Physical Chemistry

Chapter - 1

Atomic Structure

Fundamental Particles

① Electron – An electron is defined as sub atomic particle having a unit negative charge & mass equal to 1/1835th the mass of the hydrogen atom.

Mass of electron – $(9.1 \times 10^{-31} kg)$

Charge on electron – $(-1.6 \times 10^{-19} Coulomb)$

② Proton – A proton is defined as sub atomic particle having a unit positive charge & mass equal to that of hydrogen atom.

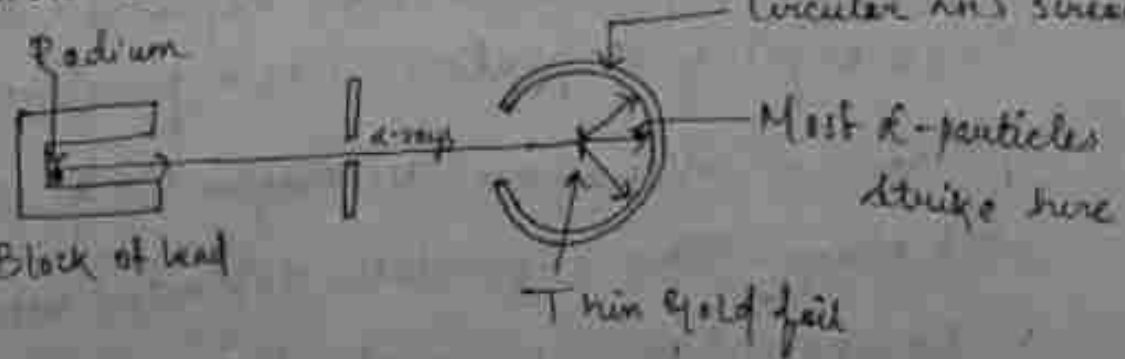
Mass of proton – $(1.67 \times 10^{-27} kg)$

Charge on proton – $(+1.6 \times 10^{-19} Coulomb)$

③ Neutron – It is defined as the neutral sub atomic particle having a mass $1.67 \times 10^{-}$

Rutherford's Atomic Model
or
Rutherford Gold Foil Experiment.

In 1911, Rutherford performed the famous Gold foil Experiment. He bombarded thin Gold foil (100 nm thick) with a beam of fast moving α-particles. The source of this α particles (or positively charged particles) was radium, a radioactive substance, placed in a block of lead. Slits were used to get a fine beam. The presence of α-particle at any point was detected with the help of a circular Zinc sulphide screen. When an α particle strikes this screen, a flash of light is given out.

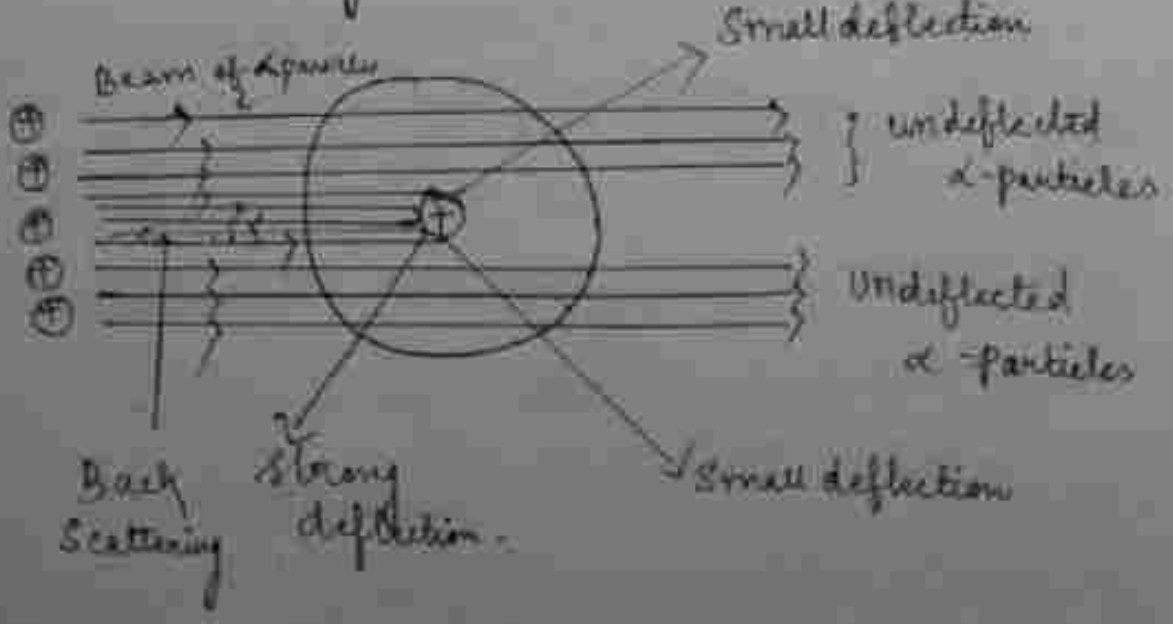


Rutherford Scattering Experiment

Observations & Conclusions

From Rutherford Scattering Experiment following are the observations & conclusions ——

1. Most of the α-particles were undeflected i.e. they passed straight through the Gold foil without any deviation. This clearly indicates the most of the parts of an atom are empty.
2. A few α-particles were found to be deflected strongly from their normal paths. This indicates the presence of a massive (heavy) positively charged body inside the atom. This massive positively charged body is called nucleus.
3. A very few (0.01%) α particles were found to be retraced their original paths (deflected through about 180°). This indicates that the size of nucleus is very small.



Postulates of Rutherford Atomic Model.

(1) An atom consists of two parts; they are i) Nucleus ii) Extra-Nuclear Part.

(2) Every atom consists of a very small but heavy positively charged body, called nucleus.

(3) The whole mass of an atom is concentrated at the nucleus.

(4) The electrostatic force of attraction (acting inward) between the nucleus & electrons is balanced by the centrifugal force (acting outward) arising due to the motion of electrons. This is why the electron do not fall into the nucleus.

Drawbacks or Failure of Rutherford's Atomic Model

(1) Stability of atom — The theory fails to explain about the stability of atoms.

As to ~~the~~ of classical electrodynamics, if an electrically charged particle revolves around circular path, then it always radiates out energy.

Thus, when electron moves around the nucleus, it continuously radiate out energy & hence, gradually move towards the nucleus in spiral path, till it collide with the nucleus.

(2) Rutherford Atomic Model failed to explain the structure of atom i.e. the distribution of electrons around the nucleus & their energies.

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

Bohr's Atomic Model

In 1913, Neil's Bohr put forward the new model of atomic structure. This atomic model is based upon the quantum theory of energy.

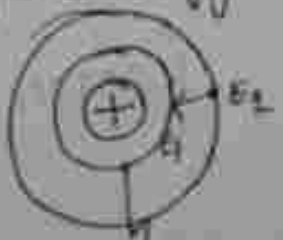
Postulates

1. An atom consists of a massive positively charged nucleus.
2. Electrons revolve around the nucleus in certain fixed circular paths called orbits or shells.
3. Each orbit has a definite energy & therefore known as stationary energy level or shell. These orbits are numbered as 1, 2, 3, 4 or designated as K, L, M, N.

4. As long as an electron remains in a particular shell, it neither emits nor absorbs any energy. ie the energy of an electron in a given orbit is fixed (or quantized). Such orbits are called stationary energy states.

5. An electron can make a transition from a stationary state of higher energy E_2 to a stationary state of lower energy E_1 by emitting energy. Similarly, on absorbing energy, the electron makes transition from lower energy E_1 to higher energy E_2.

Energy absorbed
$= E_2 - E_1$



Energy emitted
$= E_2 - E_1$.

6. Only those orbits are allowed for which the angular momentum (mvr) of the electron is integral multiple of $h/2\pi$.

Mass Number – The mass number of an element is defined as the total number of protons & neutrons in an atom.

M no. of an element = No. of protons (p) + No. of neutrons (n)

$$A = p + n$$

Atomic mass – The atomic mass of an element is relative mass of an atom of that element as compared to 1/12 the mass of an atom of carbon (C)

→ The mass number of an element is nearly equal to the atomic mass of that element.

Eg :- Copper → Atomic mass = 63.5 u
→ Mass no = 63

Carbon → Atomic mass = 12.01
→ Mass no = 12

Hydrogen → Atomic mass = 1.008
→ Mass no = 1

Isotopes - The atoms of the same elements which have the same atomic number but different mass numbers are called isotopes.

Eg - $_{1}^{1}H$, $_{1}^{2}H$, $_{1}^{3}H$ — Isotopes of Hydrogen.

$_{17}^{35}Cl$, $_{17}^{37}Cl$ — Isotopes of Chlorine.

$_{6}^{12}C$, $_{6}^{14}C$ — Isotopes of Carbon.

Isobars - The atoms of different elements having the same mass number but different atomic numbers are called Isobars.

Examples — $_{18}^{40}Ar$, $_{19}^{40}K$, $_{20}^{40}Ca$

$_{26}^{58}Fe$, $_{27}^{58}Ni$.

Isotones - Atoms of different elements having same number of neutrons but diff erent mass numbers as well as atomic numbers are called isotones.

Eg — $_{14}^{30}Si$, $_{15}^{31}P$ (neutrons = 16)

$_{6}^{14}C$, $_{7}^{15}N$, $_{8}^{16}O$ (neutrons = 8).

Bohr-Bury Scheme

Bohr-Bury Scheme deals with the arrangement of electrons in various shells.

Postulates of the Scheme are:-

1. A shell can contain a maximum $2n^2$ electrons, where n = number of the shell.

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

2. The outermost shell of an element cannot hold more than 8 electrons.

3. The penultimate shell (the shell just before the outermost shell) cannot hold more than 18 electrons.

4. A higher orbit may start filling before the lower orbit is completely filled.

Arrangements of electrons in different shells of some elements according to Bohr-Bury scheme

Element	Number of electrons			
	K-Shell	L-Shell	M-shell	N-shell
Hydrogen, $_1H$	1			
Helium, $_2He$	2			
Lithium, $_3Li$	2	1		
Fluorine, $_9F$	2	7		
Aluminium, $_{13}Al$	2	8	3	
Calcium, $_{20}Ca$	2	8	8	2
Zinc, $_{30}Zn$	2	8	18	2

Aufbau's Principle (n+l rule)

→ The word "aufbau" means "building up". The building up of orbitals means filling up of orbitals with electrons.

→ Aufbau's principle may be stated as "electrons are filled in different sub-shells in order of their increasing energies."

→ The sub-shell with lowest energy is filled first & those with higher energy are filled later.

The (n+l) Rule.

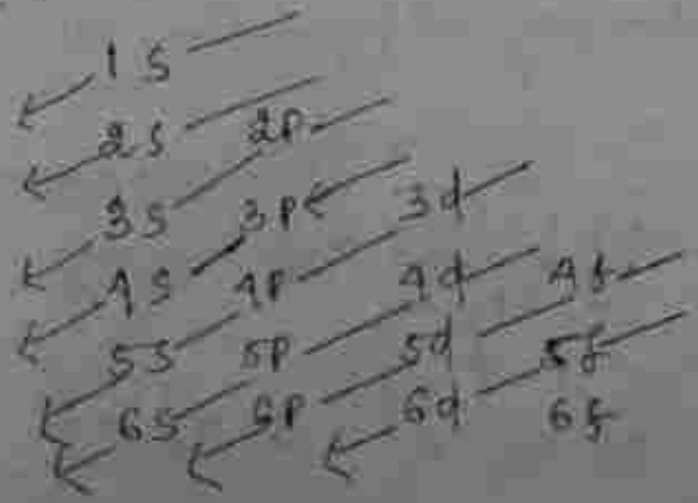
i) The subshell having lower (n+l) value possesses lower energy & is filled first.

ii) If the (n+l) value for two given sub-shells are equal, then the one with lower value of 'n' possesses lower energy & is filled first.

Following the (n+l) rule, let us compare the energy possessed by various sub-shells.

Sub shell	1S	2S	2P	3S	3P	3d	4S	4P
(n+l)	1+0 =1	2+0 =2	2+1 =3	3+0 =3	3+1 =4	3+2 =5	4+0 =4	4+1 =5

Thus, the increasing order of energy content of sub-shells is 1S < 2S < 2P < 3S < 3P < 4S < 3d < 4P.



Hund's Rule of Maximum Multiplicity

Electrons in a subshell are paired only when all the orbit

Hund's Rule of Maximum Multiplicity

Electron pairing in p, d & f orbitals cannot occur until each orbital of a given subshell contains one electron each or is singly occupied.

→ Hund's Rule is also known as Maximum multiplicity Rule

→ Consider, for example, the following illustration

For the element, nitrogen, which contains 7 electrons, the following configuration can be written :

Total Spin of unpaired e

a) $\boxed{1\downarrow}_{1s}$ $\boxed{1\downarrow}_{2s}$ $\boxed{1}\boxed{1}\boxed{1}_{2p_x\ 2p_y\ 2p_z}$ $= \frac{1}{2} + \frac{1}{2} + \frac{1}{2} = 1\frac{1}{2}$

b) $\boxed{1\downarrow}_{1s}$ $\boxed{1\downarrow}_{2s}$ $\boxed{1}\boxed{\downarrow}\boxed{1}_{2p_x\ 2p_y\ 2p_z}$ $= \frac{1}{2} - \frac{1}{2} + \frac{1}{2} = \frac{1}{2}$

c) $\boxed{1\downarrow}_{1s}$ $\boxed{1\downarrow}_{2s}$ $\boxed{1\downarrow}\boxed{1}\boxed{\ }_{2p_x\ 2p_y\ 2p_z}$ $= \frac{1}{2}$

In accordance with Hund's rule, the configuration 'a' in which the three unpaired electrons occupying $2p_x$, $2p_y$ & $2p_z$ orbitals have parallel spins (either all clockwise or anticlockwise) is correct while the configuration (b) in which the unpaired electrons don't have parallel spins is incorrect.

The configuration (c) in which the pairing of the electrons has shown in the $2p_x$ orbital without putting the third electron in $2p_z$ orbital is also not consistent with the Hund's rule of maximum multiplicity

Thus, in accordance with Hund's Rule configuration (a) with with maximum multiplicity of $\frac{1}{2}$ is correct.

Electronic Configuration

Electronic Configuration is the arrangement of an atom in different sub-shells in the increasing order of their energy.

Elements	Electronic Configuration
$_1H$	$1s^1$
$_2He$	$1s^2$
$_8O$	$1s^2 2s^2 2p^4$
$_{17}Cl$	$1s^2 2s^2 2p^6 3s^2 3p^5$
$_{18}Ca$	$1s^2 2s^2 2p^6 3s^2 3p^6$
$_{31}Ga$	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2$

Exceptional Electronic Configuration.

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

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

The above electronic configuration is due to the fact that half-filled & completely filled orbitals are more stable.

Electronic Configuration of some ions

$N^{3-} - 1s^2\ 2s^2\ 2p^6$

$Al^{3+} - 1s^2\ 2s^2\ 2p^6$

$Fe^{3+} - 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5$

$Fe^{2+} - 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6$

$Cu^{2+} - 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^9$

$Cr^{3+} - 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3$

$O^{2-} - 1s^2\ 2s^2\ 2p^6$

$Cl^- - 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

2: Chemical Bonding

Definition – Chemical bond is the force of attraction between the constituents atom.

Types of covalent bond

- Electrovalent / Ionic Bond
- Covalent Bond.
- Co-ordinate Bond.

Why do atoms combine?

The atoms of diff erent elements combine with each other in order to complete their respective octets (ie 8 electrons in their outermost shell) or duplets (ie outermost shell having 2 electrons) in case of H, Li & Be to attain stable nearest gas configuration.

Electrovalent or Ionic Bond

Definition :- An electrovalent or ionic bond formed by complete transfer of electron or electrons from one atom to the other.

Electrovalency – The no. of electrons that an atom gains or loses during the formation of an ionic bond is called its electrovalency.

Examples of compound having Ionic Bond

Formation of NaCl (Sodium chloride)

- Sodium (atomic no = 11) has electronic configuration 2, 8, 1. By losing one electron of its outermost shell, it acquires the inert gas configuration of Neon & changes into Na^+ ion.

$$Na(2,8,1) \longrightarrow Na^+(2,8) + e^-$$

- On the other hand, chlorine (atomic no = 17) having electronic configuration (2,8,7) accepts one electron released by sodium to complete its octet by attaining stable configuration of argon. In this process, chlorine is converted into chloride ion.

$$:\ddot{\underset{\cdot\cdot}{Cl}}\cdot\ (2,8,7) + e^{\ominus} \longrightarrow \left[:\ddot{\underset{\cdot\cdot}{Cl}}:\right]^-_{2,8,8}$$

$$Na^+ + \left[:\ddot{\underset{\cdot\cdot}{Cl}}:\right]^- \longrightarrow [Na]^+ \left[:\ddot{\underset{\cdot\cdot}{Cl}}:\right]^-$$

or

NaCl.

→ The above steps may be represented as follows.

$$Na\cdot\ (2,8,1) + :\ddot{\underset{\cdot\cdot}{Cl}}:\ (2,8,7) \longrightarrow Na^+\ (2,8) + \left[:\ddot{\underset{\cdot\cdot}{Cl}}:\right]^-\ (2,8) \longrightarrow NaCl.$$

Formation of $MgCl_2$ (Magnesium Chloride)

- Magnesium (atomic number = 12) has electronic configuration 2,8,2. By losing 2 electron of its outermost shell, it acquires the inert gas configuration of neon & changes into Mg^{2+} ion.

$$Mg: (2,8,2) \longrightarrow Mg^{2+}(2,8) + 2e^-$$

- On the other hand, Chlorine (atom no = 17; elect. conf = 2,8,7) on gaining one electron forms Chloride ion & acquires the stable configuration of Argon.
- Here, Magnesium atom loses two electrons & forms Mg^{2+} ion & the two electrons are transferred to two chlorine atoms, which are converted into chloride ions.

$$Mg\ (2,8,2) \longrightarrow Mg^{2+}(2,8) + 2e^-$$

$$:\ddot{Cl}: (2,7) + e^- \longrightarrow [:\ddot{Cl}:]^-$$

$$Mg^{2+} + 2[:\ddot{Cl}:]^- \longrightarrow Mg^{2+} + 2[:\ddot{Cl}:]^-$$

or

$MgCl_2$

The above steps may be represented as

$$:\ddot{Cl}: + Mg + :\ddot{Cl}: \rightarrow Mg^{2+} 2[:\ddot{Cl}:]^-$$

or

$MgCl_2$

Covalent Bond

The bond formed between the two atoms by mutual sharing of electrons between them so as to complete their octets or duplets in case of elements having only one shell is called covalent bond or covalent linkage.

Covalency – The number of electrons contributed by each atom is known as covalency.

Examples of compounds having covalent bond

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 atom approach each other, at a certain inter nuclear distance, they share their valence electrons & 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.

$$H\cdot + \cdot H \longrightarrow H:H \text{ or } H-H$$

(2) Formation of O_2 molecule —

- An oxygen atom (2,6) contains 6 valence electrons & needs two more electrons to achieve the octet.
- When two oxygen atoms approach each other, they can achieve the octets by contributing two electrons each & thus forming two bond pairs.

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

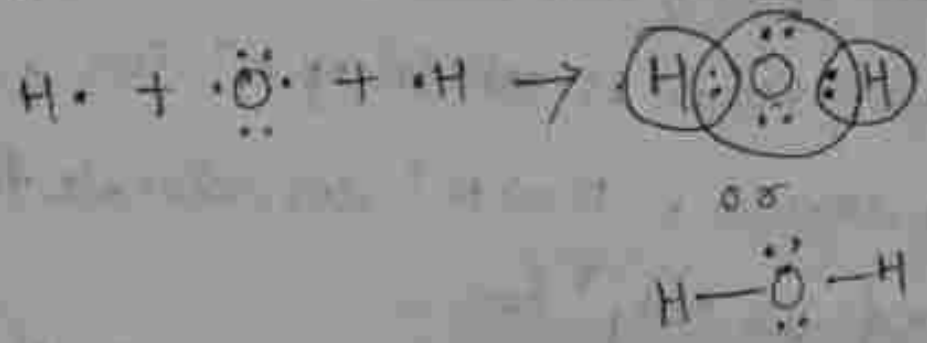
(3) Formation of NH_3

- Nitrogen atom (2,5) has 5 valence electrons & can achieve the octet by sharing three electrons, one with each of the three hydrogen atom.

- Thus NH_3 molecule contains 3 covalent bond pairs

② Formation of H_2O molecule.

- Oxygen atom (2,6) can achieve the octet by sharing two electrons, one with each of the two hydrogen atoms, leading to the formation of H_2O molecule as follows:

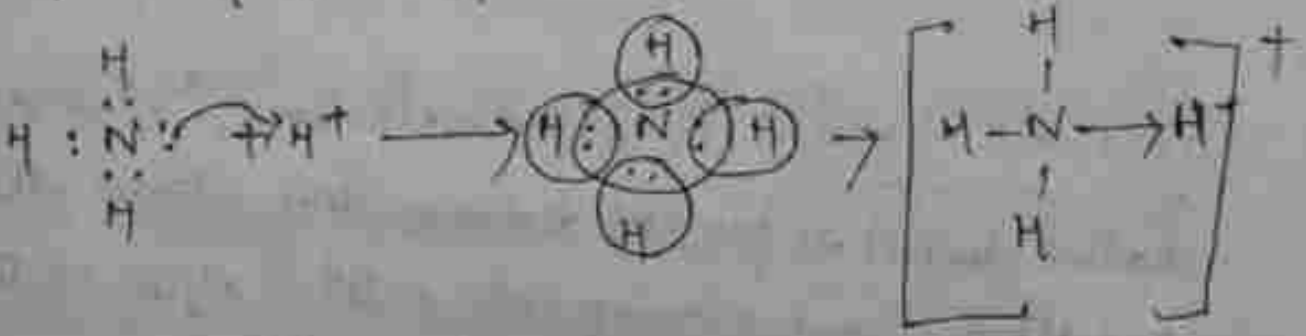


- Coordinate Bond — A coordinate bond (also called dative bond) is formed between two atoms when one atom having complete octet (after mutual sharing) donates an electron pair to the other atom, the donated electron is shared by both the atoms so as to complete their octets of duplets.
- The atom which contributes the electrons is called the donor while the other which only shares the electron pair is known as acceptor.
- This bond is usually represented by an arrow.

Examples of molecules/ions having coordinate bond

① Ammonium ion (NH_4^+) – The ion is formed by combination of NH_3 molecule with H^+ ion.

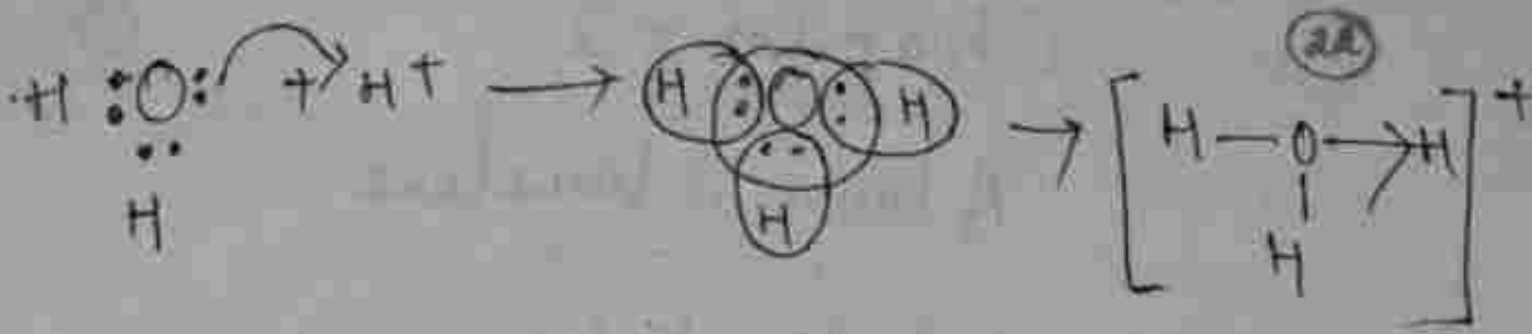
- N-atom of NH_3 molecule donates an electron pair to vacant 1s orbital of H^+ ion.
- As a result, $N \rightarrow H^+$ coordinate bond is formed in NH_4^+ ion.



Formation of NH_4^+.

② Hydronium ion (H_3O^+) – The molecule is formed by combination of water molecule with H^+ ion.

- Oxygen atom of H_2O molecule donates an electron pair to vacant 1s orbital of H^+ ion.
- As a result, $O \rightarrow H^+$ coordinate bond is formed in H_3O^+ ion.



Formation of Hydronium Ion.

Chapter-3

Acid-Base Theory

Arrhenius Theory

POSTULATES

i) A/c to Arrhenius theory, "Acids are the substances which produce H^+ ions (protons) in aqueous solution while bases are the substances which produce OH^- ions in aqueous solution."

Acids:
$$HCl(g) + aq \rightleftharpoons H^+(aq) + Cl^-(aq)$$
$$HNO_3(l) + (aq) \rightleftharpoons H^+(aq) + NO_3^-(aq).$$
$$CH_3COOH(l) + aq \rightleftharpoons H^+(aq) + CH_3COO^-(aq)$$

Base:
$$NaOH(s) + aq \rightleftharpoons Na^+(aq) + OH^-(aq)$$
$$NH_4OH + aq \rightleftharpoons NH_4^+(aq) + OH^-(aq).$$

ii) Neutralisation of an acid & base is based on the key reaction between H^+ ion & OH^- ion to form water molecules.

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

iii) During electrolysis of an aqueous solution of an acid, H^+ ions proceed to the cathode & 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) Nature of hydrogen ion & hydroxyl ion — A/c to Arrhenius, an acid releases H^+ ions in aqueous medium. However, it has been found that H^+ ion is a proton which cannot exist fundamentally independently.

ii) It fails to explain the acidic & the basic properties 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 doesn't explain the basic nature of substances like NH_3, CaO, etc which don't contain OH group.

iv) It fails to explain neutralisation reactions in absence of water. We K now that the following neutralisation reaction take place even in the absence of water.

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

$$NH_3(g) + HCl(g) \longrightarrow NH_4Cl(s).$$

Such reactions donot involve the combination of H^+ ions & OH^- ions to produce water which should occur as per Arrhenius theory.

Bronsted-Lowry Concept of Acid & Base

A/c to Lowry-Bronsted theory "Acids are the substances (molecules/ion) which donate a proton (H^+ ion) to any other substance, while bases are the substances (molecules/ions) which accept a proton (H^+ ion) from any other substance".

Postulates

- Acids are proton donors whereas base are proton acceptors.

Acids: $HCl \rightleftharpoons H^+ + Cl^-$

$H_3O^+ \rightleftharpoons H^+ + H_2O$

Bases: $NH_3 + H^+ \rightleftharpoons NH_4^+$

$CO_3^{2-} + H^+ \rightleftharpoons HCO_3^-$

$H_2O + H^+ \rightleftharpoons H_3O^+$

- Whenever an acid reacts with a base, we get another pair of acid & base. For eg, HCl reacts with water (base) to form H_3O^+ (acid) & Cl^- (base).

$HCl + H_2O \rightleftharpoons H_3O^+ + Cl^-$ (25)

(acid)$_1$ · base$_2$ · acid$_2$ base$_1$

1) Neutralisation process is simply the transfer of proton between an acid & a base.

$$HCl + NH_3 \rightleftharpoons NH_4^+ + Cl^-$$

All Arrhenius acids are Bronsted acids but all Bronsted base are not Arrhenius base

⇒ A/c to this theory an acid reacts with a base to form another pair of acid & base, this pair of acid & base differ by a proton (H^+ ion) is called a conjugate acid-base pair.

Acid $- H^+ \longrightarrow$ Conjugate Base

Base $+ H^+ \longrightarrow$ Conjugate acid.

Some Acid-Base pairs

Acid	Conjugate Base	Base	Conjugate acid
H_3O^+	H_2O	NH_2^-	NH_3
NH_4^+	NH_3	OH^-	H_2O
CH_3COOH	CH_3COO^-	$H_2PO_4^-$	H_3PO_4
H_2SO_4	HSO_4^-	HS^-	H_2S

⇒ The substance which act both as acid as well as an base is known as Amphoteric Substance.

Eg ⇒ H_2O, HS^-, HCO_3^-, HPO_4^{2-}, HSO_4^-

Limitations of Bronsted Theory

- It fails to explain the acidic nature of the substances such as SiO_2, CO_2, SO_2, BF_3, etc which cannot donate H^+ ion.
- It fails to explain the basic nature of the substances, such as Na_2O, K_2O, CaO, etc which cannot except H^+ ion.
- It fails to explain the reaction between some acids & bases which do not give another pair of acid & base. Eg - $HCl + NaOH \rightarrow NaCl + H_2O$.

Lewis Theory

A/c to lewis theory, "Acids are the substances (molecules / ions) which can accept a pair of electrons from any other substances, while bases are the substances (molecules / ions) which can donate a pair of electrons to any other substance."

Postulate

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

Examples of Acids

i) All cations are lewis Acids. Eg — Na^+, K^+, Al^{3+} etc.

ii) Neutral molecules containing electron deficient atoms are lewis acids. For eg — $AlCl_3$, $FeCl_3$, ZnH_2.

iii) Neutral molecules containing vacant -d orbitals in the central atom for the accomodation of incoming electrons act as lewis acids. For eg- $SiCl_4$, SiF_4, etc.

iv) The molecules having multiple bonding (= or ≡) between the atoms of different elements are acidic in nature. For eg - CO_2 (O=C=O), SO_2, etc.

Examples of Bases.

i) All anions are lewis bases :- F^-, Cl^-, CO_3^{2-} etc.

ii) Neutral molecules containing, at least one lone pair of electrons are lewis bases

- A/c to this theory, an acid reacts with a base to form an acid-base complex which involves a coordinate bond or dative bond.

For eg- $H_2\ddot{O}: + H^+ \longrightarrow H_3O^+$ or $\left[H_2O \rightarrow H\right]^+$

base acid

- All Bronsted lowry bases are lewis bases while the reverse is not true.

Limitations

i) According to this theory, the reaction between an acid & base results in the formation of a dative bond. Formation of a coordinate bond is a slow process. While the reactions between the acids such as HCl, HNO_3, H_2SO_4 & the bases such as NaOH, KOH, etc are instantaneous or fast.

ii) Catalytic activity of lewis acid cannot be explained.

iii) The theory fails to explain the relative strengths of different acids & bases.

Neutralisation Reaction

A neutralization reaction is when an acid & a base react to form water & salt.

$$NaOH + HCl \longrightarrow NaCl + H_2O$$

Salt – A salt is an crystalline / amorphous compound which is formed by the complete neutralisation of aqueous strong acid with an aqueous solution of a strong base.

or

Salt is regarded as ionic compounds made up of positive & negative ions. The positive part comes from a base while negative part comes from an acid.

Types of Salts

i) Normal Salts – These are the salts which are formed by the complete neutralisation of aqueous

Types of Salts

i) Normal Salts – These are the salts which are formed from strong acids (HCl, H_2SO_4, HNO_3) & strong bases ($NaOH$, KOH etc).

Example – $NaCl$, K_2SO_4, Na_2SO_4.

ii) Acidic Salts – These salts are formed by incomplete neutralisation of polybasic acids. Such salts are $NaHCO_3$, $NaHSO_4$, NaH_2PO_4

iii) Basic salts – These salts are formed by incomplete neutralisation of poly acid bases. Eg – $Mg(OH)Cl$, $Zn(OH)Cl$, $Fe(OH)Cl$.

iv) Double salts – These are the addition compounds formed by combination of two simple salts. Eg – $K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$ & $FeSO_4(NH_4)_2SO_4 \cdot 6H_2O$

v) Complex Salts – These are the compounds formed by the combination of simple salts or molecular compounds.

Eg – $K_4[Fe(CN)_6]$, $[Cu(NH_3)_4]SO_4$

vi) Mixed Salts – These are the salts which furnish more than one cation or more than one anion which dissolved in water. Eg – $CaOCl_2$, $NaKSO_4$.

4: Solutions

Solution — Homogeneous mixture of two or more chemically non reacting substances in single phase is called solution.

Concentration of solution — The amount of solute in a given solvent or solution is called concentration of solution.

Methods to Express Concentration of solution: There are different modes of expressing of solution. Some of these are:—

(1) Molarity (M): The number of moles of solute present in one litre or per litre of solution is called molarity.

It is represented as 'M' or 'mol/l'.

$$\text{Molarity (M)} = \frac{\text{No. of moles of solute}}{\text{Volume of solution in litre (ml)}} \times 1000$$

Numericals

1) 4g of NaOH are dissolved in 200 cm^3 of water. Find the molarity of solution.

Sol^n: Molarity of NaOH = $\frac{\text{no. of moles of solute}}{\text{vol. of solution (ml)}} \times 1000$

$$\text{no. of moles of solute} = \frac{\text{weight of solute}}{\text{molecular mass of solute}} = \frac{4}{40}$$

$$\text{molarity of NaOH} = \frac{4 \times 1000}{40 \times 200} = 0.5\,M \text{ or } 0.5 \text{ mol/ltr}$$

2) Calc. molarity when 73 gm of HCl is dissolved in water to make 1500 ml solution.

$$\text{Molarity of } \underset{\text{soln}}{HCl}(M) = \frac{73 \times 1000}{36.5 \times 1500} = 1.33M.$$

3) Molality (m) — Molality of a solution is defined as the no. of moles of solute present in 1kg of the solvent.

$$\text{Molality (m)} = \frac{\text{No. of moles of solute}}{\text{Weight of solvent in kg}}$$

Q What is the molality of a solution containing 0·25 mole of solute in 250 gm of the solvent?

$$\text{molality} = \frac{\text{no of moles of solute}}{\text{wt of solvent in (gm)}} \times 1000$$

$$= \frac{0.25 \text{ mol}}{250} \times 1000$$

$$= 1\text{m or } 1 \text{ mole/kg}.$$

Q 29·25 gm of NaCl is present in 529·25 gm of the solution. Find out the molality.

$$\text{molality} = \frac{\text{no. of moles of solute}}{\text{wt of solvent in (gm)}} \times 1000$$

$$= \frac{29.25}{58.5} \times \frac{1000}{529.25} = 0.945 \text{ mol/kg}$$

or

0·945 m.

Normality (N) — The number of gram equivalents of solute present in one litre of solution.

$$\text{Normality} = \frac{\text{No. of gram equivalent of solute}}{\text{Volume of solution (ml)}} \times 1000$$

$$\text{No. of gram equivalents of solute} = \frac{\text{mass of solute in gram}}{\text{Equi. wt of solute}}$$

① Find out the weight of NaOH required to prepare 2 litres of N/10 solution.

$$\text{Normality} = \frac{\text{no. of gm. equiv of Solute}}{\text{vol. of solution (ml)}} \times 1000$$

$$\Rightarrow \frac{1}{10} = \frac{x}{2} \Rightarrow x = 0.2 \text{ gram equiv}$$

$$\text{No. of gram equivalent} = \frac{\text{Wt of Solute in gm}}{\text{molecular mass}}$$

$$\Rightarrow 0.2 \text{ gram equiv} = \frac{x}{40}$$

$$\Rightarrow x = 0.2 \times 40$$

$$= 8 \text{ gm}$$

Relationship between molarity & Normality.

molarity × molecular mass of solute
= Normality × Equivalent Mass of Solute

② Calc the molarity of Seminormal Na_2CO_3 solution.

Soln: · Seminormal = 0.5 N.

$$\text{molarity} = \frac{\text{normality} \times \text{Equivalent mass of Solute}}{\text{molecular mass of solute}}$$

$$= \frac{0.5 \times 53}{106} = 0.25 \text{ M}$$

Commonly used molarity & Normality terms.

$\frac{M}{10}$ — Decimolar Solution — $\frac{1}{10}$ mole/litre = 0.1M

$\frac{N}{10}$ — Decinormal Solution — $\frac{1}{10}$ gm equiv/litre = 0.1N

$\frac{M}{100}$ — Centimolar Solution — $\frac{1}{100}$ mole/litre = 0.01M

$\frac{N}{100}$ — Centinormal Solution — $\frac{1}{100}$ gm equiv/litre = 0.01N

$\frac{M}{2}$ — Semimolar Solution — $\frac{1}{2}$ mole/litre = 0.5M

Definition of PH

PH of the solution is defined as the negative logarithm of H^+ ion concentration.

$$pH = -\log [H^+]$$

① Calculate pH of 0.001 M HCl ?

molarity = $[H^+]$

= 0.001

= 1×10^{-3}

$$pH = -\log[10^{-3}]$$

$$= -(-3)\log 10$$

$$= 3.$$

② How many grams of KOH are required to prepare 2 litre of its solution having pH = 12.

$$pH = 12.$$

$$[H^+] = 10^{-12}.$$

$$[H^+] = \frac{K_w}{[OH^-]}$$

$$\Rightarrow 10^{-12} = \frac{10^{-14}}{[OH^-]}$$

$$\Rightarrow [OH^-] = \frac{10^{-14}}{10^{-12}} = 10^{-2}$$

We required to find concentration of $[OH^-]$ as a base i.e. KOH is given.

$[OH^-]$ = molarity of KOH solution

$= 10^{-2}$ M.

$$\text{Molarity} = \frac{\text{Amt of Solute}}{\text{molecular mass of solute}} \times \frac{1000}{\text{Volume of Solution(ml)}}$$

$$10^{-2} = \frac{x}{56} \times \frac{1000}{2}$$

$$\Rightarrow x = 2 \times 56 \times 10^{-2}$$

$$= \frac{2 \times 56}{100} = 1.12 \text{ gms}$$

(37) Calculate PH of a solution containing 4 gm of NaOH present in 1 litre of its solution.

$$\text{molarity} = \frac{\text{No. of grams of solute}}{\text{mol. mass of solute} \times \text{vol. of soln (l)}}$$

$$= \frac{4}{40 \times 1} = 0.1\ M$$

Here, molarity = $[OH^-]$ as NaOH is base.

$$[H^+] = \frac{k_w}{[OH^-]}$$

$$= \frac{10^{-14}}{10^{-1}} = 10^{-13}\ M.$$

$$PH = -\log [H^+]$$

$$= -\log [10^{-13}] = -(-13) \log 10$$

$$= 13.$$

Importance of PH in Industries

1. PH play very important role in crystallization of sugar in sugar industries.
2. PH is very important for paper industries

5: Electrochemistry

What is electrochemistry?

The branch of chemistry which deals with the study of relationship between electrical energy, chemical energy & interconversion of one from into another is called electrochemistry.

What is electrolysis?

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

What is electrolyte?

The substances which conduct electricity in their fused or in aqueous solution are called electrolysis.

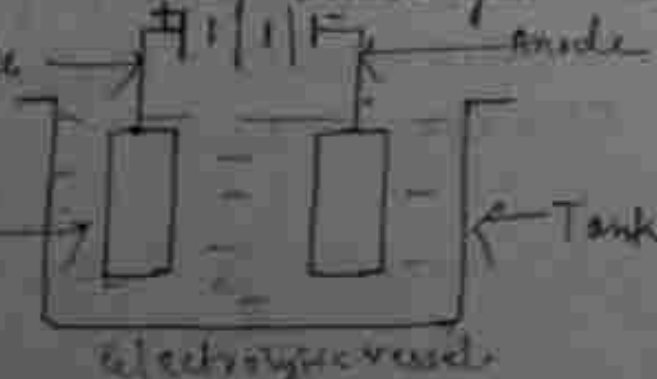
Eg:- NaCl, $CaCl_2$, etc.

Electrolytic Cell

It is a device in which electrical energy is converted in to chemical energy.

Process of Electrolysis

- The process of electrolysis is carried out in a vessel known as **electrolytic tank**.
- It is made up of some insulating material such as glass, stone, cement, etc.
- Fused electrolyte or an aqueous solution of the electrolyte is taken in an electrolytic tank & two metallic plates are dipped in the electrolyte. The plates are known as **electrodes**.
- The electrodes are connected to external source of battery. The electrode connected with positive end of the battery is called **anode** & the electrode which is connected to the negative end is called **cathode**.
- When an electric current is passed through the solution, cations move towards the cathode, whereas anions move towards the anode.
- This movement of ions towards oppositely charged electrodes is called **electrolytic conduction**.



Strong Electrolytes – The electrolytes which dissociate or ionize completely into ions in either molten or aqueous state are called strong electrolytes.

Eg:- HCl, H_2SO_4, HNO_3, KOH, $NaOH$, $NaCl$, KCl, etc.

Weak Electrolytes – The electrolytes which dissociate partially into ions in their molten or aqueous state is called weak electrolytes.

Eg:- CH_3COOH, H_2CO_3, NH_4OH, $AgCl$, etc.

Electrolysis of Aqueous Sodium Chloride (Platinum Electrode)

$$NaCl \longrightarrow Na^+ + Cl^-$$
$$H_2O \longrightarrow H^+ + OH^-$$

At cathode H^+ will be discharged because of low discharge potential

$$H^+ + e \longrightarrow H \text{ (unstable)}$$
$$H + H \longrightarrow H_2 \uparrow$$

At anode Cl^- ions are discharged easily than OH^- ions because of low discharge potential

$$Cl^- - e \longrightarrow Cl \text{ (unstable)}$$
$$Cl + Cl \longrightarrow Cl_2 \uparrow$$

Electrolysis of fused NaCl, (Platinum electrode)

In fused NaCl,

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

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

At anode : $Cl^- - e^- \longrightarrow Cl$ (unstable)

$$Cl + Cl \longrightarrow Cl_2 \uparrow$$

Therefore, at cathode sodium metal is deposited & at anode chlorine gas is liberated.

Faraday's 1st laws of Electrolysis :

According to Faraday's first law of electrolysis,

"The amount of the substance deposited or liberated at electrodes is directly proportional to the quantity of electricity passed through electrolyte."

'W' is the mass of substance deposited or liberated at electrode.

Then; $W \propto Q$

We know $Q = C \cdot t$

where C = current in amperes

t = time in seconds

Thus $W \propto C.T$

or $\boxed{W = ZCT}$

Where Z is a constant called Electrochemical Equivalent.

In the above relationship, if c = 1 ampere & t = 1 second then $\boxed{W = Z}$

Thus, electrochemical equivalent of the substance is the amount of the substance deposited or liberated on electrode, when 1A current is passed through its electrolytic solution for 1 sec.

Quantity of electric charge (Q) = 1 Amp × 1 sec
= 1 Coulomb.

$\boxed{1 \text{ Faraday} = 96500 \text{ Coulomb}}$

Faraday's Second law of Electrolysis:

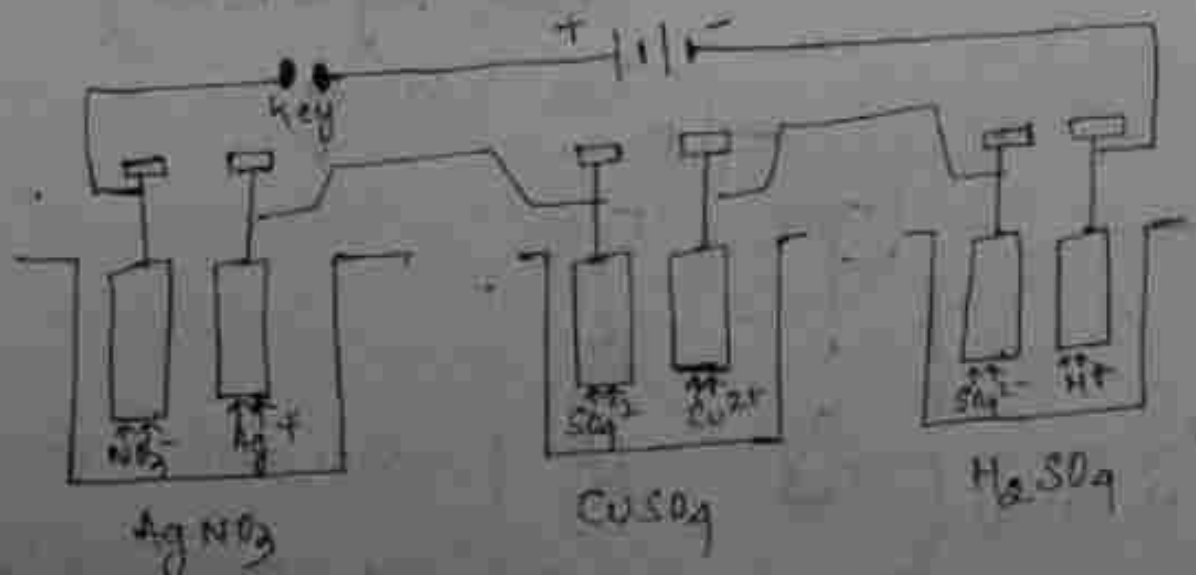
A/c to Faraday's second law of electrolysis, "The amount of substances deposited or liberated at the electrodes by passing the same quantity of electricity through solutions of different electrolytes is directly proportional to their equivalent weights or their electrochemical equivalent

Explanation :-

- Consider three electrolytic cells containing Copper Sulphate, Silver Nitrate & Sulphuric Acid respectively.
- They are connected in series as shown in diagram
- On passing the current through the three cells for some time, the three cells receive the same amount of electricity.
- The weights of Copper, Silver & Hydrogen are in the ratio of their equivalent weights.

$$\frac{\text{Weight of Copper deposited}}{\text{Weight of Silver deposited}} = \frac{\text{Equiv mass of Copper}}{\text{Equivalent mass of Silver}}$$

& $$\frac{\text{Weight of Hydrogen}}{\text{Weight of Copper deposited}} = \frac{\text{Equivalent mass of Hydrogen}}{\text{Equivalent mass of Copper.}}$$

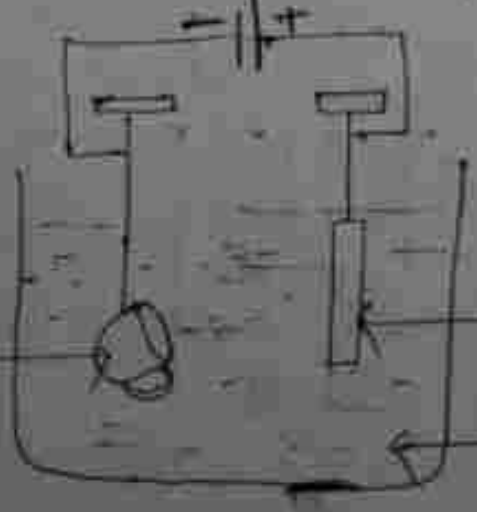


Industrial Application of Electrolysis

Electroplating :- The process of coating a layer of superior metal on inferior metals surface by electrolysis is called electroplating. The electroplating is done —

1. To protect the metal or alloy from corrosion.
2. To improve the surface & provide aesthetic look to metal.

Zinc Plating :- The process of coating a layer of Zinc metal (Superior metal) on inferior metal (Iron, ~~steel~~) by electrolysis is called "Zinc Plating".



Cup act as cathode

- The metal to be electroplated or inferior metal (Say Fe) is made cathode.
- The rod of superior metal (Zinc) is made the anode.
- $ZnSO_4$ (Zinc Sulphate Soln) is taken as electrolyte.
- On passing currents (electricity) the Zinc anode dissolve & pass into the solution in the form of ions & same no. of ions from solution deposit on cathode.

Electrode reactions :—

Anode : $Zn \rightarrow Zn^{2+} + 2e^-$

Cathode : $Zn^{2+} + 2e^- \rightarrow Zn$

6: Corrosion

What is Corrosion?

- Corrosion may be defined as gradual deterioration & consequent loss of solid metal by chemical or electrochemical reaction with its environment.

[08]

- Corrosion is a process which involves the conversion of metal into an undesirable compound (usually oxide) on exposure to atmospheric conditions ie moisture & oxygen.

What are the examples of Corrosion?

- (1) Rusting of Iron
- (2) Tarnishing of Silver
- (3) Development of green coating on copper & Bronze.

Types of Corrosion

- Atmospheric Corrosion
- Waterline Corrosion.

What is Atmospheric Corrosion?

Atmospheric Corrosion is the deterioration or destruction of a material or its vital properties due to electrochemical as well as other reactions of its surface with the constituents of the atmosphere surrounding the materials such as water, gases like CO_2 & SO_2, etc.

Mechanism of Atmospheric Corrosion

- Atmospheric Corrosion can be explained by electro-chemical theory.
- Commercial form of iron behaves like small electric cells in presence of water containing dissolved O_2, CO_2 or SO_2.

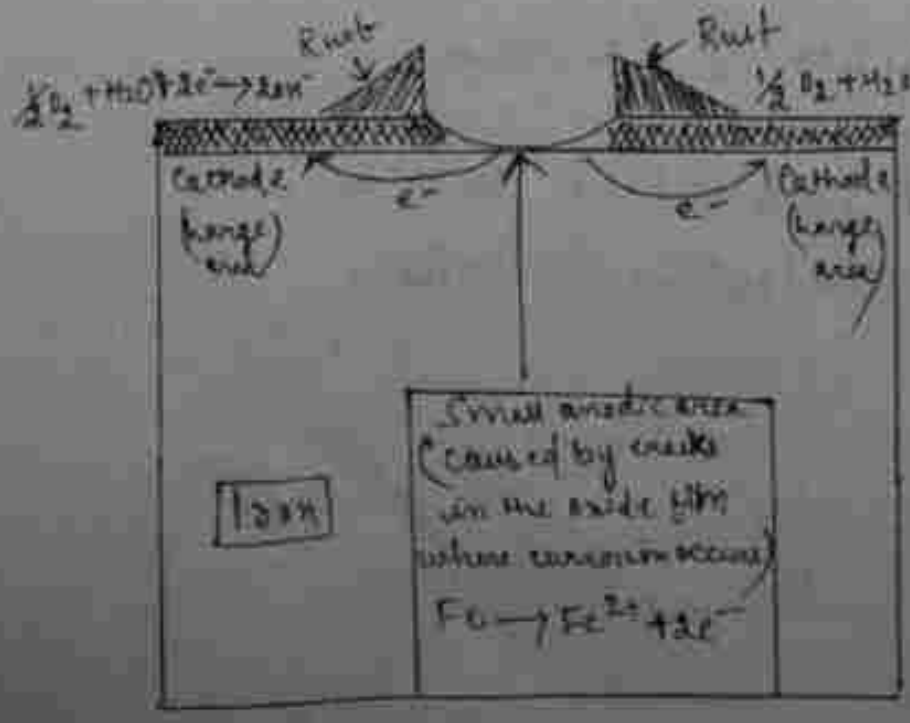


Fig: Rusting of Iron

- The surface of iron is usually coated with a thin film of iron oxide.
- However, if this iron oxide film develops some cracks, anodic areas are created on the surface, while the well-metal parts act as cathodes.
- Anodic areas are small while the rest of the surface of metal forms large cathodes

- At Anode

The metal (iron) dissolves as ferrous ions with liberation of electrons (oxidation)

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

- The liberated electrons flows from anode to cathode through iron metal, where electrons are intercepted by dissolved oxygen

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

- The Fe^{2+} ions at (anode) & OH^- ions at cathode diffuse & when they meet, ferrous hydroxide is precipitated.

$$2Fe^{2+} + 4OH^- + H_2O + O \longrightarrow 2Fe(OH)_3$$

or

$$Fe_2O_3 \cdot 3H_2O$$

(Rust)

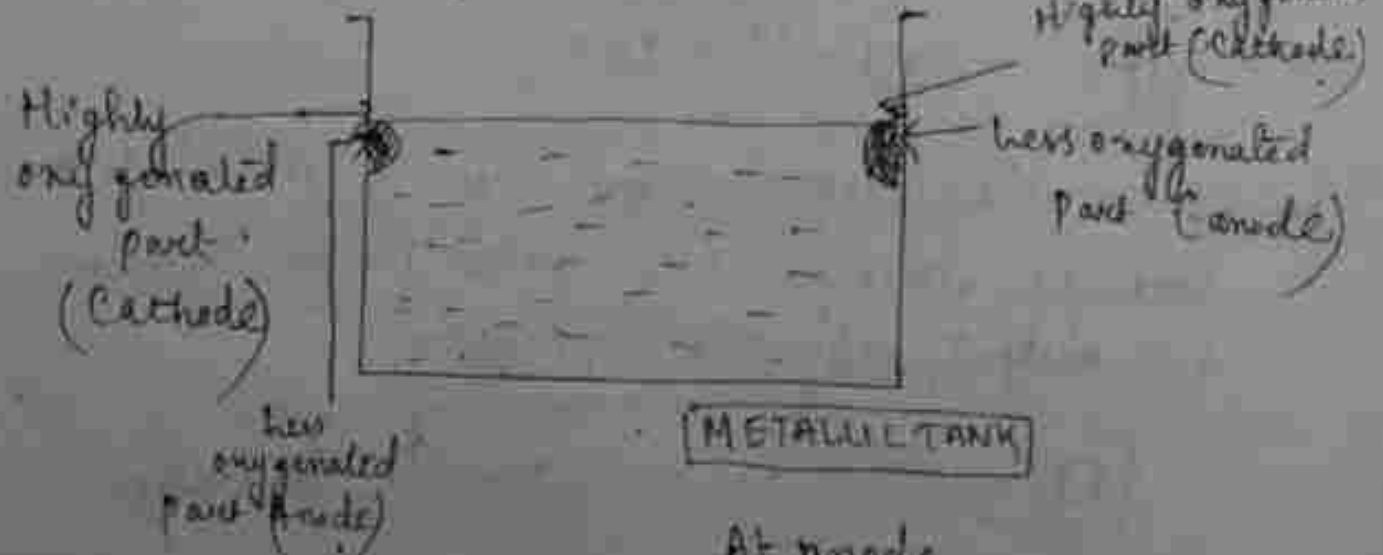
Waterline Corrosion

— Waterline corrosion occurs due to differential oxygen concentration.

— When water is stored in steel tank, considerable corrosion takes place along a line just below the level of maximum.

— The area above the waterline is cathode as it is highly oxygenated.

— The area below the waterline is anode as it is poorly oxygenated.



At anode

$2Fe \longrightarrow 2Fe^{2+} + 2e^-$ (Oxidation)

At cathode

$O + H_2O + 2e^- \longrightarrow 2OH^-$ (Reduction)

Overall Reaction

$2Fe^{2+} + 4OH^- + H_2O + O \rightarrow 2Fe(OH)_3$

or

Rust $\longrightarrow Fe_2O_3 \cdot 3H_2O$

Occurrence :

This type of corrosion occurs in ships, water tanks, pipelines, etc.

Prevention :

- We can use Antifouling paints to marine ships to prevent waterline corrosion.

Protection from Corrosion:

We can protect the metal from corrosion in various methods ——

a) Alloying — Corrosion resistance of most metals is best increased by alloying them with suitable elements, but for maximum corrosion resistance, alloy should be completely homogeneous.
— Alloys resist corrosion in 2 ways
i) Homogenity
ii) Oxide film.

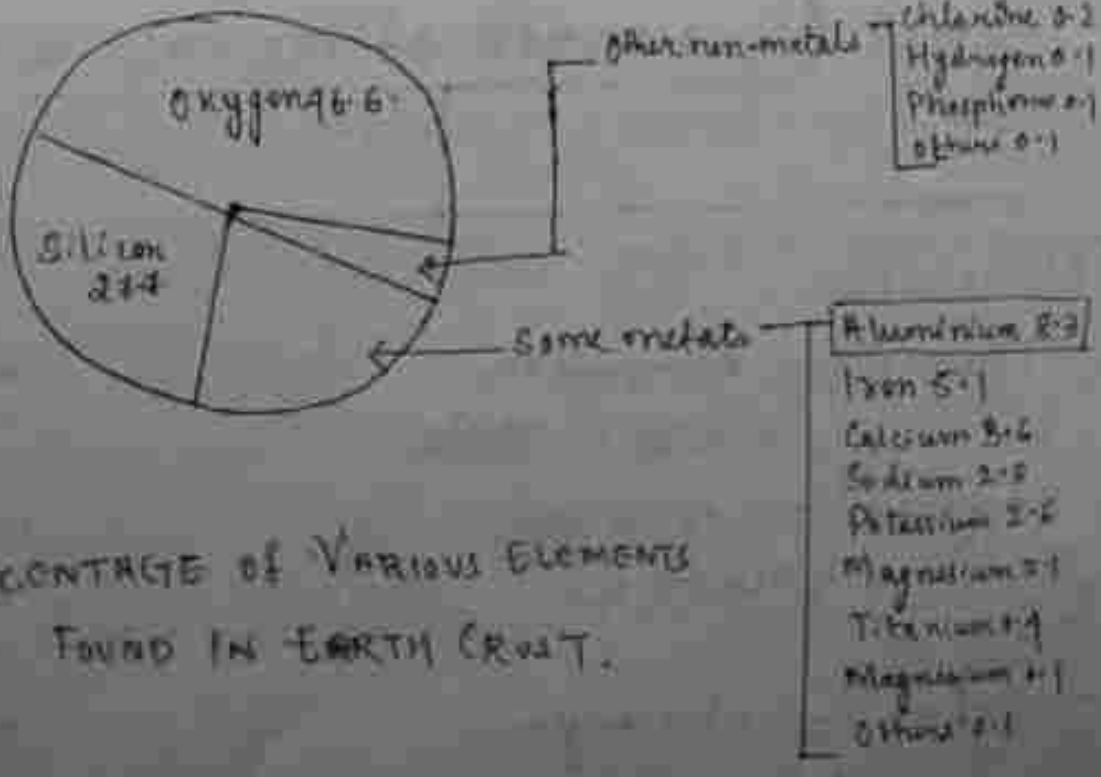
b) Galvanisation — The process of covering iron or steel with a thin coat of zinc to prevent it from rusting.
— Zinc protects the iron sacrificially, since it is more electropositive than iron.
— Zinc loses electrons in preference to iron & is consumed in course of time.

Inorganic Chemistry

Metals & Non-metals

Metals : The elements which are hard, dense, malleable, ductile, good conductor of electricity, electropositive in character, have bright lustre & have high melting point & boiling point are called metals.
Examples — Copper, Silver, Iron etc.

Non-metals : The elements which are generally not malleable, not ductile, bad conductor of electricity, electronegative in character are called non-metals.
Examples — Hydrogen, oxygen, carbon, etc.



PERCENTAGE OF VARIOUS ELEMENTS FOUND IN EARTH CRUST.

OCCURRENCE OF ELEMENTS IN NATURE

Native (free) state

→ Elements which are not attacked by moisture, oxygen & carbon dioxide of the air occur in native state.

Eg:- Gold, Platinum, etc. noble gases

Combined State

→ Elements which are readily attacked by moisture, oxygen & carbon dioxide of the air occur in the combined state in form of their compounds.

Eg:- Oxides, Sulphides, carbonates, etc of Cu, Al, Fe, Ca, etc

OCCURENCE OF METALS IN NATURE

Minerals

→ The natural minerals in which the metal or their compounds occur in the earth is known as "mineral"

→ Eg:- Cu_2S - copper glance
$CuCO_3$ - Malachite
$CuFeS_2$ - Copper Pyrites
(Minerals of Copper)

ORes

Ores are the minerals from which the concerned metal can be extracted conveniently & economically

→ Eg:- Copper Pyrite ($CuFeS_2$) is ore of copper

Minerals

Eg 1- Fe_2O_3 - Haematite
Fe_3O_4 - Magnetite
(Minerals of Iron)

Eg 3- $Al_2O_3 \cdot 2H_2O$ (Bauxite)
Al_2O_3 Corundum
(Minerals of Aluminium)

Ores

Eg 2- Fe_2O_3 & Fe_3O_4 Haematite & magnetite are ores of Iron

Eg 3- Bauxite ($Al_2O_3 \cdot 2H_2O$) is one of Aluminium-

GANGUE – The earthly or undesired or unwanted impurities present in the ore is called Gangue.

What is Metallurgy?

The Process of extracting metals from their ores conveniently & economically is called metallurgy.

Metallurgical Operation involves the following steps :–

Step 1– Crushing & Grinding of ore
Step 2 – Concentration or Dressing of ore
Step 3 – Oxidation : Conversion of ore into an oxide form (metal oxide)
Step 4 – Reduction : Conversion of metallic oxide into Crude Metal
Step 5 – Refining

I. **Crushing of ore** – The process of converting big piece (lumps) of ore into smaller pieces is called Crushing of ore.

– It is done with help of Jaw crusher.

Pulverization of Ore – The process of converting crushed ore into powder form is called pulverization of ore.

– It is done with help of ball mill or stamp mill

II Concentration of Ore / Dressing of Ore

⇒ The process of removing unwanted, earthy impurities (gangue or matrix) from the ore is called Ore-dressing or concentration of ores.

Depending on the type of impurities present in ore & nature of ore following methods are used for concentration of ore.

1) Gravity Separation
2) Magnetic Separation
3) Froth-Flotation
4) Leaching.

1- **Gravity Separation** — Gravity Separation also called hydraulic washing.

→ It is based on the differences in gravities or densities of the ore & the gangue.

— Impure crushed ore is washed with stream of running water.

— The lighter gangue particles are washed away & heavier ores are left behind.

— This can be done in specially designed tables called Wilfley tables.

— It is used for ores of tin & iron (SnO_2, Fe_2O_3)

2- **Froth Floatation Method**

→ This method is based on the difference in the wettability of the ore & the gangue particles.

→ This method is used for: concentration of sulphide ores. (ZnS, $CuFeS_2$) etc)

→ A powdered ore is mixed with water, pine oil & the mixture is agitated by air.

→ Pine oil called collector enhances the wettability of the ore & Froth-stabilisers (eg- cresols, aniline) stabilize the froth.

→ Froth contains ore particles & is light, collected at the top & can be removed.

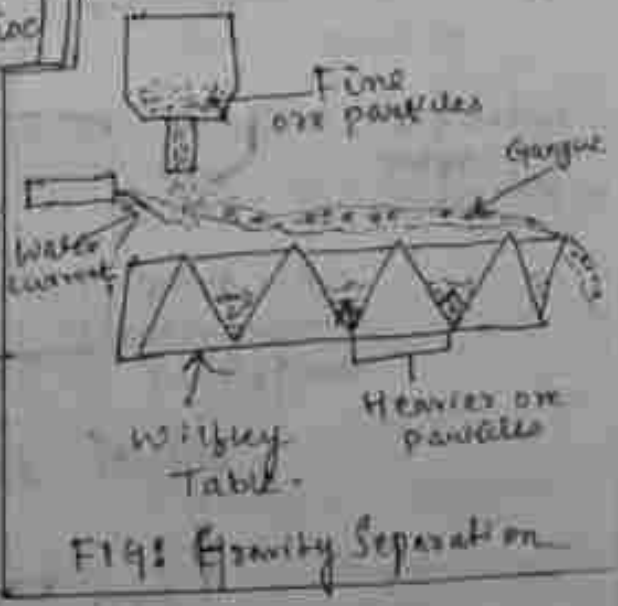
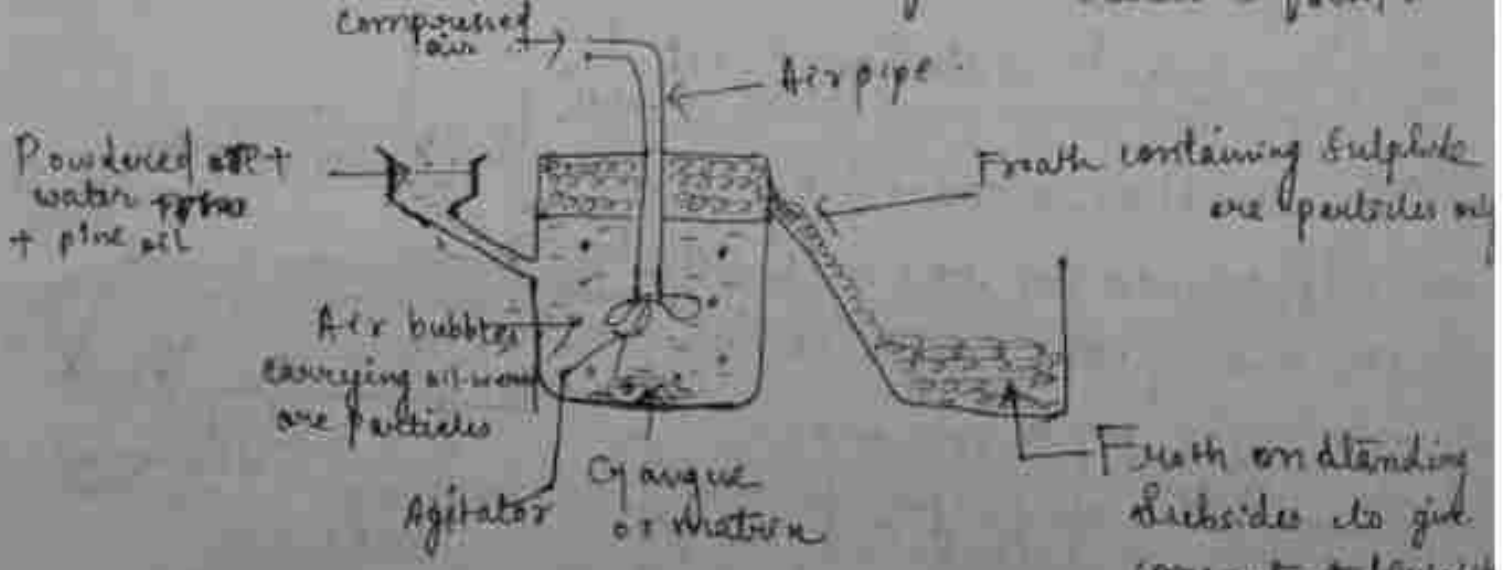


Fig: Gravity Separation

→ If the minerals to be concentrated consists of sulphides of two metals, then depressants are added.

→ The sole purpose of depressant is to speed up the formation of froth by one sulphide ore & depress the froth formation by second sulphide ore.

Eg – NaCN which combines with ZnS & forms a ~~stable~~ complex which remains in solution while PbS forms a stable froth.



FROTH FLOATATION PROCESS.

3) Magnetic Separation Method:

~~If the impurity particle~~

→ This method is used if the impurity particles are magnetic & the ore particles are non-magnetic or vice-versa.

→ In this method, an electromagnetic separator is used.

→ The separator consists of a rubber belt which moves over two rollers, one of which encloses a magnet in it.

→ The crushed ore is dropped over the belt, the magnet particles are attracted by magnet & hence fall just below the magnet. While the non-magnetic particles fall away from belt.

Eg:- Tinstone ore, SnO_2 is non magnetic. The impurity it contains — $FeWO_4$ (magnetic).

— ~~$FeCr_2O_4$~~ (chromite ore), $FeO \cdot Cr_2O_3$, is magnetic. The impurities it contains → Siliceous impurities (non magnetic)

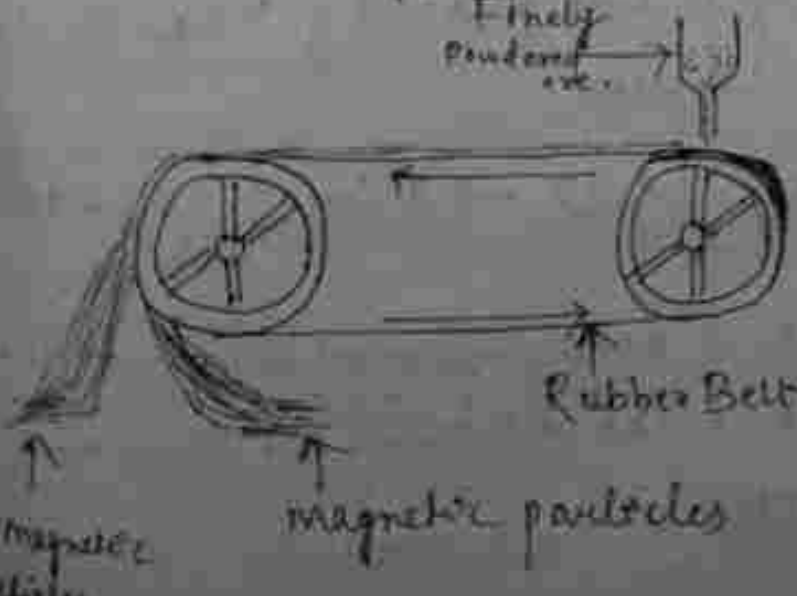


FIG: Electromagnetic Separator

4. Leaching Process.

→ LE is a chemical treatment of the ore.
→ Leaching is used if the ore is soluble in some suitable solvent.

Leaching of Bauxite Ore (Bayer's Process)

→ Bauxite ($Al_2O_3 \cdot 2H_2O$), an ore of Aluminium.
→ Bauxite contains SiO_2 as impurity.
→ The impure bauxite ore is treated with conc. NaOH

$$Al_2O_3 \cdot 2H_2O(s) + 2NaOH(aq) \rightarrow \underbrace{2NaAlO_2(aq)}_{\text{Solution}} + 3H_2O$$

$$\underset{\text{(impurity)}}{SiO_2(s)} + 2NaOH(aq) \rightarrow \underbrace{Na_2SiO_3(aq)}_{\text{Solution}}$$

→ The solution containing $NaAlO_2$ & Na_2SiO_3 is diluted with water, as a result of which a white ppt. of $Al(OH)_3$ gets precipitated & Na_2SiO_3 is left behind in solution.

$$NaAlO_2(aq) + 2H_2O \rightarrow \underset{\text{(white ppt)}}{Al(OH)_3} + NaOH$$

→ The precipitate of $Al(OH)_3$ formed is removed by filtration & heated at 1470 K to get pure alumina.

$$2Al(OH)_3 \xrightarrow{1470\,K} \underset{\text{Pure alumina}}{Al_2O_3} + 3H_2O$$

III: Conversion of the Concentrated Ore into Metal Oxide.

→ The conversion of ore into metal oxide can be done by any of the following methods :—

Calcination

- It is the process of converting an ore into its oxide by heating strongly below its melting point either in absence or limited supply of air.
- This method is commonly used to convert metal carbonates ($CaCO_3$, $MgCO_3$) & hydroxides to their respective oxides.
- Chemical changes / functions occur during Calcination :—
  1) Moisture is removed.
  2) Volatile impurities such as S, As & P are removed.
  3) Carbonate ores are converted into metal oxide.

$$CaCO_3 \xrightarrow{\Delta} CaO + CO_2\uparrow$$

$$ZnCO_3 \xrightarrow{\Delta} ZnO + CO_2\uparrow$$

$$CuCO_3 \cdot Cu(OH)_2 \xrightarrow{\Delta} 2CuO + H_2O + CO_2$$

Ore become Porous/soft

Roasting.

- It is the process of converting an ore into its metallic oxide by heating strongly at high temperature below its melting point in excess of air.
- This method is use to convert to convert sulphide ores (PbS, ZnS) to their respective oxides.
- Chemical changes / functions occur during roasting :
  1) Moisture is removed
  2) Volatile impurities such as Sulphur, P & As are removed.
  3) Sulphide ores are converted into metallic oxides.

$$2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$$

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

4) Ore becomes Porous/soft.

Difference

Calcination	Roasting
i) The ore is strongly heated in the absence of air.	i) The ore is strongly heated in presence of air
ii) The process is used for hydrated & carbonate ores.	ii) The process is used for sulphide ores.
iii) Calcination converts the hydrated oxide or carbonates into metallic oxide.	iii) Roasting converts the sulphide ores into metallic oxide.

IV. **Reduction :** Conversion of Metallic oxide into Free Crude Metal.

Smelting : — The process of extracting the metal by reduction of its oxide ore with carbon (in form of coal, coke, charcoal & co) is called Smelting.

— In this process, the roasted or calcined ore is ~~heated~~ mined with required quantity of carbon (coke or coal) & heated to a high temp above melting point in a reverberatory furnace.

$ZnO + C \xrightarrow{\Delta} Zn + CO\uparrow$

$PbO + C \xrightarrow{\Delta} Pb + CO\uparrow$

(reducible oxide → free metal)

$ZnO + CO \xrightarrow{\Delta} Zn + CO_2\uparrow$

$FeO + CO \xrightarrow{\Delta} Fe + CO_2\uparrow$

The metal thus produced is in molten state.

→ During the process of smelting, an additional substance called Flux is added which combines with the impurities to form fusible Slag

Flux + Impurity (Gangue or matrix) → Fusible Slag.

Flux — A substance added during the process of smelting to convert the gangue or matrix (impurities) into fusible mass called slag.

Slag — A fusible mass obtained during the process of smelting when flux combines with impurities.

Depending upon the nature of the impurities present in the ore, fluxes are of two types — Acidic Flux & Basic Flux

→ Acidic Flux is used to remove basic impurities during smelting.

Basic Impurity: CaO, MgO

Acidic Flux: SiO_2

$\xrightarrow{\Delta}$ $CaSiO_3$ (Slag)

$\xrightarrow{\Delta}$ $MgSiO_3$ (Slag)

→ Basic Flux is used to remove acidic impurities from the ore during smelting.

Acidic Impurity	Basic Flux	Slag
SiO_2	$CaCO_3$	$CaSiO_3 + CO_2$
SiO_2	$MgCO_3$	$MgSiO_3 + CO_2$

V. Refining Of Crude Metal

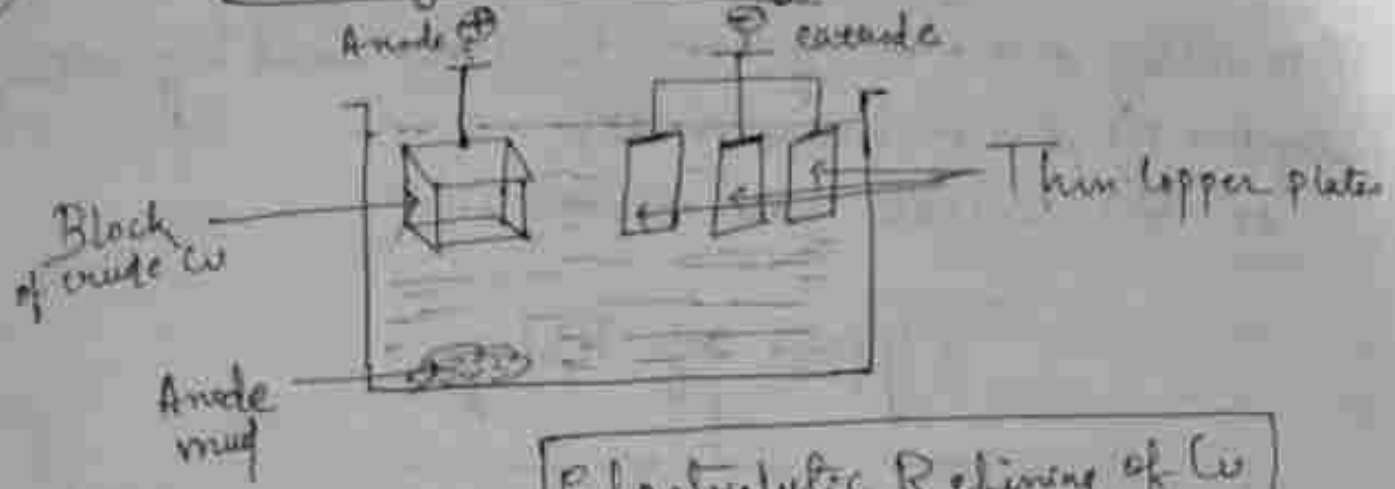
The metal extracted by any of the operations above is still impure & is called Crude metal.

" The process of purifying crude metals is called refining "

Some Methods are :—

① Distillation – It is used for ~~low boiling~~ volatile metals like Mercury, Zinc, it which contain non-volatile impurities.

(2) Electrolytic Refining



Electrolytic Refining of Cu

→ Anode – Impure Copper block
→ Cathode – Pure Thin copper plates
→ Electrolyte – $CuSO_4$ soln + H_2SO_4.
→ Anode reaction – $Cu \rightarrow Cu^{2+} + 2e^-$
→ Cathode " – $Cu^{2+} + 2e^- \rightarrow Cu$ (pure metal)

Copper (of impure anode) forms copper ions, these go into solution of electrolyte
Cu^{2+} ions go to the cathode, where they are reduced to copper gets deposited on cathode.

→ Impurities of Sb, Ag, Au & Pt are obtained at bottom anode called Anode mud.

8: Alloys:

An alloy is a homogeneous solid obtained by melting together (i) two or more metals or (ii) metals & non metals.

Types of Alloys.

Ferro-Alloys.

The alloy containing Iron as main constituent is called a ferro alloy.

Eg - Stainless Steel
Mag Manganese steel.

Non-Ferro Alloys

The alloy which does not contain iron as main constituent is called non-ferro alloy.

Eg - Brass, Bronze.

Amalgams

Alloy containing Mercury as one of the constituent are called Amalgams.

Eg :- (1) Copper amalgams
(2) Tin amalgam

Comm. Features of Alloy.

(1) Alloys are homogeneous in molten state but they may be either homogeneous or heterogeneous in Solid State.

(2) Alloy must contain a metal.

(3) In alloys, chemical properties of the component elements are retained, but certain physical properties are improved.

Composition & Uses of Important Alloys:

Alloys	Composition	Uses
1. Brass	Cu: 60%-90% Zn: 40%-10%	It is used in making: utensils, hardwares, screws, jewellery, battery caps, nameplates.
2. Bronze	Cu: 80%-95% Sn: 20%-5%	Making jewellery, water fittings, statues, medals, blades, pumpvalves, coins.
3. Alnico	Steel - 50% Ni - 21% Al - 20% Co - 9%	Used in making Permanent magnets.
4. Duralmin	Al - 95% Cu - 4% Mn - 0.5% Mg - 0.5%	Used in making airships.

Organic Chemistry

Hydrocarbon and Nomenclature

Hydrocarbons :- The Compounds containing carbon and Hydrogen are called of Hydrocarbons.

→ They bon are bonded through covalent bonds.

Classification of Hydrocarbons :-

Hydrocarbons

- open chain Compound (Aliphatic Compound)
  - Saturated — Eg- Alkane (C_nH_{2n+2})
  - Unsaturated — Eg- Alkene (C_nH_{2n}), Alkyne (C_nH_{2n-2})
- cyclic Compounds
  - Aromatic
  - Alicyclic (Non aromatic)

Aliphatic Compounds :-

→ Organic Compound containing 'C' & 'H' joined together in straight chains, branched chains

(a) Saturated Hydrocarbons :-

→ These are the Hydrocarbons containing C–C Single bonds only.

Example :- Alkane (C_nH_{2n+2})

CH_4 (methane) C_3H_8 (propane)

C_2H_6 (Ethane) C_4H_8 (Butene)

$CH_3-CH(CH_3)-CH_3$ (Isobutene) $CH_3-C(CH_3)_2-CH_3$ (neopentane)

(b) Unsaturated Hydrocarbons :-

→ These are the Hydrocarbons containing carbon-carbon multiple bond C=C (double bonds), C≡C (triple bond)

Example (i): Alkene (C_nH_{2n}). n = number of 'C'

→ General formula = C_nH_{2n}

→ Contain C=C double bond

Ex:- $CH_2=CH_2$ (Ethene)

$CH_2=CH-CH_3$ (Propene)

$CH_2=CH-CH_2-CH_3$ (Butene)

Example (ii) - Alkyne (C_nH_{2n-2})

→ General formula = C_nH_{2n-2}

→ Contain C≡C triple bond

Ex:- $CH\equiv CH$ Ethyne

$CH\equiv C-CH_3$ propyne

Aromatic Hydrocarbons:-

→ The Hydrocarbons which Obey Huckel's rule of aromaticity are called Aromatic Hydrocarbons.

Imp.

Huckel's rule of Aromaticity:-

→ It state that a Hydrocarbon is said to be aromatic if it satisfy

(i) Cyclic

(ii) planner (Each 'C' undergo sp^2 Hybridised)

(iii) contain conjugated double bond

(iv) contain $(4n+2)\pi$ electrons, where n = 0, 1, 2, 3 ... (whole no.)

Example (i)-

(Benzene)

(i) It is cyclic

(ii) planner

(iii) contain conjugated double bond

(iv) $(4n+2)\pi = 6\pi$

$\Rightarrow 4n\pi = 6\pi - 2\pi$

$\Rightarrow 4n = 4$

$\Rightarrow n = \frac{4}{4} = 1$ (whole no.)

* Since Benzene obey all four factors, It is aromatic Compound.

Example - 2

(Napthelein)

(i) It is cyclic

(ii) It is planner

(iii) Contain conjugated double bond

(iv) $(4n+2)\pi = 10\pi$

$\Rightarrow 4n = 8$

$\Rightarrow n = 8/4 = 2$ (whole no)

So, It is Aromatic Compound

Example - 3

(Anthracene)

(i) It is cyclic

(ii) It is planner.

(iii) Contain conjugated double bond

(iv) $(4n+2)\pi = 14\pi$

$\Rightarrow 4n = 12$

$\Rightarrow n = \frac{12}{4} = 3$ (whole no)

So, It is Aromatic Compound.

Qn:- check whether these compounds are Aromatic or Not.

(a) 

(b) 

(c) 

Ans:- (c) ||-1|| (i) cyclic (iii) Contain conjugated
(ii) planner double bond.
(iv) $(4n+2)\pi = 4\pi$
$\Rightarrow 4n\pi = 4\pi - 2\pi$
$\Rightarrow 4n = 2$
$\Rightarrow n = 2/4 = \frac{1}{2}$ (fractional number)

It is not aromatic as fourth factor i.e $(4n+2)\pi$ electrons is not satisfied.

(b) Not aromatic, Explain as (a)

(c) Aromatic. As it satisfy all factors of Aromaticity

Imp. Qsn:-

State and Explain Huckel's rule of Aromaticity with example.

Difference between Aliphatic and Aromatic Compounds.

Aliphatic	Aromatic
(i) In aliphatic Hydrocarbon, 'C's & 'H's are arranged in straight chain, branched manner.	(i) Carbon and Hydrogen are arranged in ring structure
(ii) Do not have pleasant odour	(ii) Have a pleasant odour.
(iii) They may be saturated and Unsaturated	(iii) All are unsaturated
(iv) Carbon to Hydrogen ratio is high.	(iv) Carbon to Hydrogen ratio is low.
(v) Have not delocalised π-electrons	(v) Have Delocalised π-electrons

(vi) Example: methane, butane. (vi) Eg: Benzene, Anthracene.

IUPAC System of Nomenclature :-

IUPAC (International Union of pure and applied Chemistry)

According to IUPAC System of Nomenclature an Organic Compound may contain the following four parts

(1) Root word (3) primary Suffix

(2) Prefix (4) Secondary Suffix

General Scheme of Naming :-

[prefix + Root word + primary Suffix + Secondary Suffix]

1. Root word :-

It refers to the number of Carbon atoms present in the parent chain of Organic Compound.

No. of 'C' atom		Root word
01	-	Meth
02	-	Eth
03	-	Prop
04	-	But
05	-	Pent
06	-	Hex
07	-	Hept
08	-	Oct.
09	-	Non
10	-	Dec

2. Prefix :-

It refers to the presence of Substituent or Side chain in the parent chain of organic Compound

	Group	Prefix
(R-)	$-CH_3$	Methyl
	$-CH_2-CH_3$	Ethyl
	$-F$	Fluoro
	$-Cl$	Chloro
	$-Br$	Bromo
	$-I$	Iodo
	$-NO_2$	Nitro
	$-OCH_3$	Methoxy
	$-OC_2H_5$	ethoxy

3. Primary Suffix :-

It refers to the (C-C) Single bond (C=C) double bond and (C≡C) triple bond in Compound

Nature of the bond		primary Suffix
All	C-C	-ane
one	C=C	-ene
TWO	C=C	-Diene
one	C≡C	-yne
Two	C≡C	-Diyne

4. Secondary Suffix :-

It refers to the presence of functional group. It gives the identity of an organic Compound

Compound	Functional group	Suffix (2nd degree)
$-OH$	Alcohol	-ol
$-CHO$	Aldehyde	-al
$>CO$	Ketone	-one
$-COOH$	Carboxylic acid	-oic acid
$-NH_2$	Amine	-amine
$-CONH_2$	Amide	-amide
$-COCl$	Acid chloride	-oyl chloride

Rules for IUPAC System of Nomenclature :-

1. Expansion of chain :- Sometimes condensed group are present in Organic Compounds. These condensed groups are to be separated.

Ex :- $CH_3-CH_2-(CH_2)_2-CH_3 \rightarrow CH_3-CH_2-CH_2-CH_2-CH_3$

$(CH_3)_2-CH-CH_3 \rightarrow CH_3-\underset{\underset{CH_3}{|}}{CH}-CH_3$

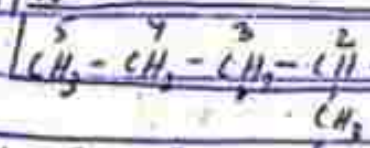
$CH_3-\underset{\underset{C_2H_5}{|}}{CH}-CH_2-CH_2-CH_3 \rightarrow CH_3-\underset{\underset{\underset{CH_3}{|}}{CH_2}}{\underset{|}{CH}}-CH_2-CH_2-CH_3$

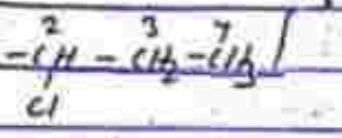
2. Selection of Longest Carbon chain :-

$CH_3-CH_2-CH_2-\underset{\underset{CH_3}{|}}{CH}-CH_2-CH_3$ → longest C-skeleton

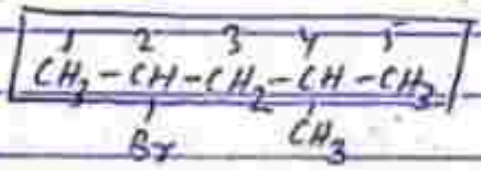
$CH_2-CH+CH_3$
$\quad\quad\;\; |$
$\quad\quad CH_2-CH_3$

3. Numbering of Carbon-chain ~~from lowest~~ is done in such a way, that gives lowest number to the substituent.

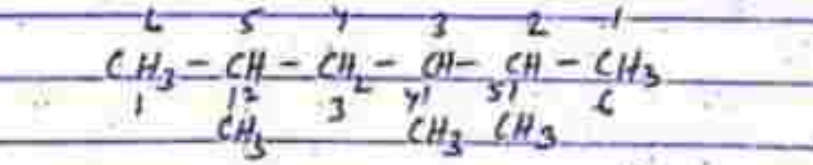




4. presence of 1 substituent end of 1 side chain at the same position from either end. in this case lowest numbering is given alphabetically which ~~have~~ appear 1st.



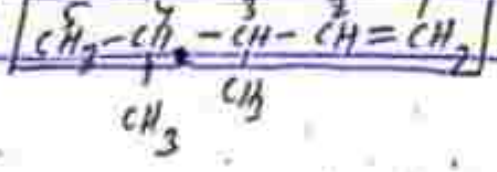
5. If same substituents are present either at the end. Numbering is done in such a way that gives lowest set of locants.



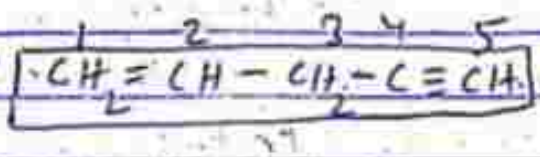
(Correct) ← 2+3+5 = 10

(wrong) → 2+4+5 = 11

6. presence of double bond / triple bond, minimum number is given to the carbon containing multiple bond

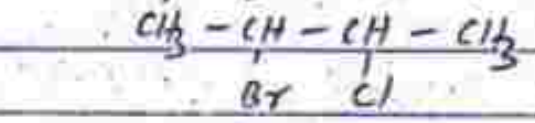


Note :- (1) If a compound containing (=) bond & (≡) bond then (C=C) is given higher priority & given lowest numbering.



Name end with :- en-yne

(2) If Compound contain more then one substituent Then naming will be alphabetical order.



2-Bromo-3-chloro Butene

Prefix +	Root word +	Primary Suffix +	Secondary Suffix
↑ Side chain or Substituent	↑ No. of 'C' atoms	↑ (-) ane (=) ene (≡) yne	↑ functional group.

Class of Compounds :-

Alkene :-

→ General formula C_nH_{2n} n=no. of C-atom.

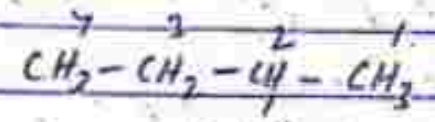
→ Representation -C- (C has tetravalent)

→ Name ends with -ane.

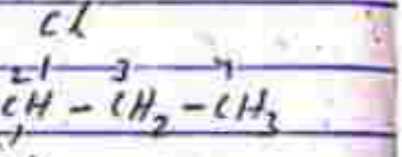
IUPAC Name of Alkane :-

Compound	Name
CH_4	Methane
CH_3-CH_3	Ethane
$CH_3-CH_2-CH_2-CH_3$	~~Propane~~ Butane
$CH_3-CH_2-CH_2-CH_2-CH_3$	Pentane
$CH_3-CH_2-CH_2-CH_2-CH_2-CH_3$	Hexane

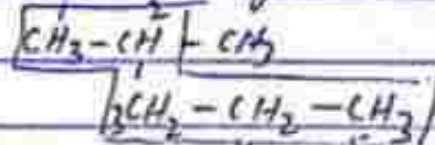
Practice



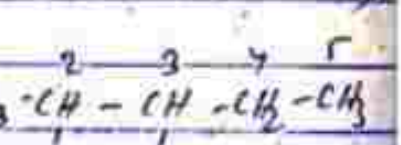
(2-methyl-Butane)



(2,2-dichloro butane)



(2-methyl-pentane.)



(3-bromo, 2-chloro pentane)

Alkene :-

→ General formula C_nH_{2n} n = no. of 'C' atom.

→ Representation $CH_2=CH_2$

$>C=C<$

→ Name ending with -ene

Compound	IUPAC Name
$CH_2=CH_2$	Ethene
$CH_2=CH-CH_3$	Propene
$CH_2=CH-CH_2-CH_3$	Butene

10 / 15

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

$CH_2=CH-CH=CH_2$ But-1,3-diene

$CH_3-CH(CH_3)-CH=CH_2$ 3-methyl-but-ene.

Practice :-

$CH_3-CH\equiv CH-C(Cl)(Br)-CH_3$ 4-Bromo,4-chloro pent-2-ene

$CH_3-CH(I)-CH=CH-CH_2$ 4-iodo-pent-2-ene

Alkyne :-

- General formula C_nH_{2n-2}
- Representation $-C\equiv C-$
- Name ends with -yne

Compound	IUPAC name
$CH\equiv CH$	Ethyne
$CH\equiv C-CH_3$	Propyne
$CH-C\equiv C-CH_2-CH_3$	Pent-2-yne

practice :-

$CH_3-C\equiv C-CH(CH_3)-CH_3$ 4-methyl pent-2-yne

$CH_2^1=CH^2-CH_2^3-C^4\equiv CH^5$ pent-1-en-4-yne

Halo alkane :- (Alkyl halide)

→ General formula - RX

where R = alkyl group. ($-CH_3$, $-CH_2-CH_3$ etc)

X = Halogen (F, Cl, Br)

→ General name - Halo alkane

Compound	IUPAC Name
CH_3-Cl	Chloro-methane
CH_3-CH_2-Br	Bromo ethane
$CH_3-CH_2-CH_2-Cl$	chloro propane
$CH_3-CH(Cl)-CH(Cl)-CH_3$	2,3-dichloro-butane

Alcohol :-

→ General formula - R-OH
R - alkyl group.

→ functional group is -OH

→ Name ends with - ol.

→ General name - alkanol.

Compound	IUPAC Name
CH_3-OH	Methanol.
CH_3-CH_2-OH	Ethanol
$CH_3-CH_2-CH_2-OH$	propanol
$CH_3-CH_2-CH_2-OH$	Butanol.

practice :-

$CH_3-CH(OH)-CH-CH_3$

Butan-2-ol.

$\overset{1}{C}H_3-\overset{2}{C}H(CH_3)-\overset{3}{C}H(OH)-\overset{4}{C}H_2-\overset{5}{C}H_3$

2-methyl-pentan-3-ol

$\overset{1}{C}H_3-\overset{2}{C}H(OH)-\overset{3}{C}(Br)(Cl)-\overset{4}{C}H_2-\overset{5}{C}H_3$

3-Bromo, 3-chloro-pentan-2-ol

Uses of some Common aromatic Compounds :-

(01) Benzene :- (Uses)

→ It is used to make plastics, resins, Synthetic fibres, rubber lubricants.

→ Used to make Dye, detergent, drugs & pesticides.

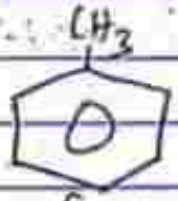
(Benzene)

(02) Toluene :-

→ It is used as solvent in paints, thinners, glues.

→ It is used as Correction fluid and nail polish remover.

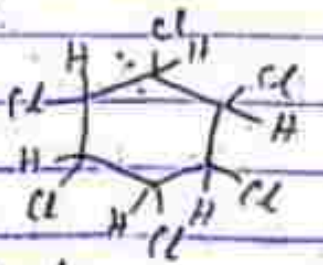
→ Used in the printing and leather tanning process.



(Toluene)

(03) BHC (Benzene Hexachloride) $C_6H_6Cl_6$

→ It is used as an important agriculture pesticide used for exterminating white ants, leaf hopper



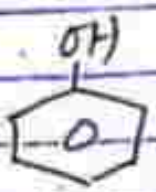
→ It is used in Pharmaceuticals

→ It is used to treat Scabies

→ It is used in shampoo.

(04) Phenol

→ It is used in plastic manufacturing industries.
→ It is used to commercially prepare phenolic resins.
→ It is used in the study and extraction of bio-molecules.
→ It is used in Cosmetic industry in the manufacturing of sun screen, Skin lightening cream, hair colouring solution.



(Phenol)

or

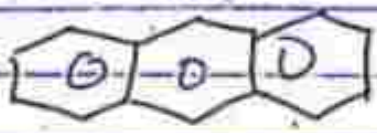
(05) Naphthalene

→ It is used to make moth balls, PVC, insecticides,
→ used to make dyes, Toilet deodorant blow
→ It is used to make pharmaceutical & resin.


(Naphthalene)

(06) Anthracene :-

→ It is used in the artificial production of the red dye Alizarin.
→ It is used in Wood preservatives, insecticides and coating materials.


Anthracene

(07) Benzoic acid

(Benzoic acid)

→ It is used in perfumes, dyes, insect repellents.
→ It is used as pH adjuster and preservative in food.
→ Preventing the growth of microbes to keep food safe

Important Questions:-

(01) State and Explain the Huckel's rule of Aromaticity with example

or

Define Aromatic Compound and explain with example

(02) IUPAC Nomenclature ?

Write

(03) Uses of Aromatic Compound

(a) Benzene (d) Benzoic acid.
(b) Toluene (e) Naphthalene
(c) phenol (f) Anthracene.

Industrial Chemistry

WATER

Water is one of the most important compounds of hydrogen and oxygen. It is a colourless liquid and possesses a high dielectric constant (80) and therefore, salts are highly ionised when dissolved in water, but not so in other solvents. It is the most convenient universal solvent. In general, water is a good solvent for ionic compounds but a poor one for co-valent compounds.

Classification of water

All the source of water can broadly be classified in to two categories.

A. Surface Water

B. Underground Water

Classification of Surface Water

- Rain Water
- River Water
- Sea Water
- Lake Water

Classification of Under Ground Water

- Spring Water
- Well Water

A. Surface water:

1. Rain water:

i. Rain is formed by the continuous evaporation and condensation of surface water.

ii. Rain water is considered to be purest form of natural water.

iii. It does not contain any dissolved minerals.

iv. However during its downward movement, it comes across a number of industrial gases like CO_2, SO_2, SO_3, NO_x etc. which dissolves them to form acid rain.

$CO_2 + H_2O \rightarrow H_2CO_3$

$SO_2 + H_2O \rightarrow H_2SO_3$

$SO_3 + H_2O \rightarrow H_2SO_4$

v. All the water obtained as a result of rain fall is not available for further use, because some of it is lost by evaporation, percolation and transpiration.

2. River water:

i. The over flown surface water (surface run off), which is seen in the form of various streams join together to form river.

ii. It is also formed due to the melting of glaciers.

iii. It contains a high percentage of dissolved minerals like NaCl, KCl, $NaNO_3$, $CaCO_3$, $NaHCO_3$ etc.

iv. More is the contact of the water with the soil more is the amount of mineral deposit in the river.

3. Lake water:

i. A lake is formed due to the collection of water in a natural basin or depression in a mountainous area or in planes, whereas natural lake is a large body of water within land with impervious bed.

ii. Lake water contains a less percentage of dissolved minerals but a very high percentage of organic matters. Presence of high percentage of organic matters is due to the decomposition of vegetable matters and dead bodies of animals during natural calamities like flood, tsunami etc.

4. Sea water:

Sea is formed when a number of rivers meet together.

i. Sea water is considered to be the most impure form of natural water.

ii. Sea water contains about 3.5% dissolved minerals of which about 2.6% is only NaCl.

iii. The percentage of minerals is gradually increasing day by day due to the continuous evaporation of sea water.

iv. Besides NaCl, it also contains other minerals such as Na_2SO_4, $KHCO_3$, $Mg(HCO_3)_2$, $Ca(HCO_3)_2$, KBr, $MgBr_2$ etc.

B. Underground water:

The sources of water which supply water from below the earth's surface are known as **underground water**. In this type of source, the water that has percolated into the ground is brought on the surface. Underground water is of two types:

a. Spring water **b. Well water**

a. Spring water:

i. Spring is formed due to the melting of glaciers. It is also formed in the mountainous area. During rainy season a part of rain water percolates into the surface of earth. It dissolves many minerals which are in the way of this water. During its downward journey when it meets hard rock, it retards back and emerges out as spring in some weak areas.

ii. It is a clearer form of natural water.

iii. It contains high percentage of dissolved minerals and thus its hardness is very high.

b. Well water:

i. It is a clearer from of natural water.

ii. It is obtained by digging the surface of earth to a high depth.

iii. It contains many dissolved minerals

iv. It also contains some organic matters.

CLASSIFICATION OF WATER

i. Soft water: Water which produces enough foam or lathers with soap solution is called **soft water.**

ii. Hard water: Water which does not produce much foam or which does not lathers with soap solution is called **hard water.**

Hardness of water: The characteristic of water by virtue of which it prevents the formation of foam with soap solution is called **hardness**. The hardness of water is due to the presence of certain dissolved minerals like **$Ca(HCO_3)_2$, $Mg(HCO_3)_2$, $CaCl_2$, $MgCl_2$, $FeSO_4$**, etc in water.

The unit of Hardness: Parts per million (PPM).

Hardness of water is of two types:

A. Temporary or Carbonate hardness

B. Permanent or Non-carbonate hardness

A. Temporary hardness: The temporary hardness of water arises due to the presence of bicarbonates of **Ca and Mg, [$Ca(HCO_3)_2$, $Mg(HCO_3)_2$]**. Temporary hardness is also called carbonate hardness.

B. Permanent of hardness: The permanent hardness of water arises due to the presence of chlorides of Ca, Mg ($CaCl_2$, $MgCl_2$) and sulphates of certain heavy metals like Fe ($FeSO_4$).

REMOVAL OF HARDNESS OR SOFTENING OF WATER

The process of decreasing the hardness of water is called **softening**. It involves decreasing the concentration of calcium and magnesium salts in water.

REMOVAL OF HARDNESS

A. Removal of Temporary Hardness:

The temporary hardness of water can easily be removed just by boiling the water. When hard water is boiled, the soluble $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$ are decomposed in to insoluble carbonates, which are removed by filtration.

$$Ca(HCO_3)_2 \xrightarrow{Boil} CaCO_3 + H_2O + CO_2 \uparrow$$

Hard Water (soluble) (insoluble)

$$Mg(HCO_3)_2 \xrightarrow{Boil} MgCO_3 + H_2O + CO_2 \uparrow$$

Hard Water (Soluble) (insoluble)

B. Removal of Permanent Hardness:

Removal of permanent hardness requires chemical treatment. Various methods used for the removal of permanent hardness are described below.

1. LIME SODA PROCESS (L – S PROCESS)

Principle:

In this process hard water is treated with a calculated quantity of lime and soda. Lime and soda convert the soluble hardness causing chemicals present in hard water in to insoluble substances.

$CaCl_2$ + Na_2CO_3 → $CaCO_3\downarrow$ + 2NaCl

(soluble) soda (insoluble)

$MgCl_2$ + $Ca(OH)_2$ → $Mg(OH)_2\downarrow$ + $CaCl_2$

(soluble) (Insoluble)

The precipitate or sludge formed is then removed by filtration to get soft water.

Lime-Soda process is of two types.

a. COLD L – S PROCESS:

Principle:

A calculated quantity of lime and soda is treated with hard water at room tem
Lime and soda react with the hardness causing chemicals present in har
precipitates or sludge formed are removed by filtration.

Construction of Apparatus:

The apparatus consists of a conical shaped steel tank, containing a rotating shaft at the middle. Also it contains a wood fibre filter.

Working Process:

Hard water and a calculated quantity of lime, soda along with a little quantity of coagulant are introduced into the apparatus. When the shaft rotates water is properly mixed with lime and soda. The soluble hardness causing chemicals present in hard water react with lime and soda to form insoluble sludge.

$CaCl_2$ + Na_2CO_3 → $CaCO_3\downarrow$ + 2NaCl

hard water **soda** **ppt**

$MgCl_2$ + $Ca(OH)_2$ → $Mg(OH)_2\downarrow$ + $CaCl_2$

hard water **lime** **ppt**

Coagulant aggregates the finely divided sludge particles which settle down in the conical sedimentation tank. The sludge is then removed from time to time through its outlet. Water is now allowed to pass through the wood-fibre filter to get soft water. The residual hardness left in this process is about 50 – 60 ppm.

b. Hot lime Soda Process:

Priniciple: This process involves treatment of hard water with a calculated quantity of lime and soda in presence of super-heated steam (at 80 ℃ to 150 ℃).

Apparatus: The apparatus consists of three main parts:

1. Reaction tank: Here the reaction of lime and soda with the hard water takes places.

2. Conical sedimentation tank: Here the precipitates (sludge) are formed and deposited.

3. Filtering unit: It consists of a number of layers of gravels which is used to filter water.

Working Process:

Hard water along with a calculated quantity of lime and soda are introduced into the reaction tank. Also super-heated steam at 80 ℃ to 150 ℃ is passed in to it. The soluble hardness causing chemicals present in the hard water react with lime and soda to form insoluble sludge which settles down in the conical sedimentation tank. The sludge formed is removed periodically through its outlet. Water is then allowed to pass thorough the filtering unit to get soft water. The residual hardness left in this process is only about 15 – 30 ppm.

Advantages of hot L-S process over Cold L-S Process

i. It is much economical.

ii. The reaction is completed within a short period.

iii. The reaction proceeds faster. Hence the softening capacity in increased.

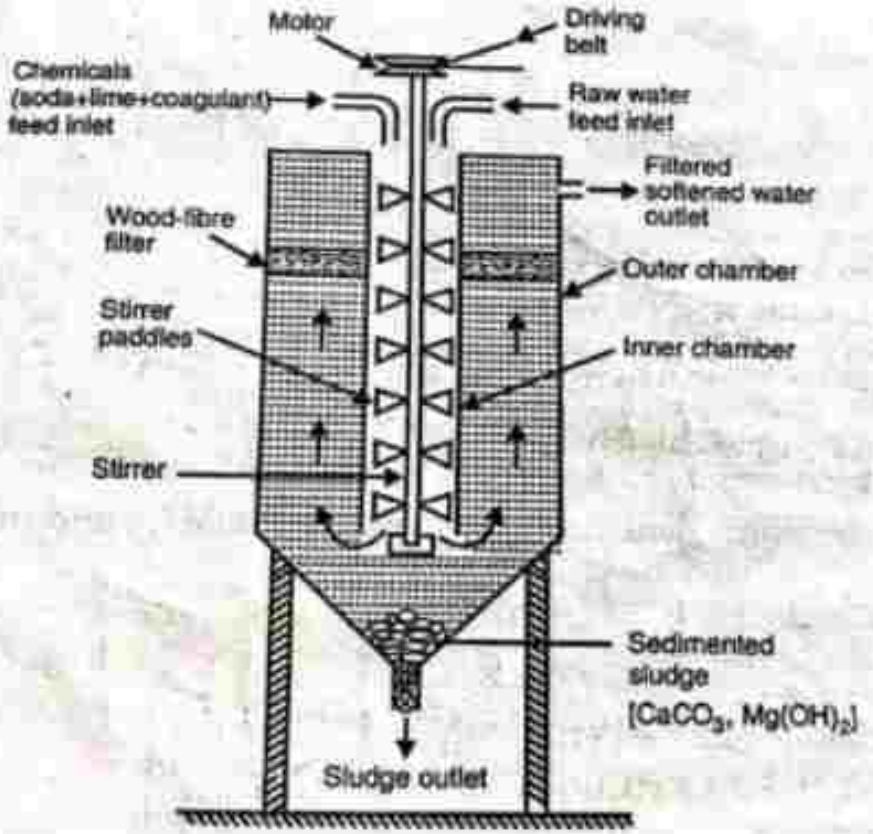


Fig. 3. Continuous cold lime-soda softener.

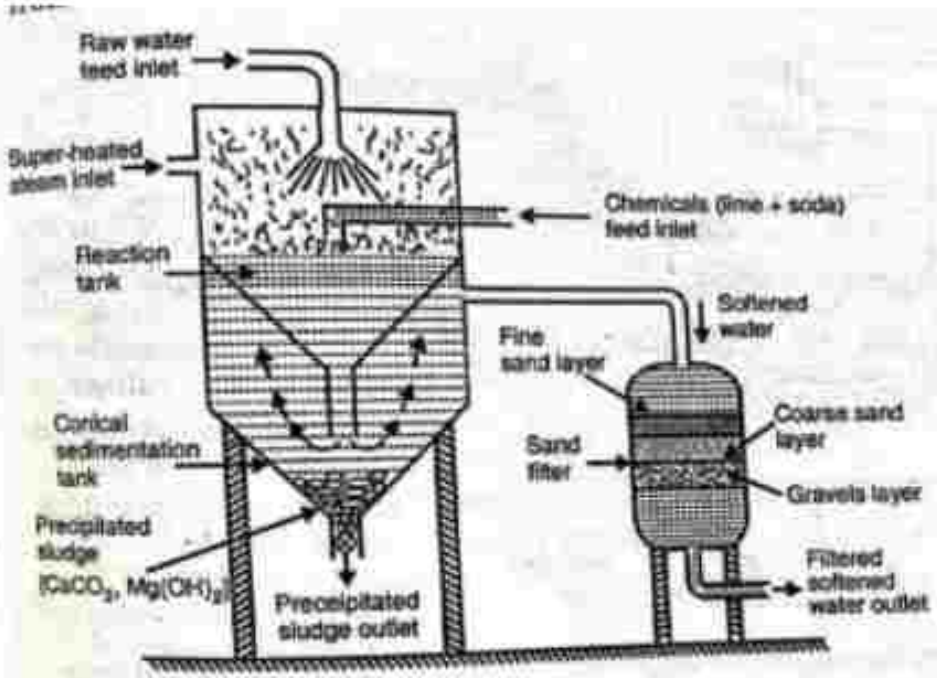


Fig. 4. Continuous hot lime-soda softener.

iv. No coagulant is required, as the sludge settles down easily.

v. Dissolved gasses like CO_2, air etc. are removed.

vi. Under hot condition viscosity of water is lowered. Thus filtration becomes easier.

vii. Pathogenic bacteria are destroyed.

viii. The residual hardness left in this process is much lower (15-30 ppm) as compared to that in the cold L-S process (50-60 ppm).

2. ION EXCHANGE PROCESS:

[Deionization process or De-mineralization process]

In this method ion-exchange resins are used. These are insoluble long chained organic copolymers having micro-porous structure. These resins contain either acidic or basic functional groups capable of exchanging their H^+ or OH^- ion with the ions present in hard water.

Ion-exchange resins are of two types:-

1) Cation-exchange resins (RH)

These resins contain acidic functional groups like – COOH, $-SO_3H$ etc. which can exchange their H^+ ions with the cations of the hardness causing chemicals present in hard water.

2) Anion-exchange resins (ROH)

These resins contain basic functional groups like – $N^+Me_3OH^-$ which can exchange their OH^- ions with the anions of hardness causing chemicals.

Process: Hard water is first passed through the cation-exchange resin. The resin exchange its H^+ ions with the cations (Ca^{2+}, Mg^{2+} etc.) of hard water.

$2RH$ + **Ca^{2+}** → **R_2Ca** + **$2H^+$**

(Cation-Exchange Resin) hard water Exhausted Resin

$2RH$ + **Mg^{2+}** → **R_2Mg** + **$2H^+$**

(Cation-Exchange Resin) hard water Exhausted Resin

Then it is passed through the anion-exchange resin which exchange its OH^- ions with the anions (Cl^-, SO_4^{2-} etc) present in the hard water.

ROH + **Cl^-** → **RCl** + **OH^-**

(Anion-Exchange Resin) hard water Exhausted Resin

Regeneration of resins:

When all the H^+ and OH^- ions of the resins are exchanged by the ions of hard water, then the resins are said to be exhausted. The cation-exchange resin can be regenerated by the treatment of dil. HCl with the exhausted cation-exchange resin.

R_2Ca + $2HCl$ → $2RH$ + $CaCl_2$

(Exhausted resin) (Regenerated resin)

Similarly, the anion-exchange resin can be regenerated by the treatment of dil NaOH solution with the exhausted anion-exchange resin.

RCl + $NaOH$ → ROH + $NaCl$

(Exhausted resin) (Regenerated resin)

Note: The residual hardness left in this process in only about 2 ppm.

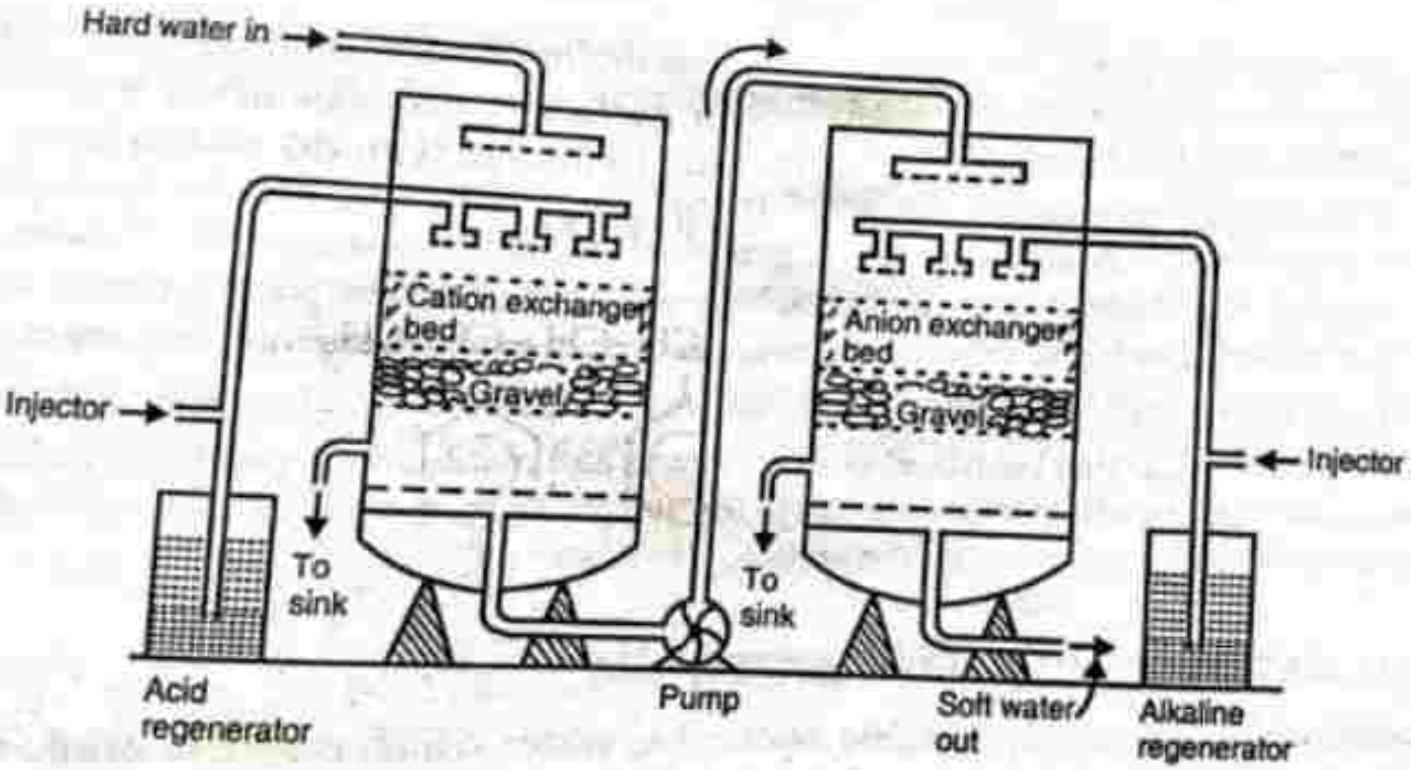


Fig. 8. Demineralization of water.

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

Chapter 11 : LUBRICANTS

Lubricants

Definition

The substance interposed between two moving/sliding surfaces with a view to reduce the frictional resistance between the two, is called a lubricant.

Lubrication

definition

The process of reducing frictional resistance between moving/sliding surfaces, by introduction of lubricants in-between them, is called lubrication.

FUNCTIONS OF LUBRICANTS

- It reduces the frictional resistance between the sliding surfaces.
- It reduces wearing & tearing of machinery parts.
- It reduces loss in energy.
- It increases the efficiency of engines.
- It acts as a cooling medium.
- It reduces expansion of metals.
- It enhances the durability of machinery parts.

TYPES OF LUBRICANTS

SOLID LUBRICANTS

It is used where:—

i) the working temperature is very high.

ii) contamination (by entry of dust or grit particles) of lubricating oil or grease is unacceptable.

iii) combustible lubricants must be avoided.

Eg- Graphite, Molybdenum disulphide, etc.

LIQUID LUBRICANTS

It is used where:—

i) the working temperature is high.

ii) the speed of the roller is very high.

iii) the sealing arrangement is perfect to prevent the loss of oil.

Eg: Petroleum oil, Animal oil (whale oil, lard oil), Blended oil (mineral oil + Petroleum oil)

SEMI-SOLID LUBRICANTS

It is used where:—

i) the working load is high & the machine is working at low speed.

ii) For sealing bearings against dirt & dust particles.

iii) In places where dripping & spurting of oil is undesirable.

Eg:- Grease

Grease (Semisolid)

A semisolid lubricant, consisting of a soap dispersed throughout a lubricating oil.

Major components of greases are;-

i) Oil component – mineral oil, waxes.
ii) Thickening component – Na, K soaps
iii) Modifiers – antioxidant.

Graphite (Solid lubricant)

- Graphite is used in powder form or as suspension in oil or water.
- The suspension of graphite in water is aquadag
The suspension of graphite in oil is called Oildag.

Structure of Graphite

Uses

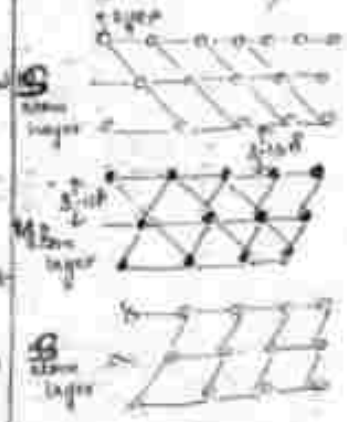
- As a lubricant in heavy machinery.
- In making electrodes for the electric furnaces.
- In making lead Pencil
- In paints & Varnishes.
- In nuclear reactors to slow down high energy neutrons

Molybdenum Disulphide (MoS_2)

(Solid lubricant)

Uses

- It is used as lubricant in form of powder along with solvent.
- It is better lubricant than Graphite
- It is stability upto 400°C. (low coefficient of friction)

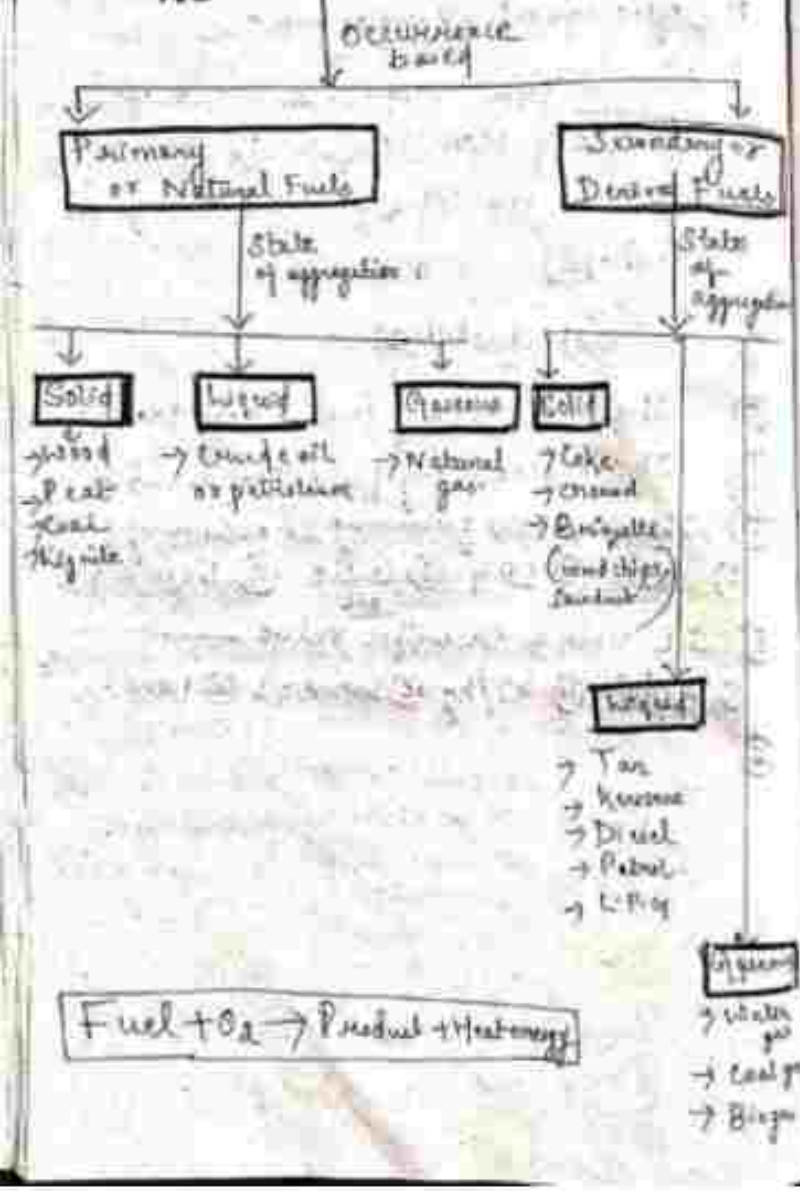


Structure of Molybdenum disulphide

Liquid lubricants or Lubricating Oil

1. Mineral oil
2. Vegetable Oil → Olive oil (lubrication of bearings)
   → Palm oil (lubrication of watches & clock)
   → Castrol (")
3. Synthetic oil → Used in jet engines, rocket motors.
4. Animal Oil → Whale oil (Light Machinery)
   → Lard oil (used in various machines)

CH-12 Fuels



Calorific Value of Fuel

→ The calorific value of a fuel is defined as the amount of heat obtained by the complete combustion of unit mass of the Fuel.

Units of Calorific Value

Solid & liquid fuels → calories per gram (cal/g) → kilo calories per kilogram (kcal/kg)

Gaseous fuels – kcal/m³ or B.Th.U/ft³ → British Thermal unit per cubic feet → British Thermal unit per pound (B.Th.U/lb)

Choice of Good Fuel

→ Fuel should have high calorific value.
→ Low moisture content
→ Moderate ignition temperature.
→ Low cost
→ Should burn in air with efficiency without much smoke.
→ Low moisture content.
→ Easy to transport & handle.
→ Products of combustion should not be harmful.

LIQUID FUELS

PETROL or GASOLINE	KEROSENE	DIESEL
⇒ It consist of hydrocarbons between pentane to octane (C_5H_{12} to C_8H_{18})	⇒ It consists of hydrocarbons between decane to hexadecane ($C_{10}H_{22}$ to $C_{16}H_{34}$)	⇒ It consists of hydrocarbons between pentadecane to octadecane ($C_{15}H_{32}$ to $C_{18}H_{38}$)
⇒ Composition C = 84% H = 15% S+S+N = 1%	⇒ Composition C = 84% H = 16% S < 0.1%	⇒ Composition C = 85% H = 12% S+O+N = 3%
⇒ Calorific Value 11,250 kcal/kg.	Calorific Value 11,100 kcal/kg.	Calorific Value 11,000 kcal/kg
USES:	USES:	USES:
⇒ It is used as a fuel in the Petrol engine. ⇒ It is used as a dry cleaning agent.	⇒ It is used as a fuel in the kitchen for domestic ⇒ It is used as a fuel in jet planes ⇒ It is used in making oil gas	⇒ It is used as a fuel in diesel engine

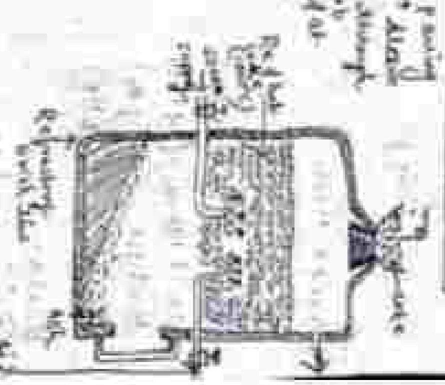
PRODUCER GAS

- It is prepared by passing air mixed with a little steam over a red hot coal or coke bed maintained at about 1100°C in a special reactor, called gas producer.
- ~~It is a mixture of~~

- Composition:-
  CO = 22 - 30%
  H_2 = 8 - 12%
  CO_2 = 3%
  N_2 = 52 - 55%
- Calorific Value
  1300 kcal/m³.
- Uses
  i) In heating furnace in metallurgical operation.
  ii) As a reducing agent.

WATER GAS

- It is made by passing alternatively steam & little air through a bed of red hot coal, maintained at 900-1000°C in a reactor.



- Composition
  CO = 41%
  H_2 = 51%
  CO_2 = 4%
  N_2 = 4%
- Calorific value
  2800 kcal/m³
- Uses
  i) used as an illuminating gas
  ii) a fuel (iii) a source of H_2 gas.

LIQUEFIED NATURAL GAS (LPG)

Composition :-

- Propane - (C_3H_8)
- n-butane - (C_4H_{10})
- iso-butane - (C_4H_{10})
- Butylene - (C_4H_8)
- Propylene - (C_3H_6)

Uses :-

→ LPG is used as a domestic fuel & as a fuel for internal combustion engines.

→ It is used as feedstock for the manufacture of various chemicals.

Calorific Value

8,700 Kcal/m³

COMPRESSED NATURAL GAS (CNG)

Composition :-

Main constituent (Methane (CH_4) about 80-90%)

- C_2H_6 = 5-10%
- H_2 = 3%
- $CO + CO_2$ = rest

Uses :-

→ Used as domestic fuel

→ Used as raw material for the manufacture of carbon black (a filler for rubber).

→ It is used in manufacture of number of chemicals.

Calorific Value

13000 Kcal/m³

COAL GAS

Composition

- H_2 = 47%
- CH_4 = 32%
- CO = 7%
- C_2H_2 = 2%
- C_2H_4 = 3%
- N_2 = 1%
- CO_2 = 1%
- rest = 4%

Uses

→ As a fuel

→ As a reducing agent in metallurgical process

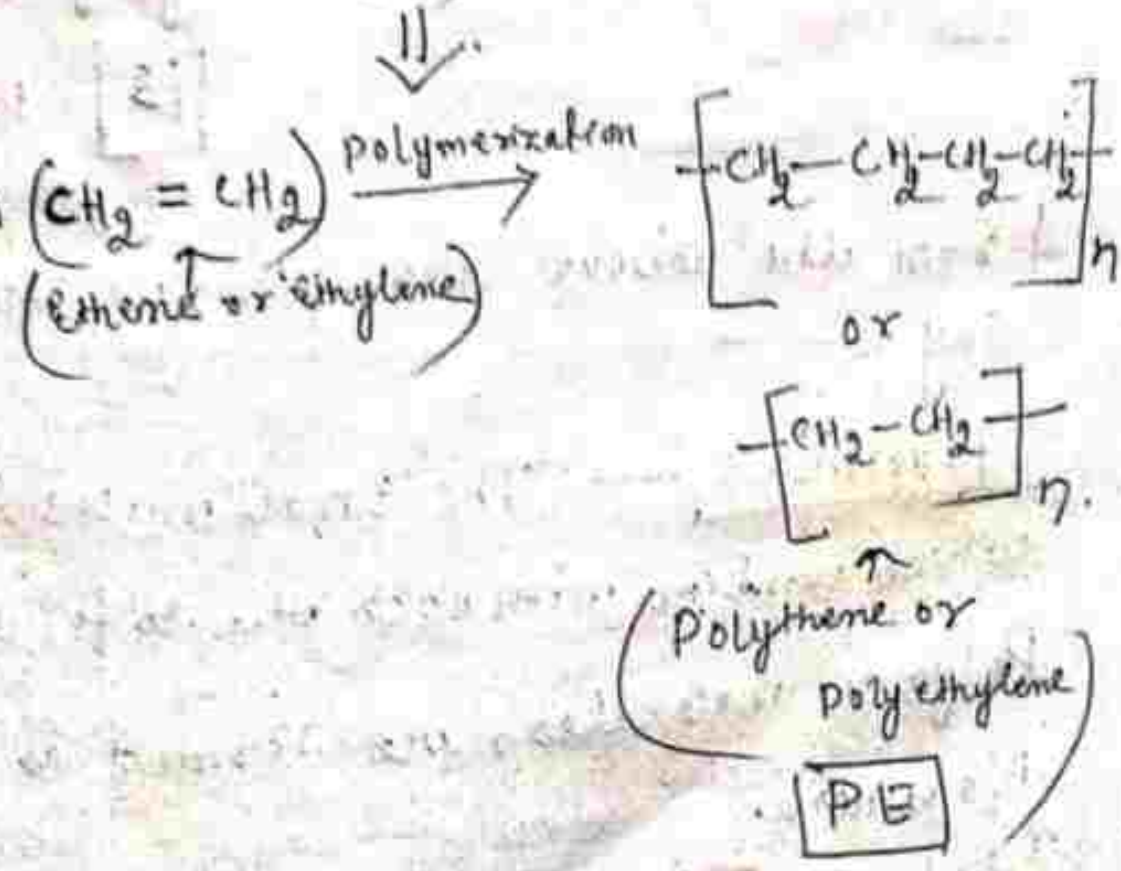
→ As an illuminant

Polymers

Poly - + Mere
(Many) (Parts or Units).

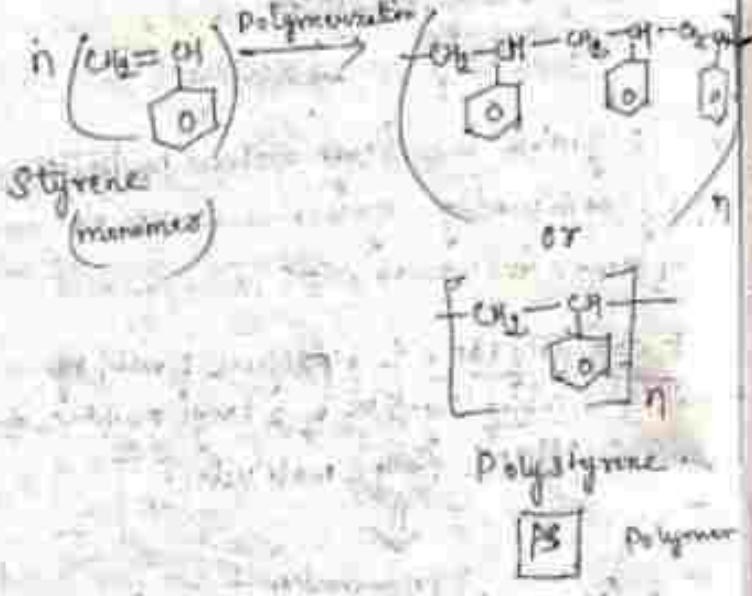
- Polymers are large molecules, built up by combining together a large number of small molecules.

Ex1- Polythene is a polymer formed by linking together of a large number of ethene (C_2H_4) molecules.



Polystyrene is a polymer

Ex 2 - by linking together a large number of styrene monomer.



Polystyrene

PS Polymer

From the above examples, we can say —

Monomers — The small molecules which combine with each other to form Polymer molecules, are termed as Monomers.

Polymerisation — The process by which the monomer molecule are linked to form big polymer molecule is called Poly-

A polymer may consist of identical monomers or monomers of different chemical structure & accordingly they are called Homopolymers & Copolymers respectively.

—M—M—M—M—M— —M1—M2—M1—M2—M1—M2—

Homopolymer Co-polymer

- Homopolymer — Polymer is made from all identical monomer molecules/units.
  Eg :— Polyethylene, Polystyrene, Polyvinyl chloride.
- Copolymers — Polymer made from different monomer units/molecules
  Eg :— Styrene Butadiene Rubber.
- Degree of polymerisation — The number of repeating units (or monomer) that combine to form polymer is called degree of polymerisation.
  → Polymers usually fall into the 5000 - 20000 molecular range.

• Natural rubber is a mixture of polymer molecules having as many as 50000 units per molecule, therefore its degree of polymerization is 50000.

Examples of Homopolymer

① Polythene (PE)

Ethene (Monomer)

Polythene (PE) polymer

(P.E)
Polythene

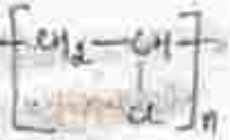
Uses:- ① low Density polyethene.
→ It is used as packaging material
→ It is used in insulating wires
→ It is used in manufacture of pipes, toys, bottles.

② High Density polyethene.
→ It is used in the manufacture of containers (buckets, tubes etc) for making house wares, pipes, bottles, toys, etc.

② Polyvinyl Chloride (P.V.C)

Vinyl Chloride

Polyvinyl chloride

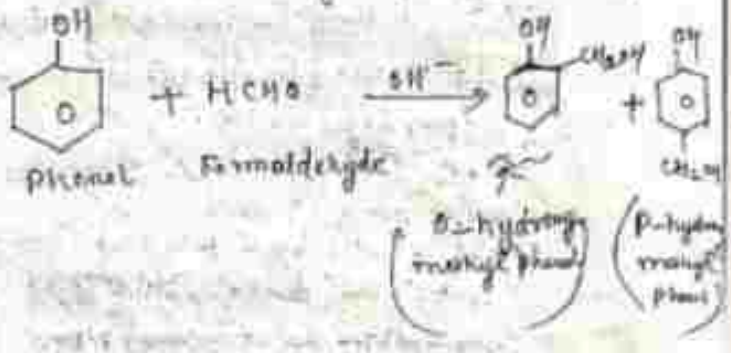


Polyvinyl chloride (PVC)

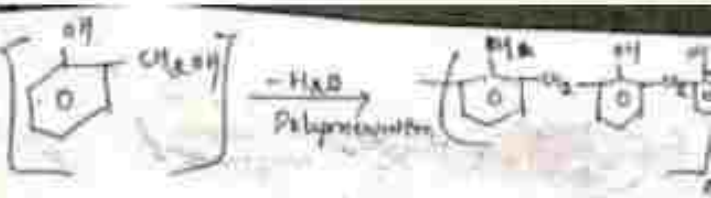
Uses:-
1) It is used for making electrical insulators.
2) It is used in manufacture of gramophone records, raincoats, PVC pipes, hand bags.

Bakelite (Phenol-Formaldehyde resin)

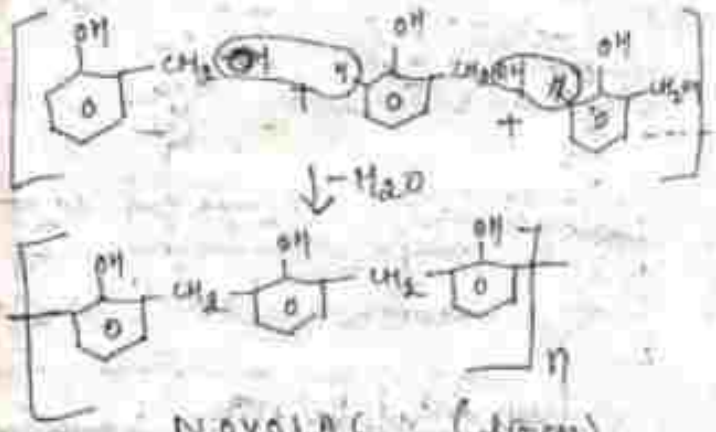
Copolymer



- It is a co-polymer of phenol & formaldehyde.
- Phenol & formaldehyde react to form ortho-hydroxy methyl Phenol & para-hydroxy methyl phenol
- The orthohydroxy methyl phenol thus formed undergoes polymerisation with another ortho-hydroxy methyl phenol to form linear polymer compound called NOVOLAC

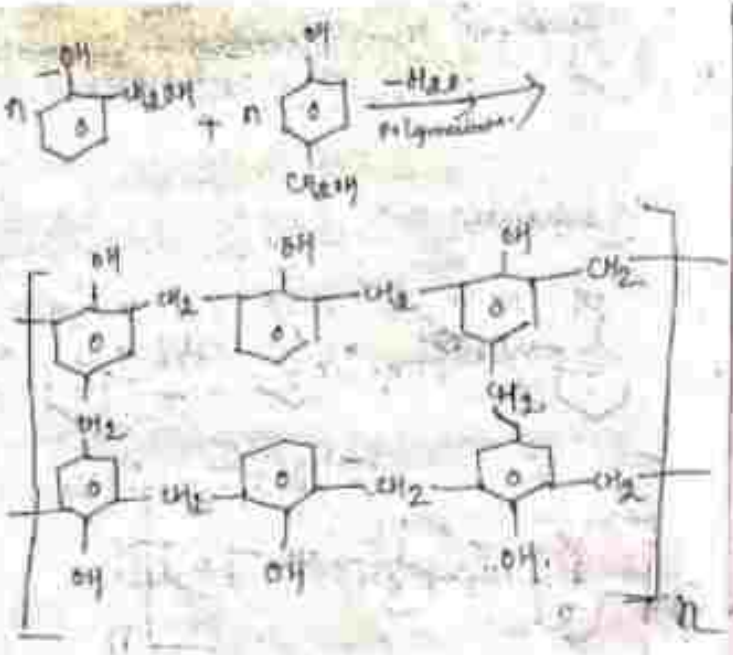


Mechanism

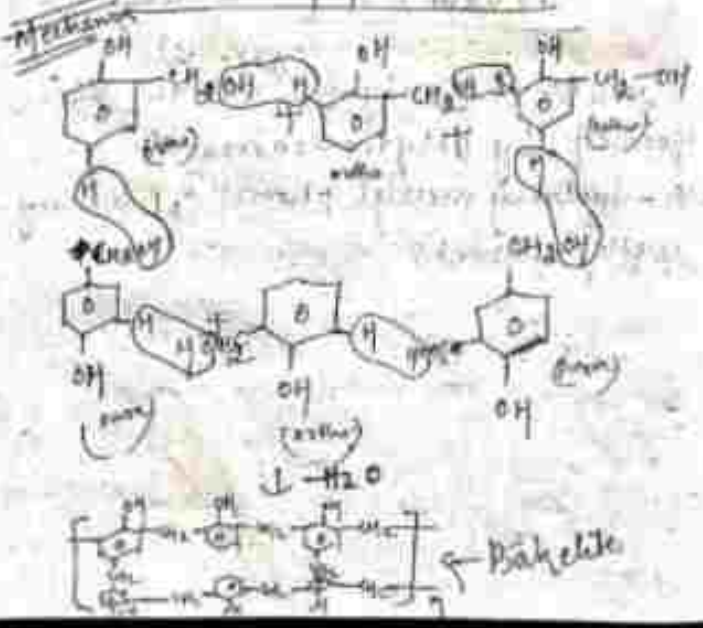


NOVOLAC (linear)

- Cross linked polymer (bakelite) can also be formed by polymerisation of o-hydroxy methyl phenol & p-hydroxy-methyl phenol.



Cross linked, bakelite.



Uses

- It is used in manufacture of insulating parts like switches, plugs, heated handles.
- As an ion-exchange resin in softening of water.
- Used in Radio & TV cabinets.
- Used in Paints & Vannishes.
- Telephone parts.

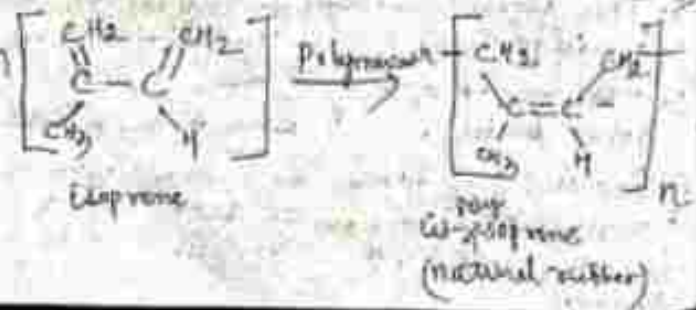
Thermosetting Polymers (e.g.- Bakelite, Melamine)	Thermoplastic Polymer (e.g.- polythene, PVC, PS)
1. They don't soften on heating.	1. They soften on heating readily.
2. Their poly molecules have 3-D network structure.	2. Their molecules have linear chain structure.
3. They are formed by condensation polymerisation.	3. They are formed by addition polymerisation.
4. They cannot be reshaped & reused.	4. They can be reshaped, softened & then reused.
5. They are hard, strong & more brittle.	5. They are usually soft, weak & less brittle.
6. Due to strong bonds & cross-linking, they are insoluble in almost all solvents.	6. They are usually soluble in organic solvents.

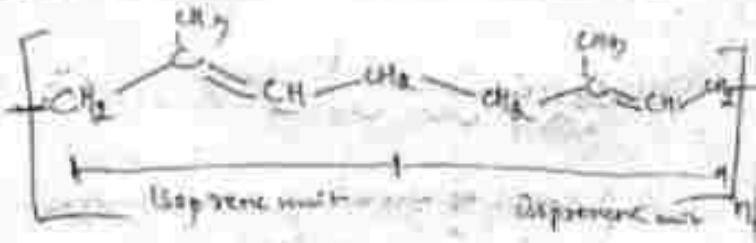
Eg of Thermosetting Polymer
└ Bakelite, Polyester

Thermoplastic Polymer
└ Polyethene,
Polyvinylchloride
Polystyrene

Elastomer — It is any rubber like elastic polymer which can be stretched to atleast thrice its length, but it returns to its original shape & dimension as soon as stretching force is released.

Natural Rubber :— It is a polymer of isoprene (2-Methyl buta-1,3-diene)





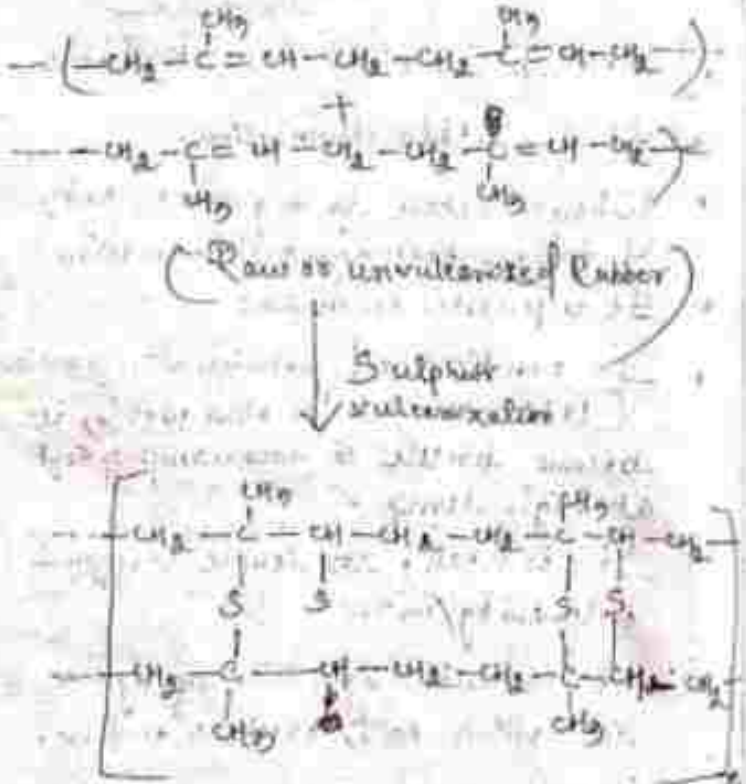
Structure of Natural Rubber
or
Cis-Polyisoprene

Drawbacks of Natural Rubber

- It has little durability.
- When stretch to a great extent, it suffers permanent deformation
- It is plastic in nature
- It can be used between temperature (10°C to 60°C). In other words, it become brittle at low temp & soft at high temp.
- It is weak, its tensile strength is only 200 kg/cm².
- It is attacked by oxidizing agents like nitric Acid, sulphuric acid etc.
- It has large water absorption capacity

Vulcanization of Rubber Imp

The process of heating raw rubber with sulphur upto 140°C in order to improve properties of rubber, is called vulcanization of Rubber.



Advantages of Vulcanization

1. It has high durability
2. It has useful temperature range −40°C to 100°C.
3. It has good tensile strength, can bear a load of 2000 kg/cm².
4. It is not attacked by oxidising agents like HNO_3, H_2SO_4.
5. It has excellent resilience, i.e. article made from it returns to original shape, when the deforming load is removed.
6. It has better electrical insulation power.
7. It has high resistance to oxidation, abrasion etc.

What is main purpose of vulcanization

The main purpose is to make the product stiff by adding sulphur which chemically at the double bonds of different rubber chains.

Chapter - 14

Chemicals in Agriculture

What are Pesticides?

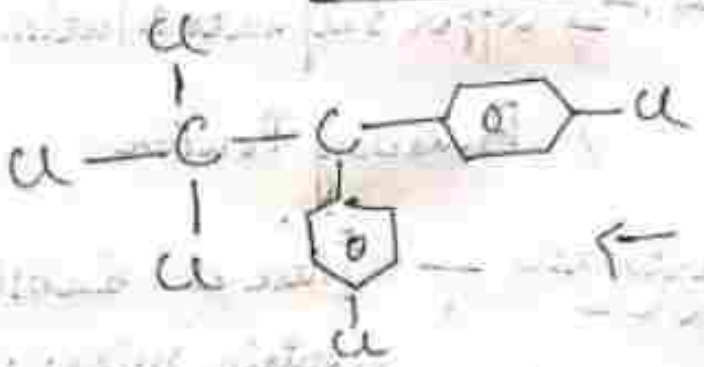
Pesticides are chemical substances that are meant to kill pests such as insects, ~~unwanted~~ herbs, fungi, etc.

- Pesticides are classified as —

a) Insecticides b) herbicides c) Fungicides.

a) Insecticides – The chemicals used to kill/control insects are called insecticides.

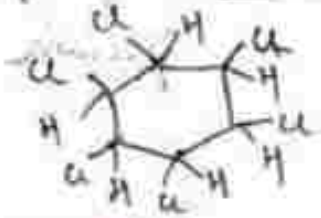
Example – ① DDT (Dichloro diphenyl trichloro ethane)



← DDT.

Uses – It is used to kill pest.

② Gammaxane (Benzene Hexa chloride) (BHC)



← BHC

Uses :- It is used in insect control.

Herbicides - Chemicals used for the removal of weeds such as grass & weeds, which may compete for growth & yield of desired crops.

Examples:- 1) Atrazine - used for control of broad leaf weeds & grass

2) Glyphosate based herbicides - It is a non-selective herbicide.

Fungicides - Chemicals used to kill microbes & fungi are called fungicides

Examples:- 1) Copper Sulphate solution

2) Bleaching Powder

Biofertilizers - These are substances that contain micro organisms, which when added to soil increase its fertility & promote plant growth

Types of Biofertilizers

a) Symbiotic Nitrogen Fixing Bacteria

→ Rhizobium } These bacteria exist in
→ Cyanobacteria } plants & help in providing nitrogen
Blue green algae - to rice plants.

b) Free-living Nitrogen Fixing Bacteria

→ Azotobacter - There are free living soil bacteria which help in nitrogen fixation

c) Phosphate Solubilizing bacteria

- These bacteria help in convert insoluble phosphorous to soluble phosphorous compounds - making them available to plants.

Importance of Biofertilizers

→ B-f improves soil fertility & yield of plants

→ B-f are eco-friendly & cost-effective

→ B-f protects the environment from pollutants since they are natural fertilizers

→ B-f don't allow pathogens to flourish.