ALMUSTAQBAL UNIVERSITY COLLEGE

Medical Laboratories Techniques Department

Stage : First year students

Subject : General chemistry -A - Lecture 5

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

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

②volume percent (V/V)%

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

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% aqueous solution of a perfume usually describe a solution prepared by diluting 5 mL of perfume with enough water to give 100 mL.

③weight/volume percent (w/V)%

weight/volume percent ($\frac{w}{V}$)% = $\frac{weight\ of\ solute(gm)}{volume\ of\ solution(\ mL)}$ 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>

Describe the preparation of one liter of 10% **($\frac{w}{V}$)** NaCl solution .

<u>Solution:</u>

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

10% = $\frac{weight\ of\ solute(g)}{1000\ mL}$ x 100%

Weight of solute (g) =$\frac{10\ x\ 1000}{100}$ = 100 g

Then (100 g) of NaCl is to be dissolved in a sufficient volume of water and the volume is to be completed to (1) liter to get $10\%\ solution\ of\ NaCl.$

<u>Example:</u>

Calculate the weight of KCl needed to prepare 200 g of 5% ($\frac{w}{w}$) KCl aqueous solution .

<u>Solution</u>

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

$$5\% = \frac{weight\ of\ solute(g)}{200\ g} \text{ x } 100\%$$

$$\text{Weight of solute, KCl (g)} = \frac{5\ x\ 200}{100} = 10 \text{ g}$$

Example:

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

Answer:

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

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

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 KNO_3 , Na_2SO_4 ,NaCl, KCl , $NaNO_3$) ويكون الحل للسؤال بنفس الطريقه لكل المواد اي لايؤثر اسم الماده في الحل .

Exercise:

Describe the preparation of (a) 2.50 L of 20% (w/v) aqueous glycerol $C_3H_8O_3$.

(b) 2.50 L of 20% (v/v) aqueous glycerol.

(c) 2.50 kg of 20% (w/w) aqueous glycerol.

Conversion to molarity:

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

Example:

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

solution:

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

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

طريقه ثانيه للحل

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

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

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 = 1mg / liter) or (1ppm = 1µg /mL)

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

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

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

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

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

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

1 g =1000 mg , 1mg = 1000 µg

1 g = 10^6µg , 1 g = 10^9 ng

$$\mathbf{Cppm} = \frac{\boldsymbol{wt(\ g\ )}}{\boldsymbol{VmL}} \boldsymbol{x}\ \mathbf{10^6}$$

Example: Prepare (500mL) of (1000 ppm) KCl aqueous solution .

solution :

$$\mathbf{Cppm} = \frac{\boldsymbol{wt(\ g\ )}}{\boldsymbol{VmL}} \boldsymbol{x}\ \mathbf{10^6}$$

$$wt_{\ g} = \frac{C_{ppm}\ x\ V_{mL}}{10^6}$$

$$wt\ (\ g\ ) = \frac{1000\ x\ 500}{10^6} = 0.5\ g$$

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.

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) = $\frac{V_{mL}}{100}$

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) = $\frac{C_{ppm}}{10}$**

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

ppm = M x M.Wt x 1000

ppm = N x Eq.Wt x 1000

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

يستخدم هذا القانون لتحويل التركيز من PPmالى المولاريه(M)

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

يستخدم هذا القانون لتحويل التركيز من PPmالى التركيز النورمالي (N)

Example: Calculate the molarity of K^+ (39.1 g/ mol) for the $K_3Fe(CN)_6$ aqueous solution of (63.3 ppm) concentration?

Solution **:**

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

63.3ppm $k_3Fe(CN)_6$ → 3x 63.3ppm K^+ = 189.9 ppm K+

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

$$Molarity\ of\ K^+ = \frac{189.9PPm}{39.1\ x1000} = 4.86 \times 10^{-3}\text{ M}$$

Example:

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

Solution:

ppm = mg/L

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

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

Second method:

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

$$\text{Molarity (M)} = \frac{\text{wt}_{\text{g}}}{\text{M. wt}\ x\ \text{V}_{\text{L}}}$$

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

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

Example :

a) Calculate the molar conc. of 1.0 ppm solutions of each of Li^+ (6.94 g/mol) and Pb^{2+} (207 g/mol).

(b) What weight of $Pb(NO_3)_2$ (331.2 g/mol) will have to be dissolved in 1 liter of water to prepare a 100 ppm Pb^{2+} solution.

Solution:

a)

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

$$Molarity(M) of Li^+ = \frac{1}{6.94\ x1000}$$ = 1.44x10^{-4} M

$$Molarity(M) of\ Pb^{2+} = \frac{1}{207\ x1000}$$ = 4.83 x 10^{-6} M

b)

$$Molarity(M) of Pb^{2+} = \frac{100}{207 x 1000} = \mathbf{4.83 \times 10^{-4}\ mole/L}$$

$Pb(NO_3)_2 \rightarrow Pb^{2+} + 2\ NO_3^-$

1 mole 1 mole

$$\mathbf{Molarity(M) of Pb(NO_3)_2 = Molarity(M) of Pb^{2+} = 4.83 \times 10{-}4\ mole/L}$$

Wt(g) = Molarity(M) x Mwt x V(L)

Wt (g) = $\mathbf{4.83 x 10^{-4} x\ 331.2\ x\ 1}$ **= 0.16 g**

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 for each of the ions present in the solution formed by mixing 2.00×10^{-3} M NaCl and 5.4×10^{-4} M HCl

Solution

$$NaCl \rightarrow Na^+ + Cl^-$$

2.00×10^{-3} 2.00×10^{-3} 2.00×10^{-3}

$$HCl \rightarrow H^+ + Cl^-$$

(5.4×10^{-4}) (5.4×10^{-4}) (5.4×10^{-4})

$pH = -\log [H_3O^+] = -\log (5.4 \times 10^{-4}) = 3.27$

$pNa = -\log (2.00 \times 10^{-3}) = 2.699$

$pCl = -\log (2.00 \times 10^{-3} + 5.4 \times 10^{-4}) = -\log (2.54 \times 10^{-3}) = 2.595$

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

$[K^+] = 0.02\ M$

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

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

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

Example :

Calculate the molar concentration of Ag^+ in a solution that has a pAg of 6.372.

Solution:

pAg = 6.372,

$[Ag+] = 10^{-pAg} = 10^{-6.372} = 4.24 \times 10^{-7}$

Exercise:

Calculate the p-value for each of the indicated ions in the following:

a- Ba^{2+}, Mn^{2+}, and Cl^- in a solution that is 7.65×10^{-3} M in $BaC1_2$ and 1.54 M in $MnCl_2$.

b- Cu^{2+}, Zn^{2+}, and NO_3 - in a solution that is 4.78×10^{-2} M in $Cu(NO_3)_2$ and 0.104 M in $Zn(NO_3)_2$

c- H + , Ba^{2+}, and CIO_4^- in a solution that is 3.35×10^{-4} M in $Ba(ClO_4)_2$ and

6.75×10^{-4} M in HClO4.

Exercise:

A solution was prepared by dissolving 1210 mg of $K_3Fe(CN)_6$ (329.2 g/mol) in sufficient water to give 775 mL. Calculate

(a) the molar concentration of $K_3Fe(CN)_6$.
(b) the weight/volume percentage of $K_3Fe(CN)_6$

(c) pK^+ for the solution.

(d) the ppm concentration of $K_3Fe(CN)_6$.