MOBULE 2

SOLUTIONS, VOLUMETRIC ANALYSIS AND WATER

Solution:

Solutions are homogeneous mixture of two or more components. The component which is present in smaller amount is called **solute**. The other component whichis present in larger amounts is called **solvent**.

Concentration of solution

The amount of solute dissolved in a known of solution is called concentration of solution.

The concentration can be expressed in the following ways:

(1). Molarity (M)

It is defined as the number of moles of a solute present in one liter of the solution.

$$\text{Molarity (M)} = \frac{no.of\ moles\ of solute}{volume\ of\ solution\ in\ liter}$$

$$\text{Molarity (M)} = \frac{W\ \times 1000}{m\ \times V\ (mL)}$$

Here, W = weight of solute in grams

m = Molar mass of solute

V = Volume of solution in mL

(2). Normality

It is defined as the number of gram equivalents of a solute present in one liter of the solution.

$$\text{Normality (N)} = \frac{no.of\ gram\ equivalents\ of solute}{volume\ of\ solution\ in\ liter}$$

$$\text{Normality (N)} = \frac{W \times 1000}{E \times V\ (mL)}$$

Here, W = weight of solute in grams

E = Equivalent weight of solute

V = Volume of solution in mL

(3). Parts per million (ppm)

It is defined as the number of parts (by mass/volume) of the solute present in million parts (by mass/volume) of the solution.

Ionic product of water

The product of the concentrations of the H^+ and OH^- ions in water is called ionic product of water K_w.

Consider the equilibrium reaction of ionization of water,

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

Then, $K_w = [H^+][OH^-]$

$[H^+] = 10^{-7}$ moles/L(For pure water at 25°C)

$[OH^-] = 10^{-7}$ moles/L (For pure water at 25°C)

$K_w = [H^+][OH^-]$

$= 10^{-7} \times 10^{-7}$

$= 10^{-14}\ mol^2/L^2$ (at 25°C)

P^H and P^{OH}

P^H

Negative logarithm of H^+ ion concentration on the basis of ten is called P^H.

$P^H = -\log_{10}[H^+]$

P^H Scale

Method of expressing H^+ ion concentration is called ***p^H scale.*** P^H scale runs from 0 to 14.

In pure water

$[H^+] = 10^{-7}$moles/L

So $P^H = -\log_{10}[H^+]$

$= -\log_{10} 10^{-7}$

$= -(-7 \times \log 10) = 7x1 = 7$

For acids $p^H < 7$ (0 to 7)

For pure water/ neutral solution pH = 7

For bases $p^H > 7$ (7 to 14)

Applications of p^H

- To find the nature of a medium- acidic, basic or neutral
- To reduce the rate of corrosion selection of p^H is important.
- In the production of potable water
- In Electroplating: p^H affects deposition of a metal on another metal
- In agriculture: The p^H of soil is important in plant cultivation
- In textile industry
- In sugar industry
- In food preservation
- In pharmaceutical industry
- In the production of dental products

$P^{OH}$and P^{OH} scale

P^{OH} is the negative logarithm of OH- ion concentration in moles/L.

$P^{OH} = -\log_{10}[OH^-]$

P^{OH} scale: The method of expressing OH- ion concentration is called **P^{OH} scale.**

Relation between p^H and p^{OH}

We have $Kw = [H^+][OH^-]$

$P^{Kw} = P^{H} + p^{OH}$ $P^{Kw} = -\log_{10}K_w = -\log(10^{-14}) = 14$

$P^{H} + p^{OH} = 14$

$P^{H} = 14 - p^{OH}$

$p^{OH} = 14 - P^{H}$

Buffer Solution

A solution which resist the change in pH when a small amount of acid or base is added or diluted is called a ***Buffer Solution***.

Classification of Buffers

Acidic Buffer

It is obtained by mixing a weak acid and its salt with a strong base. Its' pH is below 7.

Eg: Acetic acid and sodium acetate

Boric acid and borax

Carbonic acid and sodium carbonate

Basic Buffer

It is obtained by mixing a weak base and its salt with a strong acid. Its' pH is above 7.

Eg: Ammonium hydroxide and ammonium chloride

Glycine and glycine hydrochloride

Buffer Capacity or Buffer Index

It is defined as the number of moles of acid or base added to one liter of buffer to change the pH by unity.

$$Buffer\ capacity\ (\phi) = \frac{no.of\ moles\ of acid\ or\ base\ added\ to\ one\ liter\ buffer}{change\ in\ pH}$$

VOLUMETRIC ANALYSIS

It is a quantitative analysis based on volume measurements.

It involves the determination of volume of a solution required to react with a known volume of solution to be estimated.

Standard solution: A solution of known concentration is called a standard solution.

Titration: The process of finding the volume of one solution required to react completely with a known volume of other solution is known as titration.
Neutralization reaction: It is a reaction where an acid and alkali reacts to form a neutral solution of a salt and water.

Eg: $HCl + NaOH \longrightarrow NaCl + H_2O$

Equivalent point: The exact point at which the reaction is completed during titration is called **equivalent point.**

End point: The point at which the indicator shows colour change is called **end point.**

Indicators: A weak acid or a base which can change its colour with variation in pH is called an acid- base indicator.

pH range of indicators: The range of pH at which the indicator shows colour change is called the pH range of that indicator.

Indicator	pH range	Colour	
		Acid medium	Basic medium
Phenolphthalein	8.3 - 10	Colourless	Pink
Methyl orange	3.1- 4.5	Pink	Yellow
Litmus	4.5 – 8.3	Red	Blue

Choice of indicators in acid base titrations

Phenolphthalein (8.3 – 10: alkaline pH) can use only when strong base involves in titration.

Methyl orange (3.1- 4.5: acidic pH) can use only when strong acid involves in titration.

Titration of strong acid against strong base

Eg; $HCl/ HNO_3/H_2SO_4 /H_3PO_4$ Vs $NaOH/KOH$

The end point of this type of reaction comes within the range of pH 4 – 10. So both phenolphthalein and methyl orange can be used.

Titration of strong acid against weak base

HCl/HNO_3 vs. Na_2CO_3/ K_2CO_3

For this titration end point comes in between 3.5 to 7.5 pH. So methyl orange is the suitable indicator (pH range 3.1 to 4.5).

Titration of weak acid against strong base

Oxalic acid /acetic acid/carbonic acid vs. NaOH/KOH

At the end point the pH changes from 6.5 to 10. Hence phenolphthalein is the suitable indicator.

Titration of weak acid against weak base

Oxalic acid /acetic acid/carbonic acid vs.Na_2CO_3/ K_2CO_3

No sharp pH change at the end point. So none of the indicators can give correct end pont.

Principle of volumetric analysis (Normality Equation)

The product of volume and normality of titrant (solution in burette) is equal to the product ofvolume and normality of titrate (solution in titration flask).

$N_1V_1 = N_2V_2$ (Normality equation or Law of normality)

Soft and Hard Water

Water which produces lather readily with soap solution is called **Soft Water.**

Water which does not produce lather readily with soap is called **Hard Water.**

Dissolved salts of bicarbonates, chlorides or sulphates of calcium and magnesium causes Hardness.

Why hard water do not form lather with soap?

When treated with soap the dissolved impurities reacted with soap to form insoluble salts. Hence hard water do not form lather. Soap produces lather only after all the dissolved impurity get precipitated and removed.

Difference between SOFT WATER and HARD WATER

SOFT WATER	HARD WATER
1. Produces lather readily with soap	1. Does not produce lather with soap.
2. Does not form insoluble precipitate with soap.	2. Forms insoluble precipitate with soap.

3. Does not contain dissolved salts of calcium and magnesium.	3. Contains dissolved salts of calcium and magnesium.
4. Advantages: Soft water is suitable for a)Cooking purposes b) Bathing c) Laundry purposes d)Dyeing textiles e) Boilers etc.	4. Advantages a) Contains calcium and magnesium required for health b) It does not dissolve lead of lead pipes causing lead poisoning.
5. Disadvantages a) Does not contain calcium and magnesium required for health b) It dissolves lead of lead pipes causing lead poisoning.	5. Disadvantages a) Pulses do not cook well in it. b) Causes wastage of soap in laundry. c) Drinking may lead to kidney stones. d) Not suitable for dyeing due to malformation of colour. e) When used in paper industry reduces the quality of paper. f) **In steam boilers it forms the boiler scales which may lead to explosion. The chlorides hydrolyses to form hydrochloric acid which corrode the boiler metal.**

TYPES OF HARDNESS

Temporary Hardness

It is caused by the presence of bicarbonates of calcium and magnesium. It can be removed by boiling.

Permanent Hardness

It is caused by the presence of chlorides and sulphates of calcium and magnesium. It cannot be removed by boiling.

Methods of removal of hardness

1) **Lime soda Process**
   In this method required quantity of slaked lime $Ca(OH)_2$ or washing soda (Na_2CO_3) is added to the hard water. Then calcium and magnesium ions are precipitated as insoluble carbonates and it can be removed by filtration.

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

$$Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow MgCO_3\downarrow + CaCO_3\downarrow + 2H_2O$$

$$CaCl_2 + Na_2CO_3 \longrightarrow 2\,CaCO_3\downarrow + 2NaCl$$

$$MgCl_2 + Na_2CO_3 \longrightarrow 2\,MgCO_3\downarrow + 2NaCl$$

Methods of removal of permanent hardness

Ion Exchange Method

In this synthetic resins are used to remove the ions.

In the first step the hard water is passed through a tank containing cation exchanger capable of exchanging cations with H^+ ion.

$$2E\text{-}H + Ca^{2+} \longrightarrow E_2Ca + 2H^+$$

The water coming out is passing through another tank containing anion exchanger and all anions are removed.

$$E\text{-}OH + Cl^- \longrightarrow E\text{-}Cl + OH^-$$

The H^+ and OH^- combine to form water.

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

Regeneration of ion exchanger: Cation exchanger can be regenerated by treating with acid. Anion exchanger can be regenerated by treating with alkali. **(MERIT)**

This method can be used even when water is highly acidic or alkaline. **(MERIT)**

Ion exchange resins and equipment are highly expensive. **(DEMERIT)**

POTABLE WATER

The water which is safe to drink is called **potable water**. It need not be pure as distilled water.

Characteristics of potable water

- ✓ It should be clear and odourless.
- ✓ It should be pleasant to taste.
- ✓ It should be free from disease producing microbes.
- ✓ It should be free from gases like H_2S, CO_2, NH_3 etc.
- ✓ The pH should be around 8.
- ✓ It should be free from suspended impurities.
- ✓ It should be reasonably soft.

Treatment process to make potable water

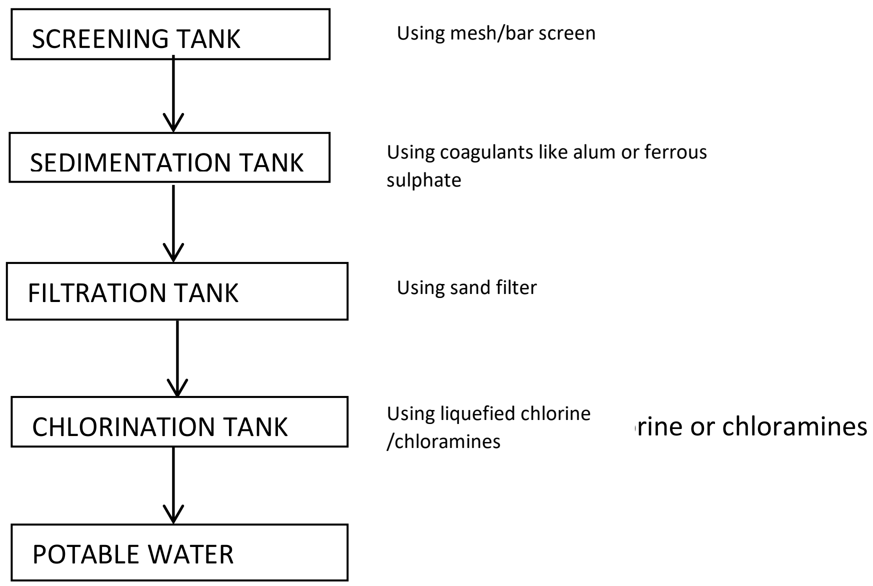
It involves the following steps

1. **Screening** **2. Sedimentation** **3. Coagulation** **4. Filtration** **5. Sterilization**.

1. **Screening**
   The raw water is passed through bar or mesh screens to remove large solid impurities like gravel, dried leaves etc.
2. **Sedimentation**
   In this step the water is allowed to stand undisturbed for 6 to 12 hours to settle down the suspended impurities under gravity.
3. **Coagulation**
   In this step coagulants are added to settle down the fine suspended impurities. Examples for coagulants: alum, ferrous sulphate, ferric chloride, sodium aluminate etc.
4. **Filtration**
   In this step the water is allowed to pass through the gravity sand filter or pressure filter in order to remove colloidal and bacterial impurities.
5. **Sterilization**

The process of destroying the disease producing microorganisms from water is called sterilization. The chemicals used for sterilization are called sterilizers. The commonly used sterilization methods are – Chlorination, treating with bleaching powder, ozone and UV irradiation.

Stages of production of potable water –Block diagram

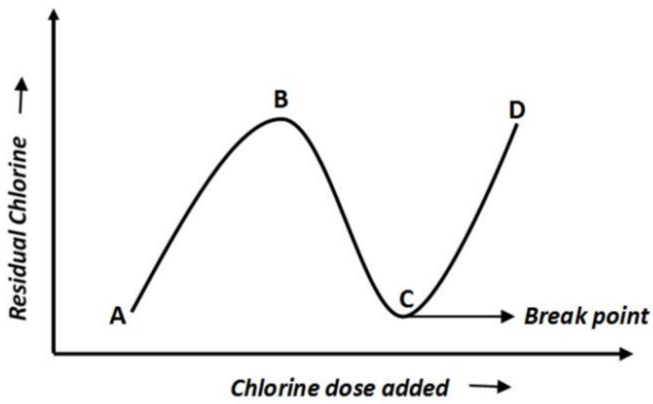


Sterilization methods

Break-point chlorination

It is the chlorination of water to the extent that living organism and organic impurities are destroyed. Over chlorination beyond break-point chlorination produces unpleasant smell and taste of chlorine.

Break-point chlorination curve: The graph connecting the residual chlorine and chlorine dose added is called *Break-point chlorination curve.* The unused chlorine left behind is called residual chlorine.



The residual chlorine increases with chlorine dose added and give straight line AB.

Then the chlorine dose added decreases up to the point C, the break point, due to the oxidation of impurities. Beyond C the residual chlorine increases and give bad smell to the water.

Advantages of break-point chlorination

1. It destroys all disease producing bacteria.
2. Removes colour and taste from water.
3. Oxidizes organic compounds, ammonia and other reducing compounds.
4. Prevent the growth of weeds in water.

Sterilization by bleaching powder

Calcium hypochlorite ($CaOCl_2$) is called bleaching powder. It can produce hypochlorus acid (HOCl) and nascent oxygen. Both can acting as powerful germicides. Calculated amount of bleaching powder can used for sterilizing water.

$$CaOCl_2 + H_2O \longrightarrow Ca(OH)_2 + Cl_2$$

$$Cl_2 + H_2O \longrightarrow HOCl + HCl$$

$$HOClHCl + (O) \longrightarrow$$

Demerits

Excess bleaching powder causes bad taste and smell.

Calcium ions makes water hard.

Sterilization by UV irradiation

UV rays kills all pathogenic bacteria. Addition of eosin can help disinfection. This is useful when chemical methods are not acceptable. This is a more expensive method.