Freezing Point Depression

PURPOSE

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

GOALS

1 To learn to accurately measure a freezing point depression for a solution.

2 To learn to use the molar mass of a solute to calculate the colligative molality.

3 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 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 some examples 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.

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

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:

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

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

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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 · kg/mol = 45°C/m. Lauric acid, $CH_3(CH_2)_{10}COOH$, is also known as dodecanoic acid has a van't Hoff factor (i) of 1.

To experimentally determine how much the freezing point decreases, 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 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

1 100 mL beaker

1 150 mL beaker

1 MicroLab Interface

1 MicroLab Thermistor Instruction Sheet

1 test tube from side shelf

1 thermistor

1 test tube holder

1 hot plate

1 spatula

1 ringstand

1 clamp

REAGENTS

~3 g stearic acid

~1 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.

Gloves are not provided for this experiment. The chemicals used in this experiment are often found in skin products. Stearic acid is a common component of cocoa or shea butter. Lauric acid

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is found in coconut oil. Remember to wash your hands with soap and water when the experiment is completed.

WASTE DISPOSAL

Test tubes containing stearic and lauric acid solutions should be placed in the labeled waste container in the lab. All remaining glassware and the thermistor should be cleaned thoroughly.

PRIOR TO CLASS

Please read the following section of Lab Safety and Practices:

Good Lab Practices[3]

Measurements[4]

Please read the following section of Lab Equipment:

Analytical Balance[5]

Please review the following videos:

Safety[6]

Using an Analytical Balance[7]

Please complete your WebAssign prelab assignment. Check your WebAssign account for due dates. Students who do not complete the WebAssign prelab assignment are required to print and hand in the prelab worksheet.

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 ($CH_3(CH_2)_{16}COOH$, T_f = 69.0°C, k_f = 4.5 °C/m)

1 Open the MicroLab program. Calibrate the thermistor as described in the MicroLab instructions provided in the lab.

2 Set the MicroLab collection increment to 2 seconds, using the detailed instructions provided in the lab.

3 Prepare a hot water bath by placing approximately 120 mL of tap water in your 150 mL beaker and heating it on the hot plate. Estimate the volume using the graduations on the beaker. Medium heat should suffice. You do not want the water to boil.

[3] ../practices/manual.html
[4] ../measurements/manual.html
[5] ../equipment/manual.html#balance
[6] https://www.youtube.com/watch?v=S_mm-PF_Iq8
[7] https://www.youtube.com/watch?v=AvbyTvgzGTs

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4 Obtain a test tube from the side shelf and place it inside a 100 mL beaker to support it. Using the weighing paper at the balance, carefully weigh approximately 3 grams of stearic acid. Record the **exact** mass of the stearic acid in Data Table A, and carefully add the entire solid to the test tube.

Data Table A. Measuring the Freezing Point of Stearic Acid

5 Using a test tube holder, place the test tube containing the acid in your hot water bath. Do not leave the hot water bath unattended at any time during the experiment. Be careful not to allow any water from the water bath to enter the test tube.

6 Using the thermistor provided, very gently stir the solid until it completely melts. Do not bend the thermistor or allow the rubber casing of the probe to touch the hot plate. Continue to heat the sample until it reaches 85°C.

7 Remove the test tube/thermistor from the hot water bath using the test tube holder and place it in the 100 mL beaker. Secure the thermistor with the clamp on the ring stand so that the sensor is not touching the bottom or sides of the test tube, and start the MicroLab Program. This will monitor the temperature every 2 seconds as the solution cools.

8 Continue to monitor the temperature until the sample becomes somewhat solid and the temperature remains constant for two minutes. Record this temperature in Data Table A as the freezing point of stearic acid. Stop the MicroLab data collection program.

9 Repeat steps 5 - 8 on the same sample to check your technique and record the freezing point in Data Table A.

10 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 the volume at approximately 120 mL.

2 Record the mass of stearic acid from Part A in Data Table B.

3 Using a clean piece of weighing paper, measure approximately 0.5 grams of lauric acid, record the exact mass in Data Table B, and carefully add the solid to the test tube containing stearic acid.

Data Table B. Freezing Point Depression by a Solute, Lauric Acid

4 Repeat steps 5 - 7 from Part A.

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

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6 Weigh an additional 0.4 grams of lauric acid on clean weighing paper, record the exact mass in Data Table B, and add it to the test tube containing the stearic and lauric acid mixture. Add the second mass to the first mass of lauric acid in Part B, and record this as the total mass of lauric acid.

7 Repeat steps 5 - 7 from Part A.

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

9 When you are finished, turn off and unplug your hot plate. Allow the solid to cool and place the test tube containing the solid in the waste container. 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. Close the MicroLab program.

10 Before leaving, enter your results in the InLab 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 teaching assistant. When all results are correct, note them and log out of WebAssign. The InLab assignment must be completed by the end of the lab period. If additional time is required, please consult with your teaching assistant.

Queston 1: Do you expect the freezing point of this solution from the first addition of lauric acid to be at a higher or lower temperature than that of the pure solvent?

Queston 2: Using your measured amounts of stearic acid and lauric acid for the first addition, calculate the colligative molality (m_c) of the resulting solution, the freezing point depression (ΔT_f) this molality should cause and the theoretical freezing point of the solution. Enter your results in Data Table B.

Queston 3: How did your measured freezing point compare to your theoretical freezing point for the first addition?
% error = ((theoretical value - actual value) × 100%)/theoretical value

Queston 4: Do you expect the freezing point of this solution from the second addition of lauric acid to be at a higher or lower temperature than that of the previous solution?

Queston 5: Using your measured amounts of stearic acid and lauric acid for the second addition, calculate the colligative molality (m_c) of the resulting solution, the freezing point depression (ΔT_f) this molality should cause and the theoretical freezing point of the solution. Enter your results in Data Table B.

Queston 6: How did your measured freezing point compare to your theoretical freezing point for the second addition?
% error = ((theoretical value - actual value) × 100%)/theoretical value

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