ALMUSTAQBAL UNIVERSITY

College of Health and Medical Techniques

Medical Laboratories Techniques Department

Stage : First year students

Subject : General Chemistry 1 - Lecture 1A

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Chemistry

Chemistry is the science that study matter, its chemical and physical properties, the chemical and physical changes it undergoes, and the energy changes that accompany those processes.

Major Areas of Chemistry

1. **ORGANIC CHEMISTRY**

Involves the study of the structure, properties, and preparation of chemical compounds of diverse substances such as plastics, drugs, solvents, industrial chemicals that consist primarily of **Carbon and Hydrogen.**

2. **Inorganic chemistry**

Involves the study of the properties and behavior of inorganic compounds. It covers all chemical compounds other than organic compounds. It studies minerals, metals, catalysts, and most elements in the Periodic Table.

3. **PHYSICAL CHEMISTRY**

Deals with the study of the effect of chemical structure on the physical properties of a substance. , the rate of a chemical reaction, the interaction of molecules with radiation, and the calculation of structures and properties.

4. **BIOCHEMISTRY**

Is related to the study of chemical reactions that take place in living beings (animals, plants and micro organisms). It tries to explain them in chemical terms.

5. **ANALYTICAL CHEMISTRY**

Involves the analysis of substance to determine its **composition and the quantity** of its components . It is concerned with answering the questions:

- **What** chemical species are present in a sample ? (Qualitative Analysis)
- **How much** of each component is present ? (Quantitative Analysis).

It is done through volumetric , gravimetric or instrumental methods .

There is a huge overlap between Chemistry and Engineering, Biology, Medicine, Physics, Geology, and other fields. Chemistry really is **a CENTRAL SCIENCE**.

Properties of Solutions

A **solution** is a homogeneous mixture of two or more substances. It is composed of one or more ***solutes*****,** dissolved in a ***solvent*****.**

For example, when sugar (the solute) is added to water (the solvent), the sugar dissolves in the water to produce a solution.

For the cases where the solvent is water, the homogeneous mixture is refered to as an **aqueous solution.**

Electrolytic solutions:

Are solutions formed from solutes that are soluble ***ionic*** compounds(electrolytes). They dissociate in solution to produce ions that behave as charge carriers. Solutions of electrolytes are good conductors of electricity.

For example, sodium chloride dissolving in water:

$$NaCl(s) \quad + \quad H_2O \quad \rightarrow \quad Na^+(aq) \quad + \quad Cl^-(aq)$$

Solid sodium chloride **dissolved sodium chloride**

Nonelectrolytic Solutions:

Are solutions formed from non dissociating *molecular* solutes (non electrolytes), and these solutions are nonconducting.

For example, dissolving Glucose sugar in water:

$$C_6H_{12}O_6(s) \quad + \quad H_2O \quad \rightarrow \quad C_6H_{12}O_6(aq)$$

Solid glucose **Dissolved glucose**

Methods of expressing concentrations-

Concentration represents the amount of dissolved substance (solute) per unit amount of solvent ,It can be expressed by:.

1) physical units : mass-volume
2) chemical units : equivalent weight- Molecular weight(mole).

Expressing concentrations By Physical units :

A. Percent concentration %

It can be expressed in several ways such as :

① Weight percent (w/w) %

Weight percent $\left(\frac{w}{w}\right)\% = \frac{weight\ of\ solute}{weight\ of\ solution} \times 100\ \%$

e.g : Nitric acid (70%) solution, means that it contains (70 g) of HNO_3 for each (100 g) of solution.

Example:

Intravenous dextrose injections are given to restore sugar levels in patients. What is the mass of sugar dissolved in 25 g of a 10 % dextrose solution?

Solution:

Weight percent $\left(\frac{w}{w}\right)\% = \frac{weight\ of\ solute}{weight\ of\ solution} \times 100\ \%$

$10\ \% = \frac{weight\ of\ solute}{25} \times 100\ \%$

Weight of solute(dextrose sugar) = $\frac{10x25}{100}$ = 2.5 g

②volume percent (v/v)%

Volume percent ($\frac{V}{V}$)% = $\frac{volume\ of\ solute}{volume\ of\ solution}$ x 100%

It is commonly used to specify the concentration of a solution prepared by diluting a pure liquid with another liquid.(e.g : perfumes) **e.g:** 5% aqueous solution of a perfume usually describe a solution prepared by diluting 5 mL of perfume with enough water to give 100 mL.

Example:

What is the volume of acetic acid needed for the preparation of 500 mL of vinegar ,aqueous solution of 7.5% (v/v) of acetic acid ?

Solution:

Volume percent ($\frac{V}{V}$)% = $\frac{volume\ of\ solute}{volume\ of\ solution}$ x 100%

7.5% = $\frac{volume\ of\ acetic\ acid}{500\ mL}$ x 100%

Volume of acetic acid = $\frac{7.5\ x\ 500}{100}$ = 37.5 mL

③weight/volume percent (w/v)%

weight/volume percent ($\frac{w}{V}$)% = $\frac{weight\ of\ solute(gm)}{volume\ of\ solution(\ mL)}$ x 100%

It is often employed to indicate the composition of dilute aqueous solution of solid dissolved in water. **e.g** : 5% aqueous potassium nitrate refers to a solution prepared by dissolving (5 g) of KNO_3 in sufficient amount of water to give (100 mL) of solution .

Example:

Calculate the $\left(\frac{w}{v}\right)$ % concentration of the aqueous solution of sodium chloride prepared by dissolving 5 g of NaCl in water and completing the volume to 250 mL .

Answer:

$$\left(\frac{w}{v}\right)\% = \frac{weight\ of\ solute(g)}{volume\ of\ solution(mL)} \text{ x } 100\%$$

$$\left(\frac{w}{v}\right)\% = \frac{5\ gm}{250\ mL} \text{ x } 100\% = 2\ \%$$

Practice exercises :

a.Calculate the (w/v)% of 0.2 L of solution containing 15 g KCl.

b. Calculate the mass (in g) of sodium hydroxide required to make 2 L of a 1 % (w/v)% solution

c. Calculate the volume (in mL) of a 25 % (w/v)% solution containing 10 g NaCl.

2.Expressing concentrations By chemical units :

The mole:

Is a unit for the amount of a chemical species , always associated with a chemical formula and represents Avogadro's number (6.022×10^{23}) of particles and represented by that formula .

Molar Mass : Is the mass in grams of 1 mole of the substance ,it is calculated by summing the atomic masses of all the atoms appearing in a chemical formula .

Molar mass = $\sum atomic\ mass$

Example :- Molar mass of glucose $C_6H_{12}O_6$:

$$M_{C_6H_{12}O_6} = \sum (6mole\ carbon + 12mole\ hydrogen + 6mole\ oxygen)atom$$

$$M_{C_6H_{12}O_6} = 6\ x12.0 + 12\ x\ 1.0 + 6\ x\ 16.0 = 180 \text{ g /mole}$$

Important Relations:-

M.wt = g /mole or mg /mmole

$$\text{No. of moles} = \frac{\text{wt}(_g)}{\text{M. wt}(_g)}$$

Wt (g) = No. of moles x M.wt

Mole $=10^{3}$mmole , mmole = 10^{-3}mole

Example1: How many grams of Na^+ (M.wt = 22.99 g /mole) are contained in (25 g) of Na_2SO_4 (M.wt = 142 g /mole)?

Solution:

$$\mathbf{Na_2SO_4 \longrightarrow 2Na^+ + SO_4^{2-}}$$

1mole 2mole 1mole

$$\text{moles of } Na_2SO_4\ (n_{Na_2SO_4}) = \frac{\text{Wt}_{(g)} Na_2SO_4}{\text{M. Wt}_{(g)} Na_2SO_4} = \frac{25}{142} = 0.176$$

No. of moles of $Na^+ (n_{Na^+})$= Number of moles Na_2SO_4 x 2

No. of moles of $Na^+ (n_{Na^+})$= 0.176 x 2 = 0.352 moles Na^+

Wt (g) = No. of moles x M.wt

Weight of Na^+(g) = moles Na^+ x 22.99(g) Na^+

Weight of Na^+(g) = 0.352 x 22.99 = 8.10 (g) Na^+

Hints

-No. of moles of Na^+ (n_{Na^+}) in NaCl is = 1 x No. of moles of NaCl as

$$\mathbf{NaCl \longrightarrow Na^+ + Cl^-}$$

1 mole 1 mole

No. of moles of Na^+ (n_{Na^+}) in $\mathbf{Na_3PO_4}$ is = 3 x No. of moles of $\mathbf{Na_3PO_4}$ as

$$\mathbf{Na_3PO_4 \longrightarrow 3Na^+ + PO_4^{3-}}\ \ \mathbf{(1\ mole\,Na_3PO_4 \longrightarrow 3moles\,Na^+)}$$

Exercise:

How many grams of Na^+ (22.99 g /mole) are contained in 25 g of Na_3PO_4 (164 g /mole)?

Exercise :

1. No. of moles of K^+ (n_{k^+}) in **K_2SO_4 = ?**
2. No. of moles of K^+ (n_{k^+}) in **KNO_3 = ?**
3. No. of moles of Mg^{2+} ($n_{Mg^{2+}}$) in **$MgSO_4$ = ?**
4. No. of moles of Fe^{3+} (n_{Fe3+}) in **$FeCl_3$ = ?**
5. No. of moles of Cl^- (n_{Cl-}) in **$FeCl_3$ = ?**

Molar concentration (M):

Molarity: Number of moles of solute per liter of solution

Or number of m moles of solute per milliliter of solution.

$$\mathbf{M} = \frac{\text{number of moles of solute}}{\text{volume of solution(liter)}}$$

Or

$$\mathbf{M} = \frac{\textbf{number of mmole of solute}}{\textbf{volume of solution mL}}$$

Molarity calculations:

$$\textbf{Molarity(M)} = \frac{\textbf{No.of moles}}{\textbf{volume(L)}} = \frac{\frac{\textbf{wt}_{(g)}}{\textbf{M.wt}}}{\textbf{V}_\textbf{L}}$$

$$\textbf{Molarity(M)} = \frac{\textbf{wt}_{(g)}}{\textbf{M.wt x V}_\textbf{L}}$$

$$\textbf{V}_\textbf{L} = \frac{\textbf{V}_\textbf{mL}}{\textbf{1000}}$$

$$\textbf{Molarity}(\boldsymbol{M}) = \frac{\textbf{wt}_{(g)}}{\textbf{M.wt x}\frac{\textbf{VmL}}{\textbf{1000}}}$$

$$\textbf{Molarity(M)} = \frac{\textbf{wt}_{(g)}\textbf{ x 1000}}{\textbf{M. wt x V}_\textbf{mL}}$$

Example: calculate the molar concentration of KNO_3 aqueous solution that contains (2.02 g) of KNO_3 (101 g /mole) in (2 L) of solution?

Solution:

$$\textbf{Molarity(M)} = \frac{wt_{(g)}}{M.wt \times V_L} = \frac{2.02_{(g)}}{101 \times 2\ L} = \mathbf{0.1\ M}$$

or

$$\textbf{Molarity(M)} = \frac{wt_{(g)} \times 1000}{M.wt \times V_{mL}} = \frac{2.02_{(g)} \times 1000}{101 \times 2000\ mL} = \mathbf{0.1\ M}$$

Example:

How many milliliters of 12 M hydrochloric acid contain 7.30 g of HCl solute (36.5 g/mole)?

Solution:

$$\textbf{Molarity(M)} = \frac{wt_{(g)} \times 1000}{M.wt \times V_{mL}}$$

$$\mathbf{V(mL)} = \frac{wt_{(g)} \times 1000}{M.wt \times Molarity(M)} = \frac{7.3 \times 1000}{36.5 \times 12} = 16.7\ mL$$

Preaparation of molar solutions

Molarity represents the number of moles of solute in one liter of solution or number of mmole in one milliliter .

e.g: a sulfuric acid(98 g/mole) solution that has an analytical concentration of (1 M) can be prepared by dissolving (1 mole) or (98 g) of H_2SO_4 in water and dilution to exactly (1 L).

$$\{\ Molarity(M) = \frac{No.of\ moles}{Vol.(\ L)} = \frac{1\ mole}{1\ L} = 1M\ \}$$

* **Example:** Describe the preparation of (2 liter) of (0.18 M) $BaCl_2$ from $BaCl_2.2H_2O$ (244.3 g/mole) .

Solution:

$BaCl_2.2H_2O \rightarrow BaCl_2 + 2H_2O$
1mole 1mole 2mole

Each (1mole $BaCl_2.2H_2O$) gives (1 mole $BaCl_2$).
for 2 liter solution we have

No. of moles $=\frac{weight\ (g)}{M.wt}$ ……….(1)

Molarity(M) = $\frac{\textbf{No.of moles}}{\textbf{volume(L)}}$

No. of moles = molarity M x volume (L)………(2)

$\frac{weight\ (g)}{M.wt}$ = molarity M x volume(L)

Weight (g) = molarity M x volume(L) x M.wt

Weight of $BaCl_2.2H_2O$(g) = 0.18 x 2 x 244.3 = 87.95 g $BaCl_2.2H_2O$
The solution is prepared by dissolving 87.95gm $BaCl_2.2H_2O$ in water and complete the volume to 2 L

<u>Example</u>:

Describe the preparation of 500 mL of 0.0740 M Cl^- solution from solid $BaCl_2$ (208 g/mole).

<u>Solution:</u>

$BaCl_2 \rightarrow Ba^{2+} + 2\ Cl^-$

1 mole 2 moles

No of moles = Molarity (mole / liter) x Volume (Liters)

moles Cl^- = 0.0740 x 0.5 = 0.037 moles Cl^-

No.of moles $BaCl_2$ needed = $\frac{1}{2}$ (No. of moles of Cl^-)

No .moles $BaCl_2$ needed = $\frac{0.037}{2}$ = 0.0185 mole weight of $BaCl_2$ = No. of moles $BaCl_2$ x M.wt

weight of $BaCl_2$ = 0.0185 x 208 = 3.85 grams

Then the required solution is prepared by dissolving 3.85 g of $BaCl_2$ in water and dilute to 0.5 L (500 mL).

Example:
Calculate the number of molecules (particles) of NaCl (58.5 g/mole) present in 1liter of 0.1 M solution.
solution:
Each 1 mole contains Avogadro's number (6.022×10^{23}) of molecules then

No. of moles = Molarity(M) x V(liter) = 0.1 x 1= 0.1 mole

$$\text{No. of moles} = \frac{No.of\ molecules}{6.02 \times 10^{23}}$$

No. of molecules = No. of moles x 6.02×10^{23} = 0.1 x 6.02×10^{23}
No. of molecules = 6.02×10^{22} molecules

Conversion to molarity:

$$\textbf{Molarity (M)} = \frac{\left(\frac{w}{V}\right)\% \times 10}{M.wt}$$

Example:

Calculate the Molarity of the solution that is 20(w/v)% of KCl (74.5 g /mole) ?

solution:

$$\text{Molarity(M)} = \frac{\left(\frac{W}{V}\right)\% \times 10}{M.wt}$$

$$\textbf{Molarity(M)} = \frac{20 \times 10}{74.5} = 2.68\ M$$

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Checking by using $\mathbf{Molarity(M)} = \frac{\mathbf{wt_{(g)}\ x\ 1000}}{\mathbf{M.wt\ x\ V_{mL}}}$

$$\mathbf{Molarity(M)} = \frac{\mathbf{20_{(g)}\ x\ 1000}}{\mathbf{74.5\ x\ 100_{mL}}} = \mathbf{2.68\ M}$$

Conversions:

1.Molarity to m mole/ L

Molarity(M) x 1000 = m mol/L

2. Molarity to mg/dL

mg/dL = m mol/L x $\left(\frac{\text{Mwt}}{10}\right)$

Then C (mg/dL) = $\frac{\boldsymbol{Molarity(M)\ x\ 1000\ x\ M.wt}}{\mathbf{10}}$

C(mg/dL) = Molarity(M) x M.wt x100

3. $\left(\frac{\mathbf{w}}{\mathbf{v}}\right)$ **% to mg/dL**

as $\mathbf{Molarity(M)} = \frac{\left(\frac{\mathbf{w}}{\mathbf{v}}\right)\%\ \mathbf{x10}}{\mathbf{M.wt}}$

Then C(mg/dL) = $\frac{\left(\frac{\mathbf{w}}{\mathbf{v}}\right)\%\ \mathbf{x10}}{\mathbf{M.wt}}$ **x M.wt x100**

C (mg/dL) = $\left(\frac{\mathbf{w}}{\mathbf{v}}\right)\%\ \mathbf{x1000}$

Example

A solution of heparin sodium, an anticoagulant for blood, contains 1.8 g of heparin sodium dissolved to make a final volume of 15 mL of solution. What is the concentration of this solution in $(\frac{w}{V})\%$ and in mg/dL ?

SOLUTION

$$(\frac{w}{V})\% = \frac{weight\ of\ solute(g)}{volume\ of\ solution(mL)} \text{ x } 100\%$$

$$(\frac{w}{V})\% = \frac{weight\ of\ heparin(g)}{volume\ of\ solution(mL)} \text{ x } 100\%$$

$$(\frac{w}{V})\% = \frac{1.8\ (g)}{15(mL)} \text{ x } 100\% = 12\%$$

$$\left(\frac{w}{V}\right)\% \text{ x1000= mg /dL}$$

12 x 1000 = 12000 mg / dL

Exercises:

1.Which of the following contains the largest number of molecules :

a) 66g of CO_2 (44 g/mole)

b) 80 g of NaOH (40 g/mole)

c) 32 g of CH_3OH (32 g/mole)

2. Describe the preparation of 500 mL of 0.0740 M Cl^- aqueous solution from solid $CaCl_2.2H_2O$ (147 g/mole).

3. Calculate the weight in grams of solid K_2SO_4 (174.26 g/mole) required to prepare 500 mL of 0.04 M aqueous solution of K^+ .