Q. Write the diff between hard and Soft water?
Q. Define hardness
Date Q. what are diff. type of hardness?
6/12/22 Q. why temporary hardness is named so?

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Unit-4.

Ans

Soft ~~Hard~~ Water	Hard ~~Soft~~ water
• It lathers easily with Soap.	• It produces less amount and late lather with soa
• Soap costs less than washing clothes with soft-water.	• Soap is more expensive in washing clothe than hard water.
• It lacks calcium and magnesium chloride, sulfate and bi carbonate salt.	• It contains calcium an magnesium chloride, Sulfate and bi carbonate salt sol
• It has less minerals.	• It has high minerals.

* Hardness — The soap consuming capacity of water is known as Hardness of water.

- There are two types of hardness —

(i) Temporary hardness

(ii) Permanent hardness.

* Temporary hardness — is a type of water hardness caused by bicarbonates of Calcium and magnesium. They are called temporary hardness as they can easily be removed by simple boiling or heating of water.

The equations follow as —

$$Ca(HCO_3)_2 \xrightarrow{\Delta} CaCO_3\downarrow + CO_2\uparrow + H_2O$$

(Soluble) White ppt (Insoluble)

$$Mg(HCO_3)_2 \xrightarrow{\Delta} MgCO_3\downarrow + CO_2\uparrow + H_2O$$

Insoluble

Hence, it is called temporary hardness of water

Q. Hardwater does not produce lather with soap? Explain why using a suitable equation.

Q. Explain why hardness is expressed in terms of equivalents of $CaCO_3$.

Ans. Hardwater does not produce lather with soap because it reacts with salts of calcium & magnesium to form their respective precipitate in the form of scum. Higher the percentage of conc. salts more will be the consumption of soap & detergents. Hence hardness can be defined as "The soap consuming capacity of water."

$$CaSO_4 + 2C_{17}H_{35}COONa \longrightarrow (C_{17}H_{35}COO)_2Ca\downarrow + Na_2SO_4$$

Sodium stearate. Scum

Ans. We calculate hardness in terms of equivalents of $CaCO_3$ because -

(i) Its molecular weight is 100, so calculation becomes easy.

(ii) And $CaCO_3$ is highly insoluble.

Multiplication factor / Eq. of $CaCO_3$ = $\frac{\text{wt of salt} \times (\text{Mol. wt of } CaCO_3)}{\text{Mol. wt of salt}}$

* Units of hardness -

1 ppm = 1 mg/L = 0.07 °Cl = 0.1 °Fr
(degree Clarke) (degree French)

Q. $CaCl_2$ = 11.1 mg/L

⇒ Eq. of $CaCO_3$ = $\frac{11.1 \times 100}{111}$

= 10 mg/L

10 mg/L = 10 ppm = 1 °Fr = 0.7 °Cl

Q. What are the diff. units to express hardness? Give their relation also.

Q. A water sample contain 11.1 mg/L of calcium chloride. Calculate its hardness in terms of equivalent of Calcium carbonate ~~and also express it in~~ °Fr, °Cl.

Q. Calculate hardness in terms of $CaCO_3$ equivalent if water sample contain 410 mg/L of calcium sulphate.

Ans - $CaSO_4$ = 40+32+16×4
= 40+32+64 = 72+48
= 120+16
= 136

Eq. of $CaSO_4$ = $\frac{410 \times 100}{136}$

= 3.05 mg/L

*Q. A water sample has following analysis - $Mg(HCO_3)_2$ - 83 mg/L, $Ca(HCO_3)_2$ - 134 mg/L, $CaSO_4$ - 124 mg/L, $MgCl_2$ - 84 mg/L, $Mg(NO_3)_2$ - 78 mg/L, $CaCl_2$ - 94 mg/L, NaCl - 50 mg/L. Calculate Temporary & Permanent hardness. Express your result in °Fr, °Cl.

Ans =

S.No.	Salt	Amount (mg/L)	Multiplication factor / Eq. of $CaCO_3$ (mg/L)
1.	$Mg(HCO_3)_2$	83	$= \frac{83}{146} \times 100 = 56.84$
2.	$Ca(HCO_3)_2$	134	$= \frac{134}{162} \times 100 = 82.7$
3.	$CaSO_4$	124	$= \frac{124}{136} \times 100 = 91.17$
4.	$MgCl_2$	84	$= \frac{84}{95} \times 100 = 88.42$
5.	$Mg(NO_3)_2$	78	$= \frac{78}{148} \times 100 = 52.70$
6.	$CaCl_2$	94	$\frac{94}{111} \times 100 = 84.6$
7.	NaCl	Not forms hardness.	

Temporary hardness = 56.84 + 82.71 = 139.55 mg/L of $CaCO_3$ = 13.955 °Fr, 9.76 °Cl

Permanent hardness = 316.95 mg/L of $CaCO_3$, = 31.695 °Fr
= 22.18 °Cl

Q. Calculate temporary & permanent hardness having following composition – $MgSO_4$ = 14.6 mg/L, $Ca(HCO_3)_2$ = 16.2 mg/L, $Mg(HCO_3)_2$ = 8.4 mg/L, $CaCl_2$ = 11.1 mg/L

Ans.

S.N	Salt	Amount (Mg/L)	Multiplication Factor / Eq. of $CaCO_3$
1.	$MgSO_4$	14.6	$= \frac{14.6}{120} \times 100 = 12.3$ mg/L
2.	$Ca(HCO_3)_2$	16.2	$= \frac{16.2 \times 100}{162} = 10$
3.	$Mg(HCO_3)_2$	8.4	$= \frac{8.4 \times 100}{146} = 5.75$
4.	$CaCl_2$	11.1	$= \frac{111}{111} \times 100 = 10$
5.	$NaCl$	×	does not impart hardness.

Temporary hardness = $Ca(HCO_3)_2 + Mg(HCO_3)_2$
= 15.75 Mg/L of $CaCO_3$.

Permanent hardness = 22.3 Mg/L of $CaCO_3$

Total hardness = 128.05 Mg/L of $CaCO_3$.

Q. Calculate permanent, temporary hardness of water sample – $Mg(HCO_3)_2$ = 70.3 mg/L

S.No	Salt	Amount (Mg/L)	Multiplication Factor
1.	$Mg(HCO_3)_2$	7.3	$= \frac{7.3}{146} \times 100 = 5$
2.	$Ca(HCO_3)_2$	16.2	$= \frac{\overset{0.1}{16.2}}{162} \times 100 = 10$
3.	$MgCl_2$	9.5	$= \frac{\overset{0.1}{9.5}}{\underset{0.1}{95}} \times 100 = 10$
4.	$CaSO_4$	13.6	$= \frac{13.6}{136} \times 100 = 10$
5.	$Mg(NO_3)_2$	25	$= \frac{25}{148} \times 100 = 16.89$
6.	$CaCl_2$	55.5	$\frac{55.5}{111} \times 100 = 50$

$NaCl$, KCl, Al_2O_3, SiO_2, Fe_2O_3, Al_2O_3 | does not impart hardness

7.	$MgSO_4$	120.	$\frac{120}{120} \times 100 = 100$
8.	KCl	– Not forms hardness –	

Temporary hardness = 15 = 1.05 °Cl.

Permanent hardness = $\frac{[illegible]}{186.89}$ = 13.08 °Cl

⇒

Q. Calculate the hardness of water sample having following composition units in °Cl.

S.No	Salt	Amount (°Cl)	Multiplication factor
	$CaSO_4$	2 =	$\frac{2 \times 100}{136} = 1.47$
1.	$CaCO_3$	20 °Cl =	20 °Cl
	$MgSO_3$	4 =	$\frac{4 \times 100}{120} = 3.3$
2.	$MgCl_2$	4 °Cl =	$\frac{4 \times 100}{95} = 4.21$
3.	Fe_2O_3	0.04 °Cl → not forms	
4.	SiO_2	0.09 °Cl → not form	

Express in ppm

1 mg/L = 0.07 °Cl

⇒ 1 °Cl = $\frac{1}{0.07}$ mg/L

⇒ ⇒ Total = ~~24.21~~ = 29.02 °Cl

= 414.42 ppm = 414.57 ppm

Q. A 100 mL of water sample has a hardness equivalent of 12.5 mL of 0.08 N $MgSO_4$. Calculate its hardness in ppm.

Ans – $N_1V_1 = N_2V_2$

(Sample) (Standard)

Q. What are boiler problems ? Discuss them in detail.

$$N_1 \times 100 = 0.08 \times 12.5$$

$$N_1 = \frac{0.08 \times 12.5}{100} = 0.01N$$

Eq. wt of N = 50.

$$\text{Strength of Hardness} = N_1 \times \text{Eq. wt} \times 1000 \ \text{mg/L}$$
$$= 0.01 \times 50 \times 1000$$
$$= 500 \ \text{ppm}.$$

Q. A 100 ml of water has a hardness equivalent of 18.5 mL of 0.05N $CaSO_4$. Calculate hardness in ppm.

Ans = $N_1V_1 = N_2V_2$

$$N_1 = \frac{18.5 \times 0.05}{100}$$
$$= 0.00925$$

$$\text{Strength} = 0.00925 \times \cancel{68}50 \times 1000$$
$$= 462.5 \ \text{ppm}$$

* Boiler problems –

1. Scalar & Sludges
2. Primming & Foaming
3. Boiler Corrosion
4. Caustic Embrittlement.

- Boiler feed water – Any natural source of water is not suitable for industrial use. Boiler feed water should have following requirements –

(i) Hardness – It should be below ~~show~~ 0.2 ppm.

(ii) Soda alkalinity – It should be in the range of 0.15 – 0.45 ppm.

Q. Write the difference between Scales & sludges.

Q. What is boiler corrosion ? Write causes and prevention for it.

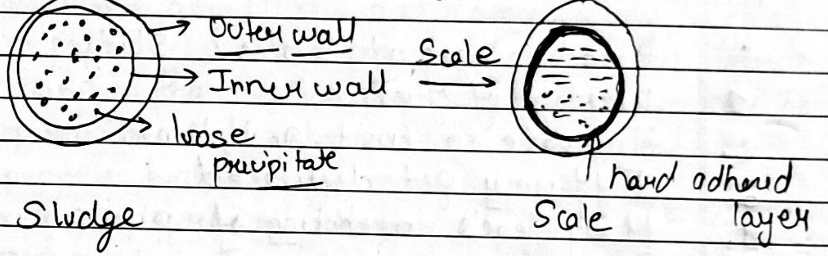
Q. Write a short note on Caustic Embrittlement.

(iii) Caustic alkalinity – Between 0.1 – 0.15 ppm.

(iv) Should not possess any suspended particle.

- Excess of salts or alkality leads to various boiler problems like –

1. Scales and ~~Studging~~ sludges –



In boiler when water is heated under high temp and high pressure which causes water to evaporate, due to evaporation the concentration of salts present in water get increased and after saturation point salts are thrown out in the form of precipitate. These precipitates may be in the form of loose accumulation (sludge). Or get adhered to the wall (scale).

- Sludge –

It is a loose accumulation of suspended solids generally at ~~and~~ colder portion of boiler or in distribution pipes. It is formed by the substances having greater solubility in hot water like $MgCl_2$, $CaCl_2$, $MgSO_4$, $MgCO_3$.

→ If sludges are not removed periodically they may settle down to form scales.

- Scales –

These are hard deposits, which stick to the

Q. What is descaling? Mention [illegible] for it.

Q. What is Calgon conditioning?

Q. What do you mean by boiler feed water?

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inner wall of the boiler and difficult to remove. $Ca(HCO_3)_2$, $Mg(HCO_3)_2$, $CaSO_4$, Silica are responsible to form scales. Silica on reaction with Ca & Mg salts leads to the formation of respective Silicates. Eg – $CaSiO_3$, $MgSiO_3$. and their removal is very difficult.

* Disadvantages of Scales & Sludges –

1. Wastage of fuel.
2. Increase in cost and time.
3. Efficiency get decreased.
4. May leads to choking of pipes.
5. Danger of explosion.

* Descaling or Prevention –

The process of removal of scales and sludges is known as descaling. It can be done either by some precautionary methods. or by adding chemicals inside the boiler. (Internal Treatment) / Internal Conditioning)

Internally we can add following chemicals –

- sodium carbonate (Na_2CO_3) (Carbon conditioning)
- By adding (Na phosphate) – $Na_3(PO_4)$ (Phosphate Conditioning)

$$CaCl_2 + Na_2CO_3 \rightarrow CaCO_3\downarrow + 2NaCl$$
$$3CaCl_2 + 2Na_3(PO_4) \rightarrow 6NaCl + Ca_3(PO_4)_2\downarrow$$

3. Calgon Conditioning –
Calgon ($Na_2[Na_4(PO_3)_6]$)

$$Na_2[Na_4(PO_3)_6] \xrightarrow{H_2O} 2Na^+ + [Na_4(PO_3)_6]^{2-}$$
$$\xrightarrow{CaSO_4} \underbrace{[Ca_2(PO_3)_6]^{2-}}_{\text{Soluble complex}} + 2Na_2SO_4$$

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4. Coagulante Conditioning –
Ex – $NaAlO_2 + H_2O \rightarrow NaOH + \overset{\text{gelatinous ppt}}{Al(OH)_3}\downarrow$
$2NaOH + MgCl_2 \rightarrow 2NaCl + \underset{\text{flocculant ppt}}{Mg(OH)_2}\downarrow$ } blow down operation

2.* Primming and foaming –
When a boiler is steaming some particles of liquid & water are also coming out (carry) along with steam This process is called primming. In other words, we can say that primming is the process used for the production of wet steam. It is caused by –

- Improper boiler design.
- Sudden temperature change.
- Presence of large amount of dissolved salts.

* Foaming – It is the production of persistent bubbles or foam in the boiler.

Primming & foaming both are objectionable because

- Dissolved salts in boiler water are carried by wet steam carried to superheater or turbine blades. where salts get ~~dissolved~~ deposited once water get evaporate and decrease their efficiency.
- Dissolved salts may enter to the part of machinery where only steam is allowed. Thereby decreasing the life of machines.
- Actual height of the water column cannot be judged properly inside the boiler.

* Primming and foaming can be avoided by following means –

1. Maintaining low water level.
2. Avoid sudden change in temperature.
3. Softened water should be used.

4. Antifoaming agents can be added.
5. Boiler should be maintained regularly.

* Boiler Corrosion —

The decay of boiler material by a chemical attack of its environment is known as boiler corrosion. In General boilers are made up of iron.

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

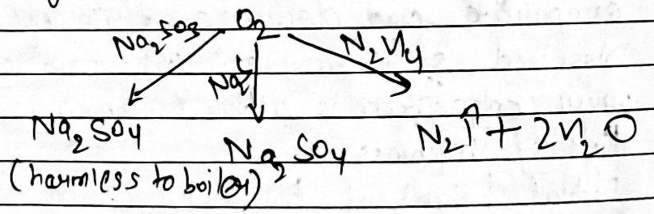
$\downarrow$

It can be caused by —

1. Due to presence of dissolved oxygen — Usually water contains 8ppm of dissolved oxygen

$$2Fe + 2H_2O + O_2 \rightarrow 2Fe(OH)_2\downarrow$$
$$\downarrow O_2$$
$$Fe(OH)_3\downarrow \xrightarrow{O_2} \underset{\text{Rust}}{[Fe_2O_3 \cdot 2H_2O]}$$

→ It can be removed by adding sodium ~~sulphate~~ Sulphite (Na_2SO_3), ~~Sulphide~~ (Na_2S) and hydrazine (N_2H_4).



2. Due to presence of dissolved CO_2 — either it may be in water sample or get ~~redu~~ produced by the decomposition of Calcium bicarbonate ($(CaHCO_3)_2$). It reacts with water to form carbonic acid (slow corrosive agent)

$$CO_2 + H_2O \rightarrow \underset{\text{Carbonic acid}}{H_2CO_3}$$

It can be removed by adding Ammonium hydroxide (NH_4OH) or liquid ammonia.

$$NH_4(OH) + CO_2 \rightarrow (NH_4)_2CO_3 + H_2O$$

3. Due to presence of dissolved acids (mineral acids) —

$$Fe + 2HCl \rightarrow FeCl_2 + H_2\uparrow$$
$$FeCl_2 + H_2O \rightarrow Fe(OH)_2 + HCl$$
$$\downarrow$$
$$Fe(OH)_3 \rightarrow [Fe_2O_3 \cdot 2H_2O$$

* ~~Caustic Embrittlement~~ —

Caustic Embrittlement —

When highly alkaline water is used or water is treated with lime Soda process.

$$Na_2CO_3 + H_2O \rightarrow 2NaOH + CO_2\uparrow$$

This NaOH makes boiler water alkaline. and can lead to generation of galvanic cell inside the boiler due to difference in the concentration of NaOH. The part of metal having higher concentration of NaOH starts behaving like an anode Which leads to Caustic Embrittlement.

* The water obtained from any natural source is not suitable to feed in the boiler and if feeded can cause various boiler problems, therefore it is better to treat water prior to feed in the boiler and that treatment is known as External Treatment

External Treatment —

1. Zeolite process
2. Ion-Exchange [illegible]cess
3.

Q. Describe zeolite process used for water softening along with advantages and limitiations.

Q. What do you mean by Permutit Process. Describe it in detail? (Zeolite Process).

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Ans - * Zeolite Process — / Permutit Process

Zein + lithos → boiling stones

Latin ' Permotire' → to exchange

Formula — $Na_2O \cdot Al_2O_3 \cdot xSiO_2 \cdot yH_2O$

Hydrated sodium alumino silicate

$x \rightarrow 2$ to 10, $y \rightarrow 2-6$.

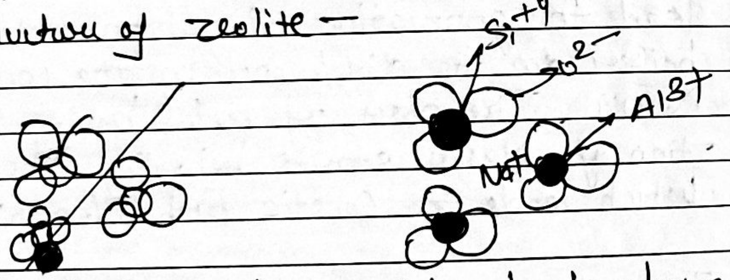
* Hydrated sodium alumino silicate can be represented by Na_2Z has capability to exchange its sodium ion with hardness causing divalent ions (Ca^{2+}, Mg^{2+})

Zeolite is of two types —

1. Natural Zeolite
2. Synthetic Zeolite.

- Synthetic Zeolite is much better in ~~[illegible]~~ porousity than natural zeolite.

Structure of zeolite —



A zeolite is can be consider be to form from the linking of several SiO_4 tetrahedron. In this tetrahedron, Oxygen atom is shared with adjacent atoms and if some of Si^{+4} ions get replaced with Al^{3+} ions. These ions occupy the original position but to balance the charge entire Na^+ ion incorporated in interstitial voids. These Na^+ ions are held loosely, therefore get exchanged with Ca^{2+}, Mg^{2+} ions present in hard water sample.

Q. Why we use brine sol^n in zeolite softener for regeneration?

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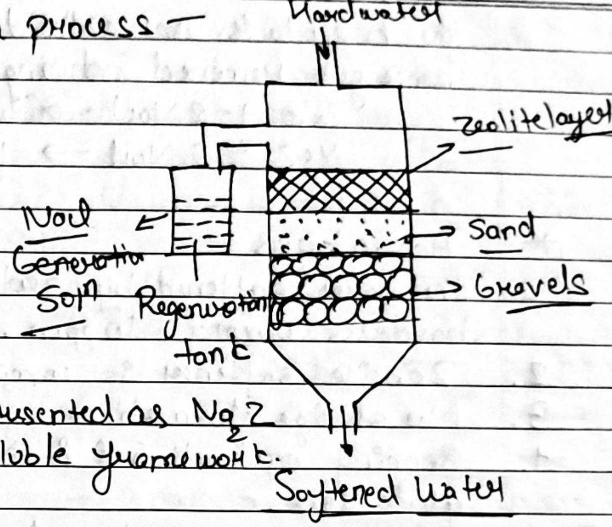
* Principle of the process —



Zeolite softener

Zeolite can be represented as Na_2Z where Z is insoluble framework.

→ When hardwater is passed through the layer of zeolite the Calcium & Magnesium ions gets exchanged with Sodium ions.

$$CaSO_4 + Na_2Z \rightarrow CaZ + Na_2SO_4$$
$$MgCl_2 + Na_2Z \rightarrow MgZ + 2NaCl$$
$$Mg(NO_3)_2 + Na_2Z \rightarrow MgZ + 2NaNO_3.$$

* Regeneration —

When all the sodium ions get exchanged with hardness causing Ca^{2+} & Mg^{2+} ions, our zeolite softener get exhausted (not capable to exchange further of Ca^{2+}, Mg^{2+} ions. Then it needs regeneration.

We use 10% brine solution for regeneration.

(i) First of all, we stop hardwater supply and then perform backwashing, followed by addition of 10% brine so[illegible] from regeneration tank, then to remove the b[illegible]ducts, it is washed and rinsed with distilled [illegible]ater.

* NaCl is cost[illegible]tive, easi[illegible]ible and

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the biproducts are chloride of calcium and magnesium hence get removed during washing.

$$CaZ + 2NaCl \rightarrow CaCl_2 + Na_2Z$$
$$MgZ + 2NaCl \rightarrow \underbrace{MgCl_2}_{\text{highly soluble.}} + Na_2Z$$

* Advantages –

1. The water softened by zeolite process has a residual hardness around 10ppm.
2. Zeolite softener is compact and occupies less space.
3. No sludge formation.
4. Running operational & Maintainaince cost is quite less.
5. Process is quick and clean.

* Disadvantage / Limitations –

1. Turbid water can't be treated with this process As turbidity will cloak the course pores.
2. This process is not suitable for highly alkaline or acidic water as It can destroy the zeolite layer.
3. The water softened by this process contains all the anions in form of sodium salts.
4. And if it contains $Na(HCO_3)_2$, then this water can't be used for high pressure boiler because it leads to caustic embrittlement and boiler corrosion.

$$NaHCO_3 + H_2O \rightarrow \underset{\downarrow \atop CE}{NaOH} + \underset{\text{boiler corrosion}}{CO_2\uparrow}$$

5. Water Sample containing Fe, Co, Mn can't be softened by this process as regeneration is difficult

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[50 – Eq wt of $CaCO_3$, 58.5 – NaCl]

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* Numericals –

1. The hardness of 10,000 L of water sample was removed by passing it through zeolite softener, the softener then required 200L of NaCl solution containing 150g/L of NaCl. for regeneration. Find the hardness of water sample.

Ans = 200L of NaCl solⁿ contains = Vol × Strength
$= 200 \times 150$
$= 30,000\ g$

In terms of $CaCO_3$ $= 200 \times 150 \times \frac{50}{58.5}$ g.meq $CaCO_3$

$= 200 \times 150 \times \frac{50}{58.5} \times 10^3$ mgeq $CaCO_3$

10,000L of water containing $= \frac{200 \times 150 \times 50 \times 10^3}{58.5 \times 10000}$

$= 2564.1$ mg eq of $CaCO_3$

Hardness $= 2564.1$ mg/L.

→ To convert it in g eq of $CaCO_3$ $= \boxed{\frac{50}{58.5}}$ – fixed.

→ For volume, 600 mg of ppm, mg/L.
600 mg — 1 L
1 mg — $\frac{1}{600}$ L

$200 \times 150 \times \frac{50}{58.5} \times 10^3 = \frac{1}{600} \times \frac{200 \times 150 \times 50 \times 10^3}{58.5}$

$= 42735.04\ L$

→ For %, 5% ⇒ 5g in 100mL
50g in 1000mL or 1L
= Strength = 50g in 1L

~~Imp~~ Q_2. A zeolite softener was completely exhausted and then regenerated by passing 100L of NaCl solⁿ. containing 100g/L of NaCl. How many litres of water sample of hardness 500ppm can be softened by using this softener.

~~Imp~~ Q_3. A zeolite softener was 90% exhausted by removing the hardness completely when 10,000L of hard water sample passed through it. The exhausted zeolite then required 200L of 3% NaCl solⁿ. for regeneration. Calculate hardness of water sample.

~~Ans.~~

4. An exhausted zeolite softener was regenerated by passing 150L of NaCl solⁿ having strength of 0.2g/L. of NaCl. Find the total volume of water that can be softened by using this ~~process~~ softener. If hardness of water is 350°cl.

Ans = Strength of NaCl = 100g/L

(100L) Amount of NaCl ~~pa~~ contains = 100×100 g

Amount of $CaCO_3$ eq. present in (100L) of NaCl = $100 \times 100 \times \frac{50}{58.5}$ g

$= 100 \times 100 \times \frac{50}{58.5} \times 10^3$ mg

Now, Volume of 550ppm = 5~~5~~0mg/L

550mg in 1L

1 mg in $\frac{1}{5~~5~~0}$

$10^4 \times \frac{50 \times 10^3}{58.5} = \frac{1}{~~550~~} \times 10^4 \times \frac{~~50~~}{58.5} \times 10^3$ ~~17094.01~~ 7.1L

$= \frac{10^{~~8~~}}{~~11~~ \times 58.5}$ = $\frac{10^7}{643.5}$ = 15540 .0019

⟹ 5.12 L

Ans 2 = 90% of hard water sample of 10^4L = 9000L

3% of NaCl — 3g in ~~1L~~ 100mL

30g in 1000mL or 1L, 30g/L

Amount of NaCl in 9000L = $30 \times \frac{9000}{200}$ g $\times 200$

$= 30 \times 9 \times 10^{~~3~~} \times 10^3$ mg

In terms of $CaCO_3$ = ~~$30 \times 9 \times 10^6$~~ $\times \frac{50}{58.5}$

$= 30 \times 200 \times 10^3 \times \frac{50}{58.5}$

$= 6 \times 10^{~~6~~} \times \frac{50}{58.5}$

Now 9000L contains = $\overset{2}{~~6~~} \times 10^{~~6~~ 3} \times \frac{50}{58.5} \times \frac{1}{~~9~~ 3 \times 10^{~~3~~}}$

$= \frac{10^5}{3 \times 58.5}$ = ~~56.98~~ mg/L = 569.8 ppm

Ans 4 = Strength of NaCl = 0.2g/L

150L of NaCl = 0.2×150 g

$= 0.2 \times 150 \times 10^3$ mg

In terms of $CaCO_3$ = $0.2 \times 150 \times 10^3 \times \frac{50}{58.5}$

Now, hardness of water = 350°cl = ~~3~~ $\frac{350}{0.07}$ mg/L

1mg/L — 0.07°cl

1°cl — $\frac{1}{0.07}$ mg/L

350°cl — $\frac{350}{0.07}$ mg/L

Now, $\frac{350}{0.07}$ mg — 1L

1mg — $\frac{0.07}{350}$ L

$0.2 \times 150 \times 10^3 \times \frac{50}{58.5}$ mg — $\frac{0.07}{350} \times 0.2 \times 150 \times 10^3 \times 50$

$\frac{30 \times 10^3 \times}{58} \times \frac{}{475}$ → short note

OH

15x

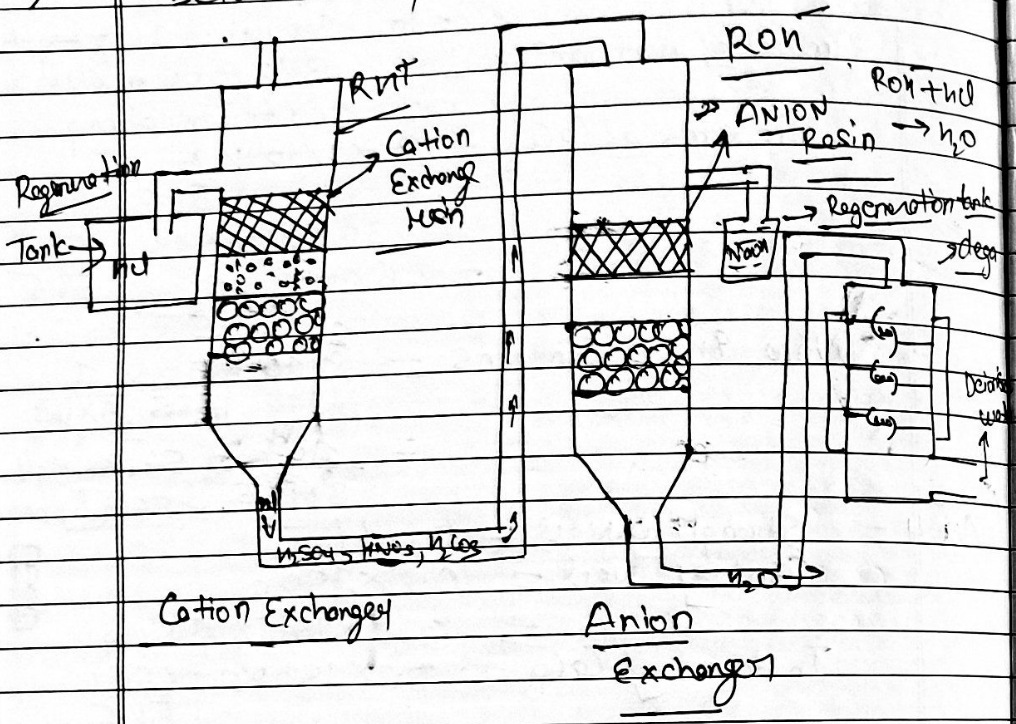
Anion exchange

Along with advantages and disadvantages.

Q. What are ion-exchange resins? Discuss ~~them~~ in detail Q.

Imp Q.

* Ion-Enchange method — / Demineralisation process)
· Deionisation process.

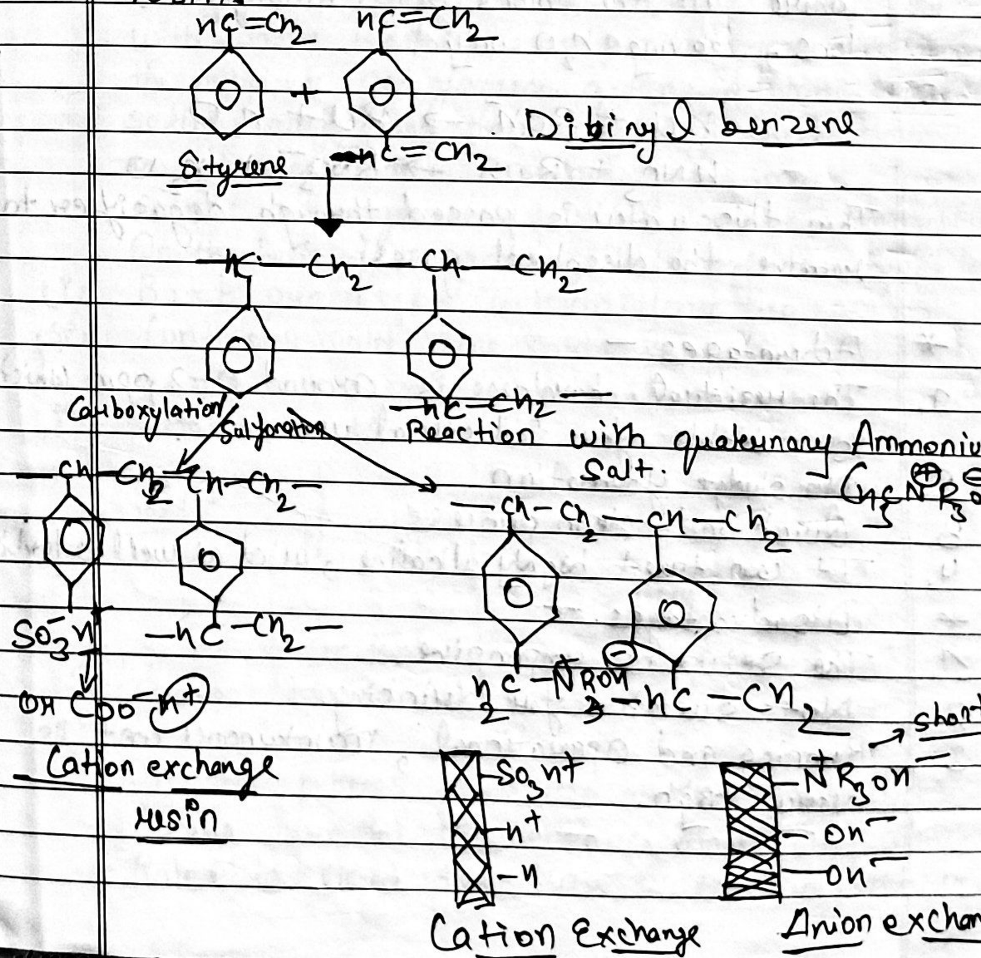


* In Zeolite process, use for water softening, the softened water contains all the anions in the form of Na salts, which can further cause various boiler problems, therefore ion-exchange process is used to remove all type of ions. It is also known as Demineralisation process because alongwith hardness causing impurities minerals also get removed. And also known as deionisation process because all ions get removed in the process. The process of complete removal of all ions present in water is known as deionisation (diminerelisation) Ion-exchange process with the help of ion-exchange resins.

* Ion-enchange resin —

Ion-enchange resins consists of cross-linked long chain organic polymers with a micro porous structure. The functional group attached to the polymeric chain is responsibl for ion enchange and on that basis ion-exch-e resins can be classified into two category Cation Exchange resin and Anion exchange res

⇒ These resins are copolymer of styrene and divin benzene. which on further reaction with acids or bases give cation and anion enchang resin.



* Theory / Process —

When Hardwater is passed through ion-exchanger in cation exchanger, hardness causing cations (Mg^{2+}, Ca^{2+}) get exchanged with (H^+) ions and anions are coming out in the form of acids.

$$2RH^+ + CaCl_2 \rightarrow R_2Ca + 2HCl$$

$$2RH^+ + Mg(NO_3)_2 \rightarrow R_2Mg + 2HNO_3$$

Then this water is subjected to anion exchanger where all the anions get exchanged with OH^- ions, leaving H_2O only.

$$HCl + ROH^- \rightarrow RCl + H_2O$$

$$HNO_3 + ROH^- \rightarrow RNO_3^- + H_2O$$

Then this water is passed through degasifier to remove the dissolved gases.

* Advantages —

1. The residual hardness is around 0-2 ppm which is suitable for industrial use.
2. No sludge formation.
3. Quick and clean process
4. It can treat highly alkaline, acid as well as turbid

* Disadvantages —

1. The setup is expensive.
2. Not suitable for drinking.
3. Running and operational, maintenance cost is very high.

Q. What is the basic principle of lime soda process? & Describe hot lime soda process.

Q. Compare zeolite, ion exchange and lime soda process.

* Lime Soda Process —
$(Ca(OH)_2)$ (Na_2CO_3)

In Lime Soda process, weighed amount of lime and soda added to the hardwater sample to convert all the soluble hardness causing impurities into insoluble precipitates which can be removed by settling and filtration. It is of two types —

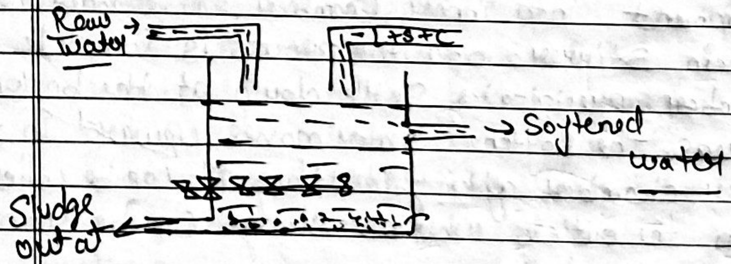
(i) Cold-lime soda process
(ii) Hot-lime soda process.

* Cold L.S. Process —

In cold Lime soda process, Lime & Soda are mixed with hard water ~~two~~ sample at room temperature. Once the precipitate get formed after some time it gets settle down. And then can be filtered. Here addition of coagulent is essential. to make precipitate coarse and granular. which can be easily filtered. On the basis of equipment, it is of two types —

(i) Batch process or Intermittent Process —
(ii) Continous Cold Lime Solda Process —

* Batch process —



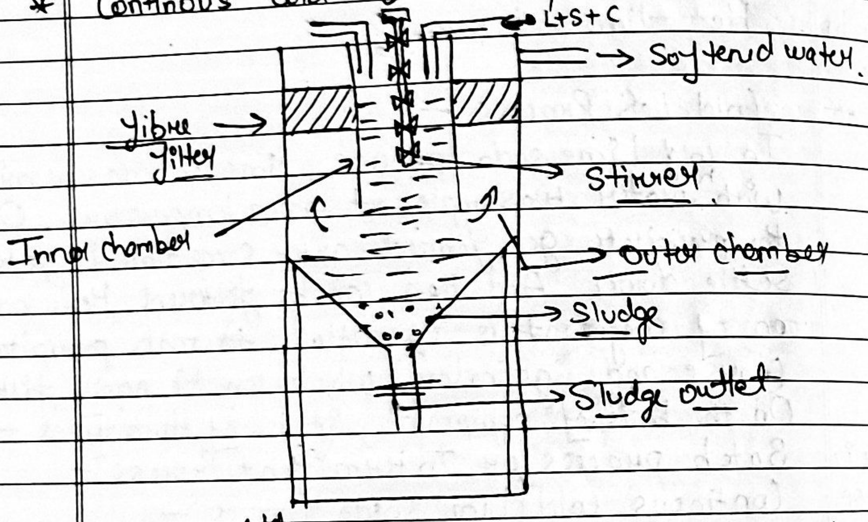
In this process, we use several iron tanks. having two inlet and two outlet ~~oo~~. One inlet is used for raw water and other one

Q. Discuss Cold-lime soda process? Alongwith adv & disadv.

Q. Write the diff. between cold lime soda and hot lime soda process.

is used for feeding chemicals (L+S+C).
The outlet at the bottom is used to remove sludge
This tank is equipped with a mechanical stirrer used for mixing of chemicals. The outlet above stirrer is used to collect softened water.

* Continous Cold-Lime soda process —



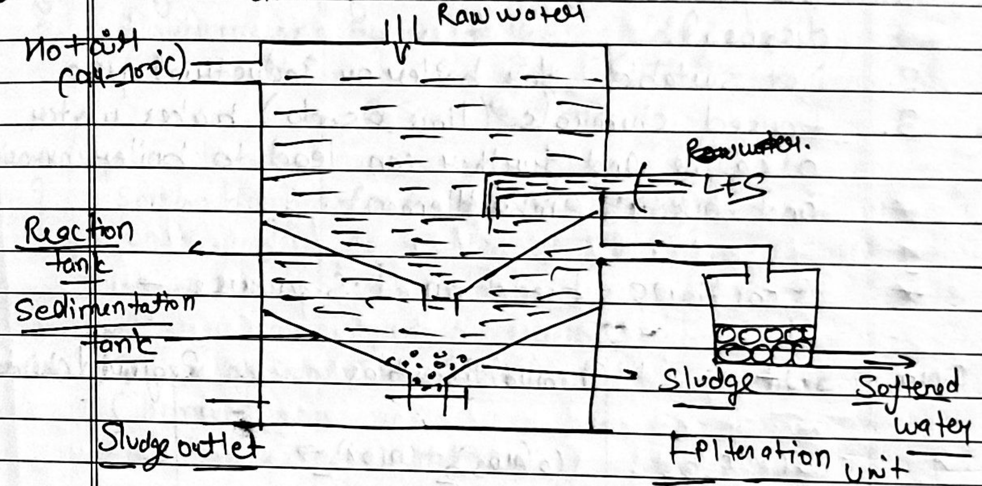
In continous cold Lime soda process, raw water alongwith required chemicals introduce from top of the equipment into inner chamber. This inner chamber contain stirrer once the process is complete outer chamber precipitates settle down at the bottom whereas the softened water moves upward in the outer chamber after filtration it can be collected from the outlet whereas sludge can be removed from the bottom.

→ Disadvantages —

1. The residual hardness of cold LS process is around 50-60 ppm, which is not suitable for boiler and industrial use.

- In cold lime soda process, addition of coagulent is essential to make the precipitate coarse and granular
- It consumes a lot of time.

Imp * Hot-Lime soda Process —



* In this process, we use hot air to increase the temp of process around 95-100°c. From top of the equipment, raw water is feeded whereas chemicals are supplied from the inlet placed above the reaction tank. At high temperature, reaction is much faster, therefore precipitate get settle down much quickly. And softened water can be removed from the outlet placed ~~in~~ between reaction tank and sedimentation tank. This water is further passed through filteration unit to remove any leftover suspended particles.

* Advantages –

1. It required less chemicals.
2. It is fast or quick process, and cost effective.
3. Residual hardness is around 20-25 ppm.

* Disadvantages –

1. L:S process creates a big problem for sludge disposal.
2. Not suitable for boiler or industrial use.
3. Unused chemicals (lime & soda) makes water alkaline and further can lead to boiler corrosion and caustic embrittlement.

* Reactions based on L:S process –

S.No.	Salt	Chemical Properties	Required chemical
1.	$Ca(HCO_3)_2$ or Temp. hardness of Ca	$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow$ $2CaCO_3\downarrow + H_2O$	L
*2.	$Mg(HCO_3)_2$ or Temp. H. of Mg.	$Mg(HCO_3)_2 + 2Ca(OH)_2 \rightarrow$ $2CaCO_3\downarrow + Mg(OH)_2\downarrow + H_2O$	2L
3.	Permanent hardness of Ca ($CaCl_2$ or $CaSO_4$)	$CaSO_4 + Na_2CO_3 \rightarrow CaCO_3\downarrow + 2Na_2SO_4$	S
4.	Permanent hardness of mg ($MgCl_2$, $Mg(NO_3)_2$, $MgSO_4$.	$MgCl_2 + Ca(OH)_2 \rightarrow CaCl_2 + Mg(OH)_2\downarrow$ $CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaCl$	L+S
5.	Dissolved gases like CO_2, H_2S.	$CO_2 + Ca(OH)_2 \rightarrow CaCO_3\downarrow + H_2O$ $H_2S + Ca(OH)_2 \rightarrow CaS\downarrow +$	L
6.	Free acids – $HCl/H_2SO_4/H^+$	(2) $2HCl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O$ $CaCl_2 + Na_2CO_3 \rightarrow 2NaCl + CaCO_3$	L+S
7.	Presence of $FeSO_4$ / $FeSO_4 \cdot 7H_2O$	$FeSO_4 + Ca(OH)_2 \rightarrow CaSO_4 + Fe(OH)_2$ $CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 + Na_2SO_4$	L+S
[1/3] *8.	Aluminium sulphate	$Al_2(SO_4)_3 + 3Ca(OH)_2 \rightarrow 3CaSO_4 + 2Al(OH)_3$ $CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 + Na_2SO_4$	L+S
*9.	Sodium bicarbonate. $NaHCO_3/HCO_3^-$	(2) $2NaHCO_3 + Ca(OH)_2 \rightarrow CaCO_3\downarrow + Na_2CO_3 + 2H_2O$	L−S
*10.	Sodium aluminate ($NaAlO_2$)	$2NaAlO_2 + 4H_2O \rightarrow 2NaOH + 2Al(OH)_3$ ≈ 1 mol of $Ca(OH)_2$	−L

* For numericals –

* Lime –

Amount of Lime $= \frac{74}{100}$ [(Temporary H. of Ca + 2× Temp H. of Mg + CO_2 + H_2S + Free acids + Permanent H. of Mg + $FeSO_4$ + $Al_2(SO_4)_3$ + $NaHCO_3$] − $NaAlO_2$] mg eq. of $CaCO_3$ ×

$= \frac{74}{100}$ [Sum] × Volume × $\left(\frac{100}{\text{Purity}}\right.$ or $\frac{100+Ex}{100}$

Purity factor $= \frac{100}{\text{Purity}}$, Excess $= \frac{100+\text{Excess}}{100}$

Amount of Soda $= \frac{106}{100}$ [Per. Hard of Ca^{2+} + Per. Hard of Mg + Free acids + $FeSO_4$ + $Al_2(SO_4)_3$ − $NaHCO_3$]

· mgeq of $CaCO_3$ × vol of water $\left(\times \frac{100}{\text{Purity}} \text{ or } \frac{100+\text{Excess}}{100}\right)$

→ $CaCO_3$ & $MgCO_3$ $\xrightarrow{2L}$ [considered $CaCO_3$].

→ Ca^{2+}, Mg^{2+} (Perm. Hardness)

$Ca^{2+} \rightarrow$ S, $Mg^{2+} \rightarrow$ L+S

* Imp for Numericals —

1. If NaCl / KCl / SiO_2 / Fe_2O_3 / Na_2SO_4 / Fe_2O_3 / K_2SO_4 are present does not impart hardness.
2. If impurities are in the form $CaCO_3$ & $MgCO_3$, they would be considered as temporary hardness. There is no need to change $CaCO_3$ but $MgCO_3$ should be changed. $\left[\frac{\cancel{84}\,100}{100\,84}\right]$ Multiplication factor.
3. If impurities are given in terms of Ca^{2+}, Mg^{2+} (divalent ions) then they would be treated as permanent hardness.
4. For Ca^{2+}, the multiplication factor will be $= \frac{100}{40}$, it will be counted for S only (Soda)
5. For Mg^{2+}, the multiplication factor will be $\frac{100}{24}$ and it will counted for L+S both.
6. If chemicals used are impure, then purity factor is used. And get multiplied with amount

$$\text{Purity} = \frac{100}{\text{Purity}(\%)}$$

7. If to complete the reaction quickly, chemicals are used in excess, then amount will get multiplied by excess factor.

$$\text{Excess factor} = \frac{100+\text{Excess}}{100}$$

8. If treated water contains OH^- & CO_3^{2-} (ions), they would be considered as the excess of chemicals.

OH^- → due to excess of lime ($Ca(OH)_2$) → ~~L+S~~ L+S

CO_3^{2-} → due to excess of soda (Na_2CO_3) → S

- HCl $= \frac{100}{2 \times 36.5}$
- $NaAlO_2 = \frac{100}{2 \times 82}$
- $NaHCO_3 \rightarrow = \frac{100}{2 \times 84}$.

→ $HCO_3^- = \frac{100}{2 \times 61}$

→ $Al_2(SO_4)_3 = \frac{100}{342/3} =$

- $FeSO_4 \cdot 7H_2O = \frac{100}{278}$
- $FeSO_4 = \frac{100}{152}$

Q. Calculate the amount of lime & soda required for softening water of 20000 L of hard water containing — (mg/L)
HCl − 7.3, Al_2SO_4 − 34.3, $MgCl_2$ − 9.5
$CaCO_3$ − 40, $CaCl_2$ − 111 mg/L.

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$FeSO_4 \cdot 7H_2O$ – 139, NaCl – 30, Dissolved CO_2 – 20, $NaHCO_3$ – 8.4

Ans =

S.N.	Salt	Amount (mg/L)	Eq. of $CaCO_3$ (mg/L)	Required chemical
1.	HCl	7.3	$\frac{7.3 \times 100}{2 \times 36.5} = 10$	L+S
2.	$Al_2(SO_4)_3$	34.2	$\frac{342 \times 100}{342} = 30$	L+S
3.	$MgCl_2$	9.5	$\frac{9.5 \times 100}{95} = 10$	L+S
4.	$CaCO_3$	40	$\frac{40 \times 100}{100} = 40$	L
5.	$CaCl_2$	111	$\frac{111 \times 100}{111} = 100$	S
6.	$FeSO_4 \cdot 7H_2O$	139	$\frac{139 \times 100}{278} = 50$	L+S
7.	NaCl	—	X	—
8.	CO_2	22	$\frac{22 \times 100}{44} = 50$	L
9.	$NaHCO_3$	8.4	$\frac{8.4 \times 100}{2 \times 84} = 5$	L+S

Required Lime = $\frac{74}{100}$ [10 + 30 + 10 + 40 + 50 + 50 + 5] × 20000

= 74 × 195 × 200 mg

= 2886000

= 2.886 kg

Soda = $\frac{106}{100}$ [10 + 30 + 10 + 100 + 50 + 5] × 20000

= $\frac{106 \times 195 \times 20000}{100}$ = 4134000

= 4.134 kg.

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Q. Calculate the qty of Lime and Soda required for softening of 50,000 L of hardwater containing $Mg(HCO_3)_2$ – 144 ppm, $Ca(HCO_3)_2$ – 25 ppm, $MgCl_2$ = 95 ppm, $CaCl_2$ = 111 ppm, Fe_2O_3 = 25, Na_2SO_4 = 15.

		Amount	Eq of $CaCO_3$	Required
1.	$Mg(HCO_3)_2$	144	$\frac{144}{146} \times 100 = 98.63$	2L
2.	$Ca(HCO_3)_2$	25	$\frac{25}{162} \times 100 =$ ~~24.75~~ 15.43	L
3.	$MgCl_2$	95	$\frac{95}{95} \times 100 = 100$	L+S
4.	$CaCl_2$	111	$\frac{111}{111} \times 100 = 100$	S
5.	Fe_2O_3	25	— X	—
6.	Na_2SO_4	15.	— X	—

⇒ Lime = $\frac{74}{100}$ (2 × 98.63 + ~~24.75~~ 15.43 + 100 + ~~100~~) × 50,000

= $\frac{74}{100}$ (197.26 + ~~24.75~~ 15.43 + 100) × 50,000

= $\frac{74}{100}$ (312.69) × 50000

= ~~11914870~~

= 11.914 kg, 11.56 kg

= 11.56

Soda = $\frac{106}{100}$ (100 + 100) × 50000

= $\frac{106 \times 200 \times 50,000}{100}$ = 10.6 kg

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Q. Calculate the amt. of L&S for 20,000 L of water whose analysis is given –

	Amount (ppm)	Eq. of $CaCO_3$	Required
$Ca(HCO_3)_2$	40.5	$= \frac{40.5 \times 100}{162} = 25.$	L
$Mg(HCO_3)_2$	86.5	$= \frac{36.5 \times 100}{146} = 25$	2L
~~$CaCl_2$~~ $Mg(SO_4)$	30	$\frac{\cancel{130} \times 100}{\cancel{120}} = 25$	L+S
$CaCl_2$	27.75	$\frac{27.75 \times 100}{111} = 25$	S

→ $Lime = \frac{74}{100}(50+25+25) \times 20,000$

$= \frac{74}{\cancel{100}}(100) \times 20,0\cancel{00}$

$= \frac{1480000}{10^6} = 1.48\ kg.$

$Soda = \frac{106}{\cancel{100}}(\cancel{100}) \times \frac{20,0\cancel{00}}{10^6}$

$= \frac{106 \times \overset{50}{\cancel{125}} \times 2000}{10^6} = 1.06\ kg.$

Q. Calculate amount of L&S needed for softening 10^5 L of water, containing

		(mg/L)		
1.	HCl	7.3	$\frac{7.3 \times 100}{2 \times 36.5} = \frac{\overset{10}{\cancel{20}}}{\cancel{2}}$	L+S
2.	$Al_2(SO_4)_3$	34.2	$\frac{8 \times \overset{0.1}{\cancel{34.2}} \times 100}{\cancel{342}} = 30$	L+S
3.	$MgCl_2$	9.5	$\frac{0.\cancel{9.5} \times 100}{\cancel{95}} = 10$	L+S
4.	$NaCl$	29.25	—	X —

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L (90%), S (98%), (10% in excess) are used for complete reaction.

$Lime = \frac{74}{100}(20+30+10) \times 10^5 \times \frac{100}{90}$

$= \frac{74}{100}(\overset{80}{\cancel{60}}) \times 10^5 \times \frac{100}{90} \times \frac{110}{100}$

$= \cancel{30}\ \cancel{4.45}\ 4.52$

$S = \frac{106}{100}(50) \times \frac{10^5}{10^6} \times \frac{100}{98} \times \frac{110}{100}$

$= 5.95$

Q. Calculate the cost of L&S required for softening 10^6 L of water containing – Analysis of raw water:

		Amount	Eq. of $CaCO_3$	Required Chemical
1.	Ca^{2+} ions	80ppm	$2\ \frac{\cancel{80} \times 100}{\cancel{40}} = 200$	S
2.	Mg^{2+} ions	48ppm	$\cancel{48} \times 100 = 200$	L+S
3.	CO_2	22 ppm	$\frac{\cancel{22} \times 100}{\cancel{44}} = \frac{\cancel{200}}{50}$	L
4.	HCO_3^-	264 ppm	$\frac{264 \times 100}{2 \times 61} = \frac{432.78}{2} = 216.39$	L
5.	H^+	2 ppm	$\frac{\cancel{2} \times 100}{\cancel{2}} = 100$	L+S

→ Treated water –

1. ~~CO_2~~ CO_3^{2-} 66 ppm → Soda (Excess)
$= \frac{6\cancel{6} \times 100}{60} = 100$

2. OH^- 34 ppm — (Lime + S)
$= 2\ \frac{\cancel{34} \times 100}{\cancel{17}} = 200$

Q. How will you determine hardness by complexo-metric method?

$$\text{Lime} = \frac{74}{100}\left(200+50+\cancel{432.28}^{\,216.39}+100+200\right)\times 10^{6}$$

$$= \frac{0.74 \times 766.39 \times \cancel{10^{6}}}{\cancel{10^{6}}} = 567.12\ \text{kg}.$$

$$\text{Soda} = \frac{106}{100}\left(200-216.39+100+300\right)\times 10^{6}$$

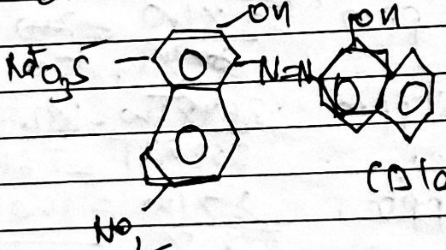
$$= \frac{1.06 \times \cancel{343.61} \times \cancel{10^{6}}}{\cancel{10^{6}}}$$

$$= \cancel{417.22}\ \ 1.06 \times 383.61 \mid 583.61$$

$$= \cancel{406.62}.$$

$$= 618.626\ \text{kg}.$$

* Determination of Hardness by EDTA method- depends upon the factor that Ca^{2+} & Mg^{2+} ion react with EBT in presence of ammonia buffer, whose pH should be around 10 to form. wine red coloured complex. which on titration give Edta, forms complexs with Edta. and EBT remains free. which gives blue colour to the solution.



→ EBT or H_3In.

* Our indicator is pH sensitive, gives different colours at different pH, that's why buffer is essential for this method.

$$HIn + HO \rightarrow H_2In^- + H_3O^+$$

$$H_2In^- + H_2O \rightarrow \underset{\text{(blue)}}{HIn^{2-}} + H_3O^+$$

$$HIn^{2-} + H_2O \rightarrow \underset{\text{(orange)}}{In^{3-}} + H_3O^+$$

$$\rightarrow \underset{\text{blue.}}{HIn^{2-}} + M^{2+} \longrightarrow \underset{\text{wine red}}{MIn^{-}}$$

$$\downarrow H_2Y^{2-}$$

$$\underset{\text{blue.}}{HIn^{2-}} + MY^{2-} + H^+.$$

* Procedure -

1. Standardiasation of EDTA solution - Fill the burette with given EDTA sol^n, meantime prepare standard hardwater (SHW) by dissolving 1g $CaCO_3$ per L. Suppose 50mL of standard hardwater uses V_1 mL of EDTA for endpoint.

2. Determination of total hardness - Suppose 50mL of water sample (unknown) consumes V_2 mL of EDTA for endpoint.

3. Determination of permanent hardness - Take 250 mL water sample in 500 mL of conical flask, boil it, till it reddles upto 50 mL. Then filtered it and after washing collect the filtrate in another conical flask and make upto 250mL by adding distill water. Suppose 50 ml of this sol^n uses V_3 mL of Edta sol^n for end point.

* Calculation -

(i) Strength of Edta -

1 L water = 1 gm $CaCO_3$

1000 mL water = 1000 mg $CaCO_3$

1 mL water = 1 mg $CaCO_3$

∴ V_1 mL of EDTA used by = 50 mL S.H.W

= 50 × 1 mL S.H.W

= 50 × (1 mg) SHW

= 50 mg $CaCO_3$

∴ V_2 mL of Edta —

50 mL ~~boiled~~ water sample consumes = V_2 mL EDTA =

= V_2 × 1 mg EDTA

= $V_2 \times \frac{50}{V_1}$ mg of $CaCO_3$

1000 mL water sample = $\frac{1}{50} \times \frac{V_2}{V_1} \times \frac{50}{1} \times 1000$

= $\frac{V_2}{V_1} \times 1000$ mg of $CaCO_3$.

* Permanent hardness —

= 50 mL of boiled water sample consumes = V_3 mL of EDTA

= V_3 × 1 mL of edta

= $V_3 \times \frac{50}{V_1}$ mg of $CaCO_3$

1000 mL of boiled water sample contains = $\frac{V_3}{50} \times \frac{50}{V_1} \times 1000$

= $\frac{V_3}{V_1} \times 1000$ mg of $CaCO_3$

Temp. Hardness = Total hardness − Perm. Hardness

= $\frac{V_2}{V_1} \times 1000 - \frac{V_3}{V_1} \times 1000$

Q. A standard H.W sample contains 1.5g of $CaCO_3$/L, 20 mL of this solⁿ requires 25 mL of edta solⁿ. 100 mL of water sample required 18 mL of Edta. ~~after~~ sample water after boiling requires 12 ml of Edta solⁿ. Calculate all type of hardness.

→ 1 L of water — 1.5 g of $CaCO_3$.

1000 mL of H_2O — 1.5 × 1000 mg of $CaCO_3$

1 L of H_2O — 1.5 mg of $CaCO_3$.

Now, V_1 = 25 mL of Edta used = 20 mL

Now, 1 mL of Edta used in = $\frac{20}{25} \times 1.5$ mg of $CaCO_3$

= 1.2 mg of $CaCO_3$.

→ ~~Total hardness~~ = V_2

~~25 mL~~ of 100 mL of water = 18 mL of Edta

= 1 mL of water sample = $\frac{18}{100}$ mL of Edta

1000 mL of water = $\frac{18}{100} \times 1.2 \times 1000$

1 L of water = 216 mg of $CaCO_3$

Total hardness = 216 mg/L of $CaCO_3$.

→ Permanent hardness

⇒ 100 mL of water = 12 mL of Edta

1000 mL of water = $\frac{12}{100} \times 1000$ mL of Edta

= $\frac{12}{100} \times 1000 \times 1.2$ mg of Edta

= 144 mg of Edta

P.H = 144 mg/L

⇒ Temp. H = 216 − 144

= 72 mg/L.

Q. 0.28g of $CaCO_3$ was dissolved in HCl. And the solⁿ was made up to 1L of distilled water. 100 mL of above solⁿ required 28 mL of Edta solⁿ on titration. 100 mL of hardwater required 35 mL of Edta. After boiling 100 mL of water required

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10 mL of Edta Sol^n. Calculate all type of hardness

0.28 g of $CaCO_3$ 1 L –

1 L — 0.28

1 L — 0.28 × 1000 mg of $CaCO_3$.

1000 mL = 0.28 × 1000 mg of $CaCO_3$

1 mL — 0.28 mg of $CaCO_3$.

⇒ 100 mL of above — 28 mL of Edta

⇒ 28 mL of Edta — 100 mL

1 mL of Edta = $\frac{100}{28}$ × 0.28 mL of edta

$= \frac{100 \times 0.28}{28} = 1$ mg of $CaCO_3$ ~~edta~~.

⇒ Total hardness –

⇒. 100 mL — 35 mL

1 mL — $\frac{35}{100}$ mL

1000 mL — $\frac{35}{100}$ × 1000

$= \frac{35}{100} \times \frac{1000}{1}$ mg

= 350 × ~~0.28~~ mg of $CaCO_3$

= 350.

Permanent Hardness – 10 mL of edta

100 ml of water – 10 mL of edta

1 ml of water = $\frac{10 \text{ ml}}{100}$

= ~~100~~ 0.4 mg of $CaCO_3$

1000 L of water = 400 mg of $CaCO_3$

PH = 400 mg/L = 400 ppm.

350 – 100 = 250 ppm.

Q. Explain

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* Determination of Alkalinity –

* Alkalinity – Acid consuming capacity of water.

Three reactions are responsible –

OH^-, CO_3^{2-}, HCO_3^-

$$Ph \left[\begin{array}{l} OH^- + H^+ \rightarrow H_2O \\ CO_3^{2-} + H^+ \rightarrow HCO_3^- \end{array} \right] \rightarrow (M)$$

$$HCO_3^- + H^+ \rightarrow H_2O + CO_2 \rightarrow \text{Methyl O.}$$

* Combination of alkalinity

1. due to OH^-, 2. due to HCO_3^- 3. due to CO_3^{2-}
4. due to OH^- & CO_3^{2-}, 7. due to CO_3^{2-} & HCO_3^{2-}
5. due to OH^- & HCO_3^-
6. due to all three

now.

now all three can't be used as –

$OH^- + HCO_3^-$ as $\rightarrow CO_3^{2-} + H_2O$

which is 3.

5 effective Combination.

* Procedure –

(V_1) Sample water $\xrightarrow{\text{2 drops of Ph}}$ Pink $\xrightarrow{\text{titrate with HCl/H}}$

Confirms OH^-, CO_3^{2-} or both.

Colourless End point $\xrightarrow[\text{M.O or M.Red.}]{\text{2 drops of}}$ Yellow $\xrightarrow[\text{with HCl}]{\text{Titrate}}$ Reddish pink

H_2SO_4

* Why Ph shows colour in acid/basic medium ?

common ion effect

$$HPh \rightleftharpoons H^+ + Ph^-$$

(Weak acid) (Pink)

Colourless

In basic ↓ $OH^- + H_2O$

not fully dissociated

the propagation of chain takes place by the step II & III

Q. Explain the thereoy of acid/base indicator"/Explain the reason for colour change in diff. medium for Ph & methyl orange.

Ans:- $HPh \rightleftharpoons H^+ + Ph^-$

HPh behaves as a weak acid and get dissociate into H^+ & Ph^-, In unionized, it is colourless whereas pink in ionised form.
In acidic medium, due to excess of H^+ ion, common ion effect leads to suppression of dissociation/backward reaction and it will remain colourless While in basic medium, forward reac^n leads to development of pink colour.

* $Me + H_2O \rightleftharpoons MeH^+ + OH^-$

Weak base (Yellow) → (Reddish pink)

Methyl orange behaves like a weak base, In basic medium due to common ion effect, backward reac^n will dominate. While in acidic medium forward reac^n dominate and lead to reddish pink color.

*

S.No.	Value	OH^-	CO_3^{2-}	HCO_3^-
1.	$P=0$	Nil	Nil	M
2.	$M=0$/ $P=M$	P/M	Nil	Nil
3.	$P=\frac{1}{2}M$.	Nil	P or $\frac{1}{2}M$	Nil
4.	$P>\frac{1}{2}M$.	$(2P-M)$	$2(M-P)$	Nil
5.	$P<\frac{1}{2}M$.	Nil	2P	M−2P

* Calaulation –

$$N_1V_1 = N_2V_2$$
(sample) (acid)

$$N_1 = \frac{N_2V_2}{V_1}$$

Strength or Amount of alkalinity = $N_1 \times$ Eq. weight (g/L) of $CaCO_3$
$= N_1 \times$ Eq. 50×1000 mg/L

Q. 100 mL of raw water sample on titration with $\frac{N}{50}$ H_2SO_4 required 12.4 mL of acid to Ph endpoint. And 15.2 mL of acid to methyl orange endpoint. Determine the type & extent of alkalinity.

Ans $P = 12.4$, $M = 15.2$
$\frac{M}{2} = 7.6$, $P > \frac{M}{2}$, OH^- & CO_3^{2-} ion present

⇒ now, For cal: of OH^-

$$N_1 = \frac{N_2V_2}{V_1}$$

$$= \frac{\frac{1}{50} \times \cancel{12.4}(9.6)}{100}$$

$$N_1 = \frac{1}{50} \times \frac{9.6}{100} = \frac{9.6}{5000}$$

$$N_1 = 0.00192$$

⇒ For Strength $= 0.00192 \times 50 \times 1000$
$= 96$ mg/L = 96 [illegible]

* For CO_3^{2-}, $N_1 = \frac{N_2V_2}{V_1} = \frac{1 \times \overset{5.6}{\cancel{[illegible]}}}{50 \times 100}$

For strength $= \frac{1.8 \times \cancel{50} \times 1000}{\cancel{50} \times 100}$
$= 18$ [illegible] mg/L

$$\text{Total} = 56 + 96 = \underline{152\ mg/L}.$$

Q. A water sample is not alkaline to phenolphthalein (P=0), however 100 mL of sample on titration with $\frac{N}{50}$ HCl required 16.9 mL of acid. Determine the type & extent of alkalinity.

Ans: For HCO_3^-

$$N_1 = \frac{\frac{1}{50} \times 16.9}{100}$$

$$\text{Strength/Amount} = \frac{1}{\cancel{50}} \times \frac{16.9}{\cancel{100}} \times \cancel{50} \times 1000$$
$$= 169\ mg/L$$

Q. 100 mL of water sample on titration with $\frac{N}{50}$ H_2SO_4 using Ph ~~required~~ consume 5 mL acid. and again required 5 mL of M.O. Determine the type & extent.

$$\underline{P = 5 = M}$$

Ans = due to OH^- →

$$\Rightarrow N_1 = \frac{N_2 \times V_2}{V_1} = \frac{1}{50} \times \frac{5}{100}$$

$$\text{Amount} = \frac{1}{\cancel{50}} \times \frac{5}{\cancel{100}} \times \cancel{50{,}000}$$
$$= \underline{50}\ mg/L$$

Q. 100 mL of water sample on titration with $\frac{N}{50}$ H_2SO_4 give a ~~titratio~~ ~~tige~~ titer value 5.8 mL of ph endpoint. 116 mL of M.O.

$$= \cancel{116} = 58$$

Q. Write a short note on reverse osmosis?

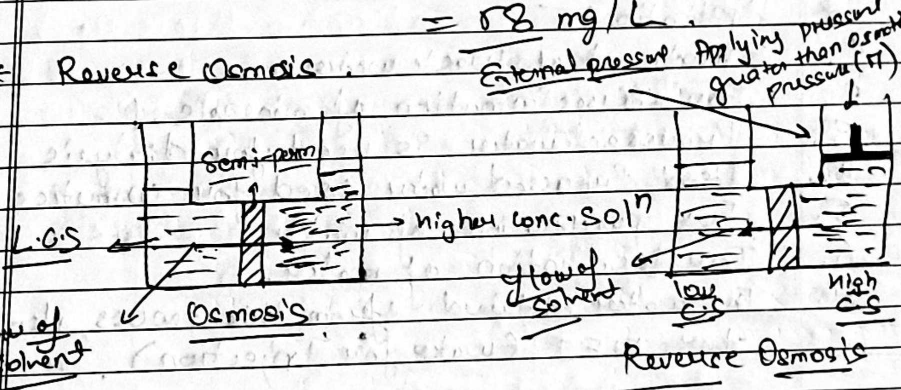
Q. What is Reverse Osmosis? Explain its ~~with~~ advantages & applications.

$$\underline{P = \frac{M}{2}} \rightarrow \text{due to } CO_3^{2-}$$

$$\therefore N_1 = \frac{1}{50} \times \frac{5.6}{100}$$

$$\text{Amount} = \frac{1}{\cancel{50}} \times \frac{5.8}{\cancel{100}} \times \cancel{50} \times 1000$$
$$= \underline{58}\ mg/L.$$

* Reverse Osmosis.



* When two solutions having different concentration are separated by semi-permeable membrane, then the flow of solvent takes place from lower concentration to higher concentrated solution until the concentration becomes equal. This phenomenon is known as Osmosis.

If a pressure more than Osmotic pressure applied to the higher concentrated solution, the flow of solvent get reversed. Now it flow from higher concentrated to lower concentrated soln. till the concentration become equal. This phenomenon is called Reverse Osmosis.

* Advantages –

1. Simple and Reliable process.
2. Quick and clean process.

Q. Define fuel?
Q. What are characteristics of a good fuel?
Q. Give the classification of fuels along with example?

3. Operating and maintenance cost is less.
Colliodal SiO_2 can be separated by only by this process
Imp→4. The life of a semipermeable membrane is approx
5. 2 years which can be exchanged within few minutes.
It means we get uninterrupted supply.

* Applications –
1. Treatment of Waste water.
2. For the reclaimation of minerals.
3. Processed water is used for dialysis
4. ~~Used~~ Processed water used for cosmetics & medication.
5. For purification of water.
6. For Desalination of water.
7. The water obtained from this process, also used for WFI (Water for Injection).

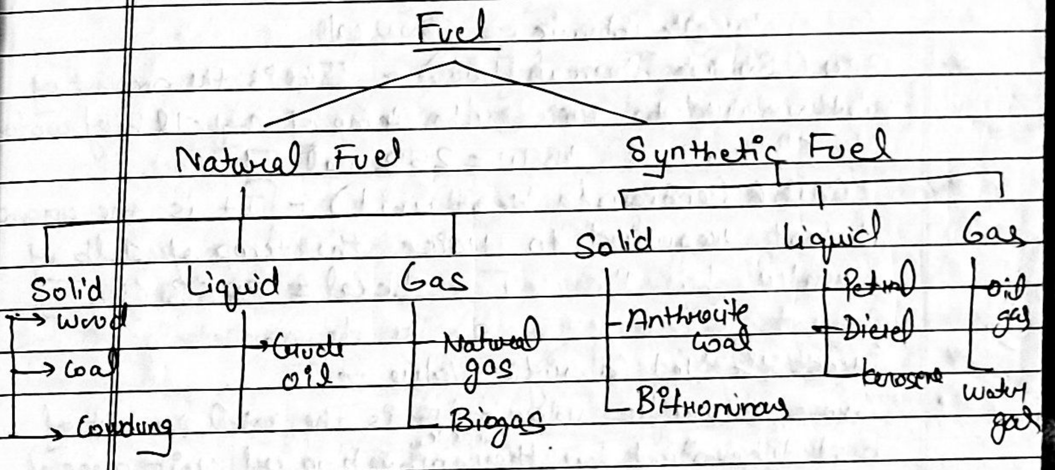
* Fuel –

Any combustible material which can be burn to supply heat energy along with eco-friendly byproducts.

* Characteristics of good fuel –
✓1 High calorific value.
✓2. Byproducts eco friendly
4. Easily available and cost effective.
✓5. Moderate Ignition Temperature.
6. Easy to store & transport.
✓7. Combustion should be non-spontaneous. Or in our control.
✓8. Speed of combustion should be low to moderate

Q. Ranking of coal? (Ranking) Classify coal on this basis. HCV/LCV
Q. Classification of fuel? GCV/NCV
Q. Define calorific value also write the difference between GCV/NCV?

✓10. Percentage of non-combustible material should be low.
11. Percentage of carbon should be high.



Ans* Coal ↓

Wood →	Peat →	Lignite →	Bituminous →	Anthracit
50%	57%	67%	83% 83%	93%

* Calorific value –
It is the most important characteristic of a fuel to judge the efficiency.
It can be defined as – The amount of heat liberated by the complete combustion of unit mass of fuel.
It is of two types –
(i) GCV (Gross calorific value) [Higher Calorific value]
(ii) NCV (Net calorific value) [lower calorific value]

* Units for calorific value –
CGS – Cal/gm , MKS – Kcal/kg
BTU – BTU/lb.

Q. ~~Wo~~ Explain why GCV also have higher value than NCV ?

→ 1 Cal – It is the amount of heat required to raise the temp. of 1g of water by 1°C. [19°C-20°C].

→ 1kcal – The amount of heat required to raise the temp of 1kg of water by 1°C.

– 1 calorie – 4.2 Joule

1k calorie – 1000 cal.

* BTU (British Thermal Unit) – It is the amount of heat required to raise the temp of ~~1g~~ 1lb of water by 1°F. [1BTU = 252 cal].

* CHU (Centigrade heat unit) – It is the amount of heat required to raise the temp of 1lb of water by 1°C [1kcal = 3.968 CHU].

Imp * Gross & Net Calorific Value –

- Gross calorific value – It is the total amount of heat liberated by the complete combustion of unit mass of fuel and combustion products are allowed to cool down to the room temperature.

→ Generally fuel contains a sufficient amount of carbon & hydrogen (C&H) in a closed container during combustion, carbon get converted in CO_2 whereas hydrogen get converted into H_2O.

$$C + O_2 \rightarrow CO_2$$

$$2H_2 + 1O_2 \rightarrow 2H_2O$$

→ When combustion products are allowed to cool down steam get condensed to form water droplets and latent heat also get evolved. During calculation for calorific value, this latent heat also get counted hence GCV also possess higher value than NCV.

- NCV (Net calorific value) – It is the amount of heat liberated by the complete combustion of unit mass

Imp Q. ~~Determination of~~ What do you mean by calorific value? How it is determined by using bomb calorimeter ~~method~~ /experiment?

of fuel and combustion products are allowed to escape. It also possess lesser value than GCV hence, also known as lower calorific value.

$$NCV = GCV - \text{Latent heat}.$$

$$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$$

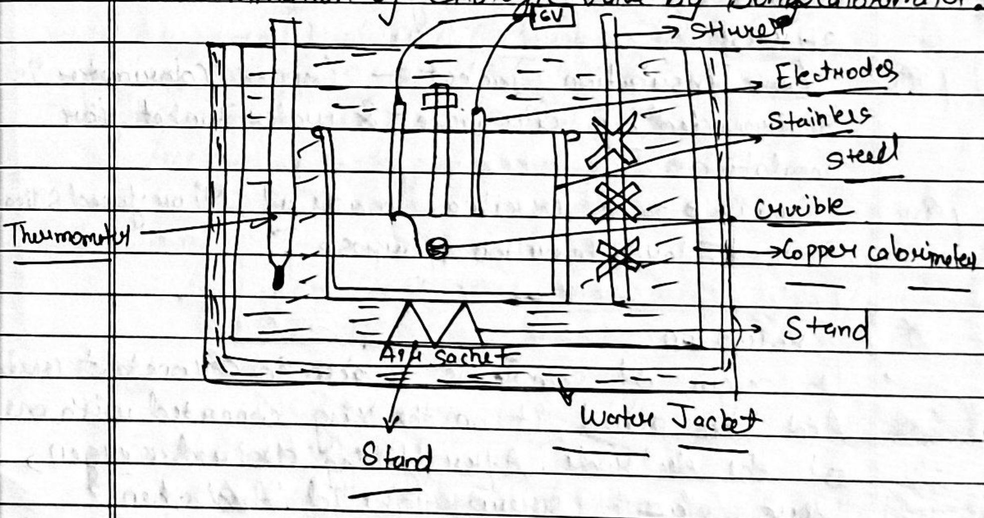
2gm 8gm 18gm

1gm of hydrogen – 9gm of water

$$NCV = GCV - \left(\frac{9}{100} \times \text{weight of } H \times \text{Latent heat}\right)$$

$$\boxed{NCV = GCV - \frac{9}{100} \times \text{wt of } H \times \text{Latent heat}}$$

Imp * Determination of Calorific value by Bomb Calorimeter.



Bomb Calorimeter

It is based on the principle of calorimetry.

Heat loss = Heat gain.

A known amount of fuel is burnt in excess of oxygen and the liberated heat transferred to a known amount of water and then to ~~a~~ known. determine the calorific value.

* Construction –

It consists of following parts –

(i) Stainless steel container. – It is a strong cylindrical container made up of steel. capable to stand upto 50 atm pressure, having three holes, two for electrodes and one for oxygen supply. With one of the electrode a ring is attached to place the crucible. (having const weight).

(ii) Copper calorimeter – The stainless steel container is placed inside the copper calorimeter having known amount of water along with a thermometer and stirrer.

(iii) Insulation Jacket – Copper Calorimeter is surrounded by air jacket & water jacket for insulation.

(iv) Crucible – A crucible made of Ni or fused silica is used. for combustion purpose.

* Procedure –

- Let x gm of sample is taken in a constant crucible. And then placed it on the ring connected with one of the electrode. After filling desired oxygen, we place it screw tight lid. And then
- Placed it inside the copper calorimeter having Wg known amount of water along with apparatus equivalent to wg. Initial temperature (T_1) is noted down.
- Then electrodes are connected with any external source like battery to initiate the combustion process. Once the process get complete, noted the maximum temperature ($T_2°$) attained.

- And then GCV can be calculated as –, once the combustion products are allowed to cool down as following –

Weight of fuel sample = x g

Weight of known amt. of water = W g

Wt of water equivalent to apparatus = w g.

Initial temp = t_1°c

Final (Max) Temp attained = t_2°c.

L = calorific value (GCV)

S = Specific heat

Heat lost = x × L.

Heat gain = [heat absorbed by water + heat absorbed by water eq. to apparatus]

$= [W \times S \times \Delta t + w \times S \times \Delta t]$

(S = 1 for water)

Heat gain = $\Delta t\,(W + w)$

According to principle of calorimetry –

Heat gain = Heat lost

$xL = (W + w)\Delta t$

$$\boxed{L \text{ or } GCV = \frac{(W+w)\,\Delta t}{x}} \text{ cal/gm.}$$

$$NCV = GCV - \left(\frac{9}{100} \times \text{Wt of H} \times \text{Latent heat}\right)$$

Correction –

* L or G.C.V. = [(W+w).(Δt + Cooling correction)] − [Acid correction + Cotton thread correction + fuse wire correction] / x

$$L \text{ or } G.C.V. = \frac{[(W+w)(\Delta t + \text{Cooling correction})] - [\text{Acid correction} + \text{Cotton thread correction} + \text{fuse wire correction}]}{x}$$

* There are four types of correction –

- Cooling correction
- Acid correction
- Cotton thread correction.
- Fuse wire correction.

Only cooling correction will be added to Temp diff. (Δt) whereas other three will be substracted because remaining three correction leads to exothermic process.

* Dulong's Formula -

$$GCV = \frac{1}{100}\left[8060C + 34500\left(H - \frac{O}{8}\right) + 2240S\right] \text{ kcal/kg.}$$

Q. A sample of coal containing 89% of C, 8% H and 3% ash. when the coal was tested in the lab for its calorific value in the bomb calorimeter The following data were Obtained -

wt of coal burnt = 0.85g , latent heat.
wt of water taken = 650g
wt of water equivalent to bomb Calorimeter = 250g
$\Delta t = 2.5°C$

Calculate GCV, NCV.

Ans. $GCV = 650.8 \times 2.5$

$= \frac{3150 \times 2.5}{0.85}$ cal/gm

$= 9264.70$ cal/g

$NCV = 9264.70 - \frac{9}{100}(8 * 580)$

$= 8847.4$ cal/gm.

If it contains cooling correction = 0.03°C, acid c = 50 cal, F.W.C = 10 cal, C.T corr = 10 cal

∴ $GCV = (3150 \times (2.53)) - 50$

Q. With the help of a neat diagram explain the working of bomb calorimeter?

Q. A sample of coal contains 91% C, 5.5% H, N-2.5% ash contains 2%. The following data were obtained when the above coal was tested in bomb calorimeter. weight of coal burnt = 1.029g, Weight of water taken = 570g, Water equivalent = 2200g $\Delta t = 3.3°C$, fuse wire correction = 3.8 cal, acid correction 62.6 cal, cotton thread correction = 1.6 cal, cooling correction = 0.047 Assuming that latent heat for H = 587 cal/gm Calculate gross & NCV.

Ans -

$$G.CV = \frac{(\overset{570}{\cancel{1.029}} + \overset{2200}{\cancel{570}})(3.3 + 0.047) - (62.6 + 1.6 + 3.6)}{1.029}$$

$$= \frac{(2770)(3.347) - 68}{1.029}$$

$$= (9271.19 - 68) = \frac{9203.19}{1.029}$$

$$= 8943.61$$

$$NCV = 8943.81 - \frac{9}{100}(5.5) \times 587$$

$$= 8943.81 - 290.56$$

$$= 8653.25$$

Q. A 0.80g sample of solid fuel was completely combusted in excess of oxygen using bomb calorimeter. The rise in temp of water is (2.5°C). Calculate HCV & LCV. If water taken in calorimeter = 2500g & water eq = 2200g. The % of H = 2.2

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And latent heat = 587 cal/g.

An- $G.CV = \frac{(4200)\times 2.5 - 0)}{0.8}$

$= \frac{10500}{0.8} = 13125$

$L.CV = 13125 - \frac{9}{100}(2.2)\times 587$

$= 13125 - 0.09\times 2.2\times 587$

$= 13125 - 116.226$

$= 13008.774.$

Q. A sample of coal has following composition by mass – C−70%, O−8%, H = 10%, N−3%, S−2%, ash content 7%. Calculate HCV, LCV.

An- $H.CV = \frac{1}{100}(8080\times 70 + 34500(10-1) + 2240\times 2)$

$= \frac{1}{100}(565600 + 310500 + 4480)$

$= 8805.8$ kcal/g.

$NCV = 8805.8 - \frac{9}{100}(10)\times 587$

$= 8805.8 - 0.09\times 10\times 587$

$= 8805.8 - 528.3$

$= +8277.5$ kcal/g

$o - (100 -)$ $0 - 4.5^{05}\%$

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Imp Q. Write the relationship between high & low calorifi value if NCV of whole sample is 7500 cal/ carbon − 85%, S − 1%, N − 2%, ash − 4%. latent − 587 cal/g. Calculate G.CV & % of hydrogen.

Ans. ~~GCV~~

$NC.V = G\cancel{CV} - \frac{9}{100}\times(H)\times 58$

$GCV = \frac{1}{100}(8080\times 85 + 34500(H - 4$
$+ 2240\times 1)$

$GCV = NCV + \frac{9}{100}(wt\ of\ H)\times 587$

$\Rightarrow NCV + \frac{9}{100}(wt\ of\ H)\times 587 = \frac{1}{100}(8080\times 85 + 34500(H - 4.$
$+ \cancel{\times}2240)$

$\Rightarrow 7500 + 0.09\times H\times 587 = \frac{1}{100}(686800 + 34500(H - \frac{4.5}{8}) + 2240)$

$\Rightarrow 7500 + H\times 587\times 0.09 = 6868 + 345(H$
$+ 22.4$

$\Rightarrow 7500 - 6868 - 22.4 = 345H - 345.0.0$
$- H\times 587\times 0.0$

$\Rightarrow 7500 - 6890.4 = 345H - 345\times 0.5625$
$609.6 \quad - H\times 52.83$

$= \cancel{7500}\ \cancel{60.96}\ 609.6 = H(345 - 52.83) - 345\times 0.5625$

$\cancel{60.96}\ 609.6 = H\times 292.17 - \boxed{194.0625}$

$H\times 292.17 = 255.0225.$

Q. Rank of cal.

Q. Explain proximate analysis used for determination of quality of coal & And why it is named so.

$h = 255.0$

$h = 2.75$. $h = 2.483$.

$\% h = 2.75$, $GCV = \underline{7645.6}$

* Coal analysis –

- Rank of coal – It is a qualitative measure of carbon content in coal sample and defined as degree or extent of maturation. On this basis, coal can be divided into two category, hard coal or soft coal.

→ Biteminous & Anthracite considered as hard coal or high rank coal.

→ whereas Peat & Lignite considered as low coal or low rank coal.

Coal Analysis

Proximate analysis

(i) % of moisture content

(ii) % of volatile matter

(iii) % of Ash content.

(iv) % of Fixed carbon.

Ultimate Analysis.

% C, % H, % N, % S, % O, % Ash.

* Proximate analysis –

~~Exp~~ Proximate analysis is named so because the data collected vary with the process adopted. It is used to give ~~[illegible]~~ valuable information about the practical utility of coal sample – It includes the following –

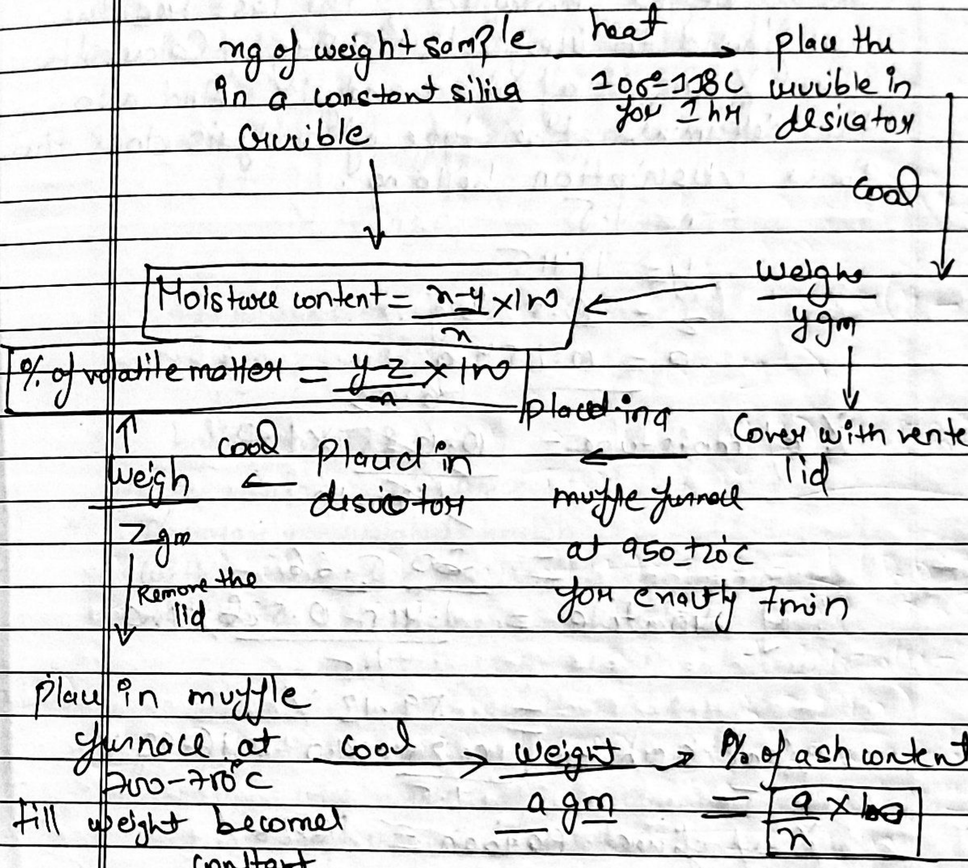
(i) % of moisture content

(ii) % of volatile matter

(iii) % of ash content

(iv) % of fixed carbon

* Flowchart for process –



% of fixed carbon = 100 – (% of moisture + % of volatile ma + % of ash cont

Q. A sample of coal was analysed as follow exactl 1.5 g of coal was weighed into a silica crucibl. After heating at 100°C for 1 hr, the residu weight 1.415 g, the crucible was then covered with vented lid and strongly heate for exactly 7 min at 950 ± 10°C. The residue weighed = 0.528 g

Q. Describe ultimate analysis used for coal sample analysis.
Q. Give the determination of Nitrogen N_2.
Q.

The crucible was then without lid until a constant weight obtained, the last residue was found to weighed 0.254g. Calculate the % result of above analysis. And also the determine the type of analysis does the above description belong.

$x = 1.5$
$y = 1.415$
$z = 0.528g$.
$a = 0.254g$
~~6.08~~

% of moisture $= \dfrac{0.0\cancel{8}5 \times 100}{\cancel{1.50}.10}$

$= \cancel{80}\ 5.66$

% of volatile $= \dfrac{1.415 - 0.528 \times 100}{1.5}$

$= 59.13\%$

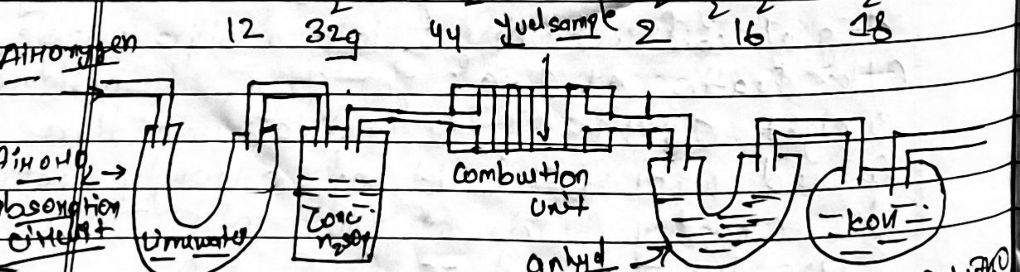
% of ash $= \dfrac{0.254 \times 100}{1.5} = 16.93\%$

% of fixed carbon $= 18.28\%$

* Ultimate analysis –
Here elemental analysis is to be done. Hence, a standard method is used for fixed result –

(i) Determination of C & H –

$C + O_2 \rightarrow CO_2$ $\quad H_2 + \frac{1}{2}O_2 \rightarrow H_2O$
$12 \quad 32g \quad 44$ $\quad 2 \quad 16 \quad 18$



Q. How will you determine sulphur in a given coal sample?
Q. Give the determination of carbon & hydrogen for the given coal sample.

% of C $= \dfrac{\text{Increase in wt of KOH} \times 12 \times 100}{\text{wt of coal sample} \times 44}$

% of H $= \dfrac{\text{Increase in wt of } CaCl_2 \times 2 \times 100}{\text{wt of coal} \times 18}$

Imp * Determination of Nitrogen – by Kjeldahl's method

$$N_2 + H_2SO_4 \longrightarrow \underset{\text{Clear soln}}{(NH_4)_2SO_4}$$

$$\downarrow 2NaOH$$

$$(NH_4)_2SO_4 \xleftarrow[V_1 mL]{\text{Standard } H_2SO_4} 2NH_3\uparrow + Na_2SO_4 + 2H_2O$$

$\downarrow$
base V_2 mL

$V_1 - V_2 \rightarrow$ acid $\overset{\text{absorbed}}{\text{used}}$ by NH_3.

* Accurately weighed known amount of sample heated with concentrated H_2SO_4 along with $CuSO_4$, K_2SO_4 till the soln becomes transparent.

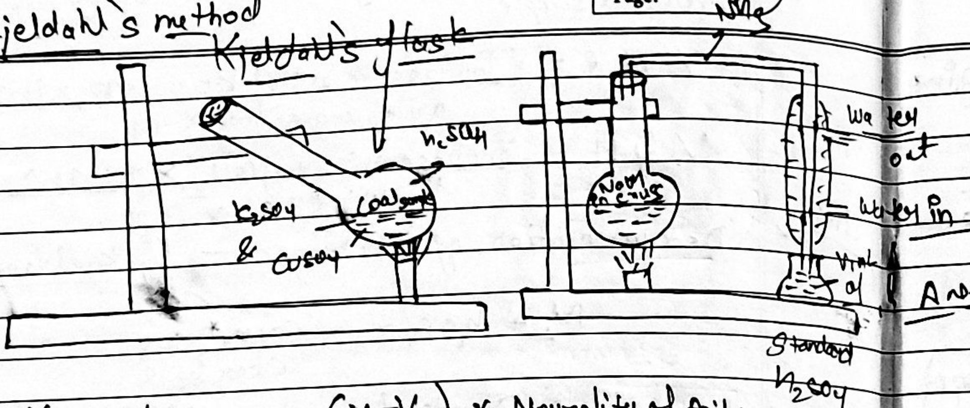
$$N_2 + H_2SO_4 \rightarrow \underset{\text{Clear soln}}{(NH_4)_2SO_4}.$$

- After that the resultant ammonium sulphate is treated with excess of NaOH to liberate ammonia
  $(NH_4)_2SO_4 \xrightarrow{2NaOH} 2NH_3\uparrow + Na_2SO_4 + 2H_2O$.

- The released ammonia is now absorbed in a known amount of standard H_2SO_4 (suppose V_1 mL) then,
  $2NH_3 \xrightarrow{\text{standard } H_2SO_4 (V_1)} (NH_4)_2SO_4$

- The unused acid can be determined by titrating with the standard base like NaOH. And then % of nitrogen can be determined.

Kjeldahl's method



$$\% \text{ of Nitrogen} = \frac{(V_1-V_2)\times \text{Normality of Acid}\times 14\times 100}{\text{wt of coal sample}\times 1000}$$

$$\% \text{ of } N = \frac{(V_1-V_2)\times N\times 1.4}{\text{wt of coal sample}}.$$

Imp

* **Determination of % of sulphur –**

Sulphur can be determined by bomb calorimeter method. The residue left in the crucible is treated with dilute HCl. And then barium ~~chlo~~ chloride solⁿ is added, which result in the formation of white ppt. of $BaSO_4$. The ppt was filtered, washed & dried till weight become constant. And then % of sulphur can be determined.

$$\underset{32}{S}\xrightarrow{O_2} SO_4 \xrightarrow{BaCl_2 \text{ sol}^n} \underset{\text{white ppt}\;233}{BaSO_4}$$

$$\% \text{ of } S = \frac{\text{wt of } BaSO_4 \times 32\times 100}{\text{wt of coal sample}\times 233}$$

* **Determination of % of ash content –**

Similar to proximate analysis.

* **Determination of % of oxygen content –**

$$100 - \% \text{ of } O = 100 - \% \text{ of } (C+H+N+S+Ash)$$

Q. 2.15 g of coal sample was analysed for ~~de~~ % of determination of % of C & H. If the inc. in $CaCl_2$ = 0.45g, and for KOH, the inc. in = 1.75g.

Ans

$$\% \text{ of } H = \frac{0.45\times \cancel{2}\times 100}{2.15\times \cancel{18}\,9} = \frac{0.45\times 100}{2.15\times 9}$$

$$= 2.32 \text{ g}$$

$$\% \text{ of } C = \frac{1.75\times 12\times 100}{2.15\times 44} = \frac{2100}{94.6} = 22.198 = 22.198 \text{ g}$$

Q. 3.12g of coal sample through Kjeldahl's method and NH_3 gas ~~thus~~ evolved absorbed in 50mL of 0.1N H_2SO_4 after absorption, the excess acid required 12.5mL of 0.1N NaOH.

$$wt = 3.12g, \quad V_1 = 50mL, \quad V_2 = 12.5$$
$$N = 0.1N.$$

$$\% \text{ of } N = \frac{(50-12.5)\times 1.4}{3.12} = \frac{37.5\times 1.4\times 0.1}{3.12}$$

$$= \frac{52.5\times 0.1}{3.12} = 1.68\%$$

Q. 1.85 g of coal sample was analysed for Kjeldahl's method and ammonia thus evolved absorbed in 50mL of 0.1 N H_2SO_4, after absorption, the residual required 8.2mL of 0.1NaOH. for exact neutralisation.

Ans

$$50.0 - 8.2 = 41.8$$

$$\% \text{ of } N = \frac{\cancel{37.5}\times 0.1\times 1.4}{3.12} = \frac{41.8\times 0.1\times 14}{3.12}$$

$$= 8.194\ \%$$

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Q. 2.60 g of coal sample in Quantative analysis give 0.1755 g of $BaSO_4$. Determine % of S.

Ans = $= \frac{0.1755 \times 32 \times 100}{2.6 \times 233} = \frac{561.6}{605.8}$

$= 0.927\ \%$

* Combustion –
Combustion is an enothermic process. Burning of fuel in presence of Oxygen called Combustion.

* Calcubtions of air Quantity –

Ex – $C + O_2 \to CO_2$ $\quad$ 1 mol = 32g = 22.4L for O_2
12g $\quad$ 32g $\quad$ 44g
1mol $\quad$ 1mol $\quad$ 1mol

- 1. Substances always combine in definite proportion
- 2. 22.4L of any gas at STP has a mass equal to 1 mol = mol. mass.

3. Nitrogen, N_2, CO_2, H_2O and ash content are non-Combustible. hence does not contribute in Combustion.

4. The mol. mass of air = 28.94 g/mol

5. Available hydrogen can be calculated as –

$$\text{Available } H = \left(\text{Mass of } H - \frac{\text{Mass of } O}{8}\right)$$

$$= \left(H - \frac{O}{8}\right) \quad \text{For } (H_2O)$$

6. The mass of any gas can be converted to volume at certain temp & pressure. by using ideal gas eq –
$PV = nRT$

Imp 7. The minimum Oxygen required for combustion = Theoretical oxygen – Oxygen present in fuel.

8. In air, oxygen is present in different proportion by weight & volume.

9. $1 m^3 = 1000L$ $\qquad$ $1L = \frac{28.94}{22.4}$

→ Convert × 100
Denominator for original
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By volume – 21%
By weight = 23%

∴ For air needed by weight $= \frac{100}{23} \times$ Net oxygen

For air needed by volume $= \frac{100}{21} \times$ Net oxygen Req. Oxygen

Q. →

S.no.	Compont	Amt.	Equation	in terms of W	in terms of V.
1	C	x	$\underset{12}{C} + \underset{32}{O_2} \to \underset{44}{CO_2}$	$x \times \frac{32}{12}$	$x \times 1$
2.	H	y	$H_2 + \frac{1}{2}O_2 \to H_2O$	$y \times \frac{16}{2}$	$y \times 0.5$
3.	S	z	$\underset{32}{S} + \underset{32}{O_2} \to SO_2$	$z \times \frac{32}{32}$	$z \times 1$
4.	CO	a	$\underset{28}{CO} + \underset{16}{\frac{1}{2}O_2} \to CO_2$	$a \times \frac{16}{28}$	$a \times 0.5$
5.	CH_4	b	$\underset{16}{CH_4} + \underset{2\times32}{2O_2} \to CO_2 + 2H_2O$	$b \times \frac{2\times32}{16}$	$b \times 2$
6	C_2H_6	c	$\underset{24+6=30}{C_2H_6} + \underset{\frac{7}{2}\times 32}{\frac{7}{2}O_2} \to 2CO_2 + 3H_2O$	$c \times \frac{16\times7}{30}$	$c \times \frac{7}{2}$

Imp Q. Calculate the weight & volume of air required for combustion – 1 kg of Carbon. Express your (result in terms of weight & volume both.)

Ans

$C + O_2 \to CO_2$
1 kg 12 $\quad$ 32

Amount of Oxygen $= \frac{1 \times 32}{12} = 2.67$ kg.

Net oxygen = 2.67 kg.

Air needed by weight $= \frac{100}{23} \times 2.67$
$= 11.61$ kg.

100 [illegible]

Amt of air at STP, 32g of O_2 = 22.4 L

$2.67 \times 1000g$ of O_2 = $2670 \times \frac{22.4}{32}$

Oxygen in L = 1869 L.

Volume of air needed = $\frac{100}{21} \times 1869$

= 8900 L

= 8.9 m³

Q. Calculate the amt of air needed for combustion of 1 m³ methane

Q. Calculate the mass of air needed for combustion 5 kg of coal containing 80% C, 15% H and rest Oxygen. (5%)

S.No.	Element	Amt	Eq →	Amt of Oxygen
1.	C	$\frac{80}{100} \times 5 = 4$ kg	$C + O_2 \to CO_2$ 12 32 44	$4 \times \frac{32}{12} = 10.67$ kg
2.	H	0.75 kg	$H_2 + \frac{1}{2}O_2 \to H_2O$	$0.75 \times \frac{16}{2} = 6$
3	O	0.25 kg		

Net oxygen = Theoretical − given

= 16.67 − 0.25

= 16.42 kg.

⇒ Weight of air = $\frac{100}{23} \times 16.42$

= 71.39 kg

32g → 22.4 L at STP.

Volume of air, $16.42 \times 1000g$ — $\frac{22.4}{32}$

= $\frac{22.4 \times 16420}{32}$

Net oxygen = 11.494 m³.

Volume of air = $\frac{100}{21} \times 11.494$

= 54.734 m³

Q. Calculate the minimum amt of air required for complete combustion of 100 kg of fuel containing 80% C, 6% H_2, 5% O_2, 2% Sulphur and rest N_2 by weight.

Soln.			
1.	C	$\frac{80}{100} \times 100 = 80$ kg	$80 \times \frac{32}{12} = 213.33$
2.	H_2	6	$6 \times \frac{16}{2} = 48$
3.	S	2	$2 \times 1 = 2$

Net oxygen = 213.33 + 50 − 5

= 263.33 − 5 = 258.33 kg

Weight of air = $\frac{100}{23} \times 258.33$

= 1123.1739 kg

⇒ 32g = 22.4 L

258.32 = $\frac{22.4 \times 258.32}{32}$

= 180.824 m³

⇒ Volume by air = $\frac{100}{21} \times 180.82$

= 861.~~05~~ m³.

861.1 m³

Q. Calculate volume of air required for complete combustion of 1 m³ gaseous fuel — CO = 48%, CH_4 = 8%, H_2 = 40%, Acetylene = 2%, N_2 = 1% and remaining ash content.

Imp →

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S.No.

1. CO 0.48 m³ $CO + \frac{1}{2}O_2 \rightarrow CO_2$ = 0.24 m³

2. CH_4 0.08 $\rightarrow CO_2 + H_2O$ 0.08×2 = 0.16

3. H_2 ~~0.04~~ 0.4 0.2

4. N —— × ——

5. C_2H_2 0.02 $C_2H_2 + \frac{5}{2}O_2 \rightarrow 2CO_2 + H_2O$, 2.5×0.02 ~~0.25×0.01~~ = ~~0.0025~~ 0.05

Net oxygen = 0.24 + ~~0.28~~ + 0.~~02~~ + ~~0.0025~~ 0.05

= 0.24 + 0.16 + 0.2 + 0.05

= 0.65 m³

Volume of air needed = $0.65 \times \frac{100}{21}$

= 3.095 m³

1 L of Air = $\frac{28.94}{22.4}$ g

3095 L = $\frac{28.94}{22.4} \times 3095$ = 3998.64

Q. The composition by 1 m³ of fuel is —

H — 2.4%
CO — 6%
CO_2 — 8%
CH_4 — 30%
C_2H_6 — 11%

C_4H_8 — 25%
O — 2%
N — 12%

Q. What is the composition of biogas?

*Q. What is biogas. Describe the working and production of biogas along with advantages & disadvantages.

* Biogas —

Biogas is produced by the degradation of biological meta[l] by the bacterial action in absence of oxygen. It is cheapest and most easily available, produced by the anaerobic fermentation of animal waste and agricultural waste. Its main component is methane

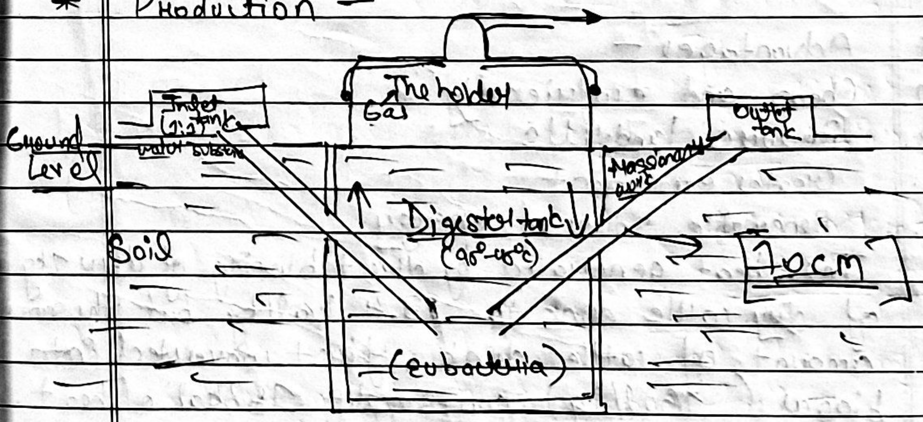
→ The average calorific value is about 5350 kcal/m³.

* Composition of Biogas —

- Methane
- Hydrogen (H_2)
- Carbondioxide (CO_2)
- Nitrogen (N_2).

Methane — 55%, H_2 (7.4%), CO_2 (35%), N_2 (2.

* Production —



Biogas ~~Material~~ Plant

→ Biogas is also known as gobar gas. It is environmental impact of biogas plant ?

manufactured in biogas plant. The essentials of biogas plants are -

(i) A digester tank
(ii) Gas holder
(iii) Pipeline

* Digester tank - is a type of well constructed of masonary work. It is built below ground level. There are two tanks - inlet tank and outlet tank. Raw material is provided in 1:1 ratio with water to the inlet tank. And then through pipeline it enters to digester tank having anaerobic bacte. The optimum temperature for fermentation is 35-45°. Once the fermentation process get complete - The gas collected in the gas holder and the residual material is removed from outlet tank in the form of slurry. In addition to, animal waste, It can also digest agricultural, poultry wastes

* Advantages -

1. Cheap and ecofriendly
2. Reduces landfills
3. Creates employment
4. Renewable source of energy

Imp 5. The heat generated by direct burning of dry 1kg of dry cattle dunk is 23.4 kcal/kg but the same amount of cattle dunk, first converted into biogas (160l/kg) can supply 1684kal of heat.

6. By producing biogas we are optimally utilising waste.

7. The resultant slurry of the biogas plant is also used as a manure having approx. nitrogen content.

*8. ~~Dis~~ It is used as a source of power and lightening in villages.

* Disadvantages / Limitations -

1. Insufficient on a larger scale.
2. Contains impurity.
3. Unstable and hazardous. - Its main composition is methane. When methane comes in contact with oxygen, it reacts violently, to create CO_2 which is highly inflamable and can lead to explosion.