ENGINEERING CHEMISTRY-CY8151

Unit-I

Water and its Treatment

Question Bank (Part-A & Part-B)

Part-A (2-marks)

1. What is hardness of water? How will you detect Hardness?

2. What is mean by soft water and hard water **(Jan 2009)**

3. Distinguish between hard water and soft water **(2002, 2010, 2013)**

4. What is temporary hardness **(or)** carbonate hardness?

5. What is Permanent hardness **(or)** Non-Carbonate Hardness?

6. Name any two salts that cause temporary hardness **(Jan 2018) (Or)**

What are the salts responsible for carbonate and non-carbonate hardness of water?

7. Distinguish between carbonate and non-carbonate hardness? **(2008, 2009)**

8. What are the Disadvantages of using hard water in boilers? **(or)**

What are boiler troubles? **(2011, 2015)**

9. What are the requisites of drinking and boiled feed water? **(2001) 10.** Soft water is not DM water whereas DM water is soft water justify. **(2013)**

11. Write the advantages of ion-exchange process?

12. What is Calgon? Why Calgon conditioning is better than Phosphate conditioning? **(or)**

What is calgon conditioning? **(2005, 2008, 2010) 13.**

What is phosphate conditioning? **(2008, 2010)**

14. Define the regeneration of zeolites?

15. Define desalination? **(Or)** What is desalination of brackish water? **(2008)**

16. Define Osmosis and Osmotic Pressure?

17. What is Reverse Osmosis? **(or)** Electrodialysis **(2018)**

18. Write the Advantages of Reverse Osmosis?

Part-B (8 Marks)

1. Determination of total hardness using EDTA method? **(2009)**
2. What are boiler troubles? How are they caused? Suggest steps to minimize the boiler troubles? **(Or)**

   What are the various boiler troubles and how they can be prevented? **(Or)**

   Discuss the disadvantages of using hard water in boilers? **(2013, 2014, 2015, 2018)**
3. What are the essential requirements of boiler feed water? **(2015, 2018)**
4. Explain how demineralization of water is done in water technology? **(Or)** Describe de-mineralization process of water softening. Explain the reactions involved. **(2010, 2015, 2016, 2017)**
5. How is the softening of water carried out using the Zeolite process? **(Or)**

   Describe the principle and procedure involved in the Zeolite process for water treatment? **(2010, 2014, 2015, 2016)**
6. How is internal treatment of boiler water carried out using boiler compounds? **(Or)**

   Give an account of internal treatment of boiler water. **(2015, 2017, 2018)**
7. Write the differences between internal and external treatment of boilers. **(Jan 2018)**
8. What is Desalination? With a neat diagram, describe desalination by reverse Osmosis method? **(2010, 2013, 2014, 2015, 2017)**

Part-A (2-marks) Hardness of water

1. **What is hardness of water? How will you detect Hardness?**

   It is the property of water which does not produce lather with soap solution.

$$2C_{17}H_{35}COONa + CaCl_2 \rightarrow (C17H_{35}COO)_2\,Ca + 2NaCl$$

Soap causing hardness — hard soap substance

2. **What is mean by soft water and hard water (Jan 2009)**

   i. Hard water:

   Water does not produce lather with soap solution but produces white precipitate (scum) is called hard water. This is due to presence of dissolved Ca and Mg salts.

$$2C_{17}H_{35}COONa + CaCl_2 \rightarrow (C17H_{35}COO)_2\,Ca + 2NaCl$$

   ii. Soft water:

   Water produces lather readily with soap solution is called soft water. This is due to the absence of Ca and Mg salts.

3. Distinguish between hard water and soft water (2002, 2010, 2013)

S.No	Hard Water	Soft Water
1.	It does not produce lather with soap solution.	It produces very good lather with soap solution.
2.	It give wine red colour with EBT indicator.	It does not give colour with EBT.

4. What is temporary hardness (or) carbonate hardness?

- It is due to the presence of bicarbonates of Ca and Mg.
- It can be removed by, 1. Boiling the water.
  2. Adding lime to the water

$$Ca(HCO_3)_2 \xrightarrow{\Delta} CaCO_3\downarrow + H_2O + CO_2$$

$$Mg(HCO_3)_2 + 2Ca(OH)_2 \xrightarrow{\text{(lime)}} Mg(OH)_2\downarrow + 2CaCO_3\downarrow + 2H_2O$$

5. What is Permanent hardness (or) Non-Carbonate Hardness? ***Permanent Hardness***

- It is due to the presence of chloride and sulphates of Ca and Mg.
- It can be removed by,
  1. Lime soda process
  2. Zeolite process.

$$CaCl_2 + \underset{\text{(soda)}}{Na_2CO_3} \longrightarrow CaCO_3\downarrow + 2NaCl$$

$$CaSO_4 + \underset{\text{(sod. zeolite)}}{Na_2Ze} \longrightarrow CaZe + Na_2SO_4$$

6. Name any two salts that cause temporary hardness (Jan 2018) (Or) What are the salts responsible for carbonate and non-carbonate hardness of water?

Carbonate hardness:

Calcium bicarbonate **$Ca(HCO_3)_2$,** Magnesium bicarbonate **$Mg(HCO_3)_2$** ***Non-carbonate hardness:***

Calcium chloride **$CaCl_2$,** Calcium sulphate **$CaSO_4$,** Magnesium chloride **$MgCl_2$,** Magnesium sulphate **$MgSO_4$.**

7. Distinguish between carbonate and non-carbonate hardness? (2008, 2009)

S.No	Carbonate Hardness	Non-Carbonate Hardness
1.	Due to the presence of bicarbonate of Ca and Mg.	Due to the presence of chloride and sulphates of Ca and Mg.

2.	It can be removed by boiling the water.	It cannot be removed by boiling the water.
3.	It is also called as alkaline hardness	It is also called as non-alkaline hardness

Boiler troubles

8. What are the Disadvantages of using hard water in boilers? (or)
What are boiler troubles? (2011, 2015)

i. Formation of scale and sludge ii. Priming and Foaming iii. Caustic embrittlement
iv. Boiler corrosion

9. What are the requisites of drinking and boiled feed water? (2001)

1	Boiler feed water	Must have zero hardness and free from dissolved gases like O_2, CO_2
2	Drinking water	i. P^H 7.0-8.5 ii. Total hardness and dissolved solids of water should be less than 500 ppm

Demineralized Water

10. Soft water is not DM water whereas DM water is soft water justify. (2013)

Soft water produced by lime soda and zeolite process, does not contain hardness producing **Ca^{2+}** and **Mg^{2+}** ions, but it will contain other ions like **Na^+, K^+, SO_4^{2-}, Cl^-** etc. But DM water does not contain both anions and cations. Thus a soft water is not DM water, whereas DM water is Soft water.

11. Write the advantages of ion-exchange process?

i. Highly acidic or alkaline water can be treated by this process.
ii. The water obtained by this process will have very low hardness (**nearly 2 ppm**).

12. What is Calgon? Why Calgon conditioning is better than Phosphate conditioning? (or) What is calgon conditioning? (2005, 2008, 2010)

Calgon conditioning:

- Calgon is Sodium hexa meta Phosphate **$Na_2[Na_4(PO_3)_6]$**
- It reacts with **$CaSO_4$** to form water soluble Complex and prevents scale forming substance.

$$2\ CaSO_4 + Na_2[Na_4(PO_3)_6] \longrightarrow Na_2[Ca_2(PO_3)_6] + 2\ Na_2SO_4.$$

- The complex is soluble in water and there is no problem of sludge disposal.
- Therefore calgon conditioning is better than Phosphate conditioning.

13. What is phosphate conditioning? (2008, 2010)

Scale formation can be avoided by adding sodium phosphate. It is used in high pressure boilers. The phosphate reacts with Ca^{2+} and Mg^{2+} salts to give soft sludges of calcium & magnesium salts.

$$3CaSO_4 + 2Na_3PO_4 \rightarrow Ca_3(PO_4)_2 + 3Na_2SO_4$$

14. Define the regeneration of zeolites?

The zeolites got exhausted after sometime. The exhausted zeolite is again regenerated with **10%** solution of **NaCl.**

$$CaZe + \longrightarrow 2NaClNa_2Ze + CaCl_2$$

$$\longrightarrow$$

$$MgZe + 2NaClNa_2Ze + MgCl_2$$

15. Define desalination? (Or) What is desalination of brackish water? (2008)

The process of removing common salt (**Sodium chloride**) from the water is known as desalination.

The water containing dissolved salts with a peculiar salty or brackish taste is called brackish water.

16. Define Osmosis and Osmotic Pressure?

Osmosis:

When two solutions of different concentrations are separated by a semi-permeable membrane, solvent flows from a region of lower concentration to higher concentration. This process is called as osmosis.

Osmotic Pressure:

The pressure which is applied to stop flow of solvent from a region of lower concentration to higher concentration is called as Osmotic pressure.

17. What is Reverse Osmosis? (or) Electrodialysis (2018)

If a hydrostatic pressure in excess of osmotic pressure is applied on the higher concentration side, the solvent flow is reversed. The solvent flows from higher concentration to lower concentration. This process is called as reverse Osmosis.

In the process of reverse osmosis pure water is separated from salt water. It is also known as Super-filtration.

18. Write the Advantages of Reverse Osmosis? *Advantages:*

1. The life time of the membrane is high, and it can be replaced with in few minutes.
2. It removes ionic, non-ionic and colloidal impurities.
3. Due to low capital cost, simplicity, low operating, this process is used for converting sea water into drinking water.

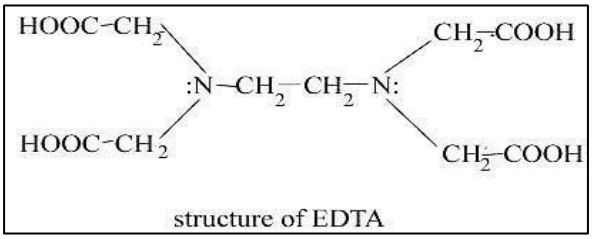
Part-B (8 Marks)

Determination of Total hardness

1. Determination of total hardness using EDTA method?

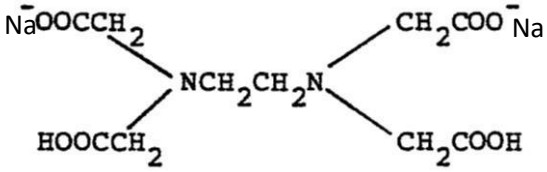
- EDTA method is widely used for the estimation of hardness of water.
- This is a complexometric method.
- More accurate, convenient and fast.

EDTA- Ethylene Diamine Tetra Acetic acid



structure of EDTA

EDTA is insoluble in water but its disodium salt (Na_2EDTA) is



soluble in water.

This salt is used as complexing agent. EDTA forms stable complexes with Ca^{+}/Mg^{+} of hard water.

Principle

The amount of hardness causing ions can be estimated by titrating the hard water against standard EDTA solution using metal ion indicator EBT.

Formation of unstable complex:

EBT - Eriochrome black – T

(Ca^{2+}/Mg^{2+}) + EBT ⟶ $[(Ca^{2+}/Mg^{2+})$ ___EBT]

Hard water Indicator Unstable wine red complex

The complex formation takes place at a pH of 9-10. In order to maintain the pH, a buffer solution having $NH_4Cl–NH_4OH$ mixture is added.

Formation of stable complex:

When the unstable wine red complex is titrated against standard EDTA solution forms a metal ion EDTA complex. When all hardness causing metal ions are complexes with EDTA, the EBT indicator is get free. The color of the indicator is steel blue. Thus the end point is change of color from wine red to steel blue.

[(Ca^{2+}/Mg^{2+})— EBT] + EDTA ⟶ [(Ca^{2+}/Mg^{2+})— EDTA

Procedure

i. Standardization of EDTA using standard hard water

Pipette out 50 ml of std. hard water in a conical flask. Add 10 ml of buffer solution and five drops of EBT indicator and titrate against EDTA from burette. The end point is the change of color wine red to steel blue.

Result = Strength of EDTA

ii. Estimation of total hardness of water sample using std. EDTA

Pipette out 50 ml of hard water sample in a conical flask. Add 10 ml of buffer solution and five drops of EBT indicator and titrate against std. EDTA from burette. The end point is the change of color wine red to steel blue.

Result = Total hardness of water sample

iii. Estimation of permanent hardness of water sample using std. EDTA

Take 100ml of hard water boil it expel the temporary hardness. Cool and filter the solution to 100 ml std. flask. Make up the solution by adding distilled water. Pipette out 50 ml of this made up solution into a conical flask. Add 10 ml of buffer solution and five drops of EBT indicator titrate against std. EDTA solution. The end point is the change of color wine red to steel blue.

Result = Permanent hardness of water sample

Temporary hardness

Therefore,

Total hardness = Temporary hardness + Permanent hardness

Temporary hardness = Total hardness – Permanent hardness

Thus, the total, permanent and temporary hardness of given water sample is estimated by the EDTA method.

Boiler troubles

2. What are boiler troubles? How are they caused? Suggest steps to minimize the boiler troubles? (Or)

What are the various boiler troubles and how they can be prevented? (Or)

Discuss the disadvantages of using hard water in boilers? (Jan 2018)

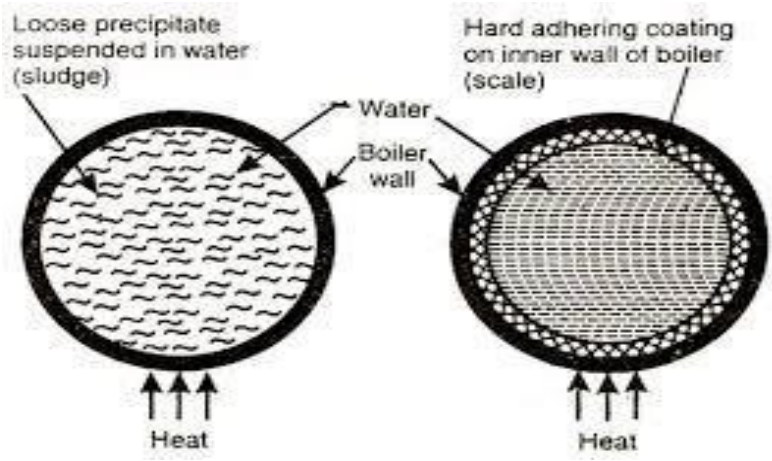
The water fed into the boiler should be free from dissolved salts and gases, suspended impurities, silica and oil.

Boiler troubles:

- Scale and sludge formation
- Priming and Foaming (carry over)
- Caustic embrittlement
- Boiler corrosion

Sludge: If the precipitate formed is soft loose and slimy it is called sludge.

Scale: If the precipitate formed is hard and adhering on the inner wall, it is called Scale.



Sludge in boiler **Scale in boiler**

Comparison of sludge and scale:

S.No	Sludge	Scale
1.	**Sludge:** If the precipitate is **loose** and **slimy** it is called as sludge.	**Scale:** If the precipitate is hard, adherent coating it is called as scale
2.	Sludge forming substances are $MgCl_2$, $MgCO_3$, $MgSO_4$ and $CaCl_2$.	Scale forming substances are $Ca(HCO_3)_2$, $CaSO_4$, $Mg(OH)_2$.
3.	**Disadvantage:** ○ Poor conductor of heat. ○ Excess of sludge formation decrease the efficiency of boiler.	**Disadvantage:** ○ Thermal insulators. ○ It decreases the efficiency of the boiler.
4.	**Prevention:** By using softened water.	**Prevention:** By using acids like HCl, H_2SO_4….
5.	Removed by "blow-down operation"	Removed by a) external treatment b) Internal treatment
6.	**Blow-down operation:** It is a process of removing a portion of concentrated water by fresh water from the boiler during steam production.	Removed by applying a) Thermal shocks b) Scrapers c) Wire brush

Disadvantages of scale formation: (WEE)

<table>
<tr><td>1.</td><td>Wastage of fuel</td><td>Scale have low thermal conductors. In order to provide overheating, this causes wastage of fuel. The wastage of fuel depends on thickness and nature of the scale.
<table>
<tr><td>Thickness of scale(mm)</td><td>0.325</td><td>0.625</td><td>1.25</td><td>2.5</td><td>12</td></tr>
<tr><td>Wastage of fuel</td><td>10%</td><td>15%</td><td>50%</td><td>80%</td><td>150%</td></tr>
</table></td></tr>
<tr><td>2.</td><td>Decrease in efficiency</td><td>Scales deposit in the valves and condenser of the boiler and choke, decreases the efficiency and boiler.</td></tr>
<tr><td>3.</td><td>Boiler explosion</td><td>Due to overheating, scales may crack and causes formation of large amount of steam and high pressure which may lead to explosion.</td></tr>
<tr><td>4.</td><td>Prevention of scale formation</td><td>At the initial stage, scale can be removed by using wire brush, scraper….
If the scales are brittle, it can be removed by thermal shocks.
Using dil.acids (for $CaCO_3$ scale) which they form suitable complexes.
If scales are loosely adhering, it can be removed by blow-down operation.</td></tr>
</table>

3. What are the essential requirements of boiler feed water? (2018)

Any natural source of water does not supply a perfectly suitable boiler feed water. The boiler feed water must have the following requirements.

S.No	Type	Amount
1.	Hardness	< 0.2 ppm
2.	Soda alkalinity	0.15-1.0 ppm
3.	Caustic alkalinity	0.15-0.45 ppm
4.	Excess soda ash	0.3-0.55 ppm
5.	Dissolved gases like O_2, CO_2	0 ppm

S.No	Specifications	Disadvantages
1.	Boiler feed water should have zero hardness	Scales and sludges will be produced, which prevents efficient heat transfer
2.	it must be free from dissolved gases like O_2, CO_2	It leads to boiler corrosion

3.	It should be free from suspended impurities	produces wet steam
4.	It should be free from oil and turbidity	produces priming and foaming
5.	It should be free from total dissolved solids	produces priming and foaming, caustic embrittlement etc.,

Demineralization of water

4. Explain how demineralization of water is done in water technology? (Or) Describe de-mineralization process of water softening. Explain the reactions involved

Demineralization Process (Or) De-Ionization Process:

- It is a process to remove almost all the ions present in hard water.
- It is carried out by using Ion-exchange resins.

1.	**Cation exchange resin:** Resins containing acidic functional groups are capable of exchanging their H^+ ions with other cation of hard water. It is denoted as **RH_2≡R-COOH Ex:** Sulphonated coals.	**Anion exchange resin:** Resins containing basic functional groups are capable of exchanging their anions with other anions of hard water. It is denoted as **$R'(OH)_2$≡R-NH_2 Ex:** Urea-formaldehyde resin.
2.	**Process:** The hard water is first passed through a cation exchange column which absorbs all the cations **(Ca^{2+}, Mg^{2+}, Na^+)**	The water coming out of the anion exchange column is completely free from cations and anions. This water is known as demineralised water (or) deionised water.
3.	**Regeneration:** When the cation exchange resins exhausted, it can be regenerated by passing a solution of **dil. HCl (or) dil. H_2SO_4.**	When the anion exchange resin is exhausted, it can be regenerated by passing a solution of **dil. NaOH.**
	$RCa + 2HCl \longrightarrow RH_2 + CaCl_2$ $RNa + HCl \longrightarrow RH + NaCl$	$R'Cl_2 + 2NaOH \longrightarrow R'(OH)_2 + 2NaCl$
4.	**Advantages:** 1. Highly acidic (or) alkaline water can be treated by this process. 2. Water containing very low hardness (**2 ppm**) can be obtained by this process.	

5.	**Disadvantages:** 1. Water containing turbidity, **Fe** and **Mn** cannot be treated, because turbidity reduces the output and **Fe, Mn** form stable compound with the resin. 2. The equipment is costly and more expensive chemicals are needed.

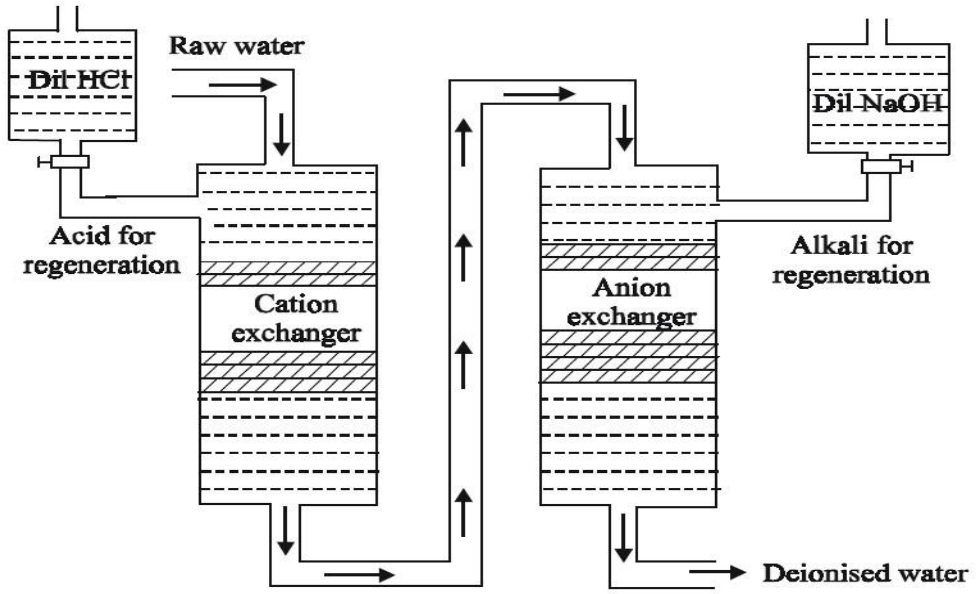


Fig. 1.3. Demineralisation process

5. How is the softening of water carried out using the Zeolite process? (Or) Describe the principle and procedure involved in the Zeolite process for water treatment?

Zeolite (or) Permutit process:

- Zeolites are naturally occuring hydrated sodium aluminosilicate. Its general formula is **$Na_2O.Al_2O_3.XSiO_2.YH_2O$ (X=2-10, Y=2-6) Types**

of Zeolites:

1. Natural Zeolites
2. Synthetic Zeolite **Natural Zeolite:**

- Green sand
- Non-Porous

Synthetic Zeolite:

- It is called as permutit.
- Porous
- Gel like structure **Uses:** Used for water softening.

Principle:

In Synthetic Zeolites, loosely held Sodium ions are replaced by **Ca^{2+}** and **Mg^{2+}** ions present in the water.

Process:

- When hard water is passed through a bed of sodium Zeolite **(Na_2Ze),** kept in a cylinder.
- Sodium Zeolite exchange its sodium ions with **Ca^{2+}** and **Mg^{2+}** ions present is hard water to form calcium Zeolites and Megnesium Zeolites.
- The softened water is enriched with large amount of Sodium salts, which do not cause any hardness.

Reactions:

Sodium Zeolite + Hard water (Ca^{2+}, Mg^{2+}) ⟶ Calcium and Magnesium Zeolite

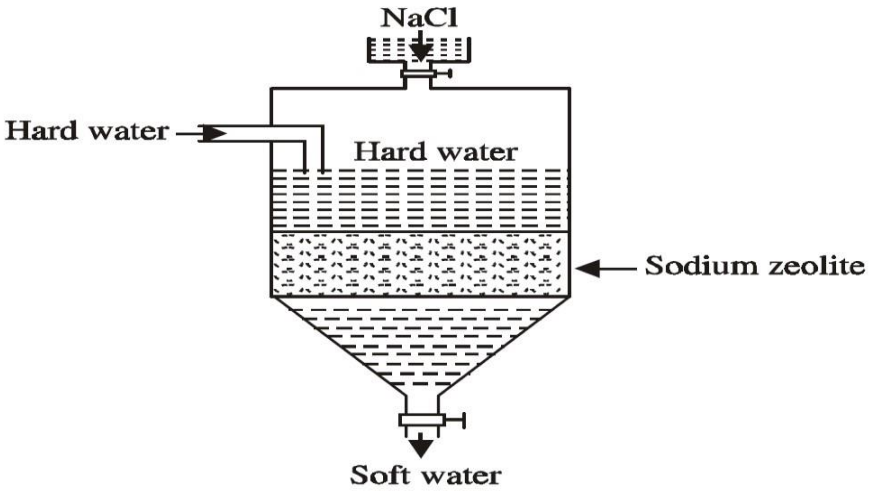


Fig. 1.4. Zeolite Process

$$CaCl_2 + Na_2Ze \longrightarrow CaZe + 2NaCl$$

$$MgCl_2 + Na_2Ze \longrightarrow MgZe + 2NaCl$$

Regeneration:

The exhausted Zeolites are regenerated by treating with **10%** solution of **NaCl.**

$$CaZe + 2NaCl \longrightarrow Na_2Ze + CaCl_2$$

$$MgZe + 2NaCl \longrightarrow Na_2Ze + MgCl_2$$

Advantages:

- Water obtained by this process will have only hardness (**1-2 ppm**) • This method is cheap, because the regenerated Zeolite can be used again.
- No sludge is formed during this process.
- The equipment used is compact and occupies a small space.
- Its operation is easy.

Disadvantages:

- Acidic water cannot be treated, because it decomposes the structure of Zeolite.
- When softened resulting in boiler corrosion and caustic embrittlement.
- Brackish water cannot be treated, because it contains Na^+ ions. So that ion exchange reaction will not occur.
- Water contain Fe, Mn cannot be treated, because regeneration is very difficult
- Turbid water cannot be treated, because it blocks the pores of the Zeolite bed.

Internal treatment of water

6. How is internal treatment of boiler water carried out using boiler compounds? (Or)

Give an account of internal treatment of boiler water. (2018)

Internal treatment:

It involves the removal of scale forming substances.

1. Carbonate conditioning:

- Scale formation can be avoided by adding Na_2CO_3 to boiler water
- It can be converted into $CaCO_3$, which can be removed easily.
- It is used only in low pressure boilers.

$$CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3 \downarrow + Na_2SO_4.$$

2. Phosphate conditioning:

- Scale formation can be avoided by adding sodium Phosphate. The phosphate reacts with $CaSO_4$ to give soft sludge of Calcium Phosphates.
- It is used in high Pressure boiler.

$$3\,CaSO_4 + 2\,Na_3PO_4 \longrightarrow Ca_3(PO_4)_2 + 3Na_2SO_4$$

3. Calgon conditioning:

- Calgon is Sodium hexa meta Phosphate $Na_2[Na_4(PO_3)_6]$
- It reacts with $CaSO_4$ to form water soluble Complex and prevents scale forming substance.
- The complex is soluble in water and there is no problem of sludge disposal.
- Therefore calgon conditioning is better than Phosphate conditioning.

$$2\,CaSO_4 + Na_2[Na_4(PO_3)_6] \longrightarrow Na_2[Ca_2(PO_3)_6] + 2\,Na_2SO_4.$$

4. Colloidal conditioning:

- Scale forming substance can be avoided by adding colloidal substance like Kerosene, gelatin, tannin and agar-agar.
- These colloidal substances get coated over scale forming substance and convert them into loose precipitate called sludge.
- It is removed by blow-down operation.

7. Write the differences between internal and external treatment of boilers. (Jan 2018)

S.No	External treatment	Internal treatment
1.	It is expensive	It is cheap
2.	No chemicals are used	Chemicals are used
3.	It is carried out before feeding the water into the boiler	It is carried out within the boiler
4.	It is used for high pressure boilers	It is used for low pressure boilers
5.	Blow down operation is not required	it requires blow down operation

Desalination of water

8. What is Desalination? With a neat diagram, describe desalination by reverse Osmosis method?

Desalination: The Process of removing common salt from the water is known as desalination.

Osmosis:

When two solution of different concentrations are separated by a semi-permeable membrane, solvent flows from a region of lower concentration to higher concentration. This process is called as osmosis.

Osmotic Pressure:

The pressure which is applied to stop flow of solvent from a region of lower concentration to higher concentration is called as Osmotic pressure.

Reverse Osmosis:

If a hydrostatic pressure in excess of osmotic pressure is applied on the higher concentration side, the solvent flow is reversed. The solvent flows from higher concentration to lower concentration. This process is called as ***reverse Osmosis***.

In the process of reverse osmosis pure water is separated from salt water. It is also known as Super-filtration.

Membrane used:

Cellulose acetate

Cellulose butyrate

Diagram:

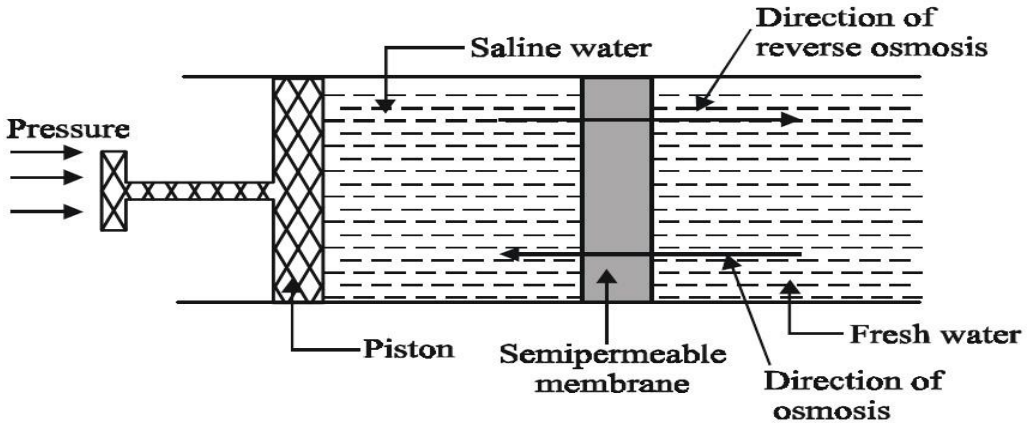


Fig. 1.5 Reverse Osmosis

Advantages:

1. The life time of the membrane is high, and it can be replaced with in few minutes.
2. It removes ionic, non-ionic and colloidal impurities.
3. Due to low capital cost, simplicity, low operating, this process is used for converting sea water into drinking water.