Colligative Properties and Concentration Discussion:

You will receive a lecture on this material in discussion section; it will not be covered in lecture. You can expect to see this material will be in the HW, a future quiz and the final.

Please read over section 14.1 and 14.4 for reference.

Concentration Definitions: (Section 14.1)

$$\text{Molarity (M)} = \frac{\text{moles solute}}{L_{\text{solution}}} \quad \text{(this was covered in lecture)}$$

$$\text{wt. \% (by mass)} = \frac{\text{mass solute}}{\text{total mass solution}} \times 100$$

$$\text{Mole fraction } (X_i) = \frac{\text{moles of solute (i)}}{\text{moles of solute (i) + moles of solvent}}$$

$$\text{molality (m)} = \frac{\text{moles of solute}}{\text{kg solvent}}$$

Sample Calculations:

Example 1: What is the weight percent of vitamin C in a solution made by dissolving 1.30 g of vitamin C, $C_6H_8O_6$, in 55.0 g of water?

ans. 2.31%

Example 2: How much water must be added to 42.0 g of $CaCl_2$ to produce a solution that is 35.0 wt% $CaCl_2$?

ans. 78.0 g H_2O

Example 3: What is the mole fraction of ethanol in a solution made by dissolving 14.6 g of ethanol, C_2H_5OH, in 53.6 g of water?

ans. 0.0963

Example 4: A solution is prepared by dissolving 17.75 g sulfuric acid, H_2SO_4, in enough water to make 100.0 mL of solution. If the density of the solution is 1.1094 g/mL, what is the mole fraction H_2SO_4 in the solution?

ans. 0.0338

Example 5: Aqueous solutions of 30.0% (by weight) hydrogen peroxide, H_2O_2, are used to oxidize metals or organic molecules in chemical reactions. Calculate the molality of this solution.

ans. 12.6 *m*

Example 6: A 1.30 M solution of $CaCl_2$ in water has a density of 1.11 g/mL. What is the molality?

ans. 1.35 *m* $CaCl_2$

Colligative Properties:

Please familiarize yourself with the following topics in you text: (section 14.4)

- Raoult's Law: Vapor Pressure
- Boiling point elevation and Freezing point depression
- Osmotic Pressure

Please give a brief discussion of each covering the equations and a calculation. Some examples are listed below.

Raoult's Law: Vapor Pressure

$$P_{solution} = X_{solvent} \times P^o$$

where: $P_{solution}$ = the vapor pressure of a mixture of solute and solvent
P^o = the vapor pressure of the pure solvent
and $X_{solvent}$ = the mole fraction of the solvent.

The expression can also be written in the form:

$$\Delta P_{solvent} = -X_{solute} \times P^o$$

Example: A KCl solution is prepared by dissolving 40.0 g KCl in 250.0 g of water at 25°C. What is the vapor pressure of the solution if the vapor pressure of water at 25°C is 23.76 mm Hg?
ans. 22.1 mm Hg

Boiling Point Elevation and Freezing Point depression:

The temperature of the normal boiling point of a solution is ***increased*** by: $\Delta T_b = K_b \times m_{total}$

The temperature of the normal freezing point of a solution is ***decreased*** by: $\Delta T_f = K_f \times m_{total}$

Where the K's are the respective boiling and freezing point constants and m_{solute} is the molality of the solution.

The molality of the solute to be used in the calculation must be the molality of the total number of particles dissolved in the solvent.

m_{total} = the normal molality for molecular compounds

m_{total} = the total molality for all ions for ionic compounds

For NaCl(aq): $m_{total} = m_{Na^+} + m_{Cl^-} = 2(m_{NaCl})$

Examples:

What is the freezing point of a solution of 1.43 g $MgCl_2$ in 100. g of water? K_f = 1.86°C/*m* for water.
ans. -0.84°C

Which of the following solutions will have the lowest freezing point? Why?

a. 0.010 *m* NaCl
b. 0.010 *m* Li_2SO_4
c. 0.035 *m* C_3H_8O
d. 0.015 *m* $MgCl_2$

ans. 0.045 m in total dissolved particles

Molar mass calculations base on freezing point depression:

$$\Delta T_f \rightarrow m_{solute} \rightarrow \text{moles solute} \rightarrow \text{molar mass (knowing mass of solute)}$$

Example: When 1.60g of a molecular compound is dissolved in 20.0g of benzene (C_6H_6) the freezing point of the solution is found to be 2.8°C. If the normal freezing point is 5.5°C and $K_f = -2.53\frac{^{o}C}{m}$, then what is the molar mass of the unknown compound?

ans. 75 g/mol

Osmosis:

$$\Pi = cRT$$

$\Pi =$ Osmotic Pressure (atm)

c = concentration in $\frac{moles}{L}$

$$R = 0.08206\frac{L \cdot atm}{mol \cdot K}$$

T = absolute temperature

A solution is prepared by dissolving 4.78 g of an unknown nonelectrolyte in enough water to make 375 mL of solution. The osmotic pressure of the solution is 1011 torr at 27 °C. What is the molar mass of the solute?

Answer: 236 g/mol