Part - B (Long Answer Questions)

1. Explain the following:

i) Why do we express hardness of water in terms of $CaCO_3$ equivalent?

Because molecular wt of $CaCO_3$ is 100 gm/mol. It is easy to calculate. Also calcium carbonate is insoluble in water. therefore it is easy to calculate its amount in water.

ii. Why hard water fails to produce lather with soap solution.

Hard water contains dissolved calcium and magnesium salts in it. So, due to presence of hardness producing salts, it doesn't produce lather.

iii. Distinguish between hard water and soft water

Hard Water	Soft Water
Which doesnot produce lather with soap solution.	Which lather easily on shaking with soap solution
Contains dissolved calcium and magnesium salt in it.	Doesnot contains dissolved Ca and Mg salt in it
Hair and sky become dry	Hair and skin become soft
~~Less~~ More fuel and time are required for cooking in hard water.	Less time and fuel are required for cooking in soft water.
Rich in minerals	Contains very few elements

2. Describe the experimental procedure for the determination of total hardness by EDTA method?

20 ml of the given water sample is pipetted out into a clean conical flask. 5ml ammonia buffer and 2 drops of EBT indicator are added and titrated against EDTA from the burette. The end point is the change of colour from wine red to steel blue. The titration is repeated to get concordant titre value.

$$\text{Erichrome Black-T} + Ca^{2+}/Mg^{2+} \longrightarrow \underset{\text{(wine red)}}{EBT\text{-}Ca^{2+}/Mg^{2+}}$$

$$\underset{\text{(wine red)}}{EBT\text{-}Ca^{2+}/Mg^{2+}} + EDTA \longrightarrow EDTA\text{-}Ca^{2+}/Mg^{2+} + \underset{\text{(steel blue)}}{EBT}$$

$$M_2V_2 = M_3V_3.$$

where

M_2 = Molarity of EDTA.

V_2 = Volume of EDTA.

M_3 = Molarity of sample water.

V_3 = Volume of sample water.

$$\text{Total hardness} = M_3 \times \text{M.wt of } CaCO_3\,(100) \times 1\text{ lit}\,(1000)$$

$$= M_3 \times 10^5 \text{ ppm.}$$

3. What is hardness of water? Explain the terms temporary and permanant hardness of water

Hardness in water is that characteristic, "which prevents the lathering of soap".

Temporary hardness of water:
The presence of magnesium and calcium bicarbonates in water makes it temporarily hard which can be removed by boiling.

Permanant hardness of water:
When the soluble salts of magnesium and calcium are present in the form of chlorides and sulphides in water, we call it permanent hardness because this hardness cannot be removed by boiling.

4. Define carbonate and non-carbonate hardness of water. Write the various disadvantages of hardwater for domestic and industrial purpose.

Carbonate hardness is also called as temporary hardness as it contains Ca nd Mg bi-carbonates.
Non-carbonate hardness is also called as permanant hardness as it contains chloride and sulphides of Ca&Mg

Disadvantages of hardwater for domestic and industrial purpose:

Domestic use:
When used for washing purposes, does not lather freely with soap and produces sticky precipitates of calcium and magnesium soaps.
When used for bathing, doesnot produce lather, skin becomes dry and cleansing quality of soap is depressed. So, a lot of it is wasted

It elevates the boiling point of water. Hence more fuel and time are required for cooking

It causes the bad effect on our digestive system.

Industrial use:

It is not good for textile industry

If the water is used for concrete making, it affects the hydration of cement and the final strength of hardened concrete.

It affects the dyeing industry too..

5. List the salts responsible for temporary and permanant hardness. Explain the units of hardness in which the hardness of water is expressed:

Temporary hardness is due to $Mg(HCO_3)_2$, $Ca(HCO_3)_2$

Permanant hardness is due to $MgSO_4$, $CaSO_4$, $MgCl_2$, $CaCl_2$

Units of hardness:

1. Parts per million:

1 ppm = 1 part of $CaCO_3$ eq hardness in 10^6 parts of water

2. Milligrams per litre (Mg/L):

1 mg/L = 1 mg of $CaCO_3$ in 1 lit of water

1 mg/L = 1 ppm

3. Clark's degree (°Cl)

1° clark = 1 part of $CaCO_3$ eq hardness per 70,000 parts of water

4. Degree french (°Fr)

1°Fr = 1 part of $CaCO_3$ hardness eq per 10^5 parts of water

7. What is the principle of complexometric method, Explain the hardness of water by complexometric method.

Complexometric method is known as EDTA method

The water sample is trated with EDTA using EBT as an indicator. and keeping the pH of water at 9.0 - 10.0. The endpoint is the change in Colour from wine-red to blue, when the EDTA soln Complexes the Ca and Mg salt completely.

Chemical required:

8. What is hard water? Compare between temporary and permanant hardness of water

→ Qno. 3

9. Explain the basic principles involved in the estimation of hardness of water by EDTA method?

Q.NO-7

10. What are different units in which the hardness of water is expressed? Explain their interconversion

Q.NO.5 +

Interconversion:

1ppm	= 1mg/L	= 0.1°Fr	= 0.07°Cl
1mg/Cl	= 1ppm	= 0.1°Fr	= 0.07°Cl
1°Cl	= 1.433°Fr	= 14.3ppm	= 14.3mg/L
1°Fr	= 10ppm	= 10mg/L	= 0.7°Cl

11. Describe the process of chlorination of portable water?

The process of adding chlorine to water is called Chlorination. The methods used for chlorination are...

→ By adding Chlorine gas:

Chlorine gas is a very good disinfectant, which can be bubbled in water. Calculated amount of chlorine gas is passed inorder to destroy pathogenic bacteria. Chlorine reacticts with water to hypochloric and hypochlorous acids

These reactions occur during this process

$$Cl_2 + H_2O \longrightarrow HOCl + HCl$$

$$HOCl \longrightarrow HCl + [O]$$

→ By adding chloramine:

When chlorine and ~~amine~~ amonia are mixed in the ratio 2:1, a compound chloramine is formed

$$Cl_2 + NH_3 \longrightarrow ClNH_2 + HCl.$$
(Chloramine)

$$ClNH_2 + H_2O \longrightarrow NH_3 + HOCl$$

$$HOCl \longrightarrow HCl + [O]$$

Chloramine compounds decompose slowly to give nascent oxygen which will be acts as good disinfectant

12. What are requisities of drinking water? Explain about coagulation and filtration in treatement method of potable water.

A) Requisities of drinking water:

→ Water should be clear, colorless, odourless.

→ Optimum hardness must be 125 ppm.

→ PH should be 7.0 - 8.5

→ Total dissolved solid (TDS) must not exeed 500ppm

→ Turbidity should not exeed 25 ppm.

→ Free from heavy metals like Lead, Arsenic, Chromium and manganese.

→ Free from pathogenic bacteria.

→ Free from dissolved gases like H_2S, CO_2 and NH_3.

Coagulation:

Coagulants like alum, sodium aluminates and aluminates aluminium 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

Filtration: It helps in removal of the colloidal and suspended impurities not removed by sedimentation. Usually salt filters are employed.

13) What is sterilization of water? How is natural water sterilized by chlorine, bleaching powder, chloramines?

The process of destroying the harmful bacteria is known as sterilization or disinfection

For chlorine process, see Q.NO – 11.

14) What is potable water? Explain how sterilization of water is carried out by using Chlorine and ozone.

Water free from contaminants or water that is safe for human consumption is called portable water

For chlorine see Q.NO - 11

By ozone:

Ozone is a powerful disinfectant and is readily absorbed by water. ozone is highly unstable and breaks down to give nascent oxygen

$$O_3 \rightarrow O_2 + [O].$$

The nascent oxygen is a powerful oxidizing agent and kills the bacteria.

15) What are ion exchange resins? Describe their application in water softening.

20) What is external treatement of water? Explained any one of the methode with a neat diagram and write its advantages and disadvantages.

18) Describe the demineralization process of softening of hardwater and write its advantages!

Ion-exchange process is also known as demineralization process. Ion-exchange process resins are insoluble. Cross linked long chain organic polymers with a microporous structure, and the "functional Groups" attached to the chains are responsible for the ion-exchanging properties.

⇒ Resins ~~a~~ with acidic functional group are capable of exchanging H^+ ions with other cations

⇒ Resins with basic functional group are capable of exchanging OH^- ions with other anions.

Resins are classified as:

I. Cation Exchange method

II. Anion exchange method.

Cation exchange resins:

Cation exchange resins are styrene divinly benzene co-polymer which on sulphonation (or) carboxylation, which contains $-COOH$, $-SO_3H$ functional groups which responsible for exchanging their hydrogen ions with cations in water.

$$2RH + Ca(HCO_3)_2 \longrightarrow R_2Ca + H_2CO_3.$$

$$2RH + Mg(HCO_3)_2 \longrightarrow R_2Mg + H_2CO_3$$

$$2RH + CaCl_2 \longrightarrow R_2Ca + 2HCl$$

$$2RH + MgCl_2 \longrightarrow R_2Mg + 2HCl$$

$$2RH + MgSO_4 \longrightarrow R_2Mg + H_2SO_4$$

$$2RH + CaSO_4 \longrightarrow R_2Ca + H_2SO_4$$

(RH = Cation exchange resin)

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

$$ROH + HCl \longrightarrow RCl + H_2O$$

$$2ROH + H_2SO_4 \longrightarrow R_2SO_4 + 2H_2O$$

$$ROH + H_2CO_3 \longrightarrow RHCO_3 + H_2O.$$

(ROH = anion exchange resin)

Ion exchange process:

⇒ In ion exchange process, hard water is allowed to pass through cation exchange resins, which remove Ca^{+2} and Mg^{+2} ions and exchange equalent amount of H^+ ions

⇒ Anions exchange resins remove bicarbonates, chlorides and sulphates from water exchange equivalent amount of OH^- ions

⇒ Thus by passing hardwater through cation hardness is observed by the following reactions.

⇒ H^+ and OH^- ions, thus released in water from respective cation and anion coloums, get combined to form water molecules

$$H^+ + OH^- \longrightarrow H_2O.$$

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.

$$R2Ca + 2HCl \longrightarrow 2RH + CaCl_2.$$

$$R2Mg + 2H_2SO_4 \longrightarrow 2RH + MgSO_4$$

The exhausted anion exchanger is regenerated by passing a dilute soln 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

Demerits:

→ The equipment is costly and more expensive chemicals are needed

→ If water contains turbidity, the output of process is reduced

→ The turbidity must be below 10 ppm; else it has to be removed by coagulation and filtration

17. Explain the desalination of water by reverse osmosis!

19. What is the principle of reverse osmosis? Explain how sea water is purified by using this technique.

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

Reverse osmosis:

Reverse osmosis is a process in which pressure greater than the osmotic pressure is applied on the high conc'n side of the membrane, the flow of solvent more from concentrated side to dil. side across the membrane.

⇒ In this process, 15-40 kg/cm² pressure is applied for seperating the water from its contaminants.

The membranes used are cellulose acetate, polymethyl acrylate and polyamide polymers. This process is known as super or hyper filtration.

Module II: Part C (Problem solving and critical thinking).

1. Why do we add buffer solution during estimation of hardness of water by EDTA method?

A. The pH needs to be at least 10 for the EDTA to let go of its H^+ ions so we get the EDTA solution we need for the reaction with Mg^{2+} and Ca^{2+}. For this reason we need a buffer which will keep the total solution at pH 10.

2. What happens when temporary hard water is boiled? Give reactions.

A. The temporary hardness of the water is removed on boiling. On boiling $Ca(HCO_3)_2$, $Mg(HCO_3)_2$ are precipitated as insoluble salts. Which can be removed through filtration.

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

$$Mg(HCO_3)_2 \xrightarrow{\Delta} Mg(OH)_2\downarrow + 2CO_2\uparrow \cancel{+H_2O}.$$

3. One litre of water sample collected from a water source in telangana has shown the following analysis. $Mg(HCO_3)_2 = 14.6$ mg. $MgSO_4 = 12$ mg $Ca(HCO_3)_2 = 16.2$ mg. $CaCl_2 = 22.2$ mg. $MgCl_2 = 9.5$ mg and organic impurities 100mg. Calculate temporary and permanent hardness in degree French.

A. given weight of the salts; $Mg(HCO_3)_2 = 14.6$ mg. $MgSO_4 = 12$ mg
$Ca(HCO_3)_2 = 16.2$ mg $CaCl_2 = 22.2$ mg $MgCl_2 = 9.5$ mg.
molecular weight of given salts $Mg(HCO_3)_2 = 146$ mg $MgSO_4 = \cancel{12}\,120$ mg.
$Ca(HCO_3)_2 = 162$ mg $CaCl_2 = 11\cancel{0}$ mg. $MgCl_2 = 95$ mg.
amounts equivalent to $CaCO_3$.

$Mg(HCO_3)_2 = \dfrac{\cancel{14.6}^{\,0.1}}{\cancel{146}} \times 100 = 10$ $\quad$ $MgSO_4 = \dfrac{\cancel{12}}{\cancel{12\phi}} \times 10\cancel{\phi} = 10$

$Ca(HCO_3)_2 = \dfrac{16.2}{162} \times 100 = 10$ $\quad$ $CaCl_2 = \dfrac{22.2}{111} \times 100 = 20$.

$MgCl_2 = \dfrac{95}{95} \times 100 = 10$.

temporary hardness is due to $Mg(HCO_3)_2$ and $Ca(HCO_3)_2$

therefore TH = 10 + 10 = 20 ~~ppm~~ $\times 0.1\,°F = 2°Fr$

permanent hardness is due to $MgSO_4$, $MgCl_2$ and $CaCl_2$

therefore PH = 10 + 10 + 20 = 40 ~~ppm~~ $\times 0.1\,°F = 4°F$.

4. One liter of water from an underground reservoir in Tirupathi Town in Andhra Pradesh showed the following analysis for its contents: $Mg(HCO_3)_2$ = 42mg; $Ca(HCO_3)_2$ = 146 mg. $CaCl_2$ = 71mg $MgSO_4$ = 48 mg. Calculate temporary permanent and total hardness of this sample of 10,000 liter of water.

A.

Salt	given weight	molecular weight	equivalent amt to $CaCO_3$.
$Mg(HCO_3)_2$	42mg	146mg	$42/146 \times 100 = 28.77$
$Ca(HCO_3)_2$	146 mg.	162mg	$146/162 \times 100 = 90.12$
$CaCl_2$.	71mg	111mg	$71/111 \times 100 = 63.96$
$MgSO_4$.	48mg.	120mg.	$48/120 \times 100 = 40$

temporary hardness = 28.77 + 90.12 = 118.89 x 10^4 per 10,000 lit

permanent hardness = 63.96 + 40 = 103.96 x 10^4 per 10,000 lit

total hardness = 222.85 x 10^4 per 10,000 lit

6. A sample of hard water contains the following dissolved salts per litre $Mg(HCO_3)_2$ = 14.6 mg $CaHCO_3$ = 16.2mg $CaCl_2$ = 111mg $CaSO_4$ = 1.36mg silica = 40 mg turbidity = 10mg. Calculate the temporary, permanent and total hardness of water in ppm, degree Clark and degree French.

A.

Salt	given weight	molecular weight	equivalent amt to $CaCO_3$.
$Mg(HCO_3)_2$	= 14.6mg	146 mg.	$14.6/146 \times 100 =$ 10
$CaHCO_3$	= 16.2mg	162mg	$16.2/162 \times 100 =$ 10
$CaCl_2$	= 111mg	111mg	$111/111 \times 100 =$ 100.
$CaSO_4$	= 1.36mg.	136mg	$1.36/136 \times 100 =$ 1

Temporary hardness = 10 + 10 = 20 ppm.

$= 20 \times 0.1°F = 2°F$

$= 20 \times 0.07°Cl = 1.4°Cl$.

permanent hardness = 100 + 1 = 101 ppm

$= 101 \times 0.1°F = 10.1°F$

$= 101 \times 0.07°Cl = 7.07°Cl$.

total hardness = 121 ppm

$= 12.1°F$

$= 8.47°Cl$.

6. Calculate temporary and permanent hardness of a water sample which contains 6.8 mg of $CaSO_4$, 33 mg of $CaCl_2$, 40 mg of $MgCl_2$, 24 mg of $MgSO_4$ per litre of the water sample. (Given molar mass of Ca = 40 gm Mg = 24 g S = 32 g O = 16 g Cl = 35 g).

A.

salt	given weight	MW	equivalent amt to $CaCO_3$.
$CaSO_4$	6.8 mg	136 mg	$6.8/136 \times 100 = 5$
$CaCl_2$	33 mg.	111 mg	$33/111 \times 100 = 29.73$.
$MgCl_2$	40 mg	95 mg	$40/95 \times 100 = 42.10$
$MgSO_4$	24 mg	120 mg	$24/120 \times 100 = 20$

temporary hardness = 0.

permanent hardness = 5 + 29.73 + 42.10 + 20 = 96.83 ppm.

7. A sample water of 100 ml required 12.6 ml of 0.02M EDTA solution with EBT as indicator and 8.4 ml of 0.02M EDTA for the same volume of water after removing the carbonate hardness. Calculate the total, permanent hardness in terms of calcium carbonate equivalants.

A. V_2 = Volume of EDTA solution (12.6ml).
M_2 = strength of EDTA solution (0.02M)
V_3 = Volume of sample hard water (100ml).
M_3 = strength of sample hardwater
Calculation of total hardness.

$$M_3 = \frac{V_2 M_2}{V_3} = \cancel{25} \times \cancel{0.025}\ \frac{12.6 \times 0.02}{100}.$$

$$= 0.00252 \times 10^5$$

total hardness = 252 ppm.

Calculation of permanent hardness.
V_2 = Volume of EDTA solution (8.4ml).
M_2 = strength of EDTA solution (0.02M).
V_4 = Volume of sample hard water after boiling cooling and filtering (100ml).
M_4 = strength of sample hard water after removing the carbonates hardness.

$$M_4 = \frac{V_2 M_2}{V_4} = \frac{8.4 \times 0.02}{100} = 0.00168 \cdot \times 10^5$$

permanent hardness. = 168 ppm.

8. A sample water of 20ml required 18.2 ml of 0.01M EDTA solution with EBT as indicator and 4.6 ml of 0.01 M EDTA for the same volume of water after removing the carbonate hardness. Calculate the total, permanent hardness in terms of calcium calbonate equivalents.

A. Calculate total hardness.
V_2 = Volume of EDTA solution (18.2ml)
M_2 = Strength of EDTA solution (0.01M)
V_3 = Volume of sample hard water (20ml).
M_3 = strength of sample hardness.

$$M_3 = \frac{V_2 M_2}{V_3} = \frac{18.2 \times 0.01}{20} = \cancel{0.00182}\ 0.0091$$

total hardness = $0.00\overset{91}{\cancel{182}} \times 10^5 = \overset{910}{\cancel{182}}$ ppm

Calculations for permanent hardness

V_2 = Volume of EDTA solution (4.6ml)

M_2 = Strength of EDTA solution (0.01M)

V_4 = Volume of sample water after removing the carbonate hardness (20ml)

M_4 = Strength of sample water after removing the carbonate hardness.

$$M_4 = \frac{M_2 V_2}{V_4} = \frac{0.01 \times 4.6}{20} = 0.0023$$

permanent hardness = $0.0023 \times 10^5 = 230$ ppm.

4. A sample water of 20ml requires 22.5ml of 0.02M EDTA solution with EBT as indicator and 14.5ml of 0.02M EDTA for the same volume of water after removing the carbonate hardness. Calculate the total, permanent hardness in terms of calcium carbonate equivalents.

A. Calculation for total hardness.

V_2 = Volume of EDTA solution (22.5 ml)

M_2 = Strength of EDTA solution (0.02M).

V_3 = Volume of sample hard water (20ml)

M_3 : Strength of sample hard water

$$M_3 = \frac{M_2 V_2}{V_3} = \frac{0.02 \times 22.5}{20} = 0.0225$$

total hardness = $0.0225 \times 10^5 = 2250$ ppm

Calculations for permanent hardness

V_2 = Volume of EDTA solution (14.5ml)

M_2 = Strength of EDTA solution (0.02M)

V_4 = Volume of sample hardwater after removing carbonate hardness (20ml)

M_4 = Strength of sample hardwater after removing carbonate hardness (

$$M_4 = \frac{M_2 V_2}{V_4} = \frac{0.02 \times 14.5}{20} = 0.0145$$

permanent hardness = $0.0145 \times 10^5 = 1450$ ppm.

10. What is the main advantage of reverse osmosis process over ion-exchange process?

A. The reverse osmosis process is simple and reliable, and capital and operating expenses are low. whereas.
In ion exchange process the equipment is costly and more expensive chemicals are needed.
Reverse osmosis removes up to ~~95~~ 97% of everything from the water, while ion exchange resin only affects positively charged ions (and is only really effective on high molecular weight ones)