ALMUSTAQBAL UNIVERSITY

College of Health and Medical Techniques

Medical Laboratories Techniques Department

Stage : First year students

Subject : Lecture 2A

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Normality (N)

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

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

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

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

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

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

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

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

Normality (N) = $\frac{wt\ x\ 1000}{\frac{Mwt\ xV(mL)}{\eta}}$

Normality (N) = $(\frac{wt\ x1000}{Mwt\ x\ V(mL)})\ \eta$

N = M . η , or M = N / η

e.g: Normality(N) of 1M KCl = 1x1 = 1 N KCl ,

Normality(N) of 1M HCl = 1x1 = 1N HCl,

Normality(N) of 1 M H_2SO_4 =2 x 1= 2N H_2SO_4

Normality(N) of 1 M Na_2CO_3 = 2x1 = 2N Na_2CO_3

I) <u>Equivalent mass in Neutralization reaction:</u>

A.Equivalent mass of acids (Eq):-

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

1.mono protic acid e.g: (HCl , HNO_3 , CH_3COOH) η=1

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

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

$Eq = \frac{63}{1} = 63\ for\ HNO_3$

2.Diprotic acid e.g: (H_2SO_4, H_2S, H_2SO_3) η= 2

Eq = $\frac{Mwt}{2} = \frac{98}{2} = 49$ for H_2SO_4

Eq = $\frac{82}{2} = 41$ for H_2SO_3

B) Equivalent mass of Bases:

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

$Eq = \frac{Mwt}{Number\ of\ OH}$

1. Mono hydroxy base e.g: (η=1)

e.g: NaOH **for KOH**

Eq. = $\frac{Mwt}{1} = \frac{40}{1}$ =40 **Eq. = $\frac{Mwt}{1} = \frac{56}{1}$ = 56**

2. Di hydroxy base (η=2)

e.g: $Ca(OH)_2$ $Zn(OH)_2$ $Ba(OH)_2$

Eq. = $\frac{Mwt}{2} = \frac{74}{2}$ = 37 Eq. = $\frac{Mwt}{2} = \frac{99.4}{2}$ =49.7 Eq. = $\frac{Mwt}{2} = \frac{171.35}{2} = 85.67$

II) 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 electrons.

Eq = $\frac{Mwt}{\eta}$ **η= change in oxidation state number**

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

Example :

$2KMnO_4 + 10FeSO_4 + 8H_2SO_4 \rightarrow 5Fe_2(SO_4)_3 + 2MnSO_4 + K_2SO_4 + 8H_2O$

$MnO_4^- + 10\ Fe^{2+} + 8\ H^+ \rightleftharpoons 10\ Fe^{3+} + MnSO_4$ (acidic medium)

Mn^{7+} → Mn^{2+} (5 e gain – reduction)

Fe^{2+} → Fe^{3+} (1 e loss – oxidation)

Eq. of $KMnO_4 = \frac{Mwt}{5} = \frac{157.9}{5} = 31.6$

3. Equivalent mass in salts:

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

(η) =∑(No. of cations x its valency)

e.g: **$BaCO_3$ (197 g/mol)**

$BaCO_3 \rightarrow Ba^{2+} + CO_3^{2-}$

η = Ba^{2+} (1) x (2+) =2

Eq. = $\frac{\boldsymbol{Mwt}}{\mathbf{2}} = \frac{\mathbf{197}}{\mathbf{2}}$ = **98.5**

Example

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

Solution:

$Na_2CO_3 \rightarrow 2Na^+ + CO_3^{2-}$

(η) =∑(No. of cations x its valency)

(η) = 2 x 1 = 2

Eq. of Na_2CO_3 = $\frac{\boldsymbol{Mwt}}{\mathbf{2}} = \frac{\mathbf{106}}{\mathbf{2}}$ =**53 g**

N = $\frac{wt}{Eq.\ x\ VL}$

Normality = $\frac{5.3gm}{53\ x\ 1L}$ = 0.1

Second method:

Normality (N) = $\left(\frac{\boldsymbol{wt\ x1000}}{\boldsymbol{Mwt\ x\ V(mL)}}\right)$ **η**

Normality (N) = $\left(\frac{\mathbf{5.3\ x1000}}{\mathbf{106\ x\ 1000(mL)}}\right)$ **2 = 0.1 N**

e.g : **$KAl(SO_4)_2$** (258 g/ mol)

(η) =∑(No. of cations x its valency)

η= [K^+ (1) x (1+)] **+**[Al^{3+}(1) x (3+)]= 4

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

e.g :

$AgNO_3$ (170 g/mol) **,** **K_2CO_3** (138 g/mol) **,** **$La(IO_3)_3$ (663.6g/mol)**

$AgNO_3$ (η = Ag^+ (1) x 1= 1)

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

K_2CO_3 (η= K^+ (2) x 1= 2)

Eq. $= \frac{Mwt}{2} = \frac{138}{2} = 69$

$La(IO_3)_3$ (η = La^{3+} (1) x 3 = 3)

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

Molarity of liquids:

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

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

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

(**sp.gr** ≈ $d_{substance}$) as $d_{H_2O} = 1$

Example:

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

Solution:

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

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

Dilution:

$$\textbf{Molarity (M)} = \frac{No.of\ moles\ (solute)}{Volume\ of\ solution (L)}$$

No. of moles solute = Molarity(M) x V(L) (by rearrangement)

The amount of solute (No. of moles)does not change during dilution .

The number of moles of solute before and after dilution is unchanged, because dilution involves only the addition of extra solvent:

No. of moles (concentrated solution) = No. of moles (diluted solution)

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

also

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

Example:

Describe the preparation of (100 mL) of (6.0 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:

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

$$M_{HCl} = \frac{1.18\ x\ \frac{37.1}{100}\ x\ 1000}{36.5} = \frac{1.18\ x\ 37.1\ x\ 10}{36.5} = 12.0\ M$$

The Molarity of the concentrated acid is 12.0M

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

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

$$12.0\ x\ V_{conc} = 6.0\ x\ 100$$

$$V_{conc} = \frac{6.0\ x\ 100}{12} = 50\ mL.$$

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 2 M H_2SO_4 (98 g /mol) from the commercial reagent that is 93% H_2SO_4 (w/w) and has a specific gravity of 1.830.

Calculation of Normality of liquids

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 /mol) from the commercial reagent that is 96% H_2SO_4 (w/w) and has a specific gravity of 1.840.

Solution:

Normality (N_{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}) = $\frac{1.840\ x\ 96\ x\ 10}{49}$ **= 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:

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

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

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

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

Example:

A 12.5% (w/w) aqueous solution of $NiCl_2$ (129.61 g/mol) 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

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

$$M_{NiCl2} = \frac{1.149\ x\ \frac{12.5}{100}\ x\ 1000}{129.61} = 0.569 \text{ M}$$

(b) The molarity of Cl^- 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

Second method:

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

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

$$\text{wt(g)} = \frac{0.569 \text{ x } 129.6 \text{ x } 500_{mL}}{1000} = 36.87 \text{ g}$$

Exercise:

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

A) The Molarity and Normality of the solution

B) The mass in grams of $Fe(NO_3)_3$ contained in each liter of this solution

Conversions:

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

**** m mol/L x $\left(\frac{\text{Mwt}}{10}\right)$ = mg/dL (mmol/L → mg/dL)**

$$[\,Molarity(M)x\ 1000]\text{x}\left(\frac{\text{Mwt}}{10}\right) = \text{mg/dL}$$

**** Molarity(M) x M.wt x 100 = mg/dL (Molarity(M) → mg/dL)**

Part per million (ppm) :

It is a convenient way to express the concentration of the very dilute solution .

(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.

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

also

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

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

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

1 g =1000 mg , 1mg = 1000 µg , 1 g = 10^6µg

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

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

solution :

$$\mathbf{Cppm} = \frac{wt(\ g\ )}{VmL} \times 10^6 \qquad wt_g = \frac{C_{ppm} \times V_{mL}}{10^6} \quad \text{(By rearrangement)}$$

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

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.

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

wt (mg) = 26.7×10^{-3}

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

يمكن ان نطبق القانون التالي بشكل مباشر :

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

Then $C_{(mg/dL)} = \frac{1068}{10}$ = 106.8 mg/dL

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 PPm الى المولاريه(M)

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

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

Example:

The maximum allowed concentration of chloride (35.5 g/mol) in drinking water supply is (2500 ppm) . express this concentration in terms of mole/liter (M) ?

Solution:

ppm = mg/L

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

$$Molarity(M) = \frac{PPm}{Mwt\ x1000} = \frac{2500}{35.5\ x\ 1000} = 7.05 \text{ x } 10^{-3} \text{ M}$$

Second method: $2500 \text{ ppm} = \frac{2500 \text{ mg}}{\text{liter}}$

$$\text{Molarity (M)} = \frac{\text{wt}_{\text{g}}}{\text{M.wt}\ x\ \text{V}_{\text{L}}} = \frac{(2500\ x\ 10^{-3})\ \text{g}}{35.5\ x\ 1} = 7.05 \text{ x } 10^{-3} \text{ M}$$

Conversions:

As $C_{(mg/dL)} = \frac{C_{ppm}}{10}$

Then $C_{(mg/dL)} = \frac{Molarity(M) x M.wt\ x1000}{10}$

** $C_{(mg/dL)}$ = Molarity(M) x M.wt x100

Example:

For the solution of 100 ppm of Fructose (180 g/mol) Calculate the concentration in:

a. Molarity **b. mmol / L** **c. mg/dL**

Solution:

a. **Molarity(M)** $= \frac{PPm}{Mwt\ x1000} = \frac{100}{180\ x1000}$ **= 5.55 x10^{-4} M**

b. **mmol/L = Molarity(M) x 1000 = 5.55 x 10^{-4} x 1000 = 0.555**

c. **mg/dL = Molarity(M) x M.wt x 100**

mg/dL = 5.55x10^{-4} x 180 x100 = 10

Or **C (mg/dL) =** $\frac{C_{ppm}}{10} = \frac{100}{10}$ = **10** mg/dL

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) pK^+ for the solution.

c) the (w/v)% of $K_3Fe(CN)_6$ (d) the ppm concentration of $K_3Fe(CN)_6$.