

INDUSTRIAL CHEMISTRY

By

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INDUSTRIAL CHEMISTRY

Chapter 10: Water Treatment

Sources of water

The source of water can broadly be classified into two types:

1. Surface Water
2. Underground Water

Surface Water: Rain Water, River Water, Sea Water, Lake water and pond water are the major sources of surface water.

Underground Water: Spring water and Tube-Well water are major sources of underground water.

CLASSIFICATION OF WATER

Water is classified into two types:

- a. Soft water
- b. Hard water

Soft water: The water which produces enough foam or lather with soap solution is called soft water.

Example: Rain water, Distilled water, Demineralized water etc. are the examples of soft water.

Hard water: The water which does not produce much foam lather with soap solution is called hard water.

Example: Pond water, River water, Sea water etc. are the examples of hard water.

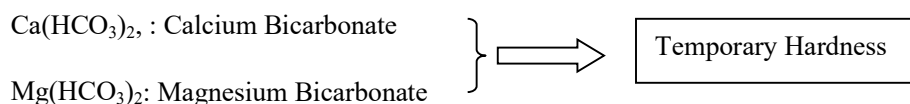
Hardness of water: The characteristic of water by virtue of which it prevents the formation of foam with soap solution is called hardness. The hardness of water is due to the presence of certain dissolved minerals like $\text{Ca}(\text{HCO}_3)_2$, $\text{Mg}(\text{HCO}_3)_2$, CaCl_2 , MgCl_2 , FeSO_4 , etc. in water.

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

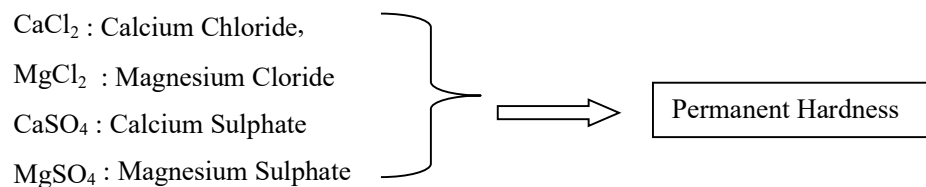
Hardness of water is of two types:

1. Temporary or Carbonate hardness
2. Permanent or Non-carbonate hardness

1. **Temporary hardness:** The temporary hardness of water arises due to the presence of bicarbonates of Ca and Mg. Temporary hardness is also called carbonate hardness.



2. Permanent of hardness: The permanent hardness of water arises due to the presence of chlorides and sulphates of Ca, Mg.



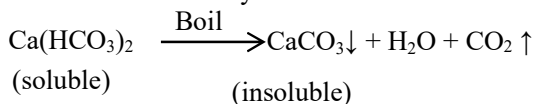
REMOVAL OF HARDNESS OR SOFTENING OF WATER

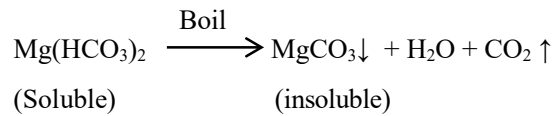
The process of decreasing the hardness of water is called softening of water . It involves decreasing the concentration of calcium and magnesium salts in water.

REMOVAL OF HARDNESS

A. Removal of Temporary Hardness:

The temporary hardness of water can easily be removed just by boiling the water. When hard water is boiled, the soluble Ca(HCO₃)₂ and Mg(HCO₃)₂ are decomposed in to insoluble carbonates, which are removed by filtration.



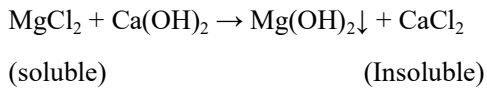
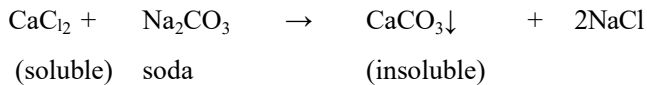


B. Removal of Permanent Hardness:

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

1. LIME SODA PROCESS METHOD/ PROCESS

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



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

Lime-Soda process is of two types.

a. COLD LIME-SODA METHOD:

Principle:

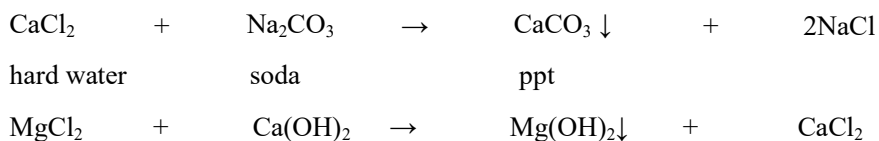
A calculated quantity of lime and soda is treated with hard water at room temperature. Lime and soda react with the hardness causing chemicals present in hard water and the precipitates or sludge formed are removed by filtration

Construction of Apparatus:

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

Working Process:

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



hard water lime ppt

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

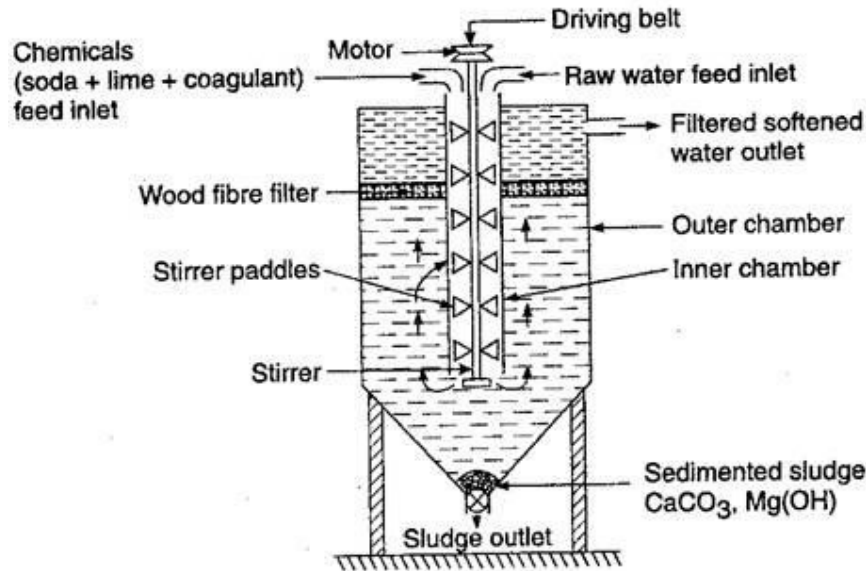


Fig. Cold Lime-Soda Method

b. HOT LIME-SODA METHOD:

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

Apparatus: The apparatus consists of three main parts:

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

Working Process:

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

The residual hardness left in this process is only about 15 – 30 ppm.

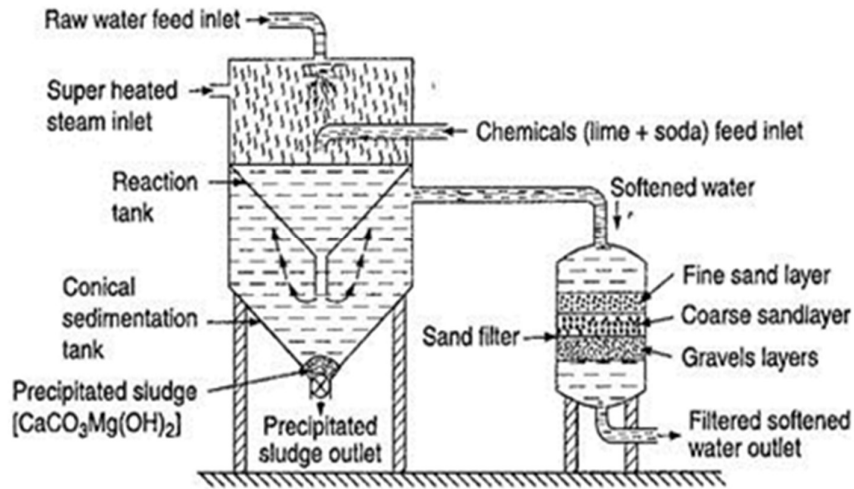


Fig. Hot Lime-Soda Method

Advantages of hot lime-soda method over cold lime-soda method

- i.** It is much economical.
- ii.** The reaction is completed within a short period.
- iii.** The reaction proceeds faster. Hence the softening capacity is increased.

- iv. No coagulant is required, as the sludge settles down easily.
- v. Dissolved gasses like CO₂, air etc. are removed.
- vi. Under hot condition viscosity of water is lowered. Thus filtration becomes easier.
- vii. Pathogenic bacteria are destroyed.
- viii. The residual hardness left in this process is much lower (15-30 ppm) as compared to that in the cold L-S process (50-60 ppm).

2. ION EXCHANGE METHOD:

[Deionization process or Demineralization process]

This is the modern method for softening of water by using ion-exchangers (ion-exchange resins). Ion-exchange resins are polymers that act as a medium for ion exchange. These are water insoluble long chain organic polymers having micro-porous structure. These resins contain either acidic or basic functional groups capable of exchanging their H⁺ or OH⁻ ion with the ions present in hard water.

Ion-exchange resins are of two types:

A. Cation-exchange resins (RH)

These resins contain acidic functional groups like – COOH, -SO₃H etc. which can exchange their H⁺ ions with the cations present in hard water.

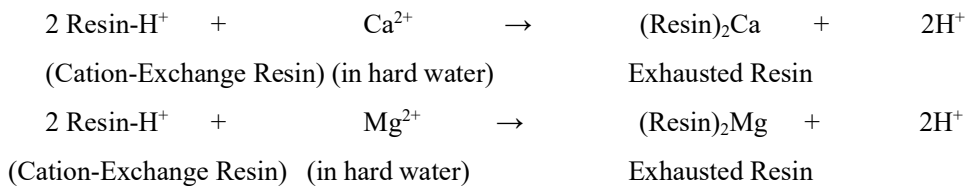
B. Anion-exchange resins (ROH)

These resins contain basic functional groups like – N⁺Me₃OH⁻ which can exchange their OH⁻ ions with the anions present in hard water.

Process

a. Removal of cations from hard water

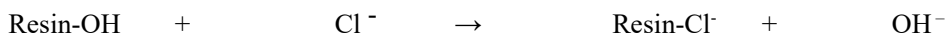
At first hard water is first passed through a column of cation-exchange resin in the first tank. So that all the cations (Ca²⁺, Mg²⁺) present in the hard water get exchanged H⁺ ions of the resins.



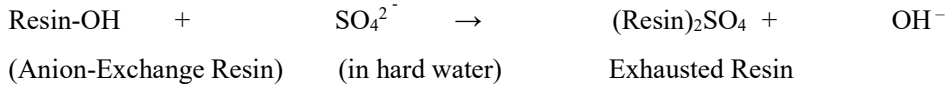
Ca²⁺ and Mg²⁺ ions are retained by the resin. The H⁺, Cl⁻ and SO₄⁻ ions remain in the cation-free water obtained from the first tank.

b. Removal of anions from hard water

The cation free water is now allowed to pass through a column of anion-exchange resin in the second tank. So that all the anions (Cl⁻, SO₄²⁻) present in the hard water get exchanged with OH⁻ ions of the resin



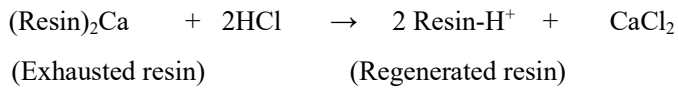
(Anion-Exchange Resin) (in hard water) Exhausted Resin



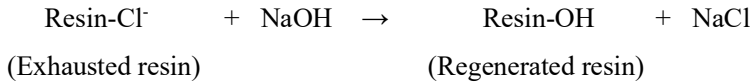
The water coming out from the second tank is free from the cations like Ca^{2+} , Mg^{2+} and the anions like Cl^- , SO_4^{2-} . Such water is known as deionised or demineralised water.

Regeneration of resins:

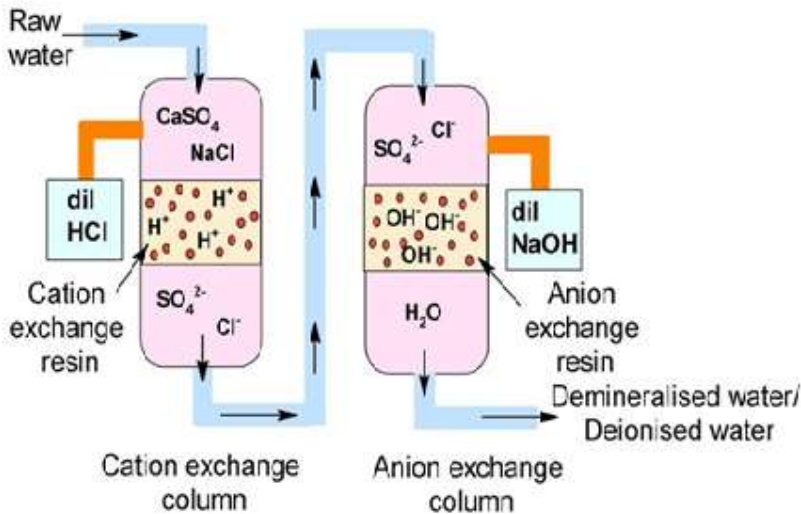
When all the H^+ and OH^- ions of the resins are exchanged by the ions of hard water, then the resins are said to be exhausted. The exhausted cation-exchange resin can be regenerated by the treatment of dil. HCl.



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



**DEMINERALISATION PROCESS/
ION-EXCHANGE PROCESS**



Chapter 11: Lubricants

The substance applied in between two moving or sliding surfaces in order to reduce the frictional resistance is called lubricant.

Functions of lubricants

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

Type of lubricants

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

1. **Solid lubricants:** These are solids at room temperature.

For example: Graphite, mica, molybdenum disulphide (MoS_2), boron trinitride (BN), etc.

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

2. **Liquid lubricants:** These are liquids at room temperature.

Example: Oils, Mobiles, petroleum oil, blended oil, animal oil, vegetable oil etc.



Functions of Liquid Lubricants:

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

Liquid lubricants are used when:

- The operating temperature is very high
- The speed of the roller is very high

- The sealing arrangement is perfect to prevent the loss of oil.

3. **Semi solid lubricants:** These are slightly thicker than liquid at room temperature.

Example: Grease Some major components of greases are:

- Oil component:** mineral oil, waxes, petroleum oils.
- Thickening component:** Na, K, Ca, Al soaps.
- Modifiers:** antioxidant, antirust agent, antiwear agents, etc.

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

Purpose of Lubrication

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

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

Chapter 12: Fuel

Fuel is a combustible matter which on burning with air or oxygen produces a large quantity of heat energy along with a low quantity residue.

Fuel + O₂ → Product(s) + Heat (This reaction is called combustion)

Characteristics of good fuel

1. Its calorific value should be high.
2. It should be cheap and readily available.
3. It should be stored for a longer period.
4. It should not produce much ash.
5. Transportation should be easy.
6. It should not produce any poisonous gas.
7. It should not produce much smoke.
8. It should have low ignition temperature.
9. It should not be explosive in nature.
10. It should not contain high percentage of moisture.

Calorific value

Calorific value is defined as the amount of heat energy produced by the complete combustion of one gram of fuel in excess of air or oxygen. Units of Calorific value are: Cal/gm, kcal/Kg, kJ/kg, British Thermal Unit (BTU) etc.

Classification of Fuel

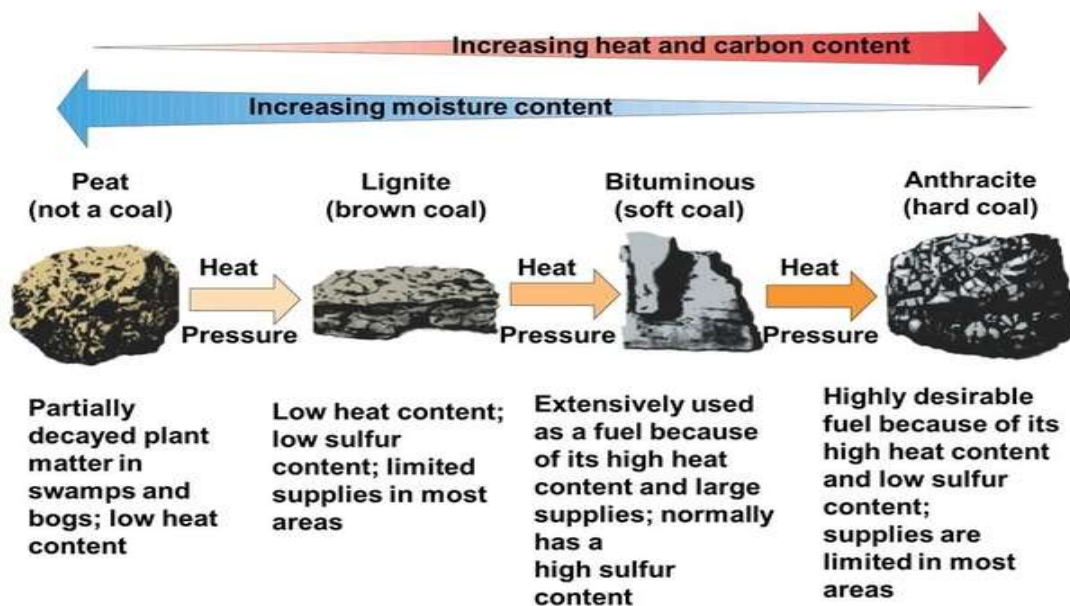
Depending upon the physical state, fuels are classified in to three types:

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

Coal

Coal is a combustible solid, which on combustion produces large amount of heat. During natural calamities big trees are uprooted from the ground and get buried under the surface of earth. After thousands of years under high temperature and pressure, wood is decomposed into coal.

Wood → Peat → Lignite → Bituminous → Anthracite



PETROLEUM

The word petroleum is coined from two Greek words, 'Petra' - means 'rock' and 'Oleum' - means 'Oil'. It is also known as rock oil and mineral oil. The organic materials in ocean bed are transformed into crude petroleum due to heat, pressure and geological conditions.

The petroleum obtained from ocean bed is not pure. That is called crude petroleum, which contains various constituents such as petrol, diesel, kerosene, paraffin, petroleum gas, etc. These are separated by fractional distillation of crude petroleum.

Petrol or Gasoline

- The fraction obtained between 40° - 120 °C, chiefly contains petrol.
- It consists of hydrocarbons between pentane to octane (C₅H₁₂ to C₈H₁₈)
- It is volatile and inflammable.
- Average Composition C = 84%, H=15%, O+S+N =1%
- Calorific Value = 11,250 Kcal / Kg.

Uses:

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

Kerosene

- i. It is obtained between $180^{\circ} - 250^{\circ} \text{C}$
- ii. It consists of hydrocarbons between decane to hexadecane ($\text{C}_{10}\text{H}_{22}$ to $\text{C}_{16}\text{H}_{34}$).
- iii. Average Composition, C = 84 % , H = 16%, S < 0.1%
- iv. Calorific value = 11, 100 Kcal/ Kg

Uses:

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

Diesel

- i. It is obtained between $250^{\circ} - 320^{\circ}\text{C}$.
- ii. It contains a mixture of hydrocarbons between pentadecane to octadecane ($\text{C}_{15}\text{H}_{32}$ to $\text{C}_{18} \text{H}_{38}$).
- iii. Average composition: C = 85%, H = 12%, Rest = 3%
- iv. Calorific Value = 11000Kcal/kg

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

Water Gas

Composition: It is a mixture of combustible gases CO and H_2 with a little quantity of non-combustible gases CO_2 and N_2 .

The average composition of water gas is

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

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

Uses: It is used as:

- i. an illuminating gas.
- ii. a fuel
- iii. a source of H_2 gas
- iv.

Producer Gas:

Composition: It is a mixture of combustible gases, CO and H_2 with large quantities of non-combustible gases CO_2 and N_2 .

The average composition of producer gas is

CO = 22- 30%, H₂ = 8 - 12 %, CO₂ = 3%, N₂ = 52 - 55 %

Its calorific value is 1300 Kcal /m³.

Uses: It is used:

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

Low Sulphur Heavy Stock (LSHS):

When heavy oil or gas oil stock is cracked at the temperature range 475° -530°C under pressure of 100 kg/cm³, high grade petrol is obtained which contains very low quantity of sulphur and is called LSHS. These are rich in aromatics and iso-paraffins. These are mainly used in locomotives.

CNG (Compressed Natural Gas):

- a. **Composition:** It mainly contains methane.
- b. **Uses:** It is used in automobiles.

LPG (Liquefied Petroleum Gas):

- a. **Composition:** It is a mixture of propane and butane.
- b. **Uses:** It is used for heating and cooking in homes, refrigeration, industrial works etc.

COAL GAS:

- a. **Composition:** It is a mixture of gases (chiefly hydrogen, methane, and carbon monoxide) obtained by the destructive distillation of coal .
- b. **Uses:** It is used for lighting and heating.

Chapter 13: Polymers

Polymer: In Greek, 'poly' means many and 'mer' means unit or part. So a polymer is defined as a chemical substance which is composed of many repeating units. A polymer is a macromolecule that contains large number of single monomer units. Polymers may be natural polymer or synthetic polymer.

For example: Starch, cellulose, silk etc. are natural polymers

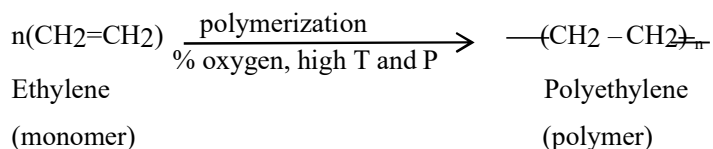
Polythene, PVC (polyvinyl chloride), Bakelite, Buna-S rubber are synthetic polymers.

Monomer: A monomer is the single repeating unit which on polymerization gives a polymer.

So, monomers are called building block of polymers

For example: Ethene is the monomer of polyethene.

Polymerization: The chemical process in which a large number of smaller molecules combine together to form a bigger molecule of high molecular mass is called polymerization.



Classification of Polymers

Polymers are classified into two types on the basis of repeating monomer units

1. Homo-polymer

1. Co-polymer

Homo-polymer

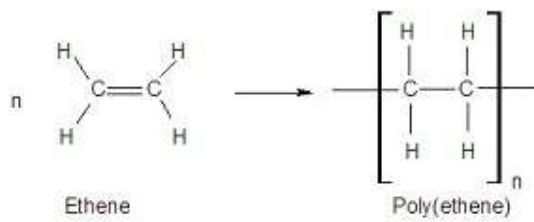
The polymer which contains identical monomer units is called a homo- polymer. In other words, the polymer formed from one type of monomer is called a homo- polymer. Example: polythene, PVC, Polystyrene etc.

Copolymer

The polymer which contains two or more different monomer units is called **co-polymer**. Example: terylene is a polymer of two monomers i.e, ethylene glycol and terephthalic acid. Other examples of co-polymer are Bakelite, Nylon-6,6, Buna- S etc.

Polyethene(Polyethylene)

Ethylene on polymerisation gives polythene.



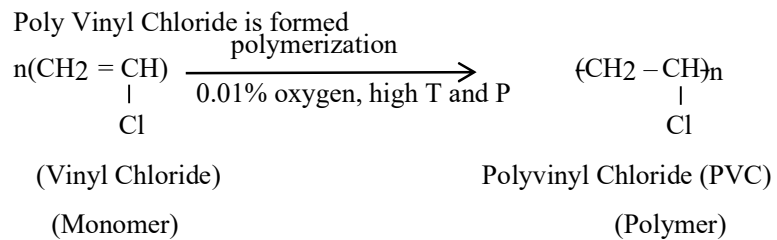
Uses of Polythene

It is used for making

- i. Plastic bags, buckets and bottles
- ii. Plastic containers
- iii. Thin transparent film(Cling film) for wrapping fish and vegetables

PVC (Poly Vinyl Chloride)

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

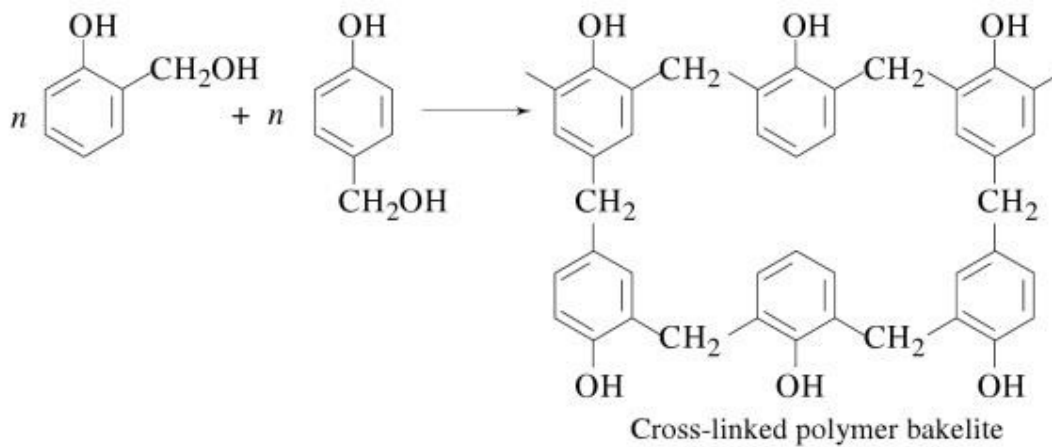


Uses of PVC: It is used for making:

- Sheets for tank lining
- Safely helmets
- Refrigerator components
- Tyres, cycle and motor cycle mudguards
- Rain coat packing
- Table cloths
- Electrical insulators
- Chemical containers

Bakelite (Phenol-Formaldehyde Resin)

It is a co-polymer of **phenol and formaldehyde**. When phenol and formaldehyde reacts together two isomeric compounds i.e, O-hydroxy methylphenol and P-hydroxy methylphenol are obtained. Then O-hydroxy methylphenol and P-hydroxy methylphenol react with each other to form a cross-linked polymer called Bakelite.



Uses: It is used in the manufacture of:

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

Thermosetting	Thermoplastic
(i)These are formed by condensation polymerization reaction.	(i)These are formed by additional polymerization reaction.
(ii)These are hard, strong and more brittle.	(ii)These are soft, weak and less brittle.
(iii)They can't be remolded.	(iii)They can be remolded.
(iv)They have network structure.	(iv)They have linear structure.
Example: Bakelite, Polyster etc.	Example: Polythene, PVC etc.

Elastomer (Rubber)

Any material which is able to regain its original shape after removal of deforming force is called elastomer.

Examples:

- a. Natural rubber
- b. Synthetic rubbers like Silicone rubber, Styrene butadiene rubber, Neoprene etc.

Natural Rubber

Natural rubber is obtained from latex, of rubber-producing plants.

The drawbacks of natural

- a. Strong tendency to absorb water and becomes weak.
- b. Easily reacts with acids, oxidizing agents, non-polar solvents etc.

*Due to the above drawbacks the natural rubber is subjected to Vulcanization.

Vulcanization of Rubber

Vulcanization is chemical process in which the raw rubber is heated with Sulphur to achieve elasticity, strength, and stability.

Advantages of Vulcanised rubber over raw rubber

Vulcanized rubber is stronger than raw rubber (non-vulcanized rubber) because its bonds are made of cross-links at an atomic level. This permits vulcanized rubber to stand up more load or stress.

Chapter 14: Chemicals in Agriculture

Pesticides

- The chemical substances used to control pests are called pesticides.
- Pest is a insect or animal which attacks crops, foods, etc. and cause serious damage in agriculture resulting in critical losses of yield, quality and profit.
- Insecticides, herbicides, fungicides etc. comes under pesticides

Insecticides

These are chemical substances which are used to kill insects.

Examples: DDT, Gammexane, Aldrin, Dieldrin, Endrin, Endosulfan etc.

Herbicides

These are chemical substances which are used to control growth of weed. So it is known as weedkillers.

Examples: Atrazine, Simazine, Glyphosate, Terbutylazine etc.

Fungicides

These are chemical substances or biological organisms used to kill parasitic fungi or their spores. A fungistatic inhibits their growth.

Examples: copper sulfate, cuprous oxide, lime-sulfur, Isoprothiolane etc.

Biofertilizers

These are substances which increase the fertility of soil and thus promote plant growth.

Examples: Blue green algae (BGA), Rhizobium, Azotobacter, Azospirillum etc.