Freezing Point Depression

PURPOSE

To predict and measure the freezing point depression caused by a solute in a solvent.

GOALS

- To learn to accurately measure a freezing point depression for a solution.
- To learn to use the molar mass of a solute to calculate the colligative molality.
- To learn to use colligative molality to calculate the resulting freezing point depression.

INTRODUCTION

A solution is a homogeneous mixture of two or more substances. For the common two-component solution, the substance present in the major proportion is called the solvent[1] and that in the minor proportion is called the **solute**. Solvent properties are often changed by the presence of the solute, generally in proportion to the amount of solute concentration. Dissolving copper sulfate in water causes the resulting solution to have a blue color. Dissolving sodium hydroxide or ammonia in water produces a basic solution. Adding molasses or honey to water produces a solution more viscous than water.

There are, however, a few properties of a solution that are affected by the concentration of particles the solute contributes to the solution regardless of their identity. These are called colligative properties[2] and include changes in osmotic pressure, vapor pressure lowering, boiling point elevation and freezing point depression.

The change in the freezing or boiling point of a solvent when a solute is added is proportional to the colligative molality (m_c) of the solution.

$$m_c = i \cdot m \tag{1}$$

where m, molality, is the moles of solute per kg of solvent, and i, the van't Hoff factor, is the number of particles produced when a solute dissolves. The van't Hoff factor for NaCl is 2 because it dissolves into Na^{1+} and Cl^{1-} in solution. For covalent compounds that do not ionize, i is one.

The lowering of the freezing point is given by the following equation:

$$\Delta T_f = k_f \cdot m_c \tag{2}$$

where ΔT_f is T_f(pure solvent) − T_f(solution), k_f is the freezing point depression constant for the solvent and m_c is the colligative molality.

[1] http://en.wikipedia.org/wiki/Solvent
[2] http://en.wikipedia.org/wiki/Colligative_properties

In this experiment, the colligative molality of a stearic acid solution containing lauric acid will be used to predict the freezing point depression. Then, this prediction will be compared to the experimentally measured freezing point of the solution. Stearic acid, $CH_3(CH_2)_{16}COOH$, is also known as *n*-octadecanoic acid and has a freezing point of 69.0°C and a k_f of 4.5°C/m. Lauric acid, $CH_3(CH_2)_{10}COOH$, is also known as dodecanoic acid and has a van't Hoff factor (i) of 1.

To perform this determination, you must know the mass of both the solvent and solute and the molecular mass of the solute. This will allow you to calculate the colligative molality of the solution, m_c. Plugging the m_c into equation 2, you can calculate the freezing point depression, ΔT_f, of the solution. Last, you must subtract this from the freezing point of the solvent to get the predicted freezing point of the solution.

In Part A of this experiment, you will determine the freezing point of pure stearic acid. In Part B, you will measure the freezing point depression caused by adding varying amounts of lauric acid to stearic acid and compare these measured values to your calculated values.

EQUIPMENT

1 crystallization dish

1 100 mL graduated cylinder

1 30 mL beaker

1 digital thermometer

1 pair of tongs

1 spatula

1 hot plate

REAGENTS

~9 g stearic acid

~2 g lauric acid

SAFETY

Stearic acid and lauric acid are nonhazardous, but prolonged contact with skin may cause irritation. If either acid is spilled on skin, wash the affected area with soap and water.

WASTE DISPOSAL

Stearic and lauric acid solutions should be placed in the labeled waste container in the lab. Solid may be warmed in a hot water bath so that it can be poured into the waste container. Any remaining solid can be dislodged with a spatula and scraped into the waste container. All glassware and the thermometer should be washed thoroughly in the sink with soap and hot water using a brush.

PRIOR TO CLASS

Please read the following sections of Lab Safety and Practices: Good Lab Practices[3] and Measurements[4].

Please read the following section in Lab Equipment: Analytical Balance[5].

Please review the following videos: Safety[6] and Using an Analytical Balance[7].

LAB PROCEDURE

Please print the worksheet for this lab. You will need this sheet to record your data.

Part A: Measuring the Freezing Point of Stearic Acid ($CH_3(CH_2)_{16}COOH$, $f_p = 69.0°C$, $k_f = 4.5$ °C/m)

1. Prepare a hot water bath in your crystallization dish by heating about 85 mL of tap water on your hot plate (∼1/2 filled). Use a graduated cylinder to measure the water. Medium heat should suffice. You do not want the water to boil.

2. Weigh an empty 30 mL beaker and record the mass in Table A. Carefully add approximately 9 grams of stearic acid to the empty beaker and again record the **exact** mass of the beaker and stearic acid in Table A. Determine the difference between the two measurements for the exact mass of stearic acid.

3. Place the beaker containing the stearic acid in your hot water bath. Do not leave a beaker in your hot water bath unattended at any time during the experiment. Be careful not to allow any water from the water bath to enter the beaker.

4. Using the digital thermometer provided, gently stir the solid until all of the solid melts. Continue to heat the sample until it reaches 85°C.

5. Remove the beaker from the hot water bath using tongs and monitor the temperature every ten seconds as the solution cools.

6. Continue to monitor the temperature until the sample becomes somewhat solid and the temperature remains constant for two minutes. Record this temperature in Table A as the freezing point of stearic acid.

7. Repeat steps 3 - 6 on the same sample to check your technique.

8. Determine the average of the two experimentally determined freezing points.

Part B: Freezing Point Depression by a Solute, Lauric Acid ($CH_3(CH_2)_{10}COOH$)

1. If necessary, add tap water to the hot water bath to keep it about half filled.

2. Weigh the 30 mL beaker with stearic acid used in Part A and record the mass in Table B in the

[3] ../practices/manual.html
[4] ../measurements/manual.html
[5] ../equipment/manual.html#balance
[6] ../movies/labsafety.html
[7] ../movies/balance.html

first addition column. Although this should be the same mass as recorded in Table A, in practice a small portion of stearic acid often sticks to the thermometer.

3. Carefully add approximately 1 gram of lauric acid to the beaker and again record the **exact** mass of the beaker plus stearic and lauric acids in Table B. Determine the difference between the two measurements for the exact mass of lauric acid.

4. Repeat steps 3 - 5 from Part A.

5. Continue to monitor the temperature until the sample becomes somewhat solid and the temperature remains constant for two minutes. Record this temperature in Table B as the measured freezing point of the first stearic and lauric acid solution.

6. Weigh the 30 mL beaker with stearic and lauric acid used in the earlier portion of B and record the mass in Table B in the second addition column.

7. Carefully add approximately 1 gram of lauric acid to the beaker and again record the **exact** mass of the beaker plus stearic and lauric acids in Table B. Determine the difference between the two measurements for the exact mass of lauric acid added during the second addition. Be sure to add this value to the amount of lauric acid from the first addition to give the **total** mass of lauric acid added. Record this in data table B.

8. Repeat steps 3 - 5 from Part A.

9. Continue to monitor the temperature until the sample becomes somewhat solid and the temperature remains constant for two minutes. Record this temperature in Table B as the measured freezing point of the second stearic and lauric acid solution.

10. When you are finished, heat the solid until it is liquid and discard in the labeled waste container. Dislodge any remaining solid with your spatula and place in the waste container. Turn off your hot plate and thoroughly clean all glassware in the sink with soap, hot water and a brush. Dry and return all equipment and glassware to the set up area.

11. Before leaving, enter your results in the In-Lab assignment. If all results are scored as correct, log out. If not all results are correct, try to find the error or consult with your lab instructor. When all results are correct, note them and log out of WebAssign. The In-Lab assignment must be completed by the end of the lab period. If additional time is required, please consult with your instructor.

