Water

Types of impurities

i) Dissolved — inorganic: carbonates, bicarbonates, sulphates of calcium & magnesium.
organic: amino acids, gases (O_2, CO_2), H_2S, etc.

ii) Suspended: inorganic: sand, clay | organic: vegetable & animal matter

iii) Biological: fungi, algae, etc.

Disadvantages of hard water:

i) washing & bathing:
No lather

2) Drinking:
Stone formation in kidneys
Bad effects on digestive system.

3) Industrial use
- Textile industry
- Paper industry
- Sugar industry
- Pharmaceutical industry

4) Boiler trouble:
- Corrosion
- Scale & sludge
- Priming & foaming
- Caustic embrittlement

Hard vs	Soft
Does not give lather	Gives lather

Temp. Hardness

- Boiling
- $Ca(HCO_3)_2 \xrightarrow{\Delta} CaCO_3 + H_2O + CO_2$

$Mg(HCO_3)_2 \longrightarrow Mg(OH)_2 + CO_2$

Degrees of hardness

- In terms of equivalent amount of $CaCO_3$
- Molecular weight = 100
- Equivalent weight = 50
- Insoluble salt

Impurity = Mass x Multiplication Factor

Units of Hardness

i) Parts per million (ppm): No. of parts of $CaCO_3$ eq. per 10^6 parts of water.

ii) Milli grams per liter (mg/litre)

- $1 (mg/l) = 1$ ppm

iii) Degree of Clarke : No. of parts of $CaCO_3$ per 70,000 parts of water

$1\ ppm = 0.07°Cl$

iv) Degree of French

$1\ ppm = 0.1° Fr$

$$\boxed{1°Cl = 1.43° Fr = 14.3\ ppm = 14.3\ mg/L}$$

v) Milliequivalent per liter:

$1\ meq/L = 50\ ppm$

Problem

Given: 13.6 mg/L $CaSO_4$

7.3 mg/L $Mg(HCO_3)_2$

Salt	Quantity (mg/L)	M wt.	Multi factor	Eq. of $CaCO_3$	Hardness
$CaSO_4$	13.6	136	100/136	$13.6 \times \frac{100}{136} = 10$	P
$Mg(HCO_3)_2$	7.3	146	100/146	$73 \times \frac{100}{146} = 5$	T

Total hardness = P+T
= 10+5
= 15ppm

Q. Convert the total hardness of samples in ppm & meq
a) 20.23°Fr
b) 31.8° cl

A. a) 1 ppm = 0.1°Fr
x = 20.23
$x = \frac{20.23}{0.1} = 202.3$ ppm

1meq = 50ppm
x = 202.3
x = 4.046 meq

b) 1ppm = 0.07°cl
x = 31.8
x = 454.28 ppm

1meq = 50 ppm
x = 454.28
$x = \frac{454.28}{50} = 9.08$ meq

Q. Classify the following salts into temp. & perm. hardness causing salts & calculate their $CaCO_3$ eq.

i) $Ca(HCO_3)_2$ — $16.2\ mg\,L^{-1}$

ii) $MgSO_4$ — $1.2\ mg\,L^{-1}$

iii) $FeCl_2$ — $12.7\ mg\,L^{-1}$

iv) NaCl — $94\ mg\,L^{-1}$

Ans:

Salt	Quantity ($mg\,L^{-1}$)	M.Wt.	Multiplication Factor	$CaCO_3$ eq.	Hardness
$Ca(HCO_3)_2$	16.2	162	$100/162$	$16.2 \times \frac{100}{162} = 10$	Temp.
$MgSO_4$	1.2	120	$100/120$	$1.2 \times \frac{100}{120} = 1$	Perm.
$FeCl_2$	12.7	127	$100/127$	$12.7 \times \frac{100}{127} = 10$	Perm
NaCl	94	—	—	—	—

Q. Classify the following impurities into temp, perm. & non-hardness causing.

A.

(i) $Ca(HCO_3)_2$ – Temp. (v) HCl — Non.

(ii) $MgSO_4$ – Perm. (vi) $Mg(HCO_3)_2$ — Temp.

(iii) $CaCl_2$ – Perm. (vii) $CaSO_4$ — Perm

(iv) CO_2 – Non. (viii) NaCl — Non.

How many gms of $CaCl_2$ dissolved per litre of water gives 150 ppm of hardness.

A.

	$CaCO_3$	$CaCl_2$
Wt.	100	111
	150	x

$$x = \frac{111 \times 150}{100}$$

$\boxed{x = 166.5\ ppm}$

Q. A water sample contains (i) $8.1\ mg\,L^{-1}$ $Ca(HCO_3)_2$ (ii) $24\ mg\,L^{-1}$ $MgSO_4$ (iii) $19\ mg\,L^{-1}$ $MgCl_2$ (iv) $296\ mg\,L^{-1}$ $Mg(NO_3)_2$ (v) $14.6\ mg\,L^{-1}$ $Mg(HCO_3)_2$

Ans: P.T.O.

Salt	Quantity (mg L^{-1})	M·Wt.	Multiplication Factor	$CaCO_3$ eq.	Hardness
$Ca(HCO_3)_2$	8·1	162	$100/162$	$8.1 \times \frac{100}{162} = 5$	Temp.
$MgSO_4$	24	120	$100/120$	$24 \times \frac{100}{120} = 20$	Perm.
$MgCl_2$	19	95	$100/95$	$19 \times \frac{100}{95} = 20$	Perm
$Mg(NO_3)_2$	296				
$Mg(HCO_3)_2$	14·6				

Q. A sample of H_2O has hardness 208ppm $CaCO_3$ eq.
Find hardness in terms of mg/L, °F, °Cl & meq/L
How many gms. of $FeSO_4$ dissolved per liter gives 210·5 ppm of hardness?

Ans:

(i) 1ppm = 1 mg/L ⟶ 208ppm $\boxed{= 208\ mg/L}$

(ii) 1ppm = 0·1°F

208 ppm = x ⟶ x = 208 × 0·1 $\boxed{= 20.8\ °F}$

(iii) 1ppm = 0·07°Cl

208 = x ⟶ $\boxed{x = 14.56\ °Cl}$

(iv) 50ppm = 1 meq

208 = x ⟶ $x = \frac{208}{50}$ $\boxed{= 4.16\ meq/L}$

M·Wt. of $FeSO_4$ = 56 + 32 + (16×4)
= 88 + 64
= 152

100 — 152

210·5 — x ⟶ $x = \frac{210.5 \times 152}{100}$ $\boxed{= 319.96\ mg/L}$

Q. Calculate all types of H_2O sample containing

Ans:

	M.Wt.	M.Factor	eq.	Hardness
$Ca(HCO_3)_2$ — 81 mg L^{-1}	162	100/162	$81 \times \frac{100}{162} = 50$	T
$MgSO_4$ — 60 mg L^{-1}	120	100/120	$60 \times \frac{100}{120} = 50$	P
$MgCO_3$ — 42 mg L^{-1}	84	100/84	$42 \times \frac{100}{84} = 50$	T
$Ca(NO_3)_2$ — 82 mg L^{-1}	164	100/164	$82 \times \frac{100}{164} = 50$	P

Total hardness = 200 ppm
Temp. hardness = 100 ppm
Perm. hardness = 100 ppm

Q. Classify the following into carbonate & non-carbonate impurities & calculate all types of hardness.

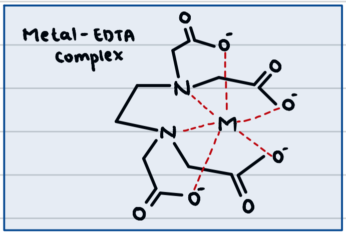
A.

	M.Wt.	M.Factor	eq.	Type
$Mg(HCO_3)_2$ — 7.1 mg L^{-1}	146	100/146	$7.1 \times \frac{100}{146} = 4.86$	C
$Ca(HCO_3)_2$ — 8.1 mg L^{-1}	162	100/162	$8.1 \times \frac{100}{162} = 5$	C
$MgCO_3$ — 4.2 mg L^{-1}	84	100/84	$4.2 \times 100/84 = 5$	C
$CaCO_3$ — 10 mg L^{-1}	100	100/100	$10 \times 100/100 = 10$	C
$MgSO_4$ — 24 mg L^{-1}	120	100/120	$24 \times \frac{100}{120} = 20$	NC

(HCO_3)
$1+12+16\times3$
$= 13+48$
$= 61$

Total impurities = 44.86 ppm
Total carbonate impurities = 24.86 ppm
Total non-carbonate impurities = 20 ppm

EDTA Method



→ Complexometric titration method.

→ Calcium & Magnesium ions form complexes at pH-9-10.

→ A basic buffer of weak base & strong acid like NH_4Cl is used.

→ Alcoholic solution of Eriochrome Black T is used as an indicator.

→ In EDTA titration: i) $(Ca^{2+} + Mg^{2+}) +$ EBT + pH 9-10 buffer = $\underbrace{\text{Ca-EBT + Mg-EBT}}_{\text{Wine Red}}$

ii) Ca-EBT + Mg-EBT + EDTA = $\underbrace{\text{Ca-EDTA + Mg-EDTA}}_{\text{Blue}}$

Q. 1g of $CaCO_3$ was dissolved in HCl & the soln. was made upto 1L distilled water. 50ml of the solution required 30ml of EDTA solution. 50mL of hard water required 40 mL of EDTA for titration. 50mL of the hard water (after boiling & filtering) → required 30mL of the EDTA soln. Calculate the temp. hardness.

Ans:

$$\frac{V_1M_1}{n_1} = \frac{V_2M_2}{n_2} \quad :- \quad M_1 = 0.01\,M \quad V_2 = 30mL$$

$$V_1 = 50mL \quad n_1 = n_2 = 1$$

$$\therefore M_2 = \frac{V_1M_1}{V_2} = \frac{50 \times 0.01}{30} = 0.016\,M$$

$$\frac{V_2M_2}{n_2} = \frac{V_3M_3}{n_3} \quad : \quad V_2 = 40mL \quad V_3 = 50mL$$

$$M_2 = 0.016 \quad n_1 = n_2 = 1$$

$$M_3 = \frac{V_2M_2}{V_3} = \frac{40 \times 0.016}{50} = 0.0128\,M \times 100 \times 1000 = 1280\text{ ppm}$$

Permanent hardness:

$$\frac{V_4M_4}{n_4} = \frac{V_2M_2}{n_2} \qquad n_1 = n_2 = 1$$

$$V_2 = 30mL \qquad V_4 = 50mL$$

$$M_2 = 0.016\,M$$

$$M_4 = \frac{M_2V_2}{V_4} = \frac{0.016 \times 30}{50} = 0.0096\,M \times 100 \times 1000 = 960\text{ ppm}$$

Temporary Hardness = Total − Perm = 1280 − 960 = $\boxed{320\text{ppm}}$

Q. 20ml of SHW containing 1.2g of $CaCO_3$ per liter required 35ml of EDTA. 50ml of hard water required 30ml of same EDTA. 100ml of hard water sample after boiling required 25ml of same EDTA. Calculate hardness.

Ans: Strength of SHW = $1.2 g/L$ = $1.2 mg/mL$

Volume of hardwater = 20mL

$\therefore$ Hardness present = 20×1.2

= 24 mg of $CaCO_3$ hardness.

20mL SHW —— 35mL EDTA

& 20mL SHW —— 24 mg of $CaCO_3$

$\therefore$ 1mL EDTA = $\frac{24}{35}$ mg of $CaCO_3$.

50mL of sample —— 30mL EDTA

Hardness = $30 \times \frac{24}{35}$ = 20.57mg of $CaCO_3$

50mL —— 20.57
1000mL —— x $\longrightarrow$ $x = \frac{20570}{50}$ = 411.4 mg of $CaCO_3$

100mL of boiled water —— 25mL EDTA

Hardness = $25 \times \frac{24}{35}$ = 17.14 mg of $CaCO_3$

100 ml —— 17.14
1000 ml —— x — $x = \frac{17140}{100}$ = 171.4 mg of $CaCO_3$

Hence: Total hardness = 411.4 ppm
Permanent hardness = 171.4 ppm
Temporary hardness = 240.0 ppm

Q. A standard hard water sample contains 0.28g of $CaCO_3$. 100mL of this Solution required 28mL of EDTA. 100mL of hard water sample required 33mL of EDTA. After boiling 100mL of sample required 10mL of EDTA. Calculate hardness.

Ans.

Strength of SHW = $0.28\ g/L = 0.28\ mg/mL$

Volume of hardwater = 100mL

Hardness = $100 \times 0.28 = 28$ mg of $CaCO_3$

28mg — 28mL EDTA

$\therefore$ 1 mL EDTA = 1mg of $CaCO_3$

100mL of HW — 33mL EDTA

Hardness = $33 \times 1 = 33$ mg of $CaCO_3$

100 — 33
1000 — x $\longrightarrow$ $x = \frac{33000}{100} = 330$ ppm

100mL of BHW — 10mL EDTA

Hardness = 10mg of $CaCO_3$

100 — 10
1000 — x $\longrightarrow$ $x = 100$ ppm.

Hence: Total hardness = 330 ppm
Permanent hardness = 100 ppm
Temporary hardness = 230 ppm

Boiler Trouble

1] Priming and Foaming

Priming: When a boiler heats up quickly, water particles get carried along with steam. This causes 'wet steam'.

→ Causes: i) Large amt. of impurities
ii) Sudden boiling
iii) High velocity of steam

→ Prevention: i) Using soft water
ii) Maintaing a lower level of water
iii) Blow down of boiler.

Foaming: It's when foam forms on the surface of water & gets carried with the steam.

→ Causes: i) Presence of large amt. of impurities.

→ Prevention: i) Adding anti-foaming chemicals
ii) using $NaAlO_2$

Troubles: i) Actual level of water can't be judged.
ii) Lower boiler efficiency.

2] Caustic Embrittlement

- Refers to cracks formed at joints due to the presence of high concentration of alkali.
- This leads to electrolysis & cracks hence formed resemble brittle fracture.

Eq. $Na_2CO_3 + H_2O \longrightarrow 2NaOH + CO_2$

The ppt. NaOH is what makes the water 'caustic'.
The iron of the boiler is dissolved as sodium ferrate.

Eq. $Fe + 2NaOH \longrightarrow Na_2FeO_2 + H_2$

- The iron at plane surfaces surrounded by dil. NaOH becomes cathodic while the iron in joints surrounded by conc. NaOH becomes anodic.

→ Prevention: i) Adding Na_2SO_4, tannin to the boiler.
ii) Using sodium phosphate (Na_3PO_4) instead of Sodium carbonate.

Troubles: cracking of boiler walls.

3] Boiler Corrosion

- Decay of boiler material by chemicals in its environment.

→ Causes: i) Dissolved O_2
ii) Dissolved CO_2
iii) Acids from dissolved salts.

i) Dissolved O_2: Water contains $8 mg L^{-1}$ of water at room temp.

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

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

→ Removal: Adding sodium sulphate or hydrazine

Eq: $2Na_2SO_3 + O_2 \longrightarrow 2Na_2SO_4$

$N_2H_4 + O_2 \longrightarrow N_2 + 2H_2O$

ii) Dissolved CO_2: Has a slow corrosive effect by production of carbonic acid.

Eq: $CO_2 + H_2O \longrightarrow H_2CO_3$

→ Removal: Addition of ammonia

Eq: $2NH_4OH + CO_2 \longrightarrow (NH_4)_2CO_3 + H_2O$

iii) Acids from dissolved Salts: Acids react with iron of the boiler to decay the metal.

Eq. $Fe + 2HCl \longrightarrow FeCl_2 + H_2$

$FeCl_2 + H_2O \longrightarrow Fe(OH)_2 + 2HCl$

$Fe(OH)_2 + H_2O + \frac{1}{2}O_2 \longrightarrow Fe_2O_3 \cdot 3H_2O$

Softning of Water

- Three methods: i) Soda-lime process
  ii) Xeolite process
  iii) Ion-exchange resins

Lime-Soda Process

- Involves conversion of soluble calcium & magnesium salts into insoluble calcium carbonates.

$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3\downarrow + 2H_2O$

$Mg(HCO_3)_2 + 2Ca(OH)_2 \longrightarrow 2CaCO_3\downarrow + Mg(OH)_2\downarrow + 2H_2O.$

- For $MgSO_4$ & $MgCl_2$, soda & lime are required.
  $MgSO_4 + Na_2CO_3 + Ca(OH)_2 \longrightarrow Mg(OH)_2 + CaCO_3 + Na_2SO_4$

- For $CaSO_4$ & $CaCl_2$, only soda is required.
  $CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3\downarrow + Na_2SO_4$

Calculations

100 parts by mass of $CaCO_3$ are equivalent to 74 parts of $Ca(OH)_2$ & 106 parts of Na_2CO_3

a) Amout of lime required for softning

$= \frac{74}{100} \cdot \left(\text{Temp. } Ca^{2+} + 2\times \text{Temp. } Mg^{2+} + \text{Perm}(Mg^{2+} + Fe^{2+} + Al^{3+}) + CO_2 + H^+(HCl/H_2SO_4) + HCO_3^- \text{ all in terms of } CaCO_3 \text{ eq.}\right)$

b) Amount of Soda required for softning:

$= \frac{106}{100}\left(\text{Perm}(Ca^{2+} + Mg^{2+} + Fe^{2+} + Al^{3+}) + H^+(HCl/H_2SO_4) + HCO_3^- \text{ all in terms of } CaCO_3 \text{ eq.}\right)$

Constituent	Reaction	Requirement
Ca^{+2} (Permanent)	(i) $CaSO_4 + Na_2CO_3$ □ $CaCO_3\downarrow + Na_2SO_4$ (ii) $CaCl_2 + Na_2CO_3$ □ $CaCO_3\downarrow + 2NaCl$	S
Mg^{+2} (Permanent)	(iii) $MgSO_4 + Na_2CO_3 + Ca(OH)_2$ □ $Mg(OH)_2\downarrow + CaCO_3\downarrow + Na_2SO_4$ (iv) $MgCl_2 + Na_2CO_3 + Ca(OH)_2$ □ $Mg(OH_2)\downarrow + CaCO_3 + 2NaCl$	L + S
HCO_3^-	(v) $2NaHCO_3 + Ca(OH)_2$ □ $CaCO_3 + H_2O + Na_2CO_3$	L - S
$Ca(HCO_3)_2$ (Temporary)	(vi) $Ca(HCO_3)_2 + Ca(OH)_2$ □ $2CaCO_3\downarrow + 2H_2O$	L
$Mg(HCO_3)_2$ (Temporary)	(vii) $Mg(HCO_3)_2 + 2Ca(OH)_2$ □ $2CaCO_3\downarrow + Mg(OH)_2\downarrow + 2H_2O$	2L
CO_2	(viii) $CO_2 + Ca(OH)_2$ □ $CaCO_3\downarrow + H_2O$	L
H^+	(ix) $2HCl + Ca(OH)_2 + Na_2CO_3$ □ $CaCO_3 + 2NaCl + H_2O$	L + S
Coagulants $FeSO_4$	(x) $FeSO_4 + Ca(OH)_2$ □ $Fe(OH)_2 + CaSO_4$ $2Fe(OH)_2 + H_2O + O_2$ □ $2Fe(OH)_3$ $CaSO_4 + Na_2CO_3$ □ $CaCO_3 + Na_2SO_4$	L + S
$Al_2(SO_4)_3$	(xi) $Al_2(SO_4)_3 + 3Ca(OH)_2$ □ $2Al(OH)_3\downarrow + 3CaSO_4 +$	L + S

Q. Calculate the quantities of lime & soda required 5000 liters of water containing the following salts:

i) $MgCl_2 = 15.5 ppm$, ii) $Ca(HCO_3)_2 = 32.5 ppm$, iii) $CaSO_4 = 22.4 ppm$, iv) $Mg(HCO_3)_2 = 14.6 ppm$,

v) $NaCl = 50 ppm$

Impurity (mg/L)	M.wt	$CaCO_3$ eq.	Requirement
i) $MgCl_2 = 15.5 ppm$	95	$15.5 \times \frac{100}{95} = 16.31$	L+S
ii) $Ca(HCO_3)_2 = 32.5 ppm$	162	$32.5 \times \frac{100}{162} = 20.06$	L
iii) $CaSO_4 = 22.4 ppm$	136	$22.4 \times \frac{100}{136} = 16.47$	S
iv) $Mg(HCO_3)_2 = 14.6 ppm$	146	$14.6 \times \frac{100}{146} = 10$	2L
v) $NaCl = 50 ppm$	—	—	—

Lime requirement:

$$= \frac{74}{100}\left(Ca(HCO_3)_2 + 2 \times Mg(HCO_3)_2 + MgCl_2\right)$$

$$= \frac{74}{100}\left(20.06 + 2 \times 10 + 16.31\right)$$

$$= \frac{74}{100} \times 56.37$$

$$= 41.71 mg$$

Lime required for 5000 litres:

$$41.71 \times \frac{5000}{1000} = \boxed{208.55 g} = 0.20855 kg$$

Soda required:

$$= \frac{106}{100}\left(MgCl_2 + CaSO_4\right)$$

$$= \frac{106}{100}\left(16.31 + 16.47\right)$$

$$= \frac{106}{100}(32.78)$$

$= 34.74 mg$ ⟶ Soda for 5000 litres of water:

$$34.74 \times \frac{5000}{1000} = \boxed{173.7 g} = 0.1737 kg$$

Q. A water sample contains the following impurities:

Ans:

Impurities		M.wt.	$CaCO_3$ eq.	Requirement
$CaCl_2$	— 55.5 $mg\,L^{-1}$	111g	$55.5 \times \frac{100}{111} = 50$	S
$NaHCO_3$	— 12.6 $mg\,L^{-1}$	84g	$12.6 \times \frac{100}{84 \times 2} = 7.5$	L-S
$MgSO_4$	— 48 $mg\,L^{-1}$	120g	$48 \times 100/120 = 40$	L+S
Fe^{2+}	— 2 $mg\,L^{-1}$	56g	$2 \times 100/56 = 3.57$	L+S
$Mg(HCO_3)_2$	— 43.8 $mg\,L^{-1}$	146g	$43.8 \times 100/146 = 30$	2L
SiO_2	— 20 $mg\,L^{-1}$	60g	$20 \times 100/60 = 33.33$	—
KCl	— 250 $mg\,L^{-1}$	74.5g	$250 \times 100/74.5 = 335.57$	—
CO_2	— 2.2 $mg\,L^{-1}$	44g	$2.2 \times 100/44 = 5$	L
$AlCl_3$	— 10 $mg\,L^{-1}$	133.5g	$10 \times 100/133.5 = 7.49$	L+S

$$\text{Lime} = \frac{74}{100}\left[7.5 + 40 + 3.57 + 30 \times 2 + 5 + 7.49\right] \times \frac{50000}{10^6} \times \frac{100}{85}$$

$$= \frac{74}{100}\left[123.56\right] \times \frac{5}{85}$$

$$= \frac{45717.2}{8500} = \boxed{5.378\ kg}$$

$$\text{Soda} = \frac{106}{100}\left[S - S + S + S + S\right] \times \frac{50000}{10^6} \times \frac{100}{95}$$

$$= \frac{106}{100}\left[50 - 7.5 + 40 + 3.57 + 7.49\right] \times \frac{\cancel{5}}{\cancel{95}}\frac{1}{19}$$

$$= \frac{53}{50} \times 93.56 \times \frac{1}{19}$$

$$= \frac{4958.68}{950} \boxed{= 5.219\ kg}$$

Note

Certain substances do not react with lime or soda.

→ KCl

→ SiO_2

→ Na_2SO_4

Q. Calculate amount of 85% pure lime & 95% pure soda required to softnen:

Ans:

Impurities	M.Wt.	$CaCO_3$ eq.	Requirements
$CaCO_3$ — 12.5	100	$12.5 \times 100/100 = 12.5$	L
$MgCO_3$ — 8.4	84	$8.4 \times 100/84 = 10$	L
$CaCl_2$ — 22.2	111	$22.2 \times 100/111 = 20$	S
$MgCl_2$ — 9.5	95	$9.5 \times 100/95 = 10$	L+S
CO_2 — 33	44	$33 \times 100/44 = 75$	L
HCl — 7.3	36.5	$7.3 \times 100/(2 \times 36.5) = 10$	L+S
HCO_3^- — 16.8	84	$16.8 \times 100/(2 \times 84) = 10$	L-S

$$\text{Lime} = \frac{74}{\cancel{100}}\left[12.5+10+10+75+10+10\right] \times \frac{10^6}{10^6} \times \frac{\cancel{100}}{85}$$

$$= \frac{74 \times 127.5}{85} \quad \boxed{= 111\,kg}$$

$$\text{Soda} = \frac{\overset{53}{\cancel{106}}}{\underset{50}{\cancel{100}}}\left[20+10+10-10\right] \times \frac{10^6}{10^6} \times \frac{100}{95}$$

$$= \frac{53 \times 30 \times \overset{2}{\cancel{100}}}{\underset{1}{\cancel{50}} \times 95} \quad \boxed{= 33.47\,kg}$$

Q. Calculate amt. of 80% pure lime & 85% pure soda required for softning 10^6 L of water containing:

Salt	ppm	M.Wt	$CaCO_3$ eq.	Requirement
$Ca(HCO_3)_2$	162	162	$162 \times 100/162 = 100$	L
$MgCl_2$	9.5	95	$9.5 \times 100/95 = 10$	L+S
NaCl	58.5	58.5	$58.5 \times 100/58.5 = 100$	—
$Mg(HCO_3)_2$	7.3	146	$7.3 \times 100/146 = 5$	2L
HCl	36.5	36.5	$36.5 \times 100/2(36.5) = 50$	L+S
CO_2	44	44	$44 \times 100/44 = 100$	L
$CaCl_2$	111	111	$111 \times 100/111 = 100$	S
$MgSO_4$	60	120	$60 \times 100/120 = 50$	L+S

Lime required: $\frac{74}{100}\left[100+10+2(5)+50+100+50\right]$

$= \frac{74}{\cancel{100}_{5}}\left[\cancel{320}^{16}\right]$

$= 236.8 \times \frac{\cancel{100}\,5}{\cancel{80}\,4}$

$\boxed{= 296 \text{ kg}}$

Soda Required $= \frac{106}{100}\left[10+50+50+100\right]$

$= \frac{106 \times 210}{100}$

$= 222.6 \times \frac{100}{85}$

$\boxed{= 261.882 \text{ kg}}$

Q. The hardness of 10,000 liters of hard water was completely removed by passing it through a zeolite softner. The softner required 5000L of NaCl containing $1170 mg L^{-1}$. Determine the hardness.

Ans: Amount of NaCl:

$$5000 \times 1170 = 5850000 \times \frac{50}{58.5} = 5000000 \text{ mg}$$

Hardness of 10000L water = 5000000

$$\therefore \text{For } 1L \longrightarrow \text{hardness} = \frac{5 \times 10^6}{10^4} \boxed{= 500 \text{ mg } L^{-1} = 500 \text{ ppm}}$$

Q. An exhausted zeolite softner was regenerated by passing 75L of NaCl Soln. having strength $75 g L^{-1}$. If hardness is 300ppm, total volume that can be softned is?

Ans. Amt. of NaCl = $75 \times 75 = 5625$ g

Quantity of NaCl = $5625 \times \frac{100}{117} = 4807.69 g = 4.81 \times 10^6$ mg $CaCO_3$ eq.

Hardness = 300ppm

So 4.81×10^6 — 300

x — 1

$$x = \frac{4.81 \times 10^6}{300} \text{ L of water}$$

$$\boxed{= 1.6 \times 10^4 \text{ L of water}}$$

Q. The hardness of 25000 L of water was removed using zeolite. For regeneration, the zeolite required 200L of NaCl containing $20 g L^{-1}$ NaCl. Calc. the hardness.

Ans:

Amt. of NaCl = Conc. × Vol.

$= 20 \times 200$

$= 4000\ g$ NaCl

$4000 \times \frac{50}{58.5} = 3418.803\ g$ of $CaCO_3$

Hardness of 25000 L — 3418.803 g

Hardness of 1L $= \frac{3418.803}{25\cancel{000}} \times 1\cancel{000}$

$\boxed{= 136.75\ mg L^{-1} = 136.75\ ppm}$

Q. A water sample with hardness 250ppm was softned by zeolite. The exhausted zeolite required 50L of 15% NaCl for regeneration. Calc. the quantity of water that can be softned.

Ans:

15% of $50L = \frac{15 \times \cancel{50}^{1}}{\cancel{100}_{2}} = 7.5 L$ of NaCl $\longleftrightarrow$ 250ppm

$7.5 \times 10^3 \times \frac{50}{58.5} = 6.41 \times 10^3$

$\frac{6.41}{200} = 0.03205 \times 10^3$ $\boxed{= 32.05\ ppm}$

Desalination of Brackish water

- Water with high conc. of dissolved solids with salty taste is brackish water.
- Eg: Sea water: containing 3.5% of dissolved salts.
- Removal: i) Electrodialysis
  ii) Reverse osmosis.

I) Electrodialysis:

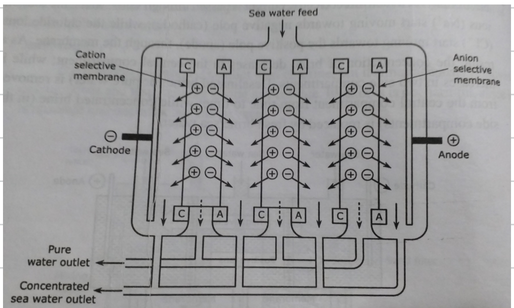


Fig. 1.13 : Electrodialysis cell

Numerical

Q. After treating 10^4 L of water by ion-exchange, the cationic resin required 200L of 0.1N HCl & the anionic resin required 200L of 0.1N NaOH for regeneration. Find the hardness.

Ans: Hardness of 10^4 litres of water = 200L of 0.1 N HCl

$= 200 \times 0.1 \times 1N\ CaCO_3$ eq

$= 20L$ of 1 N $CaCO_3$ eq

$= 20 \times 50g$ of $CaCO_3$ eq

$= 1000g$ of $CaCO_3$ eq.

So hardness of 1L water $= \frac{1000}{10^4}$ g of $CaCO_3$ eq.

$= 100mg$ of $CaCO_3$ eq.

Biological Oxygen Demand (BOD)

- Measure of amt. of oxygen required for biological oxidation of organic matter under aerobic conditions at 20°c for 5 days.
- Potable water has BOD conc. < 1 ppm.

$$BOD = [DO_{blank} - DO_{incubated}] \times \text{Dilution Facto}$$

$$\text{Dilution Factor} = \frac{\text{Vol. after dilution}}{\text{Vol. before dilution}} = \frac{\text{Vol. for titration}}{\text{Total dil. volume}}$$

Chemical Oxygen Demand (COD)

- Measure of amt. of oxygen required for the chemical oxidation of organic matter when refluxed in acidified potassium dichromate in the presence of Ag_2SO_4 or $HgSO_4$ catalyst for 3 hours.

$$C_xH_yO_z + \left(x + \frac{y}{4} - \frac{z}{2}\right)O_2 \longrightarrow x\,CO_2 + \left(\frac{y}{2}\right)H_2O$$

- Potable water has COD conc. < 1 ppm.

$$COD = \frac{(V_b - V_t) \times N_{FAS} \times 8 \times 1000}{\text{Vol. of water sample}}$$

V_b = Vol. of FAS for blank titration

V_t = Vol. of FAS for reaction mass after time.

Q. 2 BOD bottles contain each of 5mL of Sewage sample & water diluted with distilled water to 300mL. One 100 mL portion of blank consumed 6.4mL of 0.05N Sodium thiosulphate in Winkler's method. While the other 100mL portion incubated at 20°C consumed 1.6mL of thiosulphate Solution. Calculate BOD content of the sample.

Ans: $DO_{blank} - DO_{incubated} = 6.4 - 1.6 = 4.8\text{mL}$ of thiosulphate

Dilution factor $= 100/300 = 1/3$

$1L, 1N - 8g$ oxygen

$4.8mL, 0.05N = x$

$\Rightarrow x = \left[\frac{8 \times 4.8 \times 0.05}{1000}\right] \times \frac{1}{3} = 0.64 \times 10^{-3} = 6.4 \times 10^{-3} g - 5mL$

$x - 1000$

$\therefore x = \frac{6.4}{5} = 1.28g \times 10^{3} = 1280mg\,L^{-1}$

$\boxed{BOD = 1280\,ppm}$

Q. 10mL of Sewage water sample, was taken in 2 BOD bottles & diluted with distilled water to 300mL. One 100mL portion required 2mL of 0.05N thiosulphate Solution after 5 days. The other 100mL portion required 7.4mL of 0.05N thiosulphate in Wrinkler's method. Calculate BOD.

Ans: $DOB_{blank} - DOB_{incubated} = 7.4 - 2 = 5.4\text{ mL}$

Dilution factor $= \frac{100}{300} = \frac{1}{3}$

$1N - 8g$

$5.4 - x$

$\longrightarrow x = \frac{43.2 \times 0.05}{1000} = \frac{2.16}{1000} \times \frac{1}{3}$

$= 0.72 \times 10^{-3} g - 10mL \Rightarrow x = 7.2 \times 10^{-4} \times \frac{100\cancel{0}}{1\cancel{0}} = 7.2 \times 10^{-2} g$

$x - 1000mL$

$= 72 mg\,L^{-1}$

$\boxed{\text{Hence } BOD = 72\,ppm}$

Q. A 50mL of sample contains 840 ppm dissolved oxygen. After 5 days the dissolved oxygen value becomes 230 ppm after the sample was diluted to 80mL. Find BOD.

Ans: $(DOB_{blank} - DOB_{incubated}) \times$ Dilution Factor

$(840-230) \times \frac{50}{80} = \boxed{381.25 ppm}$

Q. A 10mL sample was refluxed with 20mL of $K_2Cr_2O_7$. After reflux, the excess, unreacted $K_2Cr_2O_7$ required 26.2mL of 0.1M FAS. A blank of 10mL of distilled water on reflux with 20mL of dichromate soln. required 36mL of 0.1M FAS soln. Calc. COD.

Ans: $V_b - V_t = 36 - 26.2 = (9.8)$

$$COD = \frac{(V_b - V_t) \cdot N \times 8 \times 1000}{\text{Vol. of } H_2O} = \frac{(9.8)\cdot(0.1)(8)(1000)}{10} = 784 \, mgL^{-1}$$

Hence $\boxed{COD = 784 ppm}$

Q. A 25mL of sewage water sample was refluxed with 10mL of 0.25N $K_2Cr_2O_7$ & dil H_2SO_4, Ag_2SO_4 & $HgSO_4$. The unreacted dichromate required 6.5mL of 0.1N FAS. 10mL of same $K_2Cr_2O_7$ soln. & 25mL of distilled water required 27mL of 0.1N FAS. Calc. COD.

Ans: $V_b - V_t = 27 - 6.5 = 20.5$

$$COD = \frac{(V_b - V_t) \cdot N \times 8 \times 1000}{\text{Vol. of } H_2O} = \frac{(20.5)\cdot(0.1)\cdot(8)(1000)}{25} = 656 \, mgL^{-1}$$

Hence $\boxed{COD = 656 ppm}$