

## Sources of Water

### (A) Surface water

#### Surface water -

- (i) Rain water - Purest form of natural water.
- (ii) River water - Contains dissolved minerals (from rocks) of the soil such as  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{HCO}_3^-$  of  $\text{Na}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  &  $\text{Fe}^{2+}$ .
- (iii) Lake water - Lesser dissolved minerals but more organic matter.
- (iv) Sea water - most impure form of natural water.
  - Rivers throw impurities carried by them.
  - continuous evaporation from the large surface

### Under ground water -

The rain water which percolates into the earth and travels downwards and comes out in the form of spring. It contains more dissolved salts. Well water is another example of underground water.

## Impurities in water :-

- (i) Suspended Impurities :- It may be inorganic (clay & sand) or organic (oil globules, vegetable & animal matter) in nature.
- (ii) Colloidal Impurities :- Products from organic waste, finely divided silica & clay etc.
- (iii) Dissolved Impurities :- Due to the presence of dissolved salts like carbonates, bicarbonates, chlorides & sulphates of calcium, magnesium, iron & sodium. Dissolved gases like  $\text{CO}_2$ ,  $\text{O}_2$  etc.
- (iv) Microorganisms :- Bacteria, fungi, algae, pathogens etc.

## WATER TREATMENT

The water can be classified as soft and hard water depending upon its behaviour towards soap.

1.) HARD WATER :- It does not produce lather with soap readily - ex- sea water, river water, well water and tap water.

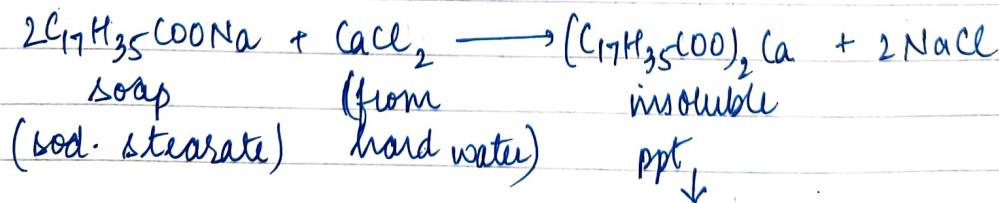
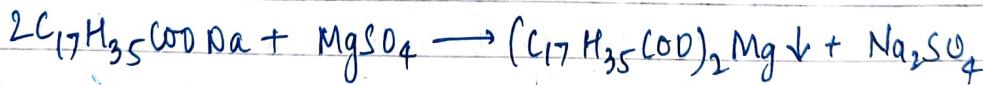
The hardness producing salts elevate the b.p. of water, thus increasing the consumption of fuel and time.

2)) SOFT WATER :- It produces lather with soap readily. ex - distilled water, rain water, demineralised water and also less fuel and time is required for cooking in soft water.

HARDNESS :- It is the soap consuming capacity of water sample.

(~~soaps~~ soaps = sodium salts of long chain fatty acids, as for eg. - sodium salts of oleic acid, palmitic acid, stearic acid, etc.)

In hard water  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  are present which react with soap as -



has no detergent value or  
of no use in washing purpose.

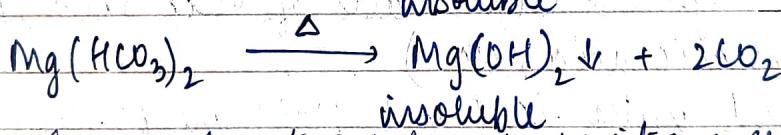
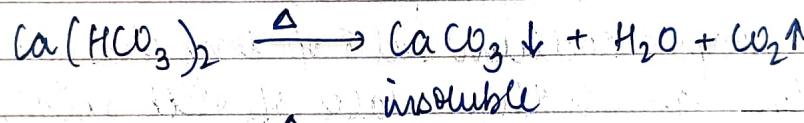
Therefore, no lather will be formed until all the  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  ions are present in hard water, resulting in wastage of soap. Other hardness causing ions are also present in hard water such as  $\text{Fe}^{2+}$ ,  $\text{Mn}^{2+}$  and  $\text{Al}^{3+}$ , but these are present in traces. Carbonic acid also consumes soap, thus contributes to hardness.

However, in practice, the hardness of a water sample is usually taken as a measure of its  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  content.

Degree of hardness :- Degree of hardness is commonly defined as the total quantity of hardness causing salts present in water. It is expressed in CaCO<sub>3</sub> equivalent.

### TYPES OF HARDNESS

1.) TEMPORARY HARDNESS (CARBONATE HARDNESS) :- It is due to the presence of bicarbonates of  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  and other heavy metals and carbonates of  $\text{Fe}^{2+}$ . It can be removed by boiling of water as -



The insoluble carbonates & hydroxides deposit as a crust at the bottom of the vessel.

2.) PERMANENT HARDNESS (NON-CARBONATE HARDNESS) :-

It is due to the presence of  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$  of  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Fe}^{2+}$  and other heavy metals. It can't be removed by boiling but by special chemical methods as -

- Lime Soda Process
- Zeolite Process
- Ion-Exchange Process

## ALKALINE AND NON-ALKALINE HARDNESS

The hardness due to  $\text{CO}_3^{2-}$ ,  $\text{HCO}_3^-$  and  $\text{OH}^-$  of the hardness producing cations, is called as alkaline hardness. It is determined by titration of water sample with HCl using HPh and MeOH as indicator.

The non alkaline hardness is obtained by subtracting the alkaline hardness from the total hardness.

## DISADVANTAGES OF HARD WATER IN DIFFERENT USES

1. Hard water causes corrosion of boilers and the scale formed prevents the efficient heat transfer.
2. Hard water produces unpleasant taste and also requires more fuels in cooking. It also has bad effect on digestive system, possibility of forming Ca-oxalate in urinary track increases.
3. The alkaline hardwater neutralizes the fruit acids which destroys the tastes of beverages.
4. Hard water causes problem in crystallization of sugar.
5. In textile industries, the hard water causes uneven drying, precipitation of basic dyes and decrease the solubility of acidic dyes.
6. Hard water consumes more soaps and detergents and salts of  $\text{Fe}^{2+}$  and  $\text{Mn}^{2+}$  impart undesirable colour to the fabric, thus it is of no use in laundry.

## UNITS OF HARDNESS

1.) PART PER MILLION (ppm) :- It is no. of parts of  $\text{CaCO}_3$  equivalent hardness per million parts of water.

$1 \text{ ppm} = 1 \text{ part of } \text{CaCO}_3 \text{ equivalent hardness in } 10^6 \text{ parts of water.}$

2.) MILLIGRAM PER LITRE (mg/L) :- It is no. of milligrams of  $\text{CaCO}_3$  equivalent hardness present in 1 L of  $\text{H}_2\text{O}$ .

$1 \text{ mg/L} \equiv 1 \text{ mg of } \text{CaCO}_3 \text{ equivalent hardness in 1 L of water.}$

$\equiv 1 \text{ mg of } \text{CaCO}_3 \text{ equivalent hardness in } 10^6 \text{ mg of water.}$

$\equiv 1 \text{ part of } \text{CaCO}_3 \text{ equivalent hardness in } 10^6 \text{ parts of water.}$

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

$$1 \text{ L} = 1 \text{ kg} = 10^6 \text{ mg}$$

3.) DEGREE FRENCH ( $^{\circ}\text{F}$ ) :- It is no. of parts of  $\text{CaCO}_3$  equivalent hardness per  $10^5$  parts of water.

$1^{\circ}\text{F} = 1 \text{ part of } \text{CaCO}_3 \text{ equivalent hardness per } 10^5 \text{ parts of water.}$

4.) CLARKE'S DEGREE ( $^{\circ}\text{C}_1$ ) :- It is no. of parts of  $\text{CaCO}_3$  equivalent hardness per  $7 \times 10^4$  (70,000) (1 gallon) parts of water.

$$(70,000 = 1 \text{ gallon})$$

ppm  $\rightarrow$   $10^6$  parts of water contains  $\text{CaCO}_3$  equivalent hardness = 1 part

${}^\circ\text{F} \rightarrow 10^5$  parts of water contains  $\text{CaCO}_3$  equivalent hardness =  $\frac{1}{10^6} \times 10^5 = \frac{1}{10} = 0.1 {}^\circ\text{F}$

$\text{Cl} \rightarrow 7 \times 10^4$  parts of water contains  $\text{CaCO}_3$  equivalent hardness =  $\frac{1}{10^6} \times 7 \times 10^4 = \frac{7}{100} = 0.07 {}^\circ\text{Cl}$

OK  $1 \text{ ppm} = 1 \text{ mg/L} = 0.1 {}^\circ\text{F} = 0.07 {}^\circ\text{Cl} = 0.02 \text{ meq/L}$

[milli equivalent per litre - No. of  $\text{CaCO}_3$  eq. hardness present in 20,000 parts of water]

### CALCIUM CARBONATES EQUIVALENTS

Hardness of water is expressed in terms of  $\text{CaCO}_3$  equivalents as -

- 1.) Its M.wt. = 100 which makes the calculation easy.
- 2.) It is most insoluble salt that can be precipitated in water treatment.

$$\text{CaCO}_3 \text{ equivalents of a hardness causing impurity (ppm)} = \frac{\text{conc}^n \text{ of impurity (mg/L)} \times \frac{\text{Eq. wt of CaCO}_3}{\text{Eq. wt of impurity}}}{\text{Eq. wt of CaCO}_3}$$

or

$$\text{CaCO}_3 \text{ eq. of impurity (ppm)} = \frac{\text{conc}^n \text{ of impurity (mg/L)} \times \frac{50}{\text{Eq. wt of impurity}}}{\text{Eq. wt of CaCO}_3}$$

## BOILER TROUBLES

6.

Boilers are used for steam generation in industries and powerhouses. If hardwater is directly fed into the boilers it may lead to the following problems :

- (i) Scale and sludge formation
- (ii) Caustic embrittlement
- (iii) Boiler corrosion
- (iv) Priming and foaming

### [A]- Scale and Sludge

In boilers steam is generated continuously by evaporation of water. As the water evaporates continuously, the conc' of dissolved salts increases, finally the solution becomes saturated. The point at which ionic product exceeds the solubility product, they are thrown out as ~~pre~~ precipitates.

→ If the precipitate formed is soft, loose and floats in boiler water it is called sludge.

Reason for sludge formation :- Sludges are formed by the substances which have greater solubility in hot water than in cold water. e.g.  $MgCO_3$ ,  $MgCl_2$ ,  $CaCl_2$ ,  $MgSO_4$ , etc.

### Disadvantages of sludge formation

- (i) Sludges are bad conductors of heat and hence a portion of heat generated is wasted which decreases the efficiency of boiler.
- (ii) Excessive sludge may cause chocking of pipe in the region where there is less water circulation.

Prevention of sludge formation - Formation of sludge formation can be prevented by frequent blow down operation (which consists of removal of a portion of concentrated water from boiler and replacing it with fresh water). 7

→ If the precipitates are in the form of hard deposits, firmly sticking on the wall of the boiler and can not be removed easily by scrapping, they are known as scales. Reasons for scale formation: salts which are soluble in cold water but insoluble in hard water e.g.  $\text{CaSO}_4$ ,  $\text{CaCO}_3$ ,  $\text{Mg}(\text{OH})_2$  etc.

### Disadvantages of scale formation :-

- (i) Wastage of fuel - Scales are bad conductors of heat; therefore, reduces the efficient heat transfer to the boiler for effective steam generation.
- (ii) Decrease in efficiency of boiler - take place as scales also deposit on the way of water circulation of boiler as condensers, valves etc.
- (iii) Lower of boiler safety :- To get sufficient supply of steam the boilers are overheated which makes boiler walls weaker and unsafe for bearing the high pressure.
- (iv) Danger of explosion - sometimes the scale deposits crack due to overheating and expansion of boiler walls. It creates very high pressure and thus the danger of explosion.

## Removal of Scale formation

- (i) Brittle scales are removed by thermal shock.
- (ii) Hard & adherent scales are removed by chemicals e.g. silicates &  $\text{CaSO}_4$  scales by EDTA &  $\text{CaCO}_3$  scales by 10% HCl solution.
- (iii) Loose and adherent scales by scrapping and blow down operation.

## Prevention of Scale formation - Scale formation

can be prevented by -

External treatment method like lime-soda, zeolite and ion-exchange method etc. or internal treatment method like calgon, phosphate and carbonate conditioning etc.

## [B] - Boiler corrosion

Loss of boiler body material or its useful properties by chemical or electrochemical interaction with its environment is known as boiler corrosion.

Corrosion in boiler may be due to -

- (i) Dissolved  $\text{CO}_2$  - (which produces carbonic acid in boiler). [NOTE:  $\text{CO}_2$  can be removed by adding  $\text{NH}_4\text{OH}$  as  $\text{CO}_2 + 2\text{NH}_4\text{OH} \rightarrow (\text{NH}_4)_2\text{CO}_3 + \text{H}_2\text{O}$  or by mechanical deaeration].
- (ii) Dissolved  $\text{O}_2$  : - Boiler material gets corroded by  $\text{O}_2$  and forms rust  $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$ . [Can be removed by adding  $\text{Na}_2\text{SO}_3$  etc as  $2\text{Na}_2\text{SO}_3 + \text{O}_2 \rightarrow 2\text{Na}_2\text{SO}_4$  or by mechanical deaeration etc.]
- (iii) By acids from dissolved salts like  $\text{MgCl}_2$  HCl from salts like  $\text{CaCl}_2$  &  $\text{MgCl}_2$  etc. is produced

in chain-like manner and cause extensive corrosion.  
[can be removed by adding alkalis].

### [C] - Caustic Embrittlement

caustic embrittlement is a type of corrosion due to which boiler material becomes brittle in presence of high concentration of causticity and thermal stress.

It is characterised by the formation of intergranular cracks on the boiler material particularly at the places of high stress like bends, joints and riveted beams etc.

During softening by lime-soda process, residual  $\text{Na}_2\text{CO}_3$  is usually present in soft water. under high pressure it decomposes as -



makes the water more alkaline or caustic.

- Prevention of corrosion - by using sod. phosphate as water softening agent in place of  $\text{Na}_2\text{CO}_3$ .
- by adding  $\text{Na}_2\text{SO}_4$  to boiler water to block the hair cracks
  - by adding tannin and lignin to block hair cracks.

### [D] - Priming & Foaming

As steam rises from the surface of boiling water in boiler it may be associated with small droplets of water. Steam containing liquid water is called as Wet steam.

The process of steam formation is known as priming, which is due to -

- (i) suspended impurities or dissolved impurities.
- (ii) sudden boiling
- (iii) high steam velocity
- (iv) faulty boiler design

Priming can be minimised by -

- (i) Proper designing
- (ii) Maintaining low water levels
- (iii) Controlled rate of steam velocity
- (iv) Efficient softening

The formation of persistent bubbles in boiler which do not break easily is known as foaming. It is causing caused by the presence of oils and alkalis in water.

Foaming can be minimised by -

- (i) Removal of foaming agent like oil, grease etc.
- (ii) Addition of castor oil and anti-foaming agent.

The process of removing hardness from water is called as softening of water :- INTERNAL TREATMENT METHODS

The treatment of raw water inside the boiler is known as internal treatment. This is also known as internal conditioning or sequestration.

In internal treatment suitable chemical are added to the boiler water either

- (a) to precipitate the scale forming impurities in the form of sludges which can be removed by blow down operation or
- (b) to convert them to into compounds which will stay in dissolved form <sup>in</sup> water. The internal treatment

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### [Na<sub>2</sub>(PO<sub>3</sub>)<sub>6</sub>]

methods are :-

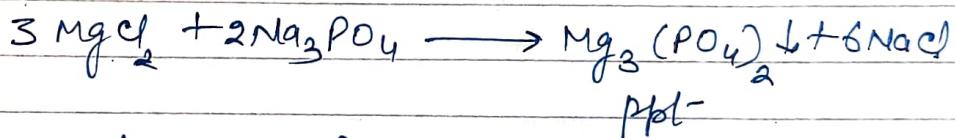
(i) CALGON CONDITIONING :- calgon is sodium hexa-metaphosphate  $Na_2[Na_4(PO_3)_6]$ . It is extensively used in internal treatment and prevent the scale and sludge formation by converting scale forming impurity like  $CaSO_4$  to highly soluble complex in low pressure boilers. By this method the calcium ions are trapped even if they are present in very small quantities.

$$2CaSO_4 + Na_2[Na_4(PO_3)_6] \rightleftharpoons Na_2[Ca_2(PO_3)_6] + 2Na_2SO_4$$

salt in hardwater (in boiler)	sod. hexa meta phosphate (calgon)	soluble complex
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Calgon conditioning is preferred as in this method, soluble complex is formed and no ppt as sludge or scale is formed. No need of removal.

(ii) Phosphate conditioning :- In this phosphate conditioning scale formation is prevented by addition of sod. phosphate which reacts with Mg and Ca salts giving non-adherent and soft sludge of Mg & Ca-phosphate respectively. This method is used for high P boilers around pH range 9.5-10.5.



The phosphates employed are  $NaHPO_4$ ,  $Na_2HPO_4$ ,  $Na_3PO_4$ . Then the ppt is removed by blowdown operation.

(iii) Carbonate conditioning :- The low pressure boilers scale formation can be avoided by adding  $Na_2CO_3$  to boiler water.



Limitation of carbonate conditioning :- Ppt

- excess  $Na_2CO_3$  in high P boilers leads to caustic embrittlement as  $Na_2CO_3$   $\xrightarrow{\text{high P.}}$   $NaOH + CO_2$
- It is applicable to low pressure boiler only.

(iv) colloidal conditioning:- Scale formation can be avoided in lower pressure boilers by adding substances like kerosene, agar-agar, tannin etc. which adsorbs over the scale forming precipitates, thereby yielding non-sticky and loose deposits which can easily removed by blow-down operation.

[ tannins and lignins are organic compounds found in plants and trees, particularly in bark, leaves and seeds ].

## EXTERNAL TREATMENT METHODS

In external treatment the water is softened by chemical processes like lime-soda, zeolite process, ion-exchange process before feeding it into the boiler.

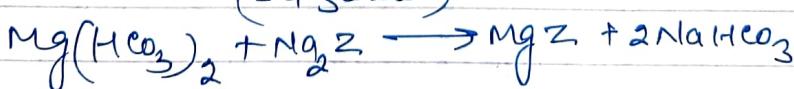
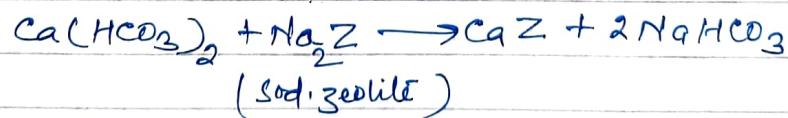
### ZEOLITE METHOD OF WATER SOFTENING

Zeolites are inorganic ion exchangers and are complex inorganic salts having the property of exchanging cations of hard water with  $\text{Na}^+$  ions. For e.g. hydrated sodium aluminium silicates :  $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot y\text{H}_2\text{O}$

Where  $x = 2-10$  and  $y = 2-6$  ( $\text{Na}_2\text{Z}$ )

Their technical name is permutil. They may be natural or synthetic. For the preparation of (non-porous) (porous)

Synthetic permutil a mixture of soda ash ( $\text{Na}_2\text{CO}_3$ ), sand ( $\text{SiO}_2$ ) and alumina ( $\text{Al}_2\text{O}_3$ ) is fused and then washed with water. A porous mass of permutil is obtained. The cations present in hard water are exchanged for sodium ions as:-



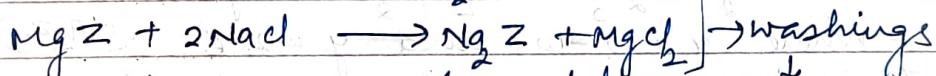
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Soluble Fe and Mn are always present in the divalent form in waters containing bicarbonates alkalinity. They may also get removed simultaneously.

The sodium ions are soluble in water and do not interfere in lather formation, hence do not cause hardness in water.

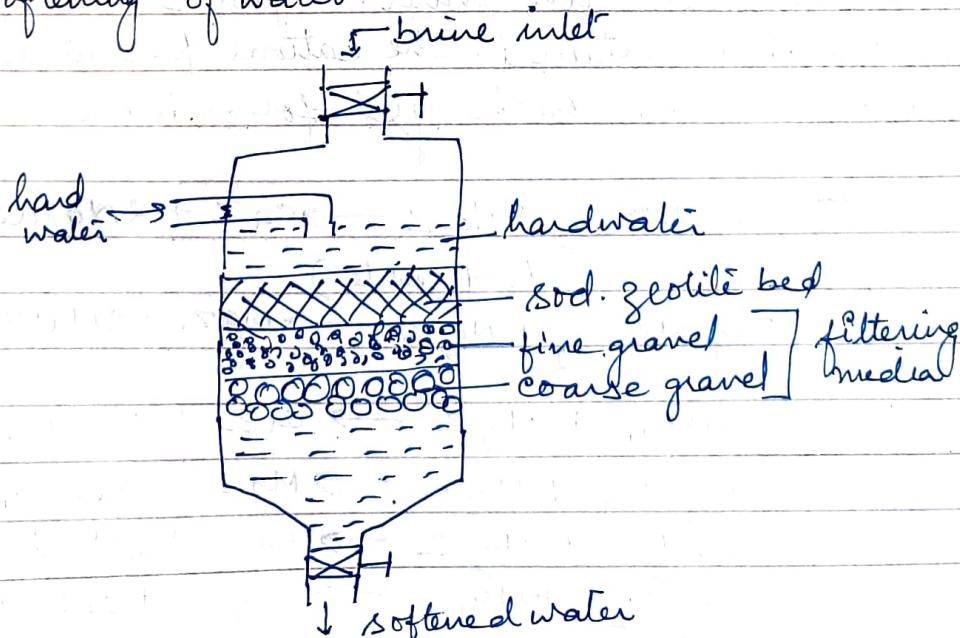
### REGENERATION OF PERMUTIT :

As the process continues, the zeolite bed gets exhausted, because a whole of sod. zeolite gets converted to calcium or magnesium zeolite. It is regenerated by passing 10% concentrated NaCl solution (brine) through it.



exhausted zeolite      regenerated zeolite      highly soluble  
can be readily rinsed out from the  
zeolite bed

The regenerated zeolite is used again for softening of water.

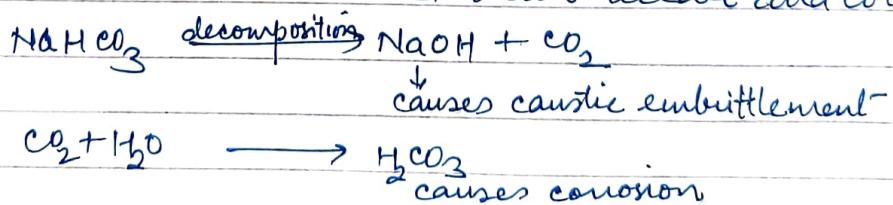


### Advantages of zeolite process :-

- 1- Hardness is removed upto 10 ppm.
- 2- Equipment used is compact and hence occupies less space.
- 3- There is no problem of sludge formation as impurities are not precipitated but exchanged by  $\text{Na}^+$ .

### Limitations and Disadvantages :-

- 1- The water having turbidity and suspended matter should be well treated before introducing it in zeolite softener as the turbidity and suspended matter clog the zeolite bed and rate of flow decrease.
- 2- The pH of water should be maintained at  $\text{pH} = 7$  as acidity or alkalinity may attack the zeolite bed.
- 3- If  $\text{Fe}^{2+}$  &  $\text{Mn}^{2+}$  ions are present in large quantities, they form their respective zeolites which cannot be regenerated again.
- 4- Hot water dissolves zeolite.
- 5- Only cations ( $\text{Ca}^{2+}$  &  $\text{Mg}^{2+}$ ) are replaced by  $\text{Na}^+$  and not the anions. The bicarbonates present in hard water get converted into sod. bicarbonate which go into softened water.
- 6- Softened water containing  $\text{NaHCO}_3$  caused caustic embrittlement and  $\text{CO}_2$  goes along with steam and makes the condensed water acidic and corrosive.



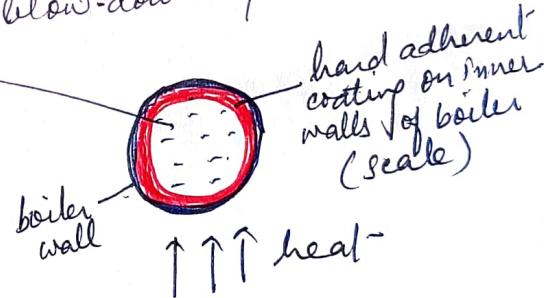
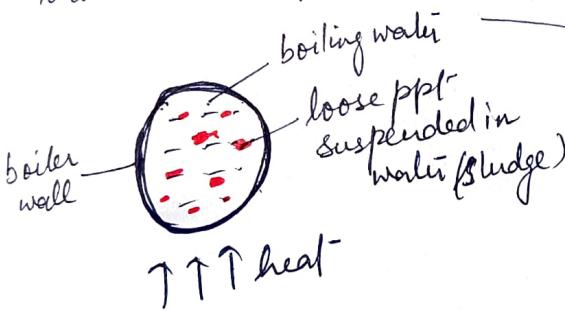
## Difference b/w sludges & scales -

### Sludges.

1. Sludges are soft, loose, & slimy precipitates.
2. They are non-adherent deposits and can be easily removed.
3. formed by substances like  $\text{CaCl}_2$ ,  $\text{MgCl}_2$ ,  $\text{MgSO}_4$ ,  $\text{MgCO}_3$  etc.
4. formed at comparatively colder portions of the boiler.
5. They decrease the efficiency of boiler but are less dangerous.
6. Can be removed by blow-down operation

### Scales

- Scales are hard deposits.
- They stick very firmly to the inner surface of boiler and are very difficult to remove.
- formed by substances like  $\text{CaSO}_4$ ,  $\text{Mg}(\text{OH})_2$ ,  $\text{CaCO}_3$ ,  $\text{CaSiO}_3$  etc.
- formed generally at heated portions of the boiler.
- Decrease the efficiency of boiler and chances of explosions are also there.
- can not be removed by blow-down operation.



## Numericals on $\text{CaCO}_3$ eq.

Q.1. A water sample contains 408 mg of  $\text{CaSO}_4$  per litre. Calculate the hardness in terms of  $\text{CaCO}_3$  eq.

Soln.  $\text{CaCO}_3$  eq. hardness =  $\frac{408 \times 50}{68} = 300 \text{ ppm}$

$$\left[ \text{Eq. wt of } \text{CaSO}_4 = \frac{\text{Mol. wt of } \text{CaSO}_4}{2} \right. \\ \left. = \frac{40 + 32 + 4 \times 16}{2} = 68 \right]$$

Q.2. How many grams of  $\text{MgCO}_3$  dissolved per litre gives 84 ppm of hardness?

$$\left[ \text{Eq. wt of } \text{MgCO}_3 = \frac{\text{Mol. wt of } \text{MgCO}_3}{2} \right. \\ \left. = \frac{24 + 12 + 3 \times 16}{2} = 42 \right]$$

$$84 = \frac{x \times 50}{42} \\ x = \frac{42 \times 84}{50} = 70.56 \text{ ppm} \\ = 70.56 \text{ mg/L} = 70.56 \times 10^{-3} \text{ g/L}$$

## Numerical on Temp. & Permanent Hardness

Q.1. Calculate the temp. and permanent hardness of a water in different units, which is having following analysis:

$$\text{Mg}(\text{HCO}_3)_2 = 73 \text{ mg/L} = \frac{73 \times 50}{73} = 50 \text{ mg/L} \left( \frac{100}{162} \right)$$

$$\text{Ca}(\text{HCO}_3)_2 = 162 \text{ mg/L} = \frac{162 \times 50}{81} = 100 \text{ mg/L} \left( \frac{100}{162} \right)$$

$$\text{CaSO}_4 = 136 \text{ mg/L} = \frac{136 \times 50}{68} = 100 \text{ mg/L} \left( \frac{100}{136} \right)$$

$$\text{MgO}_2 = 95 \text{ mg/L} = \frac{95 \times 50}{47.5} = 100 \text{ mg/L} \left( \frac{100}{95} \right)$$

$$\text{CaCl}_2 = 111 \text{ mg/L} = \frac{111 \times 50}{55.5} = 100 \text{ mg/L} \left( \frac{100}{111} \right)$$

$$\text{NaCl} = 100 \text{ mg/L} \rightarrow \text{IGNORED}$$

$$\text{Temp. hardness} = \text{Mg}(\text{HCO}_3)_2 + \text{Ca}(\text{HCO}_3)_2 \\ = 50 + 100 = 150 \text{ mg/L} = 150 \text{ ppm} \\ = 15.0^{\circ}\text{F} = 10.5^{\circ}\text{C}$$

$$\text{Perm. hardness} = \text{CaSO}_4 + \text{MgCl}_2 + \text{CaCl}_2 \\ = 100 + 100 + 100 \text{ mg/L} = 300 \text{ mg/L} = 300 \text{ ppm} \\ = 30.0^{\circ}\text{F} = 21^{\circ}\text{C}$$

$$\text{Total hardness} = 450 \text{ ppm} = 31.5^{\circ}\text{C} = 45^{\circ}\text{F}$$

Q 100 mL of water sample has a hardness equivalent to 12.5 mL of 0.08 N  $\text{MgSO}_4$ . What is its hardness in ppm?

$$\begin{array}{lcl}
 \text{Water sample} & & \text{MgSO}_4 \\
 N_1, V_1 & = & N_2, V_2 \\
 N_1 \times 100 & = & 0.08 \times 12.5 \\
 N_1 & = & \frac{1}{100}
 \end{array}$$

$$\begin{aligned}
 \text{Strength} &= N_1 \times \text{Eq. wt of MgSO}_4 \\
 &= \frac{1}{100} \times 60 = 0.6 \text{ g/L} = 600 \text{ mg/L}
 \end{aligned}$$

$$\begin{aligned}
 \text{CaCO}_3 \text{ eq. (ppm)} &= \text{Concen of impurity} \times \frac{50}{\text{Eq. wt of salt}} \\
 &= 600 \times \frac{50}{60} = \underline{\underline{500 \text{ ppm}}}
 \end{aligned}$$

## Numericals on Zeolite Method

Q. A zeolite softener was 90% exhausted by removing hardness completely when 10,000 L of hard water sample passed through it. The exhausted zeolite bed required 200 L of 3% NaCl soln for its complete regeneration. Calculate the hardness of water.

Soln. Hardness in terms of  $\text{CaCO}_3$  (ppm) 
$$= \frac{\text{Wt of NaCl (mg/L)} \times \text{Vol. of NaCl (L)}}{\frac{x}{100} \times \text{Vol. of water (L)}} \times \frac{50}{58.5}$$

3% NaCl means -  $(x = 90)$ , where  $x = \%$  of zeolite softener exhausted.

$$\begin{aligned} 100 \text{ mL} &\rightarrow 3 \text{ g NaCl} \\ 1000 \text{ mL} &\rightarrow \frac{3}{100} \times 1000 \\ (\text{L}) &= 30 \text{ g} \\ &= 30 \times 10^3 \text{ mg/L} \\ &= 30 \times 10^3 \text{ mg/L} \end{aligned}$$

$$\begin{aligned} &= \frac{30 \times 1000 \times 200}{\frac{90}{100} \times 10,000} \times \frac{50}{58.5} = 6 \times 10^6 \times 50 \\ &= \frac{6 \times 10^3 \times 50}{9 \times 58.5} = \frac{300 \times 10^3}{526.5} \end{aligned}$$

Q. 10,000 L of hard water was made soft with zeolite, the zeolite required a total amount of 8 L of NaCl soln containing 150 g/L of sodium chloride for regeneration. Calculate the hardness of water.

Soln. Hardness in terms of  $\text{CaCO}_3$  (ppm) 
$$= \frac{\text{Wt of NaCl (mg/L)} \times \text{Vol. of NaCl (L)}}{\text{Vol. of Water (L)}} \times \frac{50}{58.5}$$

$$= \frac{150 \times 10^3 \times 8}{10,000} \times \frac{50}{58.5} = 102.5 \text{ mg/L} = 102.5 \text{ ppm}$$

150 g/L i.e.

$$\begin{aligned} 1000 \text{ mL} &\rightarrow 150 \text{ g NaCl} \\ 1 \text{ L} &\rightarrow \frac{150}{1000} \\ 100 \text{ mL} &\rightarrow \frac{150}{1000} \times 100 = 15 \text{ g} \\ &= 15\% \end{aligned}$$

Q. The hardness of 50,000 L of a sample of water was removed by passing it through a zeolite softener. The softener then required 200 L of NaCl soln containing 150 g/L of NaCl for regeneration. Calculate the hardness of water sample.

$$\text{Softm. Hardness of water in terms of } \text{CaCO}_3 \text{ eq.} = \frac{150 \times 10^3 \times 200}{50,000} \times \frac{50}{58.5} = 512.8 \text{ mg/L} \\ = \text{ppm.}$$

Q. 10.00 L of hard water is softened by zeolite. The zeolite requires 800 mL of NaCl for regeneration. The soln of NaCl is of concn 150 g/L, calculate the hardness of water.

$$\text{Softm. Hardness in } \text{CaCO}_3 \text{ eq.} = \frac{150 \times 10^3 \times 800}{10,000} \times \frac{50}{58.5} = 32.051.2 \text{ L} \\ = 32.051 \times 10^3 \text{ L} \\ = 150 \times 10^3 \times 0.800(\text{L}) \times \frac{50}{58.5} = 102.5 \text{ mg/L} \\ = \text{ppm}$$

Q. An exhausted zeolite softener was regenerated by passing 150 L of NaCl soln, having a strength of 180 g/L of NaCl. If the hardness of water is 600 ppm, calculate the total volume of water that is softened by this softener.

$$\text{Hardness in (600) } \text{CaCO}_3 \text{ eq. (ppm)} = \frac{150 \times 10^3 \times 150}{\text{Vol. of water}} \times \frac{50}{58.5}$$

$$\text{Vol. of water} = \frac{150 \times 10^3 \times 150}{600} \times \frac{50}{58.5} \\ = 32.051 \times 10^3 \text{ L.}$$