

# **Vikash Polytechnic, Bargarh**

Vikash Polytechnic

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## **Lecture Note on – Applied Chemistry**

**Diploma 1<sup>st</sup> Semester**

**Branch – EE/ECE/CSE/CE/ME**



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# PHYSICAL CHEMISTRY

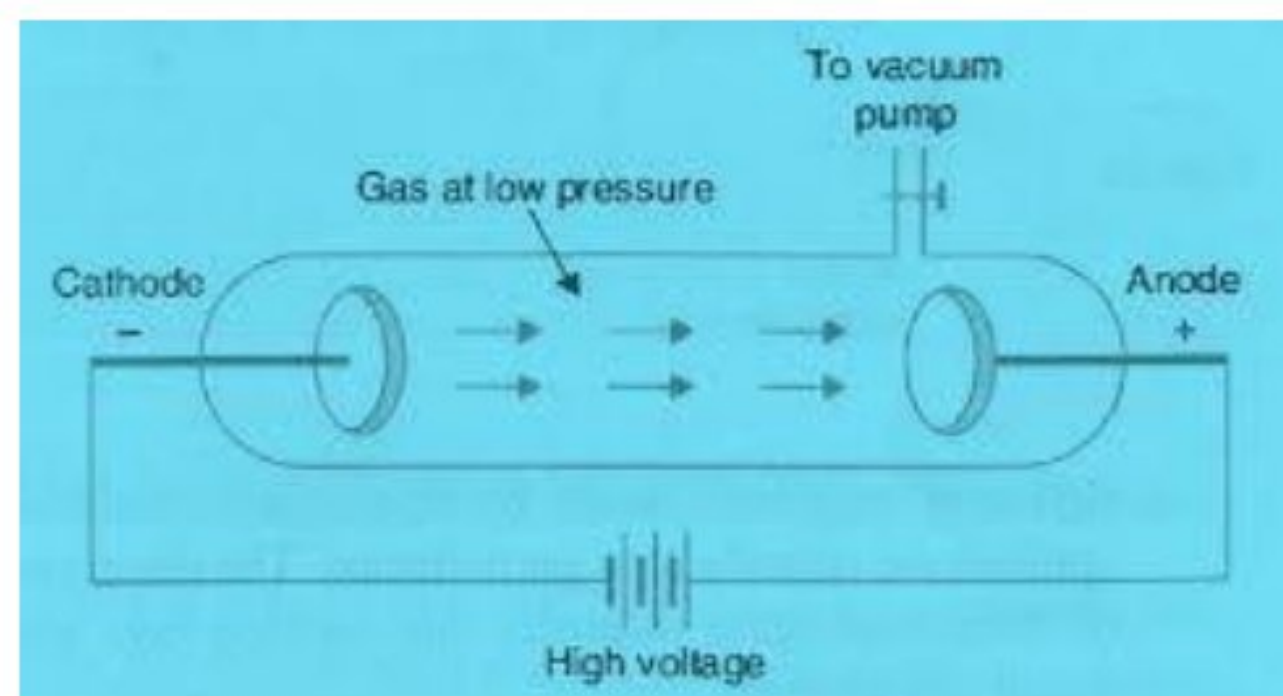
## ATOMIC STRUCTURE

According to Dalton's Atomic theory "Every matter is composed of very small particles called 'atoms' (Greek, a = cannot be; tom = cut) which cannot be further subdivided". But modern researches revealed that an atom is divisible and has a rather complex structure containing a large number of sub-atomic particles such as electrons, protons, neutrons, mesons, leptons, antiprotons, neutrinos, antineutrinos, positrons, quarks etc.

Atomic structure or the structure of an atom means, how the sub-atomic particles (electrons, protons, neutrons) are arranged inside an atom. Soon after the discovery of sub-atomic particles, different scientists put their efforts to establish the structure of an atom. Atomic structures proposed by different scientists are described as below. **Discovery of Electron:**

### **[Cathode Ray or Crookes's Discharge tube Experiment]**

In the mid 1800s, two scientists **Julius Plucker** and **William Crookes** discovered cathode rays, which was the first indication of the complex structure of an atom. When high potential difference ( 10,000 V – 30,3000 V) was applied across two electrodes in a hard glass tube, sealed at both the ends containing a gas at low





pressure (10-2mm), then a stream of **bluish light was seen travelling from cathode towards anode.**

The rays were found to cause fluorescence on the glass tube where they fall. **Sir J. J. Thomson** made an extensive study on the properties of cathode rays.

**Some important properties of these rays as follows :**

- i.** The rays are found to travel from cathode towards anode, hence are also **called cathode rays.**
- ii.** The rays travel in straight line, as is evident from the fact that they cast shadow of an opaque body placed in the path of rays.
- iii.** The rays heat up the metals on which they are made to fall upon. This shows the energetic nature of the rays.
- iv.** They produce x-rays when made to fall on certain metals under suitable conditions.
- v.** The rays cause mechanical motion when made to fall on small wheels. This clearly indicates that the rays must consist of some particles.
- vi.** They affect photographic plates.
- vii.** They ionise the gas through which they pass.
- viii.** They are deflected by electric and magnetic fields. When electric field is applied, they are found to be attracted towards the positively charged electrode which clearly indicates that the rays consist of small **negatively charged particles.**
- ix.** The specific charge or  $e/m$  of the particles of cathode rays is found to be the same irrespective of the nature of the gas inside the discharge tube. This clearly indicates that electrons are present in all matters. Hence electron is a fundamental particle of all matter.

**Charge of electron =  $- 1.6 \times 10^{-19}$  Coulomb.**

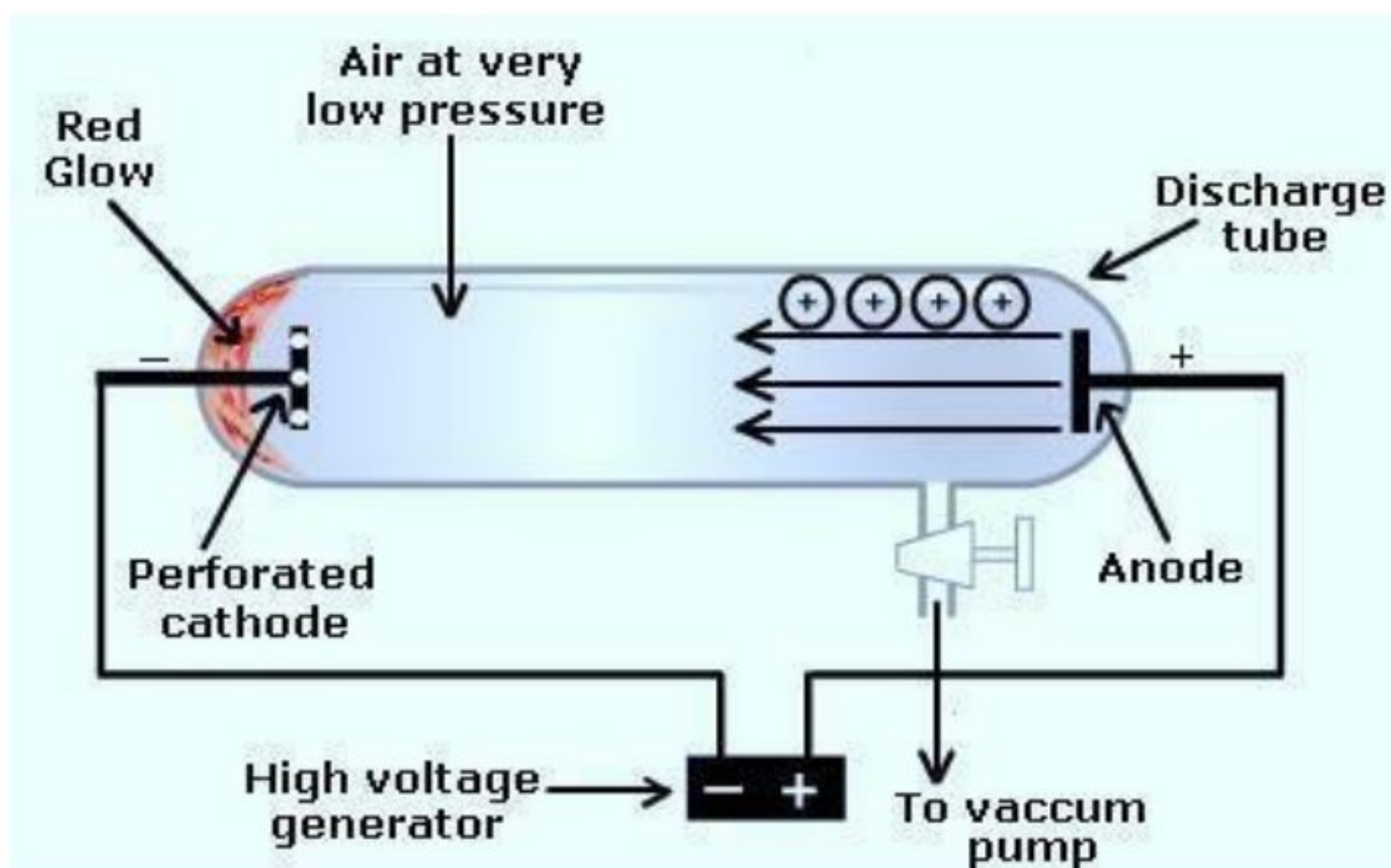
**Mass of an electron =  $9.1 \times 10^{-31}$  kg which is 1/1837 of the mass of a hydrogen atom.**



## Discovery of Proton

### [Anode Ray or Positive Ray

**Experiment]** As an atom is electrically neutral, it must contain the same number of positive charges as those of electrons (which are negatively charged). Goldstein conducted the same discharge tube experiment as in the discovery of electron, but instead of using a solid cathode he used a perforated cathode. When high potential difference was



applied across the electrodes, bluish streams of luminosity were seen at the back of the cathode. Unlike cathode rays, these rays were found to travel from anode towards the cathode. The cathode rays are also called canal rays as they pass through the holes of the perforated cathode. The properties of the rays were studied extensively by the scientist **J.J.**

**Thomson.** Some of the important properties of these rays as follows:

Like cathode rays, they travel in a **straight line**.

- i. They affect photographic plate.
- ii. They cause **phosphorescence** when made to fall on certain metallic salts.
- iii. They can **penetrate** through a thin metallic foil.
- iv. They are **deflected by electric and magnetic field**. However, the direction of deflection is opposite to that of cathode rays, i.e. they are attracted towards the negatively charged electric field. This indicates that the ray contains +vely charged particles.
- v. Unlike cathode rays, the e/m ratio the particles of these rays **are not same** for all gases.
- vi. The lightest positively charged particle found for hydrogen is called proton ( $H^+$ ) when.

This lightest particle having a unit positive charge with mass roughly equal to the mass of an atom of hydrogen was named as "proton". Or, a proton may be defined as that fundamental particle which carries a unit positive charge and has a mass nearly equal to that of hydrogen atom.



Charge on proton =  $+1.602 \times 10^{-19}$  Coulomb.

Mass of proton =  $1.672 \times 10^{-27}$  Kg.

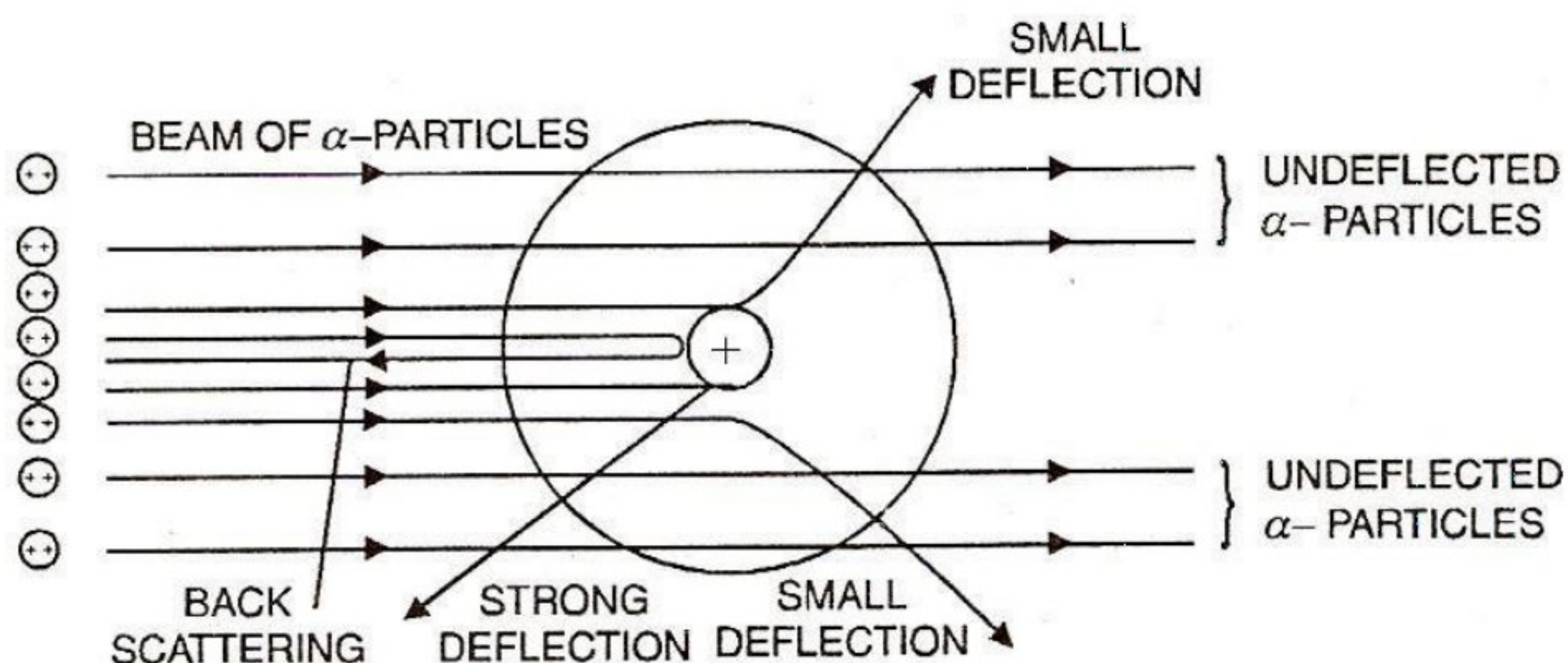
## RUTHERFORD'S ATOMIC MODEL:

### Rutherford's Gold-foil Experiment or Rutherford's $\alpha$ -scattering Experiment:

#### (Discovery of Nucleus)

In 1911, Rutherford gave the first information about the almost-correct-picture of an atom.

He bombarded a number of  $\alpha$ -particles ( $\text{He}^{2+}$  ions) emitting from a radioactive material like Uranium on a very thin gold foil. A circular zinc sulphide (**ZnS**) screen was provided at the back side of the gold foil in order to register the impressions made by the  $\alpha$ -particles.

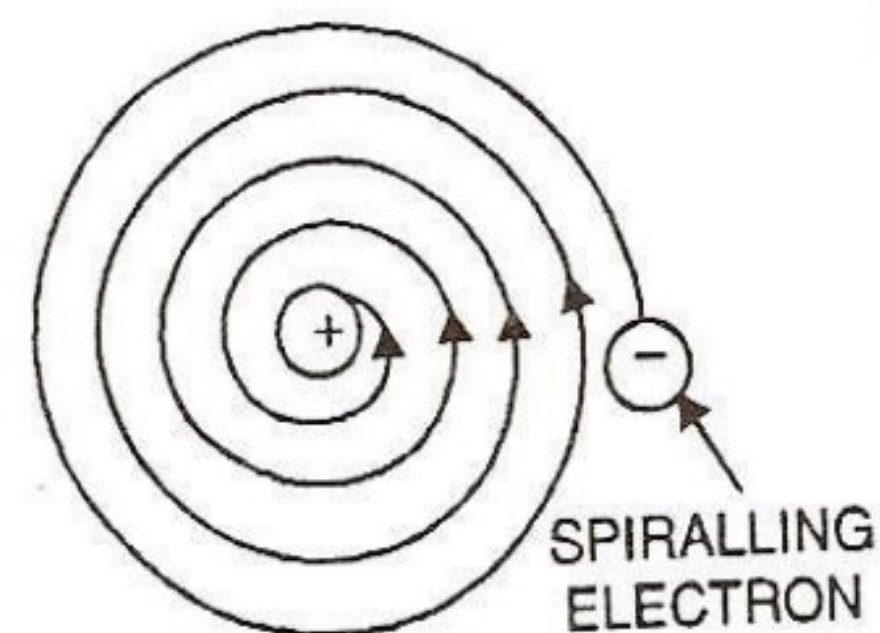


#### Observations and Conclusions:

From the  $\alpha$ - scattering experiment, Rutherford observed that:

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

The size of atomic nuclei is of the order of  $10^{-13}$  cm.



Based on the conclusions drawn from the  $\alpha$ -scattering experiment, Rutherford proposed an atomic model, as follows:-



1. An atom consists of two parts; they are (i) Nucleus and (ii) extra nuclear part.
2. Every atom consists of a very small but heavy positively charged body, called nucleus.
3. The whole mass of an atom is concentrated at the nucleus.
4. Electrons revolve around the nucleus with tremendous speed, like planets revolve around the Sun. Therefore, the electrons are also called as planetary electrons.
5. The electrostatic force of attraction (acting inward) between the nucleus and electrons is balanced by the centrifugal force (acting outward) arising due to the motion of electrons. That is why electrons do not fall into the nucleus.

### **DRAWBACKS OR FAILURES OF RUTHERFORD'S ATOMIC MODEL:**

1. Stability of Atom: The theory fails to explain the stability of atoms. According to the law of electrodynamics (by Clark Maxwell), whenever a charged particle revolves around another charged particle, the revolving charged particle emits (loses) energy continuously.
2. As the energy of the revolving electron decreases, it should be attracted towards the nucleus, and should follow a spiral path and ultimately fall into the nucleus. However this never happens
3. The model is silent about the definite energy and velocity possessed by the revolving electrons.
4. The theory fails to explain atomic spectra.

### **BOHR'S ATOMIC MODEL**

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



## Postulates of Bohr's atomic model:

1. Every atom consists of a heavy positively charged body at the centre called 'nucleus' and electrons revolve around the nucleus in certain permitted definite circular paths called 'shells', 'orbits'.
2. The stationary states or shells are designated as **K, L, M, N, O.....etc. for 1st, 2nd, 3rd, 4th** shells respectively.
3. Each shell is associated with a certain definite quantity of energy. Hence the shells are also called as 'Energy levels'.
4. The energy content of various shells are compared by the

formula:  $2\pi^2me^4Z^2$

$$E_n = - \frac{2\pi^2me^4Z^2}{n^2h^2}$$

where m = mass of an electron e = charge of an electron z = atomic

number n = number of shell or principal quantum number

(1, 2, 3...) h = Planck's constant

$$= 6.625 \times 10^{-27} \text{ erg sec}$$

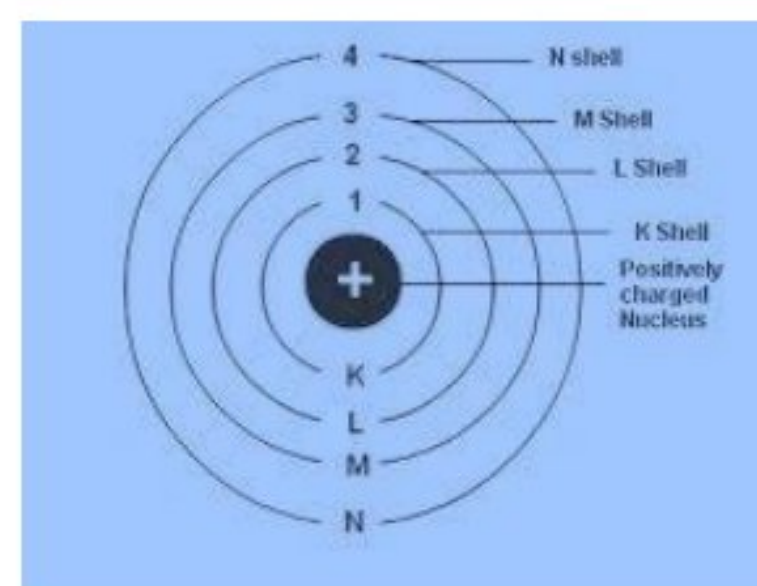
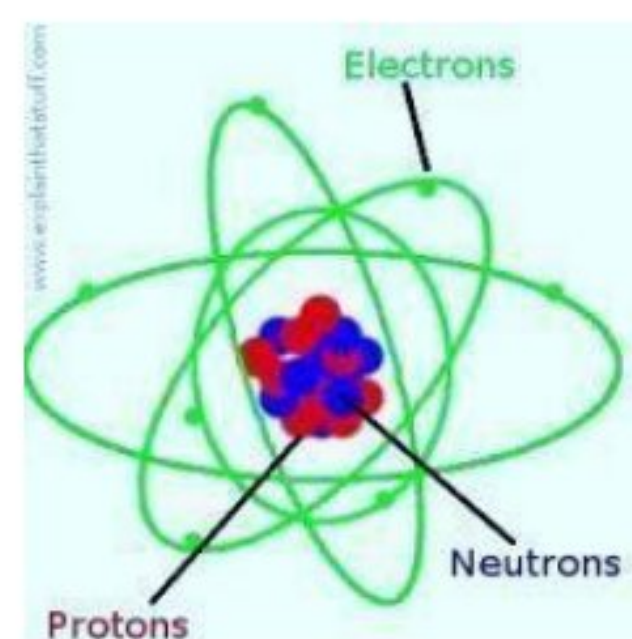
$$E_n = - \frac{1312}{n^2} \text{ KJ / mol, } n$$

for Hydrogen atom E = -1312 KJ/ mol

5. The energy content increases on moving from lower to higher shells and become zero for the shell which is present at infinite distance from the nucleus. Thus, the increasing order of energy content of the shells is: **K < L < M < N. .... and so on.**
6. The energy levels are not equally spaced.
7. Through a large number of concentric circles are possible around the nucleus, only those circular paths are allowed for the electrons to revolve for which the **angular momentum** h value (mvr) is a whole number multiple of  $\frac{h}{2\pi}$  that is  

$$mvr = \frac{nh}{2\pi}, \text{ where } n = 1, 2, 3, \dots \text{ Here, } m =$$

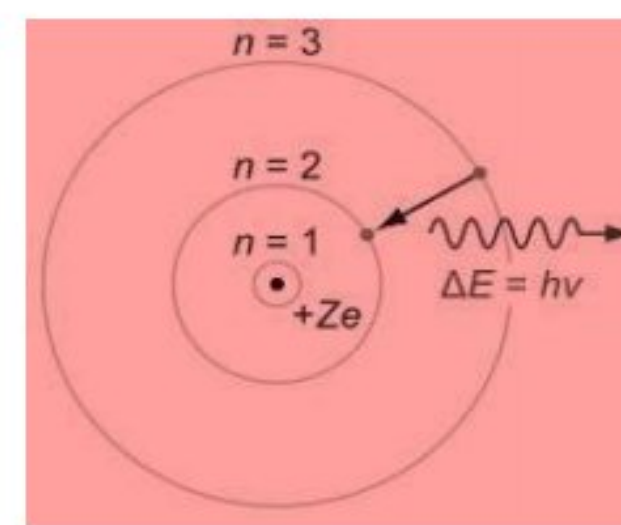
mass of the electron, v = tangential velocity of the revolving electron, r = radius of the orbit. h = Planck's constant,





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

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



## Failures of Bohr's Atomic Model

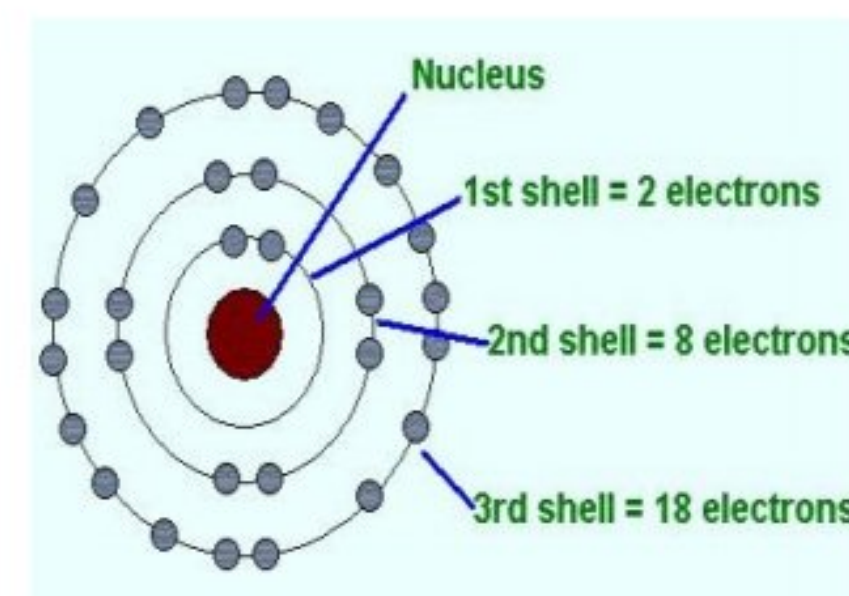
1. According to Bohr's atomic model, the path followed by electrons is two-dimensional circular. But modern researches (Heisenberg's Uncertainty Principle) revealed that electrons revolve in three-dimensional paths called orbitals.
2. It fails to explain the spectra of multi-electron species.
3. It fails to explain the relative intensities of spectral lines.
4. It fails to explain the splitting up of spectral lines when exposed to electric field (Stark Effect) and magnetic field (Zeeman Effect).
5. It fails to explain the cause of chemical combinations.

## BOHR-BURY SCHEME

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

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

Shell	Maximum number of electrons ( $2n^2$ )
K-Shell	$n=1, 2 \times 1^2 = 2$
L-Shell	$n=2, 2 \times 2^2 = 8$
M-Shell	$n=3, 2 \times 3^2 = 18$
N-Shell	$n=4, 2 \times 4^2 = 32$ and so on.



2. The outer most shell of an element cannot hold more than '8' electrons.
3. The penultimate shell (the shell just before the outer most shell) cannot hold more than '18' electrons.
4. A higher orbit may start filling before the lower orbit is completely filled.

Arrangements of electrons in different orbits of some elements according to Bohr-Bury scheme are given below.

ELEMENT	NUMBER OF ELECTRONS IN
---------	------------------------



	K- SHELL	L-SHELL	M-SHELL	N-SHELL
${}^1_1\text{H}$	1			
${}^2_2\text{He}$	2			
${}^3_3\text{Li}$	2	1		
${}^4_4\text{Be}$	2	2		
${}^5_5\text{B}$	2	3		
${}^{10}_{10}\text{Ne}$	2	8		
${}^{11}_{11}\text{Na}$	2	8	1	
${}^{12}_{12}\text{Mg}$	2	8	2	
${}^{13}_{13}\text{Al}$	2	8	3	
${}^{18}_{18}\text{Ar}$	2	8	8	
${}^{19}_{19}\text{K}$	2	8	8	1
${}^{20}_{20}\text{Ca}$	2	8	8	2
${}^{21}_{21}\text{Sc}$	2	8	9	2
${}^{22}_{22}\text{Ti}$	2	8	10	2
${}^{30}_{30}\text{Zn}$	2	8	18	2

### Aufbau's Principle

The word “**aufbau**” means “**building up**”. The building up of orbitals means filling up of orbitals with electrons.

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

The sub-shell with lowest energy is filled with electron first and those with higher energies are filled with electrons later. The energy content of the various sub-shells can be compared by  $(n+l)$  rule.

#### The $(n + l)$ Rule:

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

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

SUB-SHELL→	1s	2s	2p	3s	3p	3d	4s	4p	4d	4f	5s	5p
$(n+l)$	1+0 =1	2+0 =2	2+1 =3	3+0 =3	3+1 =4	3+2 =5	4+0 =4	4+1 =5	4+2 =6	4+3 =7	5+0 =5	5+1 =6

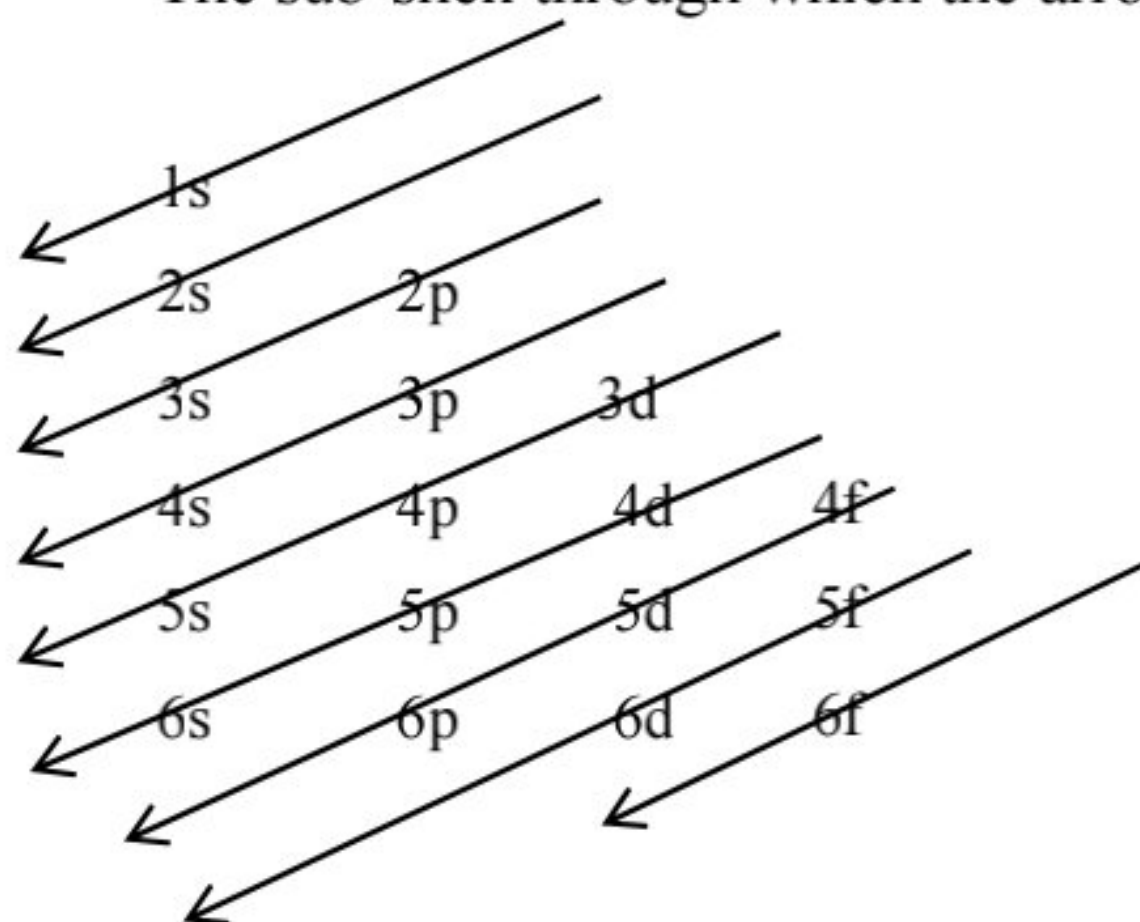


Thus, the increasing order of energy content of sub-shells is  $1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < \dots$

i. Arrange the sub-shell as given below.

ii. Draw parallel arrows as shown in the figure.

The sub-shell through which the arrow crossed first has lower energy.



## ELECTRONIC CONFIGURATIONS

Electronic configuration is the arrangement of electrons of an atom in different sub-shells in the increasing order of their energy. The electronic configurations of some elements are given below:

Elements	Electronic configurations
${}^1\text{H}$	$1s^1$
${}^2\text{He}$	$1s^2$
${}^8\text{O}$	$1s^2 2s^2 2p^4$
${}^{10}\text{Ne}$	$1s^2 2s^2 2p^6$
${}^{11}\text{Na}$	$1s^2 2s^2 2p^6 3s^1$
${}^{18}\text{Ar}$	$1s^2 2s^2 2p^6 3s^2 3p^6$
${}^{20}\text{Ca}$	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$
${}^{24}\text{Cr}$	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$
${}^{29}\text{Cu}$	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10}$
${}^{30}\text{Zn}$	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10}$

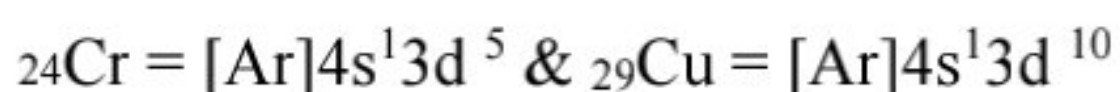
Exceptional Electronic Configuration: Some elements like 'Cr' and 'Cu' show exceptional electronic configurations. The exceptional electronic configuration is due to the fact that half-filled and completely filled orbitals are more stable due to the orbital symmetry and exchange energy.

The electronic configurations of 'Cr' & 'Cu' should be  ${}^{24}\text{Cr}$

$= [\text{Ar}]4s^2 3d^4$  &  ${}^{29}\text{Cu} = [\text{Ar}]4s^2 3d^9$  respectively.



But the actual electronic configurations are



## **CHEMICAL BONDING**

### **Definition of Chemical Bond**

Chemical bond is the force of attraction between the constituent atoms.

### **Types of Chemical Bond**

- **Electrovalent / Ionic Bond**
- **Covalent bond**
- **Co-ordinate bond**

### **Reason for chemical Bonding**

- Atoms of all elements have a tendency to acquire stable electronic configuration of the nearest inert gas. (Lewis octet rule)
- The atoms can acquire the stable electronic configuration of the nearest inert gas either by losing electron(s) or by gaining electron(s)
- This tendency of atoms to complete and hence stabilize their outer most orbit of electrons.

This is mainly responsible for chemical combination between the atoms.

### **Electrovalent or ionic Bond**

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

### **Process of Formation of electrovalent bond**

- The constituent atoms must be dissimilar in character, one with a tendency to loss electrons and the other having a tendency to gain electrons.
- The atom which loses electrons acquires positive charge and contracts. It is known as cation
  - The atom which gains electrons acquires negative charge and increases in size. It is known as anion.
- The cation and anion thus produced are held together by electrostatic lines of force and hence the linkage is called electrovalent bond.



- The compounds so produced are called electrovalent compounds.
- These are also called polar compounds since their molecules acquire polarity due to the formation of ions by electron transfer.

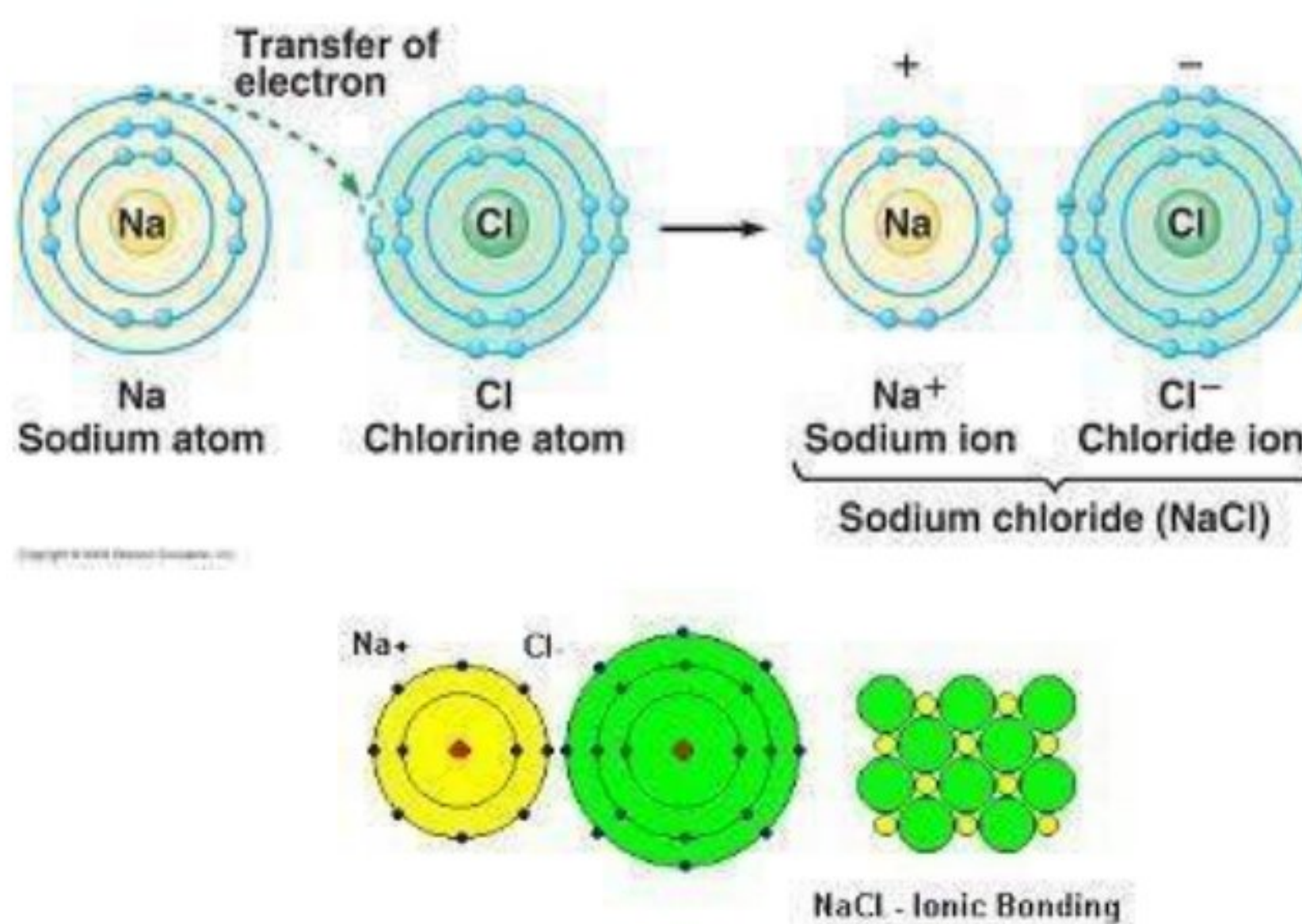
In the formation of the electrovalent bond, the electrons gained or lost are always from the outermost shell and the ions occupied acquire the nearest inert gas configuration.

### Example-1

Formation of NaCl :-

$_{11}\text{Na}$ -  $1s^2, 2s^2, 2p^6, \underline{3s^1}$   
Outermost  
electrons

$_{17}\text{Cl}$ -  $1s^2, 2s^2, 2p^6, \underline{3s^2}, \underline{3p^5}$   
Outermost  
electrons

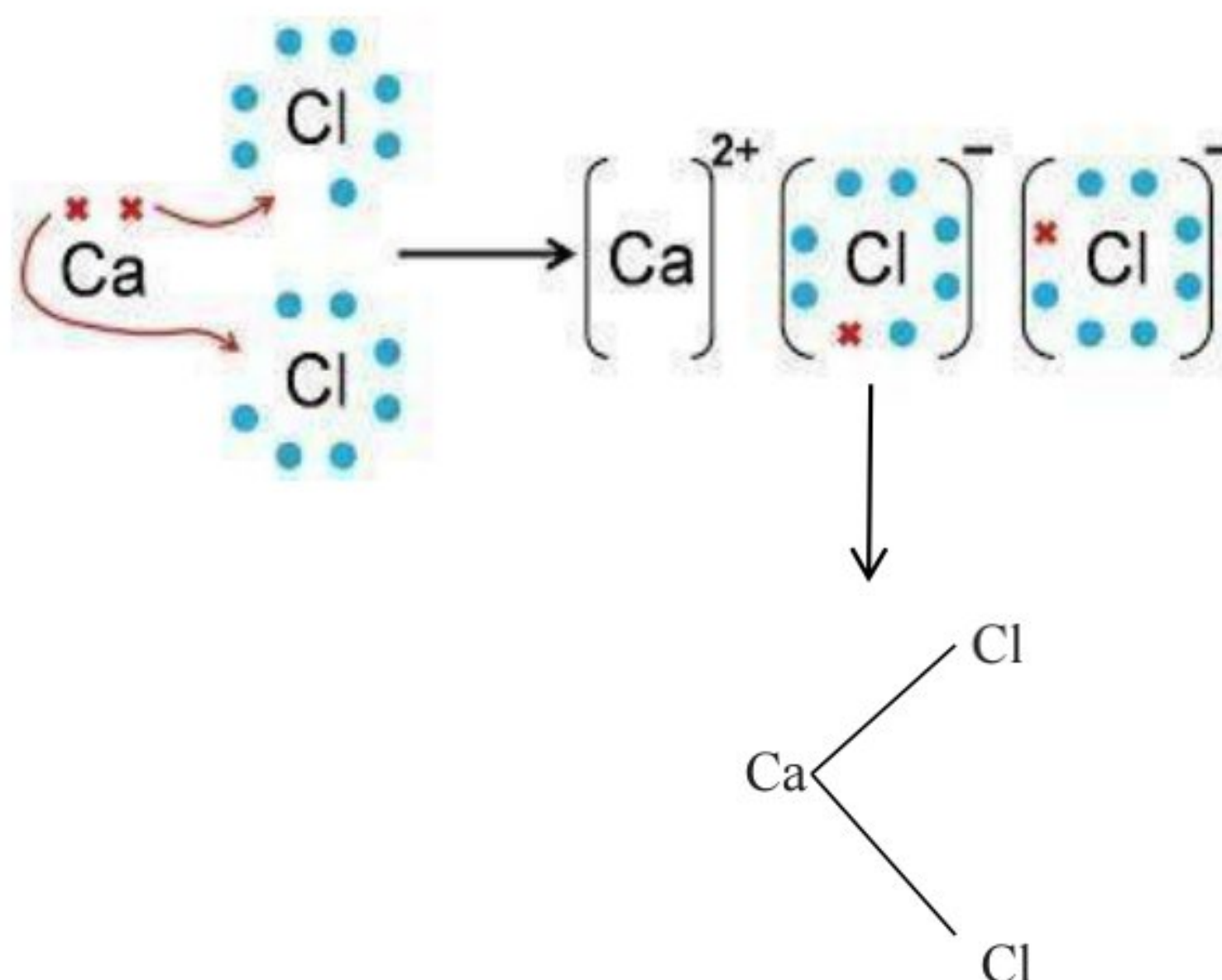


### Example-2

Formation of  $\text{CaCl}_2$

$_{20}\text{Ca}$   $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, \underline{4s^2}$   
Outermost  
electrons

$_{17}\text{Cl}$   $1s^2, 2s^2, 2p^6, \underline{3s^2}, \underline{3p^5}$   
Outermost  
electrons





## **Factors influencing formation of electrovalent bond**

The formation of an ionic or electrovalent bond is dependent upon the ease of formation of anions and cations from the neutral atoms which in turn depends upon the following major factors

### **1) Electronic structure**

Ions are easily formed when the electronic structure of the ion is more stable.

### **2) Ionic charge**

The tendency of the ion formation is more when the charge on the ion smaller.

### **3) Size**

Ion formation tendency is greater, when the atom forming the ion is smaller for anion formation and larger for cation formation.

### **4) Electron affinity**

The higher the electron affinity of an atom, the greater is the ease of formation of the anion.

### **5) Ionization potential**

The lower the ionization potential of an atom, the greater is the ease of formation of the cation.

### **6) Lattice energy**

The higher the lattice energy of the resultant ionic compound, the greater is the ease of its formation.

**The energy released when the oppositely charged ions combine to form one mole of the ionic compound is called lattice energy.**

## **Covalent Bond**

**Definition:** A covalent bond is formed by mutual sharing of one or more electron pairs and the atoms thus achieve their stability.

## **Process of formation of covalent Bond**

- The electrons for pair formation are contributed equally by the two constituent atoms and become their common property.
- The covalent bond can connect similar atoms when both of them are short of a few electrons to achieve the stable electronic configuration of nearest inert gas.
- Depending upon whether the electron pairs are shared equally between the constituent atoms or not, a covalent bond may be non-polar or polar.



## Covalent compounds are of two types

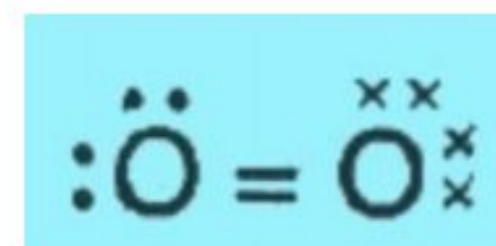
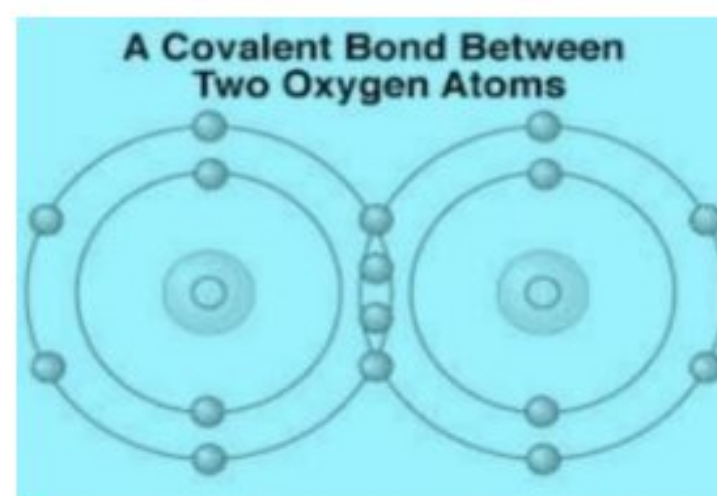
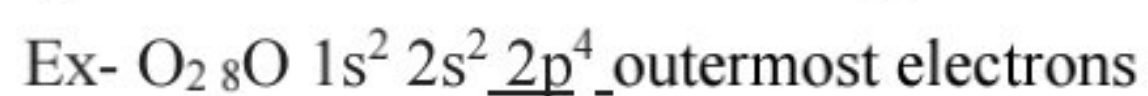
- Homoatomic molecules
- Heteroatomic molecules

### Homoatomic molecules:-

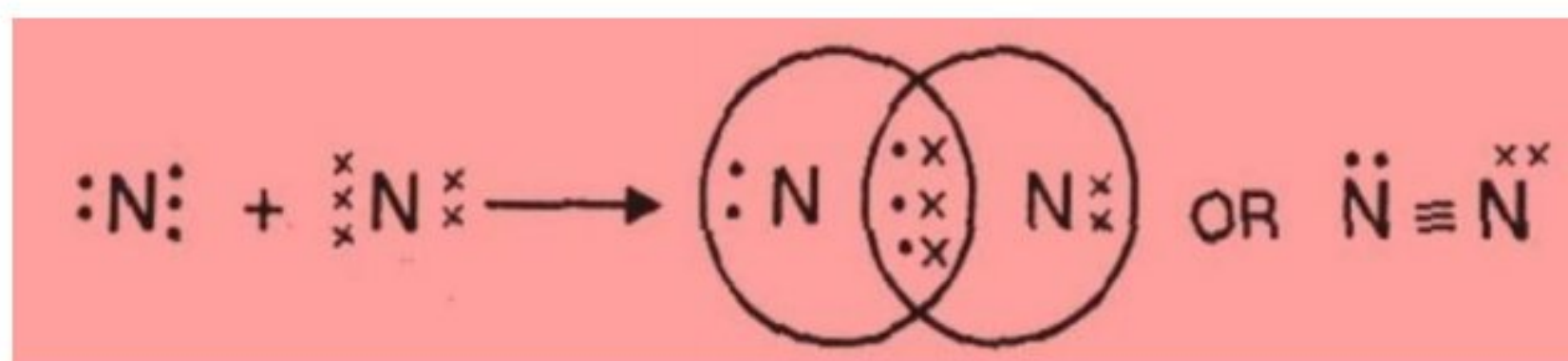
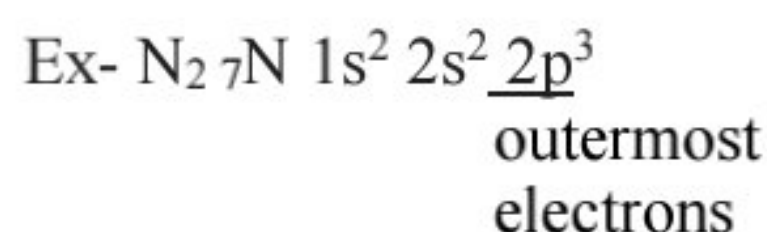
1) Formation of molecule having a single bond



2) Formation of molecule having a double bond

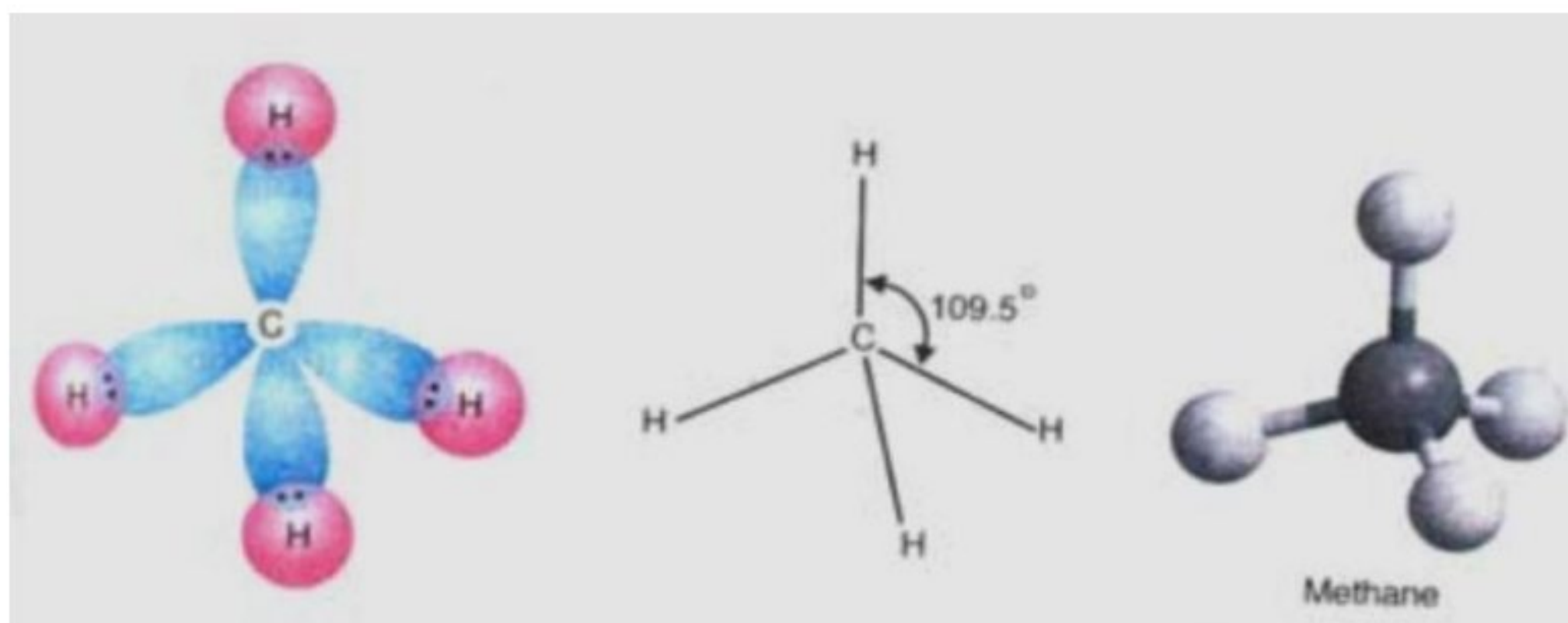
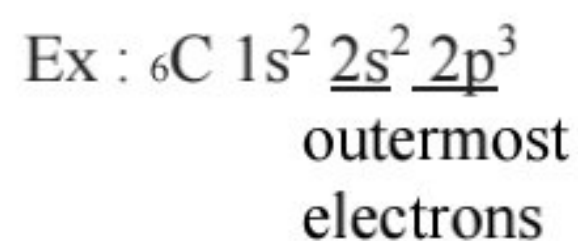


3) Formation of molecule having a triple bond



### Heteroatomic molecule:-

1) Formation of Methane ( $\text{CH}_4$ ) molecule



Four hydrogens are attached to the central carbon atom which create pressure on the carbon atom.

Hence, the atoms arrange themselves in such a manner that the molecule will become stable.

**Structure:** Tetrahedral

**Bond angle** =  $109^\circ 28'$



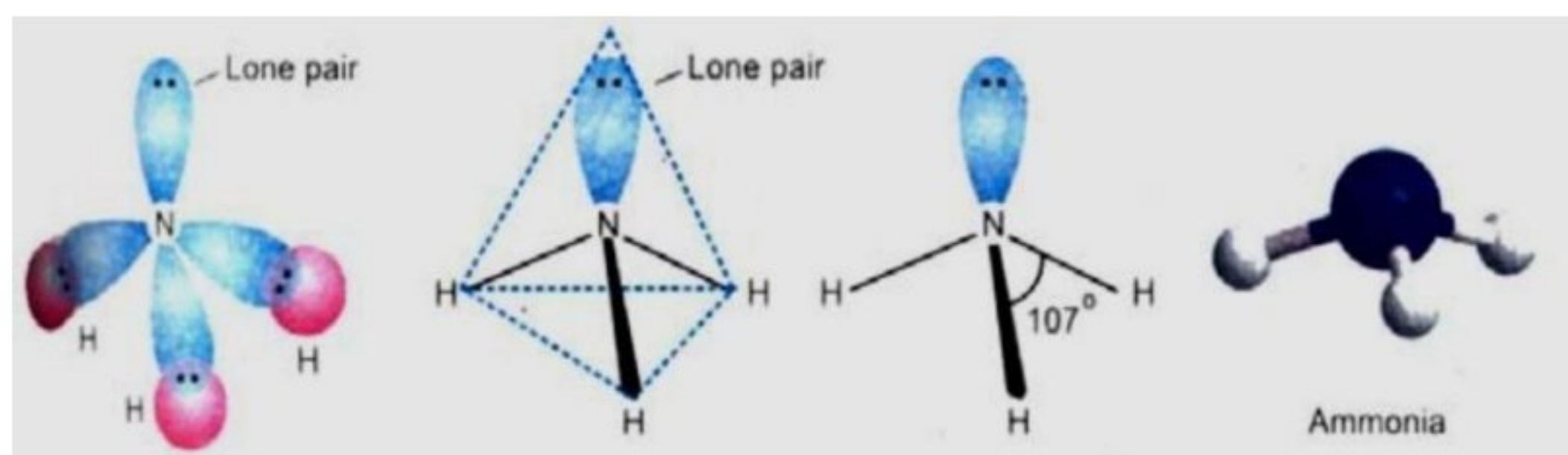
## Formation of Ammonia (NH<sub>3</sub>) Molecule

Ex:  ${}^7\text{N } 1s^2 \underline{2s^2} \underline{2p^3}$   
outermost  
electrons

${}^1\text{H } 1s^1$

**Structure:** Pyramidal

**Bond angle** = 107°

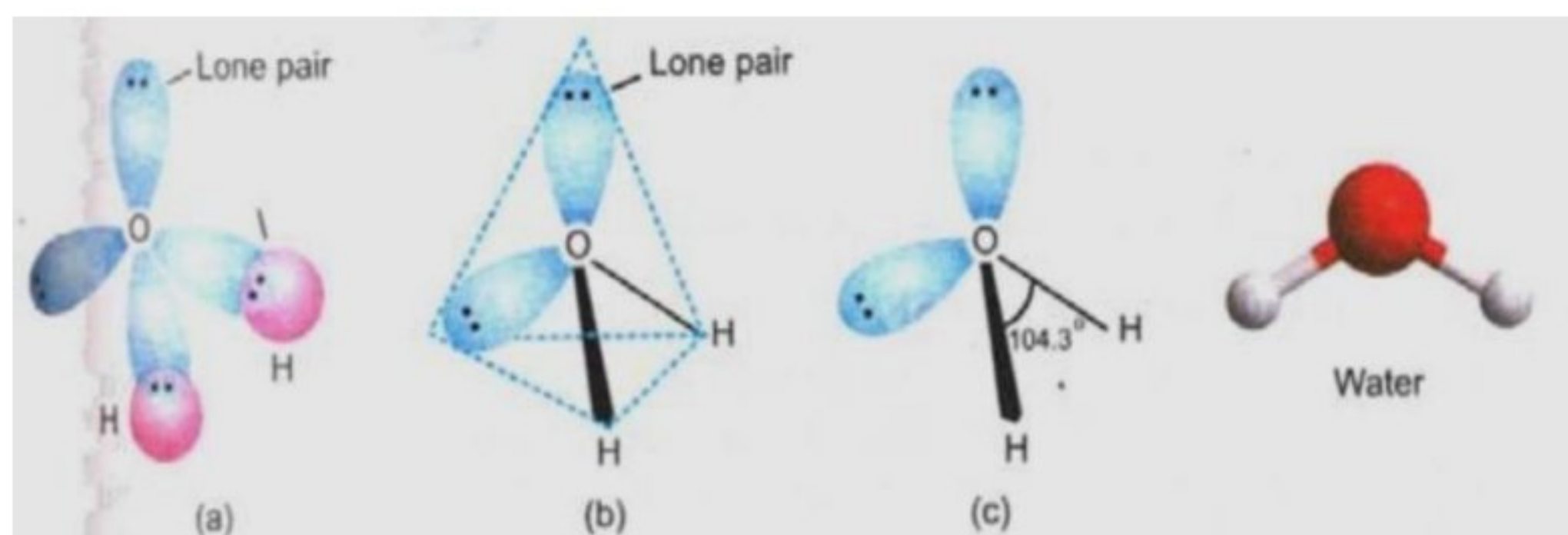


## Formation of water (H<sub>2</sub>O) molecule

$\text{H}_2\text{O } {}^1\text{H } 1s^1$   
 ${}^8\text{O } 1s^2 \underline{2s^2} \underline{2p^4}$   
outermost  
electrons

**Structure:** Angular

**Bond angle** = 104° 5'



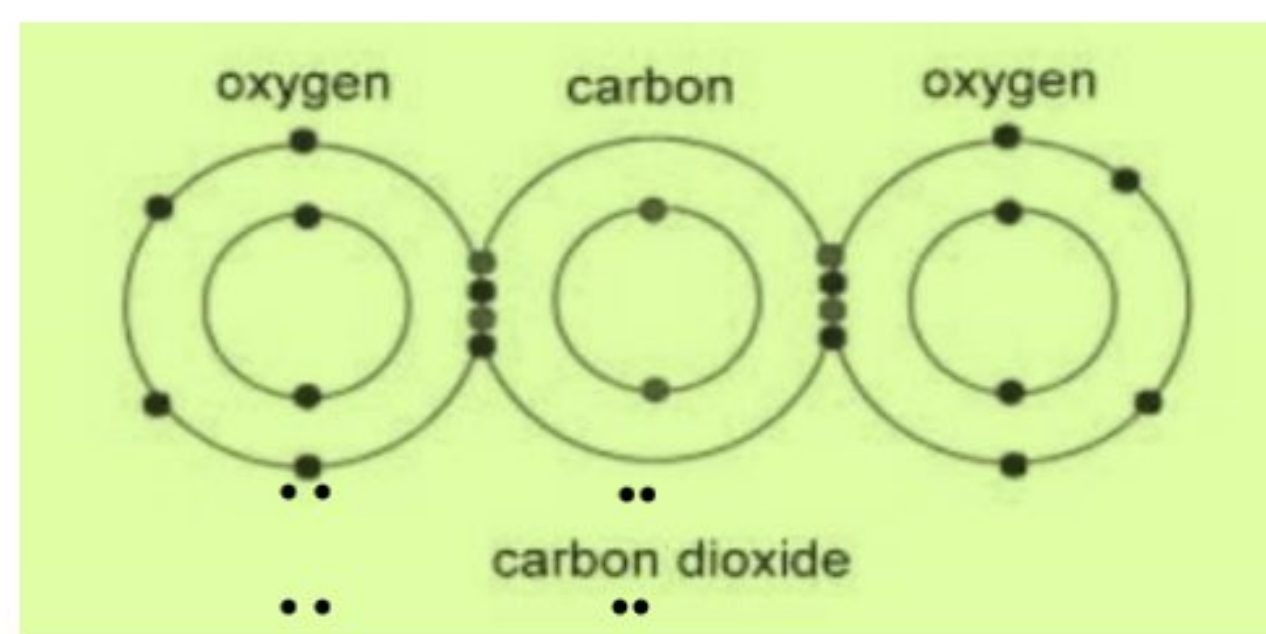
## Formation of (CO<sub>2</sub>) Carbon dioxide molecule

$\text{CO}_2$   ${}^6\text{C } 1s^2 \underline{2s^2} \underline{2p^2}$  outermost electrons  
 ${}^8\text{O } 1s^2 \underline{2s^2} \underline{2p^4}$  outermost  
electrons

**Structure:** Linear

**O = C = O**

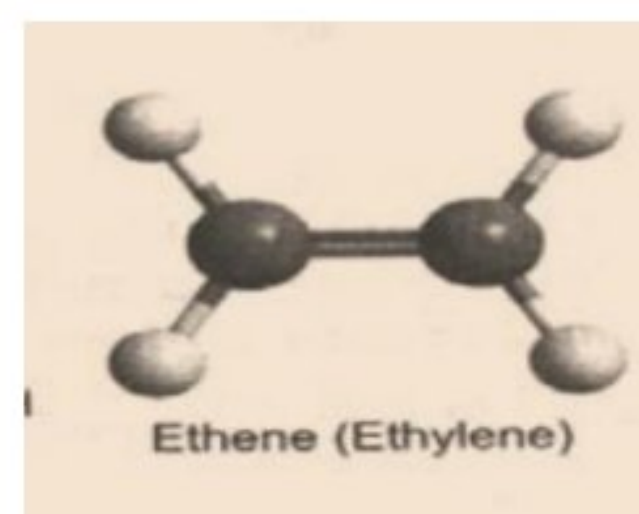
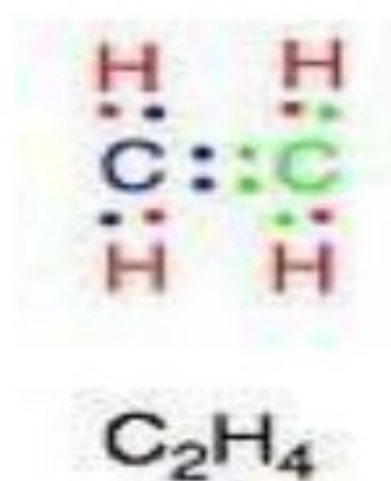
**Bond angle** = 180°



## Formation of Ethylene (C<sub>2</sub>H<sub>4</sub>) molecule

$\text{C}_2\text{H}_4$   ${}^6\text{C } 1s^2 \underline{2s^2} \underline{2p^2}$   
outermost  
electrons

${}^1\text{H } 1s^1$

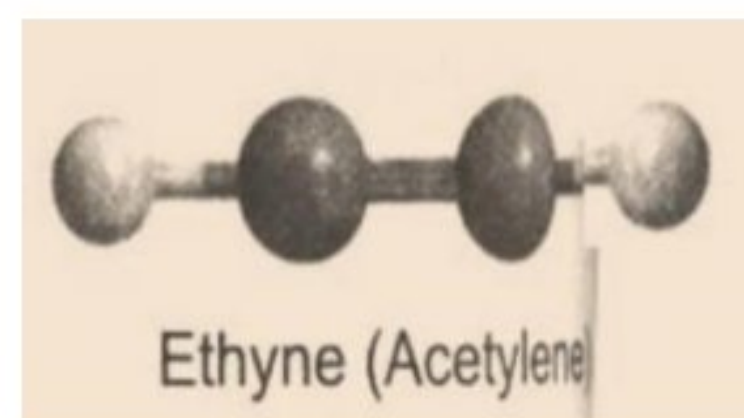
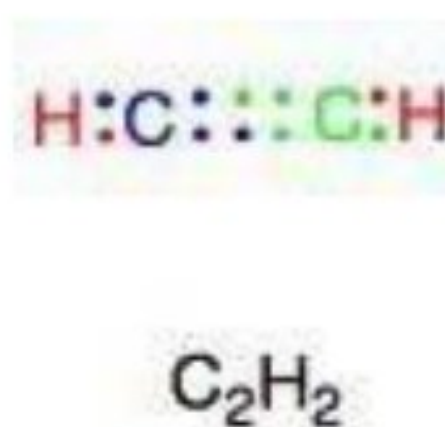




$\text{C}_2\text{H}_2$

${}_6\text{C}$      $1s^2 \underline{2s^2} \underline{2p^2}$   
outermost  
electrons

${}_1\text{H}$      $1s^1$

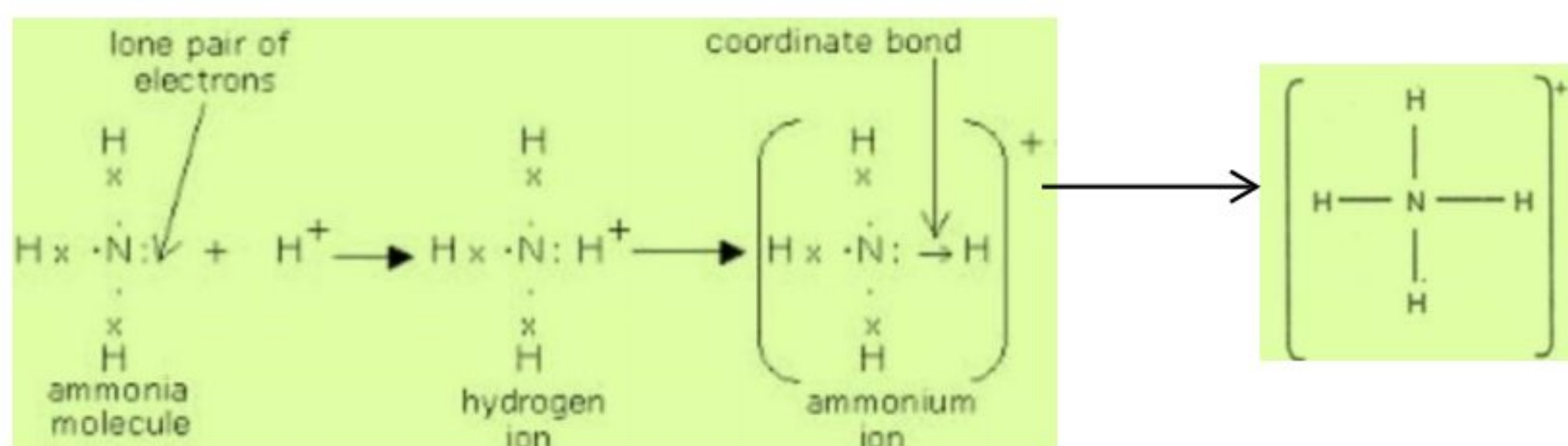


**Definition:** A co-ordinate bond is formed, when an atom with complete octet (after natural sharing) donates its pair of electrons to the other atom. The donated pair is counted towards the stability of both the atoms.

- This type of bond is formed by dissimilar atoms A and B
- Atom A has one or more lone pairs of electrons. Atom B is short of a pair of electrons than the nearest inert gas configuration.
- Atom A donates its lone pair of electrons to atom B. As a result, both the atoms get inert gas configuration.
- Atom A is called donor while atom B is called acceptor. The bond formed is called **dative or directional bond**.

${}_7\text{N}$        $1s^2 \underline{2s^2} \underline{2p^3}$   
                  outermost  
                  electrons

${}_1\text{H}$        $1s^1$

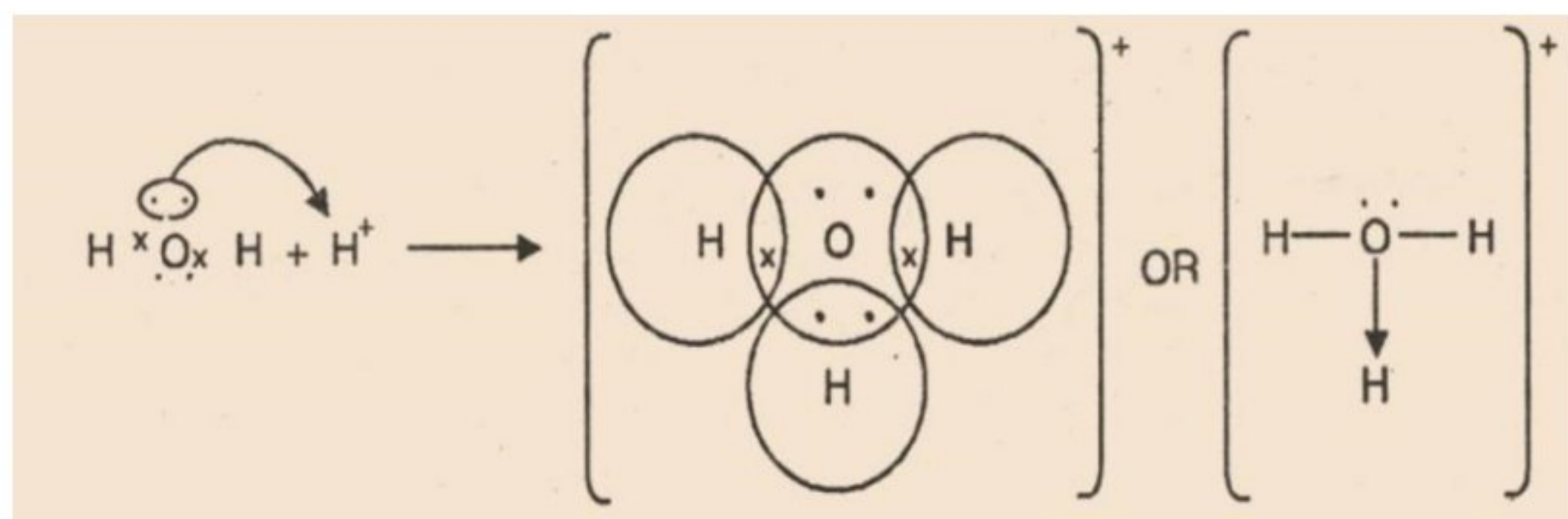


## 16



$1\text{H} \quad 1s^1$

$8\text{O} \quad 1s^2 \underline{2s^2} \underline{2p^4}$   
outermost  
electrons





# 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:  $HCl \xrightarrow{\text{water}} H^+(aq) + Cl^-(aq)$

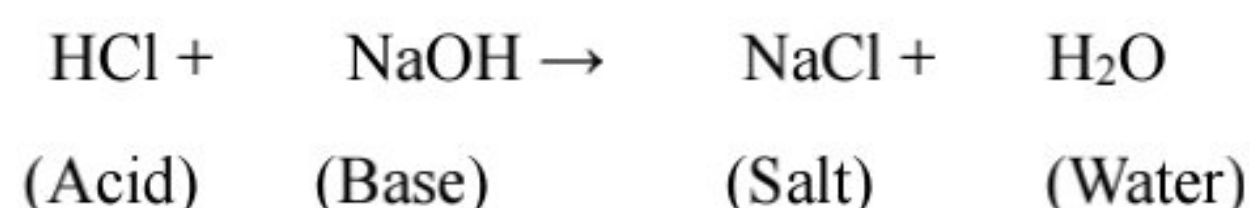
Other examples of acids are:  $HNO_3$ ,  $H_2SO_4$ ,  $CH_3COOH$  etc.

Examples of Base:  $NaOH(s) \xrightarrow{\text{water}} Na^+(aq) + OH^-(aq)$

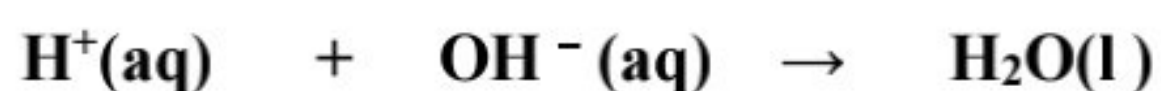
Other examples of bases are:  $KOH$ ,  $Ca(OH)_2$ ,  $Al(OH)_3$  etc **Salient**

#### Features:

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



Neutralisation reaction may be represented as:



(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 ( $H_3O^+$ ).  $H^+ + H_2O \rightarrow H_3O^+$
- 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<sub>3</sub>, H<sub>2</sub>SO<sub>4</sub>, H<sub>3</sub>PO<sub>4</sub>, CH<sub>3</sub>COOH, H<sub>2</sub>CO<sub>3</sub> 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<sub>2</sub>O, NH<sub>3</sub>, RNH<sub>2</sub>, PH<sub>3</sub>, AsH<sub>3</sub>, etc.
- ii. Ions having capacity to accept  $H^+$  ion, like  $OH^-$ ,  $CN^-$ ,  $HCO_3^-$  etc.

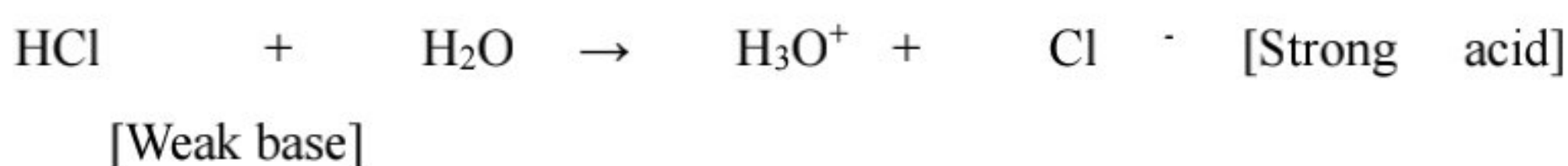
**All Arrhenius acids are Bronsted acids but all Bronsted bases are not Arrhenius bases.**

**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<sub>2</sub>O,  $HS^-$ ,  $HCO_3^-$ ,  $HPO_4^{2-}$ ,  $HSO_4^-$  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.



**Limitations of the theory:**

- i. It fails to explain the acidic nature of the substances, such as SiO<sub>2</sub>, CO<sub>2</sub>, SO<sub>2</sub>, BF<sub>3</sub>, etc. which cannot donate  $H^+$  ion.
- ii. It fails to explain the basic nature of the substances, such as Na<sub>2</sub>O, K<sub>2</sub>O, 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:  $\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$ .

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



ACID	CONJUGATE BASE	BASE	CONJUGATE ACID
HCl	Cl <sup>-</sup>	Br <sup>-</sup>	HBr
H <sub>2</sub> SO <sub>4</sub>	HSO <sub>4</sub> <sup>-</sup>	CN <sup>-</sup>	HCN
NH <sub>4</sub> <sup>+</sup>	NH <sub>3</sub>	NH <sub>2</sub> <sup>-</sup>	NH <sub>3</sub>
H <sub>2</sub> O	OH <sup>-</sup>	H <sub>2</sub> O	H <sub>3</sub> O <sup>+</sup>

### 3. 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:-

- All cations are Lewis acids: For example; Na<sup>+</sup>, K<sup>+</sup>, Ca<sup>2+</sup>, Cu<sup>2+</sup>, Al<sup>3+</sup>, Fe<sup>3+</sup> etc.
- Neutral molecules containing electron deficient atoms are Lewis acids. For example: BF<sub>3</sub>, AlCl<sub>3</sub>, FeCl<sub>3</sub>, ZnCl<sub>2</sub> etc.
- Neutral molecules containing vacant d-orbitals in the central atom for the accommodation of incoming electrons act as Lewis acids. For example: SiF<sub>4</sub>, SiCl<sub>4</sub>, etc.
- The molecules having multiple bonding (= or ≡) between the atoms of different elements are acidic in nature. For example: CO<sub>2</sub> (O = C = O), SO<sub>2</sub>, etc.

#### Examples of Bases:-

- All anions are Lewis bases: F<sup>-</sup>, Cl<sup>-</sup>, CO<sub>3</sub><sup>2-</sup> etc.
- Neutral molecules containing, at least one lone pair of electrons are Lewis bases

#### Salient Features:

- 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<sub>2</sub>O (Lewis base) and H<sup>+</sup> (Lewis acid) results in the formation of a dative bond.
- All Bronsted- Lowry bases are Lewis bases while the reverse is not always true.

#### Limitations:

- 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<sub>3</sub>, H<sub>2</sub>SO<sub>4</sub> 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.

**3. 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.

**4. 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.

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

### **TYPE OF BASES**

**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 of a base.

**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.

### TYPES OF SALT

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.

Example:

**2. Acidic salts:** The salt obtained by the partial replacement of replaceable hydrogen atoms

Acids	Normal salts	of an acid by metal atoms is called an acidic salt. These type of salts still
HCl	NaCl, KCl, CaCl <sub>2</sub> , MgCl <sub>2</sub> , etc	
HNO <sub>3</sub>	NaNO <sub>3</sub> , KNO <sub>3</sub> , Ca(NO <sub>3</sub> ) <sub>2</sub> , Mg(NO <sub>3</sub> ) <sub>2</sub> , etc.	
H <sub>2</sub> SO <sub>4</sub>	Na <sub>2</sub> SO <sub>4</sub> , K <sub>2</sub> SO <sub>4</sub> , CaSO <sub>4</sub> , MgSO <sub>4</sub> , etc.	
H <sub>3</sub> PO <sub>4</sub>	Na <sub>3</sub> PO <sub>4</sub> , K <sub>3</sub> PO <sub>4</sub> , Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> , Mg <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> , etc.	

contain one or more replaceable hydrogen atoms.

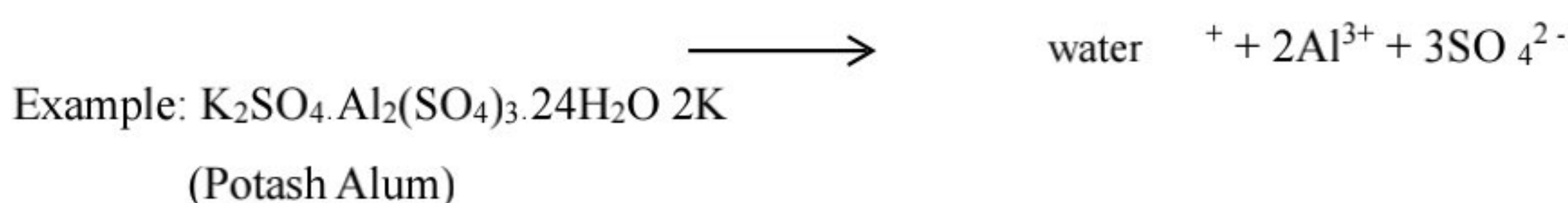
Example:



Acids	Acidic salts
H <sub>2</sub> SO <sub>4</sub>	NaHSO <sub>4</sub> , KHSO <sub>4</sub> etc.
H <sub>3</sub> PO <sub>4</sub>	NaH <sub>2</sub> PO <sub>4</sub> , KH <sub>2</sub> PO <sub>4</sub> , Na <sub>2</sub> HPO <sub>4</sub> , K <sub>2</sub> HPO <sub>4</sub> 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)<sub>2</sub>Cl etc.

**4. Double salts:** These are the molecular addition compounds obtained from two simple salts, the ions of which retain their identity. Such salts give the test of all the constituent ions when dissolved in water.





Other examples: Mohr's Salt  $[\text{FeSO}_4 \cdot (\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}]$ , Carnalite  $(\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O})$ , etc.

**5. Complex Salts:** These are the molecular addition compounds obtained by the combination of simple salts which retain their identity in aqueous solution. Such salts do not give tests of all the constituent ions in aqueous solution.

Example:  $\text{K}_4[\text{Fe}(\text{CN})_6]$  ~~water~~  $\rightarrow 4\text{K}^+ + [\text{Fe}(\text{CN})_6]^{4-}$  Other

examples:  $\text{K}_3[\text{Fe}(\text{CN})_6]$ ,  $[\text{Cu}(\text{NH}_3)_4]\text{SO}_4$ , etc.



# 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

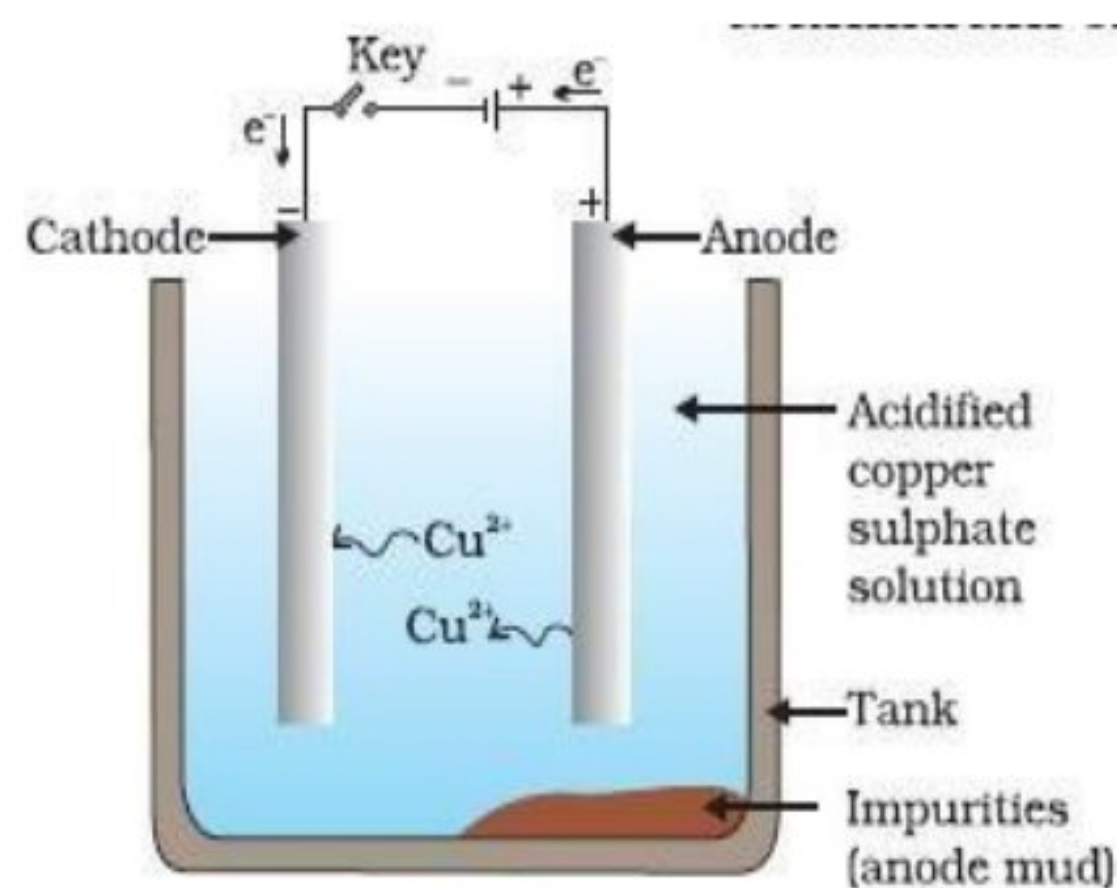
Ex- NaCl, CaCl<sub>2</sub> etc

## 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**.



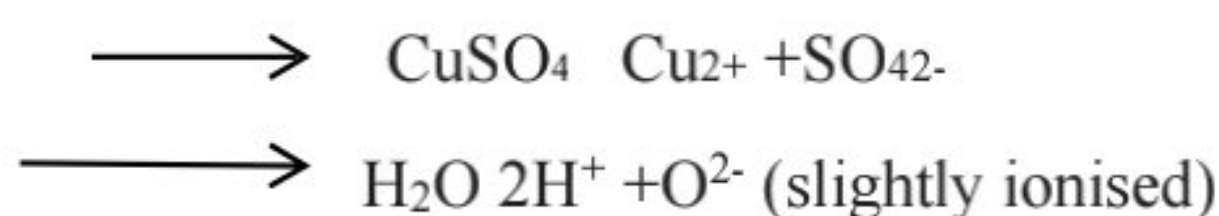


- When an electric current is passed through the solution, cations move towards the cathode, whereas anions move towards the anode.
- This movement of ions towards oppositely charged electrodes is called **electrolytic conduction**.

### Example of electrolysis

By using copper sulphate solution (using Pt electrode)

- When copper sulphate is dissolved in water it ionises as:



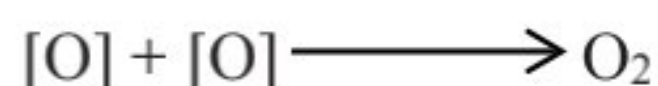
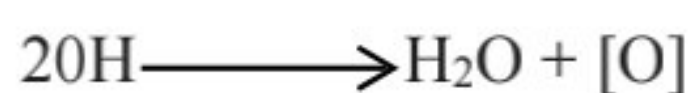
- When electric current is passed through copper sulphate solution using platinum (Pt) electrodes,  $\text{Cu}^{2+}$  and  $\text{H}^+$  ions move towards the cathode. However, only  $\text{Cu}^{2+}$  ions are discharged more readily than  $\text{H}^+$  ions because of their low discharge potentials.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

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

b)  $\text{SO}_4^{2-}$  and  $\text{OH}^-$  ions move towards anode. However, only  $\text{OH}^-$  ions are discharged more readily than  $\text{SO}_4^{2-}$  ions because of their low discharge potential. These  $\text{OH}^-$  ions lose electrons and change into neutral hydroxyl groups

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

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



### 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,  $W \propto Q$



We know  $Q = C.t$

Where  $c$  = current in amperes  
 $t$  = time in seconds

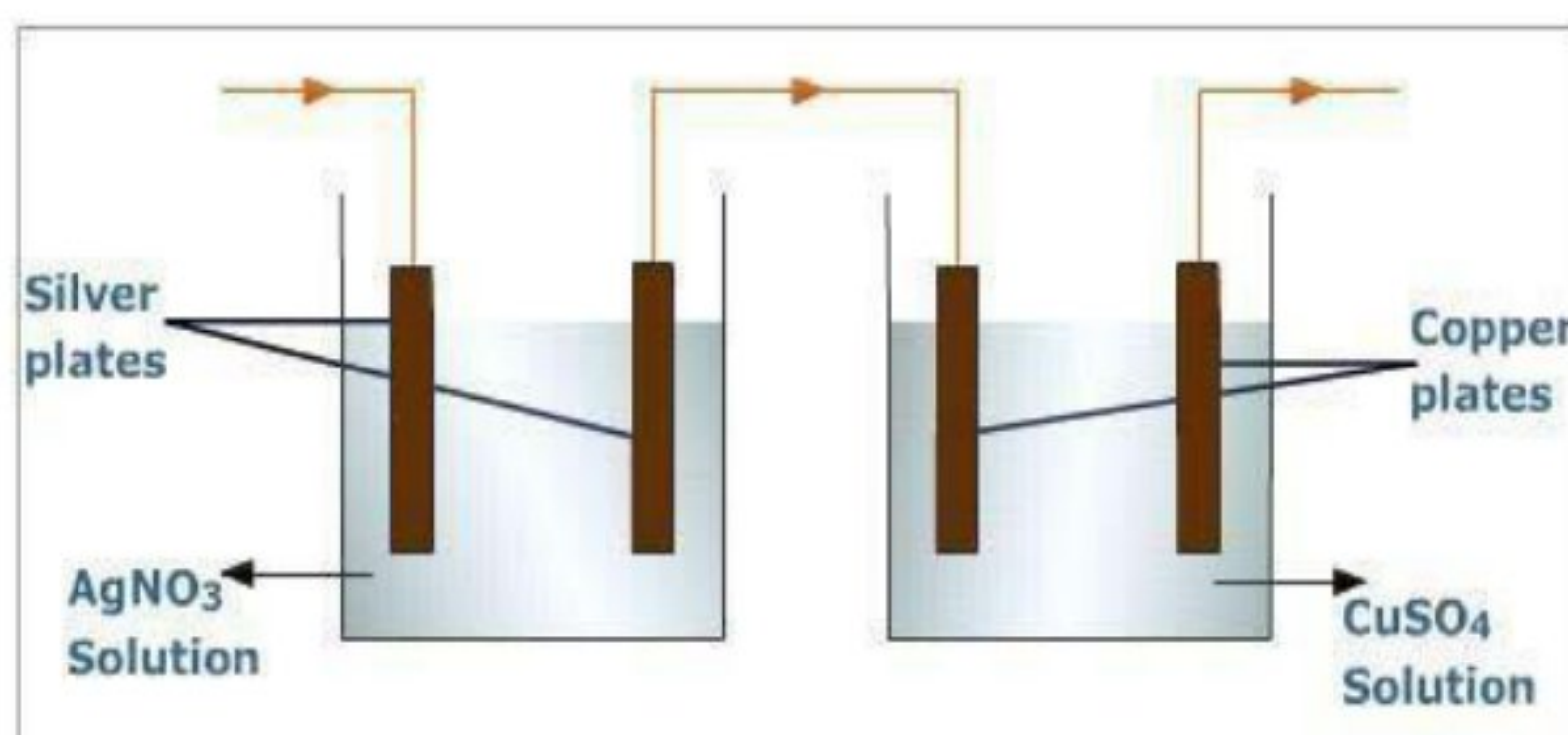
Thus  $W \propto C.T$

OR  $W = ZC.T$

Where  $Z$  is a constant called Electro chemical Equivalent In the above relationship, if  $c = 1$  ampere and  $t = 1$  second then  $W = Z$

### 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

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

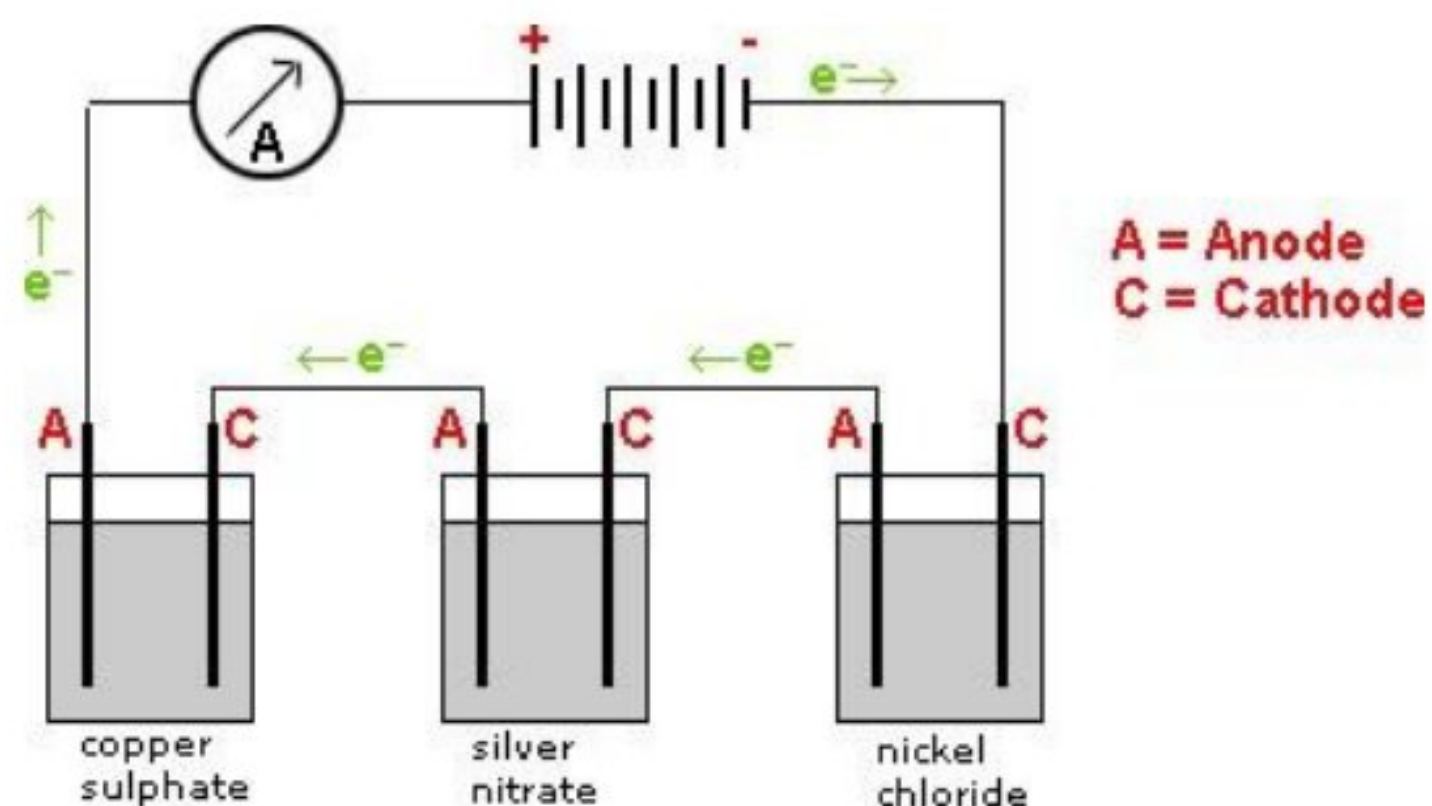
Mass of substance liberated by passage of one faraday of electricity = 1 gm equivalent.

### 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.

#### 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.

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

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

## Industrial application of Electrolysis

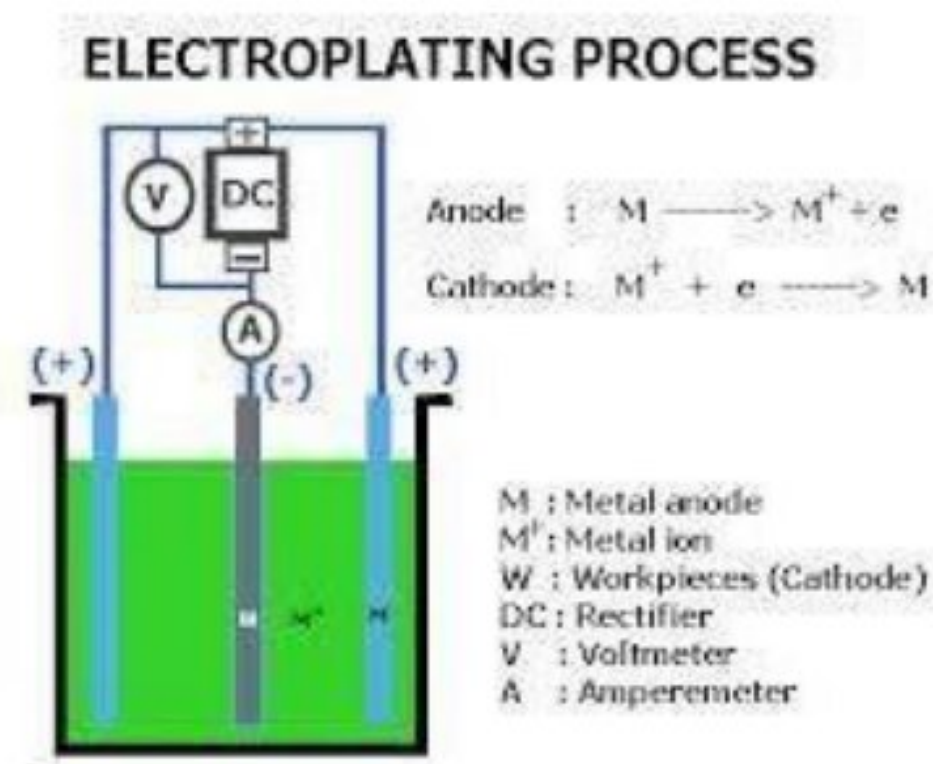
### Electroplating

Electroplating is done for the following purpose. a.

Decoration

b. Protection

c. Repairs



### 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**

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**

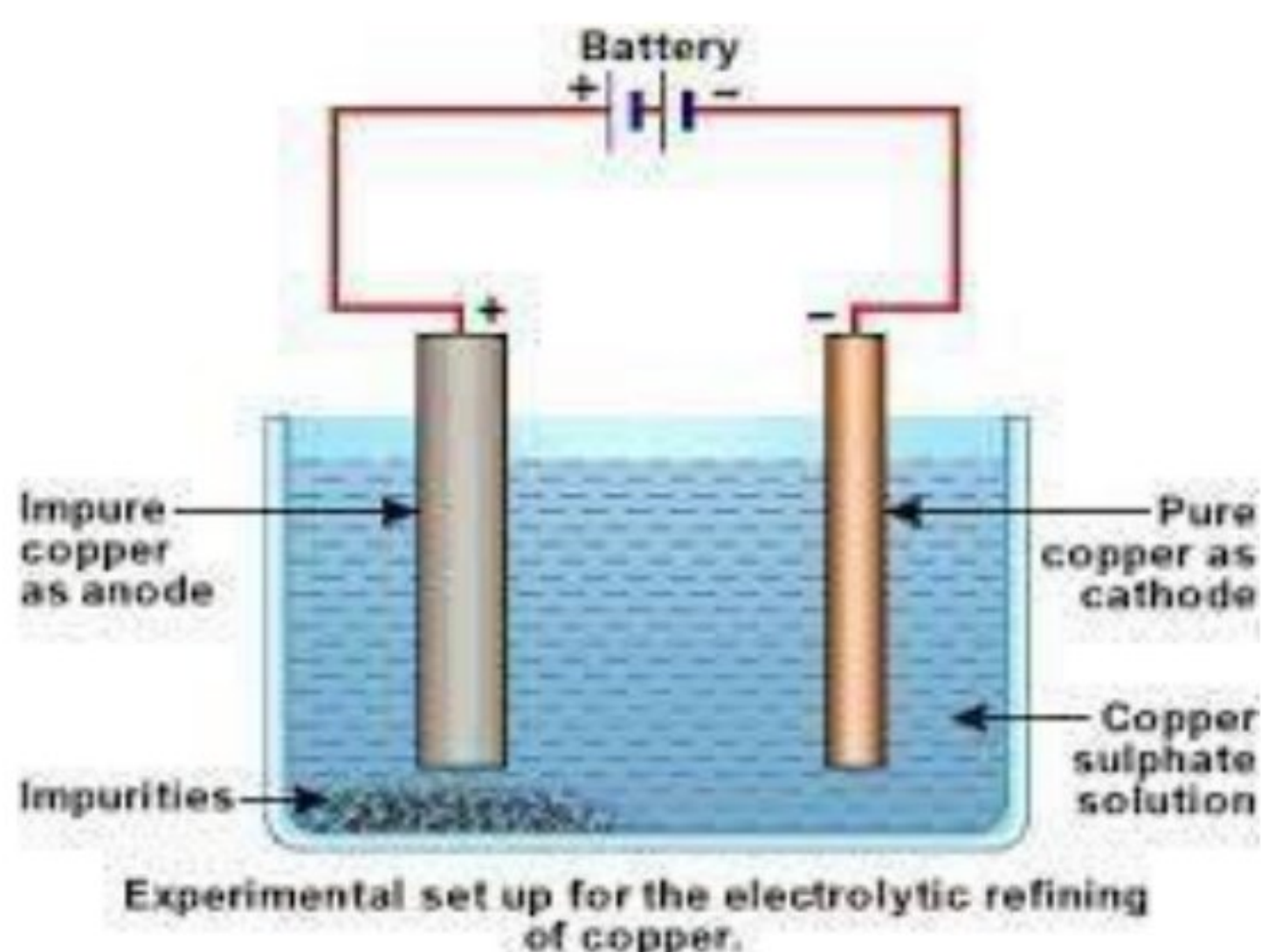
Zinc plating is done on Iron articles to protect them from rusting.

## **Electro refining:**

### **Purpose:**

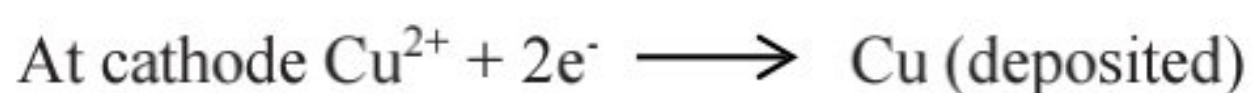
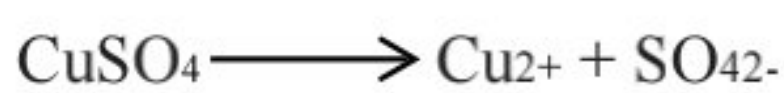
The metals obtained from their ores usually contain impurities. Therefore metals like Copper, Silver, Lead, etc. are usually purified by electrolysis.





### 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.



## CORROSION

### Definition

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

- Atmospheric Corrosion
- Waterline corrosion

### Atmospheric Corrosion

#### Example:

Tarnishing of silver, development of a green coating on Copper and Bronze and rusting of Iron are some examples of corrosion.

Rust is a case of corrosion of iron. It is hydrated Ferric Oxide  $\text{Fe}_2\text{O}_3 \cdot n\text{H}_2\text{O}$ . It is non-sticking in nature and peels off exposing more of iron surface for further rusting.



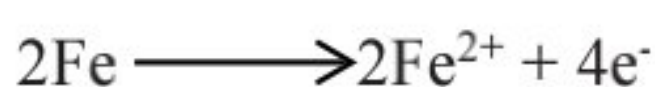
**Mechanism:**

Atmospheric rusting can be explained by electro-chemical theory.

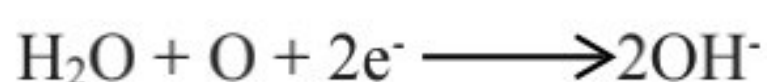
Commercial form of iron behaves like small electric cells in presence of water containing dissolved  $O_2$ ,  $CO_2$ , or  $SO_2$ .

**At anode**

Oxidation reaction occurs as

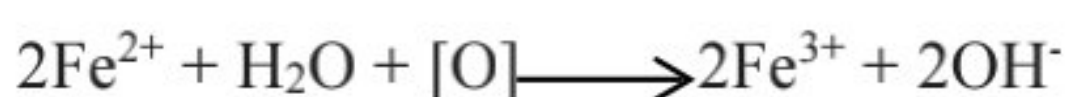
**At cathode :**

These electrons form hydroxyl ions

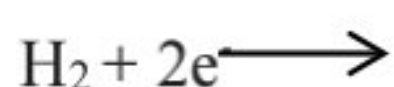
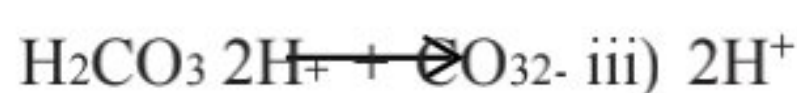


- $Fe^{2+}$  ions and  $OH^-$  ions then diffuse under the influence of dissolved oxygen and  $Fe^{2+}$  ions are oxidised to  $Fe^{3+}$  ions.

- These  $Fe^{3+}$  ions, then combine with  $OH^-$  ion to form hydrated ferric oxide i.e. rust.

**B) In presence of  $CO_2$** 

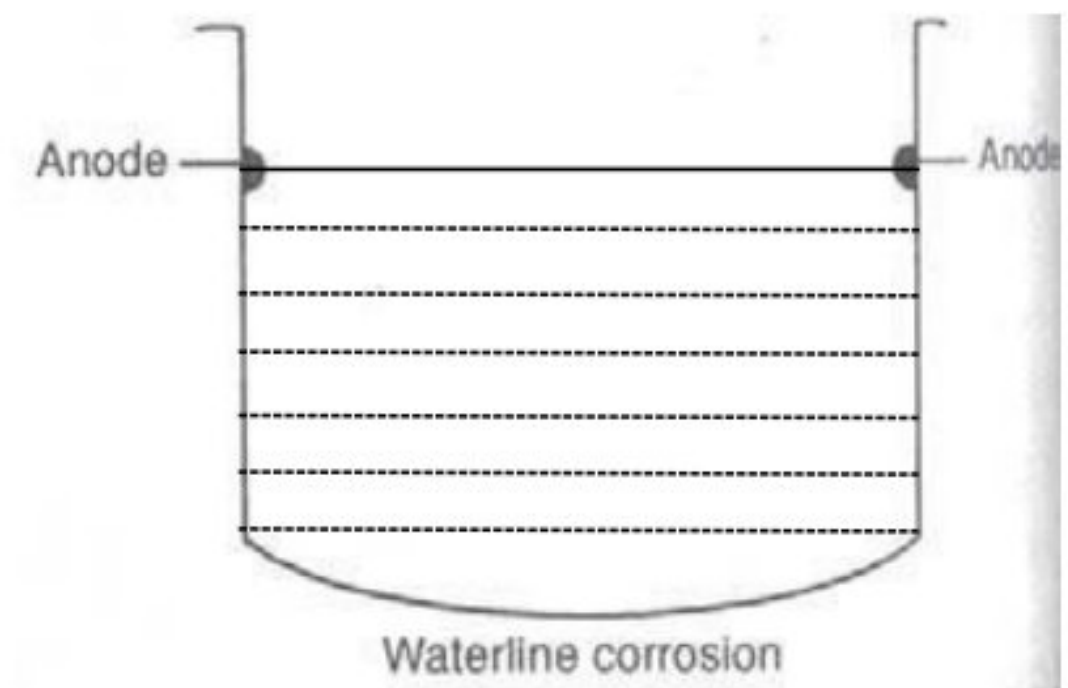
The rusting of iron also increases in water containing dissolved  $CO_2$ .

**Mechanism:****Waterline Corrosion****Reason of waterline corrosion**

- Waterline corrosion occurs due to differential oxygen concentration
- When water is stored in steel tank, considerable corrosion takes place along a line just below the level of water meniscus.



- The area above the water line is cathode as oxygen concentration is more in this area.
- The area just below the water line is anode, because here oxygen concentration is less.

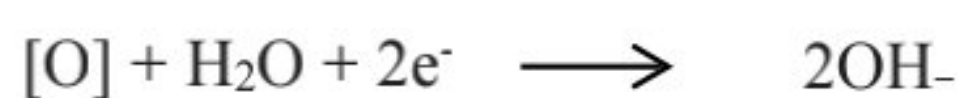
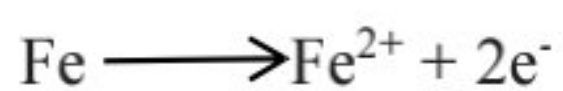


### Occurrence:

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



### Mechanism:



### Protection of corrosion:

There are many methods to protect the metal from corrosion.

But as per the syllabus, we will discuss the following methods.

a) Alloying:

By alloying of metals, we can protect those from corrosion. Alloys resist corrosion in two ways.

i) Homogeneity ii)

Oxide film



b) 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.**
- Zinc loses electrons in preference to iron and is consumed in due course of time. As zinc sacrifices itself and protect iron, it is known as sacrificing metal.

# INORGANIC CHEMISTRY



# METALLURGY

## MINERALS

“The natural material in which the metal or their compounds occur in the earth is known as mineral”. In other words the combined state occurrences of metals are called minerals. For example:  $\text{NaCl}$ ,  $\text{NaNO}_3$ ,  $\text{Na}_2\text{SO}_4$ , etc. are the minerals of ‘Na’. Similarly  $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$  (Bauxite),  $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$  (Kaolin) are the minerals of ‘Al’.

## ORE

**“Ores are the minerals from which the concerned metals can be extracted conveniently and economically.”**

For example: Both Bauxite ( $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$ ) and Kaolin ( $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$ ) are the minerals of Al. However, ‘Al’ can be extracted easily and profitably from 'Bauxite'. Thus Bauxite is an ore of Al. On the other hand it is difficult and non-profitable to extract ‘Al’ from Kaolin, hence Kaolin is simply a mineral of Aluminium. All ores are minerals, however all minerals are not ores.

### Distinction between Minerals and Ores:

MINERALS	ORES
1. The combined state of occurrence of metals is called mineral	1. Ores are the minerals from which the concerned metals can be extracted conveniently and economically
2. Extraction of metals from minerals is difficult and non-profitable	2. Extraction of metals from ores is convenient and profitable
3. Minerals contain low percentage of metals but high percentage of impurities	3. Ores contain high percentage of metals but low percentage of impurities
4. All minerals are not ores	4. All ores are minerals
5. Example: Kaolin ( $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$ ) is a mineral of Aluminium	5. Example: Bauxite ( $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$ ) is an ore of Aluminium

## METALLURGICAL OPERATION:

The art of extraction of metals from ores conveniently and economically is called metallurgy or metallurgical operation.

The following steps are followed during the process of metallurgical operation:-

**Step-I:** Crushing and Grinding



**Step-II:** Concentration or Ore Dressing

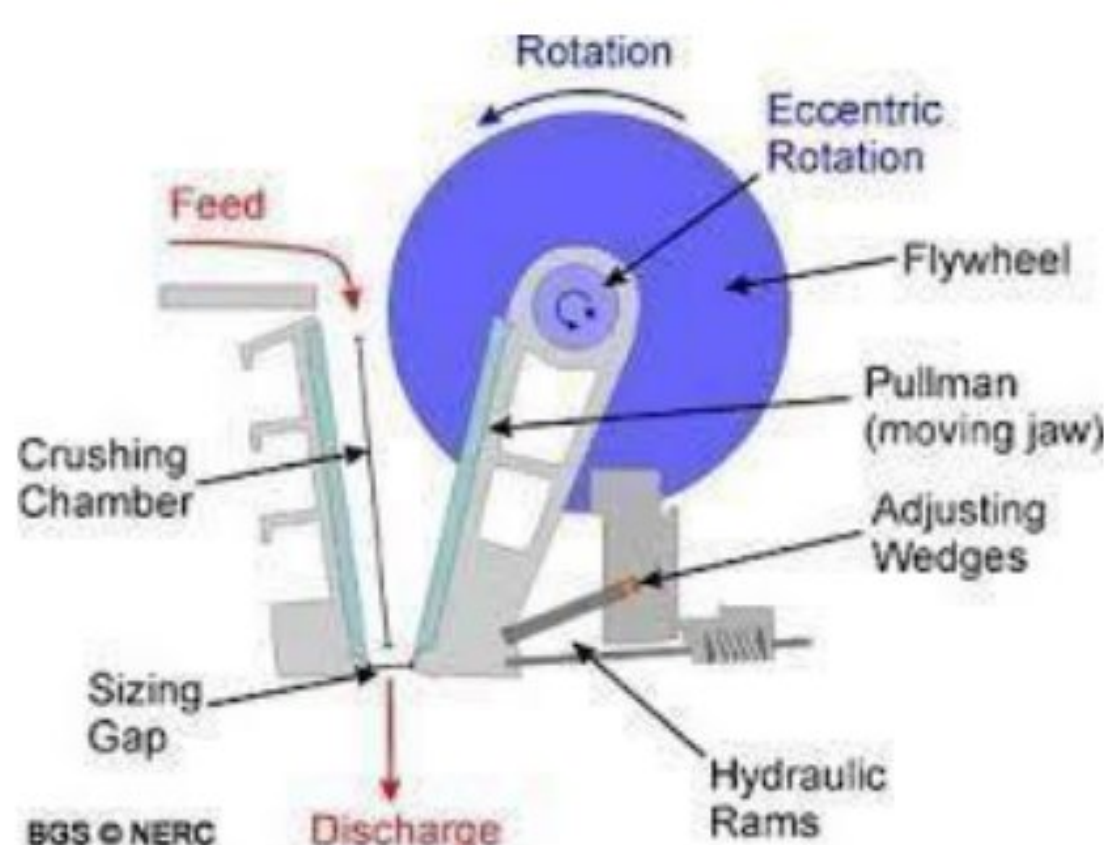
**Step-III:** Oxidation

**Step-IV:** Reduction

**Step-V:** Refining

## **STEP-I: CRUSHING AND GRINDING**

The ores obtained from mines are in the form of huge lumps. These are first crushed into small pieces with the help of jaw crusher and then grinded in to their powder form with the help of stamp mill.



**Jaw Crusher**



**Stamp Mill**

## **STEP-II: CONCENTRATION**

The process of removal of maximum impurities (gangue or matrix) from the ore is called concentration or ore dressing. The method of concentration to be followed depends upon the nature of the impurities present.

### **METHODS OF CONCENTRATION**

#### **1. GRAVITY SEPARATION METHOD**

This method of concentration is adopted only when there is a gravity difference between the ore and impurities. Normally carbonate and oxide ores are heavier than the impurities associated with them and hence they are concentrated by this method. In this method the powdered or pulverized ores are kept in some containers over a specially designed table called **wilfly table**. The table contains a number of transverse grooves. The table is kept slightly inclined position and is provided with a rocking motion. When water is spread over the ore, lighter impurities are washed away while heavier ore particles get deposited in the grooves, which are finally carried out in to the main canal.

#### **2. FROTH FLOATATION METHOD**

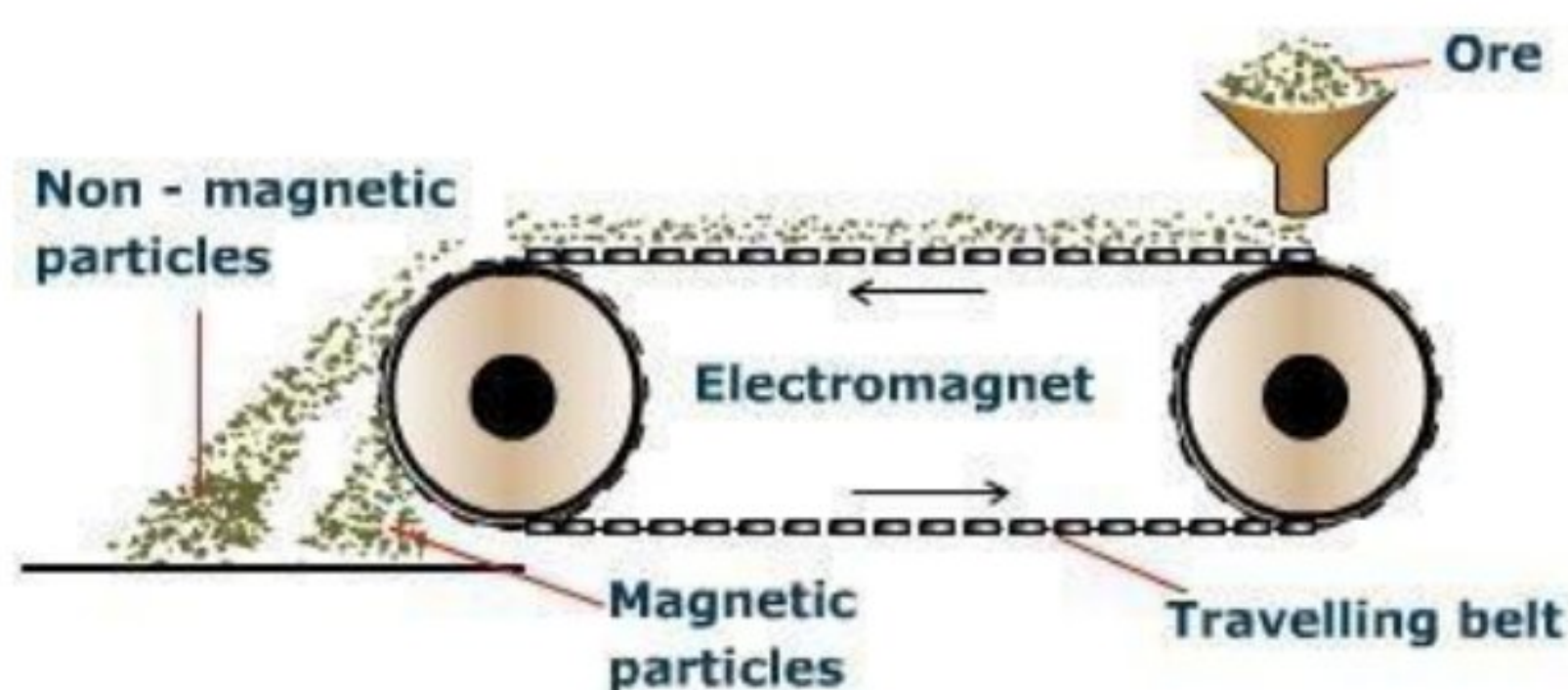
This method is suitable for the concentration of **sulphide ores** only. In this method of concentration two interconnected tanks are used. In one of the tanks, a mixture of ore, oil



(preferably pine oil), water and a little quantity of acid is agitated strongly by blowing air through it. Due to the preferential wetting of the sulphide ores by oil than by water, a layer of oil is covered over the surface of sulphide ores. These sulphide ores become lighter and float over the surface of the mixture, which are carried out in to the second container along with the foam formed due to agitation.

### 3. MAGNETIC SEPARATION METHOD

This method of concentration is suitable only when there is a difference in magnetic behaviour between the ores and the impurities. Normally magnetic ores containing non-magnetic impurities are concentrated by this method. In this



method a belt is tied over two rollers of which one is made up of magnet. Pulverized ore is added over the belt through a hopper. The pulverized ore move towards the magnetic pulley along with the rotating belt. The non-magnetic impurities fall directly below the magnetic pulley while the magnetic ore form a separate heap due to the influence of the magnetic field.

### 4. LEACHING

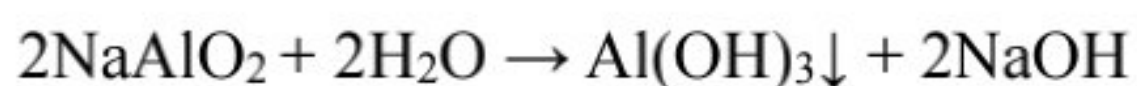
This is a chemical method in which the impure ore is treated with a suitable solvent which dissolves the ore leaving behind the impurities. The solution is filtered, impurities are discarded and the mother liquor is treated with another suitable chemical reagent to get the pure ore.

For example, impure bauxite ore is treated with dil. NaOH solution which dissolves Bauxite to form soluble Sodium Meta-aluminate.



(soluble Sodium Meta-aluminate)

The solution is filtered to remove the impurities. The solution obtained is diluted with a plenty of distilled water when a precipitate of  $\text{Al}(\text{OH})_3$  is formed.



The precipitate obtained is dried and ignited (heated) strongly to get pure Alumina.



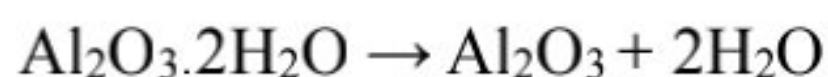
#### STEP-III: OXIDATION (Conversion of ores into metal oxides)

In the third step of metallurgical operation the concentrated ores are converted into the respective metal oxides. This is achieved by the following two methods:-

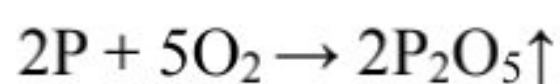
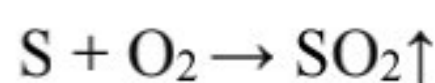
#### 1. CALCINATION



The process of heating an ore strongly below its melting point in absence of or in a limited supply of air is called **calcination**. The various functions of calcination are:- i) It removes moisture.

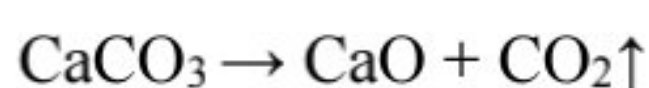


ii) It removes volatile impurities like S, P, As, Sb, etc.



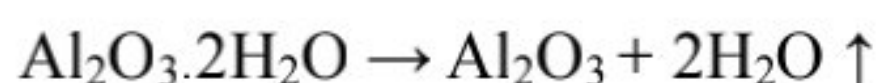
iii) It oxidizes oxidizable substances ('ous' to 'ic')

$4\text{FeO} + \text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3$  iv) It decomposes carbonates of alkali and alkaline earth metals into oxides.



## 2. ROASTING

The process of heating an ore strongly below its melting point in a free but controlled supply of air is called **roasting**. The various functions of roasting are:- i) It removes moisture.



ii) It removes volatile impurities like S, P, As, Sb, etc.

$\text{S} + \text{O}_2 \rightarrow \text{SO}_2 \uparrow$  iii) It oxidizes oxidizable substances ('ous' to 'ic')

$4\text{FeO} + \text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3$  iv) It decomposes carbonates into oxides.



v) It makes the ore porous.

The process of roasting is carried out in a reverberatory furnace.

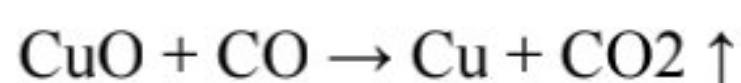
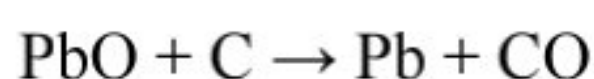
## STEP- IV: REDUCTION (Conversion of metal oxides into metals)

In this step of metallurgical operation the roasted ores are reduced to convert the metal oxides into the respective metals. The various methods of reduction are:-

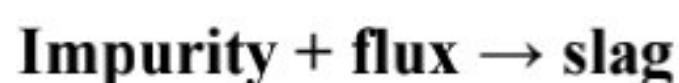
### 1. SMELTING

The process of heating a roasted ore strongly above its melting point with a suitable quantity of coke or charcoal is called smelting. During the process of smelting, metal oxides are reduced into their respective metals. For the reduction of the oxides of less electro positive metals such as Zn, Fe, Cu, Cr, W etc. the reducing agents like  $\text{H}_2\text{O}$ ,  $\text{CO}$ , Na, K etc are used.





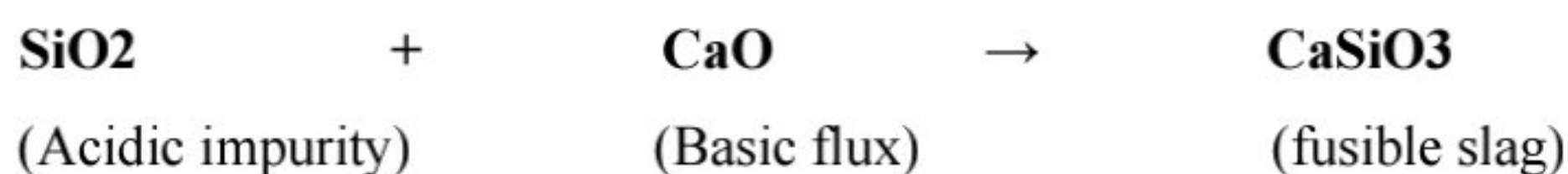
During the process of smelting, an additional substance called **flux** is added which combines with the impurities to form fusible **slag**.



Thus, “a substance added during the process of smelting to convert the gangue or matrix into fusible mass (slag) is called **flux**.”

“Slag is the fusible mass obtained during the process of smelting when flux combines with impurities”.

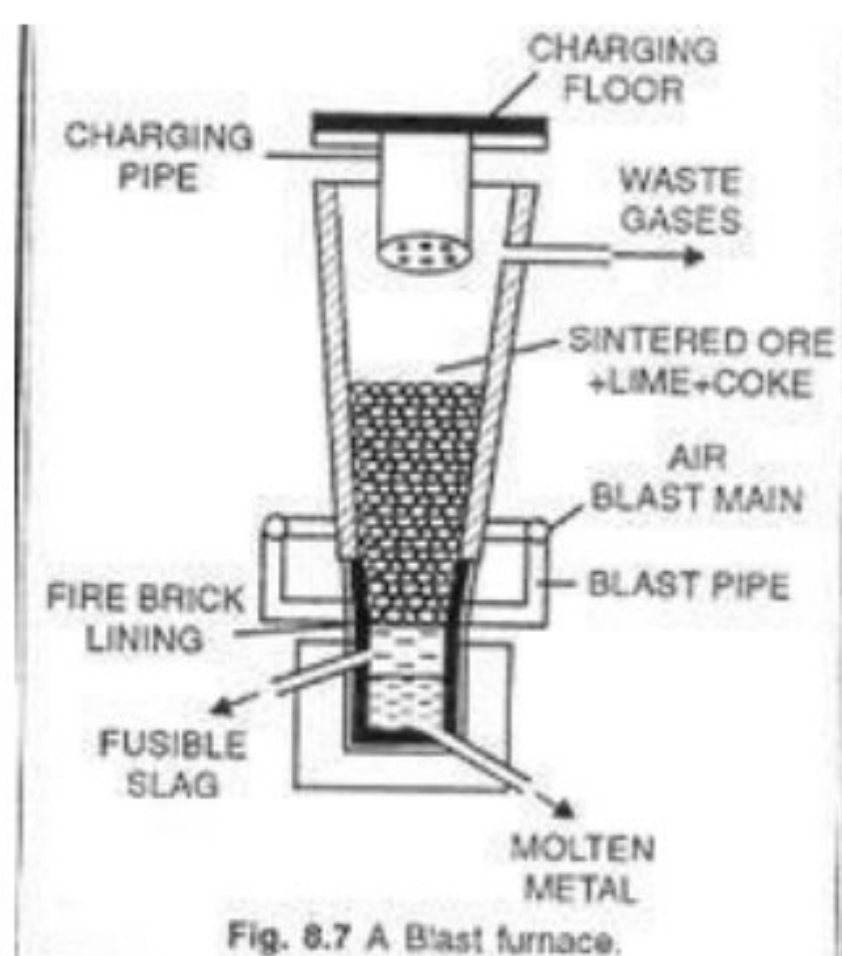
The nature of the flux to be added depends upon the nature of the impurity present. For acidic impurities basic flux while for basic impurities acidic flux are used.



Smelting is carried out in a blast furnace which is a tall cylindrical furnace made up of steel plates lined inside with fire bricks. Since the density of slag is lower it floats over the molten metal. The molten metal is tapped out at the bottom of the furnace.

## 2. ELECTROLYTIC REDUCTION

This method of reduction is employed for the reduction of chlorides or oxides of highly electro positive metals such as Na, K, Ca, Mg, Al etc., because these can't be reduced with carbon as



they would form the respective metal carbides. The molten oxides or chlorides of these metals are taken in an electrolytic cell and electricity is passed through the molten mass with the help of two electrodes. The metal ions get discharged and deposited at the cathode.

## STEP-V: REFINING

The metals obtained after reduction still contain some impurities. The process of removal of impurities from crude metal is called refining. The method of refining to be followed depends upon the nature of the metal and the impurity contaminated with it.

### 1. DISTILLATION METHOD



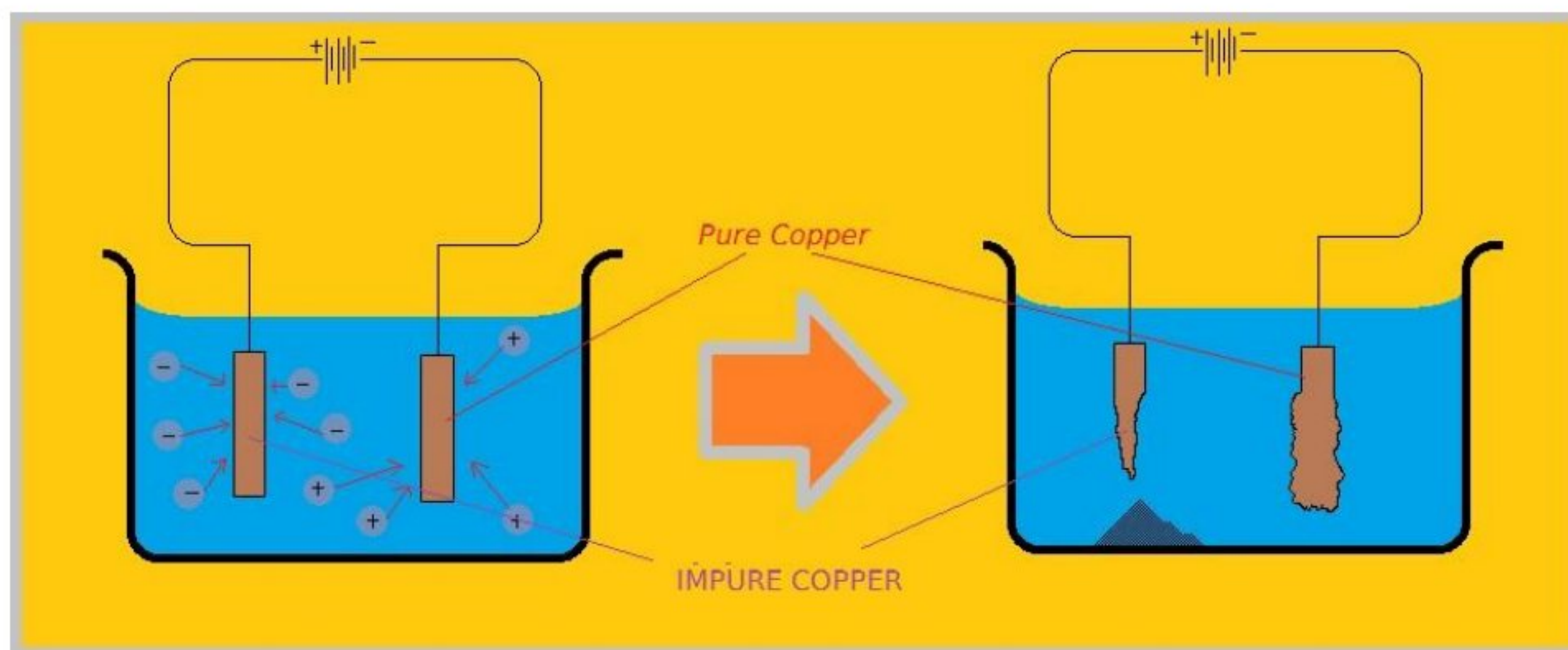
This method of refining is suitable for volatile metals like Hg, Zn, Pb etc. contaminated with non-volatile impurities. The impure metal is heated in a distillation flask attached with a water condenser. During heating the volatile metal gets evaporated and condensed which is collected in a separate container while the non-volatile impurities left at the bottom of the distillation flask.

## 2. LIQUATION METHOD

This method is suitable for refining the easily fusible metals containing non-fusible impurities. Normally metals such as Sn, Pb etc. are refined by this method. In this method of refining the impure metal is taken in a sloping hearth and is heated from the bottom. The metal liquefies and flows down the sloping hearth leaving the impurities on the hearth.

## 3. ELECTRO REFINING

This method is employed to refine the less electro positive metals such as Zn, Pb, Al, Cu etc. The impure metal bar is used as anode while a pure metal (same metal) bar is taken as cathode. Both the electrodes are dipped in a suitable aqueous salt solution of the concerned metal. During the process of electrolysis, the impure metal dissolves in its aqueous salt solution providing metal ions which get discharge deposited over the cathode.



# ALLOYS

**Definition:** The material obtained by melting together metals or metals with non-metals or metals with metalloids is called an alloy. Or in other words, “an alloy is an intimately mixed metallic solid mixture of two or more different elements, at least one of which is a metal.”

### Features of Alloy

1. Alloys are homogeneous in molten state but they may be either homogeneous or heterogeneous in solid state.
2. Alloys containing mercury as one of the constituent are called **amalgams**.
3. An alloy must contain a metal.



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

**Classification of Alloys:** Alloys can broadly be classified into two categories:-

**A. Ferro alloys B. Non-Ferro alloys**

**A. Ferro alloys:** The alloy containing iron as the main constituent is called a ferro alloy.

For example: Stainless steel, Manganese steel etc.

**B. Non-ferro alloys:** The alloy which does not contain iron as the main constituent is called non-ferro alloys. For example: Brass, Bronze, Solder, Gun metal, Bell metal etc.

## COMPOSITIONS AND USES OF BRASS, BRONZE, BELL METAL, ANILCO, GERMAN SILVER AND DURALUMIN.

Alloys	Composition	Uses
1. Brass	Cu: 60% – 90% Zn: 40%– 10%	It is used in making: utensils, hard wares, screws, jewellery musical instrument, battery caps tubes, name plates
2. Bronze	Cu: 80% – 95% Sn: 20% – 5%	Making imitation jewellery water fittings, statues, medals heavy load bearings, turbine blades, pump valves, coins
3. Alnico	Steel: 50% Ni: 21% Al: 20% Co: 9%	It is used in making permanent magnet.
4. Duralumin	Al: 95% Cu: 4% Mn: 0.5% Mg: 0.5%	It is used in making air ships



# ORGANIC CHEMISTRY

## **HYDROCARBONS AND NOMENCLATURE**

The covalently bonded carbon compounds except oxides of carbon, carbides of certain metals and nitriles of metals are called organic compounds.

The branch of chemistry which deals with the study of covalently bonded carbon compounds except oxides of carbon, carbides of certain metals and nitriles of metals is called organic chemistry.



**Hydrocarbons:** The compounds containing 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: Alkanes (methane, ethane, propane, butane, pentane, etc.)

**Unsaturated Hydrocarbons:** These are the hydrocarbons containing carbon-carbon multiple bonds ( $C = C$ ,  $C \equiv C$ ).

Example: Alkenes (ethene, propene, butene, pentene, etc.) and Alkynes (ethyne, propyne, butyne, pentyne, etc.).

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

Example:  $CH_3 - CH_2 - CH_2 - CH_3$

(n-butane)  $CH_3$

$CH_3 - CH - CH_2 - CH_3$   
|

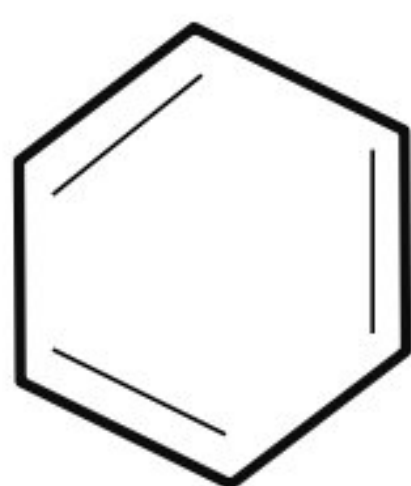
(2-methylbutane)

**Aromatic hydrocarbons:** These are the hydrocarbons which obey Huckel's rule of aromaticity.

**Huckel's Rule of Aromaticity:** The cyclic hydrocarbon containing  $(4n+2)\pi$  electrons in which single and double bonds are present in alternate positions is called an aromatic hydrocarbon.

Where  $n = 0, 1, 2, 3$ , etc.

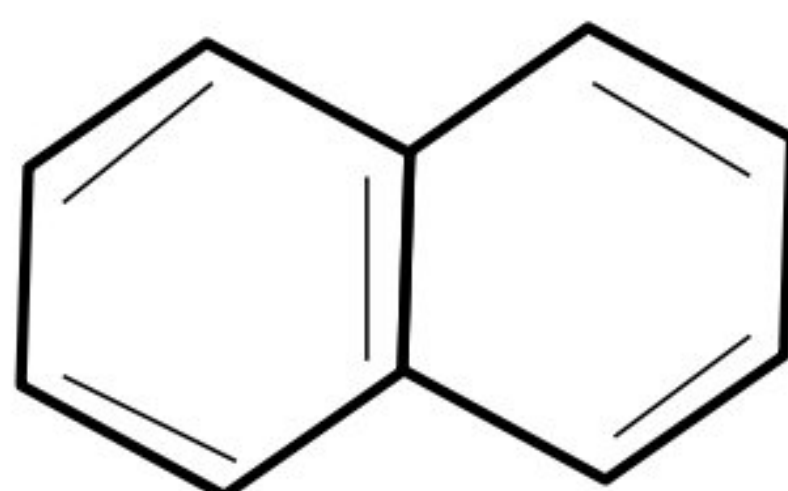
For example:



Benzene

$$(4 \times 1 + 2) \pi$$

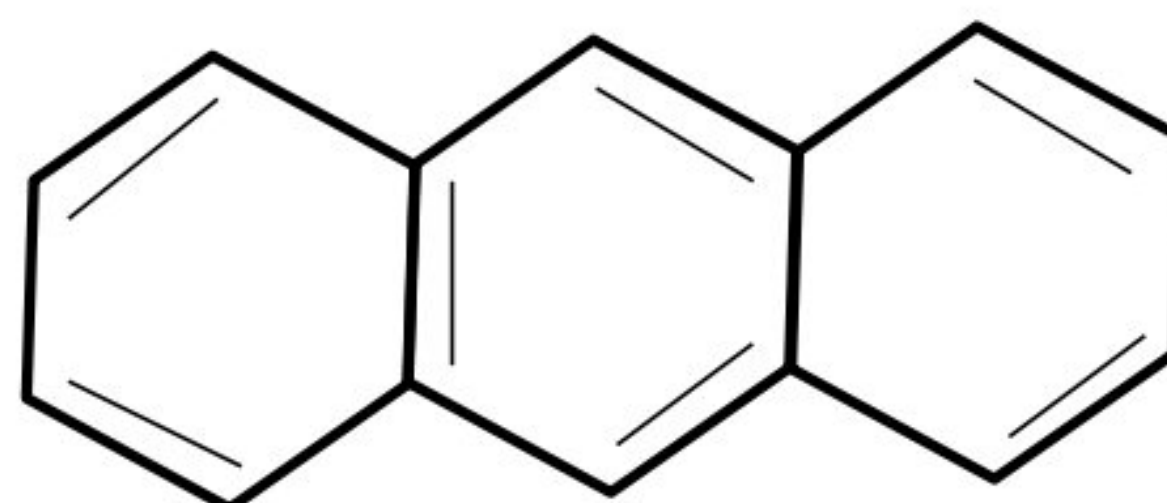
$$= 6\pi \text{ electrons}$$



Naphthalene

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

$$= 10\pi \text{ electrons}$$



Anthracene

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

$$= 14\pi \text{ electrons}$$

## IUPAC SYSTEM OF NOMENCLATURE

In early days organic compounds were named as per their sources of origin and their characteristics. Such system of nomenclature is called 'Trivial System'. Later on a systematic way of nomenclature was started at 'Geneva' called '**Geneva system**' which is finally modified by IUPAC (International Union of Pure and Applied Chemistry) System. According to IUPAC System of nomenclature an organic compound may contain the following four parts:

1. Root word



2. Prefix
3. Primary Suffix 4. Secondary Suffix

### 1. ROOT WORD:

It refers to the number of carbon atoms present in the parent chain of the organic compound.

NO. OF 'C'	ROOT WORD	NO. OF 'C'	ROOT WORD
1	Meth	6	Hex
2	Eth	7	Hept
3	Prop	8	Oct
4	But	9	Non
5	Pent	10	Dec

### 2. PREFIX:

It refers to the presence of substituent or side chain in the parent chain of the organic compound. Some groups always act as substituent or side chain. They are:

GROUP	PREFIX
-F	-fluoro
-Cl	-chloro
-Br	-bromo
-I	-iodo
-NO <sub>2</sub>	-nitro
-R	-alkyl
-OR	-alkoxy

### 3.PRIMARY SUFFIX:

It refers to the presence of carbon-carbon single (C – C), double (C = C) or triple (C ≡ C) bond in the compound.

NATURE OF THE BOND	PRIMARY SUFFIX
All C - C bond	-ane
One C = C bond	-ene
Two C = C bond	-a ---- diene
Three C = C bond	-a ---- triene
One C ≡ C bond	-yne
Two C ≡ C bond	-a ---- diyne

### 4. SECONDARY SUFFIX:



It refers to the presence of functional groups in the compound. Functional groups are the atoms or group of atoms which are responsible for the physical and chemical properties of the organic compounds.

CLASS OF COMPOUND	FUNCTIONAL GROUP	SECONDARY GROUP
-OH	Alcohol	-ol
-CHO	Aldehyde	-al
>CO	Ketone	-one
-COOH	Carboxylic Acid	-oic acid
-NH <sub>2</sub>	Amine	-amine
-CONH <sub>2</sub>	Acid Amide	-amide
-COCl	Acid Chloride	-oylchloride

## CLASS OF COMPOUNDS

### 1. ALKANES:

General formula:  $C_nH_{2n+2}$ , Representation:  $\begin{array}{c} | \\ -C \\ | \end{array}$ , Primary Suffix: -ane, IUPAC Name: Root Word +ane.

FORMULA	COMMON NAME	IUPAC NAME
CH <sub>4</sub>	Methane	Methane
C <sub>2</sub> H <sub>6</sub>	Ethane	Ethane
C <sub>3</sub> H <sub>8</sub>	Propane	Propane

### 2. ALKENES:

General formula:  $C_nH_{2n}$ , Representation:  $\begin{array}{c} \diagup \quad \diagdown \\ -C = C- \end{array}$ , Primary Suffix: -ene, IUPAC Name: Root Word +ene.

FORMULA	COMMON NAME	IUPAC NAME
C <sub>2</sub> H <sub>4</sub>	Ethylene	Ethene
C <sub>3</sub> H <sub>6</sub>	Propylene	Propene
C <sub>4</sub> H <sub>8</sub>	Butylene	Butene

### 3. ALKYNES:

General formula:  $C_nH_{2n-2}$ , Representation:  $-C \equiv C-$ , Primary Suffix: -yne, IUPAC Name: Root Word +yne.

FORMULA	COMMON NAME	IUPAC NAME
C <sub>2</sub> H <sub>2</sub>	Acetylene	Ethyne
C <sub>3</sub> H <sub>4</sub>	Propyne	Propyne
C <sub>4</sub> H <sub>6</sub>	Butyne	Butyne



#### 4. ALKYL:

General formula:  $C_nH_{2n+1}-$  or  $R-$ , Representation:  $R-$ , Common name: Alkyl, IUPAC Name: Root Word + yl.

FORMULA	COMMON NAME	IUPAC NAME
$CH_3-$	Methyl	Methyl
$C_2H_5-$	Ethyl	Ethyl
$C_3H_7-$	Propyl	propyl

#### 5. ALKYL HALIDES OR HALOALKANES:

General formula:  $C_nH_{2n+1}-X$  or  $R-X$ , where  $R$ = Alkyl,  $X$ = halogen (F, Cl, Br, I)

Representation:  $R-X$ , Common name: Alkyl halide IUPAC

Name: Halo +Root Word +ane.

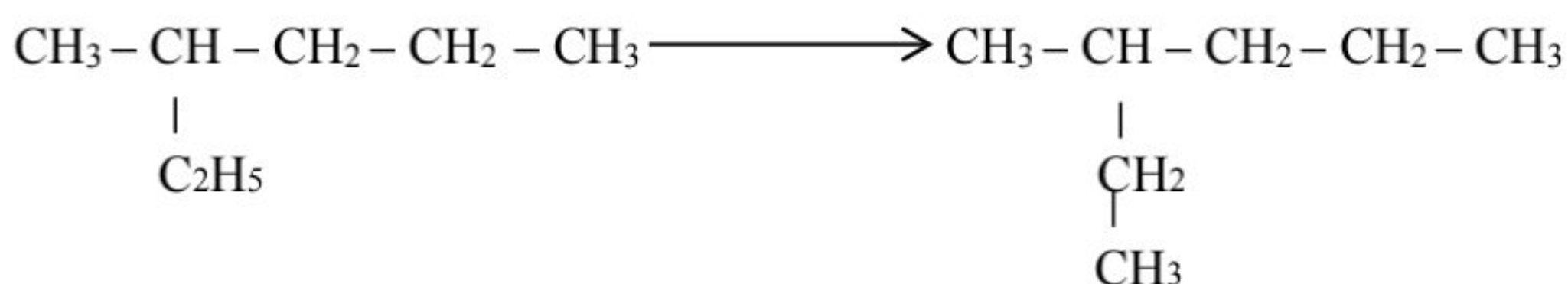
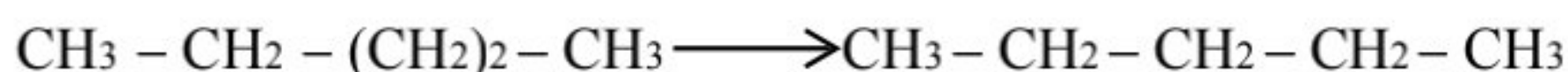
FORMULA	COMMON NAME	IUPAC NAME
$CH_3-Cl$	Methyl Chloride	Chloromethane
$C_2H_5-Br$	Ethyl Chloride	Bromoethane
$C_3H_7-Cl$	Propyl Chloride	Chloropropane

#### RULES FOR IUPAC SYSTEM OF NOMENCLATURE:

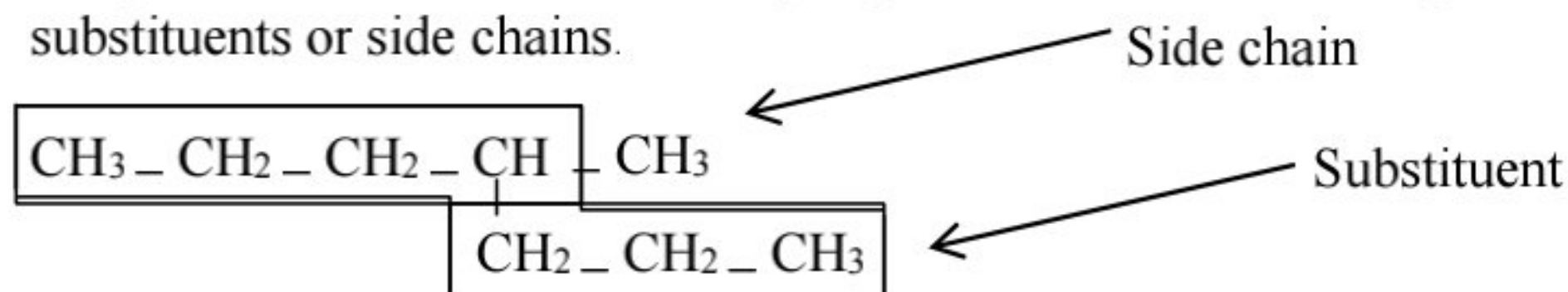
**1. Expansion of chain:** Sometimes condensed groups are present in organic compounds.

These condensed groups are to be separated.

**Ex:**



**2. Selection of Parent Chain:** The longest continuous carbon chain is called parent chain. The parent chain is selected. The groups which are outside the parent chain are called substituents or side chains.

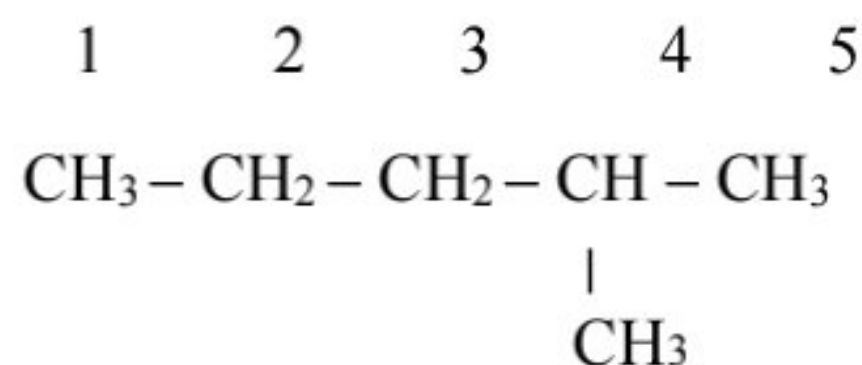
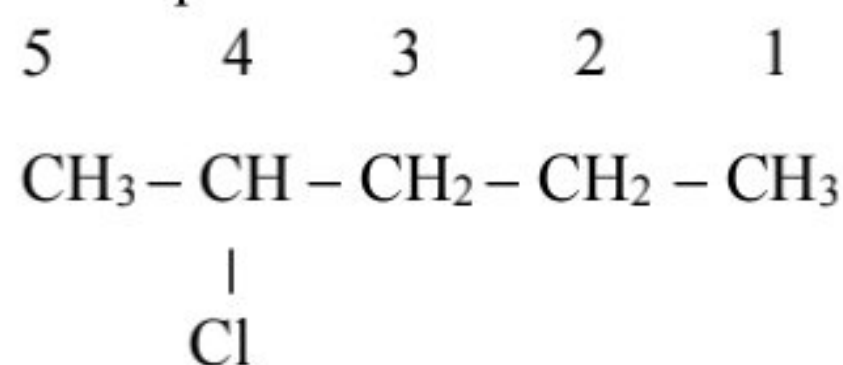




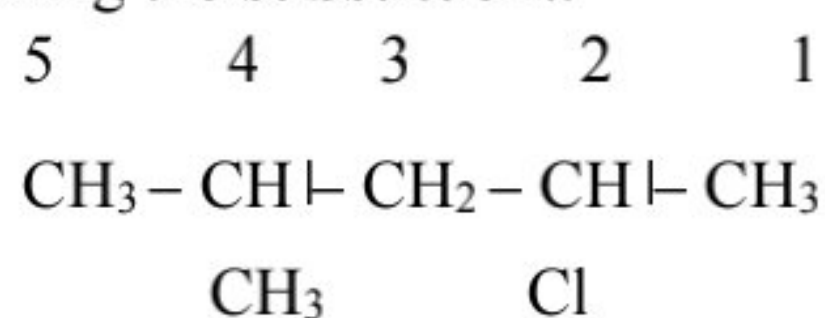
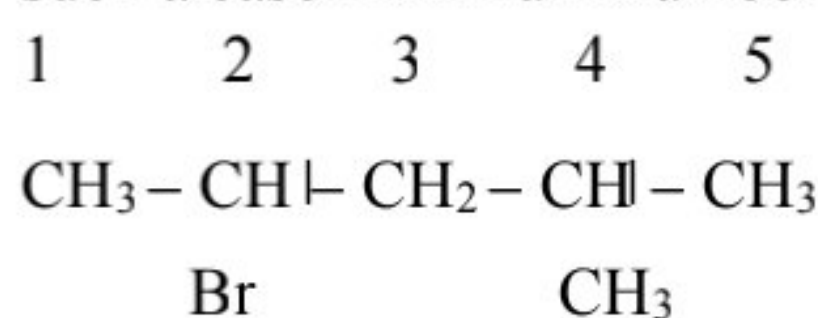
**3. Numbering of Carbon:** After selecting the parent chain, the carbon atoms of the parent chain are numbered.

**a. Presence of one Substituent (F, Cl, Br, I, NO<sub>2</sub>, etc.) or one Side Chain(CH<sub>3</sub>, C<sub>2</sub>H<sub>5</sub>, C<sub>3</sub>H<sub>7</sub>, etc.) :** If a compound contains a substituent or a side chain then **minimum number** is given to the carbon containing the substituent or the side chain.

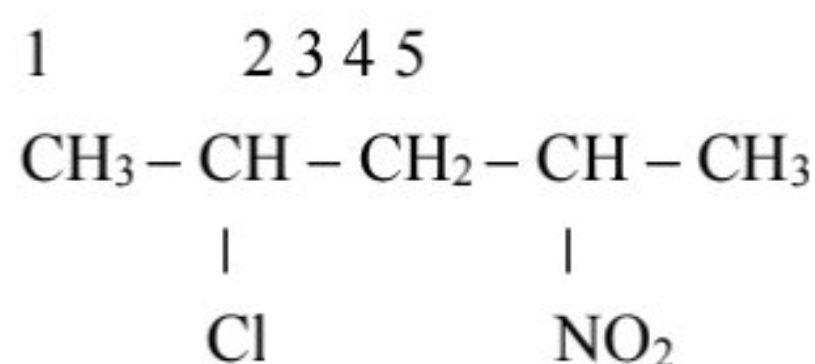
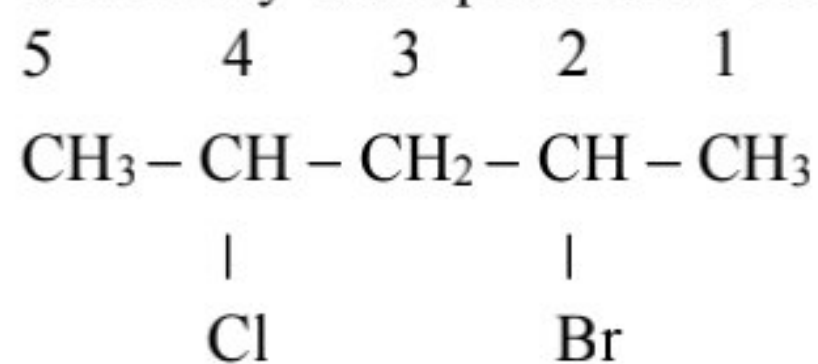
Example:



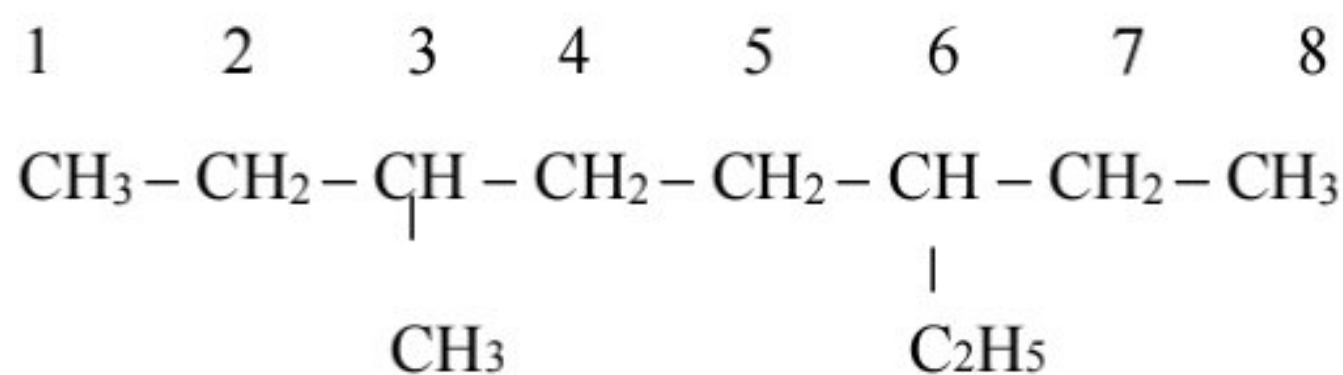
**b. Presence of 1 Substituent and 1 Side chain at the same position from either end:** In such a case minimum number is given to the carbon containing the **substituent**.



**c. Presence of two substituents at the same position from either end:** In this case minimum number is given to the carbon containing the substituent which comes 1st in dictionary i.e. alphabetical order is considered.

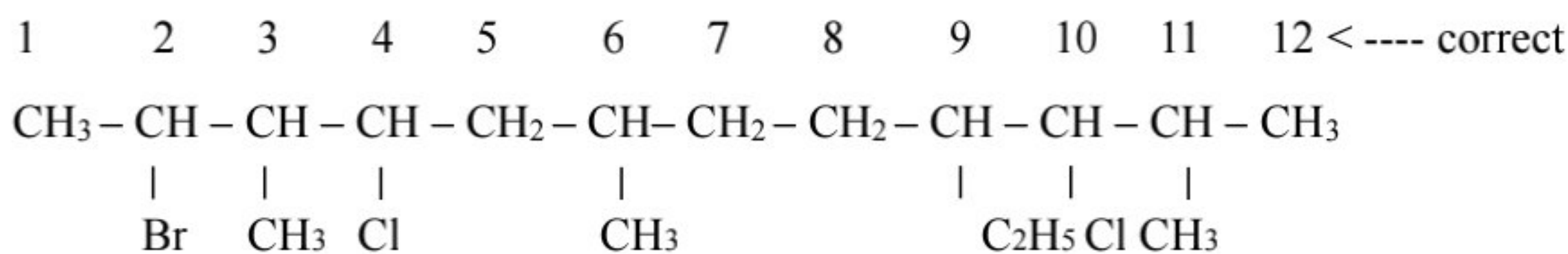


**d. Presence of two Side chains at the same positions from either end:** In this case, minimum number is given to the carbon containing the lower group.



**e. Presence of more than one substituents or side chains at any positions:** In this case

Lowest locants rule is followed.



Positions of locants:

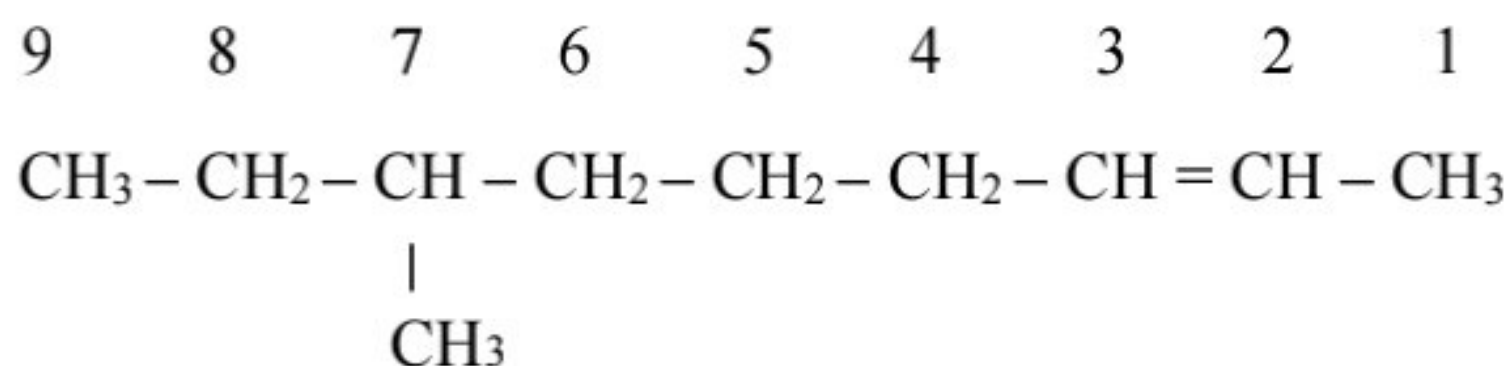
L→R: 2, 3, 4, 6, 9, 10, 11 (Correct)

R→L: 2, 3, 4, 7, 9, 10, 11 (Wrong)



**f. Presence of multiple bond:** If a compound contains a multiple bond ( $C = C$  or  $C \equiv C$ ) then, minimum number is given to the carbon containing the multiple bond irrespective of the position of the substituents or side chains.

Example:

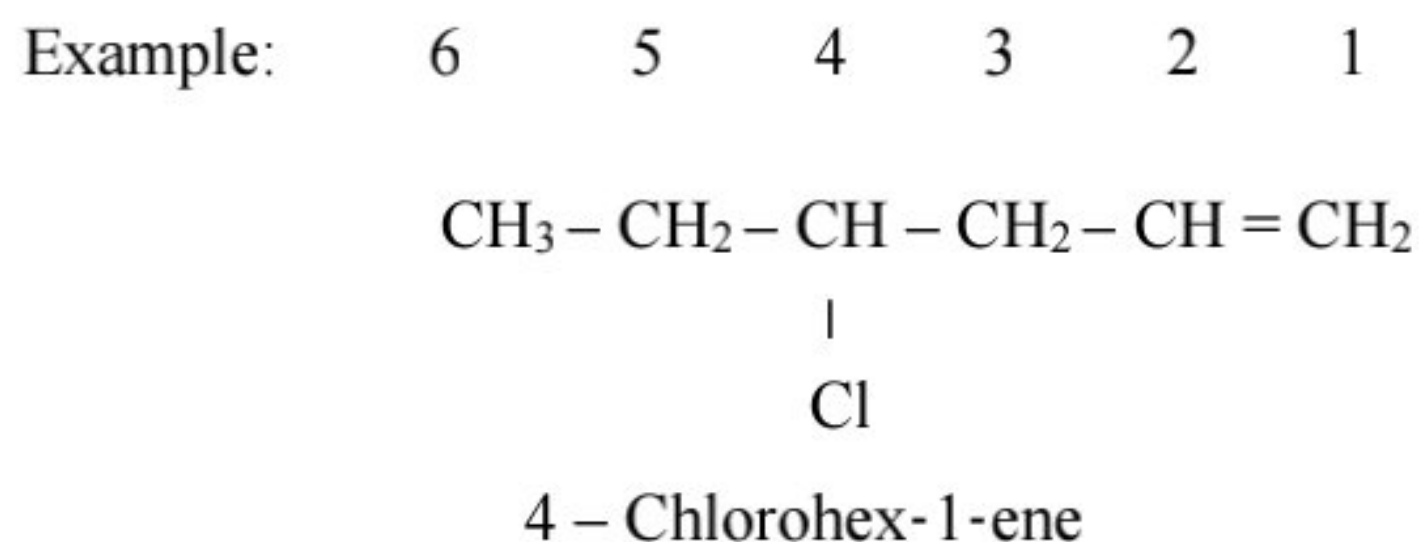
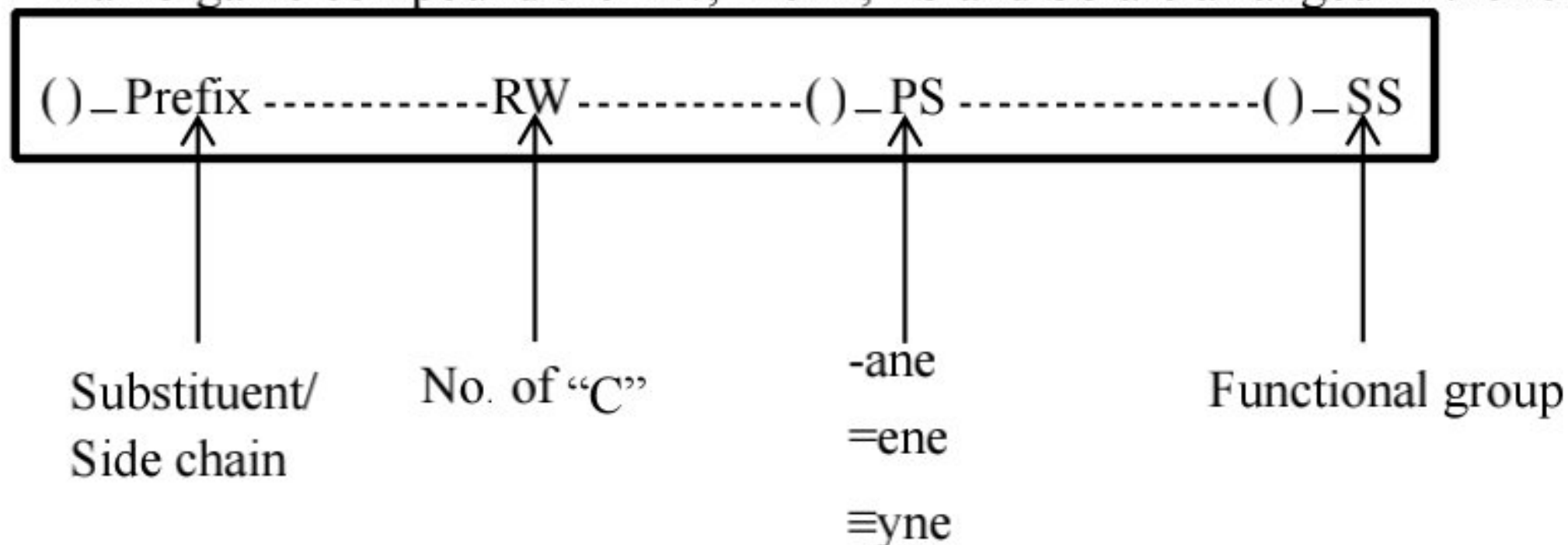


**Note: 1.** If a compound contains more than one  $=$  and/or  $\equiv$  bond then lowest locants rule is first followed. If they are at the same positions from either end then the carbon atom containing  $=$  bond is given the minimum number.

**Note: 2.** If a compound contains both  $=$  and  $\equiv$  bonds then the compound is named as  $-en-yne$ .

### 3. Arrangement of Root Word, Prefix, Primary Suffix and Secondary Suffix:

In an organic compound the RW, Prefix, PS and SS are arranged in the following way.



**4. Rules for alphabetical order:** If a compound contains more than one substituent or side chain then, while naming the substituents / side chains are arranged alphabetically. While following the rules for alphabetical order the prefixes like di, tri, tetra, etc. are ignored.



# INDUSTRIAL CHEMISTRY

## **WATER TREATMENT**

**Water** is one of the most important compounds of hydrogen and oxygen. It is a colourless liquid and possesses a high dielectric constant (80) and therefore, salts are highly ionised when



dissolved in water, but not so in other solvents. It is the most convenient universal solvent. In general, water is a good solvent for ionic compounds but a poor one for co-valent compounds.

### **Classification of water**

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

A. Surface Water

B. Underground Water

### **Classification of Surface Water**

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

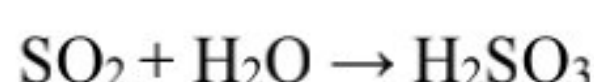
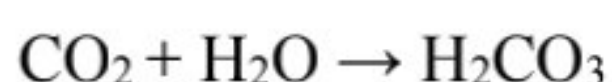
### **Classification of Under Ground Water**

- ❖ Spring Water
- ❖ Well Water

### **A. Surface water:**

#### **1. Rain water:**

- i. Rain is formed by the continuous evaporation and condensation of surface water.
- ii. Rain water is considered to be purest form of natural water.
- iii. It does not contain any dissolved minerals.
- iv. However during its downward movement, it comes across a number of industrial gases like  $\text{CO}_2$ ,  $\text{SO}_2$ ,  $\text{SO}_3$ ,  $\text{NO}_x$  etc. which dissolves them to form acid rain.



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

#### **2. River water:**

- i. The over flown surface water (surface run off), which is seen in the form of various streams join together to form river.
- ii. It is also formed due to the melting of glaciers.
- iii. It contains a high percentage of dissolved minerals like  $\text{NaCl}$ ,  $\text{KCl}$ ,  $\text{NaNO}_3$ ,  $\text{CaCO}_3$ ,  $\text{NaHCO}_3$  etc.



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

### **3. Lake water:**

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

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

### **4. Sea water:**

Sea is formed when a number of rivers meet together.

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

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

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

iv. Besides NaCl, it also contains other minerals such as  $\text{Na}_2\text{SO}_4$ ,  $\text{KHCO}_3$ ,  $\text{Mg}(\text{HCO}_3)_2$ ,  $\text{Ca}(\text{HCO}_3)_2$ , KBr,  $\text{MgBr}_2$  etc. **B. Underground water:**

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

#### **a. Spring water:**

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

#### **b. Well water:**

i. It is a clearer form of natural water. ii. It is obtained by digging the surface of earth to a high depth.

iii. It contains many dissolved minerals iv.

It also contains some organic matters.



## CLASSIFICATION OF WATER

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

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

**Hardness of water:** The characteristic of water by virtue of which it prevents the formation of foam with soap solution is called **hardness**. The hardness of water is due to the presence of certain dissolved minerals like  $\text{Ca}(\text{HCO}_3)_2$ ,  $\text{Mg}(\text{HCO}_3)_2$ ,  $\text{CaCl}_2$ ,  $\text{MgCl}_2$ ,  $\text{FeSO}_4$ , etc in water.

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

Hardness of water is of two types:

**A. Temporary or Carbonate hardness**

**B. Permanent or Non-carbonate hardness**

**A. Temporary hardness:** The temporary hardness of water arises due to the presence of bicarbonates of **Ca and Mg**,  $[\text{Ca}(\text{HCO}_3)_2, \text{Mg}(\text{HCO}_3)_2]$ . Temporary hardness is also called carbonate hardness.

**B. Permanent of hardness:** The permanent hardness of water arises due to the presence of chlorides of Ca, Mg ( $\text{CaCl}_2$ ,  $\text{MgCl}_2$ ) and sulphates of certain heavy metals like Fe ( $\text{FeSO}_4$ ).

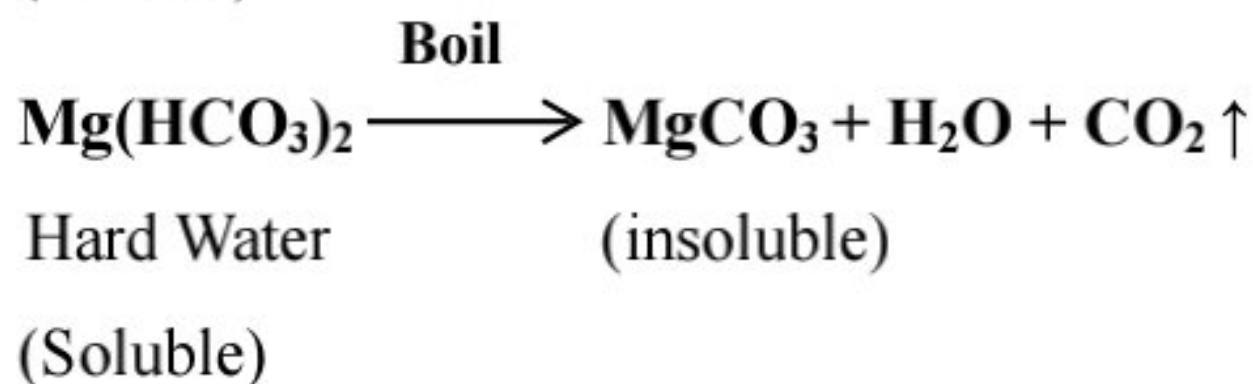
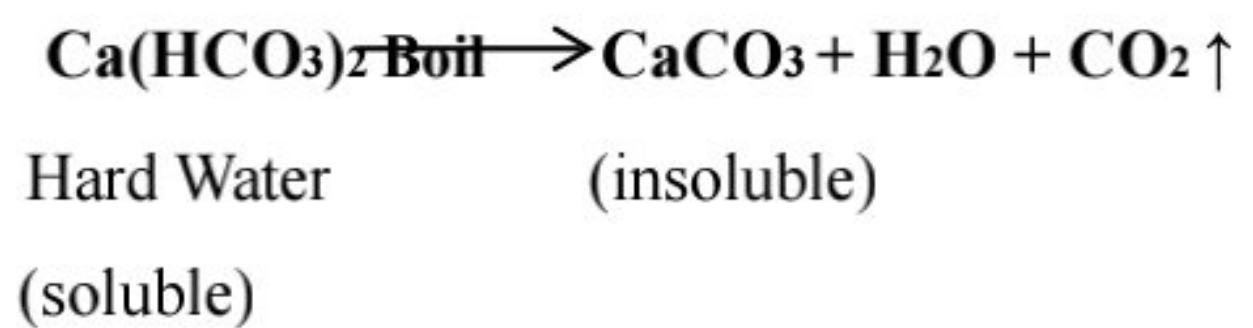
## REMOVAL OF HARDNESS OR SOFTENING OF WATER

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

### REMOVAL OF HARDNESS

#### A. Removal of Temporary Hardness:

The temporary hardness of water can easily be removed just by boiling the water. When hard water is boiled, the soluble  $\text{Ca}(\text{HCO}_3)_2$  and  $\text{Mg}(\text{HCO}_3)_2$  are decomposed in to insoluble carbonates, which are removed by filtration.



#### B. Removal of Permanent Hardness:

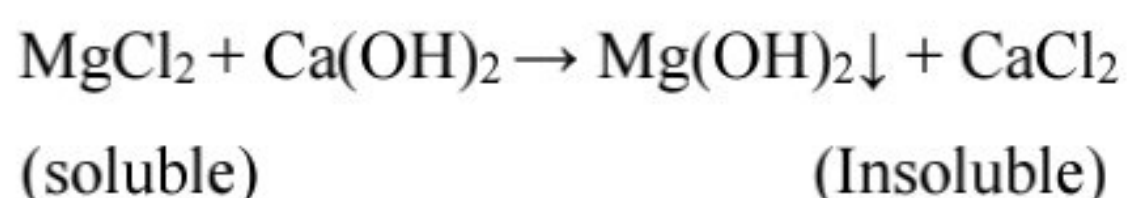
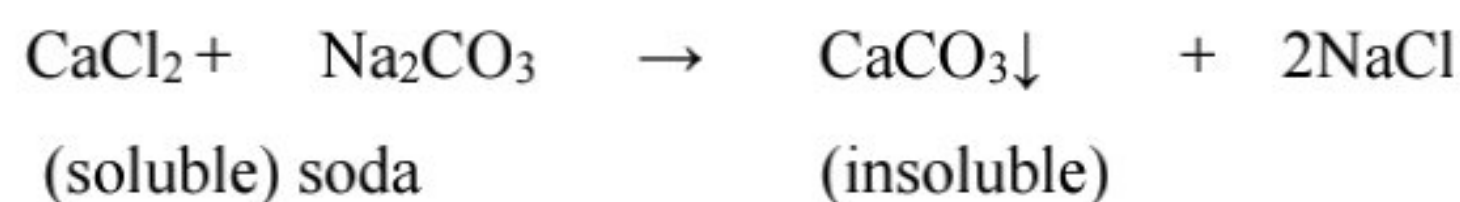


Removal of permanent hardness requires chemical treatment. Various methods used for the removal of permanent hardness are described below.

## 1. LIME SODA PROCESS (L – S PROCESS)

### Principle:

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



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

Lime-Soda process is of two types. **a.**

### COLD L – S PROCESS:

#### Principle:

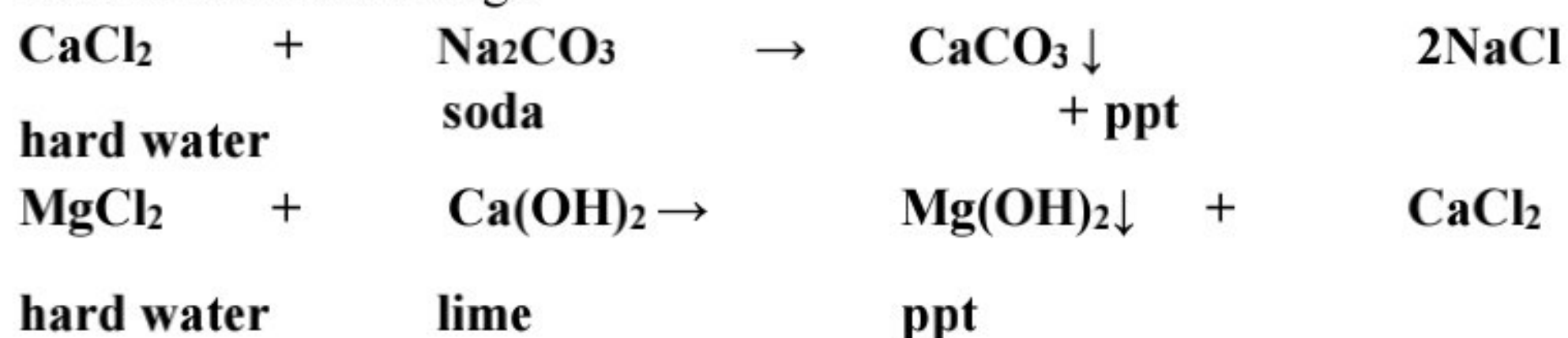
A calculated quantity of lime and soda is treated with hard water at room temperature. Lime and soda react with the hardness causing chemicals present in hard water and the precipitates or sludge formed are removed by filtration.

#### Construction of Apparatus:

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

#### Working Process:

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



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

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



**Apparatus:** The apparatus consists of three main parts:

- 1. Reaction tank:** Here the reaction of lime and soda with the hard water takes places.
- 2. Conical sedimentation tank:** Here the precipitates (sludge) are formed and deposited.
- 3. Filtering unit:** It consists of a number of layers of gravels which is used to filter water.

**Working Process:**

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

- i.** It is much economical.

- ii.** The reaction is completed within a short period.
- iii.** The reaction proceeds faster. Hence the softening capacity is increased.
- iv.** No coagulant is required, as the sludge settles down easily.
- v.** Dissolved gasses like CO<sub>2</sub>, air etc. are removed.

- vi.** Under hot condition viscosity of water is lowered. Thus filtration becomes easier.
- vii.** Pathogenic bacteria are destroyed.

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

## **2. ION EXCHANGE PROCESS:**

### **[Deionization process or De-mineralization process]**

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

Ion-exchange resins are of two types:-

#### **1) Cation-exchange resins (RH)**

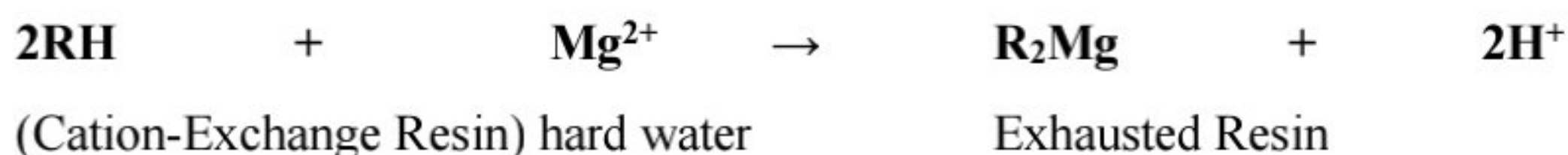
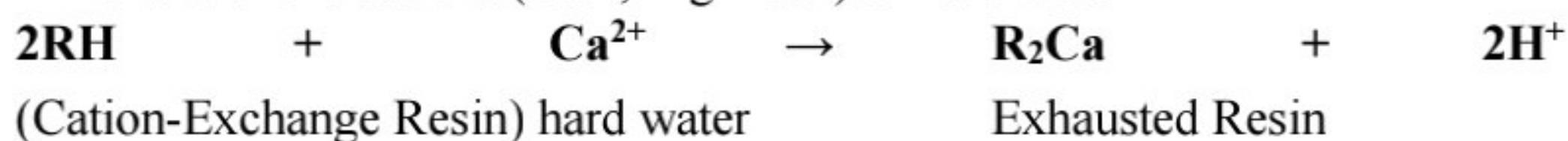
These resins contain acidic functional groups like – COOH, -SO<sub>3</sub>H etc. which can exchange their H<sup>+</sup> ions with the cations of the hardness causing chemicals present in hard water.

#### **2) Anion-exchange resins (ROH)**

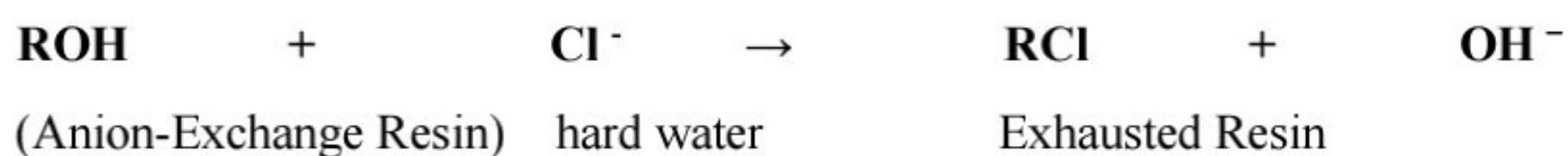
These resins contain basic functional groups like – N<sup>+</sup>Me<sub>3</sub>OH<sup>-</sup> which can exchange their OH<sup>-</sup> ions with the anions of hardness causing chemicals.



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



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

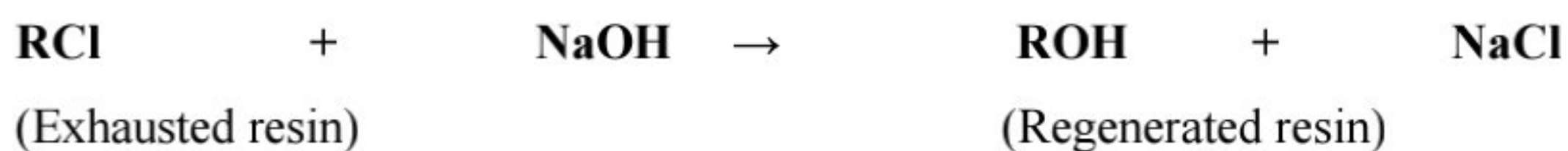


#### **Regeneration of resins:**

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



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



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



# LUBRICANTS

The substance applied in between two moving or sliding surfaces with a view to reduce the frictional resistance between them is called 'lubricant'.

## Functions of lubricants

- i. It reduces the frictional resistance between the sliding surfaces.
- ii. It reduces wearing and tearing of machinery parts
- iii. It reduces loss in energy
- iv. It increases the efficiency of engines.
- v. It enhances the durability of machinery parts.
- vi. It reduces expansion of metals
- vii. It acts as a cooling medium.

## Type of lubricants

Lubricants can be classified into three categories based upon their physical states. They are:

1. **Solid lubricants:** For example: Graphite, mica, molybdenum disulphide, boron trinitride, etc.

- It is used where the working temperature is very high
- It is used where there is a chance of contamination of the products with the lubricants.

2. **Liquid lubricants:** For example: Oils, Mobiles, petroleum oil, blended oil, animal oil, vegetable oil etc.

Functions of Liquid Lubricants: i. It acts as a cooling medium ii. It reduces the chance of rusting of metals. iii. It prevents corrosion of machinery parts.

Liquid lubricants are used when:

- The operating temperature is very high
- The speed of the roller is very high
- The sealing arrangement is perfect to prevent the loss of oil.

3. **Semi solid lubricants:** For example: Grease

Some major components of greases are:

- i. **Oil component:** mineral oil, waxes, petroleum oils.
- ii. **Thickening component:** Na, K, Ca, Al soaps.





- iii. **Modifiers:** antioxidant, antirust agent, antiwear agents, etc.

Semi solid lubricants are used where there is a chance of heavy jerk. Semi-solid lubricants stick to the rolling surfaces in spite of heavy jerk.

### **Purpose of Lubrication or functions of Lubrication**

Lubrication is highly important in industrial fields. The purposes of lubrications are:

- i. Lubrication helps to reduce frictional resistance between the moving, rolling or sliding surfaces.
- ii. It reduces wearing and tearing of machinery parts.
- iii. It reduces noise pollution
- iv. It reduces lose in energy
- v. It increases the efficiency of engines.
- vi. It enhances the durability of machinery parts.
- vii. It reduces expansion of metals
- viii. It acts as a cooling medium.

### **Viscosity**

**The property of a liquid (lubricant) by virtue of which it opposes the relative motion between its different layers is called viscosity.**

The absolute value of viscosity cannot be determined; however they can be compared with the help of a factor called 'Co-efficient of viscosity'.

- Viscosity of a liquid lubricant should moderate i.e. neither be too high nor be too low
- The viscosity of the liquid lubricant should differ much with rise or fall in temperature.

## **FUEL**

Fuel is a combustible matter which on burning with air produces a huge quantity of heat energy along with a low quantity of other by products.

**Fuel + O<sub>2</sub> → Product(s) + Heat**

In other words, fuel is defined as any combustible substance which maybe burnt to supply heat for practical applications.

### **Characteristics of good fuel**

1. Its calorific value should be high.
2. It should be cheap and readily available.
3. It should be stored for a longer period i.e. it should be non-volatile and stable.
4. It should not produce much ash.



5. Transportation should be easy.
6. It should not produce any poisonous gas.
7. It should not produce much smoke.
8. It should have low ignition temperature.
9. It should not be explosive in nature.
10. It should not contain high percentage of moisture.
11. It should contain low percentage of volatile matter.
12. It should require low storage volume.
13. It should provide uniform fuel bed.

### **Calorific value**

Calorific value may be defined as “the net 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, British Thermal Unit (BTU), etc.

### **Classification of Fuel**

Depending upon the physical state fuels may be classified in to three categories:-

1. **Solid fuel:** (Coal, wood, saw dust, rice bran, straw)
2. **Liquid fuel:** (Kerosene, Petrol, Diesel, Spirit, alcohol, LPG, CNG, etc.)
3. **Gaseous fuel:** (Methane, butane, water gas, producer gas, bio-gas, coal gas, acetylene, hydrogen etc.)

### **Wood**

- i. A freshly cut wood contains about **50% moisture**.
- ii. On air drying the moisture content reduces to about **15%**.
- iii. The average composition of a dry wood is, **C = 50%, H = 6%, O = 43%, Ash = 1%** iv.  
The calorific value = **3500 to 4500 Kcal / kg**
- v. It is largely used as a domestic fuel and seldom used for industrial purpose.

### **Coal**

**Coal is nothing but a combustible solid. It is usually stratified. That means, formed by the burial of partially decomposed vegetation in post geological ages.** During natural calamities big trees are uprooted from the ground and get buried under the surface of earth. After thousands and thousands of years under high temperature and pressure and in absence of



oxygen, by the action of bacteria wood is decomposed into coal. The progressive conversion of wood into coal is called **coalification**.

**Wood → Peat → Lignite → Bituminous → Anthracite**

### **Peat**

- i. It is either brown or black in colour.
  - ii. It is the first stage in the coalification of wood.
  - iii. It contains about **80% to 90%** moisture.
  - iv. Average composition: **C = 57%, H=6%, O=35%, Ash =2.5 to 6%.**
  - v. Calorific Value is very low.
  - vi. It is neither wood nor coal in the proper sense, but something intermediate between the two.
- Uses:** It is seldom used as fuel as it contains a high % age of moisture.

### **Lignite**

- i. It is brown in colour and soft in nature.
  - ii. It contains about **20 to 60%** moisture.
  - iii. Average composition **C = 60 to 70%, O=20%, H and N = 10 to 20%**
  - iv. Calorific value = **6500 to 7100 Kcal/kg.**
- Uses:** It is used as fuel in small scale industries and for domestic purpose.

### **Bituminous**

- i. It contains about **10% to 40% moisture.**
  - ii. Average composition: **C = 78 to 90%, O=7 to 10%.**
  - iii. Caloric value = **8000 to 8500 Kcal/kg.**
  - iv. It contains about **45% volatile matter.**
- Uses:** It is used as fuel in small scale industries and in domestic purpose.

### **Anthracite**

- i. It has dark brown or black surface.
- ii. It has higher density than other form of coal.
- iii. It is lustrous in appearance.
- iv. It contains very low percentage of moisture and volatile matter.
- v. Average Composition **C = 92 to 98%, rest = 2 to 8%**
- vi. Calorific Value = **8650 to 8700 Kcal/kg**
- vii. It contains a very low %age of ash (about 3%)

**Uses:** It is used in metallurgical operation as a reducing agent and as a fuel.



## PETROLEUM

The word petroleum is coined from two Greek words, '**Petra**' - means '**rock**' and '**Oleum**' - means '**Oil**'. It is also known as **rock oil** and **mineral oil**.

**Origin of petroleum:** It is obtained deep in the earth crust and at the bottom of sea. Petroleum is formed by the partial decomposition of aquatic creatures deep in the sea. The decomposition occurs as a result of high pressure and in the absence of air. Petroleum oil contains various constituents such as petrol, diesel, kerosene, fuel oil, paraffin, petroleum gas, etc. Also it contains water and sulphur as impurities.

### Purification of crude petroleum oil

#### **Removal of water (Cottrell's process)**

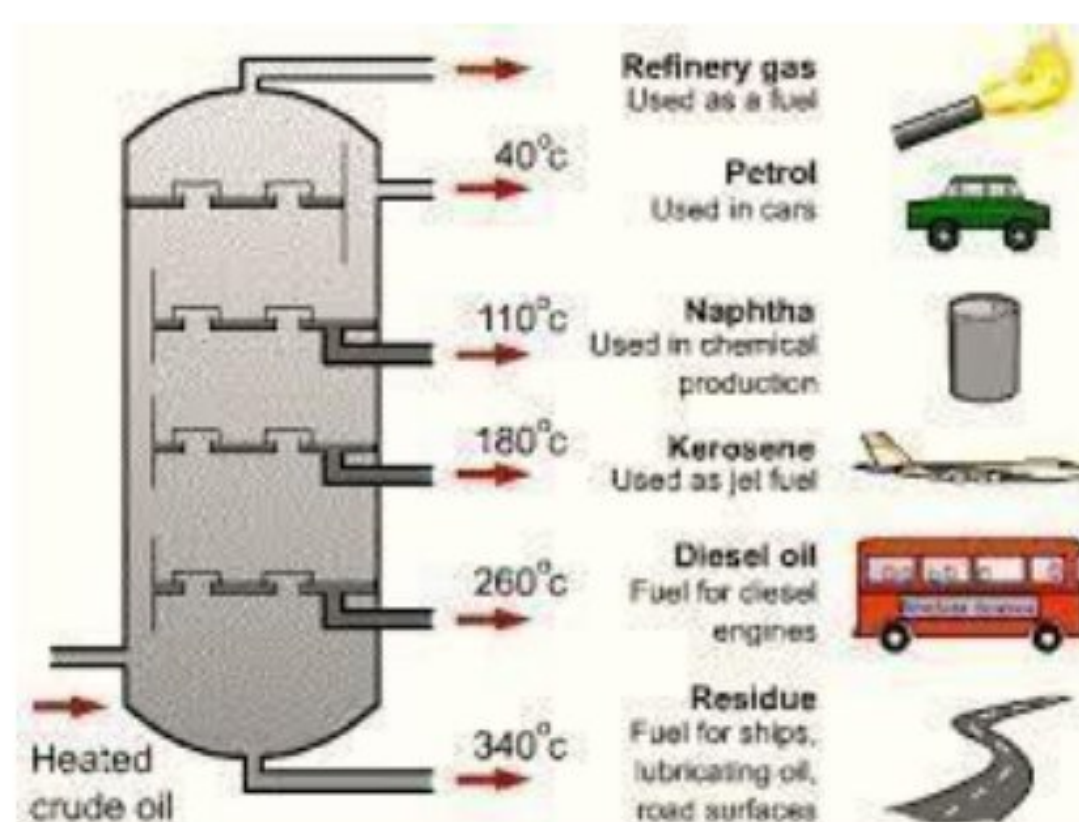
The crude petroleum oil is passed through two highly charged electrodes, when water gets separated as emulsion.

#### **Removal of sulphur**

The crude petroleum oil free from water is then passed through copper oxide (CuO) solution, so that sulphur present in the petroleum reacts with the solution giving insoluble CuS, which can be filtered off.

#### **Separation of different constituents from petroleum (Fractional Distillation Method)**

Different constituents of crude petroleum oil are separated by fractional distillation method. The crude petroleum oil is passed through a furnace where it is heated to about 4000 C, so that all the fractions are converted into their gaseous form. The vapours are then passed through a fractional distillation unit. When the vapours move in upward direction, the temperature gradually falls and fractional



condensation occurs at different heights of the distillation unit. Different fractions are collected from their respective outlets. The fraction with highest boiling point is collected at the bottom, while that with lowest boiling point is collected at the top.

#### **Petrol or Gasoline**



- i. The fraction obtained between  $40^{\circ}$  -  $120^{\circ}\text{C}$ , chiefly contains petrol. ii. It consist of hydrocarbons between pentane to octane ( $\text{C}_5\text{H}_{12}$  to  $\text{C}_8\text{H}_{18}$ )
- iii. It is volatile and inflammable.

iv. Average Composition **C = 84%, H=15%, O+S+N =1%** v.

Calorific Value = **11,250 Kcal / Kg.**

**Uses:**

- It is used as a fuel in the petrol engine.
- It is used as a dry cleaning agent.

### **Kerosene**

i. It is obtained between  **$180^{\circ}$  –  $250^{\circ}\text{C}$**  ii. It consists of hydrocarbons between decane to hexadecane ( **$\text{C}_{10}\text{H}_{22}$  to  $\text{C}_{16}\text{H}_{34}$** ).

iii. Average Composition, **C = 84 % , H = 16%, S < 0.1%**

iv. Calorific value = **11, 100 Kcal/ Kg** **Uses:**

- It is used as a fuel in the kitchen for domestic.
- It is used as a fuel in jet planes. □ It is used in making oil gas.

### **Diesel**

i. It is obtained between  **$250^{\circ}$  –  $320^{\circ}\text{C}$**

ii. It contains a mixture of hydrocarbons between pentadecane to octadecane ( **$\text{C}_{15}\text{H}_{32}$  to  $\text{C}_{18}\text{H}_{38}$** ).

iii. Average composition: **C = 85%, H = 12%, Rest = 3%** iv. Calorific Value = **11000Kcal/kg**

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

### **Water Gas**

It is a mixture of combustible gases CO and  $\text{H}_2$  with a little quantity of non-combustible gases  $\text{CO}_2$  and  $\text{N}_2$ .

The average composition of water gas is

**$\text{H}_2= 51 \%$ ,  $\text{CO} = 14 \%$ ,  $\text{CO}_2 = 4\%$ ,  $\text{N}_2 = 4\%$ ,**

Its calorific value is  **$2800 \text{ Kcal} / \text{m}^3$**  **Uses:**

It is used as:

- i. an illuminating gas. ii.
- a fuel



iii. a source of H<sub>2</sub> Gas **Producer**

**Gas:**

It is a mixture of combustible gases, CO and H<sub>2</sub> with large quantities of non-combustible gases CO<sub>2</sub> and N<sub>2</sub>

The average composition of producer gas is

**CO = 22- 30%, H<sub>2</sub> = 8 - 12 %, CO<sub>2</sub> = 3%, N<sub>2</sub> = 52 - 55 %** Its calorific value is **1300 Kcal /m<sup>3</sup>**.

**Uses:** It is used:

- i. In heating furnace in metallurgical operations.
- ii. As a reducing agent.

**Light Diesel Oil (LDO) and High Speed Diesel (HSD):** Light diesel oil and High speed diesel are produced from crude petroleum oil. The fraction obtained between 150° – 400° C contains LDO and HSD. These contain hydrocarbons having C<sub>12</sub> – C<sub>18</sub> and comprise paraffins, olefins and aromatics. LDO is normally used for the generation of electricity, in marine engines and diesel generators. HSD is normally used in buses, lorries, etc.

**Low Sulphur Heavy Stock (LSHS):** When heavy oil or gas oil stock is cracked at the temperature range 475° -530°C under pressure of 100 kg/cm<sup>3</sup>, high grade petrol is obtained which contains very low quantity of sulphur and is called LSHS. These are rich in aromatics and iso-paraffins. These are mainly used in locomotives.

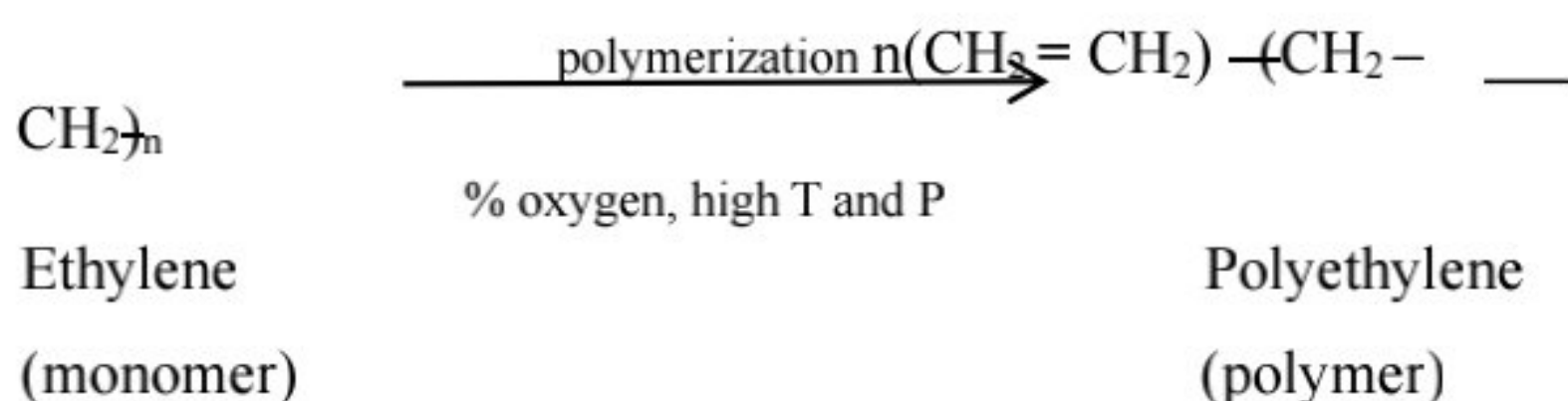


# POLYMERS

**Polymers** are one of the important products of chemical industry which have a great impact on our modern life. Plastics, synthetic fibres, synthetic rubber, etc are common examples of polymers. These polymers have multifarious uses ranging from household articles, automobiles, clothes, furniture, etc. to space aircraft, biomedical and surgical operations.

**Polymerisation:** The chemical process in which a large number of smaller molecular units are unite or joint together to form a bigger molecule of high molecular weight is called **polymerization**.

**Polymers:** Compounds of very high molecular masses formed by the combination of a large number of simple molecules are called polymers. For example: Polythene, PVC (polyvinyl chloride), Bakelite, Buna-S, Buna –N, Teflon, etc. are the examples of polymer. In Greek, ‘poly’ means many and ‘meros’ means units or parts. The simple molecules which combine to give polymers are called monomers.



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

## Classification of Polymers

Polymers may basically be classified in to two types, they are:

### i. Homo-polymer ii. Co-polymer

#### 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)

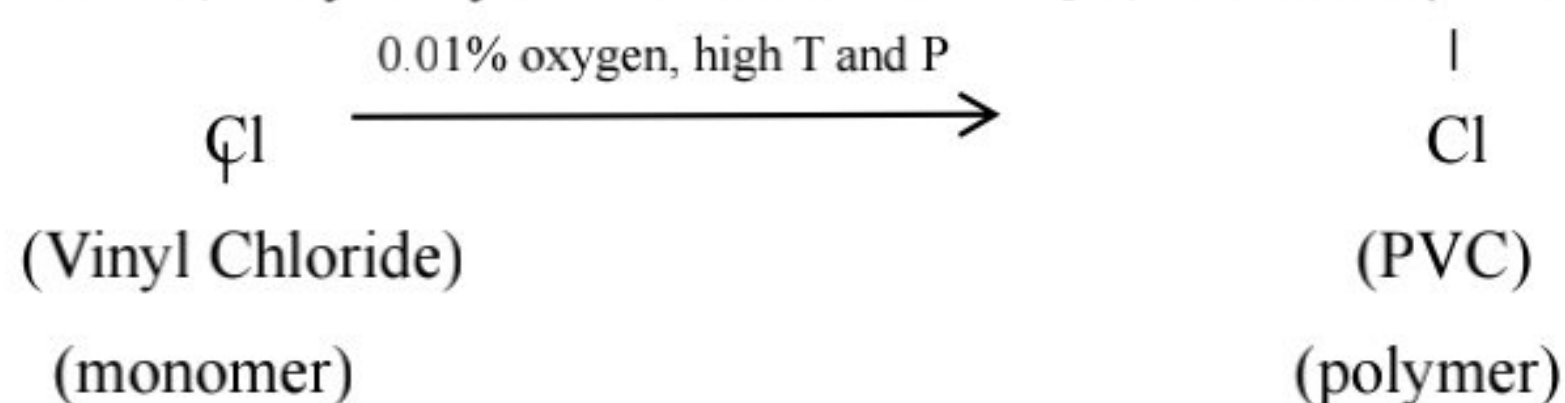
### Copolymer

A 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<sub>1</sub> – M<sub>2</sub> – M<sub>1</sub> – M<sub>2</sub> – M<sub>1</sub> – M<sub>2</sub> -----  
(Copolymer)

### PVC (Poly Vinyl Chloride)

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



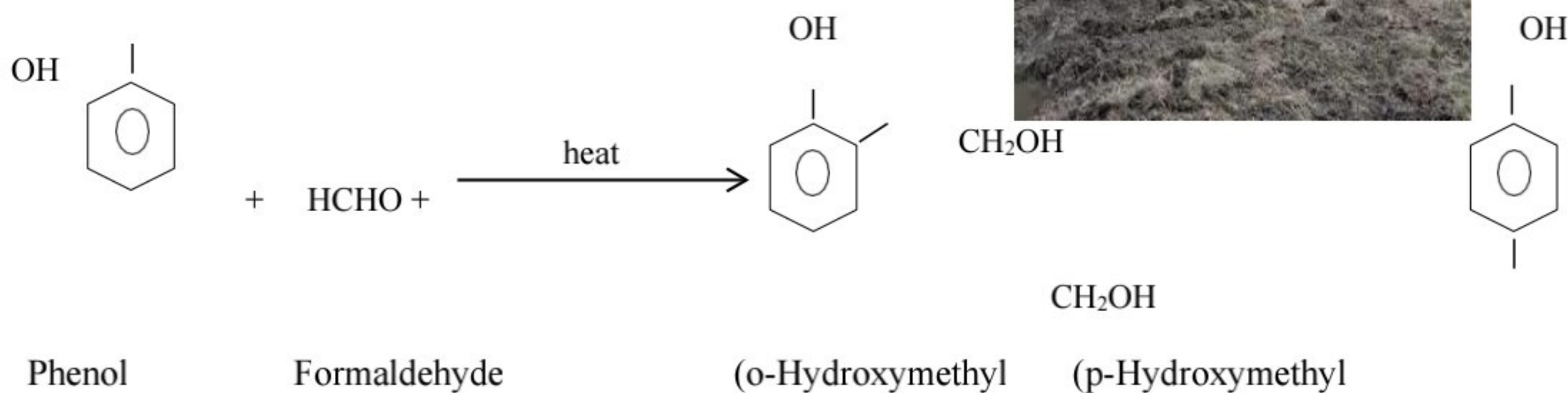
**Uses:** It is used for making:

- i. Sheets for tank lining ii. Safely helmets iii. Refrigerator components iv. Tyres, cycle and motor cycle mudguards v. Rain coat packing vi. Table cloths vii. Electrical insulators viii. Chemical containers



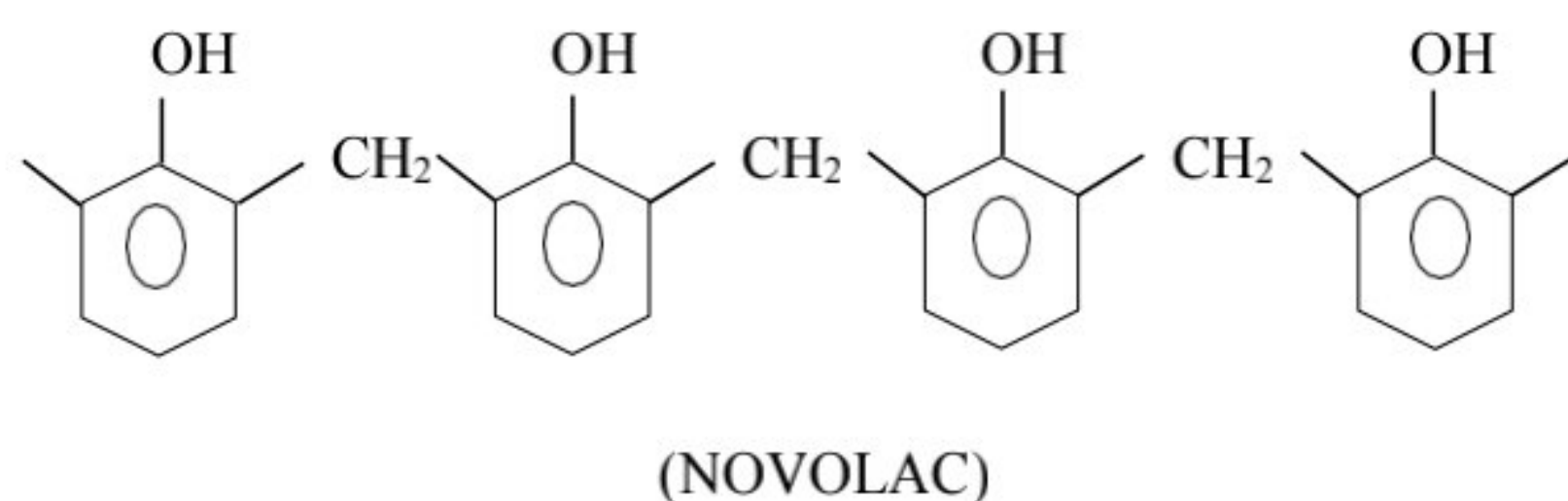
### Bakelite (Phenol-Formaldehyde Resin)

It is a co-polymer of **phenol and formaldehyde**. When phenol and formaldehyde are reacted together two isomeric compounds O-hydroxy methylphenol and P-hydroxy methylphenol are obtained.

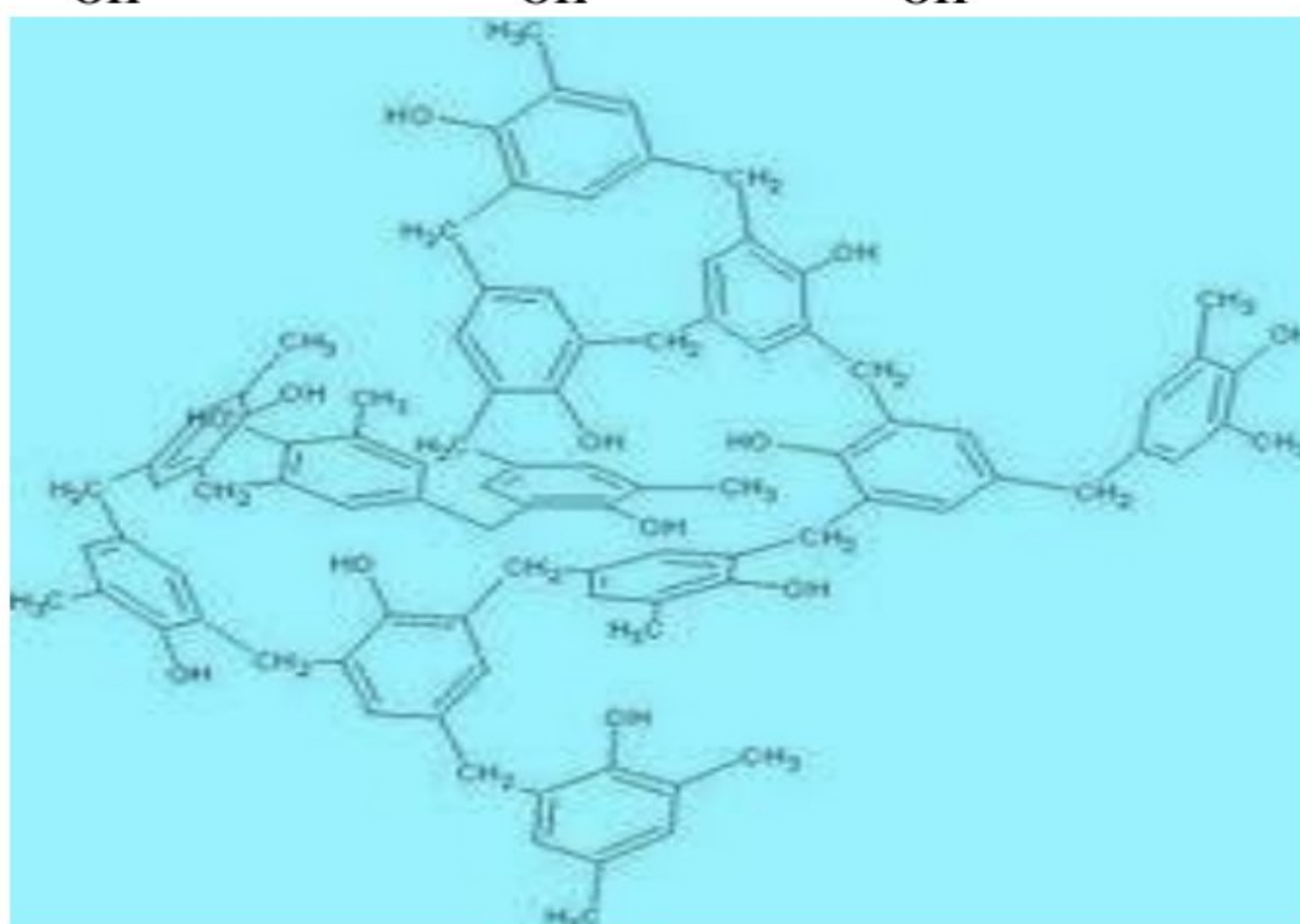
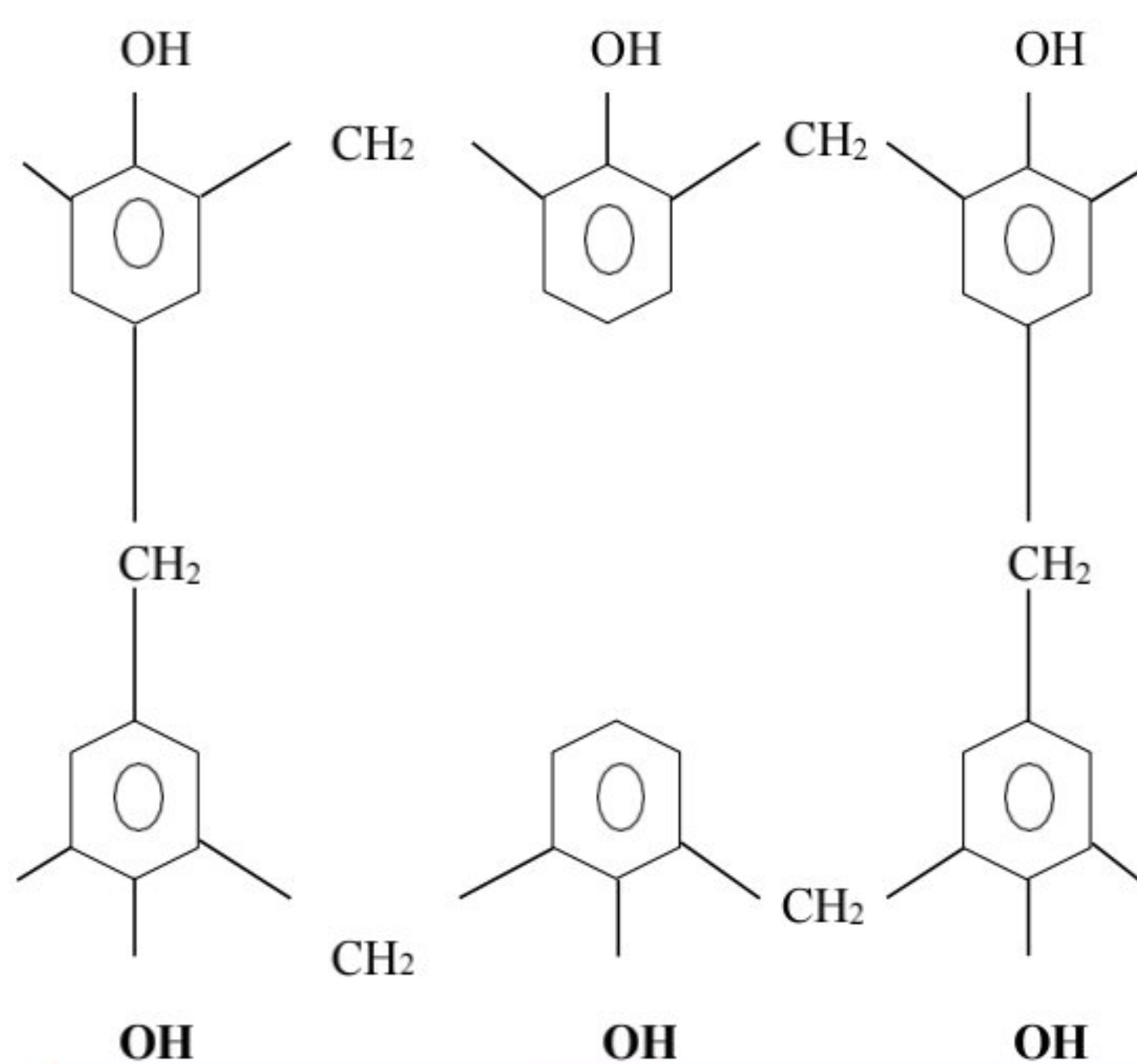




The orthohydroxy methylphenol thus formed undergoes polymerisation with phenol to form a linear polymer compound called "**NOVOLAC**".



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



## **Thermo Plastics**

1. Polymers in which the intermolecular force of attraction are in between those of elastomers and fibres are called thermo plastic.
2. These polymers have little or no cross linking, so individual polymer chain can slip past one another on heating.
3. These are linear polymers which are hard at room temperature become soft on heating again hard on cooling.
4. So these polymers can be moulded again and again into toys, buckets, etc. by the process of heating and cooling.

Example: Polythene, Polystyrene, PVC etc.

## **Thermo Setting Plastic**

1. These are semifluid highly cross linked three-dimensional network solids.
2. On heating these polymers undergo chemical change giving a hard, infusible and insoluble substance.
3. So these type of polymers can't be moulded again and again as on heating once it permanently sets into a solid which cannot be remelted and reworked.

Example: Bakelite, Urea-formaldehyde resin etc.



# **AGRICULTURE**

## ***Definition of Pesticides***

*The Food and Agriculture Organization (FAO) has defined pesticide as:*

*any substance or mixture of substances intended for preventing, destroying, or controlling any pest, including vectors of human or animal disease, unwanted species of plants or animals, causing harm during or otherwise interfering with the production, processing, storage, transport, or marketing of food, agricultural commodities, wood and wood products or animal feedstuffs, or substances that may be administered to animals for the control of insects, arachnids, or other pests in or on their bodies.*

## ***Types of Pesticides***

*These are grouped according to the types of pests which they kill:*

*Grouped by Types of Pests They Kill*

- 1. Insecticides – insects*
- 2. Herbicides – plants*
- 3. Rodenticides – rodents (rats & mice)*
- 4. Bactericides – bacteria*
- 5. Fungicides – fungi*
- 6. Larvicides – larvae*

*Based on how biodegradable they are:*

*Pesticides can also be considered as:*

### **□ Biodegradable:**

- The biodegradable kind is those which can be broken down by microbes and other living beings into harmless compounds.*
- **Persistent:***
- While the persistent ones are those which may take months or years to break down.*



*Another way to classify these is to consider those that are chemical forms or are derived from a common source or production method.*

#### *Chemically-related pesticides:*

- *Organophosphate:*

*Most organophosphates are insecticides, they affect the nervous system by disrupting the enzyme that regulates a neurotransmitter.*

- *Carbamate:*

*Similar to the organophosphorus pesticides, the carbamate pesticides also affect the nervous system by disrupting an enzyme that regulates the neurotransmitter. However, the enzyme effects are usually reversible.*

- *Organochlorine insecticides:*

*They were commonly used earlier, but now many countries have been removed Organochlorine insecticides from their market due to their health and environmental effects and their persistence (e.g., DDT, chlordane, and toxaphene).*

- *Pyrethroid:*

*These are a synthetic version of pyrethrin, a naturally occurring pesticide, found in chrysanthemums(Flower). They were developed in such a way as to maximise their stability in the environment.*

- *Sulfonylurea herbicides:*

*The sulfonylureas herbicides have been commercialized for weed control such as pyrithiobac-sodium, cyclosulfamuron, bispyribac-sodium, terbacil, sulfometuron-methyl Sulfosulfuron, rimsulfuron, pyrazosulfuron-ethyl, imazosulfuron, nicosulfuron, oxasulfuron, nicosulfuron, flazasulfuron, primisulfuron-methyl, halosulfuron-methyl, flupyrsulfuron-methyl-sodium, ethoxysulfuron, chlorimuron-ethyl, bensulfuron-methyl, azimsulfuron, and amidosulfuron.*

- *Biopesticides:*

*The biopesticides are certain types of pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals.*

#### *Examples of pesticides*

*Examples of pesticides are fungicides, herbicides, and insecticides. Examples of specific synthetic chemical pesticides are glyphosate, Acephate, Deet, Propoxur, Metaldehyde, Boric Acid, Diazinon, Dursban, DDT, Malathion, etc.*

#### **Benefits of Pesticides**

*The major advantage of pesticides is that they can save farmers. By protecting crops from insects and other pests. However, below are some other primary benefits of it.*

- *Controlling pests and plant disease vectors.*
- *Controlling human/livestock disease vectors and nuisance organisms.*
- *Controlling organisms that harm other human activities and structures.*

#### *Insecticides*



Substances which are used to kill insects are called insecticides. Insecticides have a wide application in the field of medicine, agriculture, and industry. They have the potential to alter ecosystem components majorly and are toxic to animals as well as humans. Some insecticides become concentrated as they spread in the food chain.

#### *Classification of insecticide*

- Based on chemical composition, it is classified as organic and inorganic.
- Based on the mode of entry in the insects, it is classified as contact poisons, fumigants poisons, stomach poisons, and systemic poisons.
- Based on the mode of action, it is classified as physical poisons, nerve poisons, respiratory poisons, protoplasmic poisons, general poisons, and chitin inhibitors.
- Based on toxicity, it is classified into four types:
  1. Extremely toxic – Color: red, symbol: skull and poison, oral LD50: 1-50
  2. Moderately toxic – Color: blue, symbol: danger, oral LD50: 501 – 5000
  3. Highly toxic – Color: yellow, symbol: poison, oral LD50: 51 – 500
  4. Less toxic – Color: green, symbol: caution, oral LD50: >5000
- Based on the stage of specificity, it is classified as ovicides, pupicides, larvicides, and adulticides.

#### *Types of insecticides*

There are three different types of insecticides. They are

1. Systemic – This type of insecticide is introduced into the soil for it to get absorbed by the plant roots. Once the insecticide enters the roots, it moves to external areas such as leaves, fruits, twigs, and branches. It forms a layer on the plant surface area and acts as a poison to any insect that comes to chew the plant.
2. Ingested – Some examples of ingested pesticides are rat and roach.
3. Contact – These type of insecticides act like bullets that aim only at a particular target to kill insects by its application. Usually, household insect spray works like contact insecticides as it must directly hit the insect.

#### *Classification of insecticides based on chemical nature*

Based on the chemical nature, insecticides are classified into four groups:

1. Organic insecticides
  2. Synthetic insecticides
  3. Inorganic insecticides
  4. Miscellaneous compounds
- Disadvantages of insecticides*
1. Non-target organisms – Insecticides can kill more than intended organisms and are risky to humans. Also, when insecticides mix with water sources through leaching, drift, or runoff, they harm aquatic wildlife. When birds drink such contaminated water and eat affected insects, they die. Some examples of insecticides, like DDT, were banned in the US as it affects the reproductive abilities of predatory birds.
  2. Resistance – Insects when repeatedly exposed to insecticides build up resistance until finally, they have little or no effect at all. The reproduction in insects is so quick that they produce a new generation every three to four weeks. Therefore, the resistance builds up rapidly.







