Applied Chemistry Modules

2. Module-2: Fundamentals of Analytical Chemistry

FUNDAMENTALS OF ANALYTICAL CHEMISTRY

1. Solutions

Solution is a homogenous mixture of two or more substances. Solution with only two components is called binary solution.

In a binary solution, the component with lesser proportion is called solute and component in greater proportions is called solvent.

Ex: In sugar solution, sugar is the solute and water is the solvent.

2. Methods to express the concentration of solutions

The amount of solute in a particular amount of solvent is called concentration. Some of the methods to express concentration are Molarity, Normality, Parts per million(ppm) etc.

Molarity:

Number of moles of the solute per liter of the solution is called molarity.

Number of moles= Mass/Molecular mass

Problem 1

Calculate the Molarity of a solution of NaOH containing 80 g of NaOH in 1 Litre of the solution

Problem 2

Calculate the Molarity of a solution of H_2SO_4 containing 4.9 g of H_2SO_4 in 1 L of the solution

Problem 3

What is the Molarity of a solution which contains 6.3 g of HNO_3 in 500 ml of the solution

Normality:

Number of equivalents of the solute per liter of the solution is called normality.

Number of equivalents= Mass/Equivalent mass

Equivalent weight of acid

$$\textbf{Equivalent weight of Acid} = \frac{\textbf{Molecular weight}}{\textbf{Basicity}}$$

Eg:- Equivalent weight of HCl = $\frac{\text{Molecular weight}}{\text{Basicity}} = \frac{36.45}{1} = 36.45$

Equivalent weight of H_2SO_4 = Molecular weight = 98 = 49

Basicity 2

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Equivalent weight of base

$$\textbf{Equivalent weight of base} = \frac{\textbf{Molecular weight}}{\textbf{Acidity}}$$

Eg:- Equivalent weight of NaOH = $\frac{\text{Molecular weight}}{\text{Acidity}}$ = 40/1 = 40

Equivalent weight of $Ca(OH)_2$ = $\frac{\text{Molecular weight}}{\text{acidity}} = \frac{74}{2} = 37$

Problem 4

Calculate the Normality of a solution of H_2SO_4 which contains 98 g of H_2SO_4 in 1 L of solution

Problem 5

Find the Normality of a solution which contains 4 g of NaOH in 500 ml of solution

Problem 6

What is the weight of Na_2CO_3 present in 500 ml of 0.1 N solution.

Parts per million (ppm):

It is the number of parts of solute per million parts of the solution.

ppm= (Mass of solute/ Mass of solution) x 10^6

3. Ionic product of water (K_w)

Ionic product of water is the product of the concentration of H^+ ions and OH^- ions in water.

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

$[H^+]$ = concentration of H^+ ions in moles/L

$[OH^-]$ = concentration of OH^- ions in moles/L

For pure water, at 25^{o}C,

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

Therefore, the value of K_w at 25^{o}C is 10^{-14} (moles /L)^2

When temperature increases, the dissociation of water increases. Therefore, the value K_w increases as the temperature is increased.

p^H value

pH value of a solution is the negative logarithm of H^+ ion concentration of a solution

$pH = -\log [H^+]$

p^{OH} value

It is the negative logarithm of OH^- ions concentration of a solution

$p^{OH} = -\log [OH^-]$

Relation between p^H and p^{OH}

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

Problem 7

Calculate the pH value of a solution whose OH^- ion concentration is 0.01 M

Problem 8

Calculate the pH value of a solution whose OH^- ion concentration is 0.001 M

Problem 9

What is the pH value of 0.01 M NaOH solution?

Applications of pH

- pH value can be used predict the nature of solution. pH<7, Acidic; pH>7, Basic & pH=7, neutral.
- To know the purity of drinking water. pH of drinking water is between 7 and 8.5 .
- To check the quality of soil in farming. After finding the acidic or basic character of soil, proper fertilizer can be selected.
- In wastewater treatment.
- In aquaculture. Fish thrive in pH level between 6.5 and 9.
- In food and beverage industry.

4. Buffer solution

A solution whose pH value remains same even after the addition of small amount of acid or base is called buffer solution. (ie, solutions with constant pH values)

Acidic buffer

It a is a mixture of weak acid and salt of weak acid with a strong base.

Eg:- Solution of acetic acid and sodium acetate

Basic buffer

It is a mixture of weak base and salt of weak base with a strong acid

Eg:- Solution of ammonium hydroxide and ammonium chloride

Buffer capacity

The ability of a buffer to resist the change in its pH value is known as buffer capacity

Buffer capacity = Number of moles of acid or base added to 1 Litre change in pH value

Applications of buffer

Ø The pH of blood is maintained at 7.4 by the buffer action of carbonic acid and sodium bicarbonate.

Ø The pH of gastric juice that helps the digestion of food is maintained between 1.6 and 1.7 by buffer action.

5. Volumetric analysis (Titration)

Measuring the volume of a second substance that combines with the first in known proportions is known as Volumetric analysis or titration. The exact stage at which a reaction is just complete is called the **end point of the titration.**

Indicators

These are the substances used in volumetric analysis to point out the end point of a chemical reaction by change of colour.

The common indicators used for acid-base titrations are *methyl orange* and *phenolphthalein.* They change their colour within a certain pH range.

Phenolphthalein

It is an organic weak acid with pH range of 8 to 9.8. This indicator appear as colorless in acid solution and pink in alkali solution (basic solution)

Methyl orange

It is a weak base with pH range of 3.1 to 4.5. This indicator appears golden yellow color in basic medium and orange red in acid medium

Choice of indicators

The choice of indicators of a titration depends upon the names of the acid and base. If both acid and base are strong, either phenolphthalein or methyl orange can be used as indicator. In titrations of strong base against weak acid, only phenolphthalein can be used. If the base is weak and acid is strong, only Methyl orange can be used as indicator.

Principles of volumetric analysis

Let V_1 and V_2 be the volumes of solutions reacting. If N_1 and N_2 are the Normalities of the two solutions respectively. Then Normality formula $N_1V_1 = N_2V_2$

Problem 10

20 ml of 0.1 N solution of NaOH is titrated against HCl solution. The volume of HCl used to neutralize the NaOH solution is 18.5 ml. Calculate the Normality of HCl used. Also calculate the weight of HCl in 500 ml of solution

Molecular weights and equivalents weight of some acids & bases

ACID	**Molecular weight**	**Equivalent weight**
HCl	36.5	36.5
HNO_3	63	63
H_2SO_4	98	49
BASE		

NaOH	40	40
Na_2CO_3	106	53
$Ca(OH)_2$	74	37

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6. Soft and Hard water

Water which gives lather with soap easily is called soft water.

Water which contains dissolved salts of calcium and magnesium and hence does not give lather with soap easily is called hard water.

Differences between hard and soft water

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SOFT WATER	HARD WATER
Gives lather with soap easily	Lather formation not easy
No scum formation	Forms insoluble scum
Suitable for drinking and other uses	Not suitable for drinking and other uses
Does not contain dissolved salts of calcium and magnesium	Contain dissolved salts of calcium and magnesium
Suitable for industrial applications	Not suitable for industrial applications

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Why hard water does not give lather?

Soap is sodium/potassium salt of higher carboxylic acids. When treated with hard water, soap reacts with calcium and magnesium ions in hard water to form insoluble salts (Scum). Hence no lather is formed.

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Types of hardness

Temporary hardness: Hardness due to the presence of bicarbonates of calcium and magnesium $(Ca(HCO_3)_2; Mg(HCO_3)_2$

Permanent hardness: Hardness due to the presence of chlorides and sulphates of calcium and magnesium ($CaCl_2$; $MgCl_2$; $CaSO_4$; $MgSO_4$).

Boiler scale formation

Hard water contains dissolved salts of calcium and magnesium. It forms scales (also called lime scales) on the walls of the boilers and hence to be softened before its usage in industries. These scales reduce the heat conductivity of boilers and also may cause corrosion to boiler parts.

Removal of hardness

By Boiling (To remove temporary hardness)

When boiled, the dissolved bicarbonates are converted to insoluble carbonates, which are then filtered off.

Soda lime process

In this process, calcium and magnesium ions are precipitated by adding lime ($Ca(OH)_2$) and soda ash(Na_2CO_3).

Precipitated calcium carbonate and magnesium hydroxide are filtered and removed.

Removal of permanent hardness (Ion exchange process)

Synthetic resins called cation exchanger and anion exchanger are used. Hard water is first passed through cation exchanger (E-H) capable of removing all positive ions (cations) by exchange with H^+ ions.

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

The water coming out of cation exchanger is then passed through a second tank containing an anion exchanger (E-OH).

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

H+ and OH- formed combine to give water.

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

7. Potable water

Water free from contamination and hence fit for drinking is called potable water.

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Characteristics of potable water

- Clear and odour less
- Free from microorganisms
- Free from suspended impurities
- PH should be around 8
- Total dissolved salts should be less than 500ppm
- Should be reasonably soft.

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Steps to make potable water (Municipal water treatment)

(i) Screening

(ii) Coagulation

(iii) Sedimentation

(iv) Filtration

(v) Sterilization

Screening involves passing water through suitable screens to remove macro particles in water.

In **coagulation**, suitable chemicals called coagulants (Ex: Alum, ferrous sulphate, ferric chloride etc) are added to settle finely divided suspended particles.

Sedimentation is the process in which water is allowed to stand undisturbed for a few hours, so that most of the suspended particles settle down under force of gravity.

By **filtration** process, the insoluble impurities are removed by means of filters.

The process of destroying the disease-causing bacteria and micro-organisms from the water and making it safe for drinking is called **sterilization or disinfection**. Chlorination, action of bleaching powder, ozone treatment, UV radiations etc. are some of the methods for sterilization.

Flow chart for potable water making

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Sterilization by chlorine

Chlorine gas or chlorine water can be used. The quantity of free chlorine in treated water should not exceed 0.1 to 0.2ppm.

Sterilization by bleaching powder ($CaOCl_2$)

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

$Cl_2 + H_2O \rightarrow HOCl$ (Hypochlorous acid) + HCl

$HOCl \rightarrow HCl + (O)$ (Nascent oxygen)

Hypochlorous acid and nascent oxygen are powerful germicides.

Sterilization by ultra violet radiation

UV radiation can effectively kill all pathogenic bacteria.