Concentration-2

Some basic concepts of chemistry-5

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1. The molarity of a 70% (mass/mass) aqueous solution of a monobasic acid (X) is $X \times 10^{-1}$ M (nearest integer). Given: density = 1.25 g mL^{-1}; molar mass of acid = 70 g mol^{-1}.
Explanation (simple words): In 100 g solution, solute mass = 70 g. Volume of 100 g solution $= \frac{100}{1.25} = 80$ mL = 0.08 L.
Approach: $M = \dfrac{\text{moles of solute}}{\text{volume of solution (L)}}$.
Steps:

$$n_{\text{acid}} = \frac{70}{70} = 1.00\,\text{mol}$$
$$M = \frac{1.00}{0.08} = 12.5\,\text{M} = 125 \times 10^{-1}\,\text{M}$$

Answer: $\boxed{\text{X=125}}$.
Why this formula? Molarity is defined per litre of solution;
Similar practice (with answer): A 40% w/w base (M=80, $\rho = 1.20$ g mL^{-1}): $M = \dfrac{40/80}{0.100/1.20} = \boxed{6.0\,\text{M}}$.

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2. Conc. nitric acid is 75% by mass. Volume (mL) of solution containing 30 g HNO_3? Density = 1.25 g mL^{-1}.
Explanation (simple words): 75% means 75 g acid per 100 g solution.
Approach: Required solution mass $= \dfrac{m_{\text{acid}}}{0.75}$; volume $= \dfrac{m_{\text{solution}}}{\rho}$.
Steps:

$$m_{\text{solution}} = \frac{30}{0.75} = 40\,\text{g}$$
$$V = \frac{40}{1.25} = \boxed{32\,\text{mL}}$$

Why this formula? Mass% gives solute mass per mass of solution; density converts mass $\leftrightarrow$ volume.
Similar practice (with answer): 20 g H_2SO_4 from 80% w/w acid, $\rho = 1.80$: $m_{\text{soln}} = 25$ g, $V = 25/1.80 = \boxed{13.9\,\text{mL}}$.

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3. Density of 3 M NaCl solution is 1.25 g mL^{-1}. Find its molality.
Explanation (simple words): Consider 1 L solution: moles known, mass via density gives solvent mass.
Approach: $m = \dfrac{n_{\text{solute}}}{\text{kg solvent}}$.

Steps:

$$\begin{aligned} n_{\text{NaCl}} &= 3.00\,\text{mol} \quad (\text{per 1 L}) \\ m_{\text{solution}} &= 1.25 \times 1000 = 1250\,\text{g} \\ m_{\text{solute}} &= 3 \times 58.5 = 175.5\,\text{g} \\ m_{\text{solvent}} &= 1250 - 175.5 = 1074.5\,\text{g} = 1.0745\,\text{kg} \\ m &= \frac{3.00}{1.0745} = \boxed{2.79\,\text{m}} \end{aligned}$$

Why this formula? Molality uses mass of solvent, so temperature independent.
Similar practice (with answer): 2 M KNO_3, $\rho = 1.20$ g mL^{-1} $\Rightarrow m = \dfrac{2}{1.200 - 2 \times 0.101}$ (using masses) $\approx \boxed{1.77\,\text{m}}$.

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4. 20 mL of 2.0 M NaOH is added to 400 mL of 0.5 M NaOH. Final concentration is $X \times 10^{-2}$ M (nearest integer).
Explanation (simple words): Net moles add; volume adds for same solute.
Approach: $M = \dfrac{M_1V_1 + M_2V_2}{V_1 + V_2}$ (volumes in L).
Steps:

$$\begin{aligned} n_1 &= 0.020 \times 2.0 = 0.040\,\text{mol}, \quad n_2 = 0.400 \times 0.5 = 0.200\,\text{mol} \\ n_{\text{tot}} &= 0.240\,\text{mol}, \quad V_{\text{tot}} = 0.020 + 0.400 = 0.420\,\text{L} \\ M &= \frac{0.240}{0.420} = 0.5714\,\text{M} = \boxed{57 \times 10^{-2}\,\text{M}} \end{aligned}$$

Why this formula? Conservation of matter: moles are additive; molarity is moles per litre.
Similar practice (with answer): 100 mL 1 M mixed with 100 mL 2 M (same solute): $M = \dfrac{1 \times 0.1 + 2 \times 0.1}{0.2} = \boxed{1.5\,\text{M}}$.

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5. (JEE 2024) Volume of 3 M NaOH that can be prepared from 84 g of NaOH is $X \times 10^{-1}$ dm^3.
Explanation (simple words): Moles available $= \dfrac{84}{40} = 2.1$; volume $= \dfrac{n}{M}$.
Steps:

$$V = \frac{2.1}{3.0} = 0.7\,\text{L} = \boxed{7 \times 10^{-1}\,\text{dm}^3}$$

Why this formula? Molarity definition rearranged: $V = n/M$.
Similar practice (with answer): 0.5 mol solute to make 2 M solution: volume $= \boxed{0.25\,\text{L}}$.

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6. (JEE 2024) Molarity of 1 L H_3PO_4 with 70% purity by weight (sp. gr. 1.54 g mL^{-1}). $M(H_3PO_4) = 98$.
Approach: $m_{\text{solution}} = \rho V = 1.54 \times 1000 = 1540$ g; pure acid $= 0.70 \times 1540$; $M = \dfrac{n}{V}$.
Steps:

$$\begin{aligned} m_{\text{pure}} &= 1078\,\text{g}, \quad n = \frac{1078}{98} = 11.0\,\text{mol} \\ M &= \frac{11.0}{1.00} = \boxed{11\,\text{M}} \end{aligned}$$

Similar practice (with answer): 60% w/w, $\rho = 1.50$ g mL^{-1} (1 L): $m_{\text{pure}} = 900$ g $\Rightarrow n = 9.18$ mol $\Rightarrow M = \boxed{9.18\,\text{M}}$.

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7. (JEE 2024) A solution of H_2SO_4 is 31.4% by mass and density $= 1.25$ g mL^{-1}. Find molarity (nearest integer). $M = 98$.

Steps:

$$m_{\text{soln}} = 1250\,\text{g (per 1 L)},\ m_{\text{pure}} = 0.314 \times 1250 = 392.5\,\text{g}$$
$$n = \frac{392.5}{98} = 4.01\,\text{mol} \Rightarrow M \approx \boxed{4\,\text{M}}$$

Similar practice (with answer): 20% w/w, $\rho = 1.10$ g mL^{-1}: $M = \dfrac{0.20 \times 1100}{98} = \boxed{2.24\,\text{M}}$.

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8. (JEE 2024) Molality of 0.8 M H_2SO_4 ($\rho = 1.06$ g cm^{-3}) is $X \times 10^{-3}$ m.

Approach: Take 1 L: $n = 0.8$ mol; $m_{\text{soln}} = 1060$ g; $m_{\text{solute}} = 0.8 \times 98 = 78.4$ g; solvent mass $= 981.6$ g.

Steps:

$$m = \frac{0.8}{0.9816} = 0.815\,\text{m} = \boxed{815 \times 10^{-3}\,\text{m}}$$

Similar practice (with answer): 1.0 M HNO_3, $\rho = 1.05$ g mL^{-1}: $m = \dfrac{1.0}{1.050 - 1.0 \times 0.063} \approx \boxed{1.01\,\text{m}}$.

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9. (JEE 2024) Mass of CH_3COONa needed to make 250 mL of 0.35 M solution. ($M = 82.02$)

Steps:

$$n = 0.35 \times 0.250 = 0.0875\,\text{mol}, \quad m = nM = 0.0875 \times 82.02 = \boxed{7.18\,\text{g}}$$

Similar practice (with answer): 500 mL of 0.20 M: mass $= 0.10 \times 82.02 = \boxed{8.20\,\text{g}}$.

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10. (JEE 2024) If A dissolves in a solution containing n_A, n_B, n_C moles of A, B, C, the mole fraction of C is —

Explanation (simple words): Mole fraction $x_i = \dfrac{n_i}{\sum n_j}$.

Answer: $\boxed{\text{x}_C = \dfrac{n_C}{n_A + n_B + n_C}}$.

Similar practice (with answer): For $n_A = 1, n_B = 2, n_C = 3$, $x_C = \dfrac{3}{6} = \boxed{0.5}$.

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11. (JEE 2024) Which quantity changes with temperature?

Answer: $\boxed{\textit{Molarity}}$ — mass-based measures (molality, mass

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12. (JEE 2024) Density of x M NaOH is 1.12 g mL^{-1} and molality is 3 m. Find x (M). $M = 40$.
Approach: Take 1 kg water $\Rightarrow n = 3$ mol solute; mass of solute $= 120$ g; total mass $= 1120$ g; volume $= 1120/1.12 = 1.00$ L.
Steps:

$$M = \frac{n}{V} = \frac{3}{1.00} = \boxed{3.0\,\mathrm{M}}$$

Similar practice (with answer): If density were 1.20 g mL^{-1} (still 3 m): $V = 1120/1.20 = 0.933$ L, $M = 3/0.933 = \boxed{3.21\,\mathrm{M}}$.

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13. (JEE 2024) Molality of 3 M aqueous NaCl if density $= 1.25$ g mL^{-1}.
Same method as Q3 $\Rightarrow$ Answer: $\boxed{2.79\,\mathrm{m}}$.
Similar practice (with answer): For 1 M, same density: $m = \dfrac{1}{1.25 - 1 \times 0.0585} \approx \boxed{0.86\,\mathrm{m}}$.

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14. (JEE 2024) A 0.200 M solution of anhydrous $\mathrm{CuSO_4}$ at 32°C has density 1.25 g mL^{-1}. Find its molality in $\times 10^{-3}$ m (nearest integer) for 500 mL solution.
Approach: $n = 0.2 \times 0.5 = 0.1$ mol; $m_{\mathrm{soln}} = 1.25 \times 500 = 625$ g; $M(\mathrm{CuSO_4}) = 159.5$; $m_{\mathrm{solvent}} = 625 - 15.95$.
Steps:

$$m = \frac{0.1}{(625 - 15.95)/1000} = \frac{0.1}{0.60905} = 0.164\,\mathrm{m} = \boxed{164 \times 10^{-3}\,\mathrm{m}}$$

Similar practice (with answer): If density were 1.10 g mL^{-1}: $m_{\mathrm{solvent}} = 550 - 15.95$, $m = 0.1/0.53405 = \boxed{0.187\,\mathrm{m}}$.

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15. (JEE 2024) Molarity of solution containing 5.85 g NaCl in 500 mL water.
Steps:

$$n = \frac{5.85}{58.5} = 0.100\,\mathrm{mol}, \quad M = \frac{0.100}{0.500} = \boxed{0.20\,\mathrm{M}}$$

Similar practice (with answer): 11.7 g NaCl in 250 mL $\Rightarrow M = \boxed{0.80\,\mathrm{M}}$.

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16. (JEE 2024) A solution prepared by adding 1 mol ethyl alcohol to 9 mol water. Mass percent of solute (ethanol) — integer.
Steps:

$$m_{\mathrm{ethanol}} = 1 \times 46 = 46\,\mathrm{g}, \quad m_{\mathrm{water}} = 9 \times 18 = 162\,\mathrm{g}$$
$$\%\,\mathrm{ethanol} = \frac{46}{46 + 162} \times 100 = \boxed{22\%}$$

Similar practice (with answer): 2 mol ethanol + 8 mol water: mass% $= \dfrac{92}{92 + 144} \times 100 = \boxed{39\%}$.

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17. (JEE 2024) Molality of aqueous urea = 4.44 m. Mole fraction of urea is $x \times 10^{-3}$. Find x (integer).

Approach: 1 kg water $\Rightarrow n_{\text{urea}} = 4.44$ mol; $n_{\text{water}} = 1000/18 = 55.556$ mol.

Steps:

$$x_{\text{urea}} = \frac{4.44}{4.44 + 55.556} = 0.0740 = \boxed{74 \times 10^{-3}}$$

Similar practice (with answer): If $m = 2.0$ m: $x = \dfrac{2}{2 + 55.556} = \boxed{35.7 \times 10^{-3}}$.
