

ALMUSTAQBAL UNIVERSITY COLLEGE

Medical Laboratories Techniques Department

Stage : First year students

Subject : General chemistry -A - Lecture 5

Lecturer: Assistant professor Dr. SADIQ . J. BAQIR



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) %

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

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

② volume percent (V/V)%

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

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.

③ weight/volume percent (w/V)%

$$\text{weight/volume percent } \left(\frac{w}{V} \right) \% = \frac{\text{weight of solute}(gm)}{\text{volume of solution}(mL)} \times 100\%$$

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 .

Example:

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

Solution:

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

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

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

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*.

Example:

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

Solution

$$\text{weight/volume percent } \left(\frac{w}{w} \right) \% = \frac{\text{weight of solute}(g)}{\text{weight of solution}(g)} \times 100\%$$

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

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

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:

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

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

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) تامه 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 لا يؤثر اسم الماده في الحل .

Exercise:

Describe the preparation of (a) 2.50 L of 20% (w/v) aqueous glycerol $\text{C}_3\text{H}_8\text{O}_3$.

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

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

Conversion to molarity:

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

Example:

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

solution:

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

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

طريقه ثانيه للحل

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

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

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).

$$(1 \text{ ppm} = 1 \text{ mg / liter}) \quad \text{or} \quad (1 \text{ ppm} = 1 \mu\text{g / mL})$$

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

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

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

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

also

$$C_{\text{ppm}} = \frac{\text{mass of solute}(mg)}{\text{volume of solution}(liter)}$$

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

$$C_{\text{ppm}} = \frac{\text{wt}(\mu\text{g})}{VmL} \quad (\mu\text{g} / \text{mL})$$

$$1 \text{ g} = 1000 \text{ mg} \quad , \quad 1 \text{ mg} = 1000 \mu\text{g}$$

$$1 \text{ g} = 10^6 \mu\text{g} \quad , \quad 1 \text{ g} = 10^9 \text{ ng}$$

$$C_{\text{ppm}} = \frac{\text{wt}(g)}{VmL} \times 10^6$$

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

solution :

$$C_{\text{ppm}} = \frac{\text{wt}(g)}{VmL} \times 10^6$$

$$\text{wt}_g = \frac{C_{\text{ppm}} \times V_{\text{mL}}}{10^6}$$

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

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:

$$1 \text{ mL} = 1000 \mu\text{L}$$

$$V(\text{mL}) = \frac{V(\mu\text{L})}{1000} = \frac{25(\mu\text{L})}{1000} = 25 \times 10^{-3} \text{ mL}$$

$$C_{\text{ppm}} = \frac{wt(\mu\text{g})}{V_{\text{mL}}} = \frac{26.7}{25 \times 10^{-3}} = 1068 \text{ ppm}$$

$$1 \text{ dL} = 100 \text{ mL}$$

$$V(\text{dL}) = \frac{V_{\text{mL}}}{100}$$

$$V(\text{dL}) = \frac{V(\text{mL})}{100} = \frac{25 \times 10^{-3} \text{ mL}}{100} = 25 \times 10^{-5} \text{ dL}$$

$$\text{mg} = 1000 \mu\text{g}$$

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

$$\text{wt}(\text{mg}) = 26.7 \times 10^{-3}$$

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

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

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

$$\text{ppm} = M \times \text{M.Wt} \times 1000$$

$$\text{ppm} = N \times \text{Eq.Wt} \times 1000$$

$$\text{Molarity}(M) = \frac{PPm}{Mwt \times 1000}$$

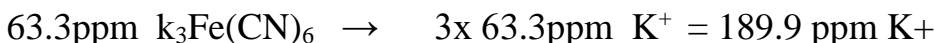
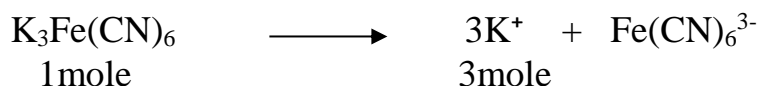
يستخدم هذا القانون لتحويل التركيز من PPm الى المولارية (M)

$$\text{Or Normality}(N) = \frac{PPm}{Eq.wt \times 1000}$$

يستخدم هذا القانون لتحويل التركيز من PPm الى 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 :



$$\text{Molarity}(M) = \frac{PPm}{Mwt \times 1000}$$

$$\text{Molarity of } K^+ = \frac{189.9 PPm}{39.1 \times 1000} = 4.86 \times 10^{-3} M$$

Example:

The maximum allowed concentration of chloride in drinking water supply is (2.50 x 10² ppm) . express this concentration in terms of mole/liter (M) ?

Solution:

$$\text{ppm} = \text{mg/L}$$

$$\text{Molarity}(M) = \frac{PPm}{Mwt \times 1000}$$

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

Second method:

$$2.5 \times 10^2 \text{ ppm} = \frac{2.5 \times 10^2 \text{ mg}}{\text{liter}}$$

$$\text{Molarity (M)} = \frac{\text{wt}_g}{\text{M. wt} \times V_L}$$

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

$$\text{Molarity (M)} = 7.05 \times 10^{-3} \text{ M}$$

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 $\text{Pb}(\text{NO}_3)_2$ (331.2 g/mol) will have to be dissolved in 1 liter of water to prepare a 100 ppm Pb^{2+} solution.

Solution:

a)

$$\text{Molarity (M)} = \frac{\text{PPm}}{\text{Mwt} \times 1000}$$

$$\text{Molarity (M) of } \text{Li}^+ = \frac{1}{6.94 \times 1000} = 1.44 \times 10^{-4} \text{ M}$$

$$\text{Molarity (M) of } \text{Pb}^{2+} = \frac{1}{207 \times 1000} = 4.83 \times 10^{-6} \text{ M}$$

b)

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



1 mole

1 mole

$$\text{Molarity}(M) \text{ of } \text{Pb}(\text{NO}_3)_2 = \text{Molarity}(M) \text{ of } \text{Pb}^{2+} = 4.83 \times 10^{-4} \text{ mole/L}$$

$$\text{Wt}(\text{g}) = \text{Molarity}(M) \times \text{Mwt} \times \text{V}(\text{L})$$

$$\text{Wt}(\text{g}) = 4.83 \times 10^{-4} \times 331.2 \times 1 = 0.16 \text{ g}$$

P- functions:

$$\text{pX} = -\log [\text{X}]$$

Examples:

$$\text{pH} = -\log[\text{H}_3\text{O}^+]$$

$$[\text{H}_3\text{O}^+] = 10^{-\text{pH}}$$

$$\text{pOH} = -\log[\text{OH}^-]$$

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

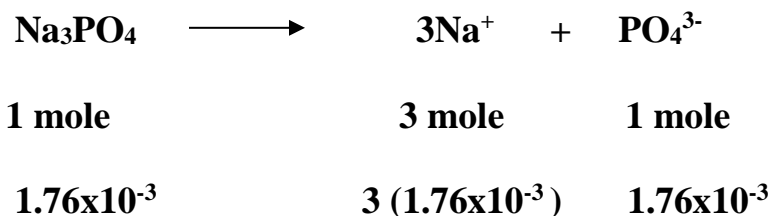
$$\text{pNa} = -\log[\text{Na}^+]$$

$$\text{pCl} = -\log [\text{Cl}^-]$$

Example:

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

Solution:



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

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

$$\text{p}(\text{PO}_4^{3-}) = -\log [1.76 \times 10^{-3}] = 2.754$$

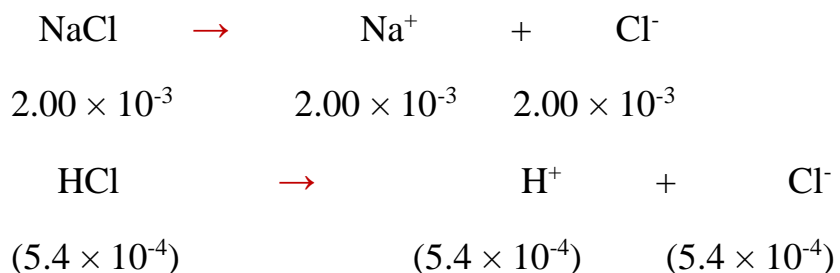
Note :



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



$$\text{pH} = -\log [\text{H}_3\text{O}^+] = -\log (5.4 \times 10^{-4}) = 3.27$$

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

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

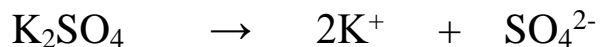
Example:

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

Solution:

$$\text{Molarity}(M) = \frac{\text{PPm}}{\text{Mwt} \times 1000}$$

$$\text{Molarity}(M) \text{ of } \text{K}_2\text{SO}_4 \text{ solution} = \frac{1740}{174 \times 1000} = 0.01 \text{ M}$$



1 mole 2 mole 1 mole

0.01 2(0.01) 0.01

$$[\text{K}^+] = 0.02 \text{ M}$$

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

$$[\text{SO}_4^{2-}] = 0.01 \text{ M}$$

$$\text{pSO}_4^{2-} = -\log (0.01) = 2$$

Example :

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

Solution:

$$\text{pAg} = 6.372,$$

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

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 BaCl_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 $\text{Cu}(\text{NO}_3)_2$ and 0.104 M in $\text{Zn}(\text{NO}_3)_2$
- c- H^+ , Ba^{2+} , and ClO_4^- in a solution that is 3.35×10^{-4} M in $\text{Ba}(\text{ClO}_4)_2$ and 6.75×10^{-4} M in HClO_4 .

Exercise:

A solution was prepared by dissolving 1210 mg of $\text{K}_3\text{Fe}(\text{CN})_6$ (329.2 g/mol) in sufficient water to give 775 mL. Calculate

- (a) the molar concentration of $\text{K}_3\text{Fe}(\text{CN})_6$.
- (b) the weight/volume percentage of $\text{K}_3\text{Fe}(\text{CN})_6$
- (c) pK^+ for the solution.
- (d) the ppm concentration of $\text{K}_3\text{Fe}(\text{CN})_6$.