



**Analytical chemistry**  
**Chemical engineering department**  
**First class / first term**  
**Al-Mustaqbal-college**  
**Lecture one**

**By**  
**Asst. lect. Ban Ali Hassan**

## Lecture one

**Solutions** : Homogenous mixture for two or more substances , one of them called solute and the other one is the solvent .

# The solute is an active substance in reaction and the solvent is active.

# There are many solutions formed by dissolving gasses in liquids like CO<sub>2</sub> in water .

# **Homogenous solution** : A partial homogenous mixing for two or more substances that will not react chemically with each other.

# **Heterogeneous solution** : Represent with suspended and colloidal solution.

# **Aqueous solution** : is the solution in which water is the solvent .

# **Non-aqueous solution** : when the solvent is any substance except water.

### Classification of solutions are depends upon :

**a) nature of molecules (or the volume of atoms or molecules of solute) ,these solutions are :**

- 1) True solution.
- 2) Suspended solution.
- 3) Colloidal solution.

**b) solute concentration in solution , it can be classified into :**

- 1) saturated solution.
- 2) unsaturated solution.
- 3) super saturated solution.

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### Units of weight and concentration:

Concentration of solution : is the weight of solute dissolved in a given amount (volume or weight) of solvent.

### Weight of solute can be expressed by :

- 1) physical units , e.g. gram(g) , milligram(mg) , kilogram(kg).
- 2) chemical units : - includes ,
  - a) g- atomic weight.
  - b) g- molecular weight.
  - c) g- formula weight.
  - d) g- ionic weight.
  - e) g- equivalent weight.

**Mole :** is the summation of the atomic weight in grams for all of the atoms in the chemical formula for the species,.

No. of moles =  $Mw(g)/M.wt(g/m)$

### Methods for the expression of concentration of solutions :

There are several methods for express the concentration of solutions :

- 1) **Molarity (M) :** moles of solute contained in one liter of solution or mol/L or ml.mol/ml
- 2) **Normality (N) :** number of g-equivalent weight of solute that are contained in a liter of solution.

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### General principles to calculate the equivalent weight :

#### a) for acids :

$$\text{eq.wt of acid} = \frac{\text{M.wt of acid}}{\text{no.of H}^+ \text{ active}}$$

There are many types of acids :

- 1) mono basic acid : HCl , HNO<sub>3</sub> , HF, ..... ect.
- 2) di basic acid : H<sub>2</sub>SO<sub>4</sub> , H<sub>2</sub>S , H<sub>2</sub>SO<sub>3</sub>, .....ect.
- 3) tri basic acid : H<sub>3</sub>PO<sub>4</sub>, .....ect.

يعتمد حساب الوزن المكافئ على التفاعل الذي يدخل به المركب الكيميائي ، فقد يحدث ان يفقد الحامض H<sup>+</sup> واحدة اثناء التفاعل لذلك يقسم الوزن الجزيئي على ١ ، او قد يستهلك 2H<sup>+</sup> في التفاعل فيقسم الوزن الجزيئي على ٢ او قد يستهلك 3H<sup>+</sup> فيقسم على ٣ .

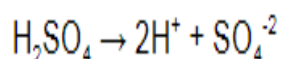
اذن يعتمد الحساب على معادلة التفاعل الكيميائي وكم يستهلك من H<sup>+</sup> في التفاعل

### 1. Sulphuric Acid (H<sub>2</sub>SO<sub>4</sub>)

For acids, X (valency factor) is the basicity

Basicity- basicity is the number of **hydrogen** ions or hydronium ions released by an acid.

In the case of sulphuric acid (H<sub>2</sub>SO<sub>4</sub>)



The number of hydrogen ion released by sulphuric acid is 2. Therefore, its valency factor or X value will be two.

The molecular weight of sulphuric acid is 94.

As we know, Equivalent weight = molecular weight / X

The equivalent weight of sulphuric acid = 98 / 2 = 49

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### b) for base :

$$\text{eq. wt of acid} = \frac{\text{M.wt of base}}{\text{no. of OH- active}}$$



$$\text{eq. wt. of NH}_4\text{OH} = \frac{\text{M.wt of NH}_4\text{OH}}{\text{no. of OH- active}} = \frac{35}{1} = 35$$



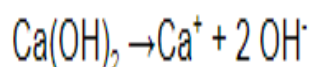
$$\text{eq. wt. of Ca(OH)}_2 = \text{-----}$$

### 1. Calcium Hydroxide $\text{Ca(OH)}_2$

For the base, X (valency factor) is the acidity

Acidity- Acidity is the number of hydroxyl ions or hydroxide ions released by a base.

In the case of calcium hydroxide base  $\text{Ca(OH)}_2$



The number of hydroxyl ions released by the calcium hydroxide base is 2. Therefore, its valency factor or X value will be two.

The molecular weight of the calcium hydroxide base is 74.

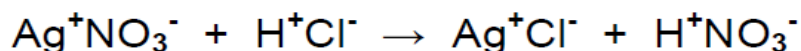
As we know, Equivalent weight = molecular weight / X

The equivalent weight of calcium hydroxide base =  $74 / 2 = 37$

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### d) for salts :

$$\text{eq.wt of salt} = \frac{\text{M.wt of salt}}{\text{No. of positive charge of salt}}$$



$$\text{eq.wt. of } \text{Ag}^+\text{NO}_3^- = \frac{\text{M.wt of Ag+NO}_3^-}{1}$$

$$\text{eq.wt. of } \text{Ag}_2^+\text{O}^{-2} = \frac{\text{M.wt}}{2}$$

$$\text{eq.wt. of } \text{Al}^{+3}\text{PO}_4^{-3} = \frac{\text{M.wt}}{3}$$

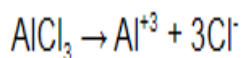
$$\text{eq.wt. of } \text{Ca}_3^{+2}(\text{PO}_4)_2^{-3} = \frac{\text{M.wt}}{6}$$

### 1. Aluminium Chloride

#### Step by Step Calculation for Finding the Equivalent Weight of Aluminium Salts

For the metals, X (valency factor) is the total positive charge on the positive ion (cation).

In the case of aluminium chloride salt  $\text{Al}(\text{Cl})_3$



The number of positive charge on aluminium cation is three. Therefore, its valency factor or X value will be three.

The molecular weight of the calcium hydroxide base is 133.34 g/mol.

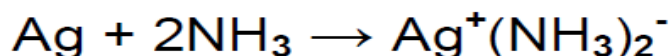
As we know, Equivalent weight = molecular weight / X

The equivalent weight of aluminium chloride salt =  $133.34 / 3 = 44.44$ .

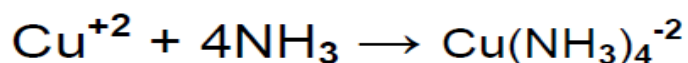
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### f) for complex ion :

$$\text{eq.wt. of complex ion} = \frac{\text{M.wt}}{\text{no.of charges}}$$



$$\text{eq.wt. of } \text{Ag}^+(\text{NH}_3)_2^- = \frac{\text{M.wt}}{1}$$



$$\text{eq.wt. of } \text{Cu}(\text{NH}_3)_4^{-2} = \frac{\text{M.wt}}{2}$$

**Example \ Calculate the molecular weight of the compound :Fe(OH)<sub>3</sub>.12H<sub>2</sub>O**

Atomic mass of iron = 55.85

Atomic mass of oxygen = 16

Hydrogen atomic mass = 1

These atomic masses can be obtained from the periodic table

Molecular weight = the sum of the atomic mass of each element in the molecular formula X the number of its presence in the formula

$$\begin{aligned} \text{Molecular weight of ( Fe(OH)}_3\text{.12H}_2\text{O)} &= 55.58 + (16+1)*3 + 12(1*2+16) \\ &= 373.58 \text{ amu} \end{aligned}$$

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**For example**, the molecular formula for hexane ( $C_6H_{14}$ ). There are 6 carbon atoms and 14 hydrogen atoms in each hexane molecule. The atomic weight of Carbon and Hydrogen can be found in the periodic table.

Carbon atomic weight: 12.01

Hydrogen atomic weight: 1.01

Molecular weight = (number of C carbon atoms) (atomic weight) +  
(number of H atoms) (H atomic weight)

$$\begin{aligned}\text{Molecular weight of hexane} &= (6 \times 12.01) + (14 \times 1.01) \\ &= 72.06 + 14.14 \\ &= 86.20 \text{ amu}\end{aligned}$$

**Example: Find the molecular weight, Mw, of the following molecules:**

$N_2$ , NO,  $C_2H_6$ ,  $N_2O_4$ ,  $C_8H_{18}O_4N_2S$ ,  $CO_2$ ,  $H_2O_2$ ,  
 $Ca(NO_3)_2$ ,  $Al_2(CO_3)_3$ ,  $MgSO_4 \cdot 7H_2O$ ,  $C_8H_{10}N_4O_2$ ,  
 $C_6H_{12}O_6$ ,  $H_2SO_4$ ,  $C_2H_5$  OH,  $Zn(NO_3)_2$ .

Atomic weight: (H = 1, C = 12, N = 14, O = 16, Mg = 24.3, Al = 27, S = 32.1,  
Ca = 40.1, Zn = 65.4)



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$$Mw_{N_2} = (2 \times 14) = 28 \text{ amu}$$

$$Mw_{NO} = (14) + (16) = 30 \text{ amu}$$

$$Mw_{C_3H_6} = (2 \times 12) + (6 \times 1) = 30 \text{ amu}$$

$$Mw_{N_2O_4} = (2 \times 14) + (4 \times 16) = 92 \text{ amu}$$

$$Mw_{C_8H_{18}O_4N_2S} = (8 \times 12) + (18 \times 1) + (4 \times 16) + (2 \times 14) + (32) = 238 \text{ amu}$$

$$Mw_{CO_2} = (12) + (2 \times 16) = 44 \text{ amu}$$

$$Mw_{H_2O_2} = (2 \times 1) + (2 \times 16) = 34 \text{ amu}$$

$$Mw_{Ca(NO_3)_2} = (40.1) + 2((14) + (3 \times 16)) = 164.1 \text{ amu}$$

$$Mw_{Al_2(CO_3)_3} = (2 \times 27) + 3((12) + (3 \times 16)) = 234 \text{ amu}$$

$$Mw_{MgSO_4 \cdot 7H_2O} = (24.3) + (32.1) + (4 \times 16) + 7((2 \times 1) + (16)) = 246.4 \text{ amu}$$

$$Mw_{C_8H_{10}N_4O_2} = (8 \times 12) + (10 \times 1) + (4 \times 14) + (2 \times 16) = 194 \text{ amu}$$

$$Mw_{C_6H_{12}O_6} = (6 \times 12) + (12 \times 1) + (6 \times 16) = 180 \text{ amu}$$

$$Mw_{H_2SO_4} = (2 \times 1) + (32.1) + (4 \times 16) = 98.1 \text{ amu}$$

$$Mw_{C_2H_5OH} = (2 \times 12) + (5 \times 1) + (16) + (1) = 46 \text{ amu}$$

$$Mw_{Zn(NO_3)_2} = (65.4) + 2((14 + 3 \times 16)) = 189.4 \text{ amu}$$

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### Formula Weight ( $F_w$ ) :

It is the sum of the atomic weights of the atoms that make up the formula, and is denoted by the symbol  $F_w$ . The formula weight is used for compounds that exist in the form of ions or molecules in nature, and examples of compounds that contain ions are: Ionic compounds such as table salt (sodium chloride)  $\text{NaCl}$

(هو مجموع الأوزان الذرية للذرات المكونة للصيغة، ويرمز له بالرمز  $F_w$ . ويستخدم وزن الصيغة للمركبات التي توجد على هيئة أيونات أو جزيئات في الطبيعة، ومن الأمثلة على المركبات التي تحتوي على أيونات: المركبات الأيونية مثل مركب ملح الطعام (كلوريد الصوديوم)  $(\text{NaCl})$ )

**Example\ Find the weight of the formula  $F_w$  for the following :**



Atomic Weights: ( $\text{Cl} = 35.5$ ,  $\text{S} = 32$ ,  $\text{Na} = 23$ ,  $\text{O} = 16$ )

$$F_{w\text{NaCl}} = 23 + 35.5 = 58.5$$

$$F_w(\text{Na}_2\text{SO}_4) = (2 \times 23) + 32 + (4 \times 16) = 142$$