PHYSICAL CHEMISTRY

Atomic structure → Atom is made up of three fundamental particles viz, electrons, protons and neutrons.

Electrons → (Discovered by J.J. Thomson)

An electron is defined as a sub-atomic particle having a unit negative charge and a mass equal to $\frac{1}{1835}$th the mass of hydrogen atom.

Charge → 1.602×10^{-19} Coulomb.

Mass → 9.11×10^{-31} kg

Protons :— A proton is defined as a subatomic particle having a unit positive charge and mass equal to that of hydrogen atom. (Discovered by Goldstein)

Charge = $+1.602 \times 10^{-19}$ coulombs.

Mass = 1.672×10^{-27} kg or 1.672×10^{-24} gm.

Neutrons → Neutron is defined as the neutral sub-atomic particle having a mass 1.675×10^{-24} g, which is nearly equal to mass of a hydrogen atom.

(Discovered by Chadwick)

Charge - Neutral

Mass = 1.675×10^{-24} g / 1.675×10^{-27} kg.

Rutherford's atomic model →

Postulates → According to Rutherford's atomic model,

(i) An atom consists of two parts,
(a) Nucleus & (b) Extra-nuclear part.

(ii) Nucleus is an extremely small positively charged part and is situated at the centre of an atom. It carries nearly the whole mass of an atom.

(iii) The electrons which balance the positive charge are distributed in the extra nuclear part i.e, space around the nucleus.

(iv) The extra-nuclear electrons are not stationary. These are revolving round the nucleus at high speeded in circular paths called orbits. The centrifugal force which arises due to the rotation of electrons balances the force of attraction. This prevents the electrons to fall into nucleus.

Rutherford's picture of an atom is comparable to solar system, the nucleus representing the sun and the revolving electrons are called planetary electrons.

Drawbacks of Rutherford's atomic model →

(i) According to Rutherford's atomic model, an atom consists of a nucleus and the electrons are revolving around it. Thus, the centrifugal force, which is produced by the circulation of electrons balances the force of attraction between the electrons and the nucleus.

But, According to Clark Maxwell, a charged particle which moves under the influence of an attractive force, continuously loses energy. Since electron is a charged particle, it must lose energy continuously. As electron loses energy, it starts coming nearer the nucleus i.e, its orbit would become smaller and smaller. As a result of this, the electron would ultimately fall into nucleus. But, we know that the revolving electrons never fall into the nucleus. Thus, Rutherford's picture of an atom is faulty.

(ii) Rutherford's model failed to explain the existence of certain definite lines in the hydrogen spectrum.

(iii) Also, Rutherford's model does not explain the structure of atoms i.e., the distribution of electrons around the nucleus and their energies.

Atomic number (Z) → Atomic no. of an element is defined as the number of unit positive charges or the protons present in the nucleus of an atom.

Since, an atom as a whole is neutral, it possesses an equal no. of electrons in the space sorrounding the nucleus.

Atomic number = Number of nuclear protons
= Number of extra-nuclear electrons.

It is denoted by the letter Z.

Mass number → The sum of protons (p) and the neutrons (n) in an atom is called its mass number.

Mass number = No. of protons + No. of neutrons = p+n.

Bohr's atomic model → An almost correct picture of atomic model was provided by a Dutch physicist Niels Bohr in 1913. The Bohr's Atomic model is based on 'Planck's Quantum Theory' and 'quantisation of energy'.

Postulates of Bohr's atomic model →

(i) An atom consicts of a heavy positively charged body at the centre called nucleus and electrons revolve around the nucleus in certain permitted circular paths called orbits or shells.

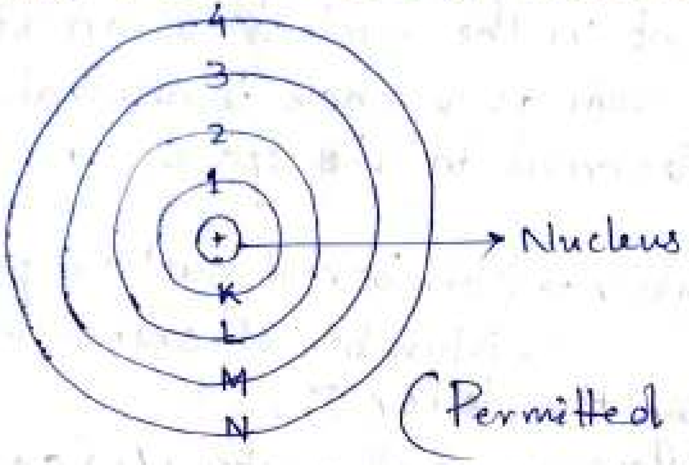
(ii) Each shell is associated with a definite amount of energy. Hence, these are also called 'energy levels'.

(iii) The energy levels or shells are designated by the letters K, L, M, N.... etc. or by the numbers 1, 2, 3, 4... etc.

(iv) Energy associated with an energy level is given by the relation

$$E_n = \frac{-1312}{n^2} \text{ kJ mole}^{-1} \text{ for hydrogen atom}$$

where, n is the number of the energy level.



(Permitted orbits)

(v) The energy content of the energy levels increases with increase in distance from the nucleus.

(vi) The energy levels are not equally spaced. The energy difference between two successive energy levels goes on decreasing with the increase in value of 'n'.

(vii) Though a large no. of concentric ~~cirl~~ circles are possible around the nucleus, only those ~~circle~~ circular paths are allowed in which the angular momentum (mvr) of the electron is a whole no. multiple of $h/2\pi$, i.e.,

$$mvr = \frac{nh}{2\pi}$$

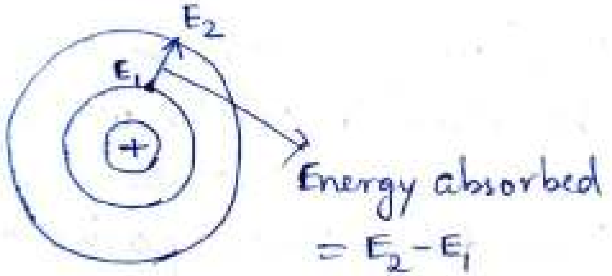
where, n = 1, 2, 3, ...
h = Planck's constant.
m = mass of the electron
v = tangential velocity of the revolving electron
& r = radius of the orbit.

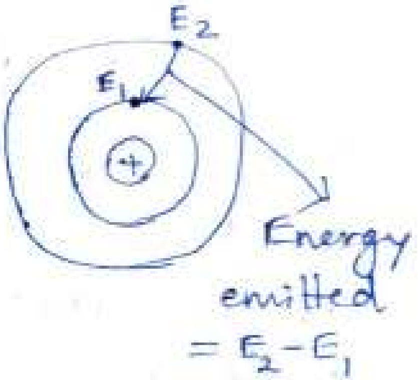
(viii) When the electrons in an atom are in their normal energy state (ground state), they keep on revolving in their respective orbits without losing energy.

(ix) An electron jumps from a lower orbit to a higher orbit, only when some external energy is absorbed by the electron. Similarly an electron jumps from a higher orbit to lower orbit, only when some energy is emitted by the electron.

(x) The amount of energy emitted or absorbed,

$\Delta E = E_2 - E_1$ or $h\nu = E_2 - E_1$.





(xi) All the laws of classical physics are applicable to electron i.e., the position, velocity, momentum can be calculated accurately.

Difference between Bohr's model & Rutherford's model of atom → The fundamental difference between Bohr's model and Rutherford's model of the atom is that Bohr's model is based on the concept of quantisation of energy and angular momentum of the electron. Quantisation means that a quantity can vary only discontinuously to get a specific value. According to Bohr's theory, electron can move only in certain permitted orbits. Rutherford's model does not give an idea about the permitted orbits.

Quantisation is the key note of Bohr's theory.

Achievement's of Bohr's theory →

The main achievements of Bohr's theory are -

(1) Stability of atom — According to Bohr's theory, an electron doesn't lose energy as long as it revolve in a particular orbit. Also, it can't jump from first orbit to the lower point as there is no orbit less than one. Thus, gradual loss of energy by the electron is not possible. Hence, atom is stable.

Thus, it removes the limitation of Rutherford's model of atom.

(2) Bohr's theory can explain the existence of various lines in hydrogen spectrum.

Limitations of Bohr's Atomic model →

(i) According to Bohr, the circular orbits of the electrons are planar. But modern ~~reas~~ researches revealed that electrons revolve in three-dimensional paths called orbitals.

(ii) It fails to explain the spectra of multi-electron atoms.

(iii) It fails to explain the cause of chemical combination.

(iv) Bohr's theory assumes a definite knowledge about position and momentum of electrons at the same time. But, according to Heisenberg's uncertainty principle, it is impossible to measure simultaneously both the exact position and momentum of a subatomic particle such as electron.

(v) It can't explain the relative intensities of spectral lines.

Bohr-Bury Scheme →

Bohr-Bury scheme deals with the arrangement of electrons in various shells. Various postulates of the scheme are –

1. A shell can contain a maximum of $2n^2$ electrons, where n = no. of the shell.

~~No~~ Shell	Maximum no. of electrons ($2n^2$)
K	$n=1$, $2\times1^2=2$
L	$n=2$, $2\times2^2=8$
M	$n=3$, $2\times3^2=18$
N	$n=4$, $2\times4^2=32$

2. The outermost orbit of an element can't contain more than 8 electrons.
3. The penultimate shell (the shell just before the outermost shell) can't contain more than 18 electrons.
4. A higher orbit may start filling before the lower orbit is completely filled.

Arrangement of electrons in various shells

Element	Electrons in K-shell	L-shell	M-shell	N-shell
$_1H$	1			
$_2He$	2			
$_3Li$	2	1		
$_4Be$	2	2		
$_5B$	2	3		
⋮	⋮	⋮		
$_{10}Ne$	2	8		
$_{11}Na$	2	8	1	
⋮	⋮	⋮	⋮	
$_{18}Ar$	2	8	8	

	K	L	M	N
$_{19}K$	2	8	8	1
$_{20}Ca$	2	8	8	2

Isotopes → Isotopes are defined as the atoms of the same element which have same atomic number but different mass numbers.

Isotopes have :-

(i) same physical & chemical properties.

(ii) same atomic no. i.e, number of protons.

(iii) same position in the periodic table.

(iv) different no. of neutrons and hence different mass numbers, density, atomic volume, melting point and boiling point.

Ex. – The three isotopes of hydrogen are –

(i) Protium, $_1H^1$ → It contains 1 electron & 1 proton.

(ii) Deuterium, $_1H^2$ → It contains 1 electron, one proton & 1 neutron.

(iii) Tritium, $_1H^3$ → It contains one electron, 1 proton and 2 neutrons.

Other examples → (a) $_{17}Cl^{35}$ & $_{17}Cl^{37}$.

(b) $_{20}Ca^{40}$, $_{20}Ca^{42}$, $_{20}Ca^{44}$ & $_{20}Ca^{48}$.

Isobars → Isobars are the atoms of different elements having the same mass number but differ in their atomic numbers.

Clearly, isobars have the same number of nucleons i.e, the sum of protons & neutrons is the same.

Since Isobars have :-

(i) Different physical and chemical properties.

(ii) Different atomic numbers.

(iii) Different position in the periodic table.

(iv) Different atomic volume, density, melting point and boiling point.

Ex - Argon and Calcium are isobars because they have the same mass number i.e., 40, but differ in their atomic numbers.

Argon $_{18}Ar^{40}$ → It contains 18 electrons, 18 protons and 22 neutrons.

Calcium $_{20}Ca^{40}$ → It contains 20 electrons, 20 protons and 20 neutrons.

Isotones → Atoms of different elements which possess the same no of neutrons are called isotones.

Ex. ~~B &~~ $_5B^{12}$ & $_6C^{13}$ are isotones because both nuclei contain 7 neutrons.

$_{32}Ge^{76}$ and $_{33}As^{77}$ are isotones because they contain the same no. of neutrons i.e., 44 each.

Aufbau Principle →

(German - Aufbau means building up)

According to this principle, the electrons are filled in various orbitals in order of their increasing energies.

Thus, an orbital with lowest energy will be filled first. The energy content of two subshells can be compared by means of (n+l) rule.

(n+l) rule →

(i) The subshell with lower (n+l) value will possess lower energy and will be filled first e.g., 4s-subshell is filled first than 3d-subshell.

(a) For 4s-subshell, $n+l = 4+0 = 4$

(b) For 3d-subshell, $n+l = 3+2 = 5$

Since $(n+l)$ value for 4s-subshell is less than 3d, the 4s-subshell has lower energy and is filled first.

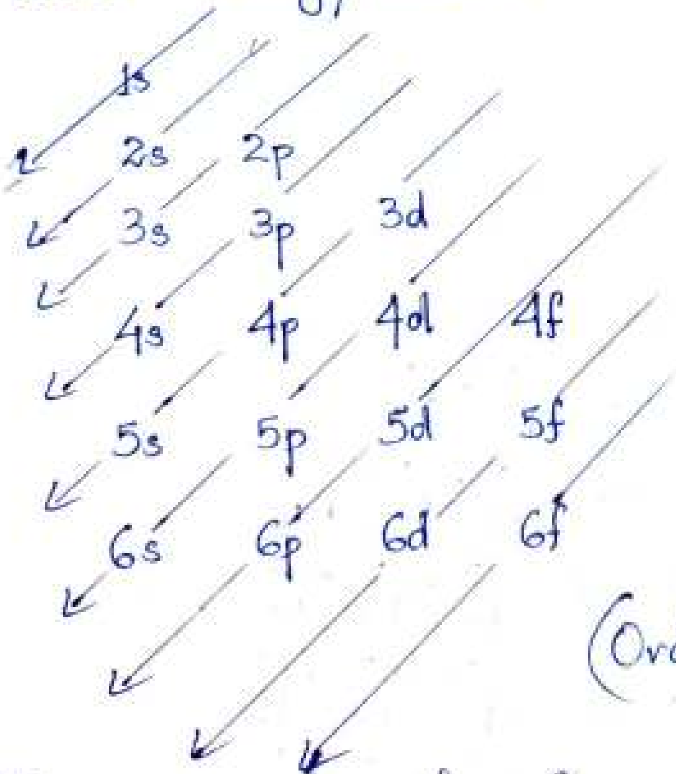
(ii) The subshell with lower value of n possesses lower energy if $(n+l)$ values for both the subshells are equal.

e.g., 3p-subshell is filled first than 4s.

(a) For 3p-subshell, $n+l = 3+1 = 4$

(b) For 4s-subshell, $n+l = 4+0 = 4$

Since, the value of 'n' $(n=3)$ is less for 3p-subshell as compared to 4s-subshell $(n=4)$, 3p-subshell has lower energy and is filled first.



(Order of filling up orbitals)

The increasing order of energies of various subshells is

$1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d$ ----

Hund's rule of maximum multiplicity

No electron pairing takes place in p, d and f-subshells until each degenerate orbital in the given subshell contains one electron.

Applying Hund's rule, the electronic configuration of some elements are –

		1s	2s	2p		
$_7N$	$1s^2\ 2s^2\ 2p_x^1\ 2p_y^1\ 2p_z^1$	↑↓	↑↓	↑	↑	↑
$_8O$	$1s^2\ 2s^2\ 2p_x^2\ 2p_y^1\ 2p_z^1$	↑↓	↑↓	↑↓	↑	↑
$_9F$	$1s^2\ 2s^2\ 2p_x^2\ 2p_y^2\ 2p_z^1$	↑↓	↑↓	↑↓	↑↓	↑
$_{10}Ne$	$1s^2\ 2s^2\ 2p_x^2\ 2p_y^2\ 2p_z^2$	↑↓	↑↓	↑↓	↑↓	↑↓

Electronic Configuration of Elements →

$_1H$ – $1s^1$

$_2He$ – $1s^2$

$_3Li$ – $1s^2\ 2s^1$

$_4Be$ – $1s^2\ 2s^2$

$_5B$ – $1s^2\ 2s^2\ 2p^1$ or, $1s^2\ 2s^2\ 2p_x^1$

$_6C$ – $1s^2\ 2s^2\ 2p^2$ or, $1s^2\ 2s^2\ 2p_x^1\ 2p_y^1$

$_7N$ – $1s^2\ 2s^2\ 2p^3$ or, $1s^2\ 2s^2\ 2p_x^1\ 2p_y^1\ 2p_z^1$

$_8O$ – $1s^2\ 2s^2\ 2p^4$ or, $1s^2\ 2s^2\ 2p_x^2\ 2p_y^1\ 2p_z^1$

$_9F$ – $1s^2\ 2s^2\ 2p^5$ or, $1s^2\ 2s^2\ 2p_x^2\ 2p_y^2\ 2p_z^1$

$_{10}Ne$ – $1s^2\ 2s^2\ 2p^6$ or $1s^2\ 2s^2\ 2p_x^2\ 2p_y^2\ 2p_z^2$

$_{11}Na$ – $1s^2\ 2s^2\ 2p^6\ 3s^1$

$_{12}Mg$ – $1s^2\ 2s^2\ 2p^6\ 3s^2$

$_{13}Al$ – $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p_x^1$

$_{14}Si$ – $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p_x^1\ 3p_y^1$

$_{15}P$ – $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p_x^1\ 3p_y^1\ 3p_z^1$

$_{16}S$ – $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p_x^2\ 3p_y^1\ 3p_z^1$

$_{17}Cl$ – $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p_x^2\ 3p_y^2\ 3p_z^1$

$_{18}Ar$ – $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p_x^2\ 3p_y^2\ 3p_z^2$

$_{19}K$ – $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$

$_{20}Ca$ – $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$

$_{21}Sc$ – $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^1$

$_{22}Ti$ – $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^2$

$_{23}V$ – $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^3$

$_{24}Cr$ – $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^5$

$_{25}Mn$ – $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^5$

$_{26}Fe$ – $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^6$

$_{27}Co$ – $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^7$

$_{28}Ni$ – $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^8$

$_{29}Cu$ – $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^{10}$

$_{30}Zn$ – $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}$

Exceptional Configuration of Chromium & Copper →

The electronic configurations of Cr & Cu are expected to be –

$_{24}Cr$:– $_{18}[Ar]\ 4s^2\ 3d^4$ & $_{29}Cu$:– $_{18}[Ar]\ 4s^2\ 3d^9$

However, the actual configurations are

$_{24}Cr$ – $_{18}[Ar]\ 4s^1\ 3d^5$ & $_{29}Cu$ – $_{18}[Ar]\ 4s^1\ 3d^{10}$.

This is because the half filled and fully filled configurations i.e., d^5, d^{10}, f^{14} have lower energy and more stability. Thus, in order to become more stable, one of the 4s electrons goes into 3d-orbitals so that 3d-orbitals get half or fully filled configurations in Cr and Cu respectively.

Chemical Bond

A chemical bond is defined as the force of attraction which holds the constituent atoms together in a molecule.

~~is known as~~

Types of chemical bonds:

There are three main types of chemical bonds.

(1) Ionic bond or electrovalent bond.

(2) Covalent bond.

(3) Co-ordinate bond.

Ionic or Electrovalent bond:

The bond which is formed by transfer of one or more electrons from one atom to the other is called the ionic bond. This type of bond is always formed between two dissimilar atoms, i.e., one is metal atom and the other is non-metal atom. The metal atom loses one or more electrons and changes into a cation while the non-metal atom gains ~~one or more~~ the electrons and changes into an anion. Thus, ionic bond is the force of attraction which exists between two oppositely charged ions in a molecule.

The compounds containing ionic or electrovalent bonds are called ionic or electrovalent compounds.

Ex. Formation of NaCl molecule:

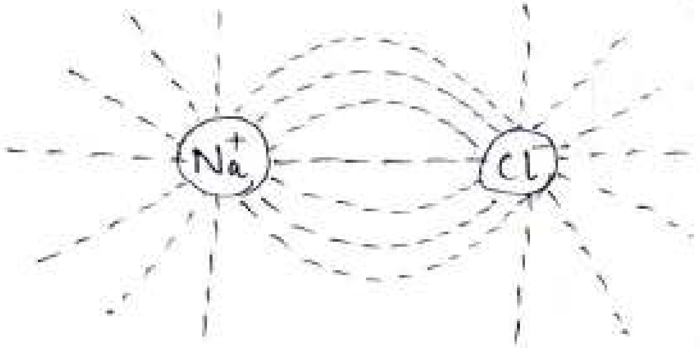
The electronic configuration of Na is 2,8,1 and that of Cl is 2,8,7.

'Na' contains one extra electron in comparision to 'Ne', and 'Cl' is short of one electron in comparision to Ar. Hence, to satisfy the octet rule and get the stable configuration of nearest inert gas, 'Na' will lose that extra electron which is gained by 'Cl'.

$$Na \rightarrow Na^{+} + e$$

$$Cl + e^{-} \rightarrow Cl^{-}.$$

In this way, Na is converted to Na^+ and Cl is converted to Cl^-. Now, a strong electrostatic force of attraction will exist between Na^+ and Cl^- ions, which leads to the formation of NaCl molecule.



Ex(2) **Formation of $MgCl_2$ molecule:**

The electronic configuration of Mg is 2, 8, 2 and that of 'Cl' is 2, 8, 7.

From the electronic configuration, it is clear that 'Mg' contains two extra electrons in comparision to 'Ne' and 'Cl' is short of one electron in comparision to 'Ar'.

Hence, to satisfy octet rule and to get stable configuration of inert gas, 'Mg' will lose two extra electrons and these two lost electrons are gained by two 'Cl' atoms.

$$Mg \rightarrow Mg^{2+} + 2e$$

$$2Cl + 2e \rightarrow 2Cl^-$$

In this way, Mg is converted to Mg^{2+} and 'Cl' is converted to Cl^-. Now, an electrostatic force of attraction exists between Mg^{2+} and ~~to~~ two Cl^- ions, which leads to the formation of $MgCl_2$ molecule.

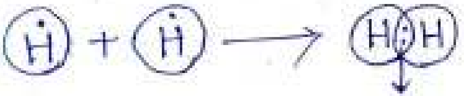
Covalent bond :

Covalent bond is defined as the force of attraction which arises by the mutual sharing of electrons between the atoms. The compound so formed is called covalent compound. Covalent bond is directional in character. The shared pair of electrons are counted towards the stability of both the participating atoms. This type of bond is formed between two similar or dissimilar atoms.

Ex. (1) Formation of H_2 molecule :

The electronic configuration of H-atom is $1s^1$. It needs one more electron to complete its valence shell. When two hydrogen atoms approach each other, at a certain internuclear distance, they share their valence electrons and form a shared pair. The shared pair belongs equally to both the atoms. The two atoms are said to be linked by a single covalent bond and H_2 molecule is formed.

$$\dot{H} + \dot{H} \longrightarrow H:H \quad \text{or} \quad H-H$$



shared electron pair

Thus, each H-atom completes its duplet or Helium and becomes stable.

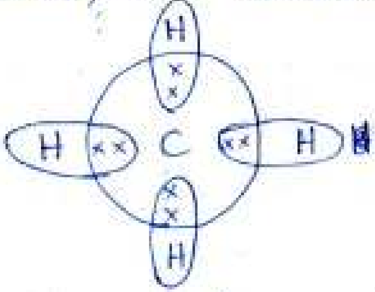
(2) Formation of CH_4 molecule :

~~Carbon~~ It is formed by the combination of one carbon atom and four hydrogen atoms. Carbon contains four valence electrons and hydrogen has one electron.

$$_6C \rightarrow 1s^2 2s^1 2p_x^1 2p_y^1 2p_z^1$$

$$_1H \rightarrow 1s^1$$

To satisfy the octet rule and get the stable configuration of nearest inert gas, carbon atom mutually shares its four valence electrons with four hydrogen atoms. Thus, four covalent bonds are formed.



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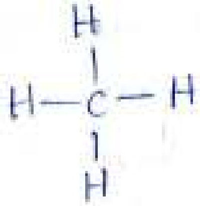


In this way, carbon will get the configuration of Neon and hydrogen will get the configuration of Helium. It is found that the structure of methane is tetrahedral with bond angles equal to 109° 28' each.

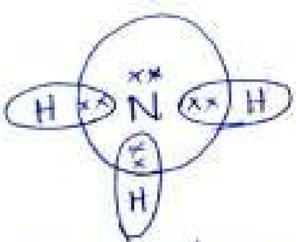
(3) Formation of NH_3 molecule:

It is formed by combination of one nitrogen atom and three hydrogen atoms. Nitrogen atom has five valence electrons and hydrogen atom contains one electron.

$${}_7N \rightarrow 1s^2\,2s^2\,2p_x^1\,2p_y^1\,2p_z^1$$

$${}_1H \rightarrow 1s^1$$

To satisfy the octet rule and get the stable configuration of nearest inert gas, nitrogen shares its three unpaired electrons with three hydrogen atoms.



or

In this way, nitrogen will get the configuration of neon and hydrogen will get the configuration of helium, which ultimately leads to the formation of NH_3 molecule.

The str. of ammonia is pyramidal with bond angle equal to 107°.

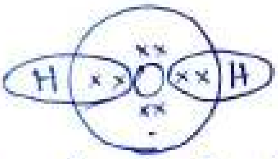
(4) Formation of H_2O :

Oxygen contains six valence electrons, So, it is short of two electrons compared to stable electronic configuration of neon, and hydrogen has one electron.

$${}_8O \rightarrow 1s^2\, 2s^2\, 2p_x^2\, 2p_y^1\, 2p_z^1$$

$${}_1H \rightarrow 1s^1$$

Hence, to satisfy the octet rule and to get stable configuration of nearest inert gas, oxygen mutually shares its two valence electrons with two hydrogen atoms. This leads to the formation of H_2O molecule.



or

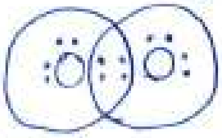
$H - \overset{\times\times}{\underset{\times\times}{O}} - H$

It is found that the structure of water is angular with bond angle equal to 104.5°.

(5) Formation of O_2 molecule :

An oxygen atom contains six valence electrons and needs two more electrons to achieve the octet. For the formation of oxygen molecule, each oxygen atom contributes two electrons, forming two bond pairs. The two electron pairs so formed are counted for the stability of both oxygen atoms.

$:\ddot{O}: + :\ddot{O}: \longrightarrow$



or $:\ddot{O}=\ddot{O}:$

The O_2 molecule contains two bond pairs and each oxygen atom in it contains two unshared pairs.

Co-ordinate bond : (Dative bond)

A co-ordinate bond is formed when an atom with complete octet (after mutual sharing) donates its pair of electrons to the other atom. The donated electron pair is counted for the stability of both the atoms.

(i) This type of bond is formed between two dissimilar atoms, A and B.

(ii) Atom A has one or more lone pair of electrons. Atom B is short of a pair of electrons than the nearest inert gas configuration.

(iii) Atom A donates its lone pair of electrons to the atom B. As a result, both atoms get inert gas configuration. Atom A is called donor while atom B is called acceptor atom. The bond formed is called co-ordinate or dative bond.

(iv) The dative bond is shown by (⟶) sign. The head of the arrow is towards the acceptor atom while the tail is towards the donor atom i.e., $A \longrightarrow B$

(v) The dative bond is directional.

Ex.(1) Formation of NH_4^+

Nitrogen has five valence electrons and hydrogen has one electron.

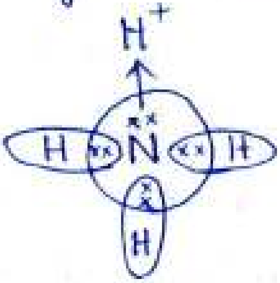
$$_{7}N \rightarrow 1s^2\, 2s^2\, 2p_x^1\, 2p_y^1\, 2p_z^1$$

$$_{1}H \rightarrow 1s^1$$

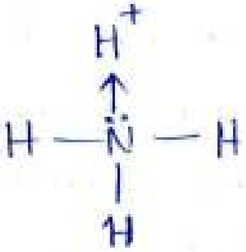
To satisfy the octet rule and get the stable electronic configuration of nearest inert gas, nitrogen shares its three unpaired electrons with three hydrogen atoms. This leads to the formation of NH_3 molecule.

In NH_3, the lone pair present on the nitrogen atom is donated to H^+ ion to form a co-ordinate bond.

As a result, both become stable by attaining inert gas configuration, which leads to the formation of NH_4^+.



or



(2) Formation of SO_2 :

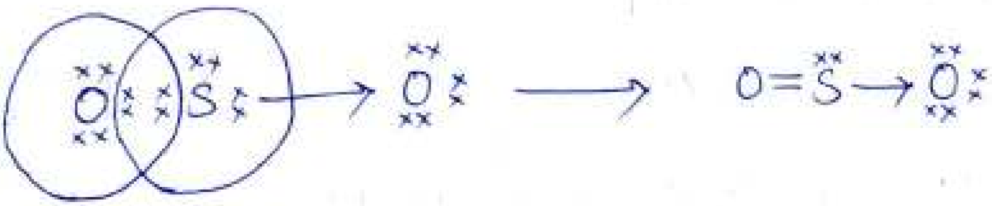
Both sulphur and oxygen have six valence electrons.

$_{16}S \rightarrow 1s^2 2s^2 2p^6 3s^2 3p_x^2 3p_y^1 2p_z^1$

$_8O \rightarrow 1s^2 2s^2 2p_x^2 2p_y^1 2p_z^1$

To satisfy the octet rule and to get the stable configuration of nearest inert gas, sulphur atom mutually shares ~~its~~ two electrons with the oxygen atom.

One lone pair of electrons present on sulphur atom is donated to another oxygen atom to form a co-ordinate bond. This leads to the formation of SO_2 molecule.



Acid- Base Theory

Concept of Arrhenius →

According to Arrhenius concept :-

(i) Acids are those substances which yield H^+ ion in aqueous solution. Thus, HCl, H_2SO_4, CH_3COOH etc. are acids because they dissociate as -

$$HCl(g) + aq \rightleftharpoons H^+(aq) + Cl^-(aq)$$

$$HNO_3(l) + aq \rightleftharpoons H^+(aq) + NO_3^-(aq)$$

$$H_2SO_4(l) + aq \rightleftharpoons 2H^+(aq) + SO_4^{2-}(aq).$$

(ii) Bases are those substances which yield OH^- ion in aqueous solution. Thus, $NaOH$, KOH, NH_4OH etc. are bases because they provide OH^- ion in aqueous solution.

$$NaOH(s) + aq \rightleftharpoons Na^+(aq) + OH^-(aq)$$

$$KOH(s) + aq \rightleftharpoons K^+(aq) + OH^-(aq)$$

$$NH_4OH(l) + aq \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

(iii) Neutralisation of an acid and a base is based on the key reaction between H^+ ions and OH^- ions to form water molecules.

$$H^+(aq) + OH^-(aq) \longrightarrow H_2O(l)$$

(iv) During electrolysis of aqueous solution of an acid, H^+ ions proceed to the cathode and negative ions to the anode. Thus,

$$HCl(g) \xrightarrow{water} H^+(aq) + Cl^-(aq)$$

At cathode, $2H^+(aq) + 2e \longrightarrow H_2(g)$

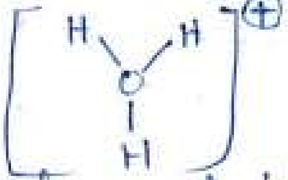
At anode, $2Cl^- - 2e \longrightarrow Cl_2(g)$

Limitations →

(i) According to Arrhenius, an acid releases H^+ ion in aqueous medium. But H^+ ion does not exist freely in aqueous solution. It combines with H_2O, as soon as it forms to give hydronium ion (H_3O^+).

$$H^+ + H_2O \longrightarrow H_3O^+$$

or,



(ii) It fails to explain the acidic and basic nature of substances in solvents other than water.

(iii) It fails to explain the acidic properties of substances like CO_2, SO_2, P_2O_5 etc. which don't contain hydrogen. Also it does not explain the basic nature of substances like NH_3, CaO etc. which do not contain OH group.

(iv) The theory fails to explain the neutralisation reactions between some acidic and basic substances which do not produce water. e.g.,

$$\underset{\text{Base}}{CaO(s)} + \underset{\text{Acid}}{SO_2(g)} \longrightarrow \underset{\text{Salt}}{CaSO_3(s)}$$

$$\underset{\text{Base}}{NH_3(g)} + \underset{\text{Acid}}{HCl(g)} \longrightarrow \underset{\text{Salt}}{NH_4Cl(s)}$$

Bronsted-Lowry Concept of Acids & Bases →

According to this theory:—

(i) An acid is a substance (molecule or ion) which has a tendency to donate a proton to any other substance, and

(ii) A base is a substance (molecule or ion) which has a tendency to accept a proton from any other substance.

In other words, acids are proton donors whereas bases are proton acceptors.

Examples of acids :-

HCl, HNO_3, H_2SO_4, CH_3COOH, HS^-, HCO_3^-, NH_4^+ etc.

Examples of Bases :-

H_2O, NH_3, RNH_2, PH_3, OH^-, CN^-, HCO_3^- etc.

$$\text{acids}\left\{\begin{array}{l} HCl \rightleftharpoons H^+ + Cl^- \\ H_3O^+ \rightleftharpoons H^+ + H_2O \end{array}\right.$$

$$\text{Bases}\left\{\begin{array}{l} NH_3 + H^+ \rightleftharpoons NH_4^+ \\ H_2O + H^+ \rightleftharpoons H_3O^+ \\ OH^- + H^+ \rightleftharpoons H_2O \end{array}\right.$$

Salient features →

(i) According to this theory, an acid reacts with a base to form another pair of acid and base.

$$\underset{Acid_1}{HCl} + \underset{Base_2}{H_2O} \rightleftharpoons \underset{Acid_2}{H_3O^+} + \underset{Base_1}{Cl^-}$$

(ii) Conjugate acid and base pairs → When an acid loses a proton, the residue will have a tendency to take up proton. So, it acts as a base. Thus,

$$\text{Acid} - H^+ \longrightarrow \text{Conjugate base}$$

&

$$\text{Base} + H^+ \longrightarrow \text{Conjugate acid}.$$

The pair of acid and base which differ by a proton is said to form a conjugate pair.

Ex. $$\underset{Base_1}{NH_3} + \underset{Acid_2}{H_2O} \rightleftharpoons \underset{Acid_1}{NH_4^+} + \underset{Base_2}{OH^-}$$

Thus, NH_4^+ ion is the conjugate acid of NH_3 molecule and OH^- is the conjugate base of H_2O molecule.

(iii) The substance which acts both as an acid as well as a base is called an amphoteric substance.

Ex. $HCl + H_2O \rightleftharpoons H_3O^+ + Cl^-$
(Base)

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$
(Acid)

With HCl, water acts as a base while with NH_3, it acts as an acid. Thus, H_2O is amphoteric.

(iv) Stronger an acid, weaker is its conjugate base and vice versa.

$HCl + H_2O \longrightarrow H_3O^+ + Cl^-$
(strong acid) (weak base)

Limitations →

(i) It fails to explain the acidic nature of substances such as SiO_2, CO_2, SO_2 etc. which can't donate H^+ ion.

(ii) It fails to explain the basic nature of substances such as CaO, MgO, BaO etc. which can't accept H^+ ion

(iii) It also fails to explain the acidic character of $AlCl_3$, $FeCl_3$, BF_3 etc.

All Arrhenius acids are Bronsted acids but all Bronsted bases are not Arrhenius bases →

According to Arrhenius, a base must furnish OH^- ion in aqueous ~~soluti~~ solution. But according to Bronsted theory, a base must accept a proton.

Thus, CO_3^{2-} ion is a Bronsted base as it can accept a proton to form HCO_3^- ion. But, it can't be an Arrhenius base as it can't furnish OH^- ion in aqueous solution.

Hence, all Arrhenius acids are Bronsted acids but all Bronsted bases are not Arrhenius bases.

Some conjugate Acid-Base pairs →

Acid	Conjugate Base	Base	Conjugate Acid
HCl	Cl^-	NH_3	NH_4^+
HNO_3	NO_3^-	H_2O	H_3O^+
H_2SO_4	HSO_4^-	OH^-	H_2O
CH_3COOH	CH_3COO^-	Cl^-	HCl
H_2CO_3	HCO_3^-	Br^-	HBr
H_3PO_4	$H_2PO_4^-$	CN^-	HCN
H_2O	OH^-	NO_3^-	HNO_3
HCN	CN^-	HSO_4^-	H_2SO_4
NH_4^+	NH_3	SO_4^{2-}	HSO_4^-
HSO_4^-	SO_4^{2-}	NH_2^-	NH_3
HBr	Br^-	HCO_3^-	H_2CO_3
HNO_2	NO_2^-	CO_3^{2-}	HCO_3^-
HPO_4^{2-}	PO_4^{3-}	F^-	HF
H_2S	HS^-	HPO_4^{2-}	$H_2PO_4^-$
HS^-	S^{2-}	$H_2PO_4^-$	H_3PO_4
HCO_3^-	CO_3^{2-}	HS^-	H_2S
$H_2PO_4^-$	HPO_4^{2-}	S^{2-}	HS^-
HF	F^-	CH_3COO^-	CH_3COOH
		NO_2^-	HNO_2

Lewis Concept (Electronic Concept) of Acids & Bases → According to Lewis theory, Acids are the substances which can accept a pair of electrons from any other substance, while bases are the substances which can donate a pair of electrons to any other substance.

In other words, acids are electron acceptors while bases are electron donors.

Examples of acids →

(a) All cations e.g., Cu^{2+}, Ag^{+}, Ca^{2+}, Fe^{3+} etc.

(b) Molecules having electron deficient atoms e.g., $FeCl_2$, $ZnCl_2$, SO_3, $AlCl_3$ etc.

(c) Molecules having atoms which can accomodate more electrons in the vacant d-orbitals in the valency shell. e.g., $SiCl_4$, SiF_4 etc.

(d) Mulecules having multiple bonds between atoms of different electronegativities e.g., CO_2, SO_2 etc.

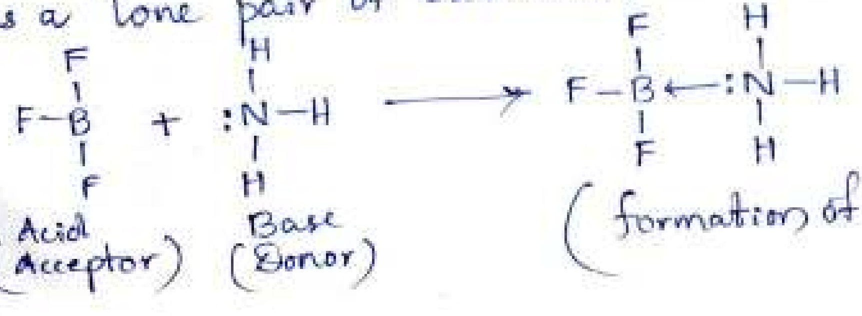
Examples of bases →

(a) All negative ions are Lewis bases e.g., OH^-, CN^-, CH_3COO^-, Cl^-, Br^-, CN^- etc.

(b) Neutral molecules having one or more lone pairs of electrons e.g., $\ddot{N}H_3$, $R\ddot{N}H_2$, $H_2\ddot{O}:$ etc.

Acid-base reactions → According to this concept, whenever an acid reacts with a base, a co-ordinate bond is formed. e.g.,

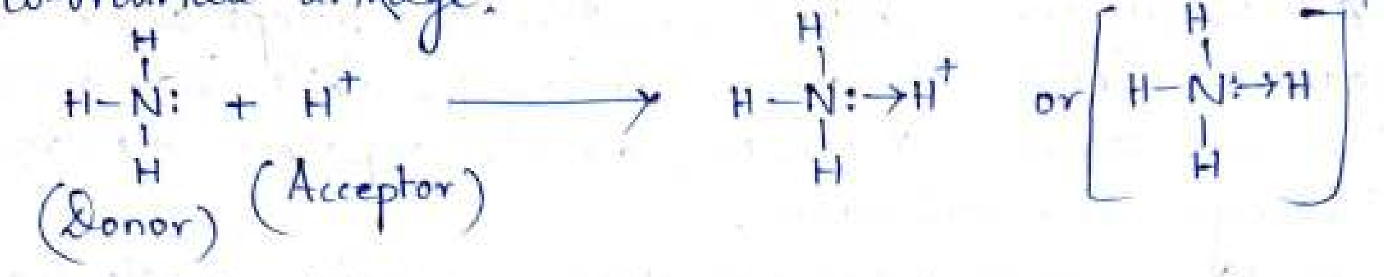
(a) BF_3 behaves as an acid as boron atom in it is electron deficient and $\ddot{N}H_3$ acts as a base as nitrogen atom in it has a lone pair of electrons.



$$BF_3 + :NH_3 \longrightarrow F_3B \leftarrow :NH_3$$

(formation of co-ordinate bond)

(b) H^+ ion is a Lewis acid and NH_3 is a Lewis base. They react to form ammonium ion by co-ordinate linkage.



$$H-\overset{H}{\underset{H}{N}}: + H^+ \longrightarrow H-\overset{H}{\underset{H}{N}}:\rightarrow H^+ \text{ or } \left[H-\overset{H}{\underset{H}{N}}:\rightarrow H \right]^+$$

Limitations →

(i) It fails to explain the strength of acids and bases as it doesn't consider ionisation.

(ii) According to this theory, an acid reacts with a base with the formation of a dative bond but no such bond is formed when HCl reacts with NaOH.

(iii) Acid-base reactions are fast and instantaneous, but the formation of dative bond is a slow process.

Comparision of Lewis concept and Bronsted-Lowry concept →

According to Bronsted theory, a base is substance which accepts a proton but according to Lewis, a base can donate a pair of electrons. As, a Lewis base carries one or more lone pair, it can also accept a proton. Thus, Lewis bases are also Bronsted bases.

Bronsted acids can donate a proton but they can't accept a pair of electrons. Hence, Bronsted acids are not Lewis acids.

Thus, all Bronsted bases are Lewis bases but all Bronsted acids are not Lewis acids.

Types of salts →

(a) Normal salt → These are the salts which are formed from strong acids (HCl, H_2SO_4, HNO_3 etc.) and strong bases ($NaOH$, KOH).

Ex. – $NaCl$, KCl, K_2SO_4, $NaNO_3$ etc.

The aqueous solution of such salts are neutral to litmus

(b) Acidic salts → Acidic salts are formed by the incomplete neutralization of polybasic acids. Such salts still contain one or more replaceable hydrogen atoms.

Ex. – $NaHCO_3$, $NaHSO_4$, Na_2HPO_4 etc.

(c) Basic salts → Such salts are formed by incomplete neutralization of poly acid bases. Such salts still contain one or more hydroxyl groups.

Ex. – $Mg(OH)Cl$, $Zn(OH)Cl$, $Fe(OH)_2Cl$ etc.

(d) Double salts → These are the addition compounds formed by the combination of two simple salts. Such salts are stable only in the solid state.

Ex – $K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$ (Potash alum)

$FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$ (Mohr's salt)

(e) Complex salts → These are the compounds formed by the combination of simple salts or molecular compounds. These are stable in the solid state as well as in solution.

Ex. – $K_4[Fe(CN)_6]$, $[Cu(NH_3)_4]SO_4$ etc.

(f) Mixed salts → These are the salts which furnish more than one cation or more than one anion when dissolved in water. Ex. – $CaOCl_2$, $NaKSO_4$, $NaNH_4HPO_4$ etc.

Units of concentration

Concentration : The amount of solute present in a given quantity of solution, is called concentration.

Standard solution: A standard solution is one, whose concentration is known.

Different ways of expressing the concentration of a solution.

(1) Strength of solution :— The strength of a solution is the number of grams of solute dissolved in one litre of solution.

$$\text{strength of solution} = \frac{\text{wt. of solute in gm}}{\text{Volume of solution in litre}}$$

$$\text{or, strength of solution} = \frac{\text{wt. of solute in gm} \times 1000}{\text{Volume of solution in ml}} \text{ gm per lit.}$$

Ex:- Calculate the strength of a solution which contains 8gm of NaOH present in 500ml.

Solution:—

$$\text{Strength of solution} = \frac{8 \times 1000}{500} = 16 \text{ gm per lit.}$$

(2) Normality:— Normality is defined as the no. of gram equivalents of the solute present per litre of the solution. It is denoted by the letter 'N'.

Mathematically,

$$\boxed{\text{Normality} = \frac{\text{No. of gram equivalents of solute}}{\text{Volume of solution in ml}} \times 1000}$$

We know that,

$$\text{No. of gram equivalents of solute} = \frac{\text{Mass of solute in grams}}{\text{Eq. wt. of the solute}}$$

If 'w' gm of solute is present in 'V' ml of solution,

then

$$\boxed{N = \frac{w}{\text{Eqv. wt. of the solute}} \times \frac{1000}{V}}$$

Unit of normality ~~is~~ gm eqv. per litre.

Ex: 200 ml of a solution contains 0.754 gm of $NaHCO_3$. Find its normality.

Solution:- Amount of solute $NaHCO_3$ (w) = 0.754 gm

Volume of solution (V) = 200 ml

Molecular mass of $NaHCO_3$ = 84

Eqv. mass of $NaHCO_3$ = $\frac{84}{1}$ = 84

Thus, normality (N) = ~~84~~ $\frac{0.754}{84} \times \frac{1000}{200} = 0.0448$

Normality can also be calculated from strength of solution

$$\boxed{N = \frac{\text{strength of solution in gm/lit}}{\text{Eqv. mass of solute}}}$$

Thus, the above problem can also be solved as

Amount of $NaHCO_3$ in 200 ml solution = 0.754 gm

Amount of $NaHCO_3$ in 1000 ml solution = $\frac{0.754}{200} \times 1000$

= 3.17 gm.

Eqv. mass of $NaHCO_3$ = 84

Normality (N) = $\frac{\text{strength in gm/lit}}{\text{Equ. mass of solute}}$

$= \frac{3.17}{84} = 0.0448$.

Normal solution:-

When 1 gm. equivalent of a solute is dissolved in 1 litre of solution, it is called a normal solution.

(3) Molarity (M) —

Molarity is the number of moles of the solute present per litre of the solution. It is denoted by the letter M.

$$\boxed{M = \frac{\text{No. of moles of the solute}}{\text{Volume of the solution in ml}} \times 1000}$$

We know that,

$$\text{No. of moles of the solute} = \frac{\text{wt. of the solute in gram}}{\text{Molecular mass of the solute}}$$

If 'w' gm of solute is present in 'V' ml of solution, then

$$\boxed{M = \frac{w}{\text{Mol. mass of the solute}} \times \frac{1000}{V}}$$

If strength of solution is given, then

$$\boxed{M = \frac{\text{strength of solution in gm/lit}}{\text{Mol. mass of the solute}}}$$

~~Ex. Calculate the~~

Unit of molarity = moles per litre.

Ex. - Calculate the molarity of sodium carbonate solution, 2.62 gm of which are dissolved in 600 ml solution.

600 ml of solution contains sodium carbonate = 2.62 gm

$$1000\text{ml of solution contains sodium carbonate} = \frac{2.62}{600} \times 1000$$

$$= 4.366 \text{ gm}.$$

Hence, strength of solution = 4.366 gms / litre.

Molecular mass of sodium carbonate = 106

~~Thus,~~

$$\text{Molarity (M)} = \frac{\text{strength in gm/lit}}{\text{Molecular mass}}$$

$$~~= 4.366 gms/lit~~ \quad = \frac{4.366}{106} = 0.041.$$

OR,

Wt. of solute (w) = 2.62 gm

Volume of solution (V) = 600 ml

Mol. mass of sodium carbonate = 106

$$\text{Molarity (M)} = \frac{2.62}{106} \times \frac{1000}{600} = 0.041$$

~~(3) Molality (m) :-~~

Molar solution : When one mole of a solute is present in one litre of solution, it is called a molar solution.

(3) Molality (m) :- Molality is defined as the no. of moles of the solute present in 1000 gm of the solvent. It is denoted by the letter 'm'.

$$\boxed{m = \frac{\text{No. of moles of the solute}}{\text{Mass of the solvent in gm}} \times 1000}$$

Unit of molality = moles per kg.

If 'w' gm of a solute is present in 'W' gm of the solvent, then,

$$\boxed{\text{molality (m)} = \frac{w}{\text{Mol. mass of the solute}} \times \frac{1000}{W}}$$

Molal solution : When one mole of solute is present in 1000 gm of the solvent, it is called a molal solution.

Ex.: Calculate the molality of K_2CO_3 solution which is formed by dissolving 2.51 gm of it in one litre solution. (density of solution = 0.85 gm/ml)

Mass of K_2CO_3 (w) = 2.51 gm.

Volume of solution = 1000 ml.

Density of solution = 0.85 gm/ml.

$$\text{Density} = \frac{\text{mass}}{\text{Volume}}.$$

∴ Mass of 1000ml solution = Density of solution × Volume of solution

$$= 0.85 \times 1000 = 850\,\text{gm}.$$

∴ Mass of solvent = Mass of solution − Mass of solute

$$= 850\,\text{gm} - 2.51\,\text{gm} = 847.49\,\text{gm}.$$

Molecular mass of K_2CO_3 = 138

$$\text{Molality (m)} = \frac{2.51}{138} \times \frac{1000}{847.49} = 0.021$$

Relationship between normality and molarity : −

We know that

$$\text{Normality (N)} = \frac{\text{strength of solution in gms/lit}}{\text{Eqv. mass of solute}}$$

$$\text{Molarity (M)} = \frac{\text{Strength of solution in gms/lit}}{\text{Mol. mass of solute}}.$$

$$\therefore \frac{\text{Molarity}}{\text{Normality}} = \frac{\text{Eqv. mass}}{\text{Molecular mass}}$$

$$\Rightarrow \boxed{\text{Molarity} = \text{Normality} \times \frac{\text{Eq. mass}}{\text{Mol. mass}}}$$

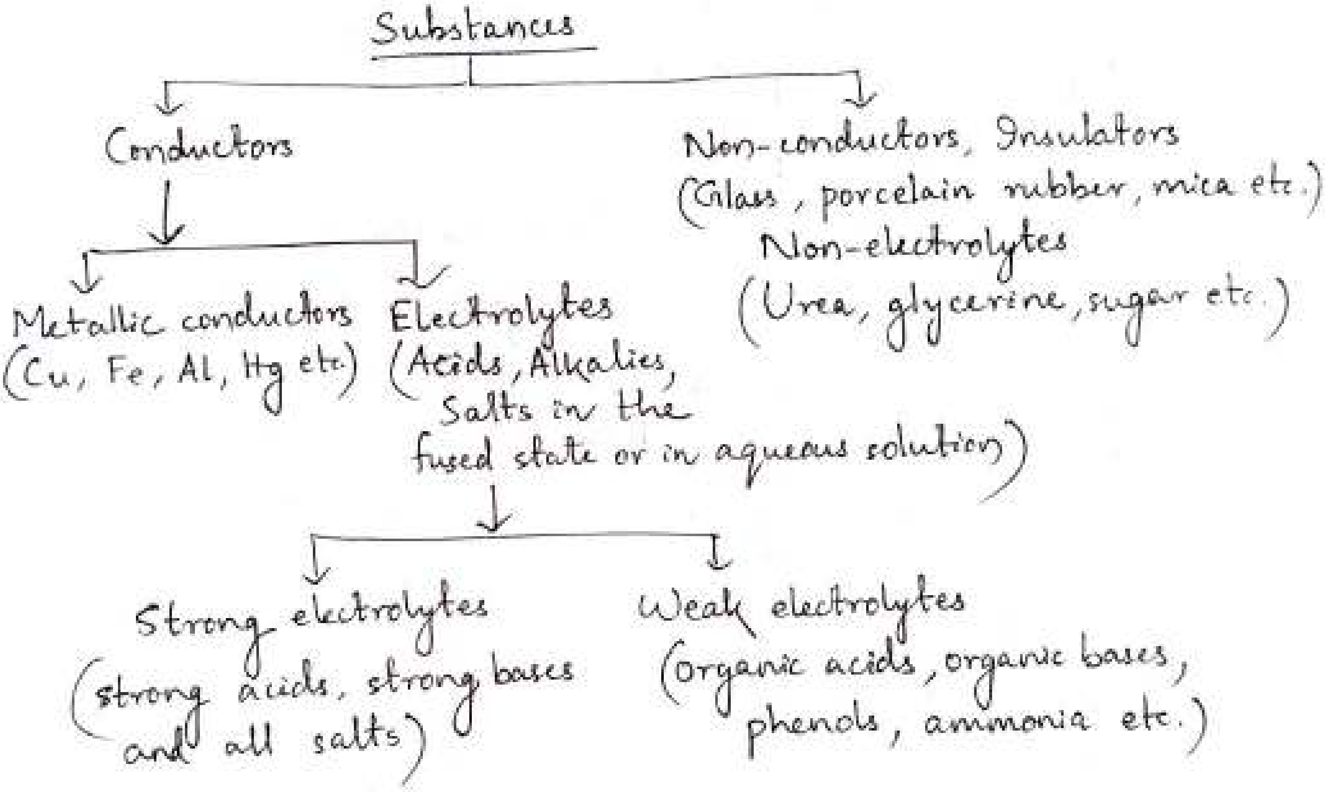
Electrochemistry

Definition :- The branch of chemistry which deals with the study of relationship between electrical energy and chemical energy and interconversion of one form into another is called electrochemistry.

Electrolytic conductor or electrolyte :-

The substance which allows electricity to pass through its aqueous solution or in the fused state is called an electrolytic conductor.

Ex. - Acids, bases, salts.



Strong and weak electrolytes :

(a) Strong electrolytes:- Substances which get completely ionised in solution or which have high degree of ionisation are strong electrolytes.

Ex. - All salts ($NaCl$, KNO_3 etc.), strong acids (HCl, H_2SO_4, HNO_3 etc.) strong bases ($NaOH$, KOH etc.)

$$\left.\begin{array}{l} NaCl \rightleftharpoons Na^+ + Cl^- \\ KOH \rightleftharpoons K^+ + OH^- \\ HCl \rightleftharpoons H^+ + Cl^- \end{array}\right\} \text{(Almost fully ionised)}$$

As strong electrolyte is fully ionised, law of chemical equilibrium cannot be applied on it.

(b) Weak electrolytes :—

Substances which get ionised only ~~slowly~~ slightly or which have low degree of ionisation are weak electrolytes.

Certain acids (viz., CH_3COOH, H_2CO_3 etc.) and bases (viz., NH_4OH, $Ca(OH)_2$ etc)

$$\left.\begin{array}{l} CH_3COOH \rightleftharpoons CH_3COO^- + H^+ \\ NH_4OH \rightleftharpoons NH_4^+ + OH^- \end{array}\right\} \text{Very slight dissociation}$$

Degree of dissociation :

The fraction of the total substance which exists as ions in solution is called its degree of dissociation.

$$\text{Degree of dissociation} = \frac{\text{No. of molecules split into ions}}{\text{Total no. of molecules dissolved}}$$

Difference between strong and weak electrolytes

Strong electrolyte	Weak electrolyte
1. Strong electrolytes get almost completely ionised ~~so~~ in solution.	1. Weak electrolytes get only slightly ionised in solution.
2. Their degree of ionisation is nearly equal to one.	2. Their degree of ionisation is much lower than one.
3. Degree of ionisation remains almost constant on dilution.	3. Degree of ionisation increases appreciably on dilution.
4. Law of equilibrium is not applicable.	4. Law of equilibrium is applicable.
5. Electrical conductivity is high.	5. Electrical conductivity is low.

Electrolysis :

The process of chemical decomposition of an electrolyte in solution or in the fused state by the passage of electric current is known as electrolysis.

Process of electrolysis :

(i) The process of electrolysis is carried out in a vessel known as electrolytic tank.

(ii) Fused electrolyte or aqueous solution of the electrolyte is taken in the electrolytic tank

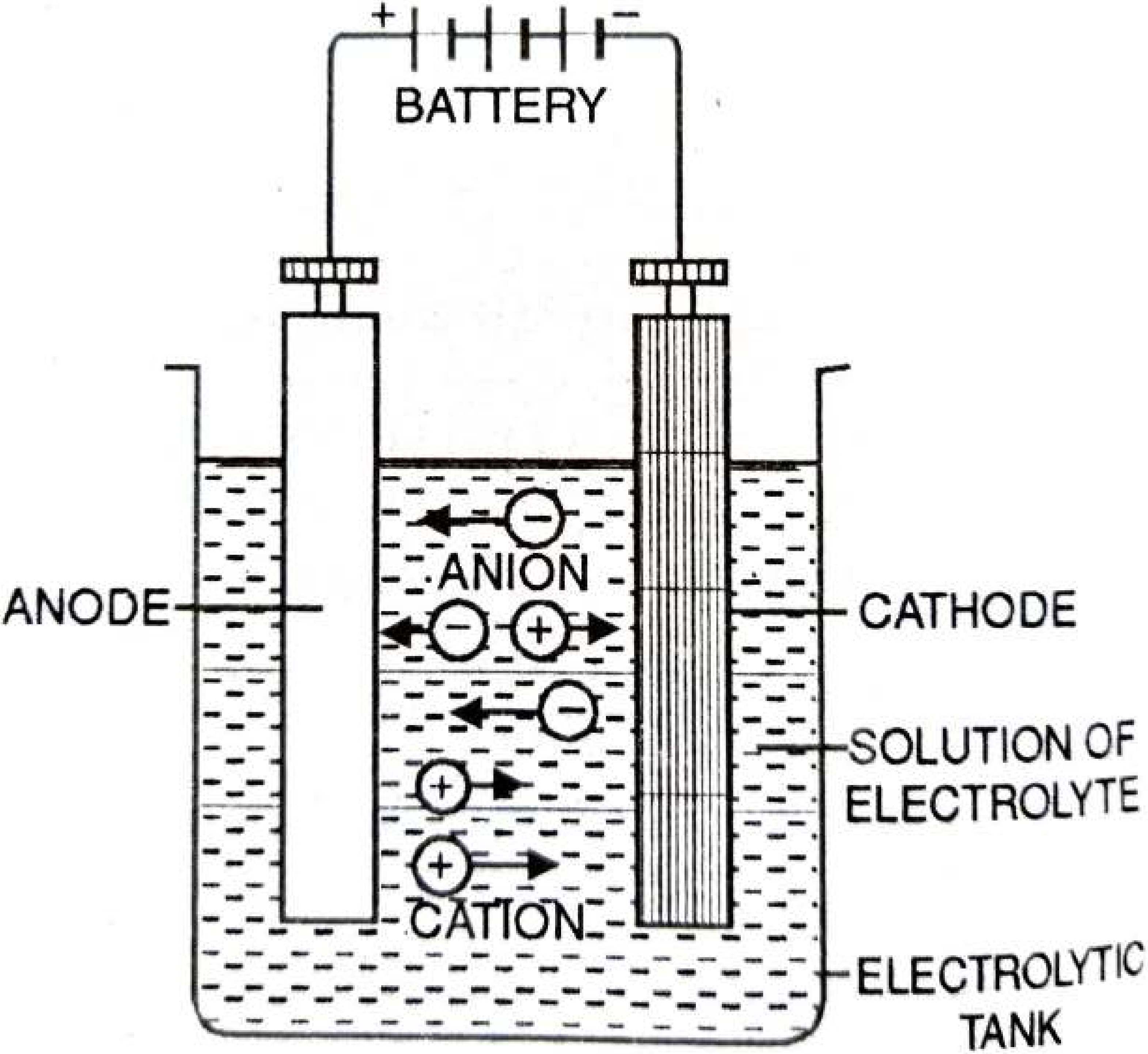
(iii) Two metallic plates are dipped in the electrolyte which are known as electrodes.

(iv) The electrode which is connected with the positive pole of the battery is called anode and the other connected with the negative pole of the battery is called cathode.

(v) When an electrolyte is dissolved in water, it breaks up into cations and anions.

(vi) When an electric current is passed through the solution, cations move towards the cathode and anions move towards the anode.

This movement of ions towards oppositely charged electrodes is called electrolytic conduction.



Process of Electrolysis

Electrolysis of fused (molten) sodium chloride :-

When sodium chloride is heated to high temp., it melts and ionises as

$$NaCl \rightleftharpoons Na^+ + Cl^-$$

When electric current is passed through this molten sodium chloride using platinum electrodes :-

(a) Na^+ ions move towards cathode, lose their charge by gain of electrons and change into neutral atoms. Thus, sodium metal is obtained at the cathode.

At cathode, $Na^+ + e^- \longrightarrow Na$ (metal)

(b) Cl^- ions move towards anode, lose their charge by loss of electrons and change into neutral atoms.

At anode, $Cl^- - e^- \longrightarrow Cl$ (atom)

The chlorine atom being unstable combines with another atom to form stable chlorine molecule.

$$Cl + Cl \longrightarrow Cl_2$$

Electrolysis of aqueous sodium chloride :-

When sodium chloride is dissolved in water, it ionises as, $NaCl \rightleftharpoons Na^+ + Cl^-$

Water also dissociates as

$$H_2O \rightleftharpoons H^+ + OH^-$$

When electric current is passed through aqueous sodium chloride solution using platinum electrodes, :-

(a) Na^+ and H^+ ions move towards cathode. However, only H^+ ions are discharged more readily than Na^+ ions because of their ~~lower~~ low discharge potential. These H^+ ions gain electrons and change into neutral atoms.

At cathode, $H^+ + e \longrightarrow H$ (atom) (unstable)

H-atom being unstable combines with another atom to form stable hydrogen molecule.

$$\underset{}{H + H} \longrightarrow \underset{\text{(stable)}}{H_2}$$

(b) Cl^- and OH^- ions move towards anode. However, only Cl^- ions are discharged more readily than OH^- ions because of their low discharge potential.

These Cl^- ions lose electrons and change into neutral atoms.

At anode,

$$Cl^- - e^- \longrightarrow \underset{\text{(unstable)}}{Cl} \text{ (atom)}$$

Chlorine atom being unstable combines with another atom to form stable chlorine molecule.

Hence, in the electrolysis of aqueous solution of sodium chloride, hydrogen is liberated at cathode while chlorine is liberated at anode.

Faraday's 1st law of electrolysis :—

The mass of the substance liberated at the electrode as a result of electrolysis is directly proportional to the quantity of electricity passed through the electrolyte.

If W is the mass of substance liberated at the electrode and Q is the quantity of electricity passed through the electrolyte, then

$$W \propto Q$$

But, $Q = c.t.$ where c = current in amperes and
t = time in seconds.

$\therefore W \propto c.t.$ or $W = Z.c.t.$

where Z is a constant and is called electrochemical equivalent.

When, $c = 1$ ampere and $t = 1$ sec,

then $W = Z$

Thus, Electrochemical equivalent of a substance is defined as the mass of substance liberated when one ampere of current is passed through the electrolyte for one second.

or,

It is the mass of the substance liberated by the passage of one coulomb of electricity.

Faraday (F) :

Faraday is a bigger unit of electricity and

1 Faraday = 96500 coulombs.

When 1 Faraday of electricity is passed through the electrolyte, then 1 gm equivalent of the substance is deposited.

Mass of the substance liberated by passage of one Faraday of electricity = 1 gm equivalent.

∴ Mass of the substance liberated by the passage of one coulomb of electricity = $\dfrac{1 \text{ gm equivalent}}{96500}$.

It is called electrochemical equivalent.

Thus,

Electrochemical equivalent, $\boxed{Z = \dfrac{W}{Q} = \dfrac{W}{c \cdot t}}$

or

Electrochemical equivalent $\boxed{Z = \dfrac{1 \text{ gm equivalent}}{965000}}$

Faraday's 2nd law of electrolysis :—

It states that when the same quantity of electricity is passed through different electrolytic solutions, the weights of different substances produced at the electrodes are proportional to their equivalent weights.

Consider three electrolytic ~~solutions~~ cells containing $AgNO_3$, $CuSO_4$ and H_2SO_4 solutions respectively and connected in series. On passing current through the three cells for some time the three cells receive the same amount of electricity.

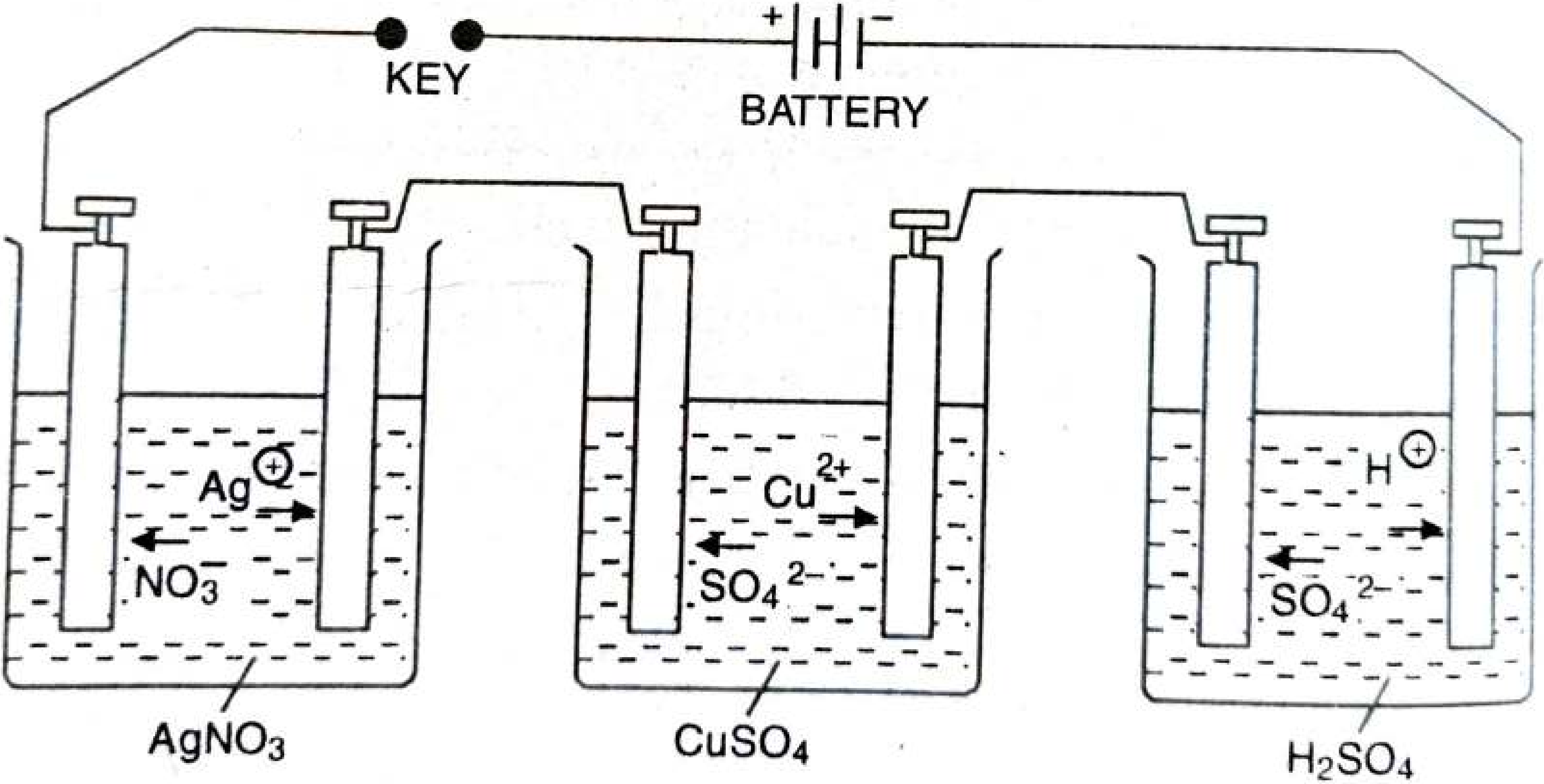
The weights of silver, copper and hydrogen liberated are in the ratio of their equivalent weights.

That is,

$$\frac{\text{Weight of silver}}{\text{Weight of copper}} = \frac{\text{Eq. wt. of silver}}{\text{Eq. wt. of copper}}$$

and

$$\frac{\text{Weight of hydrogen}}{\text{Weight of copper}} = \frac{\text{Eq. wt. of hydrogen}}{\text{Eq. wt. of copper}}$$



. Passage of same amount of electricity through different electrolytes

Industrial Application of Electrolysis :

Electroplating :—

(i) Decoration : Superior metals like chromium, zinc, gold etc. are deposited over baser metals to enhance their beauty.

(ii) Protection :— It avoids rusting of the baser metals.

(iii) Repairs :— The electro-deposition of metal between broken parts help in repairing the broken machinery.

Procedure : The article to be electroplated is thoroughly cleaned and it is then made the cathode.

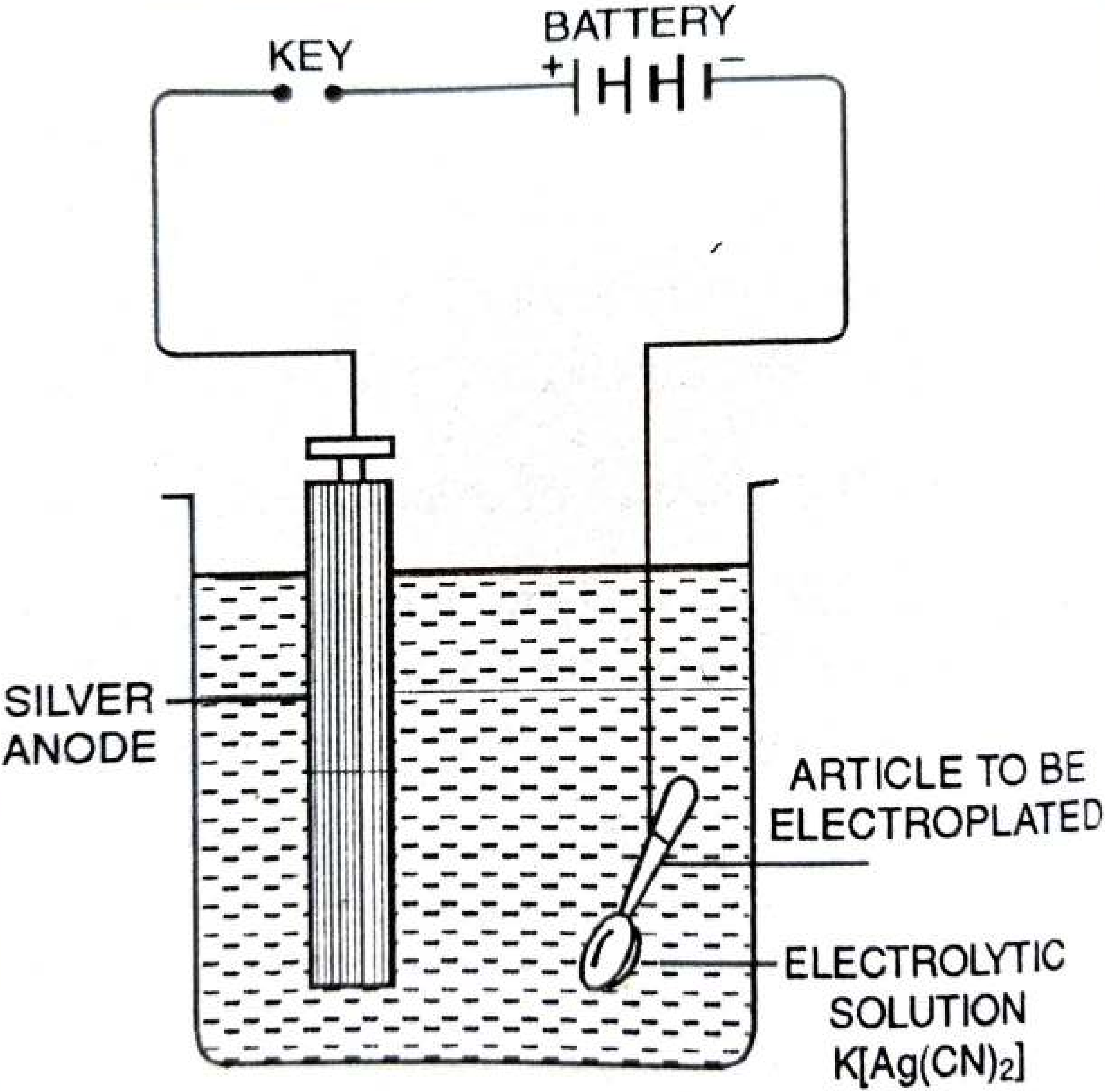
The metal to be deposited on the article is made the anode.

Electroplating is carried out in a tank called electrolytic tank.

The electrolyte is any soluble salt of the metal, whose coating is to be given to the baser metal.

The electrodes are dipped in the electrolyte and current is passed through it.

A thin layer of superior metal is deposited on the article.



Electroplating.

Zinc plating :

For zinc plating both acidic and alkaline solutions are used as electrolytic bath.

(a) The acidic solution used as electrolytic bath consists of a solution of (i) Zinc sulphate (300gm)
(ii) Sodium chloride (15g)
(iii) Aluminium sulphate (30g)
(iv) Boric acid (20g)
(v) Dextrin (15g) in 1000ml water.

(b) The alkaline solution consists of
(i) Zinc oxide (40g)
(ii) Sodium cyanide (100g)
(iii) Sodium Carbonate (10g) in 1000ml water.

The temp. of the solution is kept at 30-40°C.

Zinc plating is done on iron articles to protect them from rusting.

Corrosion :—

Corrosion is defined as a process involving the conversion of a metal into an undesirable compound (usually oxide) on exposure to atmospheric conditions like moisture and oxygen. Corrosion may also be called weeping of metals.

Types of corrosion :

Corrosion is of two types :—

(1) Atmospheric corrosion &
(2) Waterline corrosion.

Atmospheric corrosion :—

Tarnishing of silver, development of a green coating on copper and bronze and rusting of iron are some important examples of ~~corrosion~~, atmospheric corrosion.

In case of iron, corrosion is known as rusting. Chemically, rust is hydrated ferric oxide, $Fe_2O_3.nH_2O$.

Mechanism of atmospheric rusting : (Electrochemical theory)

According to electrochemical theory, commercial form of iron behaves like small electric cells in presence of water containing dissolved oxygen, CO_2 or SO_2.

At anode, oxidation occurs as

$$2Fe \longrightarrow 2Fe^{2+} + 4e^-$$

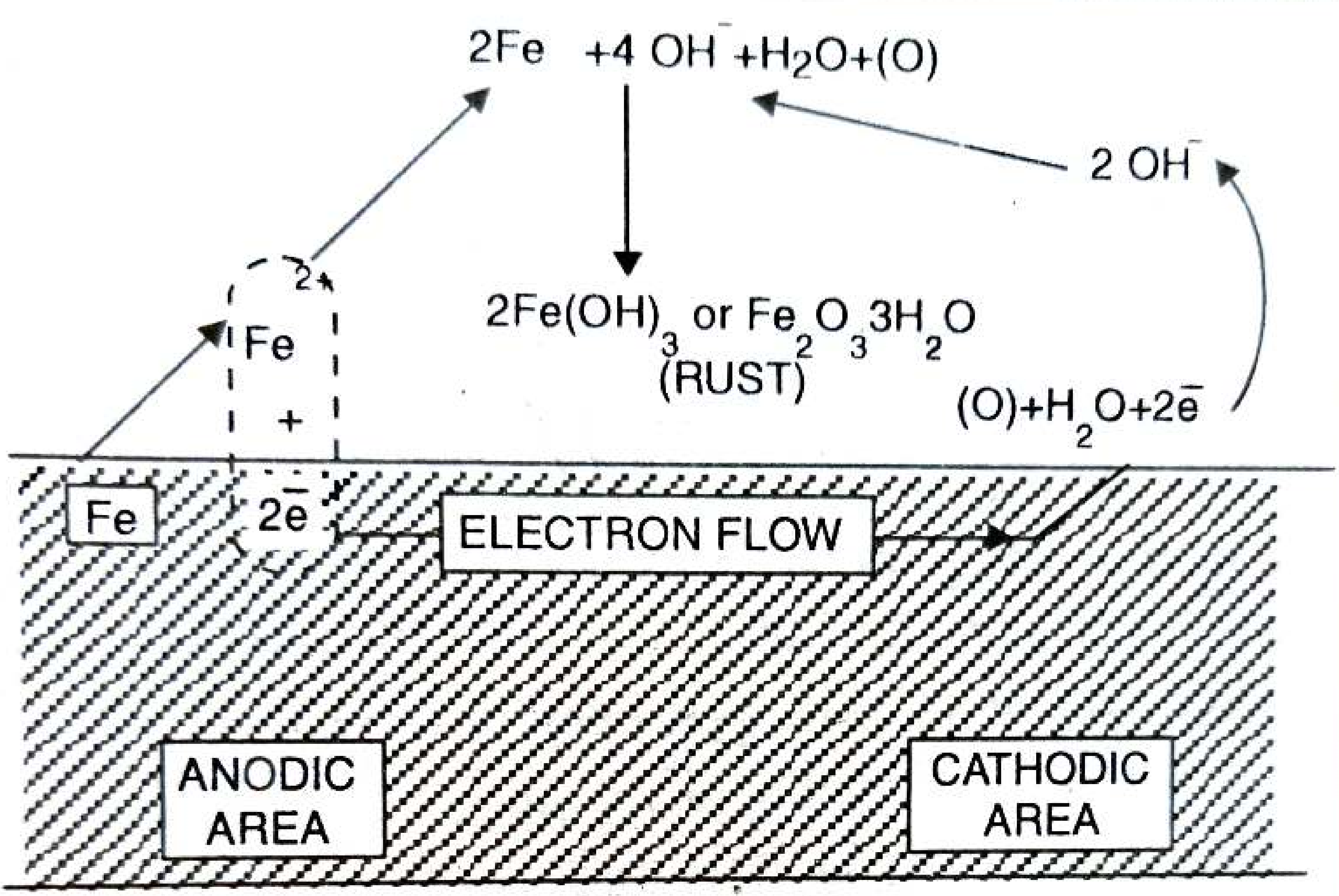
At cathode, these electrons form hydroxyl ions.

$$H_2O + O + 2e^- \longrightarrow 2OH^-$$

The Fe^{2+} ions and OH^- ions diffuse under the influence of dissolved oxygen and Fe^{2+} ions are oxidised to Fe^{3+} ions. These Fe^{3+} ions then combine with OH^- ions to form hydrated ferric oxide i.e., rust.

$$2Fe^{2+} + H_2O + O \longrightarrow 2Fe^{3+} + 2OH^-$$

$$2Fe^{3+} + 6OH^- \longrightarrow Fe_2O_3.3H_2O$$



Rusting of iron.

Why rusting of iron is quicker in saline water than in ordinary water?

It is because the saline water contains the electrolyte, NaCl which furnishes Na^+ and Cl^- ions. These ions help in the flow of current in the miniature cell set up on the iron surface. As a result the process of corrosion increases.

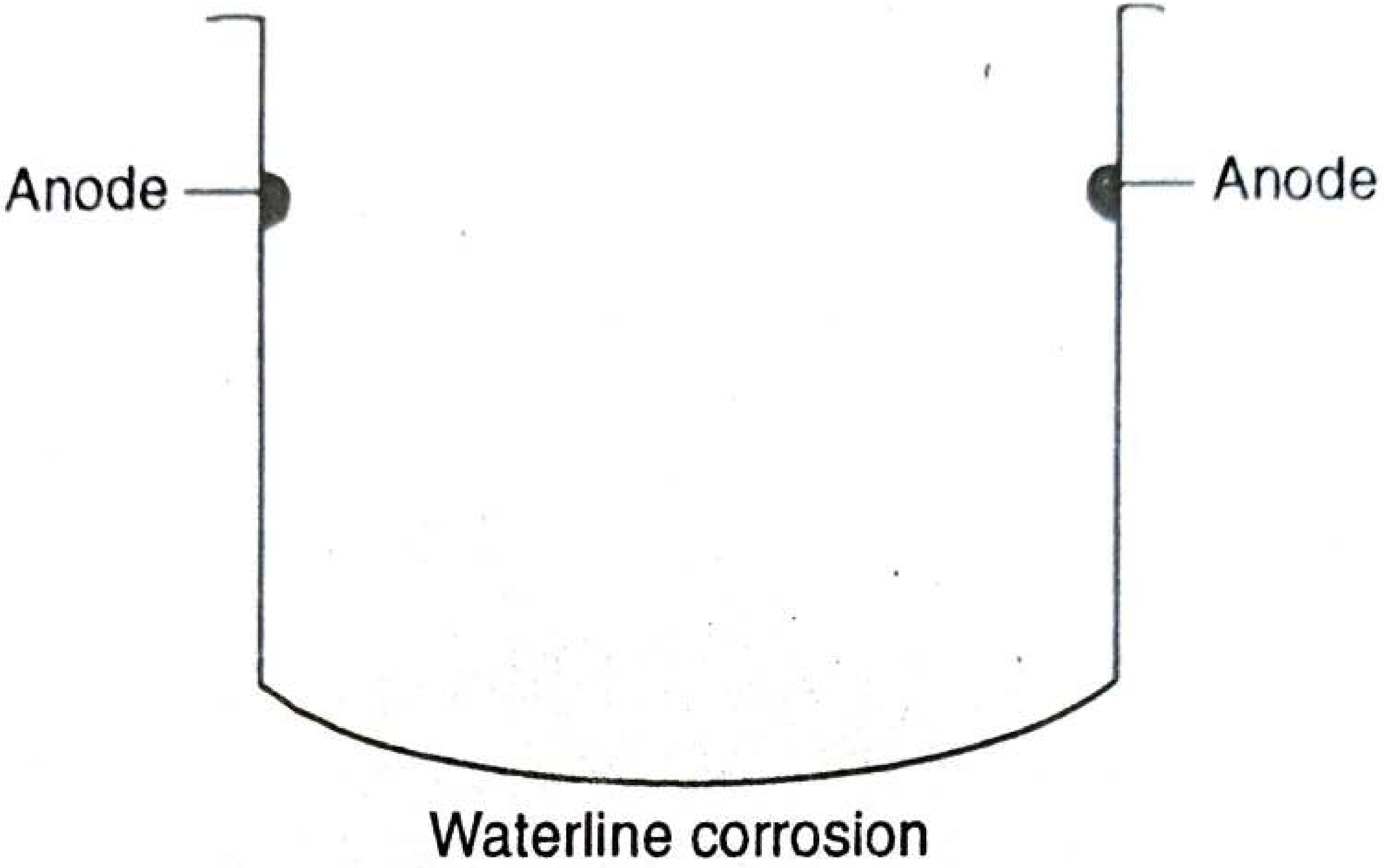
Waterline corrosion:

It is caused owing to difference in oxygen concentration. When water is stored in a steel tank, corrosion takes place along a line just below the level of water meniscus. The area above the waterline is called the cathode as oxygen concentration is more and the area just below the waterline is the anode as oxygen concentration is less. This type of corrosion is seen in ships, water tanks etc. It can be prevented to a greater extent by applying special paints at the surface of the ship containers. The reactions leading to the formation of rust are -

$$Fe \rightarrow Fe^{2+} + 2e$$

$$\frac{1}{2}O_2 + H_2O + 2e \longrightarrow 2OH^-$$

$$2Fe(OH)_2 + \frac{1}{2}O_2 \longrightarrow \underset{\text{(rust)}}{Fe_2O_3.2H_2O}$$



Water line Corrosion.

Methods to protect metals from corrosion :

Metals can be protected from corrosion by the following methods.

1. Alloying of metal:

Alloys can resist corrosion in the following two ways.

(i) Homogenity :- ~~Alloys are~~ Alloying is done with the metals which are not active to the environment. The rusting of iron is minimised by alloying it with chromium as alloying increases the homogenity of the metal, which decreases the rate of corrosion.

(ii) Oxide film : Oxide film formed on the surface of the metal also decreases corrosion. Durrion is a silica iron alloy which is highly resistant to acids owing to formation of silicon oxide film on its surface.

(2) Galvanisation :-

It is an electrochemical process. In this process, more electropositive metals are used to prevent corrosion. Corrosion occurs only at the anode. If the whole surface of the metal is turned into a cathode, corrosion can be prevented. Zinc is used to protect iron from rusting. Zinc is more electropositive metal than iron and so, it loses electrons in preference to iron. As long as there are more electropositive metals, iron is prevented from rusting. The process of preventing rust formation is called sacrificial protection. The process of covering iron with zinc is called galvanisation.

Inorganic Chemistry

Occurrence of metals in nature →

Metals are present in nature in one of the following forms.

(a) Native (b) Mineral (c) Ore

(a) Native : A few metals which are found in nature in the free or elemental state are called native. These elements are not attacked by moisture, oxygen, carbon-dioxide etc. Ex. - Ag, Au, Pt etc.

(b) Minerals : The natural materials in which the metals or their compounds are found in the earth's crust are called minerals.

Ex. - Cu_2O, ZnO etc.

These compounds also contain impurities like sand, silica etc.

(c) Ores : The minerals from which the metals can be extracted conveniently and profitably are called ores.

Ex. - Copper Glance (Cu_2S)
Galena (PbS)

All the ores are minerals but all the minerals are not ores.

For example, Fe_2O_3 (haematite) and FeS_2 (Iron pyrites) are minerals of iron. However, iron pyrites which contains lower percentage of iron and are associated with objectionable impurities like sulphur, phosphorus etc. are not used for the extraction of iron. Thus, iron pyrites are not ores of iron.

Flux, Slag & Gangue :—

Gangue / Matrix : The unwanted impurities present along with the metal in the ore are called gangue or matrix.
Ex. - Sand, Clay, Rock etc.

Flux : The substance which combines with the gangue to form a light and easily fusible material is called flux. Ex. - SiO_2, CaO etc.

Slag : The easily fusible material which is formed when flux reacts with gangue is called slag. Slag is not soluble in the molten metal.

Ex. - $CaSiO_3$, $MgSiO_3$ etc.

$$\text{Gangue} + \text{Flux} \longrightarrow \text{Slag}.$$

Types of flux :- Flux is of two types

(a) Acidic flux (b) Basic flux.

(a) Acidic flux : - When the ore contains basic impurities, like lime, the flux used is some acidic substance like silica, borax etc.

Ex.- $$\underset{\substack{\text{Gangue} \\ \text{(Basic)}}}{CaO} + \underset{\substack{\text{Flux} \\ \text{(Acidic)}}}{SiO_2} \longrightarrow \underset{\text{slg}}{CaSiO_3}$$

(b) Basic flux : When the ore contains acidic impurities like SiO_2, some basic flux like $CaCO_3$, $MgCO_3$ etc. are used.

Ex. $$\underset{\substack{\text{Gangue} \\ \text{(Acidic)}}}{SiO_2} + \underset{\substack{\text{Flux} \\ \text{(Basic)}}}{CaCO_3} \longrightarrow \underset{\text{slag}}{CaSiO_3} + CO_2\uparrow$$

Use of slag : The slag obtained during metal extraction is used for making roads, fertilizers, cements etc.

Metallurgy :- The art of extracting metal from its ores is called metallurgy. It also includes the art of making alloys.

The common steps involved in the extraction of metals are -

(a) Crushing and grinding of the ore
(b) Concentration of the ore
(c) Extraction of metals
(d) Refining of the metal.

Crushing & Grindings of ores →

Most of the ores are found in the form of huge stones. So, it is difficult to treat the ores in this form. Therefore, these are converted into powder form. The huge lumps are broken into small pieces with the help of jaw crushers and then changed into powder form by stampmill or ballmill.

Concentration of the ore —

Concentration is the process of removing maximum gangue from the ore. The following methods are used for concentration of the ore.

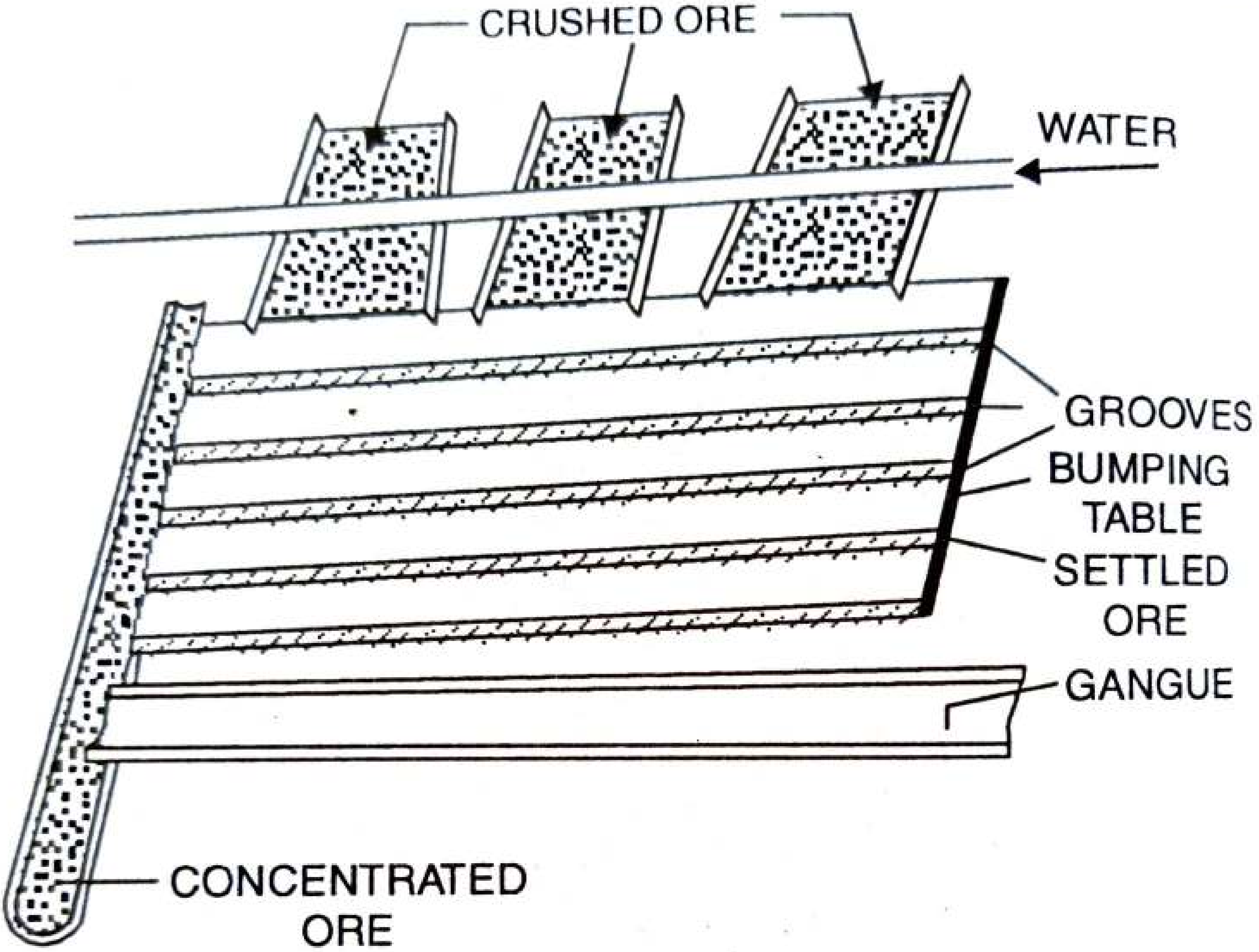
(1) Gravity separation → In this method, the less dense materials (lighter gangue) are separated from the powdered ore.

Procedure :— (i) The crushed ore is spread on long tables with transverse ridges, called wilfley tables.

(ii) The tables are given rocking motion and stream of water is flown over them.

(iii) The gangue being lighter is carried away by water while ore is detained by the ridges.

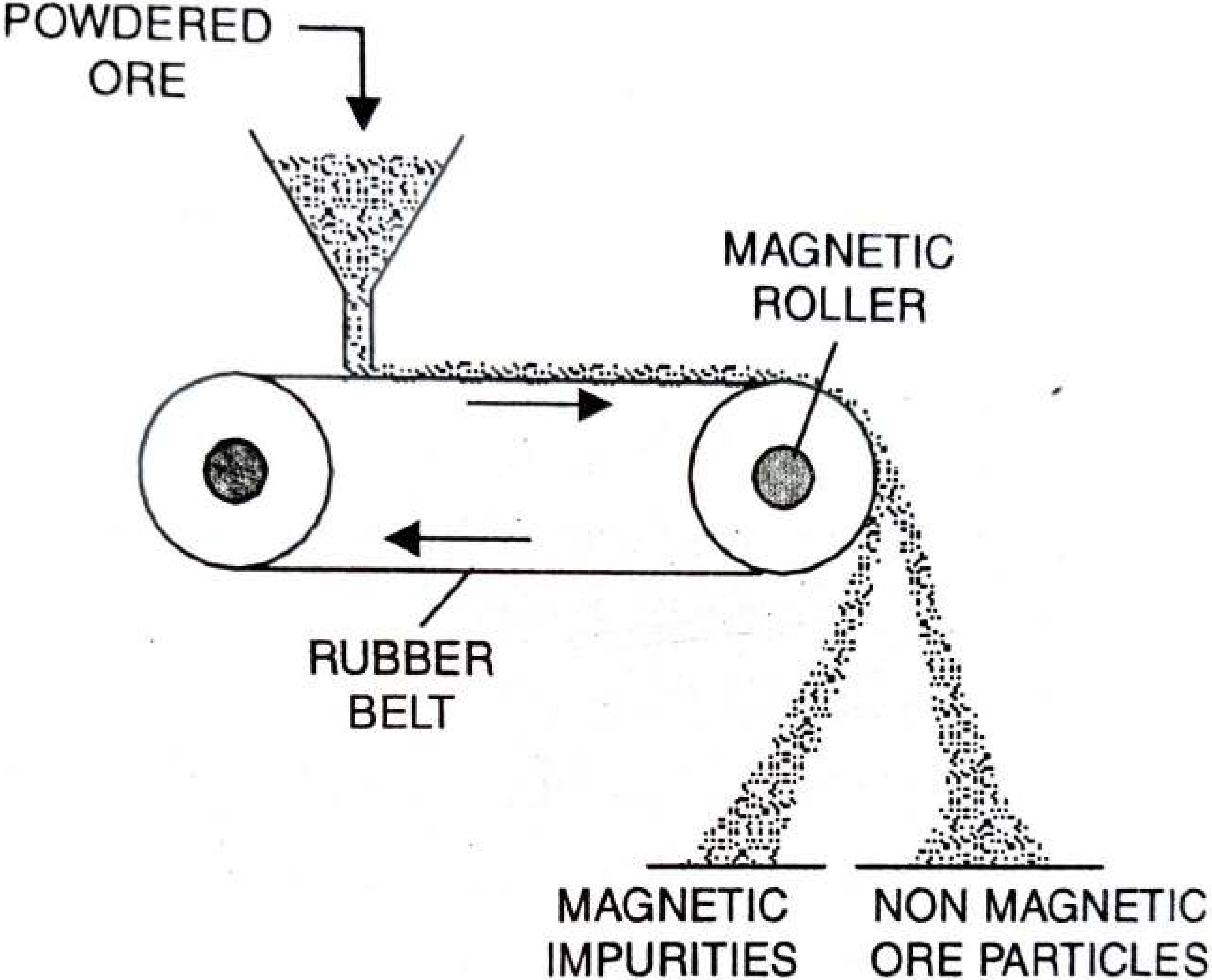
Ex. Galena (PbS) containing limestone is concentrated by this process.



Wilfley washing table.

(2) Magnetic Separation :- This method is used to concentrate the ores which differ from their impurities in the magnetic character. The powdered ore is dropped over a belt revolving round the two rollers, ~~one~~ out of which one is magnetic and the other is non-magnetic. The magnetic part of the ore is attracted by the magnetic roller and forms a heap near it, whereas the non-magnetic part of the ore forms a separate heap a little away from the magnetic impurities.

Ex. - Tin stone (SnO_2) is concentrated by this process in which the gangue ferrous tungstate ($FeWO_4$) is separated.

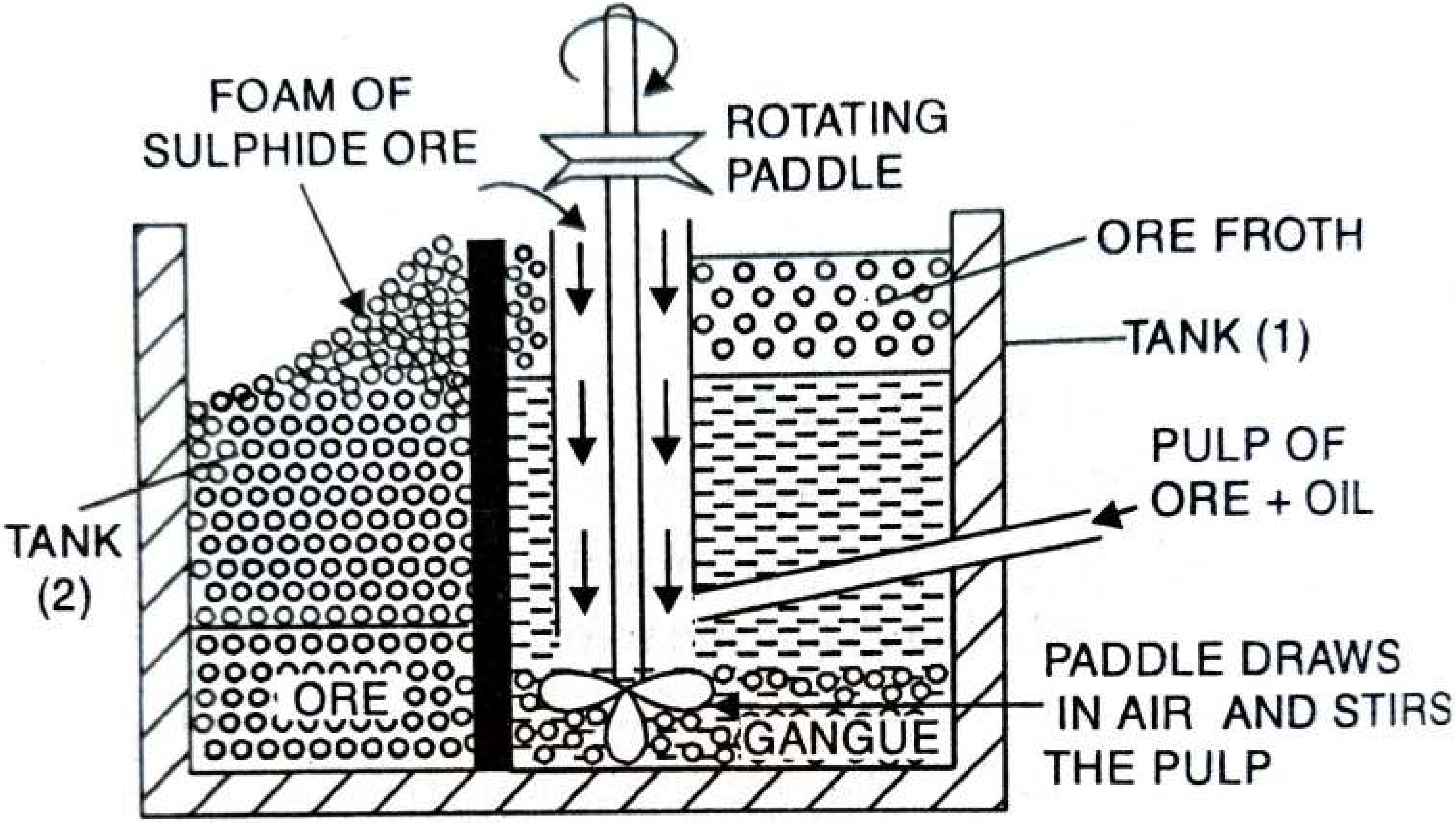


Magnetic separation.

(3) Froth floatation process :-

This method is used to concentrate the sulphide ores. It is based on the preferential wetting properties of the ore by oil. In this method, a suspension of the powdered ore is made with water and a few drops of pine oil is added to it. This suspension is vigorously mixed by passing air. The froth is formed containing sulphide ore particles, which is transferred to another vessel. After some time, the froth settles down and concentrated sulphide ore is obtained. The gangue particles are left behind in tank(1).

Ex. - Sulphide ores such as ZnS, PbS etc. are concentrated by this process.



Froth floatation process.

(4) Leaching :- It is a chemical method in which the powdered ore is treated with a suitable reagent which dissolves the ore and not the impurities. Then, the ore is ~~rev~~ recovered from the solution by suitable chemical means. The ore of aluminium (bauxite) is concentrated by leaching process. The powdered ore is ~~con~~ leached with 45% solution of NaOH. Al_2O_3 is leached out as sodium meta-aluminate leaving the impurities behind.

$$Al_2O_3 + NaOH \longrightarrow \underset{\text{(sodium meta-aluminate)}}{NaAlO_2} + H_2O$$

$$NaAlO_2 + H_2O \longrightarrow Al(OH)_3 + NaOH$$

$$2Al(OH)_3 \longrightarrow \underset{\text{(Pure alumina)}}{Al_2O_3} + 3H_2O$$

Extraction of crude metal from the concentrated ore →

The extraction of metals involves the following steps:

1. Conversion of the concentrated ore into its oxide.
2. Conversion of metal oxide to metal by reduction process.

Conversion of concentrated ore into its oxide →

It involves two methods :-

(a) Calcination : It is the process of heating the concentrated ore in the absence of air or in the limited supply of air at a temperature just below its melting point.

The process helps to remove moisture and volatile impurities such as As and Sb.

$$Fe_2O_3.3H_2O(s) \longrightarrow Fe_2O_3 + 3H_2O\uparrow$$

$$CuCO_3 \longrightarrow CuO + CO_2\uparrow$$

$$Al(OH)_3 \longrightarrow Al_2O_3 + 3H_2O$$

$$CaCO_3.MgCO_3 \longrightarrow CaO + MgO + 2CO_2$$

(b) Roasting :— It is the process of heating the concentrated ore strongly in a controlled supply of ~~air~~ oxygen in a reverberatory furnace to get metal oxide. The main functions of roasting are :—

(i) It removes moisture.

(ii) It removes volatile impurities like As and Sb.

(iii) It oxidises substances which can be easily oxidised.

$$2PbS + 3O_2 \longrightarrow 2PbO + 2SO_2$$

$$CuFeS_2 + O_2 \longrightarrow Cu_2S + 2FeS + SO_2$$

$$2Cu_2S + 3O_2 \longrightarrow 2Cu_2O + 2SO_2$$

$$4As + 3O_2 \longrightarrow 2As_2O_3\uparrow$$

$$S + O_2 \longrightarrow SO_2\uparrow$$

Differences between calcination and roasting

Calcination	Roasting
(i) It is the process of heating the concentrated ore in absence of air or in limited supply of air.	(i) It is the process of heating the concentrated ore in free supply of oxygen.
(ii) This is applicable to ores which do not require oxygen for oxide formation.	(ii) This is applicable to ore which require oxygen for oxide formation.
(iii) Carbonates and hydrated oxides are usually treated by this process.	(iii) Usually sulphide ores are treated by this process.

Conversion of metal oxide into metal (Reduction) —

Smelting :- In this method, the roasted ore is mixed with a suitable quantity of coke or charcoal and heated strongly in excess of air to a high temperature above its melting point.

For the extraction of less electropositive metals such as Pb and Zn, powerful reducing agents like C, H_2, CO, Na, K etc. may be used.

$$PbO + C \rightarrow Pb + CO$$

$$CuO + CO \rightarrow Cu + CO_2$$

$$CaI_2 + 2K \rightarrow Ca + 2KI$$

$$Cr_2O_3 + 2Al \rightarrow Al_2O_3 + 2Cr$$

Flux is used during smelting process to remove impurities in the form of slag. The nature of flux depends upon the impurities present.

$$\text{Impurities} + \text{Flux} \rightarrow \text{Fusible slag}$$

Flux is of two types.

(i) Acidic flux : Some acidic flux (e.g., SiO_2) is used to remove basic impurities like metallic oxides.

$$\underset{\substack{\text{Gangue}\\(\text{Basic})}}{CaO} + \underset{\substack{\text{Flux}\\(\text{Acidic})}}{SiO_2} \longrightarrow \underset{\substack{\text{Slag}\\(\text{Fusible})}}{CaSiO_3}$$

(ii) Basic flux : Some basic flux (e.g., CaO) is used to remove acidic impurities like SiO_2.

$$\underset{\substack{(\text{Gangue})\\(\text{Acidic})}}{SiO_2} + \underset{\substack{\text{Flux}\\(\text{Basic})}}{CaO} \longrightarrow \underset{\substack{\text{Slag}\\(\text{Flusible})}}{CaSiO_3}$$

Smelting process involves the following two steps: —

(i) Carbon reduction process:

It is the process in which the oxides of less electropositive metals are reduced by heating them strongly with coal or coke.

$$PbO + C \rightarrow Pb + CO$$

$$PbO + CO \rightarrow Pb + CO_2$$

$$Fe_2O_3 + 3C \rightarrow 2Fe + 3CO$$

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

(ii) Self-reduction process →

In the extraction of copper, the copper pyrites on roasting are partially converted into sulphides and later into their oxides.

$$2CuFeS_2 + O_2 \rightarrow Cu_2S + 2FeS + SO_2$$

$$2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$$

Cuprous oxide reacts with the remaining cuprous sulphide to form metallic copper. ~~and~~ This process is called self-reduction.

$$Cu_2S + Cu_2O \longrightarrow 6Cu + SO_2 .$$

Refining of the metal :—

The process of removal of impurities from the crude metal is called refining.

Some methods employed for refining of metals are —

(i) Distillation :— Some volatile metals like mercury, zinc lead etc. contain non-volatile impurities. For the purification of such metals, distillation is done. The pure metals volatilise while the impurities are left behind in the retort.

(ii) Electro-refining :— A suitable electrolyte is chosen and put into an electrolytic cell. Now pure metal plate is dipped into the electrolyte and made the cathode. The impure metal is made the anode and a suitable e.m.f. is applied. The pure metal from the electrolyte gets deposited on the cathode while an equivalent quantity of the metal from anode goes into the solution.

The metals, less, electropositive than the metals under examination do not go in solution but get separated as anode mud. Metals like Cu, Al, Zn, Pb and Sn are purified by this method.

Alloys

An alloy is a homogeneous solid obtained by melting together two or more metals or metals and non-metals (such as C, P, Si etc.).

Ex - Brass, Bronze etc.

Amalgam : When an alloy contains mercury as a constituent, it is called as amalgam.

Ex - Sodium amalgam, Copper amalgam etc.

Uses : (i) Sodium amalgam is used as a good reducing agent.
(ii) Copper amalgam is used for filling dental cavities.
(iii) Tin amalgam is used for silvering cheap mirrors.

Iron doesn't form amalgam with mercury. Thus, mercury can be transported in iron vessels.

Purpose of making alloys :—

(i) To increase the hardness of metal.
(ii) To get excellent finishing of metals.
(iii) To resist corrosion.
(iv) To modify the chemical activity.

Types of alloys :—

Alloys are mainly classified into :—

Ferro alloys	Non-ferro alloys
(i) These are the alloys which contain ~~Fe as~~ iron as one of the major constituent.	(i) These are the alloys which don't contain iron as one of the major constituent.
(ii) These are hard and have high magnetic properties.	(ii) These are soft and have no magnetic properties.
(iii) They have very low electrical conductivity.	(iii) They have high electrical conductivity.
(iv) These are corrosive in nature.	(iv) These are non-corrosive in nature.
(v) Ex.- Stainless steel	(v) Ex. - Bronze.

COMPOSITION AND USES OF ALLOYS

The composition and uses of various alloys are given in Table

Composition and Uses of Alloys

Name	*Composition*	*Uses*
Brass	Cu = 60–80% Zn = 40–20%	It is used extensively for outdoor applications, utensils, condenser tube, cartridges, etc.
Bronze	Cu = 75–90% Sn = 25–10%	For making utensils, coin, trays, bearings, clips, electrical connectors, springs, statues, etc.
Alnico	Steel = 50% Ni = 21% Al = 20% Co = 9%	For making permanent magnets which are used in electric motors, microphones, sensors, loudspeakers, magnetron tubes, etc.
Duralumin	Al = 95% Cu = 4% Mn = 0.5% Mg = 0.5%	Used in aircraft constructions, aircraft frames, automobiles, locomotive parts, speed boats, gun barrels, surgical instruments, etc.

ORGANIC CHEMISTRY

Organic chemistry may be defined as the chemistry of covalently bonded carbon compounds (other than metallic carbides and oxides of carbon).

Ex

Catenation → The self linking property of carbon atoms to form long chains is called catenation.

Homologous Series → A homologous series may be defined as a group of compounds in which the various members –

(i) have similar chemical properties

(ii) can be represented by same general formula.

(iii) possess the same functional group.

(iv) Any two adjacent members differ by CH_2.

The different members of a homologous series are known as homologues and the phenomenon is called homology.

Ex – The compounds methyl alcohol, ethyl alcohol, propyl alcohol, Butyl alcohol etc. constitute a homologous series.

These compounds have the same general formula $C_nH_{2n+1}OH$ and possess the same functional group i.e, $-OH$ group.

Methyl alcohol — CH_3OH

Ethyl alcohol — C_2H_5OH

Propyl alcohol — C_3H_7OH

Butyl alcohol — C_4H_9OH

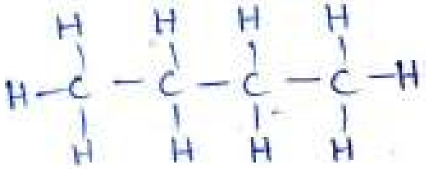
Any two adjacent members differ by CH_2.

Hydrocarbons & its types →

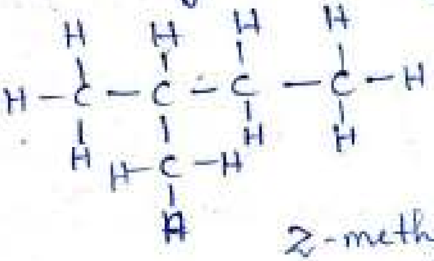
Hydrocarbons are the compounds which are made up only of carbon and hydrogen.

Types of hydrocarbons → On the basis of structure, hydrocarbons are divided into two main classes.

1. Open chain or acyclic or aliphatic hydrocarbons — These are the compounds in which the first and the last carbon are not directly joined to each other. The open chains of carbon atoms may be straight or branched.



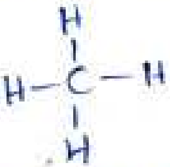
n-Butane



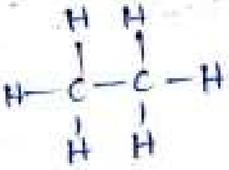
2-methyl Butane

Aliphatic hydrocarbons are further divided into saturated & unsaturated hydrocarbons.

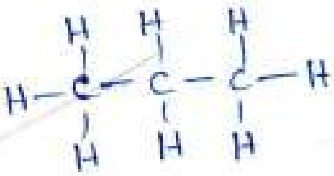
(a) Saturated hydrocarbons → These are the compounds which contain only carbon-carbon and carbon-hydrogen single bonds. These are also called alkanes.



(Methane)



(Ethane)

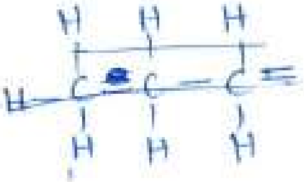


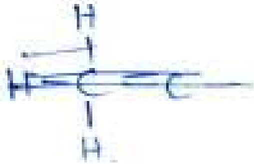
(Propane)

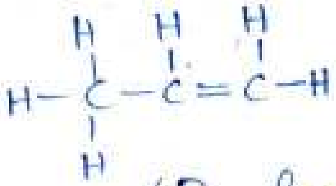
(b) Unsaturated hydrocarbons → These are the compounds which have carbon-carbon double (>C=C<) or triple ~~carb~~ (−C≡C−) bond in their molecules. These are further divided into alkenes and alkynes according as they contain a (>C=C<) double or (−C≡C−) triple bond.

Ex.

(Ethylene)







(Propylene)

$H-C\equiv C-H$

(Acetylene)

2. Closed chain or Cyclic hydrocarbons —

Compounds having closed chains or rings of carbon atoms in their molecules are called closed chain or cyclic hydrocarbons. These are further divided into (a) Alicyclic hydrocarbons
(b) Aromatic hydrocarbons.

(a) Alicyclic hydrocarbons →

These hydrocarbons contain closed chains of carbon atoms in their molecules but have many properties similar to those of open chain hydrocarbons. These are further divided into —

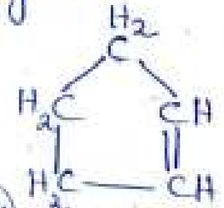
(i) Saturated alicyclic hydrocarbons or cycloalkanes.

(ii) Unsaturated alicyclic hydrocarbons or cycloalkenes and cycloalkynes.

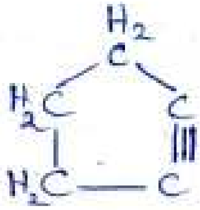
Ex.

(Cyclopropane)

(Cyclobutane)



(Cyclopentene)

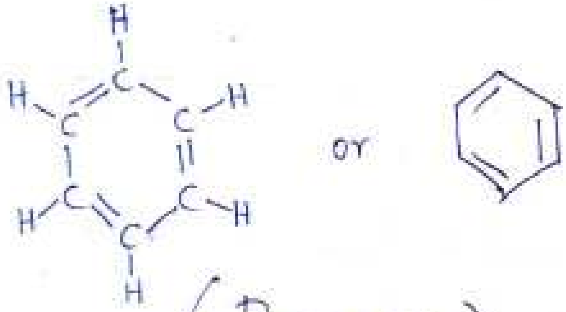


~~Cyclohexyne~~
(Cyclopentyne)

(ii) Aromatic hydrocarbons →

These are the ring compounds which obey Huckel's rule i.e., they contain $(4n+2)\pi$ electrons where, $n = 0, 1, 2$ etc.

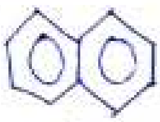
Huckel's rule → The cyclic hydrocarbons containing $(4n+2)\pi$ electrons in which single and ~~b~~ double bonds are present in alternate positions are called aromatic hydrocarbons. For example. - Benzene is a ring of six carbon atoms in which single and double bonds are present in alternate positions. Three double bonds in benzene ring means three π-bonds i.e. six π-electrons which is in accordance with Huckel's rule.



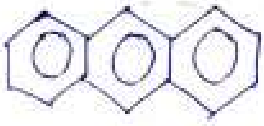
(Benzene)

Benzene obeys Huckel's rule i.e., $(4n+2)\pi$ ~~and~~ electrons where, $n = 1$ and hence aromatic.

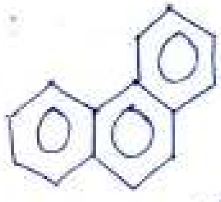
Other examples



Naphthalene
(10π e⁻s)

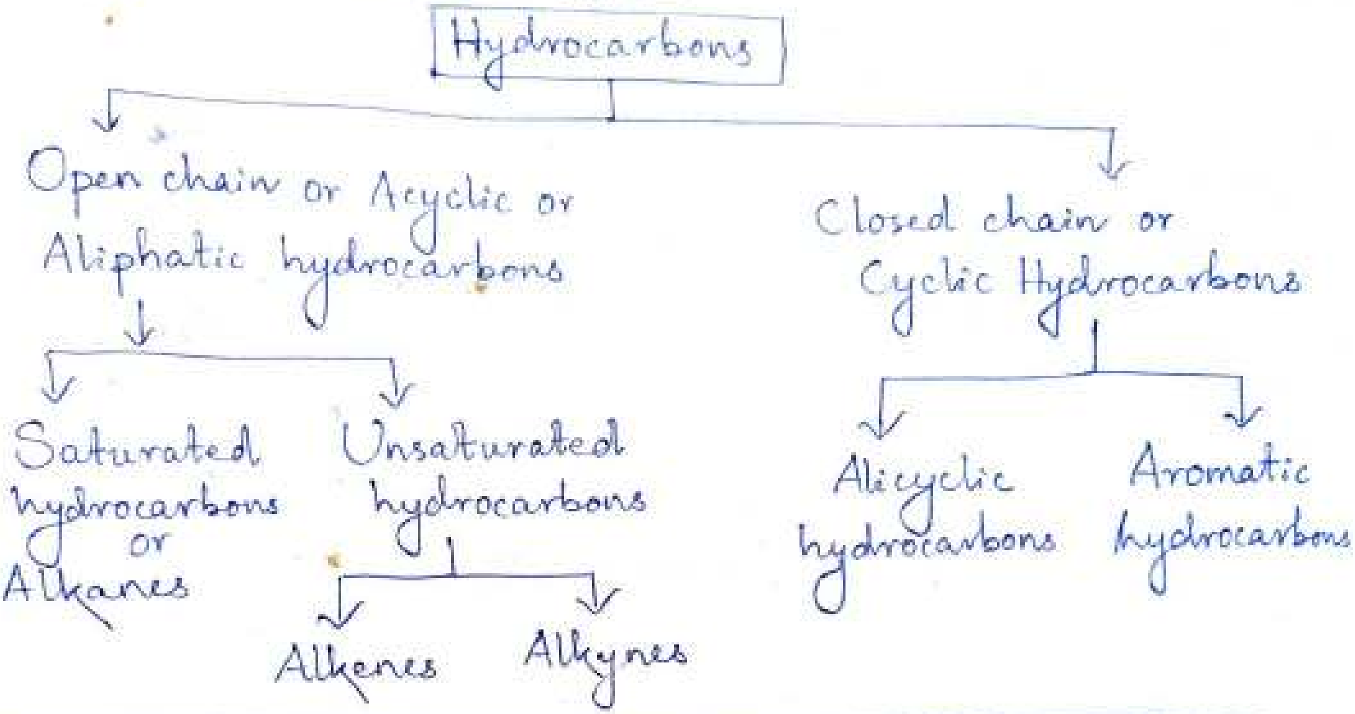


Anthracene
(14π e⁻s)



Phenanthrene
(14π e⁻s)

The broad classification of hydrocarbons can be summarised as –



Nomenclature of organic compounds →

The term 'Nomenclature' means the system of naming of organic compounds. In early days organic compounds were named as per their sources of origin and their characteristics. Such system of nomenclature is called Trivial system or Common system. Later on a systematic way of nomenclature was started at 'Geneva' called 'Geneva system' which is finally modified by IUPAC (International Union of Pure and Applied Chemistry) system.

According to IUPAC system, the name of an organic compound consists of three parts.

(a) Word root (b) Prefix (c) Suffix.

(a) Word root → It represents the no. of carbon atoms present in the parent chain of the compound.

No. of carbon atoms	Word root	No. of carbon atoms	Word root
1	Meth	6	Hex
2	Eth	7	Hept
3.	Prop	8	Oct
4.	But	9	Non
5	Pent	10	Dec

(b) Prefix → It refers to the presence of substituent or side chain in the parent chain of the organic compound.

Group	Prefix
$-F$	-Fluoro
$-Cl$	-Chloro
$-Br$	-Bromo
$-I$	-Iodo
$-NO_2$	-Nitro
$-R$	-Alkyl

(c) Suffix → Suffix is of two types.

(i) Primary suffix → It refers to the presence of carbon-carbon single ($C-C$), double ($C=C$) or triple($C\equiv C$) bond in the compound.

Type of linkage	Primary suffix
$C-C$ only, no FG (functional group)	ane
$C-C$ and FG	an
$C-C$ and $C=C$, no FG	ene
$C-C$ ~~and~~, $C=C$ & FG	en
$C-C$, $C\equiv C$ & no FG	yne
$C-C$, $C\equiv C$ & FG	yn

(ii) Secondary Suffix → It refers to the presence of functional groups in the compound.

Class of compound	Functional group	Secondary Suffix
Alcohol	−OH	−ol
Aldehyde	−CHO	−al
Ketone	>CO	−one
Carbonylic acid	−COOH	−oic acid

Class of compounds –

① Alkanes – These are open chain saturated hydrocarbons. General formula of alkanes is C_nH_{2n+2}. These are classified into (a) straight chain alkanes & (b) Branched chain alkanes.

Straight chain alkanes →

IUPAC Name → Word root + ane

No. of carbon atoms	Molecular formula	Structural formula	Name
1	CH_4	CH_4	Methane
2	C_2H_6	CH_3CH_3	Ethane
3	C_3H_8	$CH_3CH_2CH_3$	Propane
4	C_4H_{10}	$CH_3CH_2CH_2CH_3$	Butane
5	C_5H_{12}	$CH_3(CH_2)_3CH_3$	Pentane
6	C_6H_{14}	$CH_3(CH_2)_4CH_3$	Hexane

No. of carbon atoms	Molecular formula	Structural formula	Name
7	C_7H_{16}	$CH_3(CH_2)_5CH_3$	Heptane
8	C_8H_{18}	$CH_3(CH_2)_6CH_3$	Octane
9	C_9H_{20}	$CH_3(CH_2)_7CH_3$	Nonane
10	$C_{10}H_{22}$	$CH_3(CH_2)_8CH_3$	Decane

The IUPAC names and common names of straight chain alkanes are the same but prefix n (normal) is added in case of common names. For example common name of $CH_3CH_2CH_2CH_3$ is n-butane.

Types of carbon atoms in alkanes →

The carbon atoms in an alkane molecule may be classified into four types.

(i) Primary (1°) C-atom is the carbon atom attached to one or no other carbon atom.

(ii) Secondary (2°) C-atom is the C-atom bonded to other carbon atoms on two different sides.

(iii) Tertiary (3°) C-atom is the carbon atom bonded to other carbon atoms on three different sides.

(iv) Quaternary (4°) C-atom is the carbon atom attached to other carbon atoms on four different sides.

The hydrogen atoms attached to primary (1°), secondary (2°) and tertiary (3°) carbon respectively are called primary, secondary and tertiary hydrogen atoms respectively.

Alkyl groups →

These are obtained by the removal of one H-atom from an alkane. General formula of alkyl group is ~~R~~ C_nH_{2n+1} and it is represented by the symbol R.

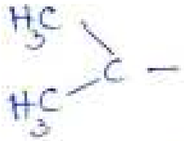
$$C_nH_{2n+2} \xrightarrow{-H} C_nH_{2n+1}$$

Examples →

CH_3- methyl

C_2H_5- ethyl

C_3H_7- Propyl



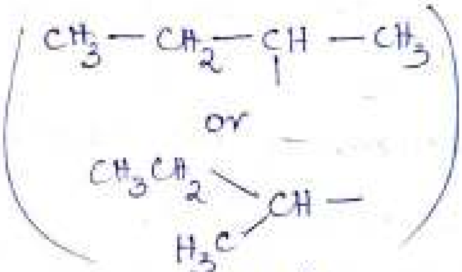
(Isopropyl)

$CH_3-CH_2-CH_2-$

(n-propyl)

$CH_3-CH_2-CH_2-CH_2-$

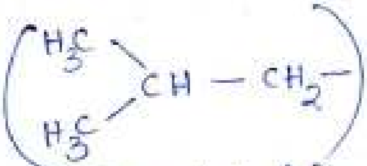
(n-butyl)



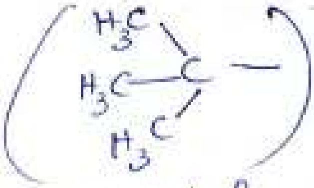
$CH_3-CH_2-\underset{|}{C}H-CH_3$

or

sec-butyl



(Iso butyl)



tert-butyl

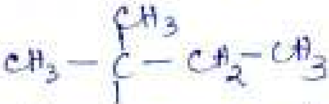
$CH_3CH_2CH_2CH_2CH_2-$

(n-pentyl)

(Isopentyl)

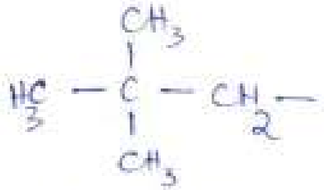
$CH_3CH_2CH_2-\underset{|}{C}HCH_3$

(sec-pentyl)



$CH_3-\overset{CH_3}{\underset{|}{C}}-CH_2-CH_3$

(tert.-pentyl)



$H_3C-C(CH_3)_2-CH_2-$

(Neopentyl)

Branched chain alkanes →

$CH_3CH_2CH_2CH_3$

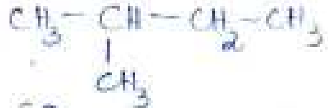
(n-Butane)

$CH_3-CH(CH_3)-CH_3$

(Isobutane)

$CH_3CH_2CH_2CH_2CH_3$

(n-pentane)



$CH_3-CH(CH_3)-CH_2-CH_3$

(Isopentane)

$H_3C-C(CH_3)_2-CH_3$

(Neo-pentane)

Prefix n-(normal) is used for straight chain alkanes. Prefix iso- is used for alkanes in which one methyl group is attached to second last carbon atom of the continuous chain. Prefix neo- is used for alkanes in which two methyl groups are attached to second last carbon atom of the continuous chain.

Alkenes → The general formula of alkenes is C_nH_{2n}.

$CH_2=CH_2$

(Ethylene/ Ethene)

$CH_3-CH=CH_2$

(Propylene/propene)

Alkenyl group → It is formed by removal of one H-atom from an alkene.

$CH_2=CH-$

(Ethenyl/vinyl)

$CH_2=CH-CH_2-$

(allyl)

Note → $CH_2=$ in the side chain is named as methylidene.

$CH_3-CH=$ in the side chain is named as ethylidene.

Alkynes →

The general formula of alkynes is C_nH_{2n-2}.

$H-C\equiv C-H$
(Acetylene or Ethyne)

$CH_3-C\equiv CH$
(propyne)

Alkynyl group → It is formed by removal of one hydrogen atom from an alkyne.

$H-C\equiv C-$
(Ethynyl or acetylide)

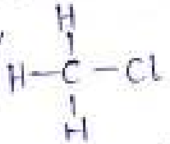
$CH_3-C\equiv C-$
(1-propynyl)

$HC\equiv C-CH_2-$
(2-propynyl)

Halogen derivatives →

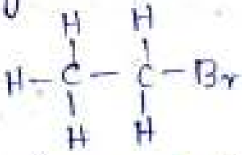
(a) **Monohalogen derivatives** → These are the compounds obtained by replacing one hydrogen atom of a hydrocarbon by one halogen atom. Their general formula is $C_nH_{2n+1}X$.

Ex. CH_3-Cl /



$H-\overset{H}{\underset{H}{C}}-Cl$

(Methyl chloride)

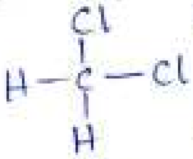


$H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-Br$ / C_2H_5Br

(Ethyl Bromide)

(b) **Dihalogen derivatives** → These are the compounds obtained by replacing two hydrogen atoms of a hydrocarbon by two halogen atoms.

Ex.



$H-\overset{Cl}{\underset{H}{C}}-Cl$ / CH_2Cl_2

(Dichloromethane)

CH_2Br_2
(Dibromomethane)

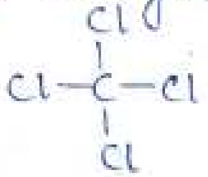
(c) **Trihalogen Derivatives**

Ex. $CHCl_3$
(Chloroform / Trichloromethane)

$CHBr_3$ (Bromoform / Tribromomethane)

(d) Tetra-halogen Derivatives –

Obtained by replacing all H-atoms of methane by halogen atoms.



$Cl-C(Cl)_2-Cl$ / CCl_4

Carbon tetrachloride

CBr_4
(Carbon tetrabromide)

Alcohols →

Saturated monohydric alcohols →

General formula – $C_nH_{2n+1}OH$ or ROH.

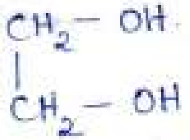
These are obtained by replacing one H-atom of an alkane by one hydroxyl group i.e, –OH.

Ex –

CH_3-OH
(methyl alcohol / methanol)

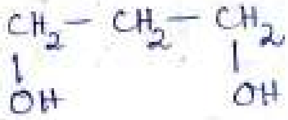
CH_3CH_2OH
(Ethyl alcohol / ethanol)

Dihydric / Trihydric alcohols



$CH_2(OH)-CH_2(OH)$

(Ethane diol)



$CH_2(OH)-CH_2-CH_2(OH)$

(Propane-1,3-diol)

$CH_2(OH)-CH(OH)-CH_2(OH)$

(Propanetriol)

IUPAC System of Nomenclature →

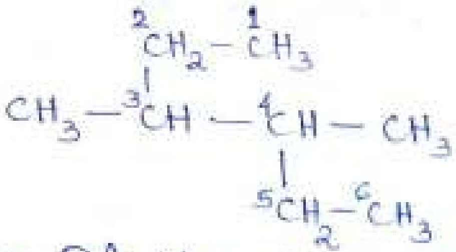
(A) Alkanes →

(1) Longest chain rule → (i) Expand the group in compact form such as

C_2H_5- as CH_3-CH_2- & C_3H_7- as $CH_3-CH_2-CH_2-$

(ii) Select the longest continuous chain of carbon atoms called the Principal chain. Other carbon atoms which are not included in the chain are called side chains or substituents (denoted as prefixes).

It may be noted that the longest chain may or may not be straight but it must be continuous, Consider the following :—

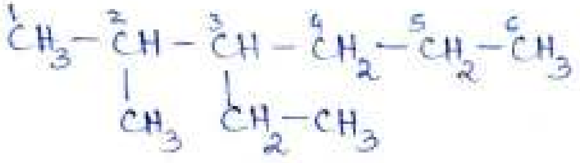


$$CH_3-\overset{\overset{2}{C}H_2-\overset{1}{C}H_3}{\overset{|}{^{3}CH}}-\underset{\underset{^{5}CH_2-^{6}CH_3}{|}}{^{4}CH}-CH_3$$

It is a continuous chain of six carbon atoms.

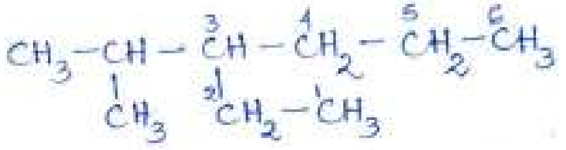
(iii) If ~~the~~ two chains of equal length are possible, select the one with the ~~larger~~ more no. of substituents.

Example :



$$\overset{1}{C}H_3-\underset{\underset{CH_3}{|}}{\overset{2}{C}H}-\underset{\underset{CH_2-CH_3}{|}}{\overset{3}{C}H}-\overset{4}{C}H_2-\overset{5}{C}H_2-\overset{6}{C}H_3$$

Continuous chain of six carbon atoms with two substituents (correct)

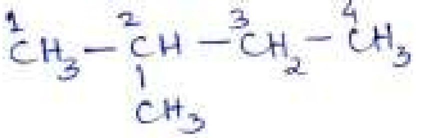


$$CH_3-\underset{\underset{CH_3}{|}}{CH}-\underset{\underset{^{2}CH_2-^{1}CH_3}{|}}{\overset{3}{C}H}-\overset{4}{C}H_2-\overset{5}{C}H_2-\overset{6}{C}H_3$$

Continuous chain of six carbon atoms with one substituent. (wrong)

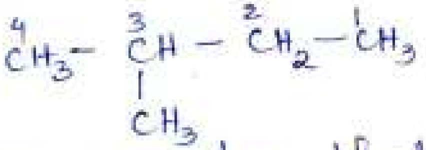
(2) Numbering the principal chain →

Number the carbon atoms in the parent chain as 1, 2, 3, 4 ... etc. starting from that end which gives the lowest possible no. to the carbon atom carrying the substituent.



$$\overset{1}{C}H_3-\underset{\underset{CH_3}{|}}{\overset{2}{C}H}-\overset{3}{C}H_2-\overset{4}{C}H_3$$

→ Correct (Locant - 2)



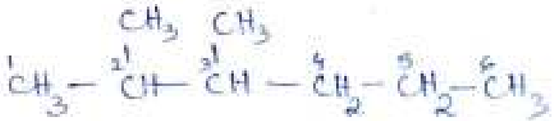
$$\overset{4}{C}H_3-\underset{\underset{CH_3}{|}}{\overset{3}{C}H}-\overset{2}{C}H_2-\overset{1}{C}H_3$$

→ incorrect (Locant - 3)

The number that indicates the position of the substituent on the parent chain is called positional number or locant.

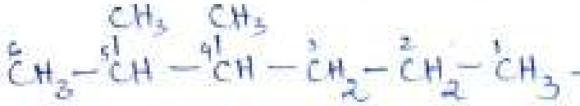
Lowest set of locant rule — When two or more substituents are present, then write the locant numbers in the form of set. The set containing lowest locant numbers is correct one.

Ex.



$$\overset{1}{C}H_3-\overset{CH_3}{\overset{2|}{C}H}-\overset{CH_3}{\overset{3|}{C}H}-\overset{4}{C}H_2-\overset{5}{C}H_2-\overset{6}{C}H_3$$

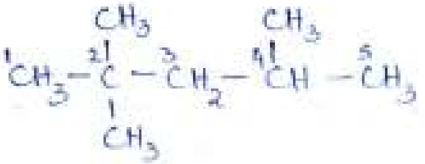
→ Correct (lowest set 2,3)



$$\overset{6}{C}H_3-\overset{CH_3}{\overset{5|}{C}H}-\overset{CH_3}{\overset{4|}{C}H}-\overset{3}{C}H_2-\overset{2}{C}H_2-\overset{1}{C}H_3$$

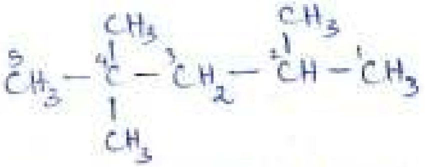
→ Incorrect (Locant set 4,5)

Similarly,



$$\overset{1}{C}H_3-\underset{CH_3}{\underset{|}{\overset{CH_3}{\overset{2|}{C}}}}-\overset{3}{C}H_2-\overset{CH_3}{\overset{4|}{C}H}-\overset{5}{C}H_3$$

Locant set (2,2,4) (Correct).



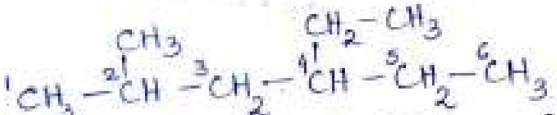
$$\overset{5}{C}H_3-\underset{CH_3}{\underset{|}{\overset{CH_3}{\overset{4|}{C}}}}-\overset{3}{C}H_2-\overset{CH_3}{\overset{2|}{C}H}-\overset{1}{C}H_3$$

Locant set (2,4,4) (Incorrect)

(3) Naming the branched chain alkanes →

(i) While writing the IUPAC name, separate the locant from substituent name by a hyphen and arrange the substituents in alphabetical order followed by word root and suffix.

i.e., Locant - substituent name + word root + suffix.

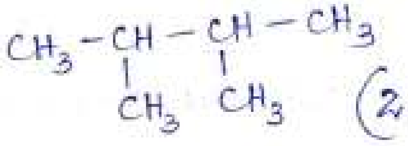


$$\overset{1}{C}H_3-\overset{CH_3}{\overset{2|}{C}H}-\overset{3}{C}H_2-\overset{CH_2-CH_3}{\overset{4|}{C}H}-\overset{5}{C}H_2-\overset{6}{C}H_3$$

(4-ethyl-2-methylhexane)

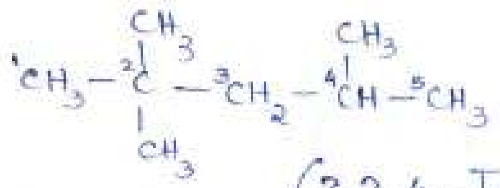
(ii) Naming same alkyl groups at different positions :—
When the same alkyl group occurs more than once on the parent chain at different positions, the positional number or locant of each alkyl group is separated by commas and prefixes di, tri, tetra. ~~etc~~ are ~~used~~ attached to the name of the alkyl group. However, the prefixes di, tri, tetra are not considered while deciding the alphabetical order of the alkyl group.

Ex.



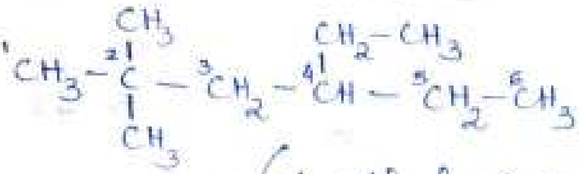
$$CH_3-\underset{CH_3}{\underset{|}{C}H}-\underset{CH_3}{\underset{|}{C}H}-CH_3$$

(2,3-dimethyl butane)



$$ {}^{1}CH_3-\overset{CH_3}{\underset{CH_3}{{}^{2}C}}-{}^{3}CH_2-\overset{CH_3}{{}^{4}CH}-{}^{5}CH_3 $$

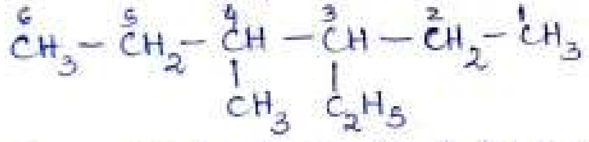
(2,2,4-Trimethyl pentane)



$$ {}^{1}CH_3-\overset{CH_3}{\underset{CH_3}{{}^{2}C}}-{}^{3}CH_2-\overset{CH_2-CH_3}{{}^{4}CH}-{}^{5}CH_2-{}^{6}CH_3 $$

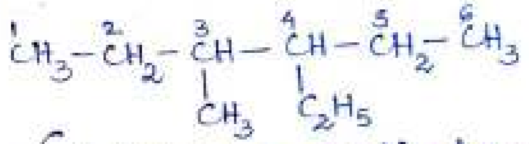
(4-ethyl-2,2-dimethyl hexane)

(iii) Naming the different substituents of equivalent positions → If two different substituents are present at equivalent positions from the two ends of the parent chain, then numbering of the chain is done in such a way that the substituent which comes first in the alphabetical order gets the lower number.



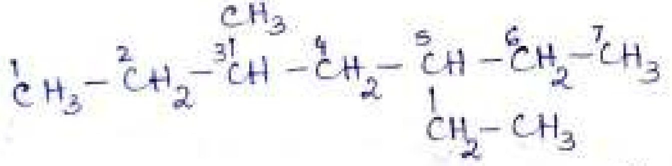
$$ {}^{6}CH_3-{}^{5}CH_2-\underset{CH_3}{{}^{4}CH}-\underset{C_2H_5}{{}^{3}CH}-{}^{2}CH_2-{}^{1}CH_3 $$

(3-Ethyl-4-methyl hexane)
(correct)



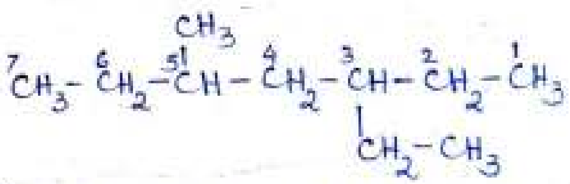
$$ {}^{1}CH_3-{}^{2}CH_2-\underset{CH_3}{{}^{3}CH}-\underset{C_2H_5}{{}^{4}CH}-{}^{5}CH_2-{}^{6}CH_3 $$

(4-Ethyl-3-methyl hexane)
(incorrect)



$$ {}^{1}CH_3-{}^{2}CH_2-\overset{CH_3}{{}^{3}CH}-{}^{4}CH_2-\underset{CH_2-CH_3}{{}^{5}CH}-{}^{6}CH_2-{}^{7}CH_3 $$

(5-ethyl-3-methyl heptane)
Incorrect

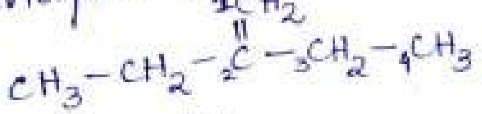


$$ {}^{7}CH_3-{}^{6}CH_2-\overset{CH_3}{{}^{5}CH}-{}^{4}CH_2-\underset{CH_2-CH_3}{{}^{3}CH}-{}^{2}CH_2-{}^{1}CH_3 $$

(3-Ethyl-5-methyl heptane)
correct

(B) Rules for naming unsaturated acyclic hydrocarbons

Select the longest continuous carbon chain which contains the maximum no. of multiple bonds as the principal chain. For example,



$$ CH_3-CH_2-\overset{{}_{1}CH_2}{\overset{\|}{{}_{2}C}}-{}_{3}CH_2-{}_{4}CH_3 $$

(It includes a double bond)

$$ CH_3-CH_2-\overset{{}^{1}CH_2}{\overset{\|}{{}^{2}C}}-\underset{{}^{4}CH-{}^{5}CH_3}{\underset{\|}{{}^{3}C}}-CH_2-CH_3 $$

(It includes two double bonds)

(b) Numbering the principal chain —

(i) If there is one multiple bond, number the carbon chain from such an end so as to give lowest ~~locant~~ numeral to the carbon atom containing the multiple bond.

$\overset{1}{C}H_3-\overset{2}{C}H=\overset{3}{C}H-\overset{4}{C}H_2-\overset{5}{C}H_3 \longrightarrow$ Correct (Locant - 2)

$\overset{5}{C}H_3-\overset{4}{C}H=\overset{3}{C}H-\overset{2}{C}H_2-\overset{1}{C}H_3 \longrightarrow$ Incorrect (Locant - 3)

The primary suffix for double bond is ene and that for triple bond is yne. Thus,

$CH_3-CH=CH-CH_3$ (But-2-ene)

$\overset{4}{C}H_3-\overset{3}{C}H(CH_3)-\overset{2}{C}\equiv\overset{1}{C}H$

(3-methyl but-1-yne)

$\overset{1}{C}H_3-\overset{2}{C}H=\overset{3}{C}H-\overset{4}{C}H_2-\overset{5}{C}H_3$ (Pent-2-ene)

(ii) If the principal chain contains two or more multiple bonds, then number the principal chain from both ends in the form of set.

$\overset{1}{C}H_3-\overset{2}{C}H=\overset{3}{C}H-\overset{4}{C}\equiv\overset{5}{C}H \longrightarrow$ Incorrect (set 2,4)

$\overset{5}{C}H_3-\overset{4}{C}H=\overset{3}{C}H-\overset{2}{C}\equiv\overset{1}{C}H \longrightarrow$ Correct (set 1,3)

If the numbering of principal chain from both ends gives the same set of locants to multiple bonds, then the set which gives lower locant to double bond is selected.

$\overset{1}{C}H_3-\overset{2}{C}H=\overset{3}{C}H-\overset{4}{C}\equiv\overset{5}{C}-\overset{6}{C}H_3 \rightarrow$ Correct set (2,4)

$\overset{6}{C}H_3-\overset{5}{C}H=\overset{4}{C}H-\overset{3}{C}\equiv\overset{2}{C}-\overset{1}{C}H_3 \longrightarrow$ Incorrect (set 2,4)

(iii) When both ~~bo~~ double and triple bonds are present in the principal chain, the compound is named as the derivative of alkyne. The suffix 'ene' always comes before 'yne' and 'e' of the ene is omitted if it is followed by suffix starting with vowel a, i, o, u or y.

Ex. — $H\overset{5}{C}\equiv\overset{4}{C}-\overset{3}{C}H_2-\overset{2}{C}H=\overset{1}{C}H_2$ (Pent-1-en-4-yne)

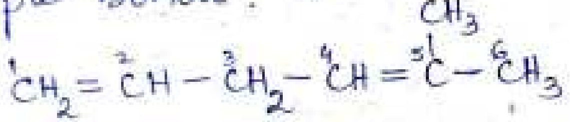
(iv) If the principal chain contains two double or two triple bonds, then suffix is diene or diyne. In such cases, 'a' is added to word root i.e., penta is written instead of pent,

hexa is written instead of hex.

$\overset{5}{C}H_2=\overset{4}{C}H-\overset{3}{C}H_2-\overset{2}{C}H=\overset{1}{C}H_2$ $H\overset{1}{C}\equiv\overset{2}{C}-\overset{3}{C}H_2-\overset{4}{C}\equiv\overset{5}{C}H$

(Penta-1,4-diene) (Penta-1,4-diyne)

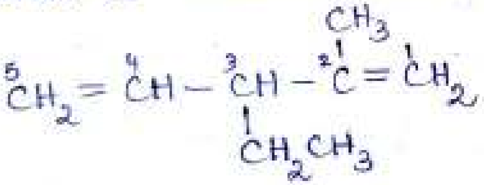
(v) In case, substituent present in the principal chain containing multiple bonds, then number the carbon chain so as to get lowest set of locants to the multiple bonds.



$\overset{1}{C}H_2=\overset{2}{C}H-\overset{3}{C}H_2-\overset{4}{C}H=\overset{\overset{CH_3}{|}}{\overset{5}{C}}-\overset{6}{C}H_3$

(5-Methylhexa-1,4-diene)

(vi) If we have the same set of locants for multiple bonds in both the numbering which gives lowest set of locants to substituents is correct one.



$\overset{5}{C}H_2=\overset{4}{C}H-\underset{\underset{CH_2CH_3}{|}}{\overset{3}{C}H}-\overset{\overset{CH_3}{|}}{\overset{2}{C}}=\overset{1}{C}H_2$

(3-Ethyl-2-methylpenta-1,4-diene)

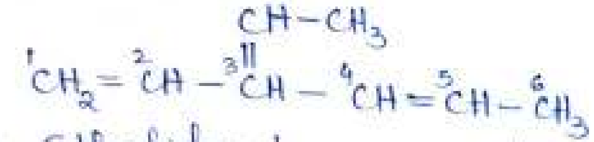
(vii) When more than two multiple bonds are present and it is not possible to accomodate all multiple bonds in the principal chain, then multiple bonds may be considered as side chains or substituents.

$CH_2=$ is methylidene

$CH_3-CH=$ is ethylidene

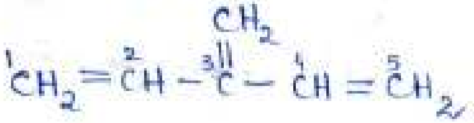
$CH_2=CH-$ is vinyl &

$CH_2=CH-CH_2-$ is allyl.

Ex. 

$$\overset{1}{C}H_2=\overset{2}{C}H-\overset{3}{\underset{}{C}}\overset{CH-CH_3}{\overset{\|}{H}}-\overset{4}{C}H=\overset{5}{C}H-\overset{6}{C}H_3$$

(3-Ethylidenehexa-1,4-diene)



$$\overset{1}{C}H_2=\overset{2}{C}H-\overset{\overset{CH_2}{\|}}{\overset{3}{C}}-\overset{4}{C}H=\overset{5}{C}H_2$$

(3-Methylidenepenta-1,4-diene)

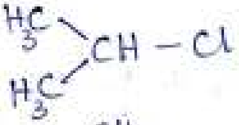
(c) Halogen Derivatives →

Common names

CH_3-Cl (methyl chloride)

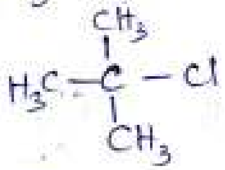
CH_3-CH_2-Cl (Ethyl chloride)

$CH_3-CH_2-CH_2-Cl$ (n-propyl chloride)



$$(H_3C)_2CH-Cl$$

(Isopropyl chloride)



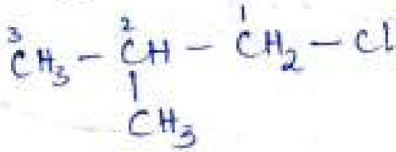
$$H_3C-\underset{CH_3}{\overset{CH_3}{C}}-Cl$$

(Tert. butyl chloride).

IUPAC system →

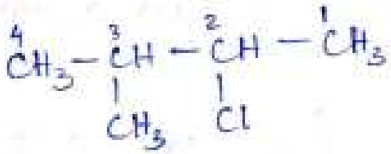
Locant no. + name of halogen + wordroot + suffix.

Ex. - CH_3-Cl (Chloromethane) CH_3-CH_2-Br (Bromoethane)



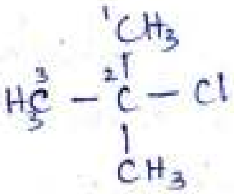
$$\overset{3}{C}H_3-\underset{CH_3}{\overset{2}{C}H}-\overset{1}{C}H_2-Cl$$

(1-chloro-2-methylpropane)



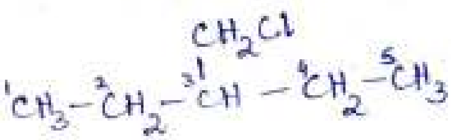
$$\overset{4}{C}H_3-\underset{CH_3}{\overset{3}{C}H}-\underset{Cl}{\overset{2}{C}H}-\overset{1}{C}H_3$$

(2-chloro-3-methyl butane)



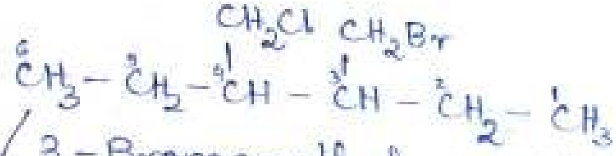
$$H_3\overset{3}{C}-\underset{CH_3}{\overset{{}^{1}CH_3}{\overset{2}{C}}}-Cl$$

(2-chloro-2-methylpropane)



$$\overset{1}{C}H_3-\overset{2}{C}H_2-\overset{CH_2Cl}{\overset{3}{C}H}-\overset{4}{C}H_2-\overset{5}{C}H_3$$

(3-chloromethyl pentane)



$\overset{6}{C}H_3-\overset{5}{C}H_2-\overset{4}{C}H(CH_2Cl)-\overset{3}{C}H(CH_2Br)-\overset{2}{C}H_2-\overset{1}{C}H_3$

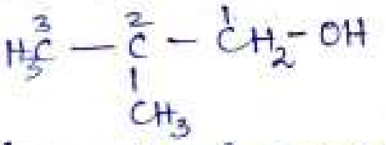
(3-Bromomethyl-4-chloromethylhexane)

(D) Alcohols → According to IUPAC system, alcohols are also called alkanols.

(i) Select the longest carbon chain containing -OH group.
(ii) Number the chain from an end so as to give least number to the carbon atom bearing -OH group.
(iii) Then write the name as

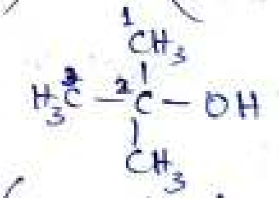
Locant - substituent + word root + primary suffix - Locant no. - ol.

Ex. CH_3-OH (methanol) $\overset{2}{C}H_3-\overset{1}{C}H_2-OH$ (Ethanol) $\overset{4}{C}H_3-\overset{3}{C}H_2-\overset{2}{C}H_2-\overset{1}{C}H_2-OH$ (Butan-1-ol)



$H_3\overset{3}{C}-\overset{2}{C}(CH_3)-\overset{1}{C}H_2-OH$

(2-methyl propan-1-ol)



$H_3\overset{3}{C}-\overset{2}{C}(\overset{1}{C}H_3)(CH_3)-OH$

(2-methyl propan-2-ol)

Writing Structural formula from IUPAC name of a compound →

(i) Write down the straight chain of carbon atoms corresponding to the word root.
(ii) Number the carbon chain starting from one end.
(iii) Note the primary suffixes (-ene or -yne) which indicate the number, kind and position of carbon-carbon double bond and triple bond in the parent chain. Draw the double and triple bonds.

(iv) Attach the functional groups and substituents at the specified positions.
(v) Attach the hydrogen atoms at the vacant position to satisfy the tetravalency of carbon atoms.

Ex. 4-methylhex-5-en-2-ol.

(i) As the word root is hex, write down a straight chain of six carbon atoms.

$$C-C-C-C-C-C$$

(ii) Number the carbon chain starting from one end.

$$\overset{1}{C}-\overset{2}{C}-\overset{3}{C}-\overset{4}{C}-\overset{5}{C}-\overset{6}{C}$$

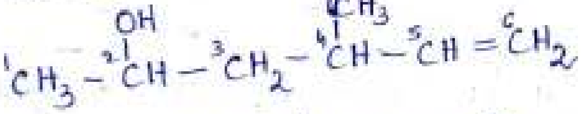
(iii) Since the primary suffix is en, it indicates the presence of double bond between carbon 5 and 6 as indicated by the locant no. 5 before the suffix.

$$\overset{1}{C}-\overset{2}{C}-\overset{3}{C}-\overset{4}{C}-\overset{5}{C}=\overset{6}{C}$$

(iv) Attach a methyl group at carbon 4 and OH group at carbon 2.

$$^{1}C-{}^{2}\overset{OH}{\overset{|}{C}}-{}^{3}C-{}^{4}\overset{CH_3}{\overset{|}{C}}-{}^{5}C={}^{6}C$$

(v) Attach hydrogen atoms at the vacant places to satisfy the tetra covalency of carbon.



$$^{1}CH_3-{}^{2}\overset{OH}{\overset{|}{C}}H-{}^{3}CH_2-{}^{4}\overset{CH_3}{\overset{|}{C}}H-{}^{5}CH={}^{6}CH_2$$

Bond line Notations →

Bond line notation is a convenient and short method of representing organic compounds. In bond line notation,
(i) Bonds are represented by lines. A single line represents a single bond, two parallel (=) lines represent a double bond and three parallel lines (≡) represent a triple bond.

(ii) Carbon atoms are denoted by line ends or line intersections.

(iii) Functional groups or the substituent groups are denoted by their symbols and abbreviations.

(iv) Hydrogen atoms are assumed to be present ~~with~~ in required numbers in order to satisfy the tetravalency of carbon.

Ex.

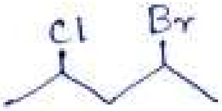
$\overset{5}{C}H_3-\overset{4}{C}H_2-\overset{3}{C}H_2-\underset{\underset{CH_3}{|}}{\overset{2}{C}H}-\overset{1}{C}H_3$ (2-methyl pentane)

$\overset{1}{C}H_2=\overset{2}{C}H-\overset{3}{C}H=\overset{4}{C}H-\overset{5}{C}H=\overset{6}{C}H-\overset{7}{C}H_3$ (Hepta-1,3,5-triene)

$\overset{1}{C}H_3-\overset{2}{C}H_2-\underset{\underset{CH_3}{|}}{\overset{\overset{CH_3}{|}}{\overset{3}{C}}}-\overset{4}{C}H_2-\overset{5}{C}H_3$ (2,2-dimethyl pentane)

$\overset{1}{C}H_2=\overset{2}{C}H-\underset{\underset{CH_2-CH_3}{|}}{\overset{3}{C}H}-\overset{4}{C}H=\overset{5}{C}H_2$ (3-ethyl penta-1,4-diene)

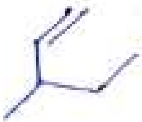
$\overset{4}{C}H_3-\overset{\overset{CH_3}{|}}{\overset{3}{C}}=\underset{\underset{OH}{|}}{\overset{2}{C}}-\overset{1}{C}H_3$ (3-methyl but-2-en-2-ol)



$\overset{5}{C}H_3-\overset{\overset{Cl}{|}}{\overset{4}{C}H}-\overset{3}{C}H_2-\overset{\overset{Br}{|}}{\overset{2}{C}H}-\overset{1}{C}H_3$ (2-bromo-4-chloro pentane)

$\overset{6}{C}H\equiv\overset{5}{C}-\overset{4}{C}H_2-\overset{3}{C}H_2-\overset{2}{C}H=\overset{1}{C}H_2$ (Hex-1-en-5-yne)

$\overset{1}{C}H_2=\overset{\overset{CH_3}{|}}{\overset{2}{C}}-\underset{\underset{CH_3}{|}}{\overset{3}{C}}=\overset{4}{C}H_2$ (2,3-dimethyl buta-1,3-diene)



$\overset{1}{C}H_2=\overset{2}{C}H-\overset{\overset{CH_3}{|}}{\overset{3}{C}H}-\overset{4}{C}H_2-\overset{5}{C}H_3$ (3-methyl pent-1-ene)

Uses of some common aromatic compounds →

(1) Benzene → Benzene is a widely used industrial chemical.
It is used to make plastics, resins, synthetic fibres, dyes, detergents, lubricants, drugs and pesticides.
It is also used as a solvent in many industries,

(2) Toluene → (i) Toluene is a very good solvent because, unlike water, it can dissolve many organic compounds.
(ii) In many commercial products, toluene is used as a solvent that is present in paint thinners, nail polish remover, glues and correction fluid.
(iii) In the explosive industry, it is essential in making the flammable, explosive compound TNT or (trinitro toluene)
(iv) In plastic industry, it is a component in the ~~manf~~ manufacturing of nylon and plastic bottles.
(v) It is also used to manufacture hair dyes and inks.

(3) BHC (Benzene Hexachloride) →
It is also known as Gammaxene.
It is used as an agricultural insecticide for exterminating white ants, leafhopper, termite etc.
It has also been used in pharmaceutical treatment for lice and scabies,

(4) Phenol → Phenol is widely used in household products and as intermediate for industrial synthesis.
It is used (in low concentrations) as a disinfectant in household cleaners and in mouthwash.
Phenols are widely used as antiseptic, disinfectant, anesthetic and houshold cleaning products.
It is also used in cosmetic industry in the manufacture of sunscreens, skin lightening creams and hair colouring solutions.

(5) Naphthalene →

Naphthalene is widely used to repel moths and cockroaches and as deodorants for urinals and bathrooms.

It is used in the industrial production of phthalic anhydride.

It is also used as an insecticide and pest repellant.

(6) Anthracene →

It is used in the artificial production of the red dye alizarin.

It is also used in wood preservatives, insecticides and coating materials.

(7) Benzoic acid →

Benzoic acid is used as a preservative in food and personal care products.

Because of its anti-fungal properties, it is an ingredient in topical anti-fungal cream, ointments and lotions that can help treat athlete's foot and ringworm.

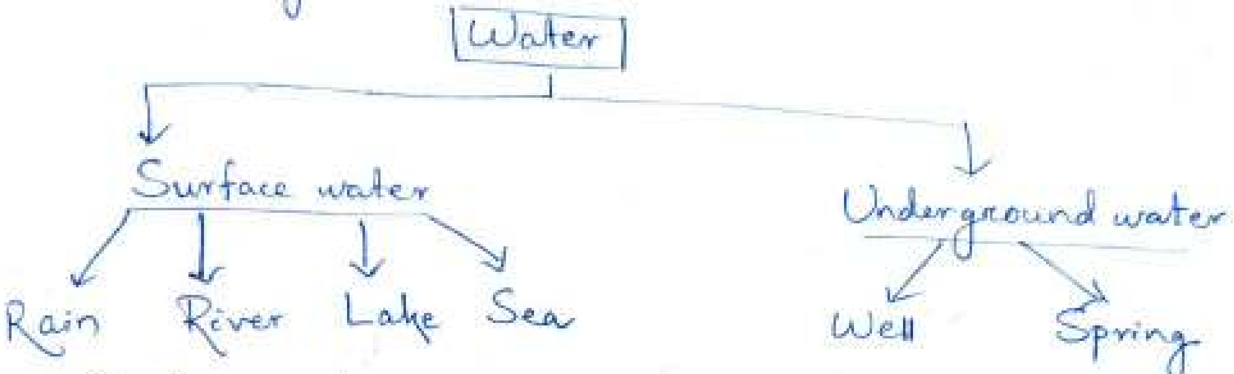
It is also used in the treatment of skin irritation caused by insect bites, burns etc.

It is used in toothpastes, jam, beverages, poultry agriculture, perfume, dye etc.

INDUSTRIAL CHEMISTRY

Water treatment -

Sources of water → Water is available from different sources. Sources of water can be classified as surface water and underground water.



(1) Surface water →

(a) Rain water → Purest form of natural water
Dissolves large amounts of industrial gases like CO_2, SO_2, NO_2 etc.
Also carries some organic and inorganic particles.

(b) River water → It starts from spring water.
Rain water and some other sources of water also add to it.
It also dissolves some soluble minerals from the soil and finally falls in the sea.

(c) Lake water → It is confined in a particular ~~space~~ place.
Contains lesser amount of dissolved minerals.

(d) Sea water → Most impure form of naturally occurring water.
Sea water contains chlorides, bromides, iodides and bicarbonates of calcium and magnesium.

(2) Underground water → A part of the rain water on the surface percolates into the earth. During its downward journey, it dissolves some minerals. This process continues till water reaches some hard rock.

Sometimes the underground water rushes upward and come out in the form of spring which contains sulphur in the colloidal form.

Types of water → Water is of 2 types.
(2) Hard water (1) Soft water &

Soft water → Water which forms lather with soap solution is called soft water.
Ex. – Rain water, demineralised water, distilled water etc

Hard water → Water which doesn't form lathier with soap solution is called hard water. Instead, it forms a curdy white precipitate.
Ex. – Sea water, river water, Pond water etc.

Hardness of water

It is the characteristic of water which prevents the lathering of soap due to the presence of bicarbonate, sulphate and chloride of calcium and magnesium in it.

Soap reacts with hard water as

$$2C_{17}H_{35}COONa + MgSO_4 \longrightarrow (C_{17}H_{35}COO)_2Mg + Na_2SO_4.$$

(Sodium stearate) soap (Impurity in hard water) (Magnesium stearate)

Types of ~~hard water~~ hardness

(1) Temporary hardness – (Carbonate hardness)
It is caused by presence of dissolved bicarbonates of Ca, and Mg.
It is named temporary hardness because the soluble bicarbonates decompose into insoluble carbonates simply on heating. Thus, water becomes soft.

$$\underset{\text{(soluble)}}{Ca(HCO_3)_2} \xrightarrow{\text{Heat}} \underset{\text{(insoluble)}}{CaCO_3}\downarrow + CO_2 + H_2O$$

Permanent hardness → It is caused by presence of chlorides or sulphates of Calcium and magnesium. It is named permanent hardness because such a hardness cannot be removed by simply boiling the water.

Unit of hardness

(1) PPM → Parts per million.

(2) mg/L → milligrams per litre.

Removal of temporary hardness by boiling

When temporary hard water is boiled, the HCO_3^- (bicarbonate) present in water decompose to give insoluble carbonates which settle down easily. Then the soft water is filtered off.

$$Ca(HCO_3)_2 \xrightarrow{\text{Heat}} CaCO_3\downarrow + CO_2 + H_2O.$$

Removal of permanent hardness

Lime soda process → It is of two types.

(a) Cold Lime soda process (b) Hot lime soda process.

(a) Cold Lime-soda process →

Principle – A calculated quantity of lime and soda are mixed with hard water at room temp. Also co-agulant like aluminium sulphate ($Al_2(SO_4)_3$) is added for removing finely divided precipitate to settle quickly.

When hard water mix properly with lime and soda, the precipitates of Ca and Mg are formed.

Ex. $$CaCl_2 + \underset{\text{(soda)}}{Na_2CO_3} \longrightarrow \underset{\text{(ppt)}}{CaCO_3}\downarrow + 2NaCl$$

$$MgCl_2 + \underset{\text{(lime)}}{Ca(OH)_2} \longrightarrow \underset{\text{(ppt)}}{Mg(OH)_2} + CaCl_2.$$

Process —

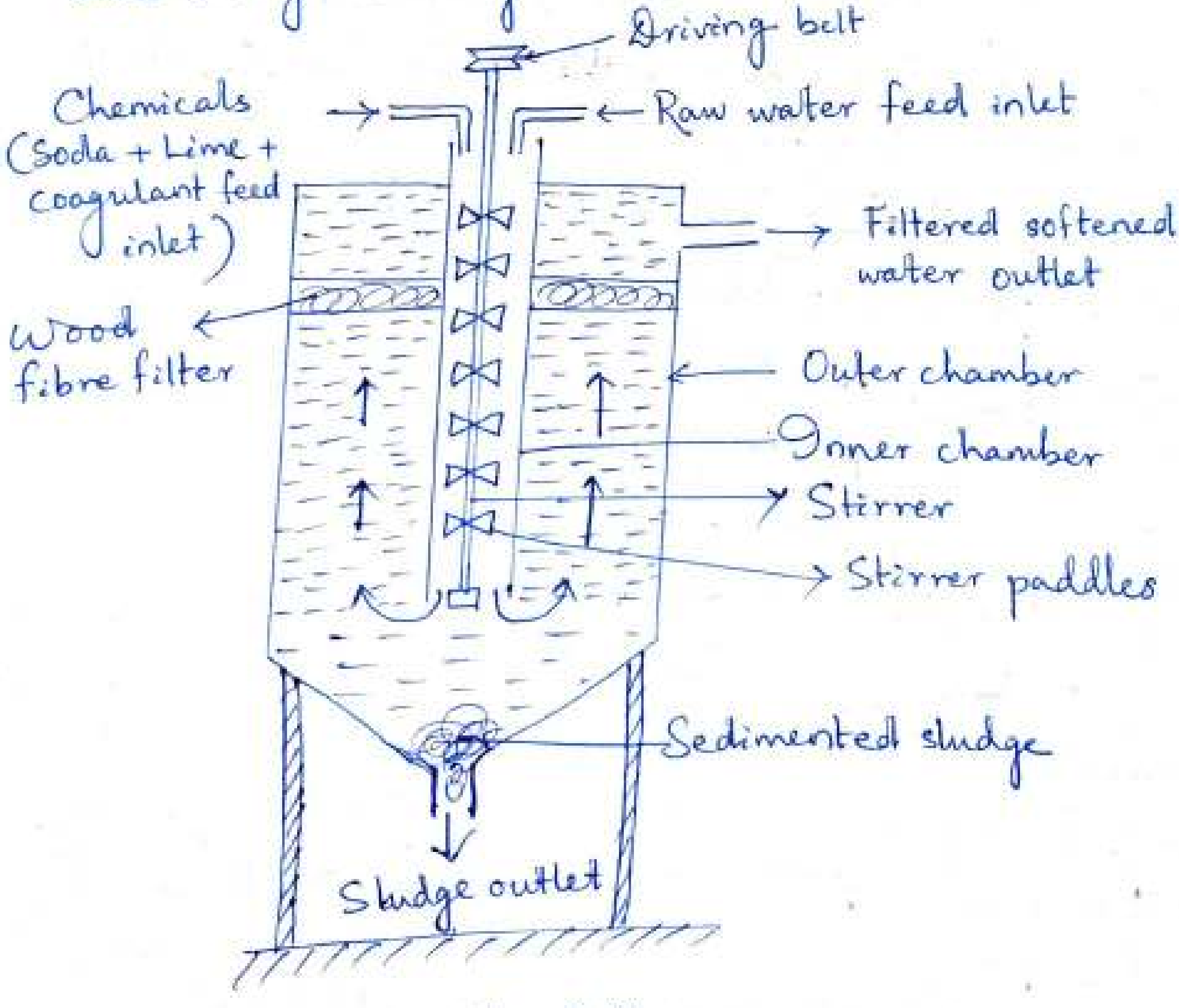
Raw water, lime ~~on~~ soda and co-agulants are added from the top inner vertical circular chamber which is fitted with rotating shaft carrying many paddles.

The dissolved salts of Ca and Mg combine with lime ~~and~~, soda and co-agulants and form an insoluble precipitate as ~~slug~~ sludge.

Softened water rises upward and the heavy sludge settles down.

Then the softened water passes through wood fibre filter and the filtered soft water is collected through the outlet.

The sludge settling down at the bottom is removed.



Cold Lime-soda Softener

Advantages →

(i) Silica and oil if any may also removed.

(ii) This process provides water containing residual hardness of about 50-60 ppm.

Dis-advantages →

(i) Can't be used for household purposes.

(ii) Not suitable for many industrial purposes.

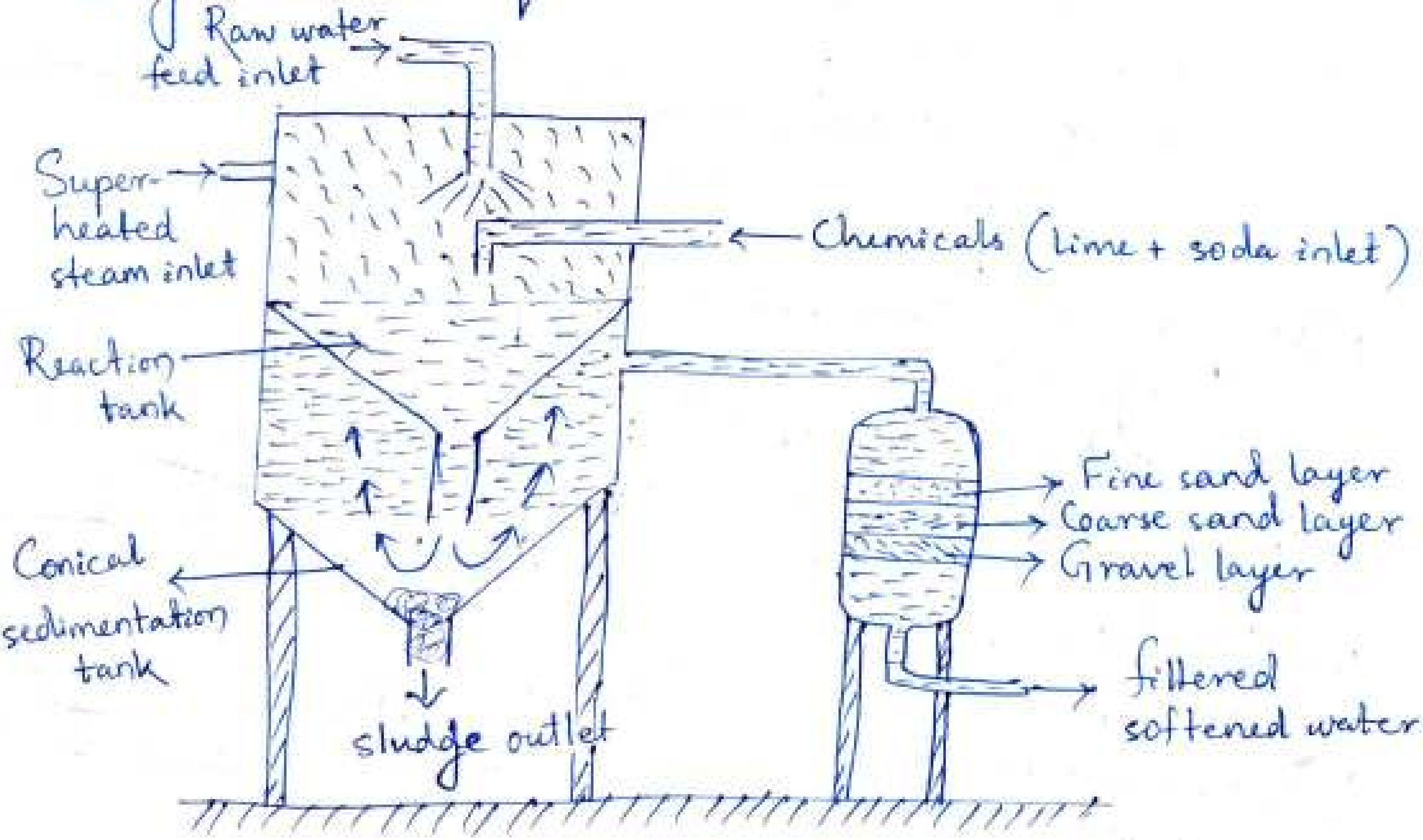
Hot Lime Soda process →

Principle → This process involves the treatment of hard water with lime and soda at a temp of 80-150°C

Process → This process is faster and reaction gets completed within 15 minutes.

The ppt. and sludges formed settles down rapidly.

As this process takes place at a higher temp, no co-agulants are required.



Hot Lime-Soda Softener

Apparatus :

The apparatus consists of 3 main parts.

(a) Reaction tank - in which hard water, lime & soda are mixed thoroughly.

(b) Conical sedimentation vessel - in which sludges settle down.

(c) Sand filter - where sludge is completely removed.

Advantages →

It is economical.

No co-agulants are required.

Mineral content of water is reduced.

The process improves corrosion resistance of the water.

Dis-advantages →

Careful operation is needed.

Disposal of sludge creates problem.

Due to residual hardness, water is not suitable for high pressure boilers.

Difference between cold lime soda process & hot lime soda process

Cold lime soda process	Hot lime soda process
1. This process is conducted at room temp. (25°C)	This process is conducted at high temp. (80°-150°C)
2. Co-agulant is required.	No co-agulant is required.
3. takes about 24 hours to complete.	This process is completed within 15 minutes.
4. Hardness left in water is about 60 ppm.	Hardness left in water is about 30 ppm.

Advantages of Hot soda lime process over cold soda lime process →

(i) The precipitation reaction becomes almost complete.

(ii) The reaction takes place faster.

(iii) The sludge settles rapidly.

(iv) No coagulant is needed.

(v) Dissolved gases are removed.

(vi) Residual hardness is low compared to the cold process.

Ion-Exchange Method →

In this method, the ions responsible for hardness are exchanged with other ions which don't make water hard.

Organic ion-exchangers (Ion-exchange resins)

These are big organic molecules having

(i) high molecular weight

(ii) Open and permeable molecular structure

(iii) acidic ($-COOH$, $-SO_3H$) or basic groups (OH^-, $-NH_2$) attached with them.

Ion-exchange resins are of 2 types.

(a) Cation-exchange resin ($R-H^{\oplus}$) → If the active ion in ion-exchanger is a cation, the resin is called cation-exchange resin. Ex.- (Resin-H^+).

(b) Anion-exchange resin ($R-OH^{\ominus}$) → If the active ion in ion-exchanger is an anion, the resin is called anion-exchange resin. Ex.- (Resin-OH^-).

Process → The hard water is passed through a column of cation exchange resin called zero-carb. All the cations present in hard water get exchanged with H^+ ions of the resin.

Ex.- $$\underset{\text{(in hard water)}}{CaCl_2} + \underset{\text{(cation-exchange resin)}}{2H^+\text{-Resin}} \longrightarrow Ca(Resin)_2 + 2H^+ + 2Cl^-$$

$$MgSO_4 + 2H^+\text{-Resin} \rightarrow Mg(\text{Resin})_2 + 2H^+ + SO_4^{2-}$$

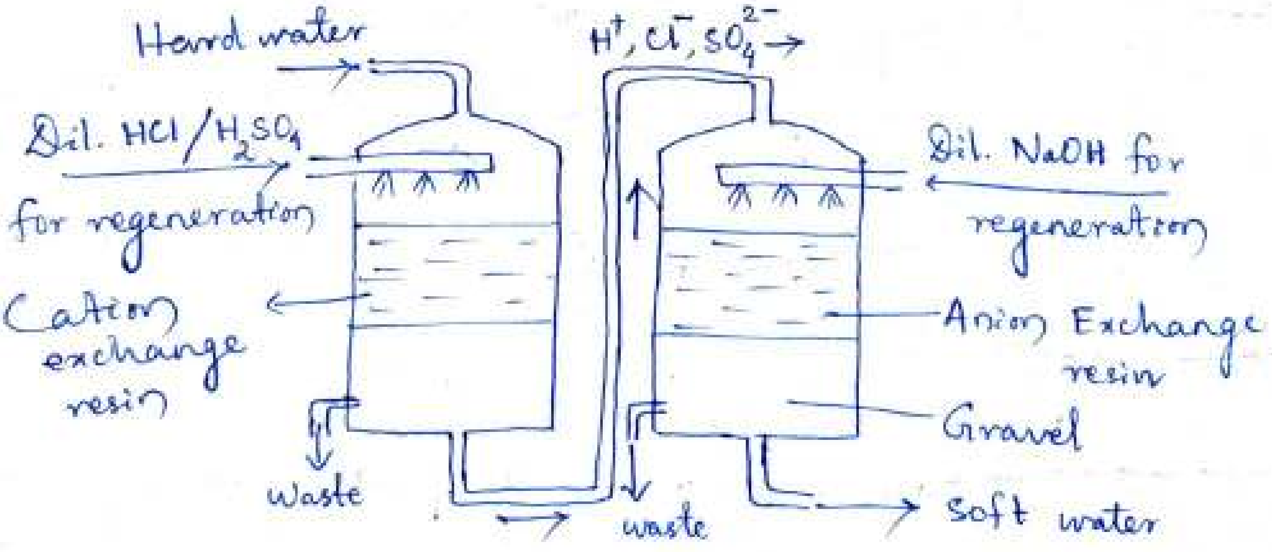
Then the hard water is passed through the column of anion exchange resin called de-acidite. All the anions present in water get exchanged with OH^- ion of the resin.

$$\underset{(\text{In water})}{Cl^-} + \underset{(\text{Anion exchange resin})}{OH^-\text{-Resin}} \longrightarrow Cl^-\text{-Resin} + OH^-$$

H^+ and OH^- ions released from the cation and anion exchange columns respectively get combined to produce water molecule.

$$H^+ + OH^- \longrightarrow H_2O$$

Thus, the water coming out from the exchanger is free from cations as well as anions. Such water is known as deionised or demineralised water.



Organic ion-exchangers

Regeneration of resins →

When all the H^+ and OH^- ions of the resins are exchanged by the cations and anions present in the hard water, then resins are said to be exhausted and regeneration can be done.

The cation exchange resin can be regenerated by the treatment ~~of~~ with moderately concentrated HCl or H_2SO_4.

$$\underset{\text{(Exhausted resin)}}{Ca(Resin)_2} + 2HCl \longrightarrow CaCl_2 + \underset{\text{(Regenerated resin)}}{2H^+\text{-}Resin}$$

The anion exchange resin can be regenerated by the treatment with moderately concentrated NaOH.

$$\underset{\text{(Exhausted resin)}}{Cl^-\text{-}Resin} + NaOH \longrightarrow \underset{\text{(Regenerated resin)}}{HO^-\text{-}Resin} + NaCl$$

The regenerated resins may be used again.

Advantages → (i) This process can be used to soften highly acidic or alkaline waters.

(ii) It produces water of very low hardness which is suitable for high pressure boilers.

Dis-advantages →

(i) The equipment is costly and can be more expensive chemicals are needed.

(ii) If water contains turbidity, then output of the process is reduced.

Lubricants

Lubricant — Lubricant is defined as any substance which is introduced between two moving / sliding surfaces to reduce the frictional resistance.

Ex. - Grease, ~~Gra~~ Graphite etc.

Lubrication → The process of reducing frictional resistance between two sliding / moving surface by the introduction of lubricants in between them is called lubrication.

Types of lubricants :

(1) Solid lubricants → These are used either in powdered form (dry state) or mixed with water or oil.

Ex. (a) Graphite (b) Molybdenum disulphide (c) Boron Nitride.

(2) Liquid Lubricants →

These are also known as lubricating oils.

Ex - Petroleum oil, Blended oil, animal & vegetable oil.

(3) Semi-solid lubricants →

Ex. - Grease.

Uses of graphite →

(i) Used in air compressors, Lathe, machine workshops, railway track joint, Open gears, chains & cast iron heating.

(ii) Used as an emulsifying agent like tanin.

(iii) Oildag is used in internal combustion engines.

(iv) Aquadag is used in food industries.

Uses of Lubricating oils →

Lubricating oils are used where
(1) Operating temp. is high.
(2) Sealing arrangement is perfect.
(3) Speed of the rollers is high.

Uses of Grease →

(1) Used where oil can't remain in place due to high load, low speed, sudden jerks like rail axle.
(2) In bearings and gears which work at high temp.
(3) Where dropping of oil affects the machine or product like production of paper, textile etc.

Purpose of Lubrication / Functions of Lubricants

(i) It reduces friction and minimises wear and tear.
(ii) It minimises loss of energy.
(iii) It reduces expansion of metals.
(iv) It acts as a seal and minimises leakage of gas.
(v) It acts as a coolant by removing heat of friction.

FUEL

Definition - Fuel may be defined as any substance which on combustion release a large amount of heat energy without producing excess by-products.

$$\text{Fuel} + O_2 \longrightarrow \text{Products} + \text{Heat}$$

Ex. - Wood, charcoal, kerosene, Diesel etc.

Classification → Fuels can be classified into →

(a) Natural or Primary fuels → Such fuels are found in nature.

Ex. — Wood, coal, petroleum, natural gas etc.

(b) Artificial or Secondary fuels →

Such fuels are prepared from primary fuels.
Ex.- Coke, Kerosene, petrol, water gas etc.

Another classification of fuels is based on the state of aggregation.

(a) Solid fuels (b) Liquid fuels (c) Gaseous fuels.

Calorific value of fuel →

It is defined as the amount of heat energy liberated by the complete combustion of unit mass or volume of fuel.

Units of calorific value →

- Calories / gram
- KCal / Kg
- B.Th.U/Lb (British thermal unit / pound).

Choice of Good fuel →

A good fuel →

(i) should have high calorific value.
(ii) Leave only small amount of residue or ash when burnt.
(iii) Ignition temperature should be moderate.
(iv) Low moisture content.
(v) Controllable combustion rate.
(vi) Products of combustion should not be harmful.
(vii) Low storage unit.
(viii) should be cheap and easy to transport.

Liquid fuels →

(a) Diesel – It is a mixture of $C_{15}H_{32}$ to $C_{18}H_{38}$.
Its calorific value is 11000 KCal/Kg.

Composition – Its average composition is
$C = 85\%$, $H = 12\%$, Rest = 3%

Uses → It is used as a diesel engine oil.

(b) Petrol → It is a mixture of hydrocarbons like C_5H_{12} to C_8H_{18}.

Calorific value is 11250 KCal/Kg.

Average composition → $C = 84\%$, $H = 15\%$, $N+O+S = 1\%$

Uses → Used as a fuel for internal combustion engines of automobiles and aeroplanes.

(c) Kerosene → It is a mixture of hydrocarbons $C_{10}H_{22}$ to $C_{16}H_{34}$.

Calorific value is 11,100 KCal/Kg.

Average composition → $C = 84\%$, $H = 16\%$, S = less than 1%

& Uses → Used as a domestic fuel in stoves, jet engines fuel for making oil gas.

Gaseous fuels →

(a) Producer gas → Producer gas is essentially a mixture of combustible gases, carbon monoxide and hydrogen with large percentage of non-combustible gases like N_2, CO_2 etc.

Composition – The average composition of producer gas is
$CO = 22-30\%$, $H_2 = 8-12\%$
$N_2 = 52-55\%$ and $CO_2 = 3\%$

Its calorific value is 1300 kCal/m^3.

Uses → (i) It is used for heating open-hearth furnances in steel and glass manufacture, muffle furnace in coke and coal gas manufacture.

(ii) As a reducing agent in metallurgical operations.

(b) Water gas →

Water gas is essentially a mixture of combustible gases, CO and H_2 with a little non-combustible gases like CO_2 and N_2.

Composition – The average composition of water gas is $H_2 = 51\%$, $CO = 41\%$, $N_2 = 4\%$, $CO_2 = 4\%$

Its calorific value is 2800 kCal/m^3.

Uses → It is used as

(i) a source of hydrogen gas.

(ii) an illuminating gas

(iii) a fuel gas

(iv) used for welding purposes.

(c) Coal gas → Coal gas is a mixture of a number of lower hydrocarbons alongwith N_2, H_2, CO and CO_2. It is a colourless gas and burns with a sooty flame.

Composition → $H_2 = 40\%$, $CH_4 = 32\%$, $CO = 7\%$, $C_2H_2 = 2\%$, $C_2H_4 = 3\%$, $N_2 = 4\%$, $CO_2 = 1\%$ and Rest = 11 %.

Calorific value – 4900 KCal/m^3.

Uses → Coal gas is used –

(i) as a fuel

(ii) as a reducing agent in metallurgical operations.

(iii) as an illuminant.

(d) LPG (Liquified Petroleum Gas) →

It is mainly C_3, C_4 hydrocarbons of alkane and alkene.

It is highly inflammable.

It is colourless and odourless but a smelling agent called ethyl mercaptan (C_2H_5SH) is added to LPG to detect the leakage.

Composition →

The average composition of L.P.G. is
n-butane = 27 %
iso-butane = 25 %
butene = 43 %
propene = 2.5 %
propane = 2.5 %

Calorific value = 27800 kCal/m^3.

Uses → mainly used as a domestic fuel and industrial fuel.
Now-a-days it is also used as a motor fuel.

(2) CNG (Compressed Natural Gas) →

It is a colourless, odourless gas.
It is very cheap and burns with a pale blue flame.
Its calorific value is 12500 kCal/m^3.

Composition →

CH_4 (methane) = 70-90 %
C_2H_6 (ethane) = 4-9 %
and traces of propane and butane.

Uses → (i) Used as a fuel for vehicles.
(ii) used as a domestic and industrial fuel.
(iii) used as a source of carbon in tyre industry.
(iv) Used for the production of H_2 gas needed in the fertilizer industry.
(v) Specially CNG is used in Low emissive vehicles like ULEV (ultra low ~~emission~~ emission vehicles).

POLYMER

Monomer : The small molecules of a substance which combine with each other as repeating units to form polymer molecules.

Ex. - Ethene (C_2H_4) is the monomer of polyethene. vinyl chloride ($CH_2=CH-Cl$) is the monomer of Polyvinyl chloride.

Polymer : Polymer may be defined as the macromolecules obtained by joining together a large no. of simple molecules through co-valent bonds in a regular fashion.

Ex. -

$$\underset{\text{(Ethene)}}{n(CH_2=CH_2)} \xrightarrow[\text{high pressure}]{250^\circ C} \underset{\text{(Polythene)}}{\left(CH_2-CH_2 \right)_n}$$

Homopolymer → The polymer which consists of identical monomers is called homopolymer.

$$-M_1-M_1-M_1-M_1-M_1-$$

Ex. - Polythene, PVC, Teflon etc.

Co-polymer → A co-polymer is formed from two or more different monomers through covalent bond.

$$-M_1-M_2-M_1-M_2-M_1-M_2-\cdots$$

Ex. - Nylon 6-6. , Buna-S-Rubber.

Degree of polymerization →

The no. of repeating units present in a polymer is called as degree of polymerization. It is denoted by the letter 'n'.

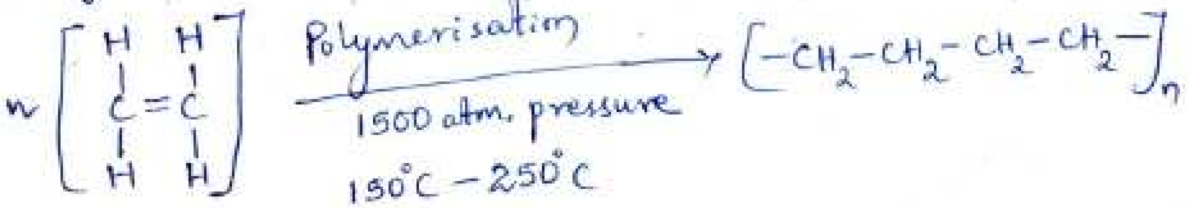
Ex. - Natural rubber contains 50000 units per molecule i.e., degree of polymerization of natural rubber is 50000.

Difference between thermoplastic & thermosetting polymers

Thermoplastic polymers	Thermosetting polymers
(1) These are formed by addition polymerization.	These are formed by condensation polymerization.
(2) These have usually linear structure.	These have three dimensional cross-linked structure.
(3) These soften and melt on heating and harden again on cooling.	These don't soften on heating but rather become hard. On prolonged heating these start burning.
(4) These can be remoulded and reshaped.	These can't be remoulded or reshaped.
(5) These are less brittle and soluble in organic solvents.	These are more brittle and insoluble in organic solvents.
(6) Ex. Polythene, PVC, Teflon, Nylon etc.	Ex. – Bakelite, Terylene etc

Composition and uses of polythene →

It is obtained by polymerization of ~~polythene.~~ ethylene. Ethylene is liquified under high pressure i.e, 1500 atmospheric pressure and then pumped into a heated pressure vessel maintained at about 150°C to 250°C in presence of ~~oxygen where~~ a traces of oxygen where it is polymerized into a waxy solid.



$$n\left[\begin{matrix} H & & H \\ | & & | \\ C & = & C \\ | & & | \\ H & & H \end{matrix}\right] \xrightarrow[\substack{1500\text{ atm, pressure} \\ 150^\circ C - 250^\circ C}]{\text{Polymerisation}} \left[-CH_2-CH_2-CH_2-CH_2-\right]_n$$

Uses → It is used for making

(i) High frequency insulator parts.

(ii) Packing materials in the form of thin films, bags etc.

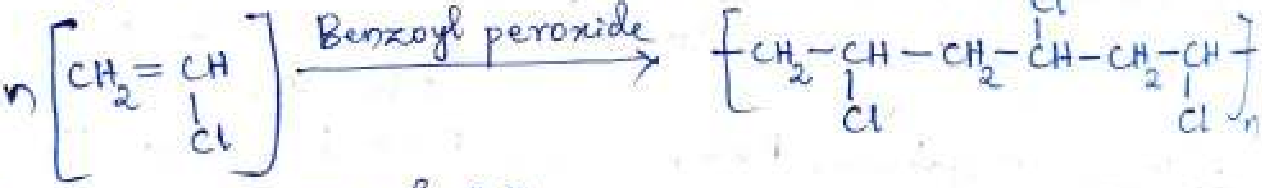
(iii) Flexible bottles, kitchen & domestic appliances.

(iv) Toys, tubes, pipes, insulating wires etc.

(v) HDPE (high density polythene) is used for making buckets, tubes etc.

Poly-vinyl chloride → (PVC)

PVC is obtained by heating water emulsions of vinyl chloride in presence of small amount of benzoyl peroxide under high pressure.



$$n\left[CH_2=\underset{Cl}{\underset{|}{CH}}\right]\xrightarrow{\text{Benzoyl peroxide}}\left[CH_2-\underset{Cl}{\underset{|}{CH}}-CH_2-\overset{Cl}{\overset{|}{CH}}-CH_2-\underset{Cl}{\underset{|}{CH}}\right]_n$$

There are 2 types of PVC.

(a) plasticized & (b) Unplasticized.

In plasticized PVC, some plasticizers are used.

Uses → It is used for making –

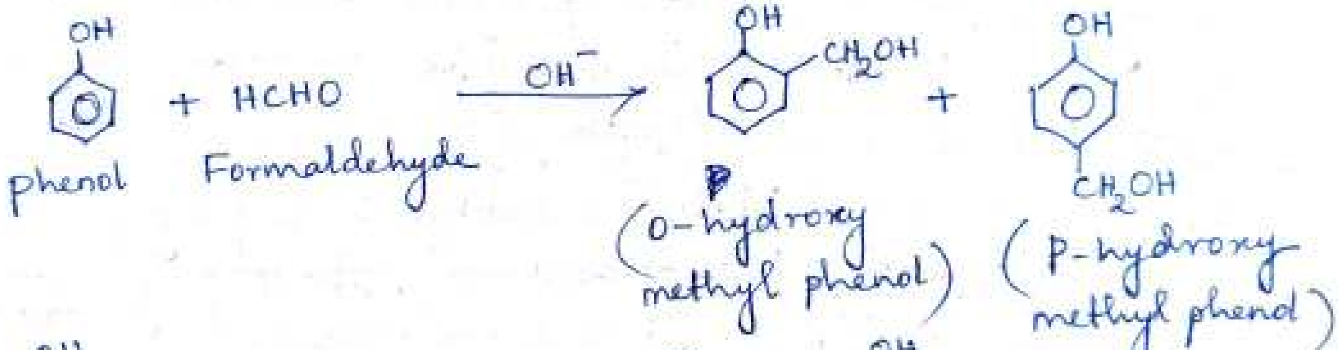
(i) Making electrical insulators.

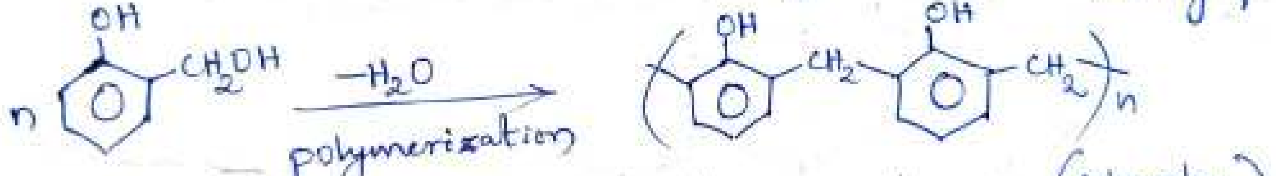
(ii) Making of gramophone records, safety helmets, refrigerator components, rain coats, plastic dolls, hand bags etc.

(iii) Making tyres, cycles and motor cycle mudguards.

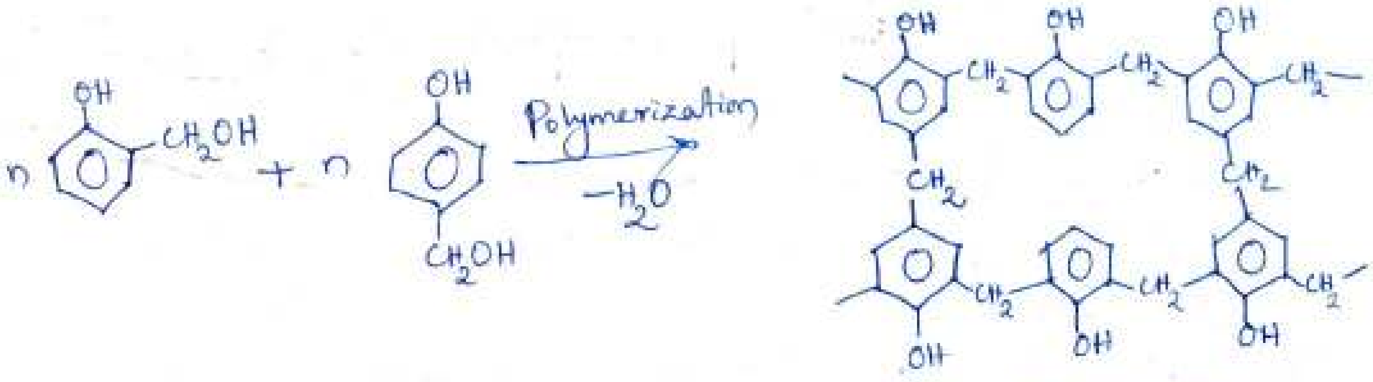
Bakelite →

It is a condensation polymer.
It is obtained by condensation of phenol with formaldehyde in presence of acidic or alkali catalyst. It is also called phenol-formaldehyde resin.
The reaction involves the formation of $-CH_2-$ (methylene) bridges in ortho, ~~meta~~ para or both ortho & para positions. As a result either a linear or cross-linked material is obtained.
The reaction is too difficult to control because condensation of ortho & para hydroxy methyl phenol leads to formation of polymeric products. The final product is dark, brittle & cross-linked product called bakelite.





Linear polymer (Novolac)



cross-linked polymer (Bakelite)

Uses → It is used -

(i) for making electrical insulation parts like switches, plugs, heaters handles etc.

(ii) For moulded articles like telephone parts, radio & television cabinets.

(iii) In paints and varnishes.

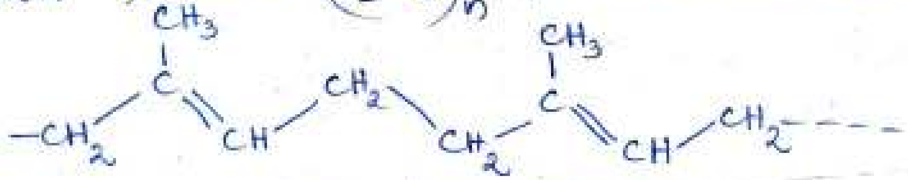
(iv) Adhesive for grinding wheels.

(v) an ion-exchanger in softening of water.

Rubber (Elastomer)

Rubber or elastomers are high polymers which can easily undergo very large reversible elongations at relatively low stresses, which can be stretched to 4-10 times its original length.

Natural rubber — Natural rubber is a polymer of isoprene (2-methyl buta-1,3-diene). It is poly-isoprene with formula $(C_5H_8)_n$. It is a cis-isomer.



(cis-polyisoprene)

It is made from the sap of a plant, called Havea - Brasillians.

Drawbacks of natural rubber →

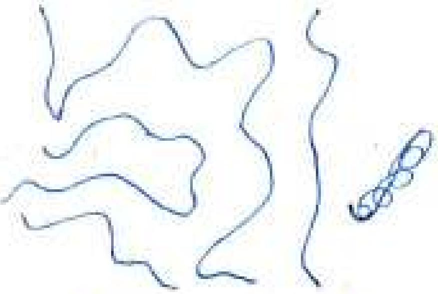
(i) Get damaged under the action of strong acids, ozone, oils etc.

(ii) Not recommended for use in alcohols, esters or among aromatic solution.

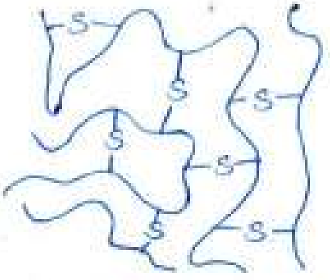
(iii) High raw material prices.

Vulcanisation of Rubber →

Vulcanisation is the process of heating raw rubber with varying amounts of sulphur at a temperature 140°C to improve some of the properties of raw rubber.

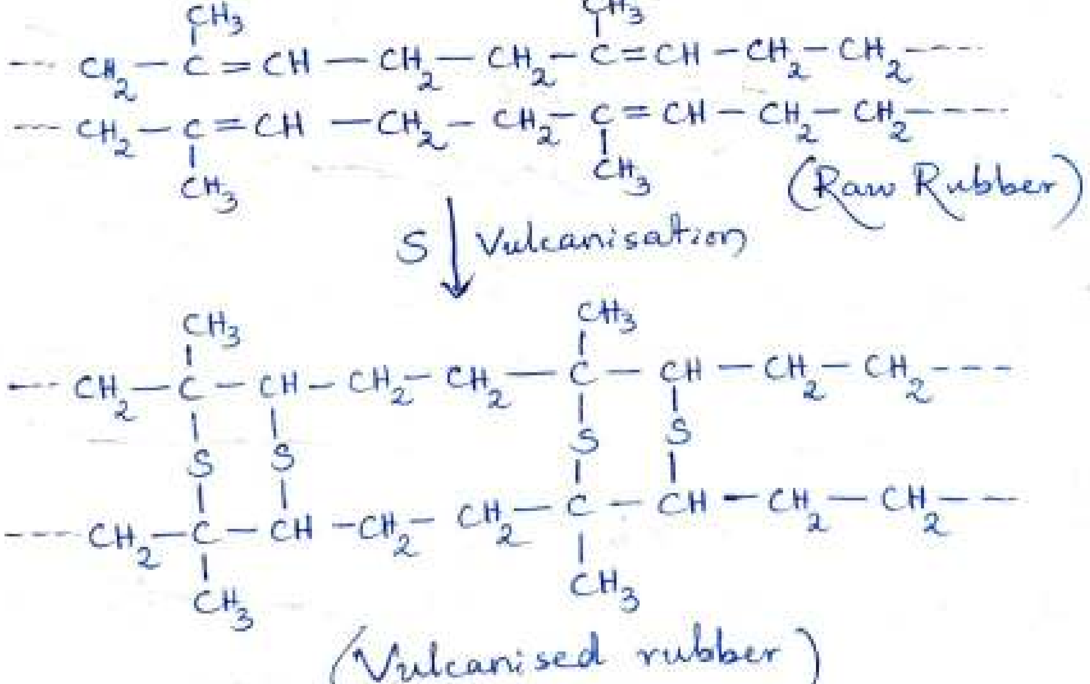


Unvulcanised rubber



Vulcanised rubber

After vulcanisation, rubber gains high tencile strength and becomes resistant to oxidation.
In this process, the added sulphur combines chemically at the double bonds of different rubber chains. Due to vulcanisation toughness and hardness of rubber increases.



$$\cdots CH_2-\overset{CH_3}{\overset{|}{C}}=CH-CH_2-CH_2-\overset{CH_3}{\overset{|}{C}}=CH-CH_2-CH_2\cdots$$
$$\cdots CH_2-\underset{CH_3}{\underset{|}{C}}=CH-CH_2-CH_2-\underset{CH_3}{\underset{|}{C}}=CH-CH_2-CH_2\cdots$$

(Raw Rubber)

$$\Big\downarrow S \text{ Vulcanisation}$$

$$\begin{array}{ccccccccccccc}
 & & CH_3 & & & & & & CH_3 & & & & \\
 & & | & & & & & & | & & & & \\
\cdots CH_2 & - & C & - & CH & - CH_2 - CH_2 - & & & C & - & CH & - CH_2 - CH_2 & \cdots \\
 & & | & & | & & & & | & & | & & \\
 & & S & & S & & & & S & & S & & \\
 & & | & & | & & & & | & & | & & \\
\cdots CH_2 & - & C & - & CH & - CH_2 - CH_2 - & & & C & - & CH & - CH_2 - CH_2 & \cdots \\
 & & | & & & & & & | & & & & \\
 & & CH_3 & & & & & & CH_3 & & & &
\end{array}$$

(Vulcanised rubber)

Advantages of vulcanisation →

Vulcanised rubber has the following advantages —

(i) High resistance to oxidation, wear etc.

(ii) High chemical resistance to organic solvents.

(iii) Better electrical insulation power.

(iv) Good tensile strength and load bearing capacity.

(v) Useful temperature range i.e., -40 to 100°C.

✓ Difference between Raw rubber & vulcanised Rubber

Raw Rubber	Vulcanised Rubber
(i) It is plastic in nature.	It is less plastic.
(ii) Water absorption tendency is high.	Water absorption tendency is low.
(iii) It swells in organic solvents.	It doesn't react with organic solvents.
(iv) It is less durable.	It is more durable.
(v) It is attacked by oxidising agents	It is not attacked by oxidising agents.

Chemicals in Agriculture

Pesticides - Pesticides are substances that are meant to control pests.

The term pesticide includes all of the following.

(i) Insecticides (ii) herbicides

(iii) fungicides. etc ~~(iv)~~

Insecticides → used to kill insects

Ex. - Chlorinated hydrocarbons like DDT, BHC etc.

Uses → Insecticides are used in agriculture, medicine, industry

other examples of insecticides → Gammaxane (BHC), Aldrin, Dieldrin.

Herbicides → Herbicides are chemicall substances used to control unwanted plants. These are commonly known as weedkillers.
Ex - Glufosinate ammonium.

Uses - Herbicides can be used to clear roadside weeds. These are commonly applied in ponds and lakes to control algae and plants such as water grasses that can interfere with activities like swimming and fishing

Fungicides → Fungicides are substances used to kill or inhibit the growth of fungi.
Ex.- Captan, Sulfur, ~~etc~~ Bleaching powder, $CuSO_4$ solution, AlP (Aluminium phosphide)

Uses - These are used to control fungi that damage plants, ~~including rusts~~, mildews and ~~blights~~

Bio Fertilizers →

~~A~~ Biofertilizers are environmental friendly substitute for harmful chemicals fertilizers.
They transform organic matter into nutrients that can be used to make plants healthy and productive.
The microorganisms in biofertilizers restore the soil's natural nutrient cycle and build soil organic matter.
These are extremely advantageous in enriching soil fertility and fulfilling plant nutrient requirements.
Ex - Rhizobium, Azotobacter, Azospirilium and blue green algae.

Uses → (i) Rhizobium inoculant is used for leguminous crops.
(ii) Azotobacter can be used with crops like wheat, maize, mustard etc.
(iii) Blue green algae is used for paddy crops
(iv) Azospirilium is used for maize, sugarcane, millets etc.