

MOLAR MASS OF A SOLUTE

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INTRODUCTION

Read and/or review Section 12.6 in your textbook.

The addition of a solute to a solvent forms a solution that freezes at a lower temperature than the temperature at which pure solvent freezes. This property is known as freezing-point depression. Thus, an aqueous solution begins to freeze at a lower temperature than pure water. The presence of one mole of a nonvolatile, nonionizable solute in a kilogram of water causes the freezing point of the solution to be 1.858°C lower than that of pure water. The amount the freezing point of a solution containing a nonionizable solute is lowered is given by the equation:

$$\Delta T_f = K_f \cdot m$$

where ΔT_f = freezing point of pure solvent - the freezing point of the solution, K_f is the freezing-point-depression constant of the solvent, and m is the molal concentration of the solution.

A freezing-point depression experiment is a simple and fairly accurate method for determining the molar mass of a solute once it is dissolved in a solvent. If the mass of both the solute and solvent in a solution are known, the molar mass of the solute can be determined by measuring the freezing points of the pure solvent and the solution.

In this experiment you will determine the molar mass of a liquid using freezing-point depression. A plot of temperature vs. time (called a cooling curve) will be used to determine freezing points.

The intersection of the two linear portions of the curve gives the freezing point.

PROCEDURE:

Prepare about 200 mL of a saturated common salt solution in a Styrofoam-jacketed beaker.

1. Put some ice in the beaker and sprinkle a spoonful of salt on top of the ice.
2. Add more layers of ice and salt to within an inch of the top.
3. Push the temperature probe into the salt solution.
4. When the reading is at least -12°C, remove the probe.
5. Gently insert a glass thermometer in the ice bath to monitor its temperature during the rest of the experiment.

Temperature vs. Time Measurements.

1. Obtain your unknown liquid assignment from your teaching assistant.
2. Determine the mass of 2.00 mL of your unknown liquid by adding 2.00 mL of the liquid from a preset pump dispenser to a small tared beaker and weighing. Discard the liquid according to your Teaching Assistant's instructions.
3. Plug the temperature probe into the Go!Link.
4. Plug the Go!Link into the USB port of the computer.
5. Start up Logger Pro on the computer by double clicking on the Logger Pro icon.
6. Choose: Experiment ; Data Collection. In the collection tab choose: Time Based. The Sample at Time Zero box should be checked and the Repeat box should not be checked. Enter 1500 s for Duration. You can always stop collecting data, but you can't add in more time once you have started. Enter 1 sample/s for Sampling Rate. Done.
7. Dispense 15.0 mL of deionized water from a pump dispenser into a dry 20 x 250 mm large test tube and insert it in the middle of the freezer surrounded by ice. Wipe the temperature probe clean and lower it into the water in the test tube. Immediately touch the data collection button (white triangle in green rectangle) on the upper portion of the computer screen. When the water freezes, make enough extra temperature readings so that the line can be analyzed. Touch the stop data collection button (white square in red rectangle) on the upper portion of the computer screen.
8. Right click on the graph (cooling curve). Choose: Graph Options; Graph Options tab. Enter a title for the graph. Be sure the title is specific enough so you will know which run of the experiment the printout goes with. If the axes are not labeled appropriately, right click on the graph. Choose: Column Options ; Data Set|X. Label and enter units for the x axes. Clear "Short Name". Done. Repeat for Data Set|Y.
9. Choose: Analyze ; Autoscale ; Autoscale.
10. Your cooling curve should have two linear portions. Drag the cursor over the first linear portion. Choose: Analyze; Linear Fit. A line should appear as well as a box containing the equation for the line. If necessary, the box can be dragged so that it does not cover up the graph. Repeat for the second linear portion.
11. Place the crosshair of the cursor at the point where the two lines intersect. The y value at this point is the freezing point. Record the freezing point in the table on the report sheet.
12. Each lab partner's report must have a Logger Pro generated printout of a single graph containing the plots and linear analysis for all three runs of the experiment.

Once you are ready to print out the graph, Click: File ; Print. Change the "orientation" to landscape under properties. Be sure that the names of all lab partners are entered in the "Name" section and that the date box is checked.

Freezing Point Measurements of a Solution of an Unknown Liquid

To begin collecting a new set of data choose: Data; Clear All Data. When you do this you will lose the data from the previous run.

Be sure the title for each graph is specific enough so that you know which part of the experiment the graph is associated with and, if necessary, label the axes appropriately.

Although the contents in the freezer will differ, the data collection and analysis procedures you use will be the same in all parts of the experiment. Don't forget to check that the time interval is set to 1500 s (Step 6). The program may remember this, but check to be sure. You do not want the data collection to stop too early.

NOTE: at higher concentrations of solute, the appearance of a thick slush marks the freezing point. It will not freeze hard, like ice. Be careful that you do not get any water or salt into the test tube when you are thawing your samples.

Trial 1. Let the system (large test tube containing 15.0 mL of deionized water) thaw in a beaker of warm water and return to room temperature. Add 2.00 mL of your unknown liquid from a preset pump dispenser. Recharge your freezer with solid salt or more ice if necessary and get the temperature down to below -12°C . Make the freezing point measurement following the general procedure that you used for pure water. Be sure to collect enough data points to be able to analyze the two linear portions of the curve. Print a copy of the cooling curve for both you and your lab partner. Each lab partner must have a copy of the graph attached to their lab report.

Trial 2. Let the system thaw. Check the freezer temperature (below -12°C). Add another 2.00 mL of your unknown liquid (total volume of unknown liquid is now 4.00 mL in 15.0 mL of water) and make the freezing point measurement. Be sure to collect enough data points to be able to analyze the two linear portions of the curve. Print a copy of the cooling curve for both you and your lab partner. Each lab partner must have a copy of the graph attached to their lab report.

Trial 3. Let the system thaw. Recharge the freezer and get the temperature down to below -15°C . Add another 2.00 mL of your unknown liquid (total volume of unknown liquid is now 6.00 mL in 15.0 mL of water) and make the freezing point measurement. Be sure to collect enough data points to be able to analyze the two linear portions of the curve. Print a copy of the cooling curve for both you and your lab partner. Each lab partner must have a copy of the graph attached to their lab report.

WASTE: Clean up your work area. Pour your salt water waste into the brine recovery bucket located in the fume hood for recovery of the salt. The unknowns/solutions should be disposed of in the appropriate waste bottle.

ADDITIONAL INFORMATION

None of the unknown liquids form ions in aqueous solution.

The *molal* freezing point depression constant, K_f , for water is $1.858^{\circ}\text{C}/m$.

DATA AND ANALYSIS SHEET: MOLAR MASS OF A SOLUTE

Name: _____

Date _____

Lab Partner _____

Attach the printouts for the cooling curves to your lab report. All names and the date must be on the printouts.

1. Unknown identification: _____

2. Mass of 2.00 mL of unknown liquid:

Mass of empty beaker: _____

Mass of beaker and 2.00 mL of unknown liquid: _____

Mass of 2.00 mL of unknown liquid: _____

3. Freezing points

	Water	Trial 1	Trial 2	Trial 3
Freezing point				

4. Determine the molar mass of your unknown liquid for each trial using the graphically determined freezing point. Determine the average molar mass.

	Trial 1	Trial 2	Trial 3
Mass of the unknown liquid			
Mass of water (assume: $d_{\text{water}} = 1.00 \text{ g/mL}$)			
Molal concentration, m , of the unknown liquid			
ΔT_f			
Molar mass of unknown liquid			
Average molar mass of unknown liquid			

Show your calculations: