# Concentration-3

Some Basic concepts of Chemistry-6

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**1. 8 g of NaOH is dissolved in 18 g of $H_2O$. Mole fraction of NaOH in solution and molality (mol $kg^{-1}$) are [JEE(Main) 2019].**

**Explanation (simple words):** 8 g NaOH $\Rightarrow$ moles solute; 18 g water $\Rightarrow$ 1 mol solvent.

**Approach:** $x_{\text{NaOH}} = \dfrac{n_{\text{NaOH}}}{n_{\text{NaOH}} + n_{\text{H2O}}}$; $m = \dfrac{n_{\text{NaOH}}}{m_{\text{solvent}}(\text{kg})}$.

**Steps:**

$$n_{\text{NaOH}} = \frac{8}{40} = 0.200\,\text{mol}, \quad n_{\text{H2O}} = \frac{18}{18} = 1.000\,\text{mol}$$
$$x_{\text{NaOH}} = \frac{0.2}{0.2 + 1.0} = \boxed{0.167} \quad (= 1/6)$$
$$m = \frac{0.200}{0.018} = \boxed{11.11\,\text{m}}$$

**Why this formula?** Mole fraction uses moles; molality uses *mass of solvent* (kg).

**Similar practice (with answer):** 4 g KOH in 36 g water: $n = 0.0711$, $x = 0.0711/(0.0711 + 2) = \boxed{0.0345}$; $m = 0.0711/0.036 = \boxed{1.97\,\text{m}}$.

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**2. Sugar ($C_{12}H_{22}O_{11}$) mass required to prepare 2.0 L of 0.10 M solution [JEE(Main) 2019].**

**Explanation (simple words):** Moles needed = $MV$; mass = $nM$.

**Steps:**

$$n = 0.10 \times 2.0 = 0.20\,\text{mol}, \ M = 342\,\text{g mol}^{-1}$$
$$m = 0.20 \times 342 = \boxed{68.4\,\text{g}}$$

**Similar practice (with answer):** 0.25 M, 1.5 L solution needs 0.375 mol $\Rightarrow$ mass $= 0.375 \times 342 = \boxed{128.25\,\text{g}}$.

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**3. A solution contains 92 g of $Na^+$ ions per kg of water. Molality of $Na^+$ in solution is [JEE(Main) 2019].**

**Approach:** $n(\text{Na}^+) = 92/23 = 4$ mol; $m = \dfrac{n}{1\,\text{kg}}$.

**Answer:** $\boxed{\boxed{4.0\,\text{m}}}$.

**Similar practice (with answer):** 36.5 g $Cl^-$ per kg water $\Rightarrow n = 1.03$ mol $\Rightarrow m = \boxed{1.03\,\text{m}}$.

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**4. Molarity after mixing 750 mL of 0.5 M HCl with 250 mL of 2.0 M HCl [JEE(Main) 2013].**

**Approach:** $M = \dfrac{M_1V_1 + M_2V_2}{V_1 + V_2}$ with volumes in L.

**Steps:**

$$M = \frac{0.5 \times 0.750 + 2.0 \times 0.250}{1.000} = \frac{0.375 + 0.500}{1.000} = \boxed{0.875\,\text{M}}$$

**Similar practice (with answer):** 200 mL 1 M + 300 mL 0.4 M $\Rightarrow M = \dfrac{0.2 + 0.12}{0.5} = \boxed{0.64\,\text{M}}$.

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**5. The mole fraction of solvent in an aqueous solution is 0.80. Find the molality.**
**Explanation (simple words):** Choose an easy basis: take 4 mol water and 1 mol solute (gives $x_{\text{solvent}} = 4/(4+1) = 0.8$).
**Steps:**

$$m = \frac{1\,\text{mol}}{(4 \times 18)\,\text{g}/1000} = \frac{1}{0.072} = \boxed{13.89\,\text{m}}$$

**Why this formula?** Molality uses *mass of solvent*, independent of temperature.
**Similar practice (with answer):** If $x_{\text{solvent}} = 0.9$, take 9 mol water and 1 mol solute: $m = 1/(9 \times 18/1000) = \boxed{6.17\,\text{m}}$.

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**6. Molality of 20% (w/w) aqueous solution of KI (M=166 g mol$^{-1}$).**
**Explanation (simple words):** In 100 g solution: 20 g KI, 80 g water.
**Steps:**

$$n_{\text{KI}} = \frac{20}{166} = 0.1205\,\text{mol}, \quad m = \frac{0.1205}{0.080} = \boxed{1.51\,\text{m}}$$

**Similar practice (with answer):** 10% (w/w) KI: $n = 10/166 = 0.0602$, $m = 0.0602/0.090 = \boxed{0.669\,\text{m}}$.

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**7. Dissolving 120 g urea (M=60) in 1000 g water gives a solution of density 1.15 g mL$^{-1}$. Find molarity [2011].**
**Steps:**

$$n = \frac{120}{60} = 2.00\,\text{mol}, \quad m_{\text{soln}} = 1000 + 120 = 1120\,\text{g}$$
$$V = \frac{1120}{1.15} = 0.9739\,\text{L}, \quad M = \frac{2.00}{0.9739} = \boxed{2.05\,\text{M}}$$

**Similar practice (with answer):** 60 g urea in 500 g water, $\rho = 1.10$ g mL$^{-1}$: $n = 1$, $V = 560/1.10 = 0.509$ L $\Rightarrow M = \boxed{1.97\,\text{M}}$.

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**8. Which mode of expressing concentration is temperature independent?**
**Answer:** $\boxed{\boxed{\text{Molality}}}$ (mass based).
**Similar practice (with answer):** Mass% or mole fraction are also $T$-independent.

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**9. A molal solution contains one mole of solute in —**
**Answer:** $\boxed{\boxed{1000\,\text{g of solvent}}}$.
**Similar practice (with answer):** True/False: 1 m means 1 mol per litre of solution. $\rightarrow$ $\boxed{\textit{False}}$.

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**10. A syrup of mass 214.2 g contains 34.2 g sugar ($C_{12}H_{22}O_{11}$). Calculate (i) molarity and (ii) mole fraction of sugar. Given density $= 1.84$ g mL$^{-1}$.**

**Explanation (simple words):** Moles sugar $= 34.2/342 = 0.100$ mol. Volume $= m/\rho$.

**Steps:**

$$V = \frac{214.2}{1.84} = 0.1164\,\text{L}$$
$$M = \frac{0.100}{0.1164} = \boxed{0.859\,\text{M}}$$
$$n_{\text{water}} = \frac{214.2 - 34.2}{18} = \frac{180.0}{18} = 10.0\,\text{mol}$$
$$x_{\text{sugar}} = \frac{0.100}{0.100 + 10.0} = \boxed{9.90 \times 10^{-3}}$$

**Why this formula?** Molarity uses litres of *solution*; mole fraction uses moles of all components.

**Similar practice (with answer):** If the density were 1.50 g mL$^{-1}$: $V = 0.1428\text{ L} \Rightarrow M = \boxed{0.700\,\text{M}}$; $x$ unchanged $= \boxed{9.90 \times 10^{-3}}$.

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**11. Molality of 1.0 L of 37% (w/v) $H_2SO_4$ (density 1.84 g mL$^{-1}$).**

**Explanation (simple words):** 37% (w/v) $\Rightarrow$ 37 g acid per 100 mL solution $\Rightarrow$ in 1 L, 370 g $H_2SO_4$. Solution mass $= 1840$ g $\Rightarrow$ solvent mass $= 1840 - 370$.

**Steps:**

$$n_{\text{acid}} = \frac{370}{98} = 3.7755\,\text{mol}, \quad m_{\text{solvent}} = 1470\,\text{g} = 1.470\,\text{kg}$$
$$m = \frac{3.7755}{1.470} = \boxed{2.57\,\text{m}}$$

**Similar practice (with answer):** For 10% (w/v), $\rho = 1.10$: 100 g acid in 1 L, $m_{\text{solvent}} = 1100 - 100 = 1000$ g, $m = \boxed{1.02\,\text{m}}$.

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**12. $8.0575 \times 10^{-2}$ kg of Glauber's salt ($Na_2SO_4 \cdot {}_{10}H_2O$) is dissolved to obtain 1 dm$^3$ of solution with density $1077.2$ kg m$^{-3}$. Calculate (i) molarity, (ii) molality, (iii) mole fraction of $Na_2SO_4$.**

**Explanation (simple words):** Molar mass($Na_2SO_4 \cdot {}_{10}H_2O$) $= 322.0$ g mol$^{-1}$; anhydrous $Na_2SO_4$ $= 142.0$ g mol$^{-1}$. Water of crystallisation becomes part of solvent.

**Steps:**

$$m_{\text{salt}} = 80.575\,\text{g}, \; n(Na_2SO_4) = \frac{80.575}{322.0} = \boxed{0.250\,\text{mol}}$$
$$\text{(i) } M = \frac{0.250}{1.000} = \boxed{0.250\,\text{M}}$$
$$m_{\text{solution}} = 1077.2\,\text{g}; \quad m_{\text{solvent}} = m_{\text{solution}} - m_{\text{anhydrous}}$$
$$m_{\text{anhydrous}} = 0.250 \times 142.0 = 35.5\,\text{g}$$
$$m_{\text{solvent}} = 1077.2 - 35.5 = 1041.7\,\text{g} = 1.0417\,\text{kg}$$
$$\text{(ii) } m = \frac{0.250}{1.0417} = \boxed{0.240\,\text{m}}$$
$$n_{\text{water}} = \frac{1041.7}{18} = 57.87\,\text{mol}$$
$$\text{(iii) } x_{Na_2SO_4} = \frac{0.250}{0.250 + 57.87} = \boxed{4.30 \times 10^{-3}}$$

**Why this formula?** For hydrated salts, the water of crystallisation contributes to the solvent after dissolution.
**Similar practice (with answer):** If 161 g of $Na_2SO_4 \cdot {}_{10}H_2O$ were used (0.5 mol): $M = \boxed{0.50\,\text{M}}$, $m \approx \boxed{0.47\,\text{m}}$, $x \approx \boxed{8.6 \times 10^{-3}}$.

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**13. A 3 M $Na_2S_2O_3$ solution has density 1.25 g $mL^{-1}$. Calculate (i) % by weight of solute, (ii) mole fraction of solute, (iii) molalities of $Na^+$ and $S_2O_3{}^{2-}$.**
**Explanation (simple words):** In 1 L: $n = 3$ mol; mass solute $= 3 \times 158 = 474$ g; mass solution $= 1250$ g; solvent mass $= 776$ g.
**Steps:**

$$\text{(i) } \%w/w = \frac{474}{1250} \times 100 = \boxed{37.9\%}$$
$$\text{(ii) } n_{\text{water}} = \frac{776}{18} = 43.11\,\text{mol},\ x_{\text{solute}} = \frac{3}{3 + 43.11} = \boxed{0.0650}$$
$$\text{(iii) } m_{\text{Na}^+} = \frac{2 \times 3}{0.776} = \boxed{7.73\,\text{m}},\quad m_{\text{S}_2\text{O}_3{}^{2-}} = \frac{3}{0.776} = \boxed{3.87\,\text{m}}$$

**Similar practice (with answer):** For a 2 M solution with $\rho = 1.20$: $\%w/w = \boxed{26.3\%}$, $x_{\text{solute}} \approx \boxed{0.043}$, $m_{\text{Na}^+} \approx \boxed{4.76\,\text{m}}$.

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**14. 100 mL of 0.50 M acetic acid is shaken with 1 g charcoal; final concentration is 0.49 M. If charcoal surface area is $3.01 \times 10^2$ $m^2$, find area occupied by one acetic acid molecule on surface.**
**Explanation (simple words):** Adsorbed moles $= \Delta(MV)$; divide surface area by number of molecules.
**Steps:**

$$n_{\text{ads}} = (0.50 - 0.49) \times 0.100 = 1.0 \times 10^{-3}\,\text{mol}$$
$$N = nN_A = 1.0 \times 10^{-3} \times 6.022 \times 10^{23} = 6.022 \times 10^{20}$$
$$A_{\text{per molecule}} = \frac{301\,\text{m}^2}{6.022 \times 10^{20}} = \boxed{5.0 \times 10^{-19}\,\text{m}^2/\text{molecule}}$$

**Similar practice (with answer):** If $\Delta c = 0.02$ M (same $V$ and area): $n = 2 \times 10^{-3}$ mol $\Rightarrow A \approx \boxed{2.5 \times 10^{-19}\,\text{m}^2}$.

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**15. A solution has $x_{\text{solute}} = 0.10$. At 298 K, its molarity equals its molality. Density $= 2.90$ g $cm^{-3}$. Find $\dfrac{M_{\text{solute}}}{M_{\text{solvent}}}$.**
**Explanation (simple words):** Let $n_s$ moles solute, $n_w = 9n_s$ moles solvent (from $x = 0.1$). In 1 L solution, mass $= \rho V = 2900$ g.
**Steps:**

$$M = m \Rightarrow n_s = \frac{1000}{9M_w}$$
$$2900 = n_s(M_s + 9M_w) = \frac{1000}{9M_w}(M_s + 9M_w)$$
$$\Rightarrow M_s = (26.1 - 9)M_w = \boxed{17.1\,M_w}$$

**Similar practice (with answer):** If $\rho = 1.45\,\text{g cm}^{-3}$ (same $x$), ratio becomes $M_s = (13.05{-}9)M_w = \boxed{4.05\,M_w}$.

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**16. A compound (M=80) is in a solvent of density 0.40 g mL$^{-1}$. Assuming solution volume ≈ solvent volume, find molarity of a 3.2 m solution.**

**Explanation (simple words):** Take 1 kg solvent: $n = 3.2$ mol solute. Volume $= m/\rho$.

**Steps:**

$$V_{\text{solvent}} = \frac{1000\,\text{g}}{0.40} = 2500\,\text{mL} = 2.50\,\text{L}$$
$$M = \frac{n}{V} = \frac{3.2}{2.50} = \boxed{1.28\,\text{M}}$$

**Similar practice (with answer):** For a 2.0 m solution in same solvent: $M = 2.0/2.50 = \boxed{0.80\,\text{M}}$.

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