

UNIT – 1 WATER TECHNOLOGY - NOTES FOR REVISION STUDIES

Topic – 1 **Boiler feed water****1. Definition:**

The setup used to produce steam in industries is known as 'Boiler'. Water is fed to the boiler and heated to produce steam. The water fed into the boiler is known as "Boiler feed water".

2. Requirements for boiler water

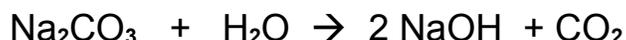
S.No	Requirements for boiler water	If not, it will cause
1	Free from hardness causing salts	Sludge and scale
2	Free from oil and greases	Foaming
3	Free from dissolved salts, suspended impurities	Caustic embrittlement
4	Free from dissolved gases, suspended salts	Boiler corrosion

3. Boiler troubles:

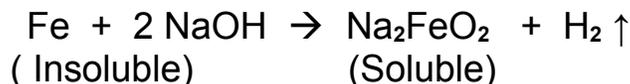
Sludge, scale, priming and foaming, caustic embrittlement, boiler corrosion are collectively known as boiler troubles.

A. Caustic Embrittlement: (Inter crystalline cracking of boiler metal)

It is the intercrystalline cracking of boiler due to Na_2CO_3 . In high pressure, Na_2CO_3 undergoes hydrolysis to produce NaOH. This makes water caustic. The NaOH containing water flows into the minute hair-cracks.



This NaOH occupies the hair line cracks of boiler metal and converts the insoluble Fe into soluble Sodium Ferrous. Thus it makes the cracks bigger in bends, joints and crevices.



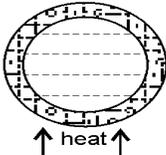
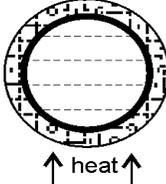
Prevention of caustic embrittlement:

1. As softening agent, we can use sodium phosphate instead of sodium carbonate.
2. The hair line cracks can be sealed by waxy materials like Tannin and Lignin.

B. Sludge and scale:

If the water contains hardness causing salts like $MgSO_4$, $MgCl_2$, $CaSO_4$, $Ca(HCO_3)_2$ on evaporation, the salts are precipitated to produce *scale and sludge*.

Differences between sludge and scale:

No	Sludge	Scale
1	Loose, slim, non-adherent precipitate	Hard, thick, strong adherent precipitate
2	Due to salts like $MgSO_4$, $MgCl_2$	Due to salts like $CaSO_4$, $Ca(HCO_3)_2$
3	Due to poor conductance, they decrease the boiler efficiency to lesser extent and causing chocking in the pipelines.	Due to poor conductance, they decrease the boiler efficiency to maximum extent, cause reduced fuel economy, improper boiling, boiler explosion etc.,
4	It can be prevented by periodical replacement of concentrated hard water by fresh water. This process is known as "blow down" method.	It can be prevented by special methods like i) external treatment of ion exchange, ii) Internal carbonate, phosphate, Calgon conditioning iii) Mechanical hard scrubbing methods.
5	<p>Diagram: Loose Precipitate Suspended in water (sludge)</p> 	<p>Adherent coating inside the boiler (scale)</p> 

C. Priming and Foaming:

1) Due to rapid boiling, the steam may carry some water droplets along with it. This is called *wet steam*. The process of wet steam production is called *Priming*. It can reduce the heat of the steam and cause corrosion in the pipelines.

Priming is due to:

- a) Improper design of boiler
- b) High water level
- c) High velocity of steam
- d) Uneven boiling

Priming can be controlled by

- i) Proper boiler design
- ii) Maintaining proper water level
- iii) Proper boiling

2) If oils and greases are present, they produce stable bubbles on the water surface. This will increase the wet steam production. This is known as "*Foaming*".

Foaming is prevented by adding

- i) Anti foaming agents (e.g.) synthetic poly amides, castor oil
- ii) Coagulants (e.g.) Aluminium hydroxide

3) Foaming and priming are collectively known as '*Carry over*'.

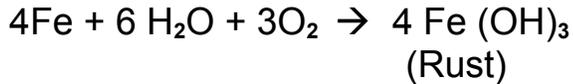
A) Boiler Corrosion

It may be due to three major reasons:

- i) Dissolved Oxygen
- ii) Dissolved CO₂
- iii) Dissolved salts like MgCl₂

Corrosion Due to dissolved oxygen:

Dissolved oxygen in presence of water, causes corrosion.

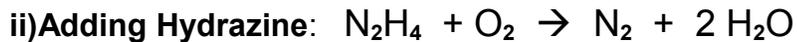


Prevention from oxygen:

a) Chemical method -



This method results in other precipitates which can have some side effects. So this method is less preferred.



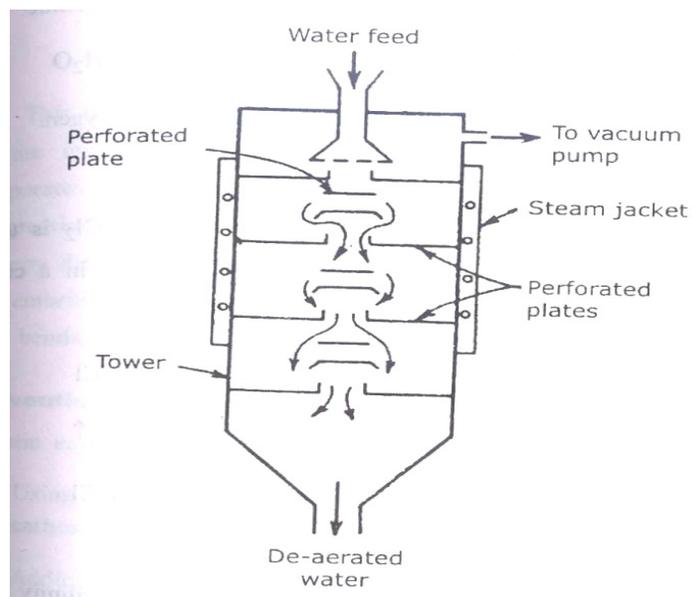
This method results in inert gas and pure water, and has no side effects. So it is preferred.

b) Mechanical deaeration method:

1. This is based on the principle that at high temperature, low pressure and high exposed area, the solubility of gases in water is decreased. So, the gases can be expelled easily.

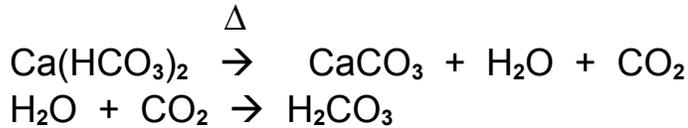
2. Here, the water is fed into the mechanical deaerator which is provided with vacuum pump, heaters and perforated plates.

3. The out coming water will be free from dissolved gases.



Corrosion due to CO₂

Salts like Calcium bicarbonate on heating produces CO₂. CO₂ dissolves in water to form carbonic acid which corrodes the boiler metal.



Prevention from CO₂

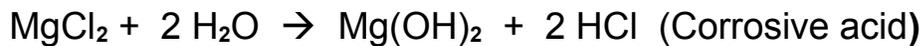
1. Chemical method: By adding calculated amount of ammonium hydroxide



2. Mechanical deaeration method (similar to oxygen method)

Corrosion due to Dissolved salts like MgCl₂

Dissolved salts like MgCl₂ cause acid formation. This will be prevented by alkali neutralisation.



Neutralisation:

Excess acidic nature is neutralized by adding alkalis and vice versa.



TOPIC -2 - TREATMENT METHODS

EXTERNAL TREATMENT METHODS:

A. Ion exchange method (Demineralisation)

Working:

1. Here all the cations and anions are completely removed. It uses two column of cation exchange column and anion exchange column filled with resins.
2. Resins are long chain, insoluble, cross linked, organic polymers. There are 2 types.
 - i) Cation exchange resins – RH⁺ (e.g) Sulphonated coals, RSO₃H
 - ii) Anion exchange resins. R'OH⁻ (e.g) Ureaformaldehyde, Amines R-NH₂
3. The water is fed into cylinder –I where all the cations are replaced by RH₂ Resins.

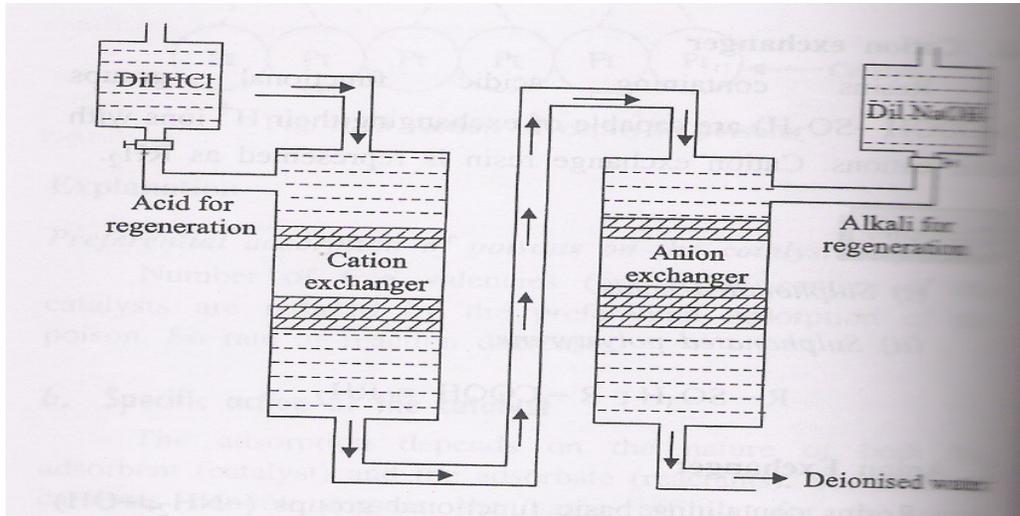


4. The cation free water is fed to cylinder II, where all the anions are replaced.



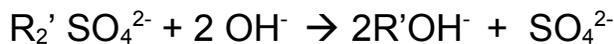
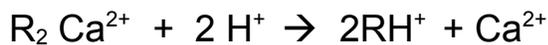
5. So, the resultant water is free from all types of ions.

Diagram:



Regeneration:

On prolonged use, as all the resins are exhausted, there will be no H^+ or OH^- ions to exchange the unwanted ions. So, they have to be regenerated. Cation resins are regenerated by HCl and anion resins by NaOH.



Advantages of Ion exchange method:

- i) Can be used for high pressure boilers also.
- ii) It can treat highly acidic or alkaline water.
- iii) We can get pure water as hardness as low of 2 ppm.

Drawbacks of Ion exchange method:

- i) Expensive
- ii) Fe, Mn cannot be removed as they form complexes with resins
- iii) Cannot be used for turbid water as they clog the resins.

Note -

Differences between soft water and dematerialized water.

S. No	Soft water	Dematerialized water
1	It does not contain hardness producing calcium and magnesium ions, but it may contain other ions like K^+ , Na^+ , Cl^- etc.	Dematerialized water does not contain any ions including hardness producing ions.
2	Softening involves removal of only hardness causing ions.	Demineralization involves removal of all the ions present in water.

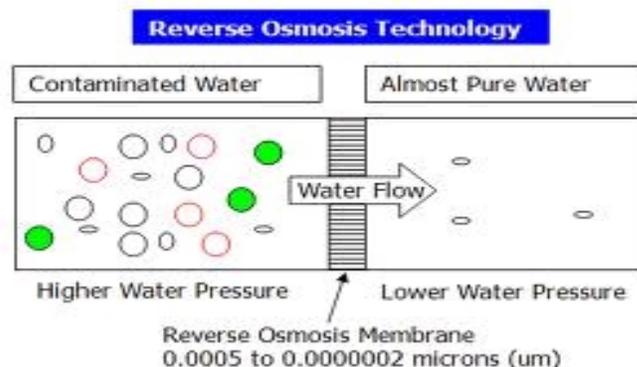
B. Reverse Osmosis Method: (Desalination): Hyperfiltration/ Super filtration/ brakish water treatment

1. Removal of common salt (NaCl) from water is called 'Desalination'.
2. Various methods:
Reverse Osmosis, Distillation, Electro dialysis, Freezing, Solar distillation, etc.,
3. Brakish water: Water containing dissolved salts with a peculiar salty taste.
4. **Osmosis:** When two different concentrated solutions are separated by a semi permeable membrane, due to osmotic pressure, low concentrated solvent flows to higher one. This is known as osmosis.
5. But when we apply an excess and opposite *Hydrostatic pressure*(15-40kg/cm²) to overcome the osmotic pressure, then higher concentrated solvent will flow to the lower one. This is known as reverse osmosis.
6. During this RO process , only the water flows across the membrane and it prevents the salt migration. So, this method is also called as ' Super filtration'.
7. The membrane is madeup of cellulose acetate,cellulose butyrate,polymethacrylate

Advantages of Reverse Osmosis:

- 1.High life time
- 2.Removes ionic, non-ionic and colloidal silica impurities , which can not be removed by demineralization method.
3. Low capital cost.
4. Simple operational procedure.
5. The membrane can be replaced within a few minutes, thereby providing uninterrupted water supply.

Diagram:



TOPIC -3 INTERNAL TREATMENT METHODS

INTERNAL TREATMENT BY BOILER COMPOUNDS:

The residual salts that are not removed by external methods can be removed by adding some chemicals directly into the boiler water. These chemicals are known as '*Boiler compounds*'. This method is known as 'Internal treatment'.

E.g) Carbonate conditioning, Phosphate conditioning , Calgon conditioning, etc.,

a) Carbonate conditioning:

Used for low pressure boilers. Here the salts like CaSO_4 are converted to easily removable CaCO_3 . But some times it produces NaOH , CO_2 and hence Carbonic acid. So it is less preferred.



b) Phosphate conditioning:

Used for high pressure boiler. No risk of CO_2 liberation.



Three types of Phosphate salts are used:

S.No	Salt	Name	Used for treating
1	Na_3PO_4	Tri sodium Phosphate	highly acidic water
2	Na_2HPO_4	Di sodium hydrogen Phosphate	slightly acidic water
3	NaH_2PO_4	Sodium di hydrogen phosphate	highly alkaline water

c) Calgon conditioning:

Calgon is the trade name of sodium hexa meta phosphate- $\text{Na}_2[\text{Na}_4(\text{PO}_3)_6]$. With calcium ions it forms a soluble complex and prevents scale and sludge formation. It is used for high and low pressure boilers.



TOPIC -4 DOMESTIC DRINKING WATER TREATMENT

Requirements of drinking (potable) water:

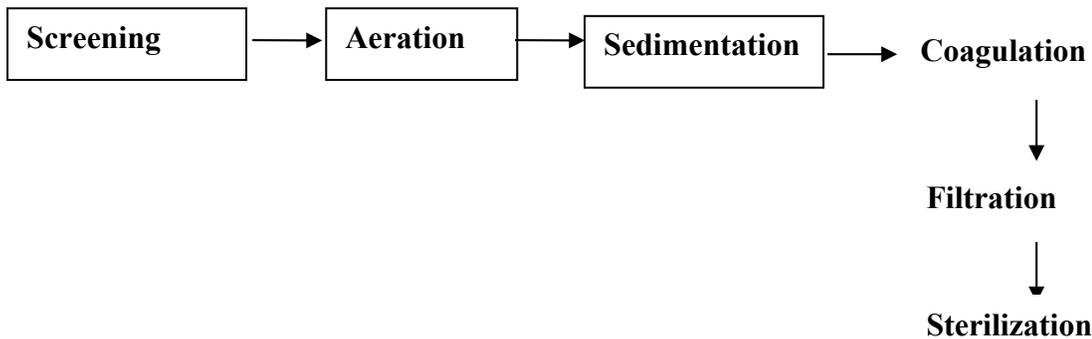
- i. Free from colour, odour, bacteria, dissolved gases
- ii. Should have pleasant taste
- iii. Dissolved oxygen should be below 10 ppm
- iv. Chloride content should be below 250 ppm.
- v. Flouride content should be below 1.5 ppm.
- vi. Hardness salt content should be below 500 ppm.
- vii. P^{H} should be in the range of 6.5 – 8.0

To get these properties, the water is treated properly.

Water treatment process:

Treatment	Done by	Purpose
Screening	Screening shutters with variable sized holes	Removes floating material like wood, plastic, papers
Aeration	Mechanical aerator	Removes Oxygen, Carbon-dioxide , toxic gases, Fe, Mn salts
Sedimentation	Allowing the water to stand for 2 – 6 hrs in a tank	Removes 75% of suspended impurities
Coagulation	Adding alum, $Al_2(SO_4)_3 \rightarrow Al(OH)_3$	Removes 100% suspended and colloidal impurities, clay, silica
Filtration	Filter bed	Removes bacteria, colour, odour, small dust particles
Sterilization/Disinfection	Boiling, ozone, chlorine, UV radiation	Destroys bacteria

Flow diagram:

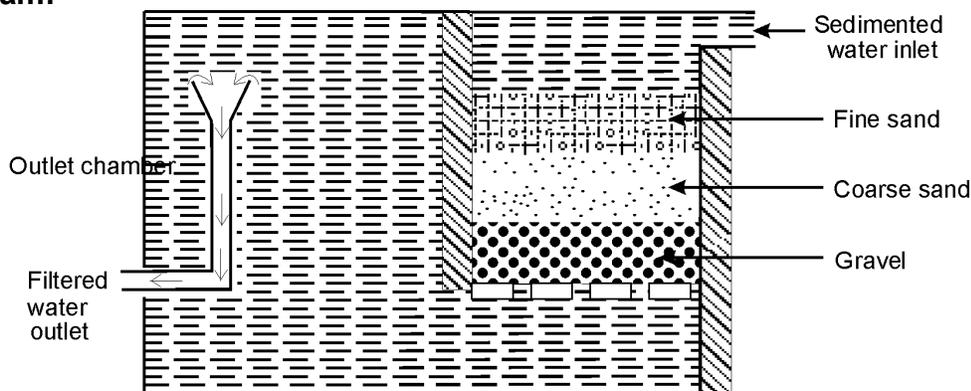


Out of the above said methods, filtration and sterilization play a vital role in domestic water treatment.

Filtration:

Filter bed consists of four layers i.e., Fine sand, coarse sand, fine gravel and coarse gravel. When water is passed through this, all the colour, odour, part of bacteria are removed. The bed needs periodic regeneration.

Diagram:



Sterilisation:

Removal of bacteria is sterilization or disinfection. There are four important sterilization methods.

1. Boiling
2. Using ozone
3. UV treatment
4. Chlorination
 - a. Passing Chlorine gas or solution
 - b. Adding chloramines salt
 - c. Adding bleaching powder

1. By boiling for 10 – 15 minutes, water can be sterilized . But it affects the taste and can not be used for higher volume water.

2. By using Ozone,(with the usual dosage of 2-3ppm for 10 – 15 minutes in disinfection tank) we produce nascent oxygen which is powerful disinfectant. Its excess is not harmful, since it is unstable and decomposes into oxygen. But, it is costly. It cannot be used and stored for long time as it is unstable.

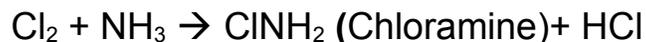
$O_3 \rightarrow O_2 + [O]$, this nascent oxygen kills bacteria.

3. By passing UV radiations from mercury vapour lamp, the swimming pool water can be sterilized. But it is costly and turbid water cannot be treated.

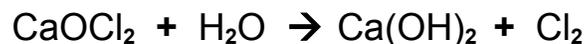
4. By chlorination:

a) Chlorine gas or solution bubbling will kill bacteria.

b) Adding chlorine and ammonia (2:1) will form chloramine. It decomposes slowly to release chlorine which kills bacteria. Its excess does not produce any irritating odour. It imparts a good taste to treated water.



c) Bleaching powder ($CaOCl_2$) reacts with water and forms hypochlorous acid which kills bacteria. Generally, 1kg powder is used for 1000 kilolitres of water.



It should be noted that chlorine should be always added a little higher than the *break point chlorination* for perfect disinfection.

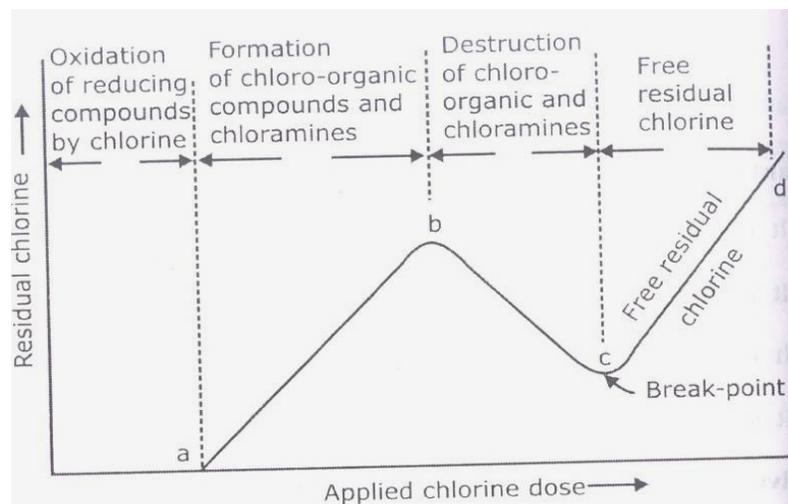
Breakpoint chlorination:

The point at which the added chlorine completely removes bacteria, NH_3 , Organic and inorganic impurities is known as “Breakpoint chlorination”.

The water contains: a)Bacteria b)Ammonia c)Organic impurity (sewage)
d)Inorganic salt impurities (Effluents, H_2S , Fe salts)

1. When we add chlorine, first it kills bacteria and oxidizes some inorganic impurities.
2. The added chlorine is completely consumed. (a).
3. Further addition of chlorine is used to combine with ammonia to form chloramines compounds. So, the residual chlorine content is increased upto (b).
- 4.As saturation level is attained, the chloramines begin to decompose to release chlorine which is utilized to remove all the types organic and inorganic impurities. So, residual chlorine level decreases. (c).
- 5.At point (c), the added chlorine removes all the types of impurities. So, the point is known as “ Break point chlorination”.
6. After this point, further addition of chlorine is not at all utilized and simply increases the residual chlorine content.(along cd)

Diagram for break point chlorination:



Advantages of break point chlorination: (Significance)

- i)It is used to remove Bacteria , Ammonia ,Organic impurity (sewage) ,Inorganic salt impurities (Effluents, H_2S , Fe salts) from water.
- ii)It prevents the growth of any weeds in water.

5. Calculation:

Step1 – Standardisation of EDTA

1 ml of Std. Hard water = 1 mg of CaCO₃ (Given)

So, 20 ml of Std. Hard water = 20 mg of CaCO₃

V₁ ml of EDTA is required for = 20 mg of CaCO₃

Therefore, 1ml of EDTA = 20 / V₁ mg of CaCO₃

Step 2: Finding Total hardness:

20ml of sample water required = V₂ ml of EDTA

$$= V_2 \times \frac{20}{V_1} \text{ mg of CaCO}_3$$

Therefore, 1000ml of sample requires = $V_2 \times \frac{20}{V_1} \times \frac{1000}{20}$ mg of CaCO₃

Hence, total hardness	=	$\frac{V_2 \times 1000}{V_1} \text{ ppm}$
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Step 3: Finding Permanent hardness:

20ml of boiled water required = V₃ ml of EDTA

$$= V_3 \times \frac{20}{V_1} \text{ mg of CaCO}_3$$

Therefore, 1000ml of boiled sample requires = $V_3 \times \frac{20}{V_1} \times \frac{1000}{20}$ mg of CaCO₃

Hence, permanent hardness	=	$\frac{V_3 \times 1000}{V_1} \text{ ppm}$
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Step 4: Temporary hardness = Total hardness – permanent hardness

TOPIC -6 ALKALINITY

Definition:

The acid neutralizing capacity is known as alkalinity. It is due to OH^- , CO_3^{2-} , HCO_3^- .

1.Aim:

To determine the type and amount of alkalinity of the water sample

2.Chemicals required:

NaOH, HCl , Sample water, Phenolphthalein, Methyl orange

3.Principle:

There are five types of alkalinity.

i) OH^- only ii) CO_3^{2-} only iii) HCO_3^- .only iv) OH^- and CO_3^{2-} v) CO_3^{2-} and HCO_3^- .

The other combinations are not possible. Because,



The possible reactions are

- $\text{OH}^- + \text{H}^+ \rightarrow \text{H}_2\text{O}$
- $\text{CO}_3^{2-} + \text{H}^+ \rightarrow \text{HCO}_3^-$ (Half neutralization of carbonate)
- $\text{HCO}_3^- + \text{H}^+ \rightarrow \text{H}_2\text{O} + \text{CO}_2$

Phenolphthalein can be used as indicator for 1 & 2. But not for 3.

Methyl orange is used for all 1 , 2 & 3 reactions.

4. Formula table

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

a) When $P=0$, both OH^- and CO_3^{2-} are absent and the alkalinity due to HCO_3^- only.

b) When $P=M$, both CO_3^{2-} and HCO_3^- are absent and the alkalinity due to OH^- only.

c) When $P = \frac{1}{2} M$, both HCO_3^- and OH^- are absent and the alkalinity due to CO_3^{2-} only.

d) $P > \frac{1}{2} M$, shows the presence of OH^- and CO_3^{2-} .

e) $P < \frac{1}{2} M$, shows the presence of CO_3^{2-} and HCO_3^- .

5. Short Procedure

S.No	Content	Titration-I Standardisation of HCl	Titration-II Alkalinity estimation
1	Burette	HCl acid	Standard HCl
2	Pipette(20 ml)	Standard NaOH	Water sample
3	Indicator	Phenolphthalein	i)Phenolphthalein ii) Methyl orange
4	Endpoint	Disappearance of pink colour	i)Disappearance of pink colour ii) Appearance of pink colour
5.	Formula	$V_1N_1=V_2N_2$	-

6. Calculation:

Volume of HCl consumed using “P” indicator = V_1 ml

Volume of HCl consumed using “M” indicator = $(V_1 + V_2)$ ml

$$\text{“P” alkalinity in terms of CaCO}_3 \text{ eqvt.} = \frac{V_1 \times \text{Normality of HCl} \times 50 \times 1000}{\text{Volume of sample taken}}$$

$$\text{“M” alkalinity in terms of CaCO}_3 \text{ eqvt.} = \frac{(V_1 + V_2) \times \text{Normality of HCl} \times 50 \times 1000}{\text{Volume of sample taken}}$$

(Multiplying by 1000 for converting ppm, 50 is equivalent wt of CaCO₃)