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:

Number of moles = $\frac{\text{number of molecules}}{Avogadros\ \ number}$

Number of moles of H_2O = $\frac{3.01\text{x}10^{25}}{6.023\text{ x }10^{23}}$ = 50 moles

Example:
Calculate the number of molecules in 0.02 mole of CO_2.

Solution:

Number of molecules = number of moles x Avogadro's number
Number of molecules = $0.02 \times 6.023 \times 10^{23}$ = 1.2×10^{22} CO_2 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 .

Molar mass (M.wt) = $\sum$ *atomic molar mass*

Example :- The molar mass for formaldhyde CH_2O is : (C=12,H=1,O=16)

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

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

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

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

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

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

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

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

$$\text{Mwt}(\text{Na}_2\text{SO}_4\,.7\text{H2O}) = \sum(2mole\ Na + 1mole\ S + 4mole\ O) + 7(2mol\ H + 1mol\ O)$$

M.wt ($Na_2SO_4 . 7H_2O$) = (2×23) + (1×32) + (4×16) + 7(2×1+1×16) = 268 g/mol

Important Relations:

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

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

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

Exercise :

a) What is the mass of 0.04 mole of N_2 (28 g/mol) ?
b) What is the number of moles in 5.6 g of PCl_5 (208 g/mol)?
c) 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:

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

1mole 2mole 1mole

$$No.of\ moles\ (n_{Na_2SO_4}) = \frac{\text{Wt}_{(g)} Na_2SO_4}{\text{M.Wt}_{(g)} Na_2SO_4} = \frac{25.0}{142.0} = 0.176 \text{ moles of } Na_2SO_4$$

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

No. of moles of Na+ = $\frac{massof\ Na2SO4}{Molar\ mass\ of\ Na2SO4}$ x No. of Na atoms in Na_2SO_4

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

mass Na^+(g) = No. of moles Na^+ x molar mass of Na^+(g/ mol)

mass Na^+ (g) = 0.352 x 23 = 8.10 (g) Na^+

or

mass of Na^+ = $\frac{massof\ Na2SO4}{Molar\ mass\ of\ Na2SO4}$ x No. of Na atoms x molar mass of Na

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

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

Examples;

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

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

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**

Na_3PO_4 $\longrightarrow$ **$3Na^+$ + PO_4^{3-}**

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_{Fe3+}) 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 $Na_2CO_3.10H_2O$. (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 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:

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

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

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

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

<u>Example:</u> 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.

<u>Solution:</u>

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

or

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

<u>Analytical Molarity</u>: 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 $BaCl_2.2H_2O$ (244.3 g/mole) .

Solution:

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

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

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

No. of moles = molarity M x volume (L)
for 2 liter of 0.18 M $BaCl_2$ solution we have
No. moles $BaCl_2$ in Solution = $0.18 \text{ mole } \frac{BaCl_2}{L} \times 2.00 \text{ L} = 0.36 \text{mole } (BaCl_2)$

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

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

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

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

Example:

Describe the preparation of 500 mL of 0.074 M Cl^- solution from solid $BaCl_2$ (208 g/mol).

Solution:

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

1 mole 2 moles

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

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

moles Cl^- = 0.074 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).

Exercises:

1. **Calculate the molarity of a solution prepared by dissolving 2.3 g of ethanol (C_2H_6O) (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 $CaCl_2.2H_2O$ (147 g/mol).

4. Calculate the weight in grams of solid $CaCl_2$ (111 g/mol) required to prepare 250 mL of 0.04 M aqueous solution of Ca^{2+} .

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 $BaCl_2$ (208 g/mol).