ALMUSTAQBAL UNIVERSITY

College of Engineering and Engineering Techniques

Stage : Second year students

Subject : Chemistry 1 - Lecture 6

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Expressing concentrations By Physical units :

A. Percent concentration (parts per hundred):

It can be expressed in several ways such as :

① Weight percent (w/w) %

Weight percent $(\frac{w}{w})\ \% = \frac{weight\ of\ component}{Total\ weight} \times 100\ \%$

Weight percent $(\frac{w}{w})\ \% = \frac{weight\ of\ solute}{weight\ of\ solution} \times 100\ \%$ **(for solutions)**

e.g : Nitric acid (70%) solution, means that it contains (70 g) of HNO_3 for each (100 g) of solution.

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

Weight percent $(\frac{w}{w})\ \% = \frac{weight\ of\ component}{Total\ weight} \times 100\ \%$

$$15.8\ \% = \frac{weight\ of\ Nickel\ g}{weight\ of\ alloy} \text{ x } 100\ \%$$

$$15.8\ \% = \frac{36.5\ g}{weight\ of\ alloy} \text{ x } 100\ \%$$

Weight of alloy $= \frac{36.5\ x100}{15.8} = 231$ **g**

Example :

A solution is prepared by dissolving 15 g of cane sugar in 60 g of water. Calculate the (w/w)% of each component of the solution.

Solution:

Mass of solution = mass of solute + mass of solvent = 15 g + 60 g = 75 g

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

$(\frac{w}{w})$ **% of Can sugar** $= \frac{weight\ of\ sugar}{weight\ of\ solution} \text{ x } 100\ \%$

$(\frac{w}{w})$ **% of Can sugar** $= \frac{15\ g}{75\ g} \text{ x } 100\ \% = 20\%$

$(\frac{w}{w})$ **% of water (solvent)** $= \frac{weight\ of\ water}{weight\ of\ solution} \text{ x } 100\ \%$

$(\frac{w}{w})$ **% of water(solvent)** $= \frac{60\ g}{75\ g} \text{ x } 100\ \% = 80\%$

Exercise:

Calculate the masses of cane sugar and water required to prepare 250 g of 25% cane sugar solution.

② volume 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% aqueous solution of a perfume usually describe a solution prepared by diluting 5 mL of perfume with enough solvent (e.g: alcohol) to give 100 mL 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**

Exercise:

58 mL of ethyl alcohol was mixed with 400 mL of water to form ethyl alcohol aqueous solution. Calculate percentage by volume (v/v)%of ethyl alcohol in the solution.

③weight/volume percent (w/v)%

weight/volume percent $(\frac{w}{V})\% = \frac{weight\ of\ solute(g)}{volume\ of\ solution(\ mL)}$ **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 (5.0 g) of KNO_3 in sufficient amount of water to give (100 mL) of solution .

<u>Example:</u>

How many grams of NaCl are needed to prepare 200 mL of a 1.5% (w/v) saline solution?

<u>Solution:</u>

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

$1.5\ \% = \frac{weight\ of\ NaCl(g)}{200\ mL}$ **x 100%**

Weight of solute (g) $= \frac{1.5\ x\ 200}{100}$ **= 3 g**

<u>Example</u>

Prepare a 20 mL of 5% KCl solution $(\frac{w}{v})\%$ **from pure solid KCl .**

<u>Solution</u>

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

$5\% = \frac{weight\ of\ KCl(g)}{20mL}$ **x 100%**

Weight of solute, KCl (g) =$\frac{5 \times 20}{100}$ = 1 g

Then 1 g of KCl is to be dissolved in water and the volume is to be completed to 20 mL.

ملاحظه:

نلاحظ ان هذا النوع من التراكيز ليس له علاقه بالكتله الموليه للماده المطلوب تحضير محلول منها والشرط المهم هنا ان تكون الماده المذابه(solute) تامة الذوبان في المحلول المحضر فيمكن ان ياتي في السؤال اي نوع ماده (مثلا $NaNO_3$, KCl ,NaCl, Na_2SO_4 , KNO_3) ويكون الحل للسؤال بنفس الطريقه لكل المواد اي لايؤثر اسم الماده في الحل .

Exercise:

Calculate the $\left(\frac{w}{v}\right)$% concentration of the aqueous solution of Calcium Nitrate prepared by dissolving 5 g of $Ca(NO_3)_2$ in water and completing the volume to 250 mL .

Exercise:

What is the mass of glucose needed to prepare 125 mL of 16% (w/v) glucose ($C_6H_{12}O_6$) solution.

<u>Conversion to molarity:</u>

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

<u>Example:</u>

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

<u>solution:</u>

$$\text{Molarity (M)} = \frac{\left(\frac{w}{V}\right)\% \times 10}{\text{M.wt}} = \frac{20 \times 10}{74.5} = 2.68\ \text{M}$$

طريقه ثانيه للحل

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

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

Conversions:

1. **Molarity(M) to m mol/L**

**** Molarity(M) x 1000 = m mol/L**

2. Molarity(M) to C(mg/dL)

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

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

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

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

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

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

C(mg/dL) = $\frac{\left(\frac{w}{v}\right)\% \times 10}{M.wt}$ **x M.wt x100**

**** 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 $(\frac{w}{V})\%$ and in mg/dL ?

SOLUTION

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

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

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

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

C (mg/dL) = 12 x 1000 = 12000 mg / dL

B. Part per million (ppm) and part per billion (ppb):

It is a convenient way to express the concentration of the very dilute solution (by ppm or ppb).

(1 ppm = 1 mg / liter) or (1 ppm = 1 μg /mL)

ppm: is a mass ratio of grams of solute to one million grams of sample or solution.

$$C_{ppm} = \frac{mass\ of\ solute(g)}{mass\ of\ sample\ or\ solution\ (g)} \times 10^6$$

ppb: is a mass ratio of grams of solute to one billion grams of sample or solution .

$$C_{ppb} = \frac{mass\ of\ solute(g)}{mass\ of\ solution\ (g)} \times 10^9$$

also

$$Cppm = \frac{mass\ of\ solute(mg)}{volume\ of\ solution(liter)}$$

$$Cppm = \frac{wt(mg)}{V\ (liter)} = \frac{\frac{wt(\mu g)}{1000}}{\frac{VmL}{1000}}$$

$$Cppm = \frac{wt(\mu g)}{VmL} \quad (\mu g / mL)$$

1 g =1000 mg , 1mg = 1000 µg

1 g = 10^6µg , 1 g = 10^9 ng

$$Cppm = \frac{wt(mg)}{V\ (liter)} = \frac{wt(g\ )x1000}{\frac{VmL}{1000}}$$

$$Cppm = \frac{wt(\ g\ )}{VmL} \times 10^6$$

Example: **What is the weight of KCl needed to Prepare (500mL) of (1000 ppm) aqueous solution ?.**

solution :

$$Cppm = \frac{wt(\ g\ )}{VmL} \times 10^6$$

$$wt_{\ g} = \frac{C_{ppm} \times V_{mL}}{10^6} = \frac{1000 \times 500}{10^6} = 0.5\ g$$

Then 0.5 g of KCl is to be dissolved in water and the volume is completed to 500 mL in a volumetric flask to get(1000 ppm) solution.

Relationship of ppm with Molarity(M) and Normality (N)

ppm = M x M.Wt x 1000

ppm = N x Eq.Wt x 1000

$$\text{Molarity(M)} = \frac{PPm}{Mwt\ x1000}$$

يستخدم هذا القانون لتحويل التركيز من PPm الى المولاريه(M)

$$\text{Or}\quad Normality(N) = \frac{PPm}{Eq.wt\ x1000}$$

يستخدم هذا القانون لتحويل التركيز من PPm الى التركيز النورمالي (N)

Example:

Calculate the molarity of K^+ for the $K_3Fe(CN)_6$ (329 g / mole) aqueous solution of (63.3 ppm) concentration?

Solution :

$$\underset{1mole}{K_3Fe(CN)_6} \longrightarrow \underset{3mole}{3K^+} + Fe(CN)_6^{3-}$$

$$\text{Molarity(M)} = \frac{PPm}{Mwt\ x1000} = \frac{63.3.9PPm}{329\ x1000} = 1.92 \times 10^{-4}\ \text{M(molarity of } K_3Fe(CN)_6)$$

Molarity of K^+ (M_{k+}) = 3 x 1.92 x 10^{-4}M = 5.77 x10^{-4} M

Example:

The maximum allowed concentration of chloride (35.5 g / mole) in drinking water supply is (2.50 x 10^2 ppm) . express this concentration in terms of mole/liter (M) ?

Solution:

$$Molarity(M) = \frac{PPm}{Mwt\ x1000}$$

$$Molarity(M) = \frac{PPm}{Mwt\ x1000} = \frac{2.5\ x\ 10^2}{35.5\ x\ 1000} = 7.05\ x\ 10^{-3}\ M$$

Second method:

$$2.5\ x10^2 ppm = \frac{2.5\ x10^2 mg}{liter}$$

ppm = mg/L

$$Molarity\ (M) = \frac{wt_{\ g}}{M.wt\ x\ V_L}$$

$$Molarity(M) = \frac{(2.5\ x\ 10^2 x\ 10^{-3})\ g}{35.5\ x\ 1}$$

Molarity (M) = 7.05 x 10^{-3} M

Example :

A 25 μL serum sample was analyzed for glucose content and found to contain 26.7 μg. Calculate the concentration of glucose in ppm and in mg/dL.

Solution:

1 mL = 1000 μL

V (mL) = $\frac{V(\mu L)}{1000} = \frac{25(\mu L)}{1000} = 25x10^{-3}$ mL

Cppm = $\frac{wt(\mu g)}{VmL} = \frac{26.7}{25x10^{-3}}$ = 1068 ppm

1 dL = 100 mL

V(dL) = $\frac{V(mL)}{100} = \frac{25x10^{-3}\ mL}{100} = 25x10^{-5}$ dL mg = 1000 μg

wt (mg) = $\frac{weight\ (\mu g)}{1000}$ = $weight\ (\mu g)$ x 10^{-3}

wt (mg) = 26.7 x 10^{-3}

Concentration (mg/dL) = $\frac{wt(mg)}{V(dL)} = \frac{26.7\ x\ 10^{-3}}{25x10^{-5}}$ = 106.8 mg/dL

** Then C (mg/dL) = $\frac{C_{ppm}}{10}$

طريقه ثانيه:

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

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

$\left(\frac{w}{V}\right)\% = \frac{26.7\ x\ 10^{-6}(g)}{25x10^{-3}(mL)}$ x 100% $= 0.1068$

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

0.1068 x 1000 = 106.8 mg/ dl

Conversion of $\left(\frac{w}{V}\right)\%$ to ppm

PPm = 10 x C(mg/dL)

** PPm $= \left(\frac{w}{V}\right)\%\ x\ 10000$

P- fuctions:

pX = - log [X]

Examples:

$pH = -\log[H_3O^+]$

$[H_3O^+] = 10^{-pH}$

$pOH = -\log[OH^-]$

$[OH^-] = 10^{-pOH}$

$pNa = -\log[Na^+]$

$pCl = -\log[Cl^-]$

Example:

Calculate the P-value of each ion in 1.76×10^{-3} M aqueous solution of Na_3PO_4.

Solution:

$$Na_3PO_4 \longrightarrow 3Na^+ + PO_4^{3-}$$

1 mole	**3 mole**	**1 mole**
1.76×10^{-3}	**$3\,(1.76 \times 10^{-3})$**	**1.76×10^{-3}**

$[Na^+] = 3 \times 1.76 \times 10^{-3} = 5.28 \times 10^{-3}$ M

$pNa^+ = -\log[5.28 \times 10^{-3}] = 2.277$

$p(PO_4^{3-}) = -\log[1.76 \times 10^{-3}] = 2.754$

Note : in case of $Na_2CO_3 \rightarrow 2Na^+ + CO_3^{2-}$ or $K_2CO_3 \rightarrow 2K^+ + CO_3^{2-}$

$NaCl \rightarrow Na^+ + Cl^-$ or $KCl \rightarrow K^+ + Cl^-$

Example:

Calculate the P-value of each ion in 1740 ppm aqueous solution of K_2SO_4 (174 g / mol).

Solution:

$$Molarity(M) = \frac{PPm}{Mwt\ x1000}$$

$$Molarity(M) of\ K2SO4\ solution = \frac{1740}{174\ x1000} = 0.01\ M$$

K_2SO_4	$\rightarrow$ $2K^+$	+	SO_4^{2-}
1 mole	2 mole		1 mole
0.01	2(0.01)		0.01

$[K^+] = 0.02$ M

$pK^+ = -\log(0.02) = 1.69$

$[SO_4^{2-}] = 0.01$ M

$pSO_4^{2-} = -\log(0.01) = 2$