoxicillin and Ampicillin.
Antihistamins	These drugs compete with histamine for finding sites of receptors and thus interfere with the natural action of histamine.	Brompheniramine & Terfenadine

Artificial Sweetening Agents

Artificial sweetener	Structural formula	Sweetness value in comparison to cane sugar
Aspartame		100
Saccharin		550
Sucralose		600
Alitame		2000

Food preservatives:

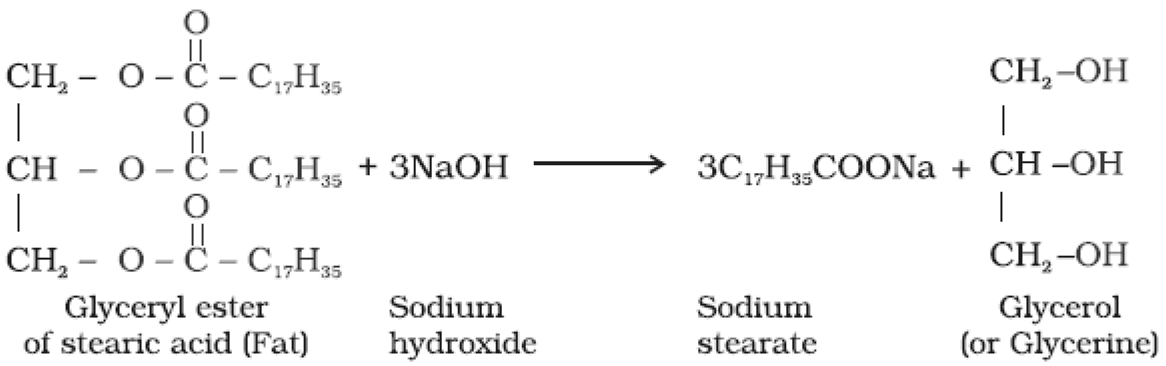
These are the chemical substances which prevent undesirable changes in flavor, colour, texture of the food during processing and storage of food.

Examples, Table salt, sugar, vegetable oils, sodium benzoate (C_6H_5COONa) etc

Cleansing Agents

Soaps:

Sodium or potassium salts of fatty acids.

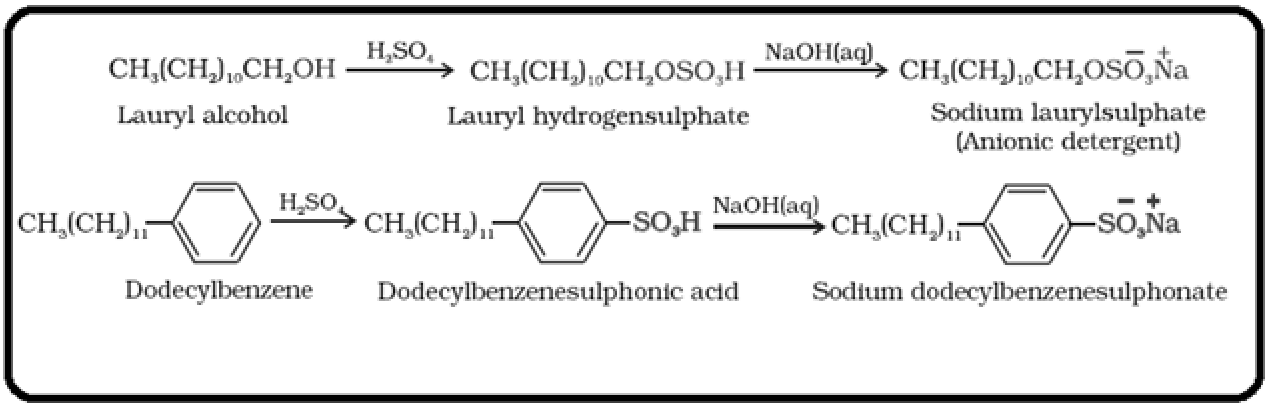


Soaps do not work with hard water as it forms insoluble salts with calcium and magnesium ions present in hard water.

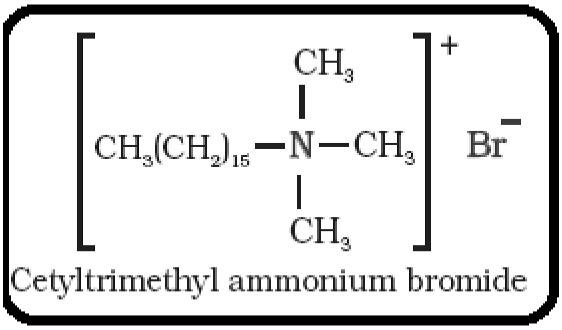
Detergents:

Sodium or potassium salts of sulphonic acids. These can work with hard water also.

Anionic Detergents: Sodium Slats of sulphonated long chain alcohols or hydrocarbons

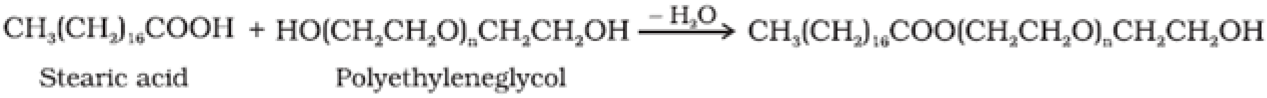


Cationic Detergents: Quaternary ammonium salts of ammines with acetates, chlorates or bromates.



Cetyltrimethyl ammonium bromide

Non-Ionic Detergents: Do not contain any ion.



$$CH_3(CH_2)_{16}COOH + HO(CH_2CH_2O)_nCH_2CH_2OH \xrightarrow{-H_2O} CH_3(CH_2)_{16}COO(CH_2CH_2O)_nCH_2CH_2OH$$

Stearic acid Polyethyleneglycol

Environmental Chemistry

Components of Environment:

- **Atmosphere:** This comprises a blanket of gaseous layer around earth.
- **Hydrosphere**: This comprises about 96% of earth's surface & includes all sources of water like oceans rivers lakes, glaciers, ground water etc.
- **Lithosphere**: It refers to earth's solid crust containing the outer mineral cover. It comprises soil, minerals, organic matter etc.
- **Biosphere:** It refers to the domain of living organism in covalent with atmosphere hydrosphere as well as lithosphere.

Environmental Pollution :

Process of contamination of the environment with harmful wastes arising mainly from human activities.

- **Pollutant:** Any substance or species produced either by a natural source or by human activity, which produces adverse effect on the environment.
- **Contaminant:** A substance which does not occurs in nature but is introduced by human activity into the atmosphere affecting its composition.
- **Source:** The site from which the pollution or contaminants originate.
- **Sink:** The material or medium which consumes or interacts with a long lived pollutant is called sink.
- **Receptor** : Anything that is affected by the pollutants.
- **Threshold limit value (TLV) :** This indicates the permissible limit of a pollutant in atmosphere to which a healthy worker is exposed during hours a day or 40 hours a week for life time without any adverse effects. TLV are determined by experimentation on animals, by use of medical knowledge, epidemiology surveys & environmental studies.

Tropospheric pollution or Air pollution:

It is the atmosphere condition in which the presence of certain concentration produce harmful effects on man and his environment. These substances include:

Primary pollutants :

Particulate Matter Inorganic gases <u>Secondary</u>

Pollutant	Source	Sink	Effect
Carbon monoxide (CO)	(a) Incomplete combustion of carbonaceous matter, automobile engines & also in defective furnaces, Incomplete combustion of fossil fuels, agricultural , slash matter and other carbon $2C + O_2 \rightarrow 2CO$ (b) Dissociation of carbon dioxide. $2CO_2 \rightleftharpoons 2CO + O_2$ (c) Reaction of carbon dioxide with carbon containing compounds at high temperature. $CO_2 + C \rightleftharpoons 2CO$	Hydroxyl & perhydroxyl radicals, atomic oxygen & ozone help in the oxidation of atmospheric CO into CO_2 . Soil is major sink for CO. Some of the microorganism present in soil remove carbon monoxide from air.	Carbon monoxide is poisonous as it combines with hemoglobin of red blood cells about 300 times faster than O_2, thus forming carboxyl hemoglobin. This decreases the transport of oxygen to the body organs & cells.
Carbon dioxide (CO_2)	It is released mainly into the atmosphere by the combustion of fossil fuels (coal, oil etc) in factories & also at homes. CO_2 is also produced by biological decay of plants	Ocean is a main sink for CO_2. Green plants for photo synthesis.	CO_2 causes narcotic effect, stimulation of respiratory center & leads to asphyxiation. The increasing concentration of CO_2 also changes climatic conditions especially by raising the general temperature.
Oxides of sulphur (SO_2)	Volcanic eruptions (natural activity) & also through combustion of sulphur bearing fuels such as coal & oil (human activity). This pollutant is also produced during roasting & smelting of sulphide ores		It causes cough, shortness of breath & spasm of larynx, acute irritation to the membrane of gas resulting tears & reduces hearing ability. SO_2 irritates the respiratory system of animals &

	(human activity) A part of SO_2 undergoes photolytic & catalytic oxidation to form SO_3. The SO_3, so formed gets converted to H_2SO_4 in the presence of moisture. This acid comes down from the atmosphere in the form of sulphuric acid rain.		human, produces leaf injuries (called necrotic bloating) to board leaved plants & gases. It also causes deterioration of fabric (cotton, rayon) paper & leather.
Oxides of Nitrogen (NO_2)	NO_2 is produced in small amounts by microbiological processes in soil. However significant amount of NO & NO_2 are emitted in to the atmosphere by natural activity.	Many natural processes acts as sink for oxides of nitrogen. These oxides are inherently unstable & decompose to N_2 & O_2 after some time. Therefore, the concentration of nitrogen oxides in the atmosphere tends to remains low.	(i) NO is biologically less active & less toxic than NO_2. Like CO it binds hemoglobin & decreases oxygen transport efficiency of blood. (ii) Inhaling of nitrogen oxides by human results in pulmonary odema & hemorrhage. (iii) The oxides of nitrogen cause damage to plants. Exposure of plants to NO_2 causes leaf spotting & break down of plant tissues. (iv) The sunlight reacts with NO_2 to produce highly active oxygen atoms.

Particulate matter:

- **Soot**
- **Metal particles**
- **Metal oxides** .
- **Lead salts**
- **Fly ash**
- **Asbestos dust**
- **Solid Hydrocarbons**
- **Dust Particulates**
- **Acid mist**.

Harmful effects of particulates

- **Effect on human beings:** Affect the human respiratory system & cause several respiratory illnesses. The particles with small size are more harmful in this context. The particulates in fact, become the carriers of the toxic substances from the atmosphere to the human & cause big health hazards.
- **Effect on visibility:** Particulates in the atmosphere cause scattering & absorption of sunlight & reduce the visibility.
- **Effect on Materials :** The adverse effect of particulates on materials include corrosion of metals (when the atmosphere is humid), erosion & soiling of building, sculptures & painted surfaces & soiling of clothes & draperies.

Stratospherical Pollution: (ozone layer & its depletion):

Role of Ozone Layer: protecting earth from the UV radiation coming from the sun.

Depletion of Ozone Layer : The equilibrium between formation & destruction of ozone has been upset by influx of several substances into the atmosphere which react with ozone to destroy it.

Effect of Depletion of Ozone layer: The influx of UV radiation reaching the surface of earth would increase which would increase in risk to skin cancer due to exposure to UV radiation, UV radiations also tend to damage the immune system.

Acid Rain:

SO_2, nitrogen oxides & acidic soots. Sulphurdioxide & nitrogen dioxide interact with water vapours in presence of sunlight to form sulphuric acid & nitric acid units.

Green House Effect & Global Warming:

The green house gases (CO2, CH4, O3, CFC'S) in the atmosphere form a thick cover around the earth. About 75% of the solar energy reaching the earth is absorbed by the earth surface. The IR radiations coming from sun are not absorbed by atmospheric gases but Earth absorbs these IR radiations of short wavelength. As a result of this the temperature of earth stands rising. Eventually, earth starts emitting infrared radiations of longer wavelengths. The partially radiated infrared radiations from the earth are absorbed by the greenhouse gases. This results in excessive heating of Earth's atmosphere. Thus the greenhouse gases add to the heating of atmosphere. This causes global warming. The atmosphere traps the sun's heat near earth's surface and keeps it warm. The reemission of the earth's energy absorbed by CO2 and other greenhouse gases present near the earths surface and its radiation back to the earth is called green house effect.

Advantages of green house effect :

- It is necessary for evaporation of water, formation of clouds, rainfall etc.
- The warm atmosphere helps in rapid growth of plants, trees etc.

Harmful effects of green house effect :

- High temperature of atmosphere may melt polar ice caps which are likely to raise the level of sea thereby sinking most of the coastal areas and causing large scale destruction.
- The high temperature may reduce crop product.

- The high temperature will reduce work efficiency of human being.
- Tropical rains and hurricane will become more frequent and also stronger causing more devastation.
- The change in ocean temperature will adversely affect the warm life.

Water Pollution:

Pollutant	Source
Microorganism	Domestic sewage
Organic wastes	Domestic sewage, animal waste, decaying animals, plants and discharge from food processing factories
Plant nutrients	Chemical fertilizers
Toxic heavy metals	Industries and chemical factories
Sediments	Erosion of soil by agriculture and strip mining
Pesticides	Chemical used for killing insects, fungi & weeds
Radioactive substances	Mining of Uranium containing minerals
Heat	Water used by industrial plants which is discharged as hot water

Biochemical Oxygen Demand (BOD) : The measure of the total contamination caused by compounds which can be oxidised in the presence of microorganisms. The BOD is taken as a realistic measure of water quality – clean water would have a BOD value of less than 5 ppm whereas highly polluted river water could have a BOD value of 17 ppm or more.

Land Pollution :

Caused by pesticides and other chemicals which are added to the soil to grow better crops.

Insecticides are the pesticides used to Control of insects by insecticides helps to curb disease and protect crops. Organo chlorines are a group of compounds which have been developed and used as insecticides.Examples: DDT (dichlorodiphenyl trichloro ethane) organo chlorines are stable in the environment, toxic to insects in small amounts, but much less go to humans, and because they are organic compounds not very soluble in water. The advantage of these insecticides is that, bring persistent

Fungicides are the pesticides used to check the growth of fungi. Fungi, are plants without chlorophyll, they cannot use solar energy for preparing their food. They live as saprophytes on decaying organic matter or as parasites at the expense of living organisms. Hence they are considered to be a threat to human interests

BIOLOGY

The Living World

Building blocks of life and their functions:

Living organism is formed of many types of inorganic as well as organic biomolecules. Inorganic compounds include water, minerals etc. and are always micro-biomolecules (small sized, low molecular weight, readily soluble in water and diffusible) while organic molecules may be micro (e.g. monosugars, amino acids etc.) or macrobiomolecules (large sized, high molecular weight, insoluble or slightly soluble and non-diffusible e.g., proteins, fats, nucleic acids, etc.). These both types of biomolecules play important roles in metabolism:

- Role of Water: Water forms 70-90% of the cellular pool. It forms 65% of human body. It is formed of H and O in the ratio of 2:1. 95% of water is found in free state and 5% in combined form in the cell.
- Role of Oxygen: Oxygen is mainly utilized in aerobic cell respiration of the nutrients inside the mitochondria to produce energy-rich ATP molecules so is essential for life. In the absence of oxygen, only 5% of energy available is released.
- Role of Sodium chloride (common salt): Sodium chloride plays an important role in metabolic functions of body especially when in ionic form.
- Role of Carbohydrates: Carbohydrates are organic compounds formed of C, H and O generally in the ratio of 1:2:1. These are commonly called saccharides (Gk. saccharon = sugar). Most organisms use carbohydrates as an important fuel, breaking these bonds and releasing energy to sustain life.
- Role of Proteins: Proteins are polymeric compounds formed by interlinking of amino acids (monomers) by peptide bonds. Out of about 100 types of amino acids, only 20 types of amino acids are of biological importance. Proteins play a vital role in the formation of structures in living organisms. Like carbohydrate and fat protein can be broken down with the release of energy.
- Role of lipids: Lipids comprise a major group of insoluble hydrocarbons having many functions. These are polymers of alcohols (e.g. glycerol) and fatty acids interlinked by ester bonds. Complex lipids such as true fats are important organic molecules that are used to provide energy.
- Role of Nucleic Acid: These are polymers of nucleotides interlinked by phosphodiester bonds, so called polynucleotides. Each nucleotide is formed of 3 components: a pentose sugar (e.g. ribose in RNA and deoxyribose in DNA), a phosphate group and an inorganic nitrogen-base (a purine or a pyrimidine).

  DNA acts as genetic material in most organisms and controls the synthesis of structural and. functional proteins. RNA also act as genetic material in all plant viruses e.g. TMV and helps in protein synthesis.

Systematics

1. The term ‘Systematics’ was proposed by Linnaeus in 1735.
2. It includes description of external morphological characters of plants or living organisms. E.g., morphological characters of root, stem, leave, flowers.
3. New systematics or Neo systematics or Biosystematics is a new branch. Its name was given by Julian Huxley (1940).
4. The term taxonomy was coined by A. P. de Candolle.
5. Carolus Linnaeus is called the father of taxonomy.
6. H. Santapau is called the father of Indian taxonomy.
    - Alpha taxonomy- Only morphological characters are used for identification and classification of plants.
    - Beta taxonomy- Involves genetical, anatomical, cytological, palynological, physiological and other characters.
    - Omega taxonomy- Analysis and synthesis of all information and types of data to develop classification system based on phylogenetic relationship.
7. **Cytotaxonomy –** The use of cytological characters of plants in classification or in solving taxonomic problems is called cytotaxonomy.
8. **Chemotexonomy –** The use of chemical compounds present in plants for classification or in solving taxonomic problems is called chemotaxonomy or chemical taxonomy. The basic chemical compounds used in chemotaxonomy are alkaloids, carotenoids, tannins, etc.
9. **Karyotaxonomy –** It is based on the characters of nucleus and chromosomes. Pattern of chromosomal bands is most specific character for classification of organisms.

Nomenclature

1. **Nomenclature** is giving distinct scientific names to various structures including living organisms for their identification.
2. The names are of two types – **vernacular** (common name) and **scientific names.**
3. **Types of Nomenclature -**
    - Polynomials nomenclature
    - Binomial nomenclature
    - Trinomial nomenclature
4. **Carolus Linnaeus** is the founder of binomial system.
5. Linnaeus proposed scientific names in his book “*Species planatarum*”.
6. In binomial nomenclature, each scientific name has 2 components – **generic name** (genus) and **specific name**(species). Eg. Solanum tuberosum (potato).

ICBN-"International Code of Botanical Nomenclature"

1. Collection of rules regarding scientific nomenclature of plants.
2. ICBN was first proposed by **Sprague, Hitchcock, Green** (1930).
3. ICBN was first accepted in 1961.

Main rules of ICBN

- Name of any species consists of two names – Generic name and Specific name.
- In plant nomenclature, tautonyms are not valid i.e. generic name and specific name cannot be the same e.g., *Magnifera indica*. But tautonyms are valid for animal nomenclature e.g., *Naja naja* (Indian cobra).
- Length of genus or species should not be less than 3 letters and not more than 12 letters e.g., *Magnifera indica*. Exception: *Riccia pathankotensis*
- First letter of genus should be in capital letters and first letter of specific name should be in small letter.
- Name of scientist (who proposed nomenclature) should be written in roman in short after the specific name e.g., *Magnifera indica* Lin.
- If any scientist has proposed wrong name then his name should be written in bracket and the scientist who corrected the name should be written after the bracket e.g., *Tsuga canadensis* (Lin.) Salisbury.

Type specimen (herbarium sheet) are of different types-

Holotype: Herbarium sheet on which the first description of plant is based.

Isotype: Isotype is any duplicate specimen of the holotype.

Lectotype: In case holotype is lost, second herbarium sheet prepared from the original plant is called lectotype.

Isolectotype: Isolectotype is any duplicate specimen of the lectotype.

Syntype: In case holotype and original plant is lost then many herbarium sheet prepared from many plants of same species is called syntype.

Isosyntype: It is a duplicate specimen of a syntype.

Neotype: In case holotype and original plant is lost then herbarium sheet prepared from other plants of same species is called neotype.

Isoneotype: any duplicate specimen of the neotype.

Paratype: Additional description sheet used in the first description of plant is called paratype. It is prepared from some other plant of same species having some variations.

Taxonomic categories

a. Species **b. Genus** **c. Family**

d. Order **e. Class** **f. Phylum** **g. Kingdom**

Biological Classification

Systems of Classification:

- Identification of differences among organisms and placing them into groups that reflect their most significant features and relationship is called **biological classification.**
- Biological classification was first proposed by Aristotle who divided plants into herbs, shrubs and trees. Animals were classified into with RBC's and without RBC's.

Two kingdom classification:

It consists of artificial and natural system of classification.

- Artificial system of classification was proposed by Linnaeus.
- The first natural system of classification was proposed by **Schimper** (1879) followed by **Eichler** (1883).

Five kingdom classification:

(1) Given by R. H. Whittaker (1969).

(2) The five kingdom classification of Whittaker was based on 3 characters:

  (a) **Complexity of cell:** Cell is prokaryote or eukaryote, on this basis, kingdom Monera is formed. And all the prokaryotes are grouped into it.

  (b) **Complexity of organism:** Organism is unicellular or multicellular, on this basis kingdom Protista was formed, and all the unicellular eukaryotes are grouped into it.

  (c) **Nutrition:** Organism is autotrophic or heterotrophic, on this basis kingdom Fungi, Plantae and Animalia were formed.

(3) The five kingdoms classified by Whittaker are:

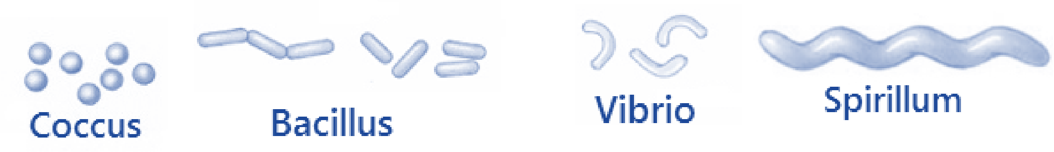
Kingdom Monera:

- Includes prokaryotes.
- Typically unicellular organisms (but one group is mycelia).
- genetic material is naked circular DNA, not enclosed by nuclear envelop.
- Ribosomes and simple chromatophores are the only subcellular organelles in the cytoplasm. The ribosomes are 70S.
- Gas vacuole may be present.
- The predominant mode of nutrition is absorpitive. But some groups are photosynthetic and chemosynthetic.

- The organisms are non-motile ior move by beating of simple gflagella or by gliding.
- Flagella composed of many interwined chains of a protein **flagellin.**
- Maoneran cells are moicroscopic.
- Most organisms bear a rigid cell wall (peptidoglycan).
- Reproduction is primarily asexual by binary fission or budding. Mitotic apparatus is not formed during cell division.
- Examples: bacteria, actinomycetes, mycoplasma and cyanobacteria.
- Smallest and most abundant organism on Earth.

Bacteria:

- Bacteria are found in various shapes like:
  a) Coccus (spherical)
  b) Bacillus (rod-shaped)
  c) Vibrio (comma shaped)
  d) Spirillum (spiral shaped)



- Bacteria found almost everywhere and can be Photosynthetic autotrophs, Chemosynthetic autotrophs or Heterotrophs.

Archaebacteria:

- Archaebacteria has different cell wall structure due to which they can live in most harsh habitats.
  a) **Halophiles** (salt-loving), e.g., halobacterium and halococcus
  b) **Thermoacidophiles** (in hot springs), e.g., sulfobolus and thermoplasma
  c) **Methanogen** (marshy area),e.g., Methanobacterium, Methanolinea
- Methanogens are also found in the guts of several ruminant animals such as cows and buffalos and they are responsible for the production of methane (biogas) from the dung of these animals.

Eubacteria:

- These are also known as true bacteria.
- They have a rigid cell wall.
- They posses flagellum, if motile.
- They also known as blue green algae or **Cyanobacteria**.
- Cyanobacteria are **photosynthetic autotrophs**.

- These are unicellular, colonial or filamentous algae.
- Colonies are surrounded by **gelatinous sheath**.
- Some of the eubacteria can fix atmospheric nitrogen by specialized cells, e.g. *Anabaena* and *Nostoc*. These special cells are called **heterocyst.**
- **Chemosynthetic autotrophs**: Oxidize various inorganic substances such as nitrates, nitrites and ammonia and use the released energy for their ATP production. They play a great role in recycling nutrients like nitrogen, phosphorous, iron and sulphur.
- **Heterotrophic bacteria**: The most abundant in nature
    a) Most of them are decomposer
    b) They are helpful in making curd from milk.
    c) They are helpful in Production of antibiotics
    d) Some are pathogen causing diseases like cholera, typhoid, and tetanus.
- Bacteria reproduce mainly by **fission**, also produce **spore** in unfavorable condition.
- Reproduce sexually by transfer of DNA form one bacteria to other, the process called **conjugation**.

Mycoplasma:

- Completely lack a cell wall.
- Smallest living cells known.
- Can survive even without oxygen.
- Pathogenic in animals and plants.

Kingdom Protista:

- All are unicellular and eukaryotic.
- Primarily aquatic, can live in moist places.
- Forms a link with the others dealing with plants, animals and fungi.
- The cell body contains a well defined nucleus and membrane bound organelles.
- Some have cilia or flagella.
- Reproduce asexually and sexually by a process involving cell fusion and zygote formation.

◈ PHOTOSYNTHETIC AUTOTROPHS

Chrysophytes:

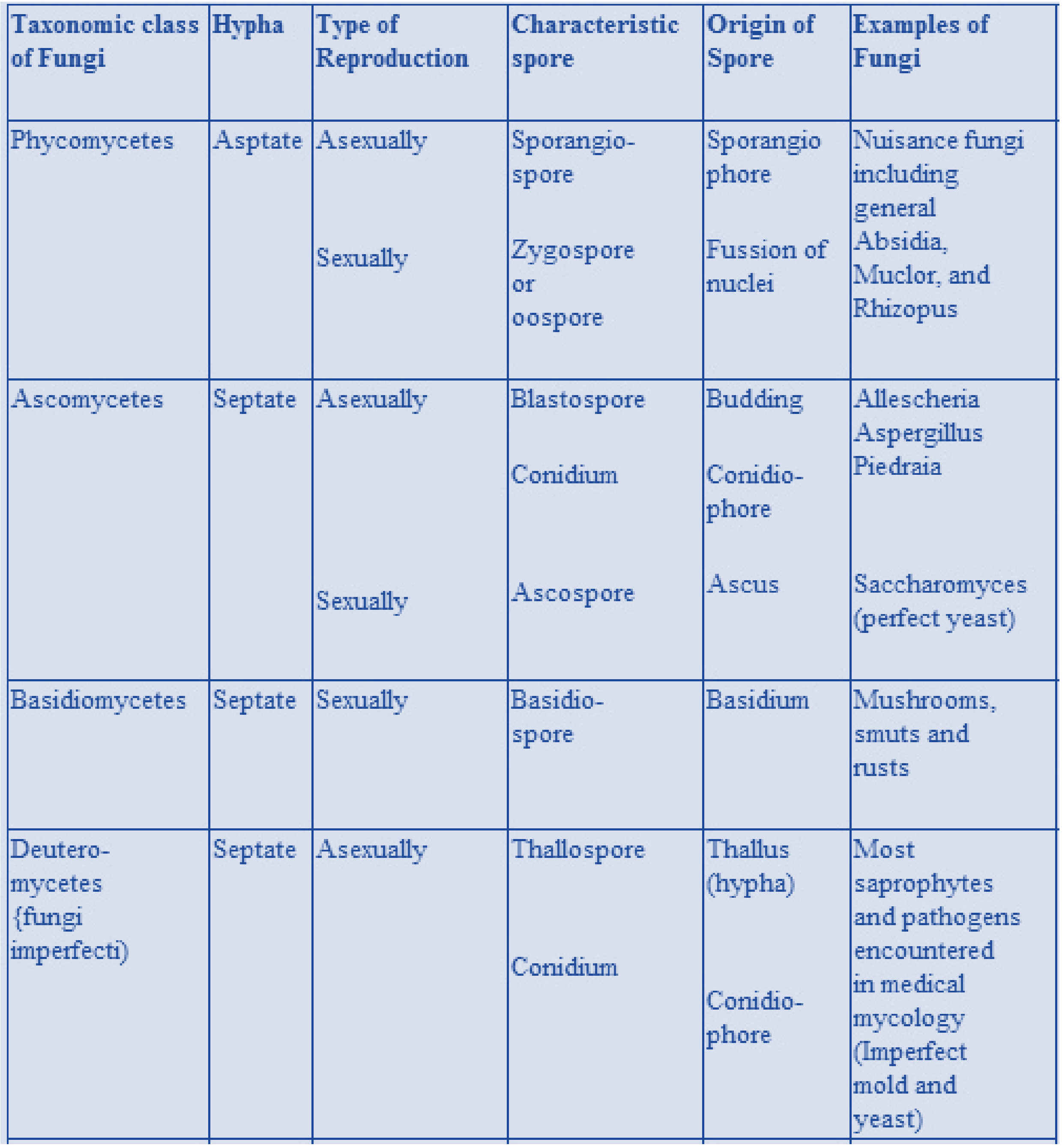
- Includes diatoms and **golden algae** (desmids)
- They are found in freshwater as well as in marine environments.
- Mostly planktonic (passive swimmer)
- Cell walls overlap to fit together like a soap box.
- Cell wall contains silica hence indestructible.
- Their accumulation forms '**Diatomaceous Earth'**.
- Used in polishing, filtration of oils and syrups.
- Diatoms are the chief '**producers'** in the oceans.

Dinoflagellates :

- Marine, photosynthetic.
- Cell wall has stiff cellulose plates.
- Appears yellow, green, brown, blue or red depending on the pigments.
- Have two flagella − one longitudinal and other transversely in a furrow between wall plates.
- Red Dinoflagellates (*Gonyaulax*) form **red tides.**

Kingdom Fungi

- Fungi are eukaryotic organisms.
- They are non-vascular.
- They reproduce by means of spores called **conidia** or **sporangiospores** or **zoospores**.
- Depending on the species and conditions both sexual and asexual spores may be produced.
- They are non-motile.
- Exhibit the phenomenon of alteration of generation.
- The vegetative body of the fungi may be unicellular or composed of microscopic threads called **hyphae**. The network of hyphae is known as **mycelium.**
- Cell wall composed of chitin.
- Fungi are heterotrophic organisms.
- Store their food as starch.
- Nutrition in fungi is saprophytic, or parasitic or symbiotic.
- Reproduction in fungi is both by sexual and asexual means. Sexual state is referred to as **teleomorph**, asexual state is referred to as **anamorph**.



Taxonomic class of Fungi	Hypha	Type of Reproduction	Characteristic spore	Origin of Spore	Examples of Fungi
Phycomycetes	Asptate	Asexually	Sporangio-spore	Sporangio phore	Nuisance fungi including general Absidia, Muclor, and Rhizopus
		Sexually	Zygospore or oospore	Fussion of nuclei	
Ascomycetes	Septate	Asexually	Blastospore Conidium	Budding Conidio-phore	Allescheria Aspergillus Piedraia
		Sexually	Ascospore	Ascus	Saccharomyces (perfect yeast)
Basidiomycetes	Septate	Sexually	Basidio-spore	Basidium	Mushrooms, smuts and rusts
Deutero-mycetes {fungi imperfecti)	Septate	Asexually	Thallospore Conidium	Thallus (hypha) Conidio-phore	Most saprophytes and pathogens encountered in medical mycology (Imperfect mold and yeast)

◈ LICHENS

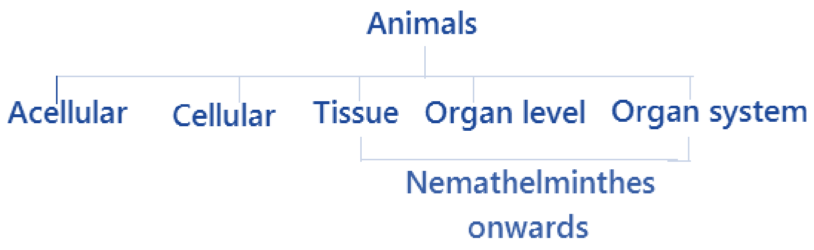
- Forms symbiotic relation with alga and fungus.
- Algal partner: phycobiont, fungal partner:mycobiont.
- Vegetative reproduction by fragmentation.
- Asexual as well as sexual reproduction.
- Three types:
  1. Crustose lichen: crust like growth,Thallus flat irregularly lobed.example:Rhizocarpon, Graphis
  2. Foliose lichen: Thallus like dry forked leaf, flat ,irregularly lobed example:Parmelia , Peltigera
  3. Fruticose lichen: Branched like a bush and attached to the substratum with the help of flattened disc. Example: Usnea , Cladonia

Kingdom Plantae

- Most of the plants are eukaryotic.
- They contain chlorophyll.
- Cells are surrounded by cell wall.
- Cell walls of plant cells are comprised of cellulose.
- They have an ability to grow by cell division. Growth occurs due to the presence of definite growing points or cells. In higher forms, growing areas are called meristems.
- In life cycle of plant cells, the interchanges occur from the embryos and are supported by other tissues and self produce.
- Plants have tissue and organ.
- They obtain their energy from sun through photosynthesis.
- Plants reproduce both sexually and asexually. **Alternation of generation** is found in plants.
- They lack motility.

Kingdom Animalia

- Animals are eukaryotic, multicellular and heterotrophic organisms.
- They have multiple cells with mitochondria
- They depend on other organisms for food.
- The size of animals ranges from a few celled organism like the mesozoans to animals weighing many tons like the blue whale.
- The animal cell contains organelles like the nucleus, mitochondria, Golgi complex, endoplasmic reticulum, ribosomes, lysosomes, vacuoles, centrioles, and cytoskeleton.
- They have tissue/organ/organ system.
- Organ systems are skeletal system, muscular system, digestive system, respiratory system, circulatory system, excretory system, reproductive system, immune system and the endocrine system.
- Most animals have the ability to move, they show rapid movement as compared to other organisms.



Plant Kingdom

Kingdom Plantae includes green, brown and red algae, liwerworts, mosses, ferns and seed plants with or without flowers. They have the following characters:-

(1) Multicellular organisms with walled and frequently vacuolate eukaryotic cells.

(2) They contain photosynthetic pigment in plastids.

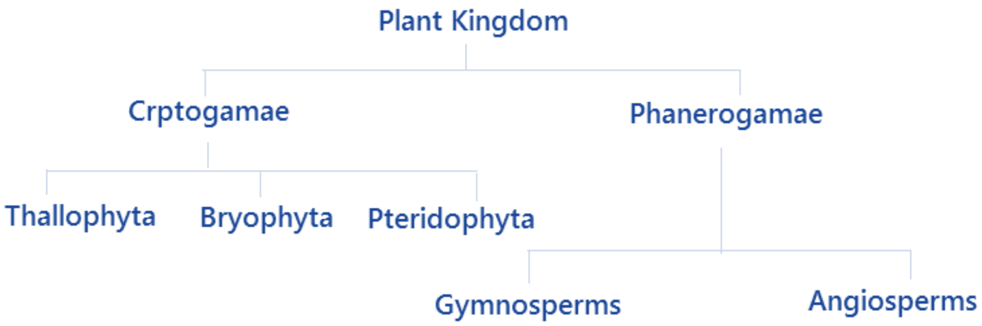
(3) Principle mode of nutrition is photosynthesis but number of plants has become absorptive.

(4) Reproduction is primarily asexual or sexual. The reproductive organs are multicellular.

(5) A multicellular embryo is formed during development from the zygote. Algae lack embryo stage.

Life cycle consists of alternating haploid gametophyte and diploid sporophyte generation. This phenomenon is called alternation of generation.

Thallophyta
Algae



(1) The branch of botany dealing with the study of algae is called as phycology or algology.

(2) It is derived from the Greek word Phykos which means 'alga' or 'sea weed'.

(3) They are simple, autotrophic non-vascular plants having unicelled sex organs and no embryo formation.

(4) According to Fritsch, (1935) the designation alga must include all holophytic organisms.

(5) Specialized habitat

(1) Chlorophyceae

Plants fresh water or marine.

Forms unicelled to parenchymatous.

Chief pigments – Chlorophyll a, b; a, b, g– carotenes, lycopene, lutein, violaxanthin.

Reserve food – Starch and oils.

Zoospore formation occurs.

Male gametes flagellate.

Sexual reproduction – Isogamous, anisogamous or oogamous.

(2) Phaeophyceae

Plants marine

Forms unicelled to parenchymatous

Chief pigments – Chlorophyll a, c; beta–carotene, fucoxanthin, lutein, violaxanthin, diatoxanthin.
Reserve food – Laminarin, mannitol and oils.

Zoospore formation occurs.

Male gametes flagellate.

Sexual reproduction – Isogamous , anisogamous or oogamous.

(3) Rhodophyceae

Plants generally marine.

Forms filamentous to parenchymatous.

Chief pigments – Chlorophyll a, d is present but chlorophyll c is absent; a, b–carotene, lutein, violaxanthin, fucoxanthin, myxoxanthin, g–phycoerythrin, g–phycocyanin and allophycocyanin.
Reserve food – Floridean starch, galactan –SO_4 polymers.

No zoospore formation.

Male gametes non-flagellate.

Sexual reproduction by specialized type of oogamy.

Life cycle haplobiontic or diplobiontic.

Bryophyta

(1) Bryophyta (Gk: Bryon = moss; phyton = plants) includes the simplest and primitive land plants.

(2) Due to peculiar type of their habitats, they are regarded as 'the amphibians of the plant kingdom'.

(3) **Habitat:** Bryophytes usually grow in moist and shady places.

(4) **Specialized habitats:** Some bryophytes grow in diverse habitats such as –

   (a) Aquatic (e.g., Riccia fluitans, Ricciocarpus natans, Riella), epiphytes (e.g., Dendroceros, Radula protensa and many mosses), saprophytes (e.g., Buxbaumia aphylla, Cryptothallus mirabilis)

   (b) Dry habitats such as dry heaths (e.g., Polytrichum juniperinum), deserts (e.g., Tortula desertorum) and dry rocks (e.g., Porella platyphylla).

(5) Sexual reproduction: The male sex organ is called as antheridium and the female as archegonium.

(6) Salient features of classes

   (i) **Hepaticopsida:** The latin word Hepatica means liver. Thus the members of hepticopsida are popularly known as liverworts.

   (ii) **Anthocerotopsida:** This class is characterized by the following characters –

   Gametophyte is thalloid. Thalli are lobed, dorsiventral, and internally homogenous without any differentiation of tissues.

   Scales are absent.

   Each cell possesses single (some times more) large chloroplast with central pyrenoid.

   Antheridia are endogenous in origin, borne singly or in groups inside the closed cavities.

   Sporogonium is differentiated into foot, meristematic zone and capsule (the seta is absent).

   Capsule has central sterile columella.

   (iii) **Bryopsida**: The members of bryopsida are commonly known as mosses. The class is characterised by the following characters –

   Gametophyte is differentiated into two stages – prostrate protonema and erect radial leafy shoot.

   Leaf-like appendages are spirally arranged on stem – like axis.

   Rhizoids are multicellular with oblique septa.

   Sex organs develop from superficial cells.

   Sporogonium is differentiated into foot, seta and capsule.

   Wall of capsule is several layered with stomata on epidermis.

   The capsule has central columella.

Pteridophyta

(1) The pteridophytes (Gk. Pteron = feather and phyton = plants ; means plants with feather like fronds or ferns). They are flowerless, seedless, spore producing vascular plants which have successfully invaded the land.

(2) **Habitat:** The plants of pteridophytes are mostly terrestrial. They prefer shady habitats.

(3) They have Sporophytic plant body

(4) **Apical growth:** The pteridophyte generally possesses a single apical cell with three cutting faces in the shoot apex.

(5) Salient features of sub-phyla

(i) Sub-phylum: Psilopsida

(a) These are the oldest known vascular plants; most of them (except Psilotum and Tmesipteris) are fossils.

(b) Plant body is relatively less differentiated.

(c) Roots are absent; instead dichotomously branched rhizome is present.

(d) Aerial axis is either naked or have small spirally arranged leaves.

(e) Sporangia are cauline (i.e., directly borne on the axis or stem); they are lateral or terminal in position. e.g., Psilotum, Tmesipteris.

(ii) Sub-Phylum: Lycopsida

(a) Plant body is differentiated into root, stem and leaves.

(b) Leaves small (i.e., microphyllous) with a single unbranched vein.

(c) Sporangia develop in the axil of the sporophylls.

(d) Sporophylls generally form compact strobili. e.g., Lycopodium, Selaginella, etc.

(iii) Sub-Phylum: Sphenopsida

(a) Stem differentiated into nodes and internodes.

(b) Leaves microphyllous, present in whorls at each node.

(c) Sporangia are borne on the sporangiophores which form compact cones at the apex of the fertile branches. e.g., Equisetum.

(iv) Sub-Phylum: Pteropsida

(a) Plant body well differentiated into root, stem and leaves.

(b) Leaves megaphyllous, pinnately compound.

(c) Sporangia develop on the ventral surface of the sporophylls, usually aggregated into sori. e.g., Dryopteris, Pteris, Pteridium, Polypodium, etc.

Angiosperms

The angiosperms, or flowering plants, constitute the most dominant and ubiquitous vascular plants of present day flora which changed the green and yellow melancholy of the earth's vegetation by the colourful brightness and fragrance of their flower.

(i) Dicotyledons :

They are show following distinguished characteristics.

(a) Tap roots found in the members of this group.

(b) The leaves in members of these class exihibit reticulate (net like) venation.

(c) The flowers are tetramerous or pentamerous having four or five members in the various floral whorls, respectively.

(d) The vascular bundles arranged in a ring, numbering 2–6, open and with cambium.

(e) The seeds of dicotyledons are with two cotyledons as the name indicate.

(ii) Monocotyledons:

They are show following distinguished characteristics:

(a) Adventitious roots found in the members of this group.

(b) The leaves are simple with parallel venation.

(c) The flowers are trimerous having three members in each floral whorl.

(d) The vascular bundles scattered in the ground tissue, many in number, closed and without cambium.

(e) The seeds of monocotyledons are with one cotyledon as the name indicates. e.g., Cereals, bamboos, sugarcane, palms, banana, lilies and orchids.

Gymnosperms

(1) Living gymnosperms are mostly perennials, xerophytic, evergreen, arboreal and woody plants.

(2) They grow as wood trees, bushy shrubs or rarely as climbers (e.g., Gnetales).

(3) None of them are herbs or annuals.

(4) External features:

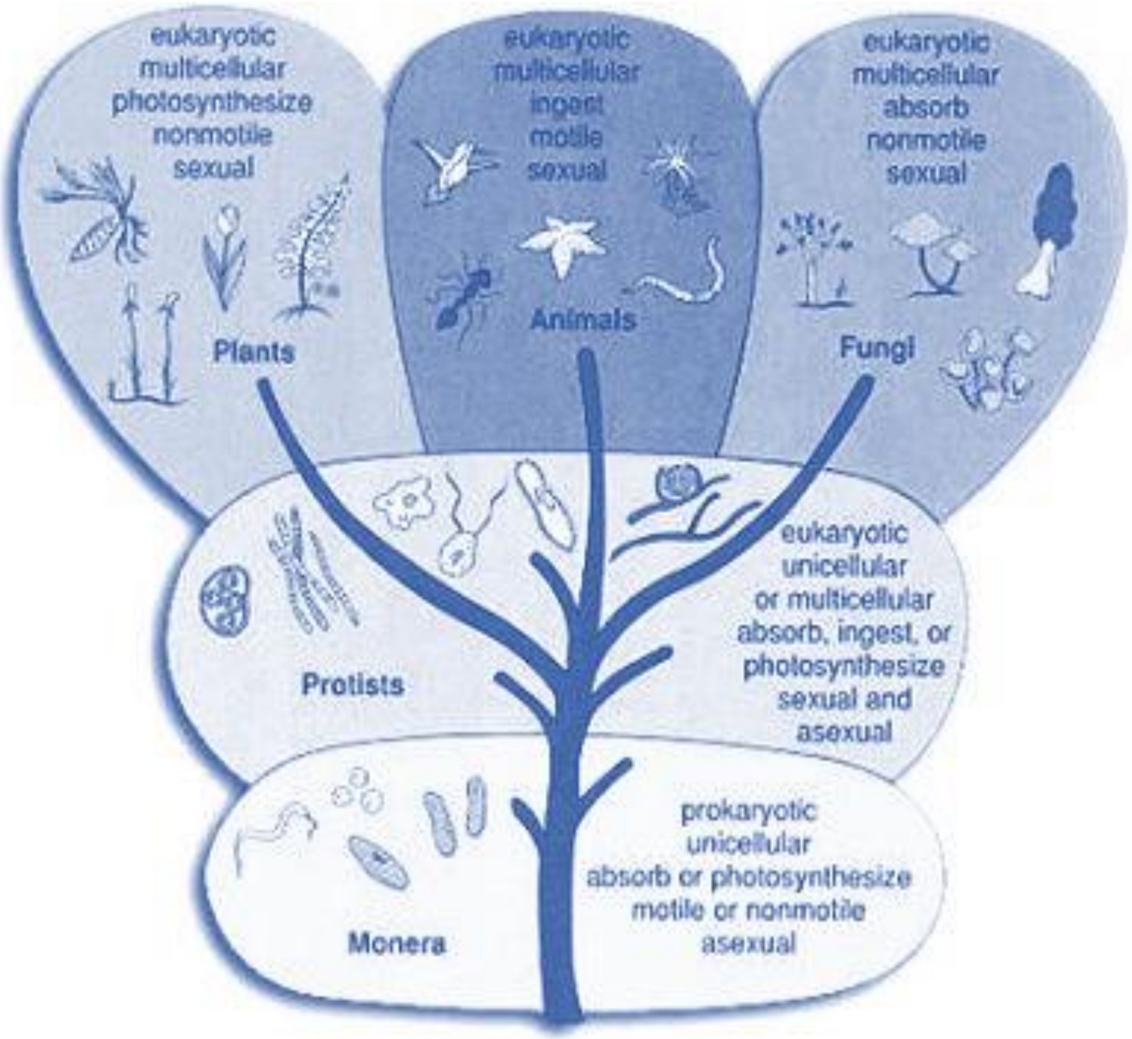
(i) The plant body is sporophyte and differentiated into root, stem and leaves.

(ii) The plant possesses well developed tap root system. In some cases the roots are symbiotically associated with algae (e.g., Coralloid roots of Cycas) or with fungi (e.g., Mycorrhizal roots of Pinus).

(iii) The stem is erect, aerial, solid, woody and branched (unbranched in Cycadales) but almost tuberous in Zamia.

(iv) The leaves may be microphyllous or megaphyllous

Animal Kingdom



(i) Characters of Non Chordata (Invertebrates): The animals which lack a notochord are called invertebrates. e.g. Amoeba, sponges, Hydra, worms, insects, etc., Invertebrates are characterised by the following salient features –

(1) The vertebral column is absent.

(2) The nerve cord is solid in nature.

(3) The nerve cord is present on the ventral side and never on the dorsal side.

(4) When alimentary canal is present, it lies dorsal to the nerve cord.

(5) Invertebrates may be acoelomate or pseudocoelomate or true coelomate.

(6) They have either asymmetry or radial symmetry or bilateral symmetry.

(7) The circulatory system is open type or closed type.

(8) They exhibit all possible type of reproduction.

- Phylum Protozoa and Porifera
- Phylum Cnidaria and Ctenophora
- Phylum Platyhelminthes and Nematoda
- Phylum Mollusca and Echinodermata

(ii) Characters of Chordata (Vertebrates): The animals which possess a notochord are called vertebrates.

(1) Aquatic, aerial or terrestrial.

(2) Body small to large, bilaterally symmetrical and metamerically segmented.

(3) A post anal tail usually projects beyond the anus at some stage and may or may not persist in the adult.

(4) Exoskeleton often present; well developed in most vertebrates.

(5) Body wall triploblastic with 3 germinal layers : ectoderm, mesoderm and endoderm.

(6) Coelomate animals having a true coelom, enterocoelic or schizocoelic in origin.

(7) A skeletal rod, the notochord, present at some stage in life cycle.

(8) A cartilaginous or bony, living and jointed...

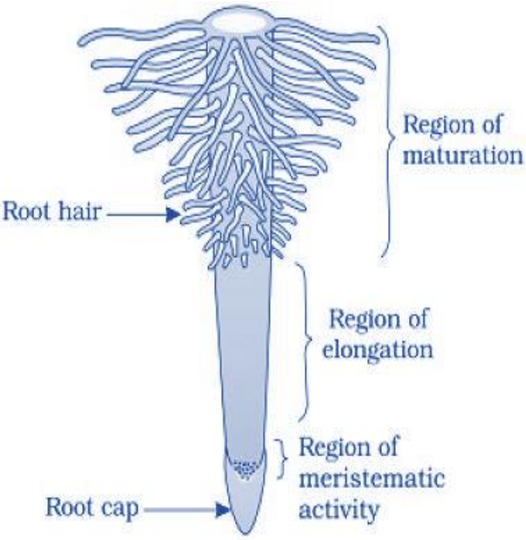
Morphology & Anatomy of flowering Plants

Morphology (Gr. *Morphos* = Form; *logos* = Study) is the branch of science which deals with the study of form and structure. In botany, it generally means the study of external features, forms and relative positions of different organs on plants.

Angiospermic or flowering plants show a great variety of shape, size and form. The size ranges from the minute *Wolffia* and *Lamna* (0.1*cm*) to the tall *Eucalyptus* (up to 100 *metre*) and large sized Banyan (*Ficus bengalensis*).

Parts of a flowering plant:

The Root



The root is usually an underground part of the plant which helps in fixation and absorption of water. The root with its branches is known as the root system.

(1) **Characteristics of the root**

- (i) The root is the descending portion of the plant axis and is positively geotropic.
- (ii) It is non-green or brown in colour.
- (iii)The root is not differentiated into nodes and internodes.
- (iv) As per the rule the root does not bear leaves and true buds.
- (v) Usually the root tip is protected by a root cap.
- (vi) The root bears unicellular root hairs.
- (vii) Lateral roots arise from the root which are endogenous in origin (arises from pericycle).

(2) **Types of root system:**

The root system is generally of two types:

- (i) **Tap root system:** The tap root system develops from radicle of the germinating seed. It is also called the normal root system. The tap root system is present in **dicotyledonous plants**.
- (ii) **Adventitious root system:** The root system that develops from any part of the plant body other than the radicle is called the adventitious root system. It is mostly seen in monocotyledonous plants.

The Stem

(1) The stem develops from the plumule of the germinating seed.

(2) The stem shows the differentiation of nodes and internodes.

(3) The place where the leaf develops on the stem is called the **node**.

(4) The portion of the stem between two successive nodes is called the **internode**.

(5) **Characteristics of stem**

(i) Stem is an ascending axis of the plant and develops from the plumule and epicotyl of the embryo.

(ii) It is generally erect and grows away from the soil towards light. Therefore, it is negatively geotropic and positively phototropic.

(iii) The growing apex of stem bears a terminal bud for growth in length.

(iv) In flowering plants, stem is differentiated into nodes and internodes.

(v) The lateral organs of stem (*i.e.*, leaves and branches) are exogenous in origin (from cortical region).

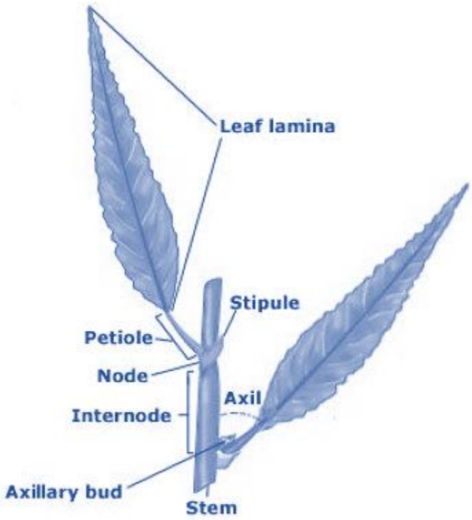
(vi) The young stem is green and photosynthetic.

(vii) Hair, if present, are generally multicellular.

(viii) In mature plants, stem and its branches bear flowers and fruits.

The Leaf

The leaf is a green, flat, thin, expanded lateral appendage of stem which is borne at a node and bears a bud in its axil. It is exogenous in origin and develops from the leaf primordium of shoot apex. The green colour of leaf is due to presence of the photosynthetic pigment – chlorophyll which helps plants to synthesize organic food. The green photosynthetic leaves of a plant are collectively called **foliage**. They are borne on stem in acropetal succession.



(1) **Characteristics of lea**

(i) The leaf is a lateral dissimilar appendage of the stem.

(ii) A leaf is always borne at the node of stem.

(iii) Generally there is always an axillary bud in the axil of a leaf.

(iv) It is exogenous in origin and develops from the swollen leaf primordium of the growing apex.

(v) The growth of leaf is limited.

(vi) The leaves do not possess any apical bud or a regular growing point.

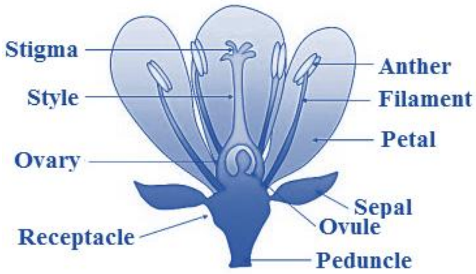
(vii) A leaf has three main parts – Leaf base, petiole and leaf lamina. In addition, it may possess two lateral outgrowths of the leaf base, called stipules.

(viii) The leaf lamina is traversed by prominent vascular strands, called veins.

Flower

It can be defined as modified dwarf shoot which is meant for sexual reproduction.

(1) Floral **Parts of a typical flower:**



(i) **Calyx:** It is the outermost whorl composed of**sepals**. The calyx may show number of modifications. They are:

Campanulate : Bell shaped, e.g., *Althaea.*

Cupulate : Cup like, e.g., *Gossypium.*

Petaloid : Enlarged and brightly coloured sepals, e.g., *Clerodendron, Mussaenda*

(ii) **Corolla:** It is composed of **petals** and is the second whorl.

The corolla may undergo modifications or possess some special appendages.

- **(a) Sepaloid :** Green or dull coloured sepal. e.g., *Anona*, *Polyalthia* and *Artabotrys.*
- **(b) Saccate :** The corolla tube may form a pouch on one side. e.g., *Antirrhinum*.
- **(c) Spurred :** Sometimes one or two petals or the entire corolla tube grow downwards forming a spur that usually stores nectar. *e.g., Aquilegia vulgaris.*
- **(d) Corona :** Special appendages of different kinds like scales, hairs develop from the corolla. Such appendages are called corona. e.g., *Passiflora, Oleander* and *Nerium*.

(iii) **Androecium:** It is the third whorl composed of **stamens**.

The mode of attachment of a filament to anther by connective is called fixation. It is of following types:

- **(a) Adnate :** Filament attached to the total length of the anther on the back. e.g., *Michelia* (Campa).
- **(b) Basifixed :** Filament is attached to the base of the anther e.g.,...

ANATOMY

A tissue may be defined as, **"a group of similar or dissimilar cells having common origin and performing a specific functions."**

Tissues are mainly divided into three categories:

(A) Meristematic tissues or Meristems

(B) Permanent tissue

(C) Secretory tissue

Meristematic Tissues or Meristems

(1) They contain immature and young cells and are capable of repeated divisions.

(2) Intercellular spaces are not present in meristematic tissue.

(3) They contain a homogeneous thin wall.

(4) They contain large nuclei associated with abundant cytoplasm.

(5) They are metabolically very active but they do not store food material.

(6) Only proto-plastids are present instead of plastids, chloroplast absent.

(7) Dense cytoplasm is present which contains several premature mitochondria.

(8) Vacuoles are absent.

(9) Meristematic cells are isodiametric in shape.

Types of meristems

The meristems may be classified on the basis of their mode of origin, position or function:

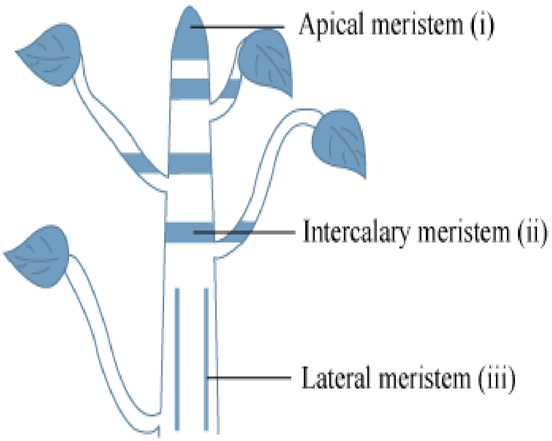
(i) **According to origin and development:** On the basis of origin, meristematic tissues are of three types :

(a) **Promeristem or Primordial meristem:** The promeristem originates from embryo and, therefore, called primordial or embryonic meristem. It is present in the regions where an organ or a part of plant body is initiated.

(b) **Primary meristem:** A primary meristem originates from promeristem and retains its meristematic activity. It is located in the apices of roots, stems and the leaf primordia.

(c) **Secondary Meristem:** They always arise in permanent tissues and have no typical promeristem. Some living permanent cells may regain the meristematic nature.

(ii) **According to position:** On the basis of their position in the plant body meristems are classified into three categories:



(a) **Apical meristem:** This meristem is located at the growing apices of main and lateral shoots and roots. These cells are responsible for linear growth of an organ.

(b) **Intercalary meristem:** These are the portions of apical meristems which are separated from the apex during the growth of axis and formation of permanent tissues. It is present mostly at the base of node (*e.g.*, *Mentha viridis*-Mint), base of internode (*e.g.*, stem of many monocots *viz.*, Wheat, Grasses, Pteridophyts like *Equisetum*) or at the base of the leaf (*e.g., Pinus*).

(c) **Lateral meristem:** These meristems occur laterally in the axis, parallel to the sides of stems and roots. This meristem consists of initials which divide mainly in one plane (periclinal) and result increase in the diameter of an organ.

(iii) **According to function:** Haberlandt in 1890 classified the primary meristem at the apex of stem under the following three types :

(a) **Protoderm:** It is the outermost layer of the apical meristem which develops into the epidermis or epidermal tissue system.

(b) **Procambium:** It occurs inside the protoderm. Some of the cells of young growing region which by their elongation and differentiation give rise to primary vascular tissue constitute the procambium.

(c) **Ground meristem:** It constitutes the major part of the apical meristem develops ground tissues like hypodermis, cortex, endodermis, pericycle, pith and medullary rays.

(iv) **According to plane of cell division:** On the basis of their plane of cell division meristem are classified into three categories :

(a) **Mass meristem:** The cells divide anticlinally in all planes, so mass of cells is formed. *e.g.,* formation of spores, cortex, pith, endosperm.

(b) **Plate meristem:** The cells divide anticlinally in two planes, so plate like area increased. *e.g.,* formation of epidermis and lamina of leaves.

(c) **Rib or File meristem:** The cells divide anticlinally in one plane, so row or column of cells is formed. *e.g,,*formation of lateral root.

Permanent Tissues

Permanent tissues are made up of mature cells which have lost the capacity to divide and have attained a permanent shape, size and function due to division and differentiation in meristematic tissues. The cells of these tissues are either living or dead, thin-walled or thick-walled. Permanent tissues are of three types :

(1) **Simple tissues:** Simple tissues are a group of cells which are all alike in origin, form and function. They are further grouped under three categories :

(i) **Parenchyma:** Parenchyma is most simple and unspecialized tissue which is concerned mainly with the vegetative activities of the plant.

(ii) **Collenchyma:** The term collenchyma was coined by Schleiden (1839). It is the tissue of primary body.

The cells of this tissue contain protoplasm and are living.

The cell walls are thickened at the corners and are made up of cellulose, hemicellulose and pectin.

(iii) **Sclerenchyma:** It was discovered and coined by Mettenius (1805).

The main feature of sclerenchyma are :

It consist of thick-walled dead cells.

The cells vary in shape, size and origin.

Special or secretory tissues

These tissue perform special function in plants, *e.g.*, secretion of resins gum, oil and latex.

These tissues are of two types :

(1) Laticiferous tissues

(2) Glandular tissues

(1) **Laticiferous tissues:** They are made up of thin walled, elongated, branched and multinucleate (coenocytic) structures that contain colourless, milky or yellow coloured juice called latex. These occur irregularly distributed in the mass of parenchymatous cells. latex is contained inside the laticiferous tissue which is of two types:

   (i) **Latex cells:**

      (a) A laticiferous cell is a very highly branched cell with long slender processes ramifying in all directions in the ground tissue of the organ.

      (b) Plants having such tissues are called simple or non-articulated laticifers. *e.g., Calotropis*(Asclepiadaceae) *Nerium*, *Vinca* (Apocyanaceae), *Euphorbia* (Eu phorbiaceae), *Ficus* (Moraceae).

   (ii) **Latex vessels:**

      (a) They are formed due to fusion of cells and form network like structure in all directions.

      (b) Plants having such tissues are called compound or *articulated laticifers*. *e.g., Argemone, Papaver*(Papaveraceae), *Sonchus* (Compositae), *Hevea, Manihot* (Euphorbiaceae).

(2) **Glandular tissue:** This is a highly specialized tissue consisting of glands, discharging diverse functions, including secretory and excretory. Glands may be external or internal.

   (i) **External glands:** They are generally occur on the epidermis of stem and leaves as glandular hair in *Plumbago*and *Boerhaavia*.

   (ii) **Internal glands:** These are present internally and are of several types. *e.g.,* oil glands in *Citrus* and *Eucalyptus*, resinous ducts in *Pinus*.

The Tissue System

A collection of tissues performing the same general function is known as a “Tissue System''. According to Sachs (1975) there are three major tissue systems in plants as follows:

(1) Epidermal tissue system

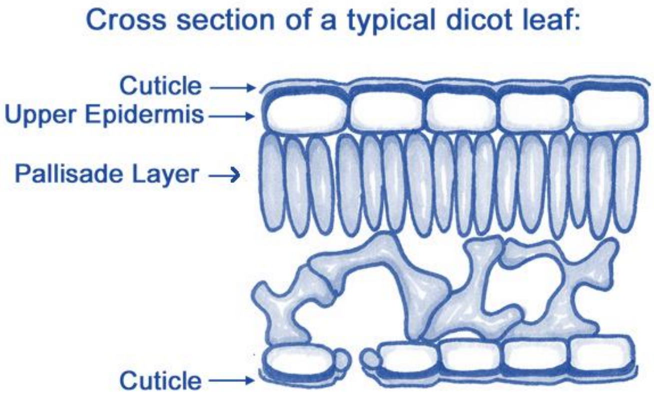
(2) Ground or fundamental tissue system

(3) Vascular tissue system

(1) **Epidermal tissue system:** The tissues of this system originate from the outermost layer of apical meristem.

(i) **Epidermis:** Epidermis is composed of single layer cells.

(ii) **Cuticle and Wax:** In aerial parts, epidermis is covered by cuticle. The epidermal cells secrete a waxy substance called cutin, which forms a layer of variable thickness (the cuticle) within and on the outer surface of its all walls. it helps in reducing the loss of water by evaporation.



(iii) **Stomata:** Stomata are minute apertures in the epidermis. Each aperture is bounded by two kidney shaped cells, called guard cells. Stomata are absent in roots.

Depending upon distribution of stomata, the leaves are :

(a) **Apple-mulberry type:** *e.g. Oxalis, Mulberry, Apple*.

(b) **Potato type:** *e.g.* Bifacial (dorsiventral leaves of pea, bean, tomato).

(c) **Oat type:** *e.g.* Suberect (isobillateral) leaves of most grasses and cereals (monocotyledens).

(d) **Nymphea type:** *e.g.* Floating leaves of *Nelumbo, Nymphia,* water lily.

(e) **Potamogeton type:** *e.g.* Submerged plants like *Hydrilla, Vallisneria, Potamogeton*.

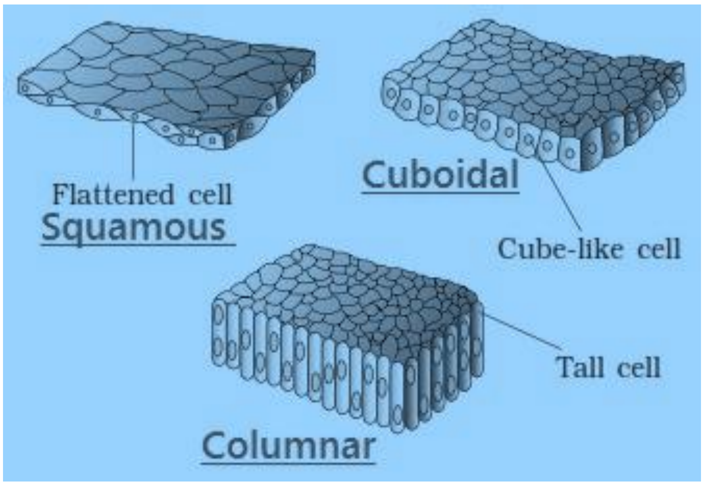
(iv) **Trichomes:** These are epidermal outgrowths present temporarily or permanently on almost all plant parts.

(v) **Root hairs:** They are enlargements of special epiblema cells called **trichoblasts** and occurs in a particular zone of young.

Structural Organization in Animals

Epithelial Tissues

- An epithelium is a tissue composed of one or more layers of cells that cover the body surface and lines its various cavities.
- It serves for protection, secretion and excretion..
- Epithelial tissue evolved first in animal kingdom.
- It originates from all the three primary germ layers. *e.g.* Epidermis arises from ectoderm, Coelomic epithelium from the mesoderm and epithelial lining of alimentary canal from the endoderm.
- **Types of Epithelium**



Glands

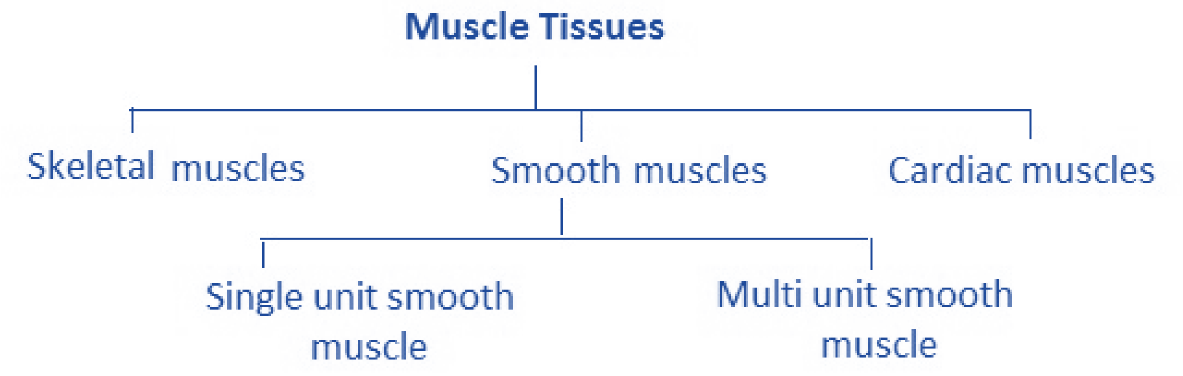
- Multicellular exocrine glands are classified by structure, using the shape of their ducts and the complexity (branching) of their ducts system as distinguishing characteristics.
- Shape include tubular and alveolar (Sac like).
- Simple exocrine glands *e.g.* intestinal glands, mammalian sweat glands, cutaneous glands of frog etc. have only one duct leading to surface.
- Compound exocrine glands have two or more ducts *e.g.* liver, salivary glands etc.

- **Structural classification of exocrine glands:**

Type	**Example**
Simple tubular	Intestinal glands, crypts of Lieberkuhn in ileum.
Simple coiled tubular	Sweat glands in man
Simple branched tubular	Gastric (stomach) gland, and Uterine gland.
Simple alveolar	Mucous gland in skin of frog, Poison gland of toad and seminal vesicle.
Simple branched alveolar	Sebaceous glands
Compound tubular	Brunner’s gland, bulbourethral gland and liver.
Compound alveolar	Sublingual and submandibular parotid salivary gland
Compound tubulo alveolar	Parotid salivary glands, Mammary gland and Pancreas.

Muscle Tissues

- Muscle cells are highly contractile (contracting to 1/3 or 1/2 the resting length).
- Muscle cells lose capacity to divide, multiply and regenerate to a great extent. Study of muscle is called myology.
- About 40% to 50% of our body mass is of muscles.
- The muscle cells are always elongated, slender and spindle-shaped, fibre-like cells, These are, therefore called muscle fibres.
- These possess large numbers of myofibrils formed of actin and myosin.

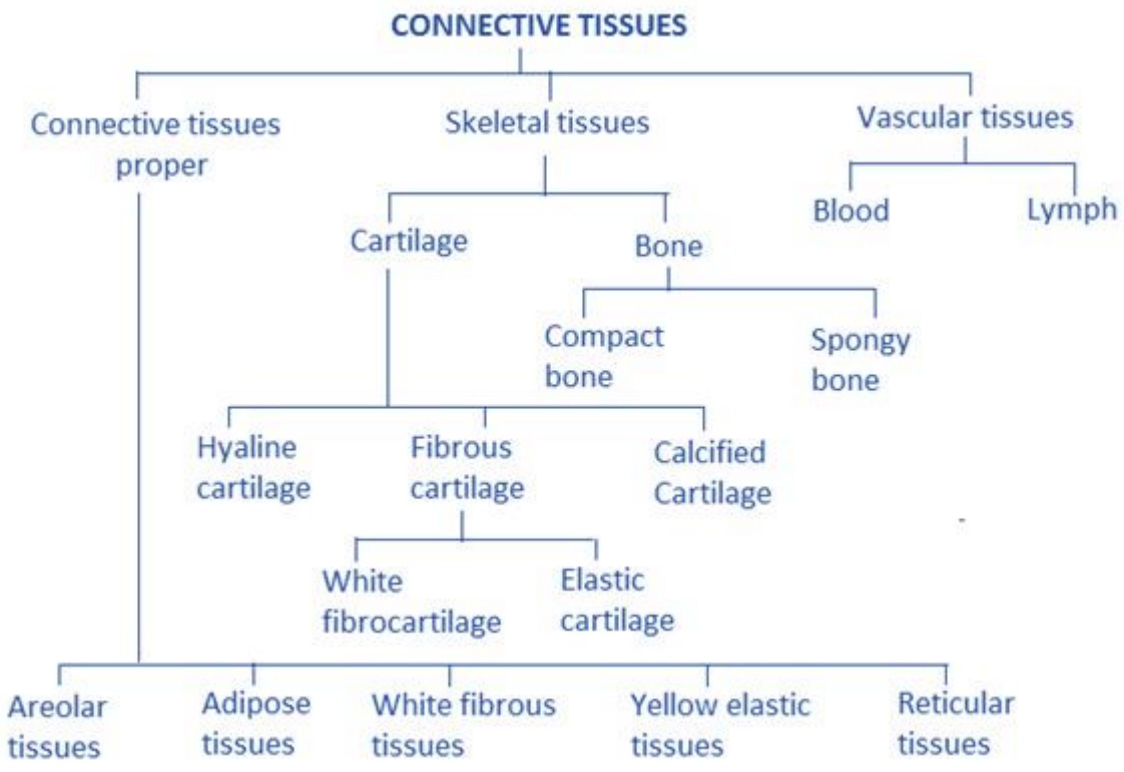


(f) **Difference between three types muscle fibres**

S.No.	Feature	Striated or Striped or Skeletal or Voluntary muscle fibres	Non-striated or Unstriped or Smooth or Visceral or Involuntary muscle fibres	Cardiac muscle fibres
1.	Shape	Long cylindrical	Fusiform (thick in middle tapering at ends) (0.02 nm to 0.2 nm long)	Network of fibres
2.	Stripes	Dark A bands and light I bands present	Absent	Present
3.	Nucleus	Many (syncytial) at periphery	Single at the centre of each cell	Many nuclei between successive end plates central position
4.	Unit	Sarcomeres, cylindrical long myofibrils placed end to end forming cylindrical myofibrils	Fusiform cells with inconspicuous borders	Oblique cross-connecting fibres make this muscle an interconnected bundle of myofibrils
5.	Attachment	To bones	To soft organs or viscera	Not attached to other organs except major blood vessels which are isolated and covered by pericardium
6.	Sarcolemma	Distinct	Absent	Absent
7.	Sarcoplasmic Reticulum	Well developed	Less extensive	Poorly formed
8.	Blood supply	Rich	Poor	Rich
9.	Contraction	Quick, fatigue fast	Slow, sustained contraction	Rhythmic, contractions originate in heart (pace maker immune to fatigue)
10.	Location	Generally peripheral, tongue, proximal part of oesophagus	Central, in hollow visceral organs, iris of the eye, dermis of the skin	Only in heart
11.	Intercalated discs	Absent	Absent	Present
12.	T-tubule system	Well developed	Lacking	Well developed
13.	Innervated nerves	Motor nerves from central nervous system (neurogenic)	Nerves from autonomic nervous system (neurogenic)	Nerves from central and autonomic nervous system (myogenic)
14.	Fibres	Unbranched	Unbranched	Fibres join by short oblique bridges
15.	Action	Voluntary	Involuntary	Involuntary

Connective Tissues

- It connects and supports all the other tissues, the intercellular element predominating.
- The cellular element is usually scanty. In function this tissue may be mechanical, nutritive and defensive.
- It is a tissue made up of matrix (abundant intercellular substance or ground substance) and living cells that connects and support different tissues.
- Connective tissue was called mesenchyme by Hertwig (1893).
- Types of connective tissues



(1) **On the basis of their texture:**

The bones are divided into two categories spongy or cancellous or tubecular bones and compact or periosteal bones

Bone	Cartilage
1. Matrix is composed of a tough, inflexible material, the ossein.	**1.** Matrix is composed of a firm, but flexible material, the chondrin.
2. Matrix is always impregnated with calcium salts.	**2.** Matrix may be free or impregenated with calcium salts.
3. Bone cells lie in lucunae singly.	**3.** Cartilage cells lie in lacunae singly or in groups of two or four.
4. Osteocytes are irregular and give off branching processes in the developing bone.	**4.** Chondroblasts are oval and devoid of processes.
5. Lacunae give off canaliculi.	**5.** Lacunae lack canaliculi.
6. There are outer and inner layers of special bone forming cells, the osteoblasts, that produce new osteocytes, which secrete new lamellae of matrix.	**6.** There are no special cartilage-forming cells. Cartilage grows by division of all chondroblasts.
7. Matrix occurs largely in concentric lamellae.	**7.** Matrix occurs in a homogenous mass.
8. Bone is highly vascular.	**8.** Cartilage in nonvascular.
9. Bone may have bone marrow at the centre.	**9.** No such tissue is present.

(6) **Number of RBC:** The number of RBCs is counted by instrument haemocytometer.

S.No.	Organism	Number of RBCs
1.	Male	5 – 5.4 million / cubic mm of blood
2.	Female	4.5 – 5 million / cubic mm of blood
3.	Infants	65 – 70 lacs/ cubic mm of blood
4.	Embryo	85 lacs/ cubic mm of blood
5.	Rabbit	70 lacs / cubic mm of blood
6.	Frog	4 lacs / cubic mm of blood

(7) **Life span of RBC:**

S.No.	Organism	Life span of RBCs
1.	Mammals and Human	120 days or 4 months
2.	Rabbit	80 days

Cell: The Unit of Life

(1) **Cytology:** (G.k. kyios = cell ; logas = study) is the branch of biology which comprises the study of cell structure and function.

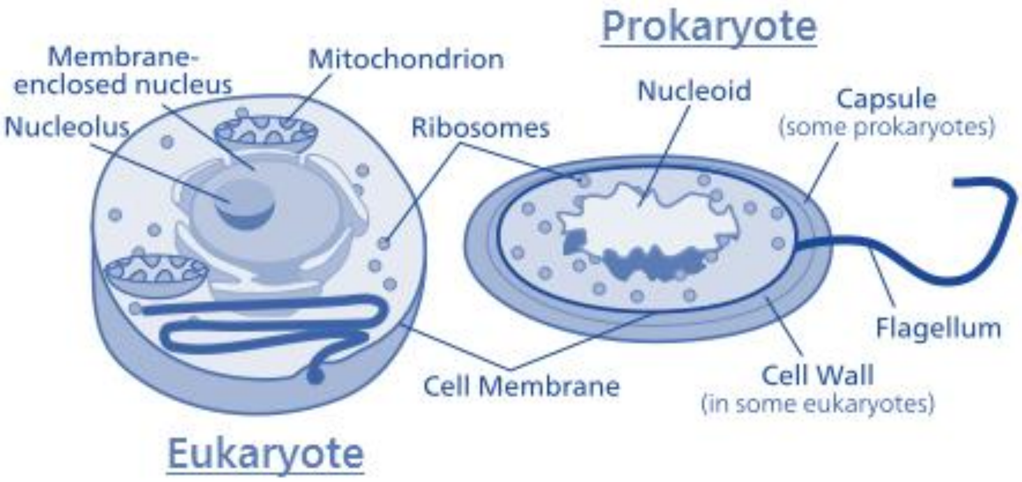
(2) Cell is the structural and functional unit of all living beings.

(3) There are two types of cells: plant cell and animal cell.

Plant cell	Animal cell
Cell wall present.	Cell wall absent.
Nucleus usually lies near periphery due to vacuole.	Nucleus present near the centre.
Centrosome is usually absent from higher plant cells, except lower motile cells.	Usually centrosome is present that helps in formation of spindle fibres.
Plastids are present, except fungi.	Plastids are absent.
Mitochondria is generally spherical or oval in shape.	Generally tubular in shape.
Single large central vacuole is present.	Many vacuoles occur, which are smaller in size.
Number of mitochondria from 200 – 2000.	Number of mitochondria is approximately 1600 – 16000 in liver cells.
Cytoplasm during cell division usually divides by cell plate method.	Cytoplasm divides by furrowing or cleavage method.
Plant cells are capable of forming all the amino acids coenzymes and vitamins.	Animal cells cannot form all the amino acids, coenzymes and vitamins.
There is no contractile vacuole.	Contractile vacuole may occur to pump excess water.
Sodium chloride is toxic to plant cells.	Tissue fluid containing sodium chloride bathes the animal cells.
Plant cells are generally well over 100 micrometer long.	Generally much smaller than 100 micrometer
Spindle formed during cell division is anastral.	Spindle formed during cell division are amphiastral.
Lysosomes present in less number.	Lysosomes present in more number.
Chromosomes are larger in size.	Chromosomes are smaller in size.

Prokaryotic cell	Eukaryotic cell
It is a single membrane system.	It is a double membrane system.
Cell wall surrounds the plasma membrane.	Cell wall surrounds the plasma membrane in some protists, most fungi and all plant cell. Animal cell lack it.
Cell wall composed of peptidoglycans. Strengthening material is mureir.	It is composed of polysaccharide. Strengthening material is chitin in fungi & cellulose in others plants.
Cell membrane bears respiratory enzymes.	It lacks respiratory enzymes.
Cytoplasm lacks cell organelles e.g., Mitochondria, ER, Golgi body etc.	Cytoplasm contains various cell organelles.
Ribosomes are 70 S type.	Ribosomes are 80 S type.
There are no streaming movements of cytoplasm.	Cytoplasm show streaming movements.
Endocytosis and exocytosis do not occur.	Endocytosis and exocytosis occur in animal cells.
Mitotic spindle is not formed in cell division.	Mitotic spindle is formed in cell division.
The mRNA does not need processing.	The mRNA needs processing.
Nuclear material is not enclosed by nuclear envelope and lies directly in cytoplasm. It is called nucleoid.	It is enveloped by nuclear envelope. Nucleus is distinct from cytoplasm.
DNA is circular and not associated with histone proteins.	Nuclear DNA is linear and associated with histone proteins extranuclear DNA is circular and protein free.
Replication of DNA occurs continuously throughout cell cycle.	Replication of DNA occurs during S- Phase of cell cycle only.
These have small size (0.5 to 10 micrometer) and have much less DNA.	These are relatively large (10 – 15 micrometer) and have much more DNA.
Sexual reproduction absent but parasexuality present.	Sexual reproduction is present.
Plasmids and pili occur in many prokaryotes **Example – E. coli**	There are no plasmids and pili in eukaryotic cells Example – Spirogyra, Chlorella
Cell division mostly amitotic.	Cell division is typically mitotic.
Plasma invaginates and from finger like process. Mesosome which take part in respiration	Absent

(4) Difference between Prokaryotic and eukaryotic cells



Primary cell wall	Secondary cell wall
Primary wall is laid inner to middle lamella	Secondary wall is laid inner to primary wall.
It is formed in a growing cell.	It is formed when the cells have stopped growing.
It is capable of extension.	Extensibility is absent except in collenchyma cells.
It is single layered.	It is three or more layered.
Cellulose content is comparatively low (5 – 20%).	Cellulose content is comparatively high (20 – 90%).
Cellulose microfibrils are shorter, wavy and loosely arranged.	They are longer, closely arranged straight and parallel.
Protein content up to 5%.	Protein content up to 1%.
Hemicellulose content is high up to 50%.	It is 25% of the total.
Lipid content up to 5 – 10%.	Lipid is absent.
Primary wall is comparatively thin 1 – 5 micrometer	It is comparatively thick 5 – 10 micrometer

(5) Difference between primary cell wall and secondary cell wall

(6) Difference between extrinsic protein and intrinsic protein

Extrinsic Protein	Intrinsic Protein
These are associated with surface only.	These lie throughout phospholipid matrix and project on both surfaces, also called transmembrane or tunnel protein.
They form about 30% of the total membrane protein.	They form about 70% of total membrane proteins.
Example – Spectrin in red blood cells & ATPase in mitochondria.	Example – Rhodopsin in retinal rod cells.

Cell Wall

(1) **Discovery:** It was first discovered by Robert Hooke in 1665.

(2) Cell wall is the outer most, rigid, protective, non living and supportive layer found in all the plant ells, bacteria, cyanobacteria and some protists.

(3) It is not found in animal cells.

Plasma Memberane

(1) **Definition:** Every living cell is externally covered by a thin transparent electron microscopic, elastic regenerative and selective permeable membrane called plasma membrane.

Protoplasm

(1) **Definition:** Protoplasm is a complex, granular, elastic, viscous and colourless substance. It is selectively or differentially permeable.

(2) It is considered as "Polyphasic colloidal system".

Cytoplasm

The substance occurs around the nucleus and inside the plasma...

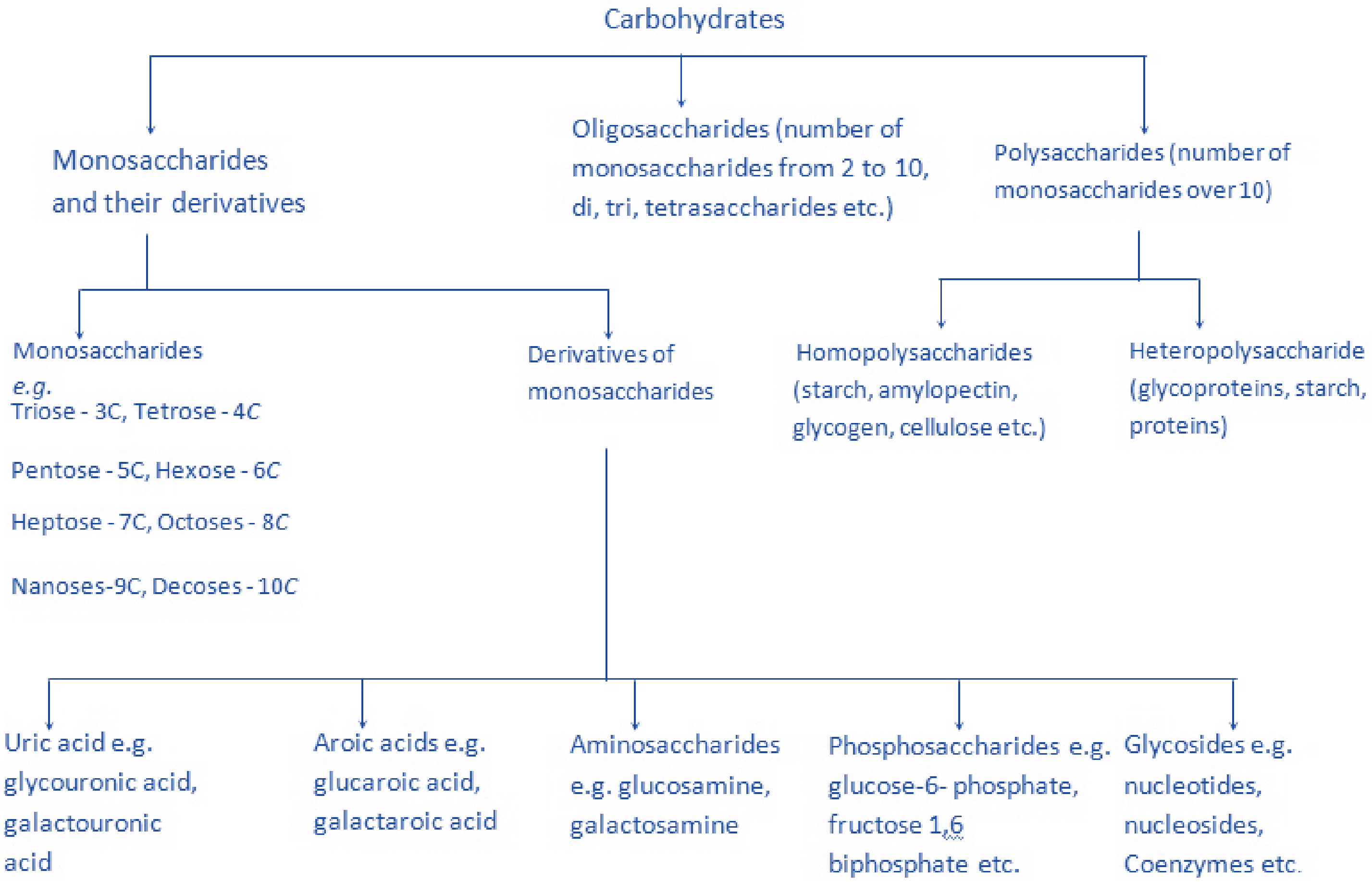
Biomolecules

Carbohydrates:

(1) e.g. sugars, glycogen (animal starch), plant starch and cellulose.

(2) **Source of carbohydrate:** Mainly photosynthesis. It exists only in 1% but constitutes 80% of the dry weight of plants.

(3) **Composition:** It consists of carbon, hydrogen and oxygen in the ratio C_nH_2N. It is also called saccharide and sugars are their basic components.



(4) **Properties of monosaccharide**

(a) Monosaccharides are colourless, sweet tasting, solids.

(b) Due to asymmetric carbon, they exist in different isomeric forms. They can rotate polarized light hence they are dextrorotatory and leavorotatory.

(c) D-glucose after reduction gives rise to a mixture of polyhydroxy alcohol, sorbitol or mannitol.

(d) The sugars with a free aldehyde or ketone group reduce Cu^{++} to Cu^{+} (cupric to cuprous)

(e) Sugars show oxidation, esterification and fermentation.

(f) The aldehyde or ketone group of a simple sugar can join an alcoholic group of another organic compound bond C-O-C the process involves loss of water and is called condensation (H-O-H) or H+OH → H_2O.

Lipids

(1) Term lipid was coined by Bloor.

(2) These are esters of fatty acids and alcohol.

(3) They are hydrophobic insoluble in water but soluble in benzene, ether and chloroform.

(4) Lipids are classified into three groups:–

(A) **Simple lipids:** These are the esters of fatty acids and glycerol. Again they are typed as:–

- (a) **Fats and Oils:** (Natural lipids or true fats). These are triglycerides of fatty acid and glycerol. Fats which are liquid at room temperature are called oils. Oils with polyunsaturated fatty acids are called polyunsaturated e.g. sunflower oil, lower blood cholesterol.
- (b) **Fatty acids:** Obtained by hydrolysis of fats. Formic acid is simplest fatty acid (HCOOH). These are of 2 types:–
  - **(i) Saturated fatty acids:** The fatty acids which do not have double bond in between carbon atoms.e.g. butyric acid, palmitic acid,hexanoic acid, etc. They have high melting points, solid at room temperature and increase blood cholesterol.
  - **(ii) Unsaturated fatty acids:** The fatty acids which have double bonds in carbon atoms. e.g. 8 hexadecanoic acid, 9 octadecanoic acid etc. They have lower melting points mostly found in plant fats, liquid at room temperature and lower the blood cholesterol.
- (c) **Waxes:** These are simple lipids composed of one molecule of long chain fatty acid and long chain monohydric alcohol. Waxes have high melting point, insoluble in water, resistant to atmospheric oxidation, chemically inert and not digested by enzymes. They reduce rate of transpiration by making plant tissue water proof and work as excellent lubricant.

(B) **Compound lipids:** They contain some additional or element. Group with fatty acid and alcohol on the basis of group they may be of following types:

- (a) **Phospholipids:** These contain phosphoric acid. It helps in transport, metabolism, blood clotting and permeability of cell membrane. It is a bipolar molecule i.e. phosphate containing end is hydrophilic whereas fatty acid molecules represent hydrophobic (non-polar tail).
- (b) **Glycolipids:** These contain nitrogen and carbohydrate beside fatty acids. Generally found in white matter of nervous system. *e.g.* sesocine frenocin.
- (c) **Chromolipids :** It includes pigmented lipids *e.g.* carotene.
- (d) **Aminolipids :** Also known as sulpholipids. It contains sulphur and amino acids with fatty acid and glycerol. Cutin and suberin are also compound lipids resistant to water and also provide mechanical support in plants.
  - (i) **Derived lipids:** These are obtained by hydrolysis of simple and compound lipids.

(5) **Functions of lipids**

  (a) Oxidation of lipids yields comparatively more energy in the cell than protein and carbohydrates. 1gm of lipids accounts for 39.1 KJ.

  (b) The oil seeds such as groundnut, mustard, coconut store fats to provide nourishment to embryo during germination.

  (c) They function as structural constituent i.e. all the membrane systems of the cell are made up of lipoproteins.

  (d) Amphipathic lipids are emulsifier.

  (e) It works as heat insulator.

  (f) Used in synthesis of hormones.

  (g) Fats provide solubility to vitamins A, D, E, and K.

Amino Acids

(1) Amino acids are normal components of cell proteins (called amino acid).

(2) They are 20 in number specified in genetic code and universal in viruses, prokaryotes and eukaryotes.

(3) **Structure and Composition :** Amino acids are basic units of protein and made up of C, H, O, N and sometimes S. Amino acids are organic acids with a carboxyl group (–COOH) and one amino group(-NH_2) on the a -carbon atom. Carboxyl group attributes acidic properties and amino group gives basic ones. In solution, they serve as buffers and help to maintain pH. General formula is R-$CHNH_2$.COOH.

(4) **Classification**

Based on R-group of amino acids

  (a) **Simple amino acids:** These have no functional group in the side chain. e.g. glycine, alanine , leucine, valine etc.

  (b) **Hydroxy amino acids:** They have alcohol group in side chain. e.g. threonine, serine, etc.

  (c) **Sulphur containing amino acids:** They have sulphur atom in side chain. e.g. methionine, cystenine.

  (d) **Basic amino acids:** They have basic group (-NH_2) in side chain. e.g. lysine, arginine.

  (e) **Acidic amino acids:** They have carboxyl group in side chain. e.g. aspartic acid, glutamic acid.

  (f) **Acid amide amino acids:** These are the derivatives of acidic amino acids. In this group, one of the carboxyl group has been converted to amide (-$CONH_2$). e.g. asparagine, glutamine.

  (g) **Heterocyclic amino acids:** These are the amino acids in which the side chain includes a ring involving at least one atom other than carbon. e.g. tryptophan, histidine.

  (h) **Aromatic amino acids:** They have aromatic group (benzene ring) in the side chain. e.g. phenylalanine, tyrosine, etc.

Nucleotides:

(1) Structurally a nucleotide can be regarded as a phosphoester of a nucleoside.

(2) A combination of nitrogens base and a sugar is called nucleoside and combination of a base, a sugar and phosphate group is known as nucleotide.

Types of nitrogen base	Nucleoside	Nucleotide
Adenine	Adenosine	Adenylic acid
Guanine	Guanosine	Guanylic acid
Cytosine	Cytidine	Cytidilic acid
Thymine	Thymidine	Thymidylic acid
Uracil	Uridine	Uridylic acid

(3) **Functions of nucleotides:** Following are the major functions of nucleotides.

(a) **Formation of nucleic acids:** Different nucleotides polymerize together to form DNA and RNA.

(b) **Formation of energy carrier:** They help in formation of ATP,AMP, ADP, GDP, GTP, TDP,TTP, UDP, etc. which on breaking release energy.

(c) **Formation of Coenzymes:** Coenzymes like NAD, NADP, FMN, FAD, CoA, etc are formed. Coenzymes are non-proteinaceous substance necessary for the activity of the enzymes.

Proteins

(1) The word protein was coined by Berzelius in 1838 and was used by G. J. Mulder first time 1840.

(2) 15% of protoplasm is made up of protein. Average proteins contain 16% nitrogen, 50–55% carbon, oxygen 20–24%, hydrogen 7% and sulphur 0.3 – 0.5%. Iron, phosphorous, copper, calcium, and iodine are also present in small quantity.

(3) **Structure of proteins:** It is due to different rearrangement of amino acids. When carboxyl group of one amino acid binded with amino group ($– NH_2$) of another amino acid the bond is called peptide bond. A peptide may be dipeptide, tripeptide and polypeptide. The simplest protein is Insulin. According to Sanger (1953) insulin consists of 51 amino acids. A protein can have up to four level of conformation.

(i) **Primary structure:** The primary structure is the covalent connections of a protein. It refers to linear sequence, number and nature of amino acids bonded together with peptide bonds only. e.g. ribonuclease, insulin, haemoglobin, etc.

(ii) **Secondary structure:** The folding of a linear polypeptide chain into specific coiled structure (α - helix) is called secondary structure and if it is with intermolecular hydrogen bonds the structure is known as ß - pleated sheet. α - helical structure is found in protein of fur, keratin of hair claws, and feathers. ß - pleated structure is found in silk fibres.

(iii) **Tertiary structure:** The arrangement and interconnection of proteins into specific loops and bends is called tertiary structure of proteins. It is stabilized by hydrogen bond, ionic bond, hydrophobic bond and disulphide bonds. It is found in myoglobin (globular proteins).

(iv) **Quaternary structure:** It is shown by protein containing more than one peptide chain. The protein consists of identical units. It is known as homologous quaternary structure e.g. lactic dehydrogenase. If the units are dissimilar, it is called as heterogeneous quaternary structure e.g. hemoglobin which consists of two α - chains and two ß - chains.

Nucleic Acid

(1) **Definition:** Nucleic acids are the polymers of nucleotide made up of carbon, hydrogen, oxygen, nitrogen and phosphorus and which controls the basic functions of the cell.

(2) These were first reported by Friedrich Miescher (1871) from the nucleus of pus cell.

(3) Altmann called it first time as nucleic acid.

(4) They are found in nucleus. They help in transfer of genetic information.

(5) **Types of nucleic acids :** On the basis of nucleotides i.e. sugars, phosphates and nitrogenous bases, nucleic acids are of two types which are further subdivided. These are DNA (Deoxyribonucleic acid) and RNA (Ribonucleic acid).

(A) DNA (Deoxyribonucleic acids)

(i) **Types of DNA:** It may be linear or circular in eukaryotes and prokaryotes respectively.

(a) **Palindromic DNA:** The DNA helical bears nucleotide in a serial arrangement but opposite in two strands.

-T-T-A-A-C-G-T-T-A-A….

-A-A-T-T-G-C-A-A-T-T….

(b) **Repetitive DNA:** This type of arrangement is found near centromere of chromosome and is inert in RNA synthesis. The sequence of nitrogenous bases is repeated several times.

(c) **Satellite DNA:** It may have base pairs up to 11 – 60bp and are repetitive in nature. They are used in DNA matching or finger printing (Jefferey). In eukaryotes, DNA is deutrorotatory and sugars have pyranose configuration.

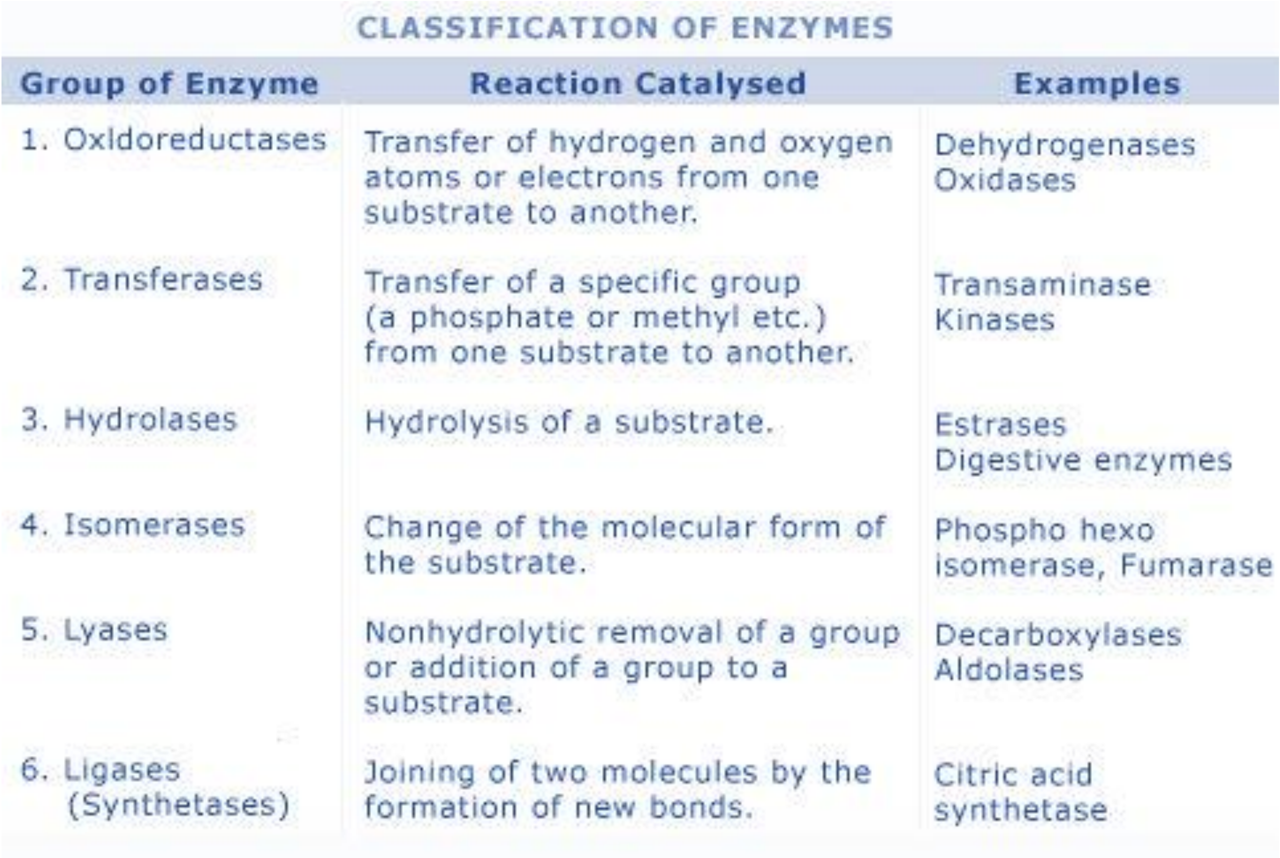
(B) RNA or Ribonucleic acid: RNA is second type of nucleic acid which is found in nucleus as well as in cytoplasm*i.e.* mitochondria, plastids, ribosomes etc. They carry the genetic information in some viruses. They are widely distributed in the cell.

Enzymes

- Enzymes (Gk. *en* = in; *zyme* = yeast) are proteinaceous substances which are capable of catalysing chemical reactions of biological origins without themselves undergoing any change.
- Enzymes are biocatalysts.
- An enzyme may be defined as "a protein that enhances the rate of biochemical reactions but does not affect the nature of final product."
- Maximum enzymes (70%) in the cell are found in mitochondrion. The study of the composition and function of the enzyme is known as **enzymology**.

Classification of Enzymes

Inorganic part of enzyme acts as prosthetic group in few enzyme they are called activator. These activators are generally...



CLASSIFICATION OF ENZYMES

Group of Enzyme	Reaction Catalysed	Examples
1. Oxldoreductases	Transfer of hydrogen and oxygen atoms or electrons from one substrate to another.	Dehydrogenases Oxidases
2. Transferases	Transfer of a specific group (a phosphate or methyl etc.) from one substrate to another.	Transaminase Kinases
3. Hydrolases	Hydrolysis of a substrate.	Estrases Digestive enzymes
4. Isomerases	Change of the molecular form of the substrate.	Phospho hexo isomerase, Fumarase
5. Lyases	Nonhydrolytic removal of a group or addition of a group to a substrate.	Decarboxylases Aldolases
6. Ligases (Synthetases)	Joining of two molecules by the formation of new bonds.	Citric acid synthetase

Cell Cycle and Cell Division

1. **Introduction:** It is the process by which a mature cell divides and forms two nearly equal daughter cells which resemble the parental cell in a number of characters.
2. A cell divides when it has grown to a certain maximum size which disturb the karyoplasmic index (KI)/Nucleoplasmic ratio (NP)/Kernplasm connection.
3. Two processes take place during cell reproduction.

- **Cell growth:** (Period of synthesis and duplication of various components of cell).

- **Cell division:** (Mature cell divides into two cells).

Cell cycle: Howard and Pelc (1953) first time described it. The sequence of events which occur during cell growth and cell division are collectively called cell cycle. Cell cycle completes in two steps:

- **Interphase**
- **M-phase/Dividing phase**
  - **(i) Interphase :** It is the period between the end of one cell division to the beginning of next cell division. It is also called resting phase or not dividing phase. But, it is actually highly metabolic active phase, in which cell prepares itself for next cell division. In case of human beings it will take approx 25 hours. Interphase is completed in to three successive stages.
    - (a) G_1 phase/Post mitotic/Pre-DNA synthetic phase/Gap Ist
    - (b) S-phase/Synthetic phase
    - (c) G_2-phase/Pre mitotic/Post synthetic phase/gap-IInd
  - **(ii) M-phase/Dividing phase/Mitotic phase**
    - (a) Nuclear division i.e. karyokinesis occurs in 4 phases – prophase, metaphase, anaphase and telophase. It takes 5-10% (shortest phase) time of whole division.
    - **(b) Cytokinesis :** Division of cytoplasm into 2 equal parts. In animal cell, it takes place by cell furrow method and in plant cells by cell plate method.

4. **Duration of cell cycle:** It depends on the type of cell and external factors such as temperature, food and oxygen. Time period for G_1, S, G_2 and M-phase is species specific under specific environmental conditions. e.g. 20 minutes for bacterial cell, 8-10 hours for intestional epithelial cell, and onion root tip cells may take 20 hours.
5. **Regulation of cell cycle:** Stage of regulation of cell cycle is G_1 phase during which a cell may follow one of the three options.
   - It may start a new cycle, enter the S-phase and finally divide.
   - It may be arrested at a specific point of G_1 phase.
   - It may stop division and enter G_0 quiscent stage. But when conditions change, cell in G_0 phase can resume the growth and reenter the G_1 phase.
6. Cell division is of three types, Amitosis, Mitosis and Meiosis.
7. Difference between cell Mitosis and Meiosis

S.No	Characters	Mitosis	Meiosis
I. General			
(1)	Site of occurrence	Somatic cells and during the multiplicative phase of gametogenesis in germ cells.	Reproductive germ cells of gonads.
(2)	Period of occurrence	Throughout life.	During sexual reproduction.
(3)	Nature of cells	Haploid or diploid.	Always diploid.
(4)	Number of divisions	Parental cell divides once.	Parent cell divides twice.
(5)	Number of daughter cells	Two.	Four.
(6)	Nature of daughter cells	Genetically similar to parental cell. Amount of DNA and chromosome number is same as in parental cell.	Genetically different from parental cell. Amount of DNA and chromosome number is half to that of parent cell.
II. Prophase			
(7)	Duration	Shorter (of a few hours) and simple.	Prophase-I is very long (may be in days or months or years) and complex.
(8)	Subphases	Formed of 3 subphases : early-prophase, mid-prophase and late-prophase.	Prophase-I is formed of 5 subphases: leptotene, zygotene, pachytene, diplotene and diakinesis.
(9)	Bouquet stage	Absent.	Present in leptotene stage.
(10)	Synapsis	Absent.	Pairing of homologous chromosomes in zygotene stage.
(11)	Chiasma formation and crossing over.	Absent.	Occurs during pachytene stage of prophase-I.
(12)	Disappearance of nucleolus and nuclear membrane	Comparatively in earlier part.	Comparatively in later part of prophase-I.
(13)	Nature of coiling	Plectonemic.	Paranemic.
III. Metaphase			
(14)	Metaphase plates	Only one equatorial plate	Two plates in metaphase-I but one plate in metaphase-II.
(15)	Position of centromeres	Lie at the equator. Arms are generally directed towards the	Lie equidistant from equator and towards poles in metaphase-I while lie at the

		poles.	equator in metaphase-II.
(16)	Number of chromosomal fibres	Two chromosomal fibre join at centromere.	Single in metaphase-I while two in metaphase-II.
IV. Anaphase			
(17)	Nature of separating chromosomes	Daughter chromosomes (chromatids with independent centromeres) separate.	Homologous chromosomes separate in anaphase-I while chromatids separate in anaphase in anaphase-II.
(18)	Splitting of centromeres and development of inter-zonal fibres	Occurs in anaphase.	No splitting of centromeres. Inter-zonal fibres are developed in metaphase-I.
V. Telophase			
(19)	Occurrence	Always occurs	Telophase-I may be absent but telophase-II is always present.
VI. Cytokinesis			
(20)	Occurrence	Always occurs	Cytokinesis-I may be absent but cytokinesis-II is always present.
(21)	Nature of daughter cells	2N amount of DNA than 4N amount of DNA in parental cell.	1 N amount of DNA than 4 N amount of DNA in parental cell.
(22)	Fate of daughter cells	Divide again after interphase.	Do not divide and act as gametes.

Plant Body Systems

Transport in Plants

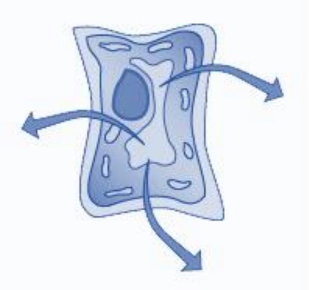
(1) Types of osmosis

Depending upon the movement of water into or outward of the cell, osmosis is of two types.

(a) **Endosmosis:** The osmotic inflow of water into a cell, when it is placed in a solution, whose solute concentration is less than the cell sap, is called endosmosis *e.g.,* swelling of raisins, when they are placed in water.

(b) **Exosmosis:** The osmotic outflow of water from a cell, when it is placed in a solution, whose solute concentration is more than the cell sap, is called exosmosis. *e.g.,*shrinkage of grapes when they are placed in strong sugar solution.

(2) Osmotic concentrations (Types of solutions)



A solution can be termed as hypotonic, hypertonic and isotonic depending upon its osmotic concentration, with respect to another solution or cell sap.

(a) **Hypotonic solution** (*hypo* = less than). A solution, whose osmotic concentration (solute potential) is less than that of another solution or cell sap is called hypotonic solution. If a cell is placed in such a solution, water start moving into the cell by the process of endosmosis, and cell become turgid.

(b) **Hypertonic solution** (*hper* = more than). A solution, whose osmotic concentration (solute potential) is more than that of another solution or cell sap is called hypertonic solution. If a cell is placed in such a solution, water comes out of the cell by the process of exosmosis and cell become flaccid. If potato tuber is placed in concentrated salt solution it would become shrink due to loss of water from its cell.

(c) **Isotonic solution** (*iso* = the same). A solution, whose osmotic concentration (solute potential) is equal to that of another solution or cell sap, is called isotonic solution. If a cell is placed in isotonic solution, there is no net change of water between the cell and the solution and the shape of cell remain unchanged. The normal saline (0.85% solution of $NaCl$) and 0.4 m to 0.5 m solution of sucrose are isotonic to the cell sap.

(3) Significance of osmosis in plants

(a) The phenomenon of osmosis is important in the absorption of water by plants.

(b) Cell to cell movement of water occurs throughout the plant body due to osmosis.

(c) The rigidity of plant organs (*i.e.,* shape and form of organism) is maintained through osmosis.

(d) Leaves become turgid and expand due to their OP.

(e) Growing points of root remain turgid because of osmosis and are thus, able to penetrate the soil particles.

(f) The resistance of plants to drought and frost is brought about by osmotic pressure of their cells.

(g) Movement of plants and plant parts, for example, movement of leaflets of Indian telegraph plant, bursting of many fruits and sporangia, etc. occur due to osmosis.

(h) Opening and closing of stomata is affected by osmosis.

(4) Turgor pressure (TP)

The plant cell, when placed in pure water, swells but does not burst. Because of negative osmotic potential of the vacuolar solution (cell sap), water will move into the cell and will cause the plasmalemma be pressed against the cell wall.

(5) Wall pressure (WP)

Due to turgor pressure, the protoplast of a plant cell will press the cell wall to the outside. The cell wall being elastic, presses back the protoplast with a pressure equal in magnitude but opposite in direction. This pressure is called **wall pressure**. Wall pressure (WP) may, therefore, be defined as '*the pressure exerted by the cell wall over the protoplast to counter the turgor pressure*.

(6) Plasmolysis (Gr. Plasma = something formed; lysis = loosing)

If a living plant cell is placed in a highly concentrated solution (*i.e.* hypertonic solution), water comes out of the cell due to exosmosis, through the plasmamembrane. The loss of water from the cell sap causes shrinkage of the protoplast away from the cell wall in the form of a round mass in the centre. "*The shrinkage of the protoplast of a living cell from its cell wall due to exosmosis under the influence of a hypertonic solution is called plasmolysis*".

(7) **Water potential (*y*)**

The movement of water in plants cannot be accurately explained in terms of difference in concentration or in any other linear expression. The best way to express spontaneous movement of water from one region to another is in terms of the difference of free energy of water between two regions. Free energy is the thermodynamic parameter that determines the direction in which physical and chemical changes must occur. The potential energy of water is called water potential. *e.g.,* water is stored behind a dam.

(8) Differences between diffusion pressure deficit and water potential

S.No.	Diffusion Pressure Deficit (DPD)	Water Potential (*y*)
(1)	The DPD was originally described by the term suction force (*Saugkraft*) by Renner. Other synonyms of the term are suction pressure (SP), enter tendency (E) and osmotic equivalent (E).	Water potential is the chemical potential of water which is equivalent to DPD with negative sign. The term water potential was coined by Slatyer and Taylor (1960).
(2)	The diffusion pressure deficit is abbreviated as DPD. The term was coined by Meyer (1938).	The symbol for water potential is a Greek letter*psi*, which is designated as *y*.

(9) Differences between active and passive absorption of water

S.No.	Active absorption	Passive absorption
(1)	Force for absorption of water is generated in the cells of root itself.	Force for absorption of water is created in the mesophyll cells.
(2)	Osmotic and non-osmotic forces are involved in water absorption.	Water is absorbed due to transpiration pull.
(3)	Water is absorbed according to DPD changes.	Water is absorbed due to tension created in xylem sap by transpiration pull.
(4)	Water moves through symplast.	Water moves mainly through apoplast.
(5)	Rate of absorption is not affected significantly by temperature and humidity.	Its rate is significantly affected by all those factors which influence the rate of transpiration.
(6)	Metabolic inhibitors if applied in root cells decrease the rate of water absorption.	No effect of metabolic inhibitors if applied in root cells.
(7)	Occurs in slow transpiring plants which are well watered.	Occurs in rapidly transpiring plants.
(8)	Rate of absorption is slow.	Very fast rate of water absorption.

(10) Differences between transpiration and evaporation

S.No.	Transpiration	Evaporation
(1)	It is a physiological process and occurs in plants.	It is a physical process and occurs on any free surface.
(2)	The water moves through the epidermis with its cuticle or through the stomata.	Any liquid can evaporate. The living epidermis and stomata are not involved.
(3)	Living cells are involved.	It can occur from both living and non-living surfaces.
(4)	Various forces (such as vapour pressure, diffusion pressure, osmotic pressure, etc) are involved.	Not much forces are involved.
(5)	It provides the surface of leaf and young stem wet and protects from sun burning.	It causes dryness of the free surface.

(11)**Types of stomata**

On the basis of orientation of subsidiary cells around the guard cells, **Metcalfe** and **Chalk** classified stomata into following types :

(i) **Anomocytic :** The guard cells are surrounded by a limited number of unspecialised subsidiary cells which appear similar to other epidermal cells. *e.g.*, in Ranunculaceae family.

(ii) **Anisocytic :** The guard cells are surrounded by three subsidiary cells, two of which are large and one is very small. *e.g.,* in Solanaceae and Cruciferae families.

(iii) **Paracytic :** The guard cells are surrounded by only two subsidiary cells lying parallel to the guard cells *e.g.*, Magnoliaceae family.

(iv) **Diacytic :** The guard cells are surrounded by only two subsidiary cells lying at right angles to the longitudinal axis of the guard cells. *e.g.*, Acanthaceae and Labiatae families.

(v) **Actinocytic :** The guard cells are surrounded by four or more subsidiary cells and which are elongated radially to stomata.

(12)Differences between transpiration and guttation

MineralNutrition

(1) **Macronutrients (Macroelements or major elements):** Nutrients which are required by plants in larger amounts (Generally present in the plant tissues in concentrations of 1 to 10 *mg per* gram of dry matter).

(2) The macronutrients include carbon, hydrogen, oxygen, nitrogen, phosphorous, sulphur, potassium, calcium, magnesium.

(3) **Micronutrients (Microelements or minor elements or trace elements):** Nutrients which are required by plants in very small amounts, *i.e.,* in traces (equal to or less than 0.1 *mg* per gram dry matter).

(4) The micronutrients include iron, manganese, copper, molybdenum, zinc, boron and chlorine. Recent research has shown that some elements, such as cobalt, vanadium and nickel, may be essential for certain plants.

(5) The usual concentration of essential elements in higher plants according to D.W. Rains (1976) based on the data of Stout are as follows:

Major Role of Nutrients

Various elements perform the following major role in the plants:

(1) **Construction of the plant body:** The elements particularly C, H and O construct the plant body by entering into the constitution of cell wall and protoplasm. They are, therefore, referred to as **frame work elements**. Besides, these (C, H and O) N, P and S also enter in the constitution of protoplasm. They are described as**protoplasmic elements**.

(2) **Maintenance of osmotic pressure:** Various minerals present in the cell sap in organic or inorganic form maintain the osmotic pressure of the cell.

(3) **Maintenance of permeability of cytomembranes:** The minerals, particularly Ca^{++}, K^{+} and Na^{+} maintainthe permeability of cytomembranes.

(4) **Influence the pH of the cell sap:** Different cations and anions influence on the *pH* of the cell sap.

(5) **Catalysis of biochemical reaction:** Several elements particularly *Fe, Ca, Mg, Mn, Zn, Cu, Cl* act as metallic catalyst in biochemical reactions.

(6) **Toxic effects:** Minerals like *Cu, As,* etc. impart toxic effect on the protoplasm under specific conditions.

(7) **Balancing function:** Some minerals or their salts act against the harmful effect of the other nutrients, thus balancing each other.

Specific Role of Macronutrients

The role of different elements is described below:

(1) **Carbon, hydrogen and oxygen:** These three elements though cannot be categorized as mineral elements, are indispensible for plant growth. These are also called **'framework elements'**.

(2) **Nitrogen:** Nitrogen is an essential constituent of proteins, nucleic acids, vitamins and many other organic molecules as chlorophyll. Nitrogen is also present in various hormones, coenzymes and ATP etc.

    (i) **Deficiency symptoms:** The symptoms of nitrogen deficiency are as follows:

        (a) Impaired growth
        (b) Yellowing of leaves due to loss of chlorophyll, *i.e.*, **chlorosis**.
        (c) Development of anthocyanin pigmentation in veins, sometimes in petioles and stems.
        (d) Delayed or complete suppression of flowering and fruiting.

(3) **Phosphorus**

- (a) Phosphorous is present abundantly in the growing and storage organs such as fruits and seeds. It promotes healthy root growth and fruit ripening by helping translocation of carbohydrates.
  - (i) **Deficiency symptoms**
    - (a) Leaves become dark green or purplish.
    - (b) Sometimes development of anthocyanin pigmentation occurs in veins which may become necrotic (**Necrosis** is defined as localised death of cells).
    - (c) Premature fall of leaves.

(4) **Sulphur**

- (i) **Functions**
  - (a) Sulphur is a constituent of amino-acids like cystine, cysteine and methionine; vitamins like biotin and thiamine, and coenzyme A.
- (ii) **Deficiency symptoms**
  - (b) Leaf tips and margins roll downwards and inwards *e.g.*, tobacco, tea and tomato.
  - (c) Premature leaf fall.
  - (d) Delayed flowering and fruiting.

(5) **Potassium**

- (i) **Functions**
  - (a) It differs from all other macronutrients in **not being a constituent** of any metabolically important compound.
  - (b) It is the **only monovalent cation** essential for the plants.
  - (c) It acts as an activator of several enzymes including DNA polymerase.
- (ii) **Deficiency symptoms**
  - (a) **Mottled chlorosis** followed by the development of necrotic areas at the tips and margins of the leaves.
  - (b) K^+ deficiency inhibits proteins synthesis and photosynthesis. At the same time, it increases the rate of respiration.
  - (c) The internodes become shorter and root system is adversely affected.

(6) **Calcium**

- (i) **Functions**
  - (a) It is necessary for formation of middle lamella of plants where it occurs as calcium pectate.
  - (b) It is necessary for the growth of apical meristem and root hair formation.
  - (c) It acts as activator of several enzymes, *e.g.*, ATPase, succinic dehydrogenase, adenylate kinase, etc.
- (ii) **Deficiency symptoms**
  - (a) Ultimate death of meristems which are found in shoot, leaf and root tips.
  - (b) Chlorosis along the margins of young leaves, later on they become necrotic.
  - (c) Distortion in leaf shape.

(7) **Magnesium**

- (i) **Functions**
  - (a) It is an important constituent of **chlorophyll**.
  - (b) It is present in the **middle lamella** in the form of magnesium pectate.
  - (c) It plays an important role in the metabolism of carbohydrates, lipids and phosphorus.
- **(ii) Deficiency symptoms**
  - (a) **Interveinal** chlorosis followed by anthocyanin pigmentation, eventually necrotic spots appears on the leaves. As magnesium is easily transported within the plant body, the deficiency symptoms first appear in the mature leaves followed by the younger leaves at a later stage.
  - (b) Stems become hard and woody, and turn yellowish green.
  - (c) Depression of internal **phloem** and extensive development of **chlorenchyma**.

Specific Role of Micronutrients

(1) **Iron**

- (i) **Functions**
  - (a) Iron is a structural component of ferredoxin, flavoproteins, iron prophyrin proteins (Cytochromes, peroxidases, catalases, etc.)
  - (b) It plays important roles in energy conversion reactions of photosynthesis (phosphorylation) and respiration.
  - (c) It acts as activator of nitrate reductase and aconitase.
- (ii) **Deficiency symptoms**
  - (a) Chlorosis particularly in younger leaves, the mature leaves remain unaffected.
  - (b) It inhibits chloroplast formation due to inhibition of protein synthesis.
  - (c) Stalks remain short and slender.

(2) **Manganese**

- (i) **Functions**
  - (a) It acts as activator of enzymes of...

Photosynthesis in Higher Plants

Chloroplast-The site of photosynthesis:

The most active photosynthetic tissue in higher plants is the mesophyll of leaves. Mesophyll cells have many chloroplasts. Chloroplast is present in all the green parts of plants and leaves. There may be over half a million chloroplasts per square millimetre of leaf surface. In higher plants, the chloroplasts are discoid or lens-shaped. They are usually 4-10*mm* in diameter and 1-3*mm* in thickness.

Chloroplast pigments:

Pigments are the organic molecules that absorb light of specific wavelengths in the visible region due to presence of conjugated double bonds in their structures. The chloroplast pigments are fat soluble and are located in the lipid part of the thylakoid membranes.

(i) **Chlorophylls:** The chlorophylls, the green pigments in chloroplast are of seven types *i.e.*, chlorophyll *a, b, c, d, e*, bacteriochlorophyll and bacterioviridin

(ii) **Carotenoids :** The carotenoids are unsaturated polyhydrocarbons being composed of eight isoprene (C_5H_8) units. They are made up of two six-membered rings having a hydrocarbon chain in between. They are sometimes called lipochromes due to their fat soluble nature.

Difference between Photosystem I and Photosystem II

S.No.	Photosystem I	Photosystem II
(1)	PS I lies on the outer surface of the thylakoids	PS II lies on the inner surface of the thylakoid.
(2)	In this system molecular oxygen is not evolved.	As the result of photolysis of water molecular oxygen is evolved.
(3)	Its reaction center is P700.	Its reaction center is P680.
(4)	NADPH is formed in this reaction.	NADPH is not formed in this reaction.
(5)	It participate both in cyclic and noncyclic photophosphorylation.	It participates only in noncyclic photophosphorylation.
(6)	It receives electrons from photosystem II.	It receives electrons from photolytic dissociation of water.
(7)	It is not related with photolysis of water.	It is related with photolysis of water.

Difference between C_3 Plants and C_4 Plants

S.No.	Characters	C_3 plants	C_4 plants
(1)	CO_2 acceptor	The CO_2 acceptor is Ribulose 1, 5 diphosphate.	The CO_2 acceptor is phosphoenol-pyruvate.
(2)	First stable product	The first stable product is phosphoglyceric acid.	Oxaloacetate is the first stable product.
(3)	Type of chloroplast	All cells participating in photosynthesis have one type of chloroplast.	The chloroplast of parenchymatous bundle sheath is different from that of mesophyll cells. Leaves have 'Kranz' type of anatomy. The bundle sheath chloroplasts lack grana. Mesophyll cells have normal chloroplasts.
(4)	Cycles	Only reductive pentose phosphate cycle is found.	Both C_4-dicarboxylic acid and reductive pentose phosphate cycles are found.
(5)	Optimum temperature	The optimum temperature for the process is 10-25°C.	In C_4 plants, it is 30-45°C.
(6)	Oxygen inhibition	Oxygen present in air (=21% O_2) markedly inhibit the photosynthetic process as compared to an external atmosphere containing no oxygen.	The process of photosynthesis is not inhibited in air as compared to an external atmosphere containing no oxygen.
(7)	PS I and PS II	In each chloroplast, photosystems I and II are present. Thus, the Calvin cycle occurs.	In the chloroplasts of bundle sheath cells, the photosystem II is absent. Therefore, these are dependent to mesophyll chloroplast for the supply of NADPH + H^+
(8)	Enzymes	The Calvin cycle enzymes are present in mesophyll chloroplast.	Calvin cycle enzymes are absent in mesophyll chloroplasts. The cycle occurs only in the chloroplasts of sheath cells.
(9)	Compensation point	The CO_2 compensation point is 50-150ppm.	CO_2 compensation point is 0-10ppm.
(10)	Photorespiration	Photorespiration is present and easily detectable.	Photorespiration is present only to a slight degree and difficult to detect.
(11)	Net rate	Net rate of photosynthesis in full sunlight (10,000-12,000 ft.c) is 15-35mg. of CO_2 per dm^2 of leaf area per h.	It is 40-80mg. of CO_2 per dm^2 of leaf area per h. That is photosynthetic rate is quite high. The plants are efficient.
(12)	Saturation intensity	The saturation intensity reached in the range of 100-4000 ft.c.	It is difficult to reach saturation even in full sunlight.

Respiration in Plants

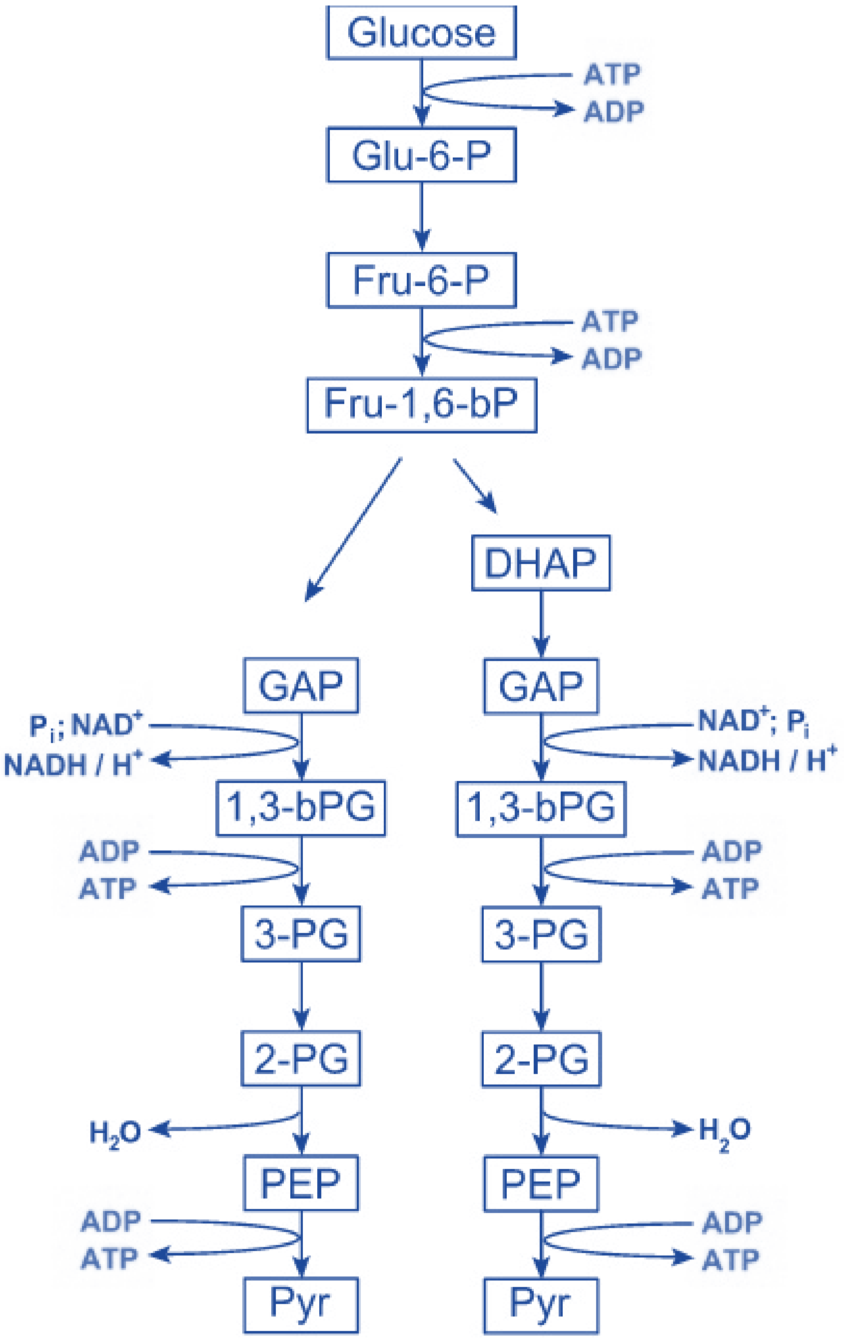
Differences between Photosynthesis and Respiration

Photosynthesis	Respiration
Occurs only in chlorophyll containing cells of plants.	Occurs in all plant and animal cells.
Takes place only in the presence of light.	Takes place continually both in light and in the dark.
During photosynthesis, radiant energy is converted into potential energy.	During respiration, potential energy is converted into kinetic energy.
Sugars, water and oxygen are products.	CO_2 and H_2O are products.
Synthesizes foods.	Oxidizeds foods.
CO_2 and H_2O are raw materials.	O_2 and food molecules are raw materials.
Photosynthesis is an endothermal process.	Respiration is an exothermal process.
Stores energy.	Releases energy.
It includes the process of hydrolysis, carboxylation etc.	It includes the process of the dehydrolysis, decarboxylation, etc.
Results in an increase in weight.	Results in a decrease in weight.
It is an anabolic process.	It is a catabolic process.
Require cytochrome.	Also require cytochrome.

(viii)	**Intermediates**	A number of intermediates are produced.	No intermediate is produced.

Glycolysis cycle

Enzymes of glycolysis and their co-factors

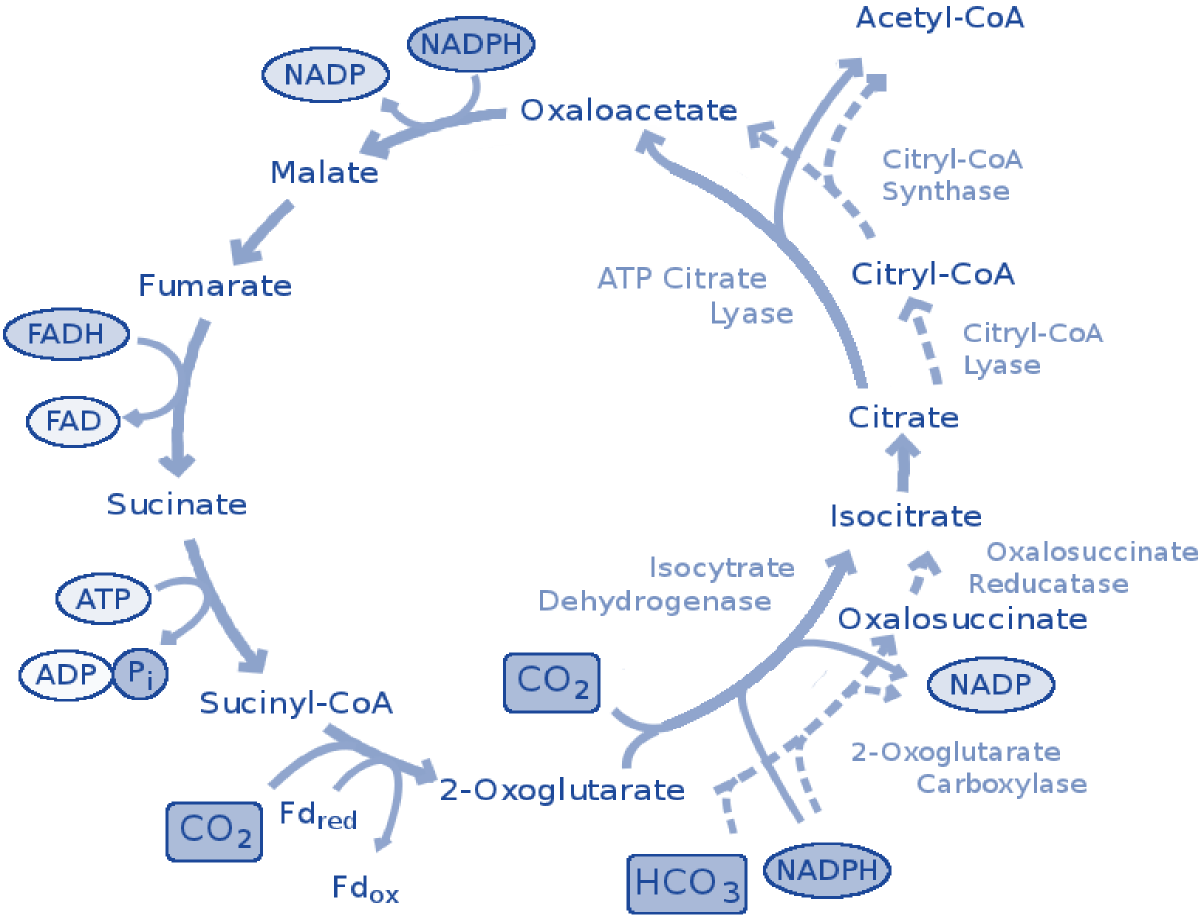


S. No.	Enzyme	Coenzyme (s) and cofactor	Activator (s)	Inhibitor (s)	Kind of reaction catalyzed
(i)	Hexokinase	Mg^{2+}	ATP^{4-}, Pi	Glucose 6-phopshate	Phosphoryl transfer
(ii)	Phosphogluco-isomerase	Mg^{2-}	-	2-dioxyglucose 6-phosphate	Isomerization
(iii)	Phosphofructo-kinase	Mg^{2+}	Fructose 2, 6-diphosphate, AMP, ADP, cAMP, K^{+}	ATP $^{4-}$, citrate	Phosphoryl transfer
(iv)	Aldolase	Zn^{2+} (in microbes)	-	Chelating agents	Aldol cleavage
(v)	Phosphotriose isomerase	Mg^{2+}	-	-	Isomerization
(vi)	Glyceraldehyde 3-phosphate dehydrogenase	NAD	-	Iodoacetate	Phosphorylation coupled to oxidation
(vii)	Phosphoglycerate kinase	Mg^{2+}	-	-	Phosphoryl transfer
(viii)	Phosphoglycerate mutase	Mg^{2+} 2,3-diphos phoglycerate	-	-	Phosphoryl shift
(ix)	Enolase	Mg^{2+}, Mn^{2+}, Zn^{2+}, Cd^{2+}	-	Fluoride+ phosphate	Dehydration
(x)	Pyruvate kinase	Mg^{2+}, K^{+}	-	Acetyl CoA, analine, Ca^{2+}	Phosphoryl transfer

Total input and output materials in glycolysis

Total Inputs	Total Outputs
1 molecule of glucose (6 *C*)	2 molecules of pyruvate (2×3 *C*)
2 ATP	4 ATP
4 ADP	2 ADP
2 × NAD	2× NADH + $2H^{+}$
2 Pi	2×H_2O

Kreb's Cycle


Acetyl-CoA
NADPH
NADP
Oxaloacetate
Malate
Citryl-CoA Synthase
Fumarate
ATP Citrate Lyase
Citryl-CoA
FADH
Citryl-CoA Lyase
FAD
Citrate
Sucinate
Isocitrate
Isocytrate Dehydrogenase
Oxalosuccinate Reducatase
ATP
Oxalosuccinate
ADP
P_i
CO_2
NADP
Sucinyl-CoA
2-Oxoglutarate Carboxylase
CO_2
Fd_{red}
2-Oxoglutarate
Fd_{ox}
HCO_3
NADPH

Enzymes of Kreb's cycle

Step	Enzyme	(Location in mitochondria)	Coenzyme(s) and cofactor (s)	Inhibitor(s)	Type of reaction catalyzed
(a)	Citrate synthetase	Matrix space	CoA	Monofluoro-acetyl- CoA	Condensation
(b)	Aconitase	Inner membrane	Fe^{2+}	Fluoroacetate	Isomerization
(c)	Isocitrate dehydrogenase	Matrix space	NAD^+, $NADP^+$, Mg^{2+}, Mn^{2+}	ATP	Oxidative decarboxylation
(d)	alpha-ketoglutarate dehydrogenase complex	Matrix space	TPP,LA,FAD,CoA, NAD^+	Arsenite,Succinyl-CoA, NADH	Oxidative decarboxylation
(e)	Succinyl-CoA synthetase	Matrix space	CoA	-	Substrate level phosphorylation
(f)	Succinate dehydrogenase	Inner membrane	FAD	Melonate, Oxaloacetate	Oxidation
(g)	Fumarase	Matrix space	None	-	Hydration
(h)	Malate dehydrogenase	Matrix space	NAD^+	NADH	Oxidation

Products formed during aerobic respiration by Glycolysis and Kreb's cycle

ATP formation in Glycolysis			
	Steps	**Product of reactions**	**In terms of ATP**
ATP formation by substrate phosphorylation	1, 3-diphosphoglyceric acid (2 moles) ® 3 phosphoglyceric acid (2 moles) Phosphoenolpyruvic acid (2 moles) ® Pyruvic acid (2 moles)	2 ATP 2 ATP	2 ATP 2 ATP
		Total	4 ATP
ATP formation by oxidative phosphorylation or ETC	1, 3 - disphosphoglyceraldehyde (2 moles) 1, 3 – diphosphoglyceric acid (2 moles)	2 $NADH_2$	6 ATP
	Total ATP formed	4 + 6 ATP =	10 ATP
ATP consumed in	Glucose (1 mole) ® Glucose 6 phosphate (1	– 1 ATP	– 1 ATP

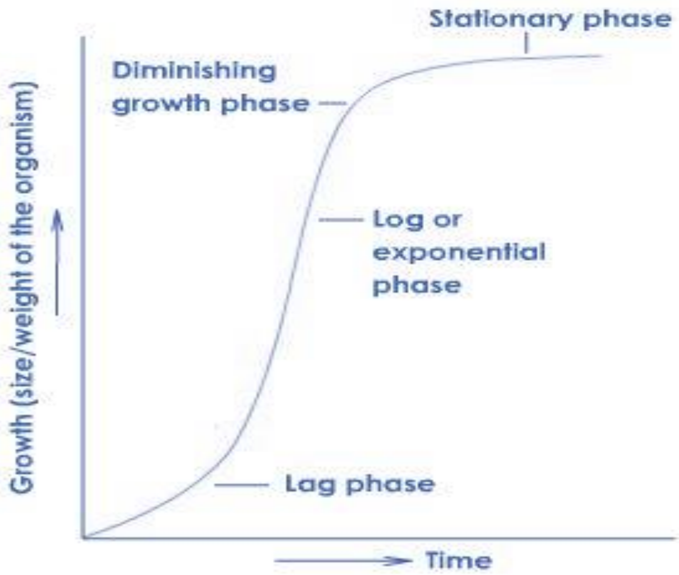
Glycolysis	mole) Fructose 6 phosphate (1 mole) ® Fructose 1, 6-diphosphate (1 mole)	– 1 ATP	– 1 ATP
		Total	2 ATP
	Net gain of ATP = total ATP formed – Total ATP consumed	**10 ATP – 2ATP**	**8 ATP**
ATP formation in Kreb's cycle			
ATP formation by substrate phosphorylation	Succinyl CoA (2 mols) ® Succinic acid (2 mols)	2 GTP	2 ATP
		Total	2 ATP
ATP formation by oxidative phosphorylation or ETC	Pyruvic acid (2 mols) ® Acetyl CoA (2 mols)	2 NADH$_2$	6 ATP
	Isocitric acid (2 mols) ® Oxalosuccinic acid (2 mols)	2 NADH$_2$	6 ATP
	a-Ketoglutaric acid (2 mols) ® Succinyl CoA (2 mols)	2 NADH$_2$	6 ATP
	Succinic acid (2 mols) ® Fumaric acid (2 mols)	2 FADH$_2$	4 ATP
	Malic acid (2 mols) ® Oxaloacetic acid (2 mols)	2 NADH$_2$	6 ATP
		Total	28 ATP
	Net gain in Kreb's cycle (substrate phosphorylation + oxidative phosphorylation)	2ATP + 28 ATP	30 ATP
Net gain of ATP in glycolysis and Kreb's cycle	Net gain of ATP in glycolysis + Net gain of ATP in Kreb's cycle	8 ATP + 30 ATP	38 ATP
Over all ATP production by oxidative phosphorylation or ETC	ATP formed by oxidative phosphorylation in glycolysis + ATP formed by oxidative phosphorylation or ETC.	6 ATP + 28 ATP	34 ATP

Aerobic, Anaerobic Respiration and Fermentation

Aerobic Respiration	Anaerobic Respiration	Fermentation
Molecular oxygen is the ultimate electron acceptor for biological oxidation. The ETS serves to transfer electrons from oxidisable donor to molecular oxygen. The early enzymatic steps involve dehydrogenation whereas the final steps are mediated by a group of enzyme called cytochromes. Ultimately the electrons are transferred to oxygen which is reduced to water. During aerobic respiration ATP is generated by coupled reaction	The ultimate electron acceptor is an inorganic compound other than oxygen. The compounds accepting the hydrogen (electrons) are nitrates, sulphates, carbonates orCO_2. Anaerobic respiration produces ATP through phosphorylation reaction involving electron transfer systems. (mechanism not known)	The final electron acceptors are organic compounds. Both electron donors (oxidizable substrate) and electron acceptors (oxidizing agent) are organic compounds and usually both substrates arise from same organic molecules during metabolism. Thus part of the nutrient molecule is oxidised and part reduced and the metabolism results in intramolecular electron rearrangement. ATP is generated by substrate level phosphorylation. This reaction differs from oxidative phosphorylation because oxygen itself is not required for ATP generation.

Plant Growth and Development

(1) The analysis of growth curve shows that it can be differentiated into three phases:



- **(i) Lag phase:** It represents initial stages of growth. The rate of growth is very slow in lag phase. More time is needed for little growth in this phase.
- **(ii) Log phase (Exponential phase):** The growth rate becomes maximum and more rapid**.** Physiological activities of cells are at their maximum. The log phase is also referred to as **grand period of growth**.

(iii) Final steady state (Stationary phase) or Adult phase: When the nutrients become limiting, growth slows down, so physiological activities of cells also slows down. This phase is indicated by the maturity of growth system. The rate of growth can be measured by an increase in size or area of an organ of plant like leaf, flower, fruit etc. The rate of growth is called efficiency index.

(2) P**hytohormones:-**

(i) Growth hormones also called **phytohormones**

(ii) Term given by Thimann (1948),

(iii) It can be defined as 'the organic substances which are synthesized in minute quantities in one part of the plant body and transported to another part where they influence specific physiological processes'.

Growth Hormones and Growth Regulators

(1) Auxins:

(i) Auxins (Gk. *auxein* = to grow) are weakly acidic growth hormones having an unsaturated ring structure and capable of promoting cell elongation, especially of shoots (more pronounced in decapitated shoots and shoot segments) at a concentration of less than 100 *ppm* which is inhibitory to the roots. Among the growth regulators, auxins were the first to be discovered.

(ii) Types of auxins: There are two major categories of auxins natural auxins and synthetic auxins:

(a) Natural auxins: These are naturally occurring auxins in plants and therefore, regarded as **phytohormones**. Indole 3-acetic acid (IAA) is the best known and universal auxin. It is found in all plants and fungi.

(b) Synthetic auxins: These are synthetic compounds which cause various physiological responses common to IAA. Some of the important synthetic auxins are 2, 4-D (2, 4-dichlorophenoxy acetic acid) is the weedicide. IBA is both natural and synthetic auxin.

(iii) Functions of auxins: Auxins control several kinds of plant growth processes. These are as follows:

(a) Cell elongation: Auxins promote elongations and growth of stems and roots and enlargement of many fruits by stimulating elongation of cells in all directions.

(b) Apical dominance: In many plants, the apical bud grows and the lower axillary buds are suppressed. Removal of apical bud results in the growth of lower buds. The auxin (IAA) of the terminal bud inhibits the growth of lateral buds. This phenomenon is known as apical dominance.

(c) Weed control: Weeds are undesirable in a field with a crop. By the spray of 2, 4-D, broad-leaved weeds can be destroyed but 2, 4-D does not affect mature monocotyledonous plants.

(d) Root differentiation

- **(e) Control of lodging**
- **(f) Parthenocarpy:** Parthenocarpy can be induced by application of IAA in a paste form to the stigma of a flower or by spraying the flowers with a dilute solution of IAA.

(2) Gibberellins:

- **(i)** Gibberellins are weakly acidic hormones having gibbane ring structure which cause cell elongation of intact plants in general and increased internodal length of genetically dwarfed plants (i.e., corn, pea) in particular.
- **(ii) Functions of gibberellin**
  - **(a) Stem elongation:** The gibberellins induce elongation of the internodes.
  - **(b) Leaf expansion:** In many plants leaves become broader and elongated when treated with gibberellic acid.
  - **(c) Reversal of dwarfism:** One of the most striking effects of gibberellins is the elongation of genetic dwarf (mutant) varieties of plants like corn and pea.
  - **(d) Bolting and Flowering:** Gibberellins induce stem elongation in ‘rosette plants’ e.g., cabbage, henbane, etc. Such plants show retarded internodal growth and profuse leaf development. In these plants just prior to the reproductive phase, the internodes elongate enormously causing a marked increase in stem height. This is called bolting.
  - **(e) Enzyme formation:** One of the most dramatic effects of GA is its induction of hydrolytic enzymes in the aleurone layer of endosperm of germinating barley seeds and cereal grains. GA stimulates the production of digestive enzymes like proteases, a-amylases, lipases which help to mobilise stored nutrients.
  - **(f) Breaking of dormancy:** Gibberellins overcome the natural dormancy of buds, tubers, seeds, etc. and allow then to grow. In this function, gibberellins act antagonistically to abscisic acid (ABA).
  - **(g) Parthenocarpy:** Gibberellins have been considered to be more effective than auxins for inducing parthenocarpy in fruits like apple, tomato and pear. GA application has also resulted in the production of large fruits and bunch length in seedless grapes.
  - **(h) Sex expression:** Gibberellins control sex expression in certain plants. In general, gibberellin promotes the formation of male flowers either in place of female flowers in monoecious plants such as cucurbits or in genetically female plants like *Cannabis, Cucumis*.

(3) Cytokinins (Phytokinins):

- **(i)** Cytokinins are plant growth hormones which are basic in nature, either aminopurine or phenyl urea derivatives that promote cell division (cytokinesis) either alone or in conjugation with auxin.
- **(ii) Functions of cytokinins**
  - **(a) Cell division:** Cytokinins are essential for cytokinesis and thus promote cell division. In presence of auxin, cytokinins stimulate cell division even in non-meristematic tissues.

(b) **Cell enlargement and Differentiation:** Under some conditions cytokinins enhance the expansion of leaf cells in leaf discs and cotyledons. These cells considered to be mature and under normal conditions do not expand.

(c) **Delay in senescence:** Cytokinin delay the senescence (ageing) of leaves and other organs by controlling protein synthesis and mobilization of resources (Disappearance of chlorophyll). It is called Richmond Lang effect.

(d) **Counteraction of apical dominance:** Auxins and cytokinins act antagonistically in the control of apical dominance. Auxins are responsible for stimulating growth of apical bud.

(e) **Breaking of dormancy:** Cytokinins breaks seeds dormancy of various types and thus help in their germination.

(f) **Accumulation and Translocation of solutes**

(4) Ethylene:

(i) Ethylene is a gaseous hormone which stimulates transverse growth but retards the longitudinal one.

(ii) Functions of ethylene

- **Fruit growth and Ripening:** Ethylene promotes fruit growth and its ripening. The harmone is used in the artificial ripening of climacteric fruits (e.g., Apple, Banana,

Human Body Systems

Digestion and Absorption

(i) **Process of conversion of complex food substances to simple absorbable forms is called digestion.**

(ii) **Intracellular**: When the process of digestion occurs within the cell in the food vacuole.

Examples:

Protozoa, Porifera, Coelenterata and free living Platyhelminthes

(iii) **Extracellular:** When the process of digestion occurs outside the cell, **Examples:** Coelenterates and phylum Platyhelminthes to phylum Chordata.

(iv) Digestion in vertebrates occurs in the digestive tract or alimentary canal. The various parts involved in digestion can be broadly grouped in two groups –

(1) Digestive tract or alimentary canal

(2) Digestive glands

On the basis of the embryonic origin, the alimentary canal of vertebrates can be divided into three parts–

(1) **Fore gut / Stomodaeum:** Ectodermal. It includes buccal cavity / oral cavity, pharynx, oesophagus, stomach and small part of duodenum.

(2) **Mid gut/Mesodaeum:** Endodermal. It includes small intestine, and large intestine.

(3) **Hind gut/Proctodaeum:** Ectodermal. It includes anal canal and anus.

Human Digestive System

The human digestive system is a complex series of organs and glands that processes food. It converts ingested food so that it can be assimilated by the organism. The human digestive system consists of following parts:-

Mouth

Mouth is also known as the oral cavity or buccal cavity. It is the first portion of the alimentary canal. Food and saliva are received by mouth. Mouth has inner lining of mucous membrane epithelium.

Digestive Glands: -

(A) Salivary glands:-

(i) These are the exocrine glands that produce saliva.

(ii) These are the glands with ducts which also secrete amylase.

(iii) Amylase is an enzyme that breaks down starch into maltose.

(iv) **Three types of salivary glands are: -**

1) Parotid gland
2) Submandibular gland
3) Sublingual gland

(B) Gastric glands:-

(i) The gastric glands (fundic gland) secrete acids and digestive enzymes.

(ii) Secretion of gastric gland is called gastric juice.

(iii) There are approximately 35 million gastric glands present in human stomach.

(C) Intestinal glands:-

(i) Intestinal glands in maamals is a collective name for **crypts of Liberkuhn** (secretes alkaline enzymatic juice) and **Brunner's glands** (secrete mucous).

(ii) Intestinal glands secrete **intestinal juice** or **sucus entericus.**

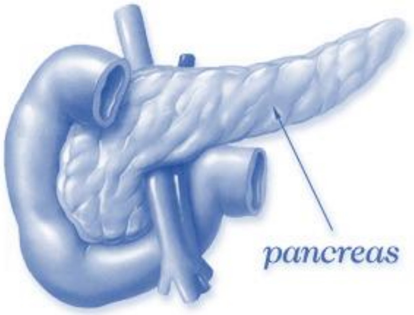
(D) Pancreas:-

(i) Pancreas has two different kind of tissue- exocrine and endocrine.

(ii) Pancreatic secretion is stimulated by **cholecystokinin** and **secretin** both.

(iii) Complete digestive juice is pancreatic juice as it contains amylolytic, lipolytic and proteolytic enzymes.

(iv) It produces several important hormones like insulin, glucagon, somatostatin and pancreatic polypeptide.



(E) Liver:-

(i) Liver is the **largest digestive gland of the body,** weighing about 1.2 to 1.5 Kg in an adult human.

(ii) It is situated in the abdominal cavity, just below the diaphragm and has two lobes (small left and large right lobe).

(iii) The liver has a wide range of functions to perform in the body:

a) It detoxifies various metabolites

b) It helps in protein synthesis.

c) Various biochemical necessary for digestion are produced by liver.

Pharynx: -

It is the opening of oral and nasal cavities. **It is classified as: -**

1) Nasopharynx
2) Oropharynx
3) Laryngopharynx

Oesophagus: -

Oesophagus connects pharynx with stomach.

Opening of oesophagus is regulated by **gastro-oesophageal sphincter.**

Stomach: –

It is a J-shaped, muscular, hollow and dilated part of the digestive system. It is located between the oesophagus and the small intestine. It has 1 liter capacity. It secretes protein-digesting enzymes (proteases) and strong acids which aid in food digestion.

The stomach has three parts:

Cardiac: The part of the stomach into which oesophagus opens.

Fundus: It is the air filled portion of stomach.

Pyloric: The portion of the stomach that opens into the small intestine

Breathing and exchange of gases

Pulmonary Volumes and Capacities

There are following respiratory volumes and capacity:

(i) **Tidal volume (TV)**: It is volume of air normally inspired or expired in one breath (i.e. inspiration and expiration) without any extra effort. It is about 500 ml in normal healthy adult. In infants it is 15 ml and in fetus it is 0 ml.

(ii) **Inspiratory reserve volume (IRV) :** By taking a very deep breath, you can inspire a good deal more than 500 ml. This additional inhaled air, called IRV is about 3000 ml.

(iii) **Expiratory reserve volume (ERV) :** If you inhale normally & then exhale as forcibly as possible, you should be able to push out 1200 ml of air in addition to 500ml. of T.V. The extra 1200 ml is called ERV.

(iv) **Residual volume (RV):** Even after expiratory reserve volume is expelled, considerable air remains in the lung, this volume, which cannot be measured by spirometry, and it is called residual volume is about 1200 ml.

(v) **Dead space**: Portion of tracheobronchial tree where gaseous exchange does not occur is called dead space. It is also called conductive zone. Dead space is 150 ml.

(vi) **Functional residual capacity (FRC):** It is the amount of air that remains in the lungs after a normal expiration. It is about 2300 ml.

FRC = ERV + RV

= 1100 + 1200 = 2300 ml.

(vii) **Vital capacity (VC):** This is the maximum amount of air that can be expired forcefully from his lungs after first filling these with a maximum deep inspiration. It is about 4600 ml.

VC = IRV + TV + ERV

= 3000+500+1100 = 4600 ml.

(viii) **Total lung capacity (TLC):** TLC is the sum of vital capacity (VC) and residual volume (RV). It is about 5800ml.

TLC = VC + RV

= 4600 + 1200 = 5800 ml.

(ix) **Inspiratory capacity (IC):** It is the total amount of air a person can inspire by maximum distension of his lungs.

I.C. = TV + IRV

= 500 + 3000 = 3500 ml.

Process of Respiration

The process of respiration is completed in 4 steps:

(i) Breathing or ventilation

(ii) Exchange of gases or External respiration

(iii) Transport of gases

(iv) Cellular respiration

(i) Ventilation or breathing:

Breathing is movement of thorax, expansion (inflation) and deflation of lungs and flow of air into the lungs and from the lungs. It is extracellular, energy consuming and physical process. Sum of inspiration and expiration is called respiratory movement. There are two steps of breathing:

(a) **Inspiration:** Intake of fresh air in lungs from outside. It is an active process. Blood pressure increases during later part of respiration.

(b) **Expiration:** Out flow of the air from the lungs is called expiration. When expiration occurs, the inspiratory muscles relax. As the external intercostal relax, ribs move inferiorly and as the diaphragm relaxes, its dome moves superiorly owing to its elasticity.

(c) **Mechanism of ventilation/breathing:**

(ii) **Exchange of gases:**

(a) **Exchange of gases in lungs:** It is also called external respiration. In this gaseous exchange oxygen passes from alveoli to pulmonary capillary blood and CO_2. Comes to alveoli from pulmonary capillary.

(b) **Release of CO_2 by the blood:** The PCO_2 (partial pressure of carbon dioxide) of blood reaching the alveolar capillaries is higher than the PCO_2 of alveolar air. Therefore, carbon dioxide diffuses from the blood of alveolar capillaries into the alveolar air.

(c) **Exchange of gases in tissues:** In the tissues, exchange of gases occurs between the blood and the tissue cells. This exchange occurs via tissue fluid that bathes the tissue cells. The blood reaching the tissue capillaries has PO_2 higher than that in the tissue cells and PCO_2 lower than that in the tissue cells.

(iii) **Transport of gases:** Blood carries O_2 from respiratory organs to the tissue cells for oxidation and CO_2 from tissue cells to respiratory organs for elimination. Blood should be slightly alkaline to help the transport of O_2 and CO_2 properly.

Difference between breathing and respiration

Breathing (Ventilation)	Respiration
It is a physical process.	It is a biochemical process.
It is simply an intake of fresh air and removal of foul air.	It involves exchange of gases and oxidation of food.
No energy is released rather used.	Energy is released that is stored in ATP.
It occurs outside the cells, hence it is an extra-cellular process.	It occurs inside the cells, hence it is an intra-cellular process.
No enzymes are involved in the process.	A large number of enzymes are involved in the process.
Breathing mechanism varies in different animals.	Respiratory mechanism is similar in all animals.
It is confined to certain organs only.	It occurs in all living cells of the body.

Composition of three samples of air

For the control of respiration following respiratory centres are found in hind brain

Type of centre	Location	Function
Inspiratory centre	Medulla oblongata	Inspiration (2 second active condition)
Respiratory centre	Medulla oblongata	Expiration (3 second inactive condition)
Apneustic centre	Pons	Slow and deep inspiration
Pneumotaxic centre	Pons	Control other centres and produce normal quite breathing
Gasping centre	Pons	Sudden and shallow respiration

Oxygen content: Total volume of O_2 in 100 *ml*. of whole blood *i.e.* volume of O_2 in physical solution form and oxyhaemoglobin form. It is equal to 19.7 + 0.3 = 20 *ml* of oxygen.

Oxygen capacity: Maximal amount of O_2 that can be held by the blood at 760 *mm Hg* pressure and 37^0C. Oxygen capacity is about 20 *ml*/100 *ml.*

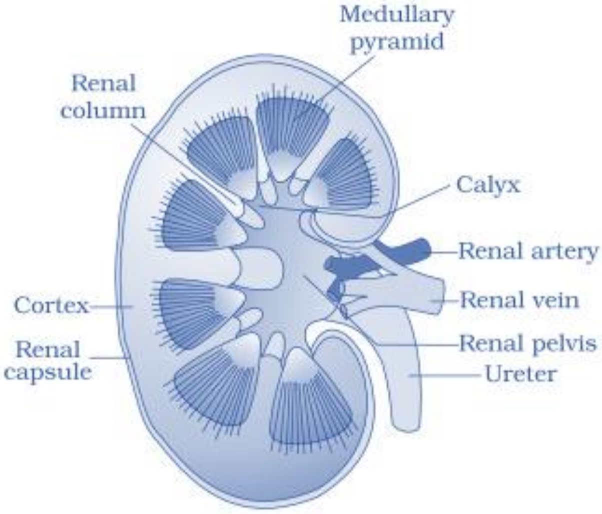
Excretory products and their Elimination

Excretion is the process by which waste products of metabolism and other non-useful materials are eliminated from an organism

Excretory system of man

Mammalian (human) urinary system consists of a pair of kidneys, a pair of ureter, a urinary bladder and a urethra.

(i) **Kidneys :** The kidneys are dark-red, bean-shaped organs about 11 *cm* long, 5 *cm* wide and 3 *cm* thick, each weight about 150 *gm* in an adult male and about 135 *gm* in adult female.



Differences between cortical and Juxtamedullary nephrons

Cortical Nephrons	Juxtamedullary Nephron
1. Form 80% of total nephrons.	1. Form only 20% of total nephrons.
2. Are small in size.	2. Are large in size.
3. Lie mainly in the renal cortex.	3. Have Bowman's capsules in the cortex near its junction with the medulla.
4. Henle's loops are very short and extend only a little into the medulla	4. Henle's loop are very long and extend deep into the medulla.
5. Control plasma volume when water supply is normal.	5. Control plasma volume when water supply is short.

(ii) **Ureters:** From the hilum of each kidney emerges a whitish tube the ureter. The ureters are about 28 *cm* long. Their wall consists of transitional epithelium surrounded by a layer of muscle fibres. Openings of the two ureters in the bladder are separate, but closely placed. These are oblique, so that the urine cannot regurgitate into the ureters when the bladder contracts. Peristalsis of ureters also cheeks regurgitation of urine.

(iii) **Urinary bladder and Urethra:** The urinary bladder is pear-shaped which is made up of smooth and involuntary muscles. The muscles are also known as detrusor muscles (muscles that has the action of expelling a substance). The lower part or neck of the bladder leads into the urethra.

Differences between male and female urethra

Male urethra	Female urethra
1. It is about 20 cm long.	1. It is just 3 – 5 cm long.
2. It has 3 regions : prostatic urethra (3–4 cm), membranous (1 cm) and penial (15 cm)	2. It is not differentiated into regions.
3. It opens out at the tip of the penis by urinogenital aperture.	3. It opens into the vulva by urinary aperture.
4. It carries urine as well as semen to the exterior.	4. It carries only urine to the exterior.
5. It has 2 sphincters.	5. It has a single sphincter.

Physiology of Excretion

Major nitrogenous excretory substance in frog, rabbit and human is urea, i.e. these are ureotelic animals. The excretory physiology in these animals may be considered under two phases, viz urea synthesis and formation and excretion of urine.

(i) **Synthesis of urea in liver:** Urea is formed in liver by two processes.

  (a) Deamination

  (b) Ornithine cycle

(ii) **Urine formation:** Urine formation occurs in the kidneys. It involves three processes glomerular filtration, reabsorption and tubular secretion.

(iii) **Mechanism of urine concentration (Counter current mechanism of urine concentration) :** Mammals form hypertonic urine. The urine is made hypertonic with the help of counter current multiplier system. This process takes place in the Henle's loop and vasa recta and it involves mainly Na^+ and Cl^-. In P.C.T. urine is isotonic. The descending limb of loop of Henle is permeable to water. Its surrounding tissue fluid is hypertonic. Hence, the water moves out and the Na^+ and Cl^- move in the descending limb by passive transport. Therefore, the filtrate in the descending limb finally becomes hypertonic.

Summary of events occurring in a nephron

Materials transferred	Nephron region	Process involved	Mechanism
1. Glucose, Amino acids, Vitamins, Hormones, Na^+, K^+, Mg^{2+}, Ca^{+2}, H_2O, Urea, Uric Acid, Creatinine, Ketone Bodies.	Bowman's capsule	Glomerular filtration	Ultrafiltration
2. Glucose, Amino Acids, Hormones, Vitamins, Na^+, K^+, Mg^{2+}, Ca^{+2}	Proximal convoluted tubule	Reabsorption	Active transport
3. Cl^-	Proximal convoluted tubule	Reabsorption	Passive transport
4. Water	Proximal convoluted tubule	Reabsorption	Osmosis
5. Urea	Proximal convoluted tubule	Reabsorption	Diffusion
6. H_2O	Narrow region of descending limb of Henle's loop	Reabsorption	Omosis
7. Na^+,K^+,Mg^{+2},Ca^{+2},Cl^-	Narrow region of ascending limb of Henle's loop	Reabsorption	Diffusion

8.Inorganic ions as above	Wide part of ascending limb of Henle's loop	Reabsorption	Active transport
9.H_2O	Distal convoluted tubule, collecting tubule, collecting duct	Reabsorption with ADH Help	Osmosis
10. Na^+	Distal convoluted tubule, collecting tubule, collecting duct	Reabsorption with aldosterone help reabsorption secretion	Active transport
11. Urea	Last part of collecting duct	Reabsorption with aldosterone help reabsorption secretion	Diffusion
12. Creatinine, Hippuric Acid, Foreign substances	Proximal convoluted tubule	Reabsorption with aldosterone help reabsorption secretion	Active transport
13. K^+, H^+	Distal convoluted tubule	Reabsorption with aldosterone help reabsorption secretion	Active transport
14. NH_3	Distal convoluted tubule	Reabsorption with aldosterone help reabsorption secretion	Diffusion
15. Urea	Ascending limb of Henle's loop (Thin part)	Reabsorption with aldosterone help reabsorption secretion	Diffusion

Differences between Rennin and Renin

S.No.	Rennin	Renin
1.	It is secreted by peptic (zymogen) cells of gastric glands into the stomach.	It is secreted by specialised cells in the afferent arterioles of the kidney cortex.
2.	Its secretion is stimulated by food.	Its secretion is stimulated by a reduction of Na^+level in tissue fluid
3.	It is secreted as an inactive form prorennin which is activated to rennin by *HCl*.	It is secreted as renin.
4.	It is a proteolytic enzyme.	It is a hormone that acts as an enzyme
5.	It helps in the digestion of milk protein casein.	It converts the protein angiotensinogen into angiotensin.

Renin

(i) Waste products of protein metabolism

(a) **Amino acids:** These are end products of protein digestion absorbed into the blood from small intestine. Certain invertebrates, like some molluscs (*eg Unio, Limnae, etc.*) and some echinoderms (*eg* Asterias) excrete excess amino acids as such. This is called aminotelic excretion or aminotelism.

(b) **Ammonia:** In most animals, excess amino acids are deaminated, i.e. degraded into their keto and ammonia groups. The keto groups are used in catabolism for producing ATP, whereas ammonia is excreted as such or in other forms.

(c) **Urea:** This is less toxic and less soluble in water than ammonia. Hence, it can stay for some time in the body.

(d) **Uric acid:** Animals living in dry (arid) conditions, such as land gastropods, most insects, land reptiles (snakes and lizards), birds *etc* have to conserve water in their bodies.

(f) **Guanine:** Spiders typically excrete their ammonia in the form of guanine. Some guanine is also formed in amphibians, reptiles, birds and earthworms. It is insoluble in water. Hence, no water is required for its excretion.

Differences between ammonotelism, ureotelism and uricotelism

S.No.	Ammonotelism	Ureotelism	Uricotelism
1.	Means excretion of nitrogenous waste mainly as ammonia.	Means excretion of nitrogenous waste mainly as urea.	Means excretion of nitrogenous waste mainly as uric acid.
2.	Uses very little energy in forming ammonia.	Uses more energy in producing urea.	Uses far more energy in producing uric acid.
3.	Its product is very toxic.	Its product is less toxic.	Its product is least toxic.
4.	Causes considerable loss of body's water.	Causes less loss of body's water.	Causes least loss of body's water
5.	Occurs in aquatic animals.	Occurs in aquatic as well as land animals.	Occurs in land animals.
6.	Examples: *Amoeba, Scypha, Hydra, Earthworm, Unio, Prawn, Salamander, Tadpole or frog, bonyfish*.	Examples: Earthworm, Cartilaginous fishes, frog, turtles, alligators, mammals (man).	Examples: Insects, land crustaceans, land snails, land reptiles birds.
7.	Animals excreting NH_3 are called ammoniotelic.	Animals excreting urea are termed uroetelic.	Animals excreting uric acid are called uricotelic.

Body movements and Locomotion

Types of Bones and their Description

Name	No.	Description
Frontal	1	Forms the forehead (anterior or front part of the top of cranium) and some upper parts (roofs) of eye orbits or sockets and nasal cavities. A newborn infant displays a faint suture in midline of frontal, indication that adult frontal is actually formed of two completely fused frontal.
Parietals	2	Articulated to and situated just behind frontal. Form the main parts of bulging top and sides of cranium.
Occipital	1	Articulated to and situated just behind parietals. Forms posterior (back) and lower (base) parts of cranium. Foramen magnum is a large perforation in this bone. On each side of the foramen, the occipital bears a prominent elevation called occipital condyle. The condyles articulate the skull with first vertebra (atlas). Thus, human skull is dicondylic.

Temporals	2	Form lower parts of right and left sides of cranium, as well as, the floor of cranial cavity. These house structures of internal and middle ears and form a part of external auditory meatuses. The middle ear of each side encloses the three small ear ossicles – malleus, incus and stapes.
Sphenoid	1	A typically butterfly-shaped bone that forms the middle and anterior parts of base of cranium in front of occipital in the middle and temporals on the sides. It articulates with all skull bones, keeping these firmly together. It also forms parts of lateral walls and floors of eye orbits.
Ethmoid	1	A small, irregular bone in front of sphenoid and behind nasal bones. It fashions the front (anterior) extremity and closer of cranial cavity. It also contributes to the architecture of eye orbits and proximal parts of nasal chambers.
Nasals	2	Small, oblong bones in middle of upper part of face, forming proximal part of the bridge of our nose. The remaining, lower part of our nose is formed of cartilage.
Inferior nasal conchae (Turbinales)	2	Two highly coiled, scroll-like processes of ethmoid bone, called conchae project into each nasal cavity from lateral wall of the proximal bony part of concerned nasal chamber. One ethmoidal concha is superior (uppermost). The other one is called middle concha, because it is followed by a thin, separate scroll-like bone which is named inferior nasal concha or turbinate.
Vomer	1	A thin, elongated, platelike bone, forming a part of the septum which separates the two nasal cavities.
Lacrimals	2	Small and thin, finger-shaped bones, each located in front part of the medial (inner) side of corresponding eye orbit. these form a part of the passages of corresponding tear ducts.
Zygomatics (Malars)	2	Cheek-bones; form the prominences of our cheeks and parts of the floor and side walls of eye orbits.
Palatines	2	L-shaped bones that form the back (posterior) part of our hard palate (roof of mouth). Also contribute to the framework of nasal cavities and floor of eye orbits.
Maxillae	2	Large, upper jaw bones that form the major part of our face and upper jaw. Comprise entire front (anterior) part of our hard palate. Also contribute to the architecture of eye orbits and nose. Bear the teeth of upper jaw.
Mandible	1	Largest bone of our face, and strongest of all bones of the body. Forms entire lower jaw and bears all lower jaw teeth. Articulated with temporal bones of skull.

Difference between Thoracic and Lumbar vertebra

S.No.	Characters	Thoracic vertebra	Lumbar vertebra
1.	Neural spine	Long undivided and downward directed.	Short, flat and upward directed.
2.	Facet for ribs	Present on transverse process and centrum.	Absent.
3.	Transverse process	Club-shaped.	Thin and elongated.

Difference between Male and Female pelvis

S.No.	Characters	Male pelvis	Female pelvis
1.	Nature of bones of pelvic girdles	Heavier and longer	Lighter and smaller
2.	Sacrum	Less concave	More concave anteriorly
3.	Pelvis	Shallow, narrow and round	Deep, wide and funnel-shaped

Muscle Contraction

From excitation to contraction to relaxation, following occurs within a skeletal muscle:

(1) An electrical signal (action potential) travels down a nerve cell. This in turn causes to release a chemical message (neurotransmitter). This chemical message is released into a small gap between the nerve cell and muscle cell. This gap is called synapse.

(2) The neurotransmitter then crosses the gap. It binds to a protein (receptor) on the muscle-cell membrane which causes an action potential in the muscle cell.

(3) The action potential spreads along the muscle cell.

(4) The action potential enters the cell through T-tubule.

(5) The action potential opens gate in the muscle's calcium store.

(6) Calcium ions flow into the cytoplasm.

(7) Calcium ions bind to troponin-tropomyosin molecules. These are located in the grooves of the actin filaments.

(8) The sites on actin where myosin can form crossbridges are covered by the rod-like tropomyosin molecule.

(9) On binding calcium ions, troponin changes shape. It then slides tropomyosin out of the groove, exposing the actin-myosin binding sites.

(10) Myosin interacts with actin by cycling crossbridges. The muscle thereby creates force, and shortens.

(11) After the action potential has passed, the calcium gates close automatically.

(12)Calcium pumps remove calcium from the cytoplasm. These pumps are located on the sarcoplasmic reticulum.

(13)As the calcium gets pumped back into the sarcoplasmic reticulum, calcium ions come off the troponin.

(14)The troponin returns to its normal shape.

(15)Troponin allows tropomyosin to cover the actin-myosin binding sites on the actin filament.

(16)As no binding sites are available now, hence no crossbridges can form, and the muscle relaxes.

Note:-

(1) The activities of muscle contraction and relaxation require energy.

(2) Muscles use energy in the form of ATP. The energy from ATP is used to reset the myosin crossbridge head and release the actin filament.

(3) In order to make ATP, the muscles do the following:

(a) Breaks down creatine phosphate.

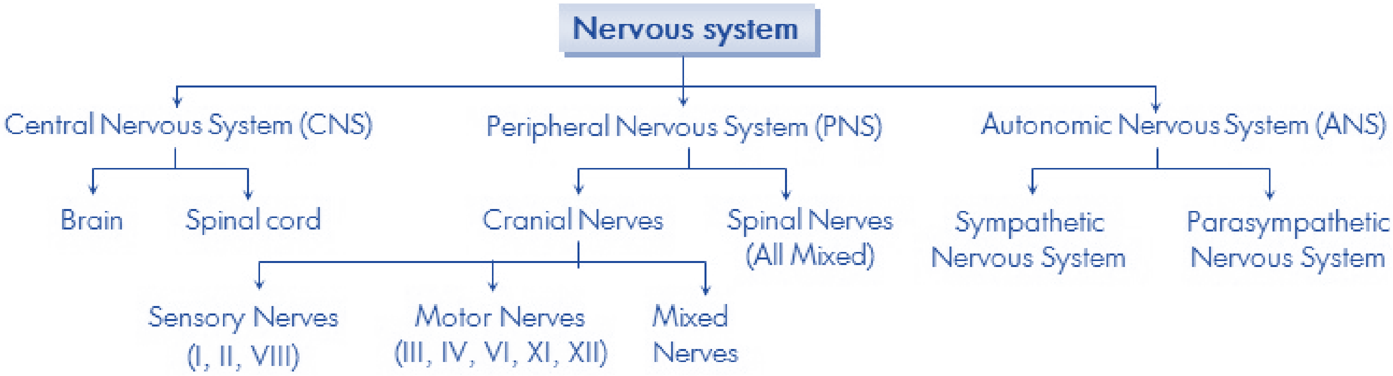
(b) Add phosphate to ADP to create ATP.

(c) Carry out anaerobic respiration, by which glucose is broken down to lactic acid and ATP is formed.

(d) Carry out aerobic respiration. Due to which glucose, glycogen, fats and amino acids are broken down in the presence of oxygen to produce ATP.

Neural Control and Cordination

Parts of nervous system



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Central nervous system:

(1) Central nervous system is made up of brain and spinal cord. CNS is covered by 3 meninges and its wall has two type of matter.

(2) **Types of matter:** CNS of vertebrates is formed of two types of matter –

- **(a)** **Grey matter:** It is formed of cell-bodies and non-medullated nerve fibres.
- **(b)** **White matter:** It is formed of only medullated nerve fibres which appear white due to presence of medullary sheath.

Brain (Encephalon): It is soft, whitish, large sized and slightly flattened structure present inside cranial cavity of cranium of the skull. In man, it is about 1200-1400 *gm* in weight and has about 10,000 million neurons. Brain is made up of 3 parts

(1) **Fore brain (Prosencephalon)**
  - (i) Olfactory lobe – Rhinencephalon
  - (ii) Cerebrum – Telencephalon
  - (iii) Diencephalon – Diencephalon

(2) **Mid brain (Mesencephalon)**
  - (i) Optic lobes – Mesencephalon

(3) **Hind brain (Rhambencephalon)**
  - (i) Cerebellum – Metencephalon
  - (ii) Medulla oblongata – Myelencephalon

Important areas in the human brain

Area	**Location**	**Function**
Premotor area	Frontal lobe	The highest centre for involuntary movements of muscles and ANS.
Motor area	Frontal lobe	Controls voluntary movements of the muscle
Broca's area	Frontal lobe	Motor speech area
Somesthetic area	Parietal lobe	Perception of general sensation like pain, touch and temperature
Auditory area	Temporal lobe	Hearing
Olfactory area	Temporal lobe	Sense of smell
Wernicke's area	Temporal lobe	Understanding speech written and spoken
Gustatory area	Parietal lobe	Sense of taste
Visual area	Occipital lobe	Sensation of light

Differences between Cerebrum and Cerebellum

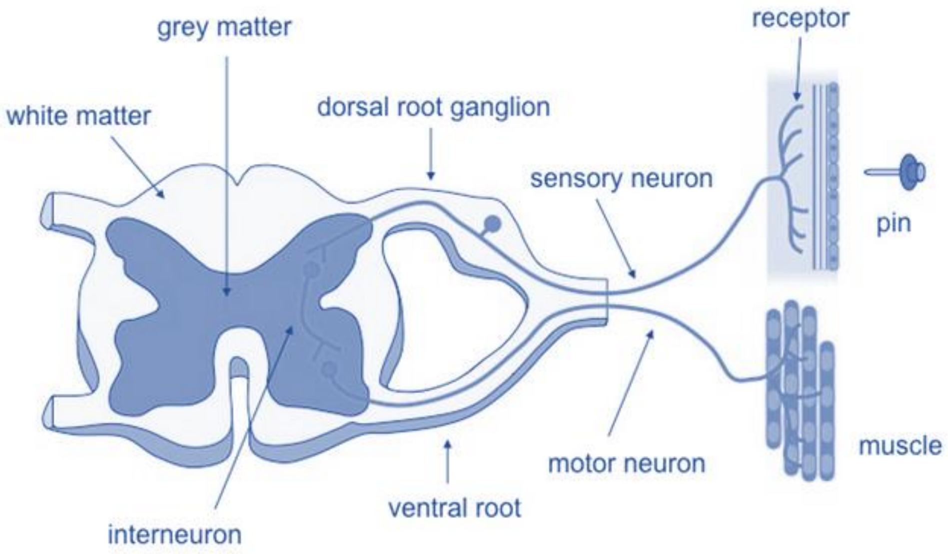
Cerebrum	Cerebellum
(1) It is the largest part of the brain, forming four-fifths of its weight.	(1) It is the second largest part of the brain, forming one-eighth of its mass.
(2) It covers the rest of the brain.	(2) It covers the medulla oblongata only.
(3) It is a part of the forebrain.	(3) It is a part of the hindbrain.
(4) It consists of 2 cerebral hemispheres each comprising 4 lobes : frontal, occipital, parietal, temporal.	(4) It consists of two cerebellar hemispheres and a median vermis.
(5) It encloses 2 lateral ventricles.	(5) It is solid.
(6) White matter does not form arbor vitae.	(6) White matter form arbor vitae.
(7) It initiates voluntary movements, and is a seat of will, intelligence, memory *etc*.	(7) It maintains posture and equilibrium.

Subdivisions, parts and associated structures of a vertebrate brain

Divisions	Subdivisions	Parts	Cavity	Associated strcutures
(I) Prosencephalon (Forebrain)	(1) Telencephalon	Rhinencephalon	I Ventricle (*Rhinocoel*)	Olfactory bulbs Olfactory tracts Olfactory lobes Palaeocortex on pallium
		Cerebral hemispheres	II or Lateral Ventricles	Corpora striata or basal ganglia Corpus callosum Neocortex on pallium Paraphysis
	(2) Diencephalon	Epithalamus (roof)		Habenulae Pineal apparatus Parapineal or parietal
		Thalamus (sides)		

		Hypothalamus (floor)		Hypothalamic nuclei Optic chiasma Median eminence Infundibular stalk Pituitary Saccus vasculosus Mamillary bodies Anterior choroid plexus
(II) Mesencephalon (Midbrain)	–	Crura cerebri (floor)	*Iter* or *cerebral aqueduct*	Cerebral peduncles
(III) Rhombencephalon (Hind brain)	(1) Metencephalon	Cerebellum		Trapezoid body Pons
	(2) Myelencephalon	Medulla oblongata	IV Ventricle (*Metacoel*)	Restiform bodies Pyramids

Reflex action



(1) The reflex actions are involuntary actions because these are not under the conscious control of the brain.

(2) The spinal cord and brain stem are responsible for most of the reflex movements.

(3) A few examples of the reflex actions are withdrawal of hand or leg if pricked by a pin, secretion of saliva as soon as one thinks of delicious food or mere its sight causes salivation, if the body part is touched with acid or hot object it is automatically, without thinking and planning is withdrawn, cycling, motor driving etc.

(4) Component of reflex action: The whole of the reflex are includes six parts –

- **(a) Receptor organs:** Receptors are windows of the body or guards of the body. These are situated on all, important organs, for example – eyes, nose, ear, tongue, integument etc. These perceive the stimuli from outside the body.
- **(b) Sensory neurons:** These are also termed afferent neurons. These carry the stimuli from receptors to spinal cord. These neurons are situated in the ganglion on the dorsal side of spinal cord.
- **(c) Nerve centre:** Spinal cord is termed as nerve centre. Synaptic connections are formed in it.
- **(d) Association neurons:** These are also called intermediate neurons or interstitial neurons. These are found in spinal cord. They transfer the impulses from sensory neurons to motor neurons.
- **(e) Motor neurons:** These are situated in the ventral horn of spinal cord. These carry the impulses to effector organs.
- **(f) Effector organs:** These are the organs, which react and behave in response to various stimuli, for example – muscles and glands.

(5) Type of reflexes: The reflexes are of following types –

- **(a)** Monosynaptic reflex
- **(b)** Polysynaptic Spinal Reflex
- **(c)** Polysynaptic Spinal/Brain Reflexes
- **(d)** Unconditioned or Simple reflex
- **(e)** Conditioned or Acquired reflex

Cranial nerves of mammal at a glance

Olfactory – sensory
Optic-sensory

Occulomotor (smallest nerve)-motor

Trochlear(pathetic)-motor

Trigeminal(dentists nerve) –mixed (a) Opthalmic-sensory (b)maxillary-sensory (c) mandibular-mixed

Abducens(shortest nerve)-motor

Facial-mixed

Auditory(vestibulocochlear)-sensory

Glossopharyngeal-mixed

Vagus(longest nerve)-mixed

Spinal accessory nerve-motor

Hypoglossal-motor

Chemical control and Coordination

Properties of hormones

(a) These are secreted by endocrine gland (biogenic in origin).

(b) Their secretions is released directly into blood (except local hormones *e.g.* gastrin).

(c) These are carried to distantly locate specific organs, called target organ.

(d) These have specific physiological action (excitatory or inhibatory). These co-ordinate different physical, mental and metabolic activities and maintain homeostasis.

(e) The hormones have low molecular weight *e.g.* ADH has a molecular weight of 600–2000 daltons.

(f) These act in very low concentration *e.g.* around10^{-10} molar.

(g) Hormones are non antigenic.

(h) These are mostly short-lived. So have a no camulative effect.

(i) Some hormones are quick acting *e.g.* adrenalin, while some acting slowly *e.g.* ostrogen of ovary.

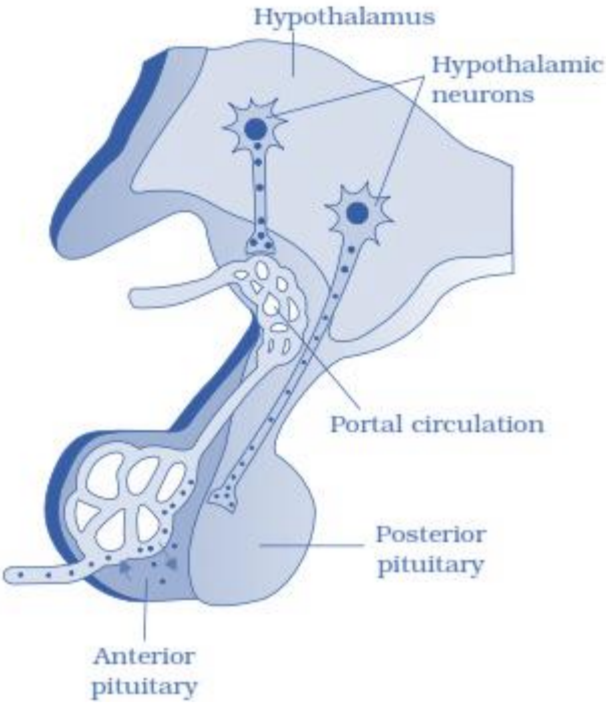
(j) Some hormones secreted in inactive form called Prohormone *e.g.* Pro-insulin.

(k) Hormones are specific. They are carriers of specific information to their specific target organ. Only those target cell respond to a particular hormone for which they have receptors.

Pituitary Gland (Hypophysis)

(1) Pituitory is known as hypophysis cerebri, its name pituitary was given by vesalius.

(2) Muller's gland of amphioxus and subneural gland of hardmania is homologous to pituitary of vertebrates.



Parts and component

(1) **Adenohypophysis (Anterior lobe)**
   - (i) Pars distalis
   - (ii) Pars tuberalis
   - (iii) Pars intermedia

(2) **Neurohypophysis (Posterior lobe)**
   - (i) Pars nervosa
   - (ii) Infundibulum

Hypothalamus

(i) **Position and Structure:** Hypothalamus is the floor of diencephalon. It is formed of masses of grey matter, called hypothalmic nuclei, containing neurosecretory cells. It is connected with anterior pituitary lobe by blood capillaries of hypophyseal portal system and with the posterior pituitary lobe by axons of its neurons, both passing through the pituitary stalk.

(ii) **Hormones of hypothalamus:** Neurosecretory cells of hypothalamus secrete neurohormones called releasing factors (RF) or inhibiting factors (IF). These neurohormones are carried by hypophyseal portal system to adenohypophysis (primary target organ) and stimulate or inhibit the release of trophic hormones from adenohypophysis. These neurohormones are proteinous in nature and formed of 3 – 20 amino acids.

Neurohormones of Adenohypophysis

Neurohormones	Physiological effects
(1) TSH-RF	
(Thyroid Stimulating Hormone – Releasing Factor)	Increased ACTH secretion from adenohypophysis.
(2) ACTH-RF	
(Adrenocorticotrophic Hormone-Releasing Factor)	Increased ACTH secretion from adenohypophysis.
(3) STH-RF	
(Somatotrophic Hormone-Releasing Factor)	Increased STH secretion from adenohypophysis
(4) SOMATOSTATIN (GROWTH INHIBITING HORMONE)	Decreased STH secretion from adenohypophysis.
(5) GTH-RF	
(Gonadotrophic Hormone-Releasing Factor)	
(i) FSH-RF	
(Follicular Stimulating Hormone-Releasing Factor)	Increased FSH secretion from adenohypophysis.
(ii) LH-RH (In female)	
(Luteinising Hormone – Releasing Factor)	Increased LH secretion from adenohypophysis.
or ICSH-RF (In male)	
(Interstitial Cells stimulating Hormone-Releasing Factor)	
(6) Prolactin-Releasing hormone (P-RH)	Increased secretion of prolactin or leutotrophic hormone.
(7) Prolactin-Inhibiting hormone (P-IH)	Increased secretion of prolactin or leutotrophic

	hormone.
(8) MSH-RF	
(Melanophore Stimulating Hormone-Releasing Factor)	Increased MSH secretion from intermediate pituitary lobe.
(9) MIF	
(Melanophore Inhibiting Factor)	Decreased MSH secretion from intermediate pituitary lobe.

List of hormones their chemical nature and functions

Name of endocrine gland	**Name of hormone and its chemical nature**	**Functions**
(1) Neurosecretory cells of Hypothalamus (Supraoptic Nucleus and Paraventricular Nucleus)	(1) Oxytocin and vasopressin nanopeptide.	(1) Milk ejection and parturition (oxytocic effect). (2) Vasoconstriction and antidiuretic (vasotocin) effects.
	(2) Gonadotropin releasing hormones	Stimulates FSH and LH sysnthesis.
	(3) Other releasing hormones *e.g.*TSHRH, MSHRH, ACTHRH, GHRH etc. Proteinaceous	Stimulate TSH, MSH, ACTH GH secretions from pituitary.
(2) Pituitary **(a) Neurohypophysis (Pass Nervosa)**	Store and release Oxytocin and Vasopressin.	Hormone release is related to physiological state and requirements.
(b) Adenohypephypsis (contains diverse cell types)	Proteincaceous or glycoprotein	Affect growth, development differential pubertal changes and other metabolic mechanism.
(3) Pineal	Melatonin-derived from the amino acid tyrosine	(1) Antagonist to FSH / LH (2) Regulates biological / circadian rhythms.
(4) Thyroid gland (amine	(a) Thyroxine, iodinated	(a) Controls basal metabolic rate (BMR). All organ /

hormone) having – NH_2 group)	amino acid called tyrosine (T_2, T_3, T_4).	system of body respond to thyroxine.
	(b) Thyrocalcitonin (Peptide)	(b) Facilitates Ca^{+2} absorption
(5) Parathyroid gland	Parathormane, Peptide	Ca^{+2} and PO^{-4} metabolism.
(6) Thymus	Thymosine (polypeptide)	Anti-FSH and LH; delays puberty
(7) Islets of lengerhans **(= Endocrine pancrease)** **(i) a-cells** **(ii) b-cells** **(iii) d-cells**	(i) Glucagon (ii) Insulin (iii) Secretin Isolated by banting polypeptide	(i) Gluconeogenesis / Glycogenolys (ii) Glycogenesis (iii) Gastric functions
(8) Adrenal gland **(a) Adrenal medulla** **(Amine hormone have – NH_2)**	(a) Catecholamines (epinephrine = adrenaline, and norepinephrine = noradrenaline (derived from tyrosine)	(a) Stresses = emergency = Fright, Fight and Flight Hormone (3F) acclerates cardiac functions muscle activity etc.
(b) Adrenal cortex	(b) Mineralcorticoids and glucocorticoids and traces of androgen and estrogen steroids derived from cholesterol	(b) Electrolyte and carbohydrate metabolism.
(9) Ovary **(a) Ganulosa cells steroid, fat soluble have sterol group derived from cholesterol**	Estrogen (Steroid) Estrone, estradiol	(a) Secondary sex character primary action on uterine endometrium mitogenic.
(b) Corpus luteum	Estrogen and Progesterone (Steroid)	(a) Secreted during luetal phase of menstrual cycle in human female and oestrous cycle of other mammals. Prepares uterine endometrium for receiving blastocytes for implantation. Progesterone is also called pregnancy hormone and is anti-FSH and anti-LH/anti-LTH.
(c) Placenta temporary endocrine gland formed	(a) Steroid secreted are estrogen and progesterone	(a) Maintenance of pregnant state prevents lactogenesis folliculogenesis, and Ovulation.

during pregnancy	(b) Relaxin-Polypeptide	(b) Act on pubic symphysis and enlarges the birth canal to facilitate birth. Acts synergestically with oxytocin during this process (parturition)
(10) Testis **(i) Sertoli cells** **(=sustentacular cells)**	Inhibin – Polypeptide	Inhibits FHS action and attenuates spermatogenesis decrementally
(ii) Leydig cells **(=Interstitial cells)**	(ii) Estradiol-Steroid Androgens (e.g. Testosterone) Steroid androstenedione)	(i) Pubertal changes in male (ii) Secy. sex characters in male (iii) Sex drives (iv) Spermatogenesis
(11) Gastro-intestinal hormones (secreted by cells of mucosa of stomach and intestine) also called hormones		Stimulates gastric juices secretion from gastric gland, movement of sphincters of stomach and increased movement of stomach
(a) Pyloric stomach (Argentophil cells) Intestine	Gastrin (i) Secreten (ii) Cholecystokinin (CCK) (iii) Enterogastrone (iv) Duedocrinin (v) Enterokinin (vi) Villikrinin	(i) Stimulates secretion of succus entericus (ii) Bile released from gall bladder (iii) Inhibits gastric secretin (iv) Stimulates secretion of mucous from Brunner's gland (v) Stimulate intestinal gland (vi) Stimulate villi movement

Circulation

Circulatory System

Functions of Circulatory System

(1) Transport of various substances such as nutrients, waste products, respiratory gases, metabolic intermediates (Such as lactic acid from muscle to liver), and vitamins hormones etc.

(2) Regulation of body pH by means of buffer, body temperature homeostasis, water balance etc.

(3) Prevention of disease by means of antibodies and antitoxins.

(4) Support or turgidity to certain organs like penis and nipples.

Heart of vertebrates

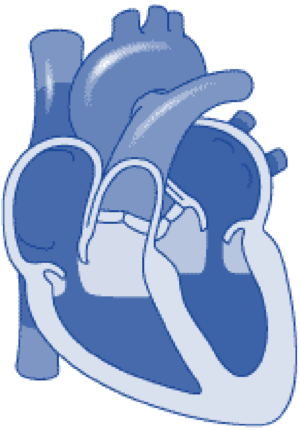
Class of vertebrates	Characteristics	Example
(1) Pisces (= Branchial heart)	Thick, muscular, made of cardiac muscles, has two chambers (i) auricle and (ii) ventricle. The heart is called venous heart since it pumps deoxygenated blood to gills for oxygenation. This blood goes directly from gills to visceral organs (single circuit circulation). A sinus venosus and conus arteriosus is present. Lung fishes have 2 auricles and 1 ventricle.	Labeo Scoliodon Neoceratodus
(2) Amphibians	**Heart consists of** (a) Two auricles (b) Undivided ventricle (c) Sinus venosus (d) Truncus arteriosus (conus + proximal part of aorta) Right auricle receives blood from all the visceral organs (deoxygenated) via precaval and post caval. Pulmonary artery carries deoxygenated blood to lungs for oxygenation. This blood returns to left auricle via pulmonary vein (Double circuit circulation)	Frog Toad
(3) Reptiles	**Heart consists of :** (a) Left and right auricle (b) Incompletely divided ventricle (Ventricle in crocodiles gavialis and alligator is completely divided) (c) Sinus venosus (d) Conus arteriosus divided into right systemic, left systemic and pulmonary arch.	Lizards Snakes Turtles
(4) Aves	**Heart consists of** (a) Left and right auricle (b) Left and right ventricle (c) Complete separation of arterial and venous circulation (d) Only right systemic arch is present (e) Sinus venosus and truncus arterisious absent	Pigeon
(5) Mammals	Same as bird except that mammals have left systemic arch.	Rabbit, man

Human Heart

Circulation of Blood through Heart

(1) The heart pumps blood to all parts of the body.

(2) The deoxygenated blood is drained into right auricle through superior and inferior vena cava and coronary sinus whereas the pulmonary veins carry oxygenated blood from lungs to the left auricle. This is called as Auricular circulation.



(3) About 70% of the auricular blood passes into the ventricles during diastole. This phase is called diastasis.

(4) The rest of 30% of blood passes into the ventricles due to auricular systole (contraction).

(5) In this way, blood reaches the ventricles and is called ventricular filling.

(6) During ventricular systole (which starts first in left ventricle than in right ventricle), the pressure increases in the ventricles, thus, forcing the oxygenated blood from left ventricle into systemic aorta and deoxygenated blood from right ventricle into pulmonary aorta.

(7) The systemic arch distributes the oxygenated blood to all the body parts except lungs while pulmonary aorta carries the deoxygenated blood to lungs for oxygenation.

Differences between Neurogenic heart and Myogenic heart

Neurogenic heart	Myogenic heart
(1) The heart beat is initiated by a ganglion situated near the heart.	(1) The heart beat is initiated by a patch of modified heart muscle.
(2) The impulse of contraction originates from nervous system.	(2) The impulse of contraction originates itself in the heart.
(3) The heart normally stops beating immediately after removal from the body. Therefore, heart transplantation is not possible.	(3) The heart removed from the body continues to beat for some time. Therefore, heart transplantation is possible.
(4) Examples: Hearts of some annelids and most arthropods.	(4) Examples: Hearts of molluscs and vertebrates.

Fractions of cardiac output :

Amount of pure blood going to an organ per minute is called as fraction of the organ.

(i) Cardiac fraction – 200 ml/min.

(ii) Hepatic fraction – 1500 ml/min. (28% of blood as liver is the busiest organ of body and has maximum power of regeneration).

(iii) Renal fraction – 1300 ml/min (25% of blood)

(iv) Myofraction – 600-900 ml/min.

(v) Cephalic organs – 700-800 ml/min.

Differences between first and seconds heart sounds

First heart sound (Lubb)	Second heart sound (Dup)
(1) It is produced by closure of bicuspid and tricuspid valves at the start of ventricular systole.	(1) It is produced by closure of semilunar valves at the start of ventricular diastole.
(2) It is low pitched, less loud and of long duration.	(2) It is higher pitched, louder, sharper and of short duration.
(3) It lasts for 0.15 seconds.	(3) It lasts for 0.1 second.
(4) Its principal frequencies are 25 to 45 cycles per second.	(4) Its principal frequency is 50 cycles per second.

Electrocardiogram (ECG)

(1) A graphic record of electrical events occurring during a cardiac cycle is called Electrocardiogram.

- **(i) Depolarisation waves:** They represent the generation of the potential difference. These waves appear only when both electrodes of galvanometer are in different fields. When both the electrodes are in same field, there are no deflection and wave drops down to base line.
- **(ii) Repolarisation waves:** They appear when depolarisation is over and the muscle fibre is returning to its original polarity. When both electrodes are in same polarity (means 100% repolarisation and 100% depolarisation), there is no deflection.
  - **(a)** ***P* wave:** Indicates impulse of contraction generated by S.A. node and its spread in atria causing atrial depolarisation. The interval *PQ* represents atrial contraction and takes 0.1 second.
  - **(b) QRS complex:** Indicates spread of impulse of contraction from A.V node to the wall of ventricles through bundle of His and pukinje fibres causing ventricular depolarisation. This complex also represents repolarization of S.A. node.

    The RS of *QRS* wave and *ST* interval show ventricular contraction (0.3 seconds). QRS is related to ventricular systole.

    - ***T* wave:** Indicates repolarisation during ventricular relaxation

Types of Blood Circulation in Human

(i) Coronary circulation: It involves blood supply to the heart wall and also drainage of the heart wall.

  (a) Coronary arteries: One pair, arising from the aortic arch just above the semilunar valves. They break up into capillaries to supply oxygenated blood to the heart wall.

  (b) Coronary veins: Numerous, collecting deoxygenated blood from the heart wall and drains it into right auricle through coronary sinus which is formed by joining of most of the coronary veins.

(ii) Pulmonary circulation: It includes circulation between heart and lungs. The right ventricle pumps deoxygenated blood into a single, thick vessel called pulmonary aorta which ascends upward and outside heart gets divided into longer, right and shorter, left pulmonary arteries running to the respective lungs where oxygenation of blood takes place.

(iii) Systemic circulation: In this, circulation of blood occurs between heart and body organs. The left ventricle pumps the oxygenated blood into systemic arch which supplies it to the body organs other than lungs through a number of arteries.

Lympahtic System

The lymphatic system is an extension of the circulatory system. It consists of a fluid known as lymph, lymph capillaries and lymph ducts.

(a) **Lymph:** It can be defined as blood minus RBC's. In addition to the blood vascular system all vertebrate possess a lymphatic system. It is colourless or yellowish fluid present in the lymph vessels. It is a mobile connective tissue like blood and is formed by the filtration of blood.

(b) **Lymph capillaries:** Small, thin, lined by endothelium resting on a basement membrane and fine whose one end is blind and other end unites to form lymphatic ducts.

(c) **Lymphatic ducts or vessels:** Numerous, present in various parts of body. These vessels are like veins as they have all the three layers – tunica externa, tunica media and tunica interna, and are provided with watch pocket or semilunar valves but valves are more in number than veins.

Reproduction in Plants & Animals

Reproduction in Organisms

Reproduction:

(1) Reproduction is defined as a biological process in which every living organism give rise to new organisms similar to themselves.

(2) Basic features of reproduction:

   (i) Replication of DNA

   (ii) Cell division (only mitotic, or both mitotic and meiotic)

   (iii) Formation of reproductive bodies or units.

   (iv) Development of reproductive bodies into offsprings.

Difference between Asexual and Sexual Reproduction

S.No.	Asexual Reproduction	Sexual Reproduction
1)	Offsprings are produced by single parents.	Involvement of single or two individual.
2)	New individual develops from one cell or a vegetative body part of one parent.	New individual develops from zygote or fusion product of two gametes, which may or may not be produced by two parents.
3)	Offsprings are genetically identical to their parents.	The offsprings are not genetically identical with their parents.
4)	Involves only mitotic divisions.	Involves meiosis at one or the other stage.
5)	It does not require the formation of sex organs.	Formation of sex organs is a pre-requisite for sexual reproduction.
6)	It does not introduce variability. Hence has no evolutionary importance.	It introduces variability and is, hence of evolutionary importance.

Asexual Reproduction

Asexual reproduction in plants

In flowering plants there are two main types of asexual reproduction:

(a) **Agamospermy –** The formation of embryo without fertilization and meiotic division. There are three different types of agamospermy:

   (i) Diplospory

   (ii) Adventive embryony

   (iii) Apospory

(b) **Vegetative propagation –**

   (i) Plants belonging to this category propagates by a part of their body other than a seed. The structural unit that is employed in place of seed for the propagation of new plants is called **propagule.**

   (ii) In angiosperms any parts of the plants – roots, stemsand leaves can be used for vegetative propagation.

(5) Following are the asexual reproductive structures:

   (a) Zoospores: aquatic fungi, *Chlamydomonas*
   (b) Conidia: *Penicillium*
   (c) Bud: *Hydra*
   (d) Gemmules: *sponges*

(6) Below given are the vegetative propagation units in plant: (Vegetative propagules)

   Runner, rhizome, sucker, tuber, offset, bulb

Sexual reproduction:

Sexual reproduction involves fusion of male and female gametes by the process of fertilization.

Features of sexual reproduction:

(a) The period between birth and sexual maturity is called juvenile phase.

(b) Juvenile phase is also known as vegetative phase in plant.

(c) **Oestrus cycle:** The cyclical changes during reproduction in non-primate mammals like cows, sheep, rats, deers, dogs, tiger etc.

(d) **Menstrual cycle:** The cyclical changes during reproduction in primate mammals like monkeys, ape, and humans.

(e) **Seasonal breeders:** The reproductive cycle takes place only in favorable seasons as in wild animals.

(f) **Continuous breeders:** They are reproductively active throughout their reproductive phase.

(g) **Gametogenesis** is the process of gamete formation.

(h) **Isogametes** are one of a pair of conjugating gametes, exhibiting no differences in form, size, structure, or sex.

(i) Gametes produced of two morphologically distinct types are called heterogametes.

(j) Male gamete is called antherozoid or sperm and the female gamete is called ovum or egg.

Sexuality in organism:

(a) Plants having only one sex organ is called heterothallic or dioecious.

(b) Plants having both male and female sex organ called homothallic or monoecious.

(c) In flowering plants, the unisexual male flower is staminate (bearing stamens), while the female is pistillate (bearing pistils).

(d) Animals having one type of reproductive system are called unisexual.

(e) Animals having both male and female reproductive system are called hermaphrodite or bisexual.

Cell division during gamete formation:

(a) Gametes in all heterogametic species are of two types namely male and female.

(b) Gametes are always haploid irrespective of parent's ploidy.

(c) Gametes are produced by a haploid parent by mitotic division.

(d) Gametes are produced by a deploid parent by meiotic division.

(e) In diploid organisms specialized cells called meiocytes undergo meiosis to produce haploid gametes.

Gamete transfer:

(a) Male and female gamete must be physically brought together to facilitate fusion called fertilization.

(b) In most cases female gametes are non-motile , male gametes are motile.

(c) In case of few fungi and algae, both male and female gametes are motile.

(d) In most cases the medium for gamete transfer is water.

(e) Number of male gametes are produced is several thousand times the number of female gametes produced to compensate the loss during transfer.

Fertilization:

The process of fusion of male and female gamete is called **fertilization or syngamy.**

Sexual Reproduction in Flowering Plants

Flower

Flower is a modified stem which functions as a reproductive organ and produces ova and/or pollen

(1) Structure of the flower:

The flower is commonly borne on short or long stalk called the pedicel. It has an upper swollen region known as receptacle (thalamus or torus).

(2) Parts of a flower:

A typical angiospermic flower consists of four whorls of floral appendages attached on the receptacle: calyx, corolla, androecium and gynoecium.

- **(i) Calyx:** It is the outermost whorl of the flower. It is composed of leaf like green sepals. The sepals are essentially green in colour but in some cases they are coloured like petals. Such a condition of calyx is called petaloid.
- **(ii) Corolla:** This is the second whorl of the flower and consists of a number of petals. Petals are generally brightly coloured and sometimes fragrant which make the flower to become attractive.
- **(iii) Androecium:** It is the third whorl of flower and is the male reproductive organ consisting of stamens. Each stamen is made of filament and anther. The filament supports anther at its tip.
- **(iv) Gynoecium:** This is the last and the fourth whorl of flower and is the female reproductive organ of the flower. It occupies the central position on the receptacle and composed of ovary, style and stigma and the component parts are called carpels.

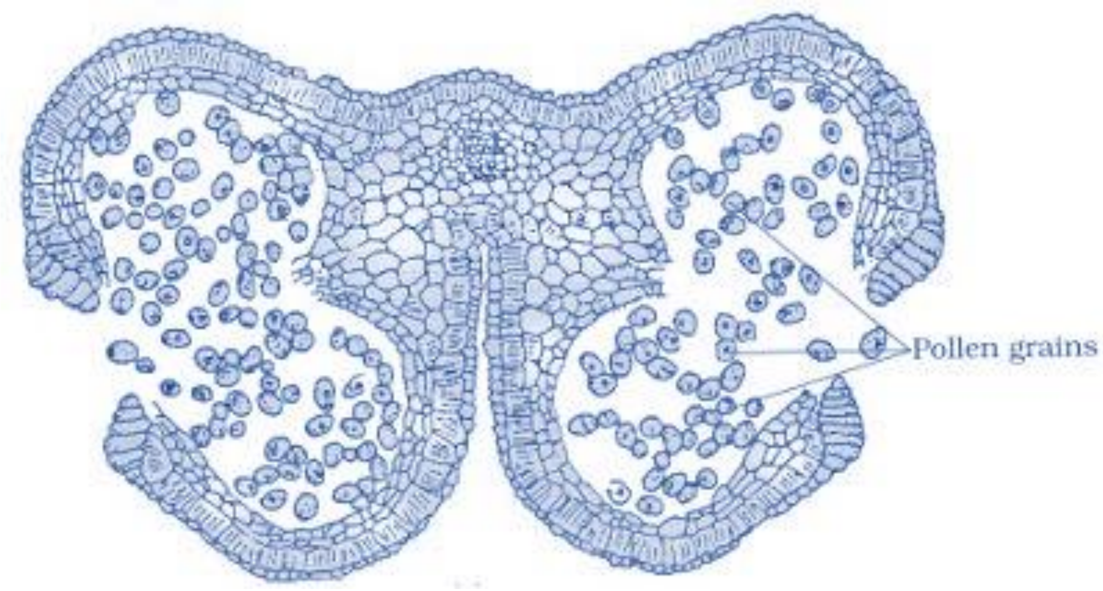
(3) Functions of a flower

- (i) Flowers are modifications of shoot to perform the function of sexual reproduction.
- (ii) Flowers of most of the angiosperms are shaped variously to help diverse modes of pollination.
- (iii) Flowers provide seat for germination of pollen, development of pollen tube, formation of gametes and fertilization.
- (iv) The ovary part of the carpel gets transformed into fruit and the ovules are transformed into seeds after fertilization.
- (v) Some floral parts like calyx and various modifications in ovaries help in the dispersal of fruits and seeds.

Microsporogenesis

The process of the formation and differentiation of microspores (pollen grains) from microspore mother cells (MMC) by reductional division is called microsporogenesis.

Microsporogenesis is well studied under following heads:



(1) Structure of anther:

The fertile portion of stamens is called anther. Each anther is usually made up of two lobes connected by a connective. In turn each anther lobe contains two pollen chambers placed longitudinally. Each pollen chamber represents a microsporangium and is filled with a large number of pollen grains or microspores.

The pollen sacs are surrounded by following 4 layers :

(i) Epidermis: This is the outermost single layered and protective. In Arceuthobium, cells of epidermis develop a fibrous thickening and the epidermis is designated as exothecium.

(ii) Endothecium: Inner to epidermis, there is a single layer of radially elongated cells. Cells of endothecium develop fibrous thickening (made up of cellulose with a little pectin and lignin) which help in the dehiscence of anther. In between these cells, a few cells without thickening are also present. These thick walled cells collectively form the stomium.

(iii) Middle layer: Three to four layers of thin walled cells situated just below the endothecium are known as middle layers. Cells of this layer are ephemeral and degenerate to provide nourishment to growing microspore mother cells.

(iv) Tarentum: This is the innermost layer of the wall. The cells are multinucleate (undergo endopolyploidy) and polyploid. Tapetal cells are nutritive.

(2) Development of anther and formation of microspores (Pollen grains):

(a) The young anther consists of homogenous mass of paranchymatous cells surrounded by epidermis. It soon becomes four lobed.

(b) In each of the four lobes, some of the hypodermal cells begin to act as archesporial initials.

(c) Each archesporial initial divides into an outer primary parietal cell and an inner primary sporogenous cell.

(d) The primary parietal cell divides to form 3-5 wall layers, i.e., endothecium, middle layers and tapetum.

(e) The primary sporogenous cells divide to produce a mass of sporogenous cells or microsporocytes.

(f) Each microspore mother cell divides meiotically to form four haploid microspores or pollen grains and remains arranged in tetrads.

(3) Development of male gametophyte (Microgametogenesis):

(a) Microspore or pollen grain is the first cell of male gametophyte (partially developed).

(b) The wall of the pollen grain is made of two layers.The outer layer is called exine. It is made up of sporopollenin (derived from carotenoid). The inner intine is thin, delicate and is made of cellulose and pectose.

(4) Pre-pollination development:

(a) Microspores start germinating in situ (i.e. while enclosed inside the microsporangium or pollen sac) and are called precocious.

(b) Microspore nucleus divides mitotically to form a smaller generative cell lying next to spore wall and a much larger vegetative cell (or tube cell).

(c) A callose layer is deposited around the generative cell. The generative cell loses its contact with the wall of microspore and becomes free in the cytoplasm.

(d) The callose layer then dissolves. The pollen grains are shed from the anther at this bicelled stage (rarely three celled).

(5) Post-pollination development:

(a) The liberated pollen grains are transferred to the receptive surface of the carpel (i.e., stigma) by the process called pollination.

(b) On the stigma, the pollen grain absorbs water and swells within a few minutes.

(c) The vegetative (or tube) cell enlarges and comes out through one of the apertures in the form of a pollen tube.

(d) The wall of pollen tube is the extension of intine. The tube secretes exogenous pectinases and other hydrolytic enzymes to create a passage for its entry.

(e) The vegetative and generative nuclei are carried by the pollen tube, the farmer lying at its tip.

(f) The generative cell divides to form two non-motile male gametes.

(g) The tube nucleus has no important function and may disintegrate.

Megasporogenesis

The process of formation of megaspore from megaspore mother cell by meiotic division is known as megasporogenesis. This process takes place in ovule.

(1) Structure of ovule:

Ovule is considered to be an integumented megasporangium. The ovule consists of the stalk and the body. The stalk is called funicle. One end of the funicle is attached to placenta and the other end to the body of the ovule. The point of attachment of funicle with the body is called hilum. Sometimes funicle gets fused with the body of the ovule one side and forms a ridge known as raphe. The body of the ovule shows two ends: the basal end, often called the chalazal end and the upper end is called micropylar end. The main body of the ovule is covered with one or two envelopes called integuments. These leave an opening at the top of the ovule called micropyle. The integuments enclose a large parenchymatous tissue known as nucellus.

(2) Development of female gametophyte (Megagametogenesis):

The process of development of female gametophyte or embryo sac from megaspore is called megagametogenesis.

(i) Monosporic type (Polygonum): In this type, only one megaspore situated towards chalazal end takes part in the development of embryo sac.

(ii) Bisporic type: In this type two megaspore nuclei take part in embryo sac formation.

(iii) Tetrasporic type: This type of embryo sac develops from four megaspore nuclei.

Pollination

(1) The process of transfer of pollen grains from an anther to the stigma of the same flower or of different flower.

(2) It is of two types:

    (i) Self pollination: This process involves the transfer of pollen grains from the anthers to the stigma of the same flower or of another flower borne by the same plant.

    (ii) Cross pollination: Cross pollination involves the transfer of pollen grains from the flower of one plant to the stigma of the flower of another plant. It is also called xenogamy.

Fertilization

The fusion of two dissimilar sexual reproductive units (gametes) is called fertilization. This process was discovered by Strasburger (1884).

Germination of pollen grain on stigma and growth of pollen tube:

Pollen grains reach the receptive stigma of the carpel by the act of pollination.

Human Reproduction

(1) **Reproduction** is the formation of new individuals of their own kind by living organisms.

(2) The **Male Reproductive System** consists of:

    (a) Primary sex organs i.e. a pair of testes suspended in a scrotum.

    (b) Secondary sorgans i.e. a pair of ducts each differentiated into an epididymis, a vas deferens and an ejaculatory duct.

    (c) A male urethra passing through an erectile penis.

    (d) Three types of Glands - a pair of seminal vesicles, a prostate gland and a pair of Cowper's glands.

(3) The **Female Reproductive system** consists of:

    (a) Primary sex organ i.e. a pair of ovaries

    (b) Secondary sex organs i.e. a pair of fallopian tubes (oviducts) , a uterus (womb), a vagina.

(4) Ovaries produce female gametes called ova.

Phases of embryonic development.

(1) **Gametogenesis :** It involve the formation of haploid sex cells or gametes called sperms and ova from diploid primary germ cells called gametogonia present in the reproductive organs called gonads (testes and ovary). It is of two types;

  (i) **Spermatogenesis:** Formation of sperm.

  (ii) **Oogenesis :** Formation of ova

(2) **Fertilization:** It involves the fusion of haploid male and female gametes to form diploid zygote. The fusion of gametic pronuclei is called Karyogamy while the mixing of two sets of chromosomes of two gametes is called amphimixis.

(3) **Cleavage:** It includes the rapid mitotic division of the zygote to form a single layered hollow spherical larva called blastula and its formation is called blastulation.

(4) **Implantation:** The process of attachment of the blastocyst (mammalian blastula) on the endometrium of the uterus is called implantation.

(5) **Gastrulation:** It includes the mass and orderly migration of the organ specific areas from the surface of blastula to their predetermined position which finally produces a 3 layered gastrula larva. It is with 3 primary layers.

(6) **Organogenesis:** It includes the formation of specific organs system from three primary germ layers of gastrula and also includes the morphogenesis and differentiation.

Fertilization

(1) **Definition:** Fusion of a haploid male gamete (spermatozoon) and a haploid female gamete (ovum) to form a diploid cell, the zygote, is called fertilization or syngamy.

(2) **Site of fertilization:** Fertilization in human female is internal as in other mammals. It takes place usually in the ampulla of the fallopian tube.

(3) **Steps of fertilization**

  (i) **Approach of sperm to ovum:**

    (a) Male discharges semen (3.5 *ml*) in the female's vagina close to the cervix during coitus. This is called ejaculation or insemination. This ejaculation contains as many as 400 million sperms but only about 100 sperms reach the fallopian tube because many sperms are either killed by the acidity of female genital tract or engulfed by the phagocytes of the vaginal epithelium.

    (b) The sperm swim in the seminal fluid at the rate of 1-4 *mm* per minute by the aspiratory action of the uterus and peristaltic movement of the fallopian tube.

    (c) Capacitation is the phenomenon of physiological maturation of sperms by breaking of acrosome membrane inside the female genital tract. It takes about 5-6 hours.

(d) Ovum is released on the 14th day of menestrual cycle trapped by the fimbriae of the ampulla of fallopian tube and move towards the uterus by peristalsis and ciliary action.

(e) At the time of ovulation, egg is at secondary oocyte stage.

(f) Fertilizability of human sperm in the female genital tract is of 12 to 24 hours while its survival value is upto 3 days and of ovum is only 24 hours though it can live for about 72 hours.

(ii) **Penetration of sperm:**

(a) The ovum secretes a chemical substance called fertilizin, which has a number of spermophillic sites on its surface where the sperm of species specific type can be bound by their antifertilizin site.

(b) This fertilizin-antifertilizin interaction causes agglutination (sticking together) of egg and sperm.

(c) The sperm generally comes in contact with ovum in the animal pole (side of ovum with excentric nucleus) while the opposite side of ovum is called vegetal pole.

(d) Ovulation in the human female occurs at secondary oocyte stage in which meiosis-I have been complted and first polar body has been released but second maturation is yet to complete.

(e) Penetration of sperm is a chemical mechanism.

(f) In this acrosome of sperm undergoes acrosomal reaction and releases certain sperm lysins which dissolve the egg envelopes locally and make the path for the penetration of sperm.

(g) These sperm lysins contain a lysing enzyme hyaluronidase which dissolves the hyaluronic acid polymers in the intercellular spaces which holds the granulosa cells of corona radiata together; corona penetrating enzyme (that dissolves the corona radiata) and acrosin (which dissolves the zona pellucida). Then it dissolves the zona pellucida.

(h) Only sperm nucleus and middle piece enter the ovum. The tail is lost.

(iii) **Cortical reaction:**

(a) Immediately after the entry of a sperm into the egg, the later shows a cortical reaction to check the entry of more sperms.

(b) In this reaction, the cortical granules present beneath the egg’s plasma membrane release chemical substance between the ooplasm and the plasma membrane (vitelline membrane).

(c) These substances raise the vitelline membrane above the egg surface. The elevated vitelline membrane is called fertilization membrane.

(d) The increased space between the ooplasm and the fertilization membrane and the chemical present in it effectively check the entry of other sperm.

(e) If polyspermy occurs, that is more than one sperm enter the secondary oocyte, the resulting cell has too much genetic material to develop normally.

(iv) **Fusion of gametic nuclei:**

(a) Entrance of spermatozoon serves to acts as stimulus which causes the second maturation division.

(b) As the head and middle piece of the sperm advance into the egg, those parts rotate through an angle of 180° so that the mitochondria and proximal centriole of the associated middle piece assume the leading position.

(c) Beside this rotation, the chromatin itself starts swelling by absorbing fluid from the surrounding cytoplasm and becomes vesicular.

(d) It is now called male pronucleus. This direction of movement of male pronucleus is called penetration path.

(e) The centriole brought in by the spermatozoon subdivides into two and as achromatic spindle is established in the center of the active cytoplasm.

(f) With the production of the second polar body, the egg nucleus or female pronucleus is ready for union with the male pronucleus provided by the sperm head.

(g) The male pronucleus which has been advancing the penetration path, now moves directly toward the female pronucleus. This in many cases involves a slight change in the course of sperm.

(h) In such cases, the later portion of its course is called the copulation path.

(i) The centrioles of middle piece of sperm form a spindle.

(j) The nuclear membrane of the gametic nuclei degenerates and two sets of chromosomes initially lie on two poles of the spindle but later these sets of chromosomes mix up and the process is called amphimixis.

(k) The fertilized egg is now called zygote and the zygote nucleus is called synkaryon.

Significance of fertilization

(a) It provides stimulus for the egg to complete its maturation.

(b) It activates the ovum to develop into a new individual by repeated mitotic division.

(c) Fertilization restores the diploid number of chromosomes (46 in man) in the zygote by adding male’s haploid set of chromosomes.

(d) It makes the egg more active metabolically.

(e) It combines the character of two parents and introduces variations. So help in evolution.

(f) Sex chromosomes of sperm is either X or Y and helps in sex determination.

(g) Fertilization membrane formed after sperm entry, checks the entry of additional sperms.

(h) Copulation path sets the axis of division.

Menstrual Cycle

(1) Menstruation occurs in human, apes and old world monkeys.

(2) Menstruation is bleeding from the uterus of adult females at intervals of one lunar month.

(3) Beginning of menstruation or first menstruation is called **menarche**.

(4) The beginning of menstruation varies. It usually occurs between 12 and 15 years.

(5) The cycle of events starting from one menstruation till the next one is called **Menstrual Cycle**.

(6) In human females, menstruation is repeated at an average interval of about 28/29 days.

(7) One ovum is released (ovulation) during the middle of each menstrual cycle.

(8) It is regulated by certain hormones, some of which are secreted by the pituitary gland.

(9) The pituitary gland is stimulated by releasing factors produced in the hypothalamus.

(10)The menstural cycle consists of changes in the ovaries and uterine wall(endometrium). Gonadotropins like FSH and LH regulate these changes

(11)During each cycle of 28 days, only one ovum from either of the ovary is released.

On a average 13 eggs per year 32 years maximum 416 eggs mature

(12)The ceasing of menstrual cycle is called menopause and occurs by the age of 45-58 years.

Reproductive Health

Reproductive health – problem and strategies

(a) India was amongst the first countries in the world to initiate to the programme “family planning” initiated in 1951.

(b) Reproductive health in a society forms a crucial part of general health.

Population explosion and birth control

(a) The rapid increase in human population size over a relatively short period is called human population-explosion.

(b) Population growth rate depends on factors like fertility, natality, mortality, migration, age and sex structure.

(c) Increased health facilities and better living conditions are the cause behind population explosion.

(d) Out of 6 billion world population 1.3 billion populations is of Indians.

(e) Rapid decline in death rate, maternal mortalility rate (MMR) and infant mortality rate (IMR) are major cause of population growth.

(f) Growth rate of Indian population is around 1.7 percent.

(g) Most of the urban people are uneducated.

(h) The regulation of conception by preventive methods or devices to limit the number of offsprings is called birth control.

(i) A birth control method which deliberately prevents fertilization are referred to as contraception.

(i) Contraceptive methods are preventive methods and are of two types – temporary and permanent.

Characteristics of an ideal contraceptive are:-

(a) User friendly

(b) Easily available

(c) Nor or least side – effects

(d) No way interferes with sexual drive

Methods of Birth Control

S. No.	Method	Action
(1)	Rhythm Method	No intercourse during woman's fertility period (day 12-20).
(2)	Withdrawl	Penis is withdrawn before ejavculation.
(3)	Tubectomy / Tubal ligation	Women's fallopian tubes are cut and tied, permanently blocking sperm release.
(4)	Vasectomy	Man's vasa deferentia are cut and tied permanently blocking sperm passage.
(5)	Intrauterine device (IUD)	Small plastic or metal device placed in the uterus to prevent implantation. Some contain copper, other release hormones.
(6)	Oral Contraceptive	Synthetic estrogens and progestrones prevent normal menstrual cycle, primarily prevent ovulation.
(7)	Male condom	Thin rubber sheath on erect penis collects ejaculated semen.
(8)	Female condom	Plastic pouch inserted into vagina catches semen.
(9)	Diaphragm	Soft rubber cup covers entrance to uterus, prevents sperm from reaching egg and holds spermicide.
(10)	Cervical cap	Miniature diaphragm covers cervix closely, prevents sperm from reaching egg and holds spermicide.
(11)	Foams, creams, jellies etc.	Chemical spermicides inserted in vagina before intercourse, prevent sperm from entering uterus.
(12)	Implant (Norplant)	Capsules surgically implanted under skin, slowly release hormone that blocks ovulation.
(13)	Injectable contraceptive (Depo-Provera)	Injection every 3 months of a hormone that is lowly released and prevents ovulation.

Amniocentesis

(a) During pregnancy, the fetus is surrounded by amniotic fluid which is a water-like substance.

(b) Amniotic fluid contains live fetal skin cells and other substances, such as alpha-fetoprotein (AFP).

(c) These substances provide important information about baby's health before birth.

(d) These days amniocentesis is being misused also, i.e., for detecting the sex of the foetus.

(e) Normal foetus is being aborted if it is a female.

Sexually transmitted diseases (STDs)

Diseases which are transmitted sexually through sexual intercourse are collectively called as Sexually Transmitted Diseases (STDs) or Venereal Diseases (VDs) or reproductive tract infections (RTI). STDs can be classified as viral, bacterial, protozoan, fungal, etc.

Causes of STD’s

STDs can be spread with any type of sexual activity, depending on the disease. STDs are most often caused by viruses and bacteria. Types of Sexually Transmitted DiseasesThe various types of sexually transmitted diseases include genital herps, chancroid, gonorrhoea, syphilis and most common HIV leading to AIDS.

(i) Chlamydiasis

  (a) Chlamydiasis is a sexually transmitted disease in humans caused by the bacterium Chlamydia trachomatis.

  (b) It is a major infectious cause of human genetial and eye diseases.

(ii) Gonorrhoea

  (a) Gonorrhoea is transmitted sexually, by oral, anal or genital sex.

  (b) Gonorrhea is caused by the bacterium Neisseria gonorrhoeae

Prevention

STDs are a major threat to a healthy society.

(i) Avoid sex with unknown partners as well as multiple partners.

(ii) Always use condoms during coitus.

(iii) In case of any doubt, go to a qualified doctor for early detection and get complete treatment if diagnosed with disease.

Infertility

(a) Inability to conceive or produce children even after 2 years of unprotected sexual cohabitation is called infertility.

(b) A large no of couples all over India are infertile.

(c) The reasons for this could be many-physical, congenital, diseases, drugs, Immunological or even Psychological.

Assisted Reproductive Technologies (ART)

Includes all fertility symptoms in which both sperms and eggs are handled. These are special techniques that assist couples to have children.

The main ART- techniques include:

(i) In-vitro fertilisation (IVF) or test tube baby

(ii) GIFT(gamete intra fallopian transfer)

Genetics & Evolution

Inheritance and Variation

Mendel's Law of Inheritance

(1) **Mendelism** means experiments performed by Mendel on genetics.

(2) Mendel's experiment involved 4 steps as selection, hybridization, selfing and calculations. His results led to the formation of laws of genetics later.

(3) Mendel performed monohybrid and dihybrid crosses and gave three principles of inheritance.

(4) Mendel's three principles of inheritance are:

  (i) Law of dominance

  (ii) Law of segregation or law of purity of gametes

  (iii) Law of independent assortment

(4) **Law of Dominance –** The dominant characters are expressed when factors are in heterozygous condition.

(5) The recessive characters are only expressed in homozygous conditions. The characters never blend in heterozygous condition. A recessive character that was not expressed in heterozygous condition may be expressed again when it becomes homozygous.

(6) **Law/Principle of segregation** states that when a pair of contrasting factor or gene is brought together in a hybrid, these factors do not blend or mix up but simply associate themselves and remain together and separate at the time of gamete formation.

(7) **Principle of independent assortment** states that genes of different characters located in different pairs of chromosomes are independent of one another in this segregation during gamete formation.

(8) **Test Cross:** A cross between F1 hybrid (Aa) and its homozygous recessive parent (aa) is called Test Cross. This cross is called test cross because it helps to find out whether the given dominant phenotype is homozygous or heterozygous.

(9) **Monohybrid cross –** When we consider the inheritance of one character at a time in a cross, this is called monohybrid cross.

(10) **Dihybrid Cross –** A cross made to study the inheritance of two pairs of contrasting traits.

Exceptions of Conclusions of Mendel

Incomplete Dominance

(1) When neither of the alleles of a character is completely dominant over the other and the F1 hybrid is intermediate between the two parents, the phenomenon is called incomplete dominance.

(2) Incomplete dominance was first discovered by Correns in Mirabilis jalapa. The plant is called as 4'O clock plant or 'Gul-e-Bans'. Homozygous red (RR) flowered variety of the plant was crossed with white (rr) flowered variety. F1 offspring had pink flowers (Rr). This is called incomplete dominance.

(3) Incomplete dominance is also known to occur in snapdragon. The phenotypic ratio and genotypic ratio in F2 generation in case of incomplete dominance is 1:2:1.

Co-dominance

(1) In co-dominance both the gene expressed for a particular character in F1 hybrid progeny. There is no blending of characters, whereas both the characters are expressed equally.

(2) Co-dominance is seen in animals for coat colour. When a black parent is crossed with white parent, a roan color in F1 progeny is produced.

Sex determination

(1) Fixing the sex of an individual as it begins life is called sex determination. The various genetically controlled sex-determination mechanisms have been classified into following categories

(2) Chromosomal theory of sex determination: The X-chromosome was first observed by German biologist, Henking in 1891 during the spermatogenesis in male bug and was described as X-body. The chromosome theory of sex determination was worked out by E.B. Wilson and Stevens (1902-1905).

(3) They named the X and Y chromosomes as sex-chromosomes or allosomes and other chromosomes of the cell as autosomes.

(4) Sex chromosomes carry genes for sex. X-chromosomes carries female determining genes and Y-chromosomes has male determining genes.

(5) The number of X and Y chromosomes determines the female or male sex of the individual, Autosomes carry genes for the somatic characters. These do not have any relation with the sex.

Sex Determination by chromosomes:

Those chromosomes which are involved in the determination of sex of an individual are called sex chromosomes while the other chromosomes are called autosomes.

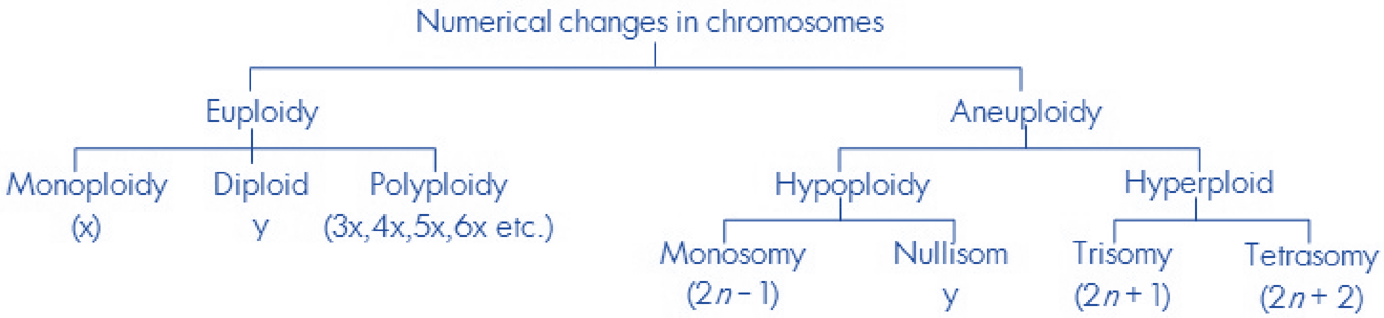
1) **XX – XY type:** In most insects including fruit fly Drosophila and mammals including human beings the females possess two homomorphic sex chromosomes, named XX. The males contain two heteromorphic sex chromosomes, i.e., XY. Hence the males produce two types of gametes / sperms, either with X-chromosome or with Y-chromosome, so they are called Heterogamety.

2) **ZZ – ZW type:** In birds and some reptiles, the males are represented as ZZ (homogamety) and females are ZW (heterogamety).

3) **XX – XO type:** In round worms and some insects, the females have two sex chromosomes, XX, while the males have only one sex chromosomes X. There is no second sex chromosome. Therefore, the males are designated as XO. The females are homogametic because they produce only one type of eggs. The males are heterogametic with half the male gametes carrying X-chromosome while the other half being devoid of it.

Numerical aberrations of chromosomes:

Each species has a characteristic number of chromosome. Variations or numerical changes in chromosomes (Heteroploidy) can be mainly of two types:



(1) **Turner's syndrome:** Such persons are monosomic for sex chromosomes *i.e.* possess only one X and no Y chromosome (XO). In other words they have chromosome number $2n - 1 = 45$. They are phenotypic females but are sterile because they have under developed reproductive organs. They are dwarf about 4 feet 10 inches and are flat chested with wide spread nipples of mammary glands which never enlarge like those in normal woman. They develop as normal female in childhood but at adolescence their ovaries remain under developed. They lack female hormone estrogen. About one out of every 5,000 female births results in Turner's syndrome.

(2) **Klinefelter's syndrome:** Since 1942, this abnormality of sex is known to geneticists and physicians. It occurs due to Trisomy of sex chromosomes which results in (XXY) sex chromosomes. Total chromosomes in such persons are $2n + 1 = 47$ in place of 46. Klinefelter (1942) found that testes in such male remain under developed in adulthood. They develop secondary sex characters of female like large breasts and loss of facial hair. Characters of male develop due to Y chromosome and those like female due to XX chromosomes. About one male child out of every 5,000 born, develops Klinefelter's syndrome.

Molecular Basis of Inheritance

DNA

1. DNA is a long polymer of deoxyribonucleotides.
2. The length of the DNA depends on the number of nucleotide pairs present in it.
3. Bacteriophage lambda has 48,502 base pairs.

Central dogma of molecular biology

1. Crick proposed the Central dogma in molecular biology
2. It states that the genetic information flows from DNA à RNA à Protein.
3. In some viruses like retroviruses, the flow of information is in reverse direction, which is from RNA à DNA à mRNA à Protein.

Structure of polynucleotide chain:

1. A nucleotide has three components-
   - (a) A nitrogen base
   - (b) A pentose sugar (ribose in RNA and deoxyribose in DNA)
   - (c) A phosphoric acid.
2. There are two types of nitrogen bases:
   - (a) Purines (Adenine and Guanine)
   - (b) Pyrimidines (Cytosine, Uracil and Thymine)
3. Adenine, Guanine and Cytosine are common in RNA and DNA.
4. Uracil is present in RNA and in DNA in place of Uracil, Thymine is present.
5. In RNA, Pentose sugar is ribose and in DNA, it is Deoxyribose.
6. Based on the nature of pentose sugar, two types of nucleosides are formed - ribonucleoside and deoxyribonucleotides.
7. Two nucleotides are joined by 3’-5’ Phosphodiester linkage to form dinucleotide.
8. More than two nucleotides join to form polynucleotide chain.
9. The two strands of DNA (called DNA duplex) are antiparallel and complementary, i.i., one in 5’->3’ direction and the other in 3”->5” direction.

History of DNA

1. DNA is an acidic substance in the nucleus.
2. It was first identified by Friedrich Meischer in 1869. He named it as ‘Nuclein”
3. In 1953 double helix structure of DNA was given by James Watson and Francis Crick, based on X-ray diffraction data produced Maurice Wilkins and Rosalind Franklin.

Packaging of DNA Helix

(1) The basic unit into which DNA is packed in the chromatin of eukaryotes.

(2) Nucleosome is the basic repeating structural (and functional) unit of chromatin, which contains nine histone proteins.

(3) Distance between two conjugative base pairs is 0.34nm

(4) The length of the DNA in a typical mammalian cell will be 6.6 X109 bp X 0.34 X10-9 /bp, it comes about 2.2 meters.

(5) The length of DNA is more than the dimension of a typical nucleus (10-6m)

DNA Replication

(1) DNA is the only molecule capable of self duplication so it is termed as a living molecule.

(2) All living beings have the capacity to reproduce because of DNA.

(3) DNA replication takes place in S-phase of the cell cycle. At the time of cell division, it divides in equal parts in the daughter cells.

(4) **Delbruck** suggested three methods of DNA replication i.e.

    (i) Dispersive

    (ii) Conservative

    (iii) Semi-conservative

(5) The process of DNA replication takes a few minutes in prokaryotes and a few hours in eukaryotes.

RNA

(1) RNA is the first genetic material.

(2) RNA is a non hereditary nucleic acid except in some viruses (retroviruses).

(3) RNA used to act as a genetic material as well as catalyst.

(4) It is a polymer of ribonucleotide and is made up of pentose ribose sugar, phosphoric acid and nitrogenous base (A,U,G,C).

(5) RNA may be of two types – genetic and non-genetic.

Genetic Code

(1) Term genetic code was given by **George Gamow (1954).** He was the first to propose the triplet code (one codon consists of three nitrogen bases).

(2) The relationship between the sequence of amino acids in a polypeptide chain and nucleotide sequence of DNA or mRNA is called genetic code.

(3) There occur 20 types of amino acids which participate in protein synthesis. DNA contains information for the synthesis of any types of polypeptide chain. In the process of transcription, information transfers from DNA to m-RNA in the form of complementary N_2-base sequence.

(4) A **codon** is the nucleotide sequence in m-RNA which codes for particular amino acid; whereas the **genetic code**is the sequence of nucleotides in **m-RNA** molecule, which contains information for the synthesis of polypeptide chain.

(5) 61 out of 64 codons code for only 20 amino acids.

(6) The main problem of genetic code was to determine the exact number of nucleotide in a codon which codes for one amino acid.

Characteristics of genetic code

(1) **Triplet in nature**

  (a) A codon is composed of three adjacent nitrogen bases which specify one amino acid in polypeptide chain.

  (b) For example- In m-RNA if there are total 90 N_2– bases. Then this m-RNA determines 30 amino acids in polypeptide chain.

(2) **Univerality**

  (a) The genetic code is applicable universally.

  (b) The same genetic code is present in all kinds of living organism including viruses, bacteria, unicellular and multicellular organisms. In all these organisms, triplet code for specific amino acid.

(3) **Non-ambiguous**

  (a) Genetic code is non ambiguous i.e. one codon specifies only one amino acid and not any other.

  (b) In this case one codon never code two different amino acids. **Exception** GUG codon which code both valine and methionine amino acid.

(4) **Non-overlapping**

  (a) A nitrogen base is a constituent of only one codon.

(5) **Comma less**

  (a) There is no punctuation (comma) between the adjacent codon i.e. each codon is immediately followed by the next codon.

  (b) If a nucleotide is deleted or added, the whole genetic code read differently.

  (c) A polynucleotide chain having 50 amino acids shall be specialized by a linear sequence of 150 nucleotides. If a nucleotide is added in the middle of this sequence, the first 25 amino acids of polypeptide will be same but next 25 amino acids will be different.

(6) **Degeneracy of genetic code**

  (a) Only two amino acids – tryptophan and methionine are specified by single codon.
  UGG for tryptophan, AUG for methionine

  (b) All the other amino acids are specified or coded by 2 to 6 codons.

  (c) Leucine, serine and arginine are coded or specified by 6-codons.

  (d) Degeneracy of genetic code is related to third position (3’-end of triplet codon) of codon. The third base is described as ‘Wobble base’.

Genomics and Human Genome project:

(1) The term genome has been introduced by **Winkler** in 1920 and the genomics is relatively new, coined by**Thomas Rodericks** in 1986.

(2) Genomics is the subdiscipline of genetics devoted to the mapping, sequencing and functional analysis of genomes. Genomics is subdivided into following types:

   (a) **Structural genomics:** It is the study of genome structure deals with the complete nucleotide sequences of the organisms.

   (b) **Functional genomics:** It is the study of genome function which includes transcriptome and proteome. Transcriptome is a complete set of RNAs transcribed from a genome while proteome is a complete set of proteins encoded by a genome and aims the determination of the structure and function of all the proteins in living organisms.

(3) The human genome project, sometimes called "biology's moon shot", was launched on october 1, 1990 for sequencing the entire human genome of 2.75 billion (2.75 ´ 10^9 or 2750000 bp or 2750000 kilobase pairs or 2750 megabase pairs) nucleotide pairs.

(4) Two important scientist associated with human genome are **Francis Collins**, director of the Human Genome Project and **J. Craig Venter**, founding president of Celera genomics.

(5) The complete sequencing of the first human chromosome, small chromosome 22, was published in December 1999.

Genome of Model organisms

S. No.	Organism	No. of base pair	No. of genes
(1)	Bacteriophage	10 thousand	–
(2)	E. coli	4.7 million	4000
(3)	Saccharomyces cerevisiae	12 million	6000
(4)	Caenorhabditis elegans	97 million	18,000
(5)	Drosophila melanogaster	180 million	13,000
(6)	Human	3 billion	30,000
(7)	Lily	106 billion	–

DNA finger printing

(1) **Alec Jeffreys et al** (1985) developed the procedure of genetic analysis and forensic medicine, called DNA finger printing.

(2) It is individual specific DNA identification which is made possible by the finding that no two people are likely to have the same number of copies of repetitive DNA sequences of the regions.

(3) It is also known as DNA profiling.

(4) The chromosomes of every human cell contain scattered through their DNA short, highly repeated 15 nucleotide segments called “mini-satellites” or variable-number Tandem Repeat (VNTR).

Technique for DNA fingerprinting

(1) Only a small amount of tissues like blood or semen or skin cells or the hair root follicle is needed for DNA fingerprinting.
(2) Typically DNA content of about 100,000 cells or about 1 microgram is sufficient.
(3) The procedure of DNA fingerprinting involves the following major steps:
    (i) DNA is isolated from the cells in a high-speed refrigerated centrifuge.
    (ii) If the sample of DNA is very small, DNA can be amplified by Polymerase Chain Reaction (PCR).
    (iii) DNA is then cut up into fragments of different length using restriction enzymes.
    (iv) The fragments are separated according to size using gel electrophoresis through an agarose gel. The smaller fragments move faster down the gel than the larger ones.
    (v) Double stranded DNA is then split into single stranded DNA using alkaline chemicals.
    (vi) These separated DNA sequences are transferred to a nylon or nitrocellulose sheet placed over the gel. This is called ‘Southern Blotting’ (after **Edward Southern**, who first developed this method in 1975).
    (vii) The nylon sheet is then immersed in a bath and probes or makers that are radioactive synthetic DNA segments of known sequences are added. The probes target a specific nucleotide sequence which is complementary to VNTR sequences and hybridizes them.
    (viii) Finally, X-ray film is exposed to the nylon sheet containing radioactive probes. Dark bands develop at the probe sites which resemble the bar codes used by grocery store scanners to identify items.

Applications of DNA fingerprinting

This technique is now used to:

(i) Identify criminals in forensic laboratories.
(ii) Settle paternity disputes.
(iii) Verify whether a hopeful immigrant is, as he or she claims, really a close relative of already an established resident.
(iv) Identify racial groups to rewrite biological evolution.

Evolution

(i) Ancient theories of origin of life:

(a) Theory of special creation.

(b) Theory of spontaneous generation or Abiogenesis.

(c) Biogenesis

(d) Cosmozoic theory

(e) Theory of sudden creation from inorganic material.

(f) Naturalistic theory

(ii) Oparin's Modern Theory:

(a) Oparin (1924) proposed that “life could have originated from non-living organic molecules.”

(b) He believed in Biochemical origin of life. Haldane (1929) also stated similar views. Oparin greatly expanded his ideas and presented them as a book “The origin of life” in 1936.

(c) According to this theory, the Earth originated about 4,500 million years ago. When the earth was cooling down, it had a reduced atmosphere. In this primitive atmosphere nitrogen, hydrogen, ammonia, methane, carbon mono-oxide and water were present. Energy was available in the form of electric discharges by lightening and ultraviolet rays. As soon as the earth crust was formed, it was very much folded. Torrential rains poured over the earth for centuries and were deposited in deep places.

(d) **Miller's Experiment:** An American scientist (Biologist) Stanley Miller (1953) performed an experiment under support Oparin's theory of origin of life. He believed that basic compounds which are essential for life can be synthesised in the laboratory by creation in the laboratory, on a small scale, the conditions which must have existed at the time of origin of life on earth.

(e) Miller took a flask and filled it with methane, ammonia and hydrogen in proportion of 2:1:2 respectively at 0°C. This proportion of gases probably existed in the environment at time of origin of life. This flask was connected with a smaller flask, that was filled with water, with the help of glass tubes. In the bigger flask, two electrodes of tungsten were fitted. Then a current of 60,000 volts was passes, through gases containing bigger flask for seven days. At the end of seven days, when the vapours condensed, a red substance was found in the U-tube. When this red substance was analyzed, it was found to contain amino acids, Glycine and nitrogenous bases which are found in the nucleus of a cell.

(f) The entire process of the origin of life, as proposed by Oparin, can be summarised as under –

(i) **The Chemical Evolution:**

(1) Step 1: Formation of simple molecules

(2) Step 2: Formation of Simple organic compounds

(3) Step 3: Formation of complex organic compounds

(4) Step 4: Formation of nucleic acids and nucleoproteins

(ii) **Organic Evolution:**

  1. Step 5: Formation of Coacervates
  2. Step 6: Formation of Primitive cell
  3. Step 7: Origin of autotrophism
  4. Step 8: Origin of Eukaryotic cells

Evidences of Organic Evolution

The following are the evidences in favour of Organic Evolution:

(i) Evidences from Classification

(ii) Evidences from Comparative Anatomy

  (a) Analogy and Homology

  (b) Vestigeal organs

(iii) Evidences from Physiology

(iv) Evidences from Serology

(v) Evidences from Embryology

(vi) Evidences from Palaeontology

(vii) Evidences from geographic distribution

(viii) Evidences from Genetics

(i) **Evidences from Classification:** All the known living animals and plants have been classified into various species, genera, families, order, classes, phyla and kingdoms. The classification of a particular animal is attempted only after its extensive study.

(ii) **Evidences from Comparative Anatomy:** In all the living animals, the basic substance of life is Protoplasm. If the species had been created separately, then there should be no relationship in the various organs and systems of animals. But on the contrary, we see that large number of animals although unlike in appearance show most of the systems and organs made on the same plan. The resemblance is very close in the members of the same group.

(iii) **Evidences from Physiology**: Various types of chemical tests exhibit many basic similarities in physiological and chemical properties that show a physiological relationship among animals.

(iv) **Evidences from Serology:** This is a method by which the reactions of blood serum are observed. From the blood are also extracted the crystals of Oxyhaemoglobin. The structure differs in different vertebrates, but in a definite order. The reaction is nearly identical in man and anthropoid monkeys, but slightly less identical with other mammals.

(v) **Evidences from Embryology:** With the exception of a few, every multi-cellular animal originates from a zygote. The development from zygote to adult shows many similarities in various organisms. The development is termed as ontogeny

(vi) **Evidences from Palaeontology:** The study of fossils and their interpretation forms one of the great evidences of evolution. An Italian scientist, Leonardo da Vinci, was the first person to recognize their importance and said they were either remains of organisms of their impressions on some sort of clay or rock.

Important living fossils

1. Peripatus (Arthropoda)	**2. Limulus (Arthropoda)**
3. Nautilus (Mollusca)	4. Neopilina (Mollusca)
5. Lingula (Brachiopoda)	6. Latimeria (Coelacanth fish)
7. Sphenodon (Reptilia)	8. Didelphis (Opossum)

(vii) **Evidences from geographic distribution:** If the study of horizontal distribution of animals on the face of this earth is made, it would be seen that animals are not evenly distributed. Two identical places with the same climate and vegetation may not have same sort of animal fauna

(viii) **Evidences from Genetics:** Johan Gregor Mendel in 1866 published his work on experimental breeing. He bred two individuals differing in certain well-defined characters, and observed the ratio in which various contrasting parental characters appeared in successive generations.

(c) **Connecting links:** Intermediate or intergrading forms between two groups of organisms:

Organism	**Connecting link between**
1. Viruses	Living and nonliving
2. Euglena (Protozoa)	Plants and animals
3. Proterospongia (Protozoa)	Protozoa and Porifera
4. Peripatus (Arthropoda)	Annelida and Arthropoda
5. Neopilina (Mollusca)	Annelida and Mollusca
6. Balanoglossus (Chordata)	Nonchordata and Chordata
7. Dipnoi (Lungfish)	Pisces and Amphibia
8. Archaeopteryx (Aves)	Reptiles and Birds
9. Prototheria (Mammalia)	Reptiles and Mammals

Theories of organic evolution

(i) **Lamarckism:** Lamarck (1744 –1829) was one of the most brilliant stars on the horizon of the history of evolution. He was the first naturalist to put forward a general theory of evolution in his famous book. Philosophic Zoologique published in 1809. His evolutionary theory may be summarised in the form of following laws:

- (a) The internal forces of life tend to increase the size of an organism.
- (b) The necessity in animals to produce new structures.
- (c) The effect of use and disuse.
- (d) Inheritance of acquired characters.

(iii) **Darwinism:** Charles Robert Darwin was undoubtedly the first naturalist who put the idea of organic evolution on sound footing. His statements and theories were based upon practical experiences and large number of proofs which he collected directly from the nature.

His main ideas about the evolution are given below –

- (a) Over – production of offspring
- (b) Limited supply of food and shelter
- (c) Struggle for existence:
  - (i) Intra –specific
  - (ii) Inter –specific
  - (iii) Environment
- (d) Survival of the fittest
- (e) Universal occurrence of variations
- (f) Inheritance
- (g) Natural selection

Difference between Darwinism and Neo–Darwinism

Darwinism (Natural Selection)	Neo–Darwinism
(1) It is the original theory given by Charles Darwin (1859) to explain the origin of new species.	(1) Neo–Darwin is a modification of the original theory of Darwin to remove its short–comings.
(2) According to this theory accumulation of continuous variations causes changes in individuals to form new species.	(2) Instead of continuous variations, mutations are believed to help form new species.
(3) It believes in the selection of individuals on the basis of accumulation of variation.	(3) Variations accumulate in the gene pool and not in the individuals.
(4) Darwinism does not believe in isolation.	(4) Neo–Darwinism incorporates isolation as an essential component of evolution.
(5) It can explain the origin of new characters.	(5) The theory can explain the occurrence of unchanged forms over millions of years.
(6) Darwinism cannot explain the persistence of certain forms in the unchanged condition.	(6) Normally only those modifications are transferred to next generation which influence germ cells or where somatic cells give rise to germ cells.

Enhancement in Food Production

Enhancement in Food Production

Poultry

Poultry includes the birds like chicken (hen), ducks, geese and turkey. Poultry farming deals with the rearing of them for their eggs and meat. it has become an important small scale industry due to modern need for palatable and nutritive food which it provides in the form of eggs as well as adult animal. An egg laying poultry bird is called layer and the poultry birds groomed for obtaining meat are called chicken or broilers.

Livestock

The word livestock refers to the domestic animals kept or dealt in for use or profit. It includes cattle, buffaloes, sheep, goats, pigs, horses, mules, donkeys and camels. The most important of these are cattle and buffaloes.

Importance of cattle and Buffaloes: Cattle and buffalo are most important forms of domesticated animals. They are next to land in use for farmers. They are widely used for:

(a) **Agricultural Operations:**
(b) **Milk:**
(c) **Transport:**
(d) Manure and fuel:
(e) **Leather:** .
(f) **Glue and gelatin:**
(g) **Meat:**
(h) **Hair:**
(i) **Hybridisation:**

Breed	Distribution
Murrah	Punjab, Haryana, Uttar Pradesh
Bhadawari	Uttar Pradesh, Madhya Pradesh
Jaffrabadi	Gujrat
Surti	Rajasthan, Gujrat
Mehsana	Gujrat
Nagpuri or Ellichpuri	Central and South India
Nili Ravi	Punjab, Haryana

Some Breeds of Indian Cattle

Milch Breeds	Distribution
1. Gir	Gujrat, Rajasthan
2. Sahiwal	Punjab, Haryana, Uttar Pradesh
3. Red Sindhi	Andhra Pradesh
4. Deoni	Andhra Pradesh

Some Breeds of Indians Buffaloes

Apiculture

(1) Apiculture is the science of rearing honeybees for obtaining honey, wax and venom. It is a profitable money-making hobby. It forms a cottage industry, when carried out on a large scale.

(2) Three species of honey bees are commonly found in india vig. *Apis indica* (The small indian bee). *Apis florea*(The little indian bee) and. *Apis dorsata* (the giant bee) other important species include *Apis milifera* (the common European bee.

(i) **Honeybee-*Apis*:** Like termites, honeybees are social insects known for producing honey and beeswax, and for living in very highly organized colonies. These feed upon nectar and pollen of flowers, possess "sucking and chewing" mouth parts, and undergo complete metamorphosis. Each colony has its own nest called honeycomb or beehive.

(ii) **Division of labour and polymorphism:** Each beehive harbours a colony of thousands of polymorphic bees belonging to a single family. The polymorphic individuals are of three main types (i) a single queen (fertile female)(ii) one to a few hundred drones (fertile males) and (iii) thousands (upto 60,000) of worker bees (sterile females).

(iii) **Life History:** Queen lays about 2,000 eggs a day. The eggs are laid in the comb, one in each cell. They hatch out into larvae in three days. They are fed on royal jelly for a few days. But the larva which develops into the queen will be fed on royal jelly continuously.

During breeding, the queen bee flies in the air along with the males. This phenomenon is called nuptial flight. During nuptial flight the queen copulates with a male Copulation occurs in the air. Then the bees return to the comb and the queen starts laying eggs.

(iv) **Bee-Hive**: Honey bee is one of the few domesticated insects. In modern days bee colonies are reared in artificial wooden boxes for maximum production of honey and wax. The artificial box where the bee colony is maintained and managed is called hive. The place where hives are kept and managed is called apiary.

(v) **Honey extraction:** Honey is stored in combs of super frames. It is extracted from the comb by a simple machine called honey extractor. It has a drum containing a rack inside to hold the super frames. It is made to rotate by a set of two-gear wheels, operated by a handle.

The super frames are removed from the hive. The caps of the comb cells are cut off by a double edged knife. Then the frames are fixed in the rack and the rack is made to rotate by operating the handle. The honey is forced out into the drum from the comb cells. From the drum the honey is collected in vessels through an exit present in the drum.

(vi) **Location of Apiary**

(a) The hives should be set, in places where there are plenty of flowering plants.

(b) They should be placed in shady places.

(c) The place should be neat and clean and free from any obnoxious smell.

(d) There should be clean drinking water nearby because each bee colony requires two glasses of water per day for their survival

(viii) **Chemical composition:** Honey contains nearly 80 different substances of importance to human beings. The important chemicals are as follows:

It contains a large amount of glucose or fructose.

Fisheries

(i) Fishes are a valuable and easily accessible source of food, rich in protein, highly nutritious and easily digestible. By the aquatic animals, they are abundantly available from sea, rivers, lakes, ponds and marshes.

(ii) **Classification of cultivable fish species**

Zoological name	Common Name	Areas of availability
(a) Fresh water fishes		
1. *Catla catla*	Catla	All over India common in Krishna and Godavari rivers
2. *Labeo rohita*	Rohu	North, East and South India
3. *Labeo calbasu*	Calbasu	North and South India
4. *Cirhinus mrigala*	Mrigal	North and South India
5. *Mystus singhala*	Singhala	All over India
6. *Heteropneustes fossilaris*	Singhi	All over India
7. *Wallago attu*	Malli	North, east and South India
8. *Clarius batrachus*	Fresh water shark magur	All over India
(b) Brackish water fishes		
9. *Chanos chanos*	Milk fish	A.P.coast
10. *Mugil cephalus*	Grey mullet	East coast
11. *Laters calcorifer*	Perch	East coast
(c) Marine fishes		
12. *Sardinella longiceps*	Oil sardine	West and south coasts
13. *Harpodon heherius*	Bombay duck	Maharastra coast
14. *Hilsa ilisha*	Hilsa/ Indian shed	Coastal India
15. *Stromateus sinensis*	Pomfret	Indo pacific coast
16. *Anguilla anguilla*	Eel	Coastal India
17. *Aluitheronema*	Salmon	East and west coast
18. *Cyano-glossus semifas- ciatus*	Flat fish	East coast of India

(iii) **Culture method:** The success in fish culture and the high production of table - size fish through carp culture depends largely on the designing and construction of ponds. The basic principles involved in designing and construction of carp culture ponds are of very specialized nature and vary from region to region depending upon several factors like topography, soil types, water supply etc. The requirements with regard to the designing and construction of fish farm are entirely different from those attributed to agriculture and animal husbandry farms.

Health & Diseases

Types of Diseases

The diseases may be broadly classified into two types: Congenital and acquired.

(i) **Congenital Diseases:** These are anatomical or physiological abnormalities present from birth. They may be caused by (i) a single gene mutation (alkaptonuria, phenylketonuria, albinism, sickle-cell anaemia, haemophilia, colour blindness); (ii) chromosomal aberrations (Down's syndrome, Klinefelter's syndrome, Turner's syndrome); or (iii) environmental factors (cleft palate, harelip). Unlike the gene-and chromosome-induced congenital defects, environmentally caused abnormalities are not transmitted to the children.

(ii) **Acquired Diseases:** These diseases develop after birth. They are further of two types: communicable and non-communicable.

  (a) **Communicable (Infectious) Diseases:** These diseases are caused by viruses, rickettsias, bacteria, fungi, protozoans and worms.

  (b) **Noncommunicable (Noninfectious) Diseases:** These diseases remain confined to the person who develops them and do not spread to others. The non-communicable diseases are of four kinds –

(1) **Organic or Degenerative Diseases:** These diseases are due to malfunctioning of some of the important organs, *e.g*, heart diseases, epilepsy. Heart diseases result from the abnormal working of some part of this vital organ. Epilepsy may result from abnormal pressure on regions of the brain.

(2) **Deficiency Diseases :** These diseases are produced by deficiency of nutrients, minerals, vitamins, and hormones, *e.g.*, kwashiorkor, beriberi, goitre, diabetes are just a few from a long list.

(3) **Allergies:** These diseases are caused when the body, which has become hypersensitive to certain foreign substance, comes in contact with that substance. Hay fever is an allergic disease.

(4) **Cancer:** This is caused by a uncontrolled growth of certain tissues in the body.

Bacterial diseases and their pathogens

Disease	Causative Bacterium
Cholera	*Vibrio comma (Vibrio cholerae)*
Pneumonia	*Diplococcus pneumoniae*
Typhoid	*Salmonella typhi*
Tetanus	*Clostridium tetani*
Diphtheria	*Corynebacterium diphtheriae*
Whooping cough	*Bordetella pertussis*
Tuberculosis	*Mycobacterium tuberculosis*

Plague	*Pasteurella pestis*
Leprosy	*Mycobacterium leprae*
Syphilis	*Treponema pallidium*
Gonorrhoea	*Neisseria gonorrhoeae*
Diarrhoeal Diseases	*Escherichia coli, Shigella dysenteriae, Campylobacter, Salmonella*
Anthrax	*Bacillus anthracis*

The Immune System

(1) **Immunity –** The ability of the body to protect against all types of foreign bodies like bacteria, virus, toxic substances etc. which enter the body.

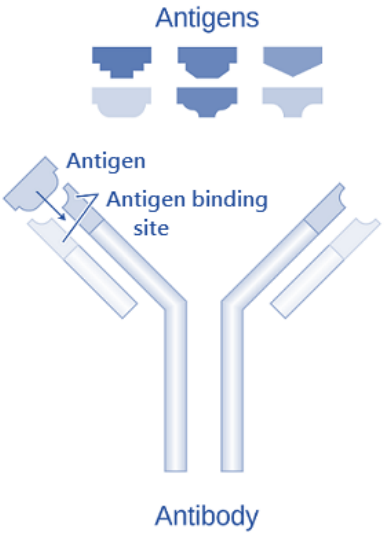
(2) The science dealing with the various phenomena of immunity, induced sensitivity and allergy is called immunology.

(3) **Immune Response -** Third line of defence. Involve production of antibodies and generation of specialized lymphocytes against specific antigens.

(4) **Antigens –** Substances which stimulate the production of antibodies, when introduced into the body.

(5) **Antibodies –** Immunoglobulins (Igs) which are produced in the body in response to the antigen or foreign bodies.

(6) All antibodies are immunoglobulins but all immunoglobulins are not antibodies.



(7) There are two major types of immunity: Innate or Natural or Non-specific immunity and Acquired or Adaptive or Specific Immunity.

Innate Immunity	Acquired Immunity
1. Includes all defence elements with which an individual is born.	1. The immunity which is acquired after the birth.
2. Consists of various types of barriers that prevent the entry of foreign agents.	2. Consists of specialized cells (T-cells and B-cells) and antibodies that circulate in the body fluid.
3. It remains throughout life.	3. It can be short lived or life long.

Malaria:

Malaria has been for thousands of years a very serious disease of the tropical and temperate regions. It was almost eliminated a few years back with the efforts of World Health Organization (WHO) and our National Malaria Eradication Programme (NMEP), but unfortunately, it has appeared again.

(a) **Symptoms:** The attack of malaria is preceded by yawning, tiredness, headache and muscular pain. During the fever, the patient feels chilly and shivers, and has acute headache, nausea and high temperature. After a few hours, the body perspires freely and the temperature becomes normal. The cycle is repeated if no medicine is taken. Blood smear made during fever shows the malarial parasites. No parasites are seen at other times. In chronic cases, there is general weakness and anaemia (paleness) due to large-scale destruction of red blood corpuscles. This is also accompanied by enlargement of spleen and liver.

(b) **Cause:** Malaria is caused by the toxins produced in the human body by the malarial parasites, *Plasmodium*.

(c) **Transmission:** The malarial parasites are carried from the infected to the healthy persons by the female*Anopheles* mosquito. The mosquito picks up the parasites with the blood, when it bites an infected person. When this infected mosquito bites a healthy person, parasites migrate into his blood with the saliva, which the mosquito injects before sucking up blood to prevent its clotting.

(d) **Types:** There are four species of *Plasmodium*, which cause different kinds of human malaria –

   (1) *P. Vivax* : It causes **benign tertian malaria,** which attacks every third day, *i.e.*, after 48 hours. The fever is mild and seldom fatal. This species is wide-spread in the tropical and temperate regions.

   (2) *P. ovale* : It also causes benign tertian malaria, which recurs every 48 hours. This species is found only in West Africa and South America.

   (3) *P. malariae* : It causes **quartan malaria,** which recurs every fourth day, *i.e.*, after 72 hours. This species is found in both tropical and temperate regions, but it is not very common.

   (4) *P. falciparum* : It alone is capable of causing three types of malaria, *viz*., quotidian malaria, which attacks almost daily, malignant tertian malaria, which occurs every 48 hours, but is very severe and often fatal; and irregular malaria. This species is found only in the tropical region.

(e) **Incubation Period:** The incubation period for malaria caused by *Plasmodium vivax* is about 10 days.

(f) **Life-history:** *Plasmodium* completes its life cycle in two phases and two hosts: asexual phase in the human host and sexual phase in the female *Anopheles* mosquito host.

Sexually Transmitted diseases

Acquired Immune Deficiency Syndrome (AIDS) :

Symptoms of AIDS: An HIV infection can be divided into 3 stages.

1. **Asymptomatic Carrier:** Only 1%-2% of those newly infected have mononucleosis-like symptoms that may include fever, chills, aches, swollen lymph glands, and an itchy rash. These symptoms disappear, and there are no other symptoms for 9 months or longer.
2. **AIDS Related Complex (ARC):** The most common symptom of ARC is swollen lymph glands in the neck, armpits, or groin that persist for 3 months or more.
3. **Full-Blown AIDS:** In this final stage, there is severe weight loss and weakness due to persistent diarrhoea and usually one of several opportunistic infections is present.
4. **Treatment of AIDS:** The drug **zidovudine** (also called azidothymidine, or AZT) and dideoxyinosine (DDI) prevent HIV reproduction in cells. Proteases are enzymes HIV needs to bud from the host cell; researchers are hopeful that a protease inhibitor drug will soon be available.

AIDS Prevention: Shaking hands, hugging, social kissing, coughing or sneezing and swimming in the same pool do not transmit the AIDS virus. You cannot get AIDS from inanimate objects such as toilets, doorknobs, telephones, office machines, or household furniture.

HIV has been isolated from semen cervical secretions, lymphocytes, plasma, cerebrospinal fluid, tears, saliva, urine and breast milk. The secretions known to be especially infectious are semen, cervical secretions, blood and blood products. Infection is spread :

(a) By sexual intercourse, vaginal and anal

(b) By infected blood, blood products, donated semen and organs

(c) By contaminated needles used :

- (1) During the treatment of patients
- (2) When drug abusers share needles

(d) From an infected mother to her child :

- (1) Across the placenta before birth
- (2) While the baby is passing through the birth canal
- (3) Possibly by breast milk

Diagnosis: Once the host is infected by HIV. HIV detected by the ELISA Test. (Enzyme–linked immunosorbent assay a positive Elisa should be can firmed using another test called the western blot test.

Cancer: Cancer is an abnormal and uncontrolled division of cells, known as cancer cells that invade and destroy the surrounding tissues. Generally Cancer is defined as uncontrolled proliferation of cells without any differentiation.

(i) Neoplasms or Tumours : A neoplasm (new growth) is a mass of tissue that grows in excess of normal in an uncordinated manner and continues to grow after the initial stimulus has ceased. Tumours are classified as benign or malignant.

(ii) **Oncology:** (G. *onkos* – mass, tumour; logos – study of) is the field of biomedicine devoted to the study and treatment of tumours.

(a) **Types of Tumors:** There are two types of tumours : benign and malignant.

(1) **Benign Tumour – (=Nonmalignant Tumour) :** It remains confined to the site of its origin and does not spread to other parts of the body. It causes limited damage to the body. It is non-cancerous.

(2) **Malignant Tumour (= Cancerous Tumour):** It first grows slowly. No symptoms are noticed. This stage is called the latent stage. The tumor later grows quickly. The cancer cells go beyond adjacent tissue and enter the blood and lymph. Once this happens, they migrate to many other sites in the body where the cancer cells continue to divide. It is **metastasis**. Only malignant tumours are properly designated as cancer.

Differences between Benign Tumour and Malignant Tumour

Benign Tumour	Malignant Tumour
(1) It remains confined to the affected organ.	(1) It also spreads to other organs of the body.
(2) Rate of growth is usually slow.	(2) Rate of growth is usually rapid.
(3) There is no latent stage.	(3) There is latent stage.
(4) It causes limited damage to the body.	(4) The cancer cells migrate to other sites of the body.
(5) There is no metastasis.	(5) There is metastasis.
(6) It is non-cancerous.	(6) It is cancerous.

(b) **Types of Cancer (Types of Malignant Tumours) :** Malignant tumours are generally classified into three main types on the basis of cell type from which they arise.

(1) **carcinomas:** cancer of epithelial tissue

(2) sarcomas: cancer of connective tissue and muscular tissue

(3) Leukemia : cancer of blood

Microbes in Human Welfare

Bacteria

(1) Study of bacteria is called bacteriology.

(2) Linnaeous placed them under genus vermes.

(3) *Nageli* classified bacteria under schizomycetes.

(4) Bacteria are unicellular, microscopic organisms.

(5) These are the smallest cell wall having prokaryotic cell.

(6) They differ from animals in having a rigid cell wall and being capable to synthesize vitamins.

Size:

(i) Bacteria are the smallest of all known cellular organisms which are visible only with the aid of microscope.

(ii) They are 3 to 5 microns (1 m = 1/1000 millimetre or about 1/25,000 inch) in length.

(iii) A few species of bacteria are approximately 15*m* in diameter.

Shape:

(i) The shape bacteria usually remain constant.

(ii) Some of them are able to change their shape and size with changes in environmental conditions. Such bacteria, which change their shape, are called pleomorphic.

(e) **Filament:** The body of bacterium is filamentous like a fungal mycelia. The filaments are very small *e.g.*Beggiota, Thiothrix etc.

(f) **Stalked:** The body of bacterium posses a stalk *e.g.* Caulobacter.

(g) **Budded:** The body of bacterium is swollen at places *e.g.* Retrodomicrobiom.

Role of Bacteria in nitrogen cycle:

Nitrogen cycle existing in nature, comprises of –

Nitrogen fixation:

(1) Many free-living soil inhabiting bacteria such as, *Azotobacter* (aerobic), *Clostridium* (anaerobic), etc. have ability to fix atmospheric nitrogen into ammonia.

(2) The other group of nitrogen fixing bacteria lives in symbiotic association with other plants.

(3) The most important symbiotic nitrogen fixing bacteria is *Rhizobium* spp.

(4) The various species of *Rhizobium* inhabit different leguminous plants. For example, *R. leguminosarium* infects soyabeans, etc.

(5) They develop root nodules and fix atmospheric nitrogen into ammonia in symbiotic association with leguminous plants.

(6) The fixed nitrogen is partly taken up by the leguminous plants and metabolised.

(7) A part of fixed nitrogen is diffused out into the surrounding soil.

Ammonification:

(1) The nitrogenous compounds of the dead remains of plants, animals and their excretory products are decomposed into ammonia by a number of bacteria and other microorganisms.

(2) The conversion of nitrogenous organic compounds into ammonia is termed as ammonification.

(3) It is carried by many ammonifying bacteria such as *Bacillus ramosus, B. vulgaris, B. mycoides,* etc.

Nitrification:

(1) Many bacteria enhance the nitrogen fertility of soil by converting ammonium compounds to nitrites (*e.g., Nitrosomonas*) and nitrites into nitrates (*e.g., Nitrobacter*).

(2) The *Nitrosomonas* group oxidizes ammonia into nitrite –

$$NH_4^+ + 3/2\,O_2 \longrightarrow NO_2^- + H_2O + H^+ + \text{Energy}\uparrow$$

(3) The *Nitrobacter* group oxidizes nitrite to nitrates –

$$NO_2^- + 1/2\,O_2 \longrightarrow NO_3^- + \text{Energy}\uparrow$$

Denitrification:

The nitrates and ammonia are converted to nitrous oxide and finally to nitrogen gas by several denitrifying bacteria, *e.g., Pseudomonas fluorescence, P. denitrificans, Bacillus subtilis, Thiobacillus denitirficans,* etc.

Useful activities

(i) **Decay of organic wastes**

(ii) **Role in improving soil fertility**

  (a) **Humus:** The microbial decomposition of organic matter and mineralization results in the formation of complex amorphous substance called **humus**. The humus improves the aeration, water holding capacity, solubility of soil minerals, oxidation-reduction potential and buffering capacity of the soil.

  (b) **Composting:** It is conversion of farm refuse, dung and other organic wastes into **manure** by the activity of saprotrophic bacteria (*e.g., Bacillus stearothermophilus, Clostridium thermocellum, Thermomonospora* spp, etc.)

  (c) **Adding sulphates:** A few sulphur bacteria (*e.g., Beggiatoa*) add sulphur into the soil by converting H_2S into sulphates.

(iii) **Sewage, disposal:** Ability of anaerobic bacteria to purify the organic matter is used in the the sewage disposal system of cities. The faeces are stored in covered reservoirs and allowed to purify.. The common bacteria involved in sewage disposal are –*Coliforms* (*E. coli*), *Streptococci, Clostridium, Micrococcus, Proteus, Pseudomonas, Lactobacillus,* etc.

(iv) **Role in Industry:**

  (a) **Lactic acid**.
  (b) **Curd**
  (c) **Cheese**
  (d) **Butter**
  (e) **Retting process**
  (f) **Vinegar**
  (v) **Role of bacteria in human being**
  (vi) **Medicinal uses**
    (a) **Vitamins**
    (b) **Serum and vaccines**
    (c) **Enzymes**.
    (d) **Antibiotics**

List of some common antibiotics, their sources and their applications

S. No.	Antibiotic	Obtained from	Used against
A	Streptomycin	*Streptomyces griseus*	Gram-positive and Gram-negative bacteria, TB, tularemia (rabbit fever), influenza, meaningitis, baciltary dysentery, etc.
B	Actidine	*S. griseus*	Plant diseases caused by fungi.
C	Chloromycetin	*S. venezuelae*	Gram-positive and Gram- negative bacteria, typhoid, rickettsias
D	Tetracycline	*S. aurefaciens*	Gram-positive and Gram-negative bacteria, rickettsiae.
E	Terramycin	*S. ramosus*	Gram positive and Gram-negative bacteria.
F	Erythromycin	*S. erythreus*	Gram positive bacteria, whooping cough, diphtheria.
G	Neomycin	*S. fradiae*	Gram- positive, Gram negative and TB bacteria.
H	Amphomycin	*S. carus*	Gram-positive bacteria,
I	Amphotericin B	*S. nodosus*	Yeast, fungi
J	Leucomycin	*S. kitasoensis*	Gram-positive bacteria.
K	Trichomycin	*S. hachijoensis*	Yeast and fungi.
L	Viomycin	*S. floridae*	Gram-positive, Gram-negative and TB bacteria.
M	Bacitracin	*Bacillus subtilis*	Gram-positive bacteria
N	Gramicidin	*B. brevis*	Gram-positive bacteria.
O	Tyrothricin	*B. brevis*	Gram-positive and Gram-negative bacteria.
P	Polymyxin B	*Aerobacillus polymyxa*	Gram-negative bacteria.

Microbes in production of biogas

Methanogens:

These are strict anaerobic bacteria and mainly occur in muddy areas and also in stomach of cattle, where cellulose is fermented by microbes. These are responsible for methane gas (CH_4) formation in bio-gas plants, because they have capacity to produce CH_4 from CO_2 or formic acid ($HCOOH$).

Biotechnology & its Applications

Recombinant DNA technology

Definition:

Genetic engineering, a kind of biotechnology, is the latest branch in applied genetics dealing the alteration of the genetic makeup of cells by deliberate and artificial means. Genetic engineering involves transfer or replacement of genes, so also known as recombination DNA technology or gene splicing.

Tools of genetic engineering:

(1) Two enzymes used in genetic engineering are restriction endonuclease and ligases.

(2) R.E. is used to cut the plasmid as well as the foreign DNA molecules of specific points while ligase is used to seal gaps or to join bits of DNA.

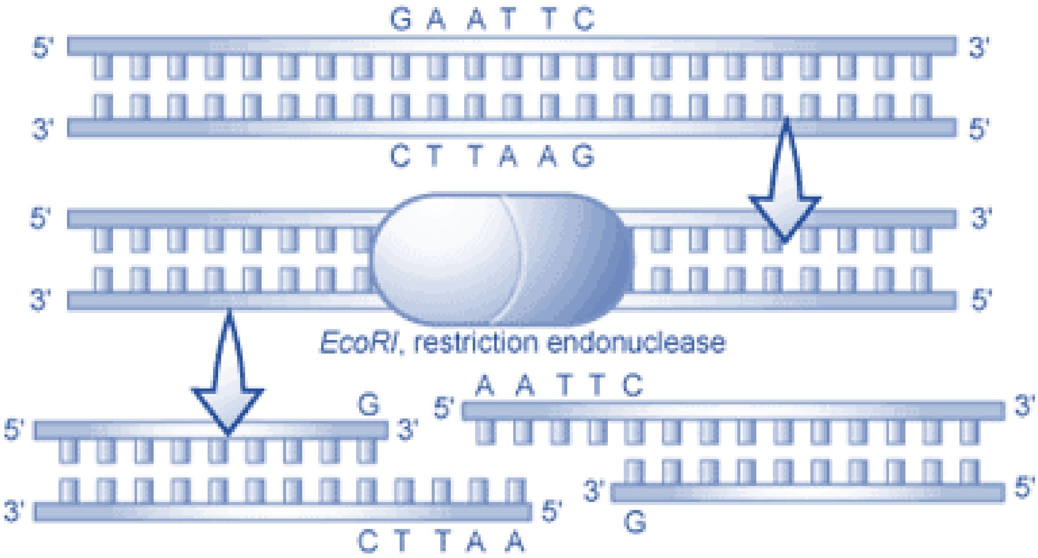
(3) The ability to clone and sequence essentially any gene or other DNA sequence of interest from any species depends on a special class of enzymes called restriction endonucleases.

(4) Restriction endonucleases are also called as molecular scissors or 'chemical scalpels'.

(5) Restriction endonucleases cleave DNA molecules only at specific nucleotide sequence called restriction sites.

(6) The first restriction enzyme identified from a bacterial strain is designated I, the second II and so on, thus, restriction endonuclease EcoRI is produced by Escherichia coli strain RY 13.

(7) Restriction enzyme called EcoRI recognizes the sequence



(8) It then cleaves the DNA between G and A on both strands. Restriction nucleases make staggered cuts; that is, they cleave the two strands of a double helix at different joints and blunt ended fragments; that is, they cut both strands at same place.

Steps of recombinant DNA technology

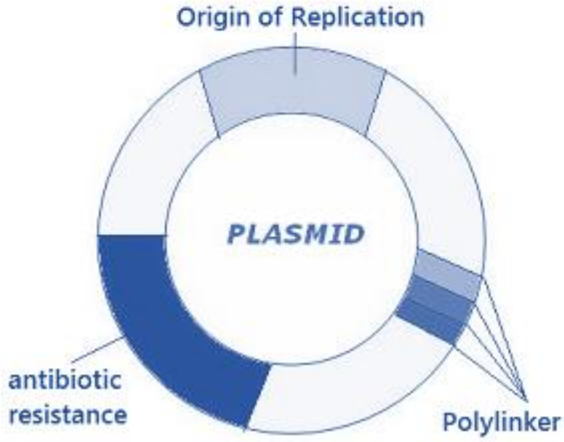
(1) Isolating a useful DNA segment from the donor organism.

(2) Splicing it into a suitable vector under conditions to ensure that each vector receives no more than one DNA fragment.

(3) Producing of multiple copies of his recombinant DNA.

(4) Inserting this altered DNA into a recipient organism.

(5) Screening of the transformed cells.



Vectors:

Vector in genetic engineering is usually a DNA segment used as a carrier for transferring selected DNA into living cells. These are as follows:

(1) **Plasmid:** Plasmid is extra chromosomal, closed circular double stranded molecules of DNA present in most eukaryotes. All plasmid carry replicons pieces of DNA that have the genetic information required to replicate. Plasmid pBR 322 was one of the first widely used cloning vectors, it contain both ampicillin and tetracycline resistance genes.

(2) **Phage:** It is constructed from the phage *l* chromosomes and acts as bacteriophage cloning vectors.

(3) **Cosmid:** The hybrids between plasmid and the phage *l* chromosome give rise to cosmid vectors.

(4) Beside all these there are artificial chromosomes like

  (i) BACs (Bacterial Artificial chromosomes)

  (ii) YACs (Yeast Artificial chromosomes)

  (iii) MACs (Mammalian Artificial chromosomes) are very efficient vectors for eukaryotic gene transfers.

Application of recombinant DNA technology:

The technique of recombinant DNA can be employed in the following ways.

(1) It can be used to elucidate molecular events in the biological process such as cellular differentiation and ageing. The same can be used for making gene maps with precision.

(2) In biochemical and pharmaceutical industry, by engineering genes, useful chemical compounds can be produced cheaply and efficiently which is shown in table.

Applications of recombinant DNA products

Medically useful recombinant products	Applications
Human insulin	Treatment of insulin-dependent diabetes
Human growth hormone	Replacement of missing hormone in short stature people
Calcitonin	Treatment of rickets
Chronic gonadotropin	Treatment of infertility
Blood clotting factor VIII/IX	Replacement of clotting factor missing in patients with Haemophilia A/B
Tissue plasminogen activator	Dissolving blood clots after heart attacks and strokes
Erythropoitin	Stimulation of the formation of erythrocytes (RBCs) for patients suffering from anaemia during kidney dialysis or side effects of AIDS patients treated by drugs
Platelet derived growth factor	Stimulation of wound healing
Interferon	Treatment of pathogenic viral infections, cancer
Interleukins	Enhancement of action of immune system
Vaccines	Prevention of infectious diseases such as hepatitis B, herpes, influenza, pertussis, meningitis, etc.

Cloning:

Cloning is the process of producing many identical organisms or clones. In this process nucleus of ovum (n) is removed and replaced by nucleus of diploid cell of same organism. Now the egg with 2*n* nucleus is transferred to the uterus of mother to have normal pregnancy and delivers clone of itself.

Examples of organism cloning

1. Cloning of sheep was done by **Dr. Ian Wilmut** (1995) of Roslin Institute, Edinberg U.K. and normal healthy lamb (DOLLY) was born in Feb, 1996. This lamb was exactly similar to her mother.
2. The first cloned calves George and Charlie were born in January 1998.
3. ANDI was the world’s first genetically altered primate produced by inserting a jelly fish gene into the embryo of a rhesus monkey.
4. Scientist at Scotland cloned POLLY and MOLLY. Unlike Dolly, polly and molly were transgenic (they carried human protein gene) polly and molly were born in july 1997.
5. **Brigitte Boissliar**, a 46-year old french chemist announced the creation of the world’s first cloned human boby nicknamed “Eve” (December 2002).

Polymerase chain reaction (PCR):

1. It was developed by **Kary Mullis** in 1983 and won Nobel Prize in 1993.
2. PCR is a method for amplifying a specific piece of DNA molecule without the requirement for time-consuming cloning procedure.
3. This process require Target DNA, a heat stable DNA polymerase, which work at optimum temperature of 70°C usually Taq DNA and four types of nucleotides with small single stranded strands of DNA of about 20 nucleotide called primers, produce multiple copy of desired DNA.

Environment & Ecosystem

Organisms and Population

Population Dynamics

(1) Population density:

(i) Population density is the number of individuals present per unit area or volume at a given time.

(ii) For instance, number of animal per square kilometer, number of trees per area in a forest, or number of plank tonic organism per cubic meter of water.

(iii) If the total number of individuals is represents by letter N and the number of units of space by Letter S, the population density D can be obtained as D=N/S.

(iv) Space is indicated in two dimensions (m^2) for land organisms, and in three dimensions (m^3) for aquatic organisms and for the organisms suspended in space.

(2) Birth rate or Natality:

(i) The birth rate of a population refers to the average number of young ones produced by birth, hatching or germination per unit time (usually per year).

(ii) In the case of humans, it is commonly expressed as the number of births per 1000 individuals in the population per year.

(iii) The maximum birth rate of a species can achieve under ideal environmental conditions is called potential natality.

(iv) The actual birth rate under the existing conditions is much less. It is termed realised natality.

(v) Crude birth rate is the number of births per 1000 persons in the middle of a given year i.e. on July.

(vi) Natality increases the population size (total number of individuals of a population) and population density.

(3) Death rate or mortality:

(i) The death rate of a population is the average number of individuals that die per unit time (usually per year).

(ii) In humans it is commonly expressed as the number of death per 1000 persons in a population per year.

(iii) Lowest death rate for a given species in most favourable conditions is called potential mortality, while the actual death rate being observed in existing conditions is called realized mortality.

(iv) Crude death rate is the number of deaths per 1000 persons in the middle of a given year i.e. on July.

(v) Mortality decreases the population size and population density both.

Difference between Natality rate and Mortality rate

Character	Natality rate	Mortality rate
(1) Definition	Number of births per 1,000 individuals of a population per year.	Number of deaths per 1,000 individuals of a population per year.
(2) Population density	Increases population size and population density.	Decreases population size and population density.

(4) Vital index:

The percentage ratio of natality over mortality is known as vital index i.e. natality / mortality ×100. It determines the growth of a population.

(5) Immigration:

It is permanent entry of additional person into the existing population of a country or region from outside. Example; Many Nepalese and Chinese come to settle in India.

(6) Emigration:

(i) It is the permanent departure of some persons from the existing population of a region to a different state or a foreign country. Example; Many Indians go to Western countries to settle there.

(ii) Immigration and emigration bring about redistribution of population, and are common in animals.

(iii) These occur for various reasons, such as search for food, escape from competition due to overcrowding, need of shelter etc.

(7) Sex ratio:

The number of females in a population per 1000 males is called sex ratio.

Sex ratio = No. of females/ 1000(males)

(8) Age structure:

(i) The age structure of a population is the percentage of individual of different ages such as young, adult and old.

(ii) Age-sex structure of a population can be shown by a pyramid-like diagram by plotting the percentage of population of each sex in each age-group.

Patterns of Population Growth:

Growth of a population can be expressed by a mathematical expression, called growth curve in which logarithm of total number of individuals in a population is plotted against the time factor. Growth curves represent interaction between biotic potential and the environmental resistance.

Two basic types of growth curves:

(a) **Sigmoid or S-shaped growth curve:** It is shown by yeast cells and most of organisms. It is formed of five phases:

  (1) **Lag phase.** In which the individuals adapt themselves to the new environment, so there is no or very little increase in population.

  (2) **Positive Acceleration phase.** It is the period of slow increase in population in the beginning.

  (3) **Logarithmic** or **Exponential phase:** It is the period of rapid rise in population due to availability of food and requirements of life in plenty and there being no competition.

  (4) **Negative Acceleration phase:** In which again there is slow rise in population as the environmental resistance increases.

  (5) **Stationary (Plateau) phase:** Finally, growth rate becomes stable because mortality and natality rates become equal to each other. So there is zero growth rate. A stable population is said to be in equilibrium, or at saturation level. This limit in population is a constant *K* and is imposed by the carrying capacity of the environment. S-shaped curve is also called logistic curve. Sigmoid growth curve was described by **Verhulst, (1839)**

(b) **J-shaped Growth curve:** It is shown by small population of **Reindeer** experimentally reared in a natural environment with plenty of food but no predators. It has only two phases:

  (1) **Lag phase:** It is period of adaptation of animals to new environment so is characterized by slow or no growth in population.

  (2) **Logarithmic or Exponential phase:** It is characterized by rapid growth in population which continues till enough food is available. But with the increase in reindeer population, there is corresponding decrease in the availability of food and space, which finally become exhausted, which leads to mass starvation and mortality. This sudden increase in mortality is called **population crash.** Lemming of Tundra, some insect, algal blooms and annual plants also show J-shaped curves. The population growth curve is S- shaped in most of the organisms, Human population also shows S-shaped curve.

Difference between S-shaped and J-shaped Growth curves

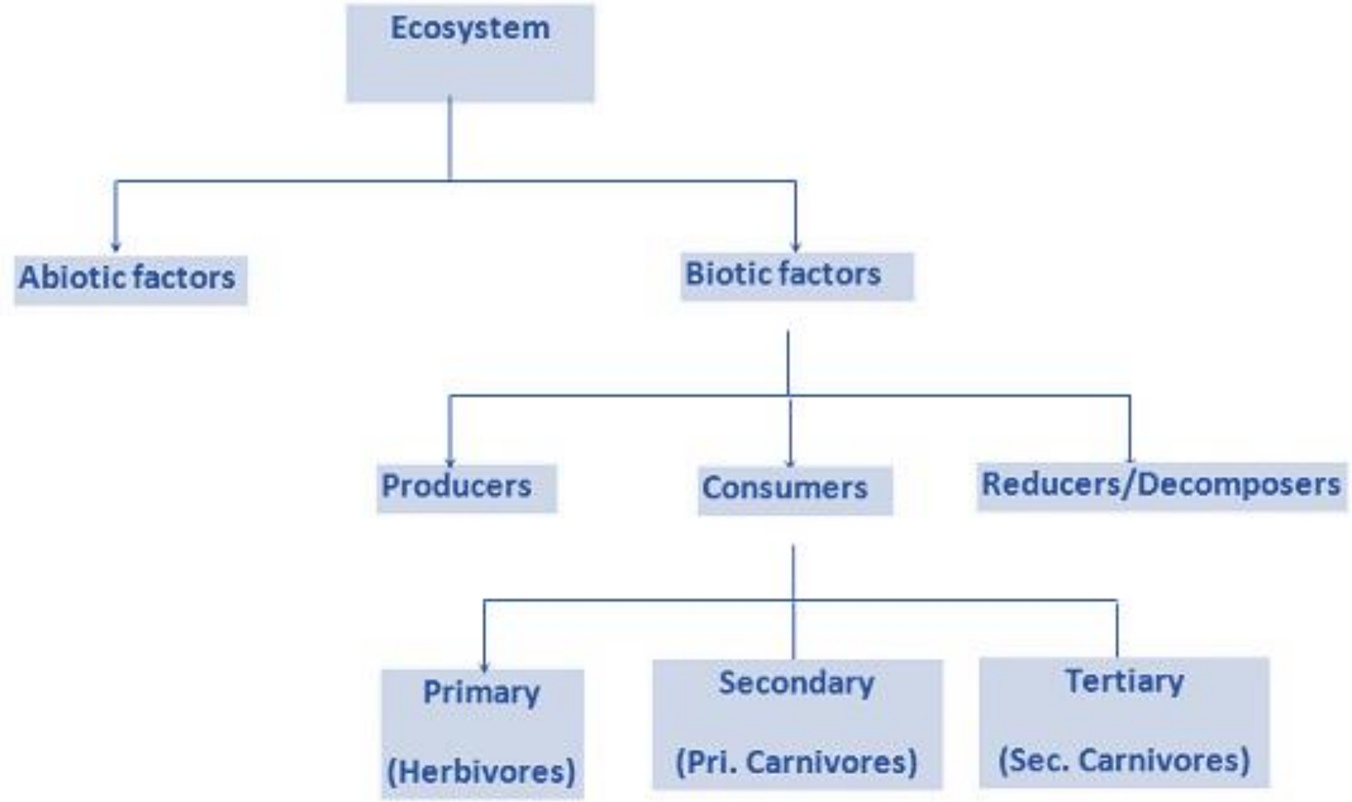
S.No.	S-shaped Growth Curve	J-shaped Growth Curve
(1)	It is formed of 5 phases: lag phase, positive acceleration phase, exponential phase, negative acceleration phase and stationary phase.	It is formed of 2 phases: lag phase and exponential phase.
(2)	Finally the population shows zero growth rate as birth rate equals death rate.	Finally, the population shows a population crash due to rapid increase in mortality rate.
(3)	*Examples.* Yeast cells in a culture medium.	*Examples.* Reindeers, algae blooms, lemmings of Tundras

Ecosystem

Ecosystem

(1) The word ecosystem was coined by **A.G. Tansley** in 1935.

(2) **Structure:** The structure of any ecosystem is formed of two components, namely:
   - (i) Abiotic factors
   - (ii) Biotic factors



Energy flow:

(1) The transfer of energy from one trophic level to another trophic level is called energy flow.

(2) The flow of energy in an ecosystem is unidirectional. That is, it flows from the producer level to the consumer level and never in the reverse direction. Hence energy can be used only once in the ecosystem.

(3) But the minerals circulate and recirculate many times in the ecosystem.

(4) A large amount of enregy is lost at each trophic level.

(5) It is estimated that 90% of the energy is lost when it is transferred from one trophic level to another.

(6) Only about 10% of the biomass is transferred from one trophic level to the next one is a food chain. And only about 10% of chemical energy is retained at each trophic level. This is called 10% law of Lindeman (1942).

Ecological pyramids:

(1) The number, biomass and energy of organisms gradually decrease from the producer level to the consumer level. This can be represented in the form of a pyramid called ecological pyramid.

(2) Ecological pyramid is the graphic representation of the number, biomass, and energy of the successive trophic levels of an ecosystem.

(3) The use of ecological pyramid was first described by Charles Elton in 1927.

(4) In the ecological pyramid, the producer forms the base and the final consumer occupies the apex.

(5) There are three types of ecological pyramids, namely:

(i) The pyramid of number:

The number of individuals at the trophic level decreases from the producer level to the consumer level. That is, in an ecosystem the number of producers is far high. The number of herbivores is lesser than the producers. Similarly, the number of carnivores is lesser than the herbivores.

(i) **In a cropland ecosystem:** In croplands the crops are more in numbers. The grasshoppers feeding on crop plants are lesser in number. The frogs feeding on grasshopper are still lesser in number. The snakes feeding on frogs are fewer in number.

Crop -> Grasshopper -> Frogs -> Snakes -> Hawks

(ii) **In a grassland ecosystem:** In grassland the grasses are there in large numbers. The consumers decrease in the following order.

Grass -> Grasshopper -> Lizard -> Hawk
Grass -> Rabbit -> Fox -> Lion

(iii) **In a pond ecosystem:** The number in a pond ecosystem decreases in the following order.

Phytoplankton -> Zooplankton -> Fishes -> Snakes

(b) The pyramid of biomass:

Biomass refers to the total weight of living matter per unit area. In an ecosystem the biomass decreases from the producer level to the consumer level.

(c) Pyramid of energy:

The energy flows in an ecosystem from the producer level to the consumer level. At each trophic level 80 to 90% of energy is lost. Hence the amount of energy decreases from the producer level to the consumer level. This can be represented in a pyramid of energy level to the consumer level. This can be represented in a pyramid of energy.

Succession

(1) Every community undergoes a series of changes until a group of organisms is established which can live and reproduce most successfully in the area. This is called biotic succession.

(2) The term succession was coined by Hult (1885).

(3) A biotic community normally undergoes continuous changes. Generally, definite and orderly sequences of communities gradually appear in an area over a period of time.

(4) A specific sequence of development of a community is related to particular set of physical and chemical conditions. This is known as sere.

(5) The last succession in a sere is called climax or a climatic climax.

(6) **Types:** Succession is of two types**:**

   (i) **Primary succession:** It includes changes which occur when living things become established on a previously uninhabited area such as a newly exposed sea floor, lake sediments or sand dunes.

   (ii) **Secondary succession:** It occurs where early communities have been damaged, leaving a few organisms and considerable organic matter. These remnant species, along with some new ones, regenerate a new community.

   (iii) **Life forms: Raunkiaer** (1934) has distinguished plants into five forms on the basis of size, shape, branching, crown, life span and perennation.

      (a) **Therophytes:** Annual plants which perennate in the form of seeds.

      (b) **Cryptophytes:** Buds are occurs very deep in the soil *e.g.* Bulbs, rhizomes, corm, tubers etc.

      (c) **Hemicryptophytes:** Perennating structures occur at ground level. Aerial shoots die in the onset of winter, e.g. rosette plants.

      (d) **Chemaephytes:** Small plants of cold areas where perennating buds or shoot apices lie at or above the ground level.

      (e) **Phanerophytes:** Perennial herbs, shrubs and trees, epiphytes, succulents, lianas, etc., where perennating buds occurs at 10 cm or more height above ground level.

Nutrient Cycling

Carbon Cycle

(1) The cycling of carbon between biotic and abiotic systems is called carbon cycle. It is a gaseous cycle.

(2) The main source of carbon is the carbon dioxide (CO_2).

(3) CO_2 is present in the air and water. Air is the main reservoir. CO_2 content of air is 0.03%. Its amount remains constant.

(4) **Flow of Carbon into the biotic system:** Carbon flows into the biotic system in two ways:

(i) **Photosynthesis:**

Carbon enters the biotic system through photosynthesis. In photosynthesis green plants utilize CO_2 and incorporate the carbon of CO_2 in glucose. Glucose is used for the synthesis of other types of carbohydrates, proteins and lipids. These compounds, containing carbon, are stored up in the plant tissues. When plants are eaten up by herbivores, the carbon flows into the body of herbivorous animals through food chain. When herbivores are eaten by carnivores, the carbon enters the body of carnivorus animals.

$$6CO_2 + 6H_2O \text{ ® } C_6H_{12}O_6 + 6O_2$$

(ii) Formation of shell:

The CO_2 dissolved in sea water is utillized by the marine animals like protozoans, corals, molluscs, algae, etc., for the construction of shell. In these animals CO_2 is converted into calcium carbonate ($CaCO_3$) which is used for the construction of shells.

$CO_2 + H_2O \text{ -> } H_2CO_3$ (Carbonic acid)
$H_2CO_3 \text{ -> } H^+ + HCO_3$ (Bicarbonate)
$HCO_3 + Ca^+ \text{ -> } H^+ + CaCO_3$ (Calcium carbonate)

(5) **Flow of Carbon into the abiotic system:** The carbon of the biotic system flows into the abiotic system in five ways:

(i) Respiration:

Plants and animals release CO_2 by respiration (biological oxidation).

$$C_6H_{12}O_6 \text{ -> } CO_2 + H_2O + \text{Energy}$$

(ii) Decomposition:

When plants and animals die, the dead bodies are decomposed into CO_2 by decomposers like bacteria, algae, etc.

(iii) Shells:

After the death of marine animals, $CaCO_3$ stored in the shells is either deposited as sedimentary rocks or dissolved in water to release CO_2 by the reversion of the above said reactions.

(iv) Coal:

A certain proportion of carbon from plants is deposited as coal. Carbon from coal returns to air in the form of CO_2through combustion and weathering.

(v) Forest fire:

Combustion of wood in the forest releases carbon from plants in the form of CO_2.

Phosphorus cycle:

(i) The cycling of phosphorus between biotic and abiotic *system* is called phosphorus cycle. It is a sedimentary cycle.

(ii) Phosphorus is an important mineral nutrient.

(iii) The main source of phosphorus is rocks. Through erosion and weathering phosphorus is made available in the soil.

(iv) Plants absorb ionic phosphate through roots. In plants it is incorporated into the protoplasmic components like DNA, RNA, AMP, ADP, ATP, GDP, GTP, NADP, phospholipids etc. from plants, it passes into herbivores and animals, the organic molecules containing phosphate are decomposed and phosphate is liberated as inorganic ion phosphate. It is again used by plants.

(v) The excess of phosphate in the bodies of animals is excreted out through faces. The bird guano (excreta) contains a large amount of phosphate.

(vi) Phosphate is also released to the soil through the combustion of forest trees and grasses.

(vii) A large amount of phosphate is lost in the sea by sedimentation. A certain amount of phosphorus gets locked in bones and teeth.

Environmental Issues

Air Pollution:

Air pollution refers to the undesirable change occurring in air causing harmful effects on man and domesticated species.

(i) **Air Pollutants :** The common air pollutants are : Dust, Smoke, Carbon monoxide (CO), Ammonia (NH_3), Sulphur dioxide (SO_2), Hydrogen sulphide (H_2S), Nitrogen dioxide (NO_2), Hydrogen cyanide, Hydrogen fluorides, Chlorines, Phosgenes, Arsines, Aldehydes, Ozone, Ionising and radiations. CO_2 is not a normal air pollutant. There is 0.03% CO_2 in the air its higher percentage is the cause of green house effect.

Types of air pollutants: It is two types:

(a) **Primary air pollutants:** Air is polluted by poisonous gases and undesirable substances. They are released by burning fossil fuels. These substances are called primary air pollutants. The primary air pollutants are the following:

- Soot released from unburned fuel.
- Sulphur dioxide (SO_2).
- Benzopyrene (hydrocarbon) released from cigarette smoke.
- Ammonia (NH_3).
- Oxides of nitrogen.
- Carbon monoxide (CO).
- Lead (Pb).

(b) **Secondary air pollutants:** Secondary air pollutants are poisonous substance formed from primary air pollutants. In bright sun light nitrogen, nitrogen oxides, hydrocarbons and O_2 interact to produce more powerful photochemical oxidants like ozone (O_3), peroxyacetyl nitrate (PAN), aldehydes, sulphuric acid, peroxides, etc. All these constitute photochemical smog, which retard photosynthesis in plants.

(ii) **Causes of air pollution**

  - (a) **Agriculture**
  - (b) **Dust:**
  - (c) **Industries**
  - (d) **Automobiles**.
  - (e) **Ionising radiations**
  - (f) **Freons**
  - (g) **Aerosols**

(iii) **Control of air pollution**

(a) The emission of exhaust from automobiles can be reduced by devices such as positive crankcase ventilation valve and catalytic converter.

(b) Electrostatic precipitators can reduce smoke and dust from industries.

(c) Gaseous pollutants arising from industries can be removed by differential solubility of gases in water.

(d) A finepray of water in the device called scrubber can separate many gases like NH_3, SO_2, etc. from the emitted exhaust.

(e) Certain gases can be removed by filtration or absorption through activated charcoal.

(f) Certain gases can be made chemically intert by chemical conversion.

(g) At the Government level pollution can be controlled by framing legislations.

(h) Vehicles based on compressed natural gas (CNG) should be introduced.

Water Pollution:

Water pollution refers to the undesirable change occurring in water which harmfully affect the life activities of man and domesticated species.

(i) **Water Pollutants:** The common water pollutants are : Domestic sewage, Industrial effluents, Pesticides, Herbicides, Fertilizers, Bacteria and Viruses, Plankton blooms and Heavy metals like Mercury, Temperature, Silt, Radioactivity, Oils etc.

(ii) **Causes of water pollution**

  - (a) **Domestic sewage**
  - (b) **Industrial effluents**
  - (c) **Thermal pollution**
  - (d) **Agricultural pollution**
  - (e) **Pesticides:**
  - (f) **Radioactive wastes** .
  - (g) **Oil pollution**
  - (h) **Eutrophication**.

(iii) **Control of water pollution**
   (a) **Sedimentation**.
   (b) **Dilution**
   (c) **Storage**.

(iv) **Land pollution**
   (i) **Land pollutants**.
   (ii) **Pesticides**

(4) Radioactive pollution:

This pollution occurs through radiations. Radiations are of two types:

(i) **Non ionising radiations:** UV rays, IR rays, etc. UV rays cause skin burning, IR rays increases atmospheric temperature and leads to the green house effect.

(ii) **Ionising radiation:** *X* – rays, x-rays, beta-rays, gamma-rays cause genetic injury on mutation.

Certain elements continuously disintegrate by emitting ionizing radiations. These elements are called radioactive isotopes. Ecologically important radioactive elements are Strontium-90, Argon-41, Iodin-131, Cobalt-60, Cesium – 137, Plutonium – 238, etc. Among these Sr-90' is the most dangerous radioactive pollutant.

Types of ionizing radiations: Radioactive isotopes release three types of radiations:

(a) **Alpha particles:** These are large particles emitted by radioactive isotopes (as U^{238}). They travel only short distances. They cannot penetrate the organisms. They cause ionization.

(b) **Beta particles:** These are small particles emitted by radioactive isotopes. They can travel long distances. They can easily penetrate the body tissues and cause ionization.

(c) **Gamma rays:** These are short wavelength rays emitted by radioactive isotopes. They can travel long distances. They can easily penetrate the body tissues and cause ionization. On the basis of the biological effects produced, the radioactive radiations can be grouped into two types, namely internal emitters and external emitters.

(5) Noise pollution

Global Warming

Increase in atmospheric concentrations of green house gases (CO_2, CH_4, CFCs, N_2O) causes **global warming**enhanced green house effect), changes in sea level, weather and climate change etc.

Biodiversity and Conservation

Diversity ranges from macromolecules to biomes.

Biodiversity on earth exists in three levels of organization:

(i) Genetic diversity

(ii) Species diversity

Genetic diversity

(i) It is related to the variations of genes within species.

Speciesdiversity

(i) it is related to the variety of species within a region.

(ii) Species richness refers to the number of species per unit area.

Biodiversity in India

(1) Out of the twelve mega biodiversity counties, India is one.

(2) India has 10 biogeographical regions, 89 national parks, 500 wild life sanctuaries, 14 biosphere reserves, 6 westlands and 35 world heritage sites.

(3) There are about 45,000 species of plants and about 90,000-1,00,000 species of animals.

Patterns of Biodiversity

(1) Biodiversity changes with change in **latitude** or **altitude.**

(2) It is minimum at the poles and maximum near or at equator. Similarly, as one moves down from higher to lower altitudes, biodiversity is increased.

Loss of bio-diversity:

(1) Caused by three factors - Population, Urbanisation and Industrialisation.

(2) The colonisation of tropical Pacific Islands by human has led to the extinction of more than 2000 species of native birds.

(3) Loss of bio-diversity in a region leads to:

    (i) Decrease in plant production.

    (ii) Less resistance to environmental disturbances such as droughts.

    (iii) Increase in variability in ecosystem processes like plant productivity, water use, pest and disease cycles etc.

Biodiversity Conservation

In situ conservation

The most appropriate method to maintain species of wild animals and plants in their natural habitats. This approach includes conservation and protection of the total ecosystems and its biodiversity through a network of protected areas.

Hot spot of biodiversity are those regions of rich biodiversity which have been declared sensitive due to direct or indirect interference of human activities.

There are 25 terrestrial hot spots in the world including two from India.

Exsitu conservation

Threatened animals and plants are taken out from their natural habitat and placed in special setting where they can be protected and given special care.

Convention on Biodiversity:

(1) "The earth Summit" held in Rio de Jeneiro in 1992 called upon all nations to take appropriate measures for conservation of biodiversity and sustainable utilization of its benefits.

(2) Second international Conference on Sustainable development held in 2002 in Johannesburg, South Africa, 190 countries pledged their commitment to achieve by 2010 a significant reduction in the current rate of biodiversity loss at global, regional and local level.