USING FREEZING POINT DEPRESSION
TO FIND MOLECULAR WEIGHT

Adapted from "Chemistry with Computers"
Vernier Software, Portland OR, 1997

LABORATORY NOTEBOOK

Objectives, Chemical & Equipment Tables, and Procedures & Observations should all be entered
into your ELN. All spectra files should be attached in the Procedures & Observations section. A
few pictures should also be attached that clearly show the solutions and equipment or
instrumentation used.

INTRODUCTION

When a solute is dissolved in a solvent, the freezing point temperature is lowered in proportion
to the number of moles of solute added. This property, known as freezing point depression is a
colligative property; that is, it depends of the ratio of solute and solvent particles and not on the
nature of the substance itself. The equation that shows this relationship is:

\[ \Delta T = K_f \cdot m \]

where \( \Delta T \) is the freezing point depression, \( K_f \) is the freezing point depression constant specific
for a given solvent (3.90 °C-kg/mol for lauric acid in this experiment), and \( m \) is the molality of
the solution. Molality (m) is used because it is independent of the volume changes that can occur
with variations in temperature, unlike molarity (M).

\[
molality (m) = \frac{\text{moles of solute}}{\text{kg of solvent}}
\]

In this experiment, the freezing temperature of the pure solvent, lauric acid,
CH\(_3\)(CH\(_2\))\(_{10}\)COOH is found first. Next the freezing point of a solution prepared from a mixture
of an unknown organic acid and lauric acid is measured. By measuring the masses of the
unknown organic acid and lauric acid in the mixture and calculating freezing point depression,
\( \Delta T \), and, the equations above can be used to find the molecular weight of the unknown acid.
molecular weight = mass / moles

Look up the melting point (freezing point) of pure lauric acid (CH₃(CH₂)₁₀COOH, also called "dodecanoic acid").

Before starting the experiment, the TA will asks you to do a quick demonstration or talk-through one of the following:
1) Assemble the glassware setup to measure the freezing temperature of lauric acid (without the chemicals or hot water).
2) How to correctly stir the lauric acid while it is cooling.
3) Explain how to remove the temperature probe after the lauric acid has solidified

Make sure you watch the videos on the course website and read the documents to prepare. These demonstrations will be done every week. Everyone will have presented at least one topic by the end of the quarter. The demonstrations should be short (>1 min) and will be graded.

PROCEDURES

1. Work in pairs. Wear safety goggles and lab aprons at all times. Keep the hot acids in the hoods. Important: This lab is "messy" and part of your score will be based on how well you clean your lab bench, equipment, hood, and balance areas. The TA will be observing closely to see that all areas are kept clean.

2. Connect the temperature probe to Channel 1 of the LabQuest 2
   - In the screen, click on the box that says “Mode:Time Based.” Change the duration to 10 minutes. Change the rate to 6 samples/minute. This will give better results when determining the freezing point of the unknown solution. Click OK.

Part A: Freezing Temperature of Pure Lauric Acid
3. Set up two water baths using 400 mL beakers. One should be placed on a hot plate in the hood and maintained at 70–80 °C. Make sure the water level remains above 200 mL in this beaker. The other should be left at room temperature (20-25°C) on your bench.

4. Wearing gloves, use a spatula to directly fill a test tube with ~8 g of solid lauric acid. (Record the precise mass of lauric acid in this step.) Place the test tube in the hot water bath (70–80°C) in the hood. **CAUTION:** Be careful not to spill the hot lauric acid on yourself and do not touch the bottom of the hot test tube.

![Figure 1](image)

5. After all the lauric acid has been liquefied wait an additional 2-3 minutes. Then bring the test tube from the fume hood to your lab station. Insert the temperature probe into the test tube, Press , and then lower the test tube into the room temperature water bath as shown in Figure 1.

6. With a very slight up and down motion of the temperature probe, *continuously* stir the lauric acid during the cooling. To prevent damage, hold the top of the probe and *not* its wire.

7. After 10 minutes, data collection will stop. **Important:** Do not attempt to pull the probe out of the solidified acid (even a little) - this might damage it. Use the hot water bath to re-melt the acid and gently remove the probe when the acid liquefies. Do not allow the tip of the temperature probe to rest on at the bottom of the test tube next to the hot plate. Carefully wipe any excess acid from the probe with a tissue. Clean up any drips or spills in the hood area.
8. To determine the (experimental) freezing temperature of pure lauric acid, you need to determine the mean (or average) temperature in the portion of the graph with nearly constant temperature. (On a cooling curve, pure compounds should have a flat phase change region while mixtures show a decreasing phase change region.) In the window, click on the beginning of the graph's flat part. Press on the screen and hold it down as you drag across the flat part of the curve, selecting only the points in the plateau. Click on the “Analyze” menu → Statistics, check the box next to temperature. The mean temperature value for the selected data is listed in the statistics box on the graph. Record this value as the freezing temperature ($T_1$) of lauric acid. Uncheck the box next to temperature to remove the statistics box from the graph. If the mean temperature is not close to the known melting point of pure lauric acid, consult your TA.

Part B: Freezing Temperature of a Solution of Unknown Organic Acid and Lauric Acid

9. Wearing gloves, add the unknown acid to the test tube (and lauric acid) from part A:
   - Weigh out ~1 g of the solid unknown acid onto weighing paper. Record the precise mass of the unknown acid. (Clean up any spills in the balance area.)
   - Add this unknown to the test tube from part A.
   - Place the test tube in a hot water bath in the hood.
   - When inserting the temp probe into the mixture stir the mixture while still in the hot bath.  
     (Important: If the acids are not mixed well, the unknown acid will form a layer at the bottom of the test tube and will not melt.) Once the mixture is melted, repeat steps 5-7 in Part A. Press , store the latest run.

10. To determine the freezing point of the unknown acid-lauric acid solution, you need to determine the temperature at which the mixture initially started to freeze. Unlike pure lauric acid, cooling a mixture of unknown acid and lauric acid results in a gradual linear decrease in temperature during the time period when freezing takes place. In the screen, locate the initial freezing temperature of the solution, see Figure 2. Record the freezing point in your notebook. Email the resulting file to our ELN.
11. If you do not have a “sharp” freezing point for Part B, use this procedure on Part B’s graph:

- Transfer the data file to laptop and open it in Logger Pro.
- Move the mouse pointer to the initial part of the cooling curve, where the temperature has an initial rapid decrease (before freezing occurred). Press the mouse button and hold it down as you drag across the linear region of this steep temperature decrease.
- Click on the Linear Fit button, .
- Now press the mouse button and drag over the next linear region of the curve (the gently sloping section of the curve where freezing took place). Press the mouse button and hold it down as you drag only this linear region of the curve.
- Click again. The graph should now have two regression lines displayed.
- Choose Interpolate from the Analyze menu. Move the mouse pointer left to the point where the two regression lines intersect. When the small circles on each cursor line overlap each other at the intersection, the temperatures shown in either examine box should be equal to the freezing temperature for the unknown organic acid-lauric acid mixture.

*Make sure to clear your email address and password on the LabQuest2 so others can’t access your email account. Shutdown the LabQuest2 and not simply put it to sleep. To shutdown the LabQuest2: press the home key, select System → Shut Down → OK.*

**CALCULATIONS**

(1) Determine $\Delta T (T_1 - T_2)$, where $T_1$ is the melting point of pure lauric acid and $T_2$ is the melting point of the unknown & lauric acid mixture.
(2) Calculate molality (m), in mol/kg, of the acid mixture.

(3) Calculate moles of unknown acid solute using the molality from above and the mass (in kg) of lauric acid solvent.

(4) Calculate the experimental molecular weight of the unknown organic acid. Use the mass of unknown acid used in the experiment and the moles of unknown acid from #3.