$VP = \chi_{H_2O} \times VP_{H_2O}$  $\Delta T = -k_f m$

**Solutions – Colligative Properties/Practice** **Name:** key

1. What is the vapor pressure of water above a 0.20 *m* glucose ($C_6H_{12}O_6$) solution at 20ºC? Use vapor pressure data from your text book. (VP $H_2O$ at 20ºC = 17.5mmHg) (ans:17.4mmHg)

$\frac{0.20 m \text{ glucose}}{1 kg\ H_2O}$  $1000 g\ H_2O \times 1 mol / 18 g = 55.49 mol$

$\chi_{H_2O} = \frac{55.4}{55.4 + 0.02} = 0.9964$  $VP_f = 0.9964 \times 17.55 mmHg = 17.44 mmHg$

2. Determine the freezing point of a
   a) 0.25 *m* urea in water (ans: -0.47ºC)  $k_f = -1.88\ ^\circ C/m$

   $\Delta T = -k_f m = -(1.86\ ^\circ C/m \times 0.25 m) = -0.465\ ^\circ C$

   $\Delta T = -0.465\ ^\circ C = T_f - T_i$

   $-0.465\ ^\circ C = T_f - 0.00$

   $T_f = -0.47\ ^\circ C$

   b) 5.0% para dichlorobenzene, $C_6H_4Cl_2$ (MW = g/mol) by mass in benzene ($C_6H_6$). (ans: 3.70ºC)  $K_f = -5.12\ ^\circ C/m$

   ① $\frac{5.0 g\ C_6H_4Cl_2}{95 \times 10^{-3} kg\ C_6H_6} \times \frac{1 mol}{147 g\ C_6H_4Cl_2} = 0.358 m$

   ② $\Delta T = -5.12\ ^\circ C/m \times 0.358 m = -1.83\ ^\circ C$

   ③ $\Delta T = -1.83\ ^\circ C = T_f - T_i = T_f - 5.53\ ^\circ C$  $T_f = 3.70\ ^\circ C$

3. Determine the boiling points of
   a) 0.44 *m* naphthalene in benzene (ans: 81.2ºC)  $k_b = 2.53\ ^\circ C/m$

   $\Delta T = 2.53\ ^\circ C/m \times 0.44 m = 1.11\ ^\circ C$

   $\Delta T = 1.11\ ^\circ C = T_f - T_i = T_f - 80.1\ ^\circ C$

   $T_f = 81.2\ ^\circ C$

   b) 1.8 M sucrose ($C_{12}H_{22}O_{11}$) in water (d= 1.23 g/mL) (ans: 101.5ºC)

   $\frac{1.8 mol}{1 L\ soln}$

   ① $1000 mL\ soln \times \frac{1.23 g\ soln}{1 mL} = 1230 g\ soln$

   $1.8 mol \times 342.3 g/mol = 616 g$ sucrose

   $1230 g - 616 g = 610 g\ H_2O$

   ② $\frac{1.8 mol}{0.610 kg} = 2.9 m$

   ③ $\Delta T = 0.512\ ^\circ C/m \times 2.9 m = 1.5\ ^\circ C$

   $\Delta T = 1.5\ ^\circ C = T_f - T_i = T_f - 100$

   $T_f = 101.5\ ^\circ C$

4. How many grams of naphthalene, $C_{10}H_8$, would you add to 50.0 g benzene ($C_6H_6$, Fpt. = 5.53 °C), to produce a solution that has the same freezing point as pure water? (ans: 6.92 g)

$T_f = 0.00°C \quad T_i = 5.53°C$ ← 0°C

$\Delta T = T_f - T_i = 0 - 5.53 = -5.53°C$

$-5.53°C = -k_f m = -5.12°C/m \times m$

$m = \frac{-5.53°C}{-5.12} = \frac{1.08 \text{ mol naph}}{1 \text{ kg benzene}}$

$\frac{1.08 \text{ mol naph}}{1000 \text{ g benz}} \times 50 \text{ g benz} \times \frac{128.2 \text{ g naph}}{1 \text{ mol naph}} = 6.92 \text{ g}$

5. A 1.45 g sample of an unknown compound is dissolved in 25.00 mL benzene ($C_6H_6$, d=0.879 g/mL). The solution freezes at 4.25 °C. What is the molar mass of the unknown? (ans: 264g/mol)

$\Delta T = (4.25 - 5.53)°C = -1.28°C$

$\Delta T_f = -k_f m \quad m = \frac{\Delta T}{-k_f} = \frac{-1.28°C}{-5.12 °C/m} = 0.250 m$

$25.00 \text{ mL benz} \times \frac{0.879 \text{ g}}{\text{mol}} = 22.0 \text{ g benz} = 0.022 \text{ kg benz}$

$0.250 m = \frac{\text{mol}}{0.022 \text{ kg benz}}$ ; $\text{mol} = 0.250 m \times 0.022 = 0.00550 \text{ mol}$

$\frac{1.45 \text{ g}}{0.00550 \text{ mol}} = 264 \text{ g/mol}$

6. Predict the approximate freezing points of: 0.10 *m* glucose ($C_6H_{12}O_6$), 0.10 *m* $CaCl_2$, 0.10 *m* $CH_3COOH$ and 0.10 *m* KI.

$\Delta T = -k_f m = -1.86°C/m \times 0.1 = -0.19°C$

0.10 m glucose $i = 1$ — $T_f = -0.19°C$

0.1 m $CaCl_2$ $i = 3$ — $T_f = (-0.19 \times 3) = -0.57°C$

0.1 m $CH_3COOH$ $i = 1$ (some ionization) — $> -0.19°C$

0.10 m KI $i = 2$ — $T_f = (-0.19 \times 2) = -0.38°C$