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 College of Health and Medical Techniques
 Medical Laboratories Techniques Department
 Stage : First year students
 Subject : General Chemistry 1 - Lecture 7
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Molarity of liquids:

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

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

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

$$\text{Specific gravity (Sp.gr)} = \frac{d_{\text{substance}}}{d_{\text{H}_2\text{O}}}$$

$$(\text{sp.gr} \approx d_{\text{substance}}) \quad \text{as } d_{\text{H}_2\text{O}} = 1 \text{ (at room temperature)}$$

Example:

Calculate the molarity of the solution of 70.5 % HNO₃ (w/w) (63 g /mole) that has specific gravity of (1.42) .

Solution:

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

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

Exercise: 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.

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 a specific gravity (sp.gr) of (1.181).

Solution:

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

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

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

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

$$M_{\text{HCl}} = \frac{1.181 \times 37.1 \times 10}{36.5} = 12 \text{ M}$$

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

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

$$12 \times V_{\text{conc}} = 6 \times 100$$

$$V_{\text{conc}} = \frac{6 \times 100}{12} = 50 \text{ mL.}$$

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

Exercise: 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.

Example:

A Nurse is preparing for an intravenous administration of glucose $\text{C}_6\text{H}_{12}\text{O}_6$ (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:

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

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

$$\text{Weight (g)} = \text{molarity(M)} \times V(\text{L}) \times \text{M.wt}$$

$$\text{Weight of glucose (g)} = 1.25 \text{ g} = 0.283(\text{M}) \times V(\text{L}) \times 180$$

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

Example:

A 6.42% (w/w) aqueous solution of NiCl₂ (129.61 g/mole) has a specific gravity of 1.149. Calculate:

- (a) Molarity of NiCl₂ in this solution.**
- (b) the molar concentration of Cl⁻ in the solution.**
- (c) mass in grams of NiCl₂ contained in 500 mL of this solution.**

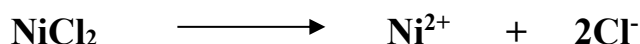
Answer:

- (a) Molarity of NiCl₂ in this solution**

$$M_{\text{NiCl}_2} = \frac{\text{sp.gr} \times \% \times 1000}{Mwt}$$

$$M_{\text{NiCl}_2} = \frac{1.149 \times \frac{6.42}{100} \times 1000}{129.61} = 0.569 \text{ M}$$

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



Each 1 mole gives 1 mole 2 mole

Molarity of Cl⁻ = 2 x Molarity of NiCl₂

Molarity of Cl⁻ = 2 x 0.569 = 1.138 M

- (c) mass in grams of NiCl₂ contained in 500 mL of this solution.**

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

$$\text{Weight} = 0.569 \times \left(\frac{500}{1000} \right) \text{ L} \times 129.61 = 36.87 \text{ g}$$

Exercise:

A solution of 12.5 (w/w)% of Fe(NO₃)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(NO₃)₃ contained in each liter of this solution**

Normality (N)

Represents the number of equivalents contained in one liter solution or the number of milli equivalents of solute contained in one milliliter of solution .

e.g: 0.2 N HCl solution contains 0.2 equivalents (eq) of HCl in liter solution or 0.2 milli equivalent (meq) of HCl in each mL of solution .

$$\text{Normality (N)} = \frac{\text{number of equivalents(solute)}}{VL(\text{solution})}$$

$$\text{Number of equivalents (eq)} = \frac{wt(g)}{eq.wt(g)}$$

$$\text{Normality (N)} = \frac{\frac{wt}{eq.wt}}{V(\text{liter})}$$

$$\text{Normality (N)} = \frac{wt(g)}{eq.wt(g) \times V(L)}$$

$$\text{Normality (N)} = \frac{wt(g)}{eq.wt(g) \times \frac{V(mL)}{1000}}$$

$$\text{Normality (N)} = \frac{wt \times 1000}{eq.wt \times V(mL)}$$

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

$$\text{Normality (N)} = \frac{wt \times 1000}{\frac{Mwt}{\eta} \times V(mL)}$$

$$\text{Normality (N)} = \frac{wt \times 1000}{\frac{Mwt \times V(mL)}{\eta}}$$

$$\text{Normality (N)} = \left(\frac{wt \times 1000}{Mwt \times V(mL)} \right) \eta$$

$$\text{Normality (N)} = \text{Molarity (M)} \cdot \eta \quad , \quad \text{or} \quad \text{Molarity (M)} = \text{Normality (N)} / \eta$$

I. Equivalent mass in neutralization reaction:

A) Equivalent mass of acids (Eq):-

Is the mass that either contribute or reacts with one mole of hydrogen ion in the reaction.

$$Eq = \frac{Mwt}{\text{number of H}}$$

1. Monoprotic acid e.g: [HCl(36.5 g/mole) , HNO₃(63 g/mole) , CH₃COOH(60 g/mole)] $\eta=1$

$$Eq = \frac{Mwt}{1}$$

$$Eq = \frac{36.5}{1} = 36.5 \text{ for HCl}$$

$$Eq = \frac{63}{1} = 63 \text{ for HNO}_3$$

2. Diprotic acid e.g: [H₂SO₄(98 g /mole), H₂CO₃(62 g/mole)] $\eta= 2$

$$Eq = \frac{Mwt}{2} = \frac{98}{2} = 49 \quad \text{for H}_2\text{SO}_4$$

$$Eq = \frac{62}{2} = 31 \quad \text{for H}_2\text{CO}_3$$

B) Equivalent mass of Bases:

Is the mass that either contribute or reacts with one mole of OH in the reaction.

$$\text{Eq} = \frac{\text{Mwt}}{\text{number of OH}}$$

1. Monohydroxy base e.g: ($\eta=1$)

e.g: NaOH (40 g/mole)

$$\text{Eq.} = \frac{\text{Mwt}}{1} = \frac{40}{1} = 40$$

e.g: KOH (56 g/mole)

$$\text{Eq.} = \frac{\text{Mwt}}{1} = \frac{56}{1} = 56$$

2. Dihydroxy base ($\eta=2$)

e.g: Ca(OH)_2 (74 g / mole)

$$\text{Eq.} = \frac{\text{Mwt}}{2} = \frac{74}{2} = 37$$

Zn(OH)_2 (99.4 g /mole)

$$\text{Eq.} = \frac{\text{Mwt}}{2} = \frac{99.4}{2} = 49.7$$

Ba(OH)_2 (171.35 g / mole)

$$\text{Eq.} = \frac{\text{Mwt}}{2} = \frac{171.35}{2} = 85.67$$

1. Equivalent mass in (oxidation – reduction) reaction (Redox):

The equivalent mass of a participant in an (oxidation–reduction) reaction is that mass which directly produce or consume one mole of electron.

$$\text{Eq} = \frac{\text{Mwt}}{\eta}$$

η = change in oxidation state number

η = numbers of electrons participate in oxidation - reduction processes (Redox)

Example :





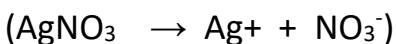
$$\text{Eq. of KMnO}_4 = \frac{Mwt}{5} = \frac{157.9}{5} = 31.6 \text{ g}$$

2. Equivalent mass for salts:

$$\text{Eq} = \frac{Mwt}{\eta}$$

$$(\eta) = \Sigma [\text{no. of cations} \times \text{its valency}(\text{cation charge})]$$

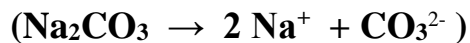
e.g: AgNO_3 (170 g/mole)



$$(\eta = \text{Ag}^+ (1) \times 1 = 1)$$

$$\text{Eq.} = \frac{Mwt}{1} = \frac{170}{1} = 170$$

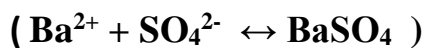
e.g: Na_2CO_3 (106 g/mole)



$$(\eta = \text{Na}^+ (2) \times 1 = 2)$$

$$\text{Eq.} = \frac{Mwt}{2} = \frac{106}{2} = 53$$

e.g: BaSO_4 (233 g/mole)



$$\eta = \text{Ba}^{2+} (1) \times (2+) = 2$$

$$\text{Eq.} = \frac{Mwt}{2} = \frac{233}{2} = 116.5$$

e.g: $\text{La}(\text{IO}_3)_3$ (663.6 g/mole)



$$(\eta = \text{La}^{3+} (1) \times 3 = 3)$$

$$\text{Eq.} = \frac{Mwt}{3} = \frac{663.6}{3} = 221.1$$

e.g: $\text{KAl}(\text{SO}_4)_2$ (258 g/mole)

$$(\eta) = \Sigma [\text{no. of cations} \times \text{its valency(cation charge)}]$$

$$\text{no. of cations} = 1 \text{K}^+ + 1 \text{Al}^{3+}$$

$$\eta = \text{K}^+ (1) \times (1+) + \text{Al}^{3+} (1) \times (3+) = 4$$

$$\text{Eq.} = \frac{M.wt}{4} = \frac{258}{4} = 64.5$$

Example

Find the Normality of the solution containing 5.3 g/L of Na_2CO_3 (106 g/mol).

Solution:

To find η for Na_2CO_3 **$(\eta) = \Sigma [\text{no. of cations} \times \text{its valency(cation charge)}]$**

No. of cations = 2Na^+ while the cation charge for $\text{Na}^+ = 1$,

$$\text{Then } (\eta) = 2 \times 1 = 2$$

$$\text{Eq. of } \text{Na}_2\text{CO}_3 = \frac{Mwt}{2} = \frac{106}{2} = 53 \text{ grams}$$

$$\text{Normality (N)} = \frac{wt}{\text{Eq.} \times VL}$$

$$\text{Normality (N)} = \frac{5.3 \text{ g}}{53 \times 1\text{L}} = 0.1\text{N}$$

Second method:

$$\text{Normality (N)} = \left(\frac{\text{wt} \times 1000}{\text{Mwt} \times V(\text{mL})} \right) \eta$$

$$\text{Normality (N)} = \left(\frac{5.3 \times 1000}{106 \times 1000(\text{mL})} \right) 2 = 0.1 \text{ N}$$

Example;

Convert the following Molarities to Normalities.

a. 2.5 M HCl b. 1.4 M H₂SO₄ c. 1.0 M NaOH d. 0.5 M Ca(OH)₂

Answer:

a. Normality (N) of 2.5M HCl = M . η = 2.5 x 1 = 2.5 N HCl,

b. Normality (N) of 1.4 M H₂SO₄ = M . η = 1.4 x 2 = 2.8 N H₂SO₄

c. Normality (N) of 1M NaOH= M . η = 1 x 1 = 1 N NaOH

d. Normality (N) of 0.5 M Ca(OH)₂ = M . η = 0.5 x 2 = 1 N Ca(OH)₂

Calculations of the Normality of liquids

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

Example:

Describe the preparation of 500 mL of 3 N H₂SO₄(98 g /mole) from the commercial reagent that is 96% H₂SO₄ (w/w) and has a specific gravity of 1.840.

Solution:

$$\text{Normality (N}_{\text{H}_2\text{SO}_4}) = \frac{\text{sp.gr} \times \% \times 1000}{\text{eq.wt}}$$

$$\text{eq.wt} = \frac{M_{\text{wt}}}{\eta}$$

For H_2SO_4 $\eta=2$ then

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

$$\text{Normality (N}_{\text{H}_2\text{SO}_4}) = \frac{1.840 \times \frac{96}{100} \times 1000}{49}$$

$$\text{Normality (N}_{\text{H}_2\text{SO}_4}) = \frac{1.840 \times 96 \times 1000}{49 \times 100}$$

$$\text{Normality (N}_{\text{H}_2\text{SO}_4}) = \frac{1.840 \times 96 \times 10}{49} = 36.04 \text{ N}$$

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:

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

$$36.04 \times V_{\text{conc}} = 3 \times 500$$

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

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

Example:

A 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

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

$$\text{Weight of } \text{Na}_3\text{PO}_4 \text{ (g)} = \frac{327.8 \text{ mg}}{1000} = 0.3278 \text{ g}$$

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

$$\text{Normality (N)} = \text{Molarity(M)} \times \eta$$

$$(\eta) = \Sigma [\text{no. of cations} \times \text{its valency (cation charge)}]$$

$$\text{For } \text{Na}_3\text{PO}_4 \quad (\eta) = \Sigma [3 \text{ Na}^+ \times (+1)] = 3$$

$$\text{Normality (N)} = 2.67 \times 10^{-3} \times 3 = 8.01 \times 10^{-3} \text{ N}$$

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



1 mole 3 mole

$$\text{Molarity of } \text{Na}^+ = 3 \times \text{Molarity of } \text{Na}_3\text{PO}_4$$

$$\text{Molarity of } \text{Na}^+ = 3 \times 2.67 \times 10^{-3} = 8.01 \times 10^{-3} \text{ M}$$