

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 .

$$\text{Molar mass (M.wt)} = \sum \textit{atomic molar mass}$$

Example :- The molar mass for formaldehyde CH_2O is :

$$M. wt_{\text{CH}_2\text{O}} = \sum (1 \textit{mole carbon} + 2 \textit{mole hydrogen} + 1 \textit{mole oxygen}) \textit{atom}$$

$$M. wt_{\text{CH}_2\text{O}} = 1 \times 12 \textit{ g} + 2 \times 1.0 \textit{ g} + 1 \times 16.0 \textit{ g}$$

$$= 30.0 \text{ g /mole of } \text{CH}_2\text{O}$$

Example :- Molar mass of glucose $\text{C}_6\text{H}_{12}\text{O}_6$:

$$M. wt_{\text{C}_6\text{H}_{12}\text{O}_6} = \sum (6\text{mole carbon} + 12\text{mole hydrogen} + 6\text{mole oxygen})$$

$$M. wt_{\text{C}_6\text{H}_{12}\text{O}_6} = 6 \times 12.0 + 12 \times 1.0 + 6 \times 16.0 = 180 \text{ g /mole}$$

Important Relations:

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

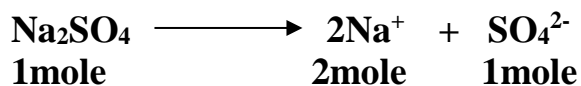
$$\text{No. moles}(n) = \frac{\text{wt}(\text{g})}{\text{M. wt}(\text{g})}$$

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

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:



$$n_{\text{Na}_2\text{SO}_4} = \frac{\text{Wt}(\text{g})\text{Na}_2\text{SO}_4}{\text{M. Wt}(\text{g})\text{Na}_2\text{SO}_4} = \frac{25.0}{142.0} = 0.176 \text{ moles of } \text{Na}_2\text{SO}_4$$

$$n_{\text{Na}^+} = \text{Number of moles } \text{Na}_2\text{SO}_4 \times 2 = \text{No. of moles of } \text{Na}^+$$

$$n_{\text{Na}^+} = 0.176 \times 2 = 0.352 \text{ moles } \text{Na}^+$$

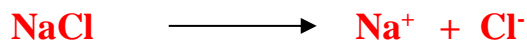
$$\text{Mass (g)} = \text{No. of moles} \times \text{molar mass}(\text{g/ mol})$$

$$\text{mass } \text{Na}^+(\text{g}) = \text{moles } \text{Na}^+ \times 22.99(\text{g}) \text{Na}^+$$

$$\text{mass } \text{Na}^+(\text{g}) = 0.352 \times 22.99 = 8.10 \text{ (g) } \text{Na}^+$$

e.g 1:

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



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



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 $\text{K}_2\text{SO}_4 = ?$
2. No. of moles of K^+ (n_{K^+}) in $\text{KNO}_3 = ?$
3. No. of moles of Mg^{2+} ($n_{\text{Mg}^{2+}}$) in $\text{MgSO}_4 = ?$
4. No. of moles of Fe^{3+} ($n_{\text{Fe}^{3+}}$) in $\text{FeCl}_3 = ?$
5. No. of moles of Cl^- (n_{Cl^-}) in $\text{FeCl}_3 = ?$

Molar concentration (M):

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

or

number of mmoles of solute per milliliter 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:

$$0.25 \text{ M} = 0.25 \text{ mol/L} \equiv 0.25 \text{ mmol/mL} = 0.25 \times 10^{-3} \text{ mole / mL}$$

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

$$C_{\text{NaCl}} \text{ in (g/mL)} = 0.25 \times 10^{-3} \text{ mole / mL} \times 58.5 \text{ g/mol} = 0.0146 \text{ g/mL}$$

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:



$$0.3 \text{ M KCl} = 0.3 \text{ mol/ L KCl} = 0.3 \text{ mol/ L K}^+$$

$$\text{Each mol of K}^+ = 39.1 \text{ g} = \text{M.wt}$$

$$\text{Then } C_{\text{K}^+} \text{ in g/Liter} = 0.3 \text{ mol/liter} \times 39.1 \text{ g /mol} = 11.7 \text{ g / liter}$$

Molarity(M) Calculations:

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

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

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

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

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:

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

or

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

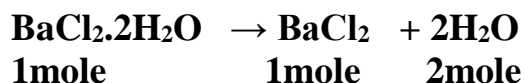
Preparation of molar solutions

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/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). **{ Molarity(M) = $\frac{1 \text{ mole}}{1 \text{ L}} = 1\text{M}$ }**

Example: Describe the preparation of (2.00 liter) of (0.18 M) aqueous solution of BaCl_2 from solid $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$ (244.3gm/mole) .

Solution:



Each (1mole $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$) gives (1 mole BaCl_2).

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

No. moles = molarity M x volume (L)

for 2 liter of 0.18 M BaCl₂ solution we have

$$\text{No. moles BaCl}_2 \text{ in Solution} = 0.18 \text{ mole} \frac{\text{BaCl}_2}{\text{L}} \times 2.00 \text{ L} = 0.36 \text{ mole (BaCl}_2\text{)}$$

Then No. moles BaCl₂.2H₂O needed = No. moles BaCl₂ = 0.36 moles

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

$$\text{The mass of (BaCl}_2\text{.2H}_2\text{O)} = 0.36 \text{ mole} \times 244.3 \text{ gm/mol} = 87.95 \text{ gm BaCl}_2\text{.2H}_2\text{O}$$

The solution is prepared by dissolving 87.95 gm of BaCl₂.2H₂O in water and complete the volume to 2.00 L

Example:

Describe the preparation of 500 mL of 0.0740 M Cl⁻ solution from solid BaCl₂ (208 g/mol).

Solution:



1 mole

2 moles

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

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

$$\text{moles Cl}^- = 0.0740 \text{ mol Cl}^- / \text{L} \times 0.5 \text{ L} = 0.037 \text{ moles Cl}^-$$

$$\text{No. moles BaCl}_2 \text{ needed} = \frac{1}{2} \text{ (No. of moles of Cl}^- \text{)}$$

$$\text{No. moles BaCl}_2 \text{ needed} = \frac{0.037}{2} = 0.0185 \text{ mol}$$

$$\text{mass BaCl}_2 = \text{moles BaCl}_2 \times \text{Mwt (208)}$$

$$\text{mass BaCl}_2 = 0.0185 \times 208 = 3.848 \text{ g}$$

Then the required solution is prepared by dissolving 3.848 g of BaCl₂ 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 1 liter 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)= $0.1 \times 1 = 0.1$ mole

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

$$\text{No. of molecules} = \text{No. of moles} \times 6.02 \times 10^{23} = 0.1 \times 6.02 \times 10^{23}$$

$$\text{No. of molecules} = 6.02 \times 10^{22} \text{ molecules}$$

Exercises:

1. Describe the preparation of 500 mL of 0.0740 M Cl⁻ aqueous solution from solid CaCl₂.2H₂O (147 g/mol).

2. Calculate the weight in grams of solid K₂SO₄ (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 BaCl₂ (208 g/mol).