Colligative Properties Discussion
Chem. 1A

The material covered today is found in sections Chapter 12.5 – 12.7
This material will not be covered in lecture, you will have homework assigned.

Colligative Property

- Comparing physical properties of a solution relative to the physical properties of the pure solvent.
- Defined: Properties that depend on the total amount of dissolved solute particles in a solvent.
- More solute particles (ions or molecules) the greater this effect.
- Example:
  Solution: NaCl dissolved in water [Na⁺(aq) & Cl⁻(aq)]
  Pure solvent: water
Colligative Properties

• Relative to a pure solvent, a solution has:
  – A lower vapor pressure
  – A higher boiling point
  – A lower freezing point
  – Osmosis occurs

• Example:
  – Pure water: b.p.=100°C  f.p.= 0°C
  – 1.00 m NaCl (aq) b.p. = 101°C  f.p. = -3.7 °C

Concentration

• Colligative properties:
  – Dependant upon the amount of solute particles.
  – Concentration is expressed in different ways for different properties. (vapor pressure, boiling point, etc...)
Concentration Units

Molarity ($M$)

$$M = \frac{\text{moles solute}}{\text{L of solution}}$$

Concentration Units

Weight (mass) %

$$\% = \frac{\text{mass solute}}{\text{Total mass of solution}} \times 100$$
Concentration Units

Mole Fraction ($X$)

$$X_i = \frac{\text{moles solute (i)}}{\text{Total moles in solution}}$$

Where “i” is the moles of one component of the solute. Total moles are all species: mols solute (i) + mols solvent

The sum of all of the mole fractions for each component are 1 exactly.

$$\sum X_i = 1$$

Concentration Units

Molality ($m$)

$$m = \frac{\text{moles solute}}{\text{kg solvent}}$$
Changes in vapor pressure: Raoult’s Law

- Vapor pressure: pressure exerted by the vapor when a liquid in a closed container is at equilibrium with the vapor.
- Vapor pressure of solution is decreased by the presence of a solute.
- More solute particles, lower vapor pressure of solution.

Raoult’s Law

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

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

The expression can also be written in the form:

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

\( \Delta P \) is the change to the vapor pressure of the pure solvent.
Raoult’s Law

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

- \( P_{\text{solution}} \) = 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.*

* If the solute involves an ionic compound then the total concentration of ions (both cations and anions) must be considered in the calculation of mole fraction.

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**Boiling Point Elevation and Freezing Point depression:**

*Molecular Compounds*

The temperature of the normal boiling point of a solution is *increased* by:

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

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

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

Where the K’s are the respective boiling and freezing point constants and \( m_{\text{solute}} \) is the molality of the solution.

For boiling point elevation: \( K_b > 0 \) (positive)
For freezing point depression: \( K_f < 0 \) (negative)
van’t Hoff factor

**Boiling and Freezing point effects involving ions:**

When solutions containing ions are involved, the total concentration of solute particles must be considered. The change in b.p. or f.p. is given by the equation:

\[ \Delta T = K \times m \times i \]

Where \( m \) is the calculated molality based on formula wt. “\( i \)” = the number of ions (van’t Hoff factor)

<table>
<thead>
<tr>
<th>compound</th>
<th>Type</th>
<th>( i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH(_2)OH</td>
<td>molecular</td>
<td>1</td>
</tr>
<tr>
<td>NaCl</td>
<td>strong electrolyte</td>
<td>2</td>
</tr>
<tr>
<td>Ba(NO(_3))(_2)</td>
<td>strong electrolyte</td>
<td>3</td>
</tr>
<tr>
<td>HNO(_2)</td>
<td>weak electrolyte</td>
<td>1 - 2</td>
</tr>
</tbody>
</table>

A semipermeable membrane allows only the movement of solvent molecules.

Solvent molecules move from pure solvent to solution in an attempt to make both have the same concentration of solute.
Osmosis at the Particulate Level

Process of Osmosis
Osmotic Pressure, $\Pi$

Equilibrium is reached when the internal pressure of the apparatus equals the external pressure of the open tube. Since the internal pressure, $P_{\text{int}}$ is greater then the atmospheric pressure, a column of liquid rises:

$$P_{\text{atm}} + P_{\text{col}} = P_{\text{int}}$$

Recall that: $P = g \times d \times h$

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Osmotic Pressure, $\Pi$

$P_{\text{col}}$ is referred to as the Osmotic Pressure, $\Pi$.

$$\Pi = cRT$$

$c$ = concentration of solute (mols/L)

$T$ = the absolute temperature (K)

$R = 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}$ $\Pi$ is in units of atm.
Now it is time to work on the problems from your hand out.

You will not have time to finish, please work on these outside of class. See your instructor or the help office if you have questions.

Solutions will be posted online soon.

You need to try your best to solve these problems as they will be on the exam and final!