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 of HNO_3 in this solution.

$$\frac{16.0\ \cancel{mol}\ HNO_3}{1\ \cancel{L}\ sol'n} \times \frac{63.0\ g}{1\ \cancel{mol}} \times \frac{1\ \cancel{L}}{1000\ \cancel{mL}} \times \frac{1\ \cancel{mL}}{1.42\ g} \times 100 = 71.0\%$$

2. Ascorbic acid, vitamin C, is a water soluble vitamin. A solution containing 80.5 g of ascorbic acid, $C_6H_8O_6$, in 210 g of water has a density of 1.22 g/mL at 55°C. Calculate **(a)** the mass % , **(b)** the mole fraction, **(c)** the molarity and **(d)** the molality of ascorbic acid in this solution.

a) $$\text{Mass \%} = \frac{80.5\ g}{80.5\ g + 210\ g} \times 100 = 27.7\%$$

b) **mole fraction**

$$\text{mol } C_6H_8O_6 = 80.5\ \cancel{g} \times \frac{1\ mol}{176.1\ \cancel{g}} = 0.457\ mol$$

$$\text{mol } H_2O = 210\ \cancel{g} \times \frac{1\ mol}{18.0\ \cancel{g}} = 11.67\ mol$$

$$X_{C_6H_8O_6} = \frac{0.457}{0.457 + 11.67} = 0.0377$$

c) **Molarity**

$$\text{Volume of sol'n} = 290.5\ \cancel{g} \times \frac{1\ mL}{1.22\ \cancel{g}} = 238\ mL$$

$$\text{Molarity} = \frac{0.457\ mol\ C_6H_8O_6}{0.238\ L\ sol'n} = 1.92\ M$$

d) $$\text{Molality} = \frac{0.457\ mol\ C_6H_8O_6}{0.210\ kg\ H_2O} = 2.18\ m$$

3. Calculate the mass of ethylene glycol, $C_2H_6O_2$, that must be added to 1.00 kg of ethanol, C_2H_5OH, to reduce its vapor pressure by 13.2 torr at 35°C. Vapor pressure of pure ethanol at 35°C is 100. torr.

$$X_{C_2H_6O_2} = \frac{\Delta P}{P^0} = \frac{13.2 \text{ torr}}{100 \text{ torr}} = 0.132$$

$$\text{mol } C_2H_5OH = 1.00 \cancel{\text{kg}} \times \frac{1000 \cancel{\text{g}}}{1 \cancel{\text{kg}}} \times \frac{1 \text{ mol}}{46.0 \cancel{\text{g}}} = 21.\underline{7}4 \text{ mol}$$

$$0.132 = \frac{x}{x + 21.\underline{7}4} \qquad x = \text{mol } C_2H_6O_2 = 3.3\underline{0}6$$

$$\text{Mass of } C_2H_6O_2 = 3.3\underline{0}6 \cancel{\text{mol}} \times \frac{62.1 \text{ g}}{1 \cancel{\text{mol}}} = 205 \text{ g}$$

4. Which of the following in each pair is likely to be the more soluble in water:

a) $CH_3CH_2CH_2CH_2OH$ or **CH_3CH_2OH**

Even though both molecules can H-bond and are therefore soluble, the longer hydrocarbon chain on the first molecule makes it less polar and less soluble than CH_3CH_2OH

b) CCl_4 or **$CaCl_2$**

$CaCl_2$ is ionic and therefore soluble in water, while CCl_4 is a non-polar molecule that is not soluble.

c) C_6H_6 or **C_6H_5OH**

The OH group on C_6H_5OH allows it to H-bond and makes it soluble compared to the non-polar molecule C_6H_6.

5. The dissolution of NH_4NO_3 in water is an endothermic process. Describe the solution process in terms of three distinct components, and show how the sum of these can lead to a positive enthalpy change.

The solvent-solvent interactions (ΔH_1) and solute-solute interactions (ΔH_2) are stronger than the solute-solvent interactions (ΔH_3), making the solution process endothermic.

6. Calculate the vapor pressure of a solution prepared by adding 32.5 g of glycerin ($C_3H_8O_3$) to 140 g of water at 70°C. (P^0=234 torr)

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

$$X_{H_2O} = \frac{7.778}{0.353 + 7.778} = 0.957 \qquad P_{sol'n} = X_{H_2O} P^0 = (0.957)(234 \text{ torr}) = 224 \text{ torr}$$

7. 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 vapor pressure of the two components: styrene, 134 mmHg and ethylbenzene, 182 mmHg.

$$\text{mol styrene} = 38.0 \text{ g} \times \frac{1 \text{ mol}}{104.1 \text{ g}} = 0.365 \text{ mol}$$

$$\text{mol ethylbenzene} = 62.0 \text{ g} \times \frac{1 \text{ mol}}{106.2 \text{ g}} = 0.584 \text{ mol}$$

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

In the vapor above the mixture,

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

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

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

Composition of the vapor

$$X_{styrene} = \frac{51.6 \text{ mmHg}}{163.6 \text{ mmHg}} = 0.315 \qquad X_{ethylbenzene} = 1 - 0.315 = 0.685$$

Note that the vapor is richer in the more volatile component (ethylbenzene)

8. A solution of antifreeze contains 25% by mass ethylene glycol ($C_2H_6O_2$) in water. Calculate the boiling point and freezing point for this solution. (K_b=0.512 °C/m and K_f=1.86 °C/m)

$$25\% = \frac{25 \text{ g } C_2H_6O_2}{100 \text{ g sol'n}}$$

$$\text{mol solute} = 25 \text{ g} \times \frac{1 \text{ mol}}{62.1 \text{ g}} = 0.40 \text{ mol}$$

$$\text{mass of solvent} = 100 \text{ g} - 25 \text{ g} = 75 \text{ g} \qquad \text{molality} = \frac{0.40 \text{ mol}}{0.075 \text{ kg}} = 5.3 \text{ m}$$

$$\Delta T_b = mK_b = (5.3 \text{ m})(0.512 \text{ }^\circ\text{C/m}) = 2.7 \text{ }^\circ\text{C} \qquad T_b = 102.7 \text{ }^\circ\text{C}$$

$$\Delta T_f = mK_f = (5.3 \text{ m})(1.86 \text{ }^\circ\text{C/m}) = 9.9 \text{ }^\circ\text{C} \qquad T_f = -9.9 \text{ }^\circ\text{C}$$

9. Calculate the freezing point of an aqueous solution that boils at 102.5 °C.

$$\Delta T_b = 2.5\ ^\circ C$$

$$m = \frac{\Delta T_b}{K_b} = \frac{2.5\ ^\circ C}{0.512\ ^\circ C/m} = 4.88\ m$$

$$\Delta T_f = m\ K_f = (4.88\ m)(1.86\ ^\circ C/m) = 9.1\ ^\circ C$$

$$T_f = -9.1\ ^\circ C$$

10. 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)

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

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

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

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

b) **mole fraction**

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

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

c) $$\text{Mass \%} = \frac{156\ g}{826\ g} \times 100 = 18.9\%$$

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

a) 32.5 g of glycerin ($C_3H_8O_3$) to 140 g of water at 70°C. ($P°$=234 torr)

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

$$X_{H_2O} = \frac{7.778}{0.353 + 7.778} = 0.957 \qquad P_{sol'n} = X_{H_2O} P^0 = (0.957)(234 \text{ torr}) = 224 \text{ torr}$$

b) 5.00 g of Na_2SO_4 to 92.0 g of water at 55°C. ($P°$=118 torr)

$$\text{mol } Na_2SO_4 = 5.00 \text{ g} \times \frac{1 \text{ mol}}{142.0 \text{ g}} = 0.0352 \text{ mol}$$

$$\text{mol } H_2O = 92.0 \text{ g} \times \frac{1 \text{ mol}}{18.0 \text{ g}} = 5.111 \text{ mol}$$

$$X_{Na_2SO_4} = \frac{0.0352}{0.0352 + 5.111} = 0.00684$$

$$\Delta P = i X_{Na_2SO_4} P^0 = 3(0.00684)(118 \text{ torr}) = 2.42 \text{ torr}$$

$$P_{sol'n} = P^0 - \Delta P = 118 - 2.42 = 116 \text{ torr}$$

12. Arrange the following solutions in the order of increasing boiling point:

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 $CaCl_2$	0.030 m

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

0.010 m $CaCl_2$ < 0.040 m glycerol < 0.025 m KCl

13. 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)

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

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

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