CHAPTER I :

BACKGROUND AND GENERAL INFORMATION

CHAPTER N° I: Background and General Information

1-Definitions

1-1-Solution

A solution can be defined as a homogeneous mixture in which the constituents are divided and dispersed within each other at the molecular level. A solution always consists of :

-a solvent (majority constituent),

-one or more solutes.

Liquid solutions (called aqueous solutions when the solvent is water).

Solutes can be :

-an gas: (CO_2 , O_2, N_2, etc.)

-an liquid: HCl, H_2SO_4, ...

-an solid: NaCl, KCl, KOH, NaOH, ...

1-2-Concentration of a species in solution:

A distinction is made between:

1-2-1 Molar concentration, Cn :

The molar concentration of a chemical species in solution C_A is the quantity of this species present in one liter of solution.

$$C_A = n_A/V_{sol} \quad (mol/l)$$

Where: n_A is the quantity of A in solution and V_{sol} is the volume of the solution.

- Preparation of aqueous solutions

Case1: From a solid :

A volume V of a solution containing species X, of molar mass M(x), at concentration [X]= C_X, is to be prepared. We need to determine the mass m(x) of species X to be weighed.

Therefore ;

$$\Rightarrow n(x) = m(x) / M(x)$$

$$C_x = n_x / V_{sol} \Rightarrow Cx = m(x)/M(x) * V_{sol}$$

Example:

Calculate the mass of NaOH needed to prepare 50 mL of a 0.01M solution.

M(NaOH) = 40 g/mol.

Solution:

We have:

$$\Rightarrow n(NaOH) = m(NaOH) / M\ NaOH)$$

$$C_{NaOH} = n_{NaOH} / V_{sol} \Rightarrow C_{NaOH} = m(NaOH) / M(NaOH) * V_{sol}$$

$$m(NaOH) = M(NaOH) \times C(NaOH) \times V_{sol}$$

$$AN: \quad m(NaOH) = 40 \times 50 \times 10^{-3} \times 0{,}01$$

$$\mathbf{m(NaOH) = 2 \times 10^{-2} g} = 0.02\,\boldsymbol{g}$$

Case2: dissolving a gas

V(G) the volume of gas to be dissolved, V the volume of the solution, Vm the molar volume of the gases under the conditions of the experiment, n(G) the quantity of gas and [G] the molar concentration of the gas in the solution.

We have :

$$n_{gaz} = V_{gaz} / Vm \quad (Vm=22.4 \text{ litre})$$

$$C_{gaz} = n_{gaz} / (V\ sol * Vm)$$

$$C_{gaz} = n_{gaz} / (V\ sol * 22.4)$$

Example:

We dissolve 20 cm^3 NH_3 gas in 500 ml of water.

-Calculate the NH_3 concentration ?

Solution:

From the previous expression we can write:

We have:

$$n_{NH3} = V_{NH3} / Vm$$

$$C_{NH3} = n_{NH3} / (V\ sol * Vm)$$

$$C_{NH3} = n_{NH3} / (V\ sol * 22.4)$$

$$AN : C_{NH3} = 20*10^{-3} / (500*10^{-3} * 22.4)$$

$$\mathbf{C_{NH3} = 1.78 * 10^{-3}\ mol/l}$$

Case3: From a liquid compound

A volume V_0 of the stock solution of concentration C_0 is taken and diluted with distilled water to obtain a dilute solution of volume V_1 and desired concentration C_1.

Determining the volume V_0 to be withdrawn

The quantity of solute in volume V_0 is:

$$\mathbf{n(X) = C_0 * V_0}$$

This quantity of matter remains in the solution after dilution. This reflects the conservation of matter:

$$\mathbf{n(X) = C_1 * V_1}$$

And the dilution relation is :

$$\mathbf{C_0 * V_0 = C_1 * V_1}$$

Therefore ; ;

$$\mathbf{V_0 = (C_1 * V_1) / C_0}$$

During dilution, the dilution factor is the ratio of the concentration of the mother solution (initial) to that of the solution obtained (final):

$$\mathbf{F = C_{initial} / C_{final}}$$

Or ;

$$F = C_0 / C_1$$

Example:

Take a volume V0 = 20 mL of an aqueous copper II sulfate solution of concentration $C_0 = 5\times10^{-2}$ mol/L. This volume is introduced into a 0.5L volumetric flask, and then made up to the mark with distilled water.

A-What is the concentration of the solution obtained?

B-Calculate the dilution factor F.

Solution :

A- The concentration of the resulting solution C_1:

We know that the concentration of solution C_1 and that of the stock solution C_0 are linked by the dilution relationship

$$C_0 * V_0 = C_1 * V_1$$

Where V_0 and V_1 denote the initial and final volumes of solution, respectively.

$$C_1 = (C_0 * V_0) / V_1$$

NA : $C_1 = (0.05 * 0.02) / 0.5$

$$C_1 = 2 * 10^{-3} \text{ mol/l}$$

B- Calculation of the dilution factor F:

Recall that ;

$$F = C_0 / C_1$$

$$F = 5*10^{-2} / 2*10^{-3}$$

$$F = 25$$

1-2-2 Mass concentration, Cmass :

This is the ratio of the mass of compound **X** contained in a certain volume of solution divided by that volume of solution. Mass is expressed in **g** and volume is often expressed in **L**.

$$C_{mass} = m(x) / v(sol)$$

Example :

We dissolve 5 g of copper sulfate (**$CuSO_4$**) in 400 mL of water. What is the mass concentration of copper sulfate?

We have: m(CuSO4) = 5g, V= 400 mL

Solution :

$$C_{mass} = m(CuSO4) / v(sol)$$

$$AN: \quad C_{mass} = 5 / (400 * 10^{-3})$$

$$\mathbf{C_{mass} = 12.5\ g/L}$$

1-2-3-Molar concentration (molality) ,Cm :

This corresponds to the quantity of compound **X** per 1 kg of solvent.

$$\mathbf{C_m = n(CuSO4) / m(solvent)(kg)}$$

1-2-4-Normal concentration (Normality) ,C_N :

The normality (or normal concentration) of a solution is the number of gram equivalents of solute contained in one liter of solution.

The unit of normality is the gram equivalent per liter, represented by the symbol C_N :

$$\mathbf{C_N = néq / V\ (sol)}$$

Normality is related to molarity by the equation :

$$\mathbf{C_N = Z * Cn}$$

-How to determine the Z parameter:

*In the case of an acid: **Z** is the number of H^+ protons.

* In the case of a base: **Z** is the number of OH^- ions.

*In the case of a salt: **Z** is the number of cations * their charge.

*In the case of a redox reaction: **Z** is the number of electrons exchanged.

Example :

Compound	HCl	H_2SO_4	H_3PO_4	NaOH	NaCL	Na_2CO_3
Parameter Z	Z=1	Z=2	Z=3	Z=1	Z=1	Z=2

1-3- Volumic mass

The volumic mass of a solution is defined by the ratio of the mass of solution **m** (sol) to the total volume **V** (sol).

$$\varrho(\text{solution}) = m(\text{solution}) / v(\text{solution})$$

1-4- Density

-For a liquid :

Density is the ratio of solution density to water density.

$$d(\text{solution}) = \varrho(\text{solution}) / \varrho(\text{water})$$

-For a gas :

Density is the ratio of gas Volumic mass to air density.

$$d(\text{gas}) = \varrho(\text{gas}) / \varrho(\text{air})$$

When , $d(\text{gas}) = M(\text{gas})/29$

1-5-Percentage or Fraction

1-5-1-Percentage or mass fraction, w(%) :

The mass percentage or mass fraction of a solute $w_x(\%)$ in solution is the quotient of the mass of this solute **m(X)** dissolved in one liter of solution by the mass of one liter of solution **m(sol).**

$$w_x(\%) = (m(X) / m(sol)) * 100$$

Example :

An ammonia solution with density 0.910 and concentration C=12.8 mol/L NH_3. Calculate the mass fraction of water and NH_3. The density of the solution is 0.910.

Knowing that: ϱ (water) = 1 g/cm^3.

Solution :

d (solution) **= 0.910 = ϱ** (solution) /**ϱ** (water)

We have :

$1cm^3 = 1 \text{ ml} = 10^{-3}L$

Wherefore,

ϱ (water) = 1 g/cm^3 => **ϱ** (water) = 1000 g/l.

Then ,

0.910 = ϱ (solution) **/1000**

=> **ϱ** (solution)**= 910 g/L**

If we consider one liter of solution (V(sol) = 1L) it weighs 910 g of solution that's to say: m (sol)=910g

in addition, 1L of solution -----------> n(NH_3)=12,8 mol de NH_3

wherefore ; m(NH_3) = n(NH3) × M(NH_3) = 12,8 × 17 = 217,6 g

=> m(H_2O) = 910 – m(NH_3) = 692,4 g.

Then ;

w_{NH3}(%) = (**m**(NH_3) / **m** (**sol**)) * 100

w_{NH3}(%) = (217.6 / 910 * 100

w_{NH3}(%) =24%

And ;

w_{H2O}(%) = (**m**(H_2O) / **m** (**sol**)) * 100

w_{H2O}(%) = 692.4 / 910.6* 100

w_{H2O}(%) = 76%

1-5-2 Percentage or molar fraction (X) :

The molar fraction of the solute is the ratio of the number of moles of solute n(x) to the total number of moles of solution n (T), where n (T) = n(solvent)+n(solute).

$$X(x) = n(x) / n_{(T)}$$

and ; $$\Sigma X_i = 1$$

Example :

Calculate the molar fraction of glycine in an aqueous solution of molality 14 mol/kg.

From the expression for molality, we can say that 1 kg of solvent (H_2O) contains 14 mol of glycine (**$C_2H_5NO_2$**).

that's to say:

$$n(glycine) = 14 \text{ mol}$$

whit, $$m(H_2O) = 1kg = 1000g$$

First, we calculate the amount of water contained in one kilogram:

$$n(H_2O) = m(H_2O) / M(H_2O) = 1000g / 18$$

$$n(H_2O) = 55.55 \text{ mol}$$

wherefore, $$n(totale) = n(glycine) + n(H_2O)$$

NA : $$n(totale) = 14 + 55.55$$

$$n(totale) = 69.55 \text{ mol}$$

Molar fraction of glycine :

$$X(glycine) = n(glycine) / n_{(T)}$$

$$\Rightarrow \quad X(glycine) = 14 / 69.55$$

$$\Rightarrow \quad X(glycine) = 0.2$$

Molar fraction of water:

$$X(glycine) + X(H_2O) = 1$$

$$=> \quad X(H_2O) = 1 - X(glycine)$$

$$=> \quad X(H_2O) = 1 - 0.2$$

$$=> \quad X(H_2O) = 0.8$$