LECTURER NOTES

ON

ENGINEERING CHEMISTRY

FOR 1st and 2nd SEMESTER

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CHAPTER-1   ATOMIC STRUCTURE

Fundamental particles:- An atom consist of three fundamental particles 1. Electron , 2. Proton 3. Neutron .

1. Electron:-

Definition:- An electron is defined as sub-atomic particle having a unit negative charge and a mass equal to 1/1835th the mass of the hydrogen .

It was discovered by **J.J.Thomsom .**

Charge of an Electron =1.602*10^{-19} coulomb .

Mass of an electron =9.11*10^{-31} Kg .

Density of an Electron =2.17*10^{17} mg/cc .

Radius of an Electron =10^{-15} cm .

Mass of one mole of an electron (N Electron) = 0.55 mgm (nearly) .   (one mole =6.022*10^{23})

Charge of one mole of an Electron = 96500 Coulomb = one Faraday .

2.Proton:- *(Discovered by Goldstien)*

A proton is defined as sub-atomic particle having a unit positive charge and mass equal to that of hydrogen atom .

Charge on proton = + 1.602*10^{-19} coulomb .

Mass of proton =1.672*10^{-27} Kg .

Mass of one mole of proton =1.007 gm (nearly) .

Charge on one mole of proton = 96500 coulomb .

3.Neutron:- *(Discovered by Chadwick)*

Neutron is defined as the neutral sub-atomic particle having a mass 1.675*10^{-27} Kg , Which is equal to mass of a hydrogen atom . Thus the nucleus consist of proton and neutrons . The proton and neutron are collectively called **Nucleons**.
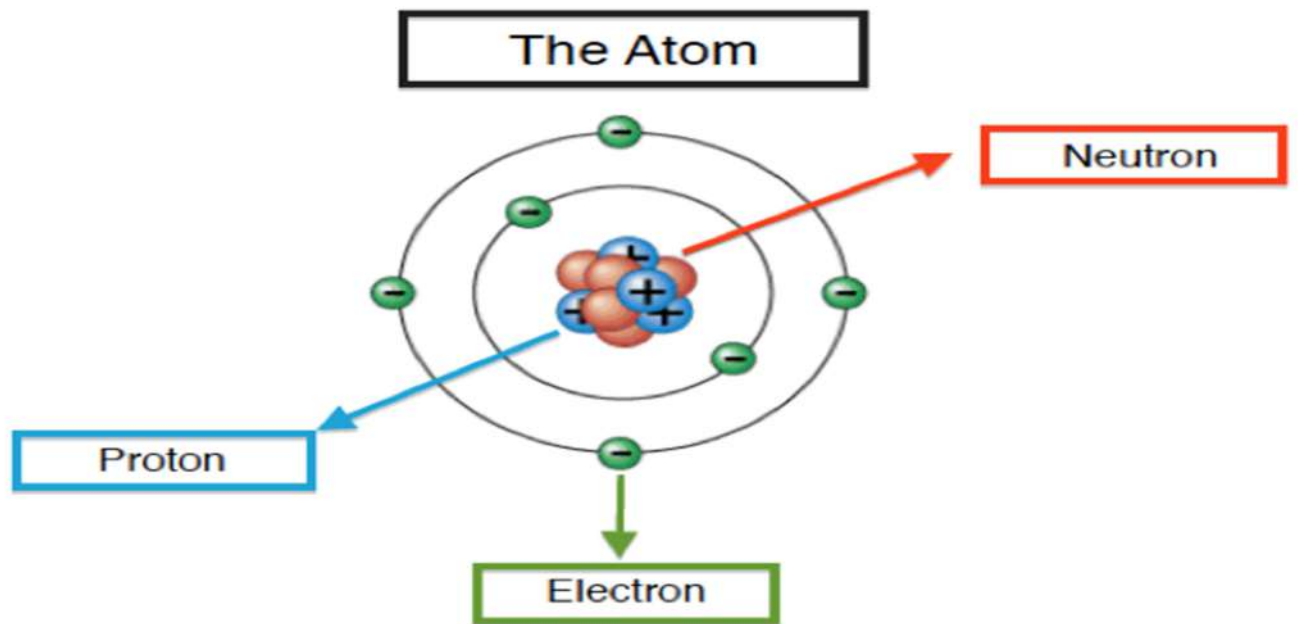
Mass of Neutron =1.675*10^{-27} kg .

Specific Charge of Neutron = 0 .

Density of Neutron =1.5*10^{14} g/cc .

Mass of one mole of Neutron =1.008 gm (nearly) .

Mass Number (A) =No of protons + No . of Neutron = p+n

Atomic Number (Z) = No. Of proton =No. Of Electron = p = e

The Atom

Neutron

Proton

Electron

RUTHERFORD'S ATOMIC MODEL:-

RUTHERFORD'S α-RAY(ALPHA RAY) SCATERING EXPERIMENT:-

Rutherford bombarded a thin sheet of gold foil(thickness 0.0004 cm) with a-particles (alpha particles) (He^{2-}) are obtained from a radioactive element like radium .

A thin lead plate with a hole cut in it , serve to form a beam of a-particles .A circular screen coated with zinc sulphide was placed on the other side of the foil.

Fig. 7.2 Rutherford's Gold Foil Experiment.
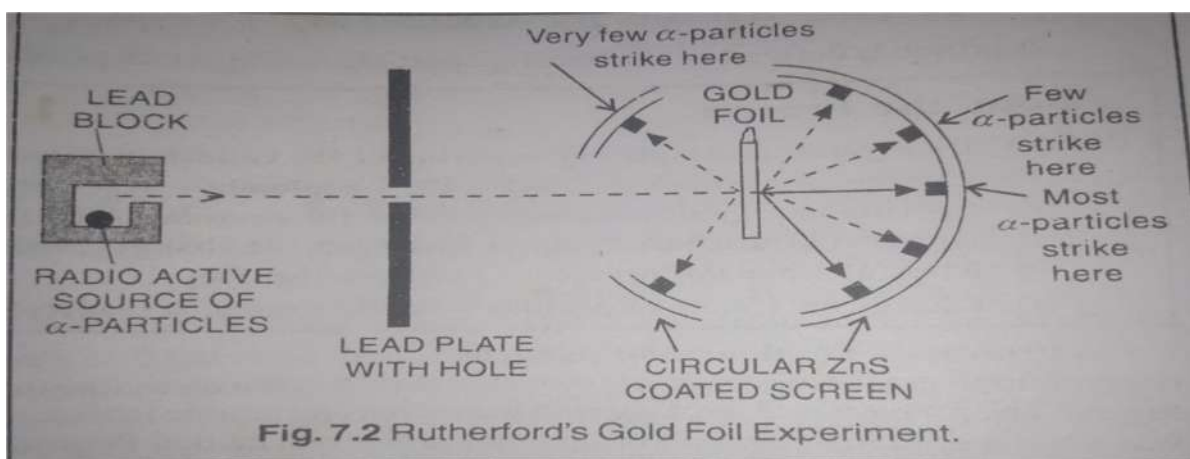
Observation-

It was observed that

1. Most of the a-particles passed straight through the gold foil and caused illuminations on the zinc sulphide.

2.Very few particles were deflected at some angles after passing through the gold foil .

3.While a very few particles (one in 10000) even retraced their path .

Fig. 7.3 Positively charged nucleus with empty space around it.
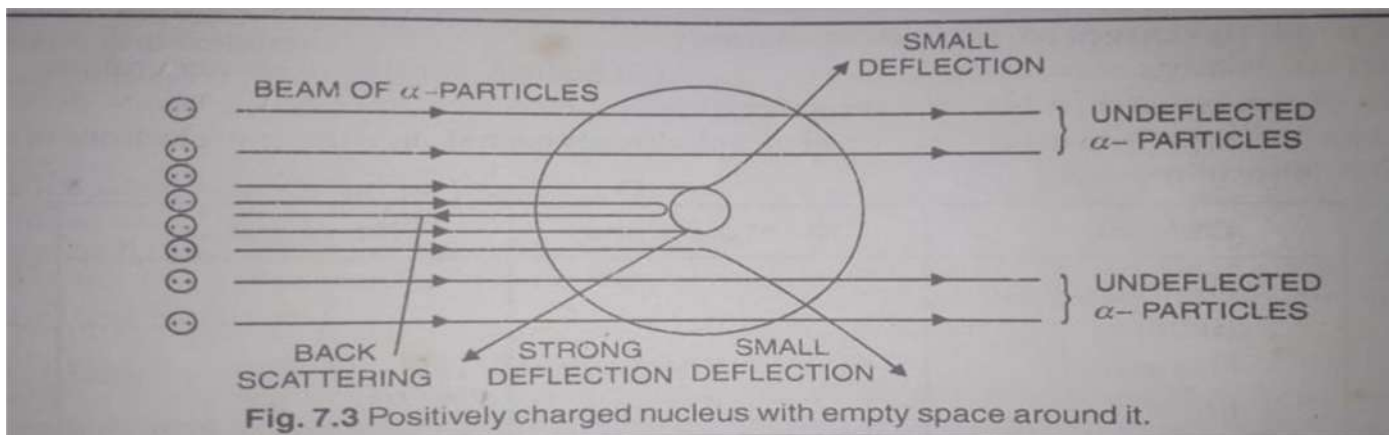
Conclusion-:From the above experiment , it was concluded that

1.Most of space in an atom is empty .

2.The scattering of a-particles in all direction further reveals that there is a heavy positive charge at the centre of the atom which causes repulsion .

Statement of Rutherford's Atomic Model:-

1.An atom consist of two parts (A) Nucleus (B) Extra-nuclear part

2.Nucleus is an extremely small positively charged part and is situated at the centre of an atom . it carries nearly the whole mass of an atom . The magnitude of the positive charge on the nucleus is different for the atoms of different element .

3.The electrons which balance the positive charge are distributed in the extra nuclear part . i.e. space around the nucleus .

4.The extra-nuclear electrons are not stationary . These are revolving around the nucleus at high speed in circular paths , called orbits . The centrifugal force which arises due to the rotation of electron balances the force of attraction . this prevents the electron to fail into nucleus . Rutherford's picture of an atom is comparable to solar system . The nucleus representing the sun and the revolving electrons are called planetary electron .

Drawbacks/Failure of Rutherford's Atomic Model:-

According to Rutherford's Atomic Model , an atom consist of nucleus and the electrons are revolving around it . Thus the centrifugal force which is produced by the circulation of electrons balances the force of attraction between the electron and nucleus .

But clark Maxwell had shown that a charged particles which moves under the influence of an attractive force continuously lose energy . Since electron is also charged particles , it must emits radiations and thus lose energy continuously . As electron loses energy , it starts coming nearer the nucleus , i.e. its orbit would become smaller and smaller . As a results of this , the electron would ultimately fall in to nucleus . but we know that the revolving electron never fall into the nucleus .Thus Rutherford's picture of an atom is faulty .

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

Atomic Number-:

Atomic number of an atom is defined as the number or unit positive charges or the proton present in the nucleus of an atom .

Atomic number = number of proton = Number of electron .

Atomic number is denoted by the letter Z .

Mass Number-:

Atomic mass which is also known as atomic weight , is the average mass of atom of an elements .

It is denoted by the letter A .

Mass number = No of proton +No of neutron

BOHR'S MODEL OF THE ATOM

Niels Bohr , (1913) proposed a theory which is not only accounted for the existence of line spectra but also suggested why atom do not collapse . he modified Rutherford's model of the atom with the help of quantum theory of radiation proposed by max Planck . the main postulates of Bohr's theory are:

1.An atom consist of a massive positively charged nucleus . the electron moving around the nucleus in certain fixed circular orbit without radiating energy . these non-radiating orbits are known as stationary states .

2.Each of the fixed circular orbit or stationary state is associated with definite amount of energy . Hence stationary state are also called energy level . the energy associated with different energy level increases with increase in distance from nucleus . The letters K ,L, M, N etc. .or the number 1 , 2, 3 ,4 etc . are used to designate the different energy level .

Figure 5.13 Bohr's planetary model
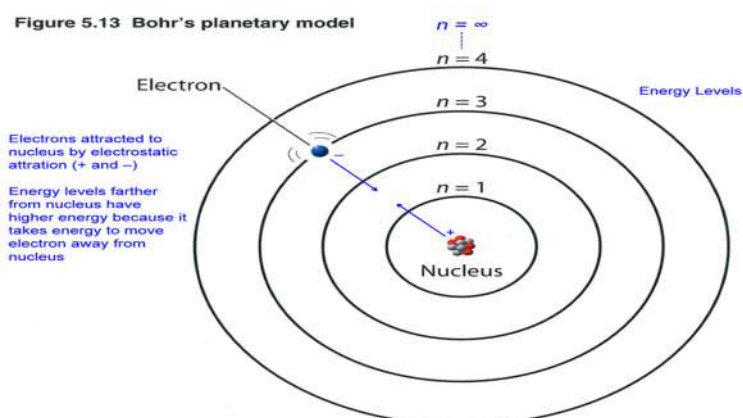
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Energy associated with an energy level is given by the relation

$$E_n = -1312/n^2 \text{ kJ mole}^{-1}$$

Here n is the number of energy level

Different energy level are not equally spaced , i.e. the energy different between two successive energy level is not same . It goes to decreasing with the increase in the value of 'n'

3.Only those orbit are permitted in which the angular momentum (mvr) of an electron is a whole number multiple of h/2pie and is given by the relation .

$$mvr = nh/2pie$$

Where n =1,2,3,4,....... , h is plank's constant , m and v represent the mass and tangential velocity respectively and r is the radius of the orbits.

4.So long as an electron revolving in a particular orbit , it can be neither emit or absorb energy .

5.The energy is emitted or absorb discontinuously in the form of quanta or small packets only . The electronic transition in the form of (a) higher to lower orbit by emission of energy and (b) lower to higher orbital by absorption of energy .

The amount of energy emitted or absorbed $hv=E_2-E_1$ OR

6.Since energy can not be lost continuously , an electron continues to move in a particular energy level without losing energy . Such a state of the atom is lnown as normal or ground state .
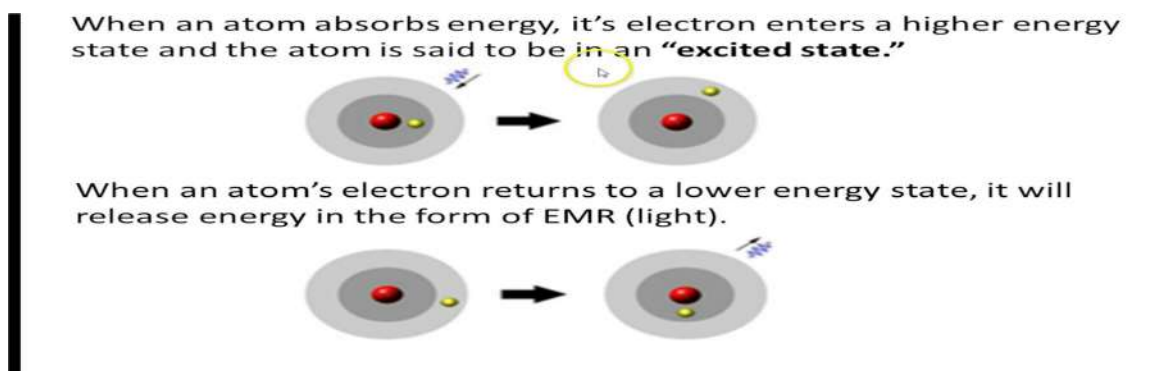
7.On gaining of energy from an external source , electron jumps from a lower energy to a higher energy level . Such a state of the atom is known as excited state . However the excited state being unstable , excited electron jumps down almost immediately to lower energy level by losing energy in the form of light radiation of suitable wavelength .

8.All the laws of classical physics are applicable to electron , i.e. the position , velocity , momemtum can be calculated accurately .

Note-The fundamental different between Bohr's model and rutherford's model of the atom is that Bohr's model based on the concept of quantisition of energy and angular momentum of electron . Acording to Borh.s theory , electron can be moves only in certain permited orbits with definite amount of energy and angular momentum . thus quantatisation is the key note of bohr's theory . Rutherford's model does not give an idea about the permiteted orbits .

ARRANGEMENT OF PLANETARY ELECTRONS

Bohr-Bury Scheme:-

Bohr-Bury (1921) gave the following rule for the distribute of electron in different orbital .

1.The maximum number of electron that can be present in an orbit is equal to $2n^2$ where n is the number of the orbit .

The maximum number of electron in various shells.

No.of the shell(n)		No of electron($2n^2$)
K-shell	1	2*1=2
L-shell	2	$2*2^2=8$
M-shell	3	$2*3^2=18$
N-shell	4	$2*4^2=32$

2.The outer most orbit of an element cannot contain more than 8 electron and their orbit immediately before it , i.e. penultimate/next orbit cannot contain more than 18 electrons.

3.It is not always necessary to complete an orbit before the next orbit starts filling . In fact a new orbit starts filling when the previous orbit gets electrons . The electronic arrangement of a few elements according to Bohr-Bury scheme are given bellow.

Element	At.No(Z)	Mass No (A)	No .of electron or proton	Neutron (A-Z)	Electron in Different orbital			
					K(1)	L(2)	M(3)	N(4)
Hyrogen	1	1	1	0	1			
Helium	2	4	2	2	2			
Lithium	3	7	3	4	2	1		
Beryllium	4	9	4	5	2	2		
Boron	5	11	5	6	2	3		
Carbon	6	12	6	6	2	4		
Nitrogen	7	14	7	7	2	5		
Oxygen	8	16	8	8	2	6		
Fluorine	9	19	9	10	2	7		
Neon	10	20	10	10	2	8		
Sodium	11	23	11	12	2	8	1	

Magnesium	12	24	12	12	2	8	2	
Aluminium	13	27	13	14	2	8	3	

Silicon	14	28	14	14	2	8	4	
Phosphorous	15	31	15	16	2	8	5	
Sulphur	16	32	16	16	2	8	6	
Chlorine	17	35	17	18	2	8	7	
Argon	18	40	18	22	2	8	8	

ISOTOPES-:

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

Ex- Elements	Atomic No.	Mass No.	No.of isotopes
Hydrogen	1	1,2,3	3
Helium	2	3,4,5	3
Chlorine	17	35,37	2
Calcium	20	40,42,44,48	4
Magnesium	12	23,24,25,26,27	5

Three isotopes of hydrogen

a. Protium $_1H^1$. It contains one electron and one proton.

b. Deuterium $_1H^2$. It contains one electron and one proton and one neutron .

c. Tritium $_1H^3$. It contains one electron and one proton and two neutron .

Hydrogen-1
mass number: 1

Hydrogen-2,
deuterium
mass number: 2

Hydrogen-3,
tritium
mass number: 3

ISOBARS-: Isobars are the atom of different elements having the same mass number but differ in their atomic numbers .

Ex-Argon $_{18}Ar^{40}$. It contain 18 proton and 18 electron and 22 neutrons.

   Calcium $_{20}Ca^{40}$. It contains 20 proton ,20electron ad 20 neutron s.
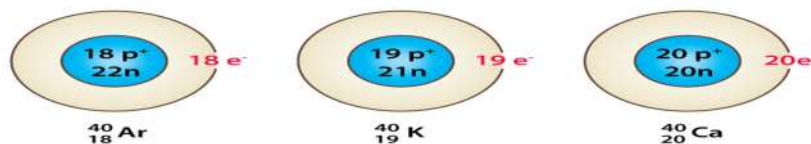
ISOTONE-: Atoms of the different elements which posses the same no of neutrons are called isotones .

Ex- $_{32}Ge^{76}$ and $_{33}As^{77}$ contain the same number of neutrons , i.e. 44 each and are thus called Isotones .

Example:

Oxygen $^{16}_{8}O$ (p=8; n=8)

Nitrogen $^{15}_{7}N$ (p=7; n=8)

Carbon $^{14}_{6}C$ (p=6; n=8)

are isotones because of having same no. of neutron (8).

QUANTUM NUMBER:-

Quantum number are the index number which are used to specify the position and energy of an electron in an atom .

There are four quantum number ,

1.Principal quantum Number (n):-

This quantum number was named as principal quantum number by Bohr and denoted as 'n' .

The value of 'n' for a shell is equal to the number of sub-shell present in that shell

Value of 'n'	Principal shell	No .of sub-shell
1	K	1(s)
2	L	2 (s, p)
3	M	3 (s, p, d)
4	N	4 (s, p, d, f)

2.Azimuthal quantum number (l) :-

This quantum number is also called as secondary , subsidiary , orbital or angular quantum number . It is denoted as 'l' .

The value of 'l' depends upon the value of n . 'l' can have zero to (n-1) .

n=1   l=0   s-sub shell   (spherically symmetrical)

n=2   l=0   s-sub shell   (dumbell shape)

l=1   p-sub shell

The different value for 'l' represent different sub-shell denoted by small letters

Value of 'l'	0	1	2	3	4	5
Sub-shell	s	p	d	f	g	h

Energy level of sub shell are in order

S < p < d < f < g

L=0   l=1   l=2   l=3   l=4

Maximum number of electrons that can be accommodated in a sub shell is calculated as 2(2l+1)

s-sub-shell   l=0   number of electron=2

p-sub-shell   l=1   number of electron=6

d-sub-shell   l=2   number of electron=10

f-sub-shell   l=3   number of electron=14

ELECTRONIC CONFIGURATION OF ELEMENT:-

It is governed by following rule :

1.Aufbau principle :

According to this principle the electrons are filled in various orbital in order of their increasing energies . Thus an orbital with lowest energy will be filled first . The energy content of the two subshells can be compared by means of (n+l) rule as explained bellow :

a)The sub shell with lower energy (n+1) value will posses lower energy and will be filled first ,

e.g. for 4s sub shell : n+l=4+0=4   for 3d subshell : n+l= 3+2=5

since (n+1) value for 4s sub shell is less than 3d , the 4s sub shell has lower energy and is filled first .

b)The sub shell with lower value of n posses lower energy if (n+1) value for both the sub shell are equal , e.g.

3p-subshell is filled first than 4s .

 For 3p-subshell : n+l=3+1=4   For 4s-subshell : n+l = 4+0=4

The value (n=3) is less for 3p-subshell as compares to that (n=4) for 4s –subshell . Hense , 3p-subshell has lower energy than 4s-subshell . it is evident from the following table that are increase order of various subshell

Subshell---→	1s	2s	2p	3s	3p	3d	4s	4p	4d	4f	5s	5p	
n	1	2	2	3	3	3	4	4	4	4	5	5	
l	0	0	1	0	1	2	0	1	2	3	0	1	

n+l	1	2	3	3	4	5	4	5	6	7	5	6

$$1s<2s<2p<3s<3p<4s<3d<4p<5s<4d<5p<6s<4f$$

Hund,s rule:-

Hund's rule: every orbital in a subshell is singly occupied with one electron before any one orbital is doubly occupied, and all electrons in singly occupied orbitals have the same spin.

Applying Hund,s rule , the electronic configuration of few elements are

1.Consider the correct electron configuration of the nitrogen (Z = 7) atom: $1s^2 \, 2s^2 \, 2p^3$

Nitrogen
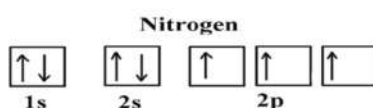
The p orbitals are half-filled; there are three electrons and three p orbitals. This is because the three electrons in the 2p subshell will fill all the empty orbitals first before pairing with electrons in them.

2. Next, consider oxygen (Z = 8) atom, the element after nitrogen in the same period; its electron configuration is: $1s^2 \, 2s^2 \, 2p^4$
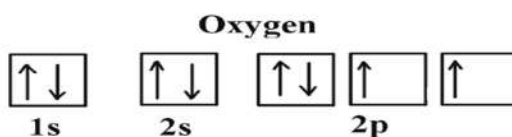
Oxygen

Oxygen has one more electron than nitrogen; as the orbital's are all half-filled, the new electron must pair up. Keep in mind that elemental oxygen is found in nature typically as dioxygen, O_2O2, which has molecular orbitals instead of atomic orbitals as demonstrated above.

Element		Z	Electron configuration
Hydrogen	H	1	$(1s)$
Helium	He	2	$(1s)^2$
Lithium	Li	3	$(1s)^2(2s)$
Beryllium	Be	4	$(1s)^2(2s)^2$
Boron	B	5	$(1s)^2(2s)^2(2p)$
Carbon	C	6	$(1s)^2(2s)^2(2p)^2$
Nitrogen	N	7	$(1s)^2(2s)^2(2p)^3$
Oxygen	O	8	$(1s)^2(2s)^2(2p)^4$
Fluorine	F	9	$(1s)^2(2s)^2(2p)^5$
Neon	N	10	$(1s)^2(2s)^2(2p)^6$
Sodium	Na	11	$(1s)^2(2s)^2(2p)^6(3s)$
Magnesium	Mg	12	$(1s)^2(2s)^2(2p)^6(3s)^2$
Aluminium	Al	13	$(1s)^2(2s)^2(2p)^6(3s)^2(3p)$
Silicon	Si	14	$(1s)^2(2s)^2(2p)^6(3s)^2(3p)^2$
Phosphorus	P	15	$(1s)^2(2s)^2(2p)^6(3s)^2(3p)^3$
Sulfur	S	16	$(1s)^2(2s)^2(2p)^6(3s)^2(3p)^4$
Chlorine	Cl	17	$(1s)^2(2s)^2(2p)^6(3s)^2(3p)^5$
Argon	A	18	$(1s)^2(2s)^2(2p)^6(3s)^2(3p)^6$
Potassium	K	19	$(1s)^2(2s)^2(2p)^6(3s)^2(3p)^6(4s)$
Calcium	Ca	20	$(1s)^2(2s)^2(2p)^6(3s)^2(3p)^6(4s)^2$
Scandium	Sc	21	$(1s)^2(2s)^2(2p)^6(3s)^2(3p)^6(3d)(4s)^2$
Titanium	Ti	22	$(1s)^2(2s)^2(2p)^6(3s)^2(3p)^6(3d)^2(4s)^2$
Vanadium	V	23	$(1s)^2(2s)^2(2p)^6(3s)^2(3p)^6(3d)^3(4s)^2$
Chromium	Cr	24	$(1s)^2(2s)^2(2p)^6(3s)^2(3p)^6(3d)^5(4s)$
Manganese	Mn	25	$(1s)^2(2s)^2(2p)^6(3s)^2(3p)^6(3d)^5(4s)^2$
Iron	Fe	26	$(1s)^2(2s)^2(2p)^6(3s)^2(3p)^6(3d)^6(4s)^2$
Cobalt	Co	27	$(1s)^2(2s)^2(2p)^6(3s)^2(3p)^6(3d)^7(4s)^2$
Nickel	Ni	28	$(1s)^2(2s)^2(2p)^6(3s)^2(3p)^6(3d)^8(4s)^2$
Copper	Cu	29	$(1s)^2(2s)^2(2p)^6(3s)^2(3p)^6(3d)^{10}(4s)$
Zinc	Zn	30	$(1s)^2(2s)^2(2p)^6(3s)^2(3p)^6(3d)^{10}(4s)^2$

Element	Atomic Number	Electronic Configuration	Group Number	Period Number
Helium	2	$1s^2$	18	1
Neon	10	$1s^2 2s^2 2p^6$	18	2
Argon	18	$1s^2 2s^2 2p^6 3s^2\, 3p^6$	18	3
Krypton	36	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2\, 4p^6$	18	4
Xenon	54	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2$ $4p^6 4d^{10} 5s^2\, 5p^6$	18	5
Radon	86	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2\, 4p^6$ $4d^{10} 4f^4 5s^2\, 5p^6 5d^{10} 6s^2\, 6p^6$	18	6

CHAPTER-2   CHEMICAL BONDING

A Chemical bond is defined as a force that holds the atoms in a molecule or ions in a crystal lattice.

TYPES OF CHEMICAL BOND:-

1.ELECTROVALENT OR IONIC BOND:-

An ionic bond is the electrostatics force of attraction between the cation (+ve charge) and the anion (-ve charge) of a molecule.

Formation of ionic bond:-

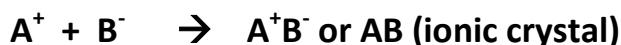The formation of an ionic bond between A^+ and B^- ions in A^+B^- ionic crystal takes place through the following step:

(a) **Loss of electron by atom A to form cation A^+**

$$A \rightarrow A^+ + e^-$$

(b) Gain of electron (lost by atom A) by atom B to form anion , B^-

$$B + e^- \rightarrow B^-$$

(c) Combination of A^+ **and** B^- ion to form A^+B^- ionic crystal by electrostatics force of attraction.

$$A^+ + B^- \rightarrow A^+B^- \text{ or AB (ionic crystal)}$$

FORMATION OF SOME IONIC COMPOUND:-

Formation NaCl(Sodiun Chloride):-

> **1. Sodium chloride (NaCl).** We know that Na-atom has one electron in its valence-shell (Na = 2, 8, 1). When this atom combines with Cl-atom, it loses its single electron residing in its valence-shell and is converted into Na⁺ ion (cation). This ion has 4-electron configuration (Na⁺ = 2, 8).
>
> $$Na(2, 8, 1) \longrightarrow Na^+ (2, 8) + e^-$$
>
> Since Cl-atom has 7 electrons in its valence-shell (Cl = 2, 8, 7), it needs one electron to get 8-electron configuration. Cl-atom, therefore, takes the single electron lost by Na-atom and forms Cl⁻ ion (anion).
>
> $$Cl (2, 8, 7) + e^- \text{ (From Na-atom)} \longrightarrow Cl^- (2, 8, 8)$$

Since Na⁺ and Cl⁻ ions have opposite charges, they are linked together by electrostatic force of attraction (i.e., ionic bond) to form Na⁺Cl⁻ or NaCl molecule.

The formation of NaCl molecule can also be shown by geometric or atomic structural diagram given in Fig. 2.1.

The combination of Na⁺ and Cl⁻ ions by electrostatic force of attraction lowers the energy of the system and hence makes it a stable compound.

IONIC EQUATIONS

$$Na - e \longrightarrow Na$$
$$(2,8,1) \qquad (2,8)$$
$$Cl + e \longrightarrow Cl$$
$$(2,8,7) \qquad (2,8,8)$$

ELECTRON DOT DIAGRAM

Na. + :Cl: ⟶ [:Na:]⁺ [:Cl:]⁻
(2,8,1) (2,8,7)   (2,8)   (2,8,8)

Na: + :Cl: ⟶ [:Na:]⁺ [:Cl:]⁻ or
(2,8,1) (2,8,7)   (2,8)   (2,8,8)

Formation of Magnesium Chloride(MgCl₂):-

3. Magnesium chloride (MgCl₂)

Magnesium chloride is formed by the transferrence of two valence electrons from Mg atom (2, 8, 2) to two chlorine atoms (2, 8, 7). Magnesium atom attains a stable electronic configuration of the nearest noble gas NEON (2, 8) by losing two electrons from its valence shell and changes to Mg^{2+}. The chlorine atoms attain stable electronic configuration of the nearest noble gas, ARGON (2, 8,8), by gaining one electron each in the valence shell, and become chloride ions. The oppositively charged Mg^{2+} and Cl⁻ ions are held together by the electrovalent bond to form magnesium chloride $Mg^{2+}(Cl^-)_2$ or $MgCl_2$.

Ionic Equations

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

$$2Cl + 2e^- \longrightarrow 2Cl^-$$
$$(2, 8, 7) \qquad (2, 8, 8)$$

$$Mg + Cl_2 \rightarrow Mg^{2+} + 2Cl^- \longrightarrow Mg^{2+}(Cl^-)_2 \text{ or } MgCl_2$$

$Mg^{2+} + 2Cl^- \rightarrow$
$Mg^{2+}Cl^-$
$\Rightarrow MgCl_2$

Electron dot diagram :

:Cl: + ·Mg· + :Cl: ⟶ [:Cl:]⁻ [:Mg:]²⁺ [:Cl:]⁻
(2,8,1) (2,8,7) (2,8,7) (2,8,8) (2,8)   (2,8,8)

2.COVALENT OR MOLECULAR BOND:-

The chemical bond that is formed between two combining atoms by mutual sharing of one or more electron of atom of non-metalic element , is called a covalent or a molecular bond.

Types of covalent bond:-

Single bond:-A covalent bond formed by the mutual sharing of only one electron pair between the two atom is called single bond.

Single bond is denoted by placing a single line (-) between two atom.

Double bond:-A double bond consist of two single bond and hence is formed by the sharing of two electron pairs between the two combining atom.

Double bond is denoted by placing a two line(=) between two atom.

Triple bond:-A triple bond consist of three single bond and hence is formed by the sharing of three electron pairs between the two combining atom.
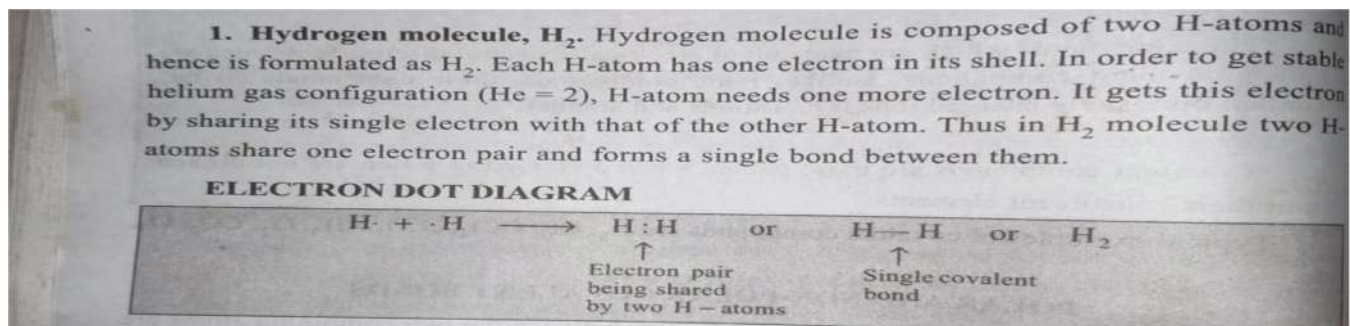
It is denoted by the placing a three line($\equiv$) between two atom.

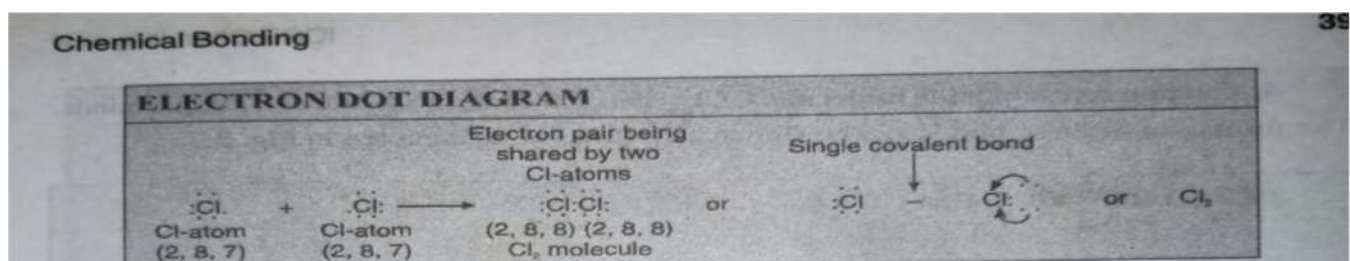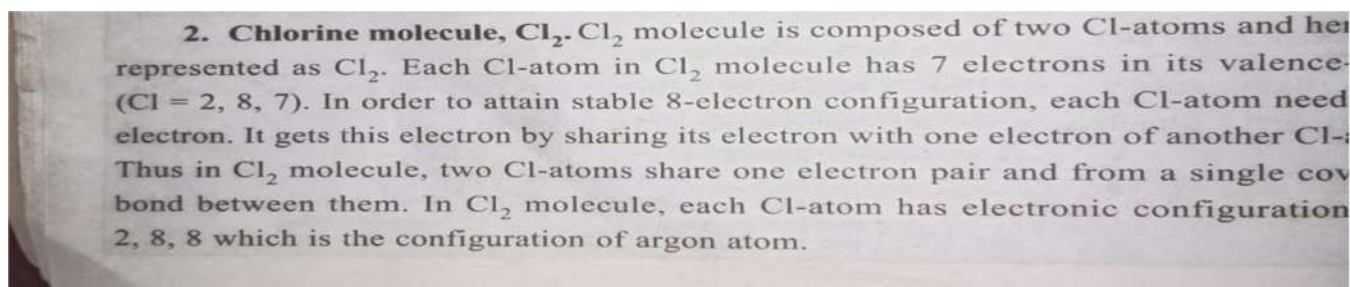Note-:The compound which contain single,double.triple covalent bond are called covalent compound.

Ex-$H_2, N_2, Cl_2, CCl_4, H_2O, NH_3, O_2, CO_2, O_3$ etc

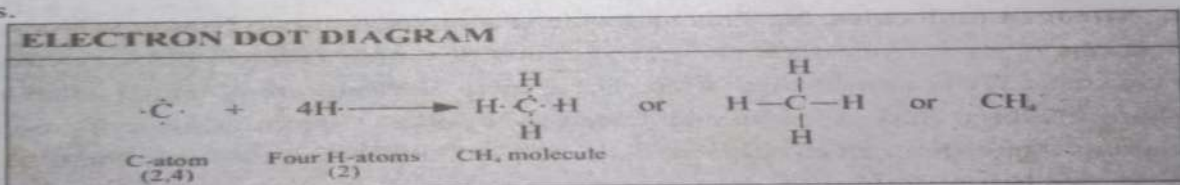## FORMATION OF SOME COVALENT BONDS:-

Formation of Hydrogen Molecule(H_2):-

1. **Hydrogen molecule, H_2.** Hydrogen molecule is composed of two H-atoms and hence is formulated as H_2. Each H-atom has one electron in its shell. In order to get stable helium gas configuration (He = 2), H-atom needs one more electron. It gets this electron by sharing its single electron with that of the other H-atom. Thus in H_2 molecule two H-atoms share one electron pair and forms a single bond between them.

ELECTRON DOT DIAGRAM

H· + ·H ⟶ H:H   or   H—H   or   H₂

Electron pair being shared by two H – atoms

Single covalent bond

Formation of Chlorine Molecule(Cl_2)-:

2. **Chlorine molecule, Cl_2.** Cl_2 molecule is composed of two Cl-atoms and her represented as Cl_2. Each Cl-atom in Cl_2 molecule has 7 electrons in its valence- (Cl = 2, 8, 7). In order to attain stable 8-electron configuration, each Cl-atom need electron. It gets this electron by sharing its electron with one electron of another Cl- Thus in Cl_2 molecule, two Cl-atoms share one electron pair and from a single cov bond between them. In Cl_2 molecule, each Cl-atom has electronic configuration 2, 8, 8 which is the configuration of argon atom.

39

Chemical Bonding

ELECTRON DOT DIAGRAM

Electron pair being shared by two Cl-atoms

Single covalent bond

:Cl· + ·Cl: ⟶ :Cl:Cl: or   :Cl — Cl: or   Cl₂

Cl-atom (2, 8, 7)   Cl-atom (2, 8, 7)   (2, 8, 8) (2, 8, 8) Cl₂ molecule

Methane Molecule(CH_4)-:

3. Methane molecule, CH_4. The electronic configuration of C-atom viz., 2, 4 sho-
that this atom requires 4 electrons to acquire stable 8-electronic configuration. Th-
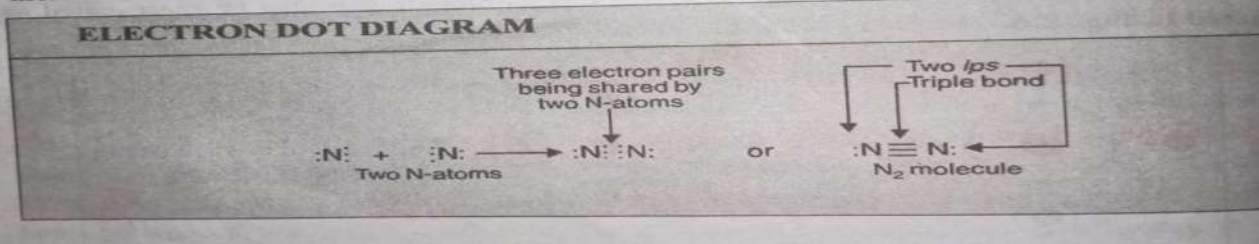configuration is achieved by C-atom when this atom shares its four electrons with four
atoms.

ELECTRON DOT DIAGRAM

| ·Ċ· | + | 4H· | ⟶ | H·Ċ·H | or | H—C—H | or | CH₄ |

C-atom (2,4)   Four H-atoms (2)   CH, molecule

The formation of four C — H bonds in CH_4 molecule can also be represented
depicted in Fig. 2.6.

Four H and C-atom   CH₄ molecule

Fig.2.6. Diagram showing the formation of four C—H single bonds in Ch₄ molecule.
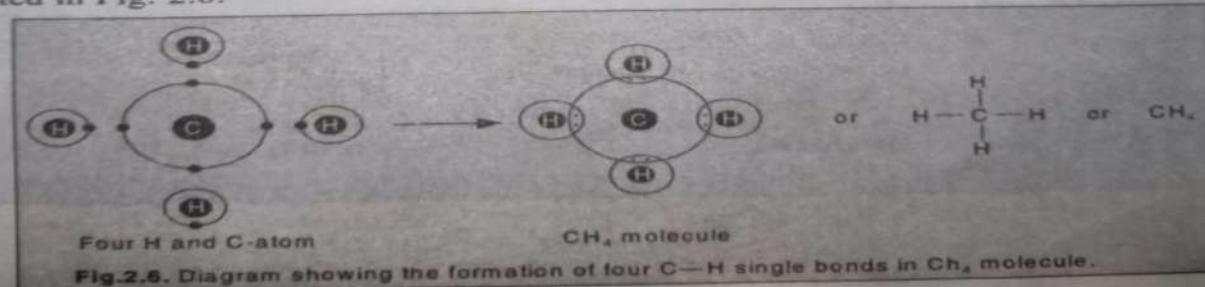
Nitrogen Molecule(N_2):-

Fig. 2.7. Diagram to snow ᵗⁿᵉ ˡᵒ...

1. Nitrogen molecules, N_2. This molecule is composed of two N-atoms. N-atom h
five electrons in its valence-shell (N = 2, 3). Thus this atom requires three electrons
achieving stable 8-electron configuration. These three electrons are obtained when one
atom shares its three electrons with three electrons of other N-atom. Thus in N_2 molecu
two N-atoms share three electron pairs with each other and form a triple bond betwe
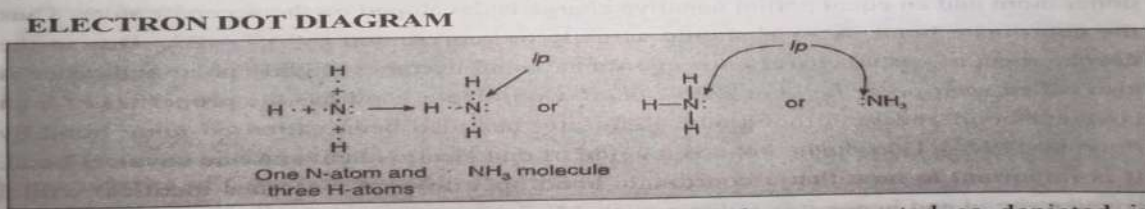them as shown below:

ELECTRON DOT DIAGRAM

Three electron pairs being shared by two N-atoms

:N: + :N: ⟶ :N::N: or   :N≡N:

Two N-atoms   N₂ molecule

Two lps — Triple bond

Water Molecule(H_2O)-:

in HCl molecule.

2. Water molecule, H_2O. H-atom has one electron in its outermost shell and O-atom
contains six electrons in its valence-shell (O = 2, 6), thus these atoms need 1 and 2 ($8 - 6 = 2$)
electrons respectively to achieve stable 2-electron and 8-electron configuration. In order to
get these stable electronic configurations, one O-atom shares its two electrons with two
electrons of two H-atoms and form two O—H covalent single bond. Four electrons (i.e.,
two electron pairs) of O-atoms remain unused or unshared pairs of electron on O-atom,
since these electron pairs are not utilised in the formation of O—H bonds. These unused
electron pairs are called *lone pairs of electrons* (*lps*). Electron pairs used in the formation of
H—O single covalent bonds are called *bonding electron pairs* (*bps*). Thus, we see that H_2O
molecule has two *bps* and two *lps*. *lps* are localised on O-atom.

ELECTRON DOT DIAGRAM

Two tps

H· + ·Ö: ⟶ H·· Ö: or $\overset{\delta+}{H}$—$\overset{\delta-}{Ö}$:

One O-atom and two H-atoms   *Two bps* H₂O molecule

represented as depicted in
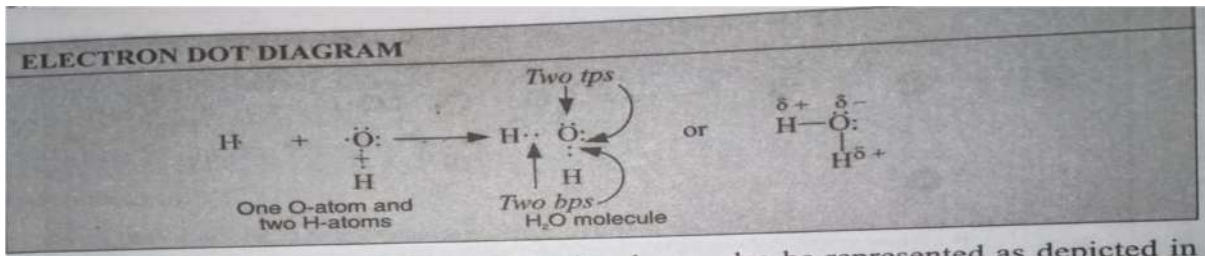
Ammonia Molecule(NH₃):-

3. Ammonia molecule, NH₃. H-atom has one electron while N-atom has 5 electrons in its valence shell (N = 2, 5), thus, these atoms need 1 (2 − 1 = 1) and 3 (8 − 5 = 3) electrons respectively to have stable 2-electron and 8-electron configurations. In order to achieve these stable configurations, one N-atom shares its three electrons with three electrons of three H-atoms and forms three N–H single bonds. Two electrons (*i.e.*, one electron pair) resides on N-atom as unshared electrons (*lp*), since these electrons do not participate in the formation of any of the three N—H bonds. Thus we see that NH₃ molecule contains three *bps* and one *lp* as shown below.

ELECTRON DOT DIAGRAM

One N-atom and three H-atoms   NH₃ molecule

represented as depicted in

CHAPTER-3   *ACID, BASE AND SALT*

THEORIES OF ACIDS AND BASES

1. ARRHENIUS THEORY:

According 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."

Example of Acid: HCl $\xrightarrow{\text{water}}$ H^+ (aq) + Cl^- (aq)
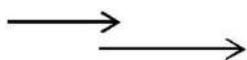
Other examples of acids are: HNO_3, H_2SO_4 ,CH_3COOH etc. Examples of

Base: NaOH (s) $\xrightarrow{\text{water}}$ Na^+ (aq) + Cl^- (aq)Other examples of bases

are: KOH, $Ca(OH)_2$, $Al(OH)_3$ etc

Salient Features:

i. According to Arrhenius theory an acid reacts with a base to
form salt and water and the reaction is called neutralisation
reaction.

HCl +   NaOH →   NaCl + H_2O

(Acid)   (Base)   (Salt)   (Water)
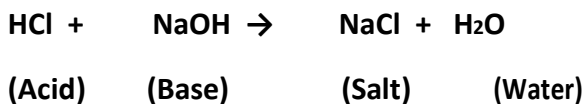
Neutralisation reaction may be represented as:

H^+(aq)   + OH^- (aq)   → H_2O(l)

(from acid)   (from base)
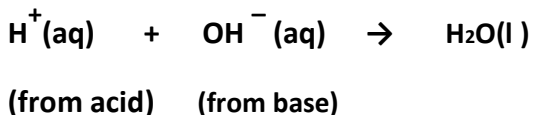
ii. Higher the degree of dissociation, higher is the acidic or basic nature of
the substance.

Limitations:

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

H^+ + H_2O → H_3O^+
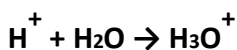
ii. The theory fails to explain the acidic and basic nature of the substances in solvents other than water.

iii. The theory fails to explain the acidic nature of the substances like SO_2, CO_2, SiO_2, P_2O_5, BF_3, $AlCl_3$, etc. which cannot provide H^+ ions.

iv. The theory fails to explain the basic nature of the substances like NH_3, PH_3, Na_2O, K_2O, CaO etc. which can't provide OH^- ions.

v. The theory fails to explain neutralisation reactions between some acidic and basic substances which do not produce water.

$HCl + NH_3 \rightarrow NH_4Cl$
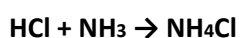
2. LOWRY- BRONSTED THEORY

According to Lowry - Bronsted theory "Acids are the substances (molecules/ions) 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".

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

Examples of acids are:

i. HCl, HNO_3, H_2SO_4 , H_3PO_4, CH_3COOH, H_2CO_3 etc.
ii. Ions having capacity to donate H^+ ion: (HS^- , HCO_3^- , HPO_4^{2-}, HSO_4^- etc.)

Examples of Bases:

i. Neutral molecules such as: H_2O, NH_3, RNH_2, PH_3, AsH_3, etc.
ii. Ions having capacity to accept H^+ ion, like OH^- , CN^- , HCO_3^- etc.
All Arrhenius acids are Bronsted acids but all Bronsted bases are not Arrhenius bases.

Salient Features:-

i. According to this theory an acid reacts with a base to form another pair of acid and base.
ii. The pair of acid and base which differ by a proton (H^+ ion) is called a conjugate acid-base pair.

Acid – H^+ $\rightarrow$ Conjugate base

Base + H^+ $\rightarrow$ Conjugate acid

iii. The substances such as H_2O, HS^- , HCO_3^-, HPO_4^{2-}, HSO_4^- etc which act as both acid (proton donor) as well as base (proton acceptor) are called amphoteric substances. iv. Stronger is an acid weaker is its conjugate base and vice versa.

HCl   +   H₂O   →   H₃O⁺   +   Cl⁻

[Strong acid]   [Weak base]
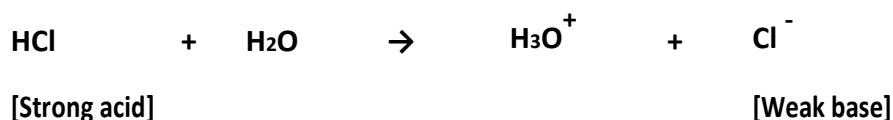
Limitations of the theory:

i. 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.

ii. It fails to explain the basic nature of the substances, such as Na_2O, K_2O, CaO etc. which cannot accept H^+ ion.

iii. It fails to explain the reaction between some acids and bases which do not give another pair of acid and base. Example: HCl + NaOH → NaCl + H_2O.

Note: Some conjugate acid-base pairs are given below:

ACID	CONJUGATE BASE	BASE	CONJUGATE ACID
HCl	Cl^-	Br^-	HBr
H_2SO_4	HSO_4^-	CN^-	HCN
NH_4^+	NH_3	NH_2^-	NH_3
H_2O	OH^-	H_2O	H_3O^+

2. LEWIS THEORY

According to Lewis theory "Acids are the substances (molecules/ions) which can accept a pair of electrons from any other substance, while bases are the substances (molecules/ions) which can donate a pair of electrons to any other substance." In other words, acids are electron acceptors while bases are electron donors.

Examples of acids:-

i.All cations are Lewis acids: For example; Na^+, K^+, Ca^{2+}, Cu^{2+}, Al^{3+}, Fe^{3+} etc.

ii. Neutral molecules containing electron deficient atoms are Lewis acids. For example: BF_3, $AlCl_3$, $FeCl_3$, $ZnCl_2$ etc.

iii. Neutral molecules containing vacant d-orbitals in the central atom for the accommodation of incoming electrons act as Lewis acids. For exam ple: SiF_4, $SiCl_4$, etc. iv. The molecules having multiple bonding (= or ≡) between the atoms of different elements are acidic in nature. For example: 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

Salient Features:

i.According to this theory, an acid reacts with a base to form an acid- base complex which involves a co-ordinate or dative bond. For example, the reaction between H_2O (Lewis base) and H^+ (Lewis acid) results in the formation of a dative bond.

ii.All Bronsted- Lowry bases are Lewis bases while the reverse is not always trur.

Limitations:

i.According to this theory, the reaction between an acid and 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 and the bases such as NaOH, KOH etc. are instantaneous or fast.

ii.Catalytic activity of Lewis acids cannot be explained because catalytic activity of many acids is due to their tendency to furnish H^+ ion. Lewis acids are lacking this activity.

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

TYPES OF ACID, BASE AND SALT

TYPES OF ACID

1. **Strong Acids:** These are the acids which undergo almost complete ionization in aqueous solution. Example: HCl, HNO_3, H_2SO_4 etc.

2. Weak Acids: These are the acids which undergo partial ionization in aqueous solution.

Example:

i.Inorganic Acids like: HCN, H_2CO_3, HF, etc.

ii.All Organic Acids like: HCOOH, CH_3COOH, C_2H_5COOH etc.

Basicity of acid – Total no. of replaceable hydrogen atoms is known as basicity of an acid.

1.**Monobasic Acids:** The acid containing only one replaceable hydrogen atom is called a monobasic acid. Example: HCl, HNO_3, HCN, CH_3COOH, H_3BO_3 etc.

2.**Dibasic Acids:** The acid containing two replaceable hydrogen atoms is called a dibasic acid. Example: H_2SO_4, H_2CO_3, H_3PO_3 etc.

3.**Tribasic Acid:** The acid containing three replaceable hydrogen atoms is called a tribasic acid. Example: H_3PO_4 etc.

<u>**TYPE OF BASES**</u>

1.**Strong Bases:** These are the bases which undergo almost complete ionization in aqueous solution. Example: NaOH, KOH, $Mg(OH)_2$, $Ca(OH)_2$, etc.

2.**Weak Bases:** These are the bases which undergo partial ionization in aqueous solution. Example: NH_4OH, etc.

*Acidity of a base – Total no. of replaceable hydroxyl groups present is known as acidity ofabase

3.**Monoacidic base:** The base containing only one replaceable OH group is called a monoacidic base. Example: NaOH, KOH, LiOH, NH_4OH, etc.

4.**Diacidic base:** The base containing two replaceable OH groups is called a diacidic base. Example: $Mg(OH)_2$, $Ca(OH)_2$, $Ba(OH)_2$, etc.

5.**Triacidic base:** The base containing three replaceable OH groups is called a triacidic base. Example: $Al(OH)_3$, $B(OH)_3$, etc.
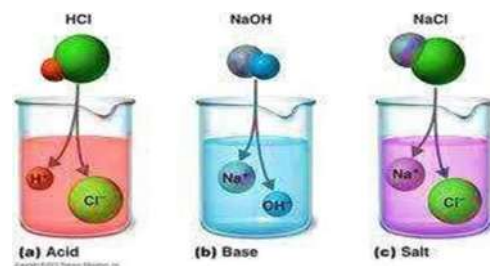
SALT

Salts are regarded as compounds made up of positive and negative ions. The positive part comes from a base while negative part from an acid. Salts are ionic compounds.

<u>**TYPES OF SALT**</u>

Salts may be classified into the following types:-

1.**Normal salts:** The salt obtained by the complete replacement of all the replaceable hydrogen atoms of an acid by metal atoms is called a normal

salt. These salts are obtained by the reaction between strong acids and strong bases. These salts are not hydrolysed in aqueous solution.

(a) Acid   (b) Base   (c) Salt

Example:

Acids   Normal salts

HCl	NaCl, KCl, CaCl$_2$, MgCl$_2$, etc
HNO$_3$	NaNO$_3$, KNO$_3$, Ca(NO$_3$)$_2$, Mg(NO$_3$)$_2$, etc.
H$_2$SO$_4$	Na$_2$SO$_4$, K$_2$SO$_4$, CaSO$_4$, MgSO$_4$, etc.
H$_3$PO$_4$	Na$_3$PO$_4$, K$_3$PO$_4$, Ca$_3$(PO$_4$)$_2$, Mg$_3$(PO$_4$)$_2$, etc.

2.**Acidic salts: The salt obtained by the partial replacement of replaceable hydrogen atoms of an acid by metal atoms is called an acidic salt. These type of salts still contain one or more replaceable hydrogen atoms.**

Example:

Acids   Acidic salts

H$_2$SO$_4$ NaHSO$_4$, KHSO$_4$ etc.

H$_3$PO$_4$ NaH$_2$PO$_4$, KH$_2$PO$_4$, Na$_2$HPO$_4$, K$_2$HPO$_4$ etc.

3.**Basic salt: These are the salts obtained by the incomplete neutralization of poly acidic bases. Such salts contain one or more 'OH' groups. Example: Ca(OH)Cl, Mg(OH)Cl, Zn(OH)Cl, Al(OH)$_2$Cl etc.**

Solution   Chapter-4

Introduction :-

A solution is a homogeneous mixture of two or more substances. In such mixture, a solute is a substance dissolved in another substance, known as a solvent.

example : salt water, and sugar dissolved in water.

→ Solutions may be of three types, they are

(i) solid solution
(ii) liquid solution &
(iii) Gaseous solution.

Atomic Weight / Mass :-

The atomic mass of an element may be defined as the average relative mass of one atom of the element as compared to the mass of an atom of carbon (12_c) taken as 12.

→ The unit of atomic mass is amu (atomic mass unit).

example :

Element	Atomic mass
Na	23 amu
O	16 amu
Ar	40 amu

Solution Chapter-4

Gram atomic mass :-

The gram atomic mass of an element is simply its atomic mass expressed in gram.

example:

Element	Gram atomic mass
H	1.008 gm
C	12 gm
O	16 gm
Ca	40 gm

Molecular Weight :-

The molecular weight of a substance is defined as the average relative mass of one molecule of it as compared to the mass of an atom of carbon (^{12}C) taken as 12.

→The unit of molecular weight is a.m.u

for example: The molecular weight / mass of sodium carbonate (Na_2CO_3) is calculated as follows;

Molecular weight of Na_2CO_3 = 2(Na) + 1(C) + 3(O)

= 2(23) + 1(12) + 3(16)

= 46 + 12 + 48

= 106 a.m.u

Similarly, the molecular mass of sodium-
-chloride (NaCl), sulphuric Acid (H_2SO_4),
pottassium carbonate (K_2CO_3) calculated as
follows :

compound	Molecular mass
NaCl (sodium chloride)	$23 + 35.5 = 58.5$ amu
H_2SO_4 (sulphuric Acid)	$2 + 32 + 64 = 98$ amu
K_2CO_3 (potassium carbonate)	$78 + 12 + 48 = 138$ amu.

Gram molecular weight :-

The gram molecular weight
of a substance is simply its molecular
weight expressed in gram.

for example:

compound	Gm.mol. weight
NaOH (sodium hydroxide)	$23 + 16 + 1 = 40$ gm.
$Al_2(SO_4)_3$ (Aluminium sulfate)	$2 \times 27 + 3 \times 32 + 12 \times 16 = 342$ gm.
Na_2CO_3 (sodium carbonate)	$2 \times 23 + 12 + 3 \times 16 = 106$ gm.

Equivalent Weight :~

Equivalent weight of a substance
is the number of parts by mass of it that
contain, combines with on displaces directly
on indirectly 1.008 parts by mass of hydrogen
8 parts by mass of oxygen on 35.5 parts by

mass of chlorine.

→ Equivalent weight has no unit.

For example:

In the compound $AlCl_3$, the equivalent weight of 'Al' can be determined as below:

In $AlCl_3$, we say that $\quad 1\,Al \equiv 3\,Cl$

i.e. $\qquad$ 27 parts of Al $\equiv 3 \times 35.5$ parts of Cl

$$\frac{27}{3} \text{ parts of } Al \equiv \frac{3 \times 35.5}{3} \text{ parts of Cl}$$

9 parts of Al $\equiv$ 35.5 parts of Cl

Thus, 9 parts by mass of Aluminium can combine with 35.5 parts by mass of chlorine. therefore the equivalent mass of 'Al' is 9.

Gram equivalent weight :-

The gram equivalent weight of a substance is its equivalent weight expressed in gram.

Example: The equivalent weight of Ca in $CaCl_2$ can be calculated as follows:

In $CaCl_2$, we say that $\quad 1\,Ca \equiv 2 \times Cl_2$

40 parts of Ca $\equiv 2 \times 35.5$ parts Cl

$$\frac{40}{2} \text{ parts of } Ca \equiv \frac{35.5 \times 2}{2} \text{ parts of Cl}$$

20 parts of Ca $\equiv$ 35.5 parts of Cl

Thus, 20 parts by mass of calcium can combine with 35.5 parts by mass of chlorine. therefore the ~~~~ Gram equivalent weight of Ca is 20 gram.

Relationship between atomic weight, equivalent weight and valency :-

The equivalent mass of an element depend upon its valency, as it is clear from the following relation.

$$\text{equivalent mass} = \frac{\text{Atomic mass}}{\text{valency}}$$

## Equivalent weight of Acid, Bases and salt :-

Equivalent weight of Acid :-

The equivalent weight of Acid is equal to the molecular weight of the Acid divided by the basicity.

$$E_{Acid} = \frac{\text{Molecular weight}}{\text{Basicity}}$$

Basicity :- Number of replaceable hydrogen atom present in one molecule of an acid is called its Basicity.

example of Basicity:

→ The number of replaceable hydrogen atoms in HCl is one. thus the basicity of HCl is one

$$HCl \longrightarrow H^+ + Cl^- \quad (Monobasic \ Acid)$$
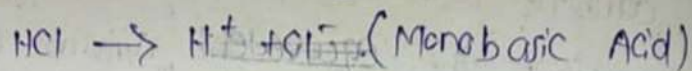
→ The basicity of sulphuric Acid is '2', Because it contains 2 replaceable hydrogen atoms.

$$H_2SO_4 \longrightarrow 2H^+ + SO_4^{2-} \quad (dibasic \ Acid)$$
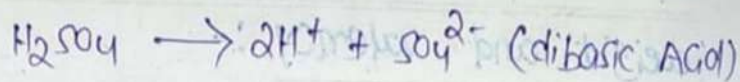
→ The basicity of phosphoric acid is '3', it contain '3' replaceable hydrogen atoms.

$$H_3PO_4 \longrightarrow 3H^+ + PO_4^{3-} \quad (Tribasic \ Acid).$$
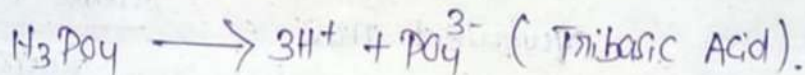
example of Equivalent weight of Acid :-

Acid	formula	Basicity	M.M (molecular mass)	Eq. mass of Acid $\left(\frac{M.M}{B}\right)$
Hydrochloric Acid	HCl	1	$1+35.5=36.5$	$\frac{36.5}{1} = 36.5$
Acetic Acid	CH_3COOH	1	60	$\frac{60}{1} = 60$
Sulphuric Acid	H_2SO_4	2	98	$\frac{98}{2} = 49$
oxalic Acid	COOH | COOH	2	90	$\frac{90}{2} = 45$
Phosphoric Acid	H_3PO_4	3	98	$\frac{98}{3} = 32.66$
Phosphorus Acid	H_3PO_3	2	82	$\frac{82}{2} = 41$

Equivalent weight of Base :-

The equivalent weight of a base is equal to the molecular weight of the base divided by the Acidity.

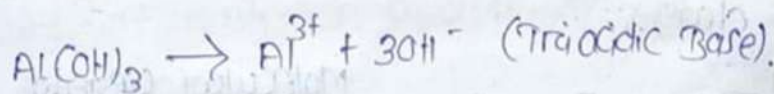$$E_{base} = \frac{Molecular\ Weight}{Acidity}$$

Acidity:- Number of hydroxyl group present in one molecule of a base is called Acidity.
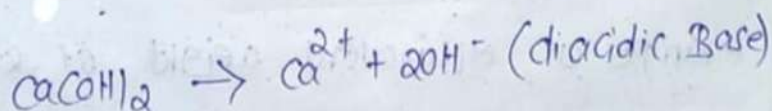
example of Acidity:

→ The number of hydroxyl group in sodium hydroxide (NaOH) is one. thus its acidity is one

$$NaOH \longrightarrow Na^+ + OH^- \quad (monoacidic\ Base).$$
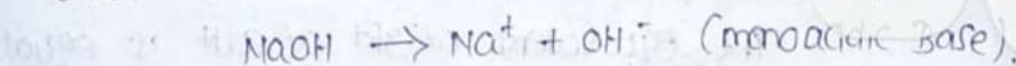
→ The acidity of Aluminium hydroxide is 3. it

$$Al(OH)_3 \longrightarrow Al^{3+} + 3OH^- \quad (Triacidic\ Base).$$

→ The acidity of calcium hydroxide is 2. it.

$$Ca(OH)_2 \longrightarrow Ca^{2+} + 2OH^- \quad (diacidic\ Base)$$

example of equivalent masses of base:

Base	formula	Acidity	molecular mass	Eq. mass = $\left(\dfrac{\text{mol. mass}}{\text{Acidity}}\right)$
Sodium hydroxide	NaOH	1	40	$\dfrac{40}{1} = 40$
Potassium hydroxide	KOH	1	56	$\dfrac{56}{1} = 56$
Calcium hydroxide	Ca(OH)$_2$	2	74	$\dfrac{74}{2} = 37$
Barium hydroxide	Ba(OH)$_2$	2	171	$\dfrac{171}{2} = 85.5$
Aluminium hydroxide	Al(OH)$_3$	3	78	$\dfrac{78}{3} = 26.$

Equivalent weight of salt :-

8/15

The equivalent weight of salt is equal to the molecular we weight of the salt divided by the total number of positive or negative charges.

$$E_{salt} = \frac{\text{Molecular weight}}{\text{Total no of +ve or -ve charge}}$$

example of equivalent weight of salt :-

Salt	molecular formula	mol. weight	Total no. of +ve on -ve charge	Eq. weight of salt
Sodium chloride	NaCl	58.5	1	$\frac{58.5}{1} = 58.5$
potassium carbonate	K_2CO_3	138	2	$\frac{138}{2} = 69$
calcium sulphate	$CaSO_4$	136	2	$\frac{136}{2} = 68$
sodium bicarbonate	$NaHCO_3$	84	1	$\frac{84}{1} = 84$
Aluminium chloride	$AlCl_3$	132.5	3	$\frac{132.5}{3} = 44.16$
ferrous chloride	$FeCl_2$	127	2	$\frac{127}{2} = 63.5$
ferric chloride	$FeCl_3$	162.5	3	$\frac{162.5}{3} = 54.16$

modes of expressions of concentration :-

concentration of a solution is the measure of the amount of solute in a given amount of solution on solvent.

-> The concentration of a solution can be expressed in the following ways.

(1) Molarity

(11) Normality

(111) Molality

(iv) Strength

(v) percentage etc.

Molarity

Molarity :- (M)

Molarity is defined as the number of moles of solute which are present in one litre (1L) of solution.

→ The unit of molarity is gram mole/litre (or/m)

Mathematically,

$$M = \frac{\omega \times 1000}{M_s \times V_{ml}}$$

where ω = weight of the solute in gram

M_s = molecular weight of the solute

V_{ml} = volume of solution in ml.

Problem-1 :- find the molarity of 40 gram of NaCl dissolved in 250ml of solution. ?

Given :

weight of the solute (ω) = 40 gram

volume of the solution (V_{ml}) = 250 ml.

molecular weight of (NaCl) M_s = 23 + 16 + 1

= 40 amu.

(iv) strength

(v) percentage etc.

Molarity

Molarity :- (M)

Molarity is defined as the number of moles of solute which are present in one litre (1L) of solution.

→ The unit of molarity is gram mole/litre $^{(gm/m)}$

Mathematically,

$$M = \frac{\omega \times 1000}{Ms \times Vml}$$

where ω = weight of the solute in gram

Ms = molecular weight of the solute

Vml = volume of solution in ml.

Problem-1 :- find the molarity of 40 gram of NaCl dissolved in 250ml of solution. ?

Given :

weight of the solute (w) = 40 gram

volume of the solution (Vml) = 250ml.

molecular weight of (NaCH) Ms = 23+16+1

= 40 amu.

$$\text{molarity (M)} = \frac{\omega \times 1000}{M_s \times V_{ml}}$$

$$= \frac{40 \times 1000}{40 \times 250} \quad 4$$

$$= 4 M.$$

Hence the molarity of the solution is 4M.

problem - 2 :- How many grams of potassium hydroxide (KOH) are required to prepare 1.5 litre of a decimolar solution?

Given :

weight of the solute (ω) = ?

molecular weight of (KOH) $M_s = 39 + 16 + 1$
$$= 56 \, amu$$

volume of the solution (V_{ml}) = 1.5 lit
$$= 1500 ml.$$

molarity of the solution (M) $= \frac{1}{10} M$
$$= 0.1 M.$$

$$\text{molarity (M)} = \frac{\omega \times 1000}{M_s \times V_{ml}}$$

$$0.1 = \frac{\omega \times 1000}{56 \times 1500}$$

$$\omega = \frac{0.1 \times 56 \times 1500}{1000}$$

$$\omega = 8.4 \, gram.$$

Hence 8.4 gram of KOH are required to prepare 1.5 lit

Normality :- (N)

Normality of a solution may be defined as the number of gram equivalent of the solute present per litre of solution.

→ The unit of normality is gram equivalent / litre

(or) N.

mathematically,

$$N = \frac{\omega \times 1000}{E_S \times Vml}$$

Where ω = weight of the solute in gm.

E_S = Equivalent weight of solute.

Vml = volume of solution in ml.

Problem-1:

5.6 gram of caustic potash (KOH) is present in 800ml of its solution. What is the normality of the solution?

Given;

weight of the solute (ω) = 5.6 gram

volume of the solution in ml (Vml) = 800ml

Equivalent weight of the solute (E_S) = $\frac{molecular\ weight}{Acidity}$

$$= \frac{39+16+1}{1} = \frac{56}{1} = 56$$

normality : $\dfrac{5.6 \times 1000}{56 \times 800}$

$= 0.125 \, N$

Hence the normality of the solution is 0.125 N.

problem-2 :- 10ml of sulphuric Acid (H_2SO_4) having density 1.2gm/ml is present in 400ml of its solution. calculate the normality of the solution?

Given ;

$$Density = \dfrac{w}{v}$$

$$w = Density \times volume$$
$$= 1.2 \times 10$$
$$= 12gm$$

weight of the solute (w) = 12gm

volume of the solution (vml) = 400ml.

Equivalent weight of the solute (E$_r$) = $\dfrac{molecular.wt}{Basicity}$

$$= \dfrac{2 \times 1 + 32 + 4 \times 16}{2}$$

$$= \dfrac{98}{2} = 49$$

$$N = \dfrac{w \times 1000}{E_r \times Vml}$$

$$= \dfrac{12 \times 1000}{49 \times 400}$$

$$= 0.612 \, N$$

Hence the normality of the solution is 0.612 N.

Molality (m) :-

Molality of a solution may be defined as the number of mole of solute present in 1kg of solvent.

→ the unit of molality is gram mole/kg or 'm'

mathematically :

$$m = \frac{\omega \times 1000}{M_S \times W}$$

where ω = weight of the solute in gm

M_S = molecular weight of solute

W = weight of the solvent in gm.

Problem-1 :- find the molality of 20gram of NaOH dissolved in 100 gram of solution?

Given,

weight of the solute (ω) = 20gm.

solution = solute + solvent

100(Given) = 20 + solvent

solvent = 80gram

weight of the solvent (W) = 80gm

molecular weight of the solute = 23+(6+1)

= 40 amu

molality = $\frac{\omega \times 1000}{M_S \times W}$

= $\frac{20 \times 1000}{40 \times 80}$

$$= 6.25 \, m$$

Hence the molality of the solution is $6.25 \, m$.

problem-2 : $5.85 \, gm$ of NaCl is present in $200 \, gm$ of water. Calculate the molality of the solution?

Given,

weight of the solute $(w) = 5.85 \, gm$

weight of the solvent $(W) = 200 \, gm$

molecular weight of the solute $(Ms) =$

$$23 + 35.5$$
$$= 58.5$$

$$\text{molality } (m) = \frac{w \times 1000}{Ms \times W}$$

$$= \frac{5.85 \times 1000}{58.5 \times 200}$$

$$= 0.5 \, m.$$

Hence the molality of the solution is $0.5 \, m$.

ELECTROCHEMISTRY .

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

Electrolysis

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

Electrolyte

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

Ex- NaCl, CaCl₂ etc

Electrolytic cell

Definition: Electrolytic cell 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 etc.

• Fused electrolyte or an aqueous solution of the electrolyte is taken in an electrolytic tank and two metallic plates are dipped in the electrolyte. These plates are known as electrodes.

• The electrodes are connected to an external source of emf (battery).The electrode which is connected with the positive end of the battery is called **anode** and the electrode which is connected to the negative end is called **cathode**.
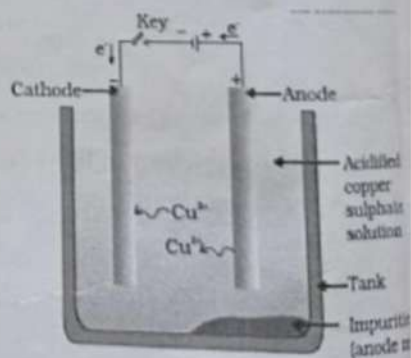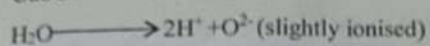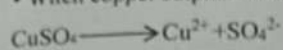
- When an electric current is passed through the solution, cations move towards the cathode, whereas anions move towards the anode.
- This movement of ions towards oppositely charged electrodes is called **electrolytic conduction.**

Example of electrolysis

By using copper sulphate solution (using Pt electrode)
- When copper sulphate is dissolved in water it ionises as:

$$CuSO_4 \longrightarrow Cu^{2+} + SO_4^{2-}$$

$$H_2O \longrightarrow 2H^+ + O^{2-} \text{(slightly ionised)}$$

- When electric current is passed through copper sulphate solution using platinum (Pt) electrodes, Cu^{2+} and H^+ ions move towards the cathode. However, only Cu^{2+} ions are discharged more readily than H^+ ions because of their low discharge potentials.
- These Cu^{2+} ions gain electrons and change into neutral atoms and get deposited at cathode.

At cathode: $Cu^{2+} + 2e^- \longrightarrow Cu$ (deposited)

b) SO_4^{2-} and OH^- ions move towards anode. However, only OH^- ions are discharged more readily than SO_4^{2-} ions because of their low discharge potential. These OH^- ions lose electrons and change into neutral hydroxyl groups

At anode: $2OH^- + 2e^- \longrightarrow 2OH$ (neutral)

- The neutral hydroxyl groups being unstable react with other neutral OH groups to form water and oxygen.

$$2OH \longrightarrow H_2O + [O]$$

$$[O] + [O] \longrightarrow O_2$$

Conclusion:

Hence during electrolysis of copper sulphate solution using platinum (unattackable) electrodes, copper and oxygen are liberated.

Faraday's 1st law of electrolysis

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

If W is the mass of substance liberated at the electrode and Q is the quantity of electricity (in coulombs) passed through the electrolyte.

Then, W ∝ Q

We know Q = C.t

Where c = current in amperes
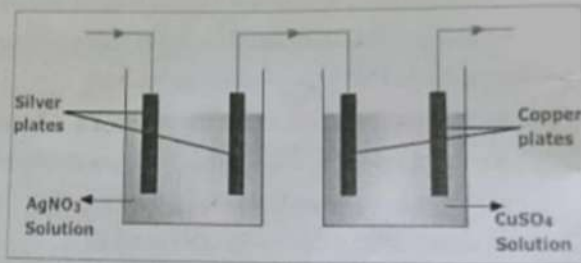
   t = time in seconds

Thus W ∝ C.T

OR $\boxed{W = ZC.T}$

Where Z is a constant called Electro chemical Equivalent

In the above relationship, if c = 1 ampere and t = 1 second

then $\boxed{W = Z}$

Definition of ECC

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


Unit of electricity - Coulomb

1 coulomb = 1 ampere x 1 second

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

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

Faraday's 2nd law of electrolysis

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

A = Anode
C = Cathode

27
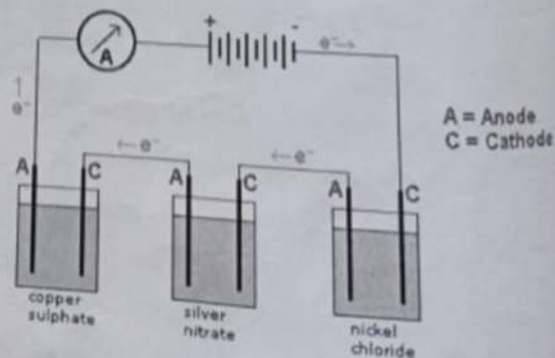
Explanation:

There are three electrolytic cells containing Copper Sulphate, Silver Nitrate and Nickel Chloride solutions respectively.

- They are connected in series as shown in the diagram above
- 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 and nickel liberated are in the ratio of their equivalent weights.

$$\frac{\text{Weight of Copper}}{\text{Weight of Silver}} = \frac{\text{Equivalent weight of Copper}}{\text{Equivalent weight of Silver}}$$

and

$$\frac{\text{Weight of Nickel}}{\text{Weight of Silver}} = \frac{\text{Equivalent weight of Nickel}}{\text{Equivalent weight of Silver}}$$

Industrial application of Electrolysis

Electroplating

Electroplating is done for the following purpose.

a. Decoration

b. Protection

c. Repairs

ELECTROPLATING PROCESS
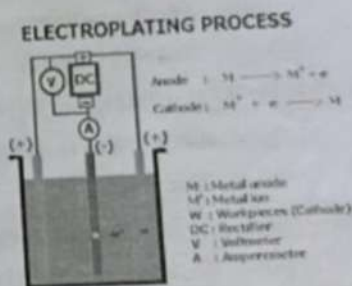
Chrome Plating

- Chromium coatings are very thin and contain a number of pores. The number of pores increases as thickness of coating increases.
- Hence the coating has a tendency to crack.
- These cracks are avoided by plating chromium coating on a nickel under coating.

Electrolytic bath

The electrolytic bath contains

a) Chromic acid (H_2CrO_4)

b) Chromic Sulphate (25% H_2CrO_4, 0.15% Chromic Sulphate)

Temperature of the bath = 40-45°C

- Anode consists of Lead and 8% Antimony
- Solution used for Chromium plating consists of

a) Chromic Oxide (250gm)

b) Sulphuric acid (25gm)

c) Water (1000ml)

Application

It is extensively used in automobile industry, dies, tools and sanitary fittings etc.

Zinc Plating

2(b)

For Zinc plating, acid and alkaline solutions are used for deposition.

Electrolytic bath

a) The acid solution used as electrolytic bath consists of a solution of:-

  i)   Zinc Sulphate (300gm)

  ii)   Sodium Chloride (15gm)

  iii) Aluminium Sulphate (30gm)

  iv)   Boric acid (20gm)

  v)   Dextrin (15gm) in 1000ml water

b) The alkaline solution consists of

  i)   Zinc Oxide (40gm)

  ii)   Sodium Cyanide (100gm)

  iii) Sodium Carbonate (10gm) in 1000ml water
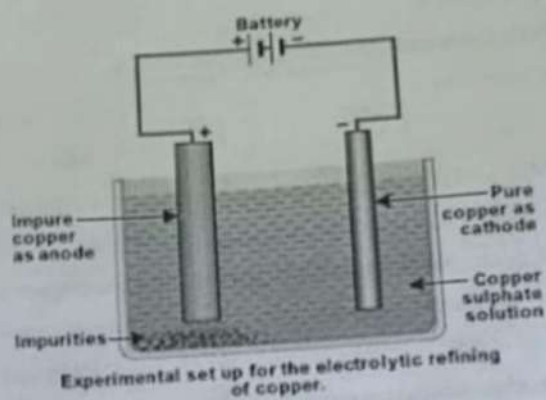
Temperature of the solution = 30-40°C
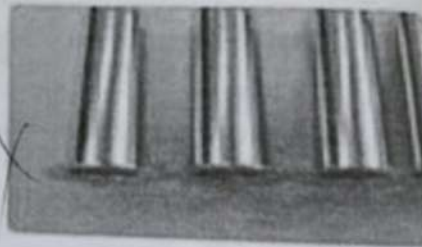
Application

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

2(b)

Electro refining:

Purpose:

The metals obtained from their ores usually contain impurities. Therefore metals like Copper, Silver, Lead, etc. are usually purified by electrolysis.

Experimental set up for the electrolytic refining of copper.

Procedure:

- The impure metal is made the cathode.
- The electrolyte used is a soluble salt of the same metal.
- In the process of electro-refining of Copper, impure Copper is made the anode, while a sheet of pure copper is made the cathode.
- Electrolyte used is an aqueous solution of Copper Sulphate acidified with dilute Sulphuric acid.
- On passing of electricity, Copper ions move towards cathode:

$$CuSO_4 \longrightarrow Cu^{2+} + SO_4^{2-}$$
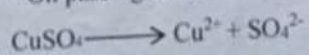
At cathode $Cu^{2+} + 2e^- \longrightarrow Cu$ (deposited)

Corrosion

Defination :- corrosion is a process which involves the conversion of metal into an undesirable compound (usually oxide) on exposure to atmospheric conditions i.e. moisture and oxygen.

Types of Corrosion :-

There are mainly two types of corrosions.

(i) Atmospheric corrosion
(ii) Water line corrosion.

Atmospheric Corrosion :- The process of development of undesirable substances usually oxide over the surface of metal when exposed to atmosphere is called atmospheric corrosion.

Example :- (a) Rusting of iron
(b) Tranishing of silver
(c) Development of green coating on copper. and Bronze.

Mechanism of Rusting of Iron :-

Pure iron does not rust. rust is a case of corrosion of iron. it is hydrated ferric oxide $Fe_2O_3 . n H_2O$.
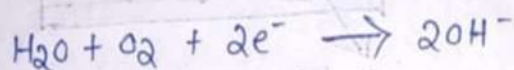
However commercial form of iron behaves like tiny electric cell in presence of water containing dissolved oxygen and acidic substances like CO_2, SO_2 etc.

At anode :- (oxidation → loss of electron)

$$2Fe \longrightarrow 2Fe^{2+} + 4e^-$$
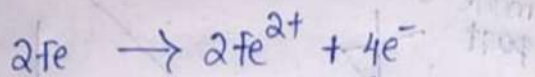
At cathod :- (Reduction → gain of electron).

These electrons form hydroxyl ions.

$$H_2O + O_2 + 2e^- \longrightarrow 2OH^-$$

The electrons combine with moisture and dissolved oxygen.

The Fe^{2+} ion and OH^- ions then diffuse under the influence of dissolved oxygen and Fe^{2+} ions are oxidized into Fe^{3+} ions. these ferric ions combine with OH^- ions to form hydrated ferric oxide, which is nothing but rust.

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

$$2Fe^{3+} + 6OH^- \longrightarrow Fe_2O_3 \cdot 3H_2O \text{ (RUST)}$$
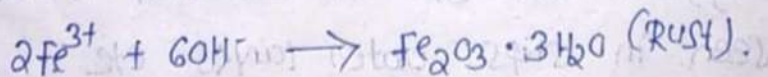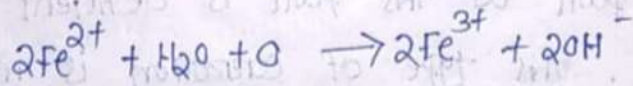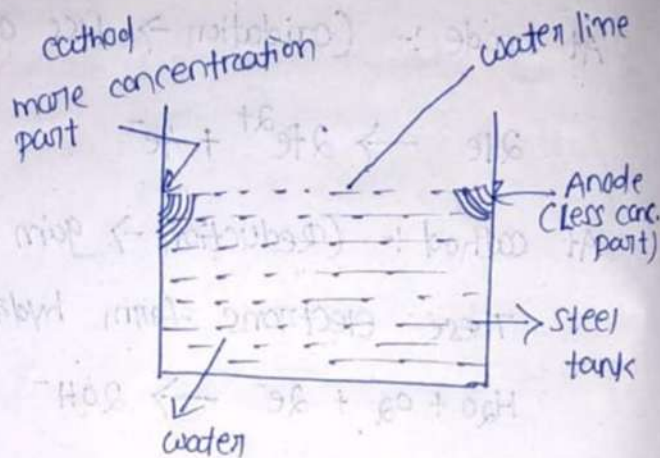
Waterline corrosion :-

This type of corrosion occur due to differential oxygen concentration

above and below the level of water. When water stored in a steel tank, it is noticed that corrosion occur along the line just below the level of water.

(ii) The

(Water line corrosion).

(II) The concentration of oxygen in the area above the water line is high and hence the area is called cathodic part.

(III) The area just below the water line is called anodic part as this part is deficient of oxygen. This type of corrosion is mostly seen in ships, water tanks etc.

Protection of corrosion:-

There are many methods to protect the metal from corrosion.

They are (i) Alloying
(ii) Galvanisation.

(i) Alloying :- By Alloying of metal, we can protect those from corrosion. Alloys resist corrosion in two ways.
→ Homogeneity
→ oxide film.

(ii) Galvanisation :- Zinc is used to protect iron from rusting, because reduction potential of zinc is less than that of iron.
→ Zinc is more electropositive and protects iron from rusting.
→ The process of covering iron with zinc is called galvanisation.

CHAPTER-7   *METALLURGY*

OCCURRENCE OF METAL:-

Metal occurs in nature in free or native as well as combined state .

a.Native state:- A few metal which have less chemical reactivity and have less or no tendency to combine with oxygen , air , moisture , carbon dioxide or other non-metal occur in nature in free state called native state .

e.g. less electropositive metals occurring in native state are copper(Cu), silver(Ag), gold(Au), platinum(Pt),bismuth(Bi) ,mercury(Hg),palladium(Pd),and antimony(Sb) .

b.Combined state:- Most of the metals which have chemical reactivity and have a tendency to combine with oxygen , air , moisture ,carbon dioxide , and other non-metal occurs in nature in combine state .

These are generally present in the form of oxides, sulphides, carbonates, silicates

,sulphates, phosphates, halides etc.

MINERALS AND ORES :-

The natural substances in which metals occur either in native state or combined state are called minerals .

The minerals , from which the metals can be economically and conveniently extracted , are called ores.

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

Some important Minerals and Ore :-

Types of ore and metals	Name of ore and Composition
Arsenide ore:-	
Nickel	Nickel glance (NiAsS)
	Kupfernickel (NiAs)
Oxide ore	
Iron	Haematite(Fe_2O_3) ,Magnetite(Fe_3O_4)
Aluminium	Bauxite ($Al_2O_3.2H_2O$)
Manganese	Pyrolusite (MnO_2)
Zinc	Zincite (ZnO)

Tin	Cassiterite(SnO_2)
Copper	Cuprite (Cu_2O)

Carbonate ore:-

Magnesium	Magnesite($MgCO_3$)
Calcium	Dolomite($CaCO_3. MgCO_3$), Lime stone($CaCO_3$)
Iron	Siderite($FeCO_3$)
Copper	Malachite($Cu(OH)_2, CuCO_3$)
Lead	Cerrussite($PbCO_3$)

Sulphide ore:-

Iron	Iron pyrites (FeS_2)
Copper	Copper glance (Cu_2S)
Lead	Galena (PbS)
Zinc	Zinc blende (ZnS)
Mercury	Cinnabar (HgS)
Silver	Silver glance or Argentite (Ag_2S)
Nickel	Nickel blende or Millerite (NiS)

Sulphate ore:-

Barium	Barytes ($BaSO_4$)
Lead	Anglesite ($PbSO_4$)
Magnesium	Epsomite ($MgSO_4.7H_2O$)
Calcium	Anhydrite ($CaSO_4$)

Hlide ore:-

Silver	Horn silver (AgCl)
Sodium	Rock salt (NaCl)
Potassium	Carnallite ($KCl.MgCl_2. 6H_2O$), Sylvine (KCl)

Calcium	Fluorspar (CaF_2)
Aluminium	Cryolite (Na_3AlF_6)

Silicate ore:-

Zinc	Hemimorphite ($2ZnO.SiO_2. H_2O$)
Aluminium	Felspar ($K_2OAl_2O_3.6\ SiO_2$) , Mica ($KAl_3H_2Si_3O_{12}$)
Potacium	Mica ($KAl_3H_2Si_3O_{12}$)

Phosphate ore:-

Lead	Pyromorphite [$3Pb_3(PO_4)_3PbCl_2$]
Calcium	Rock phosphate [$Ca_5(PO_4)_3OH$], Phosphorite[$Ca_3(PO_4)_3$]

Gangue or Matrix:-

The ore are generally associated with non-metalic impurities of earth and rocks . These are called gangue or matrix .

Metal and minerals	Places of occurrence
Iron (Haematite)	Bihar, Orissa, Madhya Pradesh, Goa, Maharashtra
Manganese (Pyrolusite)	Bihar, Orissa, Madhya Pradesh, Karnataka, Andhra Pradesh, Maharashtra, Goa, Tamil Nadu
Gold (Native)	Karnataka (Kolar gold field and Hutti gold field), Andhra Pradesh (Ramgiri gold field)
Copper (Copper pyrites, malachite)	Bihar, Orissa, Madhya Pradesh, Rajasthan, Sikkim, Andhra Pradesh, Karnataka
Aluminium (Bauxite)	Madhya Pradesh, Tamil Nadu, Orissa, Bihar, Goa, Jammu & Kashmir, Rajasthan
Tin (Tinstone)	Bihar, Orissa, Rajasthan
Chromium (Chromite)	Karnataka, Bihar, Orissa, Tamil Nadu, Andaman, Andhra Pradesh
Lead (Galena)	Rajasthan, Orissa, Gujarat, Sikkim
Zinc (Zinc blende)	Rajasthan, Orissa, Gujarat,
Titanium (Ilmenite)	Kerala
Sodium (Tincal)	Laddakh and Kashmir
Calcium (Gypsum) (Limestone) (Dolomite)	Rajasthan, Gujarat, Andhra Pradesh, Madhya Pradesh, Orissa, West Bengal, Uttar Pradesh
Magnesium (Magnesite)	Karnataka, Tamil Nadu, Uttar Pradesh, Bihar, Rajasthan
Barium (Barytes)	Andhra Pradesh, Rajasthan, Tamil Nadu, Bihar, West Bengal
Tungsten (Native)	Rajasthan, West Bengal, Karnataka, Maharashtra

MINERAL WEALTH OF INDIA :-

GENERAL METHOD OF EXTRACTION OF METAL :-

The process of extracting metals from their ores/mineral is called metallurgy ..

The process of metallurgy depends upon the nature of the ore and the impurities resent in it . Therefore , it is not possible to universal method which may be applicable to all metals .Thus the extraction of each metal involves an individual procedure . However , some common steps involved in the metallurgical operations are :

1. Crushing and grinding of ore

2. Concentration of the ore

3. Oxidation

4. Reduction

5. Refining of the metal

1.Crushing and Grinding of the ore:-

The ore occurs in nature as huge lumps . They are broken to small piece with the help of crushers or Grinders . This piece are then reduced to fine powder with the help of a ball mill or stamp mill. This process is called **pulverisation .**

2.Concebtration of the Ore:-

The ore are usually found mixed up with large amount of non-metallic impurities such as sand, mica, limestone, feldspar, earthy and rocky impurities .

The process of removal of unwanted impurities (gangue) from the ore is called **ore concentration** or **ore dressing** or **ore beneficiation** .

The powdered ore is concentrated by the following methods depending upon the nature of the impurities present in the ore .

A.Gravity separation or Levigation:- (Hydraulic washing)

In this method, the light (low specific gravity) earthy impurities are removed from the heavier metallic ore particles by washing with water. It is therefore, used for the concentration of heavier oxide ores, like haematite (Fe O 2 3)tinstone (SnO2)and gold (Au). In this method, the powdered ore is agitated with water or washed with a strong current of water. The heavier ore settles down rapidly in the grooves and the lighter sandy and earthy materials (gangue particles) are washed away.

B.Mgnetic separation:-

By this method, those ores can be concentrated which either contain impurities which are magnetic or are themselves magnetic in nature. For example, the tin ore, tin stone (SnO2)itself is non-magnetic but contains magnetic impurities such as iron tungstate (FeWO4) and manganese tungstate (MnWO4).

The finely powdered ore is passed over a conveyer belt moving over two rollers, one of which is fitted with an electromagnet . The magnetic material is attracted by the magnet and falls in a separate heap. In this way magnetic impurities are separated from non-magnetic material.
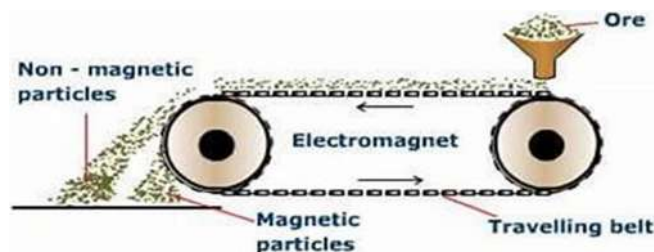

C.Froth floatation Method:-

This method is especially applied to sulphide ores, such as **galena** (PbS), **zinc blende** (ZnS), or **copper pyrites** (CuFeS2). It is based on the different wetting properties of the surface of the ore and gangue particles. The sulphide

ore particles are wetted preferentially by oil and gangue particles by water. In this process, finely powdered ore is mixed with either pine oil or eucalyptus oil. It is then mixed with water. Air is blown through the mixture with a great force. Froth is produced in this process which carries the weted ore upwards with it. Impurities (gangue particles) are left in water and sink to the bottom from which these are drawn off.
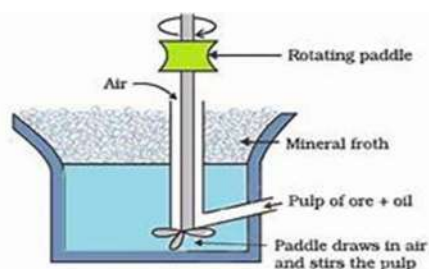
D .Leaching :-

In this method the ore is treated with a suitable chemical reagent which dissolves the ore leaving behind insoluble impurities. The ore is then recovered from the solution by a suitable chemical method. This is applied for extraction of aluminium from bauxite ($Al_2O_3.2H_2O$). Bauxite is contaminated with iron(III) oxide (Fe_2O_3), titanium (IV) oxide ($TiO2$)and silica ($SiO2$). These impurities are removed by digesting the powdered ore with aqueous solution of sodium hydroxide at 420 -450 k . under pressure. Aluminum oxide dissolves in sodium hydroxide, whereas, iron (III) oxide, silica and titanium (IV) oxide remain insoluble and are removed by filtration .

$$Al_2O_3.2H_2O + 6NaOH \longrightarrow 2Na_3AlO_3 + 3H_2O$$
$$\text{Sodium alluminate}$$
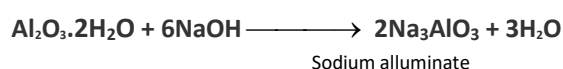
Sodium aluminate is diluted with water to obtain precipitate of aluminium hydroxide. It is filtered and ignited to obtain pure alumina.

$$2Na_3AlO_3 + 3H_2O \longrightarrow Al(OH)_3 + 3NaOH$$

$$Al(OH)_3 \xrightarrow{\Delta} Al_2O_3 + 3H_2O$$

3.Oxidation of Ore :-

The concentrated ore is converted into metal oxide by This process. This process involving two methods these are

(A) .Calcination:-

Calcination involves heating of the concentrated ore in a limited supply of air so that it loses moisture, water of hydration and gaseous volatile substances. The ore is heated to a temperature so that it does not melt. Two examples of calcination are given below:
(i) Removal of water of hydration.

$$Al_2O_3.2H_2O \xrightarrow{\Delta} Al_2O_3 + 2H_2O$$

(ii) Expulsion of CO2 from carbonate:-
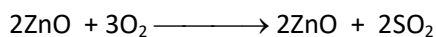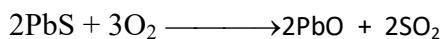
$$ZnCO_3 \longrightarrow ZnO + 2CO_2$$
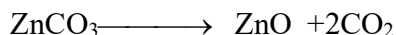
(B) Roasting:-

Roasting is a process in which the concentrated ore is heated in a free supply of air at a temperature insufficient to melt it. The following changes take place during roasting :
(i) Drying of the ore.
(ii) Removal of the volatile impurities like arsenic, sulphur, phosphorus and organic matter.

$$4As + 3O_2 \longrightarrow 2As_2O_3 \,(G)$$

$$S + O_2 \longrightarrow SO_2 (G)$$
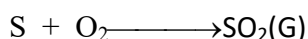
(iii) Conversion of the sulphide ores into oxides.

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

$$2ZnO + 3O_2 \longrightarrow 2ZnO + 2SO_2$$

Calcination and roasting are generally carried out in a reverberatory furnace or in a multiple hearth furnace.
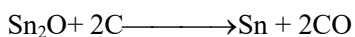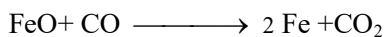
4. Reduction :-

This process is carried out after calcination or roasting of ores. In this process called *smelting,* the oxide ores are converted into the metallic state by reduction.

(A) **Smelting** :
Smelting is a process in which the oxide ore in molten state is reduced by carbon or other reducing agents to free metal.

(i) *by using carbon as a reducing agent :*
This method is used for the isolation of **iron, tin and zinc** metals from their respective oxides. The oxide ores are strongly heated with charcoal or coke. Reduction occurs by the action of carbon and/or carbon monoxide which is produced by the partial combustion of coke or charcoal.

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

$$Fe_2O_3 + CO \longrightarrow 2Fe + CO_2$$

$$FeO + CO \longrightarrow 2\,Fe + CO_2$$

$$Sn_2O + 2C \longrightarrow Sn + 2CO$$

$$ZnO + C \longrightarrow Zn + CO$$
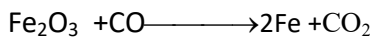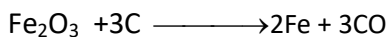
Although the ore has been concentrated in an earlier step, it is still contaminated with some gangue material which is finally removed in the reduction process by the addition of *flux* during smelting.

Flux is a chemical substance which combines with gangue at higher temperatures to form easily fusible material called *slag* which is not soluble in the molten metal.
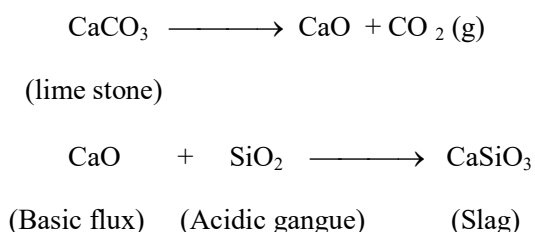**Flux are of two types :**

Basic Flux :
On heating, lime stone is converted into calcium oxide used as basic flux which combines with acidic impurities like silica in metallurgy of iron and forms fusible calcium silicate ($CaSiO_3$)

$$CaCO_3 \longrightarrow CaO + CO_2 (g)$$

(lime stone)

$$CaO + SiO_2 \longrightarrow CaSiO_3$$

(Basic flux)   (Acidic gangue)   (Slag)

Acidic flux :
SiO_2 is used as acidic flux to remove basic impurity of FeO in metallurgy of Cu.

$$SiO_2 + FeO \longrightarrow FeSiO_3$$

(Acidic flux)   (Basic Gangue)   (Slag)
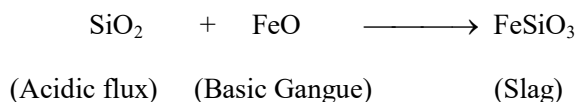
The fusible slag, such as calcium silicate formed during smelting floats over the molten metal and is thus easily removed. Another advantage is that the slag provides a covering to the molten metal thus preventing it from getting oxidized by air.

(ii) Other reducing agents :

Oxide ores which cannot be reduced by carbon or metals which show affinity to carbon by forming metal carbides, are reduced by reducing agents like aluminium, sodium, magnesium or hydrogen. *Oxide* like chromium oxide (Cr O 2 3)or manganese oxide (Mn O 3 4)are reduced by aluminium powder is a highly exothermic reaction. This process is known as *Goldschmidt's Alumino-thermite reduction method.*

$$Cr_2O_3 + 2Al \longrightarrow 2Cr + Al_2O_3 + HEAT$$

$$3Mn_3O_4 + 8Al \longrightarrow 9Mn + 4Al_2O_3 + HEAT$$
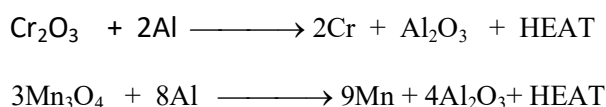
Heat is generated in the process due to the formation of Al O 2 3 which is a highly exothermic reaction.

Tungsten and molybedenum can be obtained by the reduction of their oxides by hydrogen,

$$MoO_3 + 3H_2 \longrightarrow Mo + 3H_2O$$

Titanium can be obtained by the reduction of TiO_2 by sodium
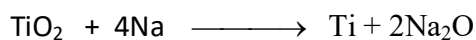
$$TiO_2 + 4Na \longrightarrow Ti + 2Na_2O$$

(iii) Self-reduction :

This is applied to the sulphide ores of copper, mercury and lead . The ores are heated in air, a part of these sulphide ores is changed into the oxide or sulphate which then reacts with the remaining part of the sulphide ore to give the metal and sulphur dioxide. The reactions showing their extraction are given below :

$$2Cu_2S + 3H_2O \longrightarrow 2Cu_2O + 2SO_2$$

(Copper glance)

$$2Cu_2O + Cu_2S \longrightarrow 6Cu + SO_2$$
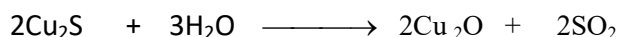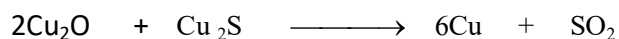
Copper produced at this stage is called *Blister copper*. The evolution of sulphur dioxide produces blisters on the surface of solidified copper metal.

$$2HgS + 3O_2 \longrightarrow 2HgO + 2SO_2$$
Cinnabar

$$2HgO + HgS \longrightarrow 3Hg + SO_2$$

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

$$PbS + 2O_2 \longrightarrow PbSO_4$$

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

$$PbS + PbSO_4 \longrightarrow 2Pb + 2SO_2$$
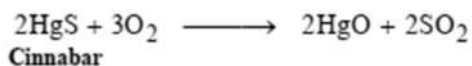
(ii) Electrolytic Reduction :

Active metals like sodium, potassium and aluminium etc., are extracted by the electrolysis of their fused (*molten*) salts. For example, sodium is obtained by the electrolysis of fused sodium chloride (Down's process). The reactions taking place in the electrolytic cell are :

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

Na^+ ions move towards the cathode and Cl^- ions move towards the anode. Following reactions take place at the electrodes :

At the Cathode $Na^+ + e^- \longrightarrow Na$ (metal)   (Reduction)
(Negative electrode)

At the Anode $Cl^- \longrightarrow Cl + e^-$ (Oxidation)
(Positive electrode)

$$Cl + Cl \longrightarrow Cl_2$$
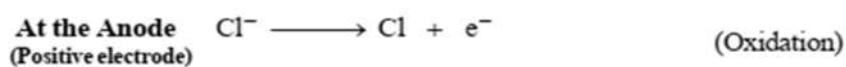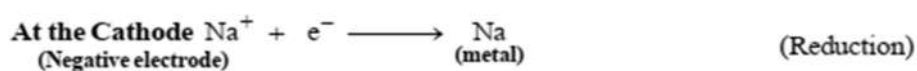
Aluminium is extracted from molten alumina (Al_2O_3) by electrolysis. The melting point of alumina is quite high (2323K) which is inconvenient for electrolysis. It dissolves in molten cryolite (Na_3AlF_6) at around 1273 k. The reactions which take place in the cell are:.

At the Cathode $Al^{3+} + 3e^- \longrightarrow Al\,(metal)$

At the Anode $C + 2O^{2-} \longrightarrow CO_2 + 4e^-$
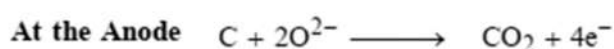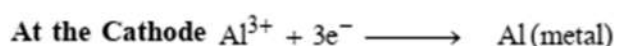
5. Refining of Metals:-

Except in the electrolytic reduction method, metals produced by any other method are generally impure. The impurities may be in the form of (i) other metals (ii) unreduced oxide of the metal (iii) non-metals like carbon, silicon, phosphorus, sulphur etc. and (iv) flux or slag. Crude metal may be refined by using one or more of the following methods :

Electrolytic Refining :

A large number of metals like copper, silver, zinc, tin etc. are refined by electrolysis. A block of impure metal is made the anode and a thin sheet of pure metal forms the cathode of the electrolytic cell containing suitable metal salt solution which acts as an electrolyte . On passing current, pure metal deposits at the cathode sheet while more electropositive impurities are left in solution. Less electropositive metals do not dissolve and fall away from the anode to settle below it as *anode mud.*
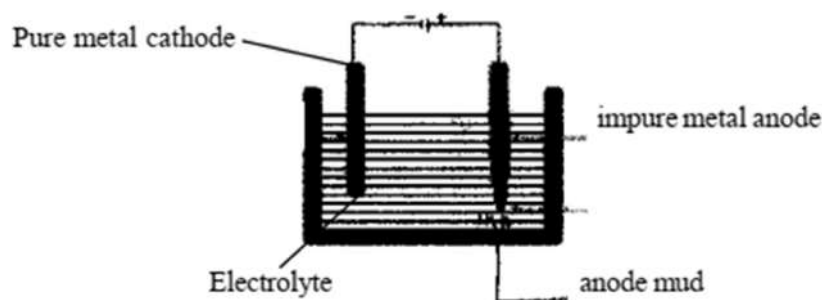
Fig. 18.8 : *Electrolytic Refining*

For example, in the electrolytic refining of crude copper (blister copper), a large piece of impure copper is made anode and a thin piece of pure copper is made the cathode. An acidified solution of copper sulphate is used as an

electrolyte. On passing an electric current of low voltage through the solution copper (II) ions obtained from copper sulphate solution go to the cathode where they are reduced to the free copper metal and get deposited.

$$Cu^{2+} + 2e^- \longrightarrow Cu \quad \text{(at cathode)}$$

An equivalent amount of the metal from the anode dissolves into the electrolyte
as Cu^{2+} ions

$$Cu \longrightarrow Cu^{2+} + 2e^- \quad \text{(at anode)}$$

As the process goes on, anode becomes thinner while the cathode becomes thicker. The impurities like silver, gold settle down at the bottom of the cell as *'anode mud'*

Distillation :

Volatile metals like zinc and mercury are purified by distillation. The pure metal distils over, leaving behind non-volatile impurities.

CHAPTER-8   *ALLOYS*

Definition:-

An alloy is a homogeneous solid obtained by melting together (a) two or more metals or (b) metals and non metals (usually carbon , phosphorus , silicon etc).

Preparation of Alloys :-

1. By Fusion. Alloys like Brass (90% Cu + 10% Zn), Bronze (90% + !0% Sn) are prepared by this method. Metals in definite ratio and non metals (if any, used to prepare a particular alloy) are put together in a big fire clay crucible and melted. The molten mass so obtained is stirred with charcoal pieces to prevent the oxidation at the surface. The homogeneous mass thus prepared on cooling solidifies to give the required alloy.
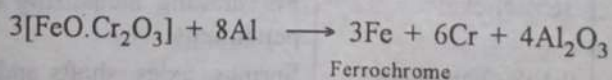
2. By Compression. Alloys like solder (67% Pb + 33% Sn), Pewter (85% Sn + 7% Cu + 6% Bi + 2% Sb), etc., are prepared by this method.

Metals and non-metals (if any) used to prepare a particular alloy are first converted into sheets, then rolled together and hammered under high pressure to get the required alloy.

3. By Using Chemical Processes. Alloys like Aluminium bronze (90% Cu + 10% Al), Ferrochrome (33% Fe + 67% Cr) are prepared by this method. Aluminium bronze is prepared by heating aluminium oxide and carbon in presence of copper.

$$Al_2O_3 + 3C + Cu \longrightarrow Cu + 2Al + 3\ CO\uparrow$$

Ferrochrome is prepared by heating chromite ($FeO.Cr_2O_3$) with powdered carbon or Al powder.

$$FeO.Cr_2O_3 + 4C \longrightarrow Fe + 2Cr + 4\ CO\uparrow$$
$$\text{Ferrochrome}$$

$$3[FeO.Cr_2O_3] + 8Al \longrightarrow 3Fe + 6Cr + 4Al_2O_3$$
$$\text{Ferrochrome}$$
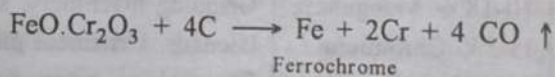
4. By Simultaneous Electro-deposition. Alloys like Brass, Bronze etc. are prepared by this method. A solution of Copper and Zinc cyanides in Potassium cyanide, *i.e.*, $K_2[Cu(CN)_4]$ and $K_2[Zn(CN)_4]$ are taken in a electrolytic cell and electric current is passed. Copper and Zinc (both less electropositve than potassium) get deposited on the cathode to give brass.

Types of Alloys:-

(a)FERRO ALLOYS:-

These alloys contain iron as one of the major component .

Common ferrous alloys are stainless steel , tool steel etc.

Cast iron , steels , and satellites are all ferrous alloy . Cast iron and steel are iron base alloys with carbon and other metals / non metals (Mn , S , Cr , Si etc) . they differ in carbon content . For example steel does not contain more than 1.3% carbon while cast may contain from 1.7-4% carbon .

Table 3. Some Special Alloy Steels.

	Name	Composition	Uses
1.	Nickel steel	2.4% Ni	For making cables, cutting tools, automobile and aeroplane parts, armour plates, etc
2.	Tungsten steel	14-20% Tungsten 3.8% Chromium	Cutting tools for high speed lathes.
3.	Chrome steel	1.5-2% Chromium	For cutting machinery and cutlery.
4.	Manganese steel	10-18% Manganese	Grinding machinery, safes.
5.	Stainless steel	11.5% Chromium	Utensils, Ornament pieces, automobile parts.
6.	Invar	36% Nickel	For making measuring instruments. Clock pendulums.
7.	Chrome-vanadium steel	0.15% Vanadium, 1% Chromium	Springs, axles, shafts and motor car frames
8.	Molybdenum steel	0.5-3% Molybdenum	Cutting tools and axles.

Composition and Uses of Alnico :-

Alnico is a family of iron alloys which in addition to iron are composed primarily of aluminium, nickel and cobalt, hence acronym al-ni-co. They also include copper, and sometimes titanium.

The general composition of Alnico alloys is Al- 8-12%, Ni- 15-26%, and Co- 5-24%. It may also contain up to 6% copper (Cu), and up to 1% titanium (Ti). Depending on the percentage of the different components, there can be various different types of Alnico alloys.

USES:-Alnico alloys are used as strong permanent magnets. Alnico alloys can deliver good flux density at very economical prices. Alnico alloys are used to manufacture Microphones, electric guitar pickups, electric motors, loudspeakers, travelling-wave tubes, Hall Effect sensors etc.

(b)Non –Fereo Alloys:-

These alloys do not have iron as one of the major constituent .These are copper , lead , and tin base alloys or alloys of the types such as ordinary bronze (90% Cu + 10 % Sn) ,   manganin (85% Cu +12%Mn +3% Ni) ,Cupronickel (80% Cu + 20% Ni) ,ordinary brass (60%Cu+ 40% Zn)

Table 4. Alloys of Copper.

	Name	Composition	Uses
1.	Brass	Cu = 60 – 80%, Zn = 40 – 20%	Utensils, condenser tubes and cartridges
2.	Bronze	Cu = 75 – 90%, Sn = 25 – 10%	Utensils, coins, statues
3.	Aluminium bronze	Cu = 90%, Al = 10%	Coins, cheap ornaments, picture frames
4.	Monel metal	Cu = 30% Ni = 67% Fe + Mn = 3%	Equipment exposed to corroding liquids. For acid container, acid pumps, etc.
5.	Bell metal	Cu = 80% Sn = 20%	Bells, Gongs
6.	Gun metal	Cu = 87% Sn = 10% Zn = 3%	Guns, casting, gears
7.	German silver	Cu = 50% Zn = 25% Ni = 25%	Utensils, Ornaments etc.
8.	Steel	Fe = 73, Cr = 18%, C = 1.3%, Ni = 7.7%	Utensils, cycle and automobile parts, cutlery.

(c)Amalagams:-

When one of the constituent metal of an alloy is mercury , it is known as Amalagam .

These are formed by treating metal , such as Tin ,Zinc , Gold , Silver , Sodium , etc , with mercury . Amalagams of different metals are use for different purposes .

I.Sodium amalgam is made to decrease the reactivity of sodium . More ever , it is used as a good reducing agent .

II. Copper amalgam is used for filling dental cavities.

III . Tin amalgam is used for silvering cheap mirrors.

Note-:Iron does not form amalgam with mercury .

Thus Mercury can be transported in iron vessels .

Composition and uses of Duralumin:-

Duralumin is an alloy, a trade name given to the earliest types of the age hardenable aluminum alloys. It is an alloy made up of 90% aluminum,4% copper, 1% magnesium and 0.5% to 1% manganese. It is a very hard alloy. Duralumin is a strong, lightweight alloy of aluminium.

USES:-

It is used for making wire, bar and rods for the screw machine products. It is used in places where good strength and good machinability are required.

- It is used in heavy-duty forgings, wheels, plates, extrusions, aircraft fittings, space booster tankage and trauck frame, and other suspension components. It finds applications in places where high strength is required, and services at elevated temperatures.

- It is used for making Aircraft structure, truck wheels, screw machine products, rivets and other structural application products.

- It is used as a sheet for the auto body panels.

- It is also used in forgings, in aircraft engine pistons, impellers of the jet enginesand the compressor rings.

- It is also used for making die and hand forgings.

Hydrocarbon

organic chemistry :~ The branch of chemistry which deals with the study of covalently bonded carbon compounds except oxides of carbon (CO, CO_2) carbonates, bicarbonades, metallic carbon is called organic chemistry.

Hydrocarbon :- compounds made up carbon and hydrogen are called hydrocarbons.
for example : alkanes, alkenes, alkynes etc.

Saturated hydrocarbons :- These are the hydrocarbons containing C-C single bonds only.
example : Alkane (methane, ethane, propane, butane, pentane etc).

unsaturated hydrocarbons :- These are the hydrocarbons containing carbon-carbon multiple bonds $(C=C, C \equiv C)$
example : Alkene (ethene, propene, butene, pentene etc).
Alkyne (ethyne, propyne, butyne, pentyne etc).

Aliphatic hydrocarbon :- The open chain hydrocarbons are called aliphatic hydrocarbon. These may be straight chain or a branched chain.

example:-

$CH_3 - CH_2 - CH_2 - CH_3$
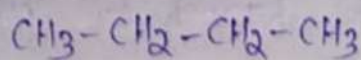
(n-butane)

(linear/straight chain).

$$CH_3 - \overset{\overset{\displaystyle CH_3}{|}}{\underset{\underset{\displaystyle CH_3}{|}}{C}} - CH_3$$
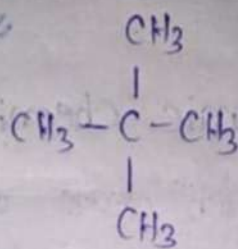
neopentane

(Branched chain).

Aromatic hydrocarbons :-

These are the hydrocarbons which obey Huckel's rue of aromaticity.

Huckel's Rule of Aromaticity :~ There are many compounds which obey The cyclic hydrocarbons containing $(4n+2)\pi$ electrons in which single and ~~double~~ double bonds are present in alternate positions is called aromatic hydrocarbons.

where n = 0, 1, 2, 3, 4 - - - etc.

for example: Benzene (C_6H_6) is a aromatic hydrocarbon. benzene is a ring of six carbon atoms having alternate single and double bonds.
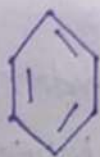
Here n = 1

Benzene (C_6H_6)

$(4 \times 1 + 2)\pi = 6\pi$ electrons.
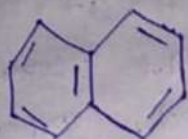
Here n = 2

Napthalene ($C_{10}H_8$)

$(4 \times 2 + 2)\pi$

10π electrons.
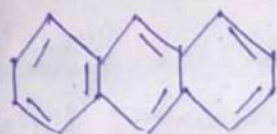
Here n = 3

Anthracene ($C_{14}H_{10}$)

$(4 \times 3 + 2)\pi$

14π electrons.

IUPAC System of Nomenclature :~

IUPAC stands for "International Union of Pure and Applied chemistry".

According to this system an organic compound may contain the following four parts.

1. Prefix
2. Root word
3. Primary suffix
4. Secondary suffix.

Prefix :~ It refers to the presence of.
     substituent of side chain in the parent
     chain of an organic compound. Some
     groups that act as a ~~substituent~~. Substituent.

Group	Prefix
-F	fluoro
-Cl	chloro
-Br	Bromo
-I	Iodo
-NO_2	Nitro
-R	Alkyl
-OR	Alkoxy.

Root Word :~ It refers to the number of
     carbon atoms present in the parent chain
     of an organic compound.

No. of 'c' atom	Root Word
1	Meth
2	Eth
3	Prop
4	But
5	Pent
6	Hex.

7	Hept
8	Oct
9	~~Neh~~ Non.
10	Dec.

Primary Suffix :~ It refers to the presence of (C-C), (C=C), (C≡C) in the compound.

Nature of Bond	Primary Suffix
All C-C bond	- ane
one C=C	- ene
Two C=C bond	-a....-diene
Three C=C bond	-a.... triene
one C≡C	-yne
Two C≡C bond	-a ... diyne

Secondary Suffix :~ It refers to the presence of functional group in the compounds.

functional group	Secondary Suffix
Alcohol (-OH)	-ol
Aldehyde (-CHO)	-al
ketone (-CO-)	-one
carboxylic acid (-COOH)	-oic acid.

Functional group	Secondary suffix
Amine ($-NH_2$)	- amine
Acid amide ($-CONH_2$)	- amide
Acid chloride ($-COCl$)	- oyl chloride

Class of compounds :-

(i) Alkanes
(ii) Alkenes
(iii) Alkynes
(iv) Alkyl halides
(v) Alcohol.

(i) Alkanes :- These are the saturated hydrocarbon in which the carbon atoms are linked by single bonds (C-C). these are also called paraffins.

General formula : C_nH_{2n+2}

where 'n' is the no. of carbon atoms.

Primary suffix : ane

n(no. of carbon atoms)	molecular formula	structural formula	common name	IUPAC Name
1	CH_4	$H - \overset{\overset{H}{\mid}}{\underset{\underset{H}{\mid}}{C}} - H$	Methane	methane
2	C_2H_6	$H - \overset{\overset{H}{\mid}}{\underset{\underset{H}{\mid}}{C}} - \overset{\overset{H}{\mid}}{\underset{\underset{H}{\mid}}{C}} - H$	Ethane	Ethane
3	C_3H_8	$H - \overset{\overset{H}{\mid}}{\underset{\underset{H}{\mid}}{C}} - \overset{\overset{H}{\mid}}{\underset{\underset{H}{\mid}}{C}} - \overset{\overset{H}{\mid}}{\underset{\underset{H}{\mid}}{C}} - H$	Propane	Propane
4	C_4H_{10}	$H - \overset{\overset{H}{\mid}}{\underset{\underset{H}{\mid}}{C}} - \overset{\overset{H}{\mid}}{\underset{\underset{H}{\mid}}{C}} - \overset{\overset{H}{\mid}}{\underset{\underset{H}{\mid}}{C}} - \overset{\overset{H}{\mid}}{\underset{\underset{H}{\mid}}{C}} - H$	Butane	Butane

(ii) Alkene :~ These are the unsaturated hydrocarbons. which have a carbon-carbon double bond $(C=C)$ in their molecules. they are also called olefins.

Generial formula : C_nH_{2n}

where 'n' is the no. of carbon atoms.

Primary suffix : ene

n(No.of carbon atoms)	molecular formula	Structural formula	common Name	IUPAC Name.
2	C_2H_4	H—C=C—H with H, H below	Ethylene	Ethene
3	C_3H_6	H—C=C—C—H with H above and H, H, H below	Propylene	Propene

Alkynes :- These are the unsaturated hydrocarbons which have a carbon carbon triple bond $(C≡C)$ in their molecules. these are also called Acetylenes.

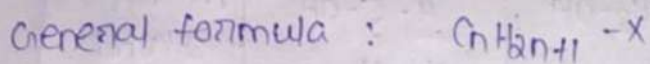General formula : C_nH_{2n-2}

where 'n' is the no. of carbon atoms

Primary suffix : yne

n(No.of carbon atoms)	Molecular formula	Structural formula	common name	IUPAC Name.
2	C_2H_2	H—C≡C—H	Acetylene	Ethyne
3	C_3H_4	H—C≡C—C—H with H above and H below	methyl acetyene	propyne

Alkyl halides or Haloalkanes :-

These are derived by replacing one H atom of an alkane by a halogen atom.

General formula : $C_nH_{2n+1} - X$

where n' is the no. of carbon atoms
and
'X' refers to halogen atom (F, Cl, Br, I)

n(No.of carbon atoms)	molecular formula.	Structural formula	common Name	IUPAC Name
1	$CH_3 - Cl$	H | H $-C-Cl$ | H	methyl chloride	chloro methane
2	$C_2H_5 - Br$	H H | | H $-C-C-Br$ | | H H	Ethyl Bromide	Bromo ethane
3	$C_2H_5 - Cl$	H H | | H$-C-C-Cl$ | | H H	Ethyl chloride	chloro ethane

Alcohol :- These are obtained by replacing one H-atom of an alkane by a hydroxyl group (-OH). the IUPAC name of alcohol is obtained by replacing é' of the corresponding alkane by ol.

General formula : $C_nH_{2n+1} - OH$
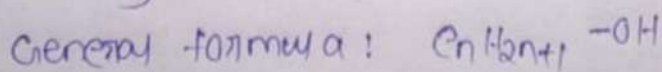
Suffix : ol

n(No. of carbon atoms)	molecular formula	structural formula	common name	IUPAC Name
1	CH_3-OH	$H-\overset{\overset{\displaystyle H}{\vert}}{\underset{\underset{\displaystyle H}{\vert}}{C}}-OH$	methyl alcohol	methanol
2	C_2H_5-OH	$H-\overset{\overset{\displaystyle H}{\vert}}{\underset{\underset{\displaystyle H}{\vert}}{C}}-\overset{\overset{\displaystyle H}{\vert}}{\underset{\underset{\displaystyle H}{\vert}}{C}}-OH$	ethyl alcohol	ethanol.
3	C_3H_7	$H-\overset{\overset{\displaystyle H}{\vert}}{\underset{\underset{\displaystyle H}{\vert}}{C}}-\overset{\overset{\displaystyle H}{\vert}}{\underset{\underset{\displaystyle H}{\vert}}{C}}-\overset{\overset{\displaystyle H}{\vert}}{\underset{\underset{\displaystyle H}{\vert}}{C}}-OH$	propyl alcohol	propanol.

RULES FOR IUPAC SYSTEM OF NOMENCLATURE:

1. **Expansion of chain:** Sometimes condensed groups are present in organic compounds. Thesecondensed groups are to be separated.
   Examples:

   (i) $CH_3 - CH_2 - (CH_2)_2 CH_3$ $\longrightarrow$ $CH_3 - CH_2 - CH_2 - CH_2 - CH_3$

   Condensed group   Expanded

   (ii) $(CH_3)_2CH - CH_3$ $\longrightarrow$ $CH_3 - CH - CH_3$
                                                           $|$
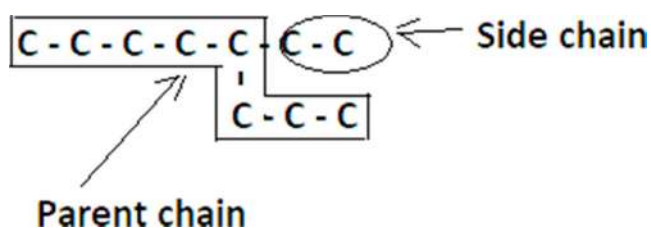 CH_3

   Condensed group   Expanded

   (iii) $CH_3 - CH - CH_3$ $\longrightarrow$ $CH_3 - CH - CH_3$
                     $|$ $|$
                    C_2H_5 CH_2
                                                           $|$
                                                          CH_3

   Condensed group   Expanded
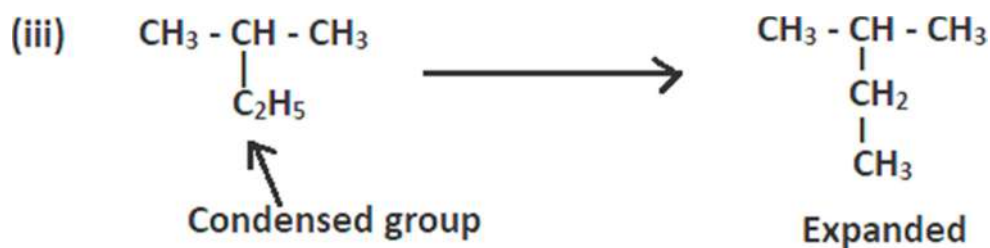
2. **Selection of Parent Chain:** The longest continuous carbon chain is called parent chain. The parent chain is selected and the groups which are outside the parent chain are called substituentor side chains.
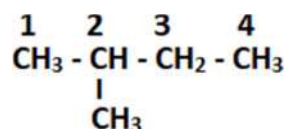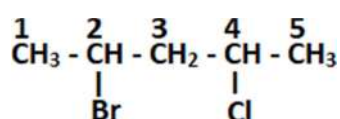   Example:

   $C - C - C - C - C$ — $C - C$ ⟵ **Side chain**
                     $|$
                   $C - C - C$

   Parent chain

3. **Numbering of Carbon atoms: (Lowest number rule or lowest sum rule).**
   a. **Presence of one substituent or one side chain:** The numbering of carbon atoms in the continuous carbon chain is done from one end to the other end, so that the carbon atom carrying the substituent get the lowest number.
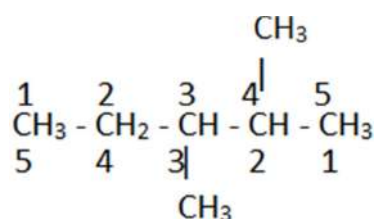   Examples:

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

   b. **Presence of 2 Substituents at the same position from either end:** In this case minimumnumber is given to the carbon containing the substituent which comes first in alphabetical order. Example:

$$\overset{1}{CH_3} - \overset{2}{CH} - \overset{3}{CH_2} - \overset{4}{CH} - \overset{5}{CH_3}$$
$$| \quad\quad |$$
$$Br \quad\quad Cl$$

   c. **Presence of more than one substituents or side chains at any positions:** In this case, number the parent chain from such an end so as to give lowest set of numbers possible to the substituents(**Lowest Sum Rule**). Example:
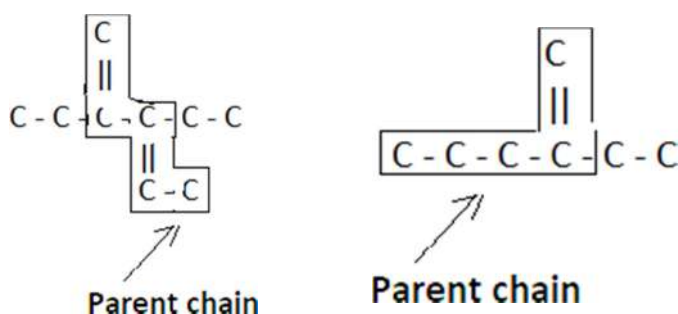
$$CH_3$$
$$|$$
$$\overset{1}{CH_3} - \overset{2}{CH_2} - \overset{3}{CH} - \overset{4}{CH} - \overset{5}{CH_3}$$
$$\quad 5 \quad\quad 4 \quad\quad 3 \quad\quad 2 \quad\quad 1$$
$$|$$
$$CH_3$$

   L → R: Sum = 3 + 4 = 7 X
   R → L : Sum = 2 + 3 = 5 √

4. **Presence of Multiple bonds (double and triple bonds):**
   (i) Select the longest continuous carbon chain as the principal chain which contains the maximumnumber of multiple bonds.
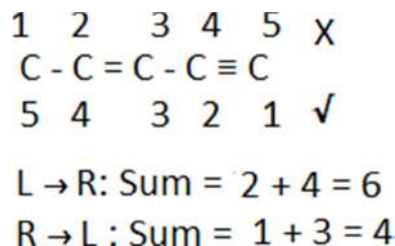   Example:

   Parent chain   Parent chain

   i. If a compound contains a multiple bond, then minimum number is given to the carboncontaining the multiple bonds, irrespective of the position of the substituent or the side chain. Example:

$$√ \overset{1}{C} - \overset{2}{C} = \overset{3}{C} - \overset{4}{C} - \overset{5}{C}$$
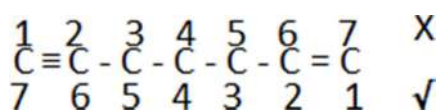$$X \; 5 \quad 4 \quad\; 3 \quad 2 \quad 1$$
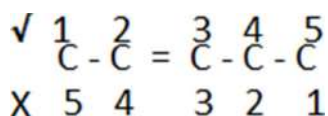
iii.   If the principal chain (parent chain) contains 2 or more multiple bonds, then number the principal chain from one end so that the multiple bonds get the lowest set of numbers. Example:

$$\begin{array}{ccccc} 1 & 2 & 3 & 4 & 5 \quad \mathsf{X} \\ C & - C & = C & - C & \equiv C \\ 5 & 4 & 3 & 2 & 1 \quad \checkmark \end{array}$$

$$L \rightarrow R: \text{Sum} = 2 + 4 = 6$$
$$R \rightarrow L: \text{Sum} = 1 + 3 = 4$$

iv.   If the numbering of principal chain from both the ends gives the same set of numbers to multiple bonds, then select the set which gives lower number to the double bond.
     Example:

$$\begin{array}{ccccccc} 1 & 2 & 3 & 4 & 5 & 6 & 7 \quad \mathsf{X} \\ C & \equiv C & - C & - C & - C & - C & = C \\ 7 & 6 & 5 & 4 & 3 & 2 & 1 \quad \checkmark \end{array}$$

5. **Presence of Functional groups:** If a compound contains a functional group then, minimum number is given to the carbon containing the functional group irrespective of the position of the substituents, side chains or even multiple bonds.
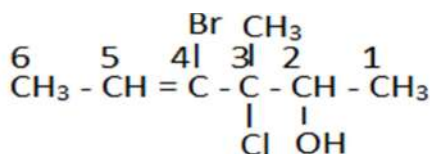   Example:

$$\underset{CH_3}{5} - \underset{CH_2}{4} - \underset{CH_2}{3} - \underset{\underset{\underset{OH}{|}}{CH}}{2} - \underset{CH_3}{1}$$
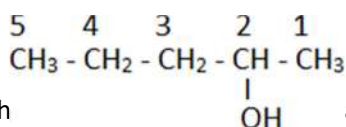
6. **Arrangement of Prefixes:** In an organic compound th   arranged in the following way.

( ) - Prefix---- Root Word ------( ) - Primary Suffix ----- ( ) - Secondary Suffix

Separate the number from the name of the substituent by a hyphen (-) and the numbers are separated by comma (,). If a particular substituent appears 2 or more times, then attach the prefix di, tri, tetra respectively to the name of the substituent and if there are 2 different substituents then they are written in alphabetical order. While following the rules for alphabetical order, the prefixes like di, tri, tetra etc. are ignored.
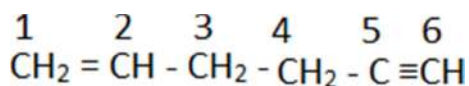   Example:

$$\underset{CH_3}{6} - \underset{CH}{5} = \underset{\underset{Br}{|}}{\overset{4}{C}} - \underset{\underset{Cl}{|}}{\overset{3}{C}} - \underset{\underset{OH}{|}}{\overset{2}{\underset{CH_3}{CH}}} - \underset{CH_3}{1}$$
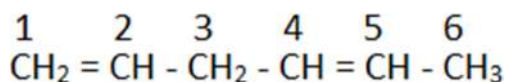
IUPAC Name: 4-Bromo-3-chloro-3-methylhex-4-en-2-ol

Note: The primary suffix for double bond is ene and for triple bond is yne. 'e' of ene is omitted if it is followed by a suffix starting with a, i, o, u, y. If the principal chain contains 2 double or two triple bonds, then suffix is diene or diyne respectively. In such cases 'a' is added to root word
Examples:

$$1 \quad 2 \quad 3 \quad 4 \quad 5 \quad 6$$
$$CH_2 = CH - CH_2 - CH_2 - C \equiv CH$$

Hex-1-en-5-yne

$$1 \quad 2 \quad 3 \quad 4 \quad 5 \quad 6$$
$$CH_2 = CH - CH_2 - CH = CH - CH_3$$

Hexa-1,4-diene

WRITING STRUCTURAL FORMULA FROM IUPAC NAMES:

Steps to be followed:

1. Arrange the carbon atoms corresponding to the root word in a single line separated by singlebonds.
2. Number the carbon atoms from any end.
3. Attach the side chains, substituents, multiple bonds and functional groups whichever is required attheir respective positions.
4. Attach hydrogen atoms to satisfy the tetravalency of each carbon atom.

TYPES OF CARBON ATOMS IN ALKANES:

1. Primary (1^0) carbon atom: It is the carbon atom attached to one carbon atom or all hydrogenatoms.
2. Secondary (2^0) carbon atom: It is the carbon atom bonded to other carbon atoms on 2 differentsides.
3. Tertiary (3^0) carbon atom: It is the carbon atom bonded to other carbon atoms on 3 different sides.
4. Quaternary (4^0) carbon atom: It is the carbon atom bonded to other carbon atoms on 4 differentsides.

RULES FOR WRITING THE COMMON NAMES OF SOME SIMPLE ALKANES:

The simple branched chain alkanes can be assigned common names. According to common system of nomenclature, all the isomeric alkanes (having same molecular formula but different structural formula) have the same parent name but are distinguished by prefixes. The prefix indicates the type of branching in the molecule.

(i) The prefix **n** (normal) is used for all those alkanes in which all the carbon atoms form a continuous chain with no branching.

$$CH_3 - CH_2 - CH_2 - CH_3 \qquad CH_3 - CH_2 - CH_2 - CH_2 - CH_3$$
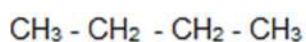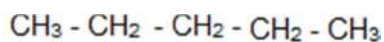
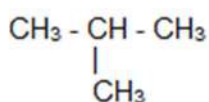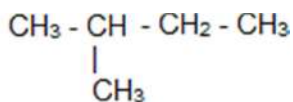n - butane   n - pentane

(ii) Prefix **iso** is used for those alkanes in which one methyl group (formed by removal of one H-atom from methane) is attached to the second last carbon atom of the continuous chain. Examples:
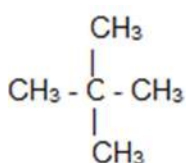
$$CH_3 - \underset{\underset{CH_3}{|}}{CH} - CH_3 \qquad CH_3 - \underset{\underset{CH_3}{|}}{CH} - CH_2 - CH_3$$

iso-butane   iso-pentane

(Iii). Prefix **neo** is used for those alkanes which have 2 methyl groups attached to the second lastcarbon atom of the continuous chain.

Examples:

CH$_3$
|
CH$_3$ - C - CH$_3$
|
CH$_3$

CH$_3$
|
CH$_3$ - C - CH$_2$ - CH$_3$
|
CH$_3$
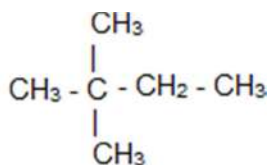
neo-pentane   neo-hexane

(iv).(If the branching occurs at any other position then these prefixes are not used.)

The prefixes **sec** and **tert** before the name of the alkyl group indicates the removal of H-atomfrom 2^0 and 3^0 carbon atoms respectively.

Examples:

2^0
CH$_3$ - CH - CH$_2$ - CH$_3$
|
OH

Sec-butyl alcohol

CH$_3$
3^0|
CH$_3$ - C - OH
|
CH$_3$
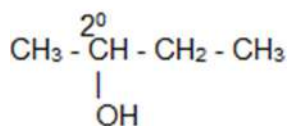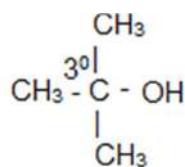
Tert-butyl alcohol

BOND-LINE REPRESENTATION: In bond line representation, each corner and terminal is considered as a carbon atom and the rest are considered as hydrogen atoms to satisfy the tetra-covalency of each carbon atom.

Examples: I.U.P.A.C names of the following bond line notation:

Substituting the carbon hydrogen atoms, we have,

2-Bromo-3-chloro-4-methylpent-2-ene

Aromatic hydrocarbons: These are the closed chain or cyclic hydrocarbons. They obey Huckel's rule of aromaticity.

Huckel's Rule of Aromaticity: The cyclic hydrocarbon containing (4n+2) π electrons in which single and double bonds are present in alternate positions is called an aromatic hydrocarbon. Where n = 0, 1, 2, 3, etc.

For example:

benzene   naphthalene   anthracene

DISTINCTION BETWEEN ALIPHATIC & AROMATIC HYDROCARBONS.

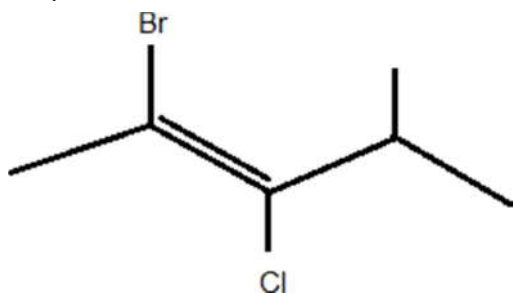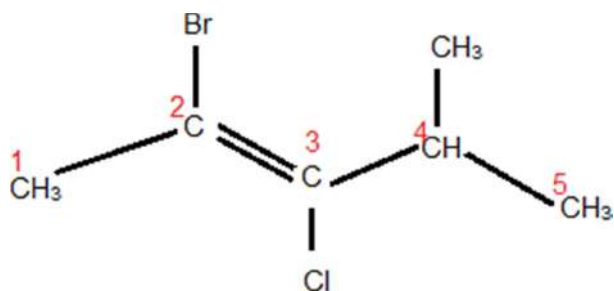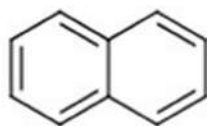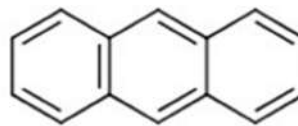| Sl. No.	Aliphatic hydrocarbons	Aromatic hydrocarbons
1	Open chain or Acyclic hydrocarbons.	Cyclic hydrocarbons containing (4n+2) □ electrons in which single and double bonds are present in alternate positions.
2	Do not obey Huckel's rule.	Obey Huckel's rule.
3	No pleasant odour.	Pleasant odour.
4	Alkanes burn with non-sooty flame.	Burn with sooty flame.
5	Examples: Alkanes, Alkenes, Alkynes.	Examples: Benzene, Napthalene, Toluene.

USE OF SOME IMPORTANT AROMATIC COMPOUNDS:

1. **Benzene:** It is used:
   - (a) in manufacturing rubber, tyres.
   - (b) in the printing industry for cleaning and maintaining printing equipment.
   - (c) as an ingredient of a variety of painting products.
   - (d) in manufacturing chemical and plastic products.
   - (e) to clean parts such as hydraulic system, fuel system components and brakes.
2. **Toluene:** It is used:
   - (a) as a solvent for paint, paint thinner, printer ink etc.
   - (b) used in the synthesis of Trinitrotoluene (TNT) explosives.
   - (c) in making elastic.
   - (d) as a radiator fluid.
   - (e) in breaking of RBC in order to extract the hemoglobin in biochemistry experiments.
3. **BHC (Benzene Hexachloride):** Also called gammaxene. It is used:
   - (a) as an important insecticide.
   - (b) as medication to remove head lice.
4. **Phenol:** It is used:
   - (a) as disinfectant in household cleaners and in mouthwash when used in small quantity.
   - (b) as surgical antiseptic.
   - c) in the manufacturing of cough syrups and other antiseptics.
   - (d) as a starting material to make plastics and drugs such as aspirin.
   - (e) in the study and extraction of biomolecules.

5. **Naphthalene:** It is used:
   (a) in the form of mothballs and toilet deodorant blocks.
   (b) in making dyes, resins, insecticides.
   (c) in manufacturing of PVC (polyvinyl chloride).

6. **Anthracene:** It is used:
   (a) in wood preservatives, insecticides.
   (b) as a scintillator for detectors of high energy photons, electrons and alpha particles.

7. **Benzoic acid:** It is used:
   (a) as a food preservative.
   (b) in mouthwash, toothpaste, facial cleanser.
   (c) in making dyes and insect repellents.
   (d) a constituent of Whitfield's ointment which is used for the treatment of fungal skin disease.

CHAPTER – 10
WATER TREATMENT

Water: -Water is one of the most plentiful and readily available of all chemicals. Next to air, water is the important constituent of life-support systems. It is called Universal Solvent because it can dissolve more substances than any other liquid. Although it is most often perceived as a liquid at normal atmospheric pressure, water exists as a solid below 0^0C and as a gas above 100^0C.

Sources of water: - The sources of water can be classified as follows.
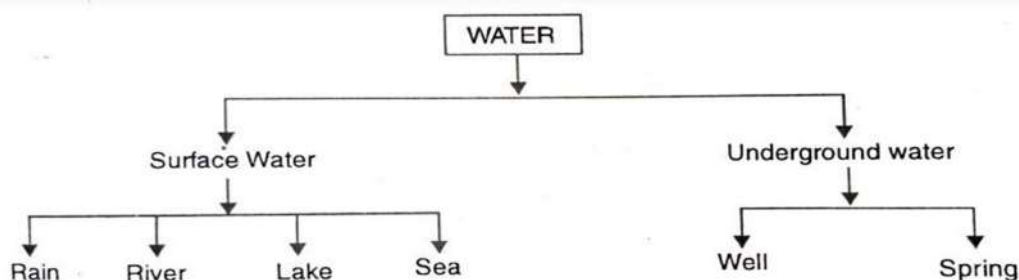
A. Surface water- Surface water is just what the name implies; it is water found in a river, lake or othersurface cavity.

1. **Rainwater:**
   - Rainwater is considered to be the purest form of natural water as impurities and salts present inwater on earth are left behind during vaporization by the sun.
   - But when the rain droplets fall, they dissolve gases like carbon dioxide, oxides of sulphur andnitrogen which make the rain slightly acidic.

   $CO_2 + H_2O \rightarrow H_2CO_3$

   $SO_2 + H_2O \rightarrow H_2SO_3$
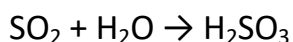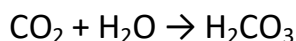
2. **River water:**
   - A river is a naturally flowing watercourse, usually freshwater, flowing towards a sea lake or anotherriver.
   - Rivers are nourished by precipitation, by surface runoff, through springs or from melting ofglaciers.
   - It contains high percentage of dissolved minerals like $NaCl$, KCl, $NaNO_3$, $CaCO_3$, $NaHCO_3$ etc.

3. **Lake water:**
   - Lake is a relatively large body of slowly moving or standing water that occupies an inland basin of appreciable size.
   - Lake water contains lesser amounts of dissolved minerals but considerable amount of suspendedand organic matters.

4. **Sea water:**
   - Sea water is the water from sea or ocean and is the most impure form of natural water.

- It contains about 3.5% of dissolved minerals out of which about 2.5% is only NaCl. Sea water also contains a number of dissolved gases like nitrogen, oxygen, carbon dioxide and noble gases and biomaterials like carbohydrates, proteins, amino acids etc.

B. Underground Water:

- Groundwater is the water that occurs below the surface of Earth, where it occupies all or part of the void spaces in soils or geologic strata.
- It is naturally replenished by rain and snow melt that seeps down into the cracks and crevices beneath the land's surface.

Underground water is of two types.

1. Spring water:

- A spring is a natural outflow of water from an underground supply to the ground surface.
- It is a clearer form of natural water.
- It contains high percentage of minerals like magnesium, calcium, sodium and potassium & thus itshardness is very high.

2. Well water:

- A well is a hole drilled, dug, or driven into the earth to obtain groundwater.
- It is a clearer form of natural water.
- It contains many dissolved minerals and some organic matter.

Types of water
Water is of 02 types:
 (1) Soft water & (2) Hard water.
1. Soft water: - Water which forms lather with soap solution is called soft water.

Ex: - Rainwater, demineralized water, distilled water etc.

2. Hard water: - Water which does not form lather with soap solution is called hard water. Instead, itforms a curdy white precipitate.

Ex: - Sea water, river water, Pond water etc.

Hardness of water:
It is the characteristic of water which prevents the lathering of soap due to the presence of bicarbonate, sulphate and chloride of calcium and magnesium in it.
Soap reacts with hard water as

$2C_{17}H_{35}COONa$ + $MgSO_4$ $\rightarrow$ $(C_{17}H_{35}COO)_2Mg$ + Na_2SO_4
(Sodium stearate) **(Impurity in hard water)** **(Magnesium stearate)**
   soap
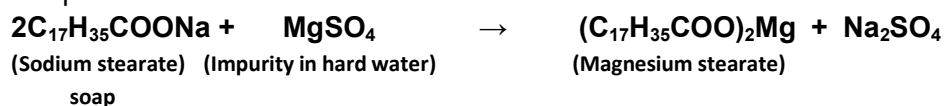
Types of hardness:

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 (HCO3)2, Mg (HCO3)2]**.

It is named temporary hardness because the soluble bicarbonates decompose into insoluble carbonates simply on heating. Thus, water becomes soft. It is also called carbonate hardness.

B. **Permanent hardness: The** permanent hardness of water arises due to the presence of chlorides of Ca, Mg ($CaCl_2$, $MgCl_2$).It is named permanent hardness because such a hardness cannot be removed by simply boiling the water.

Unit of hardness

(1) PPM – Parts per million.

(2) mg/L – Milligrams per Litre.

Softening of water or removal of hardness:

Water softening is the process of removing the dissolved calcium and magnesium salts that cause hardness in water.

Removal of temporary hardness:

When temporary hard water is boiled, the soluble bicarbonates present in water decompose to give insoluble carbonates which settle down easily. Then the soft water is filtered off.

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

Hard Water   (insoluble)

(soluble)

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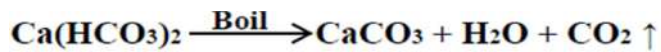
Hard Water   (insoluble)

(Soluble)

Removal of permanent hardness:

A. **Lime Soda Process:** 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 into insoluble substances called sludges.The precipitate or sludge formed is then removed by filtration to get soft water.

Lime-Soda process is of two types.

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

(soluble)   soda   (insoluble)

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

(soluble)   soda   (Insoluble)
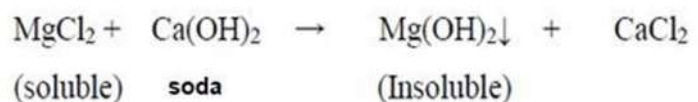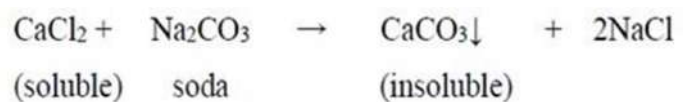
(a) Cold Lime soda process (b) Hot lime soda process

(a) Cold Lime Soda Process:

Principle: When hard water is treated with calculated amount of lime [Ca(OH)$_2$] and soda (Na$_2$CO$_3$) at room temperature 25ºC, the soluble Ca and Mg salt present in hard water are chemically converted into ppt. of calcium carbonate (CaCO$_3$) and magnesium hydroxide [Mg(OH)$_2$]. These ppts are removed by filtration. Thus, soft water is obtained.

$$CaCl_2 \quad + \quad Na_2CO_3 \quad \rightarrow \quad CaCO_3 \downarrow \quad + \quad 2NaCl$$

hard water   soda   ppt

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

hard water   lime   ppt

Process:

The apparatus consists of a conical shaped steel tank (Fig. 10.1) Raw water, lime, soda and coagulants are added from the top inner vertical circular chamber which is fitted with rotating shaft carrying many paddles. The dissolved salts of Ca and Mg combine with lime soda and coagulants and form an insoluble precipitate as sludge. Softened water rises upwards and the heavy sludge settles down. Then the softened water passes through wood fibre filter and the filtered soft water is collected through the outlet. The sludge setting down at the bottom is removed. The residual hardness left in this process is about 50 - 60 ppm.
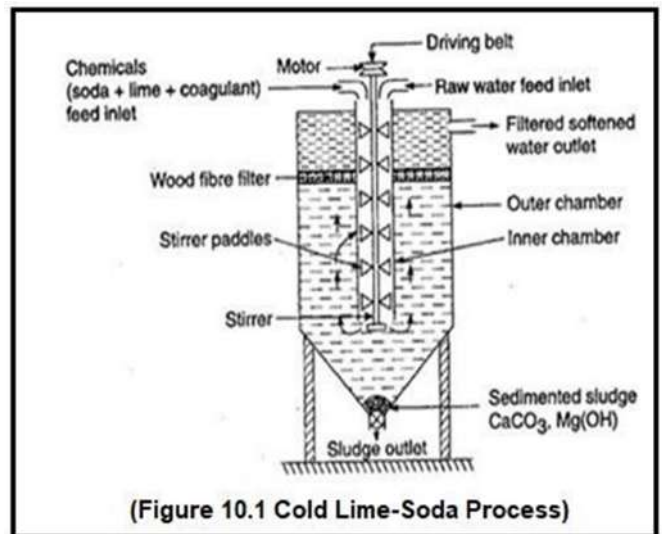
(Figure 10.1 Cold Lime-Soda Process)

Dis-advantages:

➢ It is a slow process because reactions during water softening take place in very dilute solutionsand room temp.
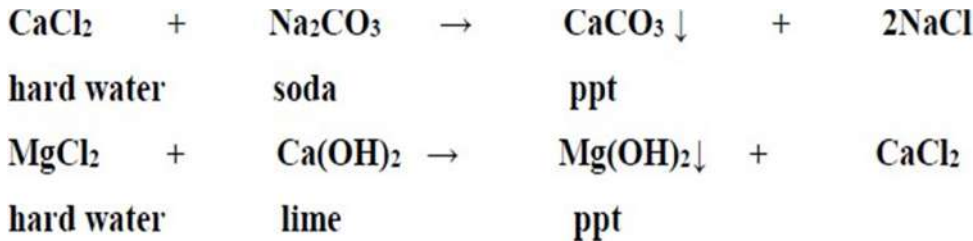➢ It requires coagulant for setting particles of ppt. formed during reaction of water softening.
➢ Softening capacity of this process is less.
➢ Soft water obtained by this process consists of dissolved gases.

(b) Hot Lime Soda process:

Principle: This process involves treatment of hard water with lime and soda at a temp. of 80-150^{0}C.
Process: In the hot lime soda process, the reactions take place at higher temperature near about boiling point of water. The chemical mixing process is same as the cold lime soda process, but steam is applied in mixture tank. As a result, precipitation becomes almost complete very quickly.

(Figure 10.2 Hot Lime-soda Process)
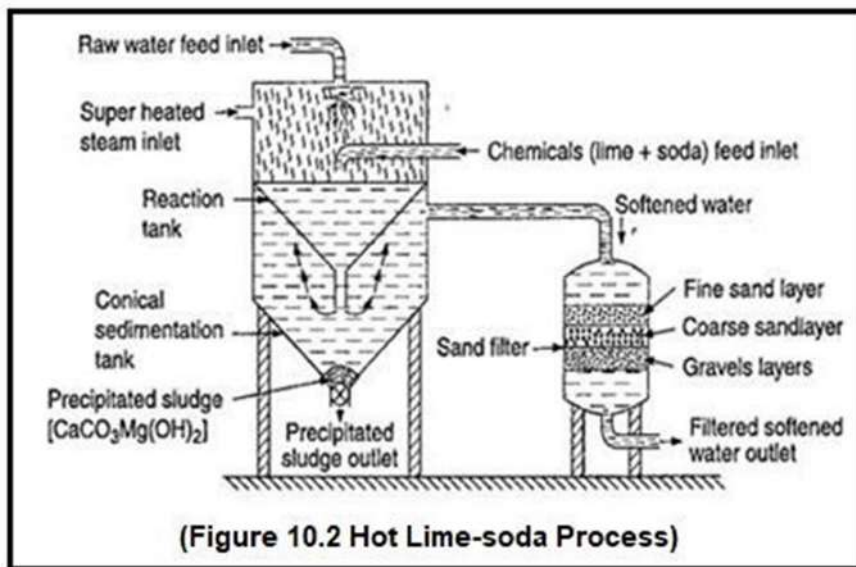
Apparatus:

The apparatus consists of 3 main parts (Fig. 10.2).

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

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

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

Advantages:

1. It is much economical.
2. The reaction is completed within a short period.
3. The reaction proceeds faster. Hence the softening capacity in increased.
4. No coagulant is required, as the sludge settles down easily.
5. Dissolved gasses like CO_2, air etc. are removed.
6. Under hot condition viscosity of water is lowered. Thus, filtration becomes easier.
7. Pathogenic bacterias are destroyed.
8. The residual hardness left in this process is much lower (15-30 ppm) as compared to that in thecold L-S process (50-60 ppm).

Dis-advantages:

➤ For efficient and economical softening careful operation and skilled supervision is required.

➤ Disposal of large amounts of sludge creates problem.

➤ This can remove hardness only up to 15ppm, which is not suitable for high pressure boilers.

Difference between cold lime soda process & hot lime soda process

Cold Lime soda process	Hot lime soda process
1. This process is conducted at room temp. (25^{0}C)	This process is conducted at 80^0 to 150^0 C.
2. It is costlier.	It is much economical.
3. The process takes longer time to complete.	It takes comparatively less time for completion.
4. The reaction is slower.	The reaction proceeds faster. Hence the softening capacity in increased.
5. Coagulant like alum is required.	No coagulant is required, as the sludge settles down easily.
6. Dissolved gases are not escaped.	Dissolved gasses like CO_2, air etc. are removed.
7. Filtration is comparatively slower.	Under hot condition viscosity of water is lowered. Thus, filtration becomes easier.
8. Pathogenic bacterias are not destroyed.	Pathogenic bacterias if any are destroyed.
9. The residual hardness left is more, i.e., 50 – 60 ppm.	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).

Advantages of Hot soda lime process over cold soda lime process: -

(i) The precipitation reaction becomes almost complete.
(ii) The reaction takes place faster.
(iii) The sludge settles rapidly.
(iv) No coagulant is needed.
(v) Dissolved gases are removed.
(vi) Residual hardness is low as compared to the cold lime-soda process.

# Ion – Exchange Process [Deionization or De-mineralization process]:

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

Organic ion-exchangers (Ion-exchange resins): -

These are organic polymers having:
(i) high molecular weight.
(ii) Open and permeable molecular structure.
(iii) acidic (-COOH, -SO$_3$H) or basic groups (-OH$^-$, -NH$_2$) attached with them.

Ion-exchange resins are of two types:

(a) Cation-exchange resin(R-H⁺): If the active ion in ion-exchanger is a cation, generally acidic functionalgroups, the resin is called cation-exchange resin, Ex – (Resin-H⁺)

(b) Anion-exchange resin (R-H⁻): If the active ion in ion-exchanger is an anion, generally basic functionalgroups, the resin is called anion-exchange resin Ex – (Resin-OH⁻)

Process: The hard water is passed through a column of cation exchange resin called zero-carb. All the cations present in hard water get exchanged with H^+ ions of the resin (Fig. 10.3).

$$2RH \quad + \quad Ca^{2+} \quad \rightarrow \quad R_2Ca \quad + \quad 2H^+$$
(Cation-Exchange Resin) hard water   Exhausted Resin

$$2RH \quad + \quad Mg^{2+} \quad \rightarrow \quad R_2Mg \quad + \quad 2H^+$$
(Cation-Exchange Resin) hard water   Exhausted Resin

Then the hard water is passed through the column of anion exchange resin. All the anions present in water get exchanged with OH- ions of the resin.

$$ROH \quad + \quad Cl^- \quad \rightarrow \quad RCl \quad + \quad OH^-$$
(Anion-Exchange Resin)   hard water   Exhausted Resin

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

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

Thus, the water coming out from the exchanger is free from cations as well as anion. Such water is known as deionized or demineralized water.

(Figure: 10.3 Organic Ion-Exchanger)

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

The cation-exchange resin can be regenerated by the treatment with dilute acids like dil. HCl or dil.H_2SO_4.

$$R_2Ca \quad + \quad 2HCl \quad \rightarrow \quad 2RH \quad + \quad CaCl_2$$
(Exhausted resin)   (Regenerated resin)

Similarly, the anion-exchange resin can be regenerated by the treatment with dilute alkali like, dil NaOH solution.

RCl   +   NaOH   →   ROH   +   NaCl

(Exhausted resin)   (Regenerated resin)
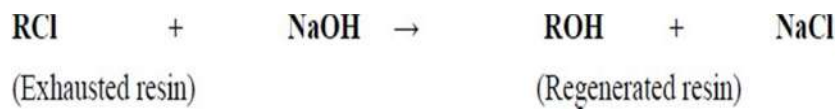
The regenerated resins may be used again.

Advantages of Ion – Exchange Process –

i.   This process can be used to soften highly acidic or alkaline water.
ii. It produces water of very low hardness (up to 2 ppm). So, it is good for treating water for use inhigh pressure boilers.

Dis-advantages of Ion – Exchange Process:

☞ The equipment is costly and more expensive chemicals are needed.
☞ If water contains turbidity, then output of the process is reduced.

CHAPTER – 11
LUBRICANTS

Introduction:

Lubricant is a substance, usually organic, introduced to reduce frictional resistance between surfaces in mutual contact, which ultimately reduces the heat generated when the surfaces move. It may also have the function of transmitting forces, transporting foreign particles, or heating or cooling the surfaces. The property of reducing friction is known as lubricity.

In addition to industrial applications, lubricants are used for many other purposes. Other uses include cooking (oils and fats in use in frying pans, in baking to prevent food sticking), bio-applications on humans (e.g., lubricants for artificial joints), ultrasound examination, medical examination. It is mainly used to reduce friction and to contribute to a better and efficient functioning of a mechanism.

Definition of Lubricants: Lubricants are the chemical substances applied in between two moving or sliding surfaces with a view to reduce the frictional resistance between them.

Types of lubricants: Basing upon the physical states, lubricants can be classified into three categories.

1. Solid lubricants: The lubricants that exist in solid form are called solid lubricants. Solid lubricants are preferred where the working temperature is very high and where there is a chance of contamination of theproducts with the lubricant.

Examples: Layered Compounds like graphite, boron trinitride, molybdenum disulphide, mica etc. are used as solid lubricants.

Uses of graphite:

☞ It is used to lubricate air compressors, railway track joints, food stuff industries, IC engines, opengears etc.
☞ Graphite mixed with oil called oil dag is used in IC engines.
☞ Graphite mixed with water called aqua dag is used in food industries.

2. Liquid lubricants: These are also known as lubricating oils. Examples:

Petroleum oil, Animal and Vegetable oil, Blended oil etc.**Uses of liquid**

lubricants: Liquid lubricants are used when,

☞ The operating temperature is high.
☞ Speed of the roller is high.
☞ The sealing arrangement is perfect to prevent the loss of oil.

3. Semisolid lubricants: Semi-solid lubricants are gel-like substances which reduce friction between twomoving surfaces. Example-greases, Vaseline, waxes, etc.

Uses of Grease:

Used where oil cannot remain in place due to high load, low speed, sudden jerks like rail axle.
☞ In bearings and gears which work at high temperature.
☞

Purpose of lubrication or Functions of lubricants:

1. It reduces friction and minimizes were and tear.
2. It reduces loss of energy.
3. It reduces noise pollution.
4. It increases the efficiency of engines.
5. It enhances the durability of machinery parts.
6. It reduces expansion of metals.
7. It acts as a coolant by removing heat of friction.

CHAPTER – 12
FUEL

Introduction:

Fuel is any material that can be made to react with other substances so that it releases energy as heat energy or to be used for work. The concept was originally applied solely to those materials capable of releasing chemical energy but has since also been applied to other sources of heat energy such as nuclear energy (via nuclear fission and nuclear fusion).

The heat energy released by reactions of fuels is converted into mechanical energy via a heat engine. Other times the heat itself is valued for warmth, cooking, or industrial processes, as well as the illumination that comes with combustion. Fuels are also used in the cells of organisms in a process known as cellular respiration, where organic molecules are oxidized to release usable energy. Hydrocarbons and related oxygen-containing molecules are by far the most common source of fuel used by humans, but other substances, including radioactive metals, are also utilized.

Fuels are contrasted with other substances or devices storing potential energy, such as those that directly release electrical energy (such as batteries and capacitors) or mechanical energy (such as flywheels, springs, compressed air, or water in a reservoir).

Definition: Fuel is defined as a combustible substance which on combustion produces a large amount of heat energy without producing excess by-products.

Fuel + $O_2 \rightarrow$ Products + Heat

Classification of Fuels:
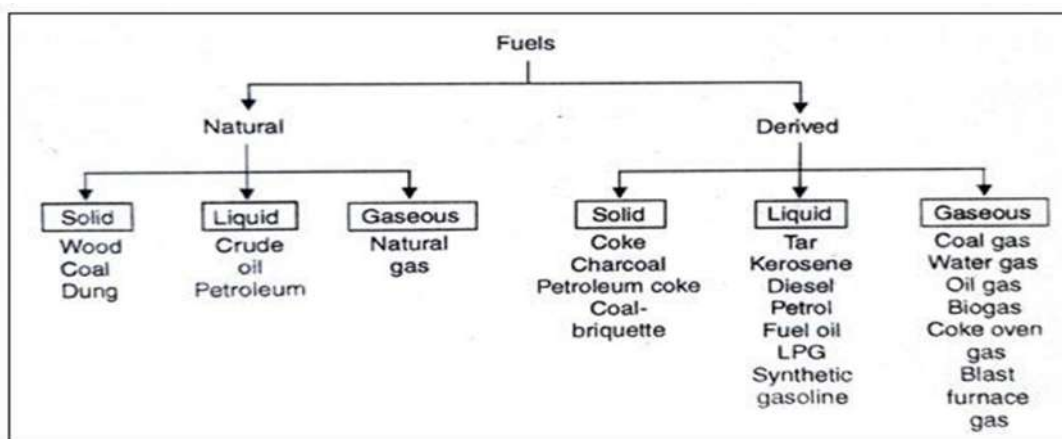
A. On the basis of their occurrence, fuels may be classified into two categories: -

1. **Natural Fuels:** Such fuels are found in nature.Ex-

   Wood, coal, petroleum, natural gas etc.

2. **Artificial Fuels:** Such fuels are prepared from natural fuels.

   Ex-Coke, kerosene, petrol, water gas, producer gas etc.

B. Based on their physical state, fuels may be classified into three categories:

1. **Solid Fuels**: Fuels which are found in their solid state at room temperature are generally referredto as Solid Fuels.

   Ex-Wood, coal, charcoal, straw etc.

2. **Liquid Fuels:** Most liquid fuels are derived from the fossilized remains of dead plants and animalsby exposure to heat and pressure in the Earth's crust.

   Ex-Petroleum, Kerosene, Petrol, Diesel, alcohol etc.

3. **Gaseous Fuels:** Most gaseous fuels are composed of hydrocarbons, carbon monoxide, hydrogen,or a mixture of them all.

   Ex- Natural gas, Coal gas, Producer Gas, Water Gas, Hydrogen etc.

Calorific value of fuel:
Calorific value may be defined as ‖the amount of heat energy produced by the complete combustion of a unit mass or unit volume of fuel in air.‖

Units of Calorific value are: Cal/gm, Kcal/Kg, KJ/Kg, B.Th./lb (British Thermal Unit/pound) etc.

Characteristics of good fuel:
1. It should have high calorific value.
2. It should be cheap and readily available.
3. It should leave only small amount of residue or ash when burnt.
4. It should have a controllable combustion rate.
5. It should not produce harmful combustion products.
6. It should not produce much smoke.
7. It should have moderate ignition temperature.
8. It should not be explosive in nature.
9. It should have low moisture content.
10.It should require low storage volume.
11.It should be easy to transport.

Composition and uses of some liquid fuels:

Diesel
 ➢ It contains a mixture of hydrocarbons between pentadecane to octadecane ($C_{15}H_{32}$ to $C_{18}H_{38}$).
 ➢ Average composition: C = 85%, H = 12%, Rest = 3%
 ➢ Calorific Value = 11,000 Kcal/kg

Uses: It is used as a fuel in diesel engine.

Petrol or Gasoline
 ➢ It contains a mixture of hydrocarbons between pentane to octane (C_5H_{12} to C_8H_{18}).
 ➢ It is volatile and inflammable.
 ➢ Average Composition C = 84%, H=15%, O+S+N =1%
 ➢ Calorific Value = 11,250 Kcal / Kg.

Uses:

☞ It is used as a fuel for internal combustion engines of automobiles.

☞ It is used as a dry-cleaning agent.

Kerosene

➢ It consists of hydrocarbons between decane to hexadecane ($C_{10}H_{22}$ to $C_{16}H_{34}$).

➢ Average Composition, C = 84 % , H = 16%, S < 0.1%

➢ Calorific value = 11,100 Kcal/ Kg

Uses:

☞ It is used as a domestic fuel in stoves.

☞ It is used as jet engine fuel for making oil gas.

Composition and uses of some gaseous fuels:

1. **Water Gas**

   (i) It is a mixture of combustible gases CO and H_2 with a little quantity of non-combustible gaseslike CO_2 and N_2.

   (ii) The average composition of water gas is H_2= 51 %, CO = 41 %, CO_2 = 4% & N_2 = 4%,

   (iii) Its calorific value is 2800 Kcal / m^3.

Uses: It is used:

☞ as a source of H_2 Gas.

☞ as a fuel.

☞ as an illuminating gas.

☞ for welding purposes.

2. **Producer Gas:**

   (i) It is a mixture of combustible gases, CO and H_2 with large quantities of non-combustible gasesCO_2 and N_2.

   (ii) The avg. composition of producer gas is CO = 22-30%, H_2 = 8-12 %, N_2 = 52-55 % & CO_2 = 3%

   (iii) Its calorific value is 1,300 Kcal /m^3.

Uses: It is used:

☞ For heating open-hearth furnaces in steel & glass manufacture, muffle furnace in coke & coal gas manufacture.

☞ As a reducing agent in metallurgical operations.

3. **Coal gas:**

   (i) It is a mixture of a number of hydrocarbons along with N_2, H_2, CO & CO_2.

   (ii) It is a colourless gas and burns with a sooty flame.

   (iii) The average composition of coal gas is

   H_2=40%, CH_4=32%, CO=7%, C_2H_2=2%, C_2H_4=3%, N_2=4%, CO_2=1% & rest=11%

   (iv) Its calorific value is 4900 Kcal /m^3.

Uses: It is used:

☞ as a fuel.

☞ as a reducing agent in metallurgical operations.

☞ as an illuminant.

4. **LPG (Liquified petroleum gas):**
    (i) It is mainly C3, C4 hydrocarbons of alkane & alkene.
    (ii) It is highly inflammable.
    (iii) It is colourless and odourless but a smelling agent called ethyl mercaptan(C_2H_5SH) is added to itto detect the leakage.
    (iv) The average composition of LPG is
    n-butane=27%, iso-butane=25%, butene=43%, propene=2.5% & propane=2.5%.
    (v) Its calorific value is 27,800 Kcal /m^3.

Uses: It is used:

☞ As a domestic fuel.
☞ As an industrial fuel.
☞ As a vehicular fuel.

5. **CNG (Compressed Natural Gas):**
    (i) It is a colourless, odourless gas and burns with a pale blue flame.
    (ii) The average composition of CNG is:
    CH_4=70-90%, C_2H_6=4-9% & traces of propane and butane.
    (iii) Its calorific value is 12500 Kcal /m^3.

Uses: It is used:

☞ as a fuel in low emissive vehicles like ULEV (ultra-low emission vehicles).
☞ as a domestic and industrial fuel.
☞ as a source of carbon in tyre industry.
for the production of H_2 gas needed in fertilizer industr

CHAPTER – 13
POLYMERS

Introduction:

Polymers are materials that are used in almost every material we encounter on a day-to-day basis. They have particular importance in today's increasingly industrial world. They are often found in the fields of science, technology and industry.

Product made from polymers are all around us: clothing made from synthetic fibers, polyethylene cups, fiberglass, nylon bearings, plastic bags, polymer-based paints, epoxy glue, polyurethane foam cushion, silicone heart valves, and Teflon-coated cookware. The list is almost endless.

Polymerization: The process of joining together a large number of simple small molecules to make large molecules of high molecular weight is called polymerization.

Polymers: Polymers are high molecular mass compounds whose structures are composed of a large number of simple molecules. For example: Polythene, PVC (polyvinyl chloride), Bakelite, Buna-S-rubber, Teflon, etc. are the examples of polymer.

The word "polymer‖ is derived from Greek word ‚poly' meaning "many" and ‚ meres ‚meaning "parts"

Monomer: Monomer is the single repeating unit which on polymerization gives a polymer. For example: Ethene is the monomer unit of polyethene.

Ethylene   Polyethylene
(Monomer)   (Polymer)
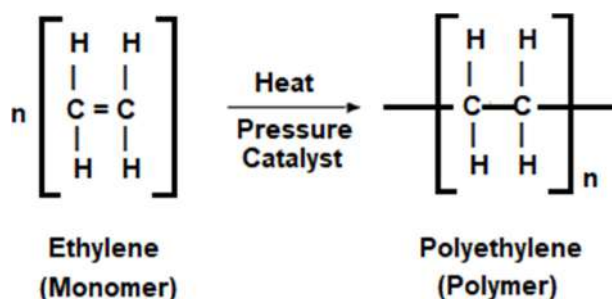
(A) Depending upon the sources, polymers may basically be classified in to two types, they are:

(i) Natural Polymers: These are the polymers which occur in the nature. Ex. Natural rubber, silk, polysaccharides, starch, cellulose, etc.

(ii) Synthetic Polymers: These are the polymers which are manufactured in industries. Ex. Polythene, PVC, Bakelite, Teflon, Nylon, Buna-S, Buna-N, etc.

(B) Depending upon the nature of monomers present, polymers may be classified into the following types.

i. Homo-polymer:

The polymer containing monomer units of identical chemical composition is called a homo-polymer. In other words, the polymer formed from one type of monomer is called a homo-polymer. Example: polythene, PVC, Polystyrene etc.

----------M – M – M – M – M---------------- *where, "A" is the monomer unit.*

(homopolymer)

ii. Copolymer:

The polymer containing monomer units of different chemical composition is called co-polymer or mixed polymer. For example: Terylene is a polymer of two monomers ethylene glycol and terephthalic acid. Other examples of co-polymer are Bakelite, Nylon-6,6, Nylon-6,10, Buna-S, Buna-N etc.

$$--------M_1 - M_2 - M_1 - M_2 - M_1 - M_2 -------$$
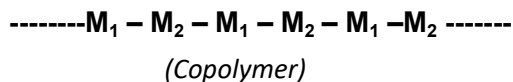
(Copolymer)

(C) Depending upon the nature of the polymeric chain/structure polymers may be classified as:

(i) **Linear polymers:** These are the polymers in which the monomer units are linked to one another to form long linear chains. These linear chains are closely packed in space. The close packing results in high densities, tensile strength and high melting and boiling points. e.g., high density polyethene, nylon and polyesters are linear polymers.

Linear chain polymer

(ii) **Branched chain polymers** In such polymers, the monomer units are linked to form long chains with some branched chains of different lengths with source. As a result of branching, these polymers are not closely packed in space. Thus, they have low densities, low tensile strength as well as low melting and boiling points. Some common Examples of such polymers are low density polyethene, starch, glycogen etc.

Branched chain polymer

(iii) **Cross-linked polymers or network polymers:** In such polymers, the monomer units are linked together to form three-dimensional network like structure. These are expected to be quite hard, rigid and brittle. Examples of cross-linked polymers are Bakelite, glyptal, melamine- formaldehyde polymer etc.

Cross linked polymer

Classification of Polymers Based on Mode of Polymerization

(i) Addition polymers: The polymers formed by the polymerization of monomers containing double or triple bonds (unsaturated compounds) without elimination of simple molecules are called addition polymers. Addition polymers have the same empirical formula as their monomers. Examples: Polythene, PVC, Polystyrene, etc.
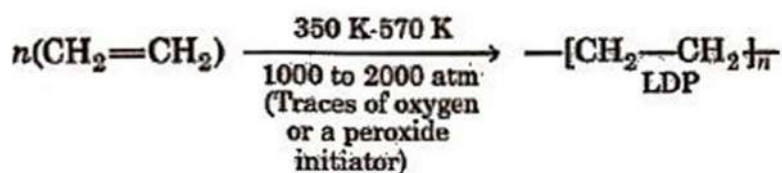
(ii) Condensation Polymers: The polymers which are formed by the combination of monomers with the elimination of small molecules such as water, alcohol, hydrogen chloride etc., are known as condensation polymers. Examples: Nylon-6,6 is formed by the condensation of hexamethylene diamine with adipic acid. Similarly, Bakelite is a condensation co-polymer of phenol and formaldehyde.

Distinction between Thermoplastics & Thermosetting.

	Thermoplastics	Thermosetting
1	These are formed by addition polymerization.	These are formed by condensation polymerization.
2	These are generally linear polymers.	These are three dimensional cross-linked polymers.
3	These are soft.	These are hard and rigid.
4	These are soluble in some solvents.	These are insoluble in any solvent.
5	These become soft on heating and become hard on cooling.	These burn to char on prolong heating.
6	These can be remoulded, reshaped and recycled.	These cannot be remoulded, reshaped and cannot recycled.
7	Examples: Polythene, PVC, Nylon, etc.	Examples: Bakelite, Urea-formaldehyde resin, Terylene, etc.

Polythene:

(i) Low density polythene (LDP)

$$n(CH_2=CH_2) \xrightarrow[\substack{1000 \text{ to } 2000 \text{ atm} \\ \text{(Traces of oxygen} \\ \text{or a peroxide} \\ \text{initiator)}}]{350 \text{ K-}570 \text{ K}} -[CH_2-CH_2]_n \\ \text{LDP}$$
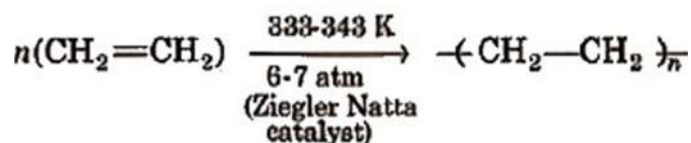
It is tough, flexible, transparent, chemically inert as well as poor conductor of electricity. It has moderate tensile strength but good tearing strength.

Uses: It is used

   i.   in the insulation of electrical wires, cables.
   ii. manufacture of bottles, toys and flexible pipes.

(ii) High density polyethylene (HDP)

$$n(CH_2=CH_2) \xrightarrow[\substack{6\text{-}7 \text{ atm} \\ \text{(Ziegler Natta} \\ \text{catalyst)}}]{333\text{-}343 \text{ K}} -(CH_2-CH_2)_n$$

It has high density due to close packing. It is also chemically inert, tougher, and harder.
Uses: It is used

   i.   in making containers,
   ii. house wares,
   iii. bottles,
   iv. toys,
   v.   electric insulation etc.

PVC (Poly Vinyl Chloride):

When vinyl-Chloride undergo polymerization in presence of a small quantity of benzyl peroxide, Poly Vinyl Chloride is formed


Vinyl chloride
(Monomer)

Polyvinyl chloride
(Polymer)
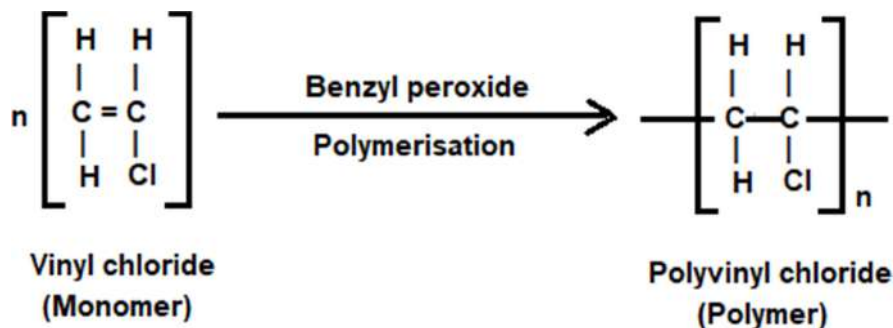
Uses: It is used for making:

vi. Sheets for tank lining
vii. Safely helmets.
viii. Refrigerator components
ix. Tyres, cycle and motorcycle mudguards
x. Raincoat packing
xi. Tablecloths
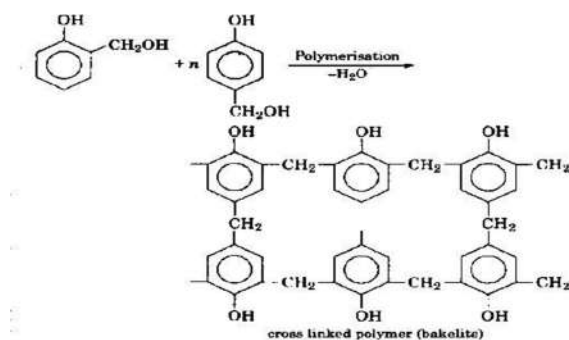*xii.* Electrical insulators
xiii. Chemical containers, etc.

Bakelite (Phenol-Formaldehyde Resin):

It is a co-polymer of **phenol and formaldehyde**. When phenol and formaldehyde are reacted togethertwo isomeric compounds *O-hydroxy methylphenol and P-hydroxy methylphenol are obtained.*
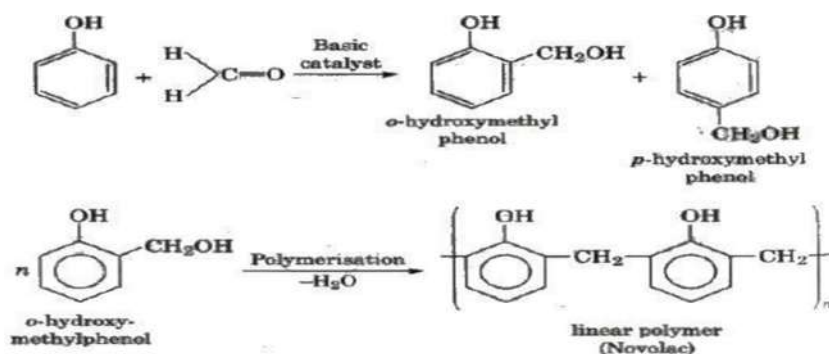
The orthohydroxy methylphenol thus formed undergoes polymerization with phenol to form a linear polymer compound called **"NOVOLAC"**.

During the process of polymerization, a little quantity of hexamethylene tetraamine $[(CH_2)_6N_4]$ is added which converts ₌novolac' into a hard resinous mass *called Bakelite.*

cross linked polymer (bakelite)

**Uses:** *It is used in the manufacture of:*

  i. *Electrical insulators like plug, switch etc.*
 ii. *Cabinets for Radio and TV*
iii. *Telephone parts*
 iv. *Paints, varnishes*
  v. *Hydrogen exchange resin for softening of hard water.*

RUBBER:

   Rubber is a naturally occurring polymer. It is obtained as *latex* from rubber trees. It is highly elastic. It can be easily deformed but regains its original shape after the stress is relieved.

   Rubber is obtained from rubber plants like *Hevea brasiliensis'* generally found in the tropical regions of *Brazil, Indonesia, Malaysia* etc. Certain saps are cut on the rubber plants and the thick milky liquid *called Latex* is collected. It is then diluted with water and filtered to remove any impurities present in it. Then, the latex is treated with acetic acid (CH_3COOH) which coagulates the latex. The coagulated latex is then passed through a creeping machine to obtain sheets of rubber. These sheets of rubber are then put into moulding machine to get moulded articles.

   Natural rubber consists of **"*isoprene*"** as the monomer units, which is in the form of the polymer polycis-isoprene. Thus, natural rubber is nothing but the polymer ***polycis-isoprene*.**
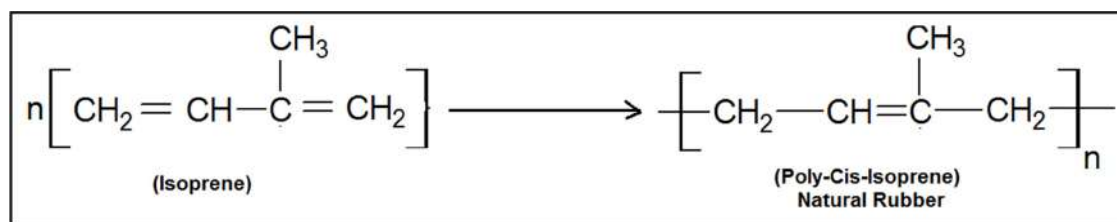

Draw backs of natural rubber:

Natural rubber or raw rubber has the following drawbacks:

  i. *It has very low thermal stability*
 ii. *It has very low tensile strength*
iii. *It has high water absorption capacity.*
 iv. *It is attacked by atmospheric oxygen and ozone.*
  v. *It is attacked by acids and alkalis.*
 vi. *It has the property of tackiness.*
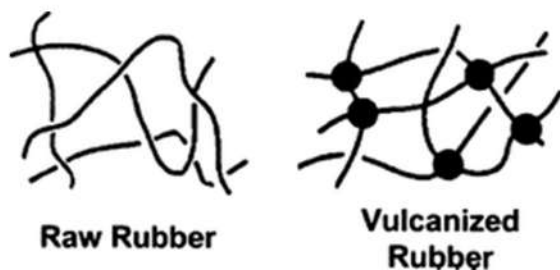
Vulcanization of rubber:

Natural rubber is a thermoplastic. There are no cross links between the polymer chains. It becomes soft and sticky when heated. It is not hard and tough. The properties of natural rubber can be modified and improved by the process of vulcanization. To improve the properties of natural rubber, it is heated with sulphur or sulphur containing compounds at a temperature of *100^0 -140^0 C.*

The chemical process in which natural rubber is heated with 4 to 6% sulphur or sulphur containing compounds with a view to overcome the drawbacks of natural rubber are called vulcanization.

(Raw Rubber) → 4 % - 6 % Sulphur / 100^0 - 140^0 C (Vulcanisation of Rubber) → (Vulcanised Rubber)
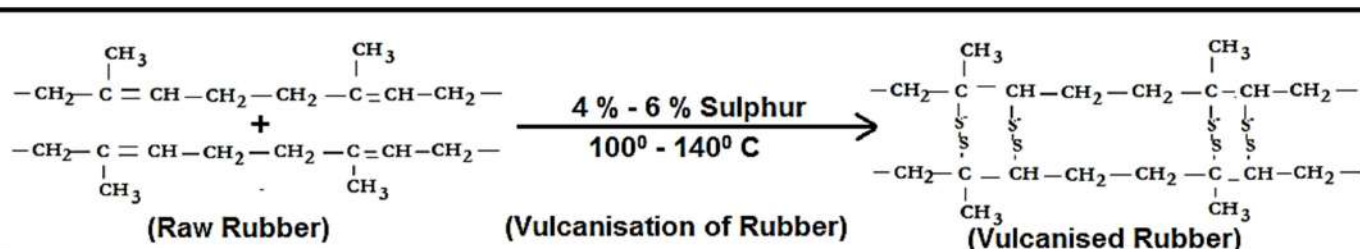
During vulcanization sulphur cross-links are formed in between the layers of polyisoprene at the carbon atoms containing double bond.

The formation of cross links makes *rubber hard, tough with greater tensile strength*. Although natural rubber is thermoplastic substance, yet on vulcanization, it is set into a given shape which is retained.

Raw Rubber   **Vulcanized Rubber**

Advantages of Vulcanization:

After vulcanization, almost all the drawbacks of raw rubber are eliminated. Vulcanized rubber:

  i. has higher thermal stability
  ii. has comparatively lower tensile strength
  iii. has low water absorption capacity.
  iv. is not attacked by atmospheric oxygen and ozone.
  v. is resistant to acids and alkalis.

CHAPTER – 14   CHEMICALS IN AGRICULTURE

Pesticides: Pesticides are chemical compounds that are used to kill pests, including insects, rodents, fungi, and unwanted plants (weeds).

The term pesticide includes all the following:

    i.   Insecticides
    ii.   Herbicides
    iii.   Fungicides.

Insecticides: Insecticides are substances used to kill insects.

Examples: - Chlorinated hydrocarbons like DDT, BHC (gammaxene), Aldrin, Dieldrin etc.

Uses- Insecticides are used in agriculture, medicine, industry and by consumers.

Herbicides: A herbicide is a chemical substance used to kill unwanted plants. These are commonly known as weedkillers.

Examples: Acetochlor, Amitrole, Arsenic acid, dinitrophenol, dipyridyl, carbamate, Propanil, Paraquat, etc.

Uses- Herbicides can be used to clear waste ground, industrial and construction sites, railways, and railway embankments as they kill all plant material with which they come into contact.

Also, these are applied in ponds and lakes to control algae & plants such as water grasses that can interfere with activities like swimming and fishing.

Fungicides: Fungicides are pesticides that prevent, kill, mitigate, or inhibit the growth of fungi on plants.

Ex- Bleaching powder, $CuSO_4$ solution, aluminium phosphide, Copper oxychloride, Carbendazim, Carboxin, Mancozeb, etc.

Uses-These are used to control fungi that damage plants.

Bio-fertilizers: Biofertilizers are the substance that contains living microorganism. Biofertilizers increase the nutrients of host plants when applied to their seeds, plant surface or soil by colonizing the rhizosphere of the plant. These are environment friendly substitute for harmful chemical fertilizers.

The microorganism in Biofertilizers restore the soil's natural nutrient cycle and build soil organic matter. These are extremely advantageous in enriching soil fertility & fulfilling plant nutrient requirements.

Ex-Rhizobium, Azotobacter, Azospirillum, Blue green algae etc.

Uses-
    i.   Rhizobium inoculant is used for leguminous crops.
    ii.   Azotobacter can be used with crops like wheat, maize. mustard etc.
    iii.   Blue green algae is used for paddy crops.
    iv.   Azospirillum is used for maize, sugarcane, millets etc.