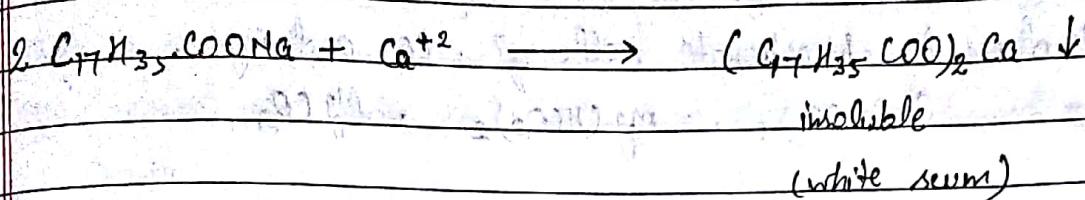
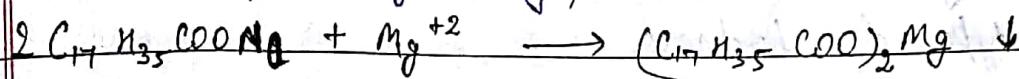


## Hardness of water



It is property of water due to which it does not form lather/froth with soap.

It is the soap consuming capacity of water due to which it fails to form lather with soap.



Hardness causing salts  $\Rightarrow$

Hardness is mainly due to the presence of  $\text{Ca}^{+2}$  &  $\text{Mg}^{+2}$ . for ex -  $\text{Ca}(\text{HCO}_3)_2$ ,  $\text{CaSO}_4$ ,  $\text{CaCl}_2$ ,  $\text{Mg}(\text{HCO}_3)_2$ ,  $\text{MgCl}_2$ ,  $\text{MgSO}_4$ ,  $\text{FeSO}_4$ ,  $\text{FeCl}_3$ ,  $\text{Al}_2(\text{SO}_4)_3$ ,  $\text{AlCl}_3$

\* Sodium and K salts do not cause any hardness.

ex (NaCl, KCl,  $\text{Na}_2\text{SO}_4$ ,  $\text{Na}_2\text{CO}_3$ ,  $\text{NaHCO}_3$  etc.)

$\text{SiO}_2$  and sand  $\Rightarrow$  No hardness

$\text{CO}_2$   $\Rightarrow$  does not cause any hardness.

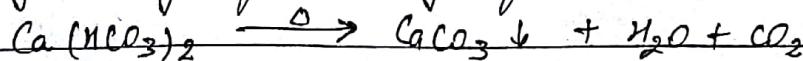
$\text{H}^+$  (acid)  $\Rightarrow$  does not cause any hardness

Type of Hardness :- On the basis of salt present, they are classified hardness into two types -

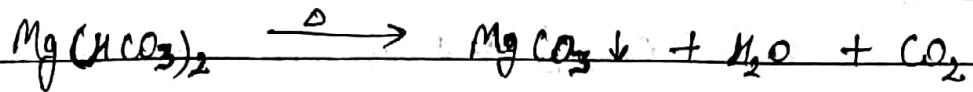
i) Temporary or Carbonate

ii) Permanent or Non-Carbonate

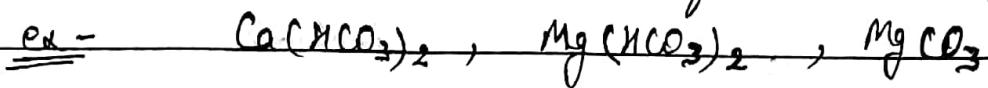
iii) Temporary or Carbonate :- This type of hardness can be removed by simply boiling followed by filtration.



(ppt. can be  
filtered)



$\Rightarrow$  It is due to bicarbonate salts of Ca and Mg.



Permanent or Non-carbonate  $\Rightarrow$  This type of hardness can't be removed by simply boiling followed by filtration alternatively some chemical method can be used to remove this type of hardness.

$\Rightarrow$  It is due to salts other than bicarbonate.



$\Rightarrow$  It is due to  $\text{SO}_4^{2-}$  or  $\text{Cl}^-$  salts of Ca and Mg.

Boiler feed water  $\Rightarrow$  The water which is used for steam generation in boiler, is called boiler feed water.

characteristics of boiler feed water :-

$\Rightarrow$  Hardness :-  $< 0.2 \text{ ppm}$

$\Rightarrow$  Caustic alkalinity :-  $< 0.45 \text{ ppm}$  ( $0.25 - 0.45 \text{ ppm}$ )

$\Rightarrow$  Soda alkalinity :-  $< 1 \text{ ppm}$

Boiler corrosion problems :- The problems which are associated with boiler feed water are called boiler problems.

(i) scale and sludge

(ii) Priming and foaming

(iii) Caustic embrittlement

(iv) Boiler corrosion

(v) Carry over.

(i) Scale

- (i) scales are the hard deposit at the wall of container or boiler  
 (ii) formed at water part of the boiler  
 (iii) scales are removed with difficulty, some chemical method are used to remove scale.  
 (iv) It is formed by  $\text{CaSO}_4$ ,  $\text{MgSO}_4$ ,  $\text{CaCO}_3$  etc.

sludge

- (i) These are loose ppt. formed at the surface of water.  
 (ii) Sludge are formed at water part of the boiler  
 (iii) These can be easily removed by blow down process or filtration  
 (iv) It is formed by  $\text{CaCl}_2$ ,  $\text{MgCl}_2$ ,  $\text{Ca}(\text{HCO}_3)$  etc.

(ii)  $\Rightarrow$  priming & foaming  $\Rightarrow$ priming

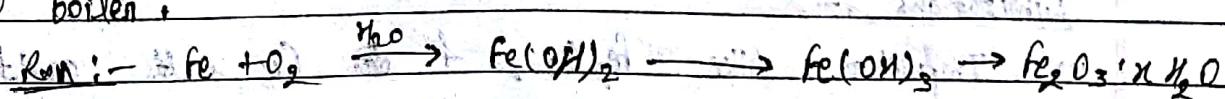
- (i) During boiling of water some water droplets are carried out with steam. This steam is called wet steam or priming

foaming

- (i) If water contains oil or fats, on boiling it forms persistent bubbles or foams are formed which do not break easily. When these bubbles are carried by steam may choke the pipeline and degrade the efficiency of machine, boiler.

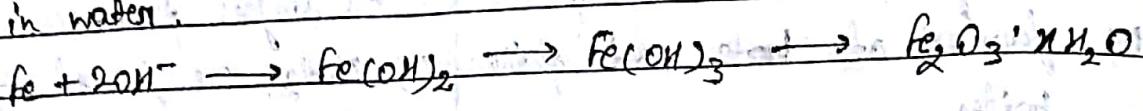
(iii) Boiler corrosion :-

If water contain soluble impurities like  $\text{O}_2$  +  $\text{CO}_2$  which on reacting with the material of boiler leads to corrosion of boiler.



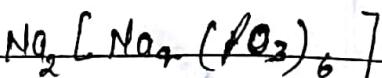
Caustic embrittlement :-

If it is caused by the presence of caustic alkalinity ( $\text{OH}^-$ ) in water.



Carry over :- The loose p.f. formed on boiling are carried by steam which may lead to choking of pipe line this process is called carry over.

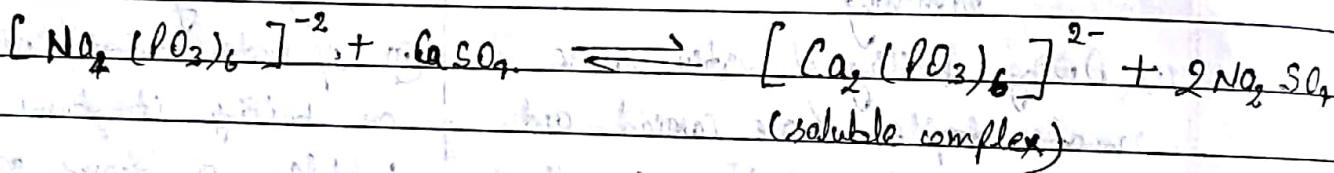
\* \* \* Method of removal of scale forming salt : (Calgon conditioning)



At room temp:-



Sod. hexameta phosphate



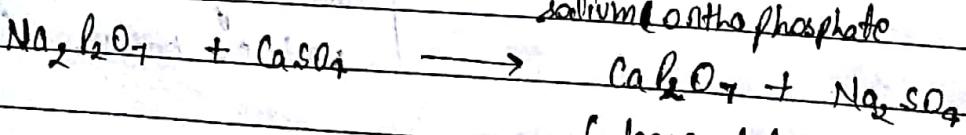
(soluble complex)

(can't removed)

At high temp  $\Rightarrow$



sodium orthophosphate



(loose sludge)

(can be removed by blow down process/  
filtration)

Limitations :-

- Impurities like  $\text{Fe}_2\text{O}_3$  &  $\text{Ca}^{2+}$  salts can't be removed by this process.

Q - Name the standard which is used for expressing / reporting hardness. why?

Sol -  $\text{CaCO}_3$  equivalent

(i) It's a most insoluble salt present in water

(ii) Its mol. wt. is 100, so which make the calculation easy.

Units for reporting hardness :-

(i) mg/litre

(ii) ppm

(iii)  ${}^{\circ}\text{French} = {}^{\circ}\text{F}$

(iv)  ${}^{\circ}\text{Clark} = {}^{\circ}\text{Cl}$

$$1 \text{ mg/l} = 1 \text{ ppm} = 0.1 {}^{\circ}\text{F} = 0.07 {}^{\circ}\text{Cl}$$

$\text{CaCO}_3$  equivalent =  $\frac{\text{Eq. wt. of } \text{CaCO}_3}{\text{Eq. wt. of salt / substance}} \times \text{Amount of Sub.}$

1 mg  $\text{MgCl}_2$

Mol. wt = 95

$$\text{Eq. wt.} = \frac{95}{2} \Rightarrow 47.5$$

$$\text{CaCO}_3 = \frac{100}{2} \Rightarrow 50$$

$$\text{CaCO}_3 \text{ eq.} = \frac{50}{47.5} \times 10 = 10.52 \text{ mg/l.}$$

Q - Calculate the hardness water sample  $\rightarrow$  10 mg/L NaCl + 10 mg/L  $\text{MgCl}_2$

Sol - same as  $\text{MgCl}_2$

## Element

At. Wt.

H

1

C

12

N

14

O

16

S

32

Cl

35.5

Na

23

Ca

40

Mg

24

Al

27

Fe

56

## Composition

eq. wt.

CaCO<sub>3</sub> equivalent

Type of hardness

CaCO<sub>3</sub> = 10 ppm

55.5

P

MgCO<sub>3</sub> = 10

97.5

P

Na<sub>2</sub>CO<sub>3</sub> = 10

—

P

Ca(HCO<sub>3</sub>)<sub>2</sub> = 10

81.5

P

~~Ca(HCO<sub>3</sub>)<sub>2</sub>~~ = 10

73

T

CO<sub>2</sub> = 10

—

T

CaSO<sub>4</sub> = 10

68

—

T = 13.01 ppm

$$13.01 \times 0.07 = 0.91^\circ \text{Cl}$$

P = 26.92 ppm

39.9

Total

$$39.9 \text{ ppm} = 3.99 \text{ f}$$

1.88 °Cl

Comp.	eq wt.	$\text{CaCO}_3$ eq.	Type of Hardness
$\text{Ca}(\text{HCO}_3)_2 = 90.5$	81	25	T
$\text{Mg}(\text{HCO}_3)_2 = 96.5$	73	31.84	T
$\text{MgSO}_4 = 27.6$	60	23	P
$\text{CaSO}_4 = 32.1$	68	23.60	P
$\text{CaCl}_2 = 22.45$	55.5	20.26	P

Total  $\Rightarrow$  123.7 mg/l on ppm //

Comp.	eq. wt.	$\text{CaCO}_3$ eq.	Type
$\text{Mg}(\text{HCO}_3)_2 = 73$	73	5	T
$\text{Ca}(\text{HCO}_3)_2 = 16.9$	81	10	T
$\text{MgCl}_2 = 9.5$	97.5	10	P
$\text{CaSO}_4 = 13.6$	68	10	P

Total  $\Rightarrow$  35 ppm //

Comp.	eq. wt.	$\text{CaCO}_3$ eq.	Types
$\text{Ca}(\text{HCO}_3)_2 = 10.5$	81	6.98	T
$\text{Mg}(\text{HCO}_3)_2 = 12.5$	73	8.56	T
$\text{CaSO}_4 = 7.5$	68	5.5	P
$\text{CaCl}_2 = 8.2$	55.5	7.38	P
$\text{MgSO}_4 = 2.6$	60	2.16	P

Total = 30.09 ppm //

(10)	Comp.	eq. wt.	$\text{CaCO}_3\ \text{eq}$	Type
	$\text{Ca}(\text{NO}_3)_2 = 10$	81	6.17	T
	$\text{Mg}(\text{NO}_3)_2 = 8.5$	73	5.82	T
	$\text{CaSO}_4 = 12$	68	8.82	P
	$\text{MgSO}_4 = 14$	60	11.66	P

$$\text{Total} = 32.47 \text{ ppm}$$

(11)	Comp.	eq. wt.	$\text{CaCO}_3\ \text{eq}$	Type
	$\text{Mg}(\text{NO}_3)_2 = 16.8$	73	11.50	T
	$\text{MgCl}_2 = 19$	97.5	20	P
	$\text{MgSO}_4 = 24$	60	20	P
	$\text{CaCl}_2 = 22.2$	85.5	20	P

$$\text{Total} = 71.5 \text{ ppm}$$

(12)	Comp.	eq. wt.	$\text{CaCO}_3\ \text{eq}$	Type
	$\text{Mg}(\text{NO}_3)_2 = 81$	73	55.47	T
	$\text{MgCO}_3 = 84$	92	100	T
	$\text{MgCl}_2 = 24.2$	97.5	25.17	P
	$\text{MgSO}_4 = 60$	60	50	P
	$\text{NaCl} = 20$			
	$\text{Ca}(\text{NO}_3)_2 = 20$	82	12.19	P - P

$$\text{Temporary hardness} = 155.47 \text{ ppm}$$

$$\text{Permanent hardness} = 87.66 \text{ ppm}$$

(2)

Comp.

$$\text{Mg}(\text{CHCO}_3)_2 = 70 \quad \text{Ca}(\text{HCO}_3)_2 = 89$$

$$\text{CaCl}_2 = 110 \quad \text{MgCO}_3 = 74$$

$$\text{MgSO}_4 = 120$$

$$\text{Ca}(\text{NO}_3)_2 = 132 \quad \text{MgSO}_4 = 70$$

$$\text{FeSO}_4 \cdot 7\text{H}_2\text{O} = 91.7 \quad \text{KCl} = 70$$

$$\text{Ca}(\text{NO}_2)_2 = 30$$

g.wt.

81

92

55.5

60

—

82

 $\text{CaCO}_3$  eqt.

50.61

88.09

20

58.33

18.29

Types

T

T

P

P

P

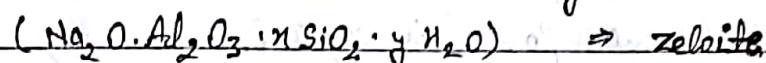
Temporary hardness  $\Rightarrow$  138.7 ppm

Permanent hardness = 96.62 ppm

Method of removal of hardness  $\Rightarrow$ 

Zeolite process :- Permutit process

Boiling stone

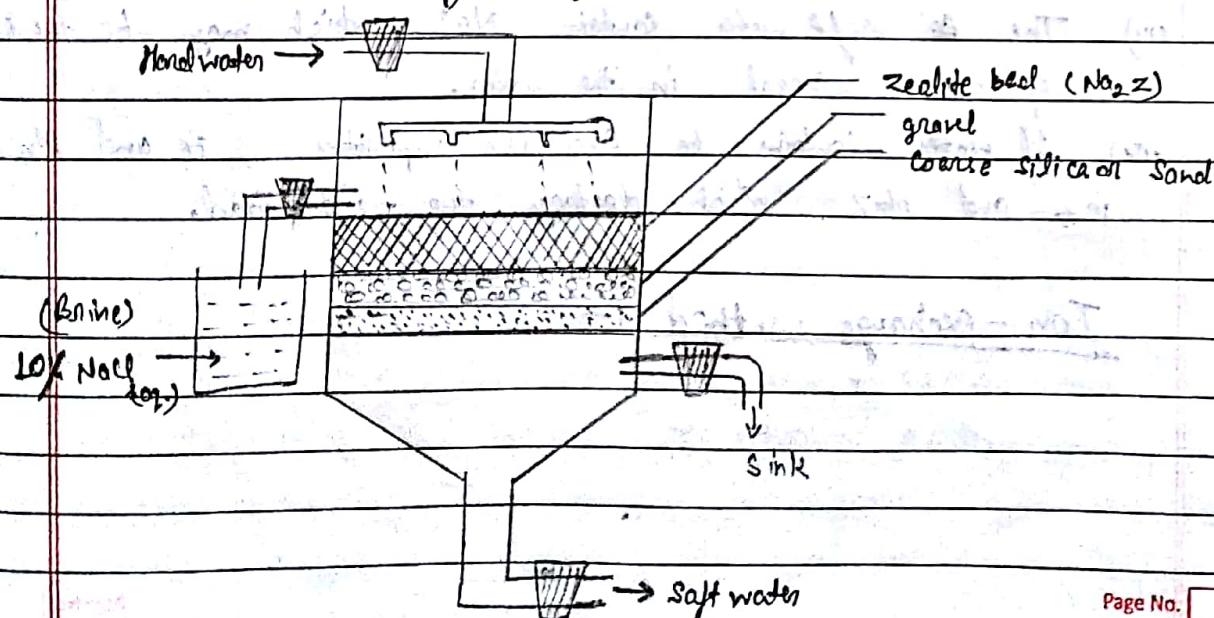


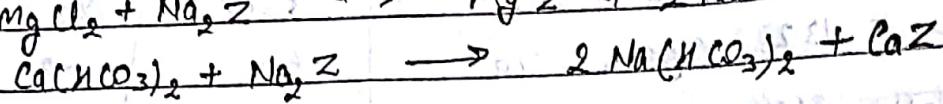
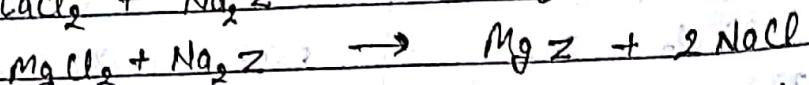
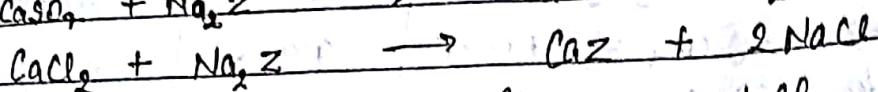
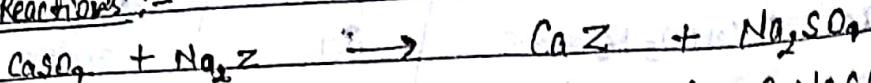
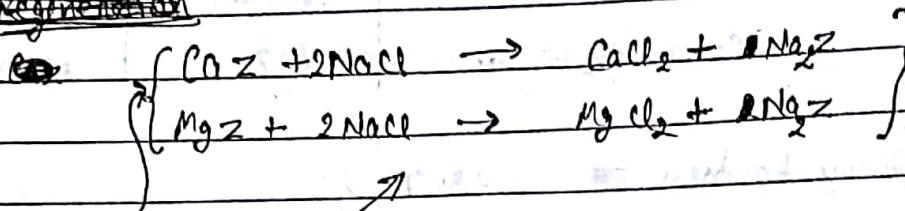
$$n \Rightarrow 9 - 10$$

$$y \Rightarrow 2 - 6$$

Natural zeolite :- Natrolite  $(\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 3\text{SiO}_2 \cdot 2\text{H}_2\text{O})$ 

Synthetic zeolite :- By heating feldspar, soda, silica etc.



Reactions :-RegenerationRegeneration  
salt.RegenerationAdvantages :-(i) Residual hardness  $< 10 \text{ ppm}$ .

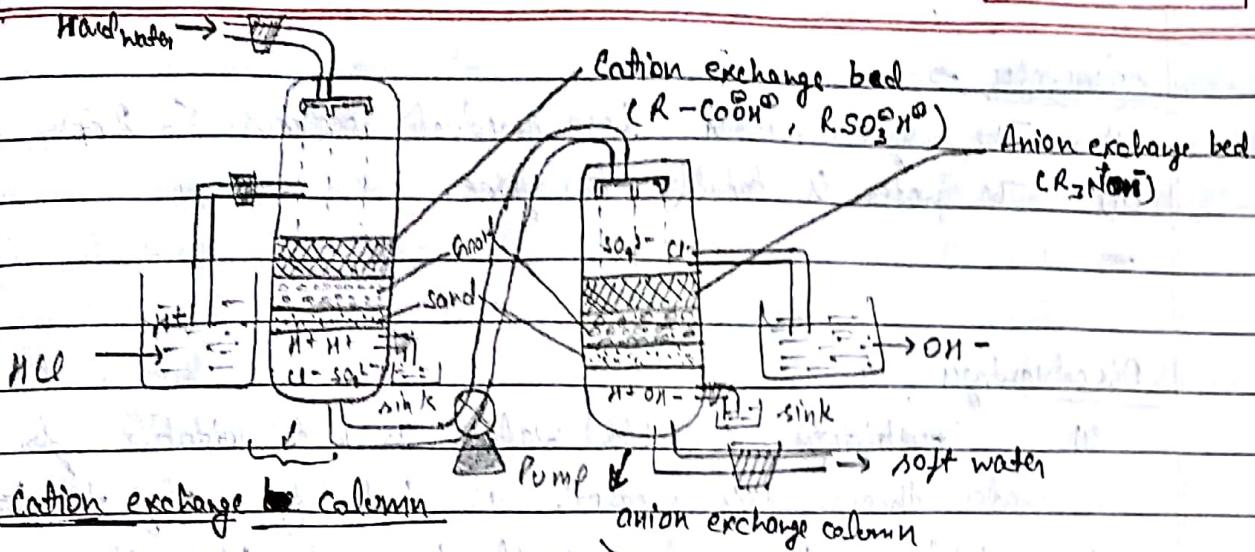
(ii) method is easy and convenient.

(iii) No skilled man power is required.

Disadvantages  $\Rightarrow$ 

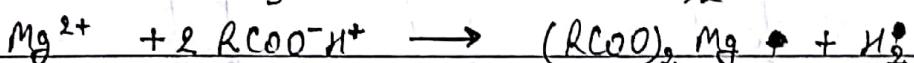
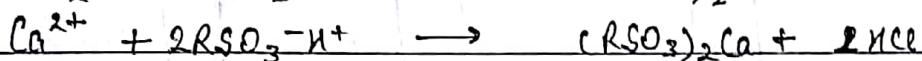
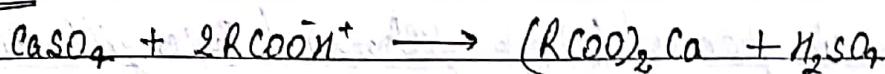
- (i) Turbid water is not suitable for softening through this method.
- (ii) The soft water still contains bicarbonate,  $\text{CO}_3^{2-}$ , which are responsible for alkalinity and leads to caustic embrittlement and boiler corrosion.
- (iii) The soft water contain  $\text{Na}^+$  which may be the cause of excess mineral in the water.
- (iv) If water contains Fe and Mn impurities, Fe and Mn form  $\text{FeZ}$  and  $\text{MnZ}$  which destroy the zeolite bed.

Ton-exchange method :-

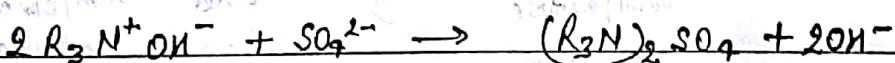
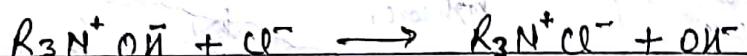


Cation exchange column  $\Rightarrow$

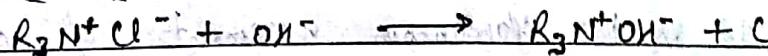
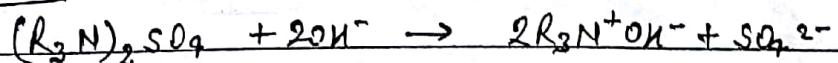
Rxn :-



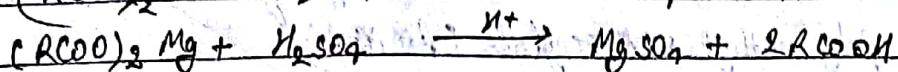
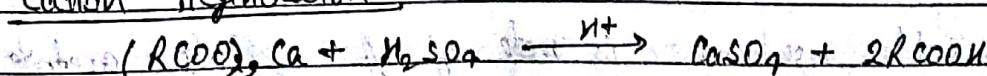
Anion exchange column  $\Rightarrow$



Regeneration



Cation regeneration  $\Rightarrow$



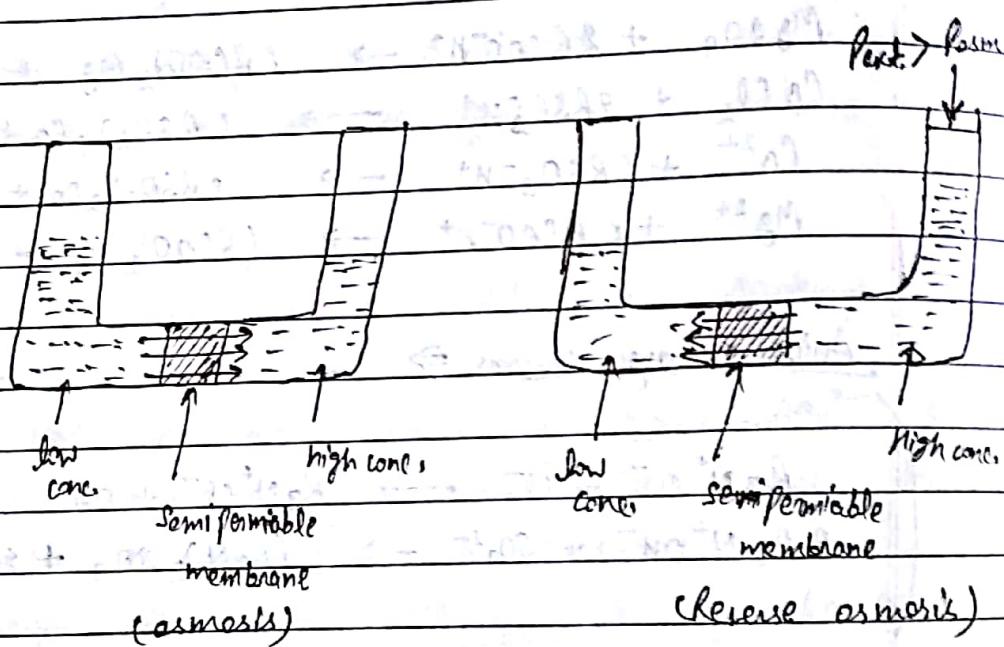
Advantages  $\rightarrow$

- (i) The softened water have residual hardness  $< 2 \text{ ppm}$
- (ii) The water is totally ion free.
- (iii)

Disadvantages  $\rightarrow$

- (i) Turbidity (Turbid) water is not suitable for softening water through this method, as turbidity clog the beds.
- (ii) Highly acidic water can't be used b/c it may destroy the beds.

Reverse osmosis process / (Hyper filtration) / Super filtration  $\Rightarrow$



Osmosis  $\rightarrow$  It is the spontaneous movement of solvent molecule from low conc. to high conc. through semi-permeable membrane

$\Rightarrow$  Semi-permeable membrane is made up of cellulose acetate, polyamide or poly methyl methacrylate (PMMA).

$\Rightarrow$  It allows to pass smaller particles ( $< 0.1 \text{ nm}$ ) such as water molecules and stop the bigger particles like  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$ .

Reverse osmosis  $\Rightarrow$  It is the movement of solvent molecules from high conc. to low conc. through semi-permeable membrane. This happens when hydrostatic pressure (ext. pressure) applied is greater than the osmotic pressure.

This method is known as the best method for water softening b/c of following advantages -

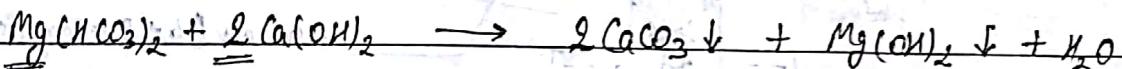
- (i) This method can be used to remove heavy metal ions like Zn, Cd, Hg, etc.
- (ii) This method can be used to remove organic molecules like pesticides, insecticides and other toxic chemicals.
- (iii) SPM can be easily replaced.

Disadvantages  $\Rightarrow$

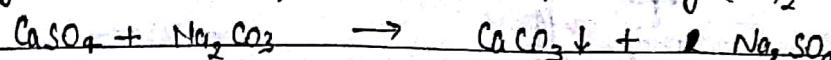
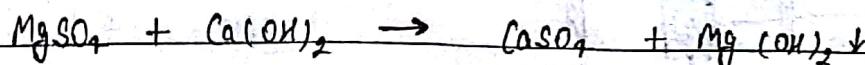
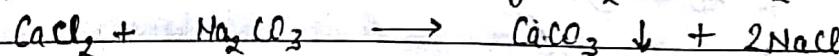
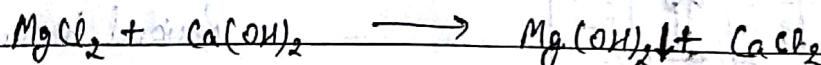
- (i) 50% of water got wasted in drain.

Lime-Soda process :-

Temporary hardness

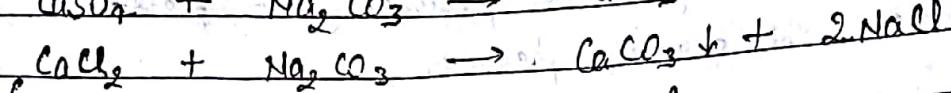
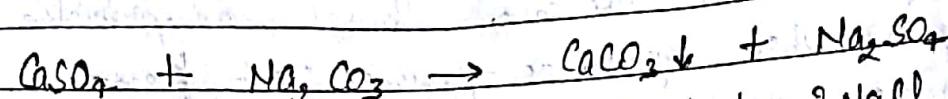


Permanent hardness of Mg.  $\Rightarrow$

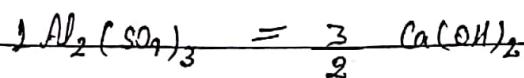
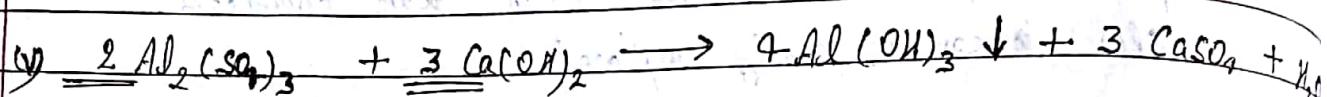
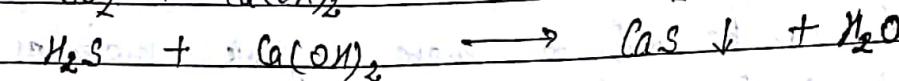
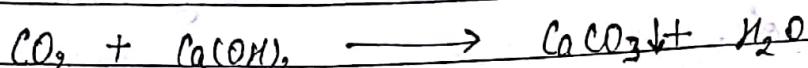
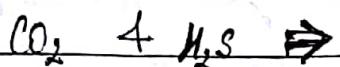


We required 1 mole of lime and 1 mole of soda.

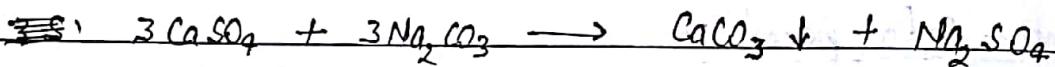
Permanent hardness of Ca  $\Rightarrow$



only 1 mole soda is required.



1 coagulant molecule requires  $\frac{3}{2}$  molecule of lime.



Cold lime-soda process  $\Rightarrow$

Hard  
water

lime

chemicals (L + S + coagulant)

soft water

filter

Residual hardness  $\Rightarrow 50-60 \text{ ppm}$

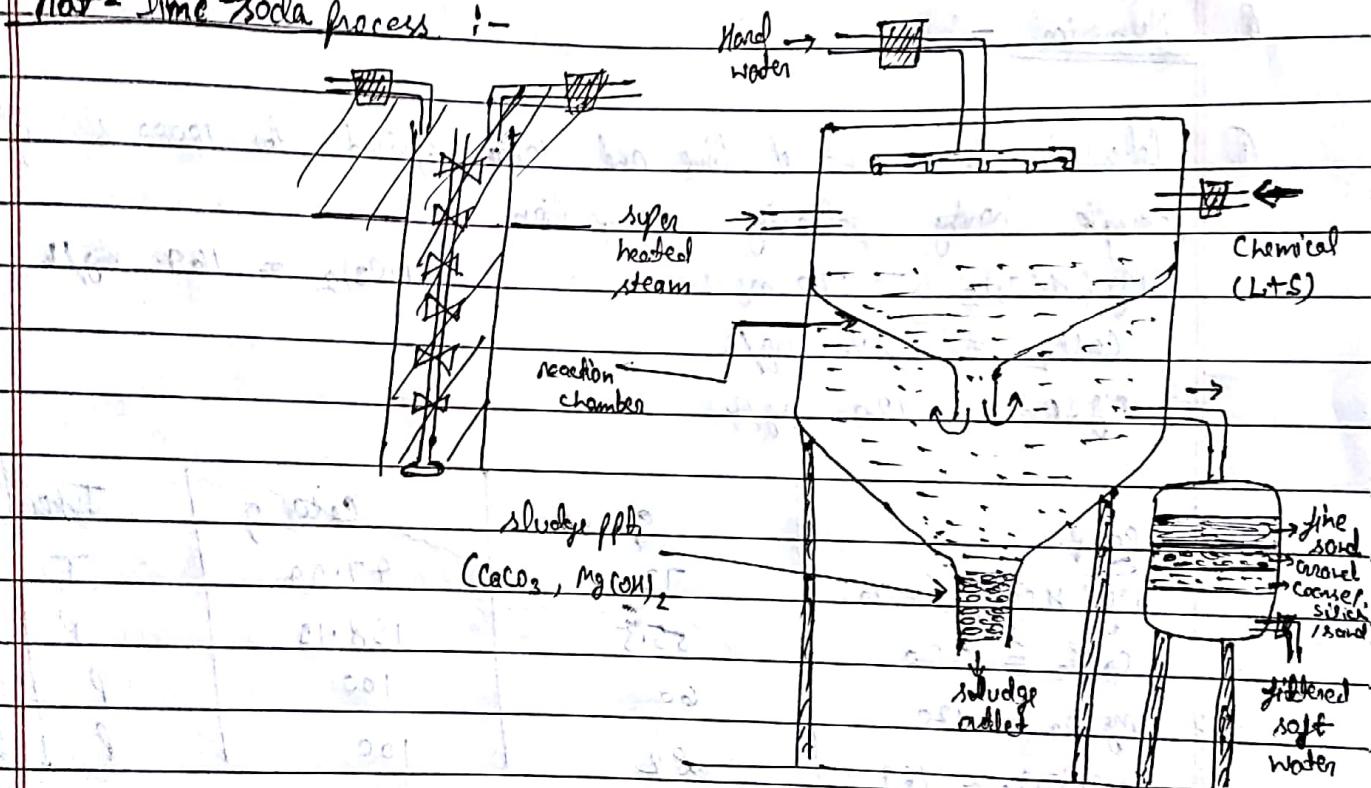
sludge  
pt.

$(\text{CaCO}_3, \text{MgCO}_3)$

sludge  
outlet

- A calculated amount of lime and soda is mixed with water to be softened.
- The <sup>hard</sup> salt present in water formed <sup>on atm.</sup> ppt. with lime and soda.
- The ppt. formed ( $\text{CaCO}_3, \text{Mg}(\text{OH})_2$ ) are very fine which do not get settle down easily.
- To make them settle down another chemical i.e. coagulant is required.
- The coagulant used are  $\text{NaAlO}_2$  and  $\text{Al}_2(\text{SO}_4)_3$ .
- These coagulant forms gelatinous ppt. of  $\text{Al(OH)}_3$  which coagulate the fine ppt. of  $\text{CaCO}_3$  and  $\text{Mg}(\text{OH})_2$ .

### Hof - Lime Soda process :-



### Hof

- (i) This process is carried out high temp.
- (ii) fast process
- (iii) no coagulant is required.
- (iv) hardness  $\rightarrow 15 \text{ ppm}$
- (v)  $\text{CO}_2/\text{H}_2\text{S}$  can't be removed.

### Cold

- (i) carried out room temp.
- (ii) slow process
- (iii) coagulant is required
- (iv) residual hardness  $50-60 \text{ ppm}$
- (v)  $\text{CO}_2/\text{H}_2\text{S}$  can't be removed

Lime required  $\Rightarrow$

$$\Rightarrow \frac{74}{100} [ \text{Temp of } \text{Ca}^{2+} + 2 \times \text{Temporary of } \text{Mg}^{2+} + 1 \times \text{Permanent of } \text{Mg}^{2+} ] \text{ mg/l}$$

Soda required  $\Rightarrow$

$$\Rightarrow \frac{106}{100} [ \text{Permanent of } \text{Ca}^{2+} + \text{Perm. of } \text{Mg}^{2+} + \dots ] \text{ mg/l}$$

① Numerical -

Calculate the amount of lime and soda required for 10000 L of water sample having following composition,

$$\text{Mg}(\text{HCO}_3)_2 = 70 \text{ mg/l}$$

$$\text{CaCl}_2 = 220 \text{ mg/l}$$

$$\text{mg SO}_4 = 120 \text{ mg/l}$$

$$\text{Ca}(\text{NO}_3)_2 = 167 \text{ mg/l}$$

Comp.	eq. wt	$\text{CaCO}_3 \text{ g}$	Type	Requirement
$\text{Mg}(\text{HCO}_3)_2 = 70$	73	47.94	T	2L
$\text{CaCl}_2 = 220$	55.5	198.19	P	S
$\text{mg SO}_4 = 120$	60	100	P	L+S
$\text{Ca}(\text{NO}_3)_2 = 167$	82	100	P	S

Lime required  $\Rightarrow$

$$\Rightarrow \frac{74}{100} [ 2 \times 47.94 ] + 100 \times 10000 \text{ mg} \Rightarrow 1949512 \text{ mg} \Rightarrow 1.9 \text{ Kg}$$

Soda required

$$\Rightarrow \frac{106}{100} [ 198.19 + 100 + 100 ] \times 10000 \text{ mg}$$

$$\Rightarrow 4220814 \text{ mg} = 4.2 \text{ Kg}$$

(Q) A water sample contains following constituent  $Mg(HCO_3)_2 = 73$ ,  $MgCl_2 = 95$ ,  $MgSO_4 = 12$ ,  $CaSO_4 = 68$ ,  $Ca(HCO_3)_2 = 81$ . Calculate the cost of chemical required for softening 90,000 L of water if purity factor of lime is 25% and soda is 90%. The cost per 100 kg of lime and soda are 75 & 2980 respectively.

Sol - Comp.	% w/w.	Calcs eq.	Requirement
$Mg(HCO_3)_2 = 73$	73	100	9 L
$MgCl_2 = 95$	97.5	100	L + S
$MgSO_4 = 12$	60	50	L + S
$CaSO_4 = 68$	68	50	S
$Ca(HCO_3)_2 = 81$	81	50	1 L

### Lime required

$$\Rightarrow \frac{74}{100} \left[ 2 \times 50 + 100 + 10 + 50 \right] \times 20000 \times \frac{100}{95}$$

$$\Rightarrow \frac{74}{100} \left[ 260 \right] \times 20000 \times \frac{100}{95}$$

$$\Rightarrow 4.05 \text{ kg}$$

$$\text{Cost} = \frac{905}{100} \times 75$$

$$= \frac{75}{100} \times 905$$

$$\Rightarrow 3.03 \text{ Rs}$$

### Soda required

$$= \frac{106}{100} \left[ 100 + 10 + 50 \right] \times 20000 \times \frac{100}{95}$$

$$\Rightarrow 3.76 \text{ kg}$$

$$\text{Cost} \Rightarrow \frac{2980}{100} \times 3.76 \Rightarrow 93.24 \text{ Rs.}$$

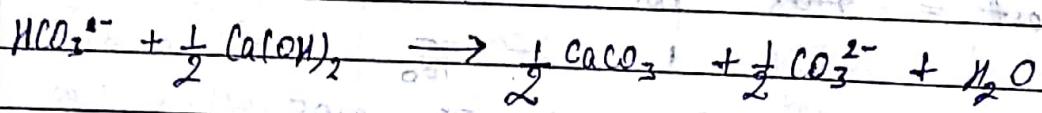
Comp.	Eq. wt.	$\text{CaCO}_3 \text{ eq.}$	
$\text{CaCO}_3 = 1.85$	50	1.85	S
$\text{CaSO}_4 = 0.34$	68	0.25	L
$\text{MgCO}_3 = 0.42$	47.5 42	0.5	L+S
$\text{MgCl}_2 = 0.76$	97.5	0.8	L+S
$\text{MgSO}_4 = 0.90$	60	0.75	
$\text{NaCl} = 2.34$	—		

$$\text{Soda} = \frac{106}{100} [0.25 + 0.8 + 0.75] \times 24000 \times \frac{100}{99}$$

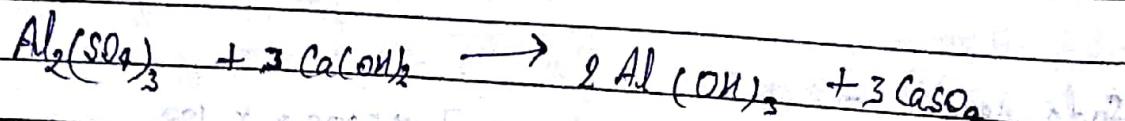
$$\Rightarrow 46.25 \text{ kg}$$

$$\Rightarrow 46.25 \text{ kg}$$

$$\text{Lime} \Rightarrow \frac{74}{100} [$$



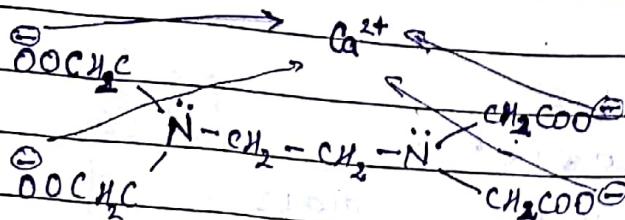
$$\Rightarrow \frac{1}{2} (\text{L-S})$$



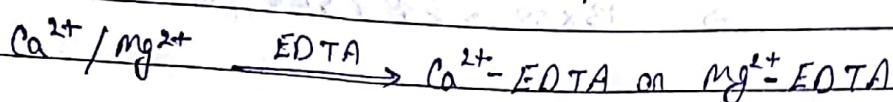
$$\Rightarrow 3L + 3S$$

## Estimation of hardness :-

EDTA (ethylene diamine tetraacetate)



Hexadentate ligand / Bridging ligand



EBT  $\Rightarrow$  Eriochrome black-T

Numerical  $\Rightarrow$

Q - 10 mL. of hard water consumed 10, 0.01 N EDTA before boiling and 6 mL. of 0.01 N EDTA after boiling. Calculate Temp., Permanent and Total Hardness.

Sol - (i)  $N_1 V_1 = N_2 V_2$   
(hardness) = C(EDTA)

$$N_1 \times 10 = 0.01 \times 10$$

$$N_1 = 0.01 \text{ N}$$

$$\text{Hardness} = 0.01 \times 50 \times 1000$$

$$\Rightarrow 500 \text{ ppm}$$

(ii) Permanent

$$N_1 V_1 = N_2 V_2$$

$$N_1 \times 10 = 0.01 \times 6$$

$$N_1 = 0.006 \text{ N}$$

Temp. = Total - per.

$$= 500 - 300$$

$$\text{Hardness} = 0.06 \times 50 \times 1000 \\ \Rightarrow 300 \text{ ppm}$$

Q - 15 ml. of hard water required 20 ml. 0.01 N EDTA, after boiling the same amount of water required 12 ml. of same EDTA soln. calculate temp., permanent and total.

Sol

Test

$$N_1 V_1 = N_2 V_2$$

$$N_1 \times 20 = 0.01 \times 20$$

$$N_1 = \frac{0.01}{20} \rightarrow 0.0005$$

$$\text{Total hardness} = 0.0005 \times 50 \times 1000 \rightarrow 13 \times 50 \rightarrow 650 \text{ ppm}$$

$$N_1 V_1 = N_2 V_2$$

$$N_1 \times 12 = 0.01 \times 20$$

$$N_1 = \frac{0.01}{12} \rightarrow 0.000833$$

$$\text{Permanent hardness} = 0.000833 \times 50 \times 1000$$

$$\text{Temp.} = 25^\circ \text{ ppm}$$

Q - A standard hard water containing 15 gm. of  $\text{CaCO}_3$ /litre. 20 ml. of this required 25 ml. of EDTA. 100 ml. of water sample required 18 ml. of EDTA. The sample water after boiling required 12 ml. of EDTA soln. calculate temp., permanent and total hardness.

Sol - (i) standardization of EDTA

1000 ml. of standard hard water contain = 15 g.  $\text{CaCO}_3$

$$1 \text{ ml. } " \text{ " } = \frac{15 \times 10^3}{1000} = 15 \text{ mg. calcs}$$

$$20 \text{ mL of SHW} = 20 \times 15 \text{ mg CaCO}_3 = 300 \text{ mg CaCO}_3$$

$$1 \text{ mL EDTA} = \frac{300}{2.5} \rightarrow 12 \text{ mg CaCO}_3$$

(ii) Total hardness :-

$$100 \text{ mL of sample water} = 18 \text{ mL of EDTA}$$

$$= 18 \times 12 \text{ mg. CaCO}_3 = 216 \text{ mg CaCO}_3$$

$$1000 \text{ mL} = \frac{216 \times 1000}{100} \rightarrow 2160 \text{ mg/L CaCO}_3$$

(iii) Permanent hardness :-

$$100 \text{ mL of sample water after boiling} = 12 \times 12 \text{ mg CaCO}_3$$

$$\rightarrow 144 \text{ mg. CaCO}_3$$

$$1000 \text{ mL. " " } = \frac{144 \times 1000}{100} \rightarrow 1440 \text{ mg/L}$$

(iv) Calculate the hardness of sample water which required 10 mL of EDTA. ~~for~~ for 10 mL of sample water, after boiling 6 mL of same EDTA soln, 20 mL of  $\text{CaCO}_3$  soln which have strength of  $15 \text{ mg/L}$ , required  $30 \text{ mL}$  of EDTA soln.

$$\text{Sol} - 1000 \text{ mL of SHW contain} = 15 \text{ g CaCO}_3$$

$$1 \text{ mL. " " } = \frac{15 \times 10^3}{1000} \Rightarrow 15 \text{ mg}$$

$$20 \text{ mL of SHW} = 20 \times 15 = 300 \text{ mg EDTA}$$

$$1 \text{ mL of EDTA} = \frac{20 \times 15}{30} \rightarrow \frac{300}{30} \rightarrow 10 \text{ mg CaCO}_3$$

(v) Total hardness:

$$100 \text{ mL of sample water contains} = 10 \text{ mL of EDTA}$$

$$\rightarrow 10 \times 10 = 100 \text{ mg CaCO}_3$$

$$1000 \text{ mL} = \frac{100 \times 1000}{100} \rightarrow 10000 \text{ mg/L CaCO}_3$$

$$\Rightarrow \text{Permanent hardness} \Rightarrow$$

100 ml. of sample water contains = 10 mg  
 $\Rightarrow 60 \text{ mg CaCO}_3$

1000 ml. of  $\Rightarrow \frac{60 \times 100}{100} \Rightarrow 6000 \text{ mg/l. CaCO}_3$

$$\text{Temp} = 6000 \text{ mg/l. CaCO}_3$$

### (Q) Zeolite-based numerical problems $\Rightarrow$

- (Q) Zeolite softener was 90% exhausted when 5000 L. of hard water passed through it. The softener required 100 L of NaCl soln which have strength of 50 gm/l. What is the hardness of water sample.

Sol  $\Rightarrow$  (i) NaCl as  $\text{CaCO}_3$  equivalent

$$1\text{L. of NaCl solution} = 50 \text{ gm of NaCl}$$

$$100 \text{ L. " } \rightarrow 5000 \text{ gm of NaCl}$$

$$\text{CaCO}_3 \text{ eq.} = \frac{50 \times 5000}{58.5} \Rightarrow 4273.5 \text{ gm of CaCO}_3$$

$$(ii) 5000 \text{ L. of Hard water} = 4273.5 \times 10^3 \text{ mg}$$

$$1\text{L. " } = \frac{4273.5 \times 10^3}{5000} \Rightarrow 854.7 \text{ ppm. } //$$

- (Q) An exhausted zeolite softener was regenerated by 150 L. of NaCl soln. having strength = 150 gm/l. of NaCl. How many litres of hard water ~~softened~~ having hardness 600 ppm can be softened by this softener.

Sol - 1 L. of NaCl sol  $\rightarrow 150 \text{ gm of NaCl}$   
 $150 \text{ L. " } \rightarrow 150 \times 150 \text{ gm of NaCl}$   
 $\rightarrow 22500.$

$$\text{CaCO}_3 \text{ eq.} \Rightarrow \frac{50 \times 22500}{58.5} \Rightarrow 19230.76 \text{ gm of CaCO}_3$$

$\text{CO}_2$  always consumed lime

GUIDER  
your writing partner

Date: \_\_\_/\_\_\_/\_\_\_

Amount of water → Amount of  $\text{CaCO}_3$   
on hardness

600 ppm

19230.76

1 ppm

19230.76

$600 \times 10^{-3}$

32.051 KL

~~Amount~~

regenerated

Q- A zeolite bed was softened by using 10% NaCl soln if 10000 L hard water of hardness by 500 mg/L was softened calculate the amount of NaCl soln.

Sol -

(i) NaCl as  $\text{CaCO}_3$  eq.

100 ml of NaCl sol = 100 gm of NaCl

$\times 500 \text{ L.} = 100 \times n \text{ g of NaCl}$

$\text{CaCO}_3 \text{ eq.} = \frac{50}{58.5} \times 100 \text{ gm of NaCl}$

Amount of water =  $\frac{\text{amt. of } \text{CaCO}_3}{\text{hardness}}$

$10,000 = \frac{\frac{50}{58.5} \times 100 \times 10^3}{500 \text{ mg/L}}$

$x = 58.5 \text{ L.}$

Q- 92% exhausted zeolite bed was regenerated by using 100 L. of 12% NaCl soln. If 10000 L. of hard water softened calculate the hardness of water softened.

Sol -

100 ml of NaCl sol = 12 gm of NaCl

$100 \text{ L.} = \frac{12 \times 100}{100} \times 10^3$

$\rightarrow 12000 \text{ gm of NaCl}$

$\text{CaCO}_3 \text{ q.} \Rightarrow \frac{50 \times 12000}{58.5} \Rightarrow 10256.41 \times 10^3 \text{ gm of NaCl}$

~~unit of hardness~~ = ~~mg/liter of water~~

$$\text{Hardness} = \frac{10256.91 \times 10^3}{10000}$$

$$\Rightarrow \cancel{\text{Hardness}} \text{ ppm } 1025.64 \text{ ppm}$$

- ① Calculate the amount of NaCl soln used for regenerating 90% exhausted zeolite bed, if 9500 L. of hardness 90 ppm water was softened. (given strength of NaCl soln is 5%).

Sol:-

$$100 \text{ ml. of NaCl soln} = 5 \text{ g. of NaCl}$$

$$9500 \text{ L.} = \cancel{5 \times 1000 \text{ ml.}} \rightarrow \cancel{5000 \text{ ml.}} \rightarrow 125 \text{ ml.}$$

$$CaCO_3 \text{ eq.} = \cancel{50 \times 125 \times 10^3} \rightarrow$$

x L.

$Ca^{+2}$	S	$\frac{1}{2}L - \frac{1}{2}S$	$\frac{1}{2}L + \frac{1}{2}S$
$Mg^{+2}$	$L+S$		
$HCO_3^{-2}$			
$CO_2$	$L$		$SiO_2, / Na/K \text{ salt}$
$H^+$	$\frac{1}{2}L + \frac{1}{2}S$		$\rightarrow \text{not used}$
$NaAlO_2$	-L		
$Al_2(SO_4)_3$	$3L + 3S$		
$Ca(HCO_3)_2 / CaCO_3$	L		
Permanent of $Mg^{+2}$	$L+S$		
Permanent of $Ca^{+2}$	S		