

■ **Synchronous orbit or geosynchronous orbit**

An orbit of the earth made by an artificial satellite with a period exactly equal to the earth's period of rotation on its axis, i.e. 23 hours 56 minutes 4.1 seconds. If the orbit is inclined to the equatorial plane the satellite will appear from the earth to trace out a figure-of-eight track once every 24 hours. If the orbit lies in the equatorial plane and is circular, the satellite will appear to be stationary. This is called a stationary orbit (or geostationary orbit) and it occurs at an altitude of 35900 km. Most communication satellites are in stationary orbits, with three or more spaced round the orbit to give worldwide coverage.

■ **Telesat**

It refers to one of a series of low altitude, active communication satellites for broad band microwave communication and satellite tracking in space.

■ **Temperature gradient**

Rate of change of temperature with distance.

■ **Temperature scale**

Any temperature scale consists of two fixed points which generally correspond to two easily reproducible systems. These are assigned certain definite values and the interval between them is divided into an equal number of parts. The Celsius scale is most commonly used and the fixed points in it are the ice point (0°C) and steam point (100°C). Interval between them is divided into 100 equal parts, each part being equal to 1°C , other scales used are, Fahrenheit, Romer and Kelvin. These are related to Celsius scale as –

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

■ **Tempering**

It refers to the process used for increasing the toughness of an alloy by heating it to a predetermined temperature, maintaining it at this temperature for predetermined time and then cooling it to room temperature at a predetermined rate.

■ **Tensile strength**

The resistance of a material to longitudinal stress. It is measured by minimum amount of longitudinal stress needed to break the material.

■ **Terminal speed**

The constant speed finally attained by a body moving through a fluid under gravity when there is a zero resultant force acting on it. See Stokes's law.

$$v_0 = \frac{2r^2(\rho - \rho')g}{9\eta}$$

Where ρ = Density of spherical body and ρ' = Density of fluid

If $\rho > \rho' \Rightarrow$ The body will move downward

If $\rho < \rho' \Rightarrow$ The body will move upward

■ **Thermal capacity or Heat capacity**

It is the amount of heat required to raise the temperature of a body by 1 °C. It is equal to the product of mass of the body and the specific heat. It is expressed in J/°C or J/K.

■ **Thermal diffusion**

It refers to the diffusion that occurs in a fluid due to temperature gradient. It is used to separate heavier gas molecules from lighter ones by maintaining a temperature gradient over a volume of gas containing particles of different masses. This method is also used to separate gaseous isotopes of an element.

■ **Thermal neutrons**

Refers to neutrons of very low speed and energy (≈ 0.1 eV)

■ **Thermal reactor**

It is a type of nuclear reactor in which the nuclear fission reactions are caused by thermal neutrons.

■ **Thermion**

Refers to an ion that is emitted by an incandescent material.

■ **Thermionic current**

It refers to the electric current that is produced due to flow of thermions.

■ **Thermionic emission**

It refers to the emission of electrons from the surface of a substance when it is heated. It forms the basis of the thermionic valve and the electron gun in cathode ray tubes. The emitted current density is given by Richardson – Dushman equation $J = AT^2e^{-\phi/kT}$

Where T = Thermodynamic temp. of the emitter

ϕ = Work function

k = Boltzmann constant

A = Some constant

■ **Thermistor**

It refers to a semi-conductor, whose electrical resistance changes rapidly with change in temperature. It is used to measure temperature very accurately.

■ **Thermocouple**

It consists of two metallic junctions of different metals whose junctions are kept at different temperatures, an e.m.f. develops across these which is proportional to the temperature difference. A measurement of e.m.f. enables one to calculate the temperature so it is used for measurement of temperatures.

■ Thermo e.m.f.

Seebeck discovered that if two dissimilar metals are joined together to form a closed circuit and their two junctions are maintained at different temperatures an e.m.f. is developed and an electric current flows in the circuit. This e.m.f.

developed is known as thermo e.m.f. is given by $E = \alpha t + \frac{1}{2} \beta t^2$

Where t = temperature difference of hot and cold junction in °C, α and β are constants which are characteristic of metals forming the thermocouple and are known as seebeck coefficients.

■ Thermoelectricity

The electricity produced due to thermo e.m.f. is called thermoelectricity.

■ Thermoelectric power

It refers to the rate of change of the thermo e.m.f. of the thermocouple with the temperature of the hot junction.

■ Thermopile

It is an arrangement of thermocouple in series. Such an arrangement is used to generate thermoelectric current or for detecting and measuring radiant energy.

■ Thermostat

A device which is used to keep the temperature in a place within in a particular range. Thermostats are present in a number of common household devices such as cookers, refrigerators, irons, freezers and heating boilers. Many thermostats are **bimetallic strips**.

■ Threshold

It refers to the minimum value of a parameter that will produce a specified effect.

■ Threshold of hearing

That minimum intensity level of a sound wave which is audible. It occurs at a loudness of about 4 phons.

■ Timbre

The characteristic quality of sound. It is independent of pitch and loudness but depends upon the relative strength of components of different frequencies, determined by resonance. It depends on the number and intensity of the overtones present.

■ Tomography

The use X-rays to photograph a selected plane of a human body with other planes eliminated. The CAT (computerised axial tomography) scanner is a ring-shaped X-ray machine that rotates through 180° around the horizontal patient, making numerous X-ray measurements every few degrees. The vast amount of information acquired is built into a three-dimensional image of the tissues under examination by the scanner's own computer. The patient is exposed to a dose of X-rays only some 20% of that used in a normal diagnostic X-ray.

Ton

It is a unit of weight 1 ton = 2000 pounds = 907.18 kg.

Tone

It refers to a sound considered with reference to its quality, strength, source etc.

Tonne (Metric Ton)

A unit of mass 1 Tonne = 10^3 kg.

Torr

A unit of pressure. 1 torr = 1333.2 microbars. One torr is equal to the pressure of 1 mm of mercury.

Torricelli's theorem

It gives us the velocity of a fluid, coming out of a vessel, at a point at a height h below its surface. According to it. $v = \sqrt{2gh}$

Torsion

It refers to the twisting of an object by two equal and opposite torques.

Torsional pendulum

In such a pendulum moment of restoring forces, $\tau = -k\theta$

$$\text{Time period } T = 2\pi \sqrt{\frac{I}{K}} \text{ Where}$$

K = Constant torsion in the thread

I = Moment of inertia of the rotating body about the thread

Torsional balance

An instrument for measuring very weak forces. It consists of a horizontal rod fixed to the end of a vertical wire or fibre or to the centre of a taut horizontal wire. The forces to be measured are applied to the end or ends of the rod. The turning of the rod may be measured by the displacement of a beam of light reflected from a plane mirror attached to it.

Total internal reflection

For such a reflection the ray must pass from a denser to a rarer medium. When a ray of light travels from a more refractive medium to a less refractive medium it undergoes total internal reflection, if angle of incidence is greater than critical angle θ_c , which can be defined as

$$\sin\theta_c = \frac{n_1}{n_2} = \frac{1}{n_2}$$

■ Transmitter

- The equipment used to generate and broadcast radio-frequency electromagnetic waves for communication purposes. It consists of a carrier-wave generator, a device for modulating the carrier wave in accordance with the information to be broadcast, amplifiers, and an aerial system.
- The part of a telephone system that converts sound into electrical signals.

■ Trajectory

It is the path traversed by a projectile, rocket etc.

■ Trans-conductance

It is the ratio of change in plate current to change in grid voltage at constant plate voltage. It is expressed in mhos.

■ Transducer

Refers to a device that receives energy from one source and retransmit it in a different form to another system or media.

■ Transformer

It is a device that is used to convert a large alternating current at low voltage into a small alternating current at high voltage or vice-versa.

■ Transients

It refers to the non-periodic portion of a wave or signal transient modulation i.e. a modulation of temporary nature.

■ Transmutation

The process in which one nuclide is converted into another nuclide.

■ Transponder

Refers to a radio or radar receiver, that automatically transmits a reply promptly on reception of a certain signal.

■ Triangle law of vectors

It states, "if two vectors can be represented in magnitude and direction by two sides of triangle taken in order, then the resultant vector can be represented in magnitude and direction by the third side of the triangle taken in opposite order." where \vec{a} , \vec{b} are two vectors and \vec{c} is the resultant vector. $\vec{c} = \vec{a} + \vec{b}$

■ Triple point

It is the temperature at which the gas, liquid and solid phase of a substance can coexist. Triple point of water is 273.16 K and 0.46 cm of mercury. All the three phases of water (solid, liquid and gas) coexist at this temperature and pressure and all the phases are equally stable.

■ Triton

Nucleus of tritium (${}^3\text{H}$) atom.

■ **Troposphere**

It is the region of atmosphere which extends upto a height of about 16 km above the earth's surface at the equator and to a height of about 8 km at the poles. The temperature in this region decreases with increase in height.

■ **Tunnel diode**

A semiconductor diode, based on the tunnel effect. It consists of a highly doped p-n semiconductor junction, which short circuits with negative bias and has negative resistance over part of its range when forward biased. Its fast speed of operation makes it a useful device in many electronic fields.

■ **Tunnel effect**

An effect in which electrons are able to tunnel through a narrow potential barrier that would constitute a forbidden region if the electrons were treated as classical particles.

■ **Turbulent flow**

Flow of liquid wherein the speed of the fluid changes rapidly in magnitude and direction. The motion of a fluid becomes turbulent when its speed increases beyond a certain typical speed.

■ **Twilight**

The soft diffused light from the sky when the sun is below the horizon.

■ **Tyndall effect**

It refers to the scattering of light by particles in its path and the beam of light becomes visible.

■ **Umbra**

It is the region of complete shadow.

■ **Uncertainty principle**

It states, "It is not possible to find accurately and simultaneously both the position and velocity of a moving particle." Mathematically $\Delta x \cdot \Delta p = \frac{h}{4\pi}$

Where Δx = Uncertainty in position, Δp = Uncertainty in momentum

■ **Unipolar transistor**

A transistor wherein current flow is due to the movement of majority carriers only.

■ **Upthrust**

Refers to the upward force that acts on an object when it is immersed in a fluid. It is equal to the mass of the fluid displaced by the object.

■ **Vacuum**

A space that is totally devoid of matter. Generally it refers to a space from which air has been removed and where the pressure is very low.

■ Valence band

Range of energies in a semi-conductor which corresponds to energy state that can be occupied by the valency electrons in the crystal.

■ Van-de-graff accelerator

It is a machine that is used to accelerate charged particles.

■ Vander wall's equation of state

It is an equation of state for real gases.

$$\left(P + \frac{n^2 a}{V^2} \right) (V - nb) = nRT$$

Where V = Volume of gas

R = Gas constant

T = Absolute temperature

n = Number of moles of gas

a, b = constant called Vander Wall's constant.

■ Vander wall forces :

These are very weak attractive forces that exist between the atoms and molecules of all the substances. These are short range forces and arise due to molecular dipoles.

■ Venturimeter

It is an apparatus used to find the rate of flow of liquids when the motion of fluid is steady and non-turbulent.

■ Vernier

A small movable device having graduated scale running parallel to the fixed graduated scale of a sextant. It is used for measuring a fractional part of one of the fixed division of the fixed scale. The smallest measurement which can be made using a vernier instrument is equal to the difference between 1 main scale division (smallest) and 1 vernier scale division.

■ Vernier caliper

A caliper made up of two pieces sliding across one another, one having a graduated scale and the other a vernier.

■ Viscosity

It is the property of the fluid by virtue of which it opposes the relative motion between its different layers. It is also called internal friction of the fluid.

■ Visible radiation

Radiation in the wave length range of 3800–7600 Å. It is visible to human eye.

■ Visual-Display Unit (VDU)

The part of a computer system or word processor on which text or diagrams are displayed. It consists of a cathode-ray tube and usually has its own input keyboard attached.

■ Voltage stabilizer

A device or circuit to maintain a voltage at its output terminals that is the substantially constant and independent of other changes in the input voltage or in the load current.

■ Voltaic Cell

A cell having two electrodes of different metals dipped in the solution of their soluble salts and arranged in such a way that they produce an electromotive force.

■ Voltameter

It is an electrolytic cell and is used to carry out the process of electrolysis.

■ Voltmeter

It is an instrument that is used for measuring the potential difference across two points in a circuit. It is always connected in parallel across the desired points in an electrical circuit.

■ Volume

It refers to the space occupied by a body.

■ Volumetric

Refers to measurement by volume.

■ Watt-meter

It is an instrument that is used for measuring power consumed in an electric circuit.

■ Wavelet

A small wave

■ Water equivalent of a substance

It is the amount of water that would need the same quantity of that for being heated through the same range of temperature as required by the substance for being heated through a given range of temperature.

■ Wave-particle duality

According to dual nature of matter, there is wave associated with every moving particle and vice-versa. The wave length of a wave associated with a moving particle having a momentum, p , is given by $\lambda = h/p$ where h is Plank's constant.

■ Weber

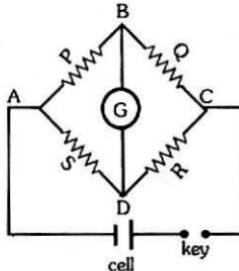
One weber is the magnetic flux linked with a surface of magnetic field one Tesla over an area of 1 sq metre. $1 \text{ Wb} = 1 \text{ Tm}^2$.

■ Weightlessness

It refers to the state, experienced by a person in an orbiting space craft, of loss of weight.

■ Wheatstone bridge

It is an electrical circuit that is used to measure the electrical resistance. It consists of resistances connected in four arms. A galvanometer (G) is connected across two opposite junctions, and a source



of e.m.f. is connected across the remaining two junctions as shown in the diagram. If three of the resistances P, Q, R are known, the fourth (S) can be determined. Keeping the resistance P, Q fixed the resistance R is varied till the

galvanometer shows zero deflection. When this is achieved $\frac{P}{Q} = \frac{R}{S}$. For maximum sensitivity all the four resistances should be of the same order.

■ White dwarf

Refer to any of a large size of very faint stars that are considered to be in the last stage of stellar evolution. Its nuclear fuel is completely exhausted and it collapses, under its own gravitation, into a small but very dense body.

■ Wiedemann-Franz law

It states that for all metals, the ratio $\frac{k}{\sigma T} = \text{constant}$, where k is the thermal conductivity. σ is electrical conductivity and T is the absolute temperature of the substance.

■ Wien's displacement law

According to it, for a black-body radiation $\lambda_m T = \text{constant}$

Where λ_m = wavelength corresponding to maximum energy radiation.
T = Absolute temperature of the body.

■ Wireless

Means having no wire

■ Work Function (ϕ)

It is the minimum energy that is required to overcome the surface force so as to liberate the electrons from the metal surface. It is measured in electron volts.

■ **X-ray**

It is a form of electromagnetic radiation of shorter wavelength as compared to visible light. X-ray can penetrate through solid and can ionise gases.

■ **X-ray Diffraction**

the diffraction of X-rays by a crystal. The wavelengths of X-rays are comparable in size to the distances between atoms in most crystals, and the repeated pattern of the crystal lattice acts like a diffraction grating for X-rays.

■ **Yard**

The former Imperial standard unit of length. In 1963 yard was redefined as 0.9144 metre exactly.

■ **Yield point**

When a rod or wire of certain material is subjected to a slowly increasing tension, the point at which a small increase in tension produces a sudden and large increase in length is called the yield point.

■ **Zeeman effect**

It refers to the splitting up of single lines in a spectrum into a group of closely spaced lines. This effect is observed when the substance emitting the spectrum is placed in a strong magnetic field. The study of this effect is used in the study of atomic structure.

■ **Zener diode**

It is a semi-conductor diode where in each side of junction is highly doped. When the junction is reverse biased, a sharp increase in the current occurs at well defined potential. Such a diode is used as a voltage regulator.

■ **Zero-gravity**

It refers to the condition wherein the apparent effect of gravity becomes zero as on a body in orbit.

■ **Zero point energy**

It is the energy possessed by atoms or molecules of a substance at absolute zero of temperature. It can not be explained by classical physics but has been accounted for as a quantum effect.

■ **Zeroth law of thermodynamics**

According to it, whenever two bodies A and B are in thermal equilibrium with another body C then bodies A and B will also be in thermal equilibrium with each other.

■ **Zero vector or Null vector**

A vector whose magnitude is zero is known as a zero vector. The direction of zero vector is not defined.

chemistry

Handbook



ars
ellence



TM

0744-5156100 | www.allen.ac.in

S.NO.	TOPIC	PAGE NO.
I. PHYSICAL CHEMISTRY		
1.	Some Basic Concepts in Chemistry	1
2.	Solutions	3
3.	Redox Reactions	8
4.	Electrochemistry	11
5.	Behaviour of gases	18
6.	Atomic structure	22
7.	Chemical Kinetics	32
8.	Thermodynamics	36
9.	Energetics	40
10.	Chemical Equilibrium	43
11.	Ionic Equilibrium	46
12.	Solid State	53
13.	Surface Chemistry	58
II. INORGANIC CHEMISTRY		
14.	Some important increasing order	62
15.	Periodic Table	69
16.	Chemical Bonding	86
17.	s-Block elements	102
18.	p-Block elements	110
19.	Coordination chemistry	138
20.	d-block (Transition elements)	145
21.	Metallurgy	150
III. ORGANIC CHEMISTRY 156		

PHYSICAL CHEMISTRY

SOME BASIC CONCEPTS IN CHEMISTRY

1. **Some useful conversion factors.** $1 \text{ \AA} = 10^{-10} \text{ m}$, $1 \text{ nm} = 10^{-9} \text{ m}$, $1 \text{ pm} = 10^{-12} \text{ m}$, $1 \text{ litre} = 10^{-3} \text{ m}^3 = 1 \text{ dm}^3$, $1 \text{ atm} = 760 \text{ mm or torr} = 101,325 \text{ Pa or Nm}^{-2}$, $1 \text{ bar} = 10^5 \text{ Nm}^{-2} = 10^5 \text{ Pa}$, $1 \text{ calorie} = 4.184 \text{ J}$, $1 \text{ electron volt (eV)} = 1.6022 \times 10^{-19} \text{ J}$, ($1 \text{ J} = 10^7 \text{ ergs}$) ($1 \text{ cal} > 1 \text{ J} > 1 \text{ erg} > 1 \text{ eV}$)
 2. 22.4 L of any gas at STP weigh equal to molecular mass expressed in grams. This mass is called 'Gram Molecular Mass' and this volume is called 'Gram Molecular Volume (G.M.V)'.
- Note.** STP conditions are 1 atm and 0°C . However, if the conditions taken are 1 bar and 0° C , instead of 22.4 L , we have, 22.7 L ($1 \text{ atm} = 1.01 \text{ bar}$).
3. **Atomic mass.** It is the average relative mass of its atoms as compared with an atom of carbon – 12 isotope taken as 12.
 - The mass of 1 atom = atomic mass (in amu)
 - The mass of 1 mole atoms = atomic mass (in g)
 eg. mass of one O atom = 16 amu
 mass of 1 mole O atoms = 16 g
 4. Calculation of average atomic mass. If an element exists in two isotopes having atomic masses ' m_1 ' and ' m_2 ' in the ratio $x : y$, then

$$\text{average atomic mass} = \frac{m_1 \times x + m_2 \times y}{x + y}.$$

5. **Molecular mass.** Molecular mass of a substance is the average relative mass of its molecules as compared with an atom of C-12 isotope taken as 12.
 - The mass of 1 molecule = molecular mass (in amu)
 - The mass of 1 mole molecules = molecular mass (in g)
 eg. Mass of 1 O_2 molecules = 32 amu
 Mass of 1 mol O_2 molecules = 32 gm

Chemistry HandBook

6. For atom $\rightarrow 1 \text{ g atom} = 1 \text{ mole}$

For molecule $\rightarrow 1 \text{ g molecule} = 1 \text{ mole}$

7. 1 amu or 1 u = $\frac{1}{12}$ th of the mass of an atom of C-12 = $1.66 \times 10^{-27} \text{ kg}$.

8. 1 mol of $\text{H}_2\text{O} \neq 22400 \text{ cc of H}_2\text{O}$ (because it is liquid). Instead, 1 mol of $\text{H}_2\text{O} = 18 \text{ cc of H}_2\text{O}$ (because density of $\text{H}_2\text{O} = 1 \text{ g/cc}$)

9. 'Fermi' is a unit of length used for expressing nuclear diameter ($1 \text{ fermi} = 10^{-13} \text{ cm} = 10^{-15} \text{ m}$) ($1 \text{ fermi} = 1 \text{ femto}$).

10. The number of molecules in one ml of a gas at STP is known as 'Loschmidt number'. Its value = $(6.02 \times 10^{23}) / 22400 = 2.687 \times 10^{19} \text{ ml}^{-1}$.

11. Mass of one mole of electrons = Mass of one $e^- \times \text{Avogadro's No.}$
 $= (9.11 \times 10^{-31} \text{ kg}) \times (6.02 \times 10^{23})$
 $= 0.55 \text{ mg}$

12. M.W. = 2 V.D.

$$\text{V.D.} = \frac{\text{density of gas}}{d_{\text{H}_2}}$$

$$d_{\text{H}_2} = 0.000089 \text{ gm/ml.}$$

$$\text{number of moles (n)} = \frac{\text{wt.}}{\text{MW / At wt}}$$

$$(n) = \frac{\text{number of particles}}{N_A}$$

$$n = \frac{\text{volume at S.T.P. (in lit)}}{22.4 \text{ litre}} \text{ or } \frac{\text{Volume at STP (in ml)}}{22400 \text{ ml}}$$

$$n = M \times V(\text{lit})$$

13. Atomic mass \times specific heat (in cal/gm) ≈ 6.4 (Dulong and Petit's law)

14. Calculations of equivalent weight.

- (I) Equivalent weight of element = $\frac{\text{Atomic weight}}{\text{Valency}}$
- (II) Equivalent weight of ions = $\frac{\text{Formula weight of ion}}{\text{Charge on ion}}$
- (III) Equivalent weight of ionic compound = equivalent weight of cation + equivalent weight of anion
- (IV) Equivalent weight of acid / base = $\frac{\text{Molecular weight}}{\text{Basicity/Acidity}}$
- (V) Equivalent weight of salt = $\frac{\text{Molecular weight}}{\text{Total charge on cation or anion}}$

15. gram equivalent = NV (lit) = $\frac{W}{E}$ = number of moles \times V.F.

$$N_1 V_1 = N_2 V_2$$

$$N_1 V_1 = \frac{W}{E_2} \times V_2$$

16. $\frac{W_1}{E_1} = \frac{W_2}{E_2}$

SOLUTION**Units of concentration**

1. % by wt. = $\frac{\text{Wt. of the solute (in g)}}{\text{Wt. of the solution (in g)}} \times 100$

2. % by wt./vol = $\frac{\text{Wt. of solute (in g)}}{\text{Vol. of solution (in cc)}} \times 100$

3. % by volume = $\frac{\text{Vol. of solute (in cc)}}{\text{Vol. of solution (in cc)}} \times 100$

4. Molarity = $\frac{\text{Moles of the solute}}{\text{Vol. of the solution (in cc)}} \times 1000$

where moles = $\frac{\text{Mass of the solute (in g)}}{\text{Molecular mass of the solute}}$

Chemistry HandBook

5. Normality = $\frac{\text{Gram equivalents of the solute}}{\text{Vol. of the solution in cc}} \times 1000$

where gmeq. = $\frac{\text{Mass of the solute (in g)}}{\text{Eq. mass of the solute}}$

6. Molality = $\frac{\text{Moles of solute}}{\text{Mass of the solvent (in g)}} \times 1000$

7. Mole fraction of solute in solution (x_2) = $\frac{n_2}{n_1 + n_2} = \frac{w_2 / M_2}{w_1 / M_1 + w_2 / M_2}$

Mole fraction of solvent in solution (x_1) = $\frac{n_1}{n_1 + n_2} = \frac{w_1 / M_1}{w_1 / M_1 + w_2 / M_2}$

where w_1, M_1 are mass and molecular mass of solvent and w_2, M_2 for the solute. $x_1 + x_2 = 1$. In general, for a solution containing many components (A, B, C.....), mole fraction of A

$$(x_A) = \frac{n_A}{n_A + n_B + n_C + \dots} \text{ and so on. } x_A + x_B + \dots = 1.$$

Strength (g/L) = N × eq. wt

Strength (g/L) = M × mol. wt.

8. Mass fraction of component A (x_A) = $\frac{w_A}{w_A + w_B}$

$$\text{Mass fraction of component B } (x_B) = \frac{w_B}{w_A + w_B} \quad x_A + x_B = 1.$$

9. Parts per million (ppm) = $\frac{\text{Mass of solute}}{\text{Mass of solution}} \times 10^6$

or ppm = $\frac{\text{vol. of solute}}{\text{vol. of solution}} \times 10^6$

10. Normality equation (for dilution of a solution or for a complete reaction between two solutions) $N_1 V_1 = N_2 V_2$

11. Molarity equation (for dilution of a solution) $M_1 V_1 = M_2 V_2$

- 12.** If V_1 cc of a solution with normality N_1 is mixed with V_2 cc of the solution with normality N_2 , then normality N_3 of the final solution can be calculated using

$$N_1 V_1 + N_2 V_2 = N_3 (V_1 + V_2).$$

- 13.** Molality, mole fraction and mass fraction do not change with temperature because they involve weights, Normality and molarity change with temperature because they involve volume.
- 14.** One molar (1 M) aqueous solution is more concentrated than one molal aqueous (1 m) solutions of the same solute.

This is because 1 M solutions contains 1 mole of the solute in 1000 cc of the solution which includes the solute i.e. mass of solvent is less than 1000 g (as density of $H_2O = 1\text{g/cc}$). However, in case of non-aqueous solution $1M > 1m$ or $1M < 1m$ or $1M = 1m$ depending upon the density of the solutions

- 15.** Alloys are solutions of solids in solids.
- 16.** According to Raoult's law, for solution containing volatile components A and B, $p'_A = x_A p_A^\circ$ and $p'_B = x_B p_B^\circ$

$$\begin{aligned} P_{\text{Total}} &= p'_A + p'_B = x_A p_A^\circ + x_B p_B^\circ \\ &= (1-x_B) p_A^\circ + x_B p_B^\circ = (p_B^\circ - p_A^\circ) x_B + p_A^\circ \end{aligned}$$

- 17.** Raoult's law for non-volatile solute containing solution :

$$\frac{p^\circ - p_s}{p^\circ} = \frac{n_2}{n_1 + n_2} \approx \frac{n_2}{n_1} \quad (\text{if solution is dilute i.e. } < 5\%)$$

$$= \frac{w_2/M_2}{w_1/M_1 + w_2/M_2} \approx \frac{w_2/M_2}{w_1/M_1} \quad (\text{if solution is dilute})$$

18. Osmotic pressure P or $\pi = C \cdot RT$

C = molar conc., T = temp. in K, R = 0.0821 L atm K⁻¹ mol⁻¹ (if P is in atm and vol. of solution in litres) or 8.314 JK⁻¹ mol⁻¹ (if P is in Nm⁻² or Pascals and vol. in m³)

19. Isotonic solutions have same osmotic pressure and same molar concentrations. If one solution has lower osmotic pressure, it is called hypotonic with respect to the more concentrated solution. The more concentrated solution is said to be hypertonic with respect to the dilute solution.

20. Elevation in boiling point, $\Delta T_b = K_b m$ where K_b = molal elevation constant and m = molality of the solution.

21. Depression in freezing point, $\Delta T_f = K_f m$ where K_f = molal depression constant and m = molality of the solution.

$$22. K_b = \frac{RT_0^2}{1000l_v} = \frac{M_1 RT_0^2}{1000\Delta H_v}$$

where T_0 = boiling point of the liquid (pure solvent)

l_v = latent heat of vaporisation per g of the solvent

ΔH_v = latent heat of vaporisation per mole of the solvent

M_1 = molecular mass of the solvent

R = gas const. 8.314 JK⁻¹ mol⁻¹ if l_v or ΔH_v is in joules or 1.987 cal K⁻¹ mol⁻¹ if l_v or ΔH_v is in calories.

$$23. K_f = \frac{RT_0^2}{1000l_f} = \frac{M_1 RT_0^2}{1000\Delta H_f}$$

where T_0 = freezing point of the liquid (pure solvent)

l_f = latent heat of fusion per g of the solvent.

ΔH_f = latent heat of fusion per mole of the solvent.

24. The lowering of vapour pressure on adding a non-volatile solute to a solvent is due to covering up partially the surface of the solution by solute particles which are non-volatile.

25. Osmotic pressure method is the best method for determination of molecular masses of polymers because for polymer solutions, observed value of any other colligative property is too low to be measured accurately.

26. Van't Hoff factor (i) = $\frac{\text{Observed value of Colligative property}}{\text{Calculated value of colligative property}}$

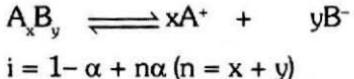
$$= \frac{\text{Calculated mol. mass}}{\text{Observed mol. mass}} = \frac{M_{\text{cal}}}{M_{\text{obs}}}$$

$$\left(\because \text{Mol mass} \propto \frac{1}{\text{Colligative property}} \right)$$

27. For solutes undergoing dissociation/association

$$\Delta T_b = i K_b m, \Delta T_f = i K_f m, \pi = i \frac{n}{V} RT$$

28. For an electrolyte $A_x B_y$ undergoing dissociation with degree of dissociation α .



$$i = 1 + (n - 1)\alpha \quad \text{or} \quad \alpha = \frac{i - 1}{n - 1}$$

29. For a solute A undergoing association



$$i = 1 - \alpha + \frac{\alpha}{n} \quad \text{or} \quad \alpha = \frac{1 - i}{1 - \frac{1}{n}}$$

30. Van't Hoff factor (i) > 1 for solutes undergoing dissociation and it is < 1 for solutes undergoing association.

31. Ethylene glycol is usually added to water in the radiator to lower its freezing point. It is called anti-freeze.

Chemistry HandBook

- 32.** Common salt (NaCl) or anhydrous CaCl₂ are used to clear snow on the roads. This is because they depress the freezing point of water to such an extent it cannot freeze to form ice.
- 33.** Freezing point is same as melting point. Hence instead of depression in freezing point, depression in melting point can be determined. For this purpose camphor is used as solvent because it has high molal depression constant K_f 39.7 \approx 40K/m.
- 34.** According to Henry's law, mass of gas dissolved \propto pressure of gas above the solution (i.e. m \propto p or m = k_Hp where k_H is called Henry's constant) or for a mixture of gases, solubility in terms of mole fraction \propto partial pressure (i.e. x_A = k_Hp_A where k_H is in atm⁻¹ or bar⁻¹ or p_A = k_Hx_A where k_H is in atm or bar)
- 35.** Raoult law is a special case of Henry's law.

REDOX REACTIONS

- 1.** **Stock notations** Expressing the oxidation state of a metal by Roman numerals like I, II, III etc. within parenthesis is called Stock notation e.g. FeSO₄ = Iron (II) sulphate; Na₂CrO₄ = Sodium chromate (VI) etc.
- 2.** **Valency** of an element is only a number and as such there is no positive or negative sign attached to it. It can neither be zero nor fractional. Oxidation number, on the other hand, refers to charge and hence has either positive or negative sign. It can also be zero or fractional. For example, oxidation state of C in CH₂Cl₂ is zero while that of Fe in Fe₃O₄ is 8/3 and of S in Na₂S₂O₃ is 2.0.
- 3.** The oxidation number of metals in amalgams and metal carbonyls, i.e., Ni(CO)₄, Fe (CO)₅, Cr(CO)₆ etc. is zero.

4. A substance acts only as an oxidising agent if the oxidation number of one of its element is in its highest oxidation state and as a reducing agent if the oxidation number of one of its elements is in its lowest oxidation state. However, if the oxidation number of one of the elements of a substance is in its intermediate oxidation state, it can act both as an oxidising as well as a reducing agent. For example,

- (a) The O.N. of N in HNO_3 , i.e. + 5 is the maximum, therefore, it can act only as an oxidising agent by accepting one or more electrons. For example,



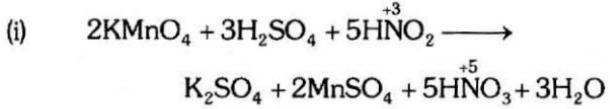
Here, the O.N. of N decreases from + 5 in HNO_3 to + 4 in NO_2 and hence it acts as an oxidising agent.

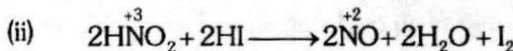
- (b) The O.N. of S in H_2S , i.e., -2 is the minimum and hence it can act only as a reducing agent by losing one or more electrons. For example,



Hence the O.N. of S increases from -2 in H_2S to 0 in elemental sulphur and hence it acts as a reducing agent.

- (c) The O.N. of N in HNO_2 i.e., + 3 is neither maximum (i.e., + 5) nor minimum (i.e. - 3), therefore, it can act both as an oxidising as well as a reducing agent. For example,

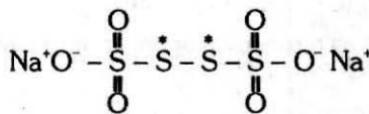




In eqn (i), the ON. of N increases from +3 in HNO_2 to +5 in HNO_3 , therefore, it acts as a reducing agent.

In eqn (ii), the ON. of N decreases from +3 in HNO_2 to +2 in NO, therefore, it acts as an oxidising agent.

5. Redox reactions are also called electron - transfer reactions since electrons are transferred from the reductant to the oxidant.
6. Oxidation is also called de-electronation while reduction is called electronation.
7. If a compound contains two or more atoms of the same element, all of them may or may not have same oxidation number e.g.
 - (i) In $\text{Na}_2\text{S}_2\text{O}_3$, one S-atom has oxidation number = -2 while the other has oxidation number = + 6.
 - (ii) In CaOCl_2 i.e., $\text{Ca}(\text{OCl})\text{Cl}$ (bleaching powder), oxidation number of one Cl = -1 while oxidation number of the other Cl = +1.
 - (iii) In Fe_3O_4 i.e., $\text{FeO} \cdot \text{Fe}_2\text{O}_3$ oxidation number of one Fe = +2 while that of each of the other two = +3.
 - (iv) In NH_4NO_3 , oxidation no. of N of NH_4^+ = -3 while that of N in NO_3^- = +5.
 - (v) In $\text{Na}_2\text{S}_4\text{O}_6$ (sodium tetrathionate) having the structure



The oxidation number of both S^* is equal to 0 (pure covalent nature) and others to sulphur atoms have O.No. = +5

ELECTROCHEMISTRY

- 1. Specific conductivity (K)** (or simply called conductivity) is the reciprocal of specific resistance i.e., $K = \frac{1}{\rho}$.

$$\text{Hence from } R = \rho \cdot \frac{l}{a}, \frac{1}{C} = \frac{1}{K} \cdot \frac{l}{a} \text{ or } K = C \times \frac{l}{a}$$

Where $\frac{l}{a}$ = cell constant

If $l = 1 \text{ cm}$ and $a = 1 \text{ cm}^2$, $K = C$. Hence conductivity is the conductance of 1 cm^3 of the conductor. Units of $K = \text{ohm}^{-1} \text{ cm}^{-1}$ or in SI units, these are $\Omega^{-1} \text{ m}^{-1}$ or Sm^{-1} ($1 \text{ S cm}^{-1} = 100 \text{ S m}^{-1}$)

- 2. Relationship between Equivalent conductivity (Λ_{eq}) and Specific conductivity (K)**

$$\Lambda_{eq} = K \times \frac{1000}{C_{eq}} = K \times \frac{1000}{\text{Normality}}$$

C_{eq} represents the concentration of the solution in gram equivalents per litre (i.e. normality of the solution).

- 3. Units of equivalent conductivity** = $\text{ohm}^{-1} \text{ cm}^2 \text{ eq}^{-1}$ or in SI units, these are $\text{S m}^2 \text{ eq}^{-1}$ ($1 \text{ S m}^2 \text{ eq}^{-1} = 10^4 \text{ S cm}^2 \text{ eq}^{-1}$ or $\text{S cm}^2 \text{ eq}^{-1} = 10^{-4} \text{ S m}^2 \text{ eq}^{-1}$)

- 4. Relationship between molar conductivity (Λ_m) and Specific conductivity (K)**

$$\Lambda_m = K \times V = K \times \frac{1000}{C_m} = K \times \frac{1000}{\text{Molarity}}$$

Where V is volume of solution in cm^3 containing one mole of the electrolyte and C_m is molar concentration (moles L^{-1})

- 5. Units of molar conductivity** = $\text{ohm}^{-1} \text{ cm}^2 \text{ mol}^{-1}$ or in SI units, these are $\text{S m}^2 \text{ mol}^{-1}$ ($1 \text{ S m}^2 \text{ mol}^{-1} = 10^4 \text{ S cm}^2 \text{ mol}^{-1}$ or $1 \text{ S cm}^2 \text{ mol}^{-1} = 10^{-4} \text{ S m}^2 \text{ mol}^{-1}$)

- 6. Effect of dilution :** Conductance increases, specific conductivity decreases, equivalent and molar conductivity increase with dilution.
- 7. Kohlrausch's law :** The law states that at infinite dilution where dissociation of all electrolytes is complete and all interionic effects disappear, each ion migrates independently of its co-ion and contributes to the total molar conductivities of an electrolyte a definite share, which depends on its own nature and not at all on the ions with which it is associated.

General formula : For molar conductance $\Lambda_m^\infty = m\lambda_c^\infty + n\lambda_a^\infty$

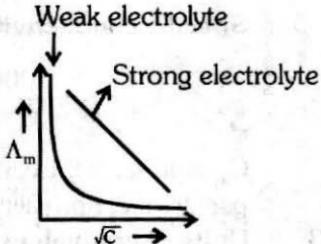
where m & n = moles of cation & anion λ_c^∞ & λ_a^∞ = molar ionic conductance at infinite dilution for cation & anion.

For equivalent conductance :

$$\Lambda_{eq}^\infty = \frac{1}{Z^+} \lambda_c^\infty + \frac{1}{Z^-} \lambda_a^\infty$$

Relation between Λ_m and Λ_{eq} .

$$\boxed{\Lambda_{eq} = \frac{\Lambda_m}{v.f.}}$$



Variation of Λ_m with conc.

- 8. Absolute value of electrode potential cannot be determined** because oxidation or reduction half reaction cannot occur alone. Moreover, a reference electrode is required.
- 9.** A negative value of standard reduction potential means that oxidation takes place on this electrode with reference to standard hydrogen electrode. The standard electrode potential of hydrogen electrode is taken as zero.
- 10. Electrochemical series**
Arrangement of different elements in increasing order of SRP is known as electrochemical series or activity series.

Application:

- (i) Greater the reduction potential of a substance stronger is the oxidising agent.
- (ii) In ECS reactivity of metals decreases from top to bottom.
- (iii) In ECS reactivity of non metals decreases from top to bottom.
- (iv) More reactive metals/non metals displaces less reactive metal/non-metal in their solution.
- (v) Metals above H₂ displace H₂ from acids.

11. A **Galvanic cell or voltaic cell** is a device used to convert chemical energy produced in a redox reaction into electrical energy.
LOAN → Left oxidation anode negative.

12. In galvanic cell, the electrode on which oxidation takes place is called anode or negative pole (because it is rich in electrons) and the electrode on which reduction takes place is called the cathode or **positive pole (being deficient in electrons)**.

13. Difference between **Galvanic and Electrolytic cell** lies is the fact that the former is used to convert chemical energy produced in the spontaneous redox reaction into electrical energy whereas in the latter, electrical energy is passed to bring about the redox reaction (electrolysis) which is otherwise non-spontaneous.

14. In a salt bridge, the electrolytes commonly used are KCl or KNO₃ or NH₄NO₃. This is because their cations and anions move almost at the same speed and hence have almost the same transport numbers.

15. KCl/NaCl/NH₄Cl etc. cannot be used in the salt bridge of a cell containing Ag⁺, Hg₂²⁺, Tl¹ & Pb⁺² ions because they react to form a precipitate of AgCl, HG₂Cl₂, TlCl or PbCl₂

$$E_{\text{Cell}}^0 = E_{\text{O.P.(Anode)}}^0 - E_{\text{O.P.(Cathode)}}^0$$

16. $E_{\text{cell}}^0 = E_{\text{Red}}^0 (\text{R.H.S. electrode}) - E_{\text{Red}}^0 (\text{L.H.S. electrode}).$

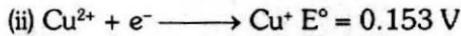
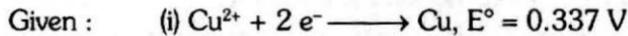
$$E_{\text{Cell}}^0 = E_{\text{R.P.(Cathode)}}^0 + E_{\text{O.P.(Anode)}}^0$$

$$E_{\text{Cell}}^0 = E_{\text{R.P.(Cathode)}}^0 - E_{\text{R.P.(Anode)}}^0$$

Chemistry Handbook

17. $E_{R.P.}^0 = -E_{O.P.}^0$ (For same electrode).
18. In balancing of half-cell reactions to get overall reaction, the equations may be multiplied by suitable integers but electrode potentials are fixed quantities and are not multiplied with that integer.
19. For a given reaction to be spontaneous, E_{cell} must be positive.
20. When the cell reaction attains equilibrium, $E_{cell} = 0$.
21. The EMF of a cell (complete redox reaction) is found by adding the oxidation potential and reduction potential of the half-cell reaction. But the electrode potential of a half-cell form two other half-cells cannot be found by simply adding their electrode potentials.

For example, suppose we have to calculate standard electrode potential of Cu^+/Cu half-cell from known values for Cu^{2+}/Cu and Cu^{2+}/Cu^+ (which are 0.337 V and 0.153 V respectively) i.e.



Subtracting equation. (ii) from equation (i) will not give the required result. We have to calculate their free energy changes. Let the free energy changes of the above three reactions be ΔG_1° , ΔG_2° and ΔG_3° respectively. Then $\Delta G_3^\circ = \Delta G_1^\circ - \Delta G_2^\circ$

$$\text{i.e. } -1 \times F \times E_{Cu+/Cu}^\circ = (-2 \times F \times 0.337) - (-1 \times F \times 0.153) \\ (\Delta G^\circ = n FE^\circ)$$

This gives $E_{Cu+/Cu}^\circ = 0.521\text{ V}$.

22. According to Faraday's first law of electrolysis,
$$\frac{W}{E} = \frac{Q}{F}$$
- Weight of substance liberated \propto Quantity of electricity passed.
 $W \propto Q$ or $W = ZQ = Z \times i \times t$ (Z = electrochemical equivalent)
23. $Z = \text{Equivalent wt. of the substance} / 96,500$ or $Z = \frac{E}{F}$

- 24.** According to Faraday's second law of electrolysis, for the same quantity of electricity passed through solutions of different electrolytes, (e.g. CuSO_4 and AgNO_3)

$$\frac{\text{Weight of Cu deposited}}{\text{Weight of Ag deposited}} = \frac{\text{Equivalent wt. of Cu}}{\text{Equivalent wt. of Ag}} \quad \boxed{\frac{W_1}{E_1} = \frac{W_2}{E_2}}$$

- 25.** In an aqueous solution of SO_4^{2-} and NO_3^- , at the anode these ions are not oxidized but H_2O is oxidized to give O_2 gas ($2\text{H}_2\text{O} \rightarrow \text{O}_2 + 4\text{H}^+ + 4\text{e}^-$).

- 26.** Any metal above H_2O in electrochemical series can not be obtained by electrolysis of its salt solution.

- 27.** **Primary cells** are those which cannot be recharged e.g. dry cell and mercury cell.

Secondary cells are those which can be recharged e.g. lead storage battery and Ni – Cd cell.

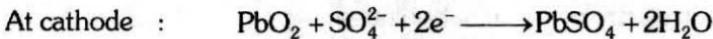
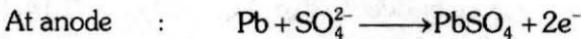
Fuel cells are those in which energy produced from the combustion of fuels can be converted into electrical energy e.g. $\text{H}_2 - \text{O}_2$ fuel cell.

28. Main features of different cells.

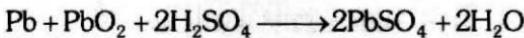
	Names of the cell/Battery	Anode	Cathode	Electrolyte
(i)	Dry cell	Zinc	Graphite	$\text{MnO}_2 + \text{C}$ black (touching cathode) $\text{NH}_4\text{Cl} + \text{ZnCl}_2$ (touching anode)
(ii)	Mercury cell	Zinc	Graphite	$\text{HgO} + \text{KOH}$ (moist)
(iii)	Lead storage battery	Lead	Lead dioxide	H_2SO_4 (38% sol ⁿ)
(iv)	Ni-Cd cell	Cadmium	Nickel dioxide	KOH sol.
(v)	$\text{H}_2 - \text{O}_2$ fuel cell	Porous carbon contg catalysts (H_2 passed)	Porous carbon contg catalyst (O_2 passed)	Conc. aq. KOH sol.

Chemistry HandBook

- 29.** A dry cell does not have a long life because the acidic NH_4Cl corrodes the zinc container even when the cell is not in use.
- 30.** Mercury cell gives a constant voltage (1.35 V) throughout its life and is used in hearing aids and watches.
- 31. Reactions occurring in lead storage battery** (a) Reactions occurring during discharge



The complete reaction may be written as

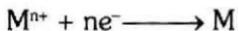


As H_2SO_4 is consumed, the voltage of the battery drops.

A factor of H_2SO_4 in charging/discharging is 1.

- 32.** In the Appolo moon flights, the source of electrical energy and that of drinking water was the $\text{H}_2 - \text{O}_2$ fuel cell.
- 33.** Corrosion is the process of change of metal surface into salts like oxides, sulphides, carbonates etc. due to attack of atmospheric gases.
- 34.** Rust is hydrated ferric oxide, $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$
- 35. Factors which enhance corrosion are**
- (i) Presence of impurities in the metal (pure metals do not corrode).
 - (ii) Presence of moisture (e.g. in rainy season)
 - (iii) Presence of electrolytes (e.g. saline water)
- 36. Corrosion can be prevented** by the following methods :
- (i) Barrier protection by oil/grease layer, paints or electroplating.
 - (ii) Sacrificial protection by coating the metal with more electropositive metal (e.g. Zn) called galvanisation.
 - (iii) Electrical protection by connecting the iron pipe to a more electropositive metal with a wire. (Cathodic protection)

- 37.** Corrosion takes place faster in saline water than in pure water.
- 38.** According to Nernst equation,
- (i) For the reaction half reaction (electrode reaction)

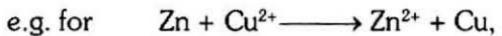


$$E_{R.P.} = E_{R.P.}^0 - \frac{RT}{nF} \ln \frac{1}{[\text{M}^{n+}]} = E_{\text{Red}}^0 - \frac{0.0591}{n} \log \frac{1}{[\text{M}^{n+}]} \text{ at } 298\text{K}$$

- (ii) For the cell reaction $a \text{A} + b \text{B} \rightleftharpoons x \text{X} + y \text{Y}$

$$E_{\text{Cell}} = E_{\text{Cell}}^0 - \frac{RT}{nF} \ln \frac{[\text{X}]^x [\text{Y}]^y}{[\text{A}]^a [\text{B}]^b} = E_{\text{cell}}^0 - \frac{0.0591}{n} \log \frac{[\text{X}]^x [\text{Y}]^y}{[\text{A}]^a [\text{B}]^b} \text{ at } 298\text{K}$$

For a pure solid, pure liquid at 1 atm, put molar conc. = 1.



$$E_{\text{Cell}} = E_{\text{Cell}}^0 - \frac{0.0591}{n} \log \frac{[\text{Zn}^{2+}]}{[\text{Cu}^{2+}]} = E_{\text{cell}}^0 - \frac{0.0591}{n} \log \frac{[\text{Product}]}{[\text{Reactant}]}$$

39. $E_{\text{Cell}}^0 = \frac{RT}{nF} \ln K = \frac{2.303 RT}{nF} \log K = \frac{0.0591}{n} \log K \text{ at } 298 \text{ K}$

(K = Equilibrium constant of the cell reaction).

40. Thermodynamic efficiency of a fuel cell (η) = $\frac{\Delta G}{\Delta H} = \frac{-nFE}{\Delta H}$

41. Calculation of ΔG , and ΔS for cell reactions.

$$\Delta G = -nFE_{\text{cell}}$$

BEHAVIOUR OF GASES

Gas law

(I) Boyle's law :

$$V \propto \frac{1}{P} \quad (n, T = \text{const})$$

$$P_1 V_1 = P_2 V_2$$

(II) Charle's law :

$$V \propto T \quad (n, P = \text{const})$$

$$\frac{V_2}{V_1} = \frac{T_2}{T_1}$$

(III) Gay Lussac's law :

$$P \propto T \quad (n, V = \text{const})$$

$$\frac{P_2}{P_1} = \frac{T_2}{T_1}$$

(IV) Avogadro's law :

$$V \propto \text{moles} \propto \text{number of molecules} \quad (P, T = \text{const})$$

$$\text{Ideal gas equation } PV = nRT$$

$$R = 0.0821 \text{ lit atm mol}^{-1} \text{ K}^{-1}$$

$$R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1} \text{ or } 8.314 \quad N \times m \text{ K}^{-1} \text{ mol}^{-1}$$

$$R = 2 \text{ cal K}^{-1} \text{ mol}^{-1}$$

$$R = 8.314 \times 10^7 \text{ erg K}^{-1} \text{ mol}^{-1}$$

2. Graham's diffusion law :

It is applicable for non reacting gases

$$r \propto \frac{1}{\sqrt{d}}$$

$$r \propto \frac{1}{\sqrt{VD}}$$

$$r \propto \frac{1}{\sqrt{Mw}}$$

(P, T = const)

$$VD = \frac{dgas}{dH_2} = \frac{Mw}{2}$$

rate of diffusion

$$r = \frac{\ell_{\text{diffused gas}}}{t_{\text{time taken}}}$$

(Where, ℓ = distance travelled by diffused gas)

$$r = \frac{V_{\text{diffused gas}}}{t_{\text{time taken}}}$$

$$r = \frac{n_{\text{diffused gas}}}{t_{\text{time taken}}}$$

3. Dalton's law of partial pressure

$$P_{\text{mixture}} = P_1 + P_2 + P_3 \dots \dots \dots \text{(T & V const)}$$

Partial pressure

$$P_{\text{moist gas}} = P_{\text{dry gas}} + P_{\text{water vapours}}$$

It is applicable for non reacting gases.

Methods of determination of partial pressure

(P_A & P_B are partial pressure)

(I) from ideal gas equation

$$P_A V = n_A RT \quad \text{and} \quad P_B V = n_B RT$$

(II) In the form of mole fraction.

$$P_A = X_A P_T = \frac{n_A}{n_t} P_T$$

$$X_A + X_B = 1$$

$$P_B = X_B P_T = \frac{n_B}{n_t} P_T$$

P_T = sum of partial pressure of all gases

(III) In the form of volume fraction

$$P_A = \frac{V_A}{V} P_T \quad \text{and} \quad P_B = \frac{V_B}{V} P_T$$

(IV) If individual pressure and individual volume are given

$$P_A = \frac{V_A}{V} P_1 \quad \text{and} \quad P_B = \frac{V_B}{V} P_2$$

P_1, P_2 = pressure of gases before mixing

P_A, P_B = pressure of gases after mixing

4. Kinetic gas equation

$$PV = \frac{1}{3} mN V_{rms}^2$$

5. Average KE (KEav)

$$KEav = \frac{3}{2} nRT \quad (\text{n moles})$$

$$KEav = \frac{3}{2} RT \quad (\text{1 mol or } N_A \text{ molecules})$$

$$KEav = \frac{3}{2} KT \quad (\text{1 molecule})$$

$$K = 1.38 \times 10^{-23} \text{ JK}^{-1} \text{ molecule}^{-1}$$

K is called Boltzman's constant

$v_{rms} = \sqrt{\frac{v_1^2 + v_2^2 + \dots v_n^2}{N}}$ $v_{rms} = \sqrt{\frac{3RT}{Mw}}$ $v_{rms} = \sqrt{\frac{3PV}{Mw}}$ $v_{rms} = \sqrt{\frac{3P}{d}}$	$v_{av} = \frac{v_1 + v_2 + v_3 \dots v_n}{N}$ $v_{av} = \sqrt{\frac{8RT}{\pi Mw}}$ $v_{av} = \sqrt{\frac{8PV}{\pi Mw}}$ $v_{av} = \sqrt{\frac{8P}{\pi d}}$	$v_{mp} = \sqrt{\frac{2RT}{Mw}}$ $v_{mp} = \sqrt{\frac{2PV}{Mw}}$ $v_{mp} = \sqrt{\frac{2P}{d}}$
---	--	--

$$v_{rms} : v_{av} : v_{mp} = \sqrt{3} : \sqrt{\frac{8}{\pi}} : \sqrt{2}$$

$$= 1 : 0.92 : 0.82$$

$$v_{mp} : v_{av} : v_{rms} = \sqrt{2} : \sqrt{\frac{8}{\pi}} : \sqrt{3}$$

$$= 1 : 1.128 : 1.224$$

7. Compressibility factor (z) = $\frac{(V_m)_{\text{obs}}}{V_i} = \frac{P(V_m)_{\text{obs}}}{RT}$

If $z = 1$, the gas show ideal gas behaviour.

If $z > 1$, the gas show positive deviation.

If $z < 1$, the gas show negative deviation.

8. **Vanderwaal's equation**

$$\left(P + \frac{an^2}{V^2} \right) (V - nb) = nRT$$

$$P_i = P_R + \frac{an^2}{V^2} \quad \Rightarrow \quad P_i > P_R$$

a↑ force of attraction↑, liquification↑

b↑, effective size of molecule↑

incompressible vol↑, compressible vol↓

(I) At high pressure, Vanderwaal's equation is $PV_m - Pb = RT$

(II) At low pressure or Moderate pressure Vanderwaal's

equation is
$$PV_m + \frac{a}{V_m} = RT$$

(III) At very low pressure, high temperature Vander waal's Eqⁿ is

$$VP = nRT$$
 Ideal gas behavior.

(IV) Gases having ↑value of a; will have ↑T_c; ↑rate of liquefaction.

ATOMIC STRUCTURE

- The word "Atom" was given by Ostwald.

DISCOVERY & THEIR DISCOVERERS

Name of Particles	Scientist	Mass	Charge
Electron	J.J. Thomson	9.1×10^{-31} kg	-1.6×10^{-19} cb
Proton	Goldstein	1.673×10^{-27} kg	$+ 1.6 \times 10^{-19}$ cb
Neutron	Chadwick	1.675×10^{-27} kg	Zero
Positron	C.D. Anderson	(same as electron)	same as proton
Anti Proton	Sugri	(same as proton)	electron
Neutrino	Pauling	Negligible	Zero
Meson	Yukawa	(200 times of electron)	(+, -, zero)
Isotopes	Soddy		
Isobar	Aston		
Cathode Ray	William Crooke's		
Anode Ray	GoldStein		
Neucleus	Rutherford		
Atomic No.	Moseley		
Nomenclature of e^-	Stoney		
Charge of e^-	Millikan		
Specific charge on e^- (e/m)	J.J. Thomson		

- **Important Definitions :**

- (i) Atomic number (Z) = no. of protons
* Moseley's relation $\Rightarrow \sqrt{v} = a(z - b)$
- (ii) Mass no. (A) = number of ($n + p$)
- (iii) Isotopes = Same Z but different A
- (iv) Average Atomic wt.

$$= \frac{m_1x_1 + m_2x_2 + m_3x_3 + \dots}{x_1 + x_2 + x_3 + \dots}$$

where m_1, m_2, m_3 are mass of isotopes

x_1, x_2, x_3 are their percentage abundance or relative ratio.

- (v) Isobars = Same A + Different Z
- (vi) Isotones/Isoneutronic/Isotonic = same no. of neutrons
- (vii) Isodiaphers = Same ($n-p$)
- (viii) Isosters = Molecules with same no. of atoms and electrons.
- (ix) Isoelectronic = Same no. of e^- s.

Electromagnetic radiations

- * The electric & magnetic components of wave have same wavelength, frequency, speed and amplitude but they vibrate in two mutually perpendicular planes.
- * EM waves do not need any medium for propagation and all EM waves travel with same velocity ($3 \times 10^8 \text{ ms}^{-1}$)
- * Relation between frequency (v), wavelength (λ), wave number (\bar{v}) and time period (T)
 - * $c = v\lambda$

$$* \quad \bar{v} = \frac{1}{\lambda} = \frac{v}{c}$$

$$1\text{cm}^{-1} = 100\text{m}^{-1}$$

$$* \quad T = \frac{1}{v} = \frac{\lambda}{c}$$

Electromagnetic Spectrum

The arrangement of various types of electromagnetic radiations in the order of their increasing or decreasing wavelength or frequency is known as electromagnetic spectrum.

Radiation	Wavelength (Å)	Frequency (Hz)
Gamma rays	0.01 to 0.1	3×10^{19} to 3×10^{20}
X-rays	0.1 to 150	2×10^{16} to 3×10^{19}
UV radiations	150 to 3800	7.9×10^{14} to 2×10^{16}
Visible rays	3800 to 7600	3.95×10^{14} to 7.9×10^{14}
Microwaves	6×10^6 to 3×10^9	1×10^5 to 1×10^9

Photoelectric effect

$$E_{\text{photon}} = \text{Threshold Energy (work function)} + KE$$

$$E_{\text{photon}} = h\nu_0 + KE$$

$$h\nu = h\nu_0 + KE$$

$$\text{or} \quad KE = h(\nu - \nu_0)$$

Plancks Quantum theory. (Important Formulae)

* $E = h\nu$ (E = Energy of one photon)

or $E = h\nu = \frac{hc}{\lambda} = hc\bar{\nu}$

* Total Energy transferred = $N \times$ Energy of one photon.

$$E_T = N \times h\nu = N \times \frac{hc}{\lambda} = N \times hc\bar{\nu}$$

Where h = plancks constant $= 6.626 \times 10^{-34} \text{ Js}$
 $= 6.626 \times 10^{-27} \text{ erg s}$
 $h \times c = 2 \times 10^{-25}$ (In SI unit)

Bohr's Model

- * Applicable for single e^- species only like H, He^+ , Li^{+2} , Be^{+3} , Na^{+10} etc.
- * Related with particle nature of electron.
- * Based on Plancks Quantum theory.

Important Formulae :

- * Angular momentum in an orbit is quantized.

$$mvr = n \times \frac{h}{2\pi}$$

- * Radius of bohr orbit = $r = \frac{n^2 h^2}{4\pi^2 m K Z e^2}$

On solving $r = 0.529 \times \frac{n^2}{Z} \text{ Å}$

where $0.529 \text{ Å} = a_0$ is called atomic unit of length (Bohr)

- * Velocity of electron in Bohr orbit

$$v = \frac{2\pi K Z e^2}{n h}$$

On solving $v = 2.18 \times 10^6 \frac{Z}{n} \text{ m/s}$

$$v = 2.18 \times 10^8 \frac{Z}{n} \text{ cm/s}$$

Energy of electron in Bohr orbit

- * Potential Energy (PE) = $-\frac{K Z e^2}{r}$ i.e. At $r = \infty$, PE = 0
- * Kinetic Energy (KE) = $\frac{1}{2} \frac{K Z e^2}{r}$ i.e. At $r = \infty$, KE = 0
- * Total Energy (TE) = $\frac{-2\pi^2 m K^2 z^2 e^4}{n^2 h^2}$

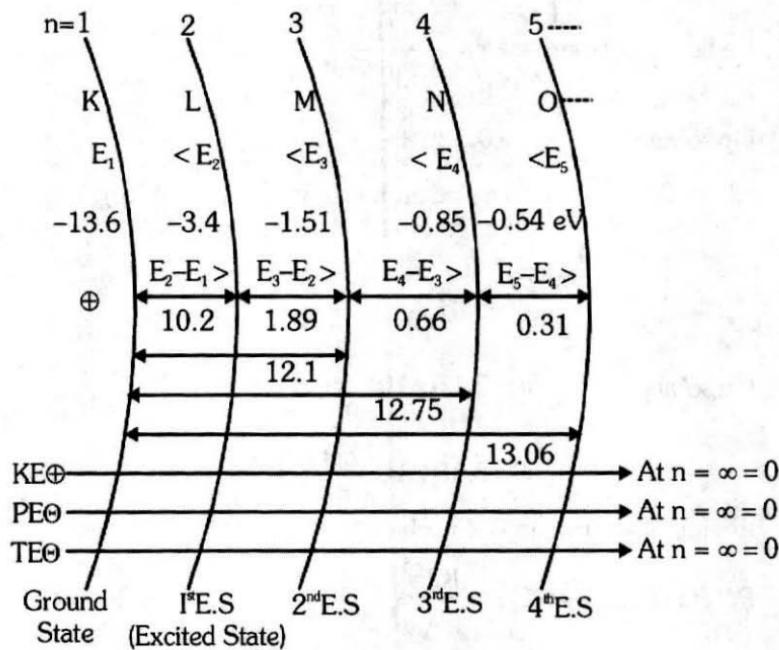
On solving TE = $-2.18 \times 10^{-18} \frac{z^2}{n^2} \text{ J/atom}$

$$= -13.6 \times \frac{z^2}{n^2} \text{ eV/atom}$$

$$= -313.6 \times \frac{z^2}{n^2} \text{ Kcal/mol}$$

$$= -1313.6 \times \frac{z^2}{n^2} \text{ KJ/mol}$$

* Relation between TE, PE and KE \Rightarrow PE = $2 \times$ TE
 \Rightarrow TE = -KE
 \Rightarrow PE = -2KE



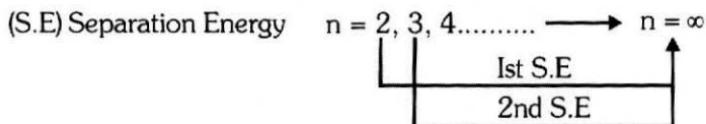
Important Shortcuts

T.E of any H-like species = TE of Hydrogen $\times Z^2$
(For same orbit)

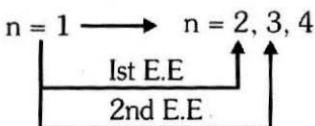
ΔE for H-like species = ΔE (For Hydrogen) $\times Z^2$
(For same transition)

Energy in n^{th} orbit-for H like species = $\frac{E_1}{n^2}$ [For same atom]

(I.E.) Ionisation Energy $\Rightarrow n = 1 \longrightarrow n = \infty$



(E.E) Excitation Energy =



Spectrum (Important points)

- * Continuous emission spectrum is given by incandescent sources.
- * Emission line spectrum is given by atoms.
- * Emission band spectrum is given by molecules.
- * Angle of deviation \propto frequency of radiation.
- * More lines are observed in emission spectrum than absorption spectrum.

Hydrogen Spectrum (n_2)

(n_1)

Lyman \rightarrow Any higher orbit \rightarrow 1	[Found in U.V. region]
Balmer \rightarrow Any higher orbit \rightarrow 2	[Found in Visible region]
Paschen \rightarrow Any higher orbit \rightarrow 3	[Found in I.R. region]
Brackett \rightarrow Any higher orbit \rightarrow 4	[Found in I.R. region]
Pfund \rightarrow Any higher orbit \rightarrow 5	[Found in I.R. region]

Rydberg Equation :

$$\bar{v} = \frac{1}{\lambda} = R_H Z^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \quad \left[\text{Where } C = \text{velocity of electromagnetic waves} \right]$$

$$v = R_H CZ^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

$$E = R_H CZ^2 h \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

Chemistry Handbook

$$\text{Where } R_H = \text{Rydberg constant} = 109678 \text{ cm}^{-1} = 10967800 \text{ m}^{-1}$$

$$\frac{1}{R_H} = 912 \text{ Å}$$

$R_H Ch$ = Energy of 1st orbit of Hydrogen

$R_H Ch Z^2$ = Energy of 1st orbit of any Hydrogen like species.

Important Point :

- * α line/First line/starting line/Initial line (First line of any series)
- * Last line/limiting line/marginal line (Last line of any series)
- * Total number of lines in emission spectrum (For $n_2 \rightarrow n_1$)

$$(\text{T.E.L}) \text{ Total Emission lines} = \frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$$

$$\text{But for } (n \rightarrow 1), \text{ T.E.L} = \frac{n(n-1)}{2}$$

de-Broglie Equation (Important Formulae)

$$* \lambda = \frac{h}{mv} = \frac{h}{P} \quad \text{Where } h = \text{Planck's constant}$$

$$* \lambda = \frac{h}{\sqrt{2mKE}} \quad m = \text{mass}$$

v = velocity

KE = Kinetic Energy

V = Potential

$$* \lambda = \frac{h}{\sqrt{2mqv}} \quad (\text{for } e^- \text{ if solved}) \text{ then } \lambda = \sqrt{\frac{150}{V}} \text{ Å}$$

Important Points :

- * When an e^- revolves in orbit then no. of waves made by e^- = orbit number (n).
- * Frequency of matter waves.

$$v = \frac{v}{\lambda} = \frac{vP}{h} = \frac{mv^2}{h} = \frac{2KE}{h} \quad [v = \text{frequency}]$$

- * Electron microscope is based on the wave nature of electron.
- * de-Broglie on the basis of Millikan's oil drop experiment (which showed particle nature) and diffraction study (which showed wave nature) suggested the dual nature of electron.

Heisenberg uncertainty principle

$$\Delta x \times \Delta P \geq \frac{h}{4\pi}$$

or $\Delta x \times \Delta v \geq \frac{h}{4\pi m}$

where Δx = Uncertainty in position

Δv = Uncertainty in velocity

ΔP = Uncertainty in momentum

 m = Mass of particle

$$\frac{h}{4\pi} = 5.27 \times 10^{-35} \text{ Js} \quad (\text{In SI unit})$$

Quantum number

In an atom each shell, subshell, orbital and electron are designated by a set of 4 quantum numbers.

1. Principal Quantum number (By Bohr)

⇒ Indicates = Size and energy of the orbit, distance of e^- from nucleus

⇒ Values n = 1, 2, 3, 4, 5.....

⇒ Angular momentum = $n \times \frac{h}{2\pi}$

⇒ Total number of e^- s in an orbit = $2n^2$

⇒ Total number of orbitals in an orbit = n^2

⇒ Total number of subshell in an orbit = n

2. Azimuthal/Secondary/Subsidiary/Angular momentum Q. No. (l)

⇒ Given by = Sommerfeld

⇒ Indicates = Sub shells/sub orbit/sub level

⇒ Values ⇒ 0, 1.....(n-1)

⇒ Indicates shape of orbital/Sub shell

Value of n	Values of ℓ [Shape]	Initial from word
⇒ eg. If $n = 4$	$l = 0$ (s) [Spherical]	Sharp
	1 [p] [Dumb bell]	Principal
	2 [d] [Double dumb bell]	Diffused
	3 [f] [Complex]	Fundamental
⇒ Total no. of e^- s in a sub - orbit = $2(2l + 1)$		
⇒ Total no. of orbitals in a sub - orbit = $(2l + 1)$		
⇒ Orbital angular momentum = $\sqrt{\ell(\ell+1)} \frac{h}{2\pi} = \sqrt{\ell(\ell+1)} \hbar$		
	$\hbar = \text{Planck's constant}$	
⇒ For H & H-like species all the subshells of a shell have same energy.		
i.e.	$2s = 2p$	
	$3s = 3p = 3d$	

3. Magnetic Quantum number (m)

- ⇒ Given by Linde
- ⇒ Indicates orientation of orbitals i.e. direction of e^- density.
- ⇒ Value of $m = -\ell \dots 0 \dots +\ell$
- ⇒ Maximum no of e^- s in an orbital = 2 (with opposite spin)

m for p sub shell =

p_x	p_y	p_z
-1	+1	0

m for d sub shell =

d_{xy}	d_{yz}	d_{z^2}	d_{xz}	$d_{x^2-y^2}$
-2	-1	0	+1	+2

4. Spin Quantum no. (m_s or s)

Given by Uhlenbeck & Goudsmit

$$\text{Values of } s = \pm \frac{1}{2}$$

Total value of spin in an atom = $\pm \frac{1}{2} \times \text{number of unpaired e}^-$

$$\text{Spin Angular momentum} = \sqrt{s(s+1)} \frac{\hbar}{2\pi}$$

Rules for filling of orbitals :

1. **Aufbau principle :** The electrons are filled up in increasing order of the energy in subshells.
 $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^{14} 5d^{10} 6p^6 7s^2 5f^{14} 6d^{10}$
2. **(n + ℓ) rule :** The subshell with lowest $(n + \ell)$ value is filled up first, but when two or more subshells have same $(n + \ell)$ value then the subshell with lowest value of n is filled up first.
3. **Pauli exclusion principle :** Pauli stated that no two electrons in an atom can have same values of all four quantum numbers.
4. **Hund's rule of maximum multiplicity :** Electrons are distributed among the orbitals of subshell in such a way as to give maximum number of unpaired electrons with parallel spin.

CHEMICAL KINETICS**Rate of reaction :**

$$ROR = \frac{1}{n_1} \cdot \frac{-d[A]}{dt} = \frac{1}{n_2} \cdot \frac{-d[B]}{dt} = \frac{1}{m_1} \cdot \frac{+d[C]}{dt} = \frac{1}{m_2} \cdot \frac{+d[D]}{dt}$$

$$\text{Rate of disappearance of } A = -\frac{d[A]}{dt}$$

$$\text{Rate of disappearance of } B = -\frac{d[B]}{dt}$$

$$\text{Rate of appearance of } C = +\frac{d[C]}{dt}$$

$$\text{Rate of appearance of } D = +\frac{d[D]}{dt}$$

Order of Reaction :

In general, order of a reaction is defined as, "the sum of the powers to which the concentration terms of the reactants must be raised in order to determine the reaction rate."

For a reaction, $mA + nB \longrightarrow C$

$$\text{Rate equation is } \frac{dx}{dt} = K[A]^x[B]^y$$

Order of reaction with respect to A = x

Order of reaction with respect to B = y

Total order of reaction = x + y

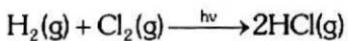
Here K is a rate constant and its value depends on

- (1) Temperature
- (2) Catalyst
- (3) Nature of reactant

Zero Order Reaction

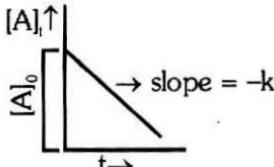
Eg. Decomposition of gases on metal surface.

Eg. Photochemical reaction.

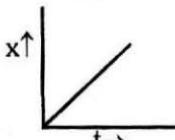


Integrated rate equation

$$[\text{A}]_t = [\text{A}]_0 - kt \quad \dots \dots \dots (1)$$



$$x = kt \quad \dots \dots \dots (2)$$

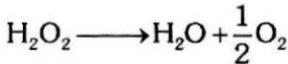


$$\text{Half life} \quad t_{\frac{1}{2}} = \frac{a}{2k} \quad \Rightarrow \quad t_{100\%} = \frac{a}{k} \quad \Rightarrow \quad t_{100\%} = 2 \times t_{\frac{1}{2}}$$

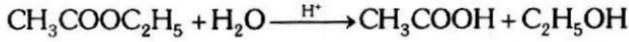
$$\text{Rate equation : } \frac{dx}{dt} = k[\text{A}]^0$$

First Order Reaction

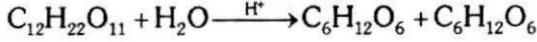
Eg. All radio active disintegration



Hydrolysis of ester in acidic medium- (Pseudo first order rxn)



Inversion of cane sugar in acidic medium- (Pseudo first order rxn)



$$\text{Rate equation : } \frac{dx}{dt} = K[\text{A}]$$

Chemistry HandBook**First Order Rate Expression :**

$$k = \frac{2.303}{t} \log \frac{a}{a-x}$$

$$\text{Half-life } (t_{1/2}) = \frac{0.693}{k}$$

$$t_{75\%} = 2 \times t_{1/2}, t_{87.5\%} = 3 \times t_{1/2}, t_{93.75\%} = 4 \times t_{1/2}, t_{100\%} = \infty$$

Integrated rate equation for n^{th} order reaction -

$$Kt = \frac{1}{(n-1)} \left[\frac{1}{(a-x)^{n-1}} - \frac{1}{a^{n-1}} \right]$$

$$t_{1/2} = \frac{1}{(n-1)} \left[\frac{2^{n-1}-1}{a^{n-1}} \right] \Rightarrow t_{1/2} \propto \frac{1}{a^{n-1}}$$

$$\frac{\left(\frac{t_{1/2}}{2}\right)_1}{\left(\frac{t_{1/2}}{2}\right)_2} = \left(\frac{a_2}{a_1}\right)^{n-1}$$

It is half life method to determine order of reaction.

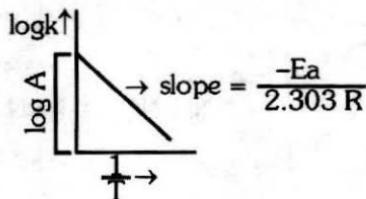
Activation Energy :

- The excess energy that is supplied to the reactant molecules in order to raise them to the level of threshold energy is called activation energy.
- Arrhenius gave a relationship between the temp. and rate constant of a reaction called Arrhenius equation;

$$k = Ae^{-E_a/RT}$$

$$\log k = \log A - \frac{E_a}{2.303RT}$$

$$\text{or } \log \frac{k_2}{k_1} = \frac{E_a}{2.303R} \left(\frac{T_2 - T_1}{T_1 T_2} \right)$$



Where k_1 = rate constant at temp. T_1

k_2 = rate constant at temp. T_2

- Temperature coefficient $\mu = \frac{k_{T+10}}{k_T}$

range of $\mu = 2 \leq \mu \leq 3$

$\frac{k_2}{k_1} = \frac{r_2}{r_1}$ at any two different temperatures.

Factors affecting activation energy are

- (1) Catalyst
- (2) Nature of reactant

(1) Factors affecting rate of reaction.

- (i) Nature of reactant.
 - (a) Physical state
 - (b) Physical size of particles
 - (c) Chemical nature
- (ii) Concentration of reactant
- (iii) Pressure
- (iv) Temperature
- (v) Catalyst
- (vi) Exposure to radiation

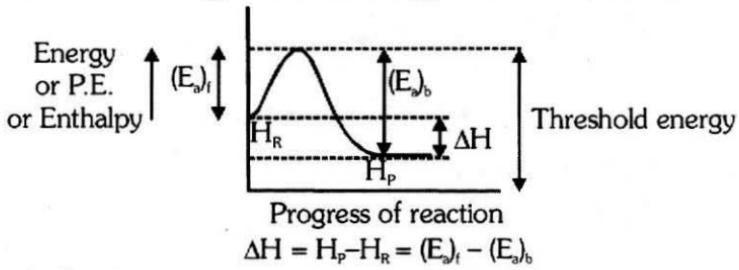
2. Collision theory -

Two conditions must be satisfied for effective collision.

- (i) Reacting molecules must possess a minimum amount of energy which is equal to threshold energy.
- (ii) Proper orientation for collision.

The excess energy that is supplied to the reactant molecules in order to raise them to the level of threshold energy is called activation energy.

Threshold energy = Potential energy of reactants + activation energy



3. Arrhenius equation :

Arrhenius gave a relationship between the temperature and rate constant of reaction called Arrhenius equation

$$K = Ae^{-E_a/RT}$$

$$\log K = \log A - \frac{E_a}{2.303RT} \quad \text{or} \quad \log\left(\frac{K_2}{K_1}\right) = \frac{E_a}{2.303R} \left[\frac{T_2 - T_1}{T_1 T_2} \right]$$

THERMODYNAMICS

Work

Mechanical work = force \times displacement = $F \times d$

Electrical work = pot. diff. \times quantity of current = $E \times Q$

Gravitational work = gravitational force \times height = $mg \times h$

Mechanical work = pressure \times change in volume = $P \times \Delta V$

For expansion $W = -ve$ ($\because V_2 > V_1$)

For compression $W = +ve$ ($\because V_2 < V_1$)

Units of work 1 cal = 4.184×10^7 erg = 4.184 J

Enthalpy :-

Enthalpy (H) is defined as the total heat content of the system at constant pressure.

$$H = E + PV$$

$$\Delta H = \Delta E + \Delta(PV)$$

or $\Delta H = \Delta E + (P_2 V_2 - P_1 V_1)$

$$\Delta H = \Delta E + P \Delta V + V \Delta P$$

$$\text{at constant pressure } \Delta H = \Delta E + P \Delta V$$

so $\Delta H = \Delta E + \Delta n_g RT$ (for chemical reaction)

First Law of Thermodynamics

Mathematically

$$q = \Delta E - w$$

or $\Delta E = q + w$

q = heat absorbed or evolved (+ve if absorbed and -ve if evolved)

For Isothermal process

$$\Delta T = 0 \therefore \Delta E = 0 \quad q = -W$$

i.e., heat absorbed is used in work done by the system.

For Adiabatic process

$$\because q = 0 \quad \therefore \Delta E = W$$

i.e., Internal energy is used up in work done by the system. If work is done on the system, its internal energy will increase or if work is done by the system its internal energy will decrease.

- In adiabatic process work behaves as state function.

For Isochoric process,

$$\Delta E = q - P \Delta V$$

$$\because \Delta V = 0 \quad q_v = \Delta E$$

i.e., heat absorbed at constant volume increases internal energy.

- For isochoric process heat behaves as state function.

For Isobaric process

$$\because \Delta P = 0 \quad q_p = \Delta H$$

Work done

- (1) For irreversible process –

$$W = -P_{ext} \times \Delta V$$

- (2) For reversible process –

$$W = - \int_{V_1}^{V_2} P dV$$

- (3) For reversible isothermal process –

$$W = -2.303 nRT \log_{10} \frac{V_2}{V_1} = -2.303 nRT \log_{10} \frac{P_1}{P_2}$$

- (4) In adiabatic process – $W = \Delta E$

$$\text{For an ideal gas } W = nC_v (T_2 - T_1)$$

$$\text{or } W = \frac{nR}{(\gamma - 1)} (T_2 - T_1)$$

- (5) When an ideal gas freely expands in vacuum then the obtained work done is zero because $P_{ext} = 0$

- (6) Reversible expansion process are more efficient than the irreversible expansion process.

Entropy

Entropy of a system is a measure of the degree of randomness or disorderliness of the system and is denoted by S .

- (1) ΔS for reversible isothermal process -

$$\Delta S = \frac{q_{rev}}{T} = \frac{-W_{rev}}{T} = \frac{2.303nRT \log \frac{V_2}{V_1}}{T}$$

$$\Delta S = 2.303 nR \log \frac{V_2}{V_1} = 2.303 nR \log \frac{P_1}{P_2}$$

(q_{rev} = heat supplied to a system at temp. T K in a reversible manner)

- (2) $\Delta S = S_{products} - S_{reactants}$ (for a chemical reaction)

- (3) $\Delta S_{total} = \Delta S_{system} + \Delta S_{surroundings}$

$$\Delta S_{total} = \frac{+q}{T_{system}} + \frac{-q}{T_{surroundings}}$$

If $T_{system} < T_{surroundings}$ heat flows a hot region to cold one ΔS_{total} is +ve and heat flow is spontaneous.

If ΔS_{total} is -ve the change is non-spontaneous.

- (4) ΔS for reversible adiabatic process

$$\Delta S = \frac{q_{rev}}{T} = 0$$

- (5) ΔS for reversible Isobaric process

$$= 2.303nC_p \log \frac{T_2}{T_1}$$

- (6) ΔS for reversible Isochoric process

$$= 2.303nC_v \log \frac{T_2}{T_1}$$

(7) ΔS for phase transition

$$q_{rev} = \Delta H_{rev} \quad \Rightarrow \quad \Delta S = \frac{\Delta H_{rev}}{T}$$

- Entropy change of fusion, $\Delta S_f = \frac{\Delta H_f}{T}$

(T = freezing point or melting point)

- Entropy change of vapourization, $\Delta S_v = \frac{\Delta H_v}{T}$ (T = boiling point)

(8) Standard entropy (S°) = entropy of one mole of a substance at 1 atm and 25°C.

Free Energy

Free energy (G) is a measure of maximum useful work done.

$$G = H - TS,$$

At constant T & P

$$\Delta G = \Delta H - T \Delta S \quad (\text{Gibbs - Helmholtz equation})$$

$$\Delta G = G_{\text{products}} - G_{\text{reactants}}$$

$$(i) \quad \Delta G^\circ = \Delta G_{f \text{ products}}^\circ - \Delta G_{f \text{ reactants}}^\circ$$

$$(ii) \quad \Delta G^\circ \text{ for the element} = 0$$

$$(iii) \quad \Delta G^\circ = -2.303 RT \log K \quad (K=\text{equilibrium constant})$$

If ΔG° is - ve, $K > 1$

$$\Delta G^\circ = 0, K = 0$$

$$\Delta G^\circ \text{ is + ve, } K < 1$$

Condition for spontaneity of a chemical reaction is $\Delta G = -ve$

ΔH	ΔS	$\Delta H - T \Delta S$	Behaviour
-ve	+ ve	$\therefore \Delta G = -ve$	Spontaneous at all temperatures
+ve	-ve	$\therefore \Delta G = +ve$	Non-spontaneous at all temperatures
+ve	+ve	$\Delta G = -ve \text{ (if } \Delta H < T \Delta S)$ $\Delta G = +ve \text{ (if } \Delta H > T \Delta S)$	Spontaneous Non-spontaneous
-ve	-ve	$\Delta G = -ve \text{ (if } \Delta H > T \Delta S)$ $\Delta G = +ve \text{ (if } \Delta H < T \Delta S)$	Spontaneous Non - spontaneous

ENERGETICS

1. Thermochemical reaction :

The balanced chemical reaction which give information about the physical states of reactant and product and heat change is called as thermo chemical reaction.



Thermochemical reactions are of two types :

(i) **Endothermic reaction** : The reaction which absorb heat.

$$\Delta H = H_p - H_r = + Ve$$

Ex. Dissociation, Fusion, Vapourization, Sulimation, Photosynthesis reaction.

(ii) **Exothermic reaction** : The reaction which evolve heat.

$$\Delta H = H_p - H_r = -Ve$$

Ex. Combustion, Neutralisation, Hydration, Respiration Reaction.

2. Heat of reaction OR Enthalpy of reaction OR ΔH_r :

The amount of heat evolved or absorbed when number of moles of the reactant indicated in the chemical reaction had completely reacted is called as heat of reaction.

Factor effecting the heat of reaction :

- (i) Quantity of reactants and products.
- (ii) Physical state of products and reactants
- (iii) Allotropic form
- (iv) Temperature
- (v) Reaction is carried out at constant volume or at constant pressure.

3. Types of heat of rection :

(i) Heat of formation (ΔH_f or $\Delta_f H$) :

Amount of heat absorbed or evolved when 1 mole of substance is formed from its constituent elements which are in their standard state called as heat of formation.

For a chemical reaction

$$\Delta H = \left(\sum \Delta H_f \right)_{\text{Product}} - \left(\sum \Delta H_f \right)_{\text{reactant}}$$

(II) Heat of combustion ($\Delta H_{\text{Comb.}}$) :

Amount of heat evolved when 1 mole of substance is completely burnt in excess of oxygen.

For a chemical reaction $\Delta H = (\sum \Delta H_{\text{comb.}})_{\text{Reactant}} - (\sum \Delta H_{\text{comb.}})_{\text{Product}}$

Note : Calorific value = $\frac{\Delta H_{\text{Comb.}}}{\text{Molecular Weight}}$ kcal/gm or kJ/gm.

(III) Heat of neutralisation ($\Delta H_{\text{neutralisation.}}$) :

If one of the acid or base or both are weak, then the heat of neutralisation is usually less than $-13.7 \text{ kcal eq}^{-1}$ or -57.3 kJ eq^{-1} .

The heat evolved when one equivalent of acid is completely neutralised by one equivalent of base in dilute solution. Its value is $-13.7 \text{ kcal/ equivalent}$ or $-57.3 \text{ kJ/equivalent}$ for the neutralisation of strong acid and strong base.

**(IV) Heat of hydrogenation ($\Delta H_{\text{Hydrogenation}}$)**

The heat evolved during the complete hydrogenation of one mole unsaturated organic compound. It is exothermic process.

(V) Heat of atomization (ΔH_{atom}) :

The amount of heat required to convert 1 mol gaseous molecule (stable substance) into constituent gaseous atoms. It is endothermic reaction.

(VI) (A) Heat of fusion (ΔH_{fusion}) :

The required amount of heat to convert 1 mol solid in to liquid.

(B) Heat of vapourization ($\Delta H_{\text{vapour.}}$) :

The required amount of heat to convert 1 mol liquid in to gas.

(C) Heat of sublimation (ΔH_{Sub}) :

The required amount of heat to convert 1 mol solid in to gas.

(VII) (A) Heat of hydration ($\Delta H_{\text{hydration}}$) :

Amount of heat evolved when one mol of anhydrous salt converted into its hydrated form. It is exothermic.

(B) Heat of solution ($\Delta H_{\text{solution}}$) :

Amount of heat absorbed or evolved when one mol of substance is dissolved in excess of solvent. It may be endothermic or exothermic.

(VIII) Bond Energy (B.E.)**(Bond dissociation energy) :**

(i) The required amount of heat to dissociate one mole gaseous bond into separate gaseous atoms is called bond dissociation energy.

$$\Delta H = \sum (\text{B.E.})_R - \sum (\text{B.E.})_P$$

(ii) The average amount of energy required to break one mole gaseous bond into separate gaseous atoms is called bond energy.

- For polyatomic molecules

$$\text{average bond energy} = \frac{\text{energy required to break all bonds}}{\text{total number of bonds}}$$

1. Laws of thermochemistry :**(I) Lavosier and Laplace law :**

Enthalpy of formation of compound is numerically equal to the enthalpy of decomposition of that compound with opposite sign.

(II) Hess Law :

The heat change in a chemical reaction always remain same whether reaction completes in one or more steps.

2. Resonance Energy :

$$\text{R.E.} = (\text{Observed } \Delta H) - (\text{Calculated } \Delta H)$$

CHEMICAL EQUILIBRIUM

- ❑ **Equilibrium is a dynamic process :** equilibrium is established in a system when reactants combine to form products at the same rate at which products combine to form reactants.

$$\left(\frac{dx}{dt} \right)_f = \left(\frac{dx}{dt} \right)_b \text{ or } R_f = R_b$$

- ❑ Chemical equilibrium can be approached from either side. A catalyst can fasten the approach of equilibrium but does not alter the state of equilibrium.
- ❑ System can be homogeneous or heterogeneous
- ❑ For a reaction in equilibrium



$$K_c = \frac{[C]^c [D]^d}{[A]^a [B]^b} \quad \text{in terms of active mass}$$

$$K_p = \frac{[p_C]^c [p_D]^d}{[p_A]^a [p_B]^b} \quad \text{in terms of partial pressure}$$

$$K_x = \frac{[X_C]^c [X_D]^d}{[X_A]^a [X_B]^b} \quad \text{in terms of mole fraction}$$

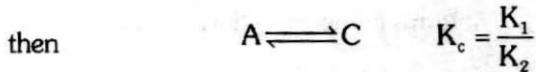
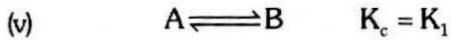
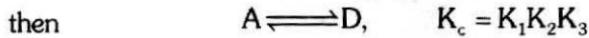
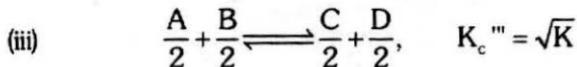
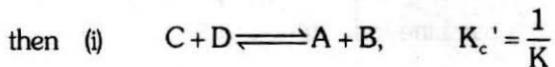
Partial pressure of solid is taken as unity and in calculation of partial pressure of solids their number of moles are not considered.

$$K_p = K_c (RT)^{\Delta n_g}$$

- (i) When $\Delta n_g = 0$ then $K_p = K_c$
- (ii) When $\Delta n_g > 0$ then $K_p > K_c$
- (iii) When $\Delta n_g < 0$ then $K_p < K_c$

$$\Delta n_g = (c + d) - (a + b)$$

M.Imp : While determining Δn_g , take only gaseous species.

Properties of equilibrium constant :

□ Reaction quotient Q for the reversible reaction



$$Q = \frac{[C][D]}{[A][B]}$$

Q is taken at any condition of system.

⇒ If $Q = K_{eq}$ then system is in equilibrium

⇒ If $Q > K_{eq}$ system proceeds in backward side to attain equilibrium

⇒ If $Q < K_{eq}$ system proceeds in forward side to attain equilibrium

□ Degree of dissociation $\propto \frac{D-d}{d(n-1)}$

For the equilibrium $A \rightleftharpoons nB$

where n is the number of moles of products from one mole of reactant, D is the theoretical vapour density (if no dissociation takes place) and d is the observed vapour density (due to dissociation or association)
 $\text{vapour density} \times 2 = \text{molecular weight}$

□ Degree of dissociation (α) =
$$\frac{\text{Number of dissociated moles (x)}}{\text{Initial number of moles (a)}}$$

Equilibrium constant (K) depends upon temperature and way of writing the reaction.

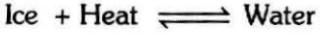
Le-Chatelier's principle : If the system at equilibrium is subjected to change of any one of the factors such as concentration, temperature or pressure, the system adjusts itself in such a way as to nullify the effect of that change.

The following conclusions have been derived from this principle.

- (i) Increases in concentration of any substance favours the reaction in which it is used up.
- (ii) High pressure is favourable for the reaction in which there is decrease in volume or number of moles.
- (iii) A rise in temperature favours the endothermic reaction.

Application of Le-Chatelier's principle :

- (i) **Ice water system (melting of ice) :**



It is an endothermic process and there is decrease in volume. Thus, the favourable conditions for melting of ice are ; (a) High temperature and (b) High pressure,

- (ii) **Solubility of gases in liquids :** When a gas dissolves in a liquid, there is decrease in volume. Thus, increase in pressure will favour the dissolution of a gas in liquid.

IONIC EQUILIBRIUM

Acid and Base

- **Arrhenius Concept :** Acid ionises in water to give H_3O^+ ion while base ionises to give OH^- ion.
- **Bronsted-Lowry's Prototic Concept :** Acid is H^+ ion donor and base is H^+ ion acceptor.
HCl and Cl^- is a conjugate acid-base pair. If acid is weak, its conjugate base is strong and vice-versa.
A substance that can accept H^+ ion as well can donate H^+ ion is called Amphiprotic or amphoteric.



A Bronsted - Lowry acid - base reaction is always favoured in the direction from the stronger to the weaker acid/base combinations.

- **Lewis Concept :**
Lewis acid is an electron - pair acceptor.
Lewis base is an electron - pair donor.
All Lewis bases are Bronsted - Lowry bases but all the lewis acid are not brosted acids.
- $K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14}$ at 298 K
 K_w is called ionic-product of water or autoionisation or autoprotolysis constant.
- In a mixture of strong acids/or bases

$$[\text{H}^+] = [\text{H}_3\text{O}^+] = \frac{\sum \text{NV}}{\Sigma V}, [\text{OH}^-] = \frac{\sum \text{NV}}{\Sigma V}$$

In a mixture of acid and base, resultant is

(a) acidic mixture if N_1V_1 (acid) > N_2V_2 (base)

$$[\text{H}_3\text{O}^+] = \frac{N_1V_1 - N_2V_2}{V_1 + V_2}$$

(b) basic mixture if N_2V_2 (base) > N_1V_1 (acid)

$$[\text{OH}^-] = \frac{N_2V_2 - N_1V_1}{V_1 + V_2}$$

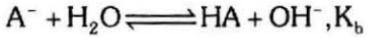
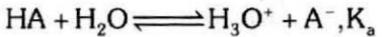
(c) neutral mixture if N_1V_1 (acid) = N_2V_2 (base)

For conjugation acid-base pairs

$$K_a K_b = K_w = 1 \times 10^{-14} \quad \text{at } 25^\circ\text{C}$$

$$K_a K_b = K_w = 10^{-12} \quad \text{at } 90^\circ\text{C}$$

Where K_a is the ionisation constant of acid and K_b is the ionisation constant of its conjugate base.



$$\text{p}K_a + \text{p}K_b = 14 = \text{p}K_w$$

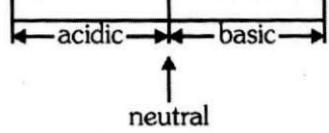
$$\text{pH} = -\log [\text{H}_3\text{O}^+]$$

$$\text{pOH} = -\log [\text{OH}^-]$$

$$\text{pX} = -\log X$$

$$\text{pH} + \text{pOH} = \text{p}K_w = 14$$

$$0 \leq \text{pH} < 7 \quad 7 \quad 7 < \text{pH} \leq 14$$



According to Ostwald dilution law $\alpha \propto \sqrt{\text{dilution}}$

Chemistry HandBook

At infinite dilution, $\alpha = 100\%$

For a weak acid by Ostwald dilution law

$$K_a = \frac{C\alpha^2}{(1-\alpha)} \approx C\alpha^2$$

$$[H^+] = \sqrt{K_a C}, \quad pH = \frac{1}{2}[pK_a - \log C]$$

$$[H^+] = C\alpha$$

and for a weak base

$$K_b = \frac{C\alpha^2}{(1-\alpha)} \approx C\alpha^2 \quad [OH^-] = C\alpha$$

$$[OH^-] = \sqrt{K_b C}, \quad pOH = \frac{1}{2}[pK_b - \log C]$$

- Ostwald dilution law is only applicable for weak electrolytes
- Buffer solutions are which have resistive nature for pH change.
 - (i) On dilution pH of buffer solution remains unchanged.
 - (ii) When small amount of SA or SB is mixed in buffer solution then pH of buffer solution remains almost unchanged.

Types of buffer solution :

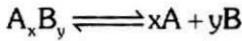
- (i) Simpler buffer solution (Aq. solution of WAWB salts)
- (ii) Mixed buffer solution
 - (a) Acidic buffer solution (WA + WASB salts)
 - (b) Basic buffer solution (WB + WBSA salts)

- Henderson - Hasselbalch equation for buffer

Acidic : $pH = pK_a + \log \frac{[\text{conjugate base}] \text{ or } [\text{salt}]}{[\text{weak acid}]}$

Basic : $pOH = pK_b + \log \frac{[\text{conjugate acid}] \text{ or } [\text{salt}]}{[\text{weak base}]}$

- Ionisation of weak electrolyte is decreased in the presence of common ion is called common - ion effect.
- Solubility product of the sparingly soluble salt A_xB_y with solubility (s) mol/litre in saturated solution



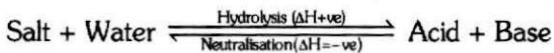
$$K_{sp} = x^x y^y (s)^{x+y}$$

- Salt analysis of inorganic mixture depends on common - ion effect and values of solubility products.

In the presence of common ion solubility of electrolyte always decreases.

Solute AB is precipitated if $[A^+][B^-] > K_{sp}$

- **Salt and Salt Hydrolysis :**



Types of salt :

- (i) General (ii) Acidic (iii) Basic (iv) Mixed (v) Double (vi) Complex

Types of general salts :-

- (a) SASB (b) SAWB (c) WASB (d) WAWB

Types of salt	Name of hydrolysis	Nature of aqueous solution and pH
SASB	—	Neutral , pH = 7
SAWB	Cationic	Acidic , pH < 7
WASB	Anionic	Basic , pH > 7

For WA - WB types of salt :

	$K_a > K_b$	$K_b > K_a$	$K_a = K_b$
Hydrolysis	Cationic-anionic	Anionic-cationic	Neutral hydrolysis
Nature	Acidic	Basic	Neutral
pH	$pH < 7$	$pH > 7$	$pH = 7$

Summary :

Type of salts	$K_h = \frac{K_w}{\text{Ionisation constant of weak acid}}$	$h = \sqrt{\frac{K_h}{C}}$	$[H^+]$	pH
SA SB	-	-	-	7
WA SB	$K_h = \frac{K_w}{K_a}$	$h = \sqrt{\frac{K_w}{K_a \times C}}$	$\sqrt{\frac{K_w \times K_a}{C}}$	$7 + \frac{1}{2} pK_a + \frac{1}{2} \log C$
SA WB	$K_h = \frac{K_w}{K_b}$	$h = \sqrt{\frac{K_w}{K_b \times C}}$	$\sqrt{\frac{K_w \times C}{K_b}}$	$7 - \frac{1}{2} pK_b - \frac{1}{2} \log C$
WA WB	$K_h = \frac{K_w}{K_a \times K_b}$	$h = \sqrt{\frac{K_w}{K_a \times K_b}}$	$\sqrt{\frac{K_w \times K_a}{K_b}}$	$7 + \frac{1}{2} pK_a - \frac{1}{2} pK_b$

□ Group precipitation

- (i) $K_{sp} > [] [] >$ Ionic product \Rightarrow unsaturated
- (ii) $K_{sp} = [] [] =$ Ionic product \Rightarrow saturated
- (iii) $K_{sp} < [] [] <$ Ionic product \Rightarrow super saturated
 \Rightarrow precipitation occurs

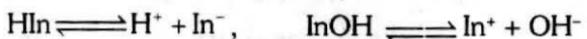
Group	Radicals	Condition for precipitation (Group reagent)	Forms of precipitation
Zero	$\text{Na}^+, \text{K}^+, \text{NH}_4^+$	1-2 drops of CH_3COOH	-
First	$\text{Pb}^{+2}, \text{Hg}^{+1}, (\text{Hg}_2^{+2}), \text{Ag}^+$	By mixing of dilute HCl	$\text{AgCl}, \text{Hg}_2\text{Cl}_2, \text{PbCl}_2$
Second	$\text{Pb}^{+2}, \text{Cu}^{+2}, \text{Hg}^{+2}, \text{Cd}^{+2}, \text{Bi}^{+3}, \text{As}^{+3}, \text{Sb}^{+3}, \text{Sn}^{+2}, \text{Sn}^{+4}$	H_2S gas passed in the presence of acidic medium	Sulphide $\text{PbS}, \text{HgS}, \text{CuS}, \text{CdS}, \text{SnS}, \text{SnS}_2, \text{As}_2\text{S}_3, \text{Sb}_2\text{S}_3, \text{Bi}_2\text{S}_3$
Third	$\text{Al}^{+3}, \text{Cr}^{+3}, \text{Fe}^{+3}$	NH_4OH mixed in the presence of NH_4Cl	Hydroxide $\text{Al}(\text{OH})_3, \text{Fe}(\text{OH})_3, \text{Cr}(\text{OH})_3$
Fourth	$\text{Zn}^{+2}, \text{Ni}^{+2}, \text{Mn}^{+2}, \text{Co}^{+2}$	H_2S gas passed in presence of basic medium	Sulphide $\text{MnS}, \text{CoS}, \text{NiS}, \text{ZnS}$
Fifth	$\text{Ba}^{+2}, \text{Sr}^{+2}, \text{Ca}^{+2}$	$(\text{NH}_4)_2\text{CO}_3$ mixed in the presence of NH_4Cl	Carbonate $\text{BaCO}_3, \text{SrCO}_3, \text{CaCO}_3$
Sixth	Mg^{+2}	By mixing of Na_2HPO_4	Hydrogen phosphate (MgHPO_4)

- For precipitation of common salt (NaCl), HCl gas is passed & for soap ($\text{C}_{17}\text{H}_{35}\text{COONa}$), NaCl is mixed.
- For amphiprotic anion (as HCO_3^-)

$$\text{pH} = \frac{\text{pK}_1 + \text{pK}_2}{2}$$

Chemistry HandBook

- For acidic indicator $[HIn]$, For basic indicator $(InOH)$



$$\text{pH} = \text{p}K_{\text{In}} + \log \frac{[\text{In}^-]}{[\text{HIn}]}, \quad \text{pOH} = \text{p}K_{\text{In}} + \log \frac{[\text{In}^+]}{[\text{InOH}]}$$

- Colour change of the indicator is explained by :

(i) Ostwald's theory

(ii) Quinonoid theory

Name of indicator	Colour in acidic medium	Colour in basic medium	Working pH range of indicators
Methyl orange (MeOH)	Orange red	Yellow	3.1 to 4.5
Methyl red	Red	Yellow	4.2 to 6.2
Phenol red	Yellow	Red	6.2 to 8.2
Phenolphthalein (HPh)	Colourless	Pink	8.2 to 10.2

ACID-BASE TITRATION

Type of titration	pH range of titration	Suitable indicators
SA/SB.	3 – 11	All indicators (MeOH, HPh etc.)
SA/WB	3 – 7	Methyl orange (MeOH) and methyl red
WA/SB	7 – 11	Phenolphthalein (HPh)
WA/WB	6.5 – 7.5	Phenol red

SOLID STATE**The Seven Crystal Systems**

Name of System	Axes	Angles	Bravais Lattices
1. Cubic	$a = b = c$	$\alpha = \beta = \gamma = 90^\circ$	Primitive, Face-centred Body centred
2. Tetragonal	$a = b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	Primitive, Body centred
3. Rhombohedral or Trigonal	$a = b = c$	$\alpha = \beta = \gamma \neq 90^\circ$	Primitive] 1
4. Orthorhombic or Rhombic	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	Primitive, Face-centred, Body centred, End centred
5. Monoclinic	$a \neq b \neq c$	$\alpha = \gamma = 90^\circ,$ $\beta \neq 90^\circ$	Primitive, End centred
6. Triclinic	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90^\circ$	Primitive] 1
7. Hexagonal	$a = b \neq c$	$\alpha = \beta = 90^\circ,$ $\gamma = 120^\circ$	Primitive] 1 Total = 14

Geometry of a cube

Number of corners = 8

Number of faces = 6

Number of edges = 12

Number of body centre = 1

Number of body diagonals = 4

Number of face diagonals = 12

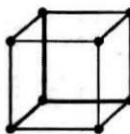
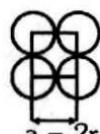
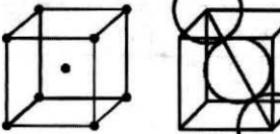
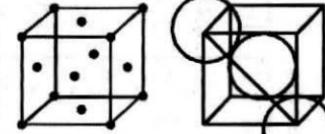
Number of face centres = 6

Number of edge centres = 12

Contribution of atom at different sites of cube :at corner = $1/8$ at face = $1/2$ at edge = $1/4$

at body centre = 1

Types of unit cell (Bravais Lattice)

	Simple Cubic Cell (SCC)	Body centred Cubic Cell (BCC) (SCC + Body centred = BCC)	Face centred Cubic Cell (FCC) (SCC + Face centred = FCC)
Geometry	  $a = 2r$	 $4r = \sqrt{3}a$	 $4r = \sqrt{2}a$
54	Number of atoms per unit cell (n) $= 8 \times 1/8 = 1$ corners	$= (8 \times 1/8) + (1 \times 1) = 2$ corners body centre	$= (8 \times 1/8) + (6 \times 1/2) = 4$ corner face centre
Co-ordination no.	6	8	12
Relation between a and r	$a = 2r$	$4r = \sqrt{3}a$	$4r = \sqrt{2}a$
Packing efficiency $P.E. = \frac{n \times 4/3\pi r^3}{V = a^3}$	$\frac{\pi}{6}$ or 52.4%	$\frac{\sqrt{3}\pi}{8}$ or 68%	$\frac{\pi}{3\sqrt{2}}$ or 74%

$$\text{Density of the unit cell} = \frac{n \times M}{V \times N_A} \text{ g cm}^{-3}$$

Where M = Molecular weight or atomic weight

Three dimensional close packing

Contents	BCC	CCP/FCC	HCP
Type of packing	ABAB..... packing but not close packing	ABCABC close packing	ABAB
No. of atoms	2	4	6
Co-ordination no.	8	12	12
Packing efficiency	68%	74%	74%
Examples	IA, Ba V & Cr group Fe	Ca, Sr, Al Co group, Ni group, Copper group, all inert gases except helium	Remaining d-block elements Be & Mg

Note : Only Mn crystallizes in S.C.C.

Voids in any close packed structure :

Per atom	/ 2 Tetrahedral void 1 Octahedral void
----------	---

Limiting radius ratio for various types of sites

Limiting radius ratio = r/R	Coordination Number of cation	Structural Arrangement (Geometry of voids)	Example
0.155 - 0.225	3	Plane Trigonal	Boron Oxide(B_2O_3)
0.225 - 0.414	4	Tetrahedral	ZnS , SiO_2
0.414 - 0.732	6	Octahedral	$NaCl$, MgO
0.732 - 1.000	8	Cubic	$CsCl$

NaCl type :For $NaCl$: Distance between two nearest ions ($r^+ + r^-$) :-

$$2r^+ + 2r^- = a$$

i.e.

$$r^+ + r^- = \frac{a}{2}$$

CsCl type :For $CsCl$: Distance between two nearest ions ($r^+ + r^-$) :-

$$2r^+ + 2r^- = \sqrt{3}a$$

For ZnS , CaF_2 , Na_2O type

$$r^+ + r^- = \frac{\sqrt{3}a}{2}$$

$$r^+ + r^- = \frac{\sqrt{3}a}{4}$$

Defects or imperfections in solids :

Schottky defect	Frenkel defect	F-centre
Equal number of cations and anions are missing from their respective position leaving behind a pair of holes.	This type of defect is created when an ion leaves its appropriate site in the lattice and occupies an interstitial site.	A compound may have excess metal ion if an anion (negative ion) is absent from its appropriate lattice site creating a 'void' which is occupied by an electron.
Density decreased C. No. is high L.R.R. is high Electrically neutral Ex. $NaCl$, $CsCl$, KCl , KBr	Density unchanged C. No. is low L.R.R is low Electrically neutral Ex. ZnS , $AgBr$, $AgCl$ etc.	Ex. $NaCl \rightarrow$ Yellow $KCl \rightarrow$ Violet

Note : $AgBr$ shows both Schottky and Frenkel defects.

B. TYPES OF IONIC CRYSTAL

57

Type of Ionic Crystal	Geometry	Co-ordination Number	No. of formula's per U.C.C.	Examples
1. NaCl (1 : 1) (Rock Salt Type)	C.C.P. Cl ⁻ - every element of C.C.P. Na ⁺ - at every OHV	6 : 6	4Na ⁺ + 4Cl ⁻ 4NaCl (4)	Halides of (Li, Na, K, Rb) Oxides and sulphides of II-A (Some exception) AgF, AgCl, AgBr, NH ₄ X
2. CsCl Type (1 : 1)	B.C.C. Cl ⁻ - at every corner Cs ⁺ - at body centre or at cubic void	8 : 8	1Cs ⁺ + 1Cl ⁻ 1CsCl (1)	Halides of 'Cs' TlCl, TlBr, CsS
3. ZnS Type (1 : 1) (Zinc Blende Type) (Sphalerite)	C.C.P. S ²⁻ - every element of C.C.P. Zn ²⁺ - at 50% of T.H.V. or at alternate tetrahedral void	4 : 4	4Zn ²⁺ + 4S ²⁻ 4ZnS (4)	BeS, BeO, CaO, AgI, CuCl, CuBr, CuI
4. CaF ₂ Type (1 : 2) (Fluorite Type)	C.C.P. Ca ²⁺ - every element of C.C.P. F ⁻ - at every T.H.V.	4Ca ²⁺ , 8F 4 : 8	4Ca ²⁺ + 8F 4CaF ₂ (4)	BaCl ₂ , BaF ₂ SrCl ₂ , SrF ₂ CaCl ₂ , CaF ₂
5. Na ₂ O Type (2 : 1) (Antiflourite)	C.C.P. Na ⁺ - at every T.H.V. O ²⁻ - every element of C.C.P.	8Na ⁺ , 4O ²⁻ 8 : 4	8Na ⁺ + 4O ²⁻ 4Na ₂ O (4)	Li ₂ O, Li ₂ S Na ₂ O, Na ₂ S K ₂ O, K ₂ S
6. ZnS Type (1 : 1) (Wurtzite) another geometry of ZnS	HCP S ²⁻ - every element of HCP Zn ²⁺ - 50% of THV or (at alternate THV)	4 : 4	6Zn ²⁺ + 6S ²⁻ 6ZnS (6)	Same as sphalerite

SURFACE CHEMISTRY

(COLLOIDAL SOLUTION)

Classification based on interaction of phases :-

LYOPHILIC AND LYOPHOBIC SOLS

Colloidal solutions in which the dispersed phase has considerable affinity for the dispersion medium, are called lyophilic sols (solvent - liking).

For example - dispersion of gelatin, starch, gum and proteins in water.

Colloidal solutions in which the dispersed phase has no affinity or attraction for the medium or for the solvent are called Lyophobic colloidal (Solvent hating) solutions.

COMPARISON OF LYOPHOBIC AND LYOPHILIC SOLS

Property	Lyophilic sol (Emulsoid)	Lyophobic sol (susponsoid)
1. Preparation	Can be easily prepared by shaking or warming the substance with solvent	Can not be prepared easily special methods are required
2. Stability	are more stable	are less stable
3. Reversibility	are reversible	are irreversible
4. viscosity	viscosity is much higher than that of solvent	viscosity is nearly same as that of the solvent
5. Surface tension	Surface tension is usually low	Surface tension is almost same as that of solvent
6. Hydration or solvation	These are highly solvated as the particles have great affinity for solvent	These are less solvated as the particles have less affinity for the solvent
7. Charge	The particles have little charge or no charge at all	The particles carry a characteristic charge either positive or negative
8. Visibility	Particles can not be seen under microscope	Particles can be seen under microscope

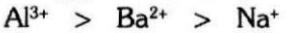
9. Coagulation or precipitation	Precipitated by high concentration of electrolytes	Precipitated by low concentration of electrolytes
10. Tyndall effect	Less Scattering	More Scattering
11. Migration in electric field	may or may not migrate as they may or may not carry charge.	migrate towards anode or cathode as these particles carry charge.
12. General Example	Mostly of organic nature Ex. Gelatin, Starch, Gum, Albumin & Cellulose Solution	Mostly of Inorganic nature Ex. Transition metal salt in water. Gold, As etc.

PEPTIZATION

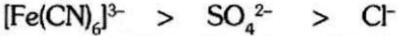
by the action of an electrolyte in solution is termed as peptization. The electrolyte used is called a **Peptizing agent**.

Hardy Schulze Rule - This rule states that the precipitating effect of an ion on dispersed phase of opposite charge increases with the valency of the ion.

The higher the valency of the flocculating ion, the greater is its precipitating power. Thus for the precipitation of As_2S_3 sol (-ve) the precipitating power of Al^{3+} , Ba^{2+} , and Na^+ ions is in the order



Similarly for precipitating Fe(OH)_3 sol (positive) the precipitating power of $[\text{Fe}(\text{CN})_6]^{3-}$, SO_4^{2-} and Cl^- ions is in the order



The minimum concentration of an electrolyte in milli moles required to cause precipitation of 1 litre sol in 2 hours is called FLOCCULATION VALUE. The smaller the flocculating value, the higher will be the coagulating power of the ion.

$$\frac{1}{\text{Flocculation power}} = \text{Flocculation value}$$

GOLD NUMBER

The number of **milligrams** of a hydrophilic colloid that will just prevent the precipitation of 10 ml of standard gold sol on addition of 1 ml of 10% NaCl solution is known as **Gold number** of that protector (Lyophilic colloid).

The precipitation of the gold sol is indicated by a colour change from red to blue when the particle size just increases.

The **smaller the gold number** of a protective Lyophilic colloid, **greater is its protection power**.

$$\text{Protection Capacity } \alpha \frac{1}{\text{Protection Number}} \\ (\text{Gold number})$$

Note : Gelatin is best protecting colloid because it has least gold number.

Types of colloids according to their size		
Multi Molecular	Macro Molecular	Associated colloids
<p>Formation by aggregation of a large number of atoms or smaller molecules of substance.</p> <p>Ex. → Gold Sol (Au), Sulphur sol (S₈)</p>	<p>Formation by aggregation of big size molecules.</p> <p>These are polymers with high molecular mass.</p> <p>Ex. → Starch, Cellulose, Protein etc.</p>	<p>These are the substances which behave as normal electrolytes at low concentration but get associated at higher concentration and behave as colloidal solutions. These associated particles are also called micelles.</p> <p>Ex. → Soap & Detergent</p>

Comparison of physi-sorption and chemi-sorption

Physical Adsorption	Chemical Adsorption (Activated ad.)
1. It is caused by intermolecular vander waal's forces.	It is caused by chemical bond formation.
2. It is not specific.	It is highly specific.
3. It is reversible.	It is irreversible.
4. Heat of adsorption is low. - 20 to -40 KJ/mol	Heat of adsorption is high. -80 to -240 KJ/mol
5. No appreciable activation energy is involved.	High activation energy is involved.
6. It forms multimolecular layers on adsorbent surface	It forms unimolecular layer under high pressure.

Critical temperature increases

Ease of liquification increases

Extent of adsorption increases (true for physisorption)

**General characteristics of catalysts:-**

- (i) A catalyst remains unchanged in mass and chemical composition but can change their physical state.
- (ii) Only a very small amount of catalyst is sufficient to catalyse a reaction.
- (iii) A catalyst does not initiate a reaction.
- (iv) Solid catalyst is more efficient when used in finely divided form.
- (v) Generally catalyst does not change the nature of products.
- (vi) A catalyst does not change the equilibrium state of a reversible reaction but helps to achieve the equilibrium state or position of equilibrium in lesser time.
- (vii) The catalyst is generally specific in nature.
- (viii) Changes rate constant of reaction.
- (ix) Does not change free energy of reaction.
- (x) Participate in mechanism of reaction.

INORGANIC CHEMISTRY

SOME IMPORTANT INCREASING ORDERS

1. Acidic property

- (i) SiO_2 , CO_2 , N_2O_5 , SO_3
- (ii) MgO , Al_2O_3 , SiO_2 , P_4O_{10}
- (iii) HClO , HClO_2 , HClO_3 , HClO_4
- (iv) CH_4 , NH_3 , H_2O , HF
- (v) SiH_4 , PH_3 , H_2S , HCl
- (vi) H_2O , H_2S , H_2Se , H_2Te
- (vii) HF , HCl , HBr , HI
- (viii) InCl_3 , GaCl_3 , AlCl_3
- (ix) BF_3 , BCl_3 , BBr_3 , BI_3

2. Bond Angle

- (i) CH_4 , C_2H_4 , C_2H_2 (Hint : % S लक्षण)
- (ii) H_2O , NH_3 , CH_4 , CO_2
- (iii) H_2O , NH_3 , CH_4 , BH_3
- (iv) NO_2^- , NO_2 , NO_2^+
- (v) H_2Se , H_2S , H_2O
- (vi) AsH_3 , PH_3 , NH_3
- (vii) PF_3 , PCl_3 , PBr_3 , PI_3
- (viii) NF_3 , NCl_3
- (ix) NF_3 , NH_3 , NCl_3
- (x) OF_2 , OH_2 , Cl_2O

3. Basic Character

- (i) LiOH , NaOH , KOH , RbOH , CsOH
- (ii) $\text{Be}(\text{OH})_2$, $\text{Mg}(\text{OH})_2$, $\text{Ca}(\text{OH})_2$, $\text{Ba}(\text{OH})_2$
- (iii) BeO , MgO , CaO , SrO
- (iv) NiO , MgO , SrO , K_2O , Cs_2O
- (v) CO_2 , B_2O_3 , BeO , Li_2O
- (vi) SiO_2 , Al_2O_3 , MgO , Na_2O
- (vii) SbH_3 , AsH_3 , PH_3 , NH_3
- (viii) F^- , OH^- , NH_2^- , CH_3^-

4. Thermal Stability

- (i) Li_2CO_3 , Na_2CO_3 , K_2CO_3 , Rb_2CO_3 , Cs_2CO_3
 - (ii) BeCO_3 , MgCO_3 , CaCO_3 , BaCO_3
 - (iii) Be(OH)_2 , Mg(OH)_2 , Ca(OH)_2 , Sr(OH)_2 , Ba(OH)_2
 - (iv) LiOH , NaOH , KOH , RbOH , CsOH
 - (v) BeSO_4 , MgSO_4 , CaSO_4
 - (vi) CsH , RbH , KH , NaH , LiH
 - (vii) SbH_3 , AsH_3 , PH_3 , NH_3
 - (viii) H_2Te , H_2Se , H_2S , H_2O
 - (ix) HI , HBr , HCl , HF
- Polarisation

5. Solubility

- (i) BaCO_3 , CaCO_3 , MgCO_3 , BeCO_3
 - (ii) Be(OH)_2 , Mg(OH)_2 , Ca(OH)_2 , Ba(OH)_2
 - (iii) BaSO_4 , SrSO_4 , CaSO_4 , MgSO_4 , BeSO_4
 - (iv) Li_2CO_3 , Na_2CO_3 , K_2CO_3 , Rb_2CO_3 , CsCO_3
 - (v) LiOH , NaOH , KOH , RbOH , CsOH
 - (vi) LiF , LiCl , LiBr , LiI
 - (vii) LiF , NaF , KF , RbF , CsF
 - (viii) BaF_2 , SrF_2 , MgF_2 , CaF_2 , BeF_2
 - (ix) CaF_2 , CaCl_2 , CaBr_2 , CaI_2
 - (x) AgI , AgBr , AgCl , AgF
 - (xi) PbO_2 , CdI_2 , RbI
- $\text{Solubility} \propto \frac{1}{\text{covalent char.}}$

6. Ionic Character

- (i) LiBr , NaBr , KBr , RbBr , CsBr
- (ii) LiF , NaF , KF , RbF , CsF
- (iii) BeCl_2 , MgCl_2 , CaCl_2 , SrCl_2 , BaCl_2
- (iv) BCl_3 , AlCl_3 , GaCl_3
- (v) VCl_4 , VCl_3 , VCl_2
- (vi) AlF_3 , MgF_2 , NaF
- (vii) AlN , Al_2O_3 , AlF_3
- (viii) HI , HBr , HCl , HF
- (ix) CuCN , AgCN
- (x) AgCl , KCl

Chemistry HandBook**7. Atomic/Ionic Size**

- (i) Mg²⁺, Na⁺, F⁻, O²⁻, N³⁻ (Hint : Isoelectronic series)
- (ii) Ca²⁺, Ar, Cl⁻, S²⁻
- (iii) O, C, S, Se
- (iv) B, Be, Li, Na
- (v) F, O, F⁻, O²⁻

8. Oxidizing Power

- (i) Cr₂O₇²⁻, MnO₄⁻
- (ii) MnO₄²⁻, MnO₄⁻
- (iii) WO₃, MoO₃, CrO₃
- (iv) GeCl₄, SnCl₄, PbCl₄
- (v) I₂, Br₂, Cl₂, F₂
- (vi) Zn⁺², Fe⁺², Pb²⁺, Cu²⁺, Ag⁺

9. Ionization Energy

- (i) Na, Al, Mg, Si
- (ii) Li, B, Be, C, O, N, F, Ne, He (Ist I.P.)
- (iii) Be, C, B, N, F, O, Ne, Li, He (IInd I.P.)

10. Melting Point

- (i) Cs, Rb, K, Na, Li
- (ii) Mg, Ba, Sr, Ca, Be
- (iii) CaI₂, CaBr₂, CaCl₂, CaF₂
- (iv) BeCl₂, MgCl₂, CaCl₂, SrCl₂, BaCl₂
- (v) NaI, NaBr, NaCl, NaF
- (vi) CsCl, RbCl, KCl, NaCl
- (vii) AlCl₃, MgCl₂, NaCl

11. Density

- (i) Na, Al, Fe, Pb, Au
- (ii) Li, K, Na, Rb, Cs
- (iii) Ca, Mg, Be, Sr, Ba
- (iv) Highest Density = Os/Ir
- (v) Lowest density = H
- (vi) Metal of lowest Density = Li

12. Boiling Point

- (i) PH₃, AsH₃, NH₃, SbH₃
- (ii) H₂S, H₂Se, H₂O
- (iii) HCl, HBr, HI, HF
- (iv) NH₃, HF, H₂O
- (v) He, Ne, Ar, Kr
- (vi) H₂O, D₂O
- (vii) H₂, Cl₂, Br₂

13. Electrical conductivity

- (i) Cr, Pt, Fe, Al, Au, Cu, Ag

14. Reactivity with water

- (i) Li, Na, K, Rb, Cs
- (ii) Be, Mg, Ca, Sr, Ba

15. Extent of Hydrolysis

- (i) CCl₄, MgCl₂, AlCl₃, SiCl₄, PCl₅
- (ii) BiCl₃, SbCl₃, AsCl₃, PCl₃, NCl₃

16. Bond strength

- (i) HI, HBr, HCl, HF
- (ii) $\text{C}-\text{I}$, $\text{C}-\text{Br}$, $\text{C}-\text{Cl}$, $\text{C}-\text{F}$
- (iii) N – N, N = N, N ≡ N
- (iv) As – H, Sb – H, P – H, N – H
- (v) N₂²⁻, N₂⁻, N₂⁺, N₂
- (vi) O₂²⁻, O₂⁻, O₂, O₂⁺, O₂²⁺
LiI, LiBr, LiCl, LiF
NaI, NaBr, NaCl, NaF
CsCl, RbCl, KCl, NaCl
BaO, SrO, CaO, MgO
- (vii) F₂, H₂, O₂, N₂
- (viii) NO⁻, NO, NO⁺
- (ix) I₂, F₂, Br₂, Cl₂
- (x) O–O, S–S
- (xi) F – F, O – O, N – N, C – C, H – H

Chemistry HandBook**17. Reducing power**

- (i) PbCl_2 , SnCl_2 , GeCl_2
- (ii) HF, HCl, HBr, HI
- (iii) Ag, Cu, Pb, Fe, Zn
- (iv) HNO_3 , H_2SO_3 , H_2S
- (v) H_3PO_4 , H_3PO_3 , H_3PO_2

18. Covalent character

- (i) LiCl , BeCl_2 , BCl_3 , CCl_4
- (ii) SrCl_2 , CaCl_2 , MgCl_2
- (iii) TiCl_2 , TiCl_3 , TiCl_4
- (iv) LiCl, LiBr, LiI
- (v) Na_2O , Na_2S
- (vi) AlF_3 , Al_2O_3 , AlN
- (vii) HF, HCl, HBr, HI

19. Strength of Hydrogen bonding (X...H-X)

- (i) S, Cl, N, O, F
- (ii) NH_3 , H_2O , HF

20. Ionic Radii in water

- (i) Cs^+ , Rb^+ , K^+ , Na^+ , Li^+
- (ii) Li^+ , Be^{+2}
- (iii) Na^+ , Mg^{+2} , Al^{+3}

21. Molar Conductivity in Water

- (i) Li^+ , Na^+ , K^+ , Rb^+ , Cs^+

22. Reactivity with Hydrogen

- (i) Cs, Rb, K, Na, Li
- (ii) Ba, Sr, Ca, Mg, Be

23. Reactivity Towards Air

- (i) Be, Mg, Cs, Sr, Ba

24. Hydration of Ions/Hydration Energy

- (i) Ba^{+2} , Sr^{+2} , Ca^{+2} , Mg^{+2} , Be^{+2}
- (ii) Cs^+ , Rb^+ , K^+ , Na^+ , Li^+
- (iii) Na^+ , Mg^{+2} , Al^{+3}

25. Electron Affinity

- (i) I, Br, F, Cl
- (ii) Cu, Ag, Au (EA, of Au is very high = 222 kJ mol⁻¹)
- (iii) O, S, F, Cl
- (iv) N, P, O, S

26. Electronegativity

- (i) As, P, S, Cl
- (ii) I, Br, Cl, F
- (iii) C, N, O, F

27. Bond Length

- (i) N_2 , O_2 , F_2 , Cl_2
- (ii) $\text{N}\equiv\text{N}$, $\text{C}\equiv\text{N}$, $\text{C}\equiv\text{C}$
- (iii) CO , $\text{C}=\text{O}$, $-\text{C}-\text{O}-$
- (iv) NO^+ , NO , NO^-
- (v) O_2 , O_3 , H_2O_2 (O-O bond length)
- (vi) CO , CO_2 , CO_3^{2-}
- (vii) N_2 , N_2^- , N_2^{2-}
- (viii) O_2^{+2} , O_2 , O_2^- , O_2^{-2}
- (ix) HF, HCl, HBr, HI

28. Dipole moments

- (i) CCl_4 , CHCl_3 , CH_2Cl_2 , CH_3Cl
- (ii) NF_3 , NH_3 , H_2O , HF
- (iii) Cis-chloropropene, Trans-chloropropene
- (iv) p, m, o-dichlorobenzene
- (v) CH_3I , CH_3Br , CH_3F , CH_3Cl
- (vi) NH_3 , SO_2 , H_2O , HF
- (vii) H_2S , H_2O
- (viii) HI, HBr, HCl, HF
- (ix) PH_3 , ASH_3 , SbH_3 , NH_3
- (x) H_2O , H_2O_2

29. Abundance of Elements

- | | | |
|-------|---------------------------|---------------|
| (i) | Elements on earth crust - | Fe, Al, Si, O |
| (ii) | Metals on earth crust - | Ca, Fe, Al |
| (iii) | Non-metals | - Si, O |
| | In atmosphere | - O, N |
| | In universe | - He, Si, H |