Colligative properties

**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)**

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

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

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

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

**Sample Calculations:**

**Example 1:** What is the weight percent of vitamin C in a solution made by dissolving 1.30 g of vitamin C, C₆H₈O₆, in 55.0 g of water?

ans. 2.31%

**Example 2:** How much water must be added to 42.0 g of CaCl₂ to produce a solution that is 35.0 wt% CaCl₂?

ans. 78.0 g H₂O

**Example 3:** What is the mole fraction of ethanol in a solution made by dissolving 14.6 g of ethanol, C₂H₅OH, in 53.6 g of water?

ans. 0.0963

**Example 4:** A solution is prepared by dissolving 17.75 g sulfuric acid, H₂SO₄, 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 H₂SO₄ in the solution?

ans. 0.0338

**Example 5:** Aqueous solutions of 30.0% (by weight) hydrogen peroxide, H₂O₂, 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 CaCl₂ in water has a density of 1.11 g/mL. What is the molality?

ans. 1.35 m CaCl₂
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**Colligative Properties:**

Please familiarize yourself with the following topics in your 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**

\[ P_{\text{solution}} = X_{\text{solvent}} \times P^o \]

where:

- \( P_{\text{solution}} \) = the vapor pressure of a mixture of solute and solvent
- \( P^o \) = the vapor pressure of the pure solvent
- \( X_{\text{solvent}} \) = the mole fraction of the solvent.

The expression can also be written in the form:

\[ \Delta P_{\text{solvent}} = -X_{\text{solute}} \times P^o \]

**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:

\[ \Delta T_b = K_b \times m_{\text{total}} \]

The temperature of the normal freezing point of a solution is *decreased* by:

\[ \Delta T_f = K_f \times m_{\text{total}} \]

Where the \( K \)'s are the respective boiling and freezing point constants and \( m_{\text{solute}} \) 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.

- \( m_{\text{total}} \) = the normal molality for molecular compounds
- \( m_{\text{total}} \) = the total molality for all ions for ionic compounds

For \( \text{NaCl(aq)} \):

\[ m_{\text{total}} = m_{\text{Na}^+} + m_{\text{Cl}^-} = 2(m_{\text{NaCl}}) \]

**Examples:**

What is the freezing point of a solution of 1.43 g \( \text{MgCl}_2 \) in 100. g of water? \( K_f = 1.86^\circ C/m \) for water.

ans. -0.84°C
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Which of the following solutions will have the lowest freezing point? Why?

a. 0.010 m NaCl
b. 0.010 m Li₂SO₄
c. 0.035 m C₃H₈O
d. 0.015 m MgCl₂

ans. 0.045 m in total dissolved particles

Molar mass calculations base on freezing point depression:

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

**Example:** When 1.60g of a molecular compound is dissolved in 20.0g of benzene (C₆H₆) the freezing point of the solution is found to be 2.8°C. If the normal freezing point is 5.5°C and \( K_f = -2.53 \frac{\degree C}{m} \), then what is the molar mass of the unknown compound?

ans. 75 g/mol

**Osmosis:**

\[ \Pi = cRT \]

\[ \Pi = \text{Osmotic Pressure (atm)} \]

\[ c = \text{concentration in} \ \frac{\text{moles}}{L} \]

\[ R = 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \]

\[ T = \text{absolute temperature} \]

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*