AP CHEMISTRY

TOPIC 12: SOLUTIONS, PART B,

Day 135:

- Colligative Properties (Boiling Point Elevation and Freezing Point Depression)

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1. A solution is prepared by dissolving 240 grams glucose ($C_6H_{12}O_6$) in 3000 grams of water. Calculate the freezing point of this solution. Glucose is a nonelectrolyte.

$$\Delta T_f = i\, k_f \text{ molality}$$

$$mol\ C_6H_{12}O_6 = \frac{240\ g}{} \times \frac{1\ mol\ C_6H_{12}O_6}{180.156\ g} = 1.332\ mol$$

$$molality = \frac{1.332\ mol}{3.000\ kg} = 0.444\ \frac{mol}{kg}$$

$$\Delta T_f = (1)(1.86^0C \cdot kg \cdot mol^{-1})(0.444\ mol \cdot kg^{-1}) = 0.827^0C$$

F.P. for water = 0 ^{0}C – 0.827 ^{0}C = - 0.827 ^{0}C

2. Calculate the boiling point for water if 722 grams of solid tin(IV) nitrate is added to 5200 mL of water.

$$\Delta T_b = i\, k_b \text{ molality}$$

$$Sn(NO_3)_4 \rightarrow Sn^{+4} + 4\ NO_3^{-1}$$

$$mol\ Sn(NO_3)_4 = \frac{722\ g}{} \times \frac{1\ mol\ Sn(NO_3)_4}{366.738\ g} = 1.969\ mol$$

$$molality = \frac{1.969\ mol}{5.200\ kg} = 0.379\ \frac{mol}{kg}$$

$$\Delta T_b = (5)(0.51^0C \cdot kg \cdot mol^{-1})(0.379\ mol \cdot kg^{-1}) = 0.966^0C$$

B.P. for water = 100^{0}C + 0.966^{0}C = 100.966^{0}C

3. A solution containing 4.50 grams of a nonelectrolyte dissolved in 125 grams of water freezes at –0.372^{0}C. Calculate the approximate molecular weight of the solute.

$$\Delta T_f = i\, k_f \text{ molality}$$

Rearrange the variables…

$$\Delta T_f = i\, k_f\, m \;\; ; \;\; \Delta T_f = i\, k_f \left(\frac{mol}{kg}\right)$$

$$\frac{(\Delta T_f)(kg)}{(i)(k_f)} = mol = \frac{(0.372\ ^0C)(0.125\ kg)(mol)}{(1)(1.86\ ^0C \cdot kg)} = 0.025\ mol$$

$$molecular\ weight = \frac{4.50\ g\ solute}{0.025\ mol\ solute} = 180\ \frac{g}{mol}$$

4. Calculate the freezing point and boiling point of an anti-freeze solution that is 50.0% by mass of ethylene glycol ($HOCH_2CH_2OH$) in water. Ethylene glycol is a nonelectrolyte.

$$\Delta T_f = i\, k_f\ molality\ ;\ \Delta T_b = i\, k_b\ molality$$

$$\frac{50.0\ g\ C_2H_6O_2}{} \times \frac{1\ mol\ C_2H_6O_2}{62.068\ g} = 0.8056\ mol$$

$$molality = \frac{0.8056\ mol}{0.050\ kg} = 16.11\ mol \cdot kg^{-1}$$

$$\Delta T_f = (1)\,(1.86\ ^0C \cdot kg \cdot mol^{-1})\,(16.11\ mol\ kg^{-1}) = 29.97\ ^0C$$

$$\Delta T_b = (1)\,(0.51\ ^0C \cdot kg \cdot mol^{-1})\,(16.11\ mol\ kg^{-1}) = 8.22\ ^0C$$

F.P. for water = 0 ^{0}C – 29.97 ^{0}C = - 29.97 ^{0}C

B.P. for water = 100^{0}C + 8.22^{0}C = 108.22^{0}C

5. What mass of glycerin ($C_3H_8O_3$), a nonelectrolyte, must be dissolved in 200.0 grams of water to give a solution with a freezing point of –1.50^{0}C?

$$\Delta T_f = (1)\,(1.86\ ^0C \cdot kg \cdot mol^{-1})\,(molality) = 1.50\ ^0C$$

$$molality = \frac{1.50\ ^0C}{1.86^0 C \cdot kg \cdot mol^{-1}} = 0.806\ mol \cdot kg^{-1}$$

$$\frac{200.0\ g_{solvent}}{} \times \frac{1\ kg_{solvent}}{1000\ g} \times \frac{0.806\ mol_{solute}}{1\ kg} \times \frac{92.0962\ g}{1\ mol\ C_3H_8O_3} = 14.8\ g$$

6. A solution containing 97.1 grams of a electrolyte (that dissociates into three particles) dissolved in 333 grams of water freezes at –14.672^{0}C. Calculate the approximate molecular weight of the solute.

$$\Delta T_f = i\, k_f\ molality$$

$$14.672\ ^0C = (3)\,(1.86^0C \cdot kg \cdot mol^{-1})\ molality$$

$$molality = \frac{14.672\ ^0C}{(3)\ 1.86^0 C \cdot kg \cdot mol^{-1}} = 2.629\ mol \cdot kg^{-1}$$

$$n_{solute} = \left(2.629 \frac{mol_{solute}}{kg_{solvent}}\right)\left(0.333\ kg_{solvent}\right) = 0.875\ mol_{solute}$$

$$molecular\ weight = \frac{97.1\ g\ solute}{0.875\ mol\ solute} = 110.98\ \frac{g}{mol}$$

Calculate the freezing point and boiling point for 17.0 moles of benzene which forms a solution (nonpolar) when 135 grams of a non-polar compound (Compound “X” with a molar mass of 57.343 grams mole^{-1} that does NOT dissociate in benzene) is added to the benzene.

$$\Delta T_f = i\, k_f \; molality \;\; ; \;\; \Delta T_b = i\, k_b \; molality$$

$$mol \text{ "X" } = \frac{135 \; g \text{ "X"}}{} \times \frac{1 \; mol \text{ "X"}}{57.343 \; g} = 2.354 \; mol$$

$$kg \; C_6H_6 = \frac{17.0 \; mol \; C_6H_6}{} \times \frac{78.0474 \; g \; C_6H_6}{1 \; mol \; C_6H_6} \times \frac{1 \; kg}{1000 \; g} = 1.3268 \; kg$$

$$molality = \frac{2.354 \; mol}{1.3268 \; kg} = 1.77 \; mol \cdot kg^{-1}$$

$$\Delta T_f = (1)(5.12\ {}^0C \cdot kg \cdot mol^{-1})(1.77\ mol\ kg^{-1}) = 9.06\ {}^0C$$

$$\Delta T_b = (1)(2.53\ {}^0C \cdot kg \cdot mol^{-1})(1.77\ mol\ kg^{-1}) = 4.47\ {}^0C$$

F.P. for water = 5.5 ^{0}C – 9.06 ^{0}C = - 3.56 ^{0}C

B.P. for water = 80.1^{0}C + 4.47^{0}C = 84.58^{0}C