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College of Health and Medical Techniques
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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:

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

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

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

($sp.gr \approx d_{substance}$) 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:

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

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

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).

<u>Solution:</u>

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

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

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

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

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

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 $C_6H_{12}O_6$ (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:

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

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

Volume needed = $\frac{1.25}{0.283 \, x \, 180}$ = 0.0245 L = 24.5 mL

Example:

A 6.42% (w/w) aqueous solution of $NiCl_2$ (129.61 g/mole) has a specific gravity of 1.149. Calculate:

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

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

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

Answer:

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

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

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

Exercise:

A solution of 12.5 (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

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 .

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

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

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

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

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

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

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

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) = ($\frac{wt\ x1000}{Mwt\ x\ V(mL)}$) η

Normality (N) = Molarity (M) . η , or Molarity(M) = Normality(N) / η

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

1.Monoprotic acid e.g: [HCl(36.5 g/mole) ,HNO_3(63 g/mole) , CH_3COOH(60 g/mole)] 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(98 g /mole), H_2CO_3(62 g/mole)] η= 2

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

Eq = $\frac{62}{2} = 31$ for H_2CO_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. Monohydroxy base e.g: (η=1)

e.g: NaOH (40 g/mole)

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

e.g: KOH (56 g/mole)

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

2. Dihydroxy base (η=2)

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

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

$Zn(OH)_2$ (99.4 g /mole)

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

$Ba(OH)_2$ (171.35 g / mole)

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

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.

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

η= change in oxidation state number

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

Example :

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

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

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

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

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

2. **Equivalent mass for salts:**

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

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

e.g: $AgNO_3$ (170 g/mole)

($AgNO_3$ → Ag+ + NO_3^-)

(η = Ag^+ (1) x 1= 1)

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

e.g: Na_2CO_3 (106 g/mole)

(Na_2CO_3 → 2 Na^+ + CO_3^{2-})

(η= Na^+ (2) x 1= 2)

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

e.g: **$BaSO_4$ (233 g/mole)**

($Ba^{2+} + SO_4^{2-} \leftrightarrow BaSO_4$)

η = Ba^{2+} (1) x (2+) =2

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

e.g: $La(IO_3)_3$ (663.6 g/mole)

($La(IO_3)_3 \rightarrow La^{3+} + 3\ IO_3^-$)

(η = La^{3+} (1) x 3 = 3)

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

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

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

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

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

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

No. of cations =2Na+ while the cation charge for Na^+ =1 ,

Then (η) = 2 x 1 = 2

Eq. of Na_2CO_3 = $\frac{Mwt}{2} = \frac{106}{2}$ =**53 grams**

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

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

Second method:

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

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

Example;

Convert the following Molarities to Normalities.

a. 2.5 M HCl b. 1.4 M H_2SO_4 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 H_2SO_4 = M . η = 1.4 x 2 = 2.8 N H_2SO_4

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

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:

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}) = $\frac{1.840\ x\ 96\ x\ 1000}{49\ x\ 100}$

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

$V_{conc} = \frac{3\ x\ 500}{36.04}$ **= 41.62 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

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

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

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

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) = $2.67 \times 10^{-3} \times 3 = 8.01 \times 10^{-3}$ 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^+ = $3 \times 2.67\times10^{-3} = 8.01\times 10^{-3}$ M