Unit-4

Ion Exchange Process

Prof. S. K. Hasan

Institute of Technology & Management, GIDA, Gorakhpur

Ion Exchange Process

In this process cations and anions present in water are replaced with H^+ and OH^- ions respectively through the ion exchange resins.

The ion exchange resins are insoluble in water, cross linked, long chain organic polymers with a micro porous structure and the functional groups attached to the chains are responsible for ion exchanging properties.

Types of Ion Exchange Resins (Ion Echangers)

The ion exchange resins are of two types:

1) Cation Exchange Resins (RH^+)

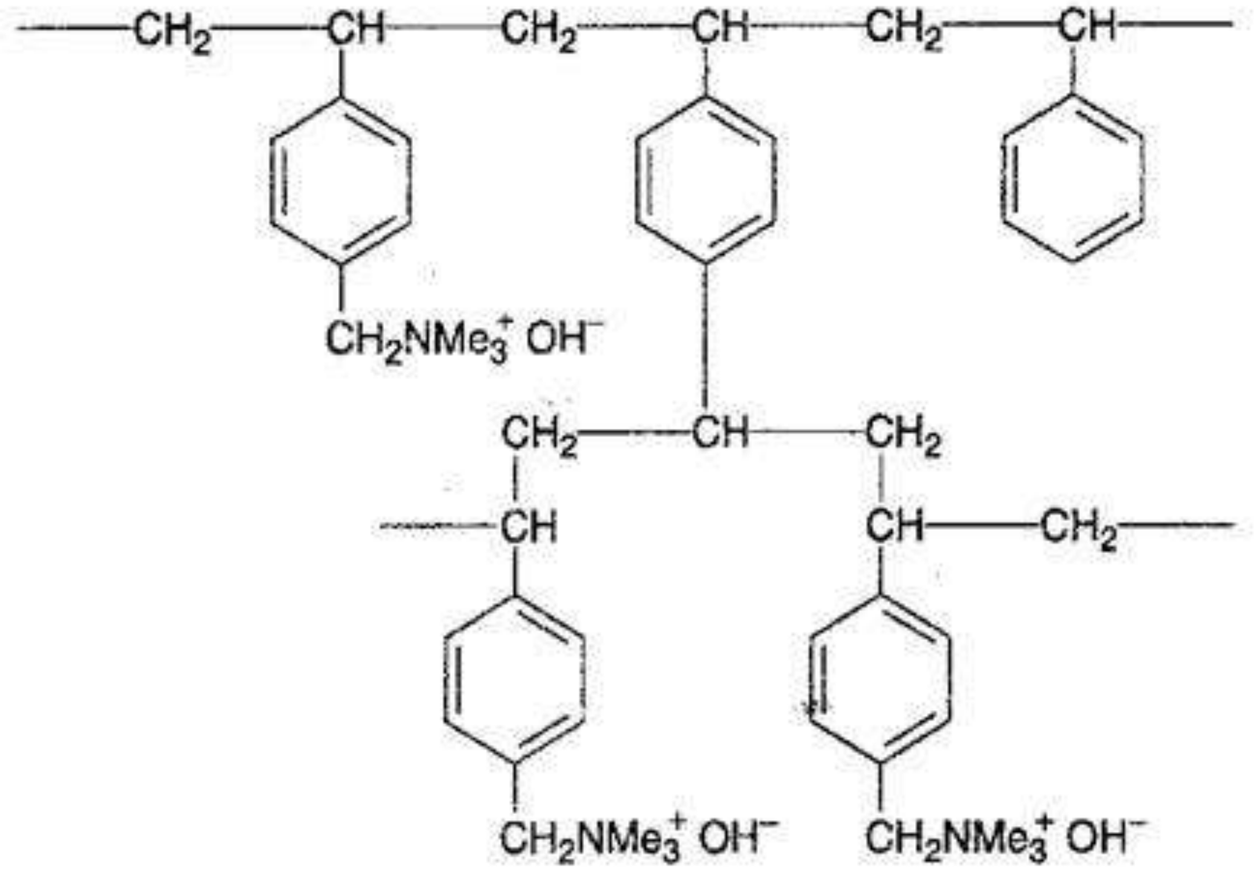
They are mainly styrene-divinyl benzene co-polymers which on sulphonation (having $-SO_3H$) or carboxylation (having–COOH) become capable to exchange their H^+ ions with cations in the water.

2) Anion Exchange Resins ($R'OH^-$)

They are styrene-divinyl benzene and amine formaldehyde copolymers which contain amino or quaternary ammonium groups. These, after treatment with dil NaOH solution, become capable to exchange their OH^- anions with anions in water.

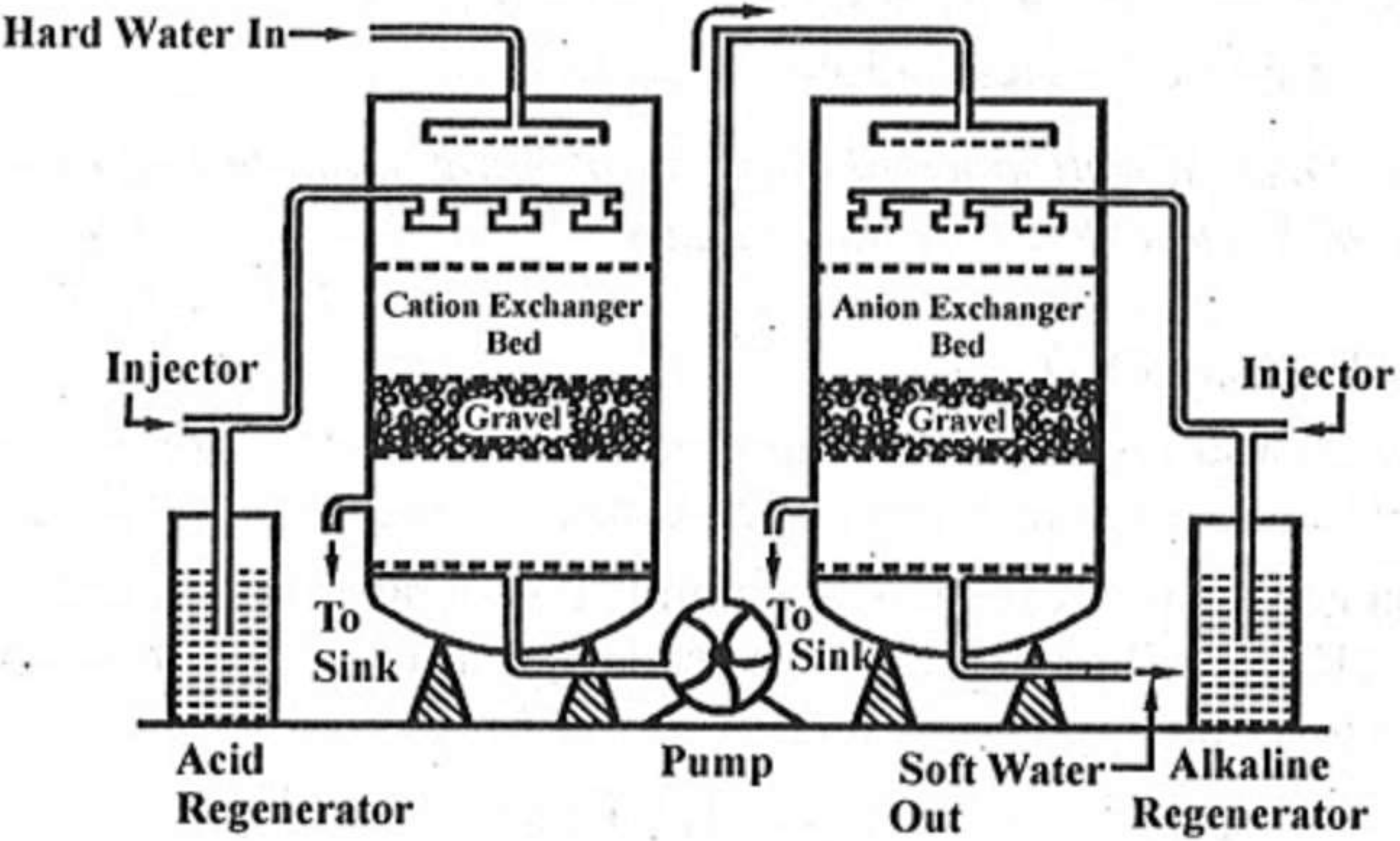
Cation Exchange Resin

Anion Exchange Resin



Me = Methyl Group

Ion Exchange Process



Working Process

Working of Cation Exchanger

Raw water is first passed through cation exchanger and the removal of cations like Ca^{+2}, Mg^{+2} etc. take place and equivalent amount of H^+ ions are released from this column to water. Thus,

$2RH+ + Ca^{+2} \rightarrow R_2Ca^{+2} + 2H^+$

$2RH+ + Mg^{+2} \rightarrow R_2Mg^{+2} + 2H^+$

Working of Anion Exchanger

After cation exchange column the hard water is passed through anion exchange column, which removes all the anions like SO_4^{2-}, Cl^- etc. present in the water and equivalent amount of OH^- ions are released from this column to water.

$R'OH^- + Cl^- \rightarrow R'Cl^- + OH^-$

$2R'OH^- + SO_4^{2-} \rightarrow R'_2SO_4^{2-} + 2OH^-$

Deionized or Demineralized Water

H^+ and OH^- ions (released from cation exchange and anion exchange columns respectively) get combined to produce water molecule. This is extra amount of water.

$$H^+ + OH^- \rightarrow H_2O$$

Thus,

water coming out from the exchanger is free from cations as well as anions. Ion-free water is known as Deionized or Demineralized water which is the pure water.

Regeneration:

The cation and anion exchangers are said to be exhausted or discharged when H^+ ions of cation exchanger and OH^- ions of anion exchanger are completely exchanged with cations and anions of raw water respectively.

Regeneration of cation exchanger is carried out by passing dil. HCl or H_2SO_4 solution into the bed.

$$\underset{\text{Exhausted}}{R_2Ca^{2+}} + 2H^+ \rightarrow \underset{\text{Regenerated}}{2RH^+} + Ca^{2+}$$

The exhausted anion exchange column is regenerated by passing a solution of dil. NaOH.

$$\underset{\text{Exhausted}}{R_2SO_4^{2-}} + 2\,OH^- \rightarrow \underset{\text{Regenerated}}{2R'OH^-} + SO_4^{2-}$$

The regenerated ion exchange resins are then used again.

Advantages:

1) Highly acidic or alkaline water samples can be purified by this process.
2) Almost completely pure water is obtained.
3) The deionised water is most suitable for boilers.

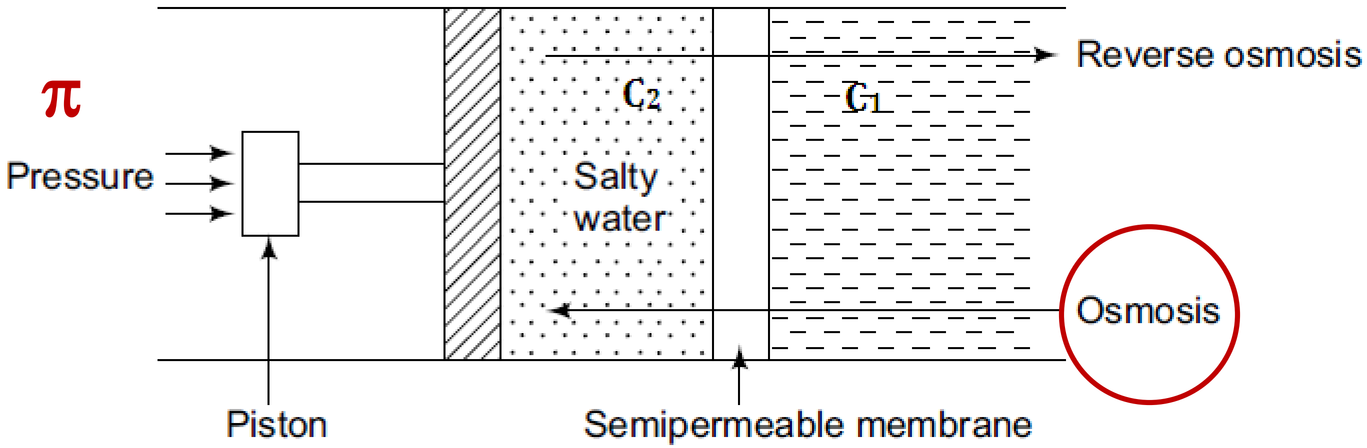
Disadvantages:

1) The ion exchanging resins are expensive hence the cost of purification is high.
2) Raw water should be free from suspended impurities (less than 10 ppm) otherwise exchanger bed will be blocked.

Reverse Osmosis

Osmosis and Osmotic Pressure

When two solutions of different concentrations are separated by a semi permeable membrane, (SPM: The membrane that allows only solvent molecules to pass through it but not the solute particles), the flow of solvent occurs from the solution of lower concentration (Diluted) to the solution of higher concentration (Concentrated). This phenomenon of flow through SPM is called as Osmosis.

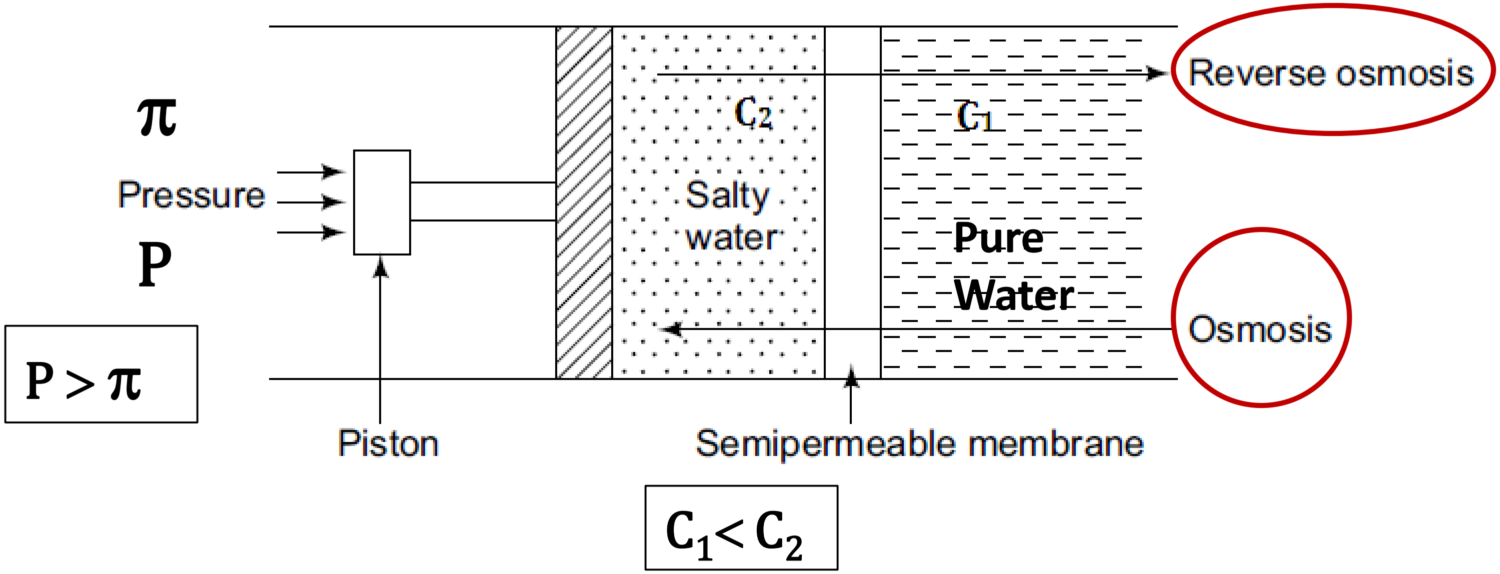


$\boxed{C_1 < C_2}$

If some pressure is applied on higher concentration side so that the process of osmosis (i. e. flow of solvent) is just stopped, that minimum pressure applied to stop the osmosis is called as **Osmotic Pressure (π).**

Reverse Osmosis

When a pressure (P) greater than the osmotic pressure is applied on higher concentration side, the flow of solvent is reversed i. e. the flow of solvent occurs from higher concentration side to lower concentration side. This reverse phenomenon is called as **Reverse Osmosis (RO).**



$P > \pi$

$C_1 < C_2$

This process can be used in purification of water.

As shown in figure, water solvent from salty water (higher concentration C_2) can move towards pure water (lower concentration side C_1). In such a manner pure water can be extracted from saline water. The TDS of drinking water is also lowered down by this method, called as RO water.

Importance

1) Reverse osmosis process has ability of removing ionic as well as non - ionic, colloidal and organic matters.
2) The membrane can be used for a quite long period.
3) The membrane can be replaced whenever needed.
4) The equipment is simple and of low cost.
5) The reverse osmosis is an important technique to convert sea water into drinking water.
6) Water for very high pressure boilers are obtained by this method.

Calgon Conditioning:

In the boilers a scale of calcium compounds is deposited that causes adverse effects on its efficiency. The scale deposited on inner walls of the boilers can be removed by changing it in a soluble compound.

Calgon (sodium hexa meta phosphate $(NaPO_3)_6$) is used in boiler to remove such scales.

It prevents the scale and sludge formation by forming soluble complex compound with $CaSO_4$.

$$Na_2[Na_4(PO_3)_6] \rightarrow 2Na^+ + [Na_4P_6O_{18}]^{-2}$$

(Sodium hexa meta phosphate)

$$2CaSO_4 + [Na_4P_6O_{18}]^{-2} \rightarrow [Ca_2P_6O_{18}]^{-2} + 2Na_2SO_4$$

Scale (Soluble complex ion)

Determination of Hardness of Water by EDTA Method

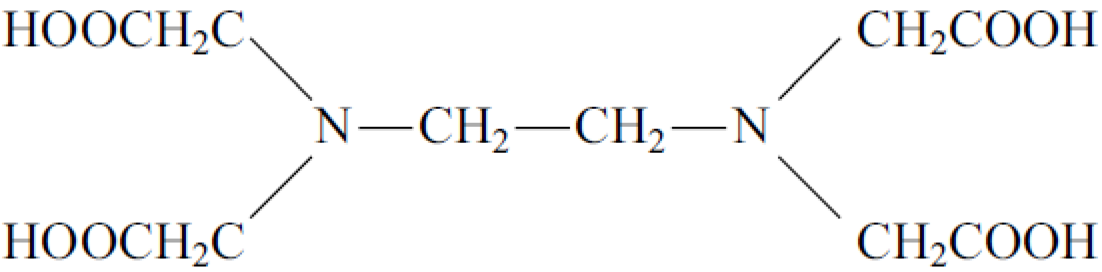
Principle

This method is based on the property that hardness causing ions Ca^{++} and Mg^{++} can form an unstable complexes with the indicator Eriochrome Black T and more stable complex with EDTA in basic medium.

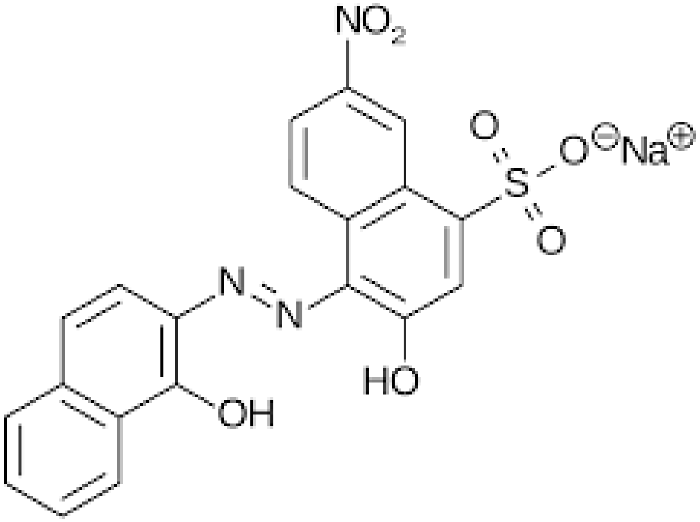
So, by volumetric analysis (Complexometric titration) the hardness of water can be determined.

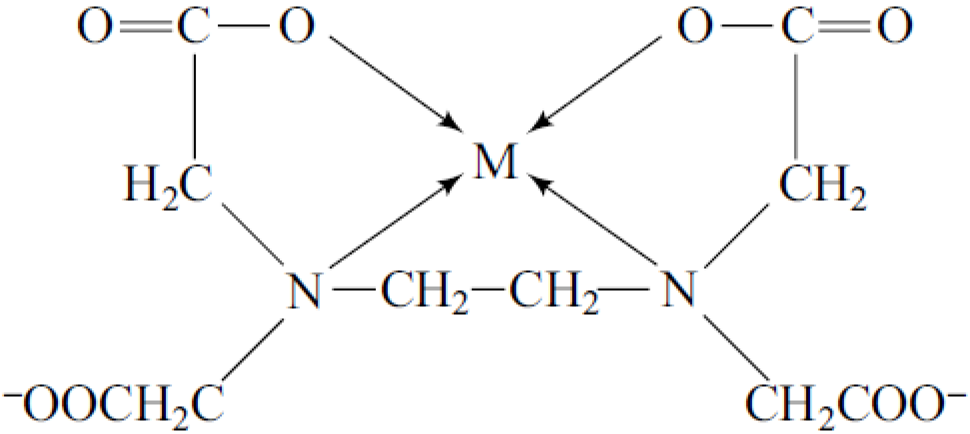
Procedure

1. A standard solution of disodium salt of ethylene diamine tetra acitic acid is taken in a burette.
2. A known amount of hard water sample is taken in a conical flask.
3. Then, basic buffer solution (pH 10) is added to the water sample.
4. Now, internal indicator Erychrome Black-T (EBT) is added to the water sample taken in the conical flask.
5. The colour of the solution becomes wine red colour due to formation of an unstable complex of Ca++ and Mg++ with EBT.
6. When EDTA solution is added to the solution in conical flask, at the End Point, wine colour turns to blue colour due to free EBT indicator.
7. The burette reading is noted down for the volume of EDTA used.
8. By equivalence equation hardness can be calculated.



EDTA (Ethylene diamine tatra acetic acid)





Metal complex of EDTA

Eryochrome Black-T
Sodium1-[1-Hydroxynaphthylazo]
6-nitro-2-naphthol-4-sulfonate.

M = Ca^{++}, Mg^{++}

Reactions

Ca^{+2} or Mg^{+2} + EBT → Ca-EBT or Mg-EBT
wine red (unstable complex)

Ca-EBT or Mg-EBT + EDTA → Ca-EDTA or Mg-EDTA + EBT
blue

Calculation

Water EDTA

$$N_1V_1 = N_2V_2$$

$$N_1 = N_2V_2/V_1$$

Total Hardness of water in terms of ppm of $CaCO_3$ $= N_1 \times$ Eq. Wt. of $CaCO_3 \times 1000$

$$= N_2\, V_2 \times 50 \times 1000/V_1$$

Q. The total hardness of a water sample was determined by EDTA method. 50 ml hard water sample required 30 ml of N/50 EDTA solution. Calculate the total hardness of water.

Solution

Water EDTA

$N_1V_1 = N_2V_2$

$N_1 = N_2V_2/V_1$

$N_1 = ?$, $V_1 = 50$ ml, $N_2 = 1/50$, $V_2 = 30$ ml

Total Hardness of water in terms of ppm of $CaCO_3$ $= N_1 \times$ Eq. Wt. of $CaCO_3 \times 1000$

$= N_2\, V_2 \times 50 \times 1000/V_1$

$= (1/50) \times 30 \times 50{,}000/50$

$= 600$ ppm 0f $CaCO_3$

Q. The hardness of a water sample was determined by EDTA method. 50 ml hard water sample required 30 ml of N/50 EDTA standard solution at room temperature and after boiling the water sample, same amount of water needed only 20 ml of standard EDTA. Calculate the Temporary and The Permanent hardness of water.

Solution

We know that temporary hardness can be removed by boiling of water. So, the calculation will be done in two steps.

1. Total Hardness - Before boiling (at room temperature):
2. Permanent hardness - After boiling

Before Boiling Water EDTA

$N_1V_1 = N_2V_2$

$N_1 = N_2V_2/V_1$

$N_1 = ?$, $V_1 = 50$ ml, $N_2 = 1/50$, $V_2 = 30$ ml

Total Hardness of water in terms of ppm of $CaCO_3$ $= N_1 \times$ Eq. Wt. of $CaCO_3 \times 1000$

$= N_2\,V_2 \times 50 \times 1000/V_1$ $= (1/50) \times 30 \times 50{,}000/50$ $= 600$ ppm 0f $CaCO_3$

After Boiling Water EDTA

$N_1 = N_2V_2/V_1$

$N_1 = ?$, $V_1 = 50$ ml, $N_2 = 1/50$, $V_2 = 20$ ml

Permanent Hardness of water in terms of ppm of $CaCO_3$ $= N_1 \times$ Eq. Wt. of $CaCO_3 \times 1000$

$= N_2\,V_2 \times 50 \times 1000/V_1$ $= (1/50) \times 20 \times 50{,}000/50$ $= 400$ ppm 0f $CaCO_3$

Thus, Temporary Hardness = Total hardness – Permanent hardness

$= 600 - 400 = 200$ ppm of $CaCO_3$

Thank You

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