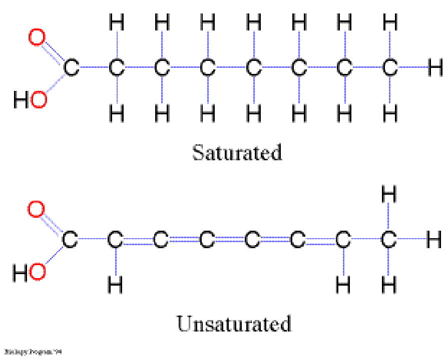
INVESTIGATION OF THE COLLIGATIVE PROPERTIES OF FATTY ACIDS

INTRODUCTION

FATTY ACIDS

Fatty acids play a relevant role in our daily life. Fatty acids are long chain hydrocarbons with a terminal carboxyl (COOH) group. Organic compounds with the COOH group are called carboxylic acids (Figure 1(a)). Fatty acids are not manufactured by the body and therefore must be included in the diet. They are required to ensure cell membrane formation, hormone synthesis and vitamin absorption among other things. It is now widely accepted that omega-3 fatty acids are essential to heart health (Figure 1 (b)). Some common natural fatty acids include, butter and lard. Have you ever noticed that if butter is left too long at too high a temperature it becomes rancid? This happens because the fatty acid (butter) has undergone auto-oxidation. Vitamins A and E are absorbed in the body using fatty acids. Fatty acids are also useful in various industrial processes, including soap manufacture. You will learn more about the reactions of fatty acids in organic chemistry.



(a)

(b)

Figure 1 (a) Molecular structure of fatty acid (b) Some sources of omega-3 fatty acids

COLLIGATIVE PROPERTIES

Colligative properties are those properties of solutions which are not affected by the nature of the solute present in the solution, but only by the amount of the solute that is present. More specifically, colligative properties change with the number of particles present in solution. The four colligative properties presented in this course are vapor pressure lowering, boiling point elevation, freezing point depression and osmotic pressure.

Since colligative properties do not depend on the nature of the solute, they may be used to determine the molecular weight of a substance. In this experiment you will determine the molecular mass of an unidentified fatty acid and use this value to identify the fatty acid. You will do this by measuring the freezing point of stearic acid before and after the addition of different amounts of the unidentified fatty acid. The difference between the freezing points of pure stearic acid and the mixture (stearic acid containing unidentified fatty acid) is the freezing point depression, ΔT_f. Given that the freezing point depression constant (K_f) for stearic acid is
4.5 ^{O}C/kg/mole and the following equation:

$$\Delta T_f = K_f m, \text{ where } m = \text{molality of solvent}$$

you will be able to determine the number of moles of solute (unidentified fatty acid) present in the solution. The molecular weight of the unidentified fatty acid can then be calculated.

REFERENCES:

McCarthy, S. and Gordon-Whylie, S. *A greener approach for measuring colligative properties* Journal of Chemical Education **2005** Vol (82) Iss. 1 pp.116.

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EXPERIMENTAL

Apparatus:

20 x 100 mm round bottom vial

Thermometers or Temperature Probe (SPARKvue)

Stand and clamps

150 mL beaker

Hot plate or Bunsen burner

Mixing wire loop

Procedure:

1. Determine the mass of the 20 x 95 mm vial on a milligram balance.

2. Place about 5 grams of stearic acid in the 20 x 100 mm round bottom tube. Determine the exact mass of stearic acid added by difference.

3. Prepare a hot water bath by filling a 150 ml beaker with about 80 mL of tap water and heating it with a Bunsen burner. Monitor the temperature of water by using a regular thermometer. The temperature of the water bath should not exceed 90°C.

4. Once the temperature of the water bath has reached 70°C, melt the stearic acid by immersing the 20 x 95 mm vial with the fatty acid sample in the hot water and moving the vial in circular motion. (A clamp would be helpful for this step as in Figure 2).

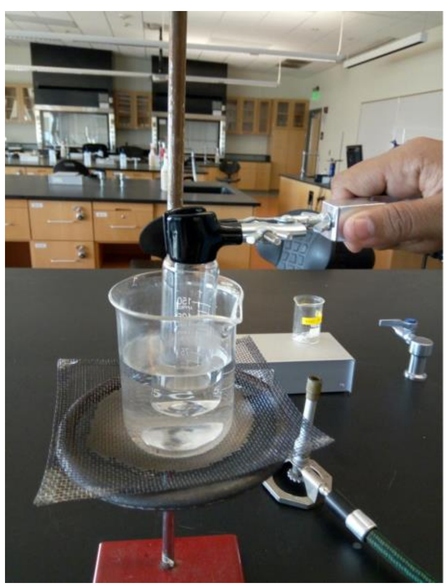

Figure 2. Melting your sample using a clamp.

5. After the stearic acid has completely melted, continuing heating until your water bath reaches 85°C (Remember no to go over 90°C). Turn off the Bunsen burner and place the temperature probe or thermometer (Figure 4) and mixing wire loop inside the vial with the sample as in Figure 3. The thermometer or temperature probe should remain in this test tube for the remainder of the experiment. Make sure the probe is immersed in your sample.

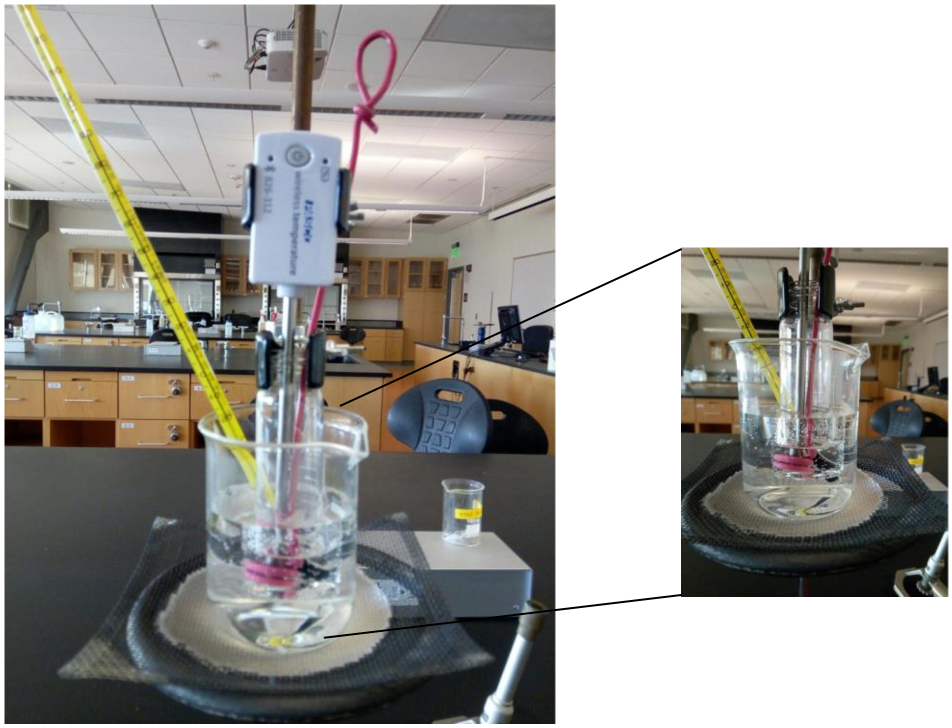

Figure 3. Final experimental set-up using a temperature probe.

6. As soon as you have your experimental set up ready mix your sample constantly by moving the wire loop up and down. If you are using a thermometer, record the temperature of the stearic acid sample every 30 seconds for about 8-15 minutes. Temperatures are collected until the temperature of the sample remains constant, changing by less than 0.2 °C per reading, for 3 minutes, (6 readings).

   If you are using a temperature probe:

   A. Turn on the Bluetooth connection on your smartphone and turn on the temperature probe
   B. Open your SPARKvue app.
   C. Choose the Sensor Data path.
   D. Connect to the temperature probe that has your device id.
   E. On the template menu select the Table and Graph option. A new window will open.
   F. Tap on the rate menu located on the lower left corner and in the window that appears change the sample interval to 15 s. Then tap on OK.
   G. Tap on Start.
   H. Collect data for 15 minutes. Make sure you are mixing your sample constantly during that period of time.
   I. Tap on Stop after the 15 minutes have elapsed.

7. Perform a second trial using the same sample.

8. To the ***same*** stearic acid sample above, add approximately 0.5 g of an unidentified fatty acid sample which will be provided by your instructor. Write down your unknown number on your notebook.

9. Repeat steps 4 through 6.

10. To the ***same*** stearic acid mixture you just measured, add an *additional* 0.5 g of the same unidentified fatty acid as in step 8.

11. Repeat steps 5 through 7 again.

DATA TREATMENT AND CALCULATIONS

In order to determine the value of ΔT_f you will need to determine the freezing point of the pure stearic acid and the stearic acid solutions. In order to do this accurately, you will plot a graph of temperature (y-axis) versus time (x-axis). You will tabulate and graph two sets of data for each experiment, one in which the temperature changes by more than 0.5 ^{o}C in a 30 second period (0.2 ^{O}c is you are using a temperature probe) and another in which the temperature changes by less than 0.5 ^{o}C (0.2 ^{O}c is you are using a temperature probe) in a 30 second period. The temperature at the point of intersection of the two lines is the freezing point of the solution (Figure 5).

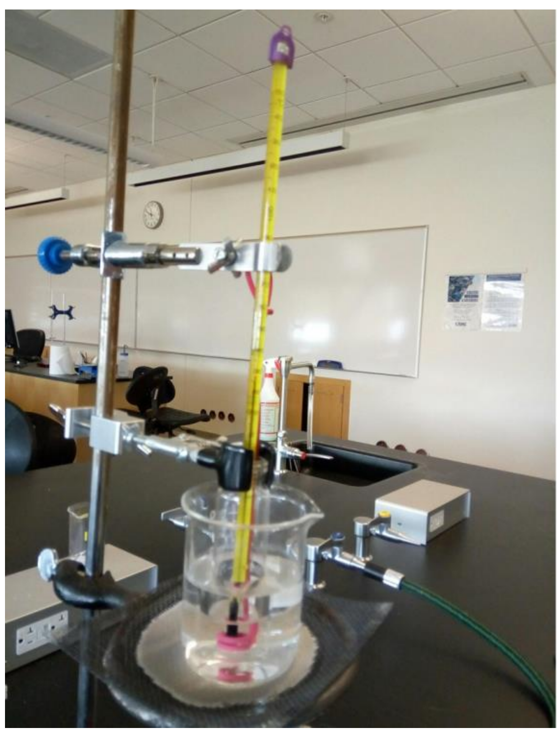

Figure 4. Final experimental set-up using a thermometer.

NOTE: If the temperature is completely constant while freezing occurs, then you need not make the plot- the intersection will be at the freezing temperature.

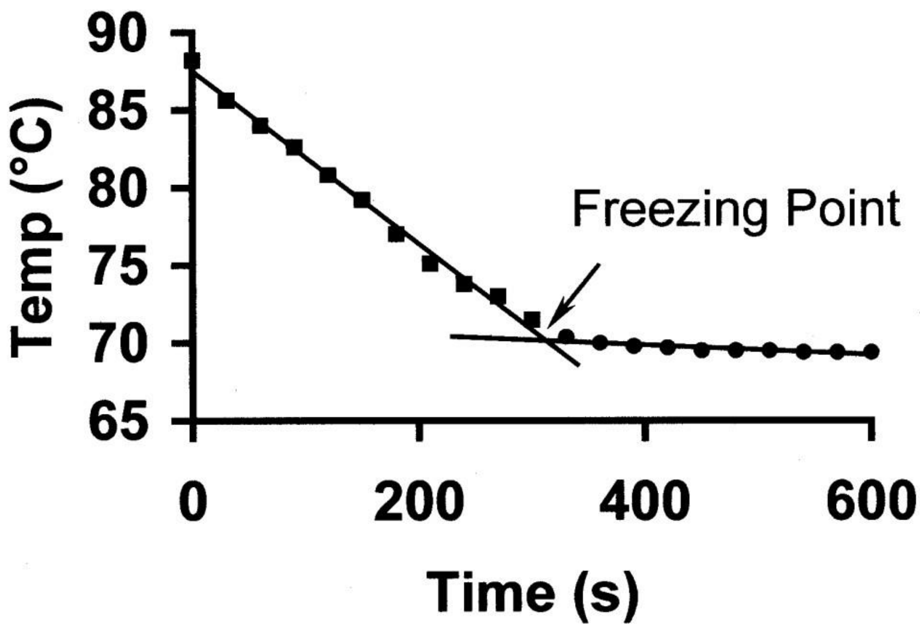

Figure 5. Example of graph used to determine freezing point of stearic acid (stearic acid mixture).

Determine the molecular mass of the unknown fatty acid using the data you have collected and Report an average value.

Given that the possible unknown fatty acids are:

Palmitic acid, $CH_3(CH_2)_{14}COOH$

Lauric acid, $CH_3(CH_2)_{10}COOH$

Myristic acid, $CH_3(CH_2)_{12}COOH$

Identify your unknown based on the molecular weight you have calculated.