BYJU'S Classes

NOTES

CHEMISTRY

MOLE CONCEPT

CONVERSION OF CONCENTRATION TERMS, DILUTION AND MIXING

What you already know

- Molality
- Mass fraction
- Parts per billion
- Mole fraction
- Mass percentage
- Mole percentage
- Parts per million

What you will learn

- Interconversion of concentration terms
- Dilution of solutions
- Addition of solutions
- Neutralisation of solutions

Finding molality of solution from given mole fraction of solute

Mole fraction of **A** in **H_2O** is **0.2**. Find the **molality of A.**

(A) 13.9 *m* (B) 15.5 *m* (C) 14.5 *m* (D) 16.8 *m*

Solution

Step 1: Find number of moles of solute

Consider 1 *mol* of the solution.

Given that mole fraction of solute = 0.2

$$\text{Mole fraction of solute} = \frac{\text{Moles of solute}}{\text{Moles of solution}}$$

$$0.2 = \frac{\text{Moles of solute}}{1\ mol}$$

Number of moles of solute = 0.2 *mol*

Step 2: Find weight of solvent

Total number of moles of solution
= moles of solute + moles of solvent

Number of moles of solvent = 1 - 0.2 = 0.8 *mol*

$$\text{Number of moles (n)} = \frac{\text{Given mass (m)}}{\text{Molar mass (M)}}$$

Given mass (m) = 0.8 × 18 = 14.4 *g*

Weight of solvent (in *kg*) = 14.4×10^{-3} *kg*

Step 3: Find molality

$$\text{Molality} = \frac{\text{Moles of solute}}{\text{Mass of solvent (in } kg)}$$

$$\text{Molality} = \frac{0.2}{14.4 \times 10^{-3}} = 13.9\ mol/kg \text{ or } 13.9\ molal$$

Hence, (a) is the correct option.

Finding molarity of solution from given mole fraction

The **mole fraction** of **methanol** in an **aqueous solution** is **0.02** and its **density** is **0.994 *g/mL***. Determine the **molarity** of the solution.

Solution

Step 1: Find moles of solute

Let us consider 1 mole of solution.

Given that mole fraction of methanol in H_2O = 0.02

$$\text{Mole fraction of solute} = \frac{\text{Moles of solute}}{\text{Moles of solution}}$$

$$0.02 = \frac{\text{Moles of solute}}{1\ mol}$$

Number of moles of solute = 0.02 *mol*

Step 2: Find masses of solvent and solute

Total number of moles of solution
= Moles of solute + Moles of solvent

Moles of solvent = 1 - 0.02 = 0.98 *mol*

Molar mass of solvent (H_2O) = 18 *g/mol*

$$\text{Number of moles (n)} = \frac{\text{Given mass (m)}}{\text{Molar mass (M)}}$$

Mass of solvent = 18 × 0.98 = 17.64 *g*

Mass of solute = 0.02 × 32 = 0.64 *g*

Step 3: Find volume of solution

Total mass of solution = Mass of solvent + Mass of solute

Total mass of solution = 17.64 + 0.64 = 18.28 *g*

Given density of solution = 0.994 *g/mL*

$$\text{Volume of solution} = \frac{\text{Mass of solution (m)}}{\text{Density of solution } (\rho)}$$

$$\text{Volume} = \frac{18.28}{0.994} = 18.39\ mL$$

$$\text{Volume} = 18.39 \times 10^{-3}\ L$$

Step 4: Find molarity of solution

$$\text{Molarity} = \frac{\text{Number of moles of solute}}{\text{Volume of solution (in } L)}$$

$$\text{Molarity} = \frac{0.02}{18.39 \times 10^{-3}} = 1.09\ mol/L$$

Finding the molality from given molarity of solution

If you are given a **2 *M* NaOH solution** having **density 1 *g/mL***, then find the **molality of the solution**.

Solution

Step 1: Find mass of solution

Let us consider the volume of solution as 1 litre or 1000 *mL*.

Given density of solution = 1 *g/mL*

Mass of solution = Volume × Density

Mass of solution = 1000 × 1 = 1000 *g*

Step 2: Find mass of solute

Given molarity of solution = 2 M

$$\text{Molarity} = \frac{\text{Moles of solute}}{\text{Volume of solution (in } L)}$$

$$2 = \frac{\text{Moles of solute (NaOH)}}{1}$$

So, number of moles of solute = 2 mol

Molar mass of solute (NaOH) = 23 + 16 + 1 = 40 g/mol

$$\text{Number of moles (n)} = \frac{\text{Given mass (m)}}{\text{Molar mass (M)}}$$

Mass of solute = 2 × 40 = 80 g

Step 3: Find mass of solvent

Total mass of solution
= Mass of solute + Mass of solvent

Mass of solvent = 1000 - 80
= 920 g or 0.92 kg

Step 4: Find molality of solution

$$\text{Molality} = \frac{\text{Moles of solute}}{\text{Mass of solvent (in } kg)}$$

$$\text{Molality} = \frac{2}{0.92} = 2.17\ mol/kg \text{ or } 2.17 \text{ molal}$$

Finding percentage concentration of solution after precipitation process

When **400 g** of a **20% solution by weight** was **cooled, 50 g** of the **solute precipitated**. Find the percentage concentration of the remaining solution.

(A) 8.57% (B) 15% (C) 12.25% (D) 9.5%

Solution

Step 1: Find mass of solvent and solute

Given mass of solution = 400 g

Percentage concentration (%w/w) = 20%

$$\text{Mass percentage} = \frac{\text{Mass of solute (in } g)}{\text{Mass of solution (in } g)} \times 100$$

$$\text{Mass of solute} = 20 \times \frac{400}{100} = 80\ g$$

Mass of solvent = Total mass of solution - Mass of solute = 400 - 80 = 320 g

Step 2: Find mass of solute after precipitation

Mass of solute = 80 - 50 = 30 g

Mass of solvent remained the same, i.e., 320 g.

Total mass of the solution after precipitation
= 320 + 30 = 350 g

Step 3: Find mass percentage (%w/w) after precipitation

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

$$\text{Mass \%} = \frac{30}{350} \times 100 = 8.57\%$$

Hence, (a) is the correct option.

Finding the molarity and molality from given mass percentage

H_2SO_4 solution has a **density of 1.84 *g/cc*** and contains **98% by mass of H_2SO_4**. Choose the correct options. (Given atomic mass of S = 32 *u*)

(A) m = 100 *m* (B) m = 500 *m* (C) M = 18.4 *M* (D) M = 20 *M*

Solution

Step 1: Find mass of solute and solvent

Consider 100 *g* of solution.

Given, 98% by mass of H_2SO_4

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

$$\text{Mass of solute } (H_2SO_4) = \frac{98}{100} \times 100 = 98\ g$$

Total mass of solution
= Mass of solute + Mass of solvent

Mass of solvent = 100 - 98 *g* = 2 *g* or 2×10^{-3} *kg*

Step 2: Find number of moles of solute and solvent

Molar mass of solute (H_2SO_4) = 98 *g/mol*

Given mass of solute = 98 *g*

$$\text{Number of moles (n)} = \frac{\text{Given mass (m)}}{\text{Molar mass (M)}}$$

Number of moles (n) = 98/98 = 1 *mol*

Molar mass of water (H_2O) = 18 *g/mol*

$$\text{Number of moles of } H_2O = \frac{2}{18} = \frac{1}{9}\ mol$$

Step 3: Find volume of solution

$$\text{Volume of solution} = \frac{\text{Mass of solution (m)}}{\text{Density of solution } (\rho)}$$

Given density of solution = 1.84 *g/cc*

$$\text{Volume} = \frac{100}{1.84}\ mL \text{ or } 100 \times \frac{10^{-3}}{1.84}\ L$$

Step 4: Find molarity of solution

$$\text{Molarity} = \frac{\text{Number of moles of solute}}{\text{Volume of solution (in } L)}$$

$$\text{Molarity} = \frac{1}{100} \times \frac{1.84}{10^{-3}} = 18.4\ M$$

Step 5: Find molality of solution

$$\text{Molality} = \frac{\text{Number of moles of solute}}{\text{Mass of solvent (in } kg)}$$

$$\text{Molality} = \frac{1}{2 \times 10^{-3}} = 500\ m$$

Hence, (b) and (c) are the correct options.

Finding the molarity, molality, percentage concentration (%w/v) from given %w/w concentration

If a given solution of **H_2SO_4** is labelled as **49% (w/w)**, then find the **correct statements** regarding the solution. (d = 1.3 *g/mL*)

(A) $m = \frac{500}{51}\ m$ (B) $m = \frac{1000}{51}\ m$ (C) %w/V = (49 × 1.3)% (D) M = 6.5 *M*

Solution

Step 1: Find mass of solute and solvent

Consider 100 g of solution.

Given, 49% by mass of H_2SO_4

Mass percentage = $\dfrac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$

Mass of solute (H_2SO_4) = $49 \times \dfrac{100}{100} = 49\ g$

Total mass of solution
= Mass of solute + Mass of solvent

Mass of solvent = 100 - 49 = 51 g or $51 \times 10^{-3}\ kg$

Step 2: Find number of moles of solute and solvent

Molar mass of solute (H_2SO_4) = 98 g/mol

Given mass of solute = 49 g

Number of moles (n) = $\dfrac{\text{Given mass (m)}}{\text{Molar mass (M)}}$

Number of moles (n) = 49/98 = 0.5 mol

Molar mass of water (H_2O) = 18 g/mol

Number of moles of H_2O = $\dfrac{51}{18} = \dfrac{17}{6}\ mol$

Step 3: Find volume of solution

Volume of solution = $\dfrac{\text{Mass of solution (m)}}{\text{Density of solution } (\rho)}$

Given density of solution = 1.3 g/cc

Volume = $\dfrac{100}{1.3}\ mL$

Volume = $100 \times \dfrac{10^{-3}}{1.3}\ L = \dfrac{1}{13}\ L$

Step 4: Find molarity of solution

Molarity = $\dfrac{\text{Number of moles of solute}}{\text{Volume of solution (in } L)}$

Molarity = $\dfrac{0.5}{\dfrac{1}{13}} = 6.5\ M$

Step 5: Find molality of solution

Molality = $\dfrac{\text{Number of moles of solute}}{\text{Mass of solvent (in } kg)}$

Molality = $\dfrac{0.5}{51 \times 10^{-3}} = \dfrac{500}{51}\ m$

Step 6: Find %w/V

Percentage concentration (%w/V)

= $\dfrac{\text{Mass of solute (in g)}}{\text{Volume of solution (in mL)}} \times 100$

(%w/V) = $\dfrac{49}{\dfrac{1000}{13}} \times 100 = (49 \times 1.3)\%$

Hence, (a), (c), and (d) are the correct options.

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Dilution

Addition of solvent in a solution decreases the molarity of the solution since molarity is inversely proportional to the volume of the solution.

If a **solution** having a **volume V_1** and **Molarity M_1** is **diluted** to a **volume V_2**, then the **concentration of the solution changes** and the **molarity decreases to M_2**.

Molarity = $\dfrac{\text{Number of moles of solute}}{\text{Volume of the solution in } mL} \times 1000$

So, number of moles of the solute = Molarity × Volume of the solution (*L*)

= Molarity × Volume of the solution (*mL*)/1000

Since number of moles of solute remains the same even after dilution, $M_1V_1 = M_2V_2$

Example

Mixing 150 *mL* water to 150 *mL* of 2 *M* NaCl solution

Final volume = 150 + 150 = 300 *mL*

Since $M_1V_1 = M_2V_2$

Where M_1 = Initial molarity

V_1 = Initial volume

M_2 = Final molarity

V_2 = Final volume

$2\ M \times 150\ mL = M_2 \times 300\ mL$

$M_2 = 1\ M$

Finding the volume of stock solution required for given dilution

29.2% (w/w) HCl stock **solution** has a **density of 1.25 *g/mL***. The **molecular weight** of **HCl** is **36.5 *g/mol***. Find the volume (*mL*) of stock solution required to prepare a **200 *mL*** solution of **0.4 *M* HCl**.

Solution

Step 1: Find mass of solute

Consider 100 *g* of solution.

Given, 29.2% by mass of HCl

$$\text{Mass percentage} = \frac{\text{Mass of solute (in } g)}{\text{Mass of solution (in } g)} \times 100$$

$$\text{Mass of solute (HCl)} = 29.2 \times \frac{100}{100} = 29.2\ g$$

Step 2: Find number of moles of solute

Molar mass of solute (HCl) = 36.5 *g/mol*

Given mass of solute = 29.2 *g*

$$\text{Number of moles (n)} = \frac{\text{Given mass (m)}}{\text{Molar mass (M)}}$$

$$\text{Number of moles (n)} = \frac{29.2}{36.5} = 0.8\ mol$$

Step 3: Find volume of solution

$$\text{Volume of solution} = \frac{\text{Mass of solution } (m)}{\text{Density of solution } (\rho)}$$

Given density of solution = 1.25 *g/cc*

$$\text{Volume} = \frac{100}{1.25}\ mL$$

$$\text{Volume} = 100 \times \frac{10^{-3}}{1.25}\ L = \frac{1}{12.5}\ L$$

Step 4: Find molarity of solution

$$\text{Molarity} = \frac{\text{Number of moles of solute}}{\text{Volume of solution (in } L)}$$

$$\text{Molarity} = \frac{0.8}{\frac{1}{12.5}} = 10\ M$$

Step 5: Find volume of solution required to have 0.4 *M* as final molarity

Initial molarity of solution (M_1) = 10 *M*

Final molarity of solution (M_2) = 0.4 *M*

Final volume of solution (V_2) = 200 *mL*

$M_1V_1 = M_2V_2$

$10 \times V_1 = 0.4 \times 200$

$V_1 = 8\ mL$

So, the volume of stock solution required is 8 *mL*.

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Addition

- In general, during addition or mixing of solutions, the **moles of solute** (if solute is same) and the **volume of solution is added**.
- Moles (n) = Concentration (M) × Volume of solution in Litre (V)
- If a solution having **volume V_1** and **molarity M_1** is **mixed** with **another solution of same solute** having **volume V_2** and **molarity M_2**, then, $M_1V_1 + M_2V_2 = M_R(V_1 + V_2)$

Where M_R is the resultant molarity of the solution.

This is because total moles after mixing = Σ(Molarity × Volume) = $M_1V_1 + M_2V_2$

Total volume after mixing = $V_1 + V_2$

$$M_R = \frac{\text{Total moles}}{\text{Total Volume}} = \frac{n_1 + n_2}{V_1 + V_2} = \frac{M_1V_1 + M_2V_2}{V_1 + V_2}$$

Example

Molarity of NaCl after mixing 150 *mL* of 2 *M* NaCl solution with another 150 *mL* of 2 *M* NaCl solution

$M_1V_1 + M_2V_2 = M_R(V_1 + V_2)$

$(2 \times 150) + (2 \times 150) = M_R \times (150 + 150)$

$M_R = 2.0\ M$

Finding volume of solution to be added in another solution to have given resultant molarity

What **volume** of a **1.4 *M* HCl** solution should be added to a **200 *mL*, 2.4 *M* HCl** solution that is finally **diluted** to **500 *mL*** so that molarity of final HCl solution becomes **1.24 *M***?

Solution

Given, final molarity of solution after dilution (M_R) = 1.24 *M*

Final volume of solution after dilution = 500 *mL*

Molarity of solution 1 (M_1) = 1.4 *M*

Consider the volume to be V_1.

Molarity of solution 2 (M_2) = 2.4 *M*

Volume of solution 2 (V_2) = 200 *mL*

We will use the following formula of addition of solutions to find out the volume of solution 1 required.

$M_1V_1 + M_2V_2 = M_R(V_1 + V_2)$

$1.4 \times V_1 + 2.4 \times 200 = 1.24 \times 500$

$1.4 \times V_1 + 480 = 620$

$V_1 = \dfrac{(620 - 480)}{1.4} = 100\ mL$

So, 100 *mL* of 1.4 *M* HCl solution has to be added to 200 *mL* of 2.4 *M* HCl to have resultant molarity of 1.24 *M* of 500 *mL* solution.

Finding resultant molarity from addition of solutions

Equal volumes of **1 *M* NaOH, 10% (w/V) NaOH** and **1 *m* NaOH (d = 1.2 *g/mL*)** are mixed. What will be the **molarity** of the **final solution**? (All aqueous)

Solution

Step 1: Find number of moles of 1 *M* NaOH solution

Let us assume 1 *L* of each solution is mixed.

Given molarity of NaOH = 1 *M*

So, number of moles of NaOH = 1 *mol*

Step 2: Find number of moles of solute in 10% (w/V) NaOH solution

Given percentage concentration = 10% (w/V)

So, the mass of solute (NaOH) in grams = 10 *g*

Volume of solution = 100 *mL*

10 *g* of solute is present in 100 *mL* of solution.

By unitary method, 1000 *mL* (1 *L*) of solution will contain $\dfrac{(1000 \times 10)}{100} = 100\ g$

Number of moles of solute (n) = $\dfrac{\text{Given mass (m)}}{\text{Molar mass (M)}}$

Molar mass of solute = 40 *g/mol*

Number of moles (n) = $\dfrac{100}{40} = 2.5\ mol$

Step 3: Find number of moles of 1 *m* NaOH solution

Given density of solution = 1.2 *g/mL* or $\dfrac{1.2\ (g)}{10^{-3}\ (L)} = 1200\ g/L$

Volume of 1 *m* solution added = 1 *L*

Mass of solution = Volume (V) × Density (ρ)

$= 1\ L \times 1200\ g/L = 1200\ g$

Mass of solute = 1 × 40 = 40 g

Mass of solvent = 1200 - 40 = 1160 g

In 1 m solution, we have 1 mol of solution in 1000 g of solvent but weight of solvent here is 1160 g

So, by unitary method, moles of solute present in 1160 g of solvent = $\frac{1160}{1000} = 1.16\ mol$

Step 4: Find resultant molarity after addition of solutions

Total number of moles of NaOH (in final solution) = 1 + 2.5 + 1.16 = 4.66 mol

Volume of resultant solution (added 1 L of each solution) = 1 + 1 + 1 = 3 L

$$\text{Molarity} = \frac{\text{Number of moles of solute}}{\text{Volume of solution (in } L)} = \frac{4.66}{3} = 1.553\ M$$

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Neutralisation

Mixing an acid and a base to produces salt and water. This reaction is known as neutralisation reaction.

Example

When 2 moles of HCl is added to 1 mole of NaOH, 1 mole of HCl is left as 1 mole of HCl reacts with 1 mole of NaOH.

If an acid or a base having volume V_1 and molarity M_1 is mixed with another acid or base of different solute having volume V_2 and molarity M_2, then, $M_R = \frac{|M_1V_1 - M_2V_2|}{V_1 + V_2}$

Where M_R is the resultant molarity of the acid or base.

Finding basicity of acid

The **formula weight** of an **acid** is **82 *u*. 100 *cm*³** of a solution of this acid containing **39.0 *g*** of the **acid per litre** was completely neutralised by **95.0 *cm*³** of aqueous **NaOH** containing **40.0 *g*** of **NaOH per litre**. What is the **basicity** of the acid?

Solution

Step 1: Find number of moles of acid

Given, 39 g of acid per litre

So, 100 mL will have 3.9 g of acid.

$$\text{Number of moles of acid} = \frac{\text{Given mass (m)}}{\text{Molar mass (M)}} = \frac{3.9}{82}\ mol$$

Step 2: Find basicity of acid

Let the basicity of acid be m.

Basicity of an acid is the number of hydrogen ions that can be furnished by one molecule of the acid.

So, number of moles of H^+ ions = m × $\frac{3.9}{82}$ *mol*

Step 3: Find moles of OH^-

Given that 40 *g* NaOH is present in 1 *L* (1000 *mL*).

By unitary method, the mass of NaOH present in 95 *mL* of the solution is $\frac{(95 \times 40)}{1000}$ *g*.

Number of moles of OH^- ions = $\frac{\text{Given mass (m)}}{\text{Molar mass (M)}} = \frac{(95 \times 40)}{(1000 \times 40)} = 95 \times 10^{-3}$ *mol*

Step 4: Neutralisation of acid and base

Number of moles of acid (H^+) = Number of moles of base (OH^-)

$\Rightarrow m \times \frac{3.9}{82}\ mol = 95 \times 10^{-3}\ mol$

m ~ 2.0

Hence, the basicity of the acid is 2.

Finding % concentration from neutralisation

5 *g* sample contains only **Na_2CO_3 and Na_2SO_4**. This **sample** is **dissolved** and the **volume** is **made** up to **250 *mL***. **25 *mL*** of this solution **neutralises 20 *mL*** of **0.1 *M* H_2SO_4**. Choose the correct option.

(A) % of Na_2SO_4 = 47.6%

(B) % of Na_2SO_4 = 57.6%

(C) % of Na_2SO_4 = 52.4%

(D) % of Na_2CO_3 = 42.2%

Solution

Step 1: Write a balanced chemical reaction

$Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + CO_2 + H_2O$

Na_2SO_4 present in the sample will not react with H_2SO_4 as Na_2SO_4 is not a basic salt.

Step 2: Find number of millimoles of acid

Given, 20 *mL* of 0.1 *M* H_2SO_4

Molarity = $\frac{\text{Number of moles of solute}}{\text{Volume of solution (in } L\text{)}}$

So, the number of moles (H_2SO_4) = 20 × 0.1 = 2 *mmol* (millimoles)

Step 3: Find mass % of Na_2CO_3 in sample

For neutralisation of a given 25 *mL* solution of sample, the number of moles of Na_2CO_3 will be equal to the number of moles of acid.

So, number of moles of Na_2CO_3 = 2 *mmol* (in 25 *ml*)

In the given 250 *mL* solution, the number of moles of Na_2CO_3 = 20 *mmol*

Molar mass of Na_2CO_3 = $23 \times 2 + 12 + 16 \times 3 = 106$ *g/mol*

$$\text{Number of moles (n)} = \frac{\text{Given mass } (m)}{\text{Molar mass } (M)}$$

Mass of Na_2CO_3 = $20 \times 106 = 2120$ *mg* = 2.12 *g*

$$\text{Mass percentage of } Na_2CO_3 = \frac{\text{Mass of solute } (Na_2CO_3)}{\text{Total mass of solution (in } g)} \times 100$$

$$\text{Mass percentage} = \left(\frac{2.12}{5}\right) \times 100 = 42.4\%$$

Step 4: Find mass % of Na_2SO_4 in sample

Mass % of Na_2SO_4 = 100 - 42.4 = 57.6%

Hence, (b) and (d) are the correct options.