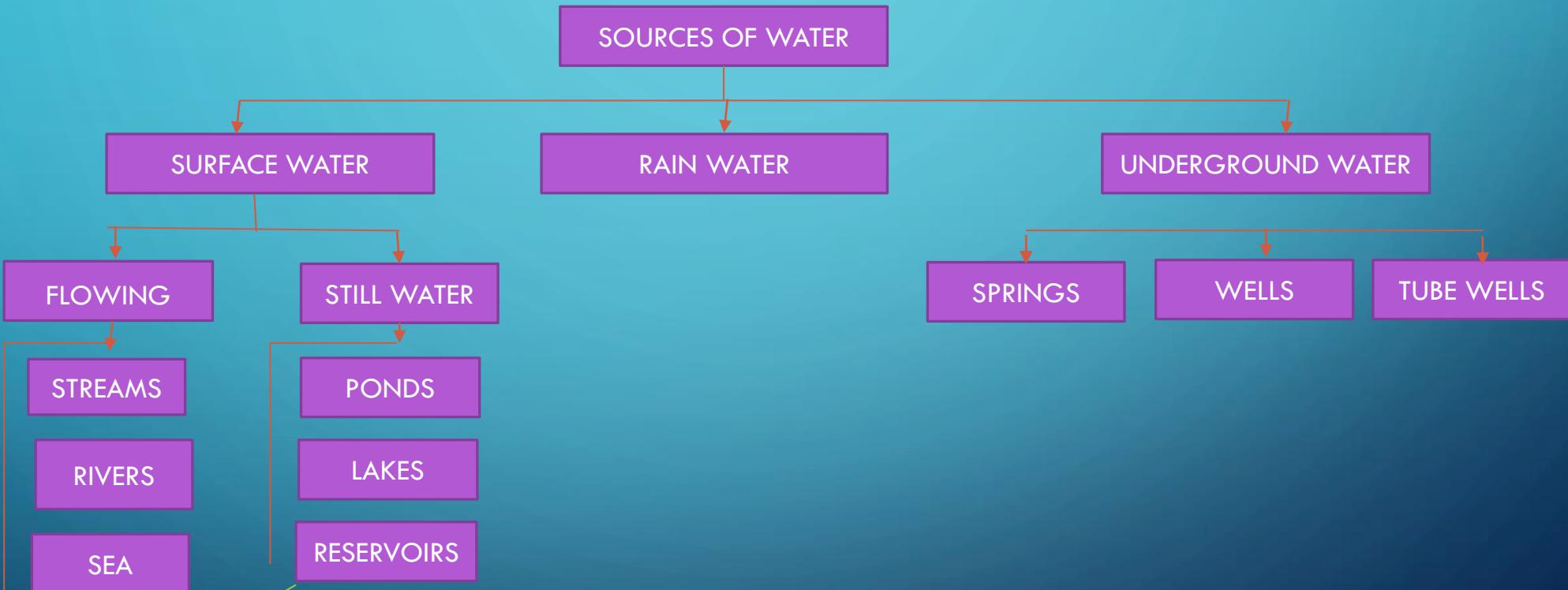




# WATER

AN ESSENTIAL INGREDIENT OF LIFE

# SOURCES OF WATER



# IMPURITIES IN WATER

- Dissolved Impurities : Carbonates, Bicarbonates, Sulphates and Chlorides of Calcium, Magnesium, Iron, Sodium and Potassium
- Dissolved Gases :  $\text{CO}_2$ ,  $\text{O}_2$ ,  $\text{N}_2$ ,  $\text{H}_2\text{S}$ ,  $\text{NH}_3$  etc
- Suspended Impurities : Inorganic – sand, clay
  - Organic – Vegetable and animal matter
- Colloidal Impurities : Finely divided silica and clay, organic waste products etc
- Micro Organisms : Bacteria, Algae , Fungi , Virus etc.

# SPECIFICATIONS FOR INDUSTRIAL WATER

The quality of water required for industries depends upon the requirement of a particular industry.

S No.	Purpose	Specifications of water	Remarks
1.	Boiler Feed Water	Very soft, Nitrate and organic compounds should be less and least amount of dissolved salts	Hard water forms scales on the wall of boiler, dissolved salts may choke pipes and may produce alkalinity.
2.	Cooling systems	Free from growth of algae, fungi etc. least amount of dissolved gases	The spray nozzles or circulating pipes may clogged
3.	Alcoholic Distillaries	Should be very pure, free from pathogenic bacteria, should not be alkaline	Should confirm to the standards of drinking water
4.	Laundries	Should be as soft as possible, free from Fe and Mn	Fe and Mn may cause stains
5.	Textiles	Should be soft and free from Fe and Mn	May cause stains

<b>6.</b>	<b>Sugar Industries</b>	<b>Free from pathogenic bacteria , free from sulphates, carbonates and nitrates</b>	<b>Sugar obtained is deliquescent</b>
<b>7.</b>	<b>Pharmaceutical Industries</b>	<b>Very pure free from any pathogenic bacteria and very soft water</b>	<b>Salts present in hard water may react with the chemicals to form undesirable substances.</b>
<b>8.</b>	<b>Confectionaries</b>	<b>Very soft, colourless, odour less and free from pathogenic bacteria</b>	

# ANALYSIS OF WATER

- HARDNESS OF WATER : Soap consuming capacity of water.
- The water which does not form lather with soap .
- Cause of Hardness : Presence of salts of Calcium and Magnesium
  - $2C_{17}H_{35}COONa + CaSO_4 \rightarrow (C_{17}H_{35}COO)_2Ca + Na_2SO_4$
  - $2C_{17}H_{35}COONa + MgCl_2 \rightarrow (C_{17}H_{35}COO)_2Mg + 2NaCl$

# **TYPES OF HARDNESS**



1. Can be removed by boiling
2. Due to presence of Bicarbonates of  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$
- 3.



4. Also called Carbonate Hardness

5. Can also be removed by addition of Lime



can not be removed by boiling  
Due to presence of Sulphates and Chlorides of  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$   
can be removed by special means

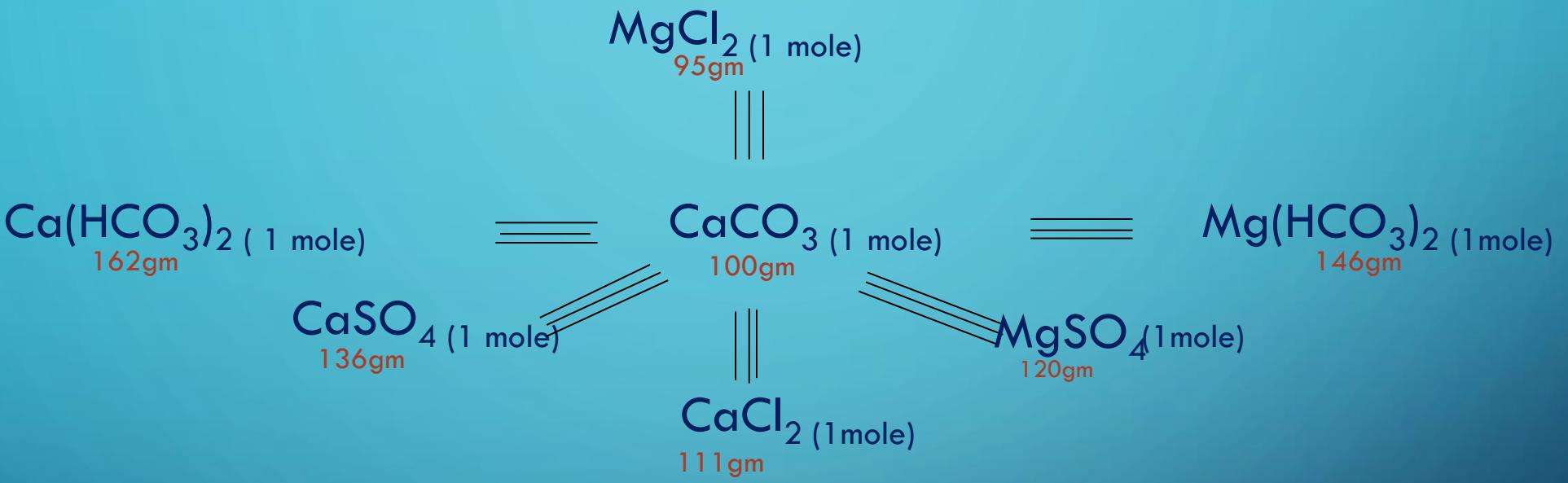
Non Carbonate Hardness

By special means

# CALCIUM CARBONATE EQUIVALENTS

- Hardness is expressed in terms of calcium carbonate equivalents.
- The reasons are:
- Molecular weight of  $\text{CaCO}_3$  is 100 which makes the calculations easier.
- It is considered as most insoluble in water.
- 
- Calcium Carbonate Equivalent = 
$$\frac{\text{Equivalent weight of CaCO}_3}{\text{Equivalent weight of substance}} \times \text{Mass of the Substance}$$

• =



# MULTIPLICATION FACTOR

# MULTIPLICATION FACTOR

Salt	Molar Mass	Multiplication factor
$\text{Ca}(\text{HCO}_3)_2$	162	100/162
$\text{Mg}(\text{HCO}_3)_2$	146	100/146
$\text{CaCl}_2$	111	100/111
$\text{MgCl}_2$	95	100/95
$\text{CaSO}_4$	136	100/136
$\text{MgSO}_4$	120	100/120
$\text{CaCO}_3$	100	100/100

<b>Salt</b>	<b>Molar Mass</b>	<b>Multiplication Factor</b>
$\text{Al}_2(\text{SO}_4)_3$	342	100/114
$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$	278	100/278
$\text{NaAlO}_2$	82	100/82 X2
$\text{HCO}_3^-$	61	100/61 X 2
$\text{CO}_3^{2-}$	60	100/60
$\text{OH}^-$	17	100/17 X2
$\text{H}^+$	1	100/1 X 2

# UNITS OF HARDNESS

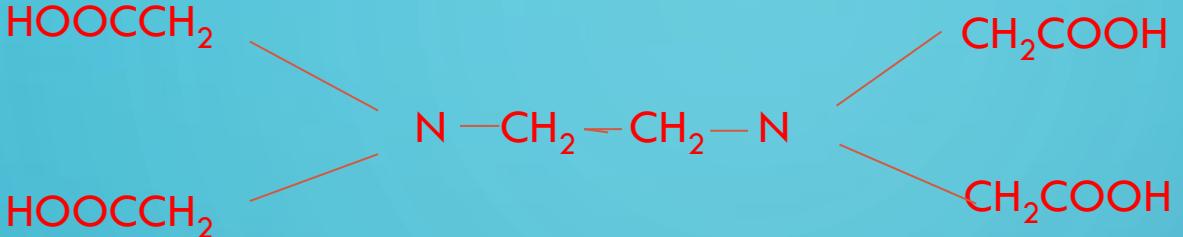
- Parts per Million (ppm): The hardness present in  $10^6$  part of water.
- Milligrams per Litre (mg/l): Hardness in milligrams present in one litre of water.
- Degree Clarke's ( $^{\circ}\text{Cl}$ ): Hardness present in 70000 parts of water.
- Degree French ( $^{\circ}\text{Fr}$ ): Hardness present in  $10^5$  parts of water.
- $1\text{ppm} = 1\text{mg/l} = 0.1\ ^{\circ}\text{Fr} = 0.07^{\circ}\text{Cl}$
- Hardness is in terms of calcium carbonate equivalents

# DETERMINATION OF HARDNESS – EDTA METHOD

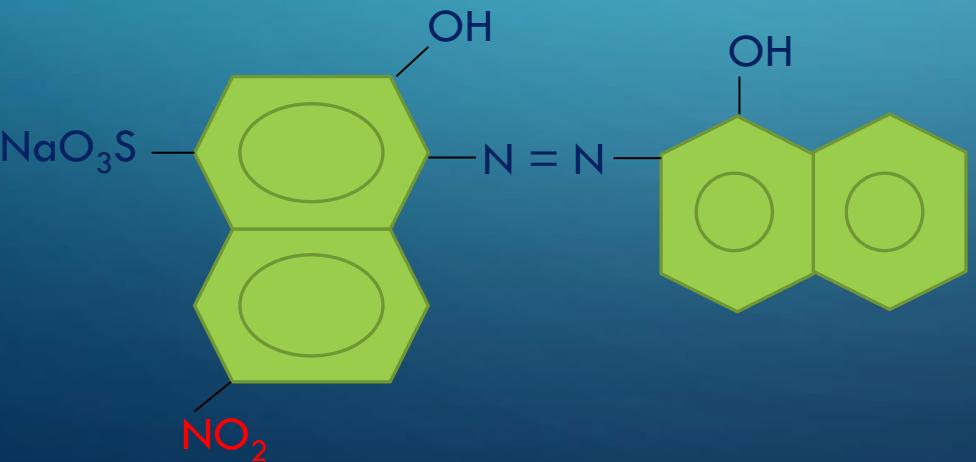
- This is an example of Complexometric titration.
- Indicator used is EBT.
- Buffer solution is added to maintain the pH of the solution.
- EDTA is hexadentate ligand.
- It is pH sensitive.
- It forms 1:1 complex with calcium or magnesium ions.
- EBT is an azo Dye.

# PRINCIPLE OF EDTA METHOD

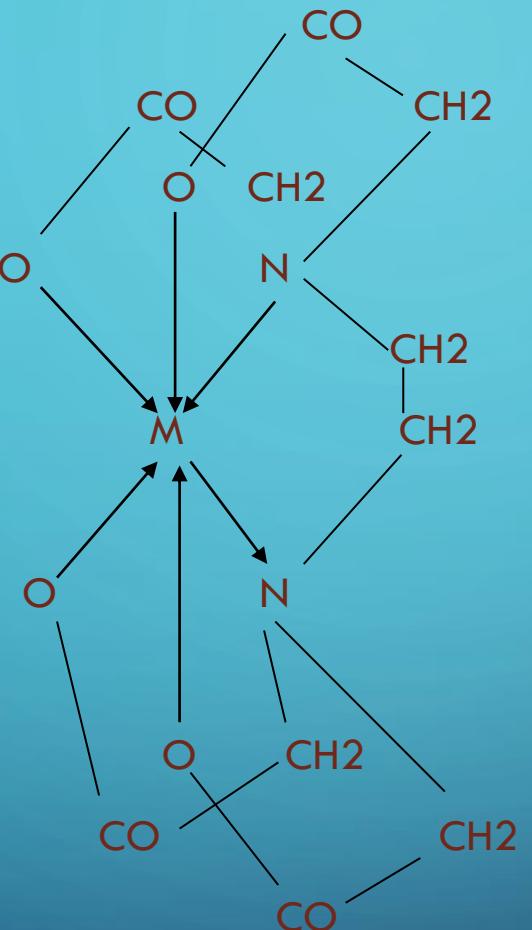
- ETHYLENE DIAMINE TETRA ACETIC ACID

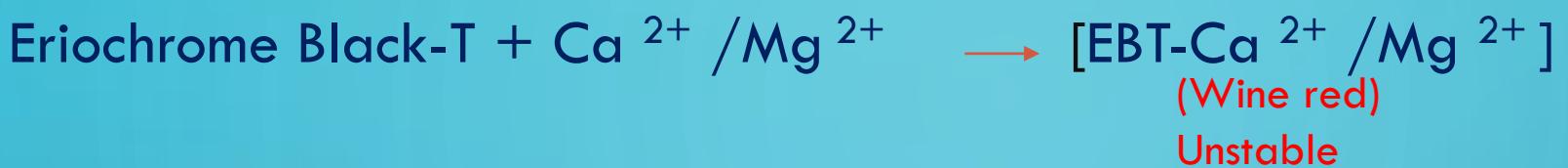


- ERIOCHROME BLACK T



## 1:1 COMPLEX OF EDTA WITH METAL ION





## EXPERIMENTAL PROCEDURE

- Preparation of solutions:
- Standard hard water: 1mg of  $\text{CaCO}_3$  / ml (0.01 M)(SHW)
- EDTA Solution: 3.7 gm / liter ( 0.01M)
- EBT: 0.5gm /500ml of alcohol
- Buffer solution: 70 gm  $\text{NH}_4\text{Cl}$  + 570ml conc.  $\text{NH}_3$  and the solution is diluted to 1 litre.

## PROCEDURE

Pipette out 50 ml of standard hard water(SHW)

Add buffer solution

Add 2-3 drops of EBT

Wine red colour is obtained

Titrate with EDTA

Wine red colour is changed to Blue

Another titrations are done in same manner with Water sample(shw) and boiled sample (bhw)

# STEPS TO PERFORM THE TITRATION

## Standardisation of EDTA

Titration with standard hard water

50 ml SHW + buffer + EBT

Add EDTA, Vol of EDTA= V1ml

1ml SHW contains = 1mg of CaCO<sub>3</sub>

50 ml SHW contain= 50mg

V1ml of EDTA is used for =50mg CaCO<sub>3</sub>

1ml EDTA is used for =  $50/V1\text{mg}$

Strength of EDTA =  $50/V1$

## TOTAL HARDNESS

with sample hard water

50ml shw + buffer+ EBT

Vol. of EDTA= V2ml

1ml EDTA consumes =  $50/V1\text{mg}$

V2 ml will consume =  $50/V1 \times V2$

50 ml shw contain =  $50/V1 \times V2\text{mg}$

1000ml will contain=

$$\frac{50 \times V2 \times 1000}{V1 \times 50}$$

Total Hardness =  $V2/V1 \times 1000$

## PERMANENT HARDNESS

with boiled sample

50ml bhw + buffer + EBT = wine red

Vol. of EDTA= V3ml

1ml EDTA consumes =  $50/V1\text{mg}$

V3 ml will consume =  $50/V1 \times V3$

50ml bhw contain =  $50/V1 \times V3\text{mg}$

$$1000\text{ml will contain} = \frac{50 \times V3 \times 1000}{V1 \times 50}$$

Permanent Hardness =  $V3/V1 \times 1000$

## CALCULATIONS :

1. Strength of standard hard water
2. Standardisation of EDTA
3. Calculation for Total hardness
4. Calculation for Permanent Hardness
5. Total – Permanent hardness = Temporary hardness

## NUMERICALS :

- 0.28 g of  $\text{CaCO}_3$  was dissolved in HCl and the solution was made to one litre with distilled water. 100ml of the above solution required 28ml of EDTA solution on titration. 100 ml of the hard water sample required 33 ml of the same EDTA solution on titration. After boiling 100ml of this water, cooling, filtering and then titration required 10ml of EDTA solution. Calculate the temporary and permanent hardness of water.
- Calculate the hardness of water sample ,whose 10 ml required 20 ml of EDTA.  
20 ml of  $\text{CaCl}_2$  solution, whose strength is 1.5 g of  $\text{CaCO}_3$  per liter required 30 ml of EDTA.

- Strength of Standard hard water = 0.28 g /l
- 100 ml of this contain =  $.28 \times 100 \text{ mg} = 28 \text{ mg} / 100 \text{ ml}$
- 28 ml of EDTA is used for = 28 mg of  $\text{CaCO}_3^{-2}$
- 1ml is used for  $= 28/28 = 1 \text{ mg/ml}$
- 1ml is used for = 1mg
- 33 ml EDTA is used for =  $1 \times 33 = 33 \text{ mg}$
- 100 ml of sample contains = 33mg of  $\text{CaCO}_3^{-2}$
- 1000 ml of sample contain =  $33 / 100 \times 1000 = 330 \text{ ppm}$
- 10 ml EDTA is used for =  $1 \times 10 = 10 \text{ mg of } \text{CaCO}_3^{-2}$
- 100 ml bhw contain = 10 mg  $\text{CaCO}_3^{-2}$
- 1000ml will contain =  $10 / 100 \times 1000 = 100 \text{ ppm}$
- Temporary Hardness =  $330 - 100 = 230 \text{ ppm}$

# ALKALINITY OF WATER

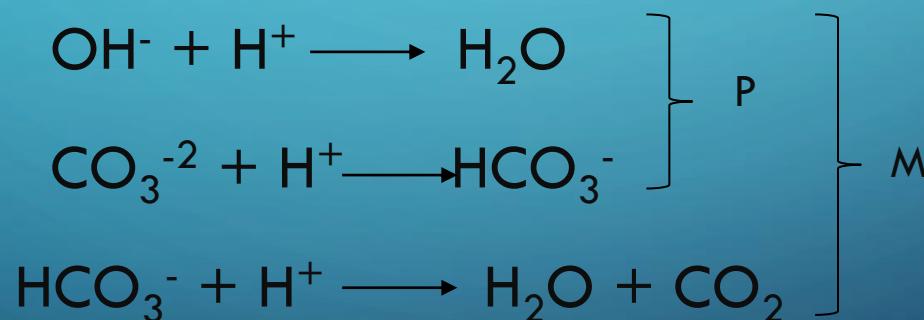
The ability of water to neutralize acids

# CAUSES OF ALKALINITY

- Presence of  $\text{CO}_3^{2-}$
- $\text{HCO}_3^-$
- $\text{OH}^-$
- All the three cannot present together because
$$\text{OH}^- + \text{HCO}_3^- \longrightarrow \text{CO}_3^{2-} + \text{H}_2\text{O}$$
- Borates
- Silicates and
- Phosphates

# DETERMINATION OF ALKALINITY

- By Acid Base Titration
- Using Phenolphthaein and Methyl Orange as indicators
- Principle of Selective use of indicators is applied



- Phenolphthalein indicates the complete neutralisation of  $\text{OH}^-$  ions and Half Neutralisation of  $\text{CO}_3^{2-}$  ions
- Methyl Orange indicates the neutralization of all the three ions. Thus we can determine the Alkalinity due to different ions. This use of indicators is called selective use of indicators
- **Procedure:**
  1. Pipette out known amount of water sample in a conical flask.
  2. Add 2-3 drops of phenolphthalein.
  3. If Pink colour is appeared titrate it with standard acid till pink colour just disappears.
  4. Note the readings of burette.
  5. Now add few drops of Methyl Orange. A yellow colour will appear.
  6. Titrate it against the same acid till red colour is appeared.

- NORMALITY OF ACID = N/50
- VOLUME OF SAMPLE WATER = 100ML
- VOLUME OF ACID USED TILL PH. END POINT =  $V_2$
- VOLUME OF ACID USED UPTO METHYL ORANGE END POINT =  $V_2'$   
OR TOTAL VOLUME OF ACID USED

# Calculations

- $N_1 V_1 = N_2 V_2$
- Water sample                                  acid
- $N_1 = N_2 V_2 / V_1$
- $= (N/50 \times V_2) / 100$
- $P = N_1 \times 50 \text{ g/l}$
- $= (N_1 \times 50) \times 1000 \text{ mg/l or ppm}$
- $= (V_2/5000) \times 50 \times 1000$
- $= 10V_2$
- 
- 

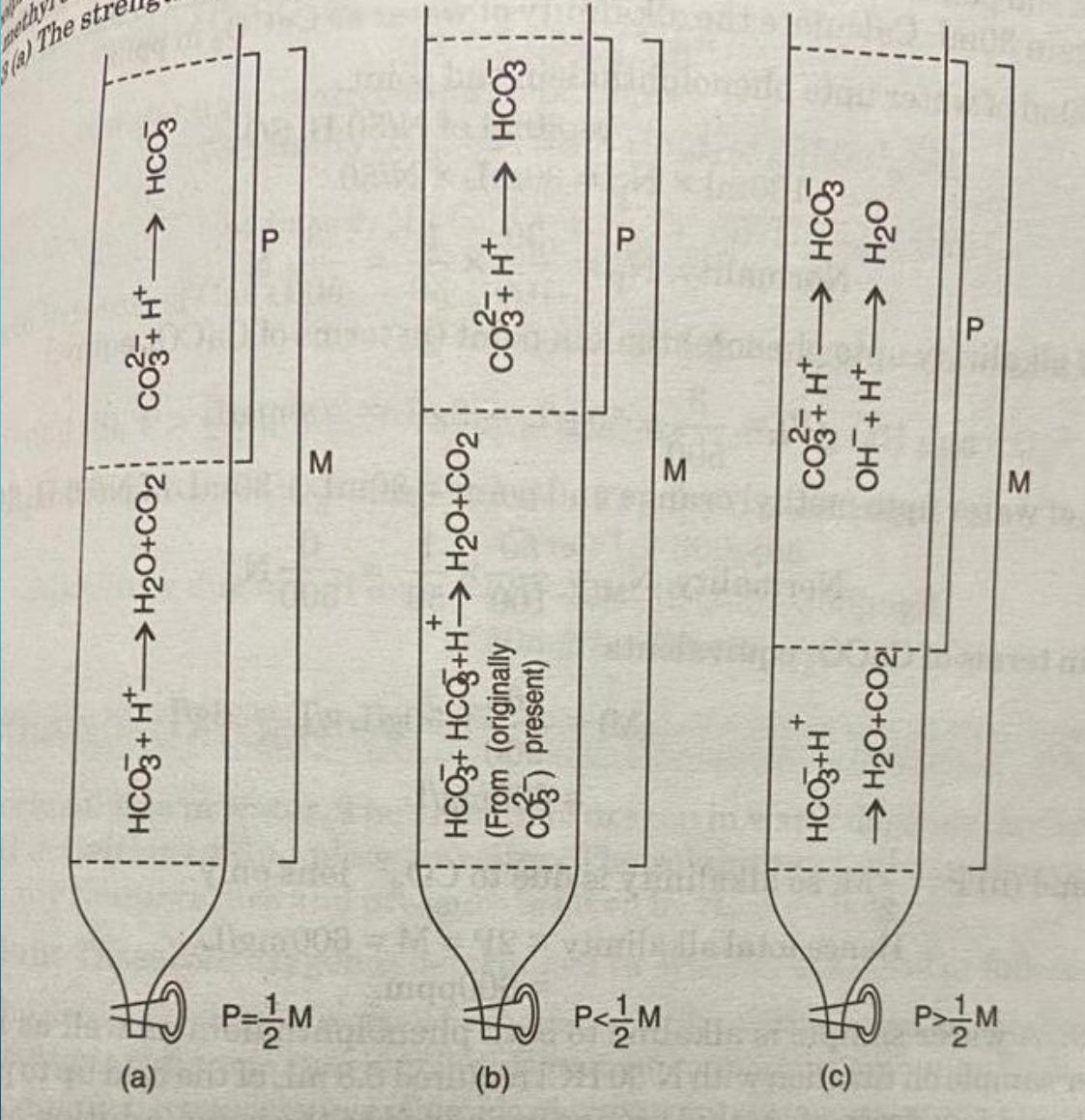
$$\begin{aligned} N_1' V_1' &= N_2' V_2' \\ \text{Water Sample} &\quad \text{Acid} \\ N_1' &= N_2' V_2' / V_1' \\ &= (N/50 \times V'_2) / 100 \\ M &= N_1' \times 50 \text{ g/l} \\ &= (V'_2 / 5000) \times 50 \times 1000 \text{ mg/l} \\ &= 10 V'_2 \end{aligned}$$

V<sub>2'</sub> is the volume of total acid used.

# TYPES OF ALKALINITY

	$\text{OH}^-$	$\text{CO}_3^{2-}$	$\text{HCO}_3^-$
$P=0$	-	-	$P$
$P = 1/2M$	-	$2P$	-
$P < 1/2M$	-	$2P$	$M-2P$
$P > 1/2M$	$2P - M$	$2(M-P)$	-
$P = M$	$P$	-	-

*Colloquium  
methyl orange  
(a) The strength of  $\text{CO}_3^{2-}$*



# BOILER FEED WATER

- Water used in Boilers is called Boiler feed water.
- A boiler is a closed vessel, in which water under pressure is transformed into steam by the application of heat.
- Steam is used to drive turbine.
- Boiler feed water should have very low hardness
- Its alkalinity should be very low

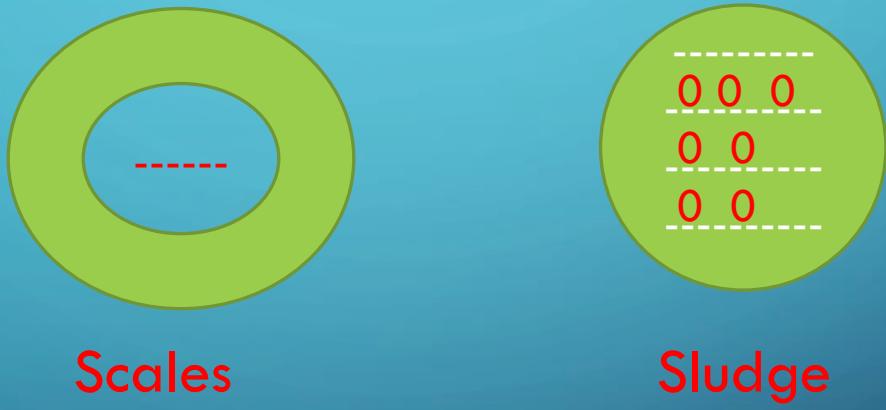
# BOILER PROBLEMS

- Scale and Sludge formation
- Boiler Corrosion
- Caustic Embrittlement
- Priming and Foaming

# SCALE AND SLUDGE FORMATION

- CAUSES:
- Dissolved Salts – When water is converted into steam, the concentration of salt increases with time. When IONIC PRODUCT > SOLUBILITY PRODUCT precipitates are formed. These ppts may stick to the walls or they may exist as loose ppt in the solution.
- The loose ppt is known as sludge and the ppt that sticks on the walls is known as Scales.

**CONT.**



# CAUSTIC EMBRITTLEMENT

## **Caustic embrittlement :**

It is the phenomenon in which the material of a boiler becomes brittle due to the accumulation of caustic substances.

- Sodium carbonate is used in softening of water by lime soda process, due to this some sodium carbonate maybe left behind in the water.



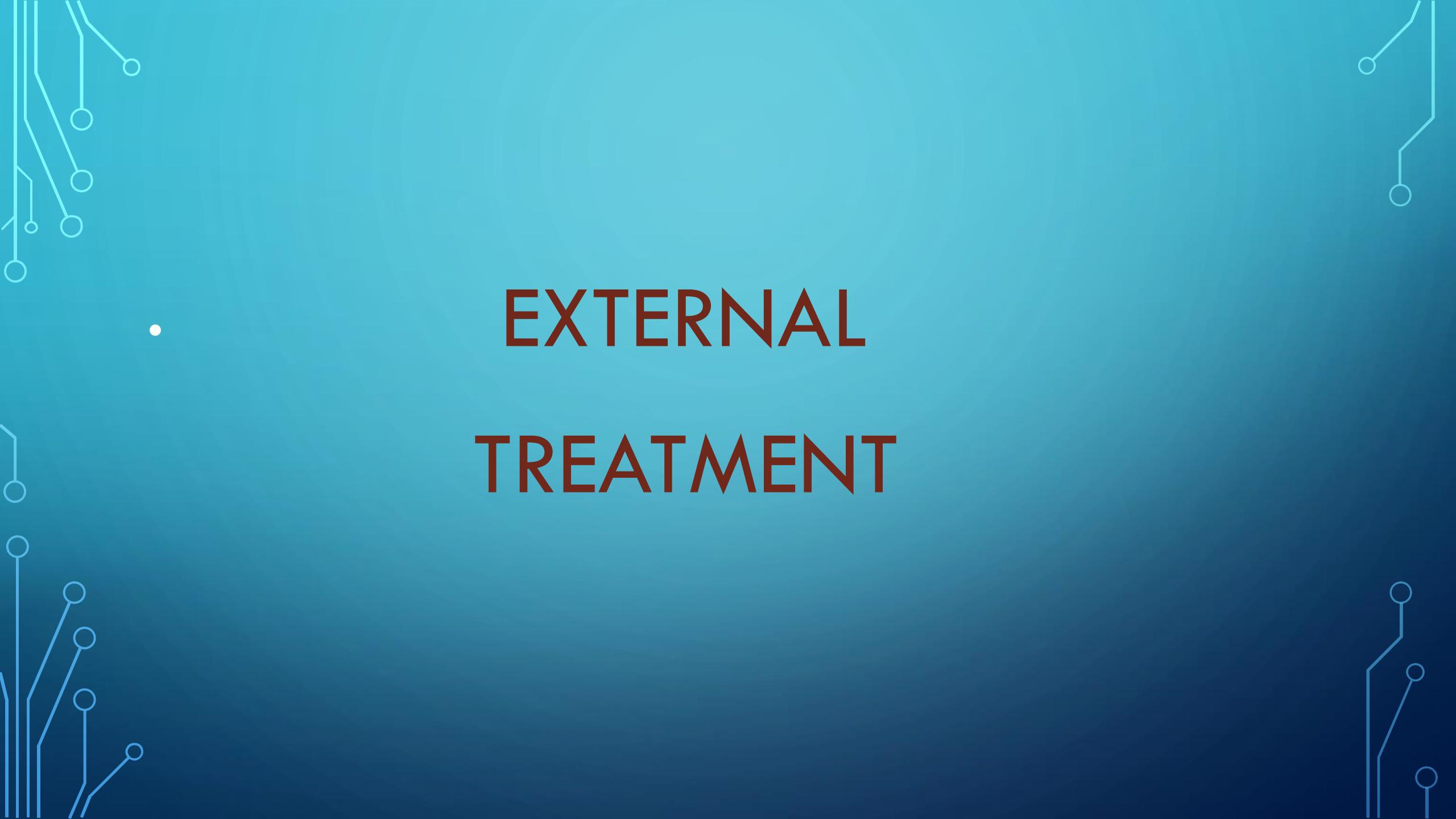
- As Conc. of NaOH increases, water flows into minute hair cracks.
- Water get evaporated and NaOH increases further and react with iron of boiler, hence cause Embrittlement.

## **Prevention:**

1. Addition of sodium sulphate or sodium phosphate. Which will block hair-cracks.
2. Addition of tannin and lignin- blocks the cracks.
3. Excess of  $\text{Na}_2\text{SO}_4$  is avoided else it will form  $\text{CaSO}_4$

## INTERNAL TREATMENT

- Colloidal Conditioning – Tannin, Agar, Kerosene etc are added
- Carbonate Conditioning – Sodium Carbonate is added
- Phosphate Conditioning – In high pressure boilers ,Sodium Phosphates are added
- Calgon Conditioning – Calgon ( Sodium Hexametaphosphate) is added



# EXTERNAL TREATMENT

# WATER SOFTENING PROCESSES

- LIME – SODA PROCESS
- ZEOLITE PROCESS
- ION EXCHANGE PROCESS

## LIME - SODA PROCESS

- Principle:
- Dissolved impurities are converted into precipitates by adding calculated amount of Lime and Soda to water.
- Some Coagulants are added to settle down the ppt of impurities.
- Carried out either hot or cold.

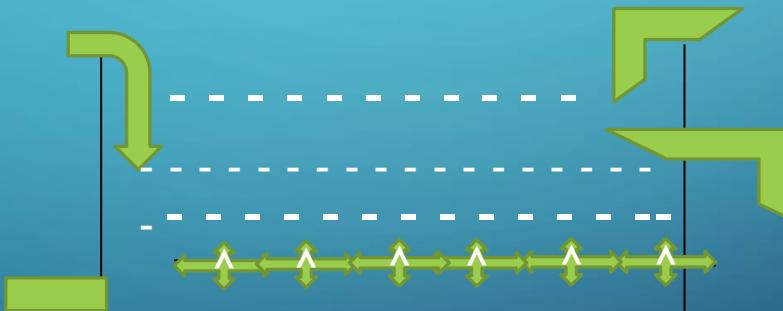
## SOME IMPORTANT POINTS

- Lime addition removes complete temporary hardness and permanent Magnesium hardness.
- Soda addition removes permanent Calcium hardness.
- $\text{NaAlO}_2$  does not react with lime or soda but with water it gives  $\text{Al}_2(\text{OH})_3$ ,  $\text{NaOH}$ .
- $\text{Ca}^{+2}$  and  $\text{Mg}^{+2}$  ions are considered as permanent hardness
- $\text{HCO}_3^-$  IONS ARE CONSIDERED AS  $\text{NaHCO}_3$

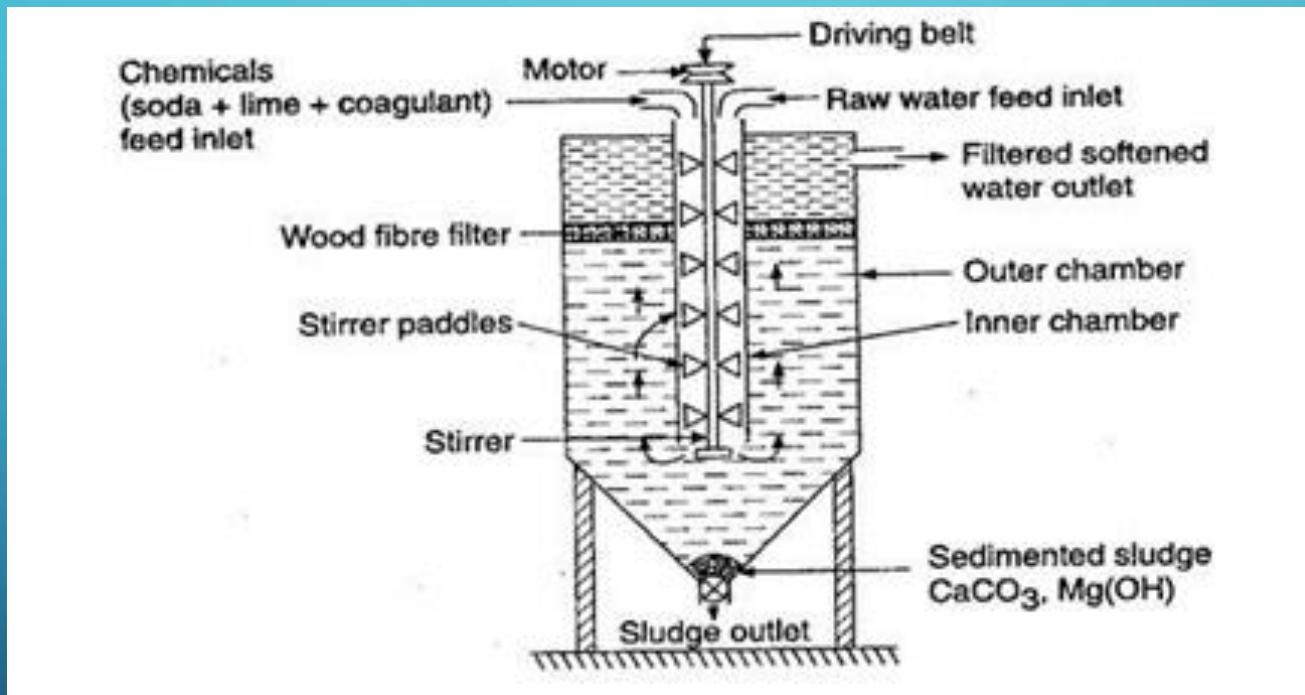
# TYPES OF LIME SODA PROCESS

- TWO TYPES:
- Hot Lime Soda process
  - Batch Process
  - Continuous Process
- Cold Lime Soda process
  - Batch Process
  - Continuous Process

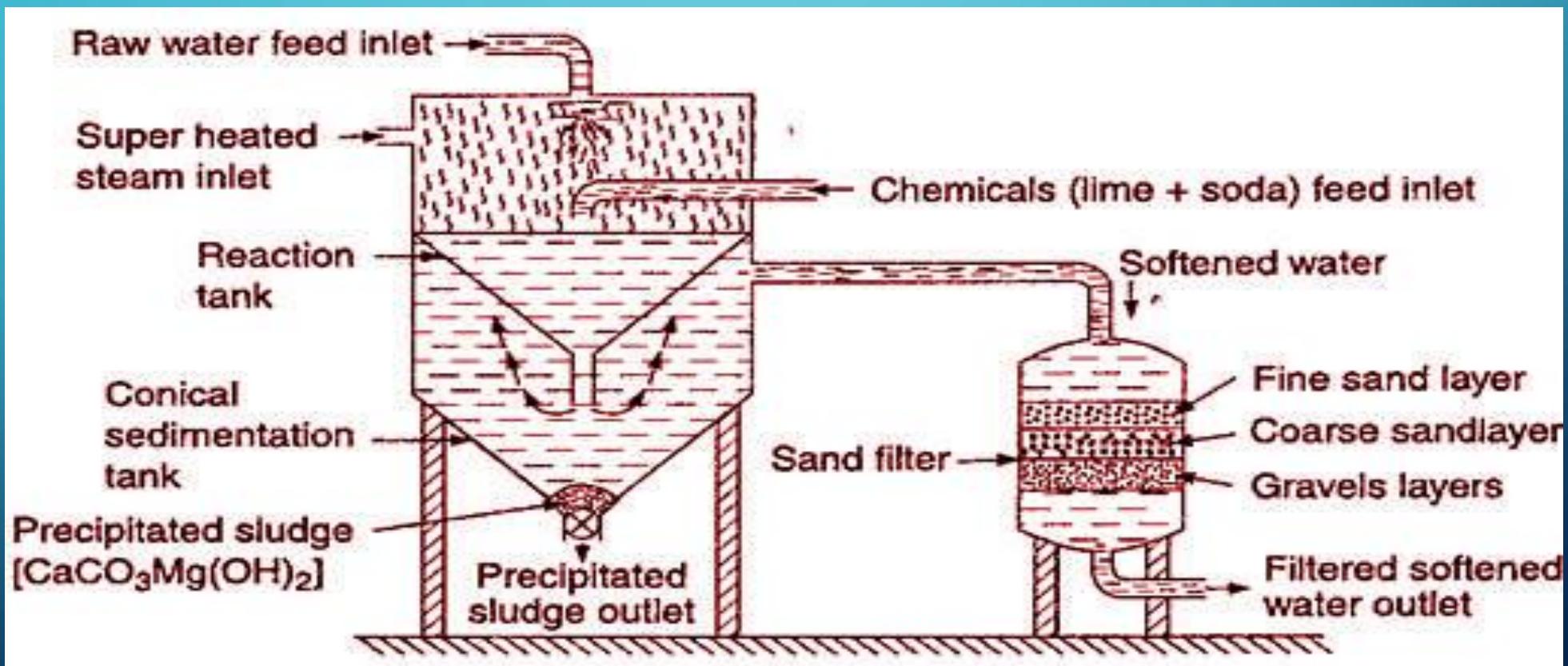
# BATCH PROCESS



# COLD LIME SODA PROCESS



# HOT LIME SODA PROCESS



# CHEMICAL REACTIONS





• Reactions with Soda:



# CALCULATIONS

- Lime Requirement =  $\frac{74}{100}$  [2x Temp. Mg + Temp. Ca + Perm. Mg + Salts of Fe & Al + CO<sub>2</sub> + Acids + HCO<sub>3</sub><sup>-</sup> - NaAlO<sub>2</sub> All in terms of CaCO<sub>3</sub> equi.]
- Soda Requirement =  $\frac{106}{100}$  [ Perm. Ca + Perm. Mg + Salts of Fe & Al + HCl + H<sub>2</sub>SO<sub>4</sub> – HCO<sub>3</sub><sup>-</sup> All in terms of CaCO<sub>3</sub> equi.]

## ANALYSIS OF TREATED WATER

- Since the treated water is shown to contain  $\text{OH}^-$  and  $\text{CO}_3^{2-}$  ions.
- These are formed by  $\text{Ca}(\text{OH})_2$  and  $\text{Na}_2\text{CO}_3$  respectively.
- During calculations the corresponding amount of these should be added
- If  $\text{OH}^-$  is there the equivalent amount should be added in lime as well as in soda requirement.
- In case of  $\text{CO}_3^{2-}$ , the equivalent amount is to be added in soda requirement.

## ADVANTAGES OF HOT LIME SODA PROCESS

- The reaction time is reduced.
- No coagulant is required
- Most of dissolved gases are removed
- Residual hardness is much less than cold process

## ADVANTAGES OF LIME – SODA PROCESS

- The process is highly economical.
- The treatment leads to an increase in the pH value of water , thus reducing the corrosion of the distribution pipes.
- This treatment also helps in reducing the total mineral content of water.
- It helps in removing iron and manganese from the water, although to a very small extent.

## DISADVANTAGES OF LIME-SODA PROCESS

- A large quantity of sludge is formed in this process, the disposal of which poses a problem .
- Careful operation and skilled supervision is required to get good results.
- This process cannot produce water having zero hardness. This is because  $\text{CaCO}_3$ , though very slightly, is soluble in water.

## NUMERICALS

- 1. Calculate the amount of lime and soda required for softening 50000 litres of water containing:  $\text{Ca}(\text{HCO}_3)_2 = 9.2\text{mg}$ ,  $\text{Mg}(\text{HCO}_3)_2 = 7.9\text{mg}$ ,  $\text{CaSO}_4 = 15.3\text{mg}$ ,  $\text{MgSO}_4 = 15 \text{ mg}$ ,  $\text{MgCl}_2 = 3 \text{ mg}$ , and  $\text{NaCl} = 4.3\text{mg}$ .
- 2. Calculate the amount of lime and soda required per litre for softening of water containing:  $\text{Ca}^{+2} = 80\text{ppm}$ ,  $\text{Mg}^{+2} = 32\text{ppm}$ ,  $\text{HCO}_3^- = 195\text{PPM}$ ,  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$  added as coagulant = 73.5ppm

<b>Constituents</b>	<b>Amount (mg)</b>	<b>Multiplication factor</b>	<b>CaCO<sub>3</sub> equivalents</b>
Ca(HCO <sub>3</sub> ) <sub>2</sub> (L)	9.2	100/162	5.68
Mg(HCO <sub>3</sub> ) <sub>2</sub> (2L)	7.9	100/146	5.41
CaSO <sub>4</sub> (S)	15.3	100/136	11.25
MgSO <sub>4</sub> (L+S)	15.0	100/120	12.5
MgCl <sub>2</sub> (L+S)	3.0	100/95	3.16
NaCl --	4.3	--	

- $L = 74/100 \times [ Ca(HCO_3)_2 + (Mg(HCO_3)_2 \times 2 + MgCl_2 + MgSO_4]$
- $= 74/100 [5.68 + 2 \times 5.41 + 3.16 + 12.5 ] \text{ per litre}$
- $= 23.39 \text{ mg/l} \times 50000 = 1170 \text{ g} = 1.17 \text{ kg}$

- $S = 106/100 [ CaSO_4 + MgSO_4 + MgCl_2 ]$
- $= 106/100 [ 11.25 + 12.5 + 3.16 ] \times 50000$
- $= 1.426 \text{ kg}$

- 3. Calculate the amount of lime(92%pure) and soda(98%pure) required for softening of 30000 litres of water , whose analysis is as follows:  $\text{Ca}(\text{HCO}_3)_2 = 40.5\text{ppm}$ ,  $\text{Mg}(\text{HCO}_3)_2 = 36.5\text{ppm}$  ,  $\text{MgSO}_4 = 30\text{ppm}$ ,  $\text{CaSO}_4 = 34\text{ppm}$ ,  $\text{CaCl}_2 = 27.75\text{ppm}$ ,  $\text{NaCl} = 10 \text{ ppm}$ .
- 4. Calculate the amount of lime and soda required for softening of 100000 litres of water using 139ppm of  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$  as a coagulant . The results of analysis of raw water and softened water are as follows:
  - Analysis of raw water:  $\text{Ca}^{+2} = 160\text{ppm}$ ,  $\text{Mg}^{+2} = 288\text{ppm}$ ,  $\text{HCO}_3^- = 1464\text{ppm}$ , dissolved  $\text{CO}_2 = 20\text{ppm}$
  - Analysis of treated water:  $\text{OH}^- = 34\text{ppm}$ ,  $\text{CO}_3^{2-} = 60\text{ppm}$

Constituents	Amount ppm	Multiplication factor	CaCO <sub>3</sub> equivalents
FeSO <sub>4</sub> .7H <sub>2</sub> O (L+S)	139	100/278	50
Ca+2 (S)	160	100/40	400
Mg+2 (L+S)	288	100/24	1200
CO <sub>2</sub> (L)	22	100/44	50
HCO <sub>3</sub> - (L-S)	1464	100/122	1200
OH <sup>-</sup> (L+ S)	34	100/34	100
CO <sub>3</sub> <sup>-2</sup> (S)	60	100/60	100

- 

$$L = 74/100 [ \text{FeSO}_4 + \text{Mg}^{+2} + \text{CO}_2 + \text{HCO}_3^- + \text{OH}^- ] \times 100000$$

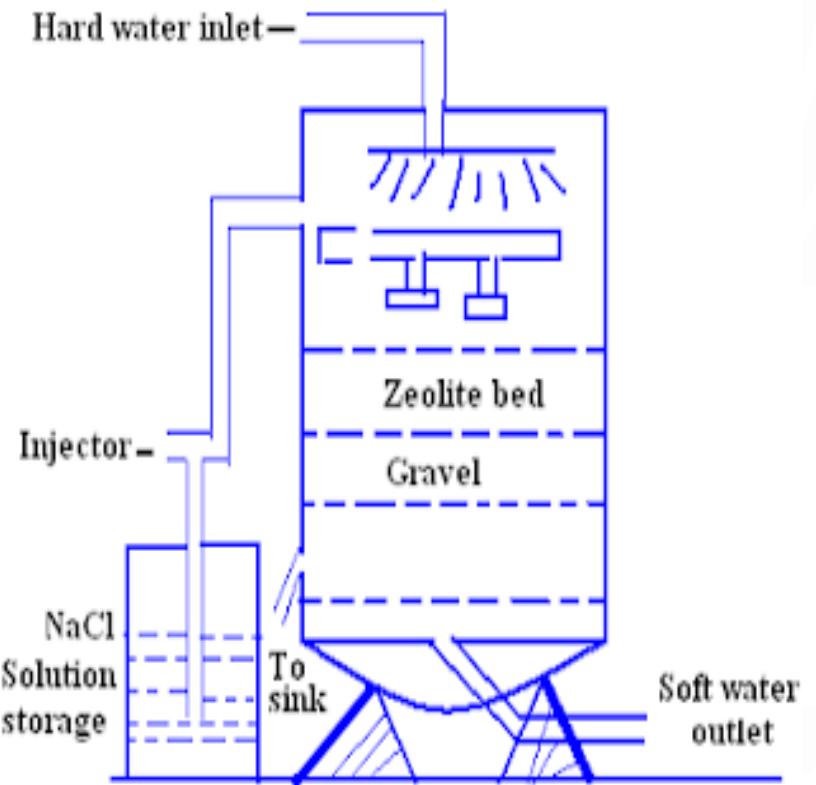
- $S = 106/100 [ \text{FeSO}_4 + \text{Ca}^{+2} + \text{Mg}^{+2} + \text{OH}^- + \text{CO}_3^{-2} - \text{HCO}_3^- ] \times 100000$

# ZEOLITE PROCESS OR BASE EXCHANGE PROCESS

- Zeolites are Sodium Aluminosilicate minerals
- General formula is ----- $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot x\text{SiO}_2 \cdot y\text{H}_2\text{O}$      $x=2-10$ ,  $y=2-6$
- They are capable of exchanging its Sodium ions
- They can be represented as  $\text{Na}_2\text{Z}$
- For softening of water by zeolite process, hard water is percolated through a bed of zeolite.
- When the water passes through the zeolite the hardness causing ions ( $\text{Ca}^{+2}$ ,  $\text{Mg}^{+2}$  etc.) are retained by the zeolite as  $\text{CaZ}$  and  $\text{MgZ}$  respectively, while the outgoing water contains equivalent amount of sodium salts. The block diagram and chemical reactions taking place in zeolite softener are:

- Two types of Zeolites are there:
- Natural : Green in colour. eg. Thomsonite ( $\text{Na}_2\text{O}, \text{Al}_2\text{O}_3 \cdot 3\text{SiO}_2 \cdot 2\text{H}_2\text{O}$ )
- Synthetic : Porous and have a gel like structure. They posses higher capacity to exchange the ions

# **ZEOLITE SOFTNER**



# CHEMICAL REACTIONS



## REGENERATION

- After some time, when the zeolite is completely changed into calcium and magnesium zeolites, then it gets exhausted (saturated with  $\text{Ca}^{+2}$  and  $\text{Mg}^{+2}$  ions) and it ceases to soften water. It can be regenerated and reused by first backwashing and then treating it with a 10% brine (sodium chloride) solution.



# ADVANTAGES OF ZEOLITE PROCESS

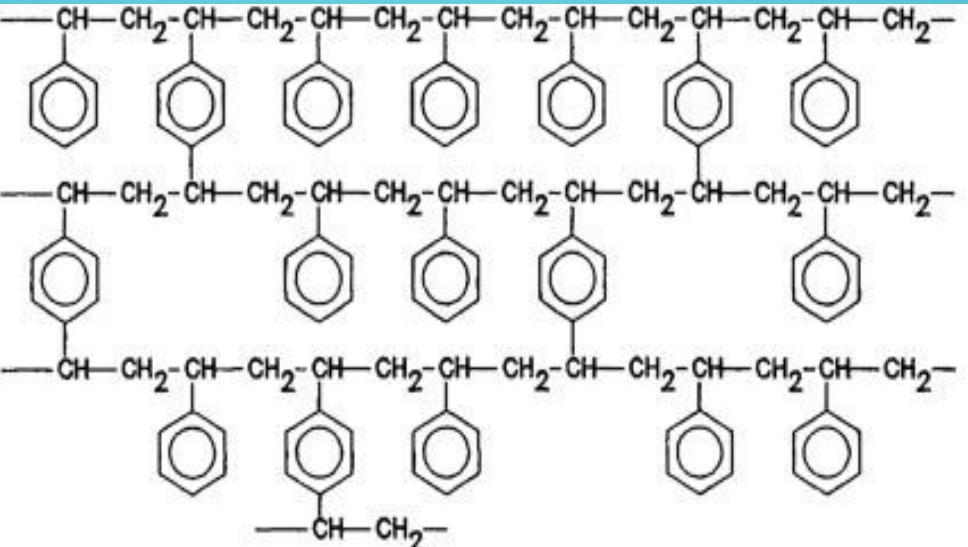
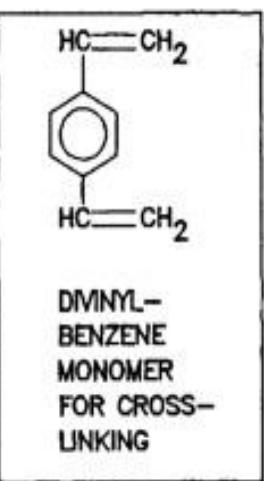
- Water having very low hardness (10ppm) is produced
- The plant is so compact and occupies less space
- No sludge is produced
- The running, maintenance and operation cost is very low
- Plant can be installed in the water pipeline

## DISADVANTAGES OF ZEOLITE PROCESS

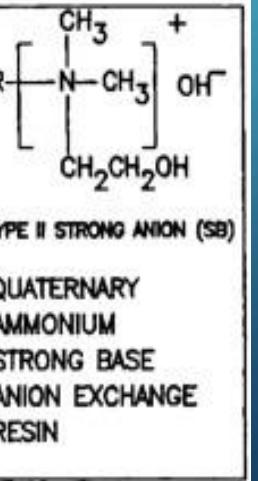
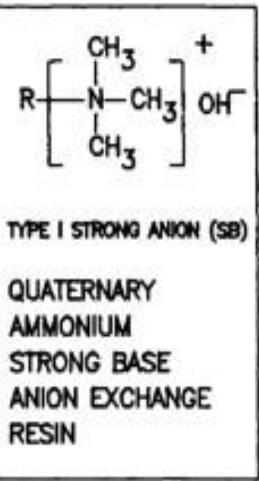
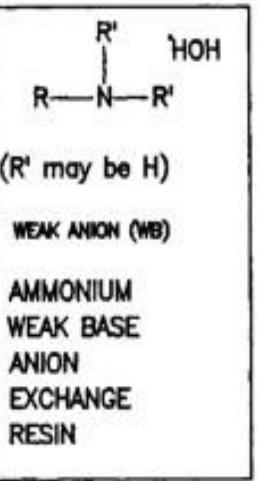
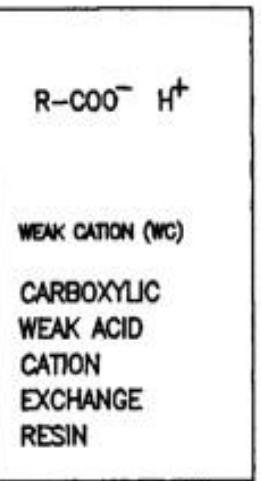
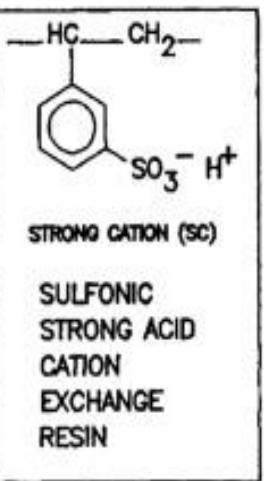
- This process is not suitable for turbid waters
- The process leaves  $\text{NaHCO}_3$  which causes priming and foaming
- Treated water contains more dissolved salts

# ION EXCHANGE PROCESS OR DEMINERALIZATION

- Recently ion-exchange resins have been used to remove all minerals from water. It is a process by which ions held on a porous, essentially insoluble solid are exchanged for ions in solution that is brought in contact with it.
- In Zeolite process only positive hardness producing ion are removed from water
- The process of complete removal of all ion present in water is known as Demineralization of water.
- For this purpose Ion Exchange resins are used
- An ion-exchange resin is a cross linked, long chain organic polymer having porous structure & some ionisable functional groups
- They are generally Styrene divinyl benzene copolymers



## POLYSTYRENE DIVINYLBENZENE BACKBONE



Ion exchange resins may be of two types depending upon the nature of the ionizable group.

**(i) Cation Exchange Resin or Cation Exchanger** - Such resins have  $-SO_3H$ ,  $-COOH$  or  $-OH$  (phenolic) group as the ionizable group. Since these resins exchange the cationic portion of minerals by their hydrogen atom, they are known as cation exchangers.

Resins having  $-SO_3H$  group are termed as strongly acidic resins whereas having  $-COOH$  group are known as weakly acidic resins

**(ii) Anion Exchange Resin or Anion Exchanger** – These resins have  $-NH_2$ ,  $-NHCH_3$ ,  $-N(CH_3)_2$  or  $-OH$  group. They exchange the anionic portion of the minerals and they are known as anion exchanger.

Resins having  $-NH_2$  group are weakly basic and having quaternary Ammonium salts are strongly basic resin

# PROCESS

- In this process first we pass hard water through cation exchange column, which removes all the cations (like  $\text{Ca}^{+2}$ ,  $\text{Mg}^{+2}$  etc.) from it and equivalent amount of  $\text{H}^+$  ions are released from this column to water.

Thus,



After this process, hard water is passed through anion exchange column, which removes all the anions (like  $\text{SO}_4^{-2}$ ,  $\text{Cl}^-$  etc.) from it, and equivalent amount of  $\text{OH}^-$  ions are released from this column to water. Thus,

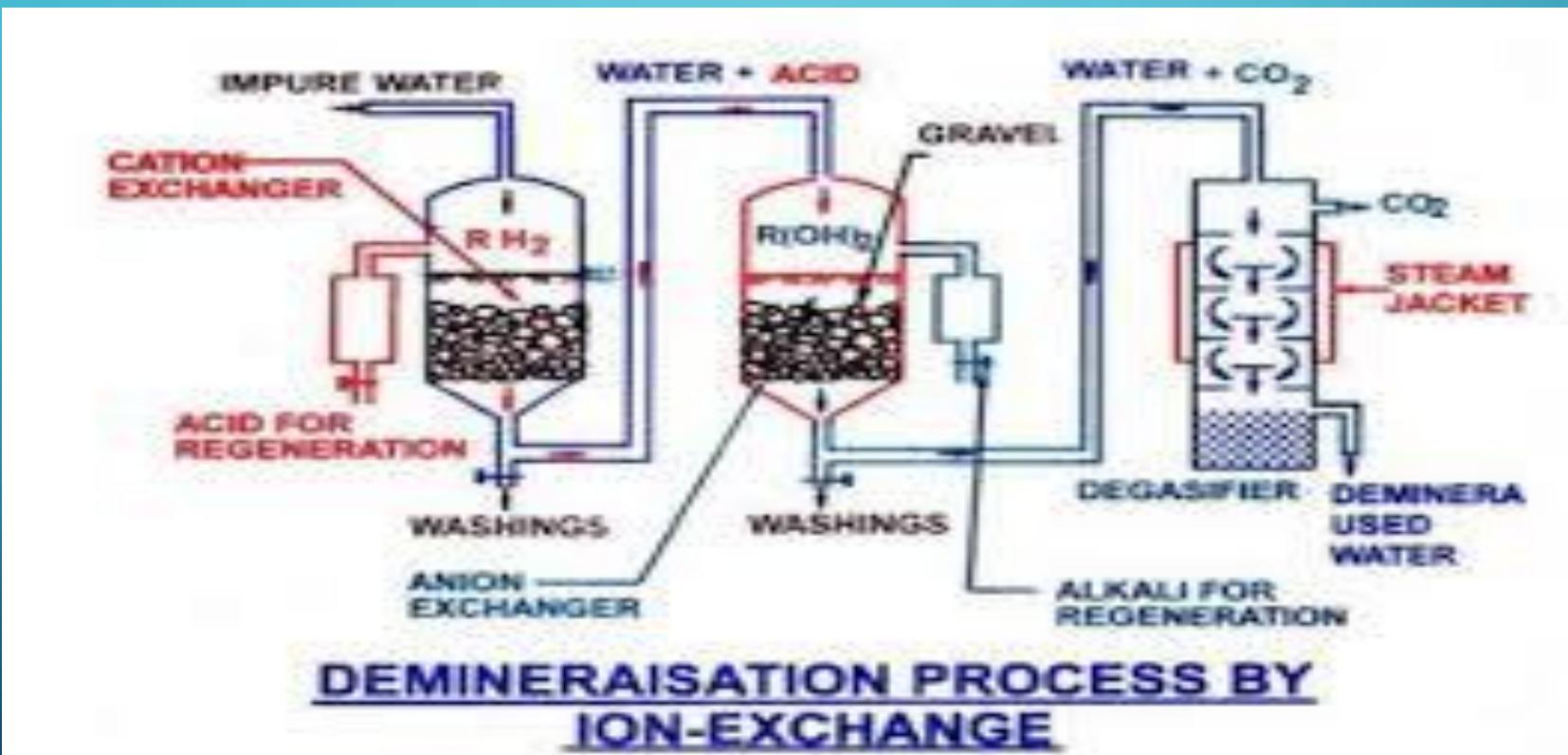


$\text{H}^+$  and  $\text{OH}^-$  ions get combined to produce water molecule



The water coming out from the exchanger is free from cations as well as anions. Ion-free water is known as a deionized or demineralized water.

# ION EXCHANGE PROCESS OR DEMINERALIZATION



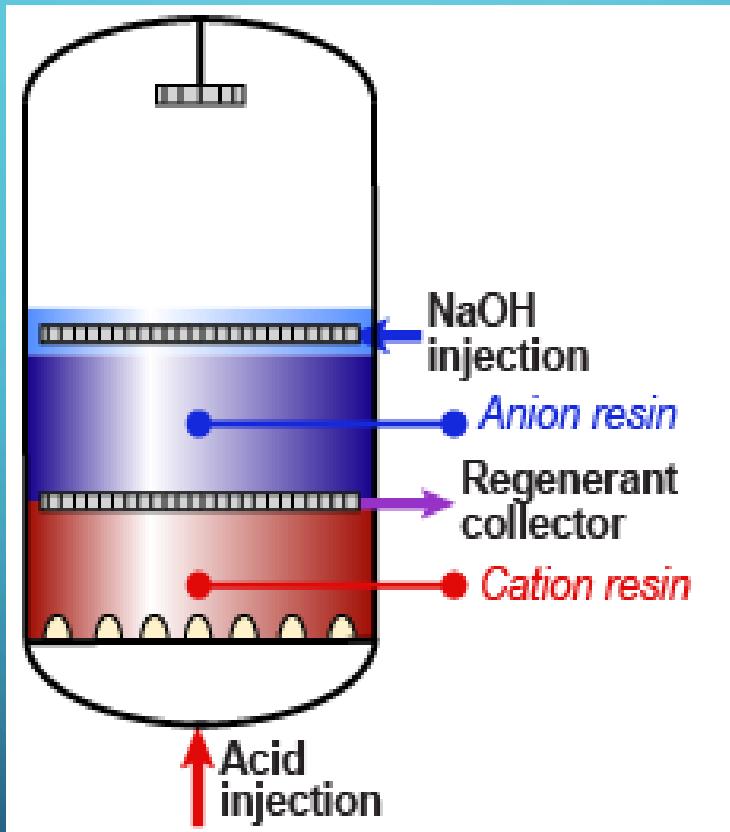
# REGENERATION OF RESINS

- After some time the cation exchangers as well as anion exchangers get exhausted
- They can be regenerated by 2%  $H_2SO_4$
- $R_2Ca^{+2} + H_2SO_4 \longrightarrow RH + CaSO_4$
- $R_2Mg^{+2} + H_2SO_4 \longrightarrow RH + MgSO_4$
- By  $NaOH$
- $R'Cl + NaOH \longrightarrow ROH + NaCl$
- $R'_2 SO_4^{-2} + 2 NaOH \longrightarrow ROH + Na_2SO_4$
- $R'_2 CO_3^{2-} + 2 NaOH \longrightarrow ROH + Na_2CO_3$

# MIXED BED ION EXCHANGER

- It consist of single column containing a mixture of strongly cation exchanger and strongly anion exchanger
- Hard water is passed through it

# MIXED BED ION EXCHANGER



## DISADVANTAGES

- Not suitable for **turbid** waters
- Not suitable for acidic or alkaline waters
- The treated water contain more dissolved salts as compared to Lime Soda process

# WATER TREATMENT FOR DOMESTIC PURPOSE

- Screening
- Sedimentation
- Coagulation and Sedimentation
- Filtration
- Disinfection
- Storage for distribution

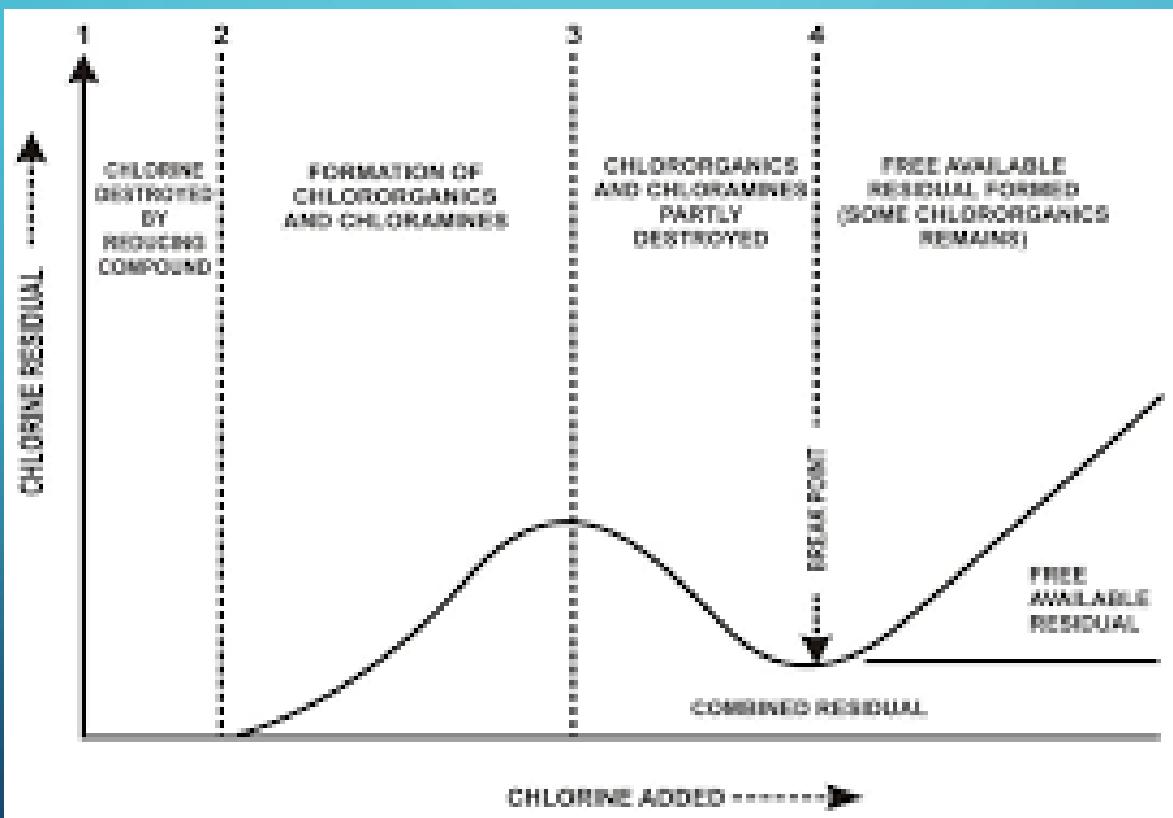
# DISINFECTION

- By:
- Chlorination
- Ozone
- $KMnO_4$
- Bleaching Powder
- Boiling

# Chlorination

- $\text{Cl}_2 + \text{H}_2\text{O} \xrightarrow{\text{PH}>8} \text{HOCl} + \text{HCl}$
- $\text{HOCl} \rightleftharpoons \text{H}^+ + \text{OCl}^-$
- HOCl, H<sup>+</sup> and OCl<sup>-</sup> are considered as free Chlorine
- $\text{HOCl} + \text{NH}_3 \longrightarrow \text{NH}_2\text{Cl} \quad \text{PH} > 7.5$
- $\text{NH}_2\text{Cl} + \text{HOCl} \longrightarrow \text{NHCl}_2 \quad \text{PH} = 5-6.5$   
 $\text{NHCl}_2 + \text{HOCl} \longrightarrow \text{NCl}_3 \quad \text{PH} < 4.5$
- NH<sub>2</sub>Cl , NHCl<sub>2</sub> and NCl<sub>3</sub> are considered as combined Chlorine

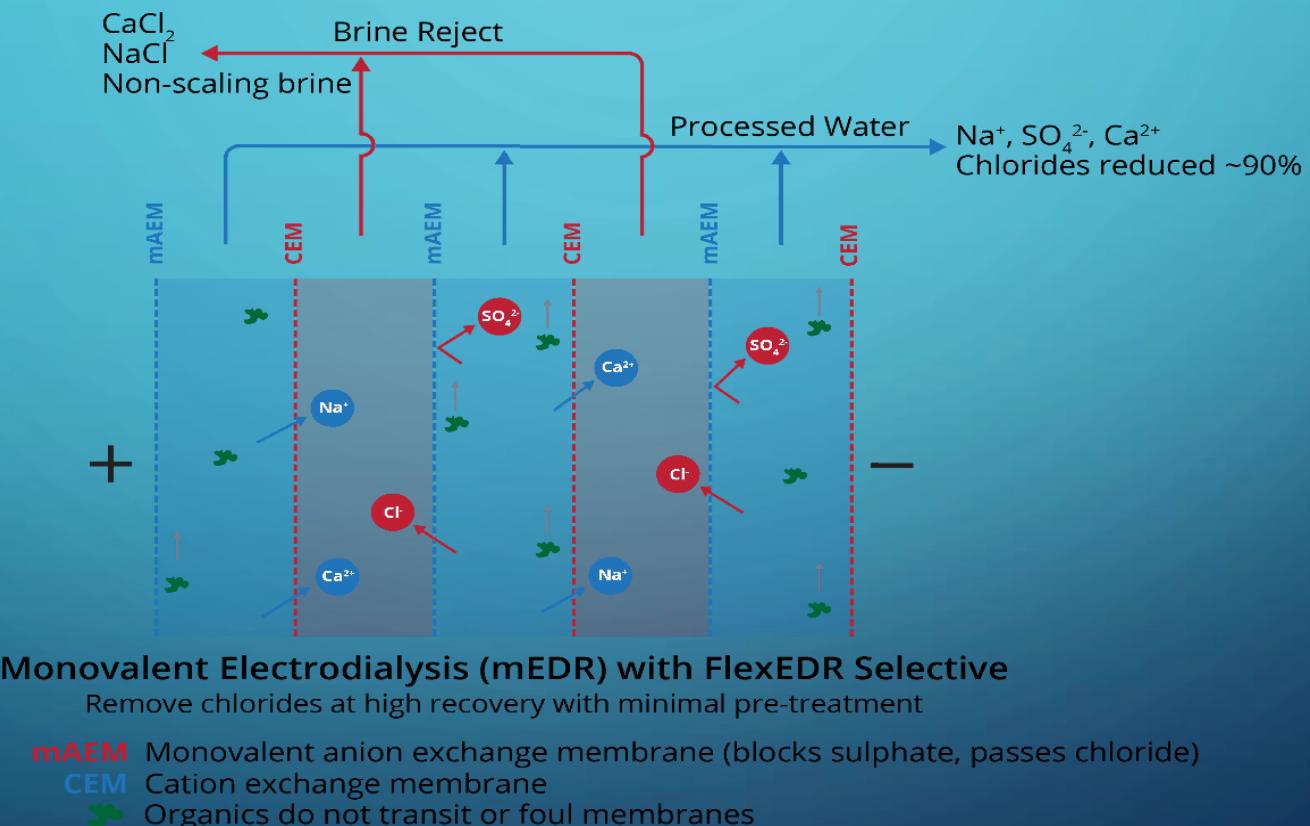
# DISINFECTION - BREAK POINT CHLORINATION



# DESALINATION OF BRACKISH WATER

- DISTILLATION
- FREEZING
- ELECTRODIALYSIS

# ELECTRODIALYSIS



# REVERSE OSMOSIS

