

# ALMUSTAQBAL UNIVERSITY

College of Health and Medical Techniques

Medical Laboratories Techniques Department

Stage : First year students

Subject : General Chemistry 1 - Lecture 3A

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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.

For the cases where the solvent is water, the homogeneous mixture is referred to as an **aqueous solution**.

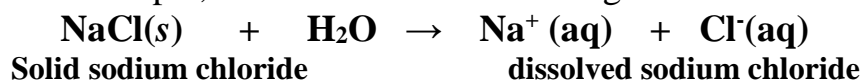
### Electrolytic solutions:

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:



### Nonelectrolytic Solutions:

Are solutions formed from non dissociating *molecular* solutes (non electrolytes), and these solutions are nonconducting.

For example, dissolving Glucose sugar in water:



## 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) %

$$\text{Weight percent } \left( \frac{w}{w} \right) \% = \frac{\text{weight of solute}}{\text{weight of solution}} \times 100 \%$$

**e.g:** Nitric acid (70%) solution, means that it contains (70 g ) of  $\text{HNO}_3$  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:

$$\text{Weight percent } \left( \frac{w}{w} \right) \% = \frac{\text{weight of solute}}{\text{weight of solution}} \times 100 \%$$

$$10 \% = \frac{\text{weight of solute}}{25} \times 100 \%$$

$$\text{Weight of solute ( dextrose sugar)} = \frac{10 \times 25}{100} = 2.5 \text{ g}$$

Exercise:

A metal alloy contains 15.8% nickel (w/w)%. What mass of the metal alloy would contain 36.5 g of nickel?

## ② volume percent (v/v)%

$$\text{Volume percent } \left( \frac{V}{V} \right) \% = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100\%$$

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(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:

$$\text{Volume percent } \left( \frac{V}{V} \right) \% = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100\%$$

$$7.5\% = \frac{\text{volume of acetic acid}}{500 \text{ mL}} \times 100\%$$

$$\text{Volume of acetic acid} = \frac{7.5 \times 500}{100} = 37.5 \text{ mL}$$

**Then the vinegar solution is prepared by dissolving 37.5 mL of acetic acid in water and completing the volume to 500 mL**

## ③ weight/volume percent $\left( \frac{w}{v} \right) \%$

$$\text{weight/volume percent } \left( \frac{w}{v} \right) \% = \frac{\text{weight of solute(gm)}}{\text{volume of solution(mL)}} \times 100\%$$

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  $\text{KNO}_3$  in sufficient amount of water to give (100 mL) of solution .

**Example:**

Calculate the  $\left(\frac{w}{v}\right)\%$  concentration of the aqueous sodium chloride solution prepared by dissolving 5 g of NaCl in water and completing the volume to 250 mL.

**Answer:**

$$\left(\frac{w}{v}\right)\% = \frac{\text{weight of solute}(g)}{\text{volume of solution}(mL)} \times 100\%$$

$$\left(\frac{w}{v}\right)\% = \frac{5\text{ gm}}{250\text{ mL}} \times 100\% = 2\%$$

**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 ( $6.022 \times 10^{23}$ ) 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 .

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

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

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

### **Important Relations:-**

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

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

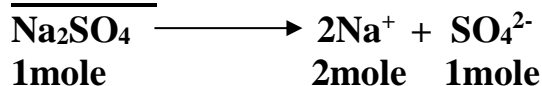
$$\text{Wt (g)} = \text{No. of moles} \times \text{M.wt}$$

$$\text{Mole} = 10^3 \text{mmole}, \quad \text{mmole} = 10^{-3} \text{mole}$$

### **Example:**

How many grams of  $\text{Na}^+$  (M.wt = 22.99 g /mole) are contained in ( 25 g ) of  $\text{Na}_2\text{SO}_4$  (M.wt = 142 g /mole)?

### **Solution:**



$$\text{moles of } Na_2SO_4 (n_{Na_2SO_4}) = \frac{\text{Wt}_{(g)} Na_2SO_4}{\text{M. Wt}_{(g)} Na_2SO_4} = \frac{25}{142} = 0.176$$

$$\text{No. of moles of } Na^+ (n_{Na^+}) = \text{Number of moles } Na_2SO_4 \times 2$$

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

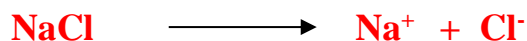
$$\text{Wt (g)} = \text{No. of moles} \times \text{M.wt}$$

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

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

## Hints

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



**1 mole**

**1 mole**

No. of moles of  $\text{Na}^+$  ( $n_{\text{Na}^+}$ ) in  $\text{Na}_3\text{PO}_4$  is = 3 x No. of moles of  $\text{Na}_3\text{PO}_4$  as



## **Exercise:**

How many grams of  $\text{Na}^+$  ( 22.99 g /mole) are contained in 25 g of  $\text{Na}_3\text{PO}_4$  ( 164 g /mole)?

## **Exercise :**

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

## Molar concentration (M):

**Molarity:** Number of moles of solute per liter of solution

Or Number of m moles of solute per milliliter of solution.

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

## Molarity calculations:

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

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

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

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

**Example:** calculate the molar concentration of  $\text{KNO}_3$  aqueous solution that contains (2.02 g ) of  $\text{KNO}_3$  (101 g /mole) in (2 L) of solution?

**Solution:**

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

Or

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

Example:

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

Solution:

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

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

### Preparation of molar solutions

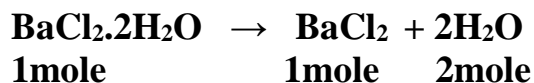
**Molarity** represents the number of moles of solute in one liter of solution or number of mmole in one milliliter .

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<sub>2</sub>SO<sub>4</sub> in water and diluting to exactly (1 L).

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

**\* Example:** Describe the preparation of (2 liter) of (0.18 M) BaCl<sub>2</sub> from BaCl<sub>2</sub>.2H<sub>2</sub>O (244.3 g/mole) .

Solution:



Each (1mole BaCl<sub>2</sub>.2H<sub>2</sub>O) gives ( 1 mole BaCl<sub>2</sub>).  
for 2 liter solution we have

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



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

No. of moles = molarity M x volume (L).....(2)

$$\frac{\text{weight (g)}}{\text{M.wt}} = \text{molarity M} \times \text{volume(L)}$$

$$\text{Weight (g)} = \text{molarity M} \times \text{volume(L)} \times \text{M.wt}$$

Weight of  $\text{BaCl}_2 \cdot 2\text{H}_2\text{O(g)} = 0.18 \times 2 \times 244.3 = 87.95 \text{ g } \text{BaCl}_2 \cdot 2\text{H}_2\text{O}$

The solution is prepared by dissolving 87.95gm  $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$  in water and complete the volume to 2 L

### Example:

Describe the preparation of 500 mL of 0.0740 M  $\text{Cl}^-$  solution from solid  $\text{BaCl}_2$  (208 g/mole).

### Solution:



1 mole

2 moles

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

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

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

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

$$\text{weight of } \text{BaCl}_2 = \text{No. of moles } \text{BaCl}_2 \times \text{M.wt}$$

$$\text{weight of } \text{BaCl}_2 = 0.0185 \times 208 = 3.85 \text{ grams}$$

Then the required solution is prepared by dissolving 3.85 g of  $\text{BaCl}_2$  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 ( $6.022 \times 10^{23}$ ) of molecules then

No. of moles = Molarity(M) x V(liter) =  $0.1 \times 1 = 0.1$  mole

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

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

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

### **Conversion to molarity:**

$$\text{Molarity (M)} = \frac{\left(\frac{w}{V}\right)\% \times 10}{\text{M.wt}}$$

**Example:**

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

**solution:**

$$\text{Molarity(M)} = \frac{\left(\frac{w}{V}\right)\% \times 10}{\text{M. wt}}$$

$$\text{Molarity(M)} = \frac{20 \times 10}{74.5} = 2.68 \text{ M}$$

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

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

## Conversions:

### 1. Molarity to m mole/ L

$$\text{Molarity(M)} \times 1000 = \text{m mol/L}$$

### 2. Molarity to mg/dL

$$\text{mg/dL} = \text{m mol/L} \times \left( \frac{\text{Mwt}}{10} \right)$$

$$\text{Then C (mg/dL)} = \frac{\text{Molarity(M)} \times 1000 \times \text{M.wt}}{10}$$

$$\text{C(mg/dL)} = \text{Molarity(M)} \times \text{M.wt} \times 100$$

### 3. $\left( \frac{w}{v} \right) \%$ to mg/dL

$$\text{as Molarity(M)} = \frac{\left( \frac{w}{v} \right) \% \times 10}{\text{M. wt}}$$

$$\text{Then C(mg/dL)} = \frac{\left( \frac{w}{v} \right) \% \times 10}{\text{M.wt}} \times \text{M.wt} \times 100$$

$$\text{C (mg/dL)} = \left( \frac{w}{v} \right) \% \times 1000$$

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  $\left( \frac{w}{v} \right) \%$  and in mg/dL ?

SOLUTION

$$\left( \frac{w}{v} \right) \% = \frac{\text{weight of solute(g)}}{\text{volume of solution(mL)}} \times 100\%$$

$$\left( \frac{w}{v} \right) \% = \frac{\text{weight of heparin(g)}}{\text{volume of solution(mL)}} \times 100\%$$

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

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

$$12 \times 1000 = 12000 \text{ mg / dL}$$

**Example:**

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

**SOLUTION**

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

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

$$\text{Weight of solute (g)} = \frac{(250)ml \times (1.5)\%}{100} = 3.75 \text{ g NaCl}$$

**Exercises:**

1. What mass of glucose is needed to prepare 125 mL of 16% (w/v) glucose ( $\text{C}_6\text{H}_{12}\text{O}_6$ ) 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  $\left(\frac{w}{V}\right)\%$  of the solution of 8.6 mg/dl of  $\text{Ca}^{2+}$
4. Which of the following contains the largest number of molecules :
  - a) 66g of  $\text{CO}_2$  (44 g/mole)
  - b) 80 g of NaOH (40 g/mole)
  - c) 32 g of  $\text{CH}_3\text{OH}$  (32 g/mole)
5. Describe the preparation of 500 mL of 0.0740 M  $\text{Cl}^-$  aqueous solution from solid  $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$  (147 g/mole).
6. Calculate the weight in grams of solid  $\text{K}_2\text{SO}_4$  (174.26 g/mole) required to prepare 500 mL of 0.04 M aqueous solution of  $\text{K}^+$ .