

ALMUSTAQBAL UNIVERSITY COLLEGE

Medical Laboratories Techniques Department

Stage : First year students

Subject : General chemistry – Part A - Lecture 2

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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 (6.023×10^{23}) of particles(molecules, atoms or ions) represented by that formula .

Avogadro's number is the number of atoms in 1 mole of an element or number of ions in 1 mole of the ionic form or number of molecules in 1 mole of a molecules .

1 mole of an element contains Avogadro's number (6.023×10^{23}) of atoms

1 mole of ions contains Avogadro's number (6.023×10^{23}) of ions .

1 mole of molecules contains Avogadro's number (6.023×10^{23}) of molecules.

Example:

Calculate the number of moles of 3.01×10^{25} water molecules.

Solution:

$$\text{Number of moles} = \frac{\text{number of molecules}}{\text{Avogadro's number}}$$

$$\text{Number of moles of H}_2\text{O} = \frac{3.01 \times 10^{25}}{6.023 \times 10^{23}} = 50 \text{ moles}$$

Example:

Calculate the number of molecules in 0.02 mole of CO_2 .

Solution:

Number of molecules = number of moles \times Avogadro's number

$$\text{Number of molecules} = 0.02 \times 6.023 \times 10^{23} = 1.2 \times 10^{22} \text{ CO}_2 \text{ molecules}$$

Exercise :

Calculate the number of moles of each of the following.

a) 3.01×10^{23} N_2 molecules

b) 4.82×10^{24} iron atoms

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

$\text{Molar mass (M.wt)} = \sum \text{atomic molar mass}$
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Example :- The molar mass for formaldehyde CH_2O is : (C=12,H=1,O=16)

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

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

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

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

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

$$M. wt_{C_6H_{12}O_6} = 6 \times 12.0 + 12 \times 1.0 + 6 \times 16.0 = 180 \text{ g/mole}$$

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

Example :- Molar mass of $Na_2SO_4 \cdot 7H_2O$: (Na = 23, S=32, O=16, H=1)

$$Mwt(Na_2SO_4 \cdot 7H_2O) = \sum (2 \text{ mole Na} + 1 \text{ mole S} + 4 \text{ mole O}) + 7(2 \text{ mol H} + 1 \text{ mol O})$$

$$M. wt (Na_2SO_4 \cdot 7H_2O) = (2 \times 23) + (1 \times 32) + (4 \times 16) + 7(2 \times 1 + 1 \times 16) = 268 \text{ g/mol}$$

Important Relations:

The Molar mass (**M.wt**) is expressed by **g/mole** or **mg/mmole**

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

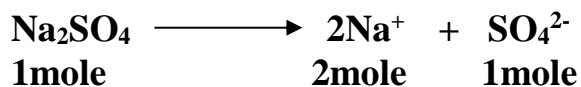
$$\text{Mole} = 10^3 \text{ mmole} \quad , \quad \text{m mole} = \frac{1}{1000} \text{ mole} = 10^{-3} \text{ mole}$$

Exercise :

- What is the mass of 0.04 mole of N_2 (28 g/mol) ?
- What is the number of moles in 5.6 g of PCl_5 (208 g/mol)?
- Calculate the molar mass of the gas which has 22.54 g in 0.23 mole.

Example: How many grams of Na^+ (M.wt = 23 g/mol) are contained in (25.0 g) of Na_2SO_4 (M.wt = 142.0 g/mol)?

Solution:



$$\text{No. of moles } (n_{\text{Na}_2\text{SO}_4}) = \frac{\text{Wt}_{(g)}\text{Na}_2\text{SO}_4}{\text{M. Wt}_{(g)}\text{Na}_2\text{SO}_4} = \frac{25.0}{142.0} = 0.176 \text{ moles of Na}_2\text{SO}_4$$

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

$$\text{No. of moles of Na}^+ = \frac{\text{mass of Na}_2\text{SO}_4}{\text{Molar mass of Na}_2\text{SO}_4} \times \text{No. of Na atoms in Na}_2\text{SO}_4$$

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

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

$$\text{mass Na}^+ (\text{g}) = 0.352 \times 23 = 8.10 (\text{g}) \text{ Na}^+$$

or

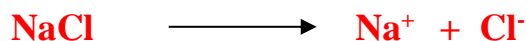
$$\text{mass of Na}^+ = \frac{\text{mass of Na}_2\text{SO}_4}{\text{Molar mass of Na}_2\text{SO}_4} \times \text{No. of Na atoms} \times \text{molar mass of Na}$$

$$\text{mass of Na}^+ = \frac{25 \text{ g}}{142 \text{ g/mol}} \times 2 \text{ Na}^+ \text{ atoms} \times 23 \text{ g/mol} = 8.10 \text{ g}$$

$$\text{Mass of Element (g)} = \frac{\text{mass of compound (g)}}{\text{Molar mass of compound } (\frac{\text{g}}{\text{mol}})} \times \text{No. of atoms} \times \text{molar mass of atom}$$

Examples;

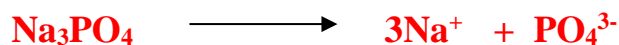
1. No. of moles of Na^+ (n_{Na^+}) in NaCl is = 1 x No. of moles of NaCl



1 mole

1 mole

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



1 mole

3 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+} ($n_{Fe^{3+}}$) in $FeCl_3 = ?$
5. No. of moles of Cl^- (n_{Cl^-}) in $FeCl_3 = ?$

Exercises:

1. Find out the mass of Ca (40 g/mol) in 20 g of $Ca_3(PO_4)_2$ (310 g/mol).
2. Calculate the mass of Na (23 g/mol) in 25 g of $Na_2CO_3 \cdot 10H_2O$. (286 g/mol)
3. Calculate the mass of Na (23 g/mol) in 25 g of Na_2CO_3 (106 g/mol)

Molar concentration (M):

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

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

or

Number of millimoles (m moles) of solute per milliter (mL) of solution.

Or

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

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

Example:

What is (C_{NaCl}) the concentration of NaCl(58.5 g/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:

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

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

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

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

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:

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

or

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

Analytical Molarity: 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).

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

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

$$\text{moles Cl}^- = 0.074 \text{ mol Cl}^- / \text{L} \times 0.5\text{L} = 0.037 \text{ moles Cl}^-$$

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

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

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

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

Then the required solution is prepared by dissolving 3.848 g of BaCl₂ in water and dilute to 0.500 L (500 mL).

Exercises:

1. Calculate the molarity of a solution prepared by dissolving 2.3 g of ethanol (C₂H₆O) (46 g/mol) in 3.5L of distilled water.
2. What is the mass of chloride [Cl⁻](35.5 g / mol) present in NaCl (58.8 g/mol) solution prepared by dissolving 4.39 g of salt in distilled water to get a solution of 250 mL?
3. Describe the preparation of 500 mL of 0.0740 M Cl⁻ aqueous solution from solid CaCl₂·2H₂O (147 g/mol).
4. Calculate the weight in grams of solid CaCl₂ (111 g/mol) required to prepare 250 mL of 0.04 M aqueous solution of Ca²⁺ .
5. 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⁺ .
6. Describe the preparation of 700 mL of 0.0740 M Cl⁻ solution from solid BaCl₂ (208 g/mol).