ALMUSTAQBAL UNIVERSITY COLLEGE

Biomedical Engineering Department

Stage : Second year students

Subject : Chemistry 1 - Lecture 4

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Methods of expressing concentrations:

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

1) **Chemical units : equivalent mass - Molar mass(mole).**
2) **Physical units : mass – volume**

1. 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 (M.wt) = $\sum \textbf{atomic molar mass}$

Example :- The molar mass for formaldhyde CH_2O is :

$$M.wt_{CH_2O} = \sum(1 mole\ carbon + 2 mole\ hydrogen + 1 mole\ oxygen) atom$$

$$M.wt_{CH_2O} = 1\ x\ 12\ g + 2\ x\ 1.0\ g + 1\ x\ 16.0\ g$$

$= 30.0\ g\ /mole\ of$ CH_2O

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

$$M.wt\ _{C_6H_{12}O_6} = \sum(6mole\ carbon + 12mole\ hydrogen + 6mole\ oxygen)$$

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

Important Relations:

M.wt is expressed by **g /mole** or mg /mmole

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

Mole $=10^3$mmole , m mole $=\frac{1}{1000}$ mole $= 10^{-3}$mole

Example: How many grams of Na^+ (M.wt =22.99 g /mol) are contained in

(25.0 g) of Na_2SO_4 (M.wt = 142.0 g /mol)?

Solution:

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

1mole **2mole** **1mole**

$$n_{Na_2SO_4} = \frac{\text{Wt}_{(g)}Na_2SO_4}{\text{M. Wt}_{(g)}Na_2SO_4} = \frac{25.0}{142.0} = 0.176 \text{ moles of } Na_2SO_4$$

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^+

Mass (g) = No. of moles x molar mass(g/ mol)

mass Na^+(g) = moles Na^+ x 22.99(g) Na^+

mass Na^+ (g) = 0.352 x 22.99 = 8.10 (g) Na^+

e.g 1:

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**

e.g 2:

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 mole **3 mole**

Exercise: How many grams of Na^+ (22.99 g /mol) are contained in

25.0 g of Na_3PO_4 (164 g /mol)?

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(M): Number of moles of solute per liter of solution

or

number of m moles of solute per milliter of solution.

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

Or

$$\text{Molarity(M)} = \frac{\text{number of mmole of solute}}{\text{volume of solution(mL)}}$$

Example:

What is (C_{NaCl}) the concentration of NaCl(58.5g/mol) in grams per milliliter(g/mL) for its 0.25 M aqueous solution?

Solution:

0.25 M =0.25 mol/L ≡ 0.25 mmol/mL = 0.25 x 10^{-3} mole / mL

C_{NaCl} in (g/mL) = 0.25 x 10^{-3} mole / mL x M.wt (g/ mol) = g / mL

C_{NaCl} in (g/mL) = 0.25 x 10^{-3} mole / mL × 58.5 g/mol = 0.0146 g/mL

Example :

Calculate(C_{K+}) the concentration of potassium ion (39.1 g/mol) in grams per liter for a 0.3 M aqueous solution of KCl (potassium chloride).

Solution:

$KCl \rightarrow K^+ + Cl^-$

0.3 M KCl = 0.3 mol/ L KCl = 0.3 mol/ L K^+

Each mol of K^+ = 39.1 g = M.wt

Then C_{K+} in g/Liter = 0.3 mol/liter x 39.1 g /mol = 11.7 g / liter

Molarity(M) Calculations:

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

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

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

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

Example: **Calculate the molar concentration of KNO_3 aqueous solution that contains (2.02 g) of KNO_3 (M.wt =101 g /mole) in (2.0 L) of solution.**

Solution:

$$\text{Molarity(M)} = \frac{wt_{(g)}}{M.wt \times V_L} = \frac{2.02_{(g)}}{101 \times 2.0\ L} = 0.10\ M$$

or

$$\text{Molarity(M)} = \frac{wt_{(g)} \times 1000}{M.wt \times V_{mL}} = \frac{2.02_{(g)} \times 1000}{101 \times 2000\ mL} = 0.10\ M$$

Preaparation of molar solutions

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

e.g: a sulfuric acid(98 g/mol) solution that has an analytical concentration of (1.0M) can be prepared by dissolving (1.0 mole) or (98 g) of H_2SO_4 in water and dilution to exactly (1.0 L). $\{ \text{Molarity(M)} = \frac{1\ mole}{1\ L} = 1M \}$

Example: **Describe the preparation of (2.00 liter) of (0.18 M) aqueous solution of $BaCl_2$ from solid $BaCl_2.2H_2O$ (244.3gm/mole) .**

Solution:

$$\underset{1mole}{BaCl_2.2H_2O} \rightarrow \underset{1mole}{BaCl_2} + \underset{2mole}{2H_2O}$$

Each (1mole $BaCl_2.2H_2O$) gives (1 mole $BaCl_2$).

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

No. moles = molarity M x volume (L)

for 2 liter of 0.18 M $BaCl_2$ solution we have

No. moles $BaCl_2$ in Solution = $0.18 \text{ mole } \frac{BaCl_2}{L} \text{x } 2.00 \text{ L} = 0.36\text{mole } (BaCl_2)$

Then No .moles $BaCl_2.2H_2O$ needed = No. moles $BaCl_2$ = 0.36 moles

Mass (g) = No.of moles x molar mass (g/mol)

The mass of ($BaCl_2.2H_2O$) = 0.36mole x 244.3 gm/mol = 87.95 gm $BaCl_2.2H_2O$

The solution is prepared by dissolving 87.95gm of $BaCl_2.2H_2O$ in water and complete the volume to 2.00 L

<u>Example</u>:

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

<u>Solution:</u>

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

1 mole 2 moles

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

$V_L = \frac{V_{mL}}{1000} = \frac{500}{1000} = 0.5 \text{ L}$

moles Cl^- = 0.0740 mol Cl^- / L x 0.5L = 0.037 moles Cl^-

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

No .moles $BaCl_2$ needed = $\frac{0.037}{2}$ **= 0.0185 mol**

mass $BaCl_2$ = moles $BaCl_2$ x Mwt (208)

mass $BaCl_2$ = 0.0185 x 208 = 3.848 g

Then the required solution is prepared by dissolving 3.848 g of $BaCl_2$ in water and dilute to 0.500 L (500 mL).

Example:

Calculate the number of molecules (particles) of NaCl (58.5 g/mol) present in 1liter of 0.1 M solution.

Answer:

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 $6.02 \times 10^{23} = 0.1 \times 6.02 \times 10^{23}$

No. of molecules = 6.02×10^{22} molecules

Exercises:

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

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

3.Calculate the weight in grams of solid NaCl (58.5 g/mol) required to prepare 250 mL of 0.04 M aqueous solution of Na^+ .

4. Describe the preparation of 700 mL of 0.0740 M Cl^- solution from solid $BaCl_2$ (208 g/mol).