REVIEW QUESTIONS
Chapter 13

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 HNO_3 in this solution.

Assume 1 L of solution:

$$16.0 \text{ mol } HNO_3 \text{ x } \frac{63.02 \text{ g}}{1 \text{ mol}} = 1008.3 \text{ g } HNO_3$$

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

$$\text{mass percent} = \frac{1008.3 \text{ g } HNO_3}{1420 \text{ g sol'n}} \text{ x}100 = 71.0\%$$

mass of solvent = 1420 g - 1008.3 g = 412 g = 0.412 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 (CH_3CN) is 0.826 g/mL. Calculate the concentration of this solution in (a) molality, (b) mole fraction of LiBr, and (c) mass percent of CH_3CN.

a) **Molality**

Assume 1 L of solution (contains 1.80 mol solute)

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

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

Mass of solvent = 826 g - 156 g = 670. g

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

b) **mole fraction**

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

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

c) **Mass % CH_3CN**= $\frac{670. \text{ g}}{826 \text{ g}}$ x100 = 81.1%

3. Both methanol (CH_3OH) and ethylene glycol ($C_2H_6O_2$) 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 ($C_3H_8O_3$)   **i = 1**
0.025 m KBr   **i = 2**
0.010 m $CaCl_2$ **i = 3**

Solution	Conc. of particles
0.040 m glycerol	**0.040 m**
0.025 m KBr	**0.050 m**
0.010 m CaCl₂	**0.030 m**

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

0.010 m CaCl₂ < 0.040 m glycerol < 0.025 m KCl

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 Al(NO_3)$_3$

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

b) **2.0 M NaOH** and 2.0 M $C_6H_{12}O_6$

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, $(NH_2)_2CO$, in 145 mL of solution? (Density of solution = 1.03 g/mL)

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

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

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

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

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

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

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 °C/m)

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

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

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

8. Stearic acid ($C_{18}H_{36}O_2$) and palmitic acid ($C_{16}H_{32}O_2$) 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 g/mL). The freezing point of the solution is found to be 5.072 °C. The freezing point of pure benzene is 5.533 °C and K_f for benzene is 5.12°C/m. What is the mass percent of palmitic acid in the stearic acid sample?

$$\Delta T_f = 5.533 - 5.072 = 0.461 \; ^\circ C$$

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

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

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

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

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 $-10.0°F$?

$T_f = -10.0 \ ^oF = -23.3 \ ^oC$

$m = \dfrac{\Delta T_f}{K_f} = \dfrac{23.3 \ ^oC}{1.86 \ ^oC/m} = 12.\underline{5}3 \ m$

mol of solute = m x kg solvent = (12.\underline{5}3)(14.5 kg) = 18\underline{1}.7 mol

mass of solute = 18\underline{1}.7 mol x $\dfrac{62.08 \ g}{1 \ mol}$ x $\dfrac{1 \ kg}{10^3 \ g}$ = 11.3 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°C. (P°=234 torr)

mol $C_3H_8O_3$ = 32.5 g x $\dfrac{1 \ mol}{92.1 \ g}$ = 0.353 mol   mol H_2O = 140 g x $\dfrac{1 \ mol}{18.0 \ g}$ = 7.7\underline{7}8 mol

$X_{H_2O} = \dfrac{7.7\underline{7}8}{0.353 + 7.7\underline{7}8} = 0.957$ $P_{sol'n} = X_{H_2O} \ P^0 = (0.957)(234 \ torr) = 224 \ torr$

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

P°$_{styrene}$ = 134 mmHg   and   P°$_{ethyl \ benzene}$ = 182 mmHg.

mol styrene = 38.0 g x $\dfrac{1 \ mol}{104.1 \ g}$ = 0.365 mol   mol ethylbenzene = 62.0 g x $\dfrac{1 \ mol}{106.2 \ g}$ = 0.584 mol

$X_{styrene} = \dfrac{0.365}{0.365 + 0.584} = 0.385$ $X_{ethylbenzene} = 1 - 0.385 = 0.615$

In the vapor above the mixture,

   $P_{styrene} = X_{styrene} \ P^0 = (0.385)(134 \ mmHg) = 51.6 \ mmHg$

   $P_{ethylbenzene} = X_{ethylbenzene} \ P^0 = (0.615)(182 \ mmHg) = 112 \ mmHg$

   $P_{total} = 112 + 51.6 = 16\underline{3}.6 \ mmHg$

Composition of the vapor

   $X_{styrene} = \dfrac{51.6 \ mmHg}{16\underline{3}.6 \ mmHg} = 0.315$ $X_{ethylbenzene} = 1 - 0.315 = 0.685$

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°C. ($P°$=234 torr)

$$\text{mol } C_3H_8O_3 = 32.5 \text{ g} \times \frac{1 \text{ mol}}{92.1 \text{ g}} = 0.353 \text{ mol} \qquad \text{mol } H_2O = 140 \text{ g} \times \frac{1 \text{ mol}}{18.0 \text{ g}} = 7.7\underline{7}8 \text{ mol}$$

$$X_{H_2O} = \frac{7.7\underline{7}8}{0.353 + 7.7\underline{7}8} = 0.957 \qquad P_{sol'n} = X_{H_2O} \, P^0 = (0.957)(234 \text{ torr}) = 224 \text{ torr}$$

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

$$\text{mol } Na_2SO_4 = 5.00 \text{ g} \times \frac{1 \text{ mol}}{142.0 \text{ g}} = 0.0352 \text{ mol} \qquad \text{mol } H_2O = 92.0 \text{ g} \times \frac{1 \text{ mol}}{18.0 \text{ g}} = 5.1\underline{1}1 \text{ mol}$$

$$X_{H_2O} = \frac{5.1\underline{1}1}{3(0.0352) + 5.1\underline{1}1} = 0.99\underline{3}3$$

$$P_{sol'n} = X_{H_2O}P^0 = (0.99\underline{3}3)(118.0 \text{ torr}) = 117.2 \text{ torr}$$

13. The vapor pressure of CCl_4 is 0.354 atm and the vapor pressure of $CHCl_3$ is 0.526 atm at 43°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.

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

$$X_{CCl_4} = \frac{0.325}{0.325 + 0.419} = 0.437 \qquad\qquad X_{CHCl_3} = 1 - 0.437 = 0.563$$

In the vapor above the mixture,

$$P_{CCl_4} = X_{CCl_4}P^0 = (0.437)(0.354 \text{ atm}) = 0.155 \text{ atm}$$

$$P_{CHCl_3} = X_{CHCl_3} \, P^0 = (0.563)(0.526 \text{ atm}) = 0.296 \text{ atm}$$

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

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

   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, $X_{CHCl_3} = 0.656$

$$P_{CHCl_3} = X_{CHCl_3} \, P^0 = (0.654)(0.526 \text{ atm}) = 0.345 \text{ atm}$$