

(Pattern 2019) In-sem.

Engineering Chemistry

UNIT -1 WATER TECHNOLOGY (Mark -15)

***Types of Impurities:**

1.Dissolved Impurities:

a) Inorganic salts **e.g. bicarbonates**, sulphates ,nitrates ,chlorides of calcium, Magnesium, Iron, Mn, Al etc

b)Gases- like carbon dioxide, nitrogen , oxygen, hydrogen sulphides

Removal Method: Mechanical deaerators & Chemical treatment

2. Suspended Impurities:

a) Clay

b) mud

c) Vegetable and animal matters

Removal Method: Filtration & Sedimentation / Settlement

3.Colloidal Impurities:

a) fine size like silica and alumina, organic wastes etc.

- These are soluble materials, other than gases
- cannot be removed by conventional filters
- referred as TDS which stands for total dissolved solids.

Removal Method : Coagulation followed by Filtration & Sedimentation

4.Bacterial Impurities:

a) Bacteria, Germs, Pathogens, Microbes, Viruses, Parasites includes - algae, beneficial bacteria that decompose wastes harmful bacteria such as those that cause cholera.

Removal Method : Filtration followed by Sterilization

***Hardness of water:**

Hardness character to water, is due to presence of dissolved salts of heavy metals like Ca^{++} , Mg^{++} , Fe^{++} , Mn^{++} , Al^{+3} .

- If carbonate, bicarbonate, sulphate, nitrate and chloride salts of bivalent cations such as Mg^{++} , Fe^{2+} , Mn^{2+} , Ca^{2+} are present in water, then the hardness of water is high as

compared to that due to presence of salts of monovalent cations such as K^+ and Na^+ , Li^+ (light metal) .

1)Soft water-Water that gives **lather with soap easily and readily** is called Soft water.

OR Water which **produce lather /foam with soap solution ,but does not develops curd/scum** is called as hard water.

2)Hard water- Hard water **forms scum when it comes in contact with water**.

OR Water which **does not produce lather /foam with soap solution, but develops curd/scum** is called as hard water.

***UNIT Of Hardness of water:**

$CaCO_3$ eq. for any salt = Mass of any salt x 50/Eq. wt of any salt

- **Miligram per liter (mg / lit):** Number of milligram of $CaCO_3$ present in 1 lit of water.

1 ppm = 1 part of $CaCO_3$ equivalent/ 10^6 parts of water.

- **Parts Per Milion (ppm):** Number of parts by wt of $CaCO_3$ present in million parts by wt of water.

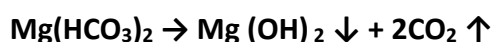
1 ppm = 1 mg/lit.

***Types of Hardness of water:**

1) Temporary Or Carbonate Hardness/Alkaline Hardness : Water that contains bicarbonate of calcium and magnesium or of both salts of heavy metals is called as Temporary Or Carbonate Hardness.

e.g Salts such as $Ca(HCO_3)_2$, $Mg(HCO_3)_2$, $MgCO_3$, $FeCO_3$.

- Removed by boiling



2)Permanent /Non- Carbonate Hardness/Non-Alkaline Hardness: Water due to dissolved salts present in water like chlorides or sulphate& nitrates of calcium or magnesium ,Fe,Mn, Al (heavy metal) is called as **Permanent /Non- Carbonate Hardness**

- e .g Salts such as $CaCl_2$, $MgSO_4$, $MgCl_2$, $CaSO_4$, $Ca(NO_3)_2$, $Mg(NO_3)_2$
- It can not be removed by boiling.



***Determination of Water Hardness By EDTA Method (Complexometric Titration):**

Theory:

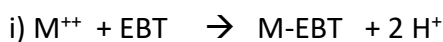
1. **Na₂EDTA:** Na₂EDTA is highly sensitive towards heavy metal ions in water and easily reacts with heavy metal .
2. **pH =10 :** During reaction of disodium EDTA & heavy metal in water H⁺ ions are formed & decrease the pH of reaction mixture, hence a buffer solution of pH =10 is necessary and to avoid reversible reaction .
3. **Complexometric titration:** Reaction of disodium EDTA & heavy metal ion ,results in the formation of cyclic co-ordination complex (chelate) ,hence the titration is known as complexometric titration.
4. **EBT:** EBT act as indicators for the EDTA titrations.

Principle

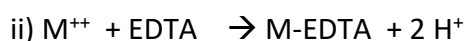
The hardness causing ions like Ca⁺⁺, Mg⁺⁺ presents in water form stable chelate complexes with disodium EDTA ,at suitable pH, and indicators give sharp end point.

- At endpoint EBT–M ion complex breaks, and EDTA forms complex with released M ion. EBT is set free giving blue color.

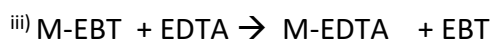
• **Reaction :**



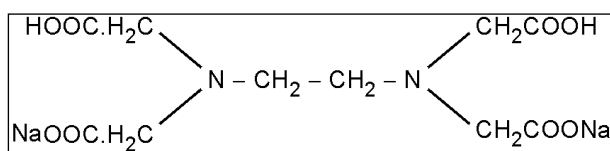
pink red/wine red (unstable complex)

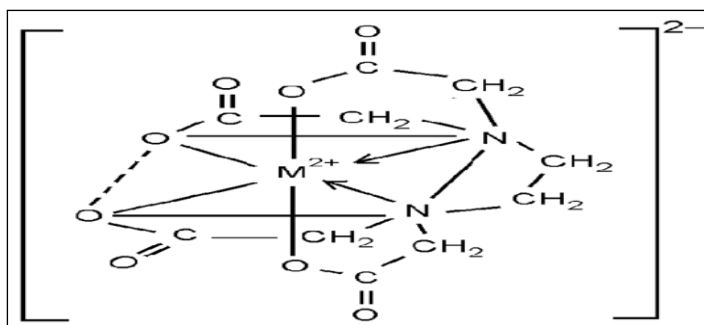


colorless (stable complex)



colorless sky blue





M-EDTA complex / chelate

Procedure:

Part I: Standardization of Na₂EDTA Vs MgSO₄

- 25 ml SHW + 10 ml buffer (pH 10) + 2–3 drops EBT indicator –wine red color – titrated against Na₂EDTA solution till sky blue.

Solution in Burette: Na₂EDTA solution.

Solution in pipette: 25 ml MgSO₄ solution

Indicator: 2–3 drops EBT

Conical flask: Above 25 ml hard water + 10 ml buffer (pH 10) + 2–3 drops EBT

End Point: wine red to sky blue

Burette Burette reading: 'X' ml or V1 ml

Part II: Total hardness of sample water Vs Na₂EDTA

- 50 ml Sample Hard Water + 10 ml buffer (pH 10) + 2–3 drops EBT indicator –wine red color –titrated against Na₂EDTA solution till sky blue.
- **Solution in Burette:** Na₂EDTA solution.
- **Solution in pipette:** 50 ml hard water
- **Indicator:** 2–3 drops EBT
- **Conical flask:** Above 25 ml hard water + 10 ml buffer (pH 10) + 2–3 drops EBT
- **End Point:** wine red to sky blue
- **Burette Burette reading:** 'y' ml

Calculation:

- I) Standardization of EDTA:

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

$$M_1V_1 = M_2V_2$$

- II) Total Hardness of water:

$$\text{Hardness of water} = y \times Z \times 100 \times 1000 / V \text{ ppm CaCO}_3 \text{ equivalent}$$

(Note: whole equation is multiplied by 1000 so as to convert in to ppm or mg/l)

***Alkalinity of water sample**

Alkalinity is defined as the capacity of a water to neutralize an acid.

-A natural water may be alkaline due to presence of hydroxides, bicarbonates, and carbonates compounds dissolved in water.

1)Hydroxides – NH_4OH , $\text{Ca}(\text{OH})_2$,

2)Bicarbonates- $\text{Ca}(\text{HCO}_3)_2$, $\text{Mg}(\text{HCO}_3)_2$, $\text{Fe}(\text{HCO}_3)_2$,

3) Carbonates- Mg CO_3 , Fe CO_3

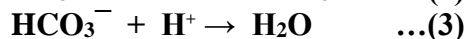
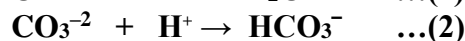
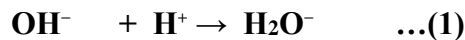
- Hydroxides, carbonates and bicarbonates estimated by titration against std acid HCl.

-In most natural and treated waters, alkalinity is imparted to the water by the carbonate system.

Theory: Alkaline water Vs HCl

- 1) All OH^- and $\frac{1}{2}$ of CO_3^{-2} gets neutralized first , Indicated by phenolphthalein (P), pink to colorless .pH of mixture decreases to about **8.7**.
- 2) Remaining $\frac{1}{2}$ of CO_3^{-2} (now present as HCO_3^-) & complete HCO_3^- (present in sample water) is neutralized on further titration -Indicated by methyl orange (M), yellow to orange at about **pH 4**.

• Reaction :



Types and Amount of alkalinities

- a) Only OH^-
- b) Only CO_3^{-2}
- c) Only HCO_3^-
- d) Any two ions: OH^- & CO_3^{-2}
- e) CO_3^{-2} & HCO_3^- ,

OH^- & HCO_3^- do not co-exist. ,they react & form $\text{H}_2\text{O} + \text{CO}_3^{-2}$



Endpoint	Alkalinity		
P & M	OH^-	CO_3^{-2}	HCO_3^-
$P = 0$	—	—	M
$P = M$	M	—	—
$P = \frac{1}{2} M$	—	M	—
$P > \frac{1}{2} M$	$2P - M$	$2(M - P)$	—
$P < \frac{1}{2} M$	—	$2P$	$M - 2P$

Procedure:

Part I: Phenolphthalein end point

- 10 ml of water sample + 1–2 drops phenolphthalein. All OH^- and $\frac{1}{2}$ of CO_3^{-2} gets neutralized.
- Solution in Burette: HCl solution.
- Solution in pipette: 10 ml hard water
- **Indicator:** 2–3 drops Phenolphthalein
 - **Conical flask:** Above 10 ml hard water+2–3 drops Phenolphthalein
 - **End Point:** pink to colorless
 - **Burette Burette reading:** 'V1' or P ml

Part II: Methyl Orange end point

- Part I Solution + 2 drops of methyl orange indicator ,If yellow solution, then continue to titrate. If orange solution, then end pt is reached. End point indicates complete neutralization of HCO_3^- which are already present in water & which are produced due to half neutralization of carbonates. End point of titration (part II) = V2 or 'M' ml
- **Calculation:**
1 ml 1N acid solution \equiv 50 mg of CaCO_3 equivalent

P Alkalinity

P Alkalinity: $(50 \times P \times N_1 \times 1000 / V)$ ppm of CaCO_3 equivalent

OR P Alkalinity = $V_1 \times Z \times 50 \times 1000 / V$ of CaCO_3 equivalent

M Alkalinity

M Alkalinity: $(50 \times M \times N_1 \times 1000 / 25)$ ppm of CaCO_3 equivalent

OR M Alkalinity = $V_2 \times Z \times 50 \times 1000 / V$ of CaCO_3 equivalent

***III effects of hard water in boiler**

- A) Caustic embrittlement**
- B) Boiler corrosion**
- C) Scale and sludge**
- D) Priming and foaming**

A) Caustic embrittlement

Definition :

- It is the **fast corrosion of boiler caused by alkaline condition of water**, during steam generation, especially high-pressure steam boilers.

Phenomenon:

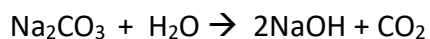
- Boiler material becomes brittle due to accumulation of caustic substances.

Caustic embrittlement Caused due to Factors

- 1) High tensile stress in the metal.
- 2) Leakages in the joints.
- 3) Presence of NaOH in boiler feed water.

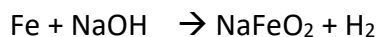
Causes of Caustic embrittlement

- Water softened by soda lime may contain unreacted quantity of Na_2CO_3 (caustic soda).
- Evaporation of water in boiler, conc. of sodium carbonate (Na_2CO_3) increase & undergo hydrolysis to form sodium hydroxide (NaOH) at high temp.



(Highly alkaline)

- NaOH penetrates in minor cracks on inner surface of boiler by capillary action.
- Boiler metal becomes weak & brittle due to caustic alkali.
- Water evaporates as result, caustic soda attacks the surrounding area, thereby dissolving iron of boiler into sodium ferrite.



(sodium ferrite)

Disadvantages of Caustic embrittlement

- 1) Embrittlement of boiler parts particularly at **stressed parts like bends, joints, rivets &** may lead to failure of boiler.

2) Two types of cells are formed

i) **Galvanic cells:** stressed parts-anode ,Un-stressed parts –cathode i.e Anode gets corroded

ii) **Concentration cell:** Higher conc. of NaOH in minor cracks stressed parts –anode , lower conc. of NaOH parts- cathode

Prevention of caustic embrittlement

1)Use of sodium phosphate instead of sodium carbonate.

2) Use of sodium sulphate.

3) Add tannin and lignin to fill crack.

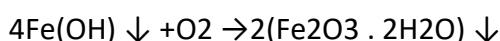
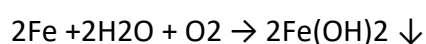
4)Adjust the pH between 8-9 range.

B) Boiler corrosion

Corrosion of boiler takes place by chemical or electro chemical reaction.

i) Due to dissolved oxygen :

- Water usually contains about 8ml. of dissolved oxygen per litre at room temperature. Dissolved oxygen in water in the presence of prevailing high temperature, attack the boiler materials.

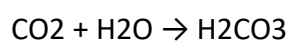


Removal of oxygen /Prevention :

1. Adding calculated quantity of Na_2SO_3 , (Sodium sulphite), hydrazine (N_2H_4) or sodium sulphide (Na_2S).
2. Mechanical de-aeration.

(ii) Due to dissolved carbon dioxide

The produced carbon dioxide reacts with water to give carbonic acid



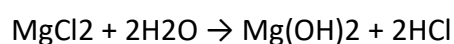
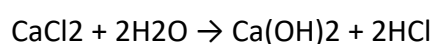
which has slow corrosive effect.

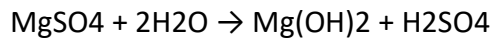
Removal of carbon dioxide /Prevention :

1. By adding NH_3 (ammonia).
2. Mechanical de-aeration.

(iii) Due to acids from dissolved salt/Hydrolysis of salts

- Water containing dissolved magnesium salts liberates acid on hydrolysis





- The liberated acid produces corrosion effect.

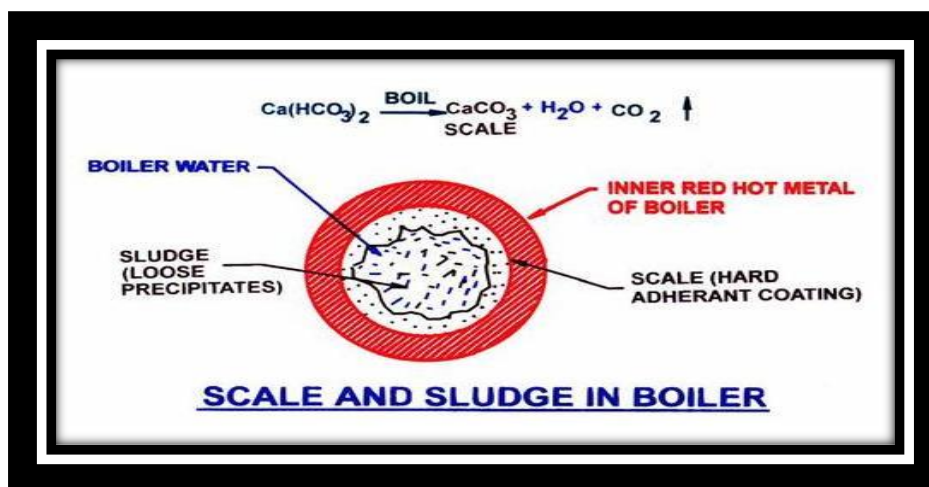
Removal Hydrolysis of salts/ Prevention :

- By keeping pH value 8 to 9.
- Boiler water should not contain salts of weak base -strong acid.

C) Scale and sludge

Defn: Scale is **hard & strong coating formed inside boiler tube** & difficult to remove.

- It is **bad conductor** of heat.



Formation of Scale :

1)**Decomposition of bicarbonate:** At high temp. bicarbonate decompose into sticky water insoluble material.



2) **Hydrolysis of Mg salt:** At high temp



3)**Presence of Silica:** Silica in the form of colloidal particles deposit as Ca ,Mg silicates.

4)**Decreased solubility of CaSO₄:** CaSO₄ lesser solubility (insoluble) at high temp. CaSO₄ will precipitate as hard scale.

Scale is composed of CaCO₃ , Mg (OH)₂ , silica , CaSO₄ Solids fused together as coat.

DISADVANTAGES OF SCALES :

- 1)WASTAGE OF FUEL:** Scale is bad conductor of heat & reduction of heat transfer to the boiler.
- 2)OVER HEATING OF BOILER:** It reduce transfer of heat from boiler to boiler water ,need to overheat the boiler.
- 3) BOILER SAFTEY DECREASES:** Excess heating causes boiler metal to become soft & weak. Reduce life of boiler & increase the maintenance of boiler.
- 4) DANGER OF EXPLOSION:** Scale cracks due to uneven expansion ,the water comes suddenly in contact with overheated boiler metal & causes large amount of steam formation suddenly & sudden high pressure ,boiler metal may burst with explosion.

Removal of Scales

1. Use suitable chemicals (internal treatment) **like EDTA, Sodium phosphate ,Calgon etc.**
2. Use **scraper or wire brush for thin scales .**
3. By **hammer & chisel**
4. **Thermal shocks** technique.
5. By blow down operation.

Prevention of Scales

1. Use softened water.
2. Use scrapper hammer & chisel .
3. By adding organic chemicals like tannin,lignin
4. Adding sodium phosphate to water
5. Adding sodium aluminate ,which trap the scale forming particles.

Sludge

Defn: If ppt. is loose, soft & slimy & does not stick permanently to the boiler is called sludge.

Formation :

- It is normally formed where **flow rate of water is lower than other part of boiler.**
- Formed at **cooler portions** of boiler parts like **edges, bends, valves, near bending of pipe.**

Disadvantages of sludge

1. Wastage of some heat .

2. May choke up the boiler pipe.
3. Reduce water flow rate in boiler

Prevention of sludge

- 1) Use of water containing very low total dissolved solids.
- 2) Use of pretreated water.
- 3) By frequent blow down operation.

Comparison between sludge and scale

Sludge	Scale
Loose slimy deposit.	Hard coating.
Easily removed.	Difficult to remove.
Formed at cooler part of boiler where flow rate is low.	Formed at hotter part of boiler.
Heat transfer is slightly affected.	Heat transfer is greatly affected.
It leads to Choke the pipe.	It leads to bulging or bursting or explosion of pipe
Formed due to increase in salt concentration	Formed due to increase in concentration of silicates, Magnesium hydroxide, calcium sulphate.

D) Priming and foaming

Priming : When the steam formation is rapid ,some water droplets are also carried along with the steam. This ‘ wet steam’ formation process is called priming

Causes of Priming

1. Presence of excessive foam
2. Faulty boiler design
3. High speed of steam generation
4. High steam velocity

Disadvantages of Priming

1. Salt deposit on machine parts thereby decrease life of machinery.
2. It also causes corrosion.

Prevention

1. Use of softened & filtered water
2. Use steam purifier
3. Rapid changes in steam rate should be avoided
4. Maintain low water level.

Foaming: : Formation of continuous foam or bubbles on the surface of water. Priming & foaming occur usually together

Causes of Foaming

1. High concentration of dissolved salts in boiler feed water
2. Presence of oil droplets & alkali
3. Presence of finely dispersed suspended materials
4. Violent agitation of boiler water.

Disadvantages of Foaming

1. Difficult to maintain the constant pressure of steam in the presence of foaming.
2. Actual height of water level can't be judged well.
3. Foaming causes wet steam formation.

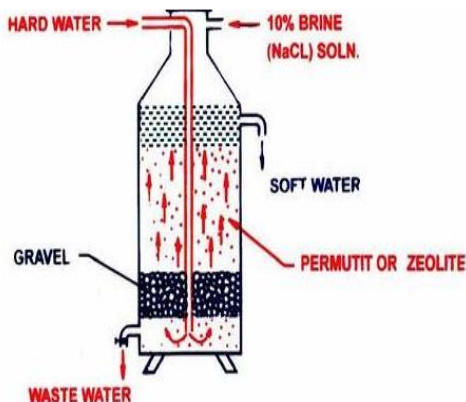
Prevention

1. Adding antifoaming agents like alcohol, castor oil.
2. Use blow down operation.
3. Removing oil from water by adding sodium aluminate

1) Zeolite/Permutit method of water softening

Principle- sodium zeolite has the property of exchanging metal ions from water with loosely held Na^+ ions in zeolite

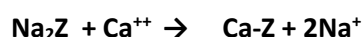
The chemical formula for permutit is $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot x\text{SiO}_2 \cdot y\text{H}_2\text{O}$. In short it is written as Na_2Z .



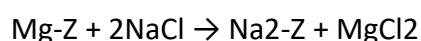
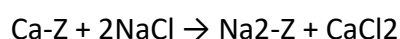
PERMUTIT'S PROCESS OF SOFTENING OF HARD WATER

Process-

1. Plant consists of steel tank containing a thick layer of sodium zeolite. The tank is also the inlet for passing the brine.
2. Raw water is introduced through an inlet. When it passes through a layer of zeolite, equilibrium is formed between sodium ions from zeolite & cations present in the water, then cations from hard water taken by zeolite & eq. amount of Na ions are released in exchange.

Reaction:**Regeneration**

When permutit is completely converted into calcium & magnesium permutit & it ceases to soften the water. It gets exhausted. At this stage, the supply of hard water is stopped & the exhausted permutit is regenerated by treating the bed with Conc. 10% NaCl solution.

**Advantages**

- Hardness can be completely removed
- 2. Easy operation. No experts required
- 3. Less time and sludge
- 4. Small area requires

Disadvantages

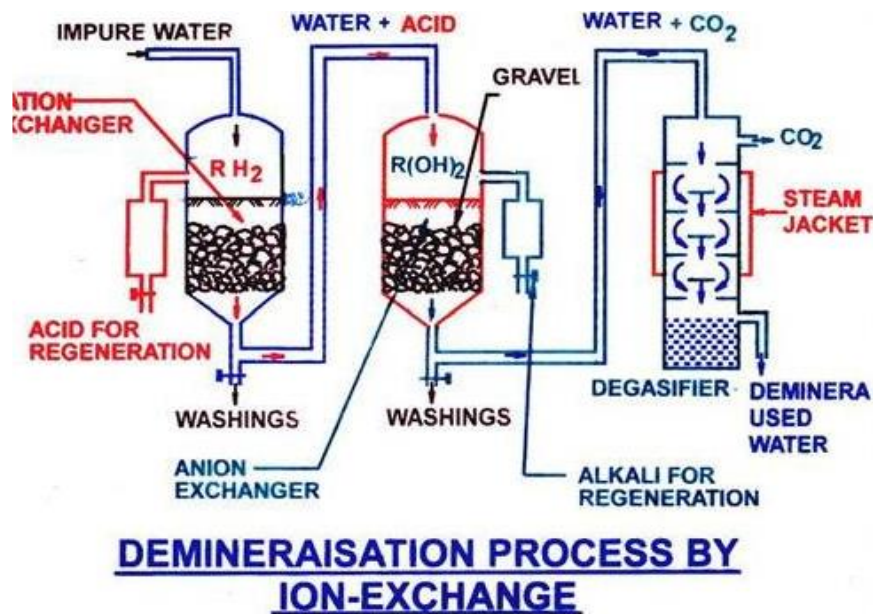
- Only Ca^+ and Mg^+ ions can be removed
- 2. Large amount of Na ions present in treated water.
- 3. Water should be free from suspended impurities to prevent clogging on Zeolite beds.

2) Ion exchange/demineralization/Deionisation process

Principle: When water containing cations & anions, is passed through the resins, cation exchanger resin captures all cations (in exchange of H^+) & anion exchanger resin captures all anions (in exchange of OH^-), to give pure & all ions free water.

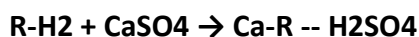
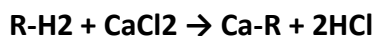
A) cation exchanger resin $-\text{RH}_2$

B) anion exchanger resin $-\text{R}'(\text{OH})_2$

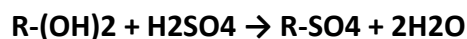
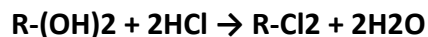


Process

1. In the process two columns, one consist of cation exchange resin & another consist of anion exchange resin are used.
2. The hard water is first allowed to pass through a column containing cation exchange resins. Which remove all the cations like Ca^{+2} , Mg^{+2} etc. and release H^+ ion.
3. Reaction in first column takes place as under.



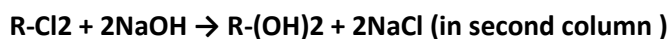
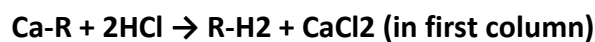
4. The anions like chloride & sulphates are converted into acid like HCl & H_2SO_4 . Which is passed through another column containing anion exchanger i.e. R(OH)_2 resin where the following reaction takes place.



5. Water thus obtained is free from all cations and anions & is called soft water or distilled water.

Regeneration:

- When both resins get fully exhausted then they are regenerated. The cation resin is regenerated by passing dilute acid solution (in first column). While anion resin is regenerated by passing dilute NaOH solution (in second column), followed by washing with water.



- The regenerated acidic and basic resins are again reused for softening of hard water.

Advantages

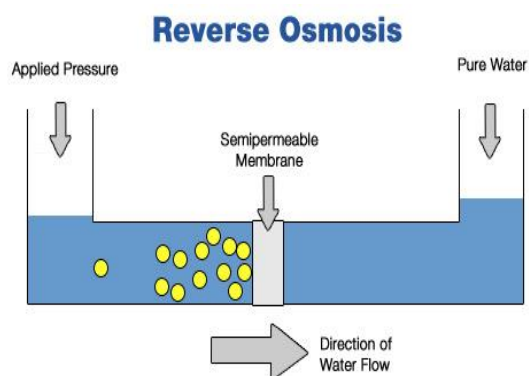
1. Water of zero hardness & no ionic impurities
2. Gaseous impurities like CO_2 , O_2 expelled ,to get water of 'Distilled water standard'.
3. Equipment occupies small space.
4. Easy to operate.
5. Self adjusts with water of any hardness.

Limitations

- 1 . Initial high investment.
- 2.Only for small scale purification of water

REVERSE OSMOSIS

Principle /Definition: The reversal of solvent flow, from higher concentration solution to lower conc. solution through a semipermeable membrane ,by applying an external pressure slightly higher than osmotic pressure of higher conc. solution ,is known as reverse osmosis



Construction

1. In the RO, we applying an external pressure slightly higher than osmotic pressure of higher conc. solution than osmotic pressure.
2. The flow of solvent takes place in reverse direction.

Method

1. Sea water /polluted /ionic pollutants is filled in RO cell.
2. A pressure of 200psi is applied on it to force solvent to pass through SPM.

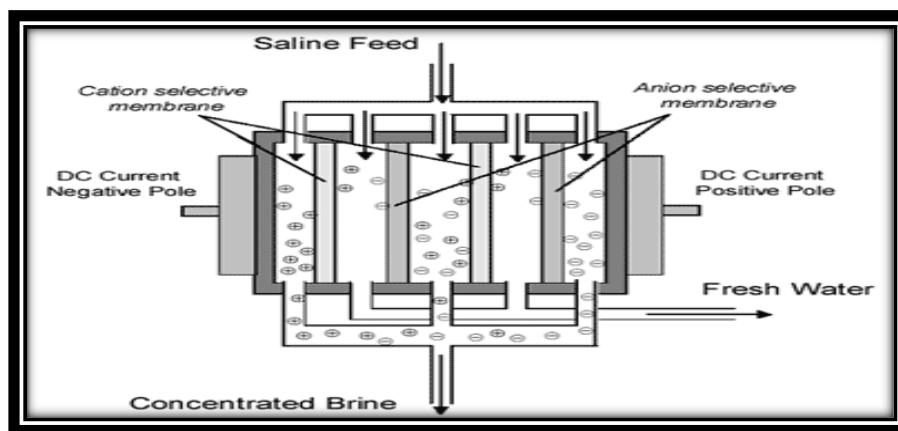
3. SPM has such porosity that it allows only small molecules of water.
4. Treated water comes out from the bottom outlet.
5. Thus, in RO we separate water from its contaminants rather than contaminants from water .

Advantages

1. RO removes all ionic ,colloidal, non-ionic impurities from water.
2. Simple to operate
3. Low cost
4. SPM is specially prepared such that it allows limited quntuty of salts to pass thr.it along with water .
5. RO technique is used to obtain drinking mineral water

Electrodialysis

Principle /Definition: Process of removing dissolved ionic impurities (salts, ionic dyes) from water by using membrane & electric field, is known as electrodialysis



CONSTRUCTION

1. Electrodialysis cell consist of a large number of paired sets of plastic membranes
2. Membranes are ion selective i) Cation selective membrane will allow only cations to pass through it , which repel anions & do not allow to go through.ii) Anion selective membrane will allow only anions to pass through it , which repel cations & do not allow to go through.
3. When electric field applied ,the cations get attracted towards cathode electrode & pass though cation selective membrane in the neighboring compartment.
4. Similarly ,anions get attracted towards anode electrode & pass though anion selective membrane in the neighboring compartment.

5. Result will be alternate compartments with salts rich water and neighboring compartment with pure water.

Applications

1. Removal of ionic pollutants (toxic salts , ionic dyes).
2. Removal of salts from sea water ,to get pure water.
3. Removal of limited quantity of salts from sea water to get drinking water.
4. Salts rich water used to recover salts.

Limitations

1. Does not remove dissolved organic matter.
2. Does not remove colloidal impurities.
3. Membrane replacement is costly

(Note : Numerical on Hardness, Alkalinity and Zeolite)

Numerical on Hardness

1) 25 ml of water sample required 8.8 ml of 0.01M EDTA to reach the end point. 25ml of the same water sample after boiling & filtration required 6.5 ml of same EDTA solution to reach the end point. Calculate total & permanent hardness of the water sample.

- $V = \text{Vol. of water sample titrated} = 25 \text{ ml}$
 $Z = \text{Molarity of EDTA solution} = 0.01M$
 $y = \text{Vol. of EDTA (Burette reading)} = 8.8 \text{ ml}$

Step- I : Total Hardness $= y \times Z \times 100 \times 1000 / V \text{ ppm CaCO}_3 \text{ eq.}$
 $= 8.8 \times 0.01 \times 100 \times 1000 / 25$
 $= \mathbf{352 \text{ ppm CaCO}_3 \text{ eq.}}$

Step- II : Permanent Hardness (after boiling & filtration)

$V = \text{Vol. of water sample titrated} = 25 \text{ ml}$
 $Z = \text{Molarity of EDTA solution} = 0.01M$
 $y = \text{Vol. of EDTA (Burette reading)} = 6.5 \text{ ml}$
 $= y \times Z \times 100 \times 1000 / V \text{ ppm CaCO}_3 \text{ eq.}$
 $= 6.5 \times 0.01 \times 100 \times 1000 / 25$
 $= \mathbf{260 \text{ ppm CaCO}_3 \text{ eq.}}$

Numerical on Zeolite

c) The hardness of water sample 50000 litres of water sample was removed by passing it through a zeolite bed. The zeolite bed then required 200 liters of NaCl solution containing 100g/liter of NaCl for regeneration. Calculate the hardness of water sample.(3M)

- Given: Hard water = 50000 lit., Vol.of NaCl solution = 200 lit., gm/lit of NaCl = 100g/lit

Step-I mg of NaCl = gm/lit x Vol. of NaCl x 1000

$$= 100 \times 200 \times 1000$$

$$= 2 \times 10^7 \text{ mg NaCl}$$

Step-II Quantity of NaCl in terms of CaCO₃ (y)

$$= \text{mg NaCl} \times 50 / 58.5 = 2 \times 10^7 \times 50 / 58.5$$

$$= 1.7094 \times 10^7 \text{ mg CaCO}_3$$

$$\text{OR} = 170940107.1 \text{ mg CaCO}_3$$

Step-III Hardness

$$\text{Hardness of water} \times \text{Litre of water} = y$$

$$\text{Hardness of water} = y / \text{Litre of water}$$

$$= 1.7094 \times 10^7 / 50000$$

$$= 341.88 \text{ ppm CaCO}_3 \text{ eq}$$

