



# Chapter-I

## Types of Impurities in Water

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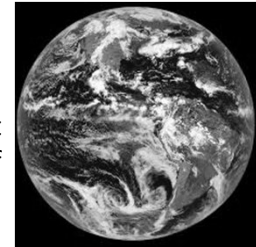
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Water is necessary for living beings (Humans, Animals & Plants).

Water is required in all human activities like domestic, agriculture and industries.

❖ Water covers 70% of the Earth i.e.  $\frac{2}{3}$ <sup>rd</sup> part of the earth.

❖ 97% of the earth water is salt water and 3% is Fresh water;  $\frac{2}{3}$ <sup>rd</sup> of fresh water is frozen in glaciers and polar ice caps.



❖ **Fresh water is renewable resource.**

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### Sources of Water

Surface Water

Frozen Water

Underground Water

Rain Water

Sea Water

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### Surface Water

Surface Water includes flowing water (Rivers & Streams) and still water (Ponds, Lakes & Reservoirs).



River Water



Streams



Pond



Lake



Reservoir

← Flowing Water

Still Water  
↓

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**River Water**

River water contains dissolved minerals like chlorides, sulphates, bicarbonates of Sodium, Magnesium, Calcium and Iron.

River water contains suspended impurities of sand and rock and organic matter.

The composition of river water is not constant and depends on its contact with soil.

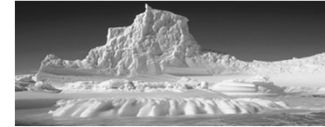
**Lake Water**

Lake water has high quantity of organic matter and lesser amount of dissolved minerals. Its chemical composition is also constant.

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**Frozen Water**

Frozen Water includes Glaciers, Icebergs.

**Underground Water**

It includes Water from well and springs.

Free from organic impurities, clear in appearance but contain large amount of dissolved salts.

**Rain Water**

Rain water is obtained as a result of evaporation from surface water.



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Rain water is the most purest form of water.

Rain water during its downward journey through the atmosphere it dissolves organic and inorganic suspended particles and gases like  $\text{NO}_x$ ,  $\text{CO}_x$  and  $\text{SO}_x$ .

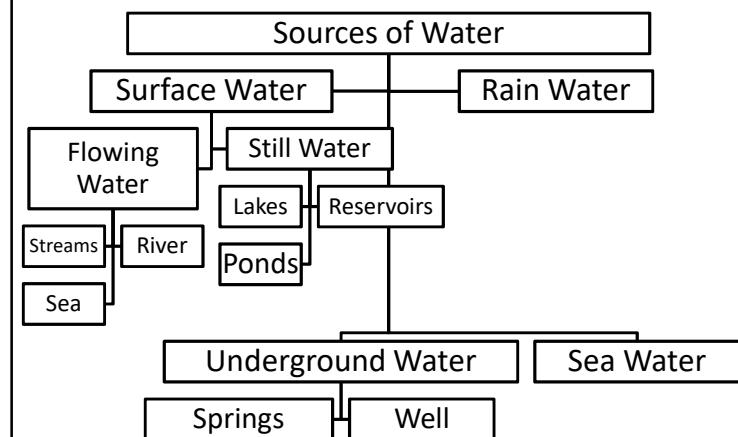
**Sea Water**

Sea water is impure due to continuous evaporation increases dissolved impurity content and impurities thrown by the rivers as they join the sea.

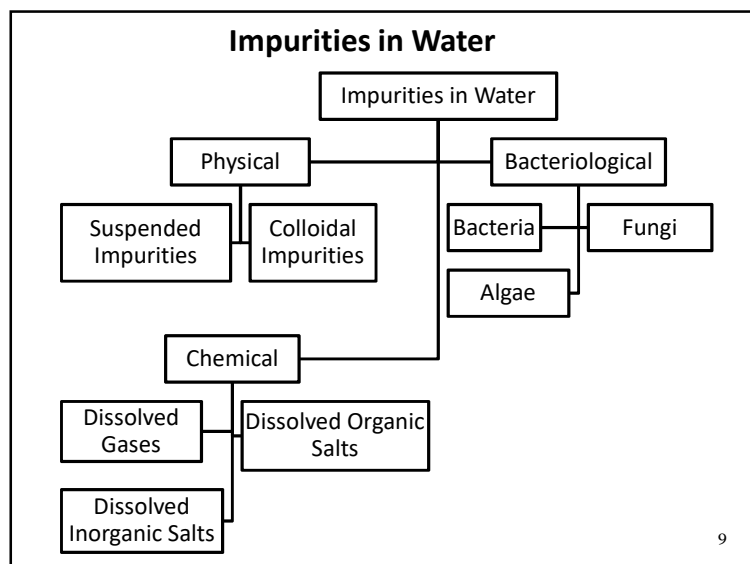
Sea water is saline.



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**Sources of Water**

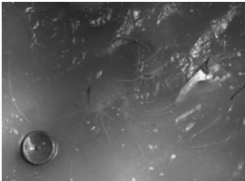
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**Impurities in Water**

**Suspended Impurities:**

- They impart turbidity, colour and odour to water.
- It may be Inorganic (Clay and Sand) or Organic (Oil, Vegetable and Animal matter) in nature.
- Suspended Impurities are Macroscopic . The size of suspended impurities ranges from 0 to 10-3 mm



**Colloidal Impurities:**

They impart turbidity, colour and odour to water. It may be Inorganic (Clay and Sand) or Organic (Oil, Vegetable and Animal matter) in nature.

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**Dissolved Impurities:**

These impurities are due to the presence of dissolved salts like Carbonates, Bicarbonates, Chlorides and Sulphates of Calcium, Magnesium, Iron and Sodium.

Hardness is due the presence of these salts.

Dissolved gases like CO<sub>2</sub>, O<sub>2</sub>, etc. also considered as dissolved impurities.

**Microorganisms:**

They include bacteria, fungi and algae.

These impurities are introduced into water by animal or vegetable waste and through sewage flowing into the water body.

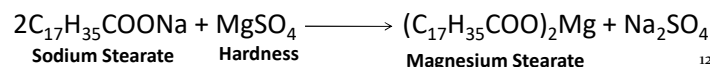
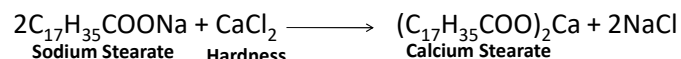
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**Hardness**

Hardness is the characteristic of water which prevents the lathering of soap.

Hardness is the soap consuming capacity of water.

Hardness is due to the presence of certain salts of Ca and Mg and other Heavy Metals ions like Al<sup>3+</sup>, Fe<sup>3+</sup>, Mn<sup>2+</sup> dissolved in it.

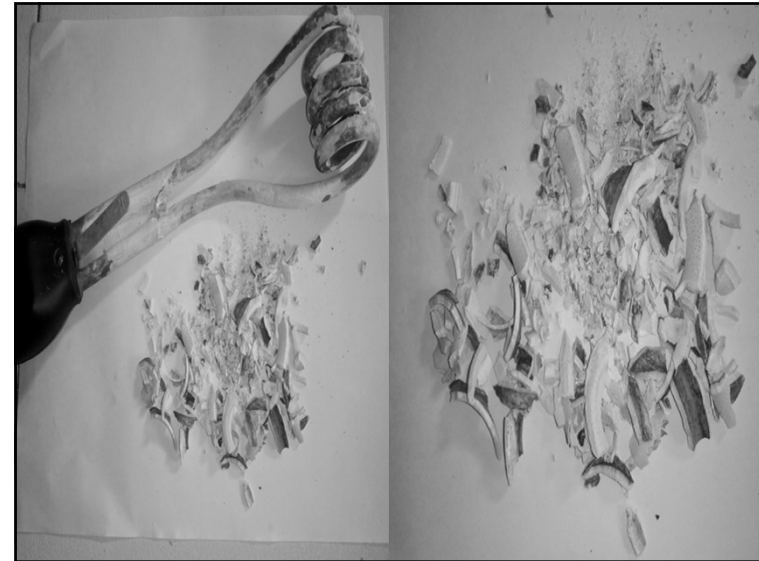


Cations which produces insoluble soap with soap solution will contribute to the hardness.

On the above basis Water is of Two Types; Hard Water and Soft Water

Hard Water	Soft Water
Water which do not produce lather with soap & form white curd/scum.	Water which produce lather with soap
Contain soluble Calcium & Magnesium salts	Do not contain dissolved Calcium & Magnesium salts
Cleansing quality is depressed	Cleansing quality is not depressed
Due to the dissolved salts boiling point of water is elevated	Less fuel and time are required for cooking of food.

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### Types of Hardness

Hardness is of Two Types

❖ Temporary Hardness / Alkaline Hardness / Carbonate Hardness

The temporary hardness is due to the presence of carbonates and bicarbonates of Calcium & Magnesium. It can be removed by physical methods like boiling.

❖ Permanent Hardness / Non-Alkaline Hardness / Non-Carbonate Hardness

The permanent hardness is due to the presence of chlorides and sulphates of Calcium, Magnesium, Salts of heavy metals & Acids. It can't be removed by physical methods like

Permanent hardness can not be removed by physical methods like boiling but it can be removed by Chemical Methods.

### Units of Hardness

❑ Parts per million (ppm): Parts of calcium carbonate equivalent hardness per  $10^6$  part of water.

❑ Milligrams per Litre (mg/L): Milligrams of calcium carbonate equivalent hardness per Litre of water.

❑ Degree Clark ( $^{\circ}\text{Cl}$ ): Parts of calcium carbonate equivalent hardness per 70,000 part of water.

❑ Degree French ( $^{\circ}\text{Fr}$ ): Parts of calcium carbonate equivalent hardness per  $10^5$  part of water.

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### Degree of Hardness

❑ The hardness of water is expressed in terms of equivalent amount  $\text{CaCO}_3$ .

❑ The reason for reporting hardness as equivalent amount of  $\text{CaCO}_3$  is the ease in calculation as its Molecular weight  $\text{CaCO}_3$  is 100 and equivalent weight is 50.

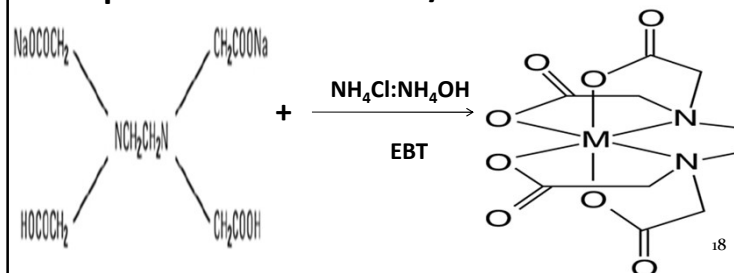
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### Relationship between the Units of Hardness

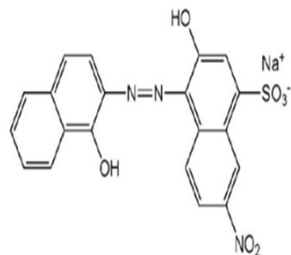
$$1 \text{ ppm} = 1 \text{ mg/L}$$

$$1 \text{ ppm} = 1 \text{ mg/L} = 0.07^\circ\text{Cl} = 0.1^\circ\text{Fr}$$

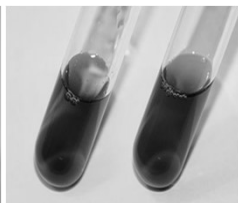
### Determination of Hardness by Complexometric Method / EDTA Method



Sodium 4-[(1-hydroxynaphthalen-2-yl-hydrazinylidene)-7-nitro-3-oxo-Y-naphthalene-1-sulfonate



Scheme 1. Structure of EBT.



Blue to wine red colour

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❑ Ethylene Diammine Tetra Acetic Acid is tetraprotic acid, due to its limited solubility, it is not used directly.

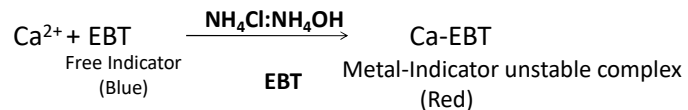
❑ Disodium salt of Ethylene Diammine Tetra Acetic Acid is used (Molecular Weight – 372.24)

❑ It combines with metal ions in 1:1 ratio in the presence of  $\text{NH}_4\text{Cl}:\text{NH}_4\text{OH}$  buffer solution and Eriochrome Black T is used as indicator.

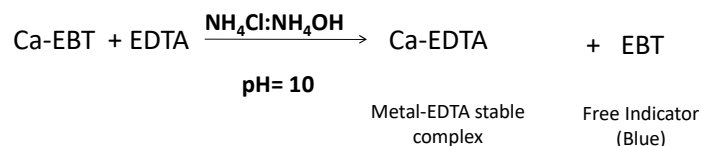
❑  $\text{NH}_4\text{Cl}:\text{NH}_4\text{OH}$  buffer solution is used because the divalent metal are stable in slightly basic solution ( $\text{pH}=10$ ).

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❑ The colour of EBT is “Blue” and when it added to hard water it forms unstable complex of “Wine Red” colour.



❑ Metal-Indicator unstable complex when titrated with EDTA to form colourless Metal-EDTA complex.



❑ End point is achieved by the appearance of Blue Colour of Free EBT.

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### Calculation of Hardness of water: Unitary Method

#### Standardization of EDTA solution

Let the strength of Standard Hard Water (SHW) = S mg / L

1 Liter of SHW contain----- S mg of  $\text{CaCO}_3$

‘ $V_{\text{Std. SHW}}$ ’ ml of SHW contain----- ( $S \times V_{\text{Std. SHW}}$ ) mg  $\text{CaCO}_3$

$V_{\text{Std. EDTA}}$  ml of EDTA -----  $V_{\text{Std. SHW}}$  ml of SHW

$V_{\text{Std. EDTA}}$  ml of EDTA -----  $S \times V_{\text{Std. SHW}}$  ml of SHW

1 ml of EDTA contain-----  $\frac{S \times V_{\text{Std. SHW}}}{V_{\text{Std. EDTA}}}$  mg  $\text{CaCO}_3$

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#### Determination of Total Hardness of Unknown Hard Water

$V_{\text{TH. UHW}}$  ml of UHW -----  $V_{\text{TH. EDTA}}$  ml of EDTA

$V_{\text{TH. UHW}}$  ml of UHW -----  $V_{\text{TH. EDTA}} \left[ \frac{S \times V_{\text{Std. SHW}}}{V_{\text{Std. EDTA}}} \right]$  mg  $\text{CaCO}_3$

1 ml of UHW -----  $\frac{V_{\text{TH. EDTA}}}{V_{\text{TH. UHW}}} \frac{S \times V_{\text{Std. SHW}}}{V_{\text{Std. EDTA}}}$  mg  $\text{CaCO}_3$

1000 ml of UHW -----  $1000 * \frac{V_{\text{TH. EDTA}}}{V_{\text{TH. UHW}}} \frac{S \times V_{\text{Std. SHW}}}{V_{\text{Std. EDTA}}}$  mg  $\text{CaCO}_3$

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#### Determination of Permanent Hardness of Unknown Hard Water

$V_{\text{PH. UHW}}$  ml of Boiled Water -----  $V_{\text{PH. EDTA}}$  ml of EDTA

$V_{\text{PH. UHW}}$  ml of UHW -----  $V_{\text{PH. EDTA}} \frac{S \times V_{\text{Std. SHW}}}{V_{\text{Std. EDTA}}}$  mg  $\text{CaCO}_3$

1 ml of BHW -----  $\frac{V_{\text{PH. EDTA}}}{V_{\text{PH. UHW}}} \frac{S \times V_{\text{Std. SHW}}}{V_{\text{Std. EDTA}}}$  mg  $\text{CaCO}_3$

1000 ml of BHW -----  $1000 * \frac{V_{\text{PH. EDTA}}}{V_{\text{PH. UHW}}} \frac{S \times V_{\text{Std. SHW}}}{V_{\text{Std. EDTA}}}$  mg  $\text{CaCO}_3$

mg  $\text{CaCO}_3$

### Determination of Temporary Hardness of Unknown Hard Water

Temporary Hardness =

$$1000 * \frac{V_{TH, EDTA}}{V_{TH, UHW}} \times \frac{S \times V_{Std, SHW}}{V_{Std, EDTA}} - 1000 * \frac{V_{PH, EDTA}}{V_{PH, UHW}} \times \frac{S \times V_{Std, SHW}}{V_{Std, EDTA}}$$

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Total Hardness =  $S \times 1000 \times \frac{V_{SHW}}{(V_{EDTA})_{SHW}} \times \frac{(V_{EDTA})_{UHW}}{V_{UHW}} \times \frac{1 \text{ mg CaCO}_3}{\text{ppm}}$

SHW =  $\frac{1 \text{ mg CaCO}_3}{\text{ppm}}$

Permanent Hardness =  $S \times 1000 \times \frac{V_{SHW}}{(V_{EDTA})_{SHW}} \times \frac{(V_{EDTA})_{BW}}{V_{BW}} \times \frac{1 \text{ mg CaCO}_3}{\text{ppm}}$

When volume of SHW & UHW/BW is same

Total Hardness =  $\frac{(V_{EDTA})_{UHW}}{(V_{EDTA})_{SHW}} \times 1000 \text{ ppm}$

Permanent Hardness =  $\frac{(V_{EDTA})_{BW}}{(V_{EDTA})_{SHW}} \times 1000 \text{ ppm}$

Temporary Hardness =  $\left[ \frac{(V_{EDTA})_{UHW}}{(V_{EDTA})_{SHW}} - \frac{(V_{EDTA})_{BW}}{(V_{EDTA})_{SHW}} \right] \times 1000 \text{ ppm}$

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### Calculation of Hardness of water: Molarity Method

#### Calculation of Molarity of Standard Hard Water

Weight of  $\text{CaCO}_3$  = W gm

Molecular weight of  $\text{CaCO}_3$  = 100

Moles of  $\text{CaCO}_3$  =  $\frac{\text{Weight (W)}}{\text{Molecular Weight}}$

Volume of water = 'V' Litre

Molarity of SHW ( $M_1$ ) =  $\frac{\text{Weight (W)}}{\text{Molecular Weight} \times V}$

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### EDTA solution Vs Standard Hard Water

SHW      EDTA

$$M_1V_1 = M_2V_2$$

$$M_2 = \frac{M_1V_1}{V_2}$$

### EDTA solution Vs Sample Hard Water

EDTA      Sample Water

$$M_2V_2 = M_3V_3$$

$$M_3 = \frac{M_2V_2}{V_3}$$

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$$\text{Total Hardness} = M3 * \text{Molecular Mass of CaCO}_3 * 1000$$

ppm

#### EDTA solution Vs Boiled Hard Water

EDTA      Boiled Sample Water

$$M2V2 = M4V4$$

$$M4 = \frac{M2V2}{V4}$$

$$\text{Permanent Hardness} = M4 * \text{Molecular Mass of CaCO}_3 * 1000$$

ppm

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Temporary Hardness =

$$\text{Total Hardness} - \text{Permanent Hardness} \quad \text{ppm}$$

#### Numerical on Hardness Estimation using EDTA Method

Annexure- 1

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### Alkalinity

Alkalinity is a measure of the ability of water to neutralize the acids.

Alkalinity of water means the total content of those substances which causes an increased hydroxide ion concentration upon dissociation or due to hydrolysis.

Alkalinity of water is due to the presence of

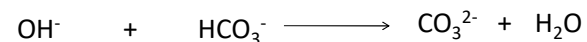
- |                                 |   |                    |
|---------------------------------|---|--------------------|
| ✓ OH <sup>-</sup>               | } | Caustic Alkalinity |
| ✓ CO <sub>3</sub> <sup>2-</sup> |   |                    |
| ✓ HCO <sub>3</sub> <sup>-</sup> |   | Temporary Hardness |

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✓ OH<sup>-</sup> and CO<sub>3</sub><sup>2-</sup>

✓ HCO<sub>3</sub><sup>-</sup> and CO<sub>3</sub><sup>2-</sup>

✓ The possibility of OH<sup>-</sup> and HCO<sub>3</sub><sup>-</sup> together is ruled out because they combine to form CO<sub>3</sub><sup>2-</sup> ions.



➤ Thus OH<sup>-</sup> and HCO<sub>3</sub><sup>-</sup> ions can not exist together in water.

➤ Hence OH<sup>-</sup>, CO<sub>3</sub><sup>2-</sup> and HCO<sub>3</sub><sup>-</sup> ions can not exist together in water.

#### Estimation of Alkalinity of water

➤ Fill the burette with N/50 HCl solution.

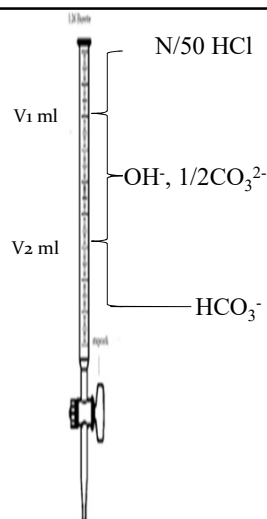
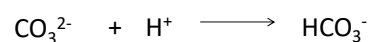
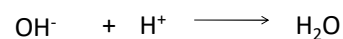
➤ Pipette out 20 ml of alkaline water sample in conical flask<sub>32</sub>



➤ Add a drop of Phenolphthalein, then the colour of solution becomes pink.

➤ Titrate against N/50 HCl till the solution becomes colourless. Note down the amount of acid used ( $V_1$  ml).

➤ Add a drop of Methyl Orange ; the solution become slightly orange. Continue the titration against N/50 HCl till the reappearance of light pink colour ( $V_2$  ml).



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### Calculation

ACID WATER

$$N_1V_1 = N_2V_2$$

$$N_2 \text{ or } N_p = \frac{N_1V_1}{V_2}$$

**Strength (P) = Normality (N<sub>2</sub>) x Equivalent weight of CaCO<sub>3</sub> x 1000 ppm**

**For the same solution;  $V_1 = V_1 + V_2$**

**For different solution;  $V_1 = V_2$**

ACID WATER

$$N_1(V_1 + V_2) = N_3V_3$$

$$N_3 \text{ or } N_M = \frac{N_1(V_1 + V_2)}{V_3}$$

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**Strength (M) = Normality (N<sub>3</sub>) x Equivalent weight of CaCO<sub>3</sub> x 1000 ppm**

### Condition of Alkalinity

S.No.	Results of Titration	Hydroxide	Carbonate	Bicarbonate
1	<b>P = 0</b>	<b>NIL</b>	<b>NIL</b>	<b>M</b>
2	<b>P = M</b>	<b>P or M</b>	<b>NIL</b>	<b>NIL</b>
3	<b>P = ½ M</b>	<b>NIL</b>	<b>2P</b>	<b>NIL</b>
4	<b>P &gt; ½ M</b>	<b>2P – M</b>	<b>2 (M – P)</b>	<b>NIL</b>
5	<b>P &lt; ½ M</b>	<b>NIL</b>	<b>2P</b>	<b>M – 2P</b>

### Numerical on Alkalinity

Annexure- 2

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### Boiler

➤ Boiler is a closed vessel which is used to convert water into steam

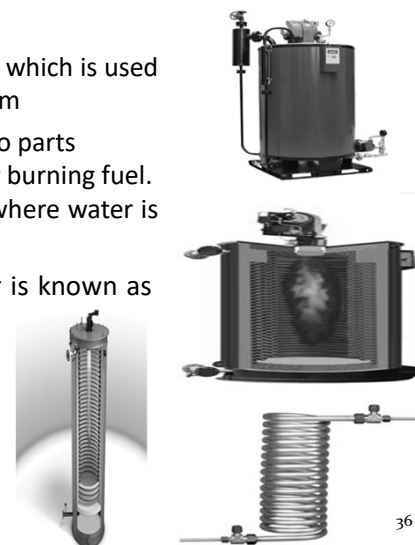
➤ Boiler is made up of two parts

**Furnace:** Provides heat by burning fuel.

**Boiler Proper:** Chamber where water is converted into steam.

➤ Water feed into boiler is known as "Boiler Feed Water".

➤ The Chemical Energy is converted into Heat Energy by combustion process which in turn is absorbed by water.



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## Boiler Problems

### ➤ Essential requirement for boiler feed water:-

It should be free from

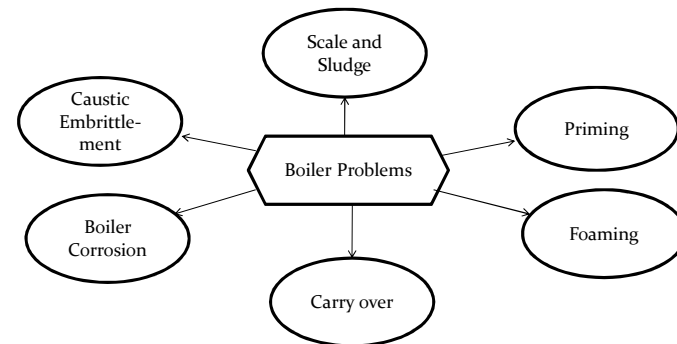
- Turbidity, Oils, Dissolved Salts
- Hardness and scale forming salts
- Dissolved  $O_2$  and  $CO_2$
- Caustic Alkali

➤ Proper treatment of boiler feed water is an important part of boiler operation and maintenance system.

➤ As the water is converted into steam, the concentration of dissolved solids increases and starts depositing inside the boiler thereby reduces boiler efficiency and leads to poor heat transfer.

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➤ If the pre-treatment of boiler feed water is not done then it may lead to "Boiler Problems" like Priming, Foaming, Scale and Sludge, Boiler Corrosion and Caustic Embrittlement.



## Boiler Problems

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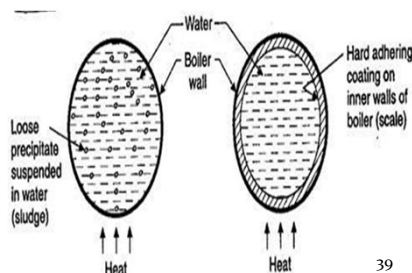
## Scale and Sludge

➤ In the boiler water is continuously evaporated to form steam. This increases the concentration of dissolved salts.

➤ A stage is reached when ionic product exceeds the solubility product ( $K_{sp} < I_p$ , **supersaturated solution**) and hence they are thrown out as precipitates.

➤ If the precipitate formed is soft loose and slimy is known as Sludge.

➤ If the precipitate formed is hard and adhering on the inner wall of the boiler is known as Scale.



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✓ If **Solubility Product =  $K_{sp}$**  and **Ionic Product =  $[A^{y+}]^x[B^{x-}]^y$**

➤  $K_{sp} = [A^{y+}]^x[B^{x-}]^y$  == Solution is Saturated

➤  $K_{sp} > [A^{y+}]^x[B^{x-}]^y$  == Solution is Unsaturated

➤  $K_{sp} < [A^{y+}]^x[B^{x-}]^y$  == Precipitation will take place

## Sludge

❖ Sludge is soft, loose and slimy precipitate formed within the boiler.



❖ Sludge is formed by substance which have higher solubility in hot water than in cold water. For example  $MgCO_3$ ,  $MgCl_2$ ,  $CaCl_2$ ,  $MgSO_4$ .

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❖ Sludge is formed at the comparatively colder part of the boiler and get collected at places where the flow rate is slow.

### Disadvantages of Sludge

- ✓ Sludge is bad conductor of Heat.
- ✓ Excessive Sludge formation affects the working of boiler and causes choking of pipes.

### Prevention of Sludge Formation

- ✓ Use of Soft Water.
- ✓ By frequently “Blow Down Operation” i.e removal of concentrated water through tap at the bottom of the boiler when extent of hardness becomes high.

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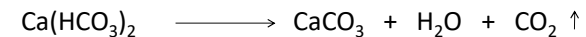
### Scale

❖ Scale are hard deposits firmly sticking to the inner wall of the boiler.



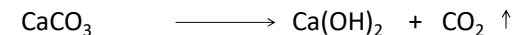
Scale is formed due to the following reasons

#### ✓ Decomposition of Calcium Bicarbonate



Scale composed of  $\text{CaCO}_3$  is soft and main cause of scale formation in the low pressure boilers.

In High pressure boiler  $\text{CaCO}_3$  is soluble due to the formation of  $\text{Ca}(\text{OH})_2$ .



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#### ✓ Decomposition of Calcium Sulphate

The solubility of  $\text{CaSO}_4$  in water decreases with the increase in temperature.  $\text{CaSO}_4$  is soluble in cold water but completely insoluble in super heated water.

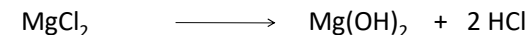
Low solubility of  $\text{CaSO}_4$  is due to the increased ionization at high temperature and less availability of water molecules for solvation at high temperature.

$\text{CaSO}_4$  precipitates as hard scale on hotter parts of boiler and high pressure boilers.

#### ✓ Hydrolysis of Magnesium Salts

Dissolved salts of Magnesium hydrolyze at high temperature to form a soft  $\text{Mg}(\text{OH})_2$  scale.

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#### ✓ Presence of Silica

Even if small quantity of  $\text{SiO}_2$  is present then it may deposit as calcium silicate ( $\text{CaSiO}_2$ ) and Magnesium Silicate ( $\text{MgSiO}_2$ ). These deposit adhere to the inner surface of boiler very firmly. The main source of silica is the Sand Filter.

### Disadvantages of Scale

- Wastage of Fuel
- Lowering of Boiler Safety
- Decrease of Boiler Efficiency
- Danger of Boiler Explosion

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### Removal of Scale Formation

- Removal by Mechanical Methods- Scrapping
- If scale is brittle, it can be removed by Thermal shocks
- If the scale is loosely adhering then it can be removed by “Blow Down Operation” (i.e. Heating the boiler & then sudden cooling.
- If the scale is adherent and hard then can be removed by dissolving them in chemicals;
- **CaCO<sub>3</sub> scale can be removed by adding 5-10% HCl**
- **CaSO<sub>4</sub> scale can be removed by adding EDTA**

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### Priming

❖ When steam is produced rapidly in the boiler, some droplets of the liquid water are carried along with the steam. This process of “Wet Steam” formation is called Priming.

#### ✓ Priming is caused by

- Presence of Dissolved impurities and Suspended impurities.
- Steam Velocities high enough to carry droplets of water into the steam pipe.
- Sudden Boiling
- Faulty design of Boiler

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#### ✓ Priming can be avoided by

- Controlling the rapid change in steaming velocities.
- Proper design of the Boiler.
- Ensuring sufficient softening.
- By blowing off the sludge and scale from time to time.
- Filtration of Boiler Feed Water

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### Foaming

❖ Foaming is the formation of persistent foam or bubbles at the water surface in the boiler which do not break easily.

❖ Foaming is caused due to the presence of Oil and Alkalis in the boiler feed water.

❖ **Oil and Alkalis reacts to form soaps which greatly reduces the surface tension of water & increases the foaming tendency of the water.**



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✓ **Foaming can be avoided by**

- Addition of Anti-foaming agent which reduces the surface tension (Like Castor oil).
- Removal of foaming agent oil from Boiler feed water.

**Carry Over**

The phenomenon of carrying of water along with impurities by steam is called carry over.

**Carry Over is due to Priming & Foaming.**

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Carry Over and Priming & Foaming occurs together and they are objectionable.

Dissolved Solids or Suspended Solids in boiler water are carried by the wet steam to super heater or steam turbine blades where they get deposit as water evaporates.

Dissolved Solids may enter the part of other machinery, thereby decreasing their life

The maintenance of the boiler pressure become difficult because of improper judgement of actual height of water column.

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**Boiler Corrosion**

❖ Boiler corrosion is the decay or disintegration of the boiler material either due to chemical or electrochemical reaction with its environment.

✓ **Boiler Corrosion is caused due to following reasons-**

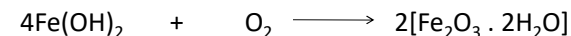
**Dissolved Oxygen:**

This is the most common reason of Boiler Corrosion. In boiler the oxygen is introduced through the raw water supply. Water usually contain 8 ppm of Oxygen at room temperature. As the water is heated this dissolved oxygen is set free and boiler starts corroding .



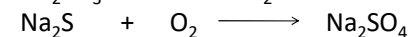
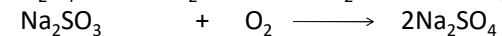
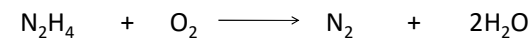
51

Dissolved oxygen reacts with Iron (Fe) in the presence of water to form Ferric Oxide (Rust).



**Removal of Dissolved Oxygen**

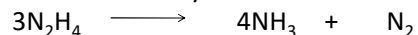
✓ **By adding Hydrazine or Sodium Sulphite or Sodium Sulphide**



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➤Hydrazine ( $\text{N}_2\text{H}_4$ ) is the ideal chemical for the removal of dissolved oxygen. It reacts with oxygen to form Nitrogen and water. Nitrogen is harmless. Hydrazine removes oxygen without increasing the concentration of dissolved solids.

➤Excess amount of Hydrazine ( $\text{N}_2\text{H}_4$ ) must not be taken because it decomposes to give Ammonia which may cause corrosion of some alloys like Brass used in condenser tubes.



➤If Sodium Sulphite or Sodium Sulphide is used for the removal of dissolved oxygen then Sodium Sulphate is formed which decomposes in high pressure boilers to form  $\text{SO}_2$ . The  $\text{SO}_2$  enters into the steam pipes and forms Sulphurous acid ( $\text{H}_2\text{SO}_3$ ) in steam condensate.

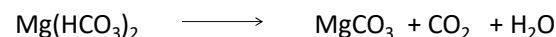
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#### ✓ By Mechanical Deaeration

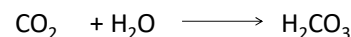
➤This process consist of spraying of water over preheated perforated plates stacked in a degasifier. Removal of dissolved oxygen is ensured by applying high temperature and vacuum.

#### Dissolved Carbon Dioxide:

Main source of  $\text{CO}_2$  in boiler water are dissolved  $\text{CO}_2$  in raw water and decomposition of Bicarbonates in water.



$\text{CO}_2$  in the presence of water forms Carbonic acid ( $\text{H}_2\text{CO}_3$ ) which has corrosive effect on boiler material.



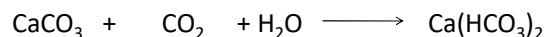
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### Removal of Carbon Dioxide

#### ✓ By Mechanical Deaeration

➤This process consist of spraying of water over preheated perforated plates stacked in a degasifier. Removal of dissolved carbon dioxide is ensured by applying high temperature and vacuum.

#### ✓ By Filtering water through Lime Stone



➤This method increases hardness.

#### ✓ By adding Ammonium Hydroxide



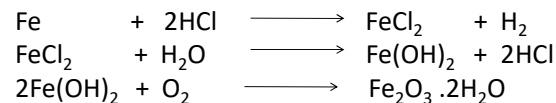
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### Boiler Corrosion due to Mineral Acids:

➤Magnesium Chloride if present in boiler feed water undergoes hydrolysis producing HCl.



Liberated HCl reacts with Iron (Fe) to form Ferrous Hydroxide which in turn is converted into Rust.



Small amount of HCl causes corrosion to larger extent since HCl is produced in chain like manner. Hence small amount of  $\text{MgCl}_2$  causes corrosion of Iron to larger extent.

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### Caustic Embrittlement

Caustic Embrittlement is the phenomenon during which the boiler material becomes brittle due to the accumulation of caustic. This type of boiler corrosion is caused by the use of highly alkaline water in the high pressure boiler.

During softening by Lime-Soda Process, it is likely that some residual Sodium Carbonate ( $\text{Na}_2\text{CO}_3$ ) may be present in the soft water.

In high pressure boilers  $\text{Na}_2\text{CO}_3$  decomposes to give Sodium Hydroxide ( $\text{NaOH}$ ) and  $\text{CO}_2$  thus makes water "Caustic".

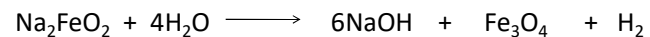


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This caustic water flow into the minute hair cracks, present in the inner side of boiler by capillary action.

On evaporation of water the dissolved caustic soda concentration increases progressively which attacks the surrounding area, thereby dissolving Iron of boiler as Sodium Ferriate ( $\text{Na}_2\text{FeO}_2$ ).



The Iron surrounded by dil.  $\text{NaOH}$  acting as Cathode, while the Iron surrounded by concentrated  $\text{NaOH}$  act as Anode.

The Iron in the anodic parts gets corroded.

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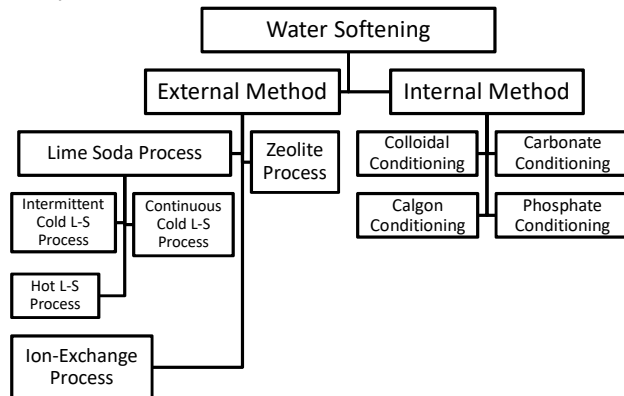
### Prevention of Caustic Embrittlement

- By adding Sodium Phosphate as softening reagent, instead of Sodium Carbonate in external treatment of boiler water.
- By adding Sodium Sulphate to boiler which blocks the hair cracks and prevents the infiltration of caustic soda solution into these areas.
- By adding tannin or lignin to boiler which blocks the hair cracks and prevents the infiltration of caustic soda solution into these areas.

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## Purification of Boiler Water or Water Softening

The hardness causing salts can be removed from water by two ways-



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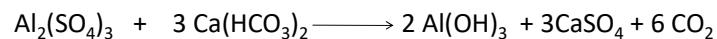
## External Method

### Lime Soda Process

- The basic principle of Lime Soda Process is to chemically convert all the soluble hardness causing impurities into insoluble precipitates which may be removed by settling or filtration.
- Calculated quantity of milk of lime  $[\text{Ca}(\text{OH})_2]$  and Sodium Carbonate  $[\text{Na}_2\text{CO}_3]$  is added.
- At Room Temperature the precipitate formed is very fine & do not settle down easily and causes difficulty in filtration.
- Fine precipitate of  $\text{CaCO}_3$  and  $\text{Mg}(\text{OH})_2$  result in "after deposition", later in pipes, boiler tubes producing scales.

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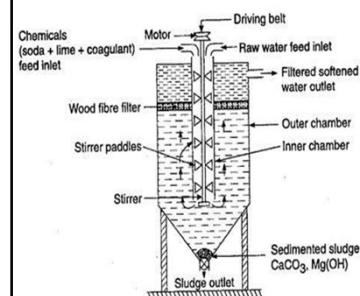
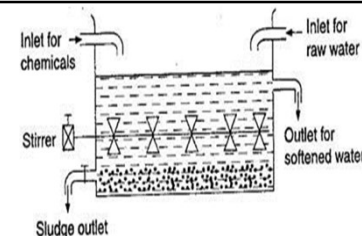
- If small amount of coagulants like Alum  $\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$ ; Aluminium Sulphate  $[\text{Al}_2(\text{SO}_4)_3]$  or Sodium Aluminate  $[\text{NaAlO}_2]$  are added, they hydrolyze to  $\text{Al}(\text{OH})_3$  which entraps the fine precipitate of  $\text{CaCO}_3$  &  $\text{Mg}(\text{OH})_2$ .



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### Batch L-S Process-

Reaction takes place at Room Temperature.  
High Softening Time  
Soft Water with residual hardness of 60 ppm is obtained.  
Coagulants are required for the removal of fine impurities.



### Continuous L-S Process-

Reaction takes place at Room Temperature.  
Low Softening Time compared to Batch Lime Soda Process.  
Soft water rise up & filter through wood-filter.  
Soft Water with residual hardness of 30-40 ppm is obtained.  
Coagulants are required for the removal of fine impurities.  
Dissolved gases are not removed.

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**Hot L-S Process-**

Reaction takes place at 94-100°C by passing super heated steam into the reaction chamber

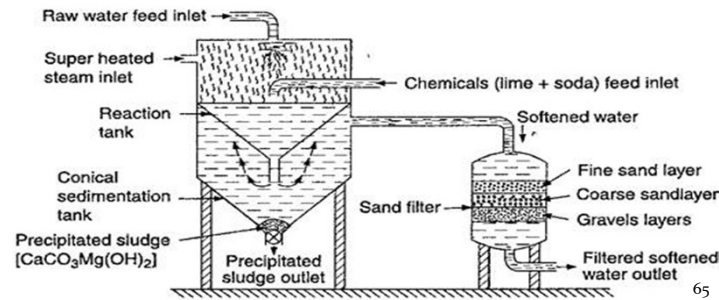
Softening rate of water is faster, Processing Time – 15 min.

Soft Water with residual hardness of 15-30 ppm residual hardness is obtained.

No Coagulant is required.

Quantity of chemicals required for softening is low.

Dissolved gases like CO<sub>2</sub> are removed to some extent.



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**Chemistry of Lime Soda Process**

Constituent	Reactions	Need
Ca(HCO <sub>3</sub> ) <sub>2</sub>	Ca(HCO <sub>3</sub> ) <sub>2</sub> + Ca(OH) <sub>2</sub> → 2CaCO <sub>3</sub> + H <sub>2</sub> O	L
CO <sub>2</sub>	CO <sub>2</sub> + Ca(OH) <sub>2</sub> → CaCO <sub>3</sub> + H <sub>2</sub> O	L
Mg(HCO <sub>3</sub> ) <sub>2</sub>	Mg(HCO <sub>3</sub> ) <sub>2</sub> + 2Ca(OH) <sub>2</sub> → 2CaCO <sub>3</sub> + Mg(OH) <sub>2</sub> + H <sub>2</sub> O	2L
CaCl <sub>2</sub>	CaCl <sub>2</sub> + Na <sub>2</sub> CO <sub>3</sub> → CaCO <sub>3</sub> + NaCl	S
CaSO <sub>4</sub>	CaSO <sub>4</sub> + Na <sub>2</sub> CO <sub>3</sub> → CaCO <sub>3</sub> + Na <sub>2</sub> SO <sub>4</sub>	
MgCl <sub>2</sub>	MgCl <sub>2</sub> + Ca(OH) <sub>2</sub> → Mg(OH) <sub>2</sub> + CaCl <sub>2</sub>	L + S
	CaCl <sub>2</sub> + Na <sub>2</sub> CO <sub>3</sub> → CaCO <sub>3</sub> + NaCl	
MgSO <sub>4</sub>	MgSO <sub>4</sub> + Ca(OH) <sub>2</sub> → Mg(OH) <sub>2</sub> + CaSO <sub>4</sub>	L + S
	CaSO <sub>4</sub> + Na <sub>2</sub> CO <sub>3</sub> → CaCO <sub>3</sub> + Na <sub>2</sub> SO <sub>4</sub>	
NaHCO <sub>3</sub>	NaHCO <sub>3</sub> + Ca(OH) <sub>2</sub> → CaCO <sub>3</sub> + H <sub>2</sub> O + Na <sub>2</sub> CO <sub>3</sub>	L - S
Free Acids (HCl)	HCl + Ca(OH) <sub>2</sub> → CaCl <sub>2</sub> + 2 H <sub>2</sub> O	L + S
	CaCl <sub>2</sub> + Na <sub>2</sub> CO <sub>3</sub> → CaCO <sub>3</sub> + NaCl	
FeSO <sub>4</sub>	FeSO <sub>4</sub> + Ca(OH) <sub>2</sub> → Fe(OH) <sub>2</sub> + CaSO <sub>4</sub>	L + S
	CaSO <sub>4</sub> + Na <sub>2</sub> CO <sub>3</sub> → CaCO <sub>3</sub> + Na <sub>2</sub> SO <sub>4</sub>	

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**Limitation of Lime Soda Process**

➤ Its not possible to remove all the hardness from water. In actual practice about 50-60 ppm will remain as residual hardness.

➤ Soft water contain appreciable concentration of soluble salts such as calcium sulphate and can not be used in high pressure boilers.

➤ We normally tolerate final total hardness on the order of 75-120 ppm as CaCO<sub>3</sub> but the Magnesium content should not exceeds 40 ppm as CaCO<sub>3</sub>.

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**Calculation of Lime & Soda Requirement**

➤ Ignore all those impurities like NaCl, KCl, K<sub>2</sub>SO<sub>4</sub>, Na<sub>2</sub>SO<sub>4</sub>, SiO<sub>2</sub>, Fe<sub>2</sub>O<sub>3</sub>, Ash which do not causes hardness.

➤ Convert all the hardness causing impurities into their CaCO<sub>3</sub> equivalent.

$$\text{Equivalent of CaCO}_3 = \frac{w \times \text{Molecular weight of CaCO}_3}{2 \times \text{Equivalent weight of Hardness producing substance}}$$

➤ Lime Requirement-

$$\frac{74}{100} [\text{Temp Ca}^{2+} + 2 \times \text{Temp Mg}^{2+} + \text{Per Mg}^{2+} + \text{Fe}^{2+} + \text{Al}^{3+} + \text{CO}_2 + \text{H}^+ + \text{HCO}_3^- - \text{NaAlO}_2] \text{ Volume of Water} \times \text{Purity}$$

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➤ Soda Requirement-

$$\frac{106}{100} [\text{Per Ca}^{2+} + \text{Per Mg}^{2+} + \text{Fe}^{2+} + \text{Al}^{3+} + \text{H}^+ - \text{HCO}_3^-] \text{ Volume of Water} \times \text{Purity}$$

➤ If 'x' is the purity of lime & 'y' is the purity of soda then  
Purity of Lime =  $100 / x$  & Purity of Soda =  $100 / y$

**Numerical on Lime Soda Process**

**Annexure-3**

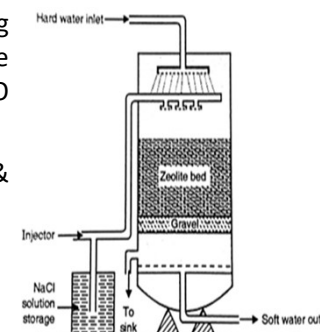
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**Zeolite Process or Permutit Process**

➤ Zeolites are naturally occurring hydrated sodium aluminosilicate (like  $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot x \text{SiO}_2 \cdot y \text{H}_2\text{O}$  where  $x = 2-10$ ,  $y = 2-6$ ).

➤ Zeolites are porous in nature & also known as Permutit.

➤ Zeolites are of two types-  
Natural Zeolite  
Synthetic Zeolite



➤ **Natural Zeolite:** Non porous, Amorphous & Durable.

**For e.g.:** Natrolite [ $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4 \text{SiO}_2 \cdot 2 \text{H}_2\text{O}$ ], Laumonite [ $\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 4 \text{SiO}_2 \cdot 4 \text{H}_2\text{O}$ ], Harmotome [ $\text{BaO} \cdot \text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 5 \text{SiO}_2 \cdot 5 \text{H}_2\text{O}$ ],

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➤ **Synthetic Zeolite**

Porous and posses gel like structure.

They are prepared by heating together sodium carbonate ( $\text{Na}_2\text{CO}_3$ ), alumina ( $\text{Al}_2\text{O}_3$ ), silica ( $\text{SiO}_2$ ).

Synthetic Zeolite posses higher exchange capacity per unit weight compared to natural zeolite.

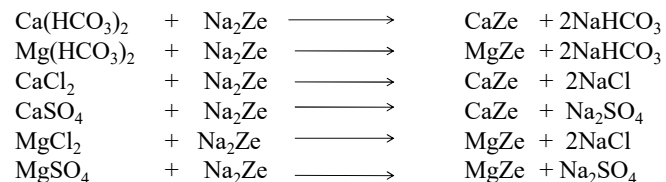
➤ **Process:**

Hard water is percolated at specified rate through bed of zeolite.

The hardness causing ions  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  etc. are retained by zeolite as  $\text{CaZe}$  &  $\text{MgZe}$  respectively and outgoing water contain Sodium Salts.

The water becomes free from hardness causing cations i.e.  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ .

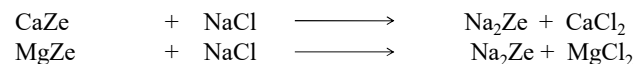
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➤ **Regeneration:**

After some time the zeolite is completely converted into  $\text{CaZe}$  &  $\text{MgZe}$ . The zeolite bed ceases to soften water i.e. it gets exhausted.

The zeolite bed is regenerated by passing concentrated Sodium Chloride (Brine) solution



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Instead of NaCl,  $\text{NaNO}_3$ , KCl,  $\text{KNO}_3$  can also be used for regeneration but NaCl is used due to its low cost & products of regeneration ( $\text{CaCl}_2$  &  $\text{MgCl}_2$ ) are highly soluble in water.

After regeneration the zeolite bed is rinsed with soft water to remove excess amount of NaCl,  $\text{CaCl}_2$  &  $\text{MgCl}_2$ .

### Limitation of Zeolite Process

- ✓ If the supplied water is turbid then suspended impurities should be removed first otherwise it will clog the pores of zeolite bed.
- ✓ If the supplied water contain large quantity of  $\text{Mn}^{2+}$  or  $\text{Fe}^{2+}$  then they must be removed first because these ions produce  $\text{MnZe}$  &  $\text{FeZe}$ , which are very difficult to regenerate.
- ✓ If mineral acids are present in the supplied water then they will destroy zeolite bed. So, supplied water must be neutralised with soda in advance.

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✓ Anions are not removed by this process. The Bicarbonate present in hard water get converted to  $\text{NaHCO}_3$  which goes into the soft water. If it is used in high pressure boilers then it dissociates into NaOH &  $\text{CO}_2$ .



✓ NaOH &  $\text{CO}_2$  are responsible for Caustic Embrittlement & Boiler Corrosion respectively.

### Advantages of Zeolite Process

- ✓ The hardness is nearly completely removed.
- ✓ Water of about 10 ppm residual hardness is produced.
- ✓ The impurities are not precipitated, so there is no danger of sludge formation.
- ✓ The process automatically adjust itself to water of different hardness.

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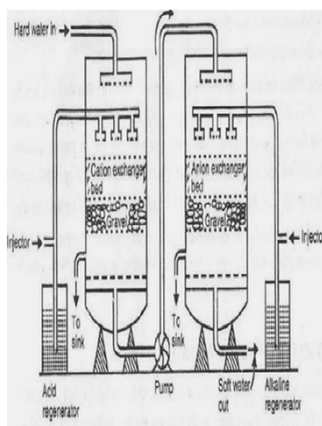
### ✓ Ion-Exchange Process

Removal of all the ions present in water is called Demineralization. The demineralization is done by Ion exchange resins.

❖ Ion exchange resin are insoluble, cross linked, high molecular weight, long chain organic polymer with microporous structure.

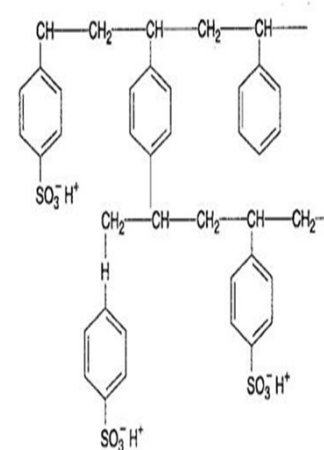
❖ The functional groups attached to the chains are responsible for ion exchange.

❖ Ion Exchange resins are of two types-  
Cation Exchange Resin ( $\text{R}^+\text{H}^+$ )  
Anion Exchange Resin ( $\text{R}^+\text{OH}^-$ )



### Cation Exchange Resins ( $\text{RH}^+$ )

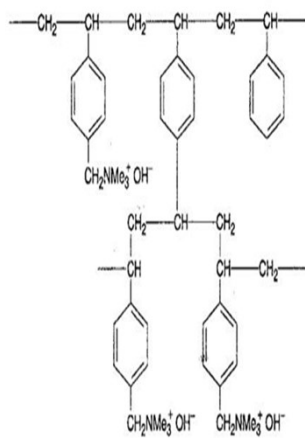
- They are styrene –divinyl benzene copolymer which on sulphonation or carboxylation becomes capable to exchange their hydrogen ions with cations in water.
- They have acidic functional group like  $-\text{SO}_3\text{H}$ ,  $-\text{COOH}$  or  $-\text{OH}$ , capable of exchanging the cationic portion of minerals with their hydrogen ions.



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**Anion Exchange Resins (R'OH<sup>-</sup>)**

- They are styrene –divinyl benzene or amine formaldehyde copolymer which contains basic functional group like amino or quaternary ammonium ( $-N^+R_3$ ) or quaternary phosphonium or tertiary sulphonium groups.
- These after treatment with dil NaOH becomes capable to exchange their  $-OH$  anions with the anions of water.



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**Process****Cation Exchange**

- The hard water is first passed through the cation exchange column which removes all the cations present in water then equivalent amount of  $H^+$  ions are released from this column into water.

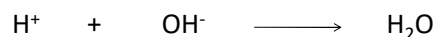
**Anion Exchange**

- After cation exchange column the water is passed through anion exchange column which removes all the anions present in water then equivalent amount of  $OH^-$  ions are released from this column into water.

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- The  $H^+$  and  $OH^-$  ions released from both the column combine to produce water.



- Thus water coming out of exchanger is free from cations as well as anions. Ion free water is known as Deionised or Demineralised water.

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**Regeneration**

- When capacities of cation and anion exchanger to exchange  $H^+$  and  $OH^-$  ions respectively are lost they are said to be exhausted.
- The exhausted cation exchange column is regenerated by passing dil HCl or dil  $H_2SO_4$ .



- The exhausted anion exchange column is regenerated by passing dil NaOH.



### Advantages of Ions Exchange Process

- ✓ The process can be used to soften highly acidic or alkaline water.
- ✓ It produces water of very low hardness (~2ppm).

### Disadvantages of Ions Exchange Process

- ✓ Turbidity in water reduces the efficiency of the process.
- ✓ Installation cost and operating cost is high.

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### Internal Treatment

- ✓ It means treating raw water inside the boiler. Its also known as sequestration.
- ✓ In this process an ion is prohibited to exhibit its original character by complexing or converting into more soluble salt by adding appropriate reagent.

➤ Internal treatment methods are-

- ❖ Colloidal Conditioning
- ❖ Carbonate Conditioning
- ❖ Calgon Conditioning
- ❖ Phosphate conditioning

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### ❖ Colloidal Conditioning

- Scale formation can be avoided in low pressure boilers by adding substances like Kerosene, tannin, agar-agar etc. which get adsorbed over the scale formation precipitate, thereby resulting in non-sticky and loose deposits which can be removed easily by blow down operation.

### ❖ Carbonate Conditioning

- Its used in low pressure boilers.
- For a salt to precipitate the ionic concentration should exceeds the solubility product [ $K_{sp} < I_p$ ].
- Scale formation can be avoided by adding  $\text{Na}_2\text{CO}_3$  to the boiler feed water.

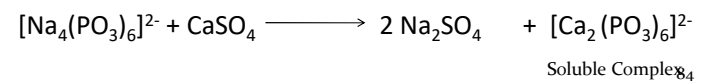
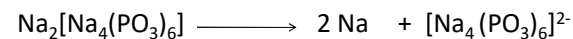
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- Scale forming salts like  $\text{CaSO}_4$  is converted into  $\text{CaCO}_3$ , which can be removed easily.

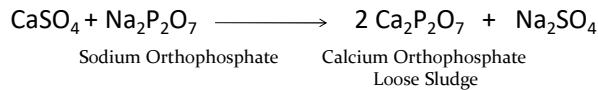
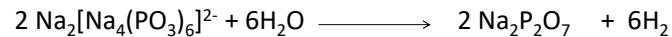


### ❖ Calgon Conditioning

- Calgon is **Sodium hexa meta phosphate** i.e.  $\text{Na}_2[\text{Na}_4(\text{PO}_3)_6]$ .
- Calgon converts the scale forming impurity like  $\text{CaSO}_4$  into soluble compound, which are harmless to boiler.



- At low temperature and pressure, it forms stable and soluble complex with calcium salt.
- At high temperature and pressure, its converted into Sodium orthophosphate which reacts with calcium salts to form calcium orthophosphate.



### ❖ Phosphate Conditioning

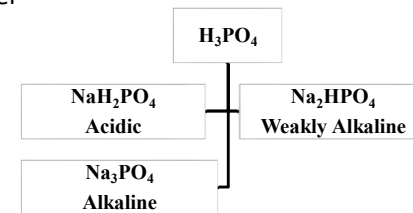
- It is applicable to high pressure boilers.

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- Scale formation is avoided by adding Sodium Phosphate which reacts with  $\text{Ca}^{2+}$  &  $\text{Mg}^{2+}$  salts to form non adherent and easily removable soft sludge of Calcium and Magnesium Phosphate.



- Choice of Phosphate salt depends upon alkalinity of boiler feed water-



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### Specification for potable water

Water is colourless, odourless, tasteless and universal solvent and usually contains several impurities (Gases, Solids and Colour)

### Specification for potable water as per Bureau of Indian Standards

S.No.	Characteristics	Desirable Limit (mg/L)
1	Colour, Odour, Taste	Colourless, Odourless and Tasteless
2	Turbidity	< 10 ppm
3	Alkalinity	pH = 7-7.5
4	pH	6.9
5	Dissolved Oxygen	---
6	Chloride	250
7	Total Hardness (as $\text{CaCO}_3$ ) mg/L	< 500

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S.No.	Characteristics	Desirable Limit (mg/L)
8	Sulphate	400
9	Nitrate	45
10	Cyannide	0.2
11	Fluoride	1.5
12	Chromium	0.05
13	Lead	0.05
14	Arsenic	0.05

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### ➤ Drinking Water Treatment

- Rivers, Lakes, Well are the most common source of water and do not confirm the specification of drinking water.
- Actual treatment method to be adopted depends upon the nature of impurities.

S.No.	Impurity	Treatment Process
1	Floating matter such as leaves, wood pieces etc.	Screening
2	Suspended Impurities such as sand, clay etc.	Sedimentation
3	Fine suspended inorganic matter	Sedimentation with Coagulation
4	Microorganisms and Colloidal impurities	Filtration
5	Pathogenic Bacteria	Disinfection

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### Screening

- It is the process of removing floating material like wood pieces, leaves, etc. from water.
- Raw water is passed through screens having holes, when floating matter is retained by them and water is allowed to pass.



### Sedimentation

- It is the process of removing suspended impurities by allowing the water to stand undisturbed in big tank for 2-8 hrs.
- Most of the particles settle down at the bottom of the tank due to gravitational force.



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### Sedimentation with coagulation

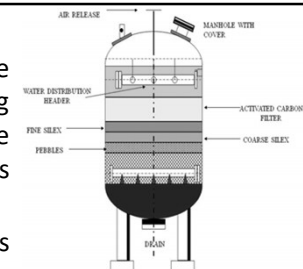
- Finely divided silica, clay and organic matter do not settle down easily and can not be removed by only by sedimentation.
- If coagulants (Alum  $[K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24 H_2O]$ , Sodium Aluminate  $NaAlO_2$ ) are added to water which hydrolyse to form gelatinous precipitate of  $Al(OH)_3$ .
- Colloidal impurities carry negative charge and coagulants give  $Al^{3+}$  ions which neutralize the colloidal particles and form flocculate. Due to force of gravity these bigger particles settle down.

Chemical Coagulants	Ideal pH range of use
$Al_2(SO_4)_3$	6.5-8.5
$NaAlO_2$	5.5-8.0
$FeSO_4$	>8.5

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### Filtration

- A water filter removes the impurities by minimizing contamination of water using fine physical barrier, a chemical process or a biological process.
- Activated Charcoal is used as decolourising agent.



### Disinfection

- The process of destroying/killing the pathogenic bacteria in water is known as disinfection.
- The process of complete destruction of all living organisms is known as sterilisation (Like Boiling). Sterilisation kills the bacteria for some time and does not provide any protection against future contamination.

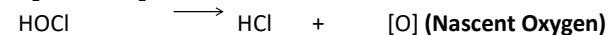
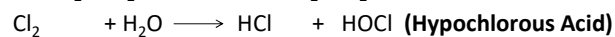
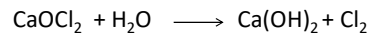
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### ➤ Methods of Disinfection

- (a) By Bleaching powder                      (b) By Chlorination  
(c) By Chloramine                              (d) By Ozone  
(e) By Ultraviolet radiation                  (f) By  $\text{KMnO}_4$

### ➤ Disinfection by bleaching powder

Disinfection can be done by adding Bleaching powder ( $\text{CaOCl}_2$ ) to the water



### Drawbacks-

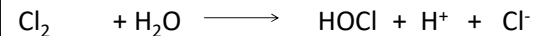
- Excess of bleaching powder imparts bad taste & smell to water.
- Bleaching powder is not stable so it deteriorates.
- It introduces Calcium in water and thus increases hardness.

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### ➤ By Chlorination

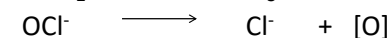
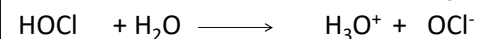
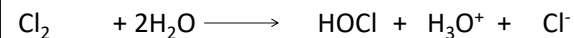
Chlorine is used as disinfectant in water treatment. It can be used directly as gas or in form of concentrated solution in water.

It produces hypochlorous acid which is germicide.



Hypochlorous Acid

Depending on pH value, hypochlorous acid gets convert into hypochlorite ion



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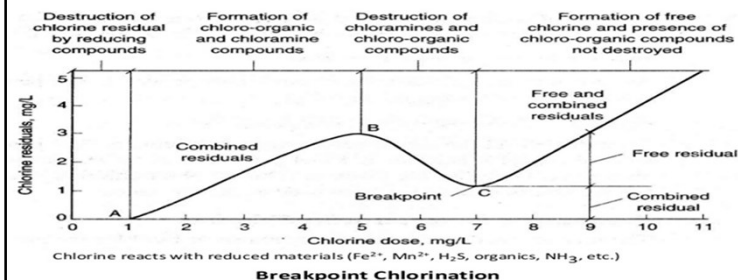
- The disinfection properties of chlorine in water are based on the oxidising power of oxygen atom & on chlorine substitution reactions.
- Hypochlorous acid ( $\text{HOCl}$ ) is electrically neutral while Hypochlorite ion ( $\text{OCl}^-$ ) is electrically negative.
- Hypochlorous acid ( $\text{HOCl}$ ) is strong disinfectant than  $\text{OCl}^-$ .  $\text{HOCl}$  breaks into  $\text{HCl}$  and atomic oxygen ( $\text{O}$ ), which is strong disinfectant.
- By nature the cell wall of pathogenic microorganism is negatively charged. Hypochlorous acid penetrates cell wall & kills the microorganisms or suffers reproductive failure.

S.No.	pH	$\text{HOCl}$	$\text{OCl}^-$
1	6	80%	20%
2	7.5	50%	50%
3	8	20%	80%

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### ➤ Break Point Chlorination / Free Residual Chlorination

- It means chlorination of water to such an extent that living organism as well as other organic impurities in water are destroyed.
- It involves addition of sufficient amount of chlorine to oxidise organic matter, reducing substances and free ammonia in raw water, leaving behind free chlorine which possesses disinfection action against pathogens bacteria.



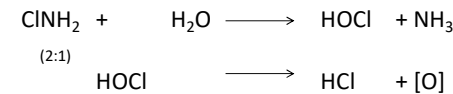


- **Stage-I:** Initially for lower chlorine doses of Chlorine, there is no free chlorine since all the added chlorine gets consumed in the oxidation of reducing substances present in water.
- **Stage-II:** As the amount of chlorine dosage is increased, amount of residual chlorine also steady increases. In this stage formation of chloro-organic takes place without oxidising them.
- **Stage-III:** At higher dose of applied chlorine, oxidation of organic compounds and microorganisms takes place & the amount of chlorine free chlorine also decreases. When oxidative destruction is complete it reaches a minima.
- **Stage-IV:** After minima, the added chlorine is not used in any reaction. Thus the residual chlorine keeps increasing in direct proportion to added chlorine.

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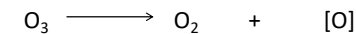
### ➤ Disinfection by Chloramine

- Chloramine has better bactericidal action than chlorine. Its more stable and does not produce any odour.



### ➤ Disinfection by Ozone

- Ozone is made by passing oxygen through ultraviolet light or an electrical discharge. Ozone is highly unstable breaks into oxygen and nascent oxygen.



- Nascent oxygen is powerful oxidising agent and oxidises organic matter and also kills bacteria. The main advantage of ozonation is lack of taste & odour.

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### ➤ Disinfection by UV Radiation

- Water is passed in thin layer around the lamp because the germicidal action of UV radiation depends on the intensity of the light, depth of exposure and contact time.
- Turbidity & minor traces of Iron reduces the light transmission.

### ➤ Sea Water Treatment

- Water containing high concentration of dissolved solids with peculiar salty or brackish taste is called brackish water. For e.g. Sea Water containing 3.5% of dissolved salts.
- The removal of dissolved solids (NaCl) from water is known as desalination process.

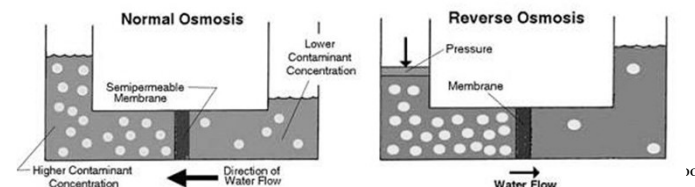
### ➤ Methods of Desalination

- |                     |                  |
|---------------------|------------------|
| (a) Reverse Osmosis | (b) Distillation |
| (c) Electrodialysis | (d) Freezing     |

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### ➤ Reverse Osmosis / Super or Hyper Filtration

- Osmosis is the phenomenon by virtue of which flow of water takes place from a region of low concentration to high concentration, when two solutions of different concentration are separated by semi-permeable membrane. Semi-permeable membrane do not allow the passage of solute but allows the passage of solvent only.
- The flow of solvent continues till the concentration is equal on both the sides of semi-permeable membrane. The driving force for osmosis is known as Osmotic Pressure.



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- If the hydrostatic pressure in excess of osmotic pressure is applied on the concentrated side, the flow of solvent reversed; it is forced to move from concentrated side to dilute side across the membrane.
- Since semi-permeable membrane do not allow the passage of solute but allows the passage of solvent only. The concentrated solution becomes more concentrated.
- There are 03 types of R.O. membrane  
 (a ) Cellulosic                      (b) Fully aromatic polyamide  
 (c ) Thin Film Composite
- The pore size of R.O. membrane is around 0.0001 micron. A pressure of about 15-40 Kg/cm<sup>2</sup> is applied for separating water from contaminants.

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### • Application

