

21. Only statement b is true. A substance freezes when the vapor pressure of the liquid and solid are the same. When a solute is added to water, the vapor pressure of the solution at 0EC is less than the vapor pressure of the solid and the net result is for any ice present to convert to liquid in order to try to equalize the vapor pressures (which never can occur at 0EC). A lower temperature is needed to equalize the vapor pressure of water and ice, hence the freezing point is depressed.

28. a. If we use 100. mL (100. g) of H₂O, we need:

$$0.100 \text{ kg H}_2\text{O} \times \frac{2.0 \text{ mol KCl}}{\text{kg}} \times \frac{74.55 \text{ g}}{\text{mol KCl}} = 14.9 \text{ g} = 15 \text{ g KCl}$$

Dissolve 15 g KCl in 100. mL H₂O to prepare a 2.0 *m* KCl solution. This will give us slightly more than 100 mL, but this will be the easiest way to make the solution. Since we don't know the density of the solution, we can't calculate the molarity and use a volumetric flask to make exactly 100 mL of solution.

- b. If we took 15 g NaOH and 85 g H₂O, the volume would probably be less than 100 mL. To make sure we have enough solution, let's use 100. mL H₂O (100. g). Let x = mass of NaCl.

$$\text{mass \% NaOH} = 15 = \frac{x}{100. + x} \times 100, \quad 1500 + 15x = 100x, \quad x = 17.6 \text{ g} \approx 18 \text{ g}$$

Dissolve 18 g NaOH in 100. mL H₂O to make a 15% NaOH solution by mass.

- c. In a fashion similar to part b, let's use 100. mL CH₃OH. Let x = mass of NaOH.

$$100. \text{ mL CH}_3\text{OH} \times \frac{0.79 \text{ g}}{\text{mL}} = 79 \text{ g CH}_3\text{OH}$$

$$\text{mass \% NaOH} = 25 = \frac{x}{79 + x} \times 100, \quad 25(79) + 25x = 100x, \quad x = 26.3 \text{ g} \approx 26 \text{ g}$$

Dissolve 26 g NaOH in 100. mL CH₃OH.

- d. To make sure we have enough solution, let's use 100. mL (100. g) of H₂O. Let x = mol C₆H₁₂O₆.

$$100. \text{ g H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.02 \text{ g}} = 5.55 \text{ mol H}_2\text{O}$$

$$\chi_{\text{C}_6\text{H}_{12}\text{O}_6} = 0.10 = \frac{x}{x + 5.55}; \quad 0.10x + 0.56 = x, \quad x = 0.62 \text{ mol C}_6\text{H}_{12}\text{O}_6$$

$$0.62 \text{ mol C}_6\text{H}_{12}\text{O}_6 \times \frac{180.16 \text{ g}}{\text{mol}} = 110 \text{ g C}_6\text{H}_{12}\text{O}_6$$

Dissolve 110 g $\text{C}_6\text{H}_{12}\text{O}_6$ in 100. mL of H_2O to prepare a solution with $\chi_{\text{C}_6\text{H}_{12}\text{O}_6} = 0.10$.

$$32. \quad \frac{1.00 \text{ mol acetone}}{1.00 \text{ kg ethanol}} = 1.00 \text{ molal}; \quad 1.00 \times 10^3 \text{ g C}_2\text{H}_5\text{OH} \times \frac{1 \text{ mol}}{46.07 \text{ g}} = 21.7 \text{ mol C}_2\text{H}_5\text{OH}$$

$$\chi_{\text{acetone}} = \frac{1.00}{1.00 + 21.7} = 0.0441$$

$$1 \text{ mol CH}_3\text{COCH}_3 \times \frac{58.08 \text{ g CH}_3\text{COCH}_3}{\text{mol CH}_3\text{COCH}_3} \times \frac{1 \text{ mL}}{0.788 \text{ g}} = 73.7 \text{ mL CH}_3\text{COCH}_3$$

$$1.00 \times 10^3 \text{ g ethanol} \times \frac{1 \text{ mL}}{0.789 \text{ g}} = 1270 \text{ mL}; \quad \text{Total volume} = 1270 + 73.7 = 1340 \text{ mL}$$

$$\text{molarity} = \frac{1.00 \text{ mol}}{1.34 \text{ L}} = 0.746 \text{ M}$$

$$38. \quad \text{a. water} \quad \text{b. water} \quad \text{c. hexane} \quad \text{d. water}$$

$$46. \quad P_{\text{C}_2\text{H}_5\text{OH}} = \chi_{\text{C}_2\text{H}_5\text{OH}} P_{\text{C}_2\text{H}_5\text{OH}}^{\circ}; \quad \chi_{\text{C}_2\text{H}_5\text{OH}} = \frac{\text{mol C}_2\text{H}_5\text{OH solution}}{\text{total mol in solution}}$$

$$53.6 \text{ g C}_3\text{H}_8\text{O}_3 \times \frac{1 \text{ mol C}_3\text{H}_8\text{O}_3}{92.09 \text{ g}} = 0.582 \text{ mol C}_3\text{H}_8\text{O}_3$$

$$133.7 \text{ g C}_2\text{H}_5\text{OH} \times \frac{1 \text{ mol C}_2\text{H}_5\text{OH}}{46.07 \text{ g}} = 2.90 \text{ mol C}_2\text{H}_5\text{OH}; \quad \text{total mol} = 0.582 + 2.90 = 3.48 \text{ mol}$$

$$113 \text{ torr} = \frac{2.90 \text{ mol}}{3.48 \text{ mol}} \times P_{\text{C}_2\text{H}_5\text{OH}}^{\circ}, \quad P_{\text{C}_2\text{H}_5\text{OH}}^{\circ} = 136 \text{ torr}$$

$$50. \quad P_{\text{total}} = P_{\text{CH}_2\text{Cl}_2} + P_{\text{CH}_2\text{Br}_2}; \quad P = \chi^L P^{\circ}; \quad \chi_{\text{CH}_2\text{Cl}_2}^L = \frac{0.0300 \text{ mol CH}_2\text{Cl}_2}{0.0800 \text{ mol total}} = 0.375$$

$$P_{\text{total}} = 0.375 (133 \text{ torr}) + (1.000 - 0.375) (11.4 \text{ torr}) = 49.9 + 7.13 = 57.0 \text{ torr}$$

$$\text{In the vapor: } \chi_{\text{CH}_2\text{Cl}_2}^V = \frac{P_{\text{CH}_2\text{Cl}_2}}{P_{\text{total}}} = \frac{49.9 \text{ torr}}{57.0 \text{ torr}} = 0.875; \quad \chi_{\text{CH}_2\text{Br}_2}^V = 1.000 - 0.875 = 0.125$$

$$58. \quad \Delta T_b = 77.85^{\circ}\text{C} - 76.50^{\circ}\text{C} = 1.35^{\circ}\text{C}; \quad m = \frac{\Delta T_b}{K_b} = \frac{1.35^{\circ}\text{C}}{5.03^{\circ}\text{C kg/mol}} = 0.268 \text{ mol/kg}$$

$$\text{mol biomolecule} = 0.0150 \text{ kg solvent} \times \frac{0.268 \text{ mol hydrocarbon}}{\text{kg solvent}} = 4.02 \times 10^{-3} \text{ mol}$$

From the problem, 2.00 g biomolecule was used that must contain 4.02×10^{-3} mol biomolecule. The molar mass of the biomolecule is:

$$\frac{2.00 \text{ g}}{4.02 \times 10^{-3} \text{ mol}} = 498 \text{ g/mol}$$

64. empirical formula mass $\approx 7(12) + 4(1) + 16 = 104 \text{ g/mol}$

$$\Delta T_f = K_f m, \quad m = \frac{\Delta T_f}{K_f} = \frac{22.3^\circ\text{C}}{40.^\circ\text{C/molal}} = 0.56 \text{ molal}$$

$$\text{mol anthraquinone} = 0.0114 \text{ kg solvent} \times \frac{0.56 \text{ mol anthraquinone}}{\text{kg solvent}} = 6.4 \times 10^{-3} \text{ mol}$$

$$\text{molar mass} = \frac{1.32 \text{ g}}{6.4 \times 10^{-3} \text{ mol}} = 210 \text{ g/mol}$$

$$\frac{\text{molar mass}}{\text{empirical formula mass}} = \frac{210}{104} = 2.0; \text{ molecular formula} = \text{C}_{14}\text{H}_8\text{O}_2$$

70. The solutions of $\text{C}_{12}\text{H}_{22}\text{O}_{11}$, NaCl and CaCl_2 will all have lower freezing points, higher boiling points and higher osmotic pressures than pure water. The solution with the largest particle concentration will have the lowest freezing point, the highest boiling point and the highest osmotic pressure. The CaCl_2 solution will have the largest effective particle concentration because it produces three ions per mol of compound.

- a. pure water b. CaCl_2 solution c. CaCl_2 solution
d. pure water e. CaCl_2 solution

76. $\pi = iMRT, \quad M = \frac{\pi}{iRT} = \frac{2.50 \text{ atm}}{2.00 \times \frac{0.08206 \text{ L atm}}{\text{K mol}} \times 298 \text{ K}} = 5.11 \times 10^{-2} \text{ mol/L}$

$$\text{molar mass of compound} = \frac{0.500 \text{ g}}{0.1000 \text{ L} \times \frac{5.11 \times 10^{-2} \text{ mol}}{\text{L}}} = 97.8 \text{ g/mol}$$

$$82. \quad \pi = MRT = \frac{0.1 \text{ mol}}{\text{L}} \times \frac{0.08206 \text{ L atm}}{\text{mol K}} \times 298 \text{ K} = 2.45 \text{ atm} \approx 2 \text{ atm}$$

$$\pi = 2 \text{ atm} \times \frac{760 \text{ mm Hg}}{\text{atm}} \approx 2000 \text{ mm} \approx 2 \text{ m}$$

The osmotic pressure would support a mercury column of $\approx 2 \text{ m}$. The height of a fluid column in a tree will be higher because Hg is more dense than the fluid in a tree. If we assume the fluid in a tree is mostly H_2O , then the fluid has a density of $\approx 1.0 \text{ g/cm}^3$. The density of Hg is 13.6 g/cm^3 .

Height of fluid $\approx 2 \text{ m} \times 13.6 \approx 30 \text{ m}$

$$94. \quad \text{a.} \quad m = \frac{\Delta T_f}{K_f} = \frac{1.32^\circ\text{C}}{5.12^\circ\text{C kg/mol}} = 0.258 \text{ mol/kg}$$

$$\text{mol unknown} = 0.01560 \text{ kg} \times \frac{0.258 \text{ mol unknown}}{\text{kg}} = 4.02 \times 10^{-3} \text{ mol}$$

$$\text{molar mass of unknown} = \frac{1.22 \text{ g}}{4.02 \times 10^{-3} \text{ mol}} = 303 \text{ g/mol}$$

$$\text{Uncertainty in temperature} = \frac{0.04}{1.32} \times 100 = 3\%; \text{ A } 3\% \text{ uncertainty in } 303 \text{ g/mol}$$

= 9

g/mol.

So, molar mass = $303 \pm 9 \text{ g/mol}$.

b. No, codeine could not be eliminated since its molar mass is in the possible range including the uncertainty.

c. We would really like the uncertainty to be $\pm 1 \text{ g/mol}$. We need the freezing point depression to be about 10 times what it was in this problem. Two possibilities are:

1. make the solution ten times more concentrated (may be a solubility problem) or
2. use a solvent with a larger K_f value, e.g., camphor

$$100. \quad 10.0 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{10 \text{ dL}}{1 \text{ L}} \times \frac{1.0 \text{ mg}}{1 \text{ dL}} \times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1 \text{ mol}}{113.14 \text{ g}} = 8.8 \times 10^{-7} \text{ mol}$$

$\text{C}_4\text{H}_7\text{N}_3\text{O}$

$$\text{mass of blood} = 10.0 \text{ mL} \times \frac{1.025 \text{ g}}{\text{mL}} = 10.3 \text{ g}$$

$$\text{molality} = \frac{8.8 \times 10^{-7} \text{ mol}}{0.0103 \text{ kg}} = 8.5 \times 10^{-5} \text{ mol/kg}$$

$$\pi = MRT, \quad M = \frac{8.8 \times 10^{-7} \text{ mol}}{0.0100 \text{ L}} = 8.8 \times 10^{-5} \text{ mol/L}$$

$$\pi = 8.8 \times 10^{-5} \text{ mol/L} \times \frac{0.08206 \text{ L atm}}{\text{K mol}} \times 298 \text{ K} = 2.2 \times 10^{-3} \text{ atm}$$