

UNIT – 1

WATER TECHNOLOGY

Impurities in water

i) **Suspended Impurities**

Suspended Impurities are insoluble like dust fine sand particles, rust, etc. Suspended impurities are visible and size of particles is greater than 1000\AA

Removal Method- They can be removed from water by **simple filtration or sedimentation**.

ii) **Colloidal Impurities**

Colloidal impurities are finely divided organic or inorganic matter of the size 10 to 1000\AA . These impurities do not settle down and are evenly distributed in water.

Removal Method- Colloidal particles in water are negatively charged. They are separated by **coagulation followed by filtration or sedimentation**. The **coagulants** are like **FeSO₄, potash alum, sodium-aluminate, aluminium sulphate** are used.

iii) **Dissolved Impurities**

Dissolved impurities are of two types –

[I] Dissolved gases-. Gases like O₂, SO₂, NH₃, H₂S, CO₂ etc are soluble in water.

[II] Dissolved salts - Presence of dissolved salts like carbonates, bicarbonates, chlorides and sulphates of calcium, magnesium, iron and sodium causes hardness in water. Organic solids like sugars alcohols carboxylic acids, urea etc is soluble in water.

Removal Method-

Dissolved gases are removed by warming the water or mechanical deaeration method.

Dissolved salts are removed by chemical treatments.

iv) **Biological Impurities**

Biological impurities in water include pathogenic bacteria, algae, fungi, viruses, parasite worms etc. Water also gets contaminated with sewage & human excreted matter.

Removal Method-

They are removed by sedimentation and filtration followed by sterilization. The sterilization can be done by using chemicals **like bleaching powder, sodium hypochlorite, chlorine, chloramines, ozone etc.** and by physical methods like **boiling of water, UV light**.

Hardness of Water

Hardness in water is the characteristic which prevents the lathering of soap. The water which does not produce lather with soap, but forms insoluble white scum or precipitate is called as hard water. On the other hand, water which forms lather easily with soap is called as soft water. **Hardness is due to presence of dissolved salts of carbonates, bicarbonates, chlorides, sulphates, nitrates of calcium & magnesium, and other heavy metals.**

On the basis of these salts, hardness is divided in to two main types –

A. Temporary Hardness/Carbonate Hardness

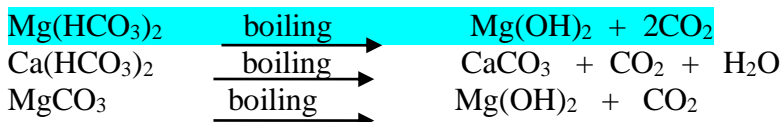
B. Permanent/Non carbonates Hardness

1. Temporary hardness is caused by presence of dissolved bicarbonates and carbonates of calcium, magnesium and other heavy metals.

e.g. CaCO_3 , MgCO_3 , $\text{Ca}(\text{HCO}_3)_2$, $\text{Mg}(\text{HCO}_3)_2$, Fe_2CO_3 etc

Temporary hardness can be largely removed by simple boiling of water.

Temporary hardness is also called as carbonate hardness or alkaline hardness.



2. Permanent/Non carbonate Hardness:

Permanent Hardness is caused by presence of dissolved chlorides, sulphates of calcium, magnesium, iron and other heavy metals. e.g. CaCl_2 , MgCl_2 , CaSO_4 , MgSO_4 etc. Unlike temporary hardness permanent hardness is not destroyed on simple boiling but can be removed by chemical treatment method. **Permanent hardness is also called as non - carbonate hardness or non - alkaline hardness.**

Total Hardness: It is the hardness due to the presence of all hardness causing salts.

i.e. Total hardness = Temporary Hardness + Permanent Hardness

Unit of Hardness: The hardness of water is always expressed in terms of calcium carbonate equivalent because calcium carbonate is most insoluble salt that can be precipitated in water treatment moreover; its molecular weight is 100.

CaCO_3 Equivalence of hardness causing salt

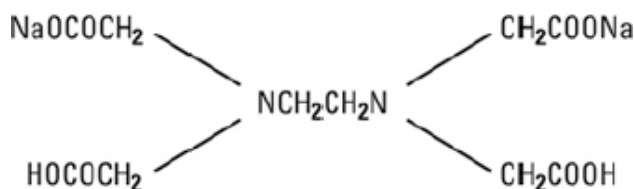
$$= \frac{\text{Mass of hardness causing salt} \times \text{Equivalent Wt. Or Molecular Wt. of } \text{CaCO}_3}{\text{Equivalent Wt. Or Molecular Wt. of hardness causing salt}}$$

- i) mg CaCO_3 eq. per lit (mg/L) – It is defined as the number of milligrams of calcium carbonate (CaCO_3) present in one litre of water.
 i.e., 1 mg/L = 1 mg of CaCO_3 eq. hardness of 1L of water.
 But 1 L of water weighs
 = 1 Kg = 1000 g = 1000 × 1000 mg = 10^6 mg.
 Thus 1 mg/L = 1 mg of CaCO_3 eq. per 10^6 mg of water
 = 1 part of CaCO_3 eq. per 10^6 parts of water = 1 ppm

- ii) ppm CaCO_3 eq. per lit – It is defined as the number of parts by weight of calcium carbonate (CaCO_3) present per million (10^6) parts by weight of water,
i.e., 1 ppm = 1 part of CaCO_3 eq. hardness in 10^6 parts of water.
- iii) degree clerk ($^\circ\text{Cl}$) & degree French ($^\circ\text{Fr}$) –
1 $^\circ\text{Fr}$ = 1 part per 10^5 parts of water
1 $^\circ\text{Cl}$ = 1 part per 70000 parts of water

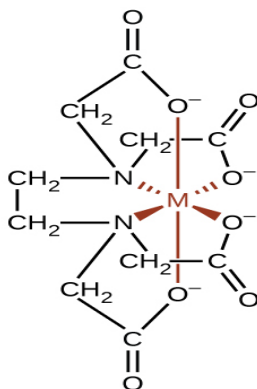
Determination of hardness of water by EDTA method

- It is a **complexometric titration** using standard EDTA reagent and EBT is used as an indicator.
- EDTA is **Ethylene diammine tetra acetic acid**. It is a **good complexing agent**.



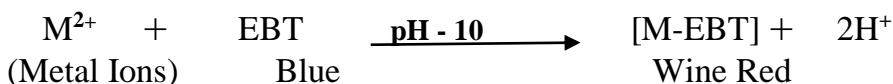
Di-Sodium EDTA

EDTA is a **hexadentate ligand**. It forms **stable, cyclic co-ordination complexes with large number heavy metal ions in hard water**. Due to this **it is possible to determine the total hardness of water using EDTA reagents**.

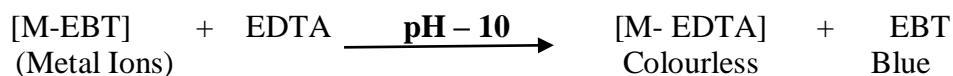


Principle – EDTA forms stable complexes easily with heavy metal ions present in hard water

Theory – Hardness of water is due to presence of dissolved salts of calcium, magnesium, iron and other heavy metals. The hard water is buffered to pH – 10 by adding buffer solution with pH – 10 and few drops of EBT indicator. EBT forms a weak complex with metal ions which has **wine red colour [M-EBT]complex**. During the course of reaction H^+ ions are released which decrease the pH of the reaction mixture. Thus buffer solution of pH – 10 is necessary during the reaction.



In the course of titration of water sample against EDTA, EDTA first combines with metal ions to give very stable and **colourless [M- EDTA]complex**.



Thus, at the equivalence point, there is change in the colour from wine red (due to metal-EBT) to blue (due to free EBT) and total hardness can be determined.

Procedure -

Titration part-I Standardization of EDTA solution:

Fill a burette with di-sodium EDTA solution and pipette out 10 ml std. MgSO_4 Solⁿ in a conical flask. Add about 5 ml buffer solution of pH-10 and 41-2 drops of EBT indicator. Titrate the wine red coloured mixture against the EDTA solution till colour changes to blue. Let the titration reading be V_1 ml.

Part II: Hardness of water sample

Take 10 ml water sample in a conical flask. Add 5 ml of buffer solution of pH 10 and 1-2 drops of EBT indicator. Titrate this wine red mixture against the standard EDTA solution till the colour change to blue. Let the titration reading be Y ml.

Calculations:

Part I: Standardization of EDTA

$$M_1V_1 = M_2V_2$$

$$\text{EDTA} = \text{MgSO}_4$$

Part II: Total hardness of water sample:

Total hardness of a water sample is determined, by using formula

$$\text{Hardness of water sample} = (Y \times Z \times 100 \times 1000) / V \quad \text{ppm CaCO}_3 \text{ equivalent.}$$

Where Y = Volume of EDTA

Z = Molarity of EDTA

V = Volume of Water sample

Temporary and permanent hardness by EDTA:

Hardness of the boiled and filtered water sample is further determined. The boiled and filtered water sample contains only permanent hardness. Permanent hardness is subtracted from total hardness to get temporary hardness

Advantages:

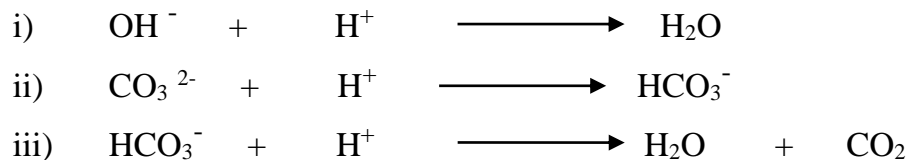
1. In EDTA titration method suitable indicators available for accurate reading.
2. Sharp colour change at the end point of titration can be observed.
3. The EDTA titration method is convenient have greater accuracy, rapid, and easy.

Alkalinity of water sample

Alkalinity in water sample is due to presence of OH^- , CO_3^{2-} , HCO_3^- .

These can be estimated separately by titration against standard acid, using phenolphthalein and methyl orange indicators.

The determination is based on the following reactions.



The titration of the water sample against a standard acid upto phenolphthalein end point (P) marks the completion of reaction (i) and (ii) only. This amount of acid used thus corresponds to hydroxide and one half of the normal carbonate.

On the other hand, titration of the water sample against a standard acid methyl orange end point (M) marks the completion of reactions (i), (ii) and (iii). Hence the total amount of acid used represents the total alkalinity (due to hydroxide, bicarbonate and carbonate ions).

Thus, P = Neutralization of OH^- and CO_3^{2-}

M = Neutralization of OH^- , CO_3^{2-} , HCO_3^-

Procedure –

- ❖ Take V ml of alkaline water sample in a conical flask and add 1-2 drops of phenolphthalein indicator in it.
- ❖ Titrate this sample against std. strong acid solution from burette, till pink colour changes to colourless. Let the burette reading be V1 ml.
- ❖ Add few drops of methyl orange indicator into the same titrating mixture and continue the titration till the yellow colour of mixture changes to orange. Note the burette reading as V2 ml.

Phenolphthalein alkalinity (P):

= $(V1 \times Z \times 50 \times 1000) / V$ ppm of CaCO_3 equivalents.

Methyl orange alkalinity OR Total alkalinity (M):

= $(V2 \times Z \times 50 \times 1000) / V$ ppm of CaCO_3 equivalents

The amount of alkalinities due to OH^- , CO_3^{2-} , HCO_3^- types are calculated from the relation between value of P & M.

Alkalinity	Quantity of OH^-	Quantity of CO_3^{2-}	Quantity of HCO_3^-
P=0	0	0	M
P=1/2M	0	2P	0
P=M	P	0	0
P<1/2M	0	2P	M-2P
P>1/2M	(2P-M)	2(M-P)	0

Ill effects of using hard water in boiler

Water is mainly used in boilers for the generation of steam and as coolant. A boiler water should correspond with following composition

- (i) Its hardness should be less than 0.2 ppm.
- (ii) Its caustic alkalinity (due to OH^-) should be between 0.15 and 0.45 ppm.
- (iii) Its soda alkalinity (due to Na_2CO_3) should be between 0.45 - 1 ppm.

But due to use of hard water some operational troubles in boiler are created known as ill effects. There are main four factors affecting boiler;

- **Priming and foaming**
- **Scale and sludge formation**
- **Boiler Corrosion**
- **Caustic embrittlement**

1. Priming and foaming

Priming: “Violent and vigorous boiling of boiler water which leads to “Wet” steam formation is called priming.” Wet steam is steam contaminated with droplets of dissolved salts. This phenomenon is called as ‘carry over’

Priming is caused by

1. Presence of considerable amount of dissolved salts
2. Very high level of boiler feed water
3. Presence of excessive foam
4. High speed of steam generation
5. Faulty boiler design

Foaming: “It is the formation of continuous foam or bubbles on the surface of water.”

Causes:

1. High concentration of dissolved salts in boiler feed water
2. Presence of oil droplets and alkalies
3. Presence of finely dispersed suspended material
4. Violent agitation of boiler feed water

Disadvantages of priming and foaming:

1. Due to foaming actual height of water column cannot be judged well.
2. Due to priming, the salts present in the droplets enter in the part of machineries where steam is being used, thereby decreasing life of machineries.
3. Dissolved salts in droplet of wet steam get deposited on evaporation of water, which reduces efficiency of machine parts.
4. Foaming causes wet steam formation.

Prevention of Priming and foaming:

1. Foaming can be prevented by adding antifoaming agents like castor oil or by adding chemical like sodium aluminate and followed by blow down operation.
2. Priming can be prevented by use of well softened or filtered water
3. Maintaining low water level in boiler can prevent priming.
4. Rapid changes in steam rate should be avoided.
5. Steam purifier can be used.

2. Sludge and scale formation

Sludge: Sludge is a soft, loose and slimy deposit of precipitated salts in boiler tube. It gets deposited at the bends and valves, affecting free flow of water.

Sludge formation:

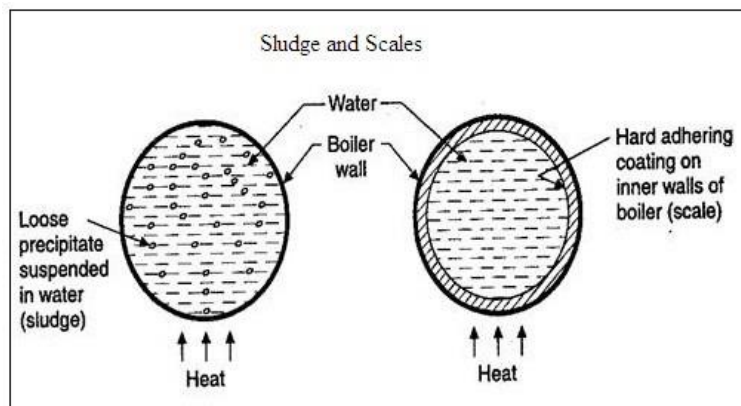
In boiler water evaporate continuously and the concentration of salt goes on increasing. After the saturation point dissolved get precipitated. If the precipitate remains in boiler tubes as loose and slimy matter, they are called as sludge. They are generally formed at cooler parts of boiler and the parts of boiler where flow rate is slow.

Disadvantages:-

1. They waste some portion of heat.
2. It disturbs working of boiler and sometimes may choke up the pipe
3. It reduces the flow rate of water in boiler.

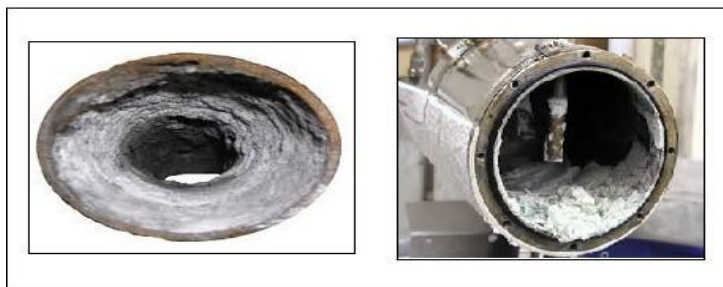
Prevention:-

1. Use of water containing very low quantity of total dissolved solids
2. Frequently making blow down operation.
3. They can be removed by using mechanical scrappers.



Scale formation:-

Definition: The **hard and strong deposits** formed inside boiler tube is called as scale.



In boiler water evaporate continuously and the concentration of salt goes on increasing. After the saturation point dissolved salts get precipitated. If the precipitate remains in boiler tubes as hard, strong, adherent matter, they are called as scales. They are generally **formed at hotter parts of boiler and are bad conductors of heat**.

Causes-

i) **Decomposition of bicarbonates:**

At high temp, bicarbonates decompose into sticky water insoluble material.



ii) **Hydrolysis of magnesium salts:** at higher temperature, magnesium salt undergoes hydrolysis, to form sticky.



iii) **Presence of silica:** Silica in the form of colloidal particles can deposit as calcium silicate or magnesium silicate as strong adhering material.

iv) **Decreased solubility of CaSO_4 :**

CaSO_4 has lesser solubility at higher temperature .Hence at high temp. CaSO_4 present in boiler will precipitate as hard scale forming material.

Disadvantage of Scales:

- ❖ **Wastage of Fuel:** Scales are bad conductors of heat and result in the reduction of heat transfer to the boil.
- ❖ **Over heating of boiler:** Scale reduces transfer of heat from boiler to boiler water, hence overheating is required to keep the required steam pressure.
- ❖ **Boiler Safety:**

Overheating of boiler is done due to scale formation. To maintain constant steam supply with required pressure boilers are overheated. Overheating makes boiler metal soft and weak which causes distortion of boiler tube & becomes dangerous in high pressure boiler.

❖ **Danger of explosion:**

When thick scale cracks due to uneven expansion, the water comes in contact with overheated boiler metal which causes large amount of steam formation & develops sudden high pressure. Due to this boiler metal may burst with explosion.

Removal of scales:

- ❖ The scale can be dissolved by use of suitable chemicals like EDTA, sodium phosphate, calgon etc and removed by blow down operation.
- ❖ Thin scales can be removed by use of scrapper or wire brush.
- ❖ Thick scales can be removed by hammer and chisel.
- ❖ To remove hard & brittle scale thermal shocks techniques is used.

Prevention of scales:

- ❖ Use of softened water.
 - ❖ Adding sodium phosphate to the water. (Phosphate conditioning).
 - ❖ Frequent blow down operations to remove the scales
 - ❖ Adding sodium aluminates, which can trap the scale forming particles.
 - ❖ Adding organic chemicals like tannin which forms coating on the scale forming particles.
- This matter becomes easily removable by blow down operation.

Differentiate between sludge and scale in boiler

Sr. No	Sludge	Scale
1.	Sludge is a loose deposit or slimy matter	Scale is hard coating
2	Sludge is soft, less adherent on boiler metal and can be removed easily by brushes, detergents.	Scale is strongly adhered to boiler metal and difficult to remove.
3	Sludge is formed at the cooler parts & where flow rate is slow.	Scale is form at the hotter parts.
4	Sludge may lead to chocking	Scale may lead to bulging of metal tube
5	Sludge formation is due to an increase in concentration of salts in boiler water.	Scales are formed due to CaSO_4 , CaCO_3 , Mg(OH)_2 , MgSiO_3 , CaSiO_3

3. Boiler Corrosion:

Boiler corrosion is decay or destruction of boiler metal either due to chemical or electrochemical reaction with its environment.

Disadvantages of corrosion are:

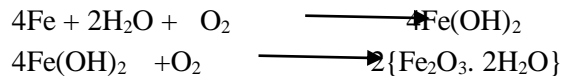
- Shortening of boiler life
- Leakage of the joints and rivets
- Increased cost of repairs & maintenance

Corrosion in boiler is due to following reasons

A] Dissolved Gases B] Dissolved Salts

A] Dissolved Gases – 1. Dissolved O₂ 2. Dissolved CO₂

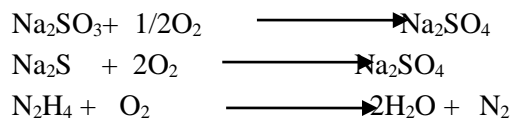
(1) **Dissolved Oxygen** – Water usually contains dissolved oxygen at room temperature. As the water is heated dissolved oxygen is set free and boiler metal starts corroding. Dissolved oxygen reacts with iron of boiler in the presence of water to form rust as follows-



Ferrous hydroxide

Removal of dissolved oxygen –

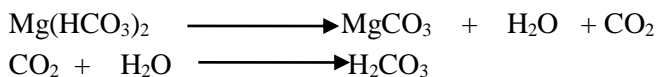
(i) By adding some quantity of Na₂SO₃ (Sodium Sulphite), Na₂S (Sodium Sulphide), hydrazine (N₂H₄).



(ii) Dissolved oxygen can also be removed by mechanical deaerators.

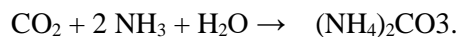
(2) Dissolved CO₂

There are two main sources CO₂ in boiler water, dissolved CO₂ in raw water and CO₂ formed by decomposition of bicarbonates.



Removal of CO₂

(i) CO₂ from water can be removed by using addition of suitable amount of NH₃



(ii) To avoid corrosion due to NH₃, its concentration restricted below 1 ppm.
CO₂ can be removed by mechanical de-aeration along with O₂

B) Hydrolysis of salts:

If water contains weak base- strong acid salts like MgCl₂, CaSO₄ etc, then they are hydrolysed at high temperature form strong acid. This acid corrodes boiler metal



To prevent corrosion due to acid formation in boiler 'the pH of water is adjusted to 8.5-9.0.

4. Caustic embrittlement:

It is the phenomenon during which the boiler material becomes highly brittle due to the accumulation and reaction of caustic substances with boiler metal.

OR

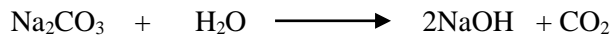
It is the phenomenon of embrittlement of boiler metal due to the accumulation and reaction of caustic soda with boiler metal.

Definition: It is the fast corrosion of boiler caused by presence of highly alkaline water in high pressure boiler.

Causes of Caustic embrittlement:

- ❖ During softening of boiler water by lime-soda process Na_2CO_3 is added to boiler water to reduce the hardness but if the amount of Na_2CO_3 exceeds, then it gets hydrolysed to form hydroxide.

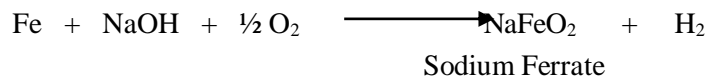
- ❖ Hydroxide makes the water caustic.



The caustic water flows into the minute-hair cracks, present in the inner side of the boiler by capillary action and react with boiler metal.

Disadvantages:

- ❖ The hydroxide formed, comes in contact with boiler metal thereby boiler metal as sodium ferrite it decreases the strength of boiler metal.



- ❖ Sodium ferrate is brittle in nature; if attack of NaOH is continuous then whole boiler becomes brittle causing failure of boiler.

Prevention:

- ❖ By using Sodium phosphate for water softening instead of Na_2CO_3 .
- ❖ By adding tannin or lignin to boiler water which blocks the cracks.
- ❖ By adjusting pH 8-9 of boiler water.
- ❖ By adding to boiler water to keep the ratio of Na_2SO_4 to NaOH as 1:1, 2:1, 3:1 at pressure 10,20 and above 20 atmospheres respectively.

Water Softening

The process in which hardness is removed or reduced, irrespective of whether it is temporary or permanent is termed as softening of water. The hardness causing salts can be removed from water by following two ways.

a) External Treatment b) Internal treatment

External

treatment

External treatment is carried out before it enters into the boiler. This treatment prevents boiler problems. It can be done by the following methods

- (i) **Zeolite process**
- (ii) **Ion- exchange process**

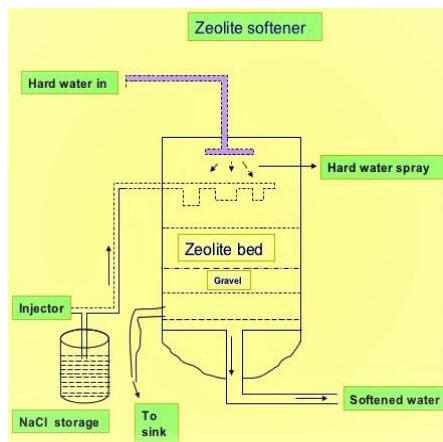
Zeolite Process

Principle - Zeolites are naturally occurring hydrated sodium alumina silicate minerals (like $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot x\text{SiO}_2 \cdot y\text{H}_2\text{O}$) where $x=2-10$, $y=2-6$. Zeolites are capable of exchanging reversibly its loosely held sodium ions for hardness producing ions like Ca^{2+} , Mg^{2+} in water.

Zeolites are also known as permutits and in Greek it means "boiling stone". Zeolite holds sodium ions loosely and can be simply represented as Na_2Ze where Ze represents insoluble radical frame work.

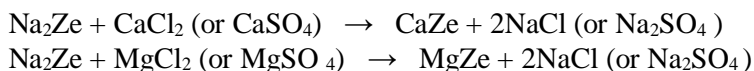
Zeolites are two types,

- (i) Natural zeolites are non porous for Ex; Natrolite $\text{Na}_2\text{Al}_3\text{O}_3 \cdot 4\text{SiO}_2 \cdot 2\text{H}_2\text{O}$
- (ii) Synthetic zeolites possess gel structure. Synthetic Zeolites possess higher exchange capacity than natural Zeolites.



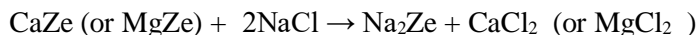
Process –

- For Softening of water by Zeolite process, hard water is passed through a bed of zeolite at a specified rate; kept in a cylindrical unit.
- The hardness causing ions (Ca^{+2} , Mg^{+2} etc.) are retained by the zeolite as CaZe and MgZe ; while the outgoing water contains sodium salts.
- Reactions taking place during the softening process are
$$\text{Na}_2\text{Ze} + \text{Ca}(\text{HCO}_3)_2 \rightarrow \text{CaZe} + 2\text{NaHCO}_3$$
$$\text{Na}_2\text{Ze} + \text{Mg}(\text{HCO}_3)_2 \rightarrow \text{MgZe} + 2\text{NaHCO}_3$$



Regeneration:

1. After some time the zeolite is completely converted into calcium and magnesium Zeolites. Eventually, the bed stops to soften water i.e.; it gets exhausted. At this stage the supply of hard water is stopped and the exhausted zeolite is reclaimed by treating the bed with a concentrated 10% NaCl solution (brine).



Limitations:

- (i) If the supply of water is turbid it will clog the pores of zeolite bed thereby making it inactive.
- (ii) Water contains large quantities of colored ions such as Mn^{+2} and Fe^{+2} they may be removed first because these ions produce Mn and Fe Zeolites, which are difficult to regenerate.
- (iii) Mineral acids destroy the zeolite bed.
- (iv) Hot water should not be used as zeolite tends to dissolve in it.

Advantages:

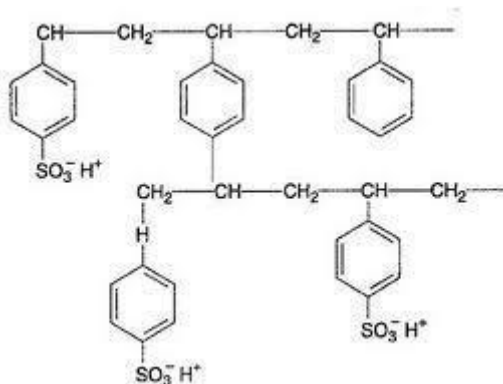
- (i) Hardness is almost completely removed and water of 5-10 ppm hardness is produced.
- (ii) Equipment used is compact and occupies small space.
- (iii) It is quite a clean process.
- (iv) It is a rapid process which requires less time.
- (v) The process automatically adjusts itself to water of different hardness.

2. Demineralization or Deionisation by Ion-exchange process

Ion exchange resins are insoluble, cross linked, long chain, high molecular weight organic polymers with micro porous structure, and the functional groups attached to the chains are responsible for the ion – exchanging properties.

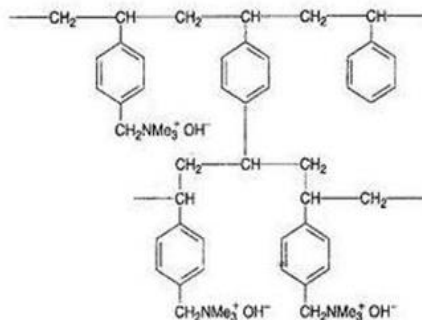
Ion exchange resins are of two types

1. **Cation exchange resins (R.H^+):** - These are the resins containing acidic functional groups ($-\text{COOH}$, SO_3H etc.) are capable of exchanging their H^+ ions with other cations, which come in their contact.



Cation exchange resin (R.H^+) are mainly styrene-divinyl benzene copolymers, which on sulphonation or carboxylation, become capable to exchange their hydrogen ions with the cations in water.

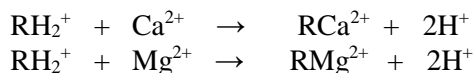
2. **Anion Exchanger resins(R^+OH^-):**-These are the resins containing basic functional groups ($-NH_2=NH$, hydrochloride, hydroxyl) are capable of exchanging their anions with other anions which comes in their contact.



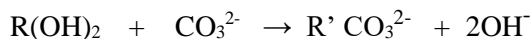
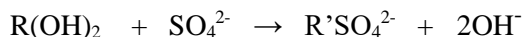
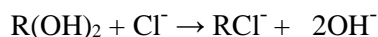
Anions exchange resins (R^+OH^-) are styrene-divinyl benzene or amine-formaldehyde, copolymers, which contains basic functional group such as amino or quaternary ammonium or quaternary phosphonium or tertiary sulphonium, groups as an integral part of the resin matrix. These after treatment with dilute NaOH solution become capable to exchange their OH^- anions with anions in water.

Principle: When water containing cations and anions is passed through the ion exchange resins, cation exchange resin captures all the cations and anion exchanger resin captures all the anions to give pure water free from all the ions.

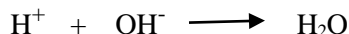
Hard water is passed first through cation exchange column, where all the cations like Ca^{+2} etc present in water are removed and equivalent amount of H^+ ions released from this column to water, thus



After cation exchange column, the hard water is passed through anion exchange column where all the anions like SO_4^{2-} , Cl^- etc present in the water are removed and equivalent amount of OH^- ions are released from this column to water thus,



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

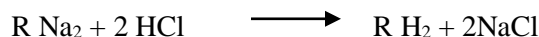


The water coming out from the exchanger is deionized or demineralised water.

Regeneration:

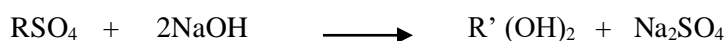
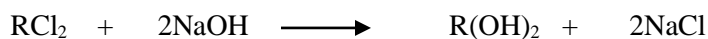
When capacities of cation and anion exchangers to exchange H^+ and OH^- respectively are lost they are said to be exhausted.

- (i) The exhausted cation exchanger is regenerated by washing with dil. HCl solution.





(ii) Cation exhausted anion exchanger resin is generated by washing with NaOH solution.



Thus the water coming out from exchanger is free from cations as well as anions. Such ion-free water is called as deionised or demineralised water. This method is also called as deionization or demineralization process.

Advantages:

1. This method gives water of very low hardness between 0-2ppm.
2. The process can be used to soften highly acidic or alkaline water.

Disadvantages:

1. Capital cost is high since equipment and chemicals both are costly.
2. If water contains turbidity then the efficiency of the process is reduced.

Desalination of brackish water

Water containing high concentration of dissolved salts with a peculiar salty or brackish taste is called brackish water. Sea water is an example of brackish water as it contains about 3.5% of dissolved salts. Removal of dissolved salts (NaCl) from water is called as desalination process. Commonly used techniques for desalination.

1. Distillation
 2. Freezing
 3. Electro-dialysis
 4. Reverse osmosis
1. **Distillation** – Huge evaporators are used for boiling the brackish water and vapours collected are condensed to get pure water. It is an expensive method for common practice.
 2. **Freezing** – When brackish water is cooled salt is left in the mother liquor and ice crystals are formed. These crystals can be easily separated, washed and melted to get pure water.
 3. **Electro-dialysis** – Electro-dialysis is based on the fact that the ions present in the saline water migrate towards their respective electrodes, through ion-selective membranes (natural or synthetic) under the influence of applied emf.
 4. **Reverse Osmosis** – The flow of solvent from higher concentration to lower concentration solution through a semi permeable membrane by applying slightly higher external pressure than osmotic pressure of higher concentration solution.

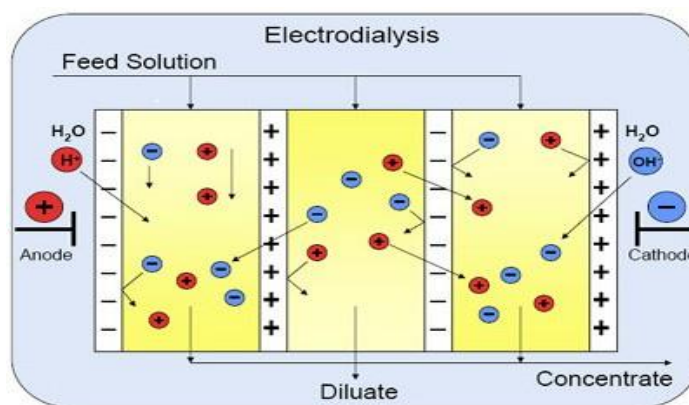
Electro-dialysis

Principle - Electro-dialysis is based on the fact that the ions present in the saline water migrate towards their respective electrodes, through ion-selective membranes (natural or synthetic) under the influence of applied emf.

Construction and working:-

- ❖ Electro-dialysis unit consist of electrodes (cathode and anode) and thin rigid ion selective membranes. The anode is placed near the anion selective membrane. Cathode is placed near the cation selective membrane.
- ❖ Cation selective membrane will allow only cation to pass through it, as this membrane consists of negatively charged fixed functional groups which repel anions.
- ❖ Anion selective membrane will allow only anions to pass through it, as this membrane consists of positively charged fixed groups which repel cations.
- ❖ When an electric field is applied, perpendicular to the direction of flow of water the cations move towards the cathode through cation selective membrane and anions move towards the anode through the anion selective membrane.
- ❖ The net result is depletion of ions in the central compartment while it increases in the two side compartments. Desalinated water is periodically drawn out from the central compartment.

Diagram:



Applications:-

1. The process is economical as per the capital cost.
2. Removal of salt from tree water, to get pure water.
3. The unit is compact and method is best suited.
4. Removal of ionic pollutants from treated industrial waste.
5. Removal of limited quantity of salts from sea water to get drinking (mineral) water.

Limitations:-

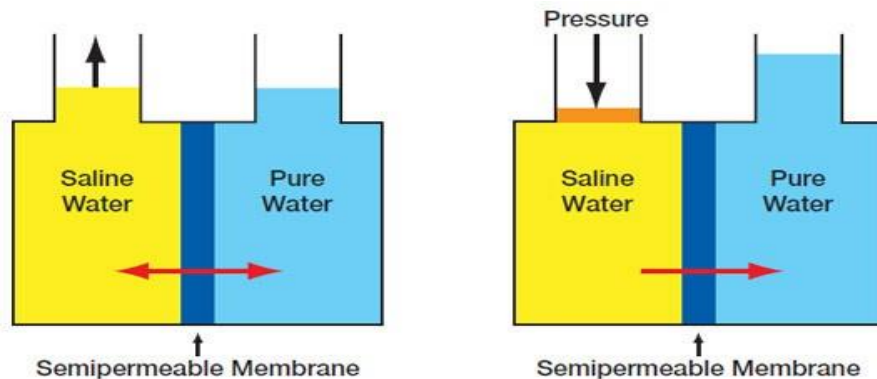
1. Electro-dialysis process does not remove dissolved organic matter.
2. It does not remove colloidal impurities.
3. Replacement of membranes is required which add cost in its use.

Reverse osmosis

Osmosis is the phenomenon in which flow of solvent takes place from a region of low concentration to high concentration when two solutions of different concentrations are separated by a semi-permeable membrane. The driving force for osmosis is osmotic pressure. This process is reversed in reverse osmosis by applying pressure greater than osmotic pressure at higher concentration.

Principle - “The flow of solvent from higher concentration to lower concentration solution through a semi permeable membrane by applying slightly higher external pressure than osmotic pressure of higher concentration solution.”

Diagram:



Process:

Semi permeable membrane made up from polymeric materials like acrylics, polyamides, aramids etc. Brackish water or sea water is filled in reverse osmosis cell. When pressure 200psi is applied on it, the water passed through semi permeable membrane and impurities remain on the membrane. Pure water is collected from lower outlet.

Advantages:

- Ionic, colloidal, non-ionic impurities are removed from water.
- Pure water for high pressure boiler can be obtained.
- It is used to obtain drinking mineral water.
- Simple to operate.
- Low cost process.