WKS
Colligative Property Calculations
(FP depression and BP elevation)

Name Answer Key
Period _______

1) What is the formula for determining the concentration of a solution in *molal, m*? Why is molality sometimes used for solutions rather than molarity?

$$m = \frac{\text{moles solute}}{\text{kg solvent}}$$

Molality is used because it does not change with temperature.

2) What is the concentration, in *m*, of a solution with 50.0 g of sucrose, $C_6H_{12}O_6$, dissolved in 250. g of H_2O?

$$\text{moles sucrose} = 50.0\text{ g } C_6H_{12}O_6 \times \frac{1\text{ mol}}{180.2\ g} = 0.277\text{ mol; kg } H_2O = 250.\text{ g} \times \frac{1\text{ kg}}{1000\ g} = 0.250\text{ kg}$$

$$m = \frac{0.277\text{ mol } C_6H_{12}O_6}{0.250\ kg} = \boxed{1.11m\ C_6H_{12}O_6}$$

3) How many grams of $CaCl_2$ are needed to make a 1.50 *m* solution with 500. g of H_2O? [Hint: set up the *molal* equation to find moles first.]

$$m = \frac{\text{mol } CaCl_2}{\text{kg } H_2O} \Rightarrow \text{mol } CaCl_2 = \left(1.50\tfrac{\text{mol}}{\text{kg}}\right)(0.500\text{ kg}) = 0.750\text{ mol } CaCl_2$$

$$\text{mass } CaCl_2 = 0.750\text{ mol } CaCl_2 \times \frac{111.0\text{ g } CaCl_2}{1\text{ mol } CaCl_2} = \boxed{83.3\text{ g } CaCl_2}$$

4) What does the van't Hoff factor, *i*, signify? What is *i* for $C_6H_{12}O_6$? NaCl? $CaCl_2$?
i signifies the number of particles that a solute breaks up into when dissolved. $i = 1$ for $C_6H_{12}O_6$; $i = 2$ for NaCl; $i = 3$ for $CaCl_2$.

5) Write the mathematical expressions for boiling point elevation (ΔT_b) and freezing point depression (ΔT_f).

$\Delta T_b = i K_b m$; $\Delta T_f = i K_f m$

6) Calculate the freezing point of a solution containing 36.2 g hexane (C_6H_{14}) in 500.0 g CCl_4. The K_f for CCl_4 is 29.8 °C/*m* and the normal freezing point for CCl_4 is –23.0°C. Assume $i = 1$ for hexane.

$$\text{mol } C_6H_{14} = 36.2\text{ g} \times \frac{1\text{ mol } C_6H_{14}}{86.17\text{ g } C_6H_{14}} = 0.420\text{ mol } C_6H_{14};\ \text{kg } CCl_4 = 500.0\text{ g} \times \frac{1\text{ kg}}{1000\text{ g}} = 0.5000$$

$$m = \frac{0.420\text{ mol } C_6H_{14}}{0.5000\text{ kg}} = 0.842m\ C_6H_{14}; \Delta T_f = (1)(29.8\ °C/m)(0.842m) = 25.0\ °C;$$

$$T_f = T_f^\circ - \Delta T_f = 23.0\ °C - 25.0\ °C = \boxed{-48.0°C}$$

7) What is the boiling point of a solution containing 63.9 g $SrBr_2$ in 100.0 g H_2O? $K_b = 0.512$ °C/*m* for water. [Hints: What is *i* for $SrBr_2$? What is the normal boiling point of H_2O?]

$$\text{mol } SrBr_2 = 63.9\text{ g } SrBr_2 \times \frac{1\text{ mol } SrBr_2}{246.5\text{ g } SrBr_2} = 0.259\text{ mol } SrBr_2;\ \text{kg } H_2O = 100.0\text{ g} \times \frac{1\text{ kg}}{1000\text{ g}} = 0.1000\text{ kg}$$

$$m = \frac{0.259\text{ mol } SrBr_2}{0.1000\ kg} = 2.59m;\ i = 3,\ \text{so}\ \Delta T_b = (3)(0.512\ °C/m)(2.59m) = 3.98\ °C;$$

$$T_b = T_b^\circ + \Delta T_b = 100.0\ °C + 3.98\ °C = \boxed{103.98\ °C}$$

8) The molal boiling point constant for ethyl alcohol is 1.22°C/*m*. Its normal boiling point is 78.4°C.

a. What is the molality of a solution of alcohol and an unknown nonvolatile molecular solute (i = 1) that boils at 79.8°C?

$$\Delta T_b = 79.8°C - 78.4°C = 1.4°C$$

$$\Delta T_b = iK_b m \Rightarrow m = \frac{\Delta T_b}{iK_b} = \frac{1.4°C}{(1)(1.22°C/m)} = \boxed{1.15m} \text{ (keep 1 extra SF)}$$

b. If 264 g of ethyl alcohol was used, what is the number of moles of the solute?

$$m = \frac{\text{mol solute}}{\text{kg solvent}} \Rightarrow \text{mol solute} = m \times \text{kg solvent} = \left(1.15\,\tfrac{\text{mol}}{\text{kg}}\right)(0.264\text{ kg}) = \boxed{0.303\text{ mol}}$$

c. Given that 14.2 g of the solute was used, hat is the molar mass of the solute?

$$\text{MM} = \frac{\text{mass solute}}{\text{mol solute}} = \frac{14.2\text{ g}}{0.303\text{ mol}} = 46.9 = \boxed{47\text{ g/mol}}$$

9) A researcher places 53.2 g of an unknown molecular solute in 505 g naphthalene (K_f = 6.80°C/*m*). The nonelectrolyte lowers naphthalene's freezing point by 8.8°C. What is the molar mass of the unknown substance?

$$\Delta T_b = iK_b m \Rightarrow m = \frac{\Delta T_b}{iK_b} = \frac{8.8°C}{(1)(6.80°C/m)} = \boxed{1.29\,m} \text{(keep 1 extra SF)}$$

$$m = \frac{\text{mol solute}}{\text{kg solvent}} \Rightarrow \text{mol solute} = m \times \text{kg solvent} = \left(1.29\,\tfrac{\text{mol}}{\text{kg}}\right)(0.505\text{ kg}) = \boxed{0.651\text{ mol}}$$

$$\text{MM} = \frac{\text{mass solute}}{\text{mol solute}} = \frac{53.2\text{ g}}{0.651\text{ mol}} = 81.7 = \boxed{82\text{ g/mol}}$$