ALMUSTAQBAL UNIVERSITY

College of Health and Medical Techniques
Medical Laboratory Techniques Department

Stage   : First year students
Subject : General Chemistry 1 - Lecture 3

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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.
 when 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 → 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 → $C_6H_{12}O_6(aq)$
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(e.g: 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 $\left(\dfrac{w}{v}\right)$ % concentration of the aqueous sodium chloride solution prepared by dissolving 5 g of NaCl in water and completing the volume to 250 mL.

Answer:

$(\dfrac{w}{v})\% = \dfrac{weight\ of\ solute(g)}{volume\ of\ solution(mL)}$ **x 100%**

$(\dfrac{w}{v})\% = \dfrac{5\ gm}{250\ mL}$ **x 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 $C_6H_{12}O_6$:

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

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

Important Relations:-

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

$$No.\ of\ moles = \frac{wt(_g)}{M.\,wt(_g)}$$

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

Mole $=10^3$mmole   ,   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

$$moles\ of\ Na_2SO_4\ (n_{Na_2SO_4}) = \frac{Wt_{(g)}Na_2SO_4}{M.\,Wt_{(g)}Na_2SO_4} = \frac{25}{142} = 0.176$$

No. of moles of Na^+ (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^+

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^-**
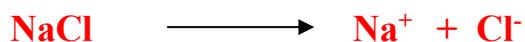
1 mole   **1 mole**

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 $\longrightarrow$ **$3moles Na^+$**)

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.

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

Molarity calculations:

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

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

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

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

Example: 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?

Solution:

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

Or

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

Example:

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

Solution:

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

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

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).

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

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

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

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

Example:

Describe the preparation of (2 liter) of (0.18 M) Ca^{2+} from $CaCl_2$ (111 g/mol).

Solution:

$CaCl_2$ → Ca^{2+} + $2Cl^-$
1mole   1mole   2mole
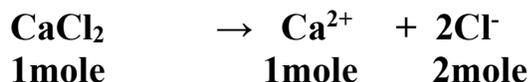
Weight (g) = molarity M x volume(L) x M.wt

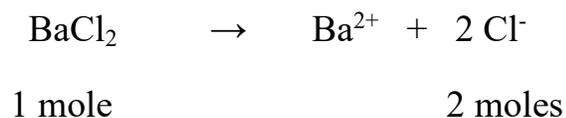Weight of $CaCl_2$ (g) = 0.18 x 2 x 111 = 39.96 g $CaCl_2$
The solution is prepared by dissolving 39.96gm $CaCl_2$ in water and complete the volume to 2 L

Example:

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

Solution:

 $BaCl_2$ → 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

No. of moles = $\dfrac{No.\,of\ molecules}{6.02\ x\ 10^{23}}$

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:

$$\textbf{Molarity (M)} = \frac{\left(\frac{\text{w}}{\text{V}}\right)\%\ \textbf{x10}}{\textbf{M.wt}}$$

Example:

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

solution:

$$\text{Molarity(M)} = \frac{\left(\frac{\text{W}}{\text{V}}\right)\%\ \text{x10}}{\text{M. wt}}$$

$$\textbf{Molarity(M)} = \frac{\textbf{20 x 10}}{\textbf{74.5}} = \textbf{2. 68 M}$$

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

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

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) = $\dfrac{Molarity(M)\ x\ 1000\ x\ M.wt}{10}$

C(mg/dL) = Molarity(M) x M.wt x100

3. $\left(\dfrac{\text{w}}{\text{V}}\right)$ % to mg/dL

as Molarity(M) $= \dfrac{\left(\frac{\text{w}}{\text{V}}\right)\% \ x10}{M.\,wt}$

Then C(mg/dL) $= \dfrac{\left(\frac{\text{w}}{\text{V}}\right)\% \ x10}{M.wt}$ x M.wt x100

C (mg/dL) $= \left(\dfrac{\text{w}}{\text{V}}\right)$ % x1000

1Liter = 10 dL

1 dL = 100 mL

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

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

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

$(\frac{w}{V})\% = \frac{1.8\,(g)}{15\,(mL)} \times 100\% = 12\%$

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

$12 \times 1000 = 12000\,mg\,/\,dL$

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

SOLUTION

$(\frac{w}{V})\% = \frac{weight\,of\,solute\,(g)}{volume\,of\,solution\,(mL)} \times 100\%$

Weight of solute (g) $= \dfrac{(volume\,of\,solution)ml \times (\frac{w}{V})\%}{100}$

Weight of solute (g) $= \dfrac{(250)ml \times (1.5\,)\%}{100}$ = **3.75 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 $CaCl_2$ (111 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^+.