Analytical chemistry

Chemical engineering department

First class / first term

Al-Mustaqbal-college

Lecture one

By

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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_2 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 :

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

There are many types of acids :

1) mono basic acid : HCl , HNO_3 , HF, ... ect.
2) di basic acid : H_2SO_4 , H_2S , H_2SO_3, ...ect.
3) tri bacic acid : H_3PO_4, ...ect.

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

اذن يعتمد الحساب على معادلة التفاعل الكيميائي وكم يستهلك من $H+$ في التفاعل .

1. Sulphuric Acid (H_2SO_4)

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_2SO_4)

$H_2SO_4 \rightarrow 2H^+ + SO_4^{-2}$

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

b) for base :

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

$$HCl + NH_4OH \rightarrow NH_4Cl + H_2O$$

$$\text{eq.wt. of } NH_4OH = \frac{\text{M.wt of NH4OH}}{\text{no.of OH- active}} = \frac{35}{1} = 35$$

$$Ca(OH)_2 + H_2SO_4 \rightarrow CaSO_4 + H_2O$$

eq.wt.of $Ca(OH)_2$ = ----------

1. Calcium Hydroxide $Ca(OH)_2$

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 Ca(OH)2

$Ca(OH)_2 \rightarrow Ca^+ + 2\ OH^-$

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 :

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

$$Ag^{+}NO_3^{-} + H^{+}Cl^{-} \rightarrow Ag^{+}Cl^{-} + H^{+}NO_3^{-}$$

$$\text{eq.wt. of } Ag^{+}NO_3^{-} = \frac{\text{M.wt of Ag+NO3}-}{1}$$

$$\text{eq.wt. of } Ag_2^{+}O^{-2} = \frac{\text{M.wt}}{2}$$

$$\text{eq.wt. of } Al^{+3}PO_4^{-3} = \frac{\text{M.wt}}{3}$$

$$\text{eq.wt. of } Ca_3^{+2}(PO_4)_2^{-3} = \frac{\text{M.wt}}{6}$$

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 $Al(Cl)_3$

$AlCl_3 \rightarrow Al^{+3} + 3Cl^{-}$

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 :

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

$$Ag + 2NH_3 \longrightarrow Ag^{+}(NH_3)_2^{-}$$

$$\text{eq.wt. of } Ag^{+}(NH_3)_2^{-} = \frac{\text{M.wt}}{1}$$

$$Cu^{+2} + 4NH_3 \longrightarrow Cu(NH_3)_4^{-2}$$

$$\text{eq.wt. of } Cu(NH_3)_4^{-2} = \frac{\text{M.wt}}{2}$$

Example \ Calculate the molecular weight of the compound :**$Fe(OH)_3.12H_2O$**

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

Molecular weight of ($Fe(OH)_3.12H_2O$) = **55.58 + (16+1)*3 +12(1*2+16)**

= **373.58** amu

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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)

Molecular weight of hexane = **(6 x 12.01) + (14 x 1.01)**
= 72.06 + 14.14
= 86.20 amu

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, $Ca(NO_3)_2$, $Al_2(CO_3)_3$, $MgSO_4.7H_2O$, $C_8H_{10}N_4O_2$, $C_6H_{12}O_6$, 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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$$Mw_{N_2} = (2 \times 14) = 28 \text{ amu}$$

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

$$Mw_{C_2H_6} = (2 \times 12) + (6 \times 1) = 30 \text{ amu}$$

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

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

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

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

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

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

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

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

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

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

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

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

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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 Fw. 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) NaCl

(هو مجموع الأوزان الذرية للذرات المكونة للصيغة، ويرمز له بالرمز Fw. 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) NaCl)

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

NaCl, Na_2SO_4 ?

Atomic Weights: (Cl = 35.5, S = 32, Na = 23, O = 16)

$Fw_{NaCl} = 23 + 35.5 = 58.5$

$Fw\ (Na_2SO_4) = (2 \times 23) + 32 + (4 \times 16) = 142$