Experiment 17
Colligative Properties

To prepare for this experiment:

- Carefully read the entire experimental guide (below).
- Answer all the prelaboratory practice problems.
- Review your Chapter 13 lecture notes (particularly the section on boiling point elevation) and bring them to lab.
- Review Experiment 3 (Graph Drawing) and bring your thermometer calibration curve to lab.

Introduction

Colligative properties are those properties of a solution that depend on the number of molecules or ions dissolved in a solution, and not on the identity of the species in solution. Examples of these properties are boiling point elevation, freezing point depression, and osmotic pressure. In this experiment, you will study boiling point elevation using sodium chloride, NaCl. You may recall from your notes that boiling point elevation is described by the equation:

$$\Delta T_b = iK_b c_m$$

where ΔT_b is the **boiling point elevation**, i is the **van't Hoff factor**, K_b is the **boiling point constant of the solvent,** and c_m is the **molality of the solution**. The boiling point elevation, ΔT_b, is the difference between the boiling point of the pure solvent and the boiling point of the solution. In theory, a solution of NaCl has a van't Hoff factor of 2, a solution of $MgCl_2$ has a van't Hoff factor of 3, and a solution of a non-dissociating substance like sugar would have a van't Hoff factor of 1.

In this experiment, you will be creating 3 salt/water solutions of varying molalities. You will use a hot plate to heat up your solutions to the boiling point and measure this temperature using a thermometer. Using this data, you will determine the boiling point constant.

Prelab Questions

1. The boiling point elevation constant of carbon tetrachloride is 4.95 ºC/m. The density of carbon tetrachloride is 1.584 g/cm^3. The normal boiling point of carbon tetrachloride is 76.8ºC.
    a. Calculate the boiling point of a solution made by mixing 25.56 grams of solid iodine with 250 ml carbon tetrachloride. (Show all work)
    b. Calculate the boiling point of a solution made by mixing 25.56 grams of solid naphthalene ($C_{10}H_8$) with 250 ml carbon tetrachloride. (Show all work)

Experimental Procedure

Part A: Determining the Boiling Point of Water and Salt Solutions

1. Fill 3 600ml glass beakers with 400ml Of Deionized Water.
2. Pick 3 different salt masses in the range of 20-80g. These 3 masses should be spread over the range to provide a nice spread of data points (one ~20g, one ~80g and one between). Calculate and record the molality of each salt solution based on the salt mass.
3. Add the chosen amount of Salt to each beaker to create the 3 different solutions.
4. Insert 1 magnetic stirrer into each beaker.
5. Place one beaker on hot plate and heat solution until boiling (until temperature is stabilized for 2-3 minutes).
6. Record temperature value (boiling point temperature).
7. Take solution off hot plate **carefully using folded paper towels.**
8. Repeat Steps 5-7 for each of the 2 other solutions and record boiling temperature.
9. Repeat the experiment one time for each solution, recording boiling point temperatures.
10. Once cooled, dump solutions down drain, clean beakers and return to cabinet. Turn off hot plate and return to cabinet.

Part B: Plotting and Calculating van't Hoff Factor

1. Use Excel to draw (and label) 1 graph.
2. Calculate the average boiling point of each solution over your 3 trial runs.
3. Calculate the change of boiling point temperature (DT) of each solution from pure water (BP = 100ºC).
4. Plot DT (Y-axis) vs. Solution Molality (X-Axis).
5. Add an extra point at (0, 0) (See Prelab).
6. Draw a line of best fit (trend line) connecting the 4 points.
7. Using the best fit line and the van't Hoff equation, calculate K_B.

Data Analysis

1. Calculate the Average Boiling point found for each different solution
2. Create a data plot in excel having the X-axis as molality and the Y-axis as the boiling point temperature elevation from pure water (100 °C).
3. Add all three data points to your graph including a data point for pure water at (0,0).
4. Using excel, calculate a linear trend line between the points, and have excel show you the equation of the line
5. Relate the equation to the given equation in the lab introduction, and see how the slope of the line relates to the boiling point constant and van't Hoff factor.
6. From this, determine the boiling point constant of water.

Prelab Questions Solutions

a. 78ºC

b. 79ºC

Prelab Questions

1. What are the units of Molality?
    a. mol solute / L solution
    b. kg solute/ mol solvent
    c. mol solute/ kg solution
    d. mol solvent/ kg solute

2. In a salt/water solution, what is the solvent and what is the solute?
    a. Solvent: Salt, Solute: Water
    b. Solvent: Water, Solute: Salt
    c. None of the Above

3. Determine the molality of pure water?
    a. 0 molal
    b. .05 molal
    c. 1 molal
    d. 10 molal

4. How many different solution molalities will be tested?
    a. 2
    b. 3
    c. 4
    d. 5

5. What is the boiling point of pure water?
    a. 0 ºK
    b. 273 ºK
    c. 100 ºC
    d. 273 ºC
    e. 373 ºC