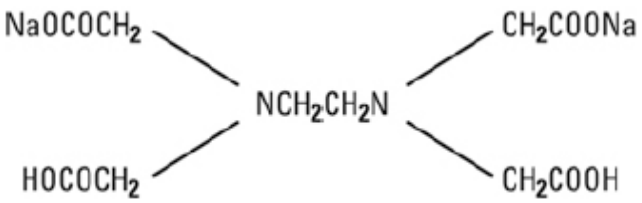
UNIT-1 QUESTION BANK WITH ANSWERS			
Sl.No		**Question**	**Marks**
1.	a.	**Define Hardness, write about Soft and Hard water.** Hardness of water defined as which prevent the lathering of soap. This is due to presence of certain salts like Ca^{+2}, Mg^{+2} dissolved in water.	[1M]
	b.	**Express the reasons why $CaCO_3$ is selected expression of the hardness?** Hardness of water is due to the presence of Bicarbonates, Chlorides and Sulphates of Calcium and Magnesium. These soluble salts get mixed with natural water **due to the following reasons:** **1.** When rain water containing CO_2 flows over the rocks of the limestone ($CaCO_3$) and Dolamite ($CaCO_3$ & $MgCO_3$), they get converted into soluble bicarbonates. Thus, water gets hardness. $CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2$ Insoluble Soluble **2.** When rain water in runoff, infiltrated in to the soil and mix with the so many salts. Thus water gets hardness.	[1M]
	c.	**Explain EDTA method? Determination of hardness By Complexometric Method.** **Introduction:** EDTA method is also called Complexometric method. Estimation of hardness can be done with this method. Hardness can be estimated by volumetric titration by using EBT indicator in the presence of pH 9-10. **EDTA Structure:**  **Chemicals Required:** **i. Preparation of standard hard water (0.01M):** Dissolve 1g of pure, dry $CaCO_3$ in 1 Litre solution. **ii. Preparation of EDTA solution:** Dissolve 4 g of pure EDTA crystals in 1 Litre of distilled water. **iii. Preparation of Indicator (EBT):** Dissolve 0.5 g of Eriochrome Black–T in 100mL alcohol. **iv. Preparation of Buffer solution (pH: 9-10):** Add 67.5g of NH_4Cl to 570 ml of Con. Ammonia solution and then dilute with distilled water to 1 Litre.	[10M]

Principle:

The Ca^{2+} and Mg^{2+} of hard water treated with buffer solution and EBT indicator which forms unstable complex, wine-red colour.

(Ca^{2+} or Mg^{2+})	+	EBT	→	[Ca – EBT] (or) [Mg – EBT]
Hardness-salts		Indicator		unstable complex (wine red)

The determination of hardness is carried out by titrating water sample with Sodium salt of Ethylene Diamine Tetra Acetic Acid (EDTA) using Eriochrome Black-T as an indicator and keeping the pH of the water at 9.0 - 10.0. The end point is the change in colour from wine - red to blue, when the EDTA solution complexes the calcium and magnesium salt completely.

[Ca – EBT] (or) [Mg – EBT]	+ EDTA	→	[Ca – EDTA] (or) [Mg – EDTA]	+	EBT
Unstable complex (wine red)			stable complex (colourless)		blue

Procedure:

1. **Standardization of EDTA solution:** Rinse and fill the burette with EDTA solution. Pipette out 20 ml of standard hard water (M_1) in a conical flask. Add 4ml of buffer solution and 2 drops of EBT indicator. Titrate with EDTA solution till wine-red colour changes to clear blue. Let volume used by **'X' ml**.

$$M_1 V_1 = M_2 V_2$$

Where, M_1 = Molarity of Standard Hard water (0.01M),
V_1 = Volume of Standard Hard water (20 ml),
M_2 = Molarity of EDTA,
V_2 = Volume of EDTA **(Xml)**.

2. **Determination of Total Hardness:** Rinse and fill the burette with EDTA solution. Pipette out 20 ml of sample water (V_3) in a conical flask. Add 4 ml of buffer solution and 2 drops indicator. Titrate with EDTA solution till wine-red colour changes to clear blue. Let volume used by **'Y' ml**.

$$M_2 V_2 = M_3 V_3$$

Where, M_2 = Molarity of EDTA,
V_2 = Volume of EDTA **(Yml)**.
M_3 = Molarity of sample water,
V_3 = Volume of Sample water (20 ml).

Total Hardness = $M_3 \times$ Molecular weight of $CaCO_3$ (100) × One Litre (1000ml)

$= M_3 \times 10^5$ ppm

3. Determination of Permanent Hardness: Take 100 ml of sample water in 250 ml beaker. Boil it to remove temporary hardness to about half of its volume and cool to room temperature, filter through filter paper to remove insoluble salts. Make up the volume to the original 100ml by adding distilled water. Now Pipette out 20 ml of this solution (V4) in a conical flask. Add 4 ml of buffer solution and 2 drops indicator. Titrate with EDTA solution till wine-red colour changes to clear blue. Let volume used by **'Z' ml**.

$$M_2 V_2 = M_4 V_4$$

Where, M_2 = Molarity of EDTA,
V_2 = Volume of EDTA (**Z ml**).
M_4 = Molarity of Permanent hard water,
V_4 = Volume of Permanent hard water (20 ml)

Permanent Hardness = $M_4 \times$ Molecular weight of $CaCO_3$ (100) × One Litre (1000ml)

$$= M_4 \times 10^5 \text{ ppm}$$

4. Determination of Temporary Hardness:
Temporary Hardness = Total Hardness - Permanent Hardness.

2. a. Distinguish between Temporary hardness and Permanent hardness. [1M]

1. Temporary Hardness: Temporary Hardness mainly caused by the presence of dissolved bicarbonates of Calcium, Magnesium ($Ca(HCO_3)_2$, $Mg(HCO_3)_2$). Temporary Hardness can be largely removed by boiling of water.

$$Ca(HCO_3)_2 \xrightarrow{\text{by heating}} CaCO_3\downarrow + H_2O + CO_2$$

Calcium bicarbonate

$$Mg(HCO_3)_2 \xrightarrow{\text{by heating}} Mg(OH)_2\downarrow + 2CO_2$$

Magnesium bicarbonate

2. Permanent Hardness: It is due to the presence of dissolved Chlorides, Nitrates and Sulphates of Calcium, Magnesium, Iron and other metals. Permanent hardness responsible salts are $CaCl_2$, $MgCl_2$, $CaSO_4$, $MgSO_4$, $FeSO_4$, $Al_2(SO_4)_3$. Permanent Hardness cannot be removed by boiling but it can be removed by the use of ***chemical agents***.

b. Describe the conversion of 10 ppm of hardness of water in to degree clark. [1M]

10 ppm × 0.07°Cl = 0.7°Cl

c. A sample of water is found to contains following analytical data in milligrams per litre $Mg(HCO_3)_2$ = 14.6, $MgCl_2$ = 9.5, $MgSO_4$ = 6.0 and $Ca(HCO_3)_2$ = 16.2. Calculate temporary and permanent hardness of water in parts per million, Degree Clarke's and Degree French. [5M]

Name of the hardness	Amount of the hardness	Molecular weight of	Amounts equivalent to
$Mg(HCO_3)_2$	1	1	14.6×100/146 = 10
$MgCl_2$	9	9	9.5×100/95 = 10
$MgSO_4$	6	1	6.0×100/120 = 5
$Ca(HCO_3)_2$	1	1	16.2×100/162 =10

		Temporary hardness [$Mg(HCO_3)_2 + Ca(HCO_3)_2$] = 10 + 10 = 20mg/Lit = 20ppm = 20×0.07°Cl = 1.4°Cl = 20×0.1°Fr = 2°Fr Permanent hardness [$MgCl_2 + MgSO_4$] = 10 + 5 = 15mg/Lit = 15ppm = 15×0.07°Cl = 1.05°Cl = 15×0.1°Fr = 1.5°Fr	
	d.	**What are the specifications of Potable water?** Water free from contaminants or water that is safe for human consumption is called potable water. The following are the **specifications of water drinking purpose.** **1.** The water should be clear (colorless), odorless and pleasant taste. **2.** The optimum hardness of water must be 125ppm. **3.** The pH of potable water should be 6.5 to 8.0. **4.** The recommended maximum concentration of total dissolved solids (TDS) in potable water must not exceed 500 ppm. **5.** The turbidity in drinking water should not exceed 25 ppm. **6.** The water must be free from heavy metals like Lead, Arsenic, Chromium and Manganese. **7.** The water must be free from pathogenic bacteria **8.** The water must be free from dissolved gases like H_2S, CO_2 and NH_3.	[5M]
3.	**a.**	**How to do the disinfection of potable water by Chlorination.** **1. By Chlorination:** The process of adding chlorine to water is called chlorination. Chlorination can be done by the following methods. **a. By adding Chlorine gas:** Chlorine gas is a very good disinfectant, which can be bubbled in the water. In this process calculated amount of chlorine gas is passed in order to destroy the pathogenic bacteria is called chlorination. Chlorine is also reacts with water and generates hypochlorous acid and nascent oxygen, which acts a powerful oxidizing agent and kills the bacteria. $Cl_2 + H_2O \rightarrow HOCl$ (Hypochlorous acid) + HCl $HOCl \rightarrow HCl + [O]$ nascent oxygen **b. By adding Chloramine:** When chlorine and ammonia are mixed in the ratio 2:1 a compound chloramine is formed. $Cl_2 + NH_3 \rightarrow ClNH_2 + HCl$ Chloramine $ClNH_2 + H_2O \rightarrow NH_3 + HOCl$ (Hypochlorous acid) $HOCl \rightarrow HCl + [O]$ nascent oxygen	[1M]

Chloramine compounds decompose slowly to give nascent oxygen which will be act as good disinfectant than the Chlorine. Chloramine gives good taste to the treated water.

b. What are the disadvantages of Ozonization ? [1M]

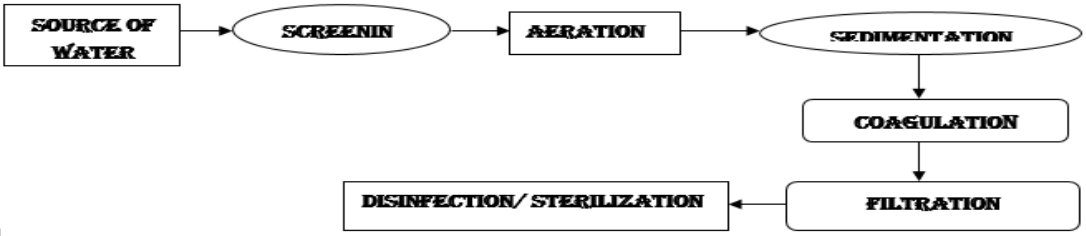
Ozonization process is costly and cannot be used in large scale, due to unstable of ozone cannot be stored for long time.

c. Explain the Steps involved in the treatment of potable water. [10M]

Treatment of water for drinking purposes mainly includes the removal of suspended impurities, colloidal impurities and harmful pathogenic bacteria. The following stages are involved in purification.

1. Screening: The water is passed through screens having larger number of holes; it retains floating impurities like wood pieces, leaves, heaver objectives etc.,

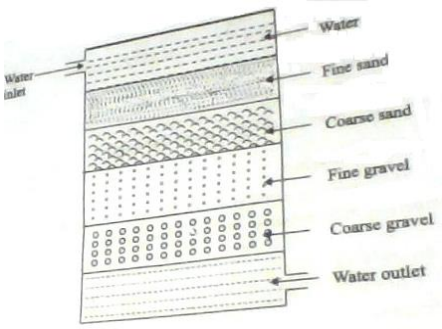
2. Aeration: The water is then subjected to aeration(reacting with air) which helps in exchange of gases between water and air, increases the oxygen content and removes the impurities like iron, manganese and dissolved gases like H_2S, CO_2 and NH_3.



3. Sedimentation: In this process water is allowed to stand for 2-6 hours without any disturbance, 75 % of suspended and colloidal impurities are settled down under gravitational force.

4. Coagulation: Coagulants like alum, sodium aluminates and Aluminum sulphate are added which produce gelatinous precipitates called flock. Flock attracts and helps accumulation of the colloidal particles resulting in setting of the colloidal particles.

5. Filtration: Filtration helps in removal of the colloidal and suspended impurities not removed by sedimentation. Usually sand filters are employed. In this filtration fine sand layer on the top supported by coarse sand layer, which is supported by gravel.

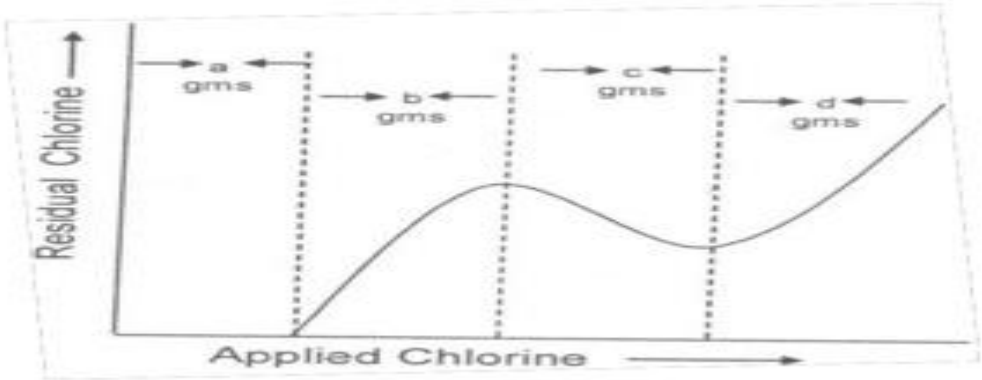


Sand filter

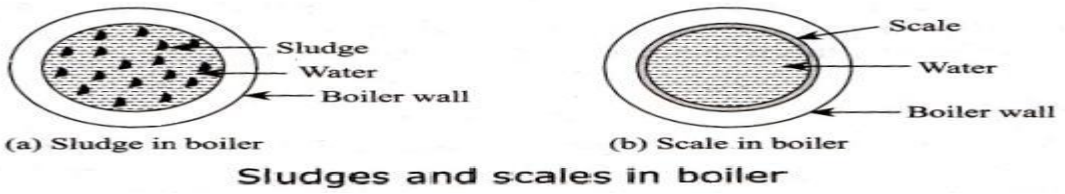
6. The colloidal impurities are retained by the fine sand layer resulting the very slow filtration of water. Periodically the top layers of the fine sand layer is scraped off, washed, dried and introduced into the filter bed for reuse.

7. Disinfection of water by sterilization: The process of destroying the harmful bacteria's is known as sterilization or disinfection.

a. By Chlorination: The process of adding chlorine to water is called chlorination. Chlorination can be done by the following methods.

		i. By adding Chlorine gas: Chlorine gas is a very good disinfectant, which can be bubbled in the water. In this process calculated amount of chlorine gas is passed in order to destroy the pathogenic bacteria is called chlorination. Chlorine is also reacts with water and generates hypochlorous acid and nascent oxygen, which acts a powerful oxidizing agent and kills the bacteria. $Cl_2 + H_2O \rightarrow HOCl$ (Hypochlorous acid) + HCl $HOCl \rightarrow HCl + [O]$ nascent oxygen **ii. By adding Chloramine:** When chlorine and ammonia are mixed in the ratio 2:1 a compound chloramine is formed. $Cl_2 + NH_3 \rightarrow ClNH_2 + HCl$ Chloramine $ClNH_2 + H_2O \rightarrow NH_3 + HOCl$ (Hypochlorous acid) $HOCl \rightarrow HCl + [O]$ nascent oxygen Chloramine compounds decompose slowly to give nascent oxygen which will be act as good disinfectant than the Chlorine. Chloramine gives good taste to the treated water.	
4.	**a.**	**What is break point chlorination?** The amount of chlorine required to kill bacteria and to remove organic matter is called break-point chlorination. The water sample is treated with chlorine and estimated for the residual chlorine in water and ploted a graph as shown below which gives the break-point chlorination. **From graph it is clear that**:  'a' gms of chlorine added oxidizes reducing impurities of water. 'b' gms of chlorine added forms chloramines and other chloro compounds. 'c' gms of chlorine added causes distruction of bacteria 'd' gms of chlorine is residual chlorine. 'c' gms is the break point for addition of chlorine to water. This is called **break- point chlorination**.	[1M]
	b.	**Which chemicals are used for the regeneration of Cation and Anion exchange resins?** The exhausted cation exchanger is regenerated by passing it through dilute acid. $R_2Ca + 2HCl \rightarrow 2RH + CaCl_2$ The exhausted anion exchanger is regenerated by passing it through dilute base. $R_2SO_4 + NaOH \rightarrow 2ROH + Na_2SO_4$	[1M]

	c.	**50 ml of standard hard water containing 1 gram of pure $CaCO_3$ per liter consumed 20 ml of EDTA. 50 ml of hard water consumed 25 ml of same EDTA solution EBT indicator. Calculate the total hardness of water sample in ppm.** **Solution:** **Strength of standard hard water sample ($CaCO_3$ solution) M_1=** $\frac{\text{Weight of } CaCO_3}{\text{Mol. wt of } CaCO_3} \times \frac{1000}{1000}$ $= \frac{1 \text{ gm}}{100} \times \frac{1000}{1000} = 0.01$ M **Strength of EDTA solution M_2** $= \frac{V_1 M_1}{V_2} = \frac{50 \times 0.01}{20} = 0.025$ M V_1 = Volume of standard hard water (50 ml), M_1 = Strength of standard hard water (0.01M) V_2 = Volume of EDTA solution (20 ml), M_2 =Strength of EDTA solution =? **Calculation of Total hardness M_3** $= \frac{V_2 M_2}{V_3} = \frac{25 \times 0.025}{50} = 0.0125$ M V_2 = Volume of EDTA solution (25 ml), M_2 =Strength of EDTA solution= 0.025M V_3 = Volume of sample hard water (50 ml), M_3 = Strength of sample hard water =? **Total Hardness** $= 0.0125 \times 10^5$ ppm $= 0.0125 \times 100$ (Mol. Wt of $CaCO_3$) $\times$ 1000 (ml)ppm = 1250 ppm.	[5M]
	d.	**What is Calgon, Phosphate and Colloidal conditioning of boiler feed water?** **1. Calgon conditioning:** Involves in adding calgon to boiler water. It prevents the scale and sludge formation by forming soluble complex compound with $CaSO_4$. Calgon = Sodium hexa meta phosphate = $Na_2[Na_4(PO_3)_6]$ $Na_2[Na_4(PO_3)_6] \rightarrow 2Na^+ + [Na_4P_6O_{18}]^{-2}$ $2CaSO_4 + [Na_4P_6O_{18}]^{-2} \rightarrow [Ca_2P_6O_{18}]^{-2} + 2Na_2SO_4$ **2. Phosphate conditioning:** The addition of sodium phosphate in hard water reacts with the hardness causing agents and gives calcium and magnesium phosphates which are soft and non-adhere and can be removed easily by blow-down operation. $3CaCl_2 + 2Na_3PO_4 \rightarrow Ca_3(PO_4)_2 + 6NaCl$ $3MgSO_4 + 2Na_3PO_4 \rightarrow Mg_3(PO_4)_2 + 3Na_2SO_4$ Generally three types of Phosphates are employed. i. Tri sodium Phosphate (Na_3PO_4): is too alkaline used for treat to too acidic water. ii. Di sodium Phosphate (Na_2HPO_4): is weakly alkaline used for treat to weakly acidic water. iii. Sodium dihydrogen Phosphate (NaH_2PO_4): is too acidic used for treat to too alkaline water. **Colloidal conditioning:** The addition of organic substances such as Kerosene, tannin, Gel. These substances gets coated over the scale forming precipitates and gives a loose and non-sticky precipitates which can be removed by using blow-down operation.	[5M]

	a.	**What is the chemical name of Calgon.** Calgon = Sodium hexa meta phosphate = $Na_2 [Na_4 (PO_3)_6]$	[1M]
	b.	**Define ppm and Degree French.** **1. Parts per Million (ppm):** The number of parts of calcium carbonate equivalent hardness presents in 10^6 parts of water. 1ppm = 1 part of $CaCO_3$ eq hardness in 10^6 parts of water. **Degree French (°Fr):** The number of parts of calcium carbonate equivalent hardness presents in 10^5 parts of water. 1° Fr = 1 part of $CaCO_3$ hardness eq per 10^5 parts of water.	[1M]
5	**c.**	**Explain the following Boiler troubles.** **i. Sludge's ii. Scales iii. Caustic Embrittlement.** **Sludge's and Scale formation:** Boilers are employed for the steam generation in power plants, where water as continuously heated to produce steam. As more and more water is removed from water in the form of steam, the boiler water gets concentrated with dissolved salts progressively reaches the saturation point. At this point the dissolved salts are precipitated out and slowly settle on the inner walls of the boiler plate. The precipitation takes place in two ways. **Sludge** is a soft, loose and slimy precipitate formed within the boiler. It is formed at comparatively colder portions of the boiler and collects in the area where flow rate is slow. Ex: $MgCO_3$, $MgCl_2$, $CaCl_2$, $MgSO_4$. **Reasons for formation of sludges:** The dissolved salts whose solubility is more in hot water and less in cold water produce sludges. **Disadvantages of sludges:** a.Sludges are bad conductors of heat and results in the wastage of heat and fuel. **b.** Excessive sludge formation leads to the settling of sludge in slow circulation areas such as pipe connections, plug openings, gauge–glass connections leading to the choking of the pipes. **Prevention of sludge formation:** By using soft water which is free from dissolved salts like $MgCO_3$, $MgCl_2$, $CaCl_2$ and $MgSO_4$ can be prevent sludge formation. By blow down operation carried out frequently can prevent sludge formation.  (a) Sludge in boiler (b) Scale in boiler Sludges and scales in boiler	[5M]

Scales: Scales are hard, adhering precipitates formed on the inner walls of the boilers. They stick very firmly on to the inner wall surface and are difficult to remove with chisel and hammer. Scales are formed by decomposition of calcium bicarbonate in low pressure boilers.

Reasons for formation of scales:

a. Decomposition of calcium bicarbonate: The calcium bicarbonate at high temperature decomposes to calcium carbonate which is insoluble salt, forms scale in low pressure boilers.

$$Ca(HCO_3)_2 \rightarrow CaCO_3 + H_2O + CO_2$$

b. Decomposition of calcium sulphate: The solubility of $CaSO_4$ in water decreases with the increase in temperature and forms precipitation on the surface of the boiler further which forms hard scale. This type of scales is formed in high-pressure boilers.

c. Hydrolysis of Magnesium salts: Magnesium salts gets hydrolyzed at high temperature forming $Mg(OH)_2$ precipitation which forms salt type scale.

$$MgCl_2 + H_2O \rightarrow Mg(OH)_2\downarrow + 2HCl$$

d. Presence of silica: Sio_2 present even in small quantities, deposits as Calcium silicates ($CaSiO_3$) or Magnesium silicates ($MgSiO_3$). The deposits form hard scale and are very difficult to remove.

Disadvantages of Scales:

a. Wastage of heat and fuels: Scales poor thermal conductivity so that rate of heat transformation is reduced.

b. Lowering of boiler safety is due to overheating of the boiler material becomes softer and weaker, which causes distortion of boiler.

c. Decrease in efficiency of the boiler due to scales deposited in the values and condensers of the boiler cause choking.

d. Danger of explosion which happens the formation of the scales, the boiler plate faces higher temperature outside and lesser temperature inside due to uneven expansion. The water comes suddenly contact with overheated portion and larger amount steam is formed immediately, this results in development of sudden high pressure which may cause explosion of the boiler.

Removal of scales:

a. If the scale formation is soft it can be removed by a scrapper, wire brush.

b . By giving thermal shocks, by sudden heating and sudden cooling which makes scale brittle and removed by scrubbing with wire brush.

c. If scale is very hard that is formed by $CaCO_3$ can be removed by washing with 5-10% HCl and $CaSO_4$ can be removed with EDTA solution.

2. Caustic Embrittlement:

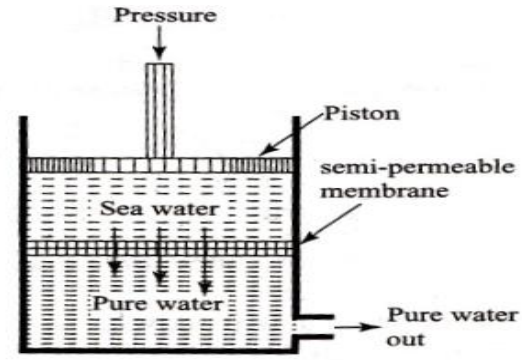
The formation of brittle and in crystalline cracks in the boiler shell is called caustic embrittlement. The main reason for this is the presence of alkali-metal carbonates and bicarbonates in feed water and also the presence of sodium sulphate. In lime-soda process, it is likely that, some residual Na_2CO_3 is still present in the softened water.

		This Na_2CO_3 decomposes to give NaOH and CO_2, due to which the boiler water becomes "Caustic". $$Na_2CO_3 + H_2O \rightarrow 2NaOH + CO_2$$ The H_2O evaporates, the concentration of NaOH increase progressively creating a concentration cell as given below thus dissolving the iron of the boiler as sodium ferrate (Na_2FeO_2). This causes embrittlement of boiler parts such as bends, joints, reverts etc, due to which the boiler gets fail. The iron at plane surfaces surrounded by dilute NaOH becomes cathodic while the iron at bends and joints surrounded by highly concentrated NaOH becomes anodic which consequently decayed or corroded. **Caustic embrittlement can be prevented:** **a.** By maintaining the pH value of water and neutralization of alkali. **b.** By using Sodium Phosphate as softening reagents, in the external treatment of boilers. **c.** Caustic embrittlement can also be prevented by adding Tannin or Lignin or Sodium sulphate which prevents the infiltration of caustic-soda solution blocking the hair-cracks.	
	d.	**Define Desalination? Explain Reverse osmosis process.** The process of removing common salt (Sodium Chloride) from the water is known as **desalination.** The water containing dissolved salts with a salty or brackish taste is called **brackish water**. Depending upon the quantity of dissolved solids, water is graded as: **i.** Fresh Water: Contains less than 1000 ppm of dissolved solids. **ii.** Brackish Water: Contains more than 1000 ppm to less than 35000 ppm of dissolved solids. **iii.** Sea Water: Contains more than 35000 ppm of dissolved solids. Sea water and brackish water can be made available as drinking water through desalination process. Desalination is carried out either by reverse osmosis or electro dialysis. **Reverse Osmosis:** Reverse Osmosis is a process in which pressure greater than the osmotic pressure is applied on the high concentration side of the membrane, the flow of solvent move from concentrated side to dilute side across the membrane. Osmosis is the phenomenon by virtue of 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. In this process pure water is separated from salt water. 15-40 kg/cm^2 pressure is applied for separating the water from its contaminants. The membranes used are cellulose acetate, polymethyl acrylate and polyamide polymers. The process is also known as **super or hyper filtration**	[5M]

Advantages:

a. It is simple and reliable process & Capital and operating expenses are low.

b. The life of the semi-permeable membrane is about two years and it can be easily replaced within a few minutes, thereby nearly uninterrupted water supply can be provided.



Reverse osmosis cell

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6 a. **Define Degree of hardness.**

The conversion of the hardness causing salts into $CaCO_3$ equivalents can be achieved by using the following formula: [1M]

$$\text{Degree of Hardness} = \frac{\text{The weight of hardness causing salts}}{\text{Molecular weight of hardness causing salts}} \times 100 \text{ (Molecular weight of } CaCO_3\text{)}$$

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b. **What are the advantages of Reverse Osmosis.** [1M]

c. It is simple and reliable process & Capital and operating expenses are low.

d. The life of the semi-permeable membrane is about two years and it can be easily replaced within a few minutes, thereby nearly uninterrupted water supply can be provided.

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c. **Discuss the Ion exchange process of softening of hard water.** [10M]

Ion exchange process is also known as demineralization process. Ion- Exchange resins are insoluble. Cross linked long chain organic polymers with a micro porous structure, and the "functional Groups" attached to the chains are responsible for the ion-exchanging properties. Resins with acidic functional group are capable of exchanging H^+ ions with other cations. Resins with basic functional groups are capable of exchanging OH^- ions with other anions. Resins are classified as:

i. Cation Exchange Resins ii. Anion Exchange Resins.

i. Cation Exchange Resins: Cation exchange resins are styrene divinyl benzene co-polymers, which on sulphonation (or) carboxylation, which contains –COOH, $–SO_3H$ functional groups which responsible for exchanging their hydrogen ions with cations in water.

$$2RH + Ca(HCO)_2 \rightarrow R_2Ca + H_2CO_3$$
$$2RH + Mg(HCO)_2 \rightarrow R_2Mg + H_2CO_3$$
$$2RH + CaCl_2 \rightarrow R_2Ca + 2HCl$$
$$2RH + MgCl_2 \rightarrow R_2Mg + 2HCl$$
$$2RH + MgSO_4 \rightarrow R_2Mg + H_2SO_4$$
$$2RH + CaSO_4 \rightarrow R_2Ca + H_2SO_4$$ (RH = Cation exchange resin)

ii. Anion Exchange Resins: Anion exchange resins are Phenol formaldehyde (or) amine formaldehyde copolymers, which contains amino or basic functional groups which responsible for exchanging their OH^- ions with anions in water.

$$ROH + HCl \rightarrow RCl + H_2O$$
$$2ROH + H_2SO_4 \rightarrow R_2SO_4 + 2H_2O$$
$$ROH + H_2CO_3 \rightarrow RHCO_3 + H_2O \text{ (ROH = anion exchange resin)}$$

In ion-exchange process, hard water is allowed to pass through cation exchange resins, which remove Ca^{+2} and Mg^{+2} ions and exchange equivalent amount of H^+ ions. Anions exchange resins remove bicarbonates, chlorides and sulphates from water exchange equivalent amount of OH^- ions.

Thus by passing hard water through cation hardness is observed by the following reactions. H^+ and OH^-ions, thus released in water from respective cation and anion exchange columns, get combined to produce water molecules.

$$H^+ + OH^- \rightarrow H_2O$$

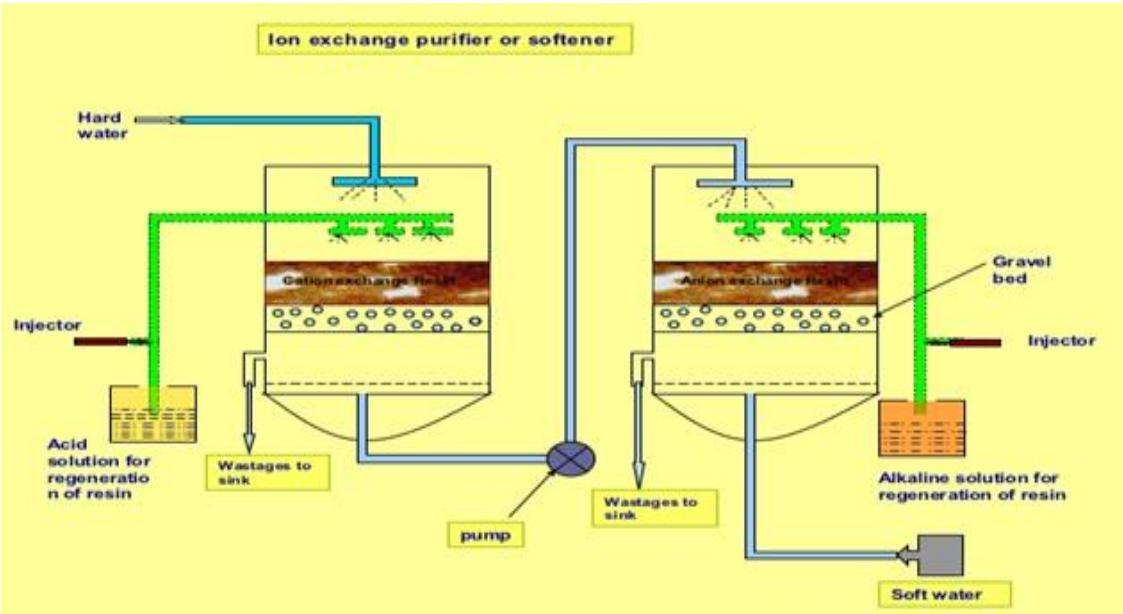
The water coming out from the exchanger is ion free from anions and cations. Thus water of zero hardness is obtained.

Regeneration: When cation exchanger losses capacity of producing H^+ ions and exchanger losses capacity of producing OH^- ions, they are said to be exhausted. The exhausted cation exchanger is regenerated by passing it through dilute sulphuric acid.

$$R_2Ca + 2HCl \rightarrow 2RH + CaCl_2$$
$$R_2Mg + 2H_2SO_4 \rightarrow 2RH + MgSO_4$$

The exhausted anion exchanger is regenerated by passing a dilute solution of NaOH.

$$R_2SO_4 + NaOH \rightarrow 2ROH + Na_2SO_4$$
$$RCl + NaOH \rightarrow ROH + NaCl$$
$$RHCO_3 + NaOH \rightarrow ROH + NaHCO_3$$



Merits of Ion-exchange process:

- The process can be used to soften highly acidic or alkaline water.
- It produces water of very low hardness (2ppm)
- So it is very good for treating water for use in high-pressure boilers.

7	a.	**What are the merits of Ion exchange process?** • The process can be used to soften highly acidic or alkaline water. • It produces water of very low hardness (2ppm) • So it is very good for treating water for use in high-pressure boilers.	[1M]
	b.	**What are the disadvantages of scales?** **1. Wastage of heat and fuels**: Scales poor thermal conductivity so that rate of heat transformation is reduced. **2. Lowering of boiler safety** is due to overheating of the boiler material becomes softer and weaker, which causes distortion of boiler. **3. Decrease in efficiency** of the boiler due to scales deposited in the values and condensers of the boiler cause choking. **4. Danger of explosion** which happens the formation of the scales, the boiler plate faces higher temperature outside and lesser temperature inside due to uneven expansion. The water comes suddenly contact with overheated portion and larger amount steam is formed immediately, this results in development of sudden high pressure which may cause explosion of the boiler.	[1M]
	c.	**Estimation fluoride ion by Ion Selective Electrode method.** An ion-selective electrode (ISE) is defined as an electro analytical sensor with a membrane whose potential indicates the activity of the ion to be determined (fluoride) in a solution. Ion-sensitive membrane may be glass, a crystalline inorganic material, or an organic ion exchanger. The membrane interacts with the ion of choice, here fluoride, allowing electrical potential of the half cell which is controlled by the fluorine concentration. The potential of the ISE is measured against a suitable reference electrode using a pH meter. The electrode potential is related to the logarithm of the concentration of the fluoride ion by the Nernst equation. $$E = E^0 + 2303 \frac{RT}{nF}.\log [M]$$ n = ion charge, the equation is valid for very dilute solutions where the ionic strength is constant. In this experiment we will use fluoride-sensitive electrode, either a saturated calomel electrode or Ag/AgCl external reference electrode to measure the fluoride ion concentration. Flouride ISEs only respond to free ionized F^- in solution and can be used to measure this ion in the presence of other fluorine compounds. **Reagents required:** NaF(dried at 100°C for 1 hour), KCl, Liquid NaF unknown Flouride ISE and Ag/AgCl reference electrode pH meter capable of displaying mV potentials	[10M]

Procedure:

Dry the NaF solid for 1 hour at 100°C.

NaF(10^{-1}): Weigh 0.42 g of NaF, dissolve in deionized water, and dilute to 100 ml in a volumetric flask. This solution is about 10^{-1} F in NaF. Transfer 10 ml of above solution to 100 ml volumetric flask and dilute with deionized water. This solution is about 10^{-2} F in NaF.

KCl (1 M): Weigh 7.55 g of KCl on a top loading balance and dissolve in 100 ml deionised water.

Prepare four 100 ml volumetric standard flasks as follows:

NaF(10^{-2} M) ml	KCl (1 M) ml	
(a) 1.00	10	Dilute each flask with deionized water
(b) 2.00	10	
(c) 5.00	10	
(d)10.00	10	

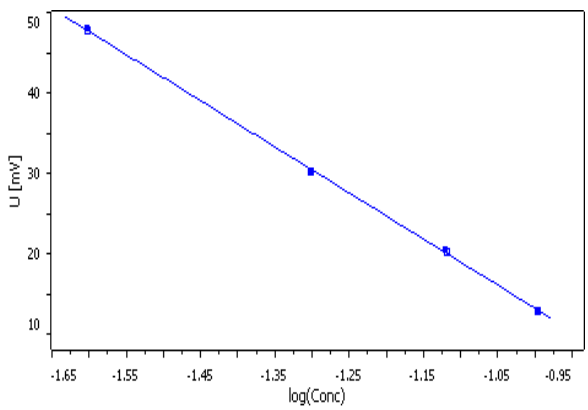
Analysis:

- Take unknown solution into a 100 ml volumetric flask and dilute upto the mark.
- Add 1 ml of prepared unknown solution and add 10 ml of KCl and dilute it to 100 ml with deionized water.
- Measure the potential in MV of the fluoride ISE Vs reference electrode for each of the four standard and for unknown solution.
- Pour about 30 ml of each standard solution (or) unknown into clean 100 ml beaker and immerse the electrode in the solution in the depth of 2 cm and then measure the electrode potential.
- After completion of the experiment rinse the electrodes with deionized water and keep the reference electrode in the appropriate solution.
- The F-ISE should be stored dry and loosely capped.

Calculations:

Calculate the molarity of NaF accurately.

Plot a graph of the concentration of NaF Vs potential. Find the best line passing through four standard solution points. Calculate the slope of the calibration curve slope = dE/dlog[NaF]



- By using calibration curve determine the Concentration of NaF in your prepared unknown solution.