

LECTURE NOTES
ON
ENGG. CHEMISTRY

FACULTY'S NAME: KUNI MAJHI
SR. LECTURER

SEMESTER: 1ST & 2ND

CHAPTER:11

LUBRICANTS

Lubricants

Lubricants are chemical substances which play important roles in engineering field industrial sector, food industries etc

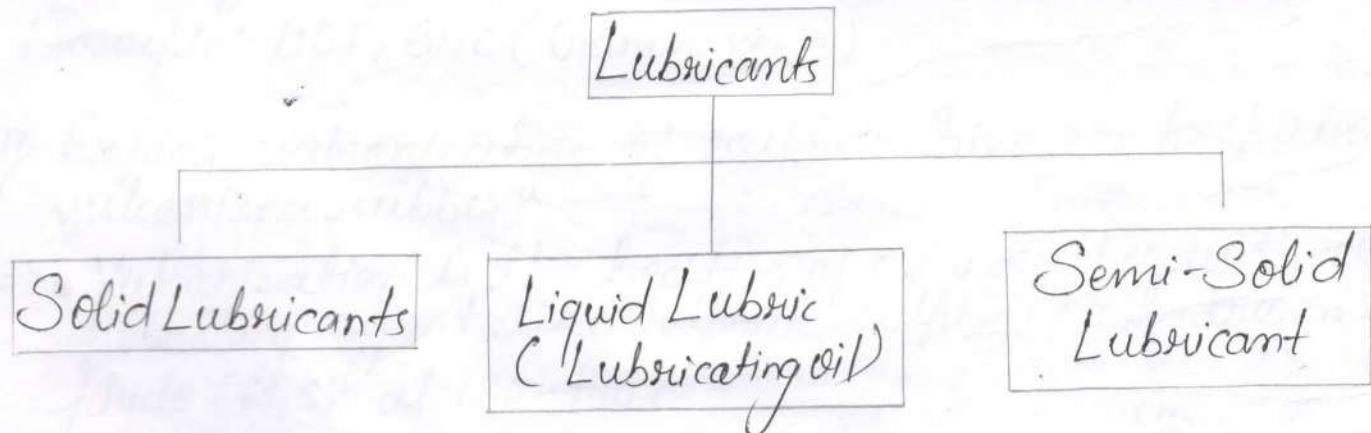
Definition of Lubricants

Lubricants are the chemical substance which applied in between two moving or sliding substance to reduce frictional resistance between them.

- Lubricants reduce frictional resistance, wear and tear, loss of energy.

Types of Lubricants

Bassing on physical state it is classified into 3 types



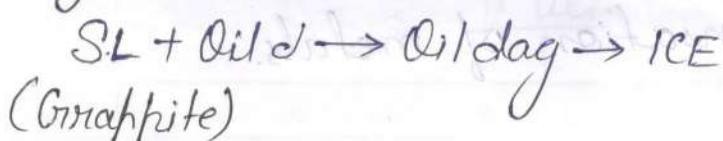
Solid Lubricants

- The lubricants which exist in solid form called solid lubricants.
- These are applied in machines running in very high temperature.
- $SL + Oil \rightarrow Oil \text{ lag} \rightarrow ICE$
 $SL + \text{water} \rightarrow \text{Aqua lag} \xrightarrow{\text{use}} \text{Food industries}$
- Example: Graphite, Mica, Talc, Molybdenum disulfide

Use of Graphite

- Soft and slippery
- Very high temperature

Railway track joint, dish breaks



Liquid Lubricant

- These are used in when machine runs in high temperature.
- Example: Petroleum, Vegetable oils, Animals oil, Synthetic Oil

Semi-Solid Lubricant

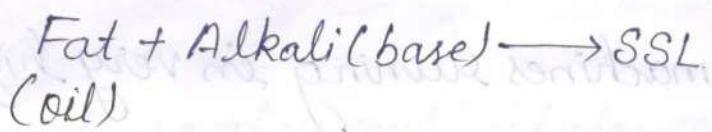
- Semi-Solid Lubricant used in when the machine is very heavy loaded & it's movement is very slow

Example: Greases, waxes, vasalines

- Uses

Uses

- It is used by using method saponification method.



Purpose of Lubrication

- It reduce frictional resistance
- It reduce wear and tear
- It reduce loss of energy
- It reduce noise pollution
- It increase the life span of machinery or machine parts
- It save power consumptions
- It reduce the expansion of metals.

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CHAPTER - 13

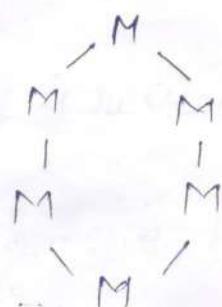
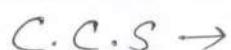
POLYMERS

- * polymer → Derived from Greek word
- * polymer → poly (many) + mers (units or parts)
- * polymer is denoted by 'P'
- * It's molecular weight lies between 5,000 - 2,00,000 units
- * Self linking of monomers form polymers.
- * Basic on Structure there are classified into two types
 1. Linear chain structure
 2. Cross-linked / 3-D chain structure
 3. Closed chain structure

Definition of polymer

A high molecular weight compound formed by the linking of small and simple molecular monomers called polymers (P).

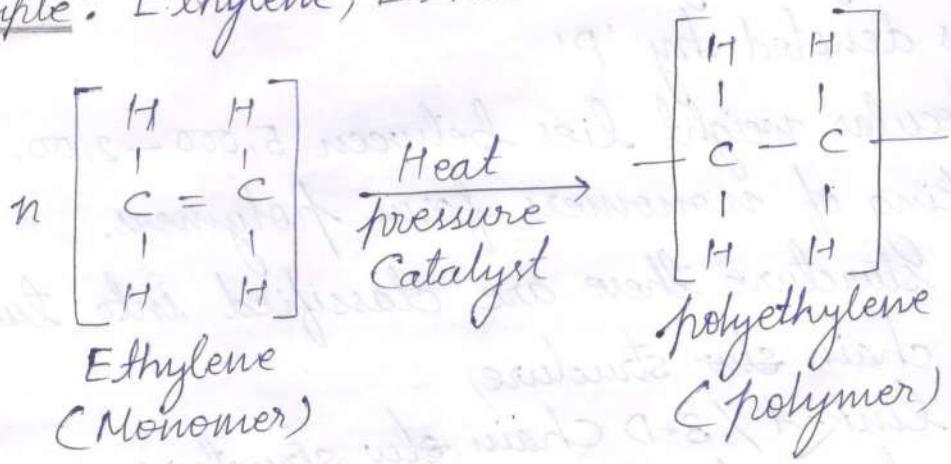
Example: polythen, PVC, Teflon, Nylon-66



Monomer :

This is a small and simple molecules which combine with each other to form polymer.

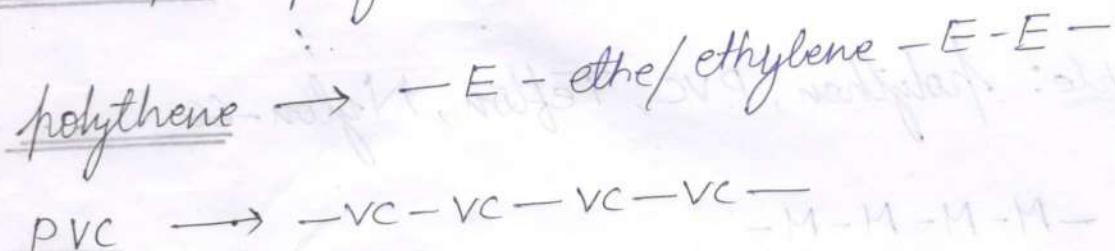
Example: Ethylene, Ethene



Homopolymer :

The polymer formed by the self linking of Identical (Same) monomers called Homopolymer.

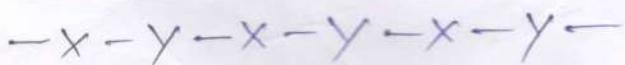
Example: polythene, PVC



Co-polymer :

The polymer formed by the linking of different types of monomers called co-polymer.

Example: Nylon-66, Bakelite



Degree of polymerisation (DP) or 'n'

- * The number of monomer present in a polymer is called degree of polymerisation.
- * It is denoted by 'DP' or 'n'.
- * This is classified into two types.
 1. High DP (High polymer)
(molecular weight lies between 3000 - 2,00,000 unit)
 2. Low DP (low polymer)
(Molecular weight above 1,000)

plastics

Thermoplastic

(Thermo softening plastic)

1. The plastics which can be soften on heating and harder on cooling called Thermoplastic.
2. These are formed by addition polymerisation.
3. These are linear in structure.
4. These are can reshaped, reused remoulded.
5. These are soft and less brittle.
6. The plasticity is reversible.
7. Example: polythene, PVC

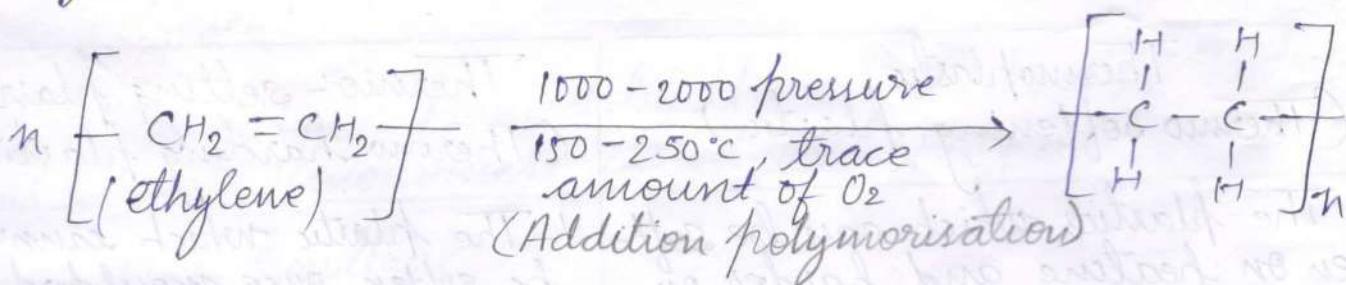
Thermo-setting plastic

(Thermo hardening plastic)

1. The plastic which can't be soften once moulded into desired shape called Thermo-setting plastic.
2. Condensation. These are formed by addition polymerisation.
3. There are cross-linked in structure.
4. They can't reshaped, reused remoulded.
5. There are hard and more brittle.
6. The plasticity property is irreversible.
7. Example: Bakelite.

Polythene

- * There is a thermo-plastic polymer.
- * These are formed by addition polymerisation
- * Its monomer is ethene or ethylene.
- * Its chemical formula is $\text{CH}_2 = \text{CH}_2$
- * The liquefying ethylene is heated by applying 1000-2000 atmospheric (atm) pressure is pumped into a vessel maintaining temperature $150 - 250^\circ\text{C}$ along with trace amount of oxygen polymerised to form a rigid, waxy, white transparent polymer called polythene.

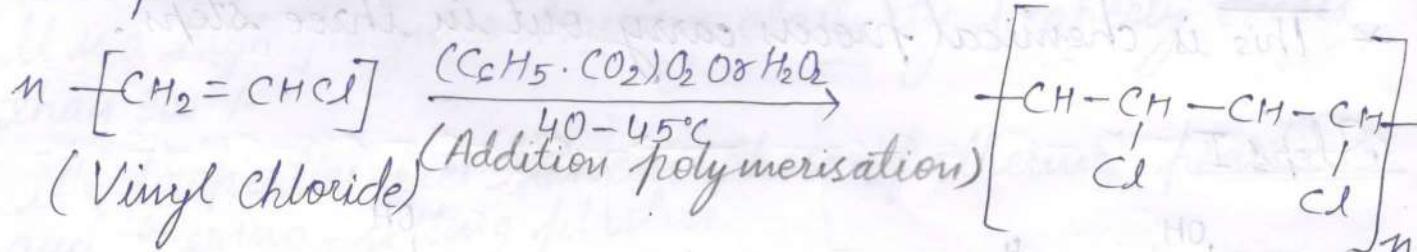


Uses of polythene

- * In packaging film.
- * In garbage bags.
- * In grocery bags.
- * In insulation for wires and cables.
- * In agricultural mulch.
- * In bottles, toys and houseware.

✓ Polyvinyl Chloride (PVC)

- * These are a thermo-plastic polymer
- * These are formed by addition polymerisation
- * Monomer of PVC is vinyl chloride.
- * It is formed by the reaction of 1:1 of vinyl chloride and water along the presence of catalyst like benzoyl peroxide or Hydrogen peroxide with maintaining temperature 40-45°C



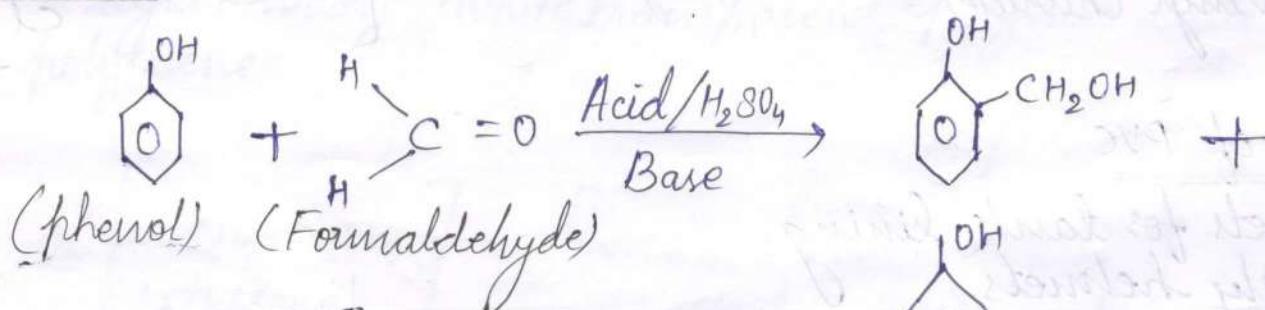
Uses of PVC

- * Sheets for tank lining.
- * Safety helmets.
- * Refrigerator components
- * Tyres, cycle and motorcycle mudguards.
- * Raincoat packing
- * Tablecloths
- * Electrical insulators
- * Chemical containers, etc.

⑤ Bakelite

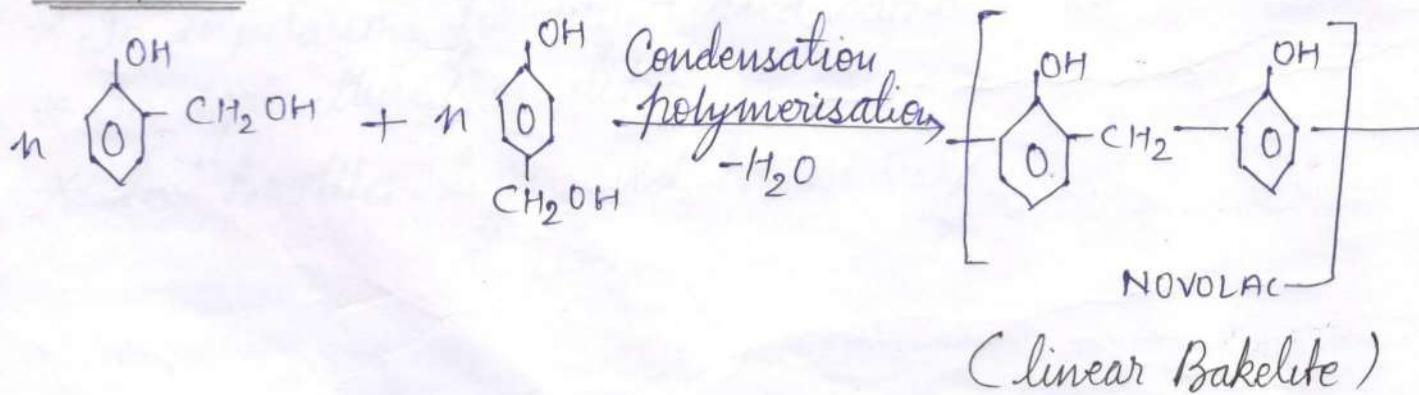
- * This is the 1st synthetic polymer. synthesized by human beings.
 - * This is a thermo-setting polymer.
 - * This is formed by condensation polymerisation of 'phenol' and 'formaldehyde'.
 - * This is chemical process carry out in three steps.

Sleps I

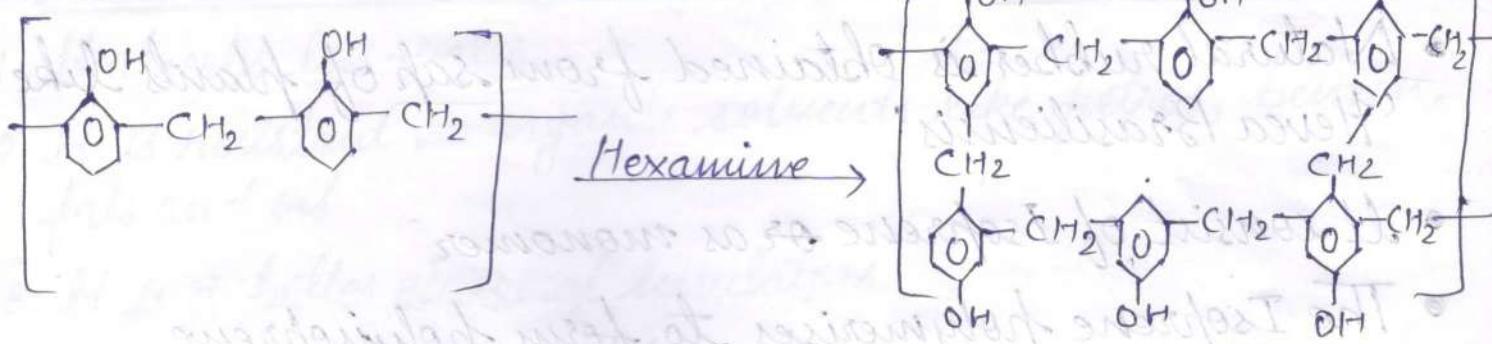


(P-hydroxy methyl phenol)

Steps II

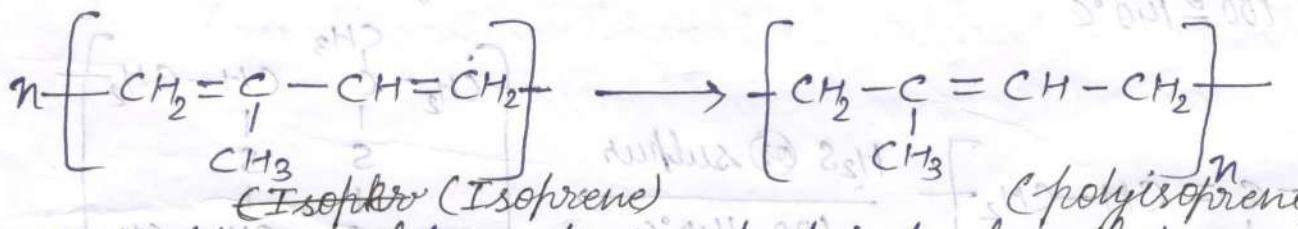


Steps 3



Rubber (Elastomer)

1. It is a high polymer having elasticity property excess than 300%.
2. Its properties lies between those of thermo-plastic and thermo-setting plastics.
3. Rubber is also called 'Elastomer'.
4. Its monomer is Isoprene
5. $[\text{Isoprene} - \text{Isoprene} - \text{Isoprene}]_n \rightarrow \text{polyisoprene}$
(Rubber)

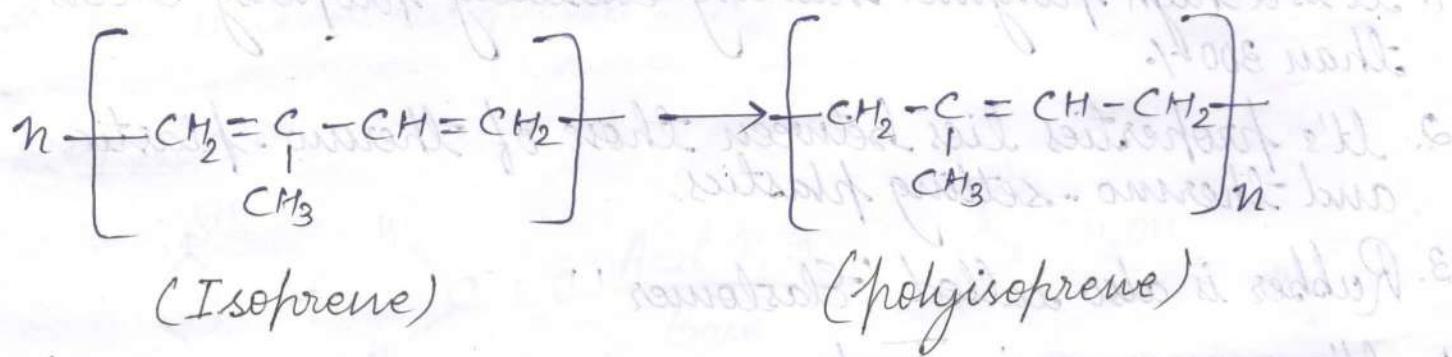


6. Rubber is obtained classified into two types

- Ⓐ Natural Rubber
- Ⓑ Synthetic Rubber.

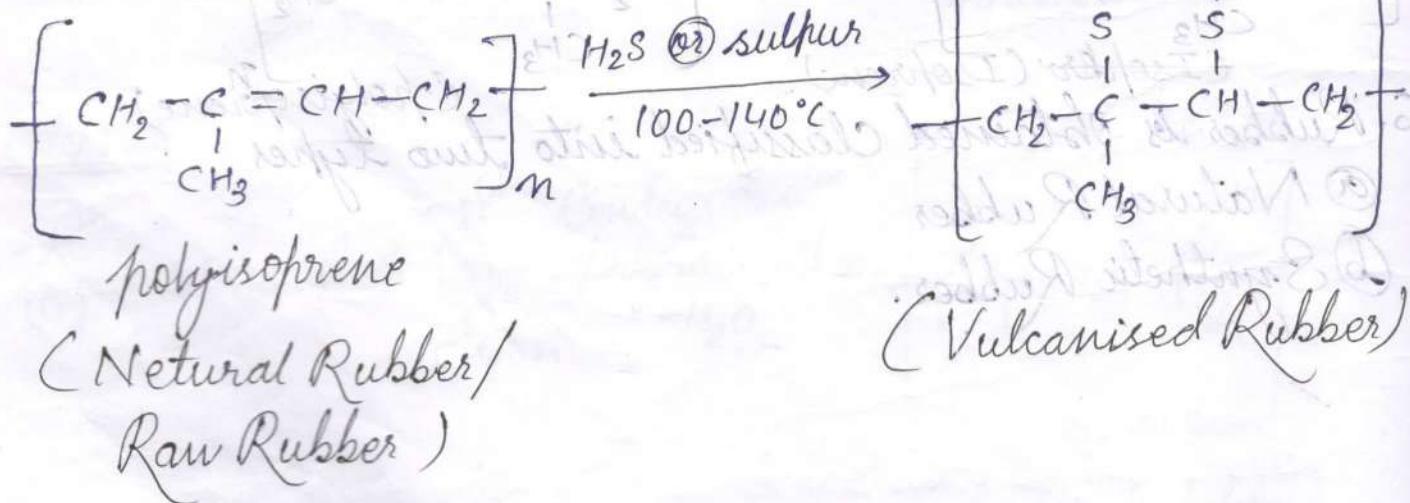
Natural Rubber

- Natural rubber is obtained from sap of plants like '*Hevea Brasiliensis*'
 - It consists of Isoprene or as monomer
 - The Isoprene polymerises to form polyisoprene (Rubber)



Imp Vulcanisation of Rubber

- Vulcanisation is the heating of raw rubber with compounding agent like sulphur or hydrogen sulphide (CH_2S) at $100\text{--}140^\circ\text{C}$



Vulcanisation of rubber property over raw rubber

1. It absorbs less water.
2. It is resistant to organic solvents like petrol, benzene, fats and oil.
3. It is a better electrical insulators.
4. It has good tensile strength.
5. It possesses higher resistance to oxygen and oxidising agents.
6. It works in -40°C to 100°C.
7. It returns to its original shape when the deformation lead is removed.

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CHAPTER : 14

CHEMICALS IN AGRICULTURE

PESTICIDES:

Pesticides are the chemical compound used to kill pest including insects, rodents, weeds/herbs, fungi, algae etc.

- It includes the following

- ① Insecticides
- ② Herbicides
- ③ Fungicides

Example: DDT, BHC (Gammexene)

INSECTICIDES

These are the chemical substances used to kill insect

Example: DDT (Dichloro Diphenyl Trichloroethane)

BHC (Benzene Hexa Chloride)

Uses

These are used in agriculture, medicines, industries and by consumers.

HERBICIDES

- These are the chemical substance used to kill herbs (weeds)/small plants.

- This is also known as 'weed Killers' or weedicides.
 - Example: Acelochlor, Propanil, Amitrole, Arsenic acid.
- Uses
- These are used to clear waste ground, kill weeds in construction sites railway sides.
 - Used to control the growth of algae in pond, river, lake etc.

FUNGICIDES

- These are the chemical substance that prevent mitigate or inhibit the growth of fungi or fungis on plants.

Example: Bleaching powder, carboxim, $CuSO_4$ solution

Uses

- These are used to control fungi which damage the plants.

BIO-FERTILIZERS

- Biofertilizers are the substance that contains living microorganism. Biofertilizers increase the nutrients of host plants when applied to their seeds, plants surface or soil by colonizing the rhizosphere of the plants.

These are environment friendly substitute for harmful chemical fertilizers.

- The microorganism in Biofertilizers restore the soil's natural nutrient cycle and build soil organic matter.

These are extremely advantageous in enriching soil fertility and fulfilling plant nutrient requirements

Example: Rhizobium, Azotobacter, Azospirillum, Blue green algae etc.

Uses of microorganism to "wattle" crops to convert N₂ into N⁺.

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

to reduce the fall in yield.

③ Fertilizers

• Positive effects of fertilizers towards yield are as follows:
1. To increase the yield of crops by reducing the yield loss due to nutrient deficiency.

2. It prevents water logging losses at field as well.

These are the chemical substances used.

Classification of Fertilizers - i) Inorganic fertilizers

• Animal manures have nutrients which are available for plants.
• It is derived from organic materials mainly from animal wastes, plants, leaves, roots, stems, etc. which are added to soil to provide organic matter to plants. It is a form of fertilizer which is available to plants.

• This is the easiest fertilizer in preparation and it contains simple ions like chloride, sulphate, nitrate, phosphate, etc. which are easily absorbed by plants.

1. Define co-polymers? Give two examples?

⇒ The polymer formed by the linkage of different types of monomer called co-polymer.

Example: ~~Polythene~~, PVC, Nylon-66, Bakelite

2. What are the monomers of Bakelite?

⇒ The monomers of bakelite is 'phenol' and 'formaldehyde'

3. What is Insecticides? Give two examples?

⇒ These are the chemical substance used to kill insect

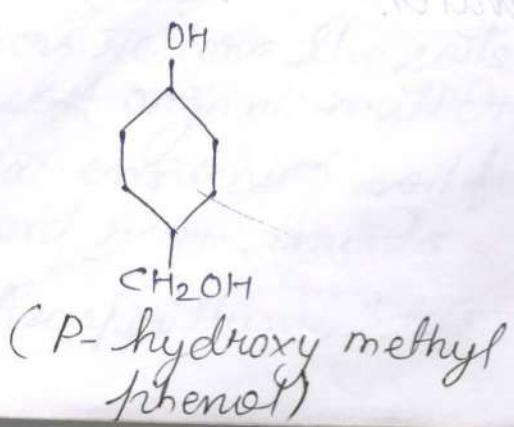
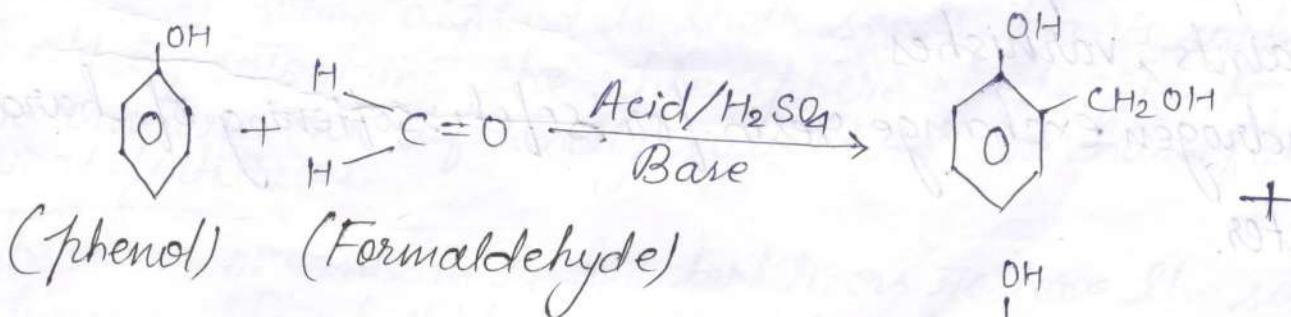
Example: DDT (Dichloro Diphenyl Trichloroethane)
BHC (Benzene Hexa Chloride)

4. State the composition, preparation & uses of Bakelite?

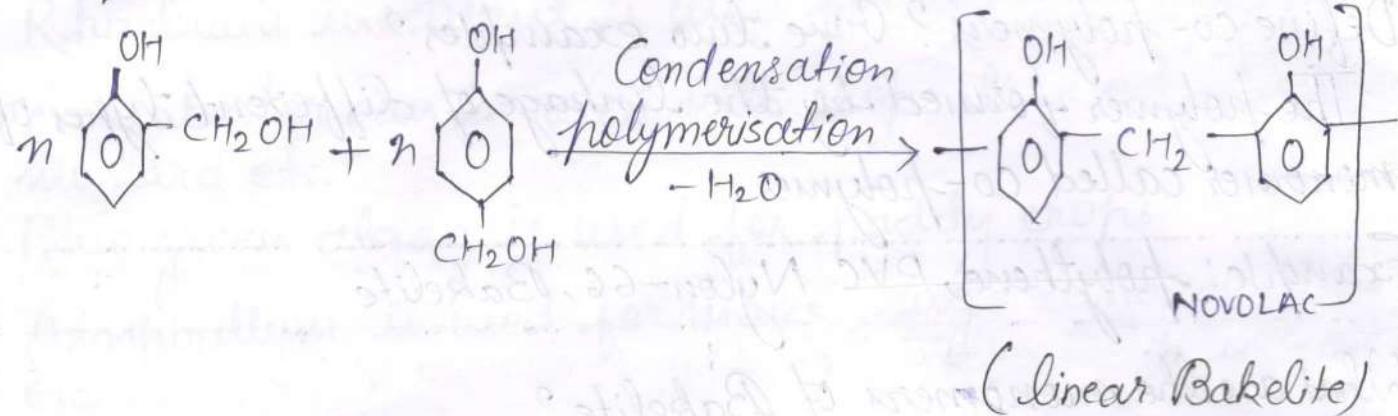
⇒ • This is the 1st synthetic polymer. Synthesized by the human beings.

- This is a thermo-setting polymer.
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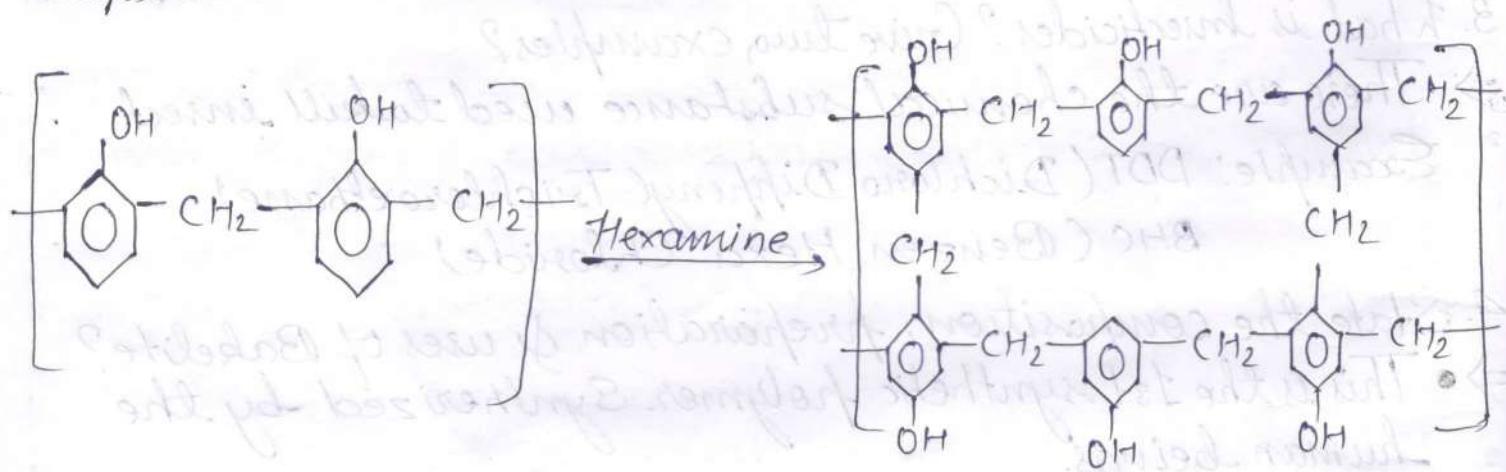
Steps I



Steps II



Steps III



Uses:

It is used in the manufacture of

- Electrical insulators like plug, switch etc.
- Cabinets for Radio and TV
- Telephone parts
- paints, varnishes
- Hydrogen exchange resin for softening of hard water.

5. States any five difference between thermoplastics & thermosetting plastics?

⇒ The difference between thermoplastics and thermosetting plastics are:

Thermoplastics	Thermo-setting plastics
(i) The plastics which can be soften on heating or harder on cooling are called thermoplastics.	(i) The plastics which can be soften once moulded into desired shape are called thermo-setting plastic.
(ii) These are formed by addition polymerisation.	(ii) These are formed by condensation polymerisation.
(iii) These are linear in structure.	(iii) These are cross-linked in structure.
(iv) These can reshaped, reused, remoulded.	(iv) These cannot be reshaped, reused, remoulded.
(v) These are soft and less brittle.	(v) These are hard and more brittle.
(vi) The plasticity is reversible.	(vi) The plasticity is irreversible.
Example: polythene, PVC	Example: Bakelite

6. Write a note on Bio-fertilizers

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

• The micro-organism in bio-fertilizers restore the soils natural nutrient cycle and build soil organic matter. These are extremely advantageous in enriching soil for fertility and fulfilling plant nutrient requirements.

Example: Rhizobium, Azotobacter, Azospirillum, Blue green algae etc.

7. Define homo-polymers? Give two examples?

⇒ The polymer formed by the self linkage of identical (same) monomers called homo-polymers.

Example: polythen, PVC

8. What is degree of polymerization?

⇒ • The number of monomer present in a polymer is called degree of polymerization

• It is denoted by 'DP' or 'n'

• This is classified into two types

(i) High Degree of polymerization (High polymer)

(Molecular weight lies between 3000 - 2,00,000 unit)

(ii) Low Degree of polymerization (low polymer)

(Molecular weight above 1000)

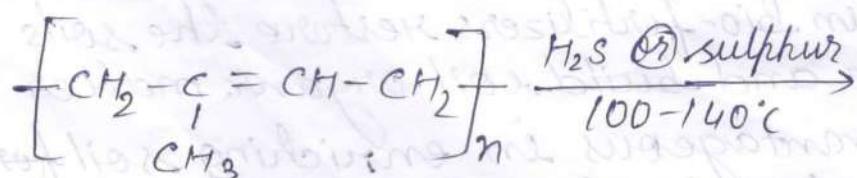
9. What is pesticide? Give two example?

⇒ Pesticides are the chemical compound used to kill pest including insects, rodents, weeds/herbs, fungi, algae etc.

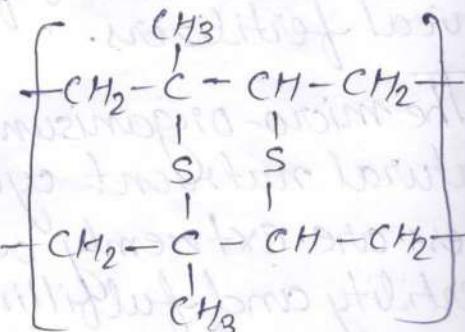
Example: DDT, BHC (Grammaxene)

10. Explain vulcanization of rubber. Give the properties of vulcanized rubber?

⇒ • Vulcanization is the heating of raw rubber with compounding agent like sulphur or hydrogen sulphide (H_2S) at $100-140^\circ C$



(Natural Rubber/
Raw Rubber)



(Vulcanized Rubber)

The properties of vulcanized Rubber :-

- It absorbs less water
- It is resistant to organic solvents like petrol, benzene, fats and oil.
- It is a better electrical insulator
- It has good tensile strength
- It possesses higher resistance to oxygen and oxidising agents.
- It works in -40°C to 100°C
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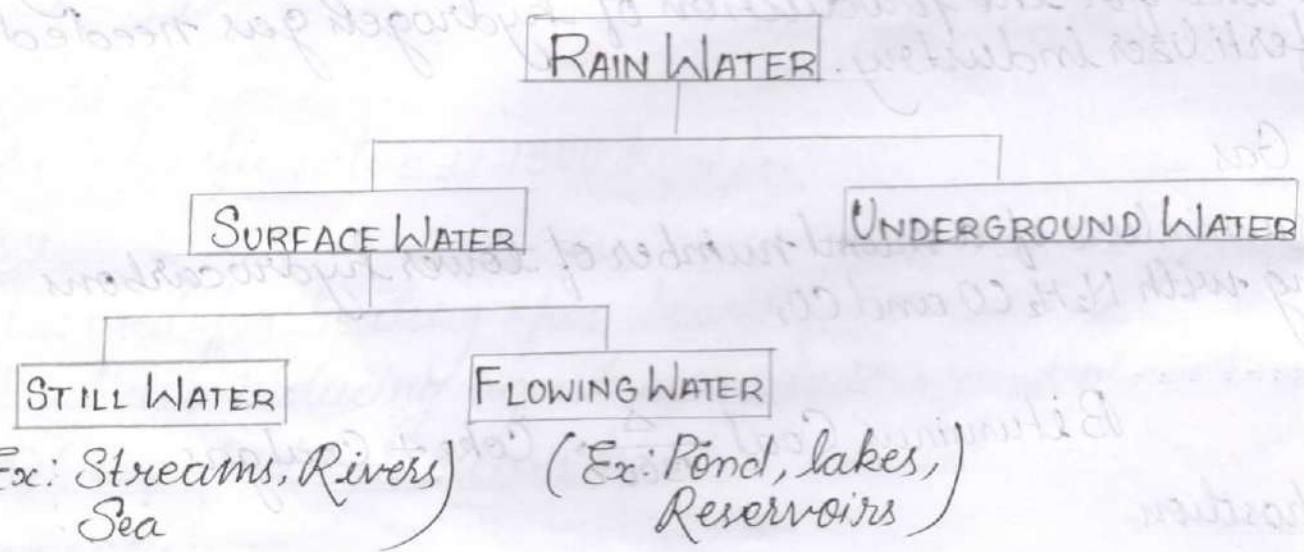
CHAPTER: 10

WATER TREATMENT

Uses

- Every form of life needs water
- It is used for domestic as well as industrial sector like dying, pharmaceutical industries food, construction side etc.

Sources of water



Introduction to water

- Water is a very useful compound with unique physical properties. It is the most abundant compound in the biosphere of earth.
- These properties are related to its electronic structure, bonding and chemistry
- Water possesses both acidic and alkaline nature

► Hence water is used for several properties

- Essential for all living beings
- Useful for drinking, bathing sanitary and washing purpose.
- Occupies unique position in industries
- Also useful for irrigation and fire fighting
- Useful for the production of steam generation.
- Used as a coolant in power and chemical parts.
- Useful for the production of steel, rayon, paper etc.
- It is also used in air conditioning.
- It is also useful in atomic energy, textiles, chemical industries and preparation of ice.

Source of water

► The source of water is broadly classified into four.

- Surface water
- Underground water
- Rain water (main source of water)
- Sea water.

Surface Water

- Flowing water: Rivers and streams
- Still water: Ponds and Lakes

Underground Water

- Spring water
- Shallow well water
- Dell well water
- Sea water
- Rain water. (purest form of water)

Impurities in water

- Dissolved Impurities
- Suspended Impurities
- Microscopic Impurities / Matter

Dissolved Impurities

- Inorganic salts.
 - The carbonates, bicarbonates, chlorides (Anions CO_3^{2-} , Cl^{2-} , SO_4^{2-} , NO_3^- etc) and sulphates of calcium, magnesium, potassium, iron and aluminum (Cations: Ca^{2+} , Mg^{2+} , Na^+ , K^+ , Fe^{3+} , Al^{3+} etc).
- Organic salt
 - Humic acid, amino acid, proteins and organic waste products.
- Dissolved gases
 - O_2 , CO_2 , N_2 oxides of nitrogen, NH_3 , H_2S

Suspended Impurities

- Inorganic : Clay and sand.
- Organic : Oil globules, vegetables and animal material.

Microscopic Impurities/ Matter

- Algae
- Bacteria
- Fungi

Types of water

① Hardness of water.

- Based on the soap action, water is of two types.
 - Soft water
 - Hardwater.

① Soft Water

The water which forms lather easily with soap is called soft water.

Example: Distilled water and rain water

① Hard Water

The water which does not form lather easily with soap but forms a white curdy precipitate is called hard water.

Example : Sea Water, River, pond, lake, sea.

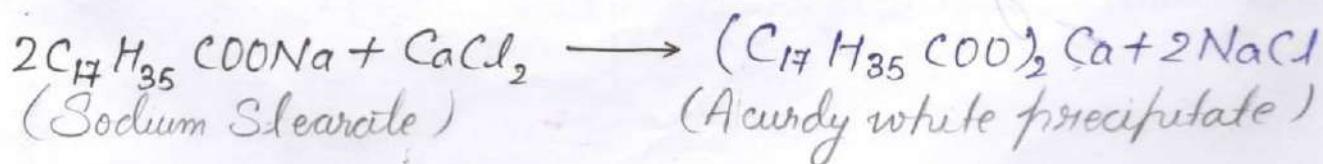
• Action of soap

Soap is described chemically as a sodium or potassium salt of higher fatty acids like stearic acid, palmitic or oleic acid.

HARD WATER

● Nature of hard water

- The water which does not form lather easily with soap but forms a white curdy precipitate is called hard water.
 - If soap is added to hard water
 - A curdy white precipitate is formed. This is due to the formation of calcium or magnesium soap.



- It contains dissolved calcium and mag.
- A lot of soap is wasted during washing and bathing
- Boiling point of water is elevated due to dissolved salts.
- So, it requires more fuel and time for cooking in hard water.

CAUSES OF HARDNESS

- Hardness of water is due to the presence of dissolved salts like bicarbonates, chlorides, sulphates of calcium and magnesium.
- These soluble salts get mixed with the natural water.
- Natural water that flows over the rocks containing chlorides and sulphates of calcium and magnesium.
- These salts dissolved in water gets hardness

VALUES OF HARDNESS

Description	Hardness Range (mg/l as CaCO_3)
Soft	0 - 75
Moderately Hard	75 - 100
Hard	100 - 300
Very hard	> 300

SOFT WATER

● Nature of soft water

- If soap is added to soft water, it is dissolved and lather is formed immediately.

Example:



(Sodium Stearate) (Formation of Lather)

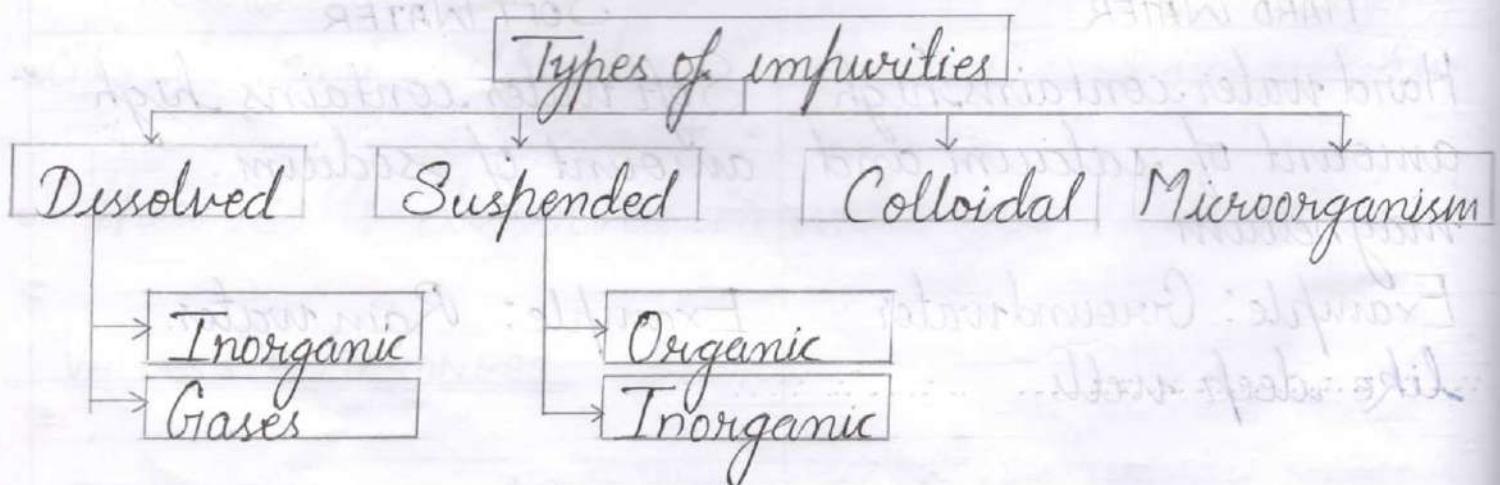
- It doesn't contain dissolved calcium and magnesium salts.
- Soap is not wasted during washing and bathing.
- Less fuel and time is required for cooking in soft water.

Differences between hard water and soft water.

HARD WATER	SOFT WATER
Hard water contains high amount of calcium and magnesium	Soft water contains high amount of sodium.
Example: Groundwater like deep wells	Example: Rain water.

Impurities in water

- Water may contain various impurities due to,
 - The ground or soil with which it comes in contact (example: Garbage, soil particles etc)
 - Its contact with sewage or industrial wastes
 - The decomposition of dead plants and animals
 - The growth of bacteria, algae, viruses etc.
 - The common impurities present in natural water can be classified into four groups that are as follows.
- Suspended impurities
- Inorganic - Sand, clay, lime, etc.
 - Organic - Plant and animal materials like discarded vegetables, dry leaves, dead materials, etc



Dissolved impurities

- Dissolved gases - NO_2 , CO_2 , SO_2 etc. which are soluble in water and make it impure
- Dissolved inorganic salts or ions
 - Cations : Ca^{2+} , Mg^{2+} , Na^+ , K^+ , Fe^{2+} , Al^{3+} , Zn^{2+} , etc.
 - Anion : CO_3^{2-} , SO_4^{2-} , HCO_3^- , Cl^- , etc.

Colloidal impurities

- Finely divided silica, clay, organic products colouring matter etc.

Microorganism

- Various pathogenic microorganisms such as bacteria, fungi, virus etc.
- The various types of impurities present in the water impact certain properties in water.
 - Presence of different chemicals impart colour, odour and taste to the water.
 - Presence of dissolved salt makes the water hard.
 - Excess quantities of metals and dissolved gases make the water corrosive in nature.
 - Presence of pathogenic bacteria in water makes it unfit for drinking or domestic purpose.
 - Suspended matter creates turbidity to the water.

SOURCES OF IMPURITIES IN WATER

The sources of impurities in water are the following
Water collects impurities from the ground, rocks or soil with which it comes in contact.

Water becomes impure when it comes in contact with sewage or industrial wastes.

Organic impurities in water are generally introduced by the decomposition of plant and animal remains
Gases like org oxygen and carbon dioxide are picked up by rainwater from the atmosphere.

EXPRESSION OF HARDNESS OF WATER

- Hardness of water is expressed in terms of number of parts of CaCO_3 (or) its equivalent present in a particular quantity of water because.
- CaCO_3 is the most insoluble salt which can be precipitated in water treatment.
- Molecular weight of CaCO_3 is 100 and its equivalent weight is 50 which is easy for calculations

Calcium carbonate equivalent

- Hardness of water is expressed in terms of parts of CaCO_3 (or) its equivalent present in a particular quantity of water because.
- If water contains CaCO_3 alone, the hardness is a measure of number of parts of CaCO_3 .
- Usually, water contains some other salts.
- Hence, all the hardness-causing impurities are first converted in terms of their respective weights equivalent to CaCO_3 by using the relation.

$$\text{CaCO}_3 \text{ equivalent} = \frac{\text{Weight of hardness producing salt} \times \text{Molecular weight of the salt}}{\text{Molecular weight of } \text{CaCO}_3}$$

CaCO_3 equivalent = Weight of hardness producing salt
 $\frac{\text{Equivalent weight of the salt}}{\text{Equivalent weight of CaCO}_3} \times$ Equivalent weight of CaCO_3

S.NO	Molecular formula of salt	Molecular weight
01	$\text{Mg}(\text{HCO}_3)_2$	146
02	$\text{Ca}(\text{HCO}_3)_2$	162
03	CaCO_3	100
04	MgCO_3	89
05	CaSO_4	136
06	MgSO_4	120
07	CaCl_2	111
08	MgCl_2	95
09	Ca^{2+}	40
10	Mg^{2+}	24
11	$\text{Ca}(\text{NO}_3)_2$	164
12	$\text{Mg}(\text{NO}_3)_2$	148

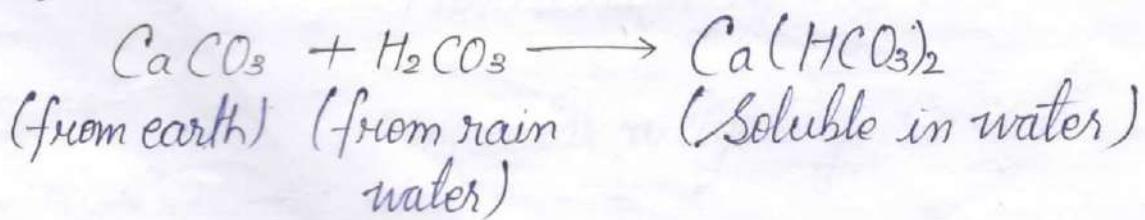
Molecular weights hardness producing salts

REASON FOR FORMATION OF LATHER EASILY

- Soap is a sodium or potassium salt of fatty acids like stearic acid, palmitic acid & oleic acid.
- Whenever soap is added to salt water, it ionises into anion of fatty acid & Na^+ .
- This anion involves in the cleaning action. So lather forms easily.
- $\text{C}_{17}\text{H}_{35}\text{COONa} \xrightarrow{\text{H}_2\text{O}} \text{C}_{17}\text{H}_{35}\text{COO}^- + \text{Na}^+$
(Sodium Stearate) (Stearate anion)
(Soap)

WHY THIS HARDNESS

- During first shower of rain carbon dioxide of air dissolves in water to form carbonic acid (H_2CO_3).
$$\text{CO}_2 + \text{H}_2\text{O} \longrightarrow \text{H}_2\text{CO}_3$$
- The above water containing H_2CO_3 reacts with calcium carbonate present in earth to form soluble calcium bicarbonate.
- The presence of bicarbonates in water make its temporary hard.

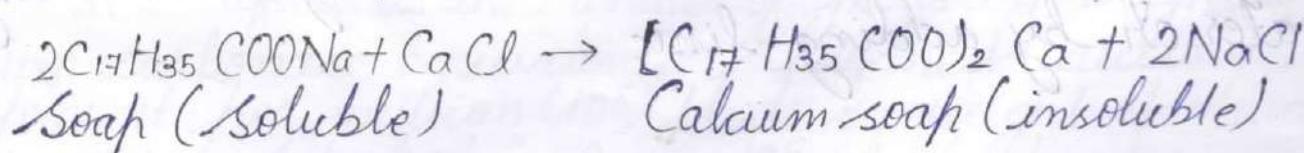


CAUSES OF HARDNESS

- Hardness: The lather preventing property of soap with water is called 'Hardness'.
 - The hardness of water is due to presence of dissolved salts like bi-carbonates, chlorides & sulphates of calcium & magnesium
 - When soap is treated with hard water, it forms insoluble calcium or magnesium salt of fatty acid.
 - It is precipitated as a white curdy substance

HARDNESS OF WATER

- Hardness was originally defined as the soap consuming capacity of a water sample
 - Soap generally consists of the sodium salt of long chain fatty acid such as oleic acid, palmitic acid and stearic acid.
 - The soap consuming capacity of water is mainly due to the presence of calcium and magnesium ions
 - These ions reacts with the sodium salts of long chain fatty acids present in the soap to form insoluble of calcium and magnesium soaps which do not possess any detergent value.



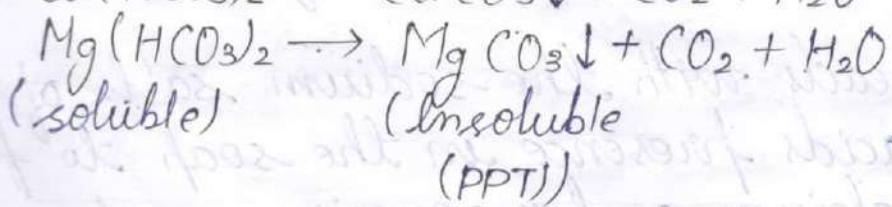
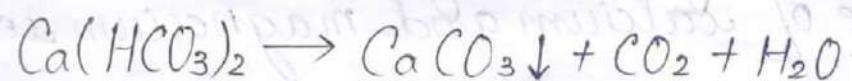
- Other metal ions like Fe^{2+} , Mn^{2+} and Al^{3+} also reacts with the soap in the same fashion, thus contributing to hardness but generally, these are present in natural water only in traces.
- Further, acids such as carbonic acid can be also cause free fatty acid to separate from soap solution and thus contribute to hardness.
- However, in practice, the hardness of a water sample is usually taken as a measure of its Ca^{2+} and Mg^{2+} content

TYPES OF HARDNESS

- The hardness of water is two types.
 - Temporary hardness (Carbonate Hardness)
 - Permanent hardness (Non-carbonate Hardness)

Temporary hardness (Carbonate Hardness)

- The hardness causes due to presence of dissolved bicarbonates of calcium and magnesium is called temporary hardness. (The formula of these compound is $\text{Ca}(\text{HCO}_3)_2$ and $\text{Mg}(\text{HCO}_3)_2$).



- This type of hardness can be removed by mere boiling of water or by adding lime

- Water Whenever water is boiled, the bicarbonates decompose to form insoluble carbonates which can be removed by filtration method.

● Permanent hardness (Non-Carbonate hardness)

- The hardness cause due to the presence of chlorides and sulphates of calcium and magnesium is called permanent Hardness. (The formula of these compounds are CaCl_2 , MgCl_2 , CaSO_4 , MgSO_4).
- Permanent hardness can't be removed by boiling
- It is removed by special methods like ion exchange process, permulti process etc.

UNITS OF HARDNESS

- There are four units of hardness.

- Parts Per Million (PPM)
- Milligrams per liter (mg/l)
- Clarke's degree of hardness ($^{\circ}\text{CL}$)
- French degree of hardness ($^{\circ}\text{F}$)

● Parts Per Million (PPM)

It is defined as the number of parts by weight of calcium carbonate equivalents of hardness causing salts present per million (10^6) parts by weight of water i.e. $1 \text{ ppm} = 1 \text{ parts of } \text{CaCO}_3 \text{ in } 10^6 \text{ parts of water}$.

- This is the most common unit for expressing the hardness of water.

Water	Parts Per Million
Soft	Less than 17
Slightly hard	17 to 60
Moderately hard	60 to 120
Hard	120 to 180
Very hard	Greater than 180

Milligram Per liter (mg/l)

It is defined as the number of milligrams of CaCO_3 equivalents of hardness causing salts present in one liter of water i.e $1 \text{ mg/liter} = 1 \text{ mg of CaCO}_3$ equivalent hardness in 1 liter of water.

$$\begin{aligned}\text{Since, Wt. of 1 liter of water} &= 1 \text{ Kg} = 1000 \text{ g} \\ &= 1000 \times 1000 \text{ mg} \\ &= 10^6 \text{ mg}\end{aligned}$$

Water hardness Scale	
Milligrams Per liter (mg/l)	Classification
Less than 17.1	Soft
17.1 - 60	Slightly hard
60 - 120	Moderately hard
120 - 180	Hard
over 180	Very hard

$1 \text{ mg/liter} = 1 \text{ mg of } \text{CaCO}_3$ Per 10^6 mg of water
 $= 1 \text{ part of } \text{CaCO}_3 \text{ per } 10^6 \text{ parts of water}$
 $= 1 \text{ ppm i.e. } 1 \text{ mg/liter} = 1 \text{ ppm}$

- Thus, mathematically both the units are equal.

④ Clarke's degree of hardness (${}^\circ\text{Cl}$)

- It is the number of grains of CaCO_3 equivalents present per gallon (10 lbs or 70,000 grains) water.
- It is the parts of CaCO_3 equivalent hardness per 70,000 parts of water (1 lb = 7000 grains and 1 gallon = 70,000 grains).

$1 {}^\circ\text{Cl} = 1 \text{ grain of } \text{CaCO}_3 \text{ per gallon of water.}$

$1 {}^\circ\text{Cl} = 1 \text{ part of } \text{CaCO}_3 \text{ per 70,000 parts of water}$

$1 {}^\circ\text{Cl} = 14.3 \text{ ppm.}$

⑤ French degree of hardness (${}^\circ\text{Fr}$)

It is defined as the number of parts of CaCO_3 equivalent hardness present per lakh or 105 parts of water

i.e. $1 {}^\circ\text{Fr} = 1 \text{ part of } \text{CaCO}_3 \text{ equivalent hardness per } 10^5 \text{ parts of water.}$

⑥ Interrelation between various units of hardness.

General hardness table

dH	mg/l (ppm)	Hardness
0-4 dH	0-70 ppm	very soft
4-8 dH	70-140 ppm	Soft
8-12 dH	140-210 ppm	Medium hard
12-18 dH	210-320 ppm	Fairly hard
18-30 dH	320-530 ppm	Hard

• $1 \text{ ppm} = 1 \text{ mg/liter} = 0.1^\circ \text{Fr} = 0.07^\circ \text{Cl}$

- $1 \text{ ppm} = 1 \text{ mg/liter} = 10^5 / 10^6^\circ \text{Fr} = 0.1^\circ \text{Fr}$

- $1 \text{ ppm} = 1 \text{ mg/liter} = 70,000^\circ \text{Cl} / 10^6 = 0.07^\circ \text{Cl}$

- So, $1 \text{ ppm} = 1 \text{ mg/liter}$

• $1^\circ \text{Cl} = 1.433^\circ \text{Fr} = 14.33 \text{ ppm} = 14.33 \text{ mg/liter}$

- $1^\circ \text{Cl} = 105 / 70,000^\circ \text{Fr} = 1.433^\circ \text{Fr}$

- $1^\circ \text{Cl} = 106 / 70,000 \text{ ppm} = 14.33 \text{ ppm} = 14.33 \text{ mg/liter}$

- So, $1^\circ \text{Cl} = 1.433^\circ \text{Fr} = 14.33 \text{ ppm} = 14.33 \text{ mg/liter}$

• $1^\circ \text{Fr} = 0.7^\circ \text{Cl} = 10 \text{ ppm} = 10 \text{ mg/liter}$

- $1^\circ \text{Fr} = 70,000 / 105^\circ \text{Cl} = 0.7^\circ \text{Cl}$

- $1^\circ \text{Fr} = 106 / 105 \text{ ppm} = 10 \text{ ppm} = 10 \text{ mg/liter}$

- So, $1^\circ \text{Fr} = 0.7^\circ \text{Cl} = 10 \text{ ppm} = 10 \text{ mg/liter}$.

CALCIUM CARBONATE EQUIVALENT

- The degree of hardness means the strength of hardness causing substances present in water. Hardness of water is never present in the form of calcium carbonate because it is insoluble in water. But it is expressed in terms of CaCO_3 equivalent.

Calculation of temporary hardness

- Temporary hardness due to the presence of bicarbonates of calcium and magnesium.
i.e., $\text{Ca}(\text{HCO}_3)_2$ and $\text{Mg}(\text{HCO}_3)_2$

$$\text{Temporary hardness} = \text{Hardness due to } \text{Mg}(\text{HCO}_3)_2 + \text{Hardness due to } \text{Ca}(\text{HCO}_3)_2$$

Solved Problems

Problem 1

- Calculate the temporary hardness of a sample water containing the following per liter
 - (a) $\text{Mg}(\text{HCO}_3)_2 = 7.3 \text{ mg}$
 - (b) $\text{Ca}(\text{HCO}_3)_2 = 16.2 \text{ mg}$

Solution

The formula used to solve this problem is

$$\text{CaCO}_3 \text{ Equivalent} = \frac{\text{Weight of the salt}}{\text{Molecular weight of the salt}} \times 100$$

Calculation of CaCO_3 equivalents.

Salt	Weight	Molecular Weight	CaCO_3 equivalent = weight / M.W. $\times 100$
$\text{Mg}(\text{HCO}_3)_2$	7.3 mg	146	$\frac{7.3}{146} \times 100 = 5 \text{ mg/l}$
$\text{Ca}(\text{HCO}_3)_2$	16.2 mg	162	$\frac{16.2}{162} \times 100 = 10 \text{ mg/l}$

Temporary hardness = hardness due to $Mg(HCO_3)_2$ + Hardness due to $Ca(HCO_3)_2$

$$= 5 + 10 = 15$$

Temporary hardness = 15 mg/l

● Calculation of Permanent hardness.

- The permanent hardness caused by chloride, sulphates of Ca and Mg.

Permanent hardness = hardness due to $CaSO_4$ + hardness due to $MgSO_4$ + hardness due to $CaCl_2$ + Hardness due to $MgCl_2$

Problem-02

- Calculate the permanent hardness of a sample water containing the following per liter.

(a) $CaSO_4$ = 13.6 mg

(b) $MgCl_2$ = 9.5 mg

(c) $CaCl_2$ = 11.1 mg

(d) $MgSO_4$ = 12.0 mg.

Solution

The formula used to solve this problem is

$$CaCO_3 \text{ Equivalent} = \frac{\text{Weight of the salt}}{\text{Molecular weight of the salt}} \times 100$$

$$(a) \text{CaSO}_4 = 13.6 \text{ mg}$$

$$\text{weight} = 13.6 \text{ mg}$$

$$\text{Molecular weight} = 136$$

$$\text{CaCO}_3 \text{ equivalent} = \frac{13.6}{136} \times 100 = 10 \text{ mg/l}$$

$$(b) \text{MgCl}_2 = 9.5 \text{ mg}$$

$$\text{weight} = 9.5 \text{ mg}$$

$$\text{M.W} = 95$$

$$\text{CaCO}_3 \text{ equivalent} = \frac{9.5}{95} \times 100 = 10 \text{ mg/l}$$

$$(c) \text{CaCl}_2 = 11.1 \text{ mg}$$

$$\text{weight} = 11.1 \text{ mg}$$

$$\text{M.W} = 111$$

$$\text{CaCO}_3 \text{ equivalent} = \frac{11.1}{111} \times 100 = 10 \text{ mg/l}$$

$$(d) \text{MgSO}_4 = 12.0 \text{ mg}$$

$$\text{weight} = 12.0 \text{ mg}$$

$$\text{M.W} = 120$$

$$\text{CaCO}_3 \text{ equivalent} = \frac{12.0}{120} \times 100 = 10 \text{ mg/l}$$

Permanent hardness = hardness due to CaSO_4 + hardness due to MgSO_4 + hardness due to CaCl_2 + hardness due to MgCl_2

$$\text{Permanent hardness} = 10 + 10 + 10 + 10 = 40 \text{ mg/l (or) ppm}$$

Estimation of total hardness

- After estimating the temporary hardness and permanent hardness, one can estimate total hardness in the following way.

$$\text{Total hardness} = \text{Temporary hardness} + \text{Permanent hardness}$$

i.e. Total hardness = Hardness due to $\text{Mg}(\text{HCO}_3)_2$ + hardness due to $\text{Ca}(\text{HCO}_3)_2$ + hardness due to CaCl_2 + hardness due to CaSO_4 + hardness due to MgCl_2 + hardness due to MgSO_4

- Permanent hardness = Total hardness - Temporary hardness.
- Temporary hardness = Total hardness - Permanent hardness.

Problem 03

- Calculate the total hardness of a sample water containing the following per liter.

$$(a) \text{Ca SO}_4 = 13.6 \text{ mg}$$

$$(b) \text{Mg}(\text{HCO}_3)_2 = 7.3 \text{ mg}$$

$$(c) \text{Ca}(\text{HCO}_3)_2 = 16.2 \text{ mg}$$

$$(d) \text{Mg Cl}_2 = 9.5 \text{ mg}$$

$$(e) \text{Ca Cl}_2 = 11.1 \text{ mg}$$

$$(f) \text{Mg SO}_4 = 12.0 \text{ mg}$$

• Solution

The formula used to solve this problem is.

$$\text{CaCO}_3 \text{ Equivalent} = \frac{\text{Weight of the salt}}{\text{Molecular weight of the salt}} \times 100$$

• Calculation of CaCO_3 equivalents

(a) $\text{CaSO}_4 = 13.6 \text{ mg}$

weight = 13.6 mg

M.W = 136 mg

$$\text{CaCO}_3 \text{ equivalent} = \frac{13.6 \times 100}{136} = 10 \text{ mg/l}$$

(b) $\text{Mg}(\text{HCO}_3)_2 = 7.3 \text{ mg}$

weight = 7.3 mg

M.W = 146

$$\text{CaCO}_3 \text{ equivalent} = \frac{7.3 \times 100}{146} = 5 \text{ mg/l}$$

(c) $\text{Ca}(\text{HCO}_3)_2 = 16.2 \text{ mg}$

weight = 16.2 mg

M.W = 162

$$\text{CaCO}_3 \text{ equivalent} = \frac{16.2 \times 100}{162} = 10 \text{ mg/l}$$

(d) $\text{MgCl}_2 = 9.5 \text{ mg}$

weight = 9.5 mg, M.W = 95

$$\text{CaCO}_3 \text{ equivalent} = \frac{9.5 \times 100}{95} = 10 \text{ mg/l}$$

(e) $\text{CaCl}_2 = 11.1 \text{ mg}$

weight = 11.1 mg, M.W = 111

$$\text{CaCO}_3 \text{ equivalent} = \frac{11.1 \times 100}{111} = 10 \text{ mg/l}$$

(f) $\text{MgSO}_4 = 12.0 \text{ mg}$

weight = 12.0 mg, M.W = 120

$$\text{CaCO}_3 \text{ equivalent} = \frac{12.0}{120} \times 100 = 10 \text{ mg/l}$$

Temporary hardness = hardness due to $\text{Mg}(\text{HCO}_3)_2$ + hardness due to $\text{Ca}(\text{HCO}_3)_2$
= $5 + 10 = 15 \text{ mg/l (or) ppm}$

Permanent hardness = hardness due to CaSO_4 + hardness due to MgSO_4 + hardness due to CaCl_2 + hardness due to MgCl_2
= $10 + 10 + 10 + 10 = 40 \text{ mg/l (or) ppm}$

Total hardness = Temporary hardness + Permanent hardness
= $15 + 40 = 55 \text{ mg/l (or) ppm}$

DISADVANTAGES OF HARD WATER

• This dissolved salts cause undesirable effects when hard water is used for various purpose like

- Domestic use
- Industrial use

● DOMESTIC USE

• Washing and bathing

➤ Hard water does not form lather easily with soap. As a result, a large amount of soap is wasted.

• Cooking

➤ The Boiling of water is increased due to presence of salts. Hence more fuel and time are required for cooking.

• Drinking

➤ Hard water cause bad effect on our digestive system. Some times, stone formation takes places either in kidney or Gal bladders.

● INDUSTRIAL USE

• Textile industry

➤ Hard water causes wastage of soap on washing yarn. Precipitates of calcium and magnesium soaps ads. There to the fabrics and cause problem.

• Paper industry

➤ Calcium, magnesium salts in water may effe the quantity of paper.

• Sugar industry

➤ Water containing sulphates, carbonates, chlorides affect the crystallization of sugar.

- Dyeing industry
- The salts of calcium and magnesium in hard water react with dyes and affect the desired shade.
- Boilers
- If hard water is used in the boilers for steam generation, it leads to the problems of scale formation and danger of explosion.

EXTERNAL CONDITIONING

- It involves the removal of hardness producing salts from the water before feeding into the boiler.
- The external treatment can be done by the following methods.
 - Lime soda process [Precipitation method].
 - Zeolite (or) Permunt process (ion-exchange method)
 - Demineralisation (or) De-ionisation (ion-exchange method)
- The above processes are the example of water softening.
- In an ion-exchange process, a reversible exchange of ions taking place between a stationary solid phase and an external liquid mobile phase.

Introduction (Lime soda Process [Precipitation method])

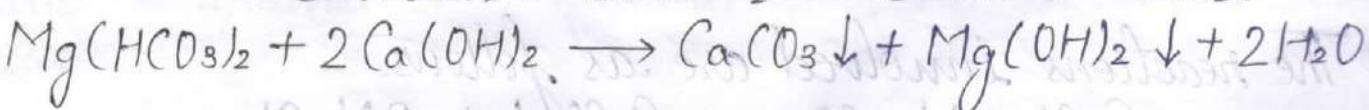
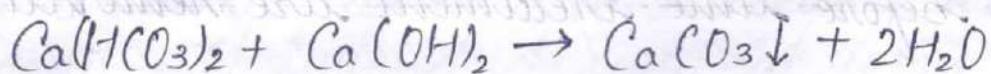
➤ The lime soda process is a very important method used for the softening of water.

Principle

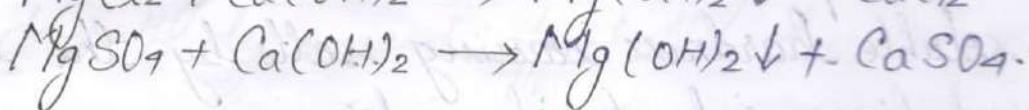
- The lime soda process involves the chemical conversion of all the soluble hardness causing salts by the addition of soda and lime into hard water.
- The soluble salts in the water is convert into insoluble precipitates which could easily be removed by settling and filtration.
- In this process water to be softened is treated with calculated amount of lime Ca(OH)_2 and soda Na_2CO_3 .
- For quick completion of reactions, the reagents may be used in 10% excess.

Functions of Lime (Ca(OH)_2)

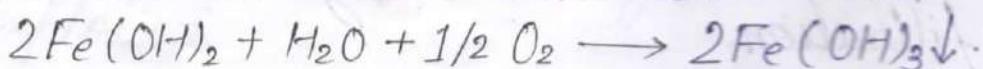
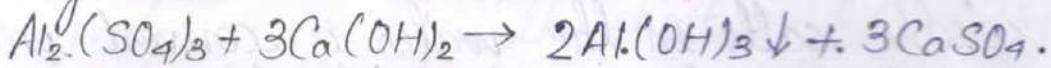
- Lime removes
 - Temporary hardness
 - Permanent magnesium hardness
 - Dissolved iron and aluminium salts
 - Dissolved CO_2 and H_2S gases
 - Free mineral acids present in water.
- The reaction involved are as follows.
 - Removal of temporary calcium and magnesium hardness



- Removal of permanent magnesium hardness



- Removal of dissolved iron and aluminium salts.



- Removal of dissolved CO_2 and H_2S



- Removal of free mineral acid

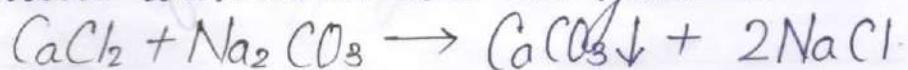


Functions of soda (Na_2CO_3)

• During the removal of Mg^{2+} , Fe^{2+} , Al^{3+} , HCl and H_2S by lime, permanent calcium hardness is introduced in the water due to formation of calcium salts.

• The permanent calcium hardness thus introduced on account of the treatment of water with lime and the permanent calcium hardness already present in water before lime treatment are removed by soda

• The reactions involved are as follows.



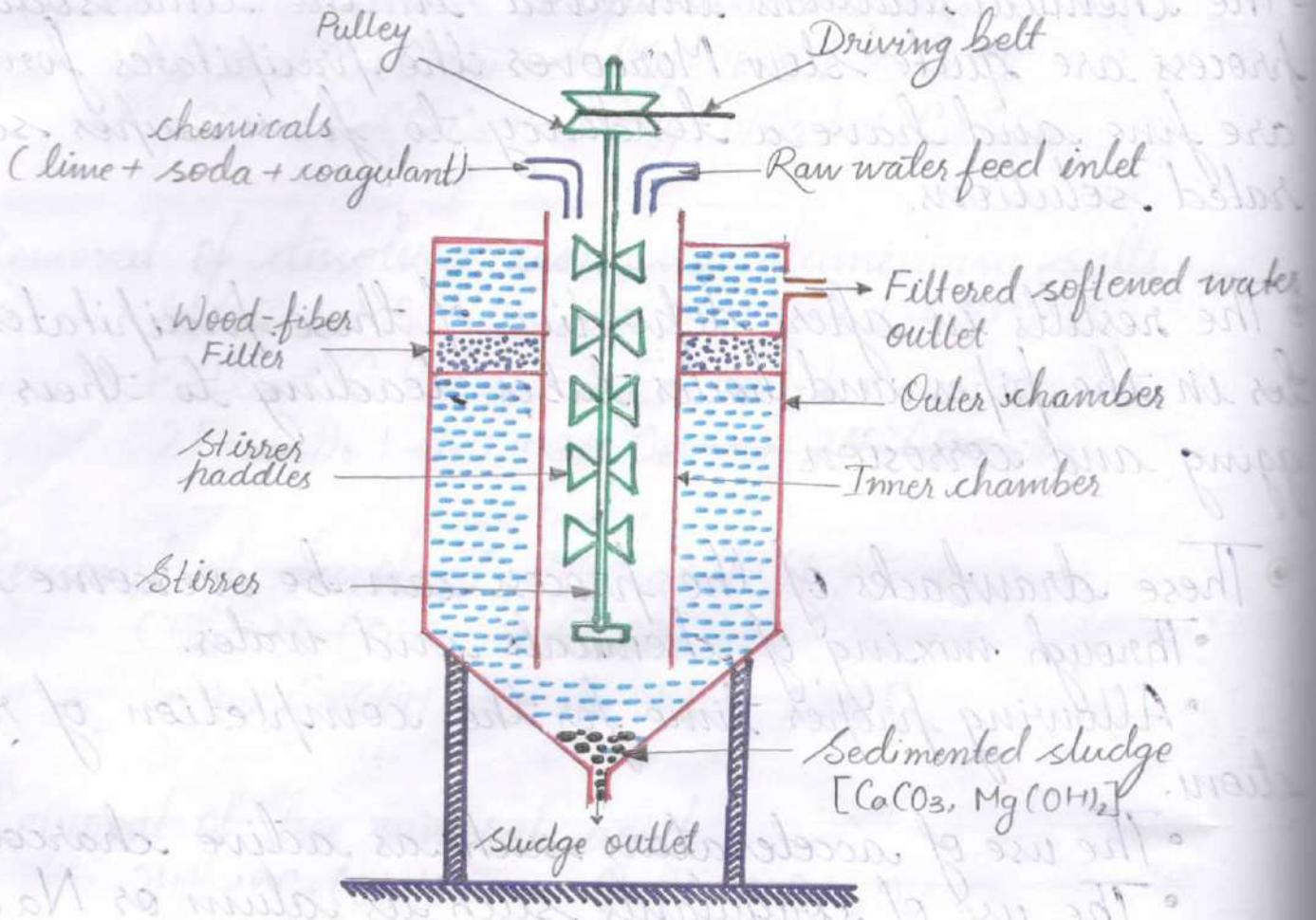
- The chemical reactions involved in the lime soda process are quite slow. Moreover the precipitates formed are fine and have a tendency to form super saturated solutions.
- The results in after deposition of these precipitates later in the pipes and boiler tubes leading to their clogging and corrosion
- These drawbacks of the process can be overcome by
 - Through mixing of chemicals and water.
 - Allowing proper time for the completion of reactions.
 - The use of accelerators such as active charcoal
 - The use of coagulants such as alum or NaAlO_2

✓ LIME SODA PROCESS

- The lime-soda process can be carried out both at room temperature as well as at higher temperature
- The process carried out at room temperature is called cold lime soda process and that process carried out at $99^\circ - 100^\circ \text{C}$ is called hot lime soda process.

✓ COLD LIME SODA PROCESS

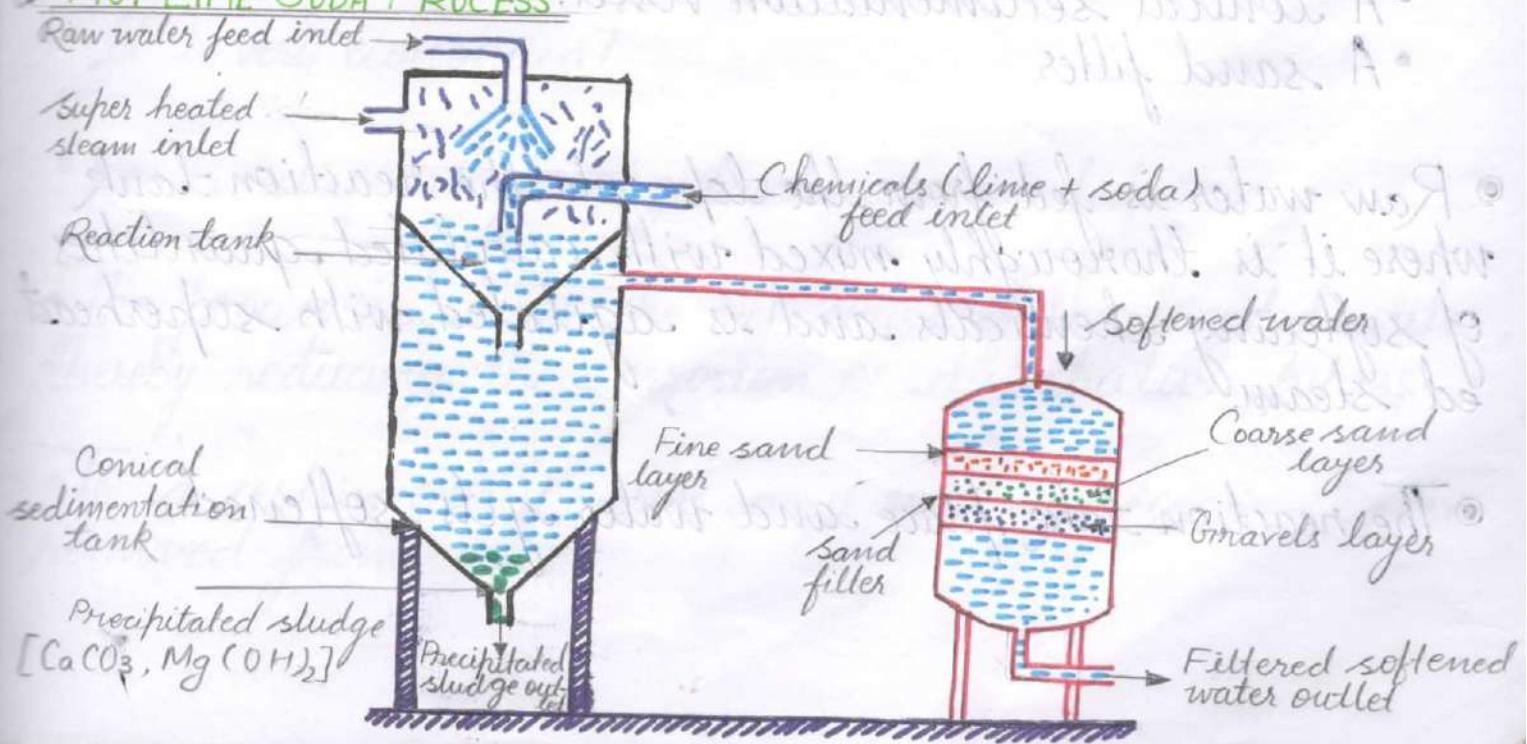
- In this method water to be softened is treated with calculated quantities of lime and soda at room temperature.



- Small amounts of a coagulant such as alum, aluminium sulphate, sodium aluminate, etc. are also added
- The coagulant helps the finely divided precipitate formed in the process to flocculate
- Sodium aluminate also helps in the removal of silica and oil present in water.
- The mixture of water calculated quantities of lime and soda and a small amount of a coagulant is fed from the top into the inner chamber of a vertical circular tank.

- The chamber is provided with a vertical rotating shaft carrying a number of paddles to ensure vigorous stirring and continuous mixing of water with the chemical added.
- The chemical reactions take place and the hardness producing salts get converted into insoluble precipitates which accumulate in the form of a heavy sludge.
- As the softened water reaches the outer coaxial chamber it rises upwards and is filtered by a wood fibre and finally taken out from an outlet provided at the top of the outer cylinder.
- The heavy sludge settles down at the bottom of the outer chamber and is taken out through an outlet.
- The softened water obtained from this process contains a residual hardness of about 50-60 ppm.

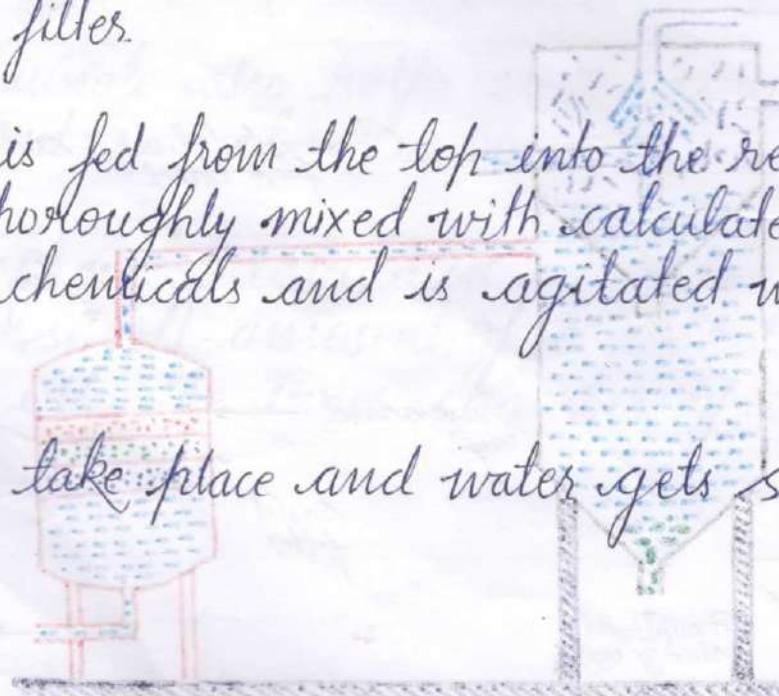
HOT LIME SODA PROCESS



- In this process, water is treated with the softening chemicals at a temperature of $94^{\circ}\text{--}100^{\circ}\text{C}$.
- Since the process is carried out at a temperature close to the boiling point of the solution.
- The reaction proceeds faster and the softening capacity of the process increases several times.
- At this temperature the viscosity of water is much less than that at room temperature. Hence rate of aggregation of particles increases and there is hardly any need of adding any coagulant.
- Moreover the dissolved gases also escape to some extent at the temperature of the process.

Method

- A typical hot lime soda water softening plant is shown in figure. It consists of
 - A reaction tank
 - A conical sedimentation vessel.
 - A sand filter.
- Raw water is fed from the top into the reaction tank where it is thoroughly mixed with calculated quantities of softening chemicals and is agitated with superheated steam.
- The reaction takes place and water gets softened.



The softened water containing sludge then enters into the sedimentation vessel where the sludge settles down.

The softened water rises up in the vessel while precipitated sludge is taken out through an outlet provided at the bottom of the vessel.

The softened water is then taken to a sand filter which ensures the complete removal of the sludge from softened water.

The softened water obtained from this process contains a residual hardness of 15-30 ppm.

Advantages of the process

- ① The hot lime soda process has the following advantages.
 - The process is much faster as compared to the cold lime soda process
 - It is very economical
 - Lesser amount of coagulants are needed
 - The process increases the pH value of the treated water, thereby reducing the corrosion of distribution pipes.
 - To a certain extent, iron and manganese are also removed from water.

- Much of dissolved gases in water are also removed
- Due to an increase in the pH, the amount of pathogenic bacteria is treated.

Disadvantages of the process

- The hot lime soda process has the following disadvantages
 - Disposal of large amount of sludge formed in the process poses problems.
 - The treated water obtained by this process is not completely softened: It still contains a residual hardness of about 15-30 ppm which is not good for boilers.

Comparison between cold and hot lime soda process

NUMERICAL CALCULATION

- The lime-soda process involves the conversion of soluble hardness producing salts into insoluble substances which could easily be removed.
- Besides the removal of hardness causing substances, the process also removes Fe^{2+} and Al^{2+} salts, free mineral acids such as HCl , H_2SO_4 and dissolved gases such as CO_2 and H_2S .
- From the chemical reaction involved in the process it is clear that.
 - One equivalent of temporary calcium hardness requires one equivalent of lime
 - One equivalent of temporary magnesium hardness requires two equivalent of lime.
 - One equivalent of temporary magnesium hardness requires one equivalent of lime.

- One equivalent each of Fe^{3+} , Al^{3+} , CO_2 , H_2S and H_2SO_4 requires one equivalent of lime.
- One equivalent of permanent magnesium hardness requires one equivalent of soda
- Soda not only removes permanent calcium hardness already present in water but also removes permanent calcium hardness introduced during the removal of permanent magnesium hardness, Fe^{3+} , Al^{3+} , HCl and H_2SO_4 by lime
- The calculation of the amount of lime and soda required for the treatment of a given sample of water
- It would be convenient to convert the amount of all the substances present in the sample in terms of CaCO_3 equivalent.
- As we have already seen CaCO_3 equivalent is given

$$\text{CaCO}_3 \text{ equivalent} = \frac{W \times 50}{E}$$

Where,

W = mass of the impurity

E = equivalent mass of the impurity

REQUIREMENT OF LIME AND SODA

The lime and soda requirements can be calculated as follows

Lime requirement

- ① 100 parts by mass of CaCO_3 are req equivalent to 79 parts by mass of Ca(OH)_2
- ② If the amount of impurities are expressed in terms of their CaCO_3 equivalent the amount of lime required to soften a given sample of water is given.

Lime required for softening

$$= \frac{79}{100} \times [\text{Temporary calcium hardness} + 2 \times \text{Temporary magnesium hardness} + \text{Permanent magnesium hardness} + \text{CO}_2 + \text{HCl} + \text{H}_2\text{SO}_4 + \text{Fe}^{2+} + \text{Al}^{3+} + \text{HCO}_3^- - \text{NaOH}_2] \text{ all expressed in terms of } \text{CaCO}_3 \text{ equivalents.}$$

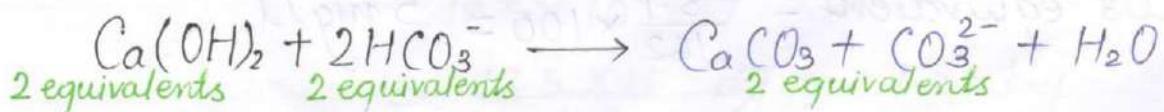
Soda requirement

- ① Soda required for softening

$$= \frac{106}{100} \times [\text{Permanent calcium hardness} + \text{Permanent magnesium hardness} + \text{HCl} + \text{H}_2\text{SO}_4 + \text{Fe}^{2+} + \text{Al}^{3+} - \text{HCO}_3^- - \text{NaAlO}_2 \text{ all expressed in terms of } \text{CaCO}_3 \text{ equivalents}]$$

- ② The following points are important to be noted.

- 1 equivalent HCO_3^- requires 1 equivalent of lime which simultaneously produces 1 equivalent of CO_3^{2-}



- 1 equivalent of CO_3^{2-} ions thus produced may be regarded as equivalent 1 equivalent of soda.
- This is why corresponding quantity of HCO_3^- in equivalent has been subtracted in the calculation of soda requirement.
- NaAlO_2 requires neither lime nor soda. However 1 equivalent of NaAlO_2 undergoes hydrolysis to produce 1 equivalent of OH^- which may be regarded as equivalent to 1 equivalent of lime.



NUMERICAL PROBLEMS

PROBLEM 01

- Calculate the quantity of lime and soda required softening of 1,00,000 liters of water containing the following salts per litre.

- $\text{Ca}(\text{HCO}_3)_2 = 8.1 \text{ mg}$
- $\text{Mg}(\text{HCO}_3)_2 = 7.3 \text{ mg}$
- $\text{CaSO}_4 = 13.6 \text{ mg}$
- $\text{MgSO}_4 = 12.0 \text{ mg}$

Solution

(a) $\text{Ca}(\text{HCO}_3)_2 = 8.1 \text{ mg}$
 $W = 8.1 \text{ mg}, M.W = 162$

$$\text{CaCO}_3 \text{ equivalent} = \frac{8.1}{162} \times 100 = 5 \text{ mg/l}$$

(b) $Mg(HCO_3)_2 = 7.3 \text{ mg}$
weight = 7.3 mg, M.W = 196

$$CaCO_3 \text{ equivalent} = \frac{7.3}{196} \times 100 = 5 \text{ mg/l}$$

(c) $CaSO_4 = 13.6 \text{ mg}$
weight = 13.6 mg, M.W = 136

$$CaCO_3 \text{ equivalent} = \frac{13.6}{136} \times 100 = 10 \text{ mg/l}$$

(d) $MgSO_4 = 12.0 \text{ mg}$
weight = 12.0, M.W = 120

$$CaCO_3 \text{ equivalent} = \frac{12.0}{120} \times 100 = 10 \text{ mg/l}$$

$$\text{Lime requirement} = \frac{74}{100} \times [\text{Temp. } Ca^{2+} + 2 \text{ temp. } Mg^{2+} + \text{Per. } Mg^{2+}]$$

$$= \frac{74}{100} \times [5 + (2 \times 5) + 10]$$

$$= \frac{74}{100} \times 25 = 18.5 \text{ mg/l}$$

The amount of lime required for 1 liter = 18.5 mg/l

The amount of lime required for 10^5 liters of water

$$= 18.5 \times 10^5 \text{ mg}$$

$$= \frac{18.5 \times 10^5}{10^6} \text{ Kg} = 1.85 \text{ Kg}$$

Lime required for 10^5 liters of water = 1.85 Kg

$$\text{Soda requirement} = \frac{106}{100} \times [\text{Per. } \text{Ca}^{2+} + \text{Per. } \text{Mg}^{2+}]$$

$$= \frac{106}{100} \times [10 + 10]$$

$$= \frac{106}{100} \times 20 = 21.2 \text{ mg/l}$$

The amount of soda required for 1 liter = 21.2 mg

The amount of soda required for 10^5 liters of water

$$= 21.2 \times 10^5 \text{ mg}$$

$$= \frac{21.2 \times 10^5}{10^6} \text{ Kg}$$

$$= 2.12 \text{ Kg}$$

Soda required for 10^5 liters of water = 2.12 Kg

Problem 02

- Calculate the quantity of lime and soda required for softening 80,000 liters of water containing the following salts per liter.

(a) $\text{Ca}(\text{HCO}_3)_2 = 40.5 \text{ mg}$

(b) $\text{Mg}(\text{HCO}_3)_2 = 14.6 \text{ mg}$

(c) $\text{CaCl}_2 = 22.2 \text{ mg}$

(d) $\text{MgCl}_2 = 19 \text{ mg}$

(e) $\text{NaCl} = 20 \text{ mg}$

Solution

(a) $\text{Ca}(\text{HCO}_3)_2 = 40.5 \text{ mg}$

weight = 40.5 mg, M.W = 162

$$\text{CaCO}_3 \text{ equivalent} = \frac{40.5}{162} \times 100 = 25 \text{ mg/l}$$

(b) $\text{Mg}(\text{HCO}_3)_2 = 14.6 \text{ mg}$

weight = 14.6 mg, M.W = 146

$$\text{CaCO}_3 \text{ equivalent} = \frac{14.6}{146} \times 100 = 10 \text{ mg/l}$$

(c) $\text{CaCl}_2 = 22.2 \text{ mg}$

weight = 22.2 mg, M.W = 111

$$\text{CaCO}_3 \text{ equivalent} = \frac{22.2}{111} \times 100 = 20 \text{ mg/l}$$

(d) $\text{MgCl}_2 = 19 \text{ mg}$

weight = 19 mg, M.W = 95

$$\text{CaCO}_3 \text{ equivalent} = \frac{19}{95} \times 100 = 20 \text{ mg/l}$$

(e) $\text{NaCl} = 20 \text{ mg}$

It doesn't produce hardness.

$$\text{Lime requirement} = \frac{74}{100} \times [\text{Temp. Ca}^{2+} + 2 \text{ Temp. Mg}^{2+} + \text{per. Mg}^{2+}]$$

$$= \frac{74}{100} \times [25 + (2 \times 10) + 20]$$

$$= \frac{74}{100} \times 65 = 48.1 \text{ mg/l}$$

Lime required for 1 litre of water = 98.1 mg
 Lime required for 80,000 liters of water = $98.1 \times 80,000$
 $= 3848000$
 $= \frac{3848000}{10^6} \text{ Kg}$
 $= 3.848 \text{ Kg}$

Lime required for 80,000 liters of water = 3.848 Kg

$$\begin{aligned}\text{Soda requirement} &= \frac{106}{100} \times [\text{Per. } \text{Ca}^{2+} + \text{Per. } \text{Mg}^{2+}] \\ &= \frac{106}{100} \times [20+20] \\ &= \frac{106}{100} \times 40 = 42.4 \text{ mg/l}\end{aligned}$$

Soda required for 1 liter of water = 42.4 mg
 Soda required for 80,000 liters of water = $42.4 \times 80,000 \text{ mg}$
 $= 3392000 \text{ mg}$
 $= \frac{3392000}{10^6} \text{ Kg}$
 $= 3.392 \text{ Kg}$

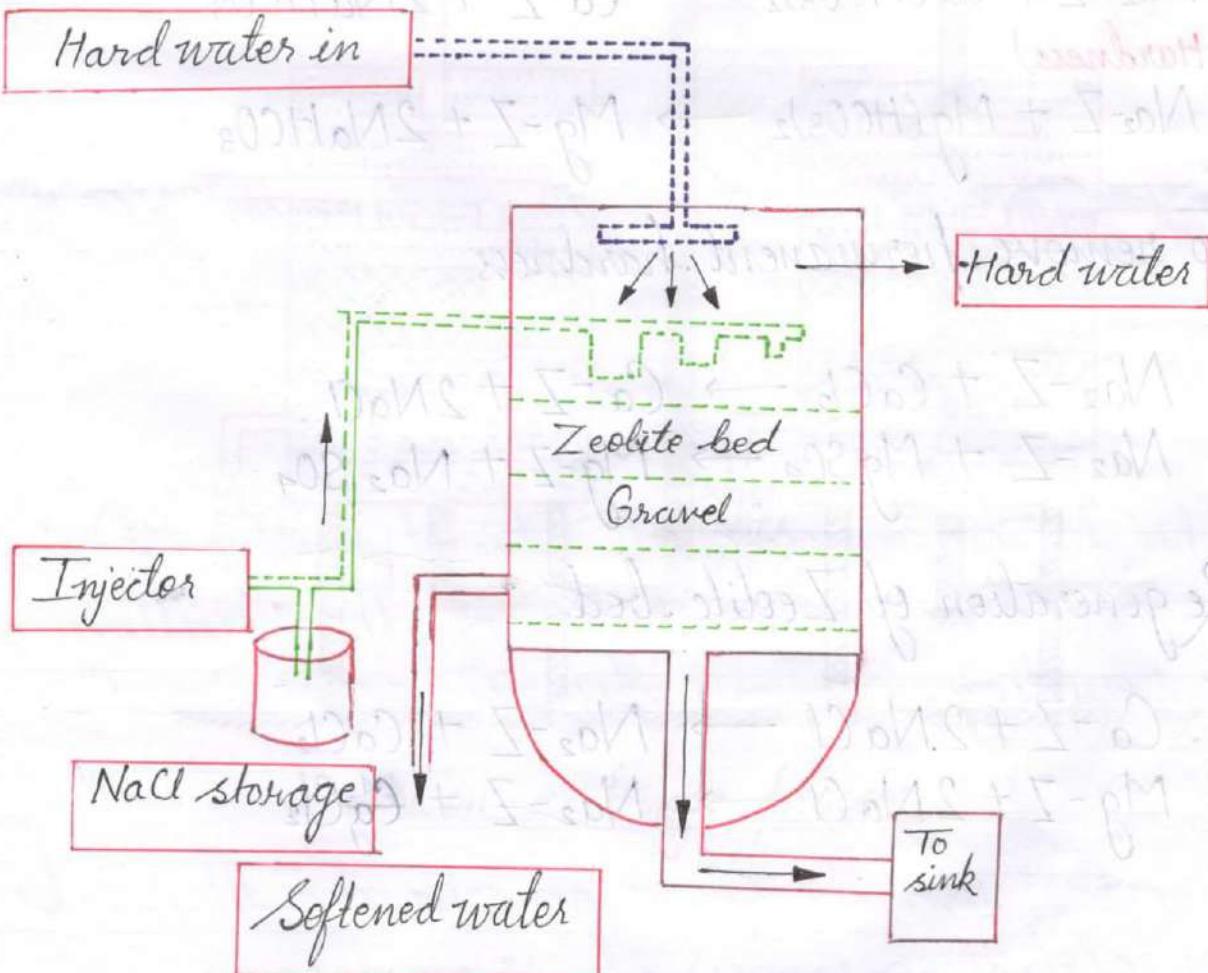
Soda required for 80,000 liters of water = 3.392 Kg

SOFTENING METHODS OF HARD WATER

- Zeolite Process
- Ion exchange Process

Zeolite (Permutit) method of softening of water

- Zeolite is a Hydrated Sodium Aluminium ortho Silicate (HSAS), capable of exchanging reversibly its sodium ions for hardness producing ions in water.
- The general chemical structure of Zeolite is given below
 $\text{Na}_2\text{Al}_2\text{Si}_2\text{O}_8 \cdot x\text{H}_2\text{O}$ [Sodium Zeolite]
- Synthetic Zeolite is better than natural Zeolite for the softening of water. Synthetic zeolites are non-porous.

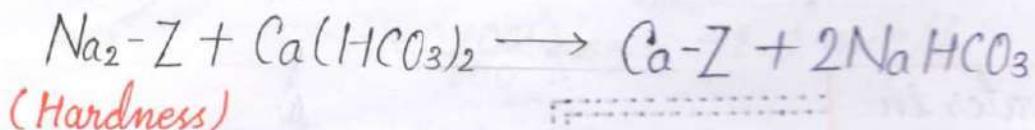


ZEOLITE PROCESS

● Process of softening by Zeolite method

- For the softening of water by the Zeolite softener, hard water is passed through the Zeolite bed at a specified rate.
- The hardness causing ions such as Ca^{2+} , Mg^{2+} are retained by the Zeolite bed as Ca-Z and Mg-Z respectively; while the outgoing water contains sodium salts.
- The following reactions takes place during softening process

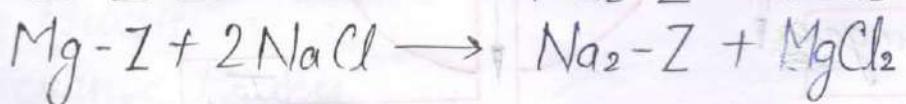
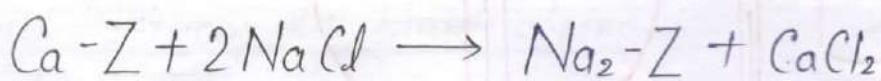
➤ To remove temporary hardness



➤ To remove permanent hardness



➤ Regeneration of Zeolite bed.



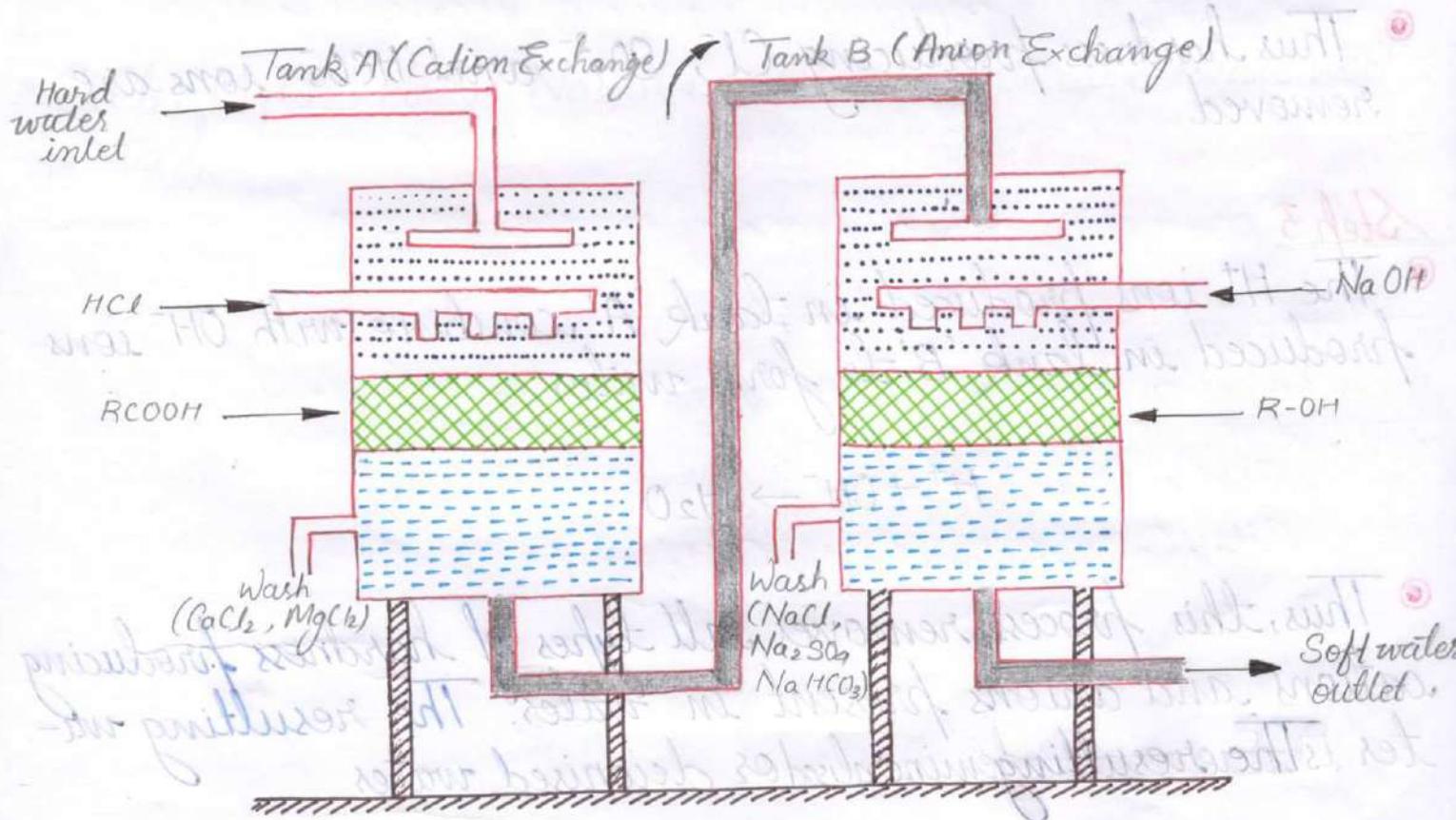
ION-EXCHANGE RESIN (OR) DEIONIZATION (OR) DEMINERALIZATION

PROCESS

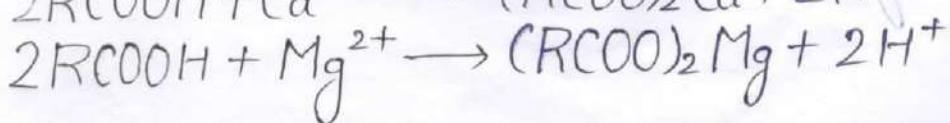
- Ion-exchange resin are insoluble, cross linked, long chain organic polymers and the functional groups attached to the chains can change their ions with hardness producing cations and anions in water.

Step 1

- The hard water is passed through a bed of cation exchange resin (RCOOH or RSO_3H) of tank 'A'. The Ca^{2+} and Mg^{2+} ions are exchanged with H^+ ions of the resin.



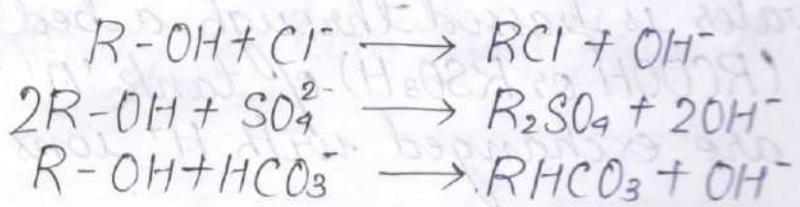
Ion-exchange process



- Thus hardness producing cations (Ca^{2+} and Mg^{2+}) are removed.
- The water coming out contains H^+ , Cl^- , SO_4^{2-} and HCO_3^- ions.

Step 2

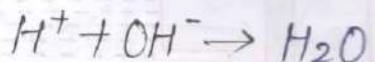
- The hard water is then passed through a bed of anion exchange resin (R-OH or R-NH_2) of tank 'B'. The Cl^- , SO_4^{2-} and HCO_3^- ions are exchanged with OH^- ions of the resin.



- Thus hardness producing Cl^- , SO_4^{2-} and HCO_3^- ions are removed.

Step 3

- The H^+ ions produced in tank 'A' combine with OH^- ions produced in tank 'B' to form water.

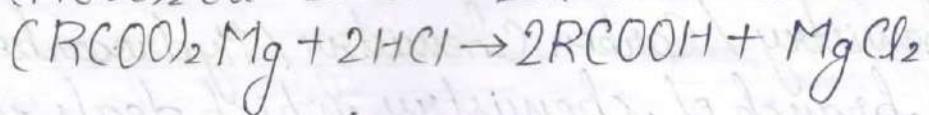
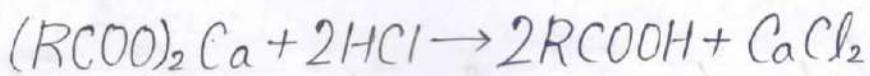


- Thus, this process removes all types of hardness producing cations and anions present in water. The resulting water is known as demineralised or deionised water.

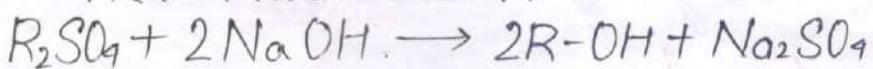
Regeneration of resins

- With constant use, the resins get exhausted. This can be regenerated as follows:

- The exhausted cation - exchange resin can be regenerated by washing dilute HCl.



- The exhausted anion exchange resin can be regenerated by washing dilute NaOH.



- $CaCl_2$, $MgCl_2$, $NaCl$, Na_2SO_4 and $NaHCO_3$ are removed as wash.

Organic Chemistry / Carbon Chemistry / Hydrocarbons

- It is the branch of chemistry which deals with the study of carbon & its compounds.
- It is the branch of chemistry which deals with the study of Hydrocarbons (Hydrogen Carbon)

Organic Compounds:

The compound which deals were of vegetable & animal origin.

In-organic Compounds:

The compound which were of mineral origin.

HYDROCARBONS

The compound containing carbon and hydrogen are called hydrocarbons.

Ex: CH_4 , C_2H_6 , C_2H_4 , C_2H_2 , C_6H_6 etc

Classification of Hydrocarbons:

HYDROCARBONS

OPEN CHAIN HC / ACYCLIC HC / ALIPHATIC HC

Salurated HC
(Straight Chain)

Alkane

Un-saturated HC
(straight Chain)

Alkene

Alkyne

CLOSED CHAIN HC / CYCLOC HC

Homo cyclic
HCs (Ring for-
med by C-atom
only)

Alicyclic HC
Eg:- Cyclo -
Propane

Aromatic HC
Eg:- Benzene,
Toluene

Benzenoids
Eg:- Benzene

Non-benzenoids
Eg:- Trophone

Saturated Hydrocarbons

i) These are the aliphatic hydrocarbons composed of carbon-carbon single bonds.

ii) These hydrocarbons follow the tetravalency of carbon atoms.

iii) The hydrocarbons linked with C-C single bond.

iv) The non-availability of electrons in the single covalent bond makes them less reactive. So, these undergoes substitution reactions.

Un-saturated Hydrocarbons

i) These are the aliphatic hydrocarbons composed of carbon-carbon multiple bonds called unsaturated hydrocarbon.

ii) These hydrocarbons doesn't follow the tetravalency of carbon atom.

iii) The hydrocarbons linked with $-C=C-$ double bond and $-C\equiv C-$ triple bond.

iv) The availability of electrons in the double or triple covalent bond makes more reactive. So, these undergoes addition reactions.

Saturated Hydrocarbons

- v. It's Primary suffix is 'ane'
- vi Example: Methane, Ethane, Propane.

Un-saturated Hydrocarbons

- v. It's Primary suffix is 'ene' or 'yne'.
- vi Example: Ethene, Propene, Ethyne, Butyne....

Aliphatic Organic Compounds, Aromatic OC

ALIPHATIC HYDROCARBONS

- i The compound containing open chain carbon atoms called Aliphatic Hydrocarbons.
- ii They are straight line in structure. Which doesn't obey Huckle's Rule.

iii The no. of carbon atoms are less in these compound.
Ex: CH_4 , C_2H_6

iv Odour - Unpleasant

v. Reactive in oxidation and reduction process

AROMATIC HYDROCARBONS

- i The compound composed of closed chain cyclic carbon atoms called Aromatic Hydrocarbons.
- ii They are cyclic in structure. Which obey Huckle's Rule.

iii The no. of carbon atoms are more in these compound.
Ex: C_6H_6 , C_6H_5

iv Odour - pleasant

v. Less reactive in oxidation and reduction processes.

IUPAC SYSTEM OF NOMENCLATURE :

IUPAC stands for "International Union of Pure and Applied Chemistry". According to this system an organic compound may contain the following four parts.

- I Root Word
- II Prefix
- III Primary Suffix
- IV Secondary Suffix

1. Root Word :

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

No. of C atom	Root word	No. of C atom	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 an organic compound. Some groups that act as a substituent or side chain are

Group	Prefix
-F	Fluoro
-Cl	Chloro
-Br	Bromo
-I	Iodo
-NO ₂	Nitro
-R	Alkyl
-OR	Alkoxy

3. PRIMARY SUFFIX

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

Nature of Bond	Primary Suffix
All C-C bond	-ane
One C=C bond	-ene
Two C=C bond	-a---diene
Three C=C bond	-a---triene
One C≡C bond	-yne
Two C≡C bond	-a---dlyne

4. SECONDARY SUFFIX

FUNCTIONAL GROUP	SECONDARY SUFFIX
Alcohol (-OH)	-ol
Aldehyde (-CHO)	-al
Ketone (-CO-)	-one
Carboxylic acid (-COOH)	-oic acid
Amine (-NH ₂)	-amine
Acid amide (-CONH ₂)	-amide
Acid chloride (-COCl)	-oylchloride

CLASS OF COMPOUNDS:

(i) Alkanes

(ii) Alkenes

(iii) Alkynes

1. ALKANES

These are the saturated hydrocarbons in which the carbon atoms are linked by single bonds (C-C). These are also called **Paraffins**.

General Formula : $C_n H_{2n+2}$, where 'n' is the no. of carbon atoms.

Primary Suffix : ane

Molecular Formula IUPAC Name Structural Formula

CH_4	Methane	$\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{H} \\ \\ \text{H} \end{array}$
C_2H_6	Ethane	$\begin{array}{c} \text{H} & \text{H} \\ & \\ \text{H}-\text{C} & -\text{C}-\text{H} \\ & \\ \text{H} & \text{H} \end{array}$
C_3H_8	Propane	$\begin{array}{c} \text{H} & \text{H} & \text{H} \\ & & \\ \text{H}-\text{C} & -\text{C} & -\text{C}-\text{H} \\ & & \\ \text{H} & \text{H} & \text{H} \end{array}$
C_4H_{10}	Butane	$\begin{array}{c} \text{H} & \text{H} & \text{H} & \text{H} \\ & & & \\ \text{H}-\text{C} & -\text{C} & -\text{C} & -\text{C}-\text{H} \\ & & & \\ \text{H} & \text{H} & \text{H} & \text{H} \end{array}$
C_5H_{12}	Pentane	$\begin{array}{c} \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \\ & & & & \\ \text{H}-\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C}-\text{H} \\ & & & & \\ \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \end{array}$
C_6H_{14}	Hexane	$\begin{array}{c} \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \\ & & & & & \\ \text{H}-\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C}-\text{H} \\ & & & & & \\ \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \end{array}$
C_7H_{16}	Heptane	$\begin{array}{c} \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \\ & & & & & & \\ \text{H}-\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C}-\text{H} \\ & & & & & & \\ \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \end{array}$
C_8H_{18}	Octane	$\begin{array}{c} \text{H} & \text{H} \\ & & & & & & & \\ \text{H}-\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C}-\text{H} \\ & & & & & & & \\ \text{H} & \text{H} \end{array}$
C_9H_{20}	Nonane	$\begin{array}{c} \text{H} & \text{H} \\ & & & & & & & & \\ \text{H}-\text{C} & -\text{C} & -\text{C}-\text{H} \\ & & & & & & & & \\ \text{H} & \text{H} \end{array}$
$\text{C}_{10}\text{H}_{22}$	Decane	$\begin{array}{c} \text{H} & \text{H} \\ & & & & & & & & & \\ \text{H}-\text{C} & -\text{C} & -\text{C}-\text{H} \\ & & & & & & & & & \\ \text{H} & \text{H} \end{array}$

2. ALKENES

These are the unsaturated hydrocarbons which have a carbon-carbon double bond ($\text{C}=\text{C}$) in their molecules. They are also called **Olefins**.

General Formula : C_nH_{2n} where 'n' is no. of carbon atoms.

Primary Suffix: yne

No. Of Car- bon atom	Molecular Formula	IUPAC Name	Structure Formula
1	CH_2	Methene	$\text{C}-\text{H}_2$
2	C_2H_4	Ethene	$\begin{array}{c} \text{H} & \text{H} \\ & \\ \text{C}=\text{C} \\ & \\ \text{H} & \text{H} \end{array}$
3	C_3H_6	Propene	$\begin{array}{c} \text{H} & \text{H} & \text{H} \\ & & \\ \text{C}=\text{C}-\text{C}-\text{H} \\ & & \\ \text{H} & \text{H} & \text{H} \end{array}$
4	C_4H_8	Butene	$\begin{array}{c} \text{H} & \text{H} & \text{H} & \text{H} \\ & & & \\ \text{C}=\text{C}-\text{C}-\text{C}-\text{H} \\ & & & \\ \text{H} & \text{H} & \text{H} & \text{H} \end{array}$
5	C_5H_{10}	Pentene	$\begin{array}{c} \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \\ & & & & \\ \text{C}=\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & & & \\ \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \end{array}$
6	C_6H_{12}	Hexene	$\begin{array}{c} \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \\ & & & & & \\ \text{C}=\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & & & & \\ \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \end{array}$
7	C_7H_{14}	Heptene	$\begin{array}{c} \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \\ & & & & & & \\ \text{C}=\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & & & & & \\ \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \end{array}$
8	C_8H_{16}	Octene	$\begin{array}{c} \text{H} & \text{H} \\ & & & & & & & \\ \text{C}=\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & & & & & & \\ \text{H} & \text{H} \end{array}$
9	C_9H_{18}	Nonene	$\begin{array}{c} \text{H} & \text{H} \\ & & & & & & & & \\ \text{C}=\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & & & & & & & \\ \text{H} & \text{H} \end{array}$
10	$\text{C}_{10}\text{H}_{20}$	Decene	$\begin{array}{c} \text{H} & \text{H} \\ & & & & & & & & & \\ \text{C}=\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & & & & & & & & \\ \text{H} & \text{H} \end{array}$

Common Suffix: -ene
Common Prefix: C_nH_m

3. Alkynes

3. ALKYNES
These are the unsaturated hydrocarbons which have a carbon-carbon triple bond ($C \equiv C$) in their molecules. These are also called Acetylenes.

General Formula: C_nH_{2n-2} where 'n' is the no. of carbon atoms

Primary Suffix: yne

Alkyl Radical	Name of the alkyl Radical	Corresponding Alkane
CH ₃	Methyl	CH ₄ (Methane)
C ₂ H ₅	Ethyl	C ₂ H ₆ (Ethane)
C ₃ H ₇	Propyl	C ₃ H ₈ (Propane)
C ₄ H ₉	Butyl	C ₄ H ₁₀ (Butane)
C ₅ H ₁₁	Pentyl	C ₅ H ₁₂ (Pentane)
C ₆ H ₁₃	Hexyl	C ₆ H ₁₄ (Hexane)
C ₇ H ₁₅	Heptyl	C ₇ H ₁₆ (Heptane)
C ₈ H ₁₇	Octyl	C ₈ H ₁₈ (Octane)
C ₉ H ₁₉	Nonyl	C ₉ H ₂₀ (Nonane)
C ₁₀ H ₂₁	Decyl	C ₁₀ H ₂₂ (Decane)

Alkyl halides or Haloalkanes:

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

General Formula: C_nH_{2n+1-X} where 'n' is the no. of carbon atom and 'X' refers to halogen atom (F, Cl, Br, I)

No of Carbon atoms	Molecular Formula	IUPAC Name	Structural Formula
1	CH ₃ -Cl	Chloromethane	$\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{Cl} \\ \\ \text{H} \end{array}$
2	C ₂ H ₅ -Br	Bromoethane	$\begin{array}{ccccc} & \text{H} & & \text{H} & \\ & & & & \\ \text{H} & - & \text{C} & - & \text{C} & - \text{Br} \\ & & & & \\ & \text{H} & & \text{H} & \end{array}$
3	C ₃ H ₇ -F	Fluoropropane	$\begin{array}{ccccc} & \text{H} & \text{H} & \text{H} & \\ & & & & \\ \text{H} & - & \text{C} & - & \text{C} & - \text{C} & - \text{F} \\ & & & & \\ & \text{H} & \text{H} & \text{H} & \end{array}$

Alcohol:

These are obtained by replacing one H-atom of an alkane by a hydroxyl group (-OH). The IUPAC Name of an alcohol is obtained by replacing 'e' of the corresponding alkane by 'ol'.

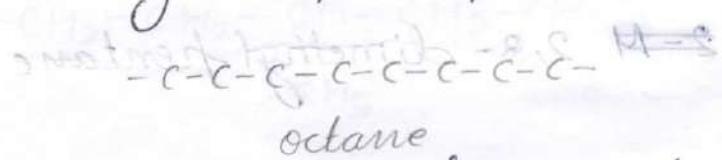
General Formula: $C_nH_{2n+1}-OH$ where 'n' is the no of carbon atoms.

Suffix: ol

No of carbon atoms	Molecular Formula	IUPAC Name	Structural Formula
1.	CH_3-OH	Methanol	$\begin{array}{c} H \\ \\ H-C-OH \\ \\ H \end{array}$
2.	C_2H_5-OH	Ethanol	$\begin{array}{c} H & H \\ & \\ H-C-C-OH \\ & \\ H & H \end{array}$

RULES FOR IUPAC SYSTEM OF NOMENCLATURE

- 1) Longest carbon chain / parent chain / principal chain select
- 2) Numbering the principal chain

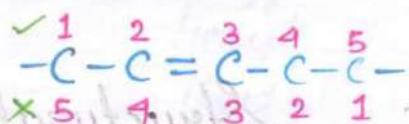


- a) Either start from both end.
- b) Follow the lowest locant rule (lowest location Number).
- c) Separate the locant from substituent name by a hyphen & arrange the substituents in alphabetical order followed by wordroot & suffix

Locant + Substituent + wordroot + Suffix

d) 2 or more same type substituents appears then we write \rightarrow di, tri etc. & use comma (,) in between substituents & hyphen, from the name of the substituents.

3) If $C-C$ & $C=C$ are there then start naming from $C=C$ bond side.

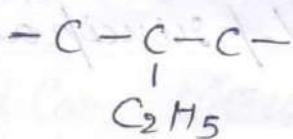


4) If $C-C$ & $C\equiv C$ are there then start numbering from $C\equiv C$ bond side.

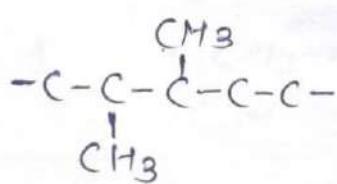
5) If functional group are attached to the main group then start numbering from F.G side

6) $C=C$ & $C\equiv C$, start numbering from lower locant to double bond is selected.

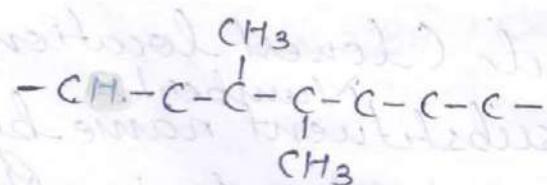
Some Example



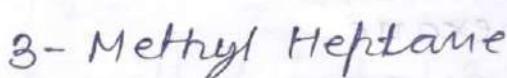
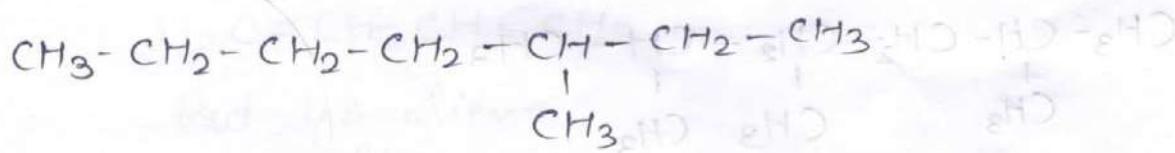
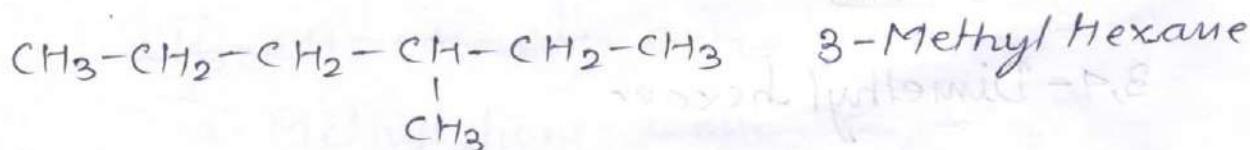
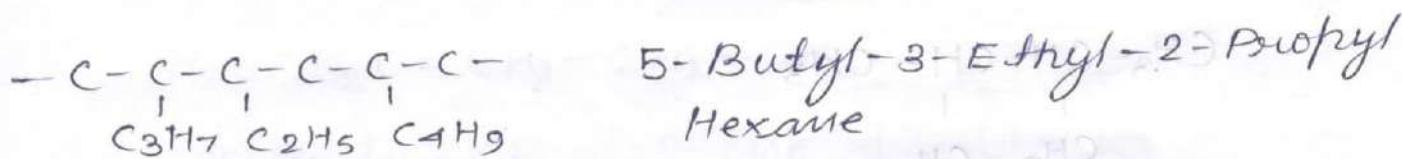
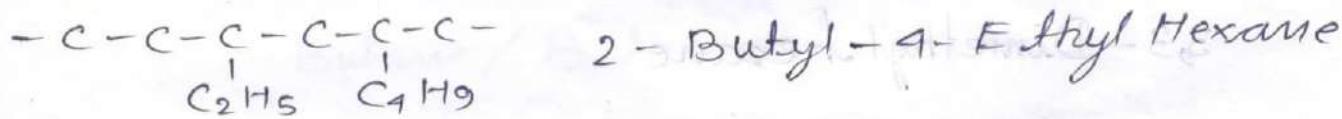
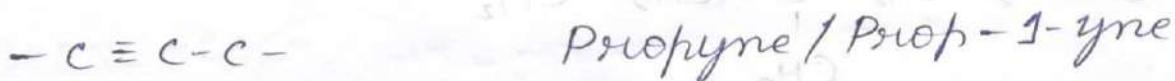
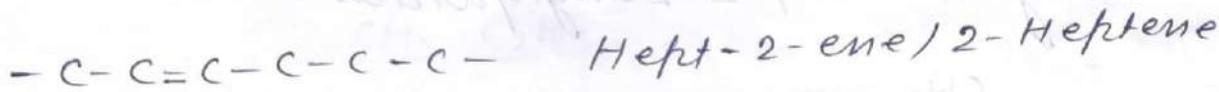
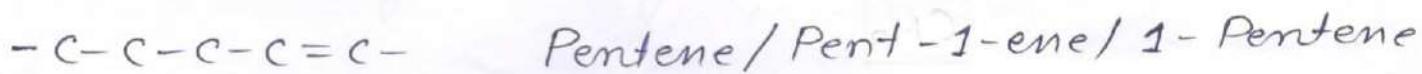
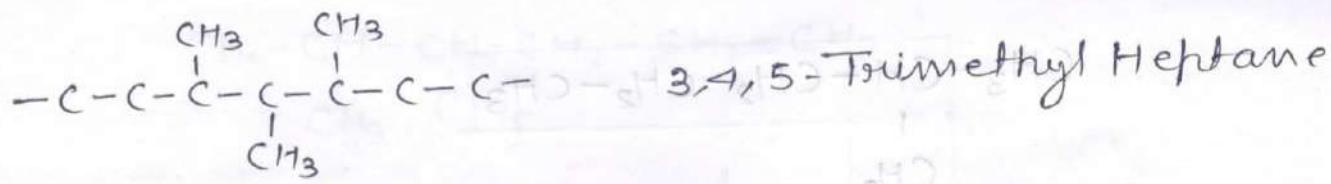
2-Ethyl Propane

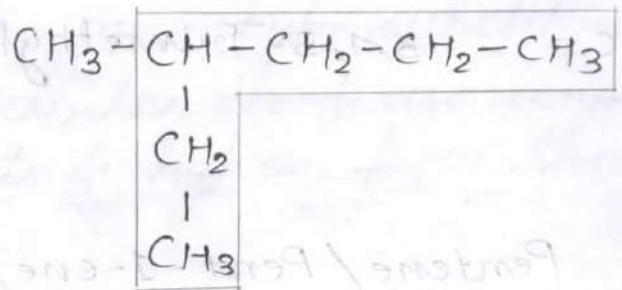


2,3-dimethyl pentane

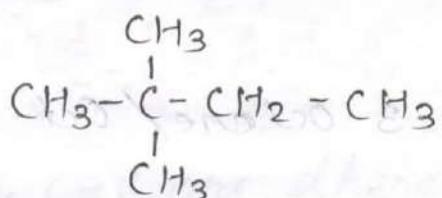


4,5-Dimethyl Heptane

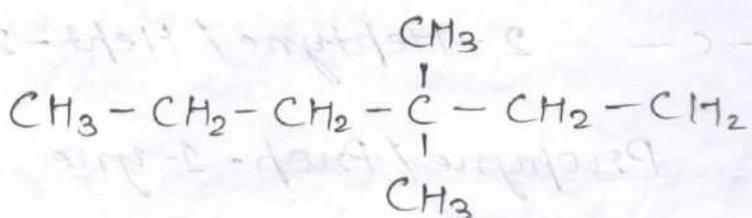




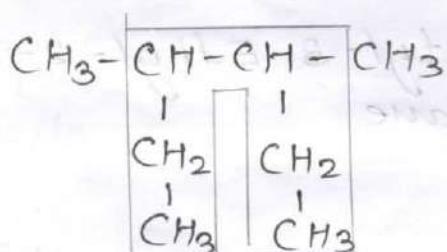
3-Methyl Hexane / 2-Ethylpentane



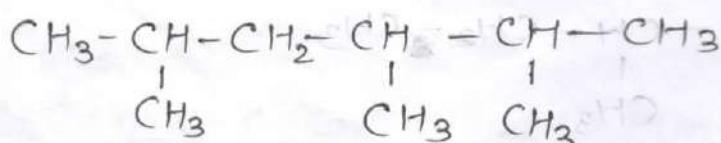
2,2-Dimethyl Butane



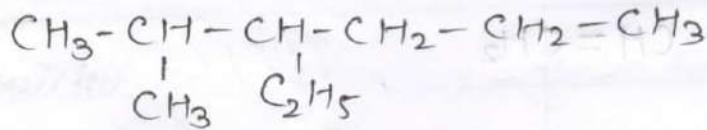
3,3-Dimethylhexane



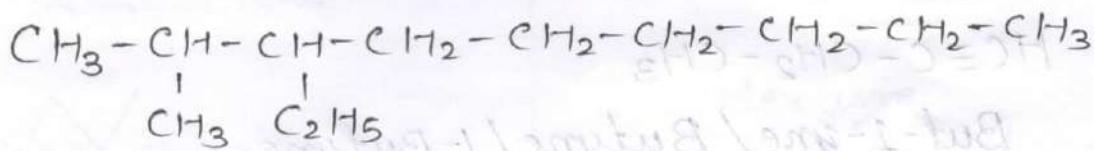
3,4-Dimethylhexane



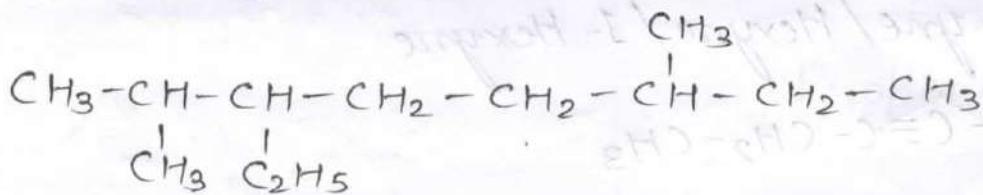
2,3,5-Trimethylhexane



3-Ethyl-2-Methyl hexane

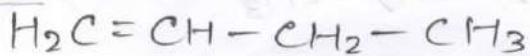


3-Ethyl-2-Methyl nonane

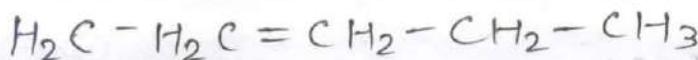


3-Ethyl-2,6-Dimethyl Octane.

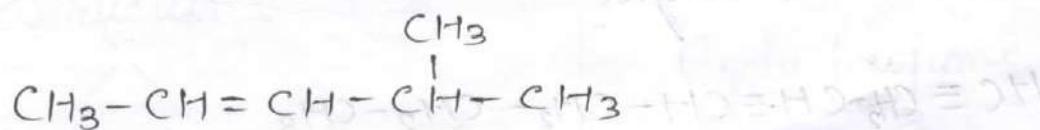
ALKENE - C=C-



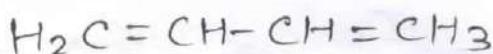
Butane / But-1-ene



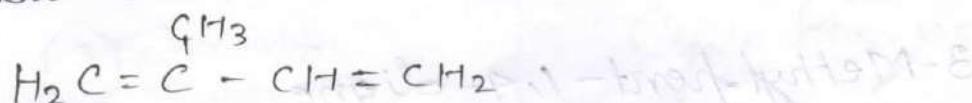
2-Pentene / Pent-2-ene



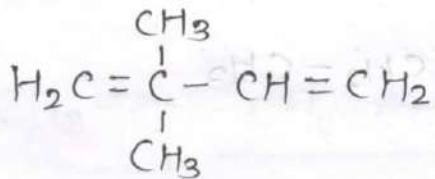
4-Methyl pent-2-ene



But-1,3-diene

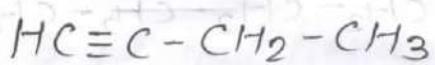


2-Methyl but-1,3-diene

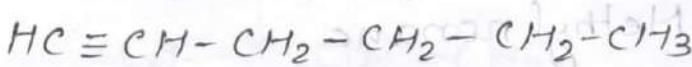


2,2-Dimethyl-but-1,3-diene

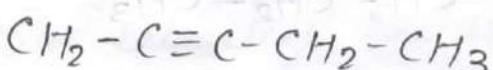
ALKYNE -C≡C-



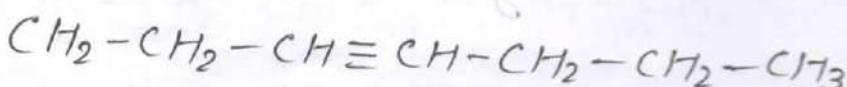
But-1-yne / Butyne / 1-Butyne



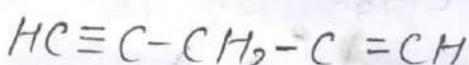
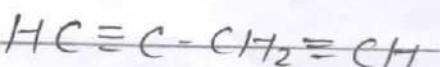
Hex-1-yne / Hexyne / 1-Hexyne



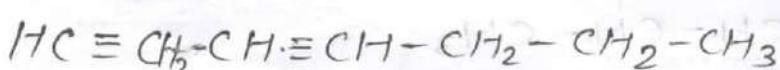
Pent-2-yne / 2-Pentyne



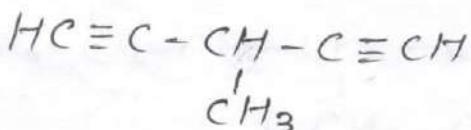
Hept-3-yne / 3-Heptyne



Pent-1,4-diyne

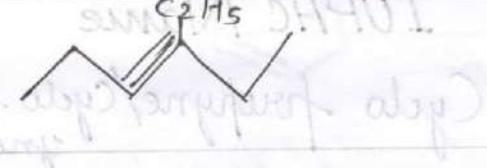
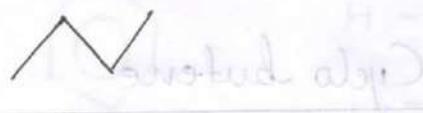


Hept-1,3-diyne



3-Methyl-pent-1,4-diyne

Structur



IUPAC Name

Propane

Butane

Hexane

Octane

Propene

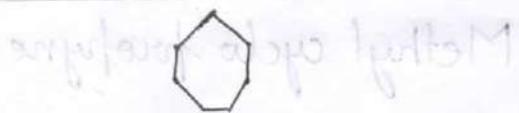
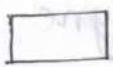
Hexene / Hex-1-ene

3-Octyne / Oct-3-yne

3-Ethyl hex-3-yne

Cyclo Compound

Structur



IUPAC Name

Cyclopropane

Cyclobutane

Cyclopentane

Cyclohexane

Cycloheptane

Structure	

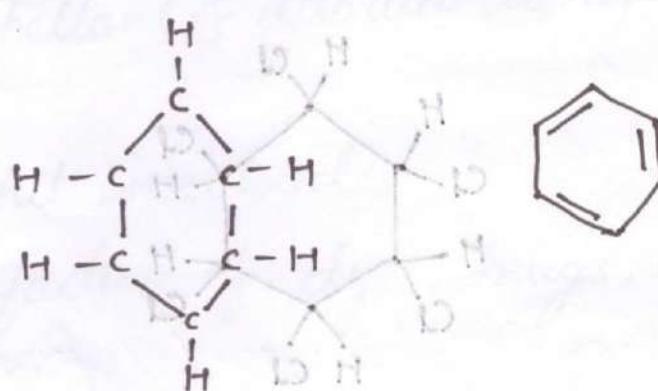
IUPAC Name	
Cyclopropane / Cyclo prop-1-ene	
Cyclobutene	
Cyclopentene	
Cyclohexene	
Cycloheptene	
Cyclo Octene	

Structure	

IUPAC Name	
Cyclo propyne / Cyclo prop-1-yne	
Cyclobutyne	
Cyclopentyne	
Cyclohexyne	
Cycloheptyne	
Cyclo octyne	
Methyl cyclo propane	

AROMATIC COMPOUND

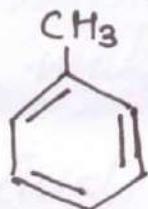
① Benzene



Uses

- ① It is used in dry cleaning.
- ② It is used as solvent.
- ③ It is used as insecticides.
- ④ It is used in motor fuel when mixed with petrol.

② Toluene

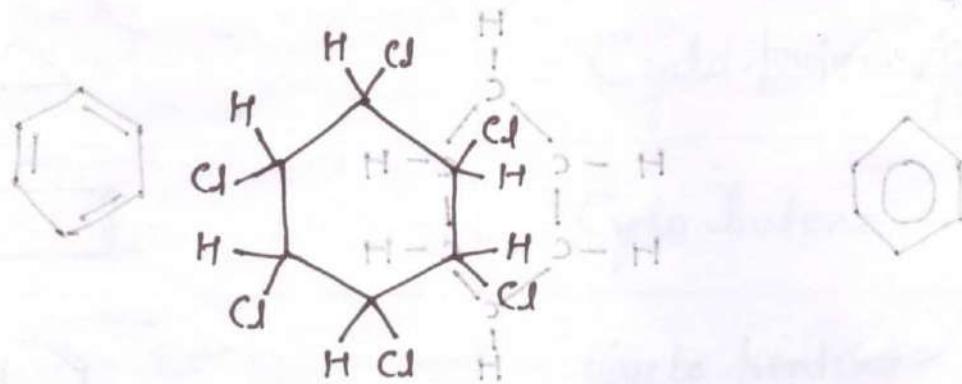


Uses

- It is used as substitute of petrol.
- It is used in manufacture of TNT (Trinitro Toluene) explosive.
- It is used as industrial solvent and in dry cleaning.
- It is used as manufacture of dyes and drugs.



III BHC (Benzene Hexa Chloride) - Gammahexachlorocyclohexane



Uses

- It is used as a powerful insecticide
- It is used to kill ants and cockroach etc.

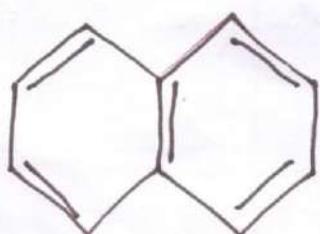
IV Phenol



Uses

- It is used as antiseptic in soaps, lotions, ointments
- It is used as preservatives of ink.
- It is used as manufacture of medicine like aspirin, salol.
- It is used to protect the entrance of snakes in the house / drain.

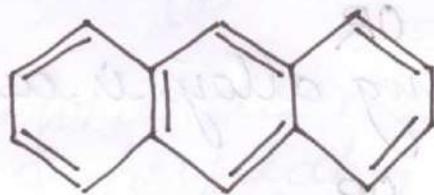
V Naphthalene



Uses

- It is used as moth repellent & also used to repels so many types of insects.
- It is used as powerful insecticides
- It is used as manufacture of dyes, drugs, explosives, synthetic resins.

(vi) Anthracene

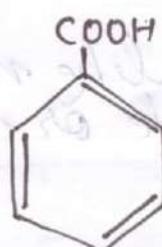


Uses

It is used in smoke screens

It is used as making alizarine

(vii) Benzoic Acid



Uses

- It is used as the treatment of skin diseases like eczema
- It is used as medicine specially as urinary in the form of its salt.
- It is used as preparation of aniline blue.
- It is used as preservative in the form of sodium benzoate in food such as fruit juices, tomato ketchup, pickles etc.

~~Ques. How do we get metals from their ores? Ans. We get metals from their ores by reduction process. In this process, we reduce the metal from its oxide or sulphide or chloride. This process is called Metallurgy.~~

METALLURGY

The art of extracting metal from its ores is called Metallurgy.

The art of preparing alloys is called Metallurgy

OR

OR

The whole process of extracting metals from their ores is called 'Metallurgy'.

Modes of occurrence

a. Native state :

Least reactive elements like noble gases & noble metals occurs in free state or native state.

Ex: Ag, Au, Pt, Ne, Ar etc.

b. Combined state:

Highly reactive elements like Fluorine, chlorine, sodium, etc. are found in combined state.

MINERALS

The compounds of various metals found in nature associated with their impurities are called Minerals.

OR

The combined state in which the metals occur in the earth's crust are known as minerals.

Ex: ZnO (Zincite), $AgCl$ (Horn silver), Cu_2O (Cuprite) Cu_2S (Copper Sulphide), $CuFeS_2$ (Copper Pyrites)

ORES

The minerals from which we can obtain metal profitably & easily

OR

Minerals from which the metals can be extracted conveniently & profitably are called Ore.

Ex: Fe (Fe_2O_3 - Hematite, Fe_3O_4 - Magnetite), Al ($Al_2O_3 \cdot 2H_2O$ - Bauxite)

- "All ores are mineral but all the minerals are not ores."

METAL, CHIEF ORES

METAL
Fe (Iron)
Al (Aluminium)
Ca (Calcium)
Zn (Zinc)
Hg (Mercury)
Pb (Lead)

CHIEF ORES
Fe_2O_3 (Hematite), Fe_3O_4 (Magnetite)
$Al_2O_3 \cdot 2H_2O$ (Bauxite)
$CaCO_3$ (Calcite), $CaCO_3$ (Limestone), $CaSO_4 \cdot 2H_2O$ (Gypsum)
ZnS (Zinc-blende), ZnO (Zincite)
HgS (Cinnabar)
PbS (Galena)

MATRIX / GANGUE

The unwanted rocky or earthy impurities associated (present) with the ore is called Gangue.

Ex: Silica (SiO_2), mud, Clay, sand, Limestone, Rock etc.

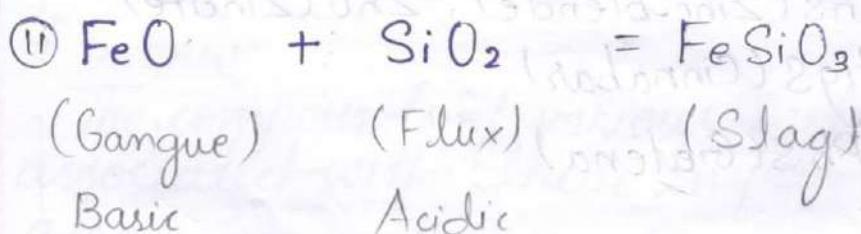
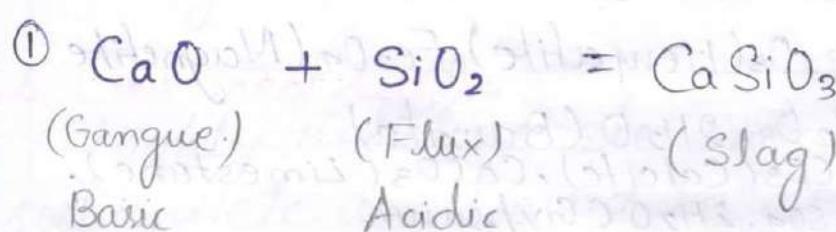
FLUX

- The chemical substance added to the ore to remove gangue is called Flux.
- The Flux is of two types
 - Acidic Flux
 - Basic Flux

ACIDIC FLUX

- When the ore contain basic impurities such as lime (CaO), MgO & FeO the acidic flux such as silica (SiO_2), Borax is used.
- It is used to remove the basic impurities like CaO , MgO

Ex: SiO_2 , P_2O_5



BASIC FLUX

- When the ore contain acidic impurities like silica (SiO_2) the basic flux such as (CaCO_3 , MgCO_3 is used to remove the gangue.
 - It is used to remove the acidic impurities like SiO_2
- Ex: CaO , MgO
- ① $\text{SiO}_2 + \text{CaCO}_3 = \text{CaSiO}_3 + \text{CO}_2$
 (Gangue) (Flux) (Slag)
 Acidic Basic
 - ② $\text{SiO}_2 + \text{MgCO}_3 = \text{MgSiO}_3 + \text{CO}_2$
 (Gangue) (Flux) (Slag)
 Acidic Basic

SLAG

The flux reacts with the gangue to form a easily fusible product/compound is called Slag.

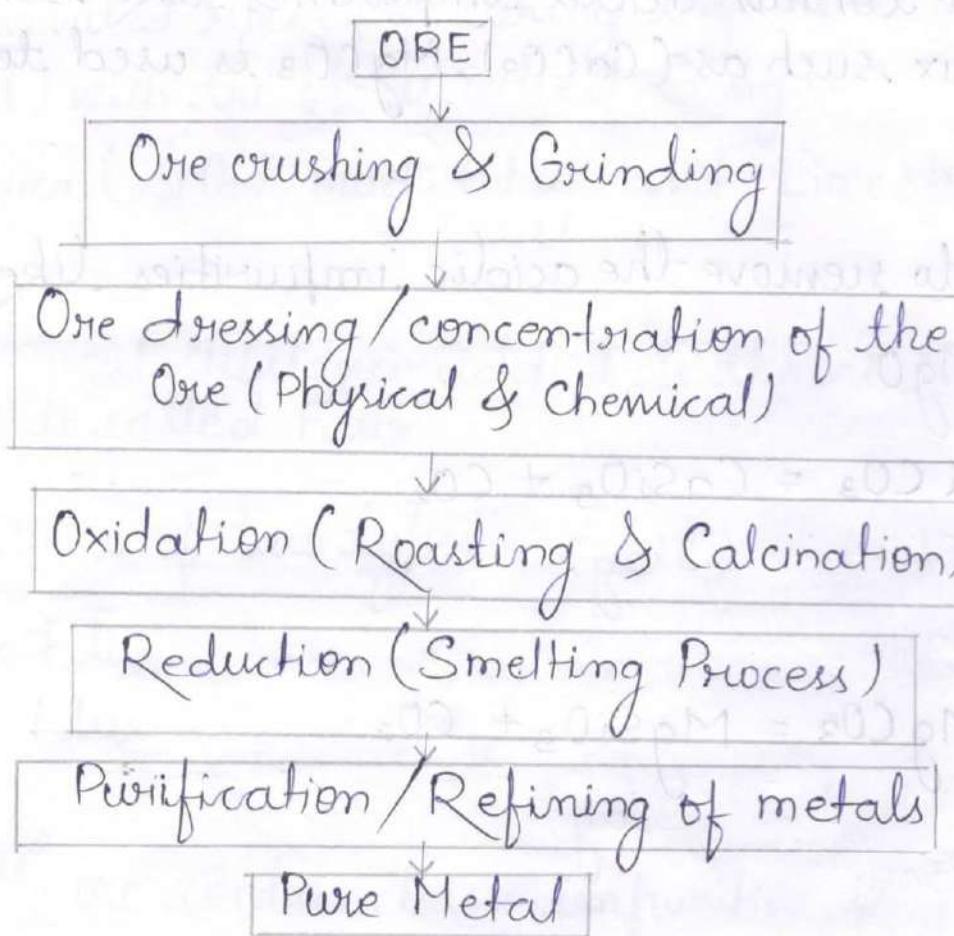
$$\text{Flux} + \text{Gangue} = \text{Slag}$$

EXTRACTION OF METALS FROM THEIR ORE (METALLURGY)

- General methods for the extraction of metals
- Pulverization of Ore
- Mineral Beneficiation of Ore
- Ore
- Ore crushing & Grinding
- Ore dressing / Concentration of the Ore
- Oxidation
- Reduction
- Purification / Refining of metals
- Pure Metals

GENERAL METHODS FOR THE EXTRACTION OF METALS

XU.F. 012/8



ORE DRESSING (CRUSHING & GRINDING)

In nature most of the ore are found in the form of huge lumps. It is very much difficult to carry out extraction process in this form.

Hence the huge lumps are broken into smaller pieces with the help of Jaw Crusher.

Again the smaller pieces of ore are then changed into a fine powder with the help of a stamp mill or a Ball mill. This process is called Pulverisation of the ore.

CONCENTRATION OF THE ORE/ DRESSING (sph.)

(Separation of Impurities)

Concentration: "Concentration is the process of removing maximum amount of gangue particles from the ore."

Concentration of ore having both physical & chemical methods.

To remove undesirable impurities, different methods are used for the concentration of ores.

Hand Picking (When impurities are of large size)

Magnetic Separation (Electro-magnetic Separation)

Hydrolic Method (Washing) / Gravity Separation

Levigation

Froth Flotation Process (Method)

Leaching

MAGNETIC SEPARATION / ELECTRO-MAGNETIC SEPARATION

This is based on separation of

- Magnetic ore from non-magnetic gangue
- Magnetic gangue from non magnetic ore.

PRINCIPLE

- Separation of ore - Magnetic Ore (e.g. Fe ore), Gangue Non-Magnetic
- Gangue Magnetic, Ore - Non-Magnetic (e.g - Al) (Aluminium ore)

PROCESS

1. The pulverised (Powdered) ore is placed on a conveyor belt, revolving around the two rollers, one of the roller is magnetic & where as another roller is non-magnetic part forms another heaps little away from the roller.
2. The magnetic particles are attracted to the magnetic wheel (Roller) & fall near to magnetic roller & non-magnetic, particles forms another heap little away from the roller.

Example: Tin stone (SnO_2).

HYDROLY WASHING METHOD/ GRAVITY SEPARATION/ LEVIGATION

This process is based on the separation of ore & gangue due to difference in density of particles.

PRINCIPLE

Separation of ore Denser ore particles settle on grooves on a vibrating sloped table. (The heavier ore particles are settled down)

GANGUE

Lighter gangue particles washed down by water or washed along with the water.

Example: PbS

DENSITY

Mass divided by volume (m/v).

The amount of mass per unit of volume

PROCESS

- The powdered ore is poured over a vibrating slatted table with grooves (along narrow cut hard material) & a jet of water is allowed to flow over it.
- The denser ore particle settled down in the grooves as shown in figure & lighter gangue particles are washed along the water.
- E.g. PbS (ore) + CaCO_3 (Limestone) - gangue - An ore of lead, galena (PbS) is purified by this method
- This process is used where particles are heavier than impurities
- If object is heavy & compact it has a high density

OXIDATION

- The extraction of the crude metal from the concentration of ore is done in this process
- Conversion of ore into metal oxide
- It involves / It is done by two methods such as Roasting & Calcination.

ROASTING

1. The process of heating the concentration of sulphide ore in the presence of excess supply of air below its melting point.

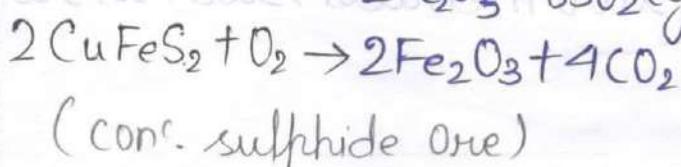
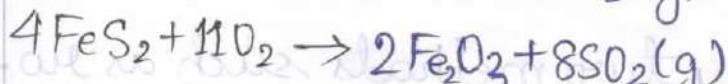
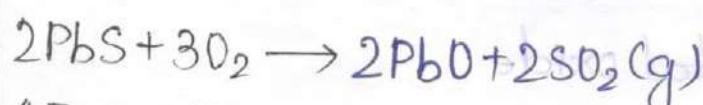
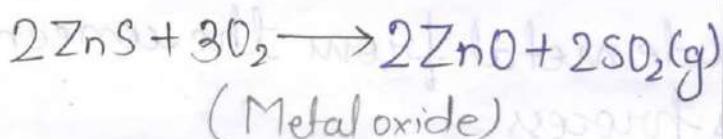
CALCINATION

4. The process of heating the concentration of carbonate (CO_3^{2-}) & hydrosulfide ores in the absence of air at a temperature just below its melting point.

ROASTING

2. Usually Sulphide ores are treated by the process.
3. The aim of this process is to remove the volatile impurities.
4. In this process oxidation reaction takes place.
5. The aim of this process is to convert the ore into oxide.

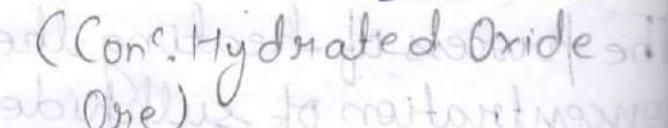
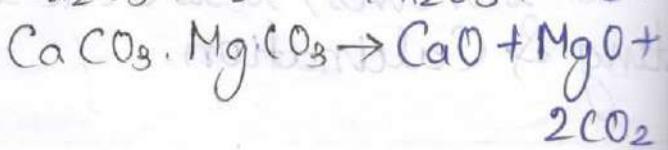
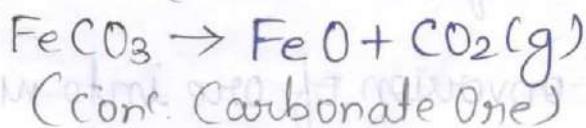
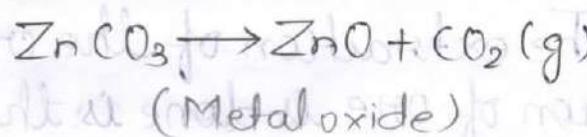
Ex:



CALCINATION

2. Usually Carbonates & hydrated Oxide ores are treated by this process.
3. The aim of this process is to remove the moisture, volatile impurities.
4. In this process thermal decomposition takes place.
5. The aim of this process is to convert the ore into oxides.

Ex:



MELTING POINT/FREEZING POINT

- The temperature at which a material changes from a solid to a liquid (melts).
- Melting point of water/ice = 0°C

BOILING POINT

- The boiling point is the temperature at which a material changes from a liquid to a gas.
- Boiling Point of water is = 100°C

CHEMICAL METHOD OF CONCENTRATION OF ORE (LEACHING)

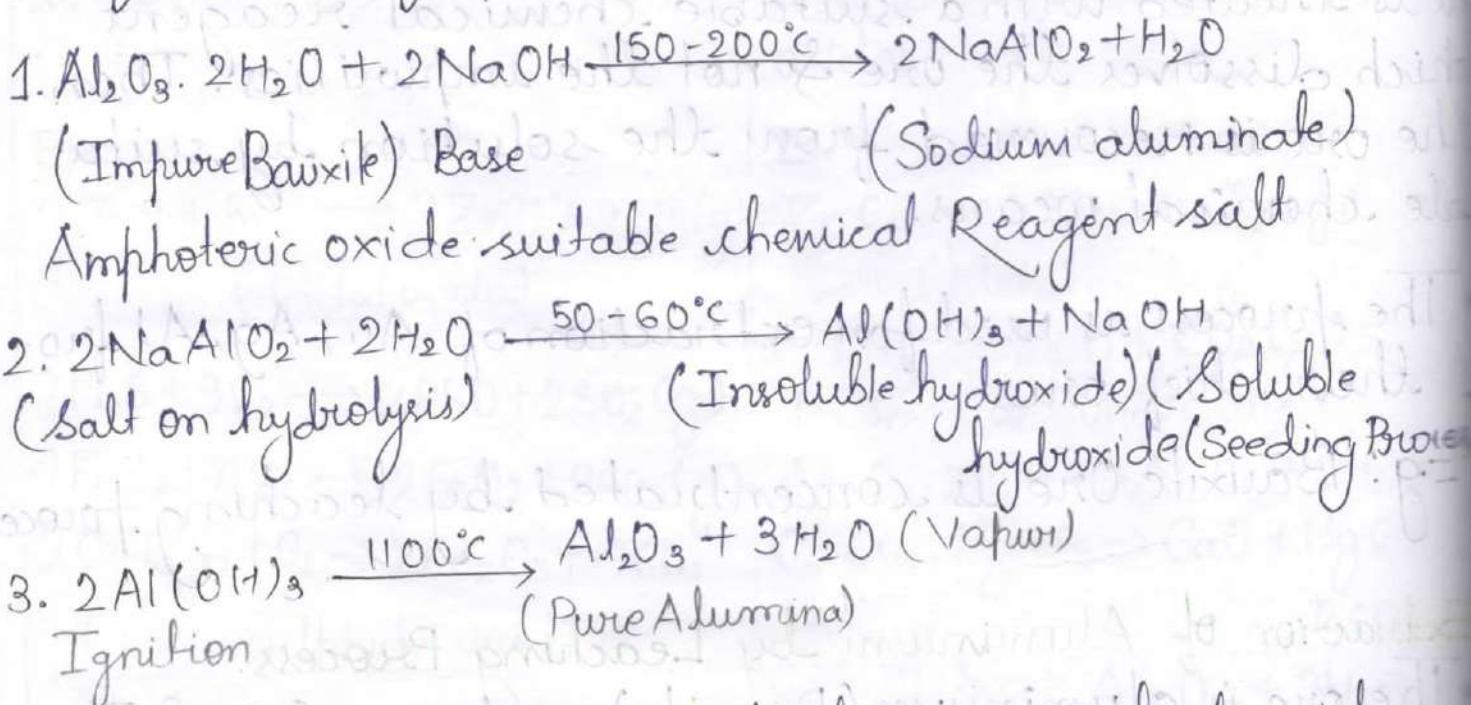
- It is a chemical method in which the powdered ore is treated with a suitable chemical reagent which dissolves the ore & not the impurities. Then the ore is recovered from the solution by suitable chemical means.
- The process is used for extraction of Au, Ag, Al from their chief ores.

E.g: Bauxite Ore is concentrated by leaching proc

Extraction of Aluminium by Leaching Process.

- The ore is aluminium (Bauxite) contains SiO_2 & Iron oxide TiO_2 as impurities
- Ore (Bauxite - Al_2O_3) - Main Ore, Gangue (SiO_2 , Fe_2O_3 , TiO_2)

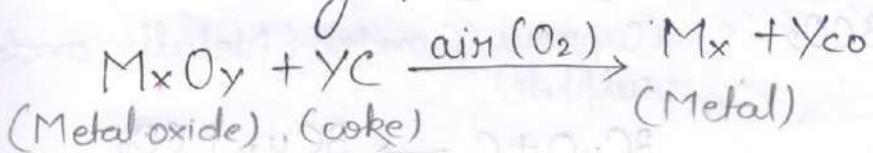
- The powdered ore is concentrated with 45% solution of NaOH (suitable reagent)
 - In this way, Al_2O_3 is leached out as sodium aluminate (2NaAlO_2) leaving the impurities behind. (& SiO_2 as sodium silicate).
 - The solution is filtered to remove insoluble impurities.
 - The filtrate is seeded with a little freshly precipitated aluminium hydroxide. (Seeding Process)
 - The precipitated is separated by filtration, dried & ignited to get pure alumina.



- By ignition of precipitated aluminium hydroxide, it filtered dried then we get pure Alumina.
 - Leaching Process is also employed in concentration of silver (Ag) & gold (Au) ore.

REDUCTION PROCESS (CONVERSION OF METAL OXIDE INTO METAL)

- The metal oxide ore is reduced to the metal by using smelting Process
 - Smelting Process: In this process (method), the roasted ore or calcinated ore is mixed with a suitable quantity of coke or charcoal which acts as a reducing agent.
 - The mixture is heated strongly in excess supply of air above melting point.



- This process carried out in blast furnace for the extraction of less electropositive metals such as Pb, Zn etc, & powerful reducing agent (C, CO, Na, Ca, Al, K, H₂, Mg) etc. may be used.
 - Flux is also used during the smelting process to remove impurities in from of slag.
 - Smelting process involves (done) by the following two steps:
 1. Carbon reduction Process
 2. Self/auto reduction Process

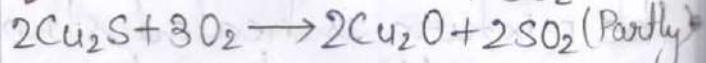
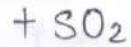
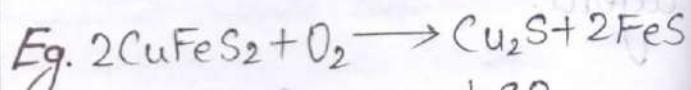
CARBON REDUCTION PROCESS

1. In this process the metal oxides of less electropositives are reduced by heating them strongly.



SELF REDUCTION PROCESS

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



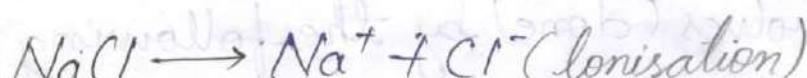
(Cuprous (C. oxide) (Metallic oxide) sulphide)



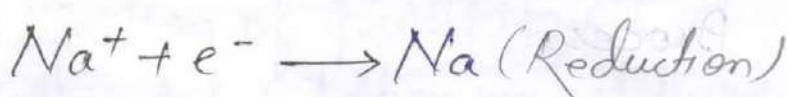
ELECTROLYTIC REDUCTION

- The highly electropositive metals like Na, K, Mg, Ca, Al etc. are extracted by the electrolysis of their oxides, hydroxides or chlorides in fused state.

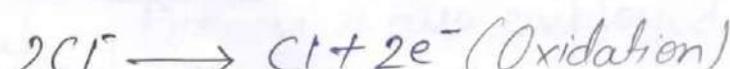
Eg. Sodium (Na) is extracted by the electrolysis of molten NaCl.



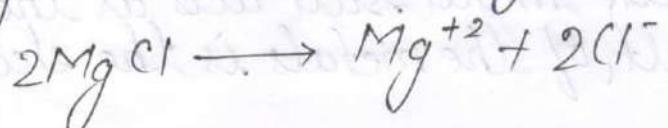
At Cathode :



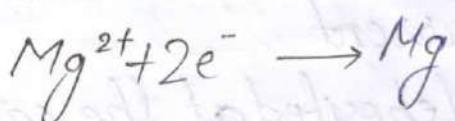
At anode :



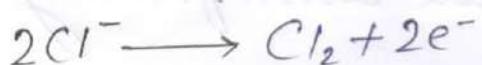
- Mg is also extracted by the electrolysis of molten $MgCl_2$



At cathode



At anode



~~Electrolytic Refining~~

- This method is used for the purification of basic metals like Cu, Al, Zn, Pb etc.

- The impure metals are taken as anode & pure metal is taken as cathode.

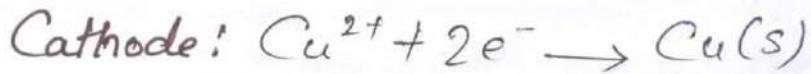
Anode: Thick block of impure metal

Cathode: Thin sheet of pure metal

Electrolyte:

- The solution of a soluble metal salt acts as the electrolyte. The soluble salt of the metal is the electrolyte.
- On electrolysis / By passing current
 - (a) Pure metal from the anode is deposited at the cathode.
 - (b) The impurities from anode settle down forming anode mud/anode sludge.

In this way, we can refine the crude metals.



PURIFICATION / REFINING OF THE METALS

- The metals obtained by the above methods usually contains some impurities such as the following

Metal oxides left un-reduced, residual slag or flux & oxidizable impurities (ex- arsenic, phosphorus, silicon, carbon)

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

The following methods are generally used for the refining of metals such as.

1. Distillation Refining
2. Liquation
3. Oxidation

DISTILLATION REFINING

- DISTILLATION REFINING

 - This method is used for refining of very low boiling metals/volatile metals like Zn, Cd, Pb etc.
 - The impure metal is boiled to obtain the pure metal as distillate.
 - The impurities left over in the retort
 - For refining volatile metals
Eg. Zn, Hg.
 - On heating
 - (a) Pure metal-vapourizes, condensed & collected.
 - (b) Non-volatile impurities remain behind.

Liquation

- This method is used for refining of low melting metals like Bi, Pb, Sn, Hg etc.
- The impure metal is placed on the sloping hearth of reverberatory furnace & heated from below.
- The pure metal flows down as liquid & impurities left behind on the hearth.
- On heating
 - (a) Pure metal - liquefies & flows down the sloping furnace
 - (b) Non-volatile impurities are infusible & remain behind.

Oxidation

- For refining metals by oxidation of their impurities
Eg. Iron
- On oxidation
 - (a) Pure metal - remains behind in the molten form
 - (b) Impurities e.g. P, S, C - oxidised by air to their respective oxides.

LECTURE NOTES
ON
ENGG. CHEMISTRY

FACULTY'S NAME: KUNI MAJHI
SR. LECTURER

SEMESTER: 1ST & 2ND

CHAPTER-2

CHEMICAL BONDING

CHEMICAL BOND

A chemical bond is defined as the force of attraction which holds the atoms together and forms molecule.

Ex: H-H, O=O, Cl-Cl, Na-Cl

TYPES OF CHEMICAL BOND

1. Covalent Bond
2. Ionic bond
3. Coordinate bond.

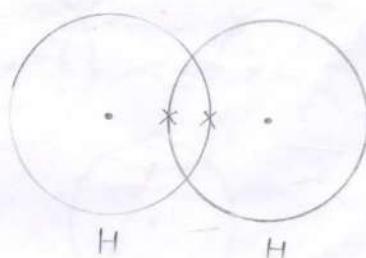
COVALENT BOND

It is defined as the bond which is formed by the mutual sharing of electrons between two atoms.

Ex: H₂, O₂, H₂O, CH₄

FORMATION OF H₂

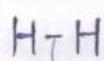
- Electron configuration of, H - 1s'
- H has 1 electron in it's outermost shell
- H required one more electron to satisfy octet rule
- Two H atoms mutually share one electron each to form H₂ molecule.



Formation of H₂

Structure of H₂

CHAPTER - 5



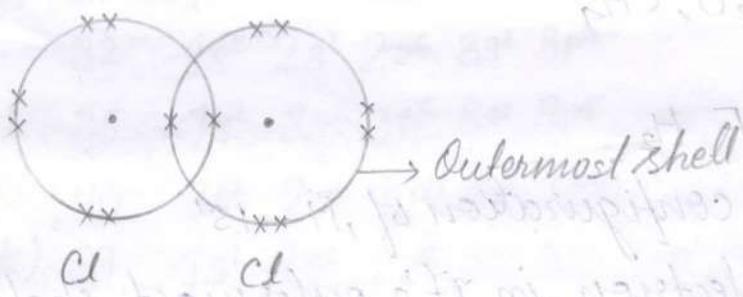
Bond pair of electron

OCTET RULE

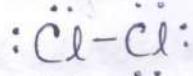
Every element want to have 8 electron in their outermost shell to become stable this is called octet rule.

Formation of Cl₂

- Electronic configuration of Cl. — $1s^2, 2s^2, 2p^6, 3s^2, 3p^5$
- Cl has 7 electron in it's outermost shell.
- Cl required one more electron to satisfied octet rule
- Two Cl atom mutually shares one electron each to form Cl₂ molecule

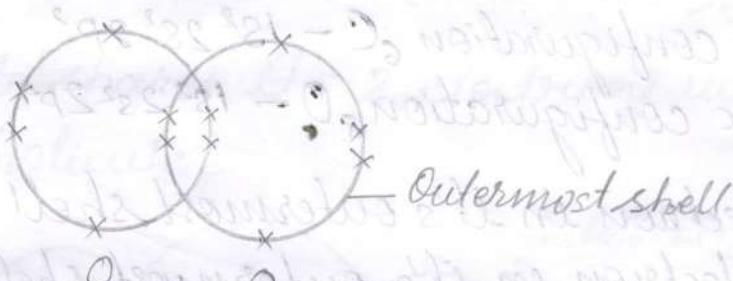


Structure of Cl₂



Formation of O₂

- Electronic configuration of O - $1s^2, 2s^2, 2p^4$
- O has 6 electrons in its outermost shell.
- O required 2 more electron to satisfy octet rule.
- Two O atom ~~muta~~ mutually shares 2 electrons each to form O₂ molecule.

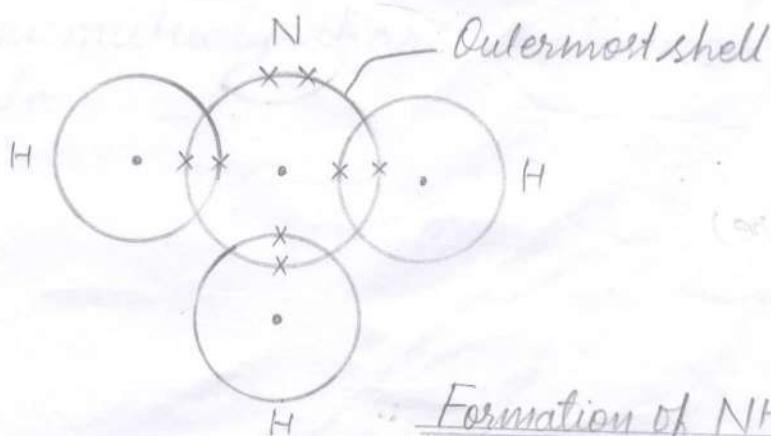


Formation of O₂

Structure of O₂

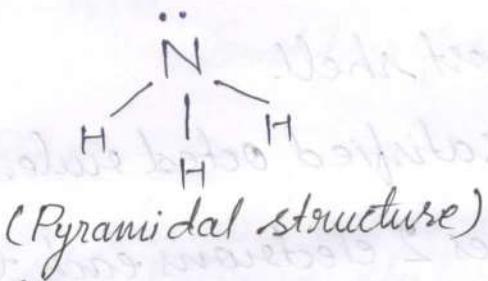
Formation of O₂ NH₃

- Electronic configuration, N - $1s^2, 2s^2, 2p^3$
Electronic configuration, H - $1s^1$
- N has 5 electron in its outermost shell
O has 1 electron in its outermost shell.
- N required 3 more electron to become stable.
H required 1 more electron to become stable.
- N mutually share 3 electrons with 3 H-atom to form NH₃ molecule



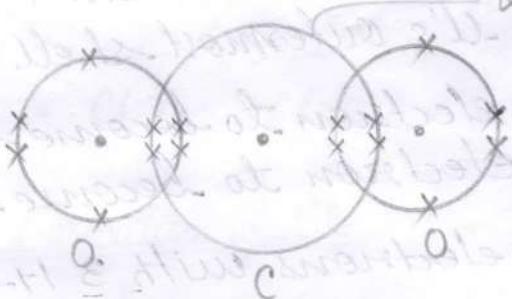
Formation of NH₃

Structure of NH₃ (Ammonia)



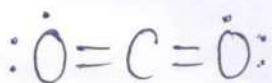
Formation of CO₂ (Carbon dioxide)

- Electronic configuration $_{\text{C}} - 1S^2 2S^2 2P^2$
- Electronic configuration $_{\text{O}} - 1S^2 2S^2 2P^4$
- C has 4 electron in it's outermost shell
- O has 6 electron in it's outermost shell.
- C required 4 more electron to become stable
- O required 2 more electron to become stable
- C atom mutually shares it's 4 electrons with 2 O-atoms to form CO₂ molecule.



Formation of CO₂

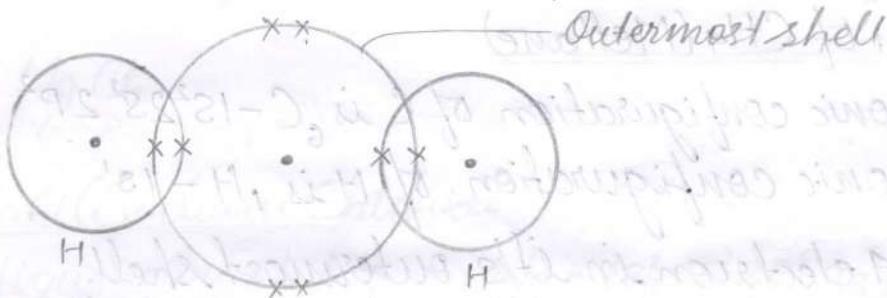
Structure of CO₂



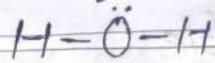
(Linear structure)

Formation of H_2O

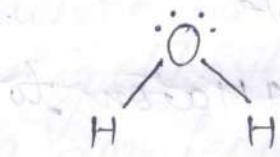
- Electronic configuration of H is $1H-1S^1$
- Electronic Configuration of O is $8O-1S^2 2S^2 2P^4$
- H has 1 electron in it's outermost shell
- O has 6 electron in it's outermost shell.
- H required 1 more electron to become stable
- O required 2 more electron to become stable
- O atom mutually shares it's 2 electrons with 2 H atoms to form H_2O molecule.



Structure of H_2O

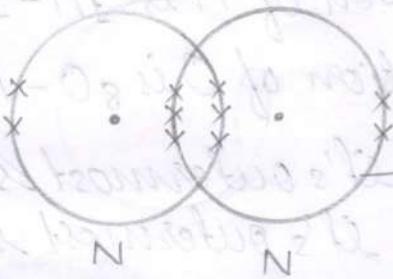


Formation of H_2O



Formation of N_2

- Electronic configuration of N is, $N-1S^2 2S^2 2P^3$
- N has 5 electron in it's outermost shell.
- N required ~~3~~ 3 more electron to satisfied octet rule
- Two N atom mutually shares 3 electron each to form N_2 molecule.



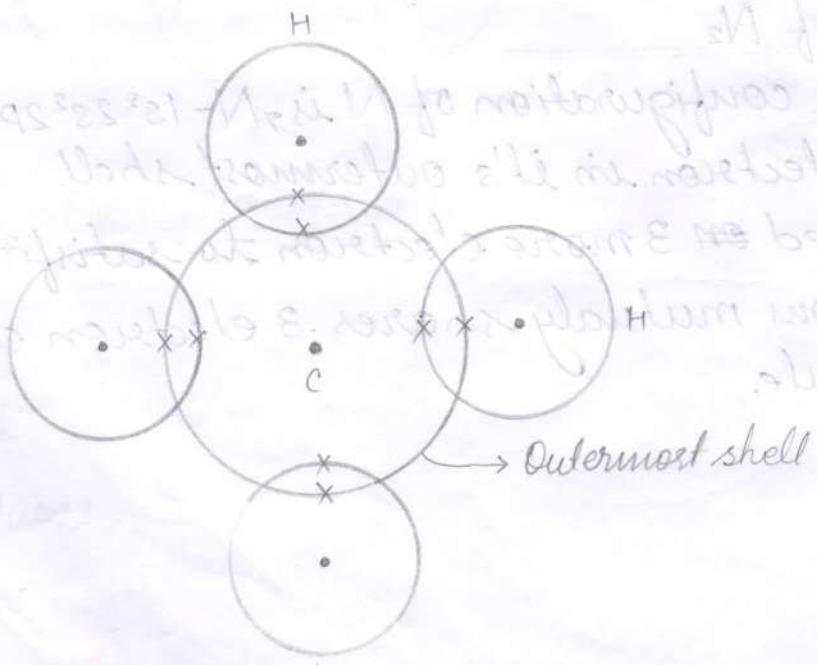
Formation of N_2

Structure of N_2



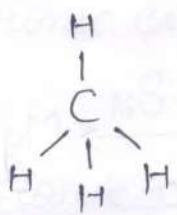
Formation of CH_4 (Methane)

- Electronic configuration of C is $C-1S^2 2S^2 2P^2$
Electronic configuration of H is $H-1S^1$
- C has 4 electron in it's outermost shell.
H has 1 electron in it's outermost shell.
- C required 4 more electron to become stable
H required 1 more electron to become stable
- C atom mutually share it's 4 electron with 4 H atom to form CH_4 molecule.



Formation of CH_4

Structure of CH₄



(Tetrahedral structure)

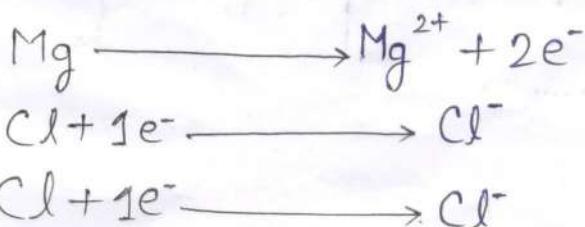
Ionic Bond

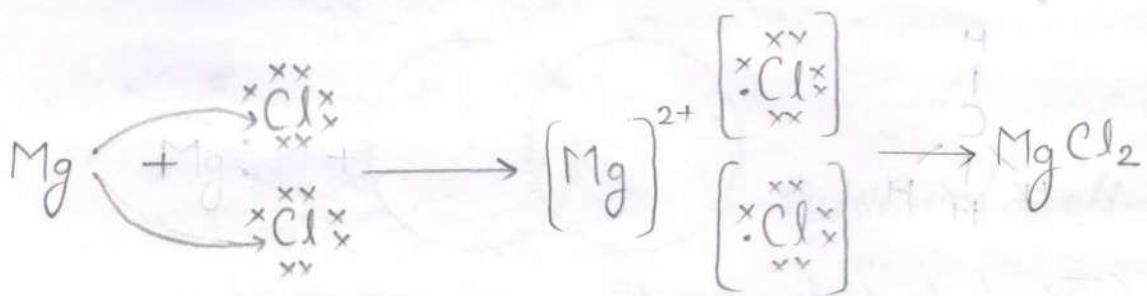
It is defined as the bond which is formed by the transfer of one or more electrons from one atom to the other atom.

Ex: NaCl, KCl, MgCl₂

Formation of NaCl (Sodium Chloride)

- Electronic configuration of Na is, $_{11}Na - 1S^2 2S^2 2P^6 3S^1$
Electronic configuration of Cl is, $_{17}Cl - 1S^2 2S^2 2P^6 3S^2 3P^5$
- Sodium has 1 electron in its outermost shell.
Chlorine has 7 electron in it's outermost shell.
Being oppositely charged N^-
- Na donates one electron and forms Na^+ ion (sodium cation)
- Cl accepts the electron donated by sodium and forms Cl^- ion (Chloride anion)
- Being oppositely charged Na^+ & Cl^- held together by electrostatic force of attraction and forms ionic bond.

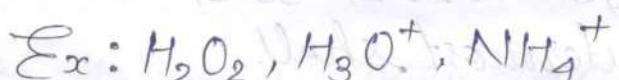




Co-ORDINATE BOND

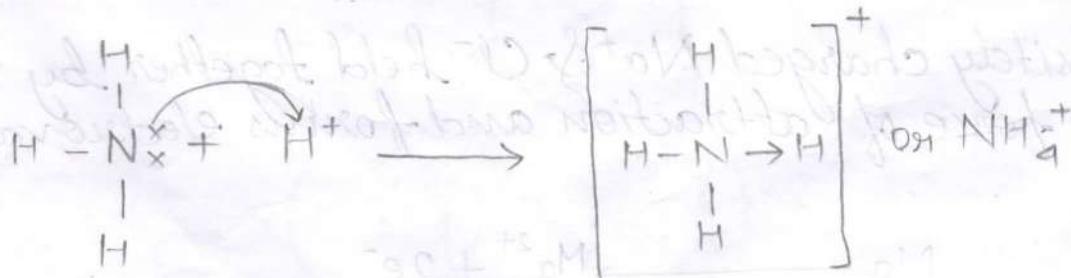
A co-ordinate bond is formed when an atom with complete octet donates its pair of electrons to the other atom. The donated pair is counted for the stability of both the atoms.

- It is formed between two dissimilar atoms.
- It is denoted by sign → (single headed arrow)
- It is directional in nature



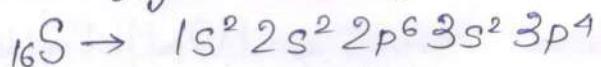
FORMATION OF NH_4^+ (AMMONIUM) ION

- NH_3 donates its lone pair of electron to H^+ ion and forms NH_4^+ ion.

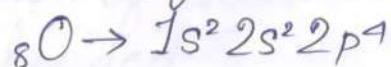


FORMATION OF SULPHUR DIOXIDE (SO_2)

- Electronic configuration of S is



- Electronic configuration of O is



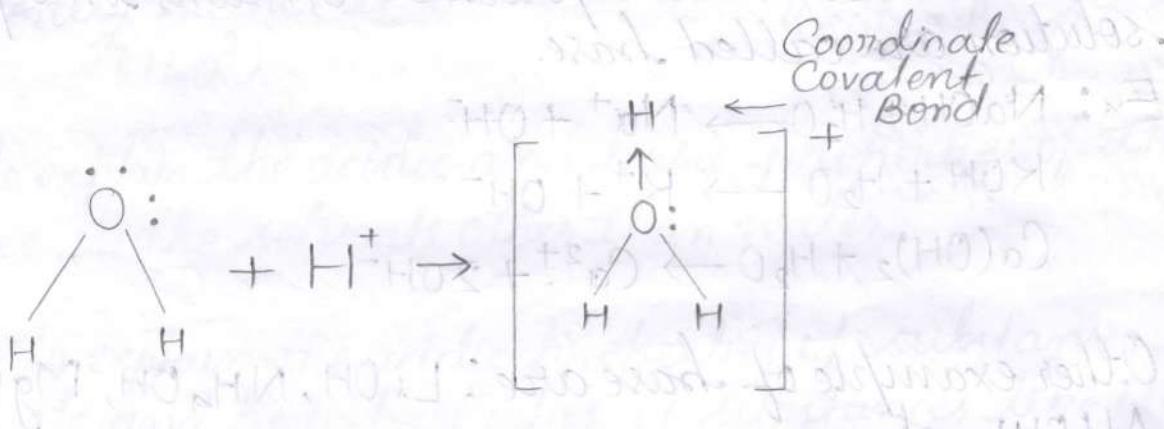
- Here sulphur donates its lone pair to oxygen atom



Coordinate bonding in SO_2

FORMATION OF H_3O^+ (Hydronium) Ion

- H_2O donates its lone pair of electron to H^+ ion and forms H_3O^+ ion.

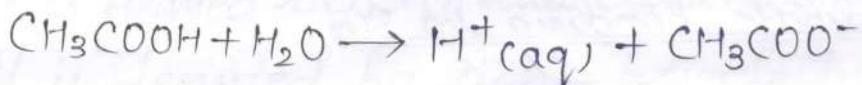
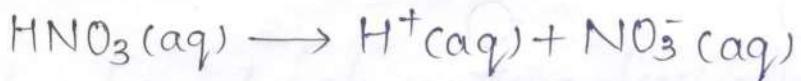


ACID AND BASE THEORY

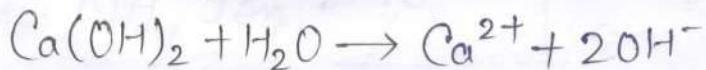
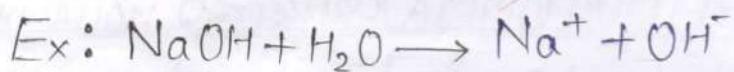
ARRHENIUS THEORY:

According to Arrhenius theory.

1. The substances which produce H^+ ions (Protons) in aqueous solution are called acid.



2. The substances which produce OH^- ions in aqueous solution are called base.



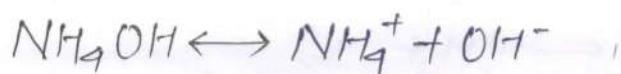
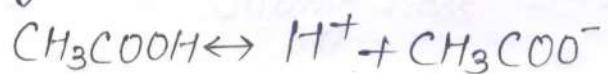
Other example of base are: LiOH, NH₄OH, Mg(OH)₂, Al(OH)₃, etc.

3. The acids and bases which can ionize completely called strong acids and strong bases.

Eg: HCl, H₂SO₄, KOH, NaOH.

The acids and bases which do not ionize completely are called weak acids and weak bases.
Eg: CH_3COOH , NH_4OH

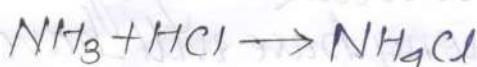
4. The ionisation of weak acids and bases are shown by double headed arrow.



5. According to Arrhenius theory an acid reacts with a base to form salt and water and the reaction is called Neutralization Reaction.

LIMITATIONS

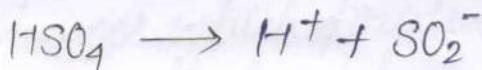
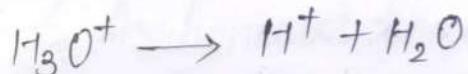
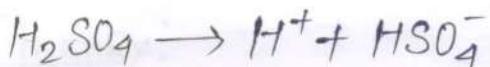
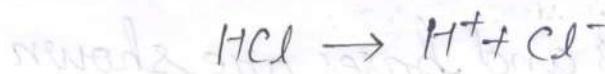
- According to this theory acid produces H^+ ions in aqueous solution but it has been found that H^+ ion cannot exist independently rather it exists in the form of Hydrogen ion (H_3O^+).
- It fails to explain the acidic and basic properties of the substances in the solvents other than water.
- It fails to explain the acidic properties of substances like CO_2 , SO_2 etc and basic properties of substances like NH_3 , CaO etc which do not contain H^+ or OH^- ions.
- It fails to explain the neutralization reaction in the absence of water like



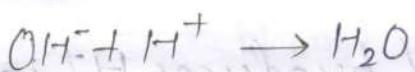
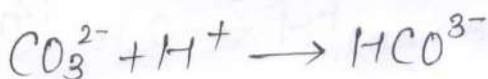
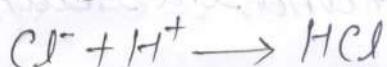
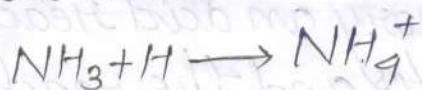
BRONSTED-LOWRY THEORY

According to this theory

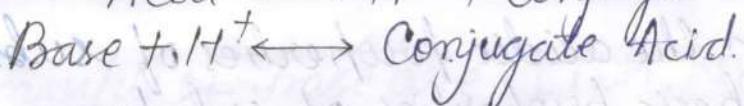
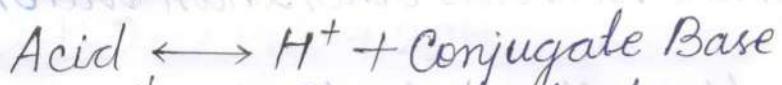
1. Acids are the substances, which can donate a proton (H^+)



2. Bases are the substances, which can accept a proton (H^+)

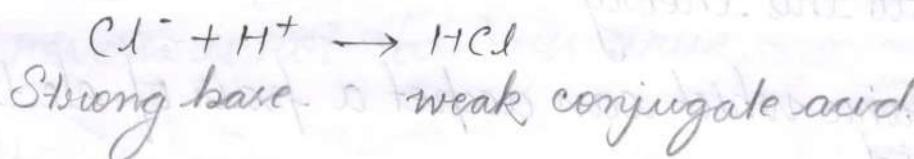
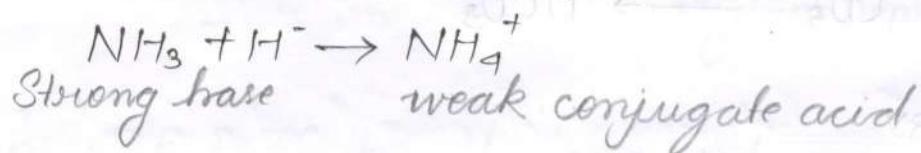
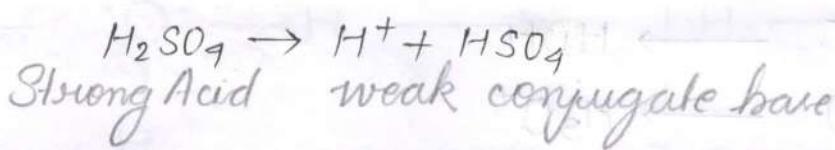
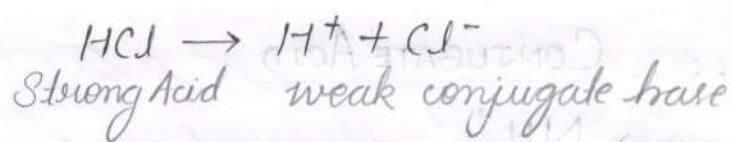


3. When an acid loses a proton, the residue formed will have a tendency to accept protons and similarly, when a base accepts a proton residue will have a tendency to lose a proton and it acts as an Acid. This pair of acid and base which differ by a proton is called conjugate Acid Base pair



Acid conjugate base.

4. A strong acid will have a weak conjugate base and vice versa. Similarly a strong base will have weak conjugate acid and vice versa.



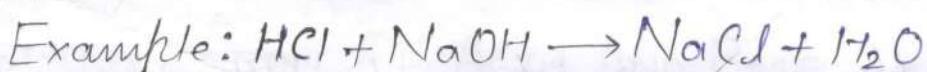
NOTE: All Arrhenius acids are Bronsted-Lowry acids; (HCl , HNO_3 , H_2SO_4 , H_3PO_4 , CH_3COOH , $\text{H}_2\text{C}_2\text{O}_4$ etc), however the reverse is not true.

LIMITATIONS

It fails to explain the acidic nature of the substances, such as SiO_2 , CO_2 , SO_2 , BF_3 , etc which cannot donate H^+ ion.

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

It fails to explain the reaction between some acids and bases which do not give another pair of acid and base.



BONUS POINT

<u>ACID</u>	<u>CONJUGATE BASE</u>
HF	F^-
HBr	Br^-
HNO_3	NO_3^-
$\text{HC}_2\text{H}_3\text{O}_2$	$\text{C}_2\text{H}_3\text{O}_2^-$
H_2SO_4	HSO_4^-
H_3O	OH^-

<u>BASE</u>	<u>CONJUGATE ACID</u>
NH_3	NH_4^+
OH^-	HOH
H_2O	H_3O^+
CO_3^{2-}	HCO_3^-

LEWIS THEORY

According to this theory

1. The substance which can accept a pair of electron is called acid

Ex: All cations e.g. Ca^{2+} , Mg^{2+} , Al^{3+} , Na^+ , H^+

Molecules having multiple bond e.g. CO_2 , SO_2 etc.

Molecules having atoms with vacant orbitals e.g.

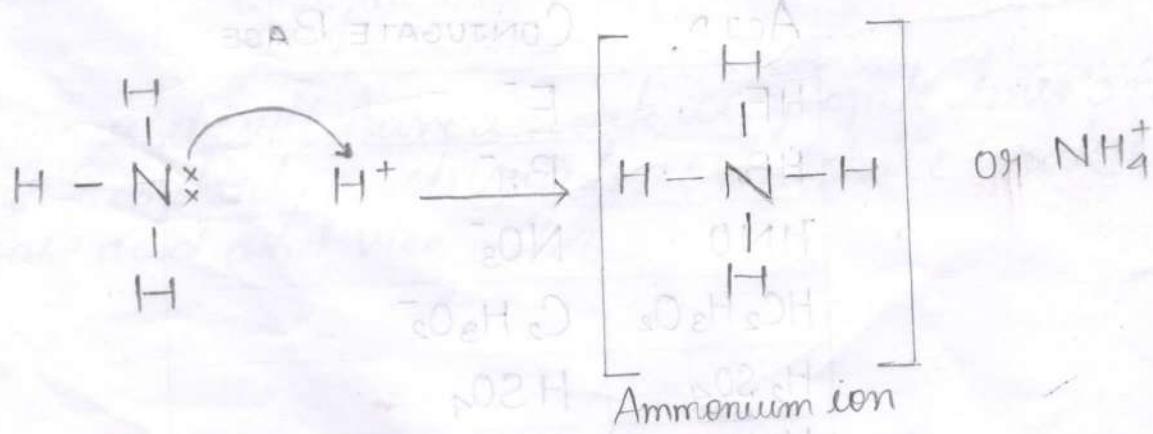
BF_3 , AlCl_3 , FeCl_3 , FeBr_3

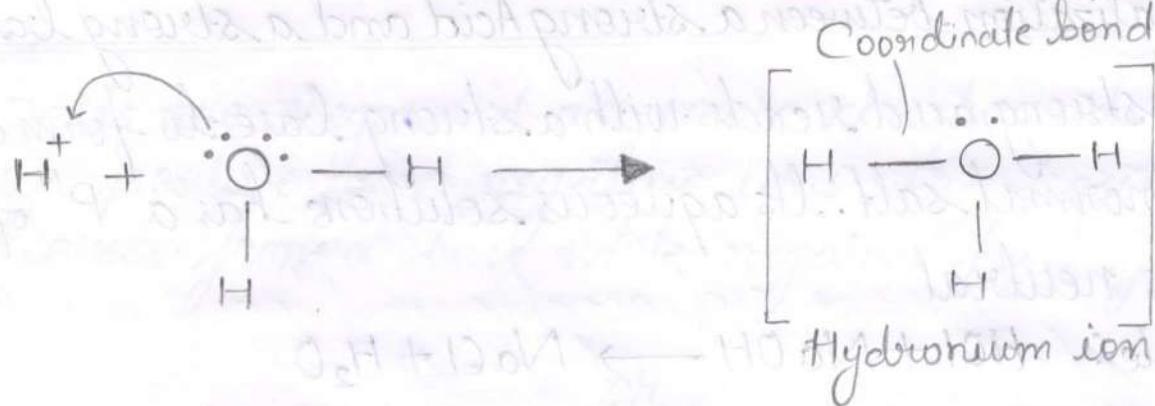
2. The substance which can donate a pair of electron is called base.

Ex: All anions e.g. Cl^- , OH^- , F^- , Br^- , CO_3^{2-} , NO_3^- etc

Neutral molecules having lone pairs of electrons e.g.
 NH_3 , PH_3 , PCl_3 , H_2O etc.

3. According to this theory, an acid reacts with a base to form a co-ordinate or dative bond.





NOTE: All Brønsted-Lowry bases are Lewis bases while the reverse is not always true.

LIMITATION

- The theory fails to explain the relative strength of different acids and bases.
- It fails to explain reaction between some acids and bases where no co-ordinate bond is formed.
- It couldn't explain the acidic nature as well of well known acid like HCl , HNO_3 , H_2SO_4 , etc. which cannot accept electrons.
- It fails to explain the basic nature of well known bases like NaOH , KOH etc. which cannot donate electrons.
- It couldn't explain acid-catalyzed reactions, where H^+ ion plays important role.

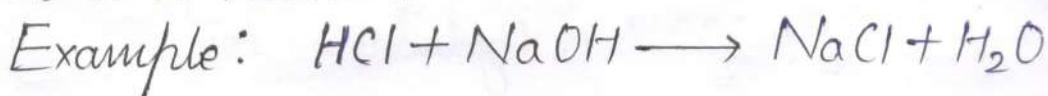
NEUTRALIZATION OF ACIDS AND BASES:

According to Arrhenius Theory, acid react with bases to form salt and water. This type of reaction is called neutralization reaction.

Neutralization reaction may take places as follows.

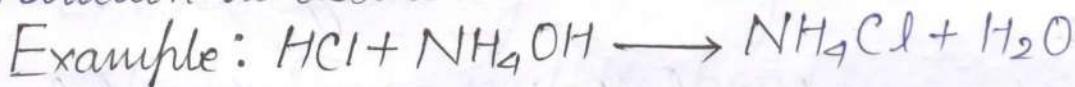
Neutralization between a strong Acid and a strong base:

A strong acid reacts with a strong base to form a simple or normal salt. Its aqueous solution has a P^H of about 7 and is neutral.



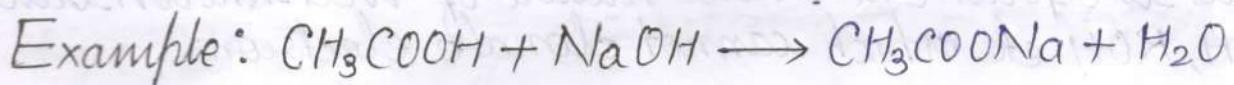
Neutralization between a strong Acid and a weak Base:

A strong acid reacts with a weak base to form a acidic salt. Its aqueous solution has a $P^H < 7$ and the solution is acidic.



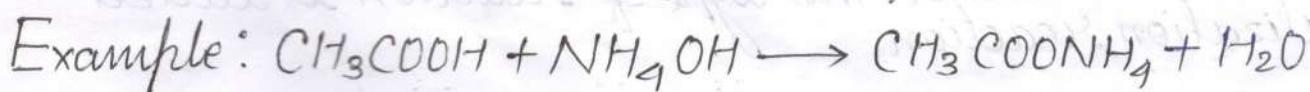
Neutralization between a Weak Acid and a Strong Base:

A weak acid reacts with a strong base to form a basic salt. Its aqueous solution has a $P^H > 7$ and is alkaline.



Neutralization between a Weak Acid and a Weak Base:

A weak acid reacts with a weak base to form a neutral salt. Its aqueous solutions has a $P^H > 7$ and is alkaline.



SALTS

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

Or

Salts are ionic compounds which produce cation other than H^+ and anion other than OH^- in aqueous solution.

Or

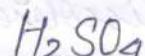
Salts are the compounds formed by the neutralization between acid and bases.

Type of salts:

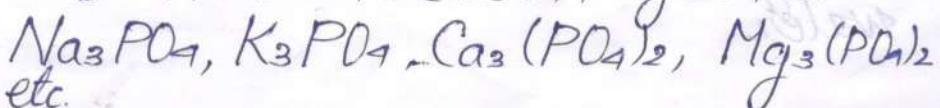
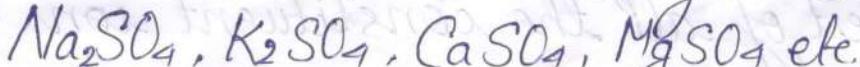
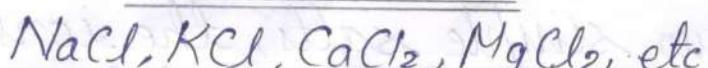
Salts may be classified into the following types:

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 hydrolyzed in aqueous solution.

Ex: Acids



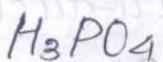
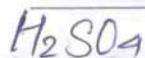
Normal salts



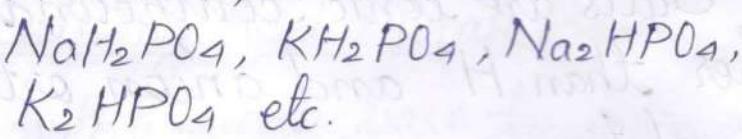
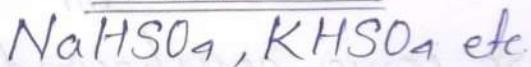
Acidic Salts:

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

Ex: Acids



Acidic salts



Also, these are the salts obtained by the neutralization between strong acids and weak bases.

For examples: NH_4Cl , NH_4NO_3 , $(\text{NH}_4)_2\text{SO}_4$, etc.

Basic Salt:

These are the salts obtained by the incomplete neutralization of poly acidic bases. Such salts contain one or more OH groups.

Example: $\text{Ca}(\text{OH})\text{Cl}$, $\text{Mg}(\text{OH})\text{Cl}$, $\text{Zn}(\text{OH})\text{Cl}$, $\text{Al}(\text{OH})_2\text{Cl}$ etc.

Also, these are the salts obtained by neutralization reaction between weak acids and strong bases.

Ex: CH_3COONa , CH_3COOK , Na_2CO_3 , K_2CO_3 , etc.

Double Salts:

These are the molecular addition compound obtained from two simple salts, the ions of which retain their identity in aqueous solution. Such salts give the test of all the constituent ions when dissolved in water.

Ex: Mohr's Salt $[FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O]$

carnalite (KCl , $MgCl_2$, $6H_2O$), etc.

Complex Salts:

These are the molecular addition compounds obtained by the combination of simple salts, the ions of which lose their identity in aqueous solutions. Such salts do not give tests of all the constituent ions in aqueous solution.

Ex: $K_3[Fe(CN)_6]$, $[Cu(NH_3)_4]SO_4$, etc.

Mixed Salts:

These are the salts which give either more than one cation or more than one anion in aqueous solution.

Ex: Bleaching powder $Ca(OCl)Cl$,
Sodium Potassium sulphate $NaKSO_4$, etc.



Electrostatic Bond

The bond which is formed by the transfer of one or more electrons from one atom to another atom is called electrostatic bond.

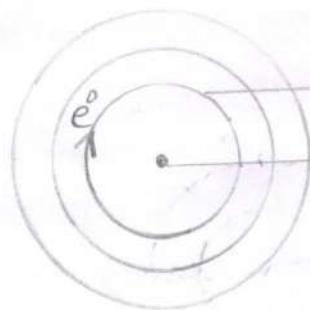
LECTURE NOTES
ON
ENGG. CHEMISTRY

FACULTY'S NAME: KUNI MAJHI
SR. LECTURER

SEMESTER: 1ST & 2ND

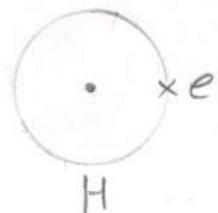
CHAPTER : 1

ATOMIC STRUCTURE



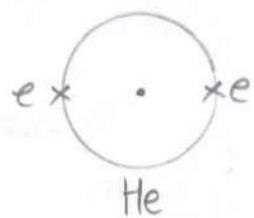
→ Orbit / Shell
→ Nucleus (proton + Neutron)
(two particle)

Symbol $\leftarrow H \rightarrow$ 1 proton
Atomic number $\leftarrow 1 \rightarrow$ 1 Electron

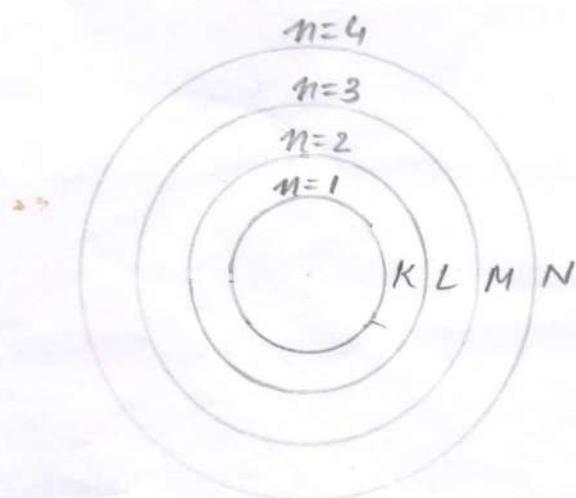


Helium (He)

$_2^2 He$ 2 proton
 2 Electron



Maximum number of electron in a shell = $2n^2$



$$K - \text{Shell} \rightarrow 2n^2 = 2 \times (1)^2 = 2 \times 1 = 2$$

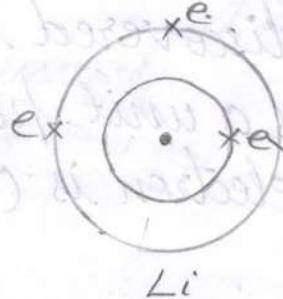
$$L - \text{Shell} \rightarrow 2n^2 = 2 \times (2)^2 = 2 \times 4 = 6$$

$$M - \text{Shell} \rightarrow 2n^2 = 2 \times (3)^2 = 2 \times 9 = 18$$

$$N - \text{Shell} \rightarrow 2n^2 = 2 \times (4)^2 = 2 \times 16 = 32$$

Lithium (Li)

${}^3\text{Li}$ 3 proton
 3 electron



Shell	Sub Shell	Orbital
K	S	1l
L	S, P	1l 1l 1l 1l
M	S, P, d	1l 1l 1l 1l 1l 1l 1l 1l 1l
N	S, P, d, f	1l 1l 1l 1l 1l 1l 1l 1l 1l 1l 1l 1l

Atom

John Dalton proposed (1808) that atom is the smallest invisible particle of matter. Atomic radii are of order 10^{-8} cm. It contains three sub atomic particles namely electrons, protons and neutrons.

Electron

- It was discovered by JJ Thomson.
- It carries a unit positive charge ($+1.6 \times 10^{-19}$ C)
- Mass of electron is (9.11×10^{-31} kg)

Proton

- It was discovered by Rutherford
- It carries a unit positive charge ($+1.6 \times 10^{-19}$)
- Mass of proton is 1.007276 u

Neutron

- It was discovered by James Chadwick
- Neutrons are neutral particles.
- Mass of neutron is 1.67×10^{-24} g or 1.008665 amu.

Thomson's atomic model

- According to JJ Thomson atom is a positive sphere with a number of electrons distributed within the sphere.
- It is also known as plum pudding model.
- It explains the neutrality of an atom.
- This model couldn't explain the results of ionisation and scattering experiments carried out by Rutherford.

Rutherford's Alpha Scattering Experiment

- Rutherford bombarded a thin sheet of gold foil (of thickness 0.00004 cm) with alpha particles.
- Alpha particles are generated from a radioactive element like radium.
- A thin lead plate with a hole cut in it was taken as a slit to form a beam of alpha particles.

- A circular screen coated with zinc sulphide was placed on the other side of the foil.

OBSERVATIONS

- Most of the alpha particles passed straight through the gold foil and cause illumination on the screen.
- Very few alpha particles are deflected at some angles after passing through the gold foil
- A rare number of alpha particles (one in 10,000) were collide with gold foil and bounced back.

CONCLUSION

From the above observation Rutherford concluded that.

- Most of the space of an atom is empty.
- Deflection of alpha particles at some angles states there is a small but heavy and positive charge particle is present at the centre of the atom which is called as nucleus.

Postulates of Rutherford's Atomic Model

- An atom consists of two parts.
 - (i) Nucleus
 - (ii) Extra nuclear part
- Nucleus is extremely small but heavy and positive charge situated at the centre of an atom.
- Nucleus consists of proton and neutron.
- Nucleus carries of proton and neutron
- Nucleus carries nearly the whole mass of an atom.
- The extra nuclear part of the atom is empty space around the nucleus where electrons are revolving around the nucleus.
- As the atom is neutral the number of electron present in it is equal to the number of protons.

Failure of Rutherford's Atomic model

- It doesn't explain the distribution of electrons in an atom and their energy.
- This atomic model doesn't obey the law of electrodynamic. When a charge particle revolve round an oppositely charged centre it loses energy continuously and come closer and closer towards the nucleus and ultimately fall into the nucleus. Thus Rutherford's model of atom is faulty.
- It couldn't explain the line spectra of an atom.

Postulates of Bohr's Atomic Model

- An atom consists of a massive positively charged nucleus.
- Electron revolves around the nucleus in certain fixed circular orbits without losing or gaining energy.
- Such orbits are called stationary states or main energy levels and numbered as $1, 2, 3, 4$ etc or alphabetically designated as K, L, M, N etc respectively.

- Energy associated with an orbit is given by

$$E_n = -1312/n^2 \text{ KJ/mole for H-atom}$$

where n = number of energy levels

- Electrons revolve only on those circular orbit for which the angular momentum is integral multiple of $nh/2\pi$

$$L = mvr = nh/2\pi$$

where m = mass of electron,

v = velocity of electron

r = radius of orbit

n = number of orbit

h = plank's constant

- Transition of electrons between two stationary states can take place by absorption or emission of energy.

$$\Delta E = E_2 - E_1 \text{ or } h\nu = E_2 - E_1$$

where ΔE = change of energy

E_2 = energy of second shell

E_1 = energy of first shell

h = plank's constant

- While revolving in a particular orbit an electron neither gain energy nor lose energy. The energy of a shell in an atom is fixed.

Bohr-Bury Scheme

The distribution of electron in different orbits is given by Bohr and Bury as follows.

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

Where n = number of the orbit.

For 1st shell, $n=1$, number of electrons = $2n^2 = 2 \times (1)^2 = 2$

For 2nd shell, $n=2$, number of electrons = $2n^2 = 2 \times (2)^2 = 8$

For 3rd shell, $n=3$, number of electrons = $2n^2 = 2 \times (3)^2 = 18$

For 4th shell, $n=4$, number of electrons = $2n^2 = 2 \times (4)^2 = 32$

- The outermost orbit of an element cannot contain more than 8 electrons and the penultimate shell cannot contain more than 18 electrons.
- It is not always necessary to complete the orbit before the next orbit starts filling.

Atomic number

- Atomic number of an element is defined as the number of the protons present in the nucleus of an atom.
- Ex: Hydrogen has one proton, so atomic number of hydrogen is 1

Atomic Mass

- The atomic mass of mass of an element is defined as the relative average mass of its atom as compared to the mass of carbon taken as 12 (^{12}C)
- Hence atomic mass of an element is the number which shows how many times the mass of that atom is heavier than $1/12^{\text{th}}$ the mass of the carbon atom (^{12}C) or 1 amu.
- Atomic mass is a number and it has no unit.
- Atomic mass of nitrogen is 14 or 14 amu. That means one atom of nitrogen is 14 times heavier than $1/12^{\text{th}}$ mass of an atom of carbon (^{12}C).

Mass Number

- The sum of number of protons and number of neutrons present in the nucleus of an atom is known as the mass number.
- Example: C has 6 proton and 6 neutrons

Isotopes

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

Example: H^1 , H^2 , H^3 .



Isobars

- Isobars are defined as the atoms of different elements having same mass number but different atomic number.

Example: ${}_{18}^{40}\text{Ar}$ ${}_{20}^{40}\text{Ca}$

Isotones

- Isotones are defined as the atoms of different element having same number of neutrons.

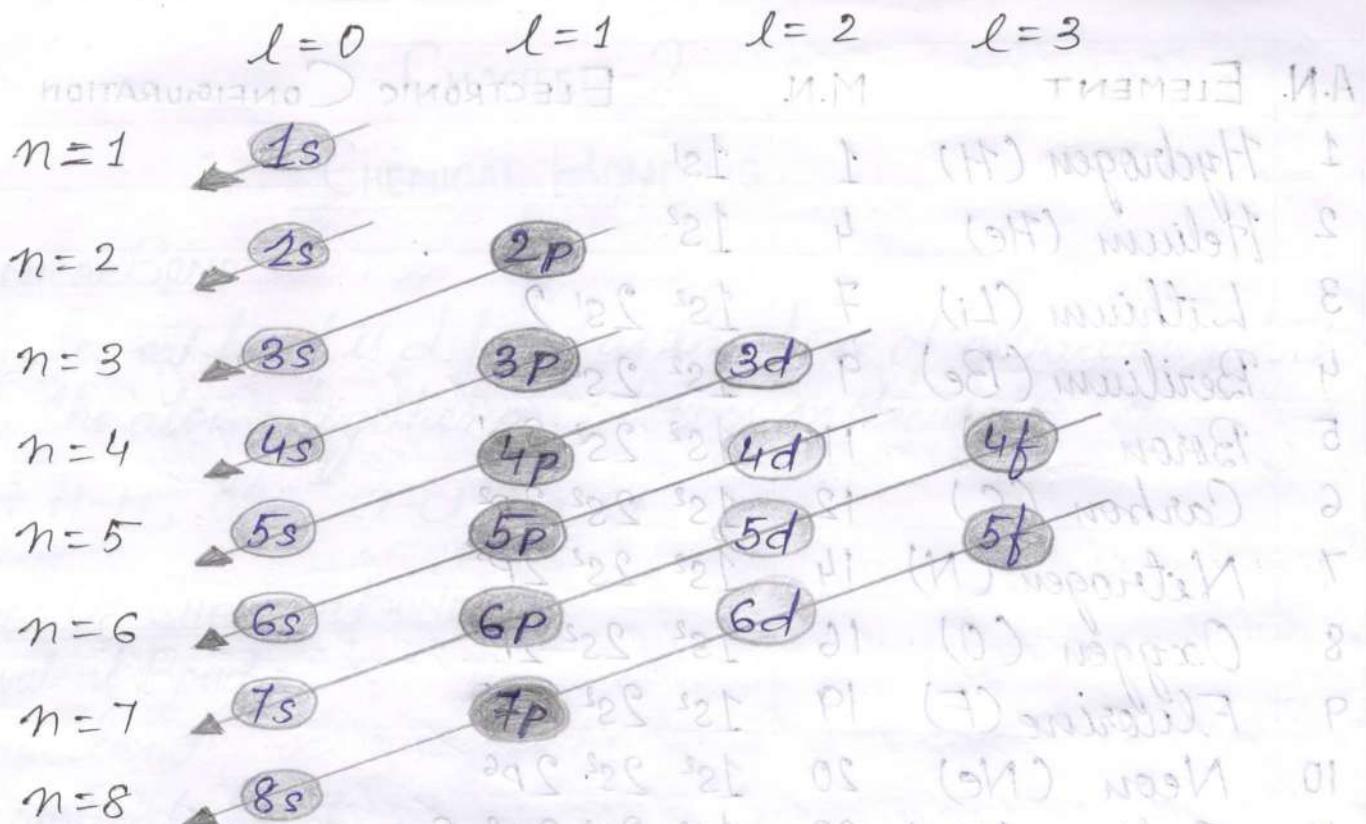
Example: ${}_{32}^{76}\text{Ge}$ ${}_{33}^{77}\text{As}$

Aufbau principle

- According to this principle, as the atom of different this electrons are filled in various orbitals in order of their increasing energies.
- Thus an orbital with lowest energy will be filled first.
- The energy of various sub-shell can be determined by $(n+l)$ rule.
- $(n+l)$ Rule: The sub-shell with lower $(n+l)$ value will possess lower energy and will be filled first.

Sub Shell	<u>$(n+l)$ value</u>
1s	$1+0=1$
2p	$2+1=3$
3d	$3+2=5$

Thus energy order of above sub-shells will be $1s < 2p < 3d$



Hund's Rule

- According to this rule, pairing of electrons doesn't take place in p , d and f orbitals unless each degenerate orbital in the given sub-shell is singly filled.

OR

Orbitals of same sub-shell first get singly filled and then pairing occurs.

Example:

Nitrogen N $1s^2 2s^2 2p^3$

$1s$	$2s$	$2p_x$	$2p_y$	$2p_z$
$1L$	$1L$	1	1	1

Oxygen O $1s^2 2s^2 2p^4$

$1s$	$2s$	$2p_x$	$2p_y$	$2p_z$
$1L$	$1L$	1	1	1

Nitrogen N $1s^2 2s^2 2p^3$

$1L$	$1L$	1	1	1
------	------	-----	-----	-----

$1L$	$1L$	$1L$	1
------	------	------	-----

✗

A.N.	ELEMENT	M.N.	ELECTRONIC CONFIGURATION
1	Hydrogen (H)	1	$1s^1$
2	Helium (He)	4	$1s^2$
3	Lithium (Li)	7	$1s^2 2s^1$
4	Berillium (Be)	9	$1s^2 2s^2$
5	Boron (B)	11	$1s^2 2s^2 2p^1$
6	Carbon (C)	12	$1s^2 2s^2 2p^2$
7	Nitrogen (N)	14	$1s^2 2s^2 2p^3$
8	Oxygen (O)	16	$1s^2 2s^2 2p^4$
9	Fluorine (F)	19	$1s^2 2s^2 2p^5$
10	Neon (Ne)	20	$1s^2 2s^2 2p^6$
11	Sodium (Na)	23	$1s^2 2s^2 2p^6 3s^1$
12	Magnesium (Mg)	24	$1s^2 2s^2 2p^6 3s^2$
13	Aluminum (Al)	27	$1s^2 2s^2 2p^6 3s^2 3p^1$
14	Silicon (Si)	28	$1s^2 2s^2 2p^6 3s^2 3p^2$
15	Phosphorus (P)	31	$1s^2 2s^2 2p^6 3s^2 3p^3$
16	Sulfur (S)	32	$1s^2 2s^2 2p^6 3s^2 3p^4$
17	Chlorine (Cl)	35	$1s^2 2s^2 2p^6 3s^2 3p^5$
18	Argon (Ar)	40	$1s^2 2s^2 2p^6 3s^2 3p^6$
19	Potassium (K)	39	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
20	Calcium (Ca)	40	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$
21	Scandium (Sc)	45	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$
22	Titanium (Ti)	48	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2$
23	Vanadium (V)	51	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^3$
24	Chromium (Cr)	52	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$
25	Manganese (Mn)	55	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^5$
26	Iron (Fe)	56	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$
27	Cobalt (Co)	59	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^7$
28	Nickel (Ni)	59	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$
29	Copper (Cu)	63	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10}$
30	Zinc (Zn)	65	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10}$