

Unit-I WATER TECHNOLOGY

total to 15 In-SEM Exam = 15 Marks

* Question Paper Pattern :-

- Que. 1 (a) — 5 Marks { mit substrate }
 (b) — 4 Marks } Theory {
 (c) — 3 Marks }
 (d) — 3 Marks (Numerical)

OR 1 question carried to

- Que. 2 (a) — 5 Marks { Theory }
 (b) — 4 Marks { Solved }
 (c) — 3 Marks } Numerical

- Numerical on Hardness (i) Alkalinity,
 Zeolite Method.

* Reference books for Unit-I :-

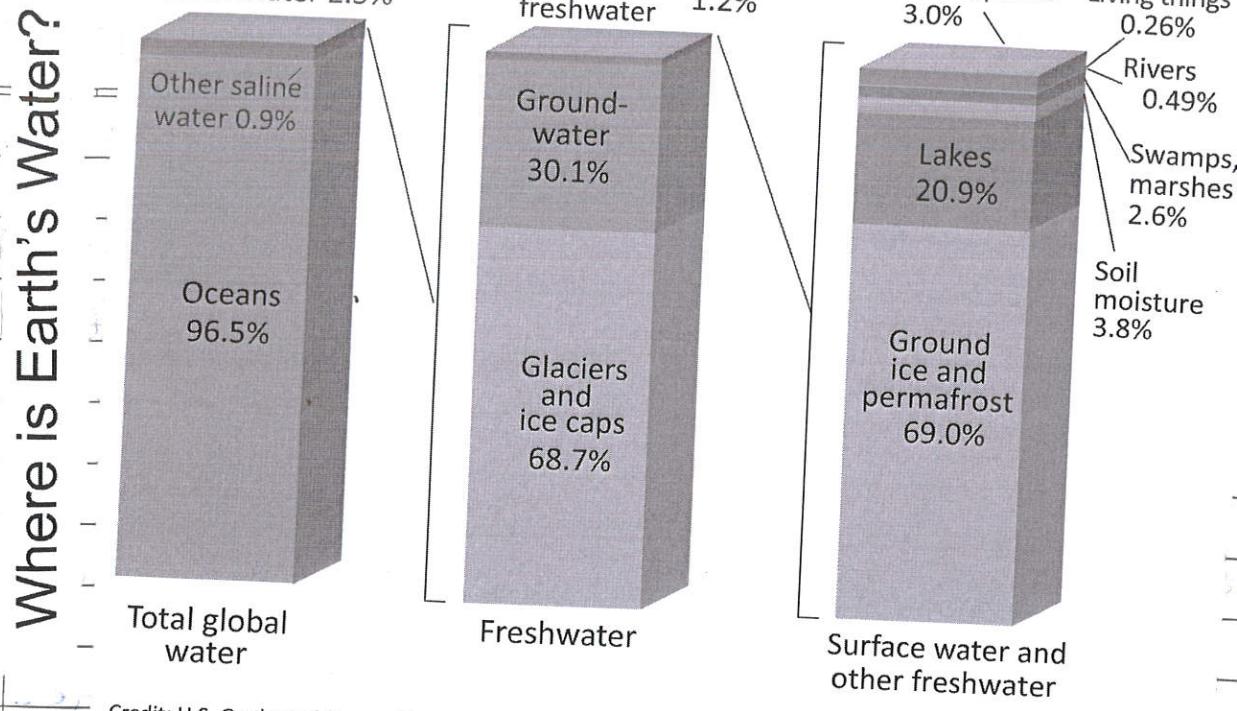
- (i) Engg. Chemistry by Jain & Jainlal
- (ii) _____ by S.S. Dara
- (iii) _____ by S.K. Singh (ii)
- (iv) _____ by O.G. Palana
- (v) _____ by Sashit Chawla

* Course Objective :-

To understand technology involved in analysis and improving quality of water as commodity.

* Index / Mind Map of Unit-I :-

- Pre-requisites of Water
 - Sources of water
 - Impurities in water
- Introduction - Diagram A + B (2)
- Types of water Diagram A + B (2)
 - Hard water
 - Soft water
- Hardness of water - Types, Units, Determinants of hardness, Numerical.
- Alkalinity - Theory, Principle / Defn., Determinants of alkalinity, Numerical. Diagram C (2)
- Disadvantages / ill effects of hard water in boilers - (i) Boiler corrosion Defn., Causes, (ii) Caustic Embrittlement Defn., Causes, (iii) Priming & Foaming Effects & Prevention, Difference, etc., (iv) scales & sludges Prevention, Difference, etc.
- Water Purification Treatment - Diagram D (2)
 - i) Zeolite & Numerical, Principle, Diag., Process,
 - ii) Demineralisation Reactions, Adv., Disadv., Limitations
- Water Purification Method - Diagram E (2)
 - RO & Electrodialysis - Principle, Diagram, Method, Applications, Advantages, etc.



Sources of water :-

Rain
Purest form

Surface
River
Sea
Lake

Underground
wells
bore wells
Spring

Impurities in water :-

Suspended
e.g. mud, waste,
organic matter

Biological
bacteria, algae, fungi

Colloidal
clay, mud
colloidal
particles

Dissolved
gases
Salts

Removal By
methods Filtration

By
sterilization
(Cl_2 , Ozone,
UV light)

By
coagulation
using
coagulating
agent
(Potash or
sodium
alum)

By
Softening
treatment

Types of water :-

Hard water

(does not form lather with the soap readily)

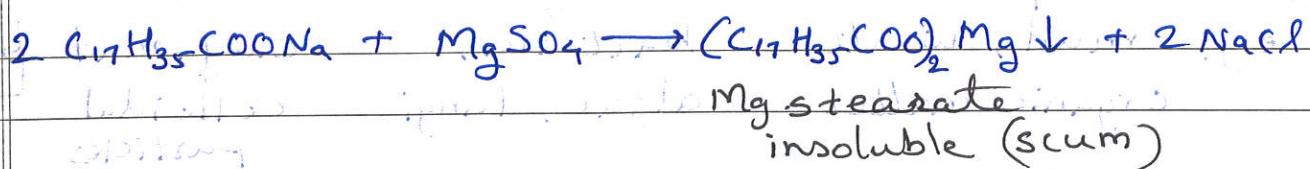
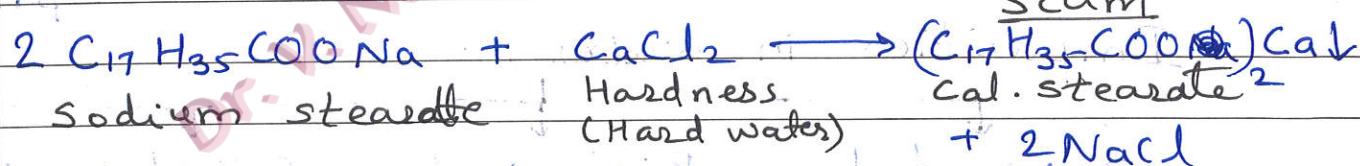
Soft water

(Forms lather easily with the soap)

Hard water - Presence of dissolved salts i.e. Ca^{+2} , Mg^{+2} , Fe^{+2} , Mn^{+2} , Al^{+3} , etc. in water

Hardness - Soap consuming or lather forming capacity due to presence of certain salts of Ca & Mg, other heavy ions in the form of chlorides, sulphates, nitrates, bicarbonates.

Re⁷ betⁿ soap & Ca or Mg from hard water -



Unit of Hardness :-

- i) mg per lit. ii) ppm

$$1 \text{ ppm} = 1 \text{ mg/lit.}$$

- iii) Other units \rightarrow °C_l (degree clark)
°F₂ (degree French)

Types of Hardness :-

Temporary
or Carbonate
or Alkaline

Permanent
or Non-carbonate
or Non-alkaline

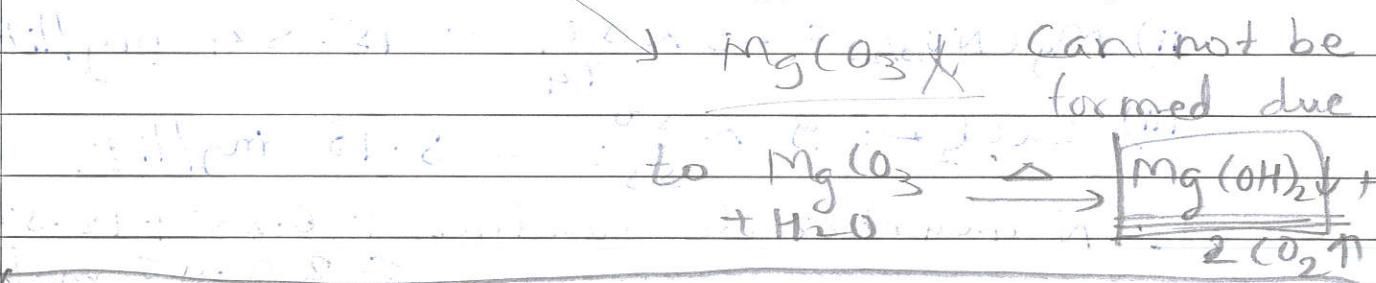
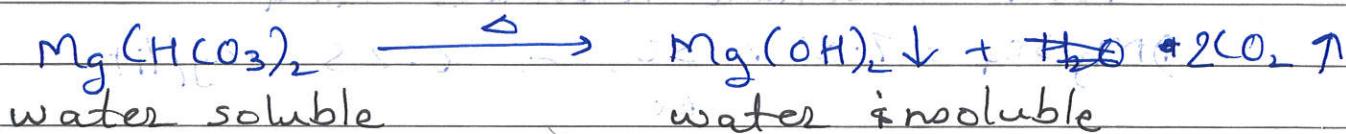
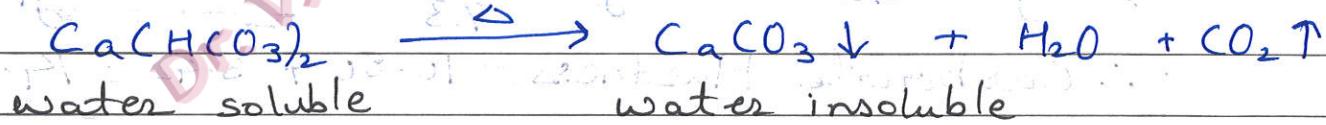
This can be removed
by merely boiling &
then filtration

This can not be removed
easily by boiling, &
requires softening
methods.

It occurs due to
presence of bicarbonates
of Ca, Mg, Fe, Al, Mn, etc.
i.e. $\text{Ca}(\text{HCO}_3)_2$, $\text{Mg}(\text{HCO}_3)_2$

It occurs due to
presence of chlorides,
sulphates, nitrates of
Ca, Mg, Fe, Al, Mn, etc.
i.e. CaCl_2 , MgCl_2 , CaSO_4 ,
 MgSO_4 , $\text{Ca}(\text{NO}_3)_2$, $\text{Mg}(\text{NO}_3)_2$

Reactions :-



$$\text{Total Hardness} = \text{Temp. Hardness} + \text{Permanent Hardness}$$

Determination of Hardness in CaCO_3 terms:-

$$\text{CaCO}_3 \text{ eq. of given salt} = \frac{\text{wt of given salt in mg/lit}}{\text{Eq.wt of given salt}} \times \frac{50}{}$$

Numerical :-

Ques. Calculate total, carbonate & non-carbonate hardness for 3 lit in CaCO_3 eq. for following -

$$\text{MgSO}_4 = 7.5 \text{ mg}, \text{Mg(NO}_3)_2 = 23 \text{ mg}, \text{Mg(HCO}_3)_2 = 5 \text{ mg},$$

$$\text{Ca(HCO}_3)_2 = 17.5 \text{ mg}, \text{CaCl}_2 = 9 \text{ mg}, \text{FeSO}_4 = 3 \text{ mg}$$

$$\text{Silica } (\text{SiO}_2) = 2 \text{ mg.}$$

→ Carbonate Hardness Data →

$$\text{Ca(HCO}_3)_2 = 17.5 \text{ mg. \& Mg(HCO}_3)_2 = 5 \text{ mg.}$$

$$\text{i) CaHCO}_3 = 17.5 \times \frac{50}{81} \quad (\text{Eq. wt of Ca(HCO}_3)_2 = 81) \\ = 10.80 \text{ mg/lit} \quad \text{As mole.wt of } \text{HCO}_3^- = 60 \quad \therefore \frac{60}{2} = 30 \quad \therefore \frac{162}{2} = 81$$

$$\text{ii) MgHCO}_3 = 5 \text{ mg} \times \frac{50}{73} = 3.42 \text{ mg/lit}$$

$$\therefore \text{Carbonate Hardness} = 10.80 + 3.42 = 14.22 \text{ mg/lit}$$

• Non-Carbonate hardness data -

$$\text{i) MgSO}_4 = 7.5 \times \frac{50}{60} = 6.25 \text{ mg/lit}$$

$$\text{ii) Mg(NO}_3)_2 = 23 \times \frac{50}{74} = 15.54 \text{ mg/lit}$$

$$\text{iii) CaCl}_2 = 9 \times \frac{50}{55} = 8.18 \text{ mg/lit.}$$

$$\therefore \text{Non-carbonate hardness} = 6.25 + 15.54 + 8.18 \\ = 29.97 \text{ mg/lit}$$

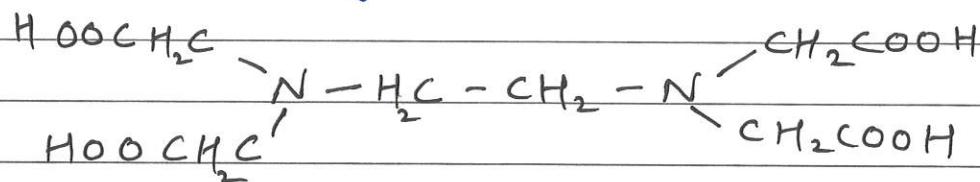
∴ Total Hardness = Carb. hardness + Non-Carb. hard.

$$= 14.22 + 29.97 \\ = 44.19 \text{ mg/lit}$$

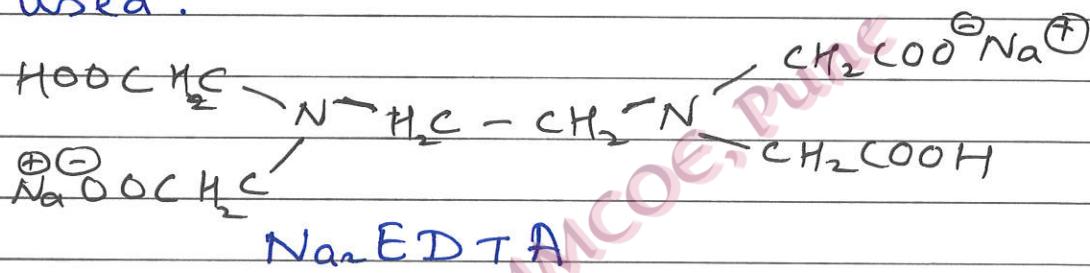
$$\text{But for 3 lit} = 44.19 \times 3 = 132.57 \text{ mg/lit.}$$

Determination of Hardness using EDTA :-

EDTA :- Ethylene Diamine Tetra Acetic acid



EDTA is sparingly / partially soluble, hence disodium salt of EDTA (completely soluble) is used.



Procedure -

Burette :- standard solⁿ of EDTA

Conical Flask :- Hard water (Ca^{2+} or Mg^{2+})

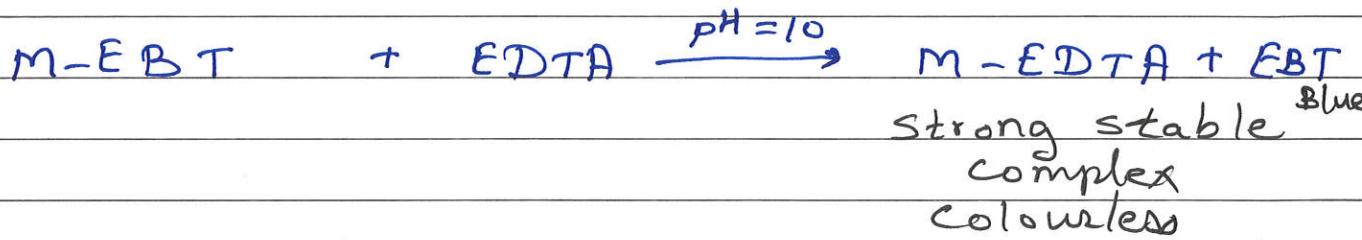
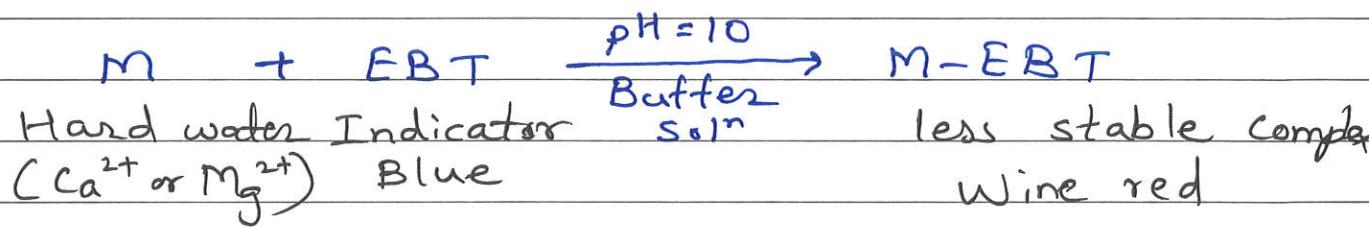
Indicator:- Eriochrome Black T (EBT)

Buffer solⁿ :- pH = 10 (NH_4Cl + NH_4OH)

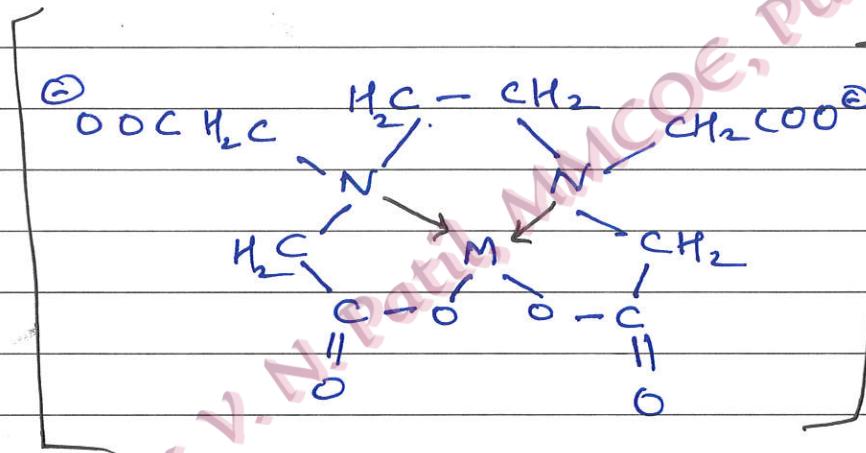
It is a complexometric titration, where EDTA is hexadentate ligand, forms chelate with metal ion from hard water.

- Fill the burette with standard EDTA solⁿ.
- Take 10 ml Hard water in conical flask.
- Add 10 ml Buffer solⁿ in it to maintain pH of the solⁿ, also add few drops of EBT to observe wine red colour.
- Titrate this CF solⁿ vs EDTA solⁿ from burette till blue colour is appeared.
- Note the reading, repeat the same process to find mean reading.

Reactions :-



Structure of Metal - EDTA complex :-



where
 $M =$
 Ca^{2+} or
 Mg^{2+}

Calculations :-

$$1 \text{ ml } 1 \text{ M EDTA} \equiv 100 \text{ mg } \text{CaCO}_3 \text{ eq.}$$

$$\therefore \text{Hardness} = \frac{\gamma \times M_2 \times 10^5}{V} \quad \left[\text{mg/lit or ppm} \right]$$

where γ = Burette reading of EDTA soln

M_2 = Molarity of EDTA soln

V = Vol^m of hard water.

Numericals on Hardness :-

Formulae :-

$$\text{Hardness} = \frac{y \times M_2 \times 10^5}{V}$$

mg/lit or
ppm

Total Hardness = Temp. Hard + Perm. Hard.

$$\text{Total Hardness} = \text{Temp. Hard} + \text{Perm. Hard}$$

- 1) From the following results, calculate temp., permanent & total hardness of water in ppm.
50 ml water required 14 ml of 0.01 M EDTA when titrated using MEBT indicator. 50 ml of boiled water required 9 ml of 0.01 M EDTA.

Given - Molarity of EDTA, $M_2 = 0.01 \text{ M}$

$$\text{Vol}^{\text{m}} \text{ of hard water} = 50 \text{ ml}$$

$$\text{For total hardness, } y = 14 \text{ ml}$$

$$\text{For perm. } y = 9 \text{ ml (boiled water)}$$

$$\text{Total Hardness} = \frac{y \times M_2 \times 10^5}{V} = \frac{14 \times 0.01 \times 10^5}{50}$$

$$= 280 \text{ ppm}$$

$$\text{Permanent Hardness} = \frac{y \times M_2 \times 10^5}{V} = \frac{9 \times 0.01 \times 10^5}{50}$$

$$= 180 \text{ ppm}$$

$$\text{Temp. Hardness} = \text{Total Hard.} - \text{Perm. Hard.}$$

$$= 280 - 180$$

$$= 100 \text{ ppm}$$

2) 25 ml of water sample required 17.5 ml of 0.02 M EDTA for end point. Calculate hardness of given water sample.

→ Given -

$$\text{Vol}^m \text{ of hard water} = V = 25 \text{ ml}$$

$$\text{Molarity of EDTA, } M_2 = 0.02 \text{ M}$$

$$\text{Burette reading, } y = 17.5 \text{ ml}$$

$$\text{Hardness} = ?$$

$$\text{Hardness} = \frac{y \times M_2 \times 10^5}{V}$$

$$= \frac{17.5 \times 0.02 \times 10^5}{25}$$

$$= 1400 \text{ ppm}$$

3) 100 ml water sample requires 19.5 ml of M/40 Na₂EDTA solⁿ for end point. 100 ml same water sample after boiling & filtration required 10.7 ml of Na₂EDTA solⁿ. Calculate alkaline, non-alkaline & total hardness of water sample.

→ Answer →

$$\text{Total Hardness} = 487.5 \text{ mg/lit or ppm}$$

$$\text{Non-alkaline hard.} = 287.5 \text{ mg/lit or ppm}$$

$$\text{Alkaline hard.} = 220 \text{ ppm or mg/lit.}$$

Alkalinity :-

Alkaline ions - OH^\ominus , CO_3^{2-} , HCO_3^-

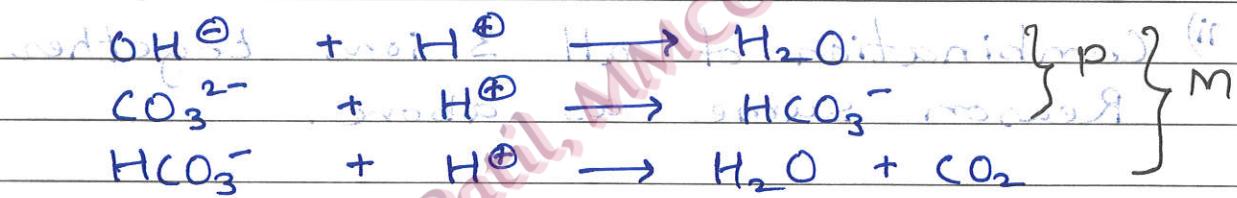
Defⁿ of Alkalinity - It is the amount of alkaline ions (OH^\ominus , CO_3^{2-} , HCO_3^-) present in water sample using phenolphthalein (PP) & methyl orange (Mo) indicators via neutralisation titration.

$\text{OH}^\ominus = \text{NaOH}, \text{Ca(OH)}_2, \text{Mg(OH)}_2, \text{etc.}$

$\text{CO}_3^{2-} = \text{Na}_2\text{CO}_3, \text{CaCO}_3, \text{MgCO}_3, \text{etc.}$

$\text{HCO}_3^- = \text{NaHCO}_3, \text{Ca(HCO}_3)_2, \text{Mg(HCO}_3)_2, \text{etc.}$

Reactions :-



Procedure :-

Burette :- standard HCl M & g

Conical flask :- Alkaline water sample

Indicator :- Phenolphthalein & Methyl Orange

End Point :- (Pink to colourless) (Yellow to orange)

- i) Fill the burette with HCl solⁿ
- ii) Take alkaline water sample in C.F.
- iii) Add few drops of indicators.
- iv) Titrate till the end point. Note the readings.
- v) Find out type & amount of alkalinity using standard alkaline table.

Alkalinity :-

2 moles of HCl reacts with 1 mole of alkali.

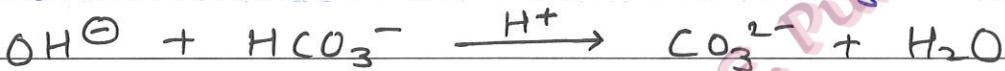
1 mole of alkali reacts with 1 mole of acid.

Types of alkalinity :- Total 7.

- i) Only OH^- H_2O - most acidic
- ii) Only CO_3^{2-} H_2O - most basic
- iii) Only HCO_3^- H_2O - not suitable to
- iv) Combination of OH^- & CO_3^{2-} is also not
- v) Combination of CO_3^{2-} & HCO_3^- is not
- vi) Combination of OH^- & HCO_3^- is not
- vii) Combination of all 3 ions together.

But following alkalinity is not possible -

- i) Combination of OH^- & HCO_3^- because



- ii) Combination of all 3 ions together -
Reason same as above.

Standard Alkalinity Table :-

Relaⁿ betⁿ OH^- CO_3^{2-} HCO_3^-
 $\text{P} \& \text{m}$ L.O.H Alkalinity = alkalinity = alkalinity

$\text{P} = 0$ (most acidic) \therefore least basic

$\text{P} \neq \text{m}$ (most basic) \therefore not suitable

$\text{P} = \frac{1}{2}(\text{m} + \text{P})$ (most basic at limit) $\therefore 2\text{P} = \text{m}$

$\text{P} > \frac{1}{2}\text{m}$ $(2\text{P} - \text{m})$ $2(\text{m} - \text{P})$ -

$\text{P} < \frac{1}{2}\text{m}$ L.O.H Alkalinity \therefore $2\text{P} + (\text{m} - 2\text{P})$

A. In presence of phenolphthalein

Calculation \rightarrow aim to convert into molar with HCl (i)

$$P = \frac{x \times N \times 50 \times 1000}{V \times 1000}$$

$$M = \frac{y \times N \times 50 \times 1000}{V \times 1000}$$

wheresthat unitless because of prior

x = burette reading for phenolphthalein

y = $\frac{w}{V}$ Methyl Orange

N = Normality of HCl

V = Volum of alkaline water sample

Numerical on Alkalinity -

i) 50 ml alkaline water sample requires 9.2 ml of N/50 HCl coupto phenolphthalein end point And further 3.2 ml of acid for complete neutralization. Calculate types of amount of alkalinites.

Given :- $V = 50 \text{ ml}$
 $N = N/50 = 0.02 \text{ N}$
 $x = 9.2 \text{ ml}$
 $y = 9.2 + 3.2 \text{ ml} = 12.4 \text{ ml}$

$$P = \frac{x \times N \times 50 \times 1000}{V} = \frac{9.2 \times 0.02 \times 50 \times 1000}{50} = 184 \text{ ppm}$$

$$M = \frac{y \times N \times 50 \times 1000}{V} = \frac{12.4 \times 0.02 \times 50 \times 1000}{50} = 248 \text{ ppm}$$

$$P = 184 \text{ ppm}, M = 248 \text{ ppm} \quad (\because \frac{1}{2}M = 124 \text{ ppm})$$

$$\therefore P > \frac{1}{2}M$$

∴ Following alkalinites are present

$$OH^- = (2P - M) = 120 \text{ ppm}$$

$$CO_3^{2-} = 2(M - P) = 128 \text{ ppm}$$

$$\therefore OH^- = 120 \text{ ppm}$$

$$\& CO_3^{2-} = 128 \text{ ppm}$$

2) 50 ml water sample on titration with N/40 HNO₃ gave 3.7 ml reading for P.P. end point & 15.1 ml for M.O. end point.
Calculate type and amount of alkalinites.

Given :-

$$V = 50 \text{ ml}$$

$$\text{N/40} = 0.025 \text{ N}$$

$$x = 3.7 \text{ ml} \times 0.025 \text{ N}$$

$$y = 15.1 \text{ ml} \times 0.025 \text{ N}$$

$$\rightarrow \text{Ln P.M} = \text{Ln } 3.7 + 2.8 \text{ N.P}$$

$$P = \frac{x \times N \times 50 \times 1000}{V}$$

$$= \frac{3.7 \times 0.025 \times 50 \times 1000}{50}$$

$$= 92.5 \text{ mg ppm}$$

$$M = \frac{y \times N \times 50 \times 1000}{V}$$

$$= \frac{15.1 \times 0.025 \times 50 \times 1000}{50}$$

$$= 377.5 \text{ mg ppm}$$

$$P = 92.5 \text{ ppm}$$

$$M = 377.5 \text{ ppm} \quad (\because \frac{1}{2}M = 188.75)$$

$$\therefore P < \frac{1}{2}M$$

Following alkalinites are present -

$$\therefore CO_3^{2-} = 2P = 185 \text{ ppm}$$

$$\& HCO_3^- = (M - 2P) = 192.5 \text{ ppm}$$

$$\boxed{CO_3^{2-} = 185 \text{ ppm}}$$

$$\boxed{HCO_3^- = 192.5 \text{ ppm}}$$

- 3) A water sample is not alkaline to PP. However, 15.1 ml 0.2 N H_2SO_4 required for Mo end point for 100 ml water sample. Calculate type and amount of alkalinities.

Given :-

$$V = 100 \text{ ml}$$

$$N = 0.2 \text{ N}$$

$$x = 0 \text{ ml}$$

$$y = 15.1 \text{ ml} \quad (\text{as it is})$$

$$\text{As } x = 0 \text{ ml} \quad \therefore \boxed{P = 0}$$

Hence, following alkalinity is present -

$$HCO_3^- = M = \frac{y \times N \times 50 \times 1000}{(4-M) V}$$

$$= \frac{15.1 \times 0.2 \times 50 \times 1000}{100}$$

$$= 1510 \text{ ppm}$$

$$\boxed{\therefore HCO_3^- = 1510 \text{ ppm}}$$

- 4) 50 ml alkaline water sample requires 10.5 ml N/40 HCl for PP end point & total 14.1 ml for Mo end point. Find types & amount of alkalinities.

Given -

$$V = 50 \text{ ml}$$

$$x = 10.5 \text{ ml}$$

$$N/40 = 0.025 \text{ N}$$

$$y = 14.1 \text{ ml} \quad (\text{total})$$

$$\rightarrow P = \frac{x \times N \times 50 \times 1000}{V}$$

$$= \frac{10.5 \times 0.025 \times 50 \times 1000}{50}$$

$$= 262.5 \text{ ppm}$$

$$M = \frac{y \times 8V \times 50 \times 1000}{V}$$

$$= \frac{14.1 \times 0.025 \times 50 \times 1000}{50}$$

$$= 352.5 \text{ ppm}$$

$$\boxed{P = 262.5 \text{ ppm}}, \boxed{M = 352.5 \text{ ppm}} \quad \frac{1}{2}M = 176.25 \text{ ppm}$$

$$\boxed{P > \left(\frac{1}{2}M\right)_{\text{min}}} \quad \text{Lm 1.41 = 1.5}$$

Following alkalinites are present -

$$\text{OH}^- = (2P - M) = 172.5 \text{ ppm}$$

$$\text{&} \text{CO}_3^{2-} = 2(M - P) = 180 \text{ ppm.}$$

$$\boxed{\text{OH}^- = 172.5 \text{ ppm}}$$

$$\boxed{\text{CO}_3^{2-} = 180 \text{ ppm.}}$$

$\text{H}_2\text{O} \cdot \text{O} \cdot \text{H}$

(1.41) Lm 1.41 = 1.5

$\text{H}_2\text{O} \cdot \text{O} \cdot \text{H}$

Lm 1.41 = 1.5

Disadvantages of using hard water in boilers:

- i) Boiler Corrosion (Defⁿ, Causes, Effects / Disadvantages)
- ii) Caustic Embrittlement (Defⁿ, Causes, Effects / Disadvantages)
- iii) Priming & Foaming (Effects / Disadvantages)
- iv) Scales & Sludges (Preventions)

Boiler Corrosion:

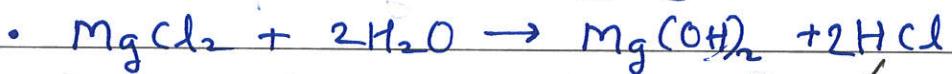
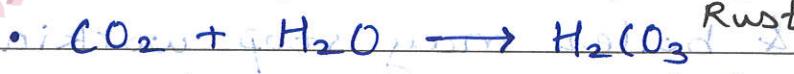
Defⁿ- Decomposition of metal due to its equipment chemical/electrochemical reaction due to presence of dissolved O_2 , CO_2 , hydrolysis of salt.

Causes - Presence of dissolved O_2 , CO_2 ,

hydrolysis of salts.

Effects / - $4\text{Fe} + 2\text{H}_2\text{O} \rightarrow 4\text{Fe(OH)}_2 \rightarrow$

$4\text{Fe(OH)}_2 + \text{O}_2 + 2\text{H}_2\text{O} \rightarrow 2(\text{Fe}_2\text{O}_3 + 2\text{H}_2\text{O})$ Rust



It decomposes to acid (i.e. This acid corrodes the boiler metal.)

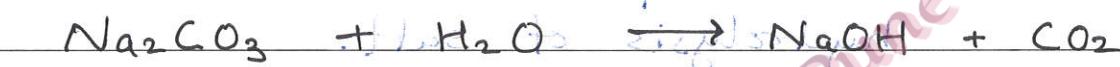
Preventions - i) By adding calculated quantity (Prevention of $\text{Na}_2\text{S}_2\text{O}_3$ or Na_2HPO_4 or Na_2S measures) to the water (ii) By chemical treatment.

ii) Caustic Embrittlement :-

Defⁿ - Formation of brittle cracks in boiler tube is caustic embrittlement. A type of boiler corrosion due to highly alkaline water (especially in high pressure boilers).

Causes :- Excess free Na_2CO_3 which remains

(i) behind during water treatment by lime soda method, undergoes decomposition to give



Sodium ferrate

Disadvantages/ :- Formation of caustic soda

Effects :- (NaOH) attacks inner walls of boiler, joints, rivets, etc. Due to this, life of boiler reduces, maintenance cost increases & boiler may stop working.

Preventions :- i) Use of sodium phosphate instead of sodium carbonate.

ii) By treating boiler walls with tannin or lignin which blocks hairline cracks.

iii) Adjusting the pH of the feed water carefully between 8.1 & 9.

iii) Priming & Foaming :-

Priming -

Defⁿ :- It is the process of formation of wet steam i.e. steam contaminated with water droplets.

Foaming -

Defⁿ :- It is the formation of persistent or continuous foam or bubbles on the surface of water in boilers.

Causes of Priming :- i) Improper boiler design.
ii) Presence of large amount of dissolved salts.
iii) Very high level of boiler-feed water.

Causes of Foaming :- i) Presence of oil droplets, soaps in boiler-feed water.
ii) Violent/vigorous agitation of boiler feed H₂O
iii) Presence of finely dispersed suspended material.

Disadvantages / Effects of Priming & foaming :-

- i) Difficult to maintain constant pressure of steam in boilers in presence of foam.
- ii) Blastage of fuel
- iii) Reduces machine efficiency.

Prevention of Priming & Foaming :-

- i) Proper boiler design.
- ii) Removal of dissolved impurities.
- iii) Adding antifoaming chemicals like castor oil
- iv) Maintaining low level of water prevents priming.

iv) Scales & Sludges :-

Difference between scales & sludges:-

Properties Scales Sludges

1. Definition	Strong, hard and adherent precipitates	Smooth, soft loose particles
2. Adherance	strongly adhered	loosely adhered
3. Formation	At hotter parts of boiler	At cooler parts of boiler

4. Causes

- (i) Decomposition of bicarbonates: $\text{Ca}(\text{HCO}_3)_2 \xrightarrow{\Delta} \text{CaCO}_3 \downarrow + \text{H}_2\text{O} + \text{CO}_2 \uparrow$
- (ii) Hydrolysis of Mg Salts: - $\text{MgCl}_2 + 2\text{H}_2\text{O} \xrightarrow{\Delta} \text{Mg(OH)}_2 \downarrow + 2\text{HCl}$
- (iii) Presence of silica
- (iv) Decreased solubility of CaSO_4 .

Formed due to increase in concn of salts like Na_2CO_3 , MgSO_4 , CaCl_2 , MgCl_2 , MgCO_3

5. Problem In extreme Case

May lead to explosion of boiler

May lead to chocking and blockage

6. Harmful

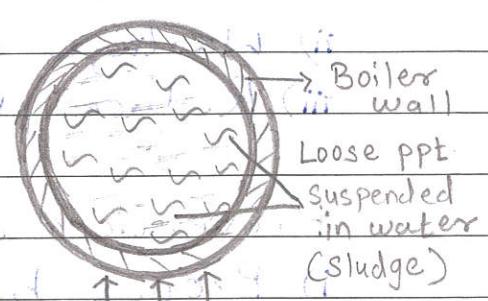
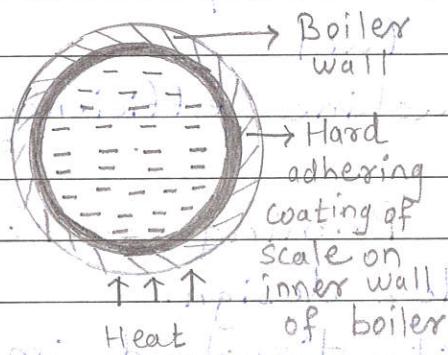
More harmful

Less harmful

7. Removal methods

By EDTA treat- ment, Using hammer & chiesel, down operation Thermal shocks to boiler.

8. Diagram

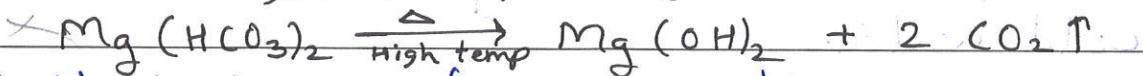
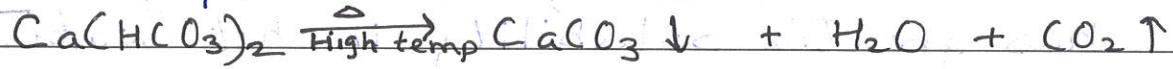


Scales :-

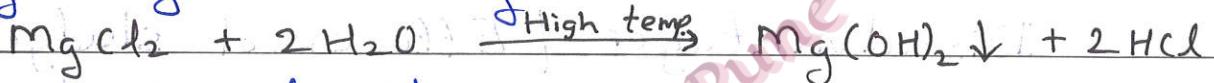
Definition :- Hard & strong adherent particles as precipitates formed inside the boilers, which are bad conductor of heat, is known as 'scale'.

Causes of scale formation :-

i) Decomposition of bicarbonates -



ii) Hydrolysis of Mg salts -



iii) Presence of silica

iv) Decreased solubility of CaSO_4 .

Disadvantages / Effects of scale -

i) Wastage of fuel.

ii) Decrease in efficiency of the boiler

iii) Danger of boiler explosion.

Prevention & Removal of scales -

i) Use of scraper / wire brush.

ii) Using hammer & chisel.

iii) Thermal shocks to boiler.

iv) Treatment with EDTA, sodium phosphate, calgon, etc. internal treatment methods.

Prevention of scales -

i) Use of softened water as boiler feed water

ii) Adding sodium aluminate to trap scale forming particles.

Sludges :-

Definition - The smooth, slimy & loose deposit of precipitated salts in boiler tube is called as 'sludges'.

Causes - These are formed by substances such as $MgCO_3$, $MgCl_2$, $CaCO_3$, $MgSO_4$ which has greater solubility in hot water than cold water.

Disadvantages / Effects of sludges -

- As sludges are poor conductors of heat, they waste some portion of heat.
- Excessive sludge formation may choke or block pipes.
- It reduces water flow rate in boiler.

Prevention / Removal of sludges -

- Frequently performing blow down operation.
- Use of wire brush, scrapers, etc.
- By using soft water.

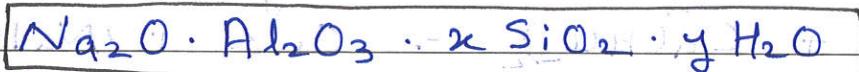
Prevention -

Use of soft water

Water softening by Zeolite Process :-

Zeolite (Greek word Zein - boiling, lithos - stone) i.e. boiling stone.

Structure of zeolite -



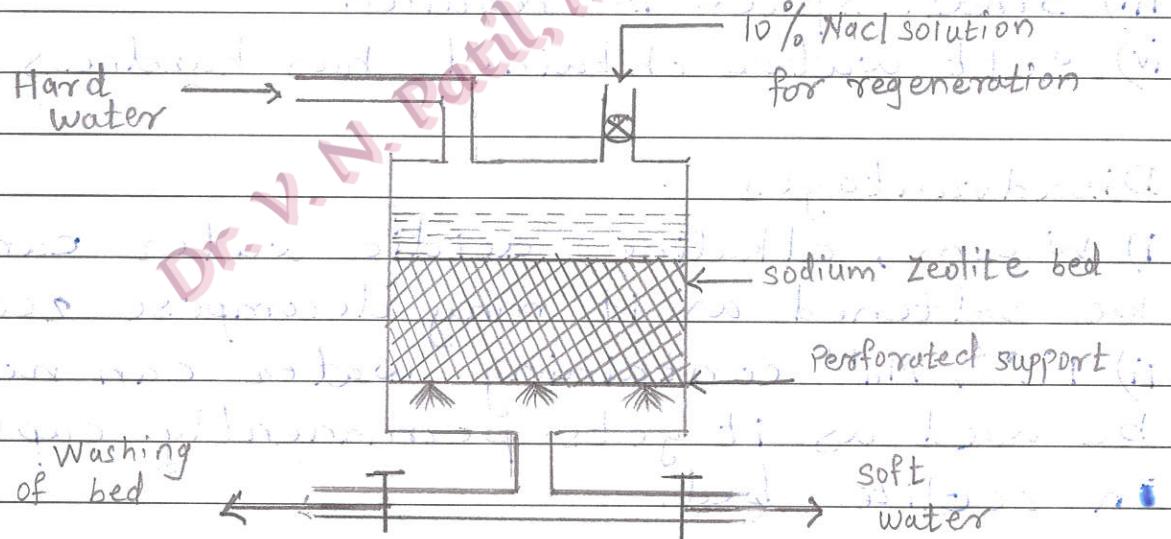
where $x = 2$ to 10
 $y = 2$ to 6

Hydrated Sodium Alumino Silicate

Principle of Zeolite -

Zeolite has loosely attached sodium (Na^+) ions which can be reversibly exchanged with Ca^{+2} , Mg^{+2} ions from hard water, to give soft water.

Diagram -



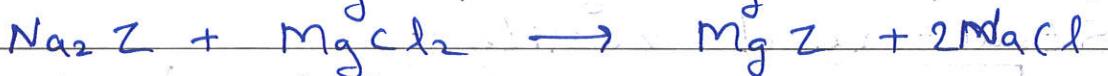
Process - i) Hard water is allowed to pass through zeolite bed.

ii) When hard water percolates through zeolite bed, exchange of Na^+ from zeolite bed with Ca^{+2} , Mg^{+2} from hard water takes place & soft water is obtained.

iii) Zeolite is regenerated by with brine soln (10%) NaCl .

Reactions :-

i) Hardness Removing reactions -



ii) Regeneration reactions -



Advantages -

- i) Low cost operating process.
- ii) Compact equipment with easy process.
- iii) Small space is required.
- iv) Soft water obtained has hardness 5-10 ppm.

Disadvantages -

- i) Warm, alkaline, acidic water can not be softened as it may decompose zeolite.
- ii) Fe^{+2} , Mn^{+2} containing water can not be used as it gets permanently captured in zeolite bed.

Limitation -

- i) Applicable only for small scale treatment.
- ii) Obtained soft water contains more sodium salts, which may cause caustic embrittlement in high pressure boilers.

Numerical on Zeolite :-

Formulae -

Step-1 :-

$$\text{mg of NaCl} = \text{conc. of NaCl} \times \text{Vol}^m \text{ of } \text{NaCl} \times 1000$$

in g/lit

Step-2 :-

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

Step-3 :-

$$\text{Hardness} = \frac{\text{CaCO}_3 \text{ eq. of NaCl}}{\text{Vol}^m \text{ of hard water}}$$

- 1) A zeolite bed get exhausted which is regenerated by passing 4.8 lit of 10% NaCl soln. Bed get exhausted by 1200 lit of water sample. Calculate hardness of water sample.

- Given :-

$$\text{Vol}^m \text{ of hard water} = 1200 \text{ lit.}$$

$$\text{Vol}^m \text{ of NaCl} = 4.8 \text{ lit}$$

$$\text{Conc}^n \text{ of NaCl} = 10\% = 100 \text{ g/lit} \quad (10\% = \frac{100 \text{ g}}{100 \text{ ml}} = 100 \text{ g/lit})$$

$$\text{Hardness} = ?$$

$$\rightarrow \text{Step-1 : mg of NaCl} = \text{conc}^n \text{ of NaCl} \times \text{Vol}^m \text{ of NaCl} \times 1000$$

in g/lit

$$= 100 \times 4.8 \times 1000$$

$$= 4.8 \times 10^5$$

$$\text{Step-2 : CaCO}_3 \text{ eq. of NaCl} = \frac{\text{mg of NaCl} \times 50}{58.5}$$

$$= \frac{(4.8 \times 10^5) \times 50}{58.5}$$

$$= 4.102 \times 10^5$$

$$\text{Step-3 : Hardness} = \frac{\text{CaCO}_3 \text{ eq. of NaCl}}{\text{Vol}^m \text{ of Hard water}} = \frac{4.102 \times 10^5}{1200}$$

2) An exhausted zeolite bed was regenerated by 160 lit of NaCl having strength 160 g/lit. How many lit. of NaCl hard water of hardness 420 ppm as CaCO_3 can be softened by this softener.

- Given :-

$$\text{Vol}^m \text{ of hard water} = ?$$

$$\text{Vol}^m \text{ of NaCl} = 160 \text{ g/lit.}$$

$$\text{Conc}^n \text{ of NaCl} = 160 \text{ lit}$$

$$\text{Hardness} = 420 \text{ ppm}$$

Step - 1 :-

$$\text{mg of NaCl} = \text{conc}^n \text{ of NaCl} \times \text{Vol}^m \text{ of NaCl} \times 1000$$

$$= 160 \times 160 \times 1000$$

$$= \underline{\underline{256 \times 10^5}}$$

Step - 2 :-

$$\text{CaCO}_3 \text{ eq. of NaCl} = \frac{\text{mg of NaCl}}{\text{NaCl eq.}} = \frac{150}{58.5}$$

$$= 256 \times 10^5 \times \frac{50}{58.5}$$

$$= \underline{\underline{218.80 \times 10^5}}$$

Step - 3 :-

$$\text{Hardness} = \frac{\text{CaCO}_3 \text{ eq. of NaCl}}{\text{Vol}^m \text{ of hard water}}$$

$$\therefore \text{Vol}^m \text{ of hard water} = \frac{\text{CaCO}_3 \text{ eq. of NaCl}}{\text{Hardness}}$$

$$= \frac{218.80 \times 10^5}{420}$$

$$= \underline{\underline{52095.23 \text{ lit.}}}$$

3) How many lit. of 8% NaCl soln will be reqd to regenerate a zeolite bed which has capacity of 2500 lit. of water of 400 mg. equivalent hardness per lit?

- Given :-

$$\text{Conc}^n \text{ of NaCl} = 8\% = 80 \text{ g/lit}$$

$$\text{Vol}^m \text{ of hard water} = 2500 \text{ lit.}$$

$$\text{Hardness} = 400 \text{ mg/lit.}$$

$$\text{Vol}^m \text{ of NaCl} = ?$$

$$\text{Step - 3 :- Hardness} = \frac{\text{CaCO}_3 \text{ eq. of NaCl}}{\text{Vol}^m \text{ of hard water}}$$

$$\therefore \text{CaCO}_3 \text{ eq. of NaCl} = \frac{\text{Vol}^m \text{ of hard water} \times \text{hardness}}{400}$$

$$= \frac{2500 \times 400}{400}$$

$$= 10,00,000 = \underline{\underline{10^6}}$$

Step - 2 :-

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

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

$$= 10^6 \times \frac{58.5}{50} = \underline{\underline{11.7 \times 10^5}}$$

Step - 1 :-

$$\text{mg of NaCl} = \text{Vol}^m \text{ of NaCl} \times \text{conc}^n \text{ of NaCl} \times 1000$$

$$\therefore \text{Vol}^m \text{ of} = \frac{\text{mg of NaCl}}{\text{conc}^n \text{ of NaCl} \times 1000}$$

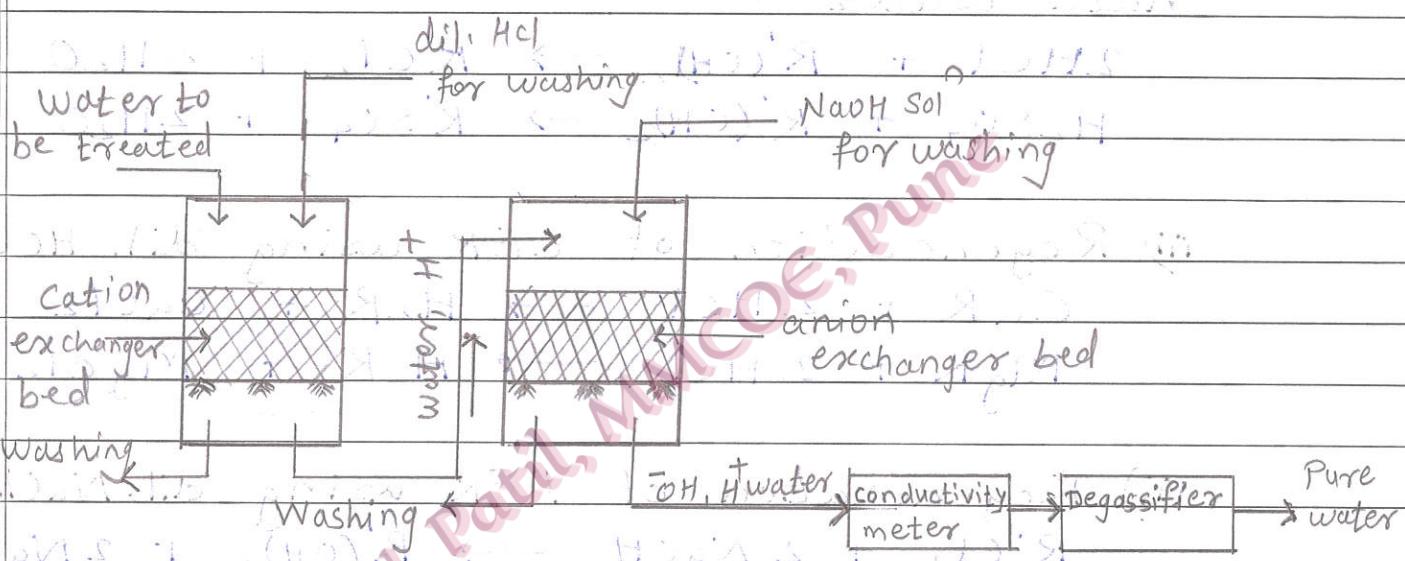
$$= \frac{11.7 \times 10^5}{80 \times 1000} = \underline{\underline{14.62 \text{ lit.}}}$$

Demineralization / Deionization Method :-

Principle :-

This method is used to obtain pure water using cation exchanger resin CER (H_2R) & anion exchanger resin AER ($R'(OH)_2$).

Diagram :-

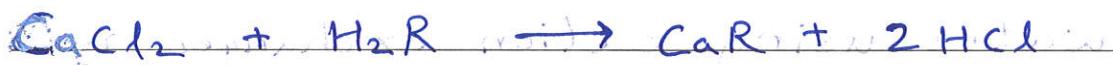


Process :-

Hard water is allowed to pass through CER, where exchange of cations from hard water with H_2R takes place and such acidic water is passed through AER, where exchange of anions from hard water with $R'(OH)_2$ takes place. Water obtained through this process is treated with conductivity meter & then degassifies to obtain pure water free from impurities. Later CER & AER are regenerated by dil. HCl & dil. NaOH respectively.

Reactions →

i) CER reactions to remove cations from hard water -



ii) AER reactions to remove anions from hard water -



iii) Regeneration of CER using dil. HCl -



iii) Regeneration of AER using dil. NaOH -



Advantages :-

- i) Water obtained by this process has very low hardness: 0-2 ppm.
- ii) Suitable for high pressure boilers.
- iii) Highly acidic or alkaline water also can be purified.

Disadvantages :-

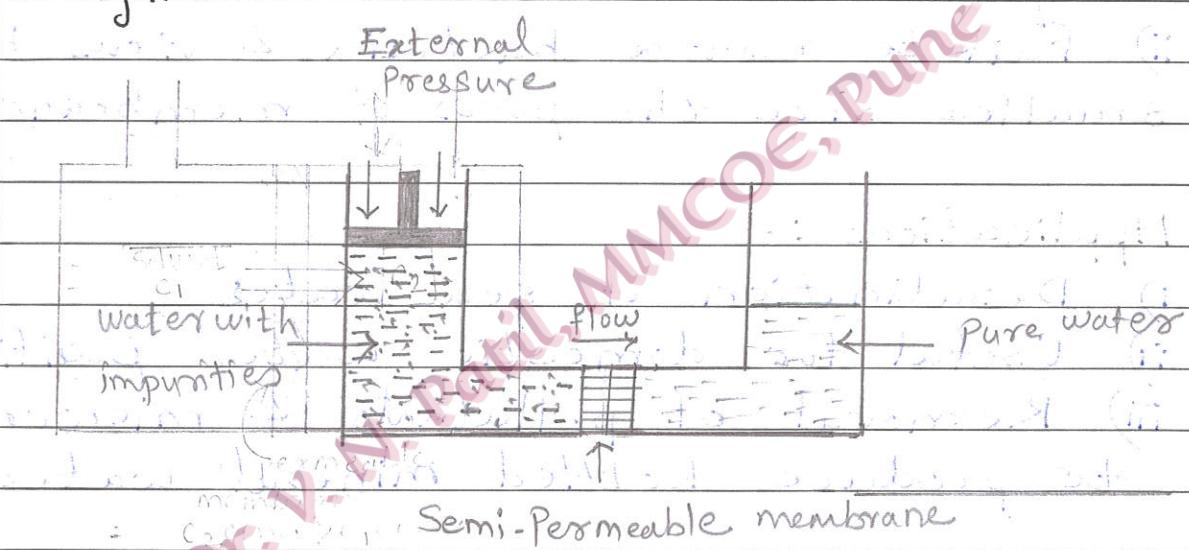
- i) Expensive chemicals are required.
- ii) Costly equipment.
- iii) Highly turbid water can block the resin, ultimately reducing output.

Purification of water :-

1) Reverse Osmosis (RO) -

Principle - In RO, water i.e. solvent flows from High concentration to Low concentration through semi-permeable membrane (SPM) by applying external pressure slightly higher than the osmotic pressure, to result in obtaining pure water.

Diagram :-



Process - RO is used to purify water by removing dissolved ions or molecules.

- Water is forced to pass through SPM, under high pressure.
- Water diffuses through SPM & dissolved salts remain behind on the surface of mem-
- Thus, water is separated from its contaminants rather than contaminants from water.
- RO membrane (SPM) are made up of cellulose acetate, acrylics, polyamides, aramids, etc.

Advantages :-

- i) Low cost process.
- ii) Simple equipment.
- iii) Easy to operate.
- iv) Drinking mineral water is obtained.
- v) Useful for high pressure boilers.

Limitations :-

- i) Periodic replacement of SPM is required.
- ii) Fails to remove bacteria & virus having smaller size than the pores of membrane.

Applications :-

- i) Desalination of sea water.
- ii) Useful for domestic water purification.
- iii) Removal of pollutants & microorganisms to produce bottled mineral water.

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MMCOE, Pune

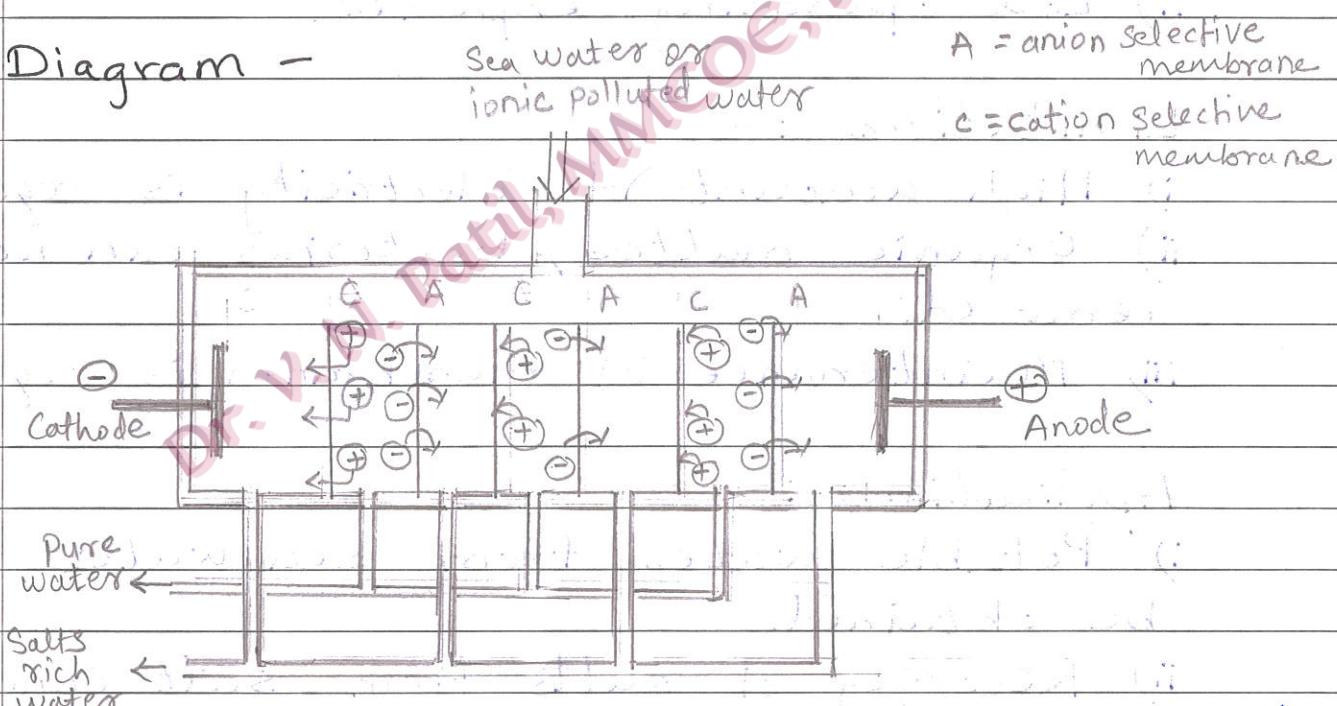
2) Electrodialysis :-

Definition -

It is the process of removing dissolved ionic impurities (such as salts, ionic pollutants, dyes) from water using membranes in presence of electric field.

Principle - This method is used to separate salts from sea water using cation selective membrane & anion selective membrane in presence of electric field.

Diagram -



Construction - It consists of an electrodialysis cell/unit containing cation selective membrane (CSM) & anion selective membrane (ASM).

- CSM has charge '-ve' i.e. $-SO_3^-$, $-COO^-$ which attracts only cations by repelling anions from sea water.

- ASM has charge '+ve' i.e. $-NR_3^+$ which attracts only anions by repelling cations from sea water.

Working :- The saline water is allowed to flow in alternate compartments of unit, in perpendicular direction to unit.

- Under the influence of electric field, cations & anions from water move towards CSM & ASM respectively.
- Thus, from alternate compartments conc. salts & pure water is obtained.

Advantages :-

- i) Compact equipment.
- ii) Low operating expenses.

Limitations :-

- i) High amount of electricity is required.
- ii) Organic matter, bacteria can not be removed.
- iii) Maintenance of membranes is required.

Applications :-

- i) Potable water from sea water can be obtained.
- ii) Recovery of salts from salt concentrated water.
- iii) Removal of toxic salts from industrial waste.