

Module Trouble II

Boiler Trouble

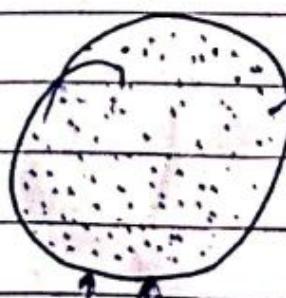
- Scale and Sludge formation
- Caustic Embrittlement.
- Boiler Corrosion
- Priming and foaming

Scale and Sludge formation

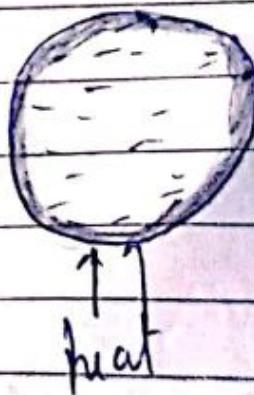
→ Due to continuous evaporation of water in boilers, the concentration of dissolved salts in hardwater increases progressively and finally when ionic product exceeds the solubility product, these salts are precipitated precipitated on the inner wall of boiler.

→ If the precipitate are loose, slimy and floating they are known as sludge.

→ If the precipitated matter form a hard coating inside the boiler surface they are called scales.



loose and
floating precipitate
(Sludge)



hard
coating
(scale)

Cross section of boiler

Formation of sludge

Sludge \rightarrow It is a soft loose and slimy precipitate formed in the boiler. It can be easily removed with a wire brush. Sludge is formed in comparatively colder area of boilers and are collected in areas where flow rate is slow or bends in the pipe.

Causes of sludge formation.

Sludge are formed by substances which have greater solubility in hot water than in cold water.

Example \rightarrow $MgCO_3$, $MgCl_2$, $CaCl_2$, $MgSO_4$.

Disadvantages of Sludge formation.

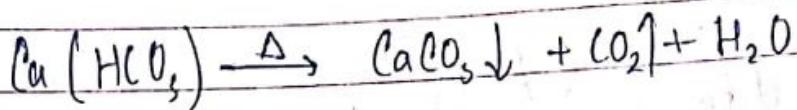
- \rightarrow Poor conductor of heat
- \rightarrow If the sludge is formed continuously it may get deposited as scale.
- \rightarrow Excess sludge can choke the pipe connection and disturb the working of boiler.

Prevention

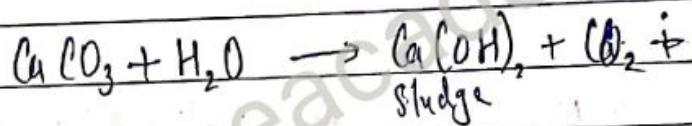
- \rightarrow Using soft water in boilers.
- \rightarrow frequent blow down operation
- \rightarrow

Scale → Scales are hard deposited which stick very firmly inner surface of the boiler. Scales are main cause of boiler trouble. Cause of the scale formation: decomposition of Ca^{+2} formation of CaCO_3

→ Example → decomposition of $\text{Ca}(\text{HCO}_3)_2$:



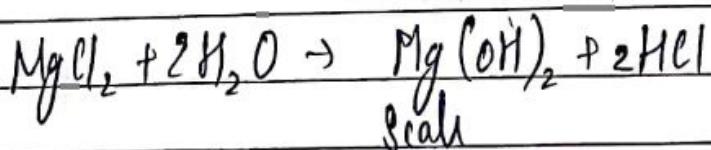
→ In low pressure boilers calcium carbonate is the main cause of scale formation, but in high pressure boilers CaCO_3 reacts with to give Ca(OH)_2 as sludge



→ Deposition of CaSO_4 .

This is the main cause of scale formation & very difficult to remove. Hydrolysis

→ Hydrolysis of Mg salts.



→ Precursors of silica

Silica reacts with calcium & Mg metals to form $\text{MgSiO}_3 \rightleftharpoons \text{CaSiO}_3$ which gets deposited as scales.

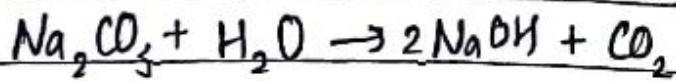
Disadvantage of scale formation

- Wastage of fuel.
- Decrease in efficiency of water.
- Danger of explosion & lowering of boiler safety.
- Removal of scale
 - Scales are brittle it can be removed by thermal shock or acid shock.
 - Scales can be removed with the help of chisel and hammer.

Caustic Embrittlement

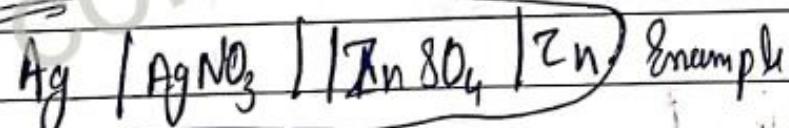
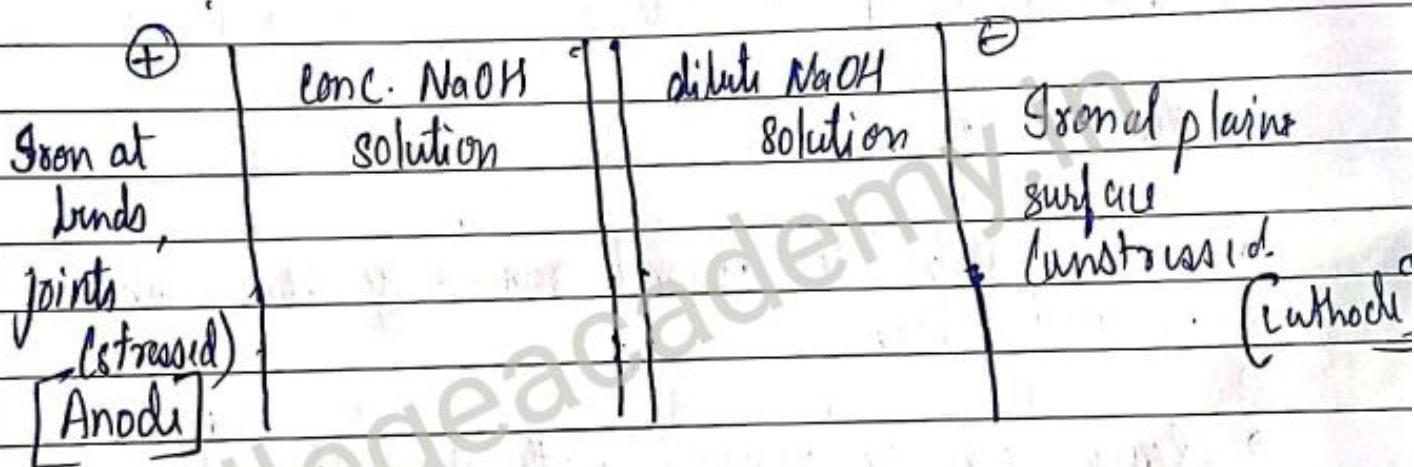
It is a type of boiler corrosion which makes boiler material brittle this is caused by using highly alkaline water in the boiler.

During lime-soda process since Na_2CO_3 is usually present in small proportion in the softened water. Na_2CO_3 in high pressure boilers decomposes to give NaOH and CO_2 .



It makes the boiler water caustic. the water containing NaOH flows into the minute hair cracks in the inner wall of boiler by capillary action. Water evaporates & the concentration of NaOH increases.

This caustic soda attacks the surrounding areas and dissolving iron of boiler wall as Sodium ferrate.
 [Note] This causes brittleness of boiler at stressed path like bends and joints it can be expressed by concentration cell.



It can be avoided by

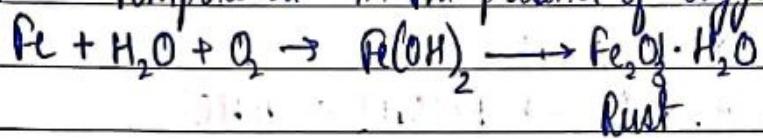
- i) Maintaining pH between 7-8.
- ii) Using Na_3PO_4 instead of Na_2CO_3 by addition of.
- iii) By addition of tannin & lignin & cetyl-agents, which bores the minute hair cracks.

Boiler Corrosion

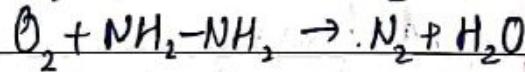
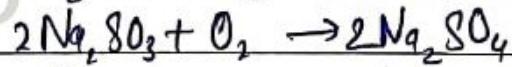
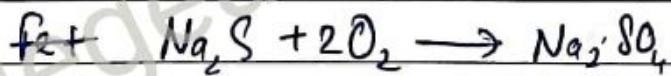
It can be defined as, loss of boiler material or deterioration of its useful properties due to chemical or electrochemical interaction with its environment.

Dissolved Oxygen (D.O.)

Water contains about 8 ml of dissolved Oxygen per litre at room temperature in the presence of oxygen & moisture. Rust forms



Dissolved oxygen can be removed by addition calculated amount of Na_2SO_3 , Na_2S , $\text{NH}_2 = \text{NH}_3$.



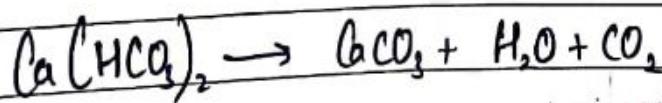
By mechanical aeration

Dissolved CO_2

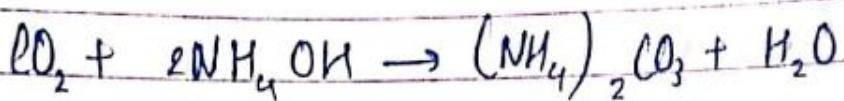
Dissolved CO_2 in water forms H_2CO_3



It is released if water contains Bi-carbonates

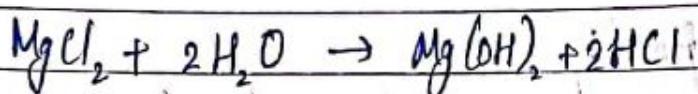


Removal by addition of calculated NH_4OH

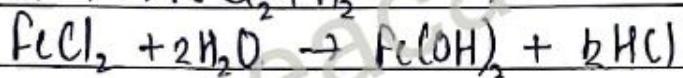
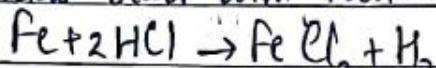


Acids from dissolved salts.

If MgCl_2 present in water on hydrolysis it gives:



Fouling acids react with iron



So small amount of MgCl_2 can generate reaction.
It can be avoided by addition of some alkali from outside to neutralize the acid.

Priming and foaming:

When boiler water contains large amounts of dissolved salts and steaming rapidly some of the particles of water are carried along with the steam.

The process of water stream formation is known as priming.

→ Priming is influenced by suspended and dissolved impurities.

→ i)

→ ii) sudden boiling

iii) faulty design of boilers.

High velocity of steam.

= foaming

Formation of persistent foam or bubbles which do not break easily is known as foaming.

foaming is influenced by in the

i) Presence of substances like oil, grease, clay, organic matter or sludge

Priming & foaming occurs together. They are objectionable because

i). Dissolved salts in boiler water are carried by wet steam so get deposited as water vapour salts.

→ Working of machinery is affected.

→ Maintenance of boiler pressure is difficult.

This can be avoided by using soft water in boilers maintaining low water levels.

Avoiding rapid change in steam production

By addition of Anti-foaming agent and NaAlO_2

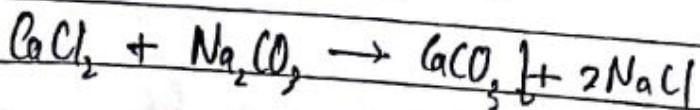
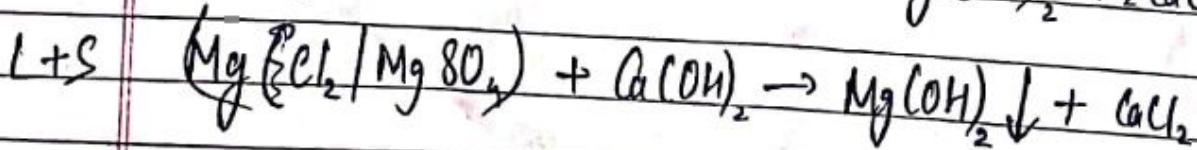
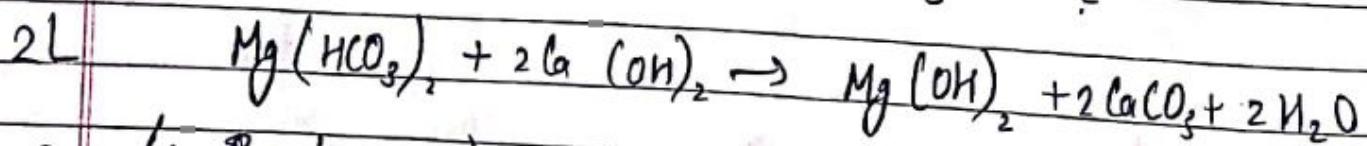
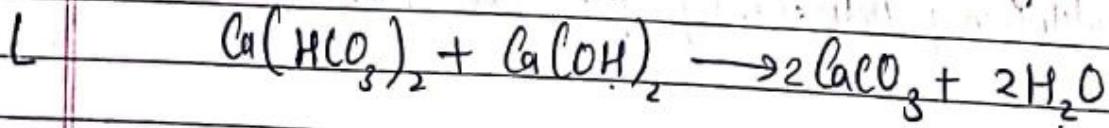
Lime Soda (L-S method)

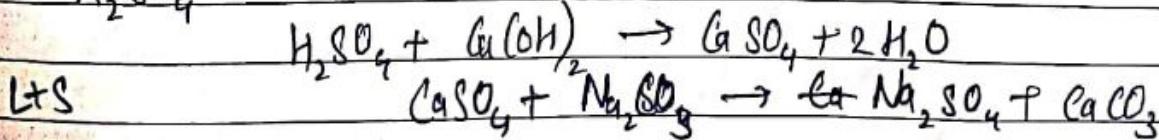
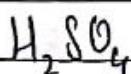
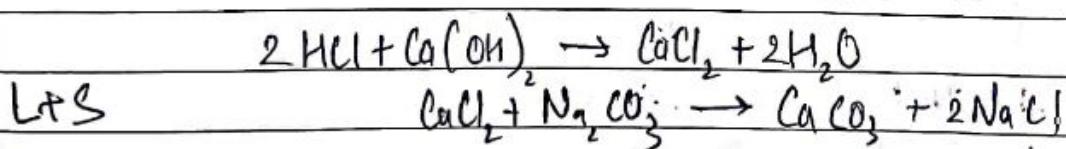
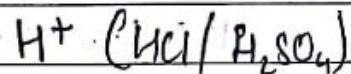
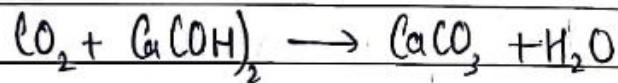
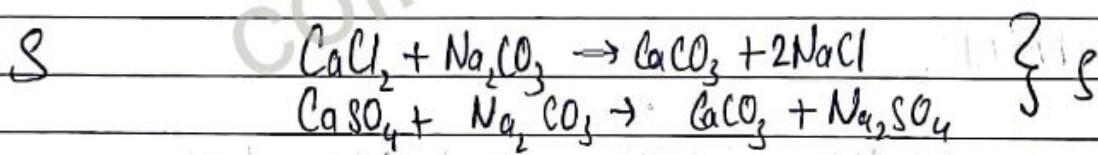
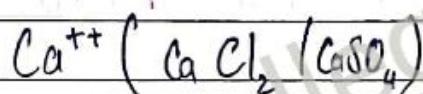
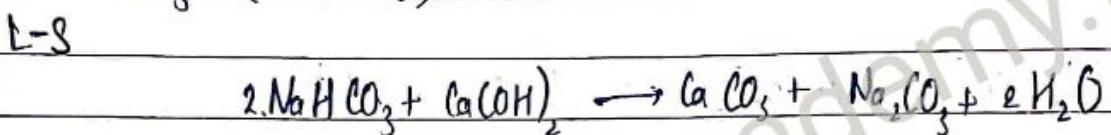
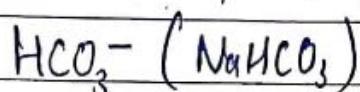
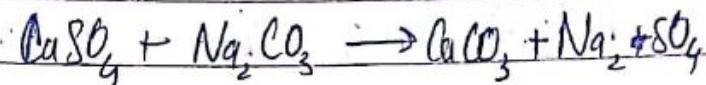
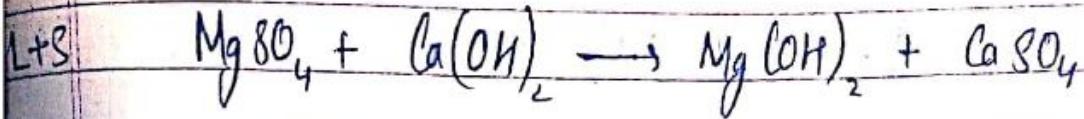
In this method hard water is treated with calculated amount of slaked lime $\text{Ca}(\text{OH})_2$ and soda Na_2CO_3 in reaction tanks so as to convert hardness producing chemicals into insoluble compounds which are then removed by settling and sedimentation.

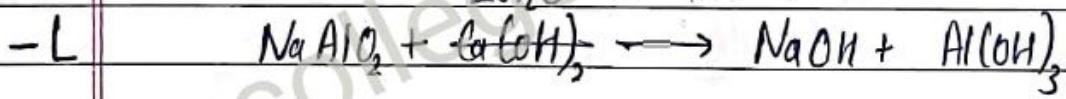
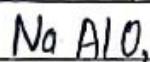
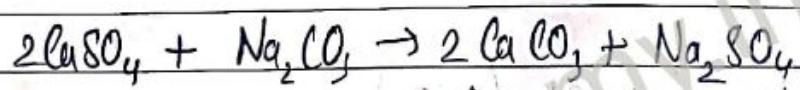
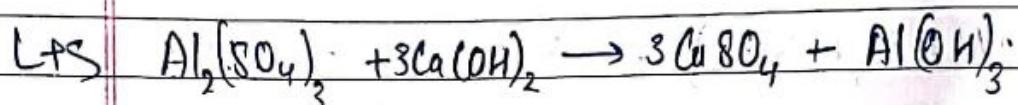
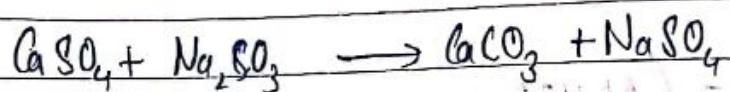
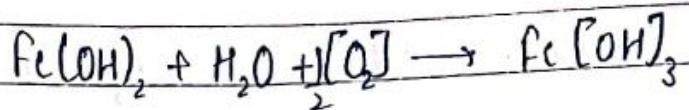
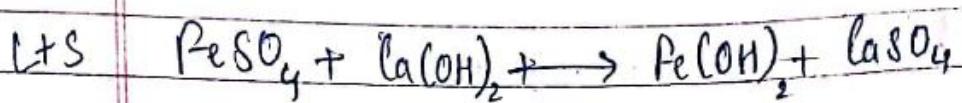
$$L = \frac{74}{100} \left[(\text{Temp } \text{Ca}^{++} + 2 \times \text{Temp } \text{Mg}^{2+}) + (\text{Perm } \text{Mg}^{++} + \text{Fe}^{++} + \text{Al}^{+3}) + (\text{Temp } \text{NaAlO}_2 + \text{H}^+ + \text{HCO}_3^-) \right] \times \frac{\text{Vol of Water}}{10^6} \times \frac{100}{\% \text{ of purity}}$$

$$S = \frac{106}{100} \left[(\text{Perm } \text{Ca}^{++} + \text{Mg}^{2+} + \text{Al}^{+3} + \text{Fe}^{2+}) + \text{H}^+ - \text{HCO}_3^- \right] \times \frac{\text{Vol of Water}}{10^6} \times \frac{100}{\% \text{ of purity}}$$

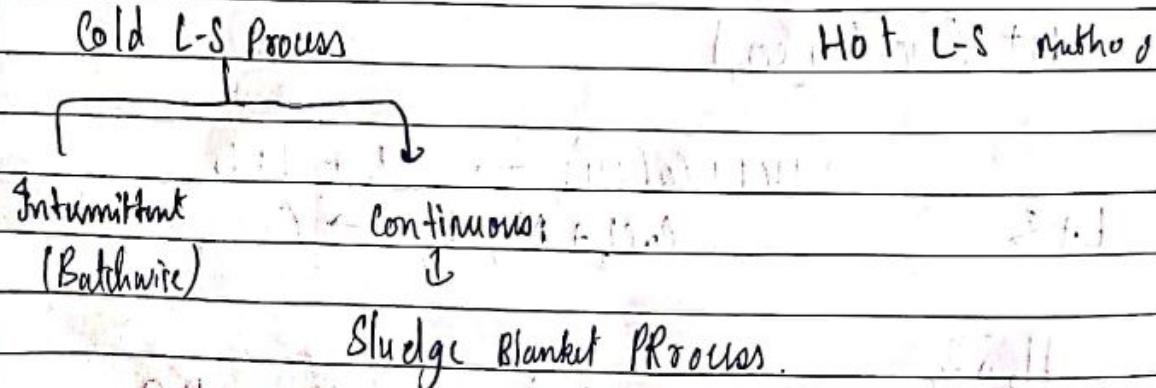
Reaction of Lime

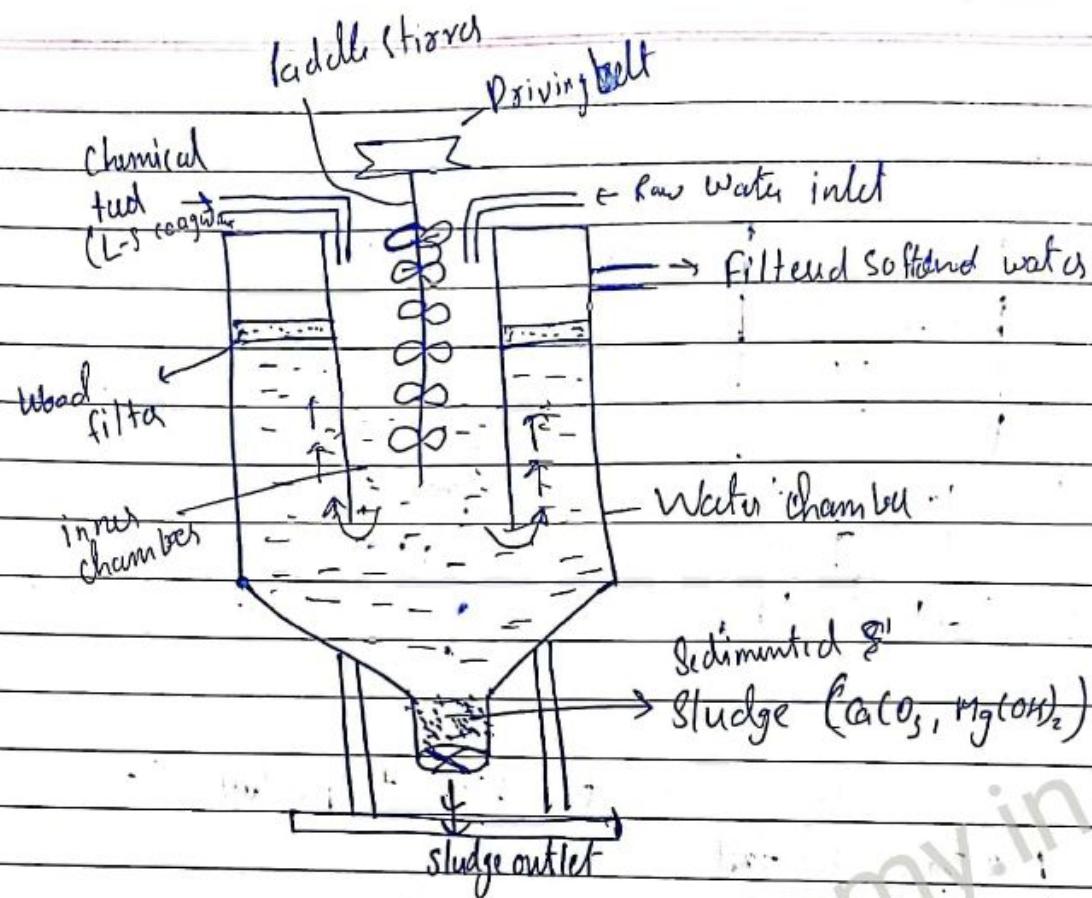






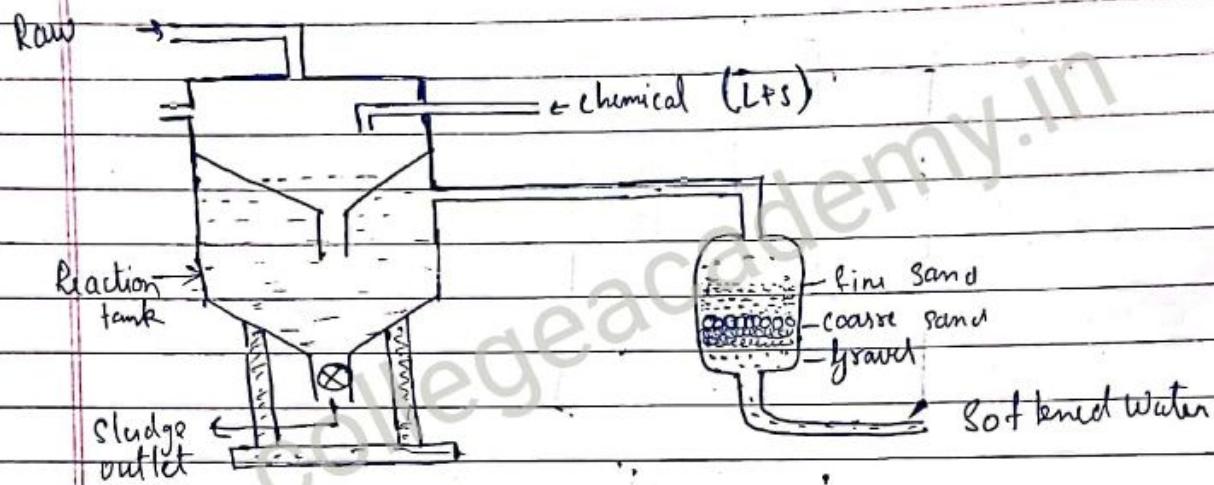
L-Soda Process (NaCl + CO₂)





- 1) Filtration
- 2) Softening
- 3) Clarification sedimentation

→ Short retention period (1 hour)
 → Small equipment
 → Higher efficiency.



Chemicals are added at high temperature .. ($80-90^{\circ}\text{C}$)

Reactions are fast.

Precipitation is more complete.

Settling rate & filtration rate are increased.

Advantages of lime soda method.

Treated water is alkaline

So less corrosion tendency.

Pathogens are removed due to alkaline nature.

It requires careful operation and skilled supervision.

Sludge disposal is a problem.

Pathogenic

51. kpm
1.2-1.5 lakh

disinfectant
20/100
ppm

Zeolite Method (Pumulit method)

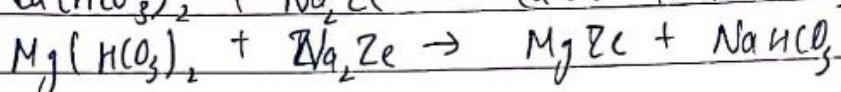
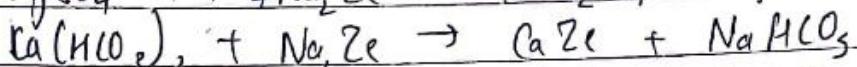
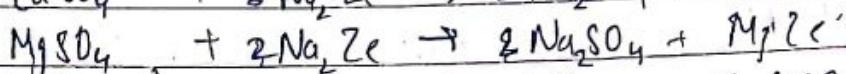
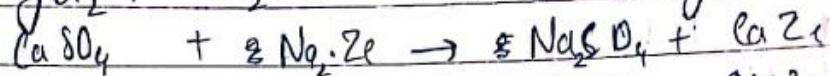
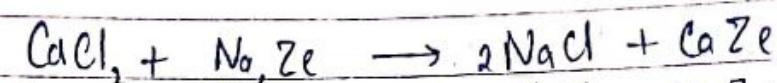
Zein boiling lithos - stones means boiling stones.
Chemical Name $\rightarrow \text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot x\text{SiO}_2 \cdot y\text{H}_2\text{O}$ Hydrated sodium alumino silicate.

Natural zeolite \rightarrow Natroselite $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2 \cdot 2\text{H}_2\text{O}$

Synthetic zeolite \rightarrow Solution of sodium aluminate and sodium silicate

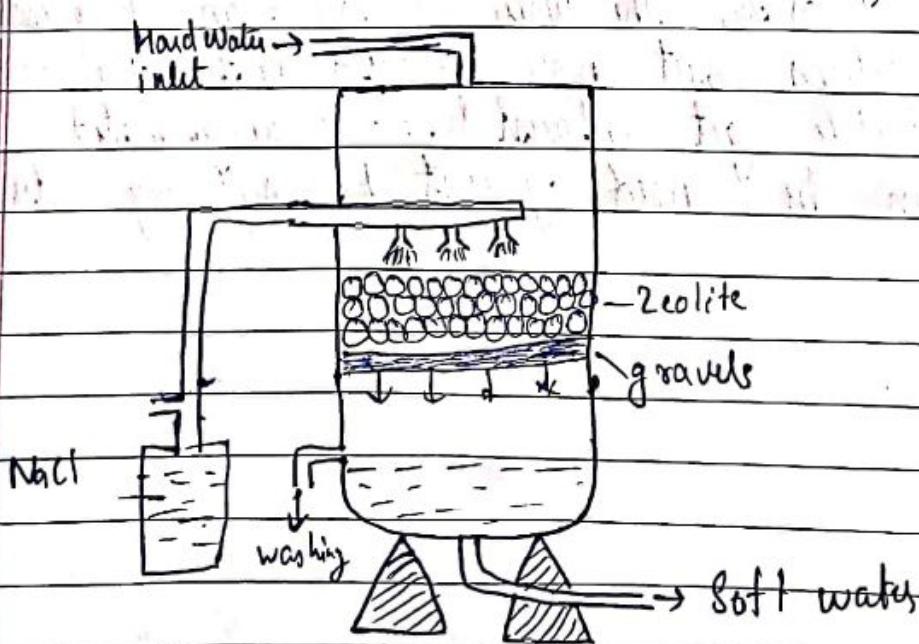
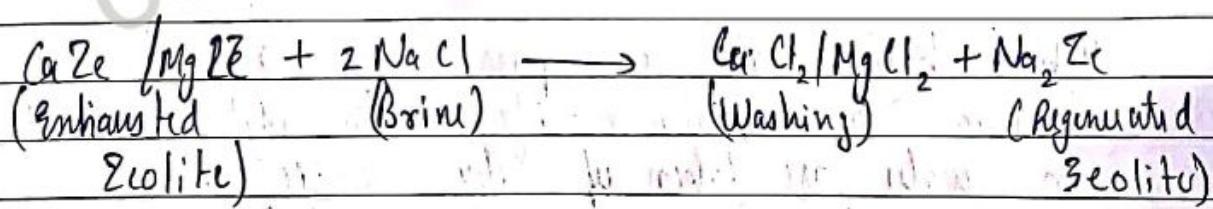
Principle of Zeolite method.

When hard water is passed over a bed of sodium zeolite, calcium & Mg ions ($\text{Ca}^{++}, \text{Mg}^{2+}$) present in water are taken up by zeolite and simultaneously releasing equivalent Na^{+} ions in exchange for them. The water gets free from hardness causing cations but more concentrated with Na^{+} ions when zeolite get exhausted. It is regenerated and can be used again for softening water.



Regeneration of zeolite

When zeolite is completely converted into CaZe & MgZe, it gets to soft water and become exhausted it is regenerated by treating with 10% brine solution.



Advantages of Zeolite method

- i) No sludge method.
- ii) Zeolite can be used again & again.
- iii) Residual hardness is 10-15 ppm.
- iv) Water doesn't become alkaline.

Limitations

- i) Water should not get turbid otherwise turbidity (suspended matter) can be deposited in the pores of Zeolite.
- ii) If iron ions are present in water from zeolite formed, cannot be regenerated.

The hardness of 10,000 litres of sample water was completely removed by zeolite softener. The zeolite softener required 60 litres of NaCl solution containing 1.5 kg per litre of NaCl for regeneration. Calculate hardness of water sample.

45 kg
10,000 litres

$$\frac{45 \times 1000 \times 1000}{10,000} = 4500 \text{ mg/L}$$

$$N_1 V_1 = N_2 V_2$$

$$N_1 \times 10,000 = N_2 \times 60$$

$$[Hardness] = \frac{1500 \times 60 \times 56 \times 1000}{58.5 \times 10000} = \frac{1500}{58.5} = 1$$

$$N_1 = N_2$$

An

200 litres of NaCl solution of strength 0.2 g/L of NaCl
 find the total volume of water
 that can be softened

350 Cl

24 500.5 ppm

$$N_x 100 = N_w \times V_w$$

$$\frac{0.2 \times 100}{58.5} = N_w \times V_w$$

$$500.5 = N \times 50 \times 1000$$

$$\frac{500.5}{50 \times 1000}$$

$$0.1001 = N$$

$$\frac{0.2 \times 200}{58.5} = V$$

$$\frac{3.41}{0.1001} = V$$

$$6.8 \text{ L} = V$$

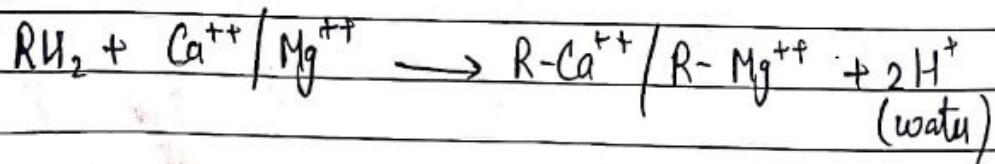
Ion-exchange / De-ionization / demineralization method

In this method a reversible exchange of ions occurs bt between the stationary ion exchange phase and the external liquid phase. Ion exchange resins are insoluble in water, cross linked long chain, high polymers which are permeable and its functional groups attached to chain are involved in ion exchanging properties.

i) Cationic exchangers (RH_2)

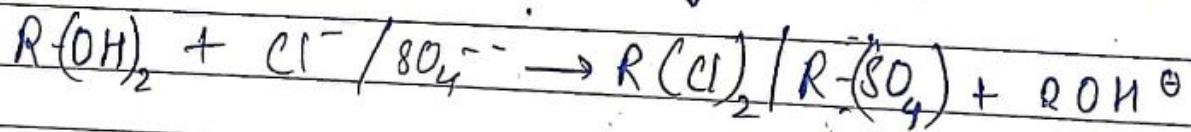
Divinyl-benzene-polymer
Sulphonated styrene..

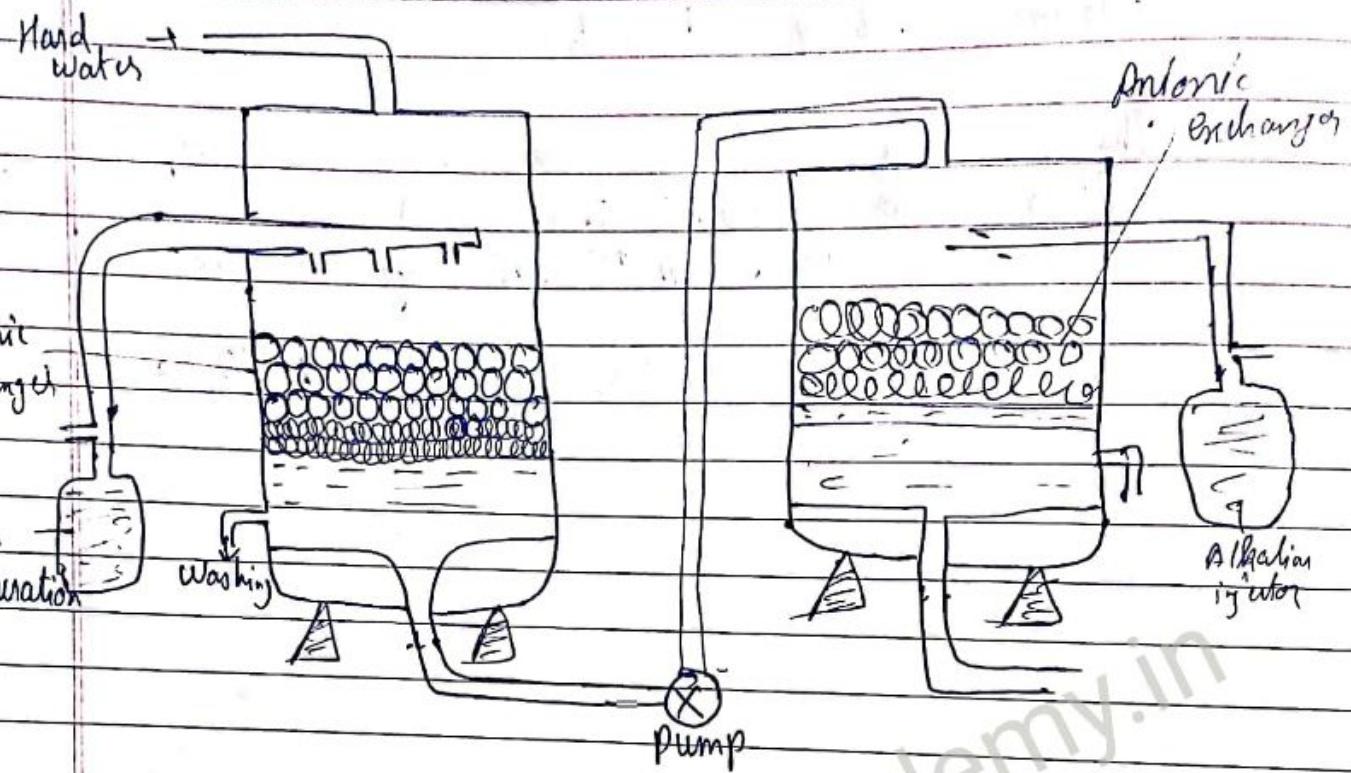
Resin containing sulphonated acidic functional group ($COOH$, $-SO_3H$) carbonylic group exchange their ions with other cations, these compounds are capable of exchanging cations like Ca^{2+} , Mg^{2+} , by H^+ ions.



Anionic Exchangers ($R(OH)_2$)

The exchangers containing basic functional groups exchange their anions with other anions. These are capable of exchanging anions (Cl^- , SO_4^{2-} , by OH^- ions)





Advantages

A Number of

- 1) It produces water of very low hardness. (0-2 ppm)
- 2) Process can be used highly acidic or alkaline water

3)

Disadvantages

1) Capital cost is high because equipment & chemicals both are costly.

2) If turbidity is present in water it decreases the efficiency of process.

Water is first passed through

- 1) Cationic exchanger
- 2) Anionic exchanger

3) This is because cation exchangers are easily attacked by alkali where as all type of ionic exchangers are not attacked by acid.

When water is first passed through a cationic exchanger, salts present in water are converted into corresponding acids, which on passing through anion exchanger do not harm it.

If reverse sequence is used

Then

Alkali produced

so such sequence is avoided.

Date _____
Page _____

Calculate the quantities of Lime & Soda required for softening 50,000 litres of water containing the following salts per litre.

102	$\text{Ca}(\text{HCO}_3)_2 = 8.1 \text{ mg}$	$\rightarrow S$	L
146	$\text{Mg}(\text{HCO}_3)_2 = 7.5 \text{ mg}$	$\rightarrow S \cdot 14$	$2L$
130	$\text{CaSO}_4 = 13.6 \text{ mg}$	$\rightarrow 10$	S
120	$\text{MgSO}_4 = 12.0 \text{ mg}$	$\rightarrow 10$	$L+S$
95	$\text{MgCl}_2 = 2 \text{ mg}$	$\rightarrow 2.1$	$L+S$

$$L = 24 \left[\frac{S + 2 \times S \cdot 14 + 12.1}{100} \right] \times \frac{50,000}{10^3} = 1.01 \text{ kg}$$

84% 92%

Calculate quantities of Lime & Soda in kg for softening 8,00,000 litres of water using 82.8 ppm of NaAlO_2 as coagulant. Impurities present in water are as follows

-L	$\text{NaAlO}_2 \rightarrow 32.8 \text{ mg/L}$	$100/32.8$	20
S	$\text{Ca}^{+2} = 240 \text{ mg/L}$	$100/90$	600
L+S	$\text{Mg}^{2+} = 36 \text{ mg/L}$	$100/24$	400
L-S	$\text{HCO}_3^- = 73.2 \text{ mg/L}$	$100/122$	+8'600
L	$\text{CO}_2 = 44 \text{ mg/L}$	$100/44$	100
	$\text{NaCl} = 60 \text{ mg/L}$		
	$\text{Fe}_2\text{O}_3 = 100 \text{ mg/L}$		



180
100

P

45
110
2 + 32
4

Imp if Ca^{++} & Mg^{++} are present in ionic form
they may be considered as permanent.

$$L = \frac{74}{100} \left(0 + \left(\frac{400}{106} \right) + 100 - 20 + 600 \right) \times \frac{3 \times 10^5}{10^6} \times \frac{100}{84}$$

$$= \frac{74 \times 3 \times 10^5}{840} = 285.4 \text{ Kg}$$

$$S = \frac{106}{100} \left[\frac{400}{106} \right] \times \frac{3 \times 10^5}{10^6} \times \frac{100}{92}$$

$$= 138.26 \text{ Kg}$$

Turbid Hard water using $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ as coagulant
278 ppm gave the following results on
analysis 1×10^6 Litres of water

$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$	278 ppm	$100/278$	$100/100$	L+S
Ca^{++}	240 ppm	$100/240$	$100/600$	S
Mg^{++}	96 ppm	$100/96$	$100/400$	L+S
CO_2	44 ppm	$100/44$	$100/100$	L
HCO_3^-	732 ppm	$100/732$	$100/600$	L-S
SiO_4	44 ppm	X	X	X
NaCl	58 ppm	X	X	X

$$L = \frac{74}{100} [400 + 100 + 600 + 160] \times \frac{10^6}{10^6} \times 100$$

$$= 74 \times \frac{1200}{1000} : 740 \text{ kg} = 8880 \\ = 884$$

$$S = \frac{106}{100} [-600 + 400 + 600] \times \frac{10^6}{10^6}$$

$$= \frac{106}{100} \times 500 : 424 \text{ kg} \\ = 530 \text{ kg}$$

A hard water sample has a following

L	$\text{Ca}(\text{HCO}_3)_2 \rightarrow 162 \text{ ppm}$	$\rightarrow \text{Mg}$	$100/162$	100 ppm
L	$\text{Mg}(\text{HCO}_3)_2 \rightarrow 73 \text{ ppm}$		$100/146$	50 ppm
S	$\text{CaCl}_2 \rightarrow 111 \text{ ppm}$		$100/111$	100
L+S	$\text{MgCl}_2 \rightarrow 95 \text{ ppm}$		$100/95$	100
S	$\text{CaSO}_4 \rightarrow 136 \text{ ppm}$		$100/136$	100
L+S	$\text{MgSO}_4 \rightarrow 120 \text{ ppm}$		$100/120$	100
L+S	$\text{Fe}(\text{BO}_4)_2 \cdot 7\text{H}_2\text{O} \rightarrow 139 \text{ ppm}$		$100/278$	50
	$\text{CO}_2 \rightarrow 44 \text{ ppm}$		$100/44$	100 ppm

Calculate Temp. & P. Hardness & Limi Soda required. 10^6 litres of water.

Temp Hardness = 150 ppm

Permanent Hardness = 450 ppm

$$\begin{aligned}
 L &= \frac{74}{100} \left[(100 + 2 \times \frac{50}{73}) + (200 + 50 + 0) + 0 + 0 + 0 + 0 \right] \times \frac{10^6}{10^6} \\
 &= \frac{74}{100} \left[(280 + 250) \right] \\
 &\quad - \frac{74}{100} \times 4596 \frac{350}{241} \\
 &= 367.04 \text{ Kg} \\
 &= 441.04 \text{ 407 Kg}
 \end{aligned}$$

$$\begin{aligned}
 S &= \frac{10.6}{100} (200 + 100 + 50) \\
 &= 477 \text{ Kg}
 \end{aligned}$$

27 Calculate d & S for softening 10^6 litres of water.
10 ppm of NaAlO_2

71-L	NaAlO_2	10 ppm	$100/32.8$	6.097
74-S	Ca^{++}	95 ppm	$100/40$	237.5
66-S	Mg^{++}	40 ppm	$100/24$	166.6
L	CO_2	66 ppm	$100/44$	150
L-S	HCO_3^-	264 ppm	$100/122$	216.4
L+S	H^+	2 ppm	$100/2$	100

$$\begin{aligned}
 L &= \frac{74}{100} \left[0 + (166.6 + 0 + 0) + 150 - \frac{6.097}{20.48} + 100 + 216.4 \right] \\
 &= 463.39 \text{ Kg}
 \end{aligned}$$

$$\begin{aligned}
 S &= \frac{10.6}{100} \left[(237.5 + 166.6 + 0 + 0) + 100 - 216.4 \right] \\
 &= 304.962 \text{ Kg}
 \end{aligned}$$