

Solution:

Topic: concentration of solution.

Introduction :-

When several non-reacting substance are mixed, then there are three possible type of mixtures:

a) Coarse mixture (sand + salt) & (sugar + salt).

b.) Colloidal dispersion (gum + water) & (fine clay + water)

c.) True solution (salt + water)

In the coarse mixture there exist heterogeneity where as in true solution there is complete homogeneity. In colloidal dispersion, the heterogeneity is not readily apparent & it is not homogeneous.

Distinction between Solute & solvent:

I) Phase method:

Let there be a substance 'A' in solid phase & 'B' in liquid phase then if the phase of the resulting mixture is?

a.) solid, then solute = B, solvent = A.

b.) liquid, then solute = A, solvent = B

II) Amount Method:

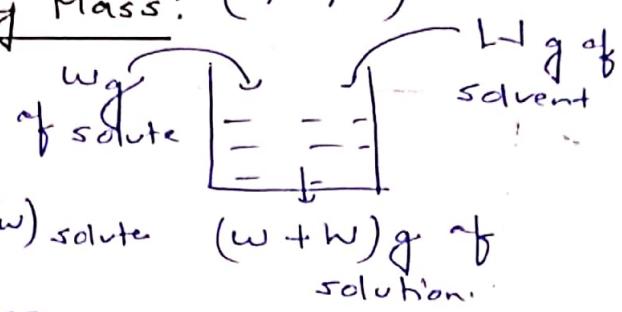
According to this method, the substance which is in larger proportion by mass is solvent while the one in lesser proportion is solute.

e.g.: A solid mixture of A & B. if $w_A > w_B$ then solute is B & solvent is A.

Method of Expressing the concentration of solution:

1.) Mass Percentage or Percent by Mass: (%w/w)

Mass percentage



$$\text{Mass Percentage of solute } (\% \text{w/w})_{\text{solute}} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

$$(\% \text{w/w})_{\text{solute}} = \frac{w \text{g}}{(w + w) \text{g}} \times 100$$

Similarly, Mass percentage of solvent (<%w/w>)_{solvent}.

$$= \frac{\text{Mass of solvent}}{\text{Mass of solution}} \times 100$$

$$(\% \text{w/w})_{\text{solvent}} = \frac{w \text{g}}{(w + w) \text{g}} \times 100$$

Mass percentage is unitless.

$$\text{Also, } (\% \text{w/w})_{\text{solute}} + (\% \text{w/w})_{\text{solvent}} = 100$$

Proof: $\frac{w \text{g}}{(w + w) \text{g}} \times 100 + \frac{w \text{g}}{(w + w) \text{g}} \times 100$
 $\frac{(w + w) \text{g}}{(w + w) \text{g}} \times 100 = 100$

Q2) A solution of NaOH 40% (w/w) of NaOH in 10 litres of solution. Calculate

- Mass of NaOH & solvent (take solvent = water)
- Moles of NaOH & solvent.
- Given density of solution is 1.5 g / mL.

2) Volume Percentage or Percentage by volume; ($\%v/v$)

Volume percentage of solvent ($\%v/v$)_{solvent} of solute

$$= \frac{V_{mL}}{(v+V) \text{ mL}} \times 100$$

Volume Percentage of solute ($\%v/v$)_{solute}

$$= \frac{V_{mL}}{(v+V) \text{ mL}} \times 100$$

Like Mass percentage, Volume percentage, is a unitless quantity.

wg of solute

(3) Mass by Volume Percentage ($\%w/v$)_{solute}

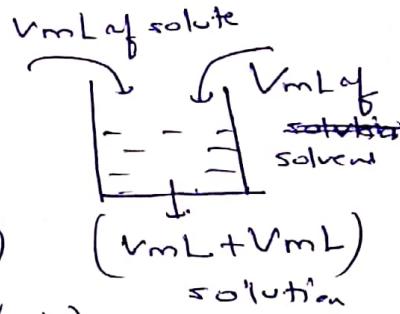
$$= \frac{\text{Mass of solute}}{\text{Volume of solution}} \times 100$$

$$= \frac{wg}{V_{mL}} \times 100$$

V mL of solution

Let us suppose, Expressing ($\%v/v$)_{solute} to ($\%w/v$)_{solute}.

Given, ρ_{solute} = density of solute. (in g/mL)



ρ_{solvent} = density of solvent. (in g/mL)

V_{solute} = Volume of solute. (in mL)

V_{solvent} = Volume of solvent (in mL)

M_{solute} = Mass of solute (in g) = $V_{\text{solute}} \times \rho_{\text{solute}}$.

$$(\%w/v)_{\text{solute}} = \frac{V_{\text{solute}} \times \rho_{\text{solute}}}{(V_{\text{solute}} + V_{\text{solvent}})} \times 100$$

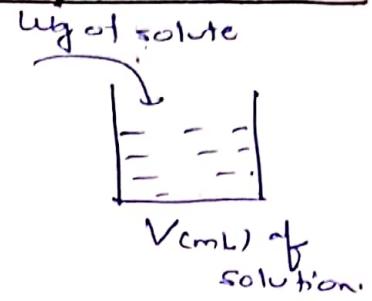
Expressing ($\%w/w$)_{solute} from ($\%v/v$)_{solute}:

$$(\%w/w)_{\text{solute}} = \left(\frac{\rho_{\text{solute}} \times V_{\text{solute}}}{\rho_{\text{solute}} \times V_{\text{solute}} + \rho_{\text{solvent}} \times V_{\text{solvent}}} \right) \times 100$$

4) Molarity (M) :

$$\text{Molarity (M)} = \frac{\text{no. of moles of solute}}{\text{Volume of solution in L}}$$

= \frac{w\text{g}}{M\text{g/mol} \times V\text{L}}



Let $M_{\text{solute}} = \text{Molecular wt. of solute}$ (mole g/mole)

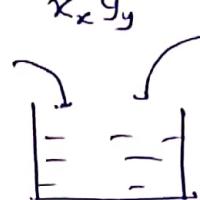
then, no. of moles of solute = $\frac{w\text{g}}{M\text{g/mol}}$

$$\text{Volume of solution} = \frac{V\text{mL}}{1000(\text{mL/L})}$$

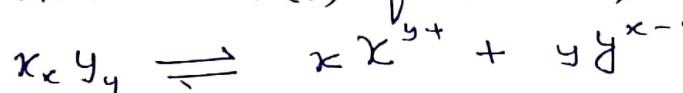
so, $\boxed{\text{Molarity} = \left(\frac{w/M}{V/1000} \right) \text{mol/L}}$

case-I

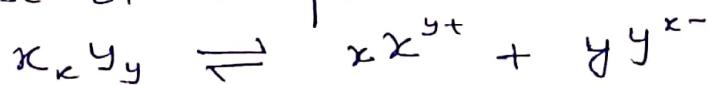
Molarity of ionic compound:



Suppose, an ionic compound $X_x Y_y$ dissolved in $V(L)$ of solution, then,



In case of complete dissociation.

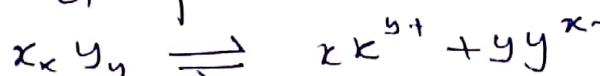


Initial	1	0	0
Eq ^m	0	x	y

so, Molarity (of cation) = $\frac{x \text{ mole}}{V \text{ L}}$.

Molarity (of anion) = $\left(\frac{y}{V} \right) \text{ mol/L}$.

In case of partial dissociation,

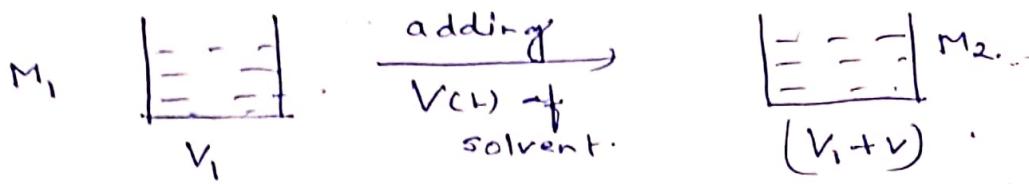


Initial	1	0	0
Eq ^m	$(1-\alpha)$	$x\alpha$	$y\alpha$

Molarity (of cation) = $\frac{x\alpha}{V} \text{ mol/L}$.

Molarity (of anion) = $\left(\frac{y\alpha}{V} \right) \text{ mol/L}$.

Case-2: Molarity of dilution.



In both of solution, mass of solute / moles of solute remains constant.

$$\text{In 1st solution, } M_1 = \frac{n_1}{V_1} \quad \therefore n_1 = \text{no. of moles of solute in soln' 1}$$

$$n_1 = M_1 V_1 \quad \text{--- (1)}$$

$$\text{2nd solution, } M_2 = \frac{n_2}{V_2} \quad \therefore n_2 = \text{no. of moles of solute in soln' 2, after dilution}$$

$$n_2 = M_2 V_2 \quad \text{--- (2)}$$

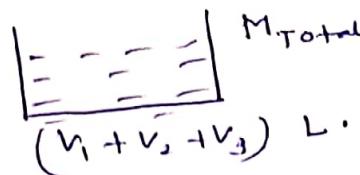
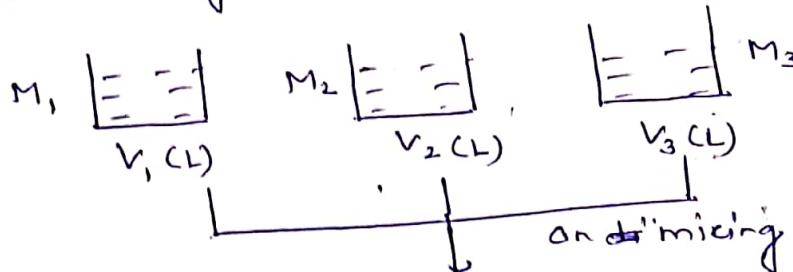
During dilution, no. of moles remain constant.

$$n_1 = n_2$$

$$M_1 V_1 = M_2 V_2$$

$$M_2 = \frac{M_1 V_1}{V_2} = \left(\frac{M_1 V_1}{V_1 + V} \right)$$

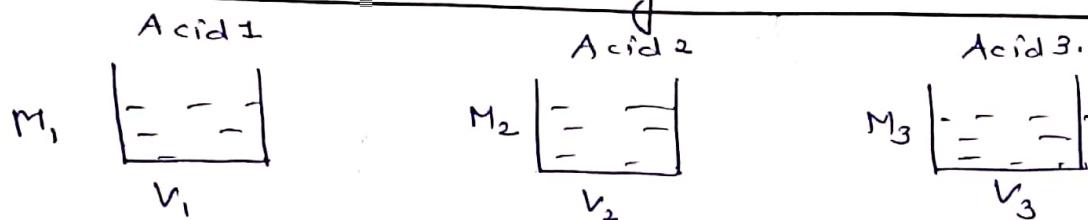
Case-3: Mixing of two solution:



$$M_{\text{Total}} (V_1 + V_2 + V_3) = M_1 V_1 + M_2 V_2 + M_3 V_3$$

$$M_{\text{Total}} = \frac{(M_1 V_1 + M_2 V_2 + M_3 V_3)}{(V_1 + V_2 + V)}$$

Case-4.) Molarity of Mixing of two or more acid with different basicity: (6)



Basicity: κ_1

$$M_1 (\text{H}^{\oplus} \text{ from Acid 1}) = \frac{\kappa_1 n_1}{V_1} \quad \text{where, } n_1 = \text{no. of moles of Acid 1.}$$

$$M_2 (\text{H}^{\oplus} \text{ from Acid 2}) = \frac{\kappa_2 n_2}{V_2} \quad n_2 = \text{no. of moles of Acid 2.}$$

$$M_3 (\text{H}^{\oplus} \text{ from Acid 3}) = \frac{\kappa_3 n_3}{V_3} \quad n_3 = \text{no. of moles of Acid 3.}$$

Upon Mixing three solutions,

Resulting Molarity will be M_{Total} .

$$M_{\text{Total}} = \frac{M_1 V_1 + M_2 V_2 + M_3 V_3}{V_1 + V_2 + V_3}$$

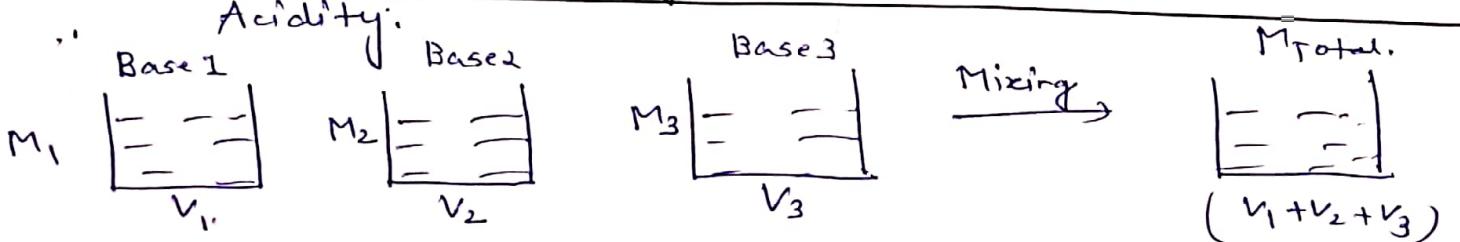
From eq, ①, ② & ③

$$M_{\text{Total}} = \frac{(\kappa_1 n_1 + \kappa_2 n_2 + \kappa_3 n_3)}{V_1 + V_2 + V_3}$$

Generalize :

$$M_{\text{Total}} = \frac{\sum_{i=1}^n (\text{basicity})_i \times n_i}{\sum_{i=1}^n V_i}$$

Case-5.) Molarity of Mixing two or more base with different Acidity.



Basicity: γ_1

$$M_{\text{Total}} (\text{OH}^{\ominus}) = \frac{(\gamma_1 n_1 + \gamma_2 n_2 + \gamma_3 n_3)}{V_1 + V_2 + V_3}$$

Generalize :

Generalize,

$$M_{\text{Total}} = \frac{\sum_{i=1}^n (\text{acidity})_i \times n_i}{\sum_{i=1}^n V_i}$$

pH of solution obtained from mixing:

1) pH of Mixing Acidic solution:

$$pH = -\log [H^{\oplus}]$$

For acidic solution Mix,

$$M_{\text{Total}} (H^{\oplus}) = \left(\frac{M_1 V_1 + M_2 V_2 + M_3 V_3}{V_1 + V_2 + V_3} \right)$$

$$pH = -\log \left[\frac{M_1 V_1 + M_2 V_2 + M_3 V_3}{(V_1 + V_2 + V_3)} \right]$$

$$pH = -\log \left[\frac{\sum_{i=1}^n (\text{basicity})_i \times n_i}{\sum_{i=1}^n V_i} \right]$$

2) pH of Mixing basic solution,

$$pH (\text{Basic}) = 14 - pOH.$$

$$= 14 + \log \left[\frac{M_1 V_1 + M_2 V_2 + M_3 V_3}{\sum_{i=1}^n V_i} \right]$$

$$= 14 + \log \left[\frac{\sum_{i=1}^n (\text{Acidity})_i \times n_i}{\sum_{i=1}^n V_i} \right].$$

3) pH of Mixing Acidic & Basic solution.

Mixing of Acidic & Basic solution led to neutralization of solution; $H^{\oplus} + OH^{\ominus} \rightleftharpoons H_2O$:

$$pH = (pH)_{\text{Acidic}} - (pOH)_{\text{Basic.}}$$

$$= -\log \left[\frac{\sum_{i=1}^n (\text{basicity})_i \times n_i}{V_i} \right] + \log \left[\frac{\sum_{j=1}^m (\text{acidity})_j \times n_j}{V_j} \right].$$

Mixing may result into,

a) Acidic solution ; $M_{\text{Total}} (H^{\oplus}) > M_{\text{Total}} (OH^{\ominus})$

b) Basic solution ; $M_{\text{Total}} (H^{\oplus}) < M_{\text{Total}} (OH^{\ominus})$

c) Neutral solution ; $M_{\text{Total}} (H^{\oplus}) = M_{\text{Total}} (OH^{\ominus})$.