ALMUSTAQBAL UNIVERSITY

College of Engineering and Engineering Techniques

Stage : Second year students

Subject : Chemistry 1 - Lecture 5

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Molarity of liquids:

The molarity of liquids Can be determined by applying the following formula:

$$\text{Molarity of liquid(M)} = \frac{sp.gr\ x\ \left(\frac{w}{w}\right)\%\ x1000}{Mwt}$$

$$\text{Specific gravity (Sp.gr)} = \frac{density\ of\ substance}{density\ of\ water}$$

$$\text{Specific gravity (Sp.gr)} = \frac{d_{substance}}{d_{H_2O}}$$

($sp.gr \approx d_{substance}$) as $d_{H_2O} = 1$ (at room temperature)

Example:

Calculate the molarity of the solution of 70.5 % HNO_3 (w/w) (63 g /mole) that has specific gravity of (1.42) .

Solution:

$$\text{Molarity(M)} = \frac{sp.gr\ x\ \left(\frac{w}{w}\right)\%\ x\ 1000}{Mwt}$$

$$M = \frac{1.42\ x\ \left(\frac{70.5}{100}\right) x\ 1000}{63.0} = \frac{1.42\ x\ 70.5 x\ 10}{63.0} = 15.9\ M$$

Example :

Calculate the molarity of NaOH (40 g/mole) solution of 50 $\left(\frac{w}{w}\right)$% knowing that its specific gravity(sp.gr) is 1.525 .

Solution:

$$\text{Molarity(M)} = \frac{sp.gr\ x\ \left(\frac{w}{w}\right)\%\ x\ 1000}{Mwt}$$

$$\text{Molarity (M)} = \frac{1.525\ x\ \left(\frac{50}{100}\right) x\ 1000}{40} = \frac{1.525\ x\ 50\ x\ 10}{40} = 19.06\ M$$

Example:

Describe the preparation of (100 mL) of (6 M) HCl from its concentrated solution that is 37.1 % (w/w) HCl (36.5 g /mole) and has specific gravity (sp.gr) of (1.181) .

Solution:

1. نحسب تركيز الحامض الاصلي (المركز) من القانون التالي:

$$M_{HCl} = \frac{sp.gr\ x\ \left(\frac{w}{w}\right)\%\ x\ 1000}{Mwt}$$

$$M_{HCl} = \frac{1.181\ x \frac{37.1}{100}\ x\ 1000}{36.5}$$

$$M_{HCl} = \frac{1.181 x\ 37.1\ x\ 1000}{36.5\ x\ 100}$$

$M_{HCl} = \frac{1.181 \; x \; 37.1 \; x \; 10}{36.5} = 12 \; M$

The Molarity of the concentrated acid is 12 M

الان نذهب الى قانون التخفيف لحساب الحجم المطلوب اخذه من الحامض المركز وتخفيفه الى الحجم المطلوب (100 مللتر في هذا المثال) وكمايلي:

No. of moles of Conc. solution = No. of moles of dil. Solution

also

No. of m moles of Conc. solution = No. of m moles of dil. Solution

$M_{conc.} V_{conc.} = M_{dil.} V_{dil.}$

$12 \; x \; V_{conc} = 6 \; x \; 100$

$V_{conc} = \frac{6 \; x \; 100}{12} = 50 \; mL.$

Then 50 mL of concentrated acid is to be diluted to 100 mL to give 6 M solution

Example:

Describe the preparation of 500 mL of 3 M H_2SO_4 (98 g /mole) from the commercial reagent that is 93% H_2SO_4 (w/w) and has a specific gravity of 1.830.

Solution:

1. **We have to calculate the concentration of the original conc. Solution**

$M_{H2SO4} = \frac{sp.gr \; x \; \% \; x \; 1000}{M.wt}$

$$M_{H2SO4} = \frac{1.830\ x\ \frac{93}{100}\ x\ 1000}{98}$$

$$M_{H2SO4} = \frac{1.830\ x\ 93\ x\ 1000}{98\ x\ 100}$$

$$M_{H2SO4} = \frac{1.830\ x\ 93\ x\ 10}{98} = 17.37\ M$$

لحساب الحجم المطلوب اخذه من الحامض المركز وتخفيفه الى الحجم المطلوب (500 مللتر في هذا المثال) نطبق قانون التخفيف التالي:

$$M_{conc.}\ V_{conc.} = M_{dil.}\ V_{dil.}$$

$$17.37\ x\ V_{conc} = 3\ x\ 500$$

$$V_{conc} = \frac{3\ x\ 500}{17.37} = 86.36\ mL.$$

Then 86.36 mL of concentrated acid is to be diluted to 500 mL to give 3 M solution.

Calculation of the Normality of liquids

$$\text{Normality of liquid(N)} = \frac{sp.gr\ x\ \left(\frac{w}{w}\right)\%\ x\ 1000}{eq.wt}$$

Example:

Describe the preparation of 500 mL of 3 N H_2SO_4(98 g /mole) from the commercial reagent that is 96% H_2SO_4 (w/w) and has a specific gravity of 1.840.

Solution:

M $_{H2SO4}$ **=** $\frac{sp.gr \ x \ \% \ x \ 1000}{eq.wt}$

eq.wt = $\frac{Mwt}{\eta}$

For H_2SO_4 **η=2 then**

eq.wt = $\frac{98}{2}$ = 49

Normality (N $_{H2SO4}$ **) =** $\frac{1.840 \ x \ \frac{96}{100} \ x \ 1000}{49}$

Normality (N $_{H2SO4}$ **) =** $\frac{1.840 \ x \ 96 \ x \ 1000}{49 \ x \ 100}$

Normality (N $_{H2SO4}$ **) =** $\frac{1.840 \ x \ 96 \ x \ 10}{49}$ **= 36.04 N**

The Normality of the concentrated acid is 36.04 N

لحساب الحجم المطلوب اخذه من الحامض المركز وتخفيفه الى الحجم المطلوب (500 مللتر في هذا المثال) نطبق قانون التخفيف التالي:

$N_{conc.} V_{conc.} = N_{dil.} V_{dil.}$

36.04 x V_{conc} **= 3 x 500**

$$V_{conc} = \frac{3 \times 500}{36.04} = 41.62 \text{ mL.}$$

Then 41.62 mL of concentrated acid is to be diluted to 500 mL to give 3 N solution.

Example:

A Nurse is preparing for an intravenous administration of glucose $C_6H_{12}O_6$ (180 g/mole) How many mL of the solution of 5 % (w/w) glucose , its specific gravity is 1.020 , will be needed to provide 1.25 g of glucose ?

Solution:

$$\text{Molarity (M)} = \frac{sp.gr \times \left(\frac{w}{w}\right)\% \times 1000}{Mwt}$$

$$\text{Molarity (M)} = \frac{1.020 \times \left(\frac{5}{100}\right) \times 1000}{180} = 0.283 \text{ M}$$

Weight (g) = molarity(M) x V(L) x M.wt

Weight of glucose (g) = 1.25 g = 0.283(M) x V(L) x 180

$$\text{Volume needed} = \frac{1.25}{0.283 \times 180} = 0.0245 \text{ L} = 24.5 \text{ mL}$$

Example:

A solution of 6.42 (w/w)% of $Fe(NO_3)_3$ (241.86 g/mole) has a specific gravity of 1.059. Calculate:

(a) the molar concentration of this solution.

(b) the mass in grams of $Fe(NO_3)_3$ contained in each liter of this solution

solution:

a) To calculate the molar concentration of the solution

$$M_{Fe(NO3)3} = \frac{\text{sp.gr x \% x 1000}}{\text{Mwt}}$$

$$M_{Fe(NO3)3} = \frac{1.059 x \frac{6.42}{100} x\ 1000}{241.86} = 0.281$$

(b) the mass in grams of $Fe(NO_3)_3$ contained in each liter of this solution(i.e: the concentration of solution in g / L).

Weight (g) = Molarity x volume(liter) x M.wt

Weight = 0.281 x 1 liter x 241.86 = 67.96 g

The concentration of solution in g / L = 67.96 g / L

Second method:

$$\text{Molarity(M)} = \frac{wt_{(g)}\ x\ 1000}{M.wt\ x\ V_{mL}}$$

$$wt(g) = \frac{\text{Molarity(M)}\ x\ M.wt\ x\ V_{mL}}{1000}$$

$$wt(g) = \frac{0.281\ x\ 241.86\ x\ 1000_{mL}}{1000} = 67.96\ g$$

Example:

A 12.5% (w/w) aqueous solution of $NiCl_2$ (129.61 g/mole) has specific gravity of 1.149. Calculate:

(a) the Molarity of $NiCl_2$ in this solution.

(b) the molar concentration of Cl^- in the solution.

(c) the mass in grams of $NiCl_2$ contained in 500 mL of this solution.

Answer:

(a) the Molarity of $NiCl_2$ in this solution

$$M_{NiCl2} = \frac{sp.gr\ x\ \%\ x\ 1000}{Mwt}$$

$$M_{NiCl2} = \frac{1.149\ x \frac{6.42}{100} x\ 1000}{129.61} = 0.569\ M$$

(b) the molarity of Cl^- concentration in the solution.

$$NiCl_2 \longrightarrow Ni^{2+} + 2Cl^-$$

Each 1 mole gives 1 mole 2 mole

Molarity of Cl^- = 2 x Molarity of $NiCl_2$

Molarity of Cl^- = 2 x 0.569 = 1.138 M

(c) the mass in grams of $NiCl_2$ contained in 500 mL of this solution.

Weight (g) = Molarity x volume(liter) x M.wt

Weight = 0.569 x ($\frac{500}{1000}$) L x 129.61 = 36.87 g

Example:

A solution was prepared by dissolving 327. 8 mg of Na_3PO_4 (163.9 g /mole) in sufficient amount of water to give 750 mL . Calculate:

A) The Molarity and Normality of the solution

B) the Molar concentration of Na^+ in the solution.

solution:

A) The Molarity and Normality of the solution

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

Weight of Na_3PO_4 (g) = $\frac{327.8\ mg}{1000}$ = 0.3278 g

$$\textbf{Molarity(M)} = \frac{0.3278 \times 1000}{163.9 \times 750} = 0.00267\ M = 2.67 \times 10^{-3}\ M$$

Normality (N) = Molarity(M) x η

(η) = Σ [no. of cations x its valency (cation charge)]

For Na_3PO_4 (η) = Σ [3 Na^+ x (+1)] = 3

Normality (N) = 2.67×10^{-3} x 3 = 8.01×10^{-3} N

B) the Molar concentration of Na^+ in the solution.

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

1 mole 3 mole

Molarity of Na^+ = 3 x Molarity of Na_3PO_4

Molarity of Na^+ = 3 x 2.67×10^{-3} = 8.01×10^{-3} M

Example :

**The concentration of an aqueous solution of NaOH (40 g/mole) is 10% (w/w)% . The density of the solution is 1.070 g /mL. Calculate:
a)molarity, b)molality and c) mole fraction of NaOH in water.**

Solution:

a)Molarity (M) = $\frac{sp.gr\ x\ \left(\frac{w}{w}\right)\%\ x\ 1000}{Mwt}$

Molarity (M) = $\frac{1.070\ x\ \left(\frac{10}{100}\right)\ x\ 1000}{40} = 2.675\ M$

b) Molality

Molality (m) = $\frac{No.of\ moles\ of\ NaOH\ x\ 1000}{weight\ of\ water\ (solvent)}$

2.675 M = 2.675 mole /liter

Weight of NaOH g = molarity(M) x V(L) x M.wt

Weight of NaOH g = 2.675 x 1(L) x 40 = 107 g

No. of moles of NaOH (solute)= $\frac{weight}{Mwt} = \frac{107}{40} = 2.675$

Weight of 1Lof NaCl solution g = density x volume=1.070 x1000 = 1070 g

Weight of water (solvent) g = 1070 -107 = 963 g

Molality (m) = $\frac{No.of\ moles\ of\ NaOH\ x\ 1000}{weight\ of\ water\ (solvent)} = \frac{2.675\ x\ 1000}{963} = 2.778$

c) Mole fraction

Moles of water (solvent) = $\frac{963}{18} = 53.5$

Mole fraction of NaOH = $\frac{2.675}{2.675+53.5} = 0.048$

Mole fraction of water = $\frac{53.5}{2.675+53.5} = 0.952$

Exercise:

The concentration of the aqueous solution of glucose (180 g/mole) is 10 % (w/w) and its density is 1.20 g/mL. Calculate:

a) molarity b) molality and c) mole fraction of the solution.