

CHAPTER – WATER

Introduction: Water is one of the most important substance on earth. All plants and animals requires water to survive. If there was no water there would be no life on earth. Water is also essential for the healthy growth of farm crops and farm stock and is used in the manufacture of many products. Probably every manufactured product uses water during some part of the production process. Industrial water use includes water used for such purposes as fabricating, processing, washing, diluting, cooling, or transporting a product; incorporating water into a product. Some industries that use large amounts of water produce such commodities as food, paper, chemicals, refined petroleum, or primary metals.

Different sources of water : Rain water, river water, lake water, sea water, underground water, spring and well water

Q1) What are the different types of impurities in water?

Ans: Impurities in water is classified into three types:

1) Physical Impurities:

a) Colour: Yellowish colour indicates the presence of chromium and appreciable amount of organic matter. Yellowish red colour indicates the presence of iron, while red brown colour indicates the presence of peaty matter.

b) Turbidity: It is due to the colloidal, extremely fine suspension such as clay, slit, finely divided matters (organic and inorganic) micro- organisms like plankton etc.

c) Taste: It is due to the presence of dissolved mineral in water produces taste, but not odour. Bitter taste can be due to the presence of iron, aluminum, manganese, sulphate or excess of lime. Soapy taste can be due to the presence of large amount of sodium bi carbonate. Brackish taste is due to the presence of unusual amount of salts.

d) Odour: Odour in water is undesirable for domestic as well as industrial purposes. Disagreeable odour is due to the presence of living organisms, decaying vegetation including algae, bacteria, fungi and weeds.

2) Chemical Impurities :

(i) Acidity: Surface waters and ground waters attain acidity from industrial wastes like acid, mine, drainage, pickling liquors etc.

(ii) Gases: All natural waters contain dissolved atmosphere CO_2 . Its solubility depends upon temperature, pressure and dissolved mineral content of water. On the other hand dissolved oxygen in water is essential to the life of aquatic organisms such as fishes. Polluted waters and sewages contains nitrogen in the form of nitrogeous organic compounds and urea, which are partially converted into NH_3 .

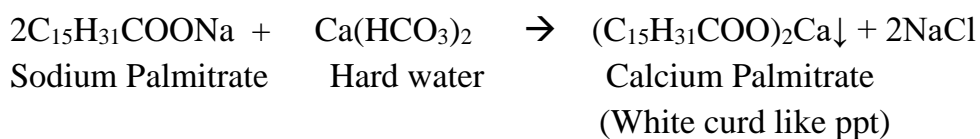
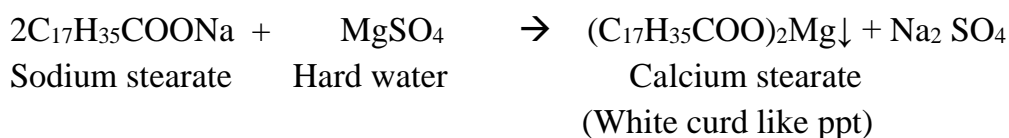
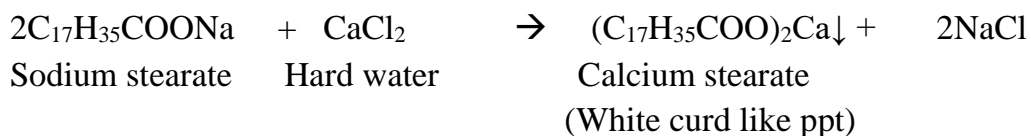
3) Biological Impurities: Biological impurities in water are caused by the presence of living organisms. These include algae, protozoa, pathogens, bacteria, viruses, microbes, and parasites along with their cysts (eggs) in contaminated water. The latter are simply called germs, microorganisms that can reproduce at alarming rates.

Q2) Define Soft water and Hard water with reactions?Ans: **Soft Water:-**

- Water which immediately (easily) produces good amount of lather (foam) with soap is called as **Soft water**.
- It is free from soluble salts of Calcium and Magnesium such as CaCl_2 , MgCl_2 , MgSO_4 , CaSO_4 , $\text{Ca}(\text{HCO}_3)_2$, and $\text{Mg}(\text{HCO}_3)_2$ etc
- Soft water does not react with soap and hence does not produce insoluble curd like precipitate of Ca and Mg stearate or palmitate.

Hard Water:-

- Water which does not immediately (easily) produces good amount of lather (foam) with soap is called as **Hard water**.
- It contains Ca and Mg soluble salts such as CaCl_2 , MgCl_2 , MgSO_4 , $\text{Ca}(\text{HCO}_3)_2$, and $\text{Mg}(\text{HCO}_3)_2$ along with soluble salts of some heavy metals like Fe, Mn, Al etc.
- Hard water reacts with soap producing insoluble curd like precipitate of Ca and Mg stearate and palmitrate as shown below.
- **Reactions:**

**Q3) What are the disadvantages of Hard water?**Ans:- **a) Domestic use:**

i) Washing: Hard water when used for washing, does not produce lather with soap but instead forms a white sticky precipitate of Ca, Mg soaps. This continues till all the hardness causing salts present in water are precipitated. Thereafter the soap produces lather. This causes the following disadvantages i) A lot of soap is wasted. ii) Formation of spots and streaks on the cloth. iii) Staining due to the adherence of the precipitates on the cloth.

ii) Bathing: Hard water does not lather freely with soap solution and instead forms a sticky precipitate on the body causing irritation to the skin.

iii) Cooking: Presence of dissolved salts in water causes effects such as:

Boiling point of water rises, as a result the food takes a longer time to cook and therefore fuel is wasted. The dissolved salts are deposited as bicarbonates on the inner walls of the heating utensils.

iv) Drinking: Hard water gives a) Unpleasant taste to water. b) Increases the possibility of causing kidney stones.

b) Industrial Use:

i) Textile Industry: In this industry water is used for dyeing, bleaching and washing purpose. During washing if hard water is used, a lot of soap gets wasted.

During dyeing exact shades of color are not obtained with hard water. On white clothes Fe and Mn may form colored spots.

ii) Sugar Industry: Water containing sulphates, nitrates, carbonates etc, if used in sugar refining causes difficulties in the crystallization of sugar and it may also decompose on storage.

iii) Paper Industry: Calcium and Magnesium salts tend to react with chemicals used to provide a smooth and glossy finish to the paper. Iron salts affect the color of the paper being produced.

iv) Laundry: Hard water causes wastage of soap. Iron and manganese salts causes coloration of the clothes.

v) Concrete making: Water containing chlorides and sulphates if used in concrete making, affects the hydration of cement and the final strength of the hardened concrete.

vi) Pharmaceutical Industry: Salts present in the hard water may react with the chemicals present in the pharmaceutical like drug, injections, ointments etc and produce undesirable products.

vii) Steam Generation in boilers: Hard water when used in boilers can results in :

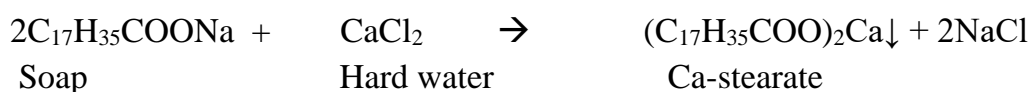
i) Scale and Sludge formation .ii) Corrosion iii) Priming and Foaming iv) Caustic Embrittlement.

Q4) What is hardness of water and explain it types?

Ans) Hardness of water is defined as “The soap consuming capacity of a water sample”.

a) Hard water consists of Ca and Mg soluble salts such as CaCl_2 , CaSO_4 , MgCl_2 , MgSO_4 , $\text{Ca}(\text{HCO}_3)_2$, and $\text{Mg}(\text{HCO}_3)_2$. which are responsible for hardness in water.

b) These salts react with the soap to form white curd like precipitate and does not allow soap to produce good amount of lather. When whole of the hardness causing ions are precipitated out as shown in reaction below, further addition of soap produces lather.



TYPES OF HARDNESS:**Temporary Hardness/Temporary Hard water/Carbonate Hardness/Alkaline Hardness:**

i) Temporary hardness of water is caused due to the presence of bicarbonates of Ca and Mg ie $\text{Ca}(\text{HCO}_3)_2$, and $\text{Mg}(\text{HCO}_3)_2$. It is called temporary hardness because this types of hardness can be removed just by boiling, as shown :



On boiling soluble $\text{Ca}(\text{HCO}_3)_2$ and $\text{Mg}(\text{HCO}_3)_2$ decompose into insoluble carbonates, which is removed by filtration.

It is also called as “Alkaline hardness”.

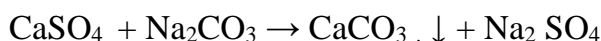
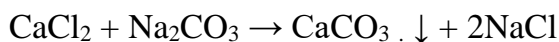
ii) Permanent Hardness/Permanent Hard water/Non Carbonate Hardness/Non Alkaline Hardness.

Permanent hardness of water is caused due to the presence of Chlorides and sulphates of Ca , Mg and Fe ie. CaCl_2 , CaSO_4 , MgCl_2 , MgSO_4 , FeCl_2 , FeSO_4 ,

It is called as permanent because such type of hardness cannot be removed simply by boiling.

Permanent hardness of water can be removed by adding calculated amount of Lime and Soda.

ie. $\text{Ca}(\text{OH})_2$ and Soda (Na_2CO_3) as shown below,



Insoluble Ca and Mg salts are removed by filtration. Hardness caused by chlorides and sulphates of Ca and Mg is called as Non-Alkaline Hardness

Q5) What is degree of hardness in water? How is it expressed?

Ans) The net amount of hardness causing impurities present in a finite volume (usually one litre) is called ‘Degree of Hardness’

It is expressed in terms of CaCO_3 . CaCO_3 is selected as standard as the molecular weight of CaCO_3 is 100 and Equivalent weight of CaCO_3 is 50.

Also it is the most insoluble salt that gets precipitated during softening of hard water.

Degree of Hardness(H) = $\frac{\text{Mass of Hardness Producing substance}}{\text{Equivalent weight of } \text{CaCO}_3}$

Equivalent weight of hardness producing substance (h.p.s)

$$H = \frac{\text{Mass of hardness producing substance}}{\text{Equivalent weight of h.p.s}} \times 50$$

Equivalent weight of h.p.s

The ratio, $\frac{\text{Equivalent weight of CaCO}_3}{\text{Equivalent weight of h.p.s}}$ is referred as Multiplication factor

If the h.p.s has a bivalent cation, the ratio is expressed as $\frac{\text{Molecular weight of CaCO}_3}{\text{Molecular weight of h.p.s}}$

Q6) Define the following terms:

- Parts per million:** It is the number of parts of calcium carbonate equivalent hardness per 10^6 parts of water sample.
- Milligram per litre (mg/l) :** It is the number of milligrams of calcium carbonate equivalent hardness present per litre of water.

Thus, 1mg/lit = 1mg of CaCO_3 equivalent in 10^6 mg of water.

= 1 part of CaCO_3 equivalent in 10^6 mg of water

= 1ppm

1mg/l = 1ppm

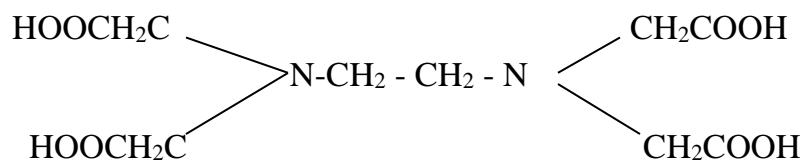
Conversion table of some impurities in water into equivalent of CaCO_3

Sr No	Salt	Molecular weight	Equivalent weight	Multiplication factor
1.	$\text{Ca(HCO}_3)_2$	162	81	100/162
2.	$\text{Mg(HCO}_3)_2$	146	73	100/146
3.	CaSO_4	136	68	100/136
4.	CaCl_2	111	55.5	100/111
5.	MgSO_4	120	60	100/120
6.	MgCl_2	95	47.5	100/95
7.	$\text{Mg(NO}_3)_2$	148	74	100/148
8.	CaCO_3	100	50	100/100
9.	MgCO_3	84	42	100/84
10.	HCO_3^-	61	61	100/122
11.	OH^-	17	17	100/34
12.	CO_3^{2-}	60	30	100/60
13.	$\text{Al}_2(\text{SO}_4)_3$	342	57	100/114
14.	CO_2	44	22	100/44
15.	$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$	278	139	100/278
16.	H^+	1	1	100/2
17.	NaAlO_2	82	82	100/164

Q7) Explain EDTA titration method and describe how is it use for estimation of hardness in water sample?

Ans) Ethylene Diamine tetra acetic acid (EDTA)

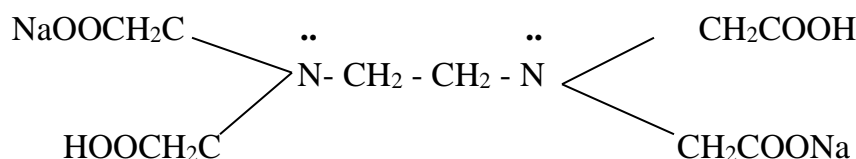
Structure:



EDTA[H₄Y]

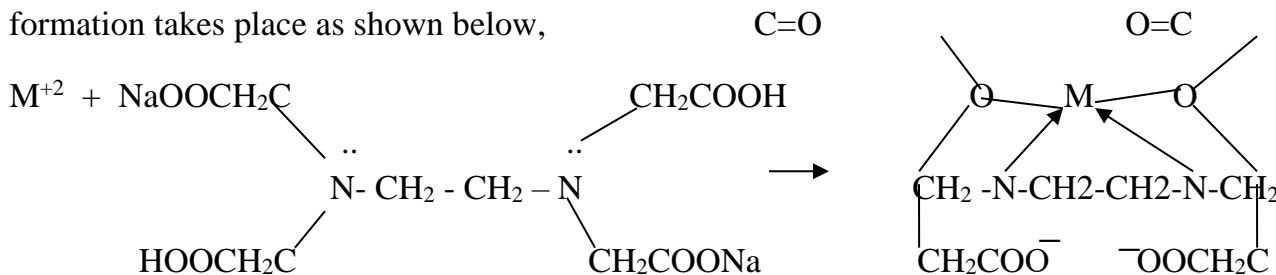
EDTA represented as H₄Y is sparingly soluble in water, hence its di-sodium salt (Na₂H₂Y) is generally used in complexometric titration.

Structure:



Disodium salt of EDTA (Na₂H₂Y)

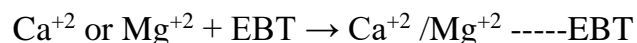
EDTA is a hexadentate ligand. It binds the metal ions in water ie Ca⁺² or Mg⁺² to give highly stable chelate complex. Therefore, this method is called as Complexometric titration. The complex formation takes place as shown below,



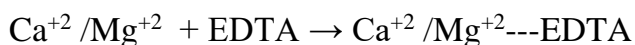
Principle of EDTA method:

EDTA forms a stable complexes with Ca⁺² or Mg⁺² and other metal cations in aqueous solution. Thus total hardness can be determined by titrating Ca⁺² or Mg⁺² present in an aliquot of the sample with Na-EDTA solution, using NH₄Cl, NH₄OH buffer solution of pH-10 and Eriochrome Black T (EBT) as the metal indicator.

The indicator forms a wine red colored unstable complex with Ca⁺² or Mg⁺² and whole solution turns wine red.

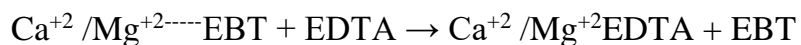


When this wine red color solution is titrated with EDTA it first combines with free metal ions to give colourless stable metal EDTA complex.



Colorless and Stable

When all the free metal ions have reacted with EDTA the next drop of EDTA solution displaces the indicator (EBT) from the weak wine red colour complex and the indicator is set free giving back its original colour ie Blue. Since the stability of $\text{Ca}^{+2} / \text{Mg}^{+2}\text{EDTA}$ is greater than $\text{Ca}^{+2} / \text{Mg}^{+2}\text{EBT}$



Wine red Colourless Blue

Thus , the end point is from wine red to blue.

Preparation and Procedure:

Standard Hard Water: Prepared by dissolving 1gm of pure ,dry CaCO_3 in minimum quantity of distilled water and then making the volume upto 1litre with distilled water.

EDTA solution: 4gm of pure EDTA crystals and 0.1gm of MgCl_2 is dissolved in 1 litre of distilled water

EBT Indicator: 0.5gm EBT indicator is dissolved in 100ml of alcohol.

Buffer solution: 67.5gm of NH_4Cl is added to 570ml of concentrated ammonia solution and then diluted with distilled water to 1 litre.

Standardisation of EDTA water:

50ml of Std hard water solution is taken in a conical flask .10-15ml of the buffer solution and 4-5 drops of the indicator solution is added to it. The solution is titrated against the EDTA solution taken in the burette. Let the volume be $V_1\text{ml}$.

Determination of Total Hardness:

50ml of the unknown hard water solution is taken in the conical flask and titrated in a similar manner. Let the volume be $V_2\text{ ml}$.

Determination of Permanent Hardness:

250ml of the hard water sample is boiled till its volume reduces to about $1/5^{\text{th}}$.The solution is filtered to remove the precipitates of bicarbonates salts. The filtrate and the washings given to the precipitates are collected and the volume made back to 250ml with distilled water.

50ml of this solution is taken in a conical flask and titrated in the same manner as described earlier. Let the volume be $V_3\text{ml}$.

Calculations:

V1ml of EDTA = 50ml of Std Hard water = 50mg of CaCO_3 hardness

1ml of EDTA = $50/V_1$ mg of CaCO_3 hardness

50ml of hard water = V_2 ml of EDTA(1)

= $V_2 \times 50/V_1$ mg of CaCO_3 hardnessfrom (1)

1000ml of hard water = $1000 \times V_2 \times 50 / V_1 \times 50$ mg of CaCO_3 hardness

Total hardness = $1000 \times V_2/V_1$ mg/lit or ppm(2)

Now, 50ml of boiled hard water = V_3 ml of EDTA

From ...(1), = $V_3 \times 50/V_1$ mg of CaCO_3 hardness

1000ml of boiled hard water = $(1000 \times V_3 \times 50/V_1 \times 50)$ mg of CaCO_3 hardness

Permanent hardness = $1000 \times V_3/V_1$ mg/lit or ppm ---- From (2) and (3)

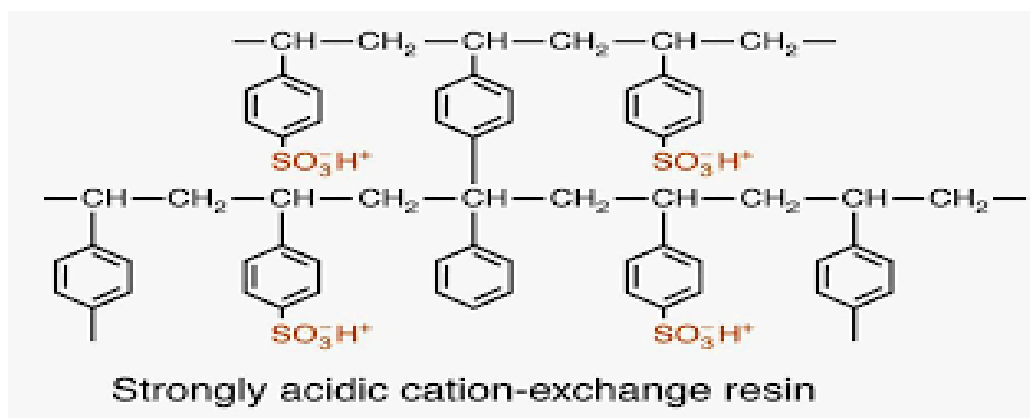
Q8) What are Ion-Exchange resins? How are they classified?

Ans) “Ion –Exchange resins are insoluble , cross – linked ,long chain, high molecular weight organic polymers with a microporous structure .The functional groups attached to the chains are responsible for the ion-exchanging properties.”

Ion exchange resins are of two types

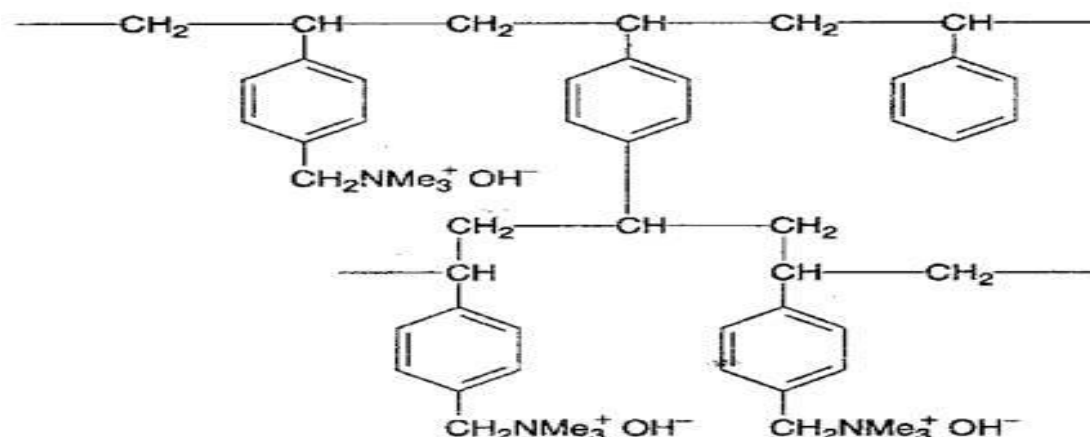
1)Cation Exchange resins (RH_2^+)

These resins are mainly styrene –divinyl benzene copolymers and contain acidic functional group like COOH , SO_3H , H^+ etc that are capable of exchanging their H^+ ions with other cations present in water. It is represented as RH_2^+ . Commercial cation exchanger is AMBERLITE IR – 120



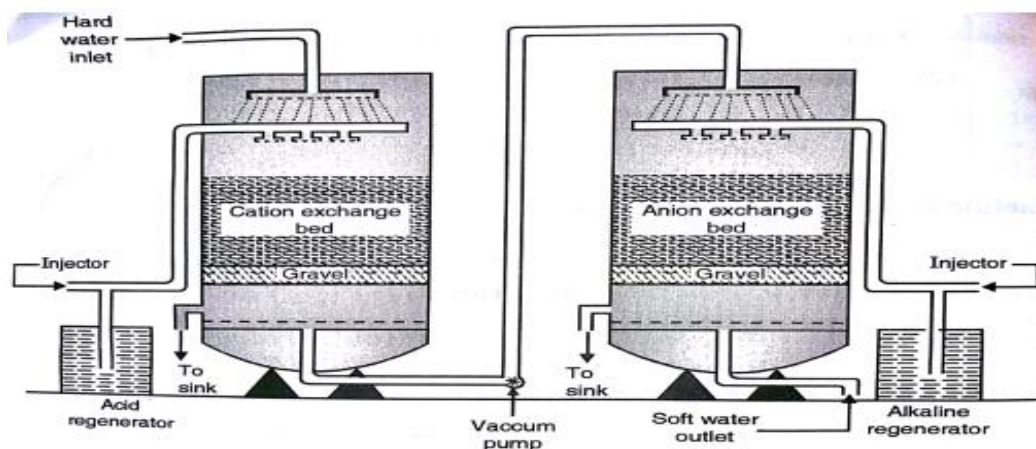
2) Anion Exchange Resin : (ROH^-)₂

These resins are styrene – divinyl benzene or amine –formaldehyde copolymers containing amino or quaternary ammonium or tertiary sulphonium hydroxyl functional group that are capable of exchanging their anions with the anions in water. Commercial anion exchange is Amberlite IR 400. It is represented as $(\text{ROH})_2$



Q9) Explain the Ion-Exchange process or demineralization process for the softening of water?

Ans)

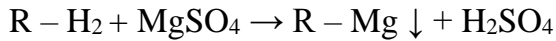
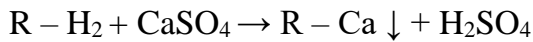
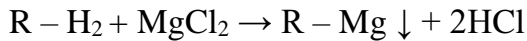
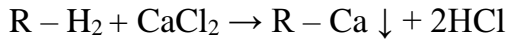
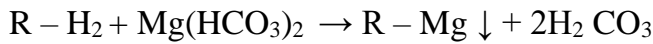
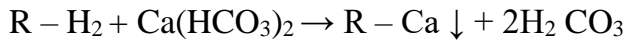


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Demineralisation Diag. 2

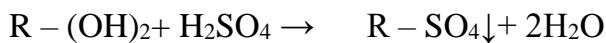
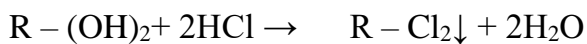
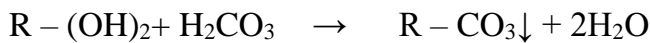
Defination: A process in which a reversible exchange of ions takes place between the stationary ion exchange phase and the external liquid mobile phase is called as Ion Exchange Process

Process: Hard water is first passed through cation exchange column. All the cations like Ca^{+2} , Mg^{+2} etc. present in water are removed and an equivalent amount of H^{+} are discharged from the column into water as shown in the following reactions.



Thus, all the salts are converted into the corresponding acids in the cation exchange column.

The water is next pumped into the anion exchange column. All the anion present in the column get absorbed into the bed and an equivalent amount of OH^- ions discharged from the bed enters the water as shown in the following reactions;

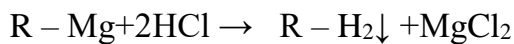
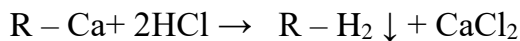


H^+ and OH^- , released from cation and anion exchange columns respectively get combines to form water molecule. Thus, the water coming out of exchange is free from cations as well as anions. Ion free water, is known as deionised or demineralised water.

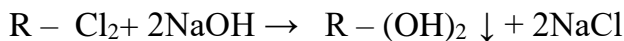
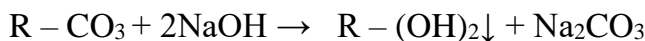
Regeneration

When capacities of cation and anion exchangers to exchange H^+ , and OH^- ions respectively are lost, they are said to be exhausted. These columns are regenerated by acid and alkali solutions respectively as given below.

The cation exchange column is regenerated using dil. HCl.



While in order to regenerate anion exchange resins, diluted NaOH is passed through it



The columns are then washed with deionised water and the washing is passed into the drain. The regenerated column is used again.

Advantages:-

- 1) The residual hardness is only around 0-2 ppm.
- 2) The process can be used to treat both acidic as well as alkaline water.
- 3) The equipment is compact.
- 4) The process is suitable even for removing colored metal ions like Mn^{+2} , Fe^{+2}
- 5) No sludge is produced.

Disadvantages:-

- 1) The equipment is costly.
- 2) Turbid water blocks the pores of the exchangers, hence turbidity has to be removed before pouring the water in the exchanger. Turbidity must be less than 10ppm.

Q10) Explain the BOD and COD . What is their significance.

Ans:- Biochemical Oxygen Demand (BOD): The amount of free oxygen required for the biological oxidation of the organic matter under aerobic condition at 20°C and for a period of 5 days. Unit = mg/lit or ppm

Determination of BOD:- A known volume of sample of sewage is diluted with a known volume of diluted water, whose dissolved oxygen content is predetermined. The whole solution is incubated in a closed bottle at 20°C for 5 days. After this unused O_2 is determined. The difference between the original oxygen content in diluted water i.e. Blank (DO_b) and unused oxygen of solution after 5 days (DO_i) gives the BOD.

$$BOD = (DO_b - DO_i) \times \frac{\text{Volume of undiluted sample}}{\text{Volume of diluted sample}}$$

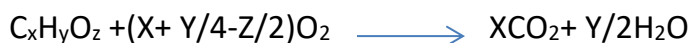
Significance:- It indicates the amount of decomposable organic matter in the sewage. Larger the concentration of decomposable organic matter, greater is the BOD.

It enables us to determine the degree of pollution at any time in the sewage stream.

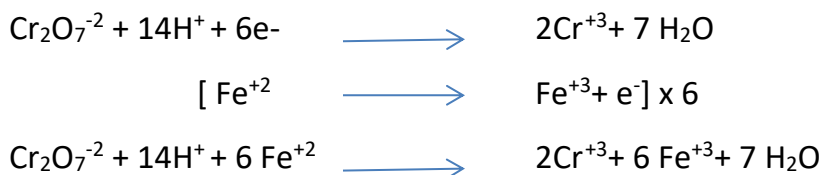
Chemical Oxygen Demand (COD):- It is the amount of oxygen consumed under specified conditions in the oxidation of organic and oxidizable inorganic matter.

Determination of COD:- A known volume of sample is refluxed with a known excess of standard potassium dichromate ($K_2Cr_2O_7$) and dil. H_2SO_4 in presence of a little Ag_2SO_4 catalyst and $HgSO_4$ for 1 ½ hours. The unreacted $K_2Cr_2O_7$ is then titrated against Ferrous Ammonium Sulphate i.e. Mohr's salt solution [$FeSO_4(NH_4)_2 \cdot SO_4 \cdot 6H_2O$]. The O_2 equivalent of $K_2Cr_2O_7$ consumed is taken as a measure of COD.

Reaction:



The unreacted dichromate solution is titrated against $[\text{FeSO}_4(\text{NH}_4)_2, \text{SO}_4 \cdot 6\text{H}_2\text{O}]$ using Ferroin as indicator. At end point, blue colour changes to wine red.



The COD is calculated as follows:
$$\text{COD} = \frac{(V_1 - V_2) \times N \times 8 \times 1000}{X}$$

where V_1 = Volume of FAS for Blank titration and V_2 = Volume of FAS for sample titration,

N = Normality of FAS, X = The volume of sample taken for test.

Significance :- COD measures the biological oxidisable and biologically inert organic matter such as cellulose. COD values can be employed to estimate BOD values.

Determination of COD takes just 3 hours. Since in the COD test both biologically oxidisable and the biologically inert matter are oxidized, the COD value for a sample is always higher than BOD value.

Q11) Explain Electrodialysis?

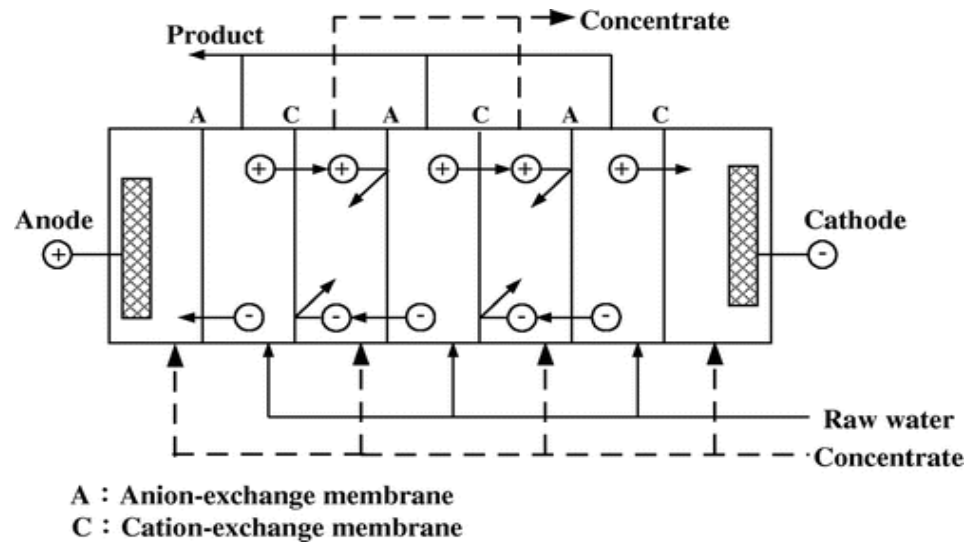
Ans) Water with high levels of dissolved salt is not suitable for domestic, industrial or irrigation uses. Sea water contains 3.5% dissolved salts. It can be desalinated into fresh water by the process of desalination for which membrane technology is employed. The following methods are used for desalination of water by using membrane technology.

Electrodialysis:- It is a method in which the ions are pulled out of the salt water by passing direct current, using electrodes and thin rigid plastic membrane pair (natural or synthetic).

Working:-

When direct electric current is passed through saline water, the sodium ions (Na^+) start moving towards negative pole (cathode) while the chloride ion (Cl^-) start moving towards the positive pole anode, through the membrane. As a result the concentration of brine decreases in the central compartment while it increases in the two side compartments.

Desalinated brine (or pure water) is removed from the central compartment from time to time, while concentrated brine is replaced by fresh sea water.



For more efficient separation, ion selective membranes, which are permeable to only one kind of ions with specific charge, have been used in recent years.

Cation selective membranes are permeable to only cations and anion selective membranes are permeable to only anions.

The ion selective membrane pores are designed with fixed charge while exclusively allows one type of charged ions to pass through its pores and does not allow oppositely charged.

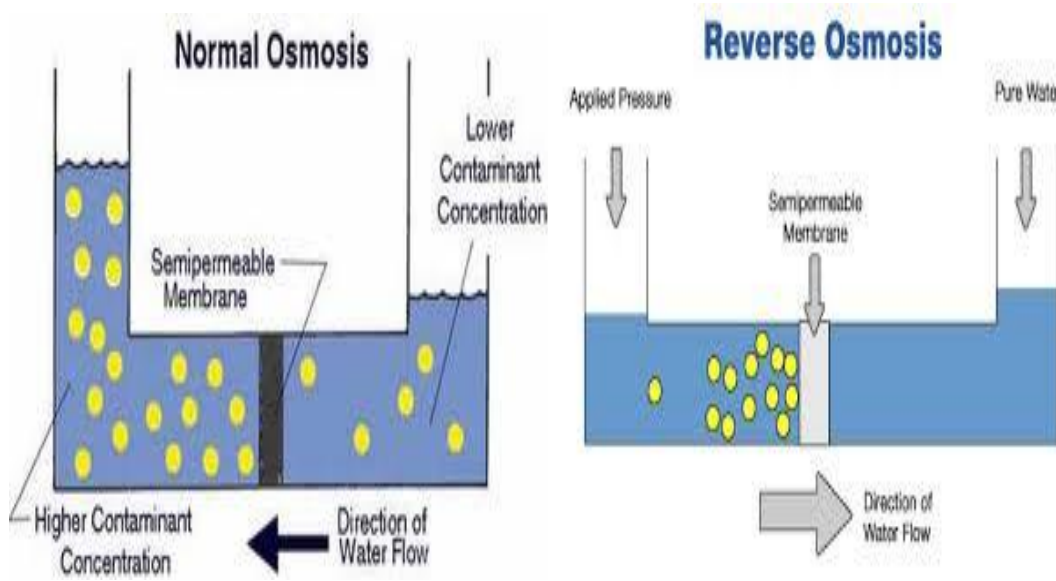
An electrodialysis cell consists of a large number of paired sets of rigid plastic membranes. Saline water is passed under a pressure of (about 5-6kg m⁻²) between membrane pairs and an electric field is applied perpendicular to the direction of water flow. The fixed positive charges inside the membrane repel positively charged ions (Na⁺), yet permit negatively charged ions (Cl⁻) to pass through. Similarly, the fixed negative charges inside the other type of membrane repel negatively charged ions (Cl⁻), yet permit positively charged ions (Na⁺) to pass through. Thus, water in one component of the cell is deprived of its salts, while the salt concentration in adjacent compartments is increased. Hence, we get alternate streams of pure water and concentrated brine.

Advantages:

- 1) It is most compact unit.
- 2) Cost of installation of the plant

Q12) Give a brief account of Reverse Osmosis.

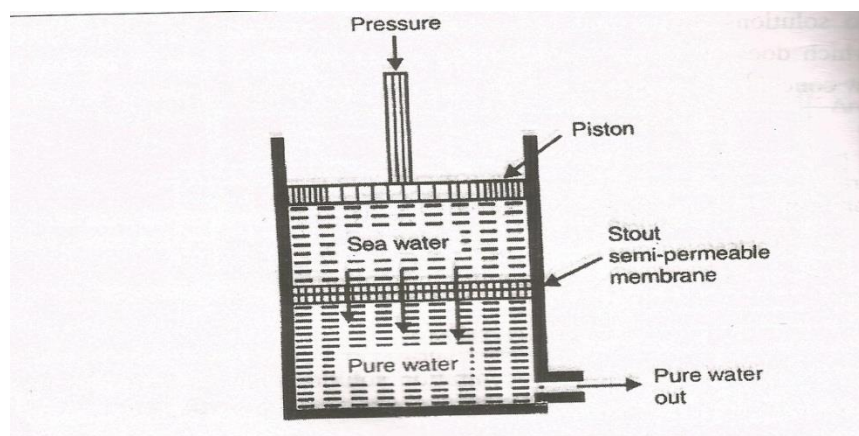
Ans



Definitions:-Osmosis: When two solutions of unequal concentration are separated by a semi-permeable membrane the solvent flows from the dilute solution to the concentrated solution.

Reverse Osmosis: When a hydrostatic pressure in excess of osmotic pressure is applied on the concentrated side, the solvent flow is reversed i.e. The solvent is forced to move from the concentrated solution to the dilute solution. Thus in reverse osmosis, pure solvent is separated from its salts and other impurities, rather than removing impurities from water. This membrane filtration is sometimes also called as '**Super filtration**' or '**Hyper filtration**'

Desalination:-



Process:-Pressure of the order of 15 to 40kg/cm² is applied to the sea water to be treated.

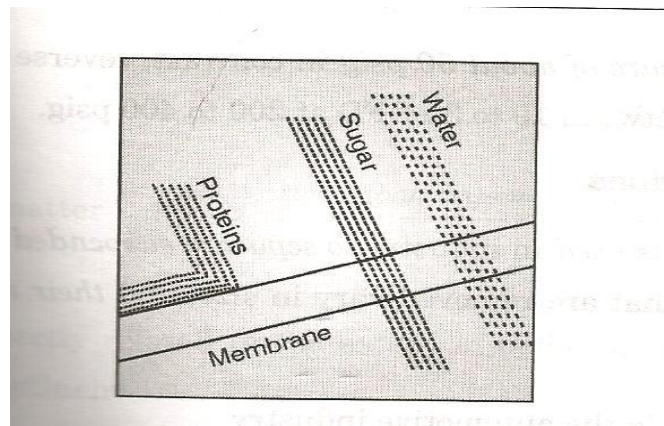
The pure water is forced out through the semi-permeable membrane, leaving behind the dissolved salts and other impurities. The membrane usually consists of very thin films of cellulose acetate, affixed on either side of a perforated tube.

Nowadays, membranes made of polymethylmethacrylate and polyimide polymers are being used.

Advantages of Reverse Osmosis Over Conventional Processes

- 1) Compared with other conventional water treatment process, reverse osmosis has proven to be the most efficient means of removing salts, chemical contaminants and heavy metals, such as lead from drinking water.
- 2) For waters with total dissolved solids of 200 or more, reverse osmosis is less expensive than ion exchange.
- 3) Compared with distillation, reverse osmosis use only a fraction of the total energy and does not have high temperature problems or scaling and corrosion.
- 4) Simple to operate and maintain.

Q13) Write a short note on 'Ultrafiltration'



Ans) Ultrafiltration, like reverse osmosis is a cross flow separation process. It consists of membranes with pore size in the range of 0.1 to 0.001 micron.

When pressure is applied on the feed, the feed water flows through the semi – permeable membrane depending upon their MWCO. [MWCO is the smallest molecular weight species for which membrane has more than 90% rejection].

The stream of liquid that comes through the membrane is called as **Permeate**. The other liquid stream is called as '**Concentrate**' and gets progressively concentrated in those species removed by the membrane.

In cross flow separation, therefore the membrane itself does not act as a collector of molecules but merely as a barrier to these species.

Ultrafiltration membranes will remove high molecular weight substances, colloidal materials, and organic and inorganic polymeric molecules.

Low molecular – weight organics and ion such as sodium, calcium , magnesium , chloride, and sulfate are not removed by UF membranes,

Because only high molecular weight species are removed , the osmotic pressure differential across the UF Membrane surface is negligible.

Low applied pressure are therefore sufficient to achieve high flux rates from an ultra -filtration membrane.

Flux is defined as ‘ The amount of permeate produced per unit area of membrane surface per unit time.

Generally flux is expressed as gallons per square foot per day (GFD) or as cubic meters per square meters per day ($M^3/M^2/Day$).

UF membranes can have extremely high fluxes but in most practical application the flux varies between 50 and 200 GED at an operating pressure of about 50 psi in contrast, reverse osmosis membranes only produce between 10 to 30 GFD at 200 to 400 psi.

Q14)Distinguish between Hard water and soft water

Hard water	Soft water
1) Water which does not immediately produces good amount of lather with soap is called as Hard water.	1)) Water which immediately produces good amount of lather with soap is called as Soft water.
2) It contains dissolved salts of calcium , magnesium and heavy metals. Eg. $CaCl_2$, $CaSO_4$, $MgCl_2$, $MgSO_4$, $Ca(HCO_3)_2$, $Mg(HCO_3)_2$, $FeSO_4$ etc	2) It does not contains dissolved salts of calcium, magnesium and other heavy metals. Eg. $CaCl_2$, $CaSO_4$, $MgCl_2$, $MgSO_4$, $Ca(HCO_3)_2$, $Mg(HCO_3)_2$, $FeSO_4$ etc
3) It forms a curd like insoluble milky white precipitate.	3) It does not forms a curd like insoluble milky white precipitate.
4) It is not suitable for both industrial and domestic use.	4) It is suitable for both industrial and domestic use.

Distinguish between Temporary Hardness and Permanent Hardness.

Temporary Hardness	Permanent Hardness
1)It is due to bicarbonates and carbonates of Ca^{2+} , Mg^{2+} etc	1)It is due to chlorides, sulphates ,nitrates of Ca^{2+} , Mg^{2+} , Fe^{2+} etc other than carbonates and bicarbonates.
2) It is known as carbonate or alkaline hardness.	2)It is known as non-carbonate or non alkaline hardness.
3)It leads to formation of loose deposits of carbonates and hydroxides of Ca^{2+} , Mg^{2+} respectively if used in boilers.	3) It leads to formation of adherent scales.
4) It can be removed by simple techniques such as boiling and filtering	4) It cannot be removed by simple techniques such as boiling and filtering.

Comparison BOD & COD

SR NO	BOD	COD
1)	It measures the oxygen demand of biodegradable pollutants only.	It measures the oxygen demand for biodegradable pollutants along with non – biodegradable pollutants
2)	Less stable measurement method as it uses microorganisms which are susceptible to pH, temperature and other variables in the water.	More stable measurement method as it uses potassium dichromate which oxidizes regardless of water conditions.
3)	Slow process. It takes five days.	Fast process. It takes 2-3 hours.
4)	BOD values are generally less than COD values.	COD values are generally greater than BOD values.
