PAGE NO.:
DATE: / /

# Assignment-1

## Part-A

Q1) Which salts are responsible for temporary and permanent hardness of water.

Ans Temporary = Presence of Ca, Mg bicarbonates and carbonate of iron.
Permanent = Presence of chlorides and sulphates of Ca, Mg, Fe ..

Q2) What are different unit of hardness. Write formula of inter conversion of these units.

Ans ppm, mg/L, °Cl (degree clark), °F (degree french), (°d) degree german are units of hardness

1 ppm = 1 mg/l = 0.07°Cl = 0.1°F = 0.056°dH

Q3) What is priming and foaming ?

Ans = Priming = It is carryover of inter droplets along with steam. Process of 'wet steam' formation is priming.

Foaming = Production of persistent foam in boilers which do not break easily. It is due to presence of substance like oils (reduce surface tension of water).

Q4) Write General formula of Zeolites.

Ans $M_{x/n} \cdot (AlO_2)x \cdot (SiO_2)y \cdot m H_2O$

M = metal cation ($Na^+$, $Ca^{2+}$) n = Valency of M
x = no of Al atoms y = no of Si atoms

PAGE NO. :
DATE : / /

$y/x \geq 1$ ( ratio of Si/Al is atleast 1:1)

m = no of water molecules associated

Zeolites are microporous, aluminosilicate, minerals commonly used in water softening catalysis.

Q5) Write names of internal treatment methods used for water softening.

Ans Colloidal Conditioning
Phosphate Treatment
Carbonate Conditioning
Calgon Conditioning
Treatment with $NaAlO_2$,
Electrical Conditioning.
Radioactive Conditioning
Complexiometric Method.

Part B

Q1) Describe Ion Exchange Method for softening of hard water.

Ans Ion Exchange method is a widely used technique that involves the removal of $Ca^{2+}$ and $Mg^{2+}$ ions which are responsible for water hardness, replacing with $Na^+$ or $K^+$.

Ion Exchang Resin : Uses a resin that contains $Na^+$ or $K^+$ ions. Resin is typically in form of

small beads or granules and is packed in a column or vessel.
Resin are insoluble, cross linked, long chain organic polymers with a microporous structure and "functional group" attached :- are responsible for ion exchange.

Process = ① Hard water flows through ion exchange resin. Resin beads are saturated with $Na^+$ or $K^+$

② Ions are exchanged $Ca^{2+}$ & $Mg^{2+}$ with $Na^+$ or $K^+$

$$2\,Na^+_{resin} + Ca^{2+}_{water} \rightarrow Ca^{2+}_{resin} + 2\,Na^+_{water}$$

③ Now water is softened.
④ Over time, resin becomes saturated with $Ca^{2+}$, $Mg^{2+}$ and loses its effectiveness.
Resin must be regenerated using a concentrated salt sol$^n$ (NaCl or KCl).

Q2) Explain different methods used for Sterilization, Treatment of water for Domestic Purposes.
Ans It is crucial to ensure it is free from harmful microorganisms.

① Boiling : Boil water for 10-15 minutes. All the disease producing bacteria are killed.
② Chlorination : Addition of Cl or Cl compounds

$$Cl_2 + H_2O \rightarrow HOCl + HCl$$

hypochlorous acid

Provides residual disinfection.

PAGE NO. :
DATE : / /

③ UV radiation :-
Water is exposed to UV light typically through a UV lamp.
Kills microorganisms by destroying their DNA. Effective against bacteria, viruses.

④ Ozonation = $O_3$ gas is bubbled through water. Oxidizes and kills bacteria and removes some chemicals and tastes.

⑤ Distillation :-
Water is heated to produce steam, which is then condensed back into liquid form.
Removes salts, most chemical contaminants.

⑥ Filtration = Water is passed through filter to remove particle, sediments.
Remove particulates. Advanced filters can remove viruses and protozoa.

⑦ Iodine Treatment = Addition of iodine tablets or tincture to water. Used in emergency situations.

Q3) Why hardness is expressed in terms of equivalents of $CaCO_3$. A given sample of water contains following salts
$MgSO_4$ - 50 mg/l, $Mg(HCO_3)_2$ - 73 mg/l, $CaSO_4$ - 68 mg/l. Calculate degree of hardness in °F, °C and ppm.

Ans. Hardness in terms of $CaCO_3$ because it has molar mass of 100 and most insoluble ppt. It is most common scale forming material and its equivalent weights simplify the calculations.

PAGE NO.:
DATE: / /

## Multiplication factor.

(x) $MgSO_4$ : eq wt. = $\frac{120}{60}$ ⇒ 2

$Mg(HCO_3)_2$ : eq wt = $\frac{146}{73}$ ⇒ 2.

$CaSO_4$ = eq wt = $\frac{136}{68}$ ⇒ 2.

eq wt of $CaCO_3$ = 50 g/mol.

# $CaCO_3$ equivalent of $MgSO_4$ = $50 \times \left(\frac{50}{60}\right)$ ⇒ 41.54 mg/l.

$Mg(HCO_3)_2$ = $\left(\frac{73}{73}\right) \times 50$ ⇒ 50 mg/l.

$CaSO_4$ = $\frac{68}{68} \times 50$ ⇒ 50 mg/l.

= Total hardness = 141.54 ppm.

°F = 0.1 x 141.54 ⇒ 14.1 °F

°C = 0.07 x 141.54 = 9.89 °C

Part C) Q1) 100 ml of a sample of water required 20 ml of 0.1 M EDTA for titration using EBT as indicator. After boiling 100 ml of same sample, required 10 ml of 0.01 M EDTA. Calculate total, permanent, and temporary hardness.

Ans Vol of water sample = 100 ml

Total hardness = $\frac{20 \text{ ml} \times 0.1 \text{ M} \times 1000 \times 100}{100}$

= 2000 mg/L of $CaCO_3$

1 mg/L of $CaCO_3$ = 50 ppm = $\frac{100}{2}$ eq wt

Total Hardness in ppm = 2 x 50 = 100 ppm.

Permanent Hardness = $\frac{10 \times 0.01 \times 1000}{100}$ = 100 mg/L of $CaCO_3$

Permanent hardness in ppm = 1 × 50 = 50 ppm.

Temporary hardness =
200 − 100 = 100 ppm

Total hardness = $\frac{\text{Vol of EDTA (before boiling)} \times \text{Molarity} \times 1000}{\text{Vol of water sample}}$

Q2) A hard water sample having following composition has to be softened using lime Soda process
$MgSO_4$ - 84 ppm, $Mg(HCO_3)_2$ = 56 ppm,
$CaSO_4$ - 98 ppm, $Ca(HCO_3)_2$ = 220 ppm,
$MgCl_2$ - 130 ppm. Calculate the amount of lime and soda required to soften $10^6$ l of water. Also write chemical reaction involved in Lime Soda Process.

Ans ★ $Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 \downarrow + 2H_2O$ (L)
Lime is used to remove $Ca(HCO_3)_2$.

★ $Mg(HCO_3)_2 + 2Ca(OH)_2 \rightarrow Mg(OH)_2 \downarrow + 2CaCO_3 \downarrow + 2H_2O$ (2L)

★ $CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 \downarrow + Na_2SO_4$ (S)
Soda ash is used to remove $CaSO_4$.

★ $MgSO_4 + Ca(OH)_2 \rightarrow Mg(OH)_2 \downarrow + CaSO_4$ (L+S)
($CaSO_4$ ↓ removed by soda ash.)

★ $MgCl_2 + Ca(OH)_2 \rightarrow Mg(OH)_2 \downarrow + 2NaCl$ (L)

PAGE NO.:
DATE: / /

Total lime requirment =
2L for $Mg(HCO_3)_2$ + 1L for $Ca(HCO_3)_2$ +
1L for $MgCl_2$ + 1L for $MgSO_4$

$= 112 + 220 + 130 + 84 \Rightarrow 546$ ppm.

Total lime requirement (Kg) $= \frac{546 \times 10^6}{1000 \times 10^6} \Rightarrow 546$ Kg.

Total Soda Requirement =
1S for $CaSO_4$ + 1S for $MgSO_4$ =

$\Rightarrow 98 + 84 \Rightarrow 182$ ppm

Total Soda in kg $= \frac{182 \times 10^6}{1000 \times 10^6} = 182$ kg.

Hence, total lime required is 546 kg
and total soda required is 182 kg

$10^6$

Q3) Explain Boiler Corrosion and Caustic Embrittlement.

Ans. Caustic Embrittlement = Type of boiler corrosion caused by using highly alkaline water in boiler.

Leading to brittle failure of the boiler metal, especially along grain boundaries.

Causes of Caustic Embrittlement:
High Alkalinity.
Form$^{n}$ of Concentrated caustic zones.

Avoided by:
- using Sodium Phosphate.
- Adding tannin, lignin.
- Adding $Na_2SO_4$ to boiler water.
- Boiler designs to minimize area where concentrated caustic can be form

# Boiler Corrosion: Degradation of boiler metal components due to chemical or electro-chemical reactions with water and its impurities.

Causes:
① Dissolved oxygen:
DO in water in presence of prevailing high temp, attacks boiler material.

$$2Fe + 2H_2O + O_2 \rightarrow 2Fe(OH)_2 \downarrow$$

$$4Fe(OH)_2 \downarrow + O_2 \rightarrow 2[Fe_2O_3 \cdot 2H_2O] \downarrow$$

ferrous hydroxide → Rust

② Dissolved Carbon:

$$CO_2 + H_2O \rightarrow H_2CO_3$$

$$Fe + H_2CO_3 \rightarrow FeCO_3 + H_2$$

$CO_2$ released inside the boiler, if water used for steam generation contains bicarbonate.

PAGE NO. :
DATE : / /

(3) Acidic Water =

Water with low pH can lead to dissolution of metal surfaces, causing thinning and pitting. Water containing dissolved Mg salts liberate acid on hydrolysis.

$MgCl_2 + 2H_2O \rightarrow Mg(OH)_2 \downarrow + 2HCl$

$Fe + 2HCl \rightarrow FeCl_2 + H_2 \uparrow$.

$FeCl_2 + 2H_2O \rightarrow Fe(OH)_2 \downarrow + 2HCl$.

29/8/24