

REVIEW QUESTIONS

Chapter 12

1. Commercial nitric acid has a density of 1.42 g/mL and is 16.0 M. Calculate the mass of percent and molality of HNO₃ in this solution.

Assume 1 L of solution:

$$16.0 \text{ mol HNO}_3 \times \frac{63.02 \text{ g}}{1 \text{ mol}} = 1008.3 \text{ g HNO}_3$$

$$1.00 \text{ L sol'n} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{1.42 \text{ g}}{1.00 \text{ mL}} = 1420 \text{ g sol'n}$$

$$\text{mass percent} = \frac{1008.3 \text{ g HNO}_3}{1420 \text{ g sol'n}} \times 100 = 71.0\%$$

$$\text{mass of solvent} = 1420 \text{ g} - 1008.3 \text{ g} = 412 \text{ g} = 0.412 \text{ kg}$$

$$\text{molality} = \frac{16.0 \text{ mol HNO}_3}{0.412 \text{ kg solvent}} = 38.8 \text{ m}$$

2. The density of a 1.80 M solution of LiBr in acetonitrile (CH₃CN) is 0.826 g/mL. Calculate the concentration of this solution in (a) molality, (b) mole fraction of LiBr, and (c) mass percent of CH₃CN.

a) Molality

Assume 1 L of solution (contains 1.80 mol solute)

$$\text{Mass of solution} = 1000 \text{ mL} \times \frac{0.826 \text{ g}}{1 \text{ mL}} = 826 \text{ g}$$

$$\text{Mass of solute} = 1.80 \text{ mol} \times \frac{86.85 \text{ g}}{1 \text{ mol}} = 156 \text{ g}$$

$$\text{Mass of solvent} = 826 \text{ g} - 156 \text{ g} = 670. \text{ g}$$

$$\text{Molality} = \frac{1.80 \text{ mol LiBr}}{0.670 \text{ kg}} = 2.69 \text{ m}$$

b) mole fraction

$$\text{mol solvent} = 670. \text{ g} \times \frac{1 \text{ mol}}{41.05 \text{ g}} = 16.3 \text{ mol}$$

$$X_{\text{LiBr}} = \frac{1.80}{1.80 + 16.3} = 0.0994$$

c) Mass % CH₃CN = $\frac{670. \text{ g}}{826 \text{ g}} \times 100 = 81.1\%$

3. Both methanol (CH_3OH) and ethylene glycol ($\text{C}_2\text{H}_6\text{O}_2$) are used as antifreeze. Which is more effective—that is, which produces a lower freezing point if equal amounts of each are added to the same amount of water?

Methanol would be more effective as antifreeze because it has a lower molar mass (32.0 g/mol) compared with ethylene glycol (62.1 g/mol)). Therefore the same mass of methanol produces more moles per gram of solute, a greater molality and a greater effect on boiling and freezing points of the solvent.

4. Arrange the following solutions in the order of increasing boiling point. (Assume complete dissociation for strong electrolytes)

0.040 m glycerol ($\text{C}_3\text{H}_8\text{O}_3$)	$i = 1$
0.025 m KBr	$i = 2$
0.010 m CaCl_2	$i = 3$

<u>Solution</u>	<u>Conc. of particles</u>
0.040 m glycerol	0.040 m
0.025 m KBr	0.050 m
0.010 m CaCl_2	0.030 m

The greater the concentration of the particles in solution, the greater the boiling point. Therefore,



5. For each pair of solutions listed below, determine which will have the higher boiling point. (Assume complete dissociation for strong electrolytes)

- a) **1.5 M NaCl** and 0.5 M $\text{Al}(\text{NO}_3)_3$

NaCl has greater particle concentration (3.0 M vs. 2.0 M)

- b) **2.0 M NaOH** and 2.0 M $\text{C}_6\text{H}_{12}\text{O}_6$

NaOH has greater particle concentration (4.0 M vs. 2.0 M)

- c) 0.4 M Na_2CO_3 and **0.7 M KCl**

KCl has greater particle concentration (0.14 M vs. 0.12 M)

6. What are the freezing and boiling points of an aqueous solution containing 2.02 g of urea, $(\text{NH}_2)_2\text{CO}$, in 145 mL of solution? (Density of solution = 1.03 g/mL)

$$\text{mol solute} = 2.02 \text{ g} \times \frac{1 \text{ mol}}{60.07 \text{ g}} = 0.0336 \text{ mol}$$

$$\text{mass of solution} = 145 \text{ mL} \times \frac{1.03 \text{ g}}{1 \text{ mL}} = 149.35 \text{ g}$$

$$\text{mass of solvent} = 149.35 \text{ g} - 2.02 \text{ g} = 147.3 \text{ g} = 0.1473 \text{ kg}$$

$$\text{molality} = \frac{0.0336 \text{ mol}}{0.1473 \text{ kg}} = 0.228 \text{ m}$$

$$\Delta T_b = mK_b = (0.228 \text{ m})(0.512 \text{ }^\circ\text{C/m}) = 0.117 \text{ }^\circ\text{C} \quad T_b = 100.117 \text{ }^\circ\text{C}$$

$$\Delta T_f = mK_f = (0.228 \text{ m})(1.86 \text{ }^\circ\text{C/m}) = 0.424 \text{ }^\circ\text{C} \quad T_f = -0.424 \text{ }^\circ\text{C}$$

7. A solution of an unknown nonvolatile, non-electrolyte compound was prepared by dissolving 0.250 g of the unknown in 40.0 g of CCl_4 . The boiling point of the resultant solution was measured to be 0.357°C higher than the pure solvent. Calculate the molar mass of the unknown solute. ($K_b = 5.02 \text{ }^\circ\text{C/m}$)

$$m = \frac{\Delta T_b}{K_b} = \frac{0.357 \text{ }^\circ\text{C}}{5.02} = 0.0711$$

$$\text{mol solute} = m \times \text{kg solvent} = (0.0711)(0.040 \text{ kg}) = 0.002844 \text{ mol}$$

$$\text{Molar mass} = \frac{0.250 \text{ g}}{0.002844 \text{ mol}} = 87.9 \text{ g/mol}$$

8. Stearic acid ($\text{C}_{18}\text{H}_{36}\text{O}_2$) and palmitic acid ($\text{C}_{16}\text{H}_{32}\text{O}_2$) are common fatty acids. Commercial grades of stearic acid usually contain palmitic acid as well. A 1.115-g sample of commercial grade stearic acid is dissolved in 5.00 mL of benzene ($d = 0.879 \text{ g/mL}$). The freezing point of the solution is found to be $5.072 \text{ }^\circ\text{C}$. The freezing point of pure benzene is $5.533 \text{ }^\circ\text{C}$ and K_f for benzene is $5.12 \text{ }^\circ\text{C/m}$. What is the mass percent of palmitic acid in the stearic acid sample?

$$\Delta T_f = 5.533 - 5.072 = 0.461 \text{ }^\circ\text{C}$$

$$m = \frac{\Delta T_f}{K_f} = \frac{0.461 \text{ }^\circ\text{C}}{5.12 \text{ }^\circ\text{C/m}} = 0.0900 \text{ m}$$

$$\text{mol of solute} = m \times \text{kg solvent} = (0.0900)(5.00 \text{ mL} \times \frac{0.879 \text{ g}}{1 \text{ mL}} \times \frac{1 \text{ kg}}{10^3 \text{ g}}) = 0.000396 \text{ mol}$$

$$\text{mass of solute} = 0.000396 \text{ mol} \times \frac{256.48 \text{ g}}{1 \text{ mol}} = 0.1016 \text{ g solute}$$

$$\% \text{ palmitic acid} = \frac{0.1016 \text{ g}}{1.115 \text{ g}} \times 100 = 9.11\%$$

9. What is the minimum mass of ethylene glycol ($C_2H_6O_2$) that must be dissolved in 14.5 kg of water to prevent the solution from freezing at $-10.0^\circ F$?

$$T_f = -10.0^\circ F = -23.3^\circ C$$

$$m = \frac{\Delta T_f}{K_f} = \frac{23.3^\circ C}{1.86^\circ C/m} = 12.53 \text{ m}$$

$$\text{mol of solute} = m \times \text{kg solvent} = (12.53)(14.5 \text{ kg}) = 181.7 \text{ mol}$$

$$\text{mass of solute} = 181.7 \text{ mol} \times \frac{62.08 \text{ g}}{1 \text{ mol}} \times \frac{1 \text{ kg}}{10^3 \text{ g}} = 11.3 \text{ kg solute}$$

10. Calculate the vapor pressure of a solution prepared by adding 32.5 g of glycerin ($C_3H_8O_3$) to 140.0 g of water at $70^\circ C$. ($P^\circ = 234 \text{ torr}$)

$$\text{mol } C_3H_8O_3 = 32.5 \text{ g} \times \frac{1 \text{ mol}}{92.1 \text{ g}} = 0.353 \text{ mol} \quad \text{mol } H_2O = 140 \text{ g} \times \frac{1 \text{ mol}}{18.0 \text{ g}} = 7.778 \text{ mol}$$

$$X_{H_2O} = \frac{7.778}{0.353 + 7.778} = 0.957 \quad P_{\text{sol'n}} = X_{H_2O} P^\circ = (0.957)(234 \text{ torr}) = 224 \text{ torr}$$

11. A mixture of styrene (C_8H_8 , 38%) and ethylbenzene (C_8H_{10} , 62%) is separated by fractional distillation at $90^\circ C$. What is the composition of the vapor in equilibrium with this mixture at $90^\circ C$, given the following vapor pressure of the two components at this temperature:

$$P^\circ_{\text{styrene}} = 134 \text{ mmHg} \quad \text{and}$$

$$P^\circ_{\text{ethyl benzene}} = 182 \text{ mmHg.}$$

$$\text{mol styrene} = 38.0 \text{ g} \times \frac{1 \text{ mol}}{104.1 \text{ g}} = 0.365 \text{ mol} \quad \text{mol ethylbenzene} = 62.0 \text{ g} \times \frac{1 \text{ mol}}{106.2 \text{ g}} = 0.584 \text{ mol}$$

$$X_{\text{styrene}} = \frac{0.365}{0.365 + 0.584} = 0.385$$

$$X_{\text{ethylbenzene}} = 1 - 0.385 = 0.615$$

In the vapor above the mixture,

$$P_{\text{styrene}} = X_{\text{styrene}} P^\circ = (0.385)(134 \text{ mmHg}) = 51.6 \text{ mmHg}$$

$$P_{\text{ethylbenzene}} = X_{\text{ethylbenzene}} P^\circ = (0.615)(182 \text{ mmHg}) = 112 \text{ mmHg}$$

$$P_{\text{total}} = 112 + 51.6 = 163.6 \text{ mmHg}$$

Composition of the vapor

$$X_{\text{styrene}} = \frac{51.6 \text{ mmHg}}{163.6 \text{ mmHg}} = 0.315$$

$$X_{\text{ethylbenzene}} = 1 - 0.315 = 0.685$$

12. Calculate the vapor pressure of a solution prepared by adding

a) 32.5 g of glycerin ($C_3H_8O_3$) to 140.0 g of water at $70^\circ C$. ($P^\circ = 234$ torr)

$$\text{mol } C_3H_8O_3 = 32.5 \text{ g} \times \frac{1 \text{ mol}}{92.1 \text{ g}} = 0.353 \text{ mol} \quad \text{mol } H_2O = 140 \text{ g} \times \frac{1 \text{ mol}}{18.0 \text{ g}} = 7.778 \text{ mol}$$

$$X_{H_2O} = \frac{7.778}{0.353 + 7.778} = 0.957 \quad P_{\text{sol'n}} = X_{H_2O} P^\circ = (0.957)(234 \text{ torr}) = 224 \text{ torr}$$

b) 5.00 g of Na_2SO_4 to 92.0 g of water at $55^\circ C$. ($P^\circ = 118.0$ torr)

$$\text{mol } Na_2SO_4 = 5.00 \text{ g} \times \frac{1 \text{ mol}}{142.0 \text{ g}} = 0.0352 \text{ mol} \quad \text{mol } H_2O = 92.0 \text{ g} \times \frac{1 \text{ mol}}{18.0 \text{ g}} = 5.111 \text{ mol}$$

$$X_{H_2O} = \frac{5.111}{3(0.0352) + 5.111} = 0.9933$$

$$P_{\text{sol'n}} = X_{H_2O} P^\circ = (0.9933)(118.0 \text{ torr}) = 117.2 \text{ torr}$$

13. The vapor pressure of CCl_4 is 0.354 atm and the vapor pressure of $CHCl_3$ is 0.526 atm at $43^\circ C$. A solution is prepared from equal masses of these compounds at this temperature.

a) Calculate the mole fraction of $CHCl_3$ in the vapor above this solution.

$$\text{mol } CCl_4 = 50.0 \text{ g} \times \frac{1 \text{ mol}}{153.81 \text{ g}} = 0.325 \text{ mol} \quad \text{mol } CHCl_3 = 50.0 \text{ g} \times \frac{1 \text{ mol}}{119.37 \text{ g}} = 0.419 \text{ mol}$$

$$X_{CCl_4} = \frac{0.325}{0.325 + 0.419} = 0.437$$

$$X_{CHCl_3} = 1 - 0.437 = 0.563$$

In the vapor above the mixture,

$$P_{CCl_4} = X_{CCl_4} P^\circ = (0.437)(0.354 \text{ atm}) = 0.155 \text{ atm}$$

$$P_{CHCl_3} = X_{CHCl_3} P^\circ = (0.563)(0.526 \text{ atm}) = 0.296 \text{ atm}$$

$$P_{\text{total}} = 0.155 + 0.296 = 0.451$$

$$X_{CHCl_3} = \frac{0.296 \text{ atm}}{0.451 \text{ atm}} = 0.656$$

b) If the vapor above the original solution is condensed and isolated in a separate flask, what would be the vapor pressure of $CHCl_3$ above this new solution?

In the condensed liquid, $X_{CHCl_3} = 0.656$

$$P_{CHCl_3} = X_{CHCl_3} P^\circ = (0.654)(0.526 \text{ atm}) = 0.345 \text{ atm}$$