ALMUSTAQBAL UNIVERSITY

College of Health and Medical Techniques

Medical Laboratories Techniques Department

Stage : First year students

Subject : General Chemistry 1 - Lecture 3A

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Methods of expressing concentrations-

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:

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

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:

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

Solid glucose → **Dissolved glucose**

Concentration:

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 ($\frac{w}{w}$) % = $\frac{weight\ of\ solute}{weight\ of\ solution}$ x 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 sugar mass dissolved in 25 g of a 10 % dextrose solution?

Solution:

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

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

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

Exercise:
A metal alloy contains 15.8% nickel (w/w)%. What mass of the metal alloy would contain 36.5 g of nickel?

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% solution of a perfume usually describes a solution prepared by diluting 5 mL of perfume with enough solvent(ethanol)to give 100 mL of solution.

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

Then the vinegar solution is prepared by dissolving 37.5 mL of acetic acid in water and completing the volume to 500 mL

③weight/volume percent $\left(\frac{w}{v}\right)\%$

weight/volume percent $\left(\frac{w}{v}\right)\%$ **=** $\frac{weight\ of\ solute(gm)}{volume\ of\ solution(\ mL)}$ **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 sodium chloride solution prepared by dissolving 5 g of NaCl in water and completing the volume to 250 mL.

Answer:

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

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

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 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 $C_6H_{12}O_6$:

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

$$M_{C_6H_{12}O_6} = 6\ x 12.0 + 12\ x\ 1.0 + 6\ x\ 16.0 = 180 \text{ g /mole}$$

Important Relations:-

Molar mass(M.wt) units are g /mole or mg /mmole

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

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

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

Example:

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:

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

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 $\text{Na}^+ (n_{\text{Na}^+})$= Number of moles Na_2SO_4 x 2

No. of moles of $\text{Na}^+ (n_{\text{Na}^+})$= 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

NaCl $\longrightarrow$ Na^+ + Cl^-

1 mole 1 mole

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

Na_3PO_4 $\longrightarrow$ $3Na^+$ + PO_4^{3-} (1 moleNa_3PO_4 $\longrightarrow$ 3molesNa^+)

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.

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

Molarity calculations:

$$\text{Molarity}(M) = \frac{\text{No.of moles}}{\text{volume(L)}} = \frac{\frac{wt_{(g)}}{M.wt}}{V_L}$$

$$\text{Molarity}(M) = \frac{wt_{(g)}}{M.wt \times V_L}$$

$$V_L = \frac{V_{mL}}{1000}$$

$$\text{Molarity}(M) = \frac{wt_{(g)}}{M.wt \times \frac{VmL}{1000}}$$

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

<u>Example:</u> 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?

<u>Solution:</u>

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

Or

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

Example:

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

Solution:

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

$$\textbf{V(mL)} = \frac{\textbf{wt}_{(g)}\ \textbf{x 1000}}{\textbf{M.wt x Molarity(M)}} = \frac{\textbf{7.3 x 1000}}{\textbf{36.5 x 12}} = 16.7\ \text{mL}$$

Preaparation of molar solutions

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

For example, a sulfuric acid(98 g/mole) solution with an analytical concentration of (1 M) can be prepared by dissolving (1 mole) or (98 g) of H_2SO_4 in water and diluting to exactly (1 L).

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

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

Solution:

$BaCl_2.2H_2O$ → $BaCl_2$ + $2H_2O$
1mole 1mole 2mole

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

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

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 diluting it to 0.5 L (500 mL).

Example:
Calculate the number of molecules (particles) of NaCl (58.5 g/mole) present in 1 litre 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:

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

Example:

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

solution:

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

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

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

$$\textbf{Molarity(M)} = \frac{20_{(g)} \times 1000}{74.5 \times 100_{mL}} = 2.68\ \text{M}$$

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**

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

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

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

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

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

$$\left(\frac{w}{V}\right)\% \text{ x } 1000 = \text{mg /dL}$$

12 x 1000 = 12000 mg / dL

Example:

How many grams of NaCl are needed to prepare 250 mL of a 1.5% (w/v) saline solution?

SOLUTION

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

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

$$\text{Weight of solute (g)} = \frac{(250)ml\ x\ (1.5)\%}{100} = 3.75 \text{ g NaCl}$$

Exercises:

1. **What mass of glucose is** needed to prepare 125 mL of 16% (w/v) glucose ($C_6H_{12}O_6$) solution?

2. **What is the** Volume of aqueous solution needed to prepare a 2 % (w/v) KCl solution from 1.20 g KCl.?
3. Calculate the concentration in $(\frac{w}{V})\%$ of the solution of 8.6 mg/dl of Ca^{2+}

4. 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)

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

6. 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^+.