

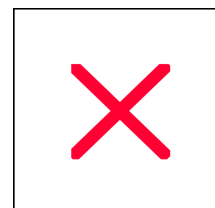
Activity C25: Molar Mass Determination by Freezing Point Depression (Temperature Sensor)

Concept	<i>DataStudio</i>	<i>ScienceWorkshop</i> (Mac)	<i>ScienceWorkshop</i> (Win)
Molar mass	C25 Molar Mass.DS	C25 Molar Mass	C25_MOLA.SWS

Equipment Needed	Qty	Equipment Needed	Qty
Temperature Sensor (CI-6505A)	1	Test tube, Pyrex, 25 x 150 mm	1
Balance (SE-8723)	1	Protective gear	PS
Base and Support Rod (ME-9355)	1	Chemicals and Consumables	Qty
Beaker, 250 mL (for water bath)	1	Para-dichlorobenzene (PDB)	15 g
Clamp, Buret (SE-9446)	1	"unknown"	2 g
Hot plate (for water bath)	1	Water	200 mL
Slit stopper	1	Weighing paper	3
Spatula	1		

What do you think?

The temperature of a mixture of pure water and pure ice is 0 °C. What happens to the temperature of the water/ice mixture if you add sodium chloride (table salt) to the mixture? Is the change in temperature determined by the amount of salt that you add? Are there any other substances that can have a similar effect on the freezing point of water? Will this change in the freezing point temperature happen for substances other than water?



Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background

Freezing point depression is an example of a *colligative* property. Colligative properties depend on the concentration of solute particles (total number of moles per liter) and not on their size or specific properties. A pure substance has a specific freezing point temperature. The freezing point of the substance is lowered when another substance is dissolved in the pure substance. The freezing point *depression* (i.e., drop in freezing point temperature) depends on the total number of solute particles. For example, because sodium chloride molecules dissociate into Na⁺ and Cl⁻ ions in solution, one mole of 'salt' becomes two moles of ions. The freezing point temperature drops twice as much as it would if the solute does not dissociate into ions. Using salt on icy roads during the winter in snowy areas is an example of freezing point depression.

Chemists use the following concept and equation. The freezing point depression, ΔT_f , of a solvent is given by:

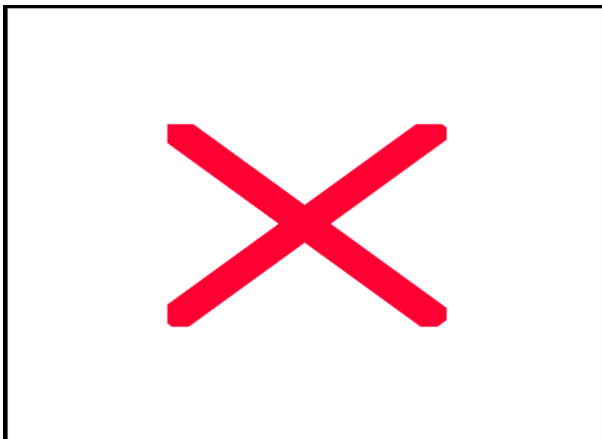
$$\Delta T_f = -K_f m$$

where K_f is the molal freezing point depression constant for the solvent and m is the molality of the total solute particles.

The *molality* is ratio of the number of moles per solute and the mass of the solvent. Therefore, you can determine the number of moles of the unknown solute from its molality, m , and the mass of the solute. Since the *molar mass* of the unknown is the ratio of the mass of the solute to the number of moles, you can determine the molar mass of an *unknown* compound by means of the freezing point depression of para-dichlorobenzene (PDB).

How to Determine the Freezing Point

As a pure substance cools in its liquid state, the temperature drops at a constant rate until it begins to solidify. While freezing, its temperature levels off at a temperature known as its freezing point. Occasionally the temperature drops a little below the actual freezing point before

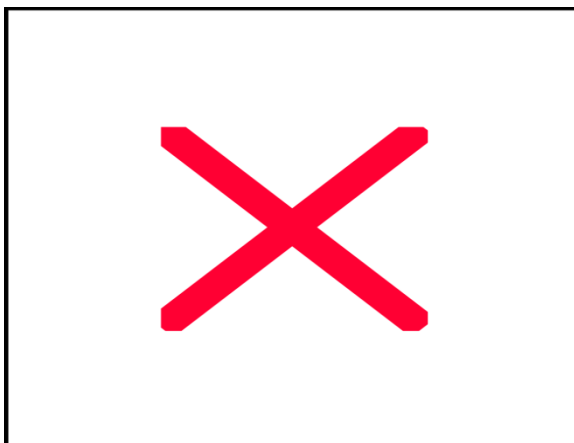


leveling off at the actual freezing point. This is known as super cooling. See the diagram below.

A solution may continue freezing over a broad temperature range. To get an good value for its freezing point draw a line through the original cooling curve of the liquid and a second through the area where it has tapered off slightly. The temperature at the point at which they intersect can be considered to be the freezing point. See the diagram below.

SAFETY REMINDERS

- Wear protective gear while handling chemicals.
- Follow directions for using the equipment.
- Make sure the room is well ventilated.
- Dispose of all chemicals and solutions properly.



For You To Do

In this activity, measure the freezing point temperature of a pure organic substance, para-dichlorobenzene (PDB). Then measure the freezing point temperature of a solution of PDB and a measured amount of an unknown compound. The para-dichlorobenzene acts as the solvent and the unknown compound is the solute.

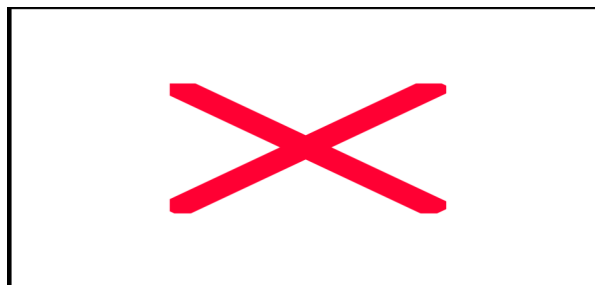
Use the Temperature Sensor to measure the change in temperature as melted PDB solidifies. Compare the freezing point temperature for pure PDB with the freezing point temperature of PDB mixed with an unknown substance. Use *DataStudio* or *ScienceWorkshop* to record, display, and analyze the data. Use the data to calculate the molar mass of the unknown compound.

Pre-Lab

Fill the 250 -mL beaker a little over half full with water. Begin to heat the water to 65 or 70 °C. As the water is heating, continue with the rest of the setup.

PART I: Computer Setup

1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the DIN plug of the Temperature Sensor to Analog Channel A on the interface.
3. Open the file titled as shown;



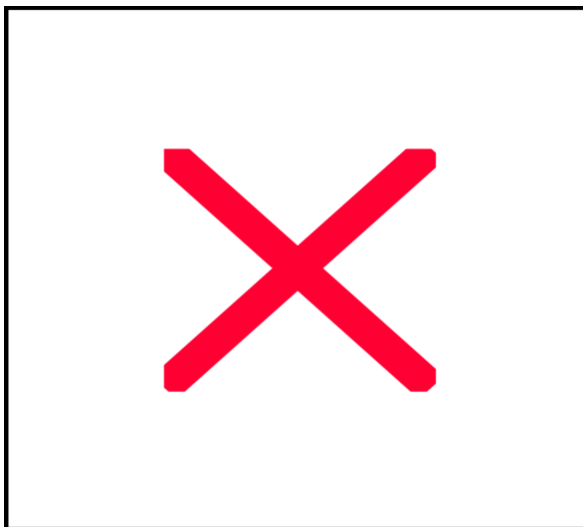
<i>DataStudio</i>	<i>ScienceWorkshop</i> (Mac)	<i>ScienceWorkshop</i> (Win)
C25 Molar Mass.DS	C25 Molar Mass	C25_MOLA.SWS

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook
 - The *ScienceWorkshop* document has a Digits display and a Table display of Temperature and a Graph display with a plot of the Temperature versus Time.
4. Data recording is set so there is one measurement per 15 seconds.

PART II: Sensor Calibration and Equipment Setup

You do not need to calibrate the Temperature Sensor.

1. Measure 15.00 gram of para-dichlorobenzene (p-dichlorobenzene or PDB). Record the exact mass to 0.01 g. Put the PDB into a clean dry 25 by 150-mm Pyrex test tube.
2. Use a base and support rod, clamp, and slit stopper to set up the test tube with the PDB as shown.



3. When the water bath is hot enough, turn off the heat source and lower the test tube and the Temperature Sensor into the hot water bath.
 - NOTE: Never heat p-dichlorobenzene over an open flame.
 - As the material melts, you can stir it gently with the Temperature Sensor.
4. Start to monitor the temperature of the PDB. Every fifteen seconds the Digits display will show the temperature.
5. When the melting is complete and the temperature is between 60 and 65 °C, stop monitoring the temperature (Hint: Click the STOP button.)

PART IIIA: Data Recording - Pure PDB

1. Raise the test tube. Immediately start recording data for determining the freezing point of the pure PDB.
2. Stir gently with the sensor throughout the entire run.
3. Continue recording data until all the material seems completely frozen.
4. Make a note of the apparent freezing point of the PDB.
5. When the PDB is solid, stop the data recording for Run #1.

PART IIIB: Data Recording - PDB and 1 gram Unknown

1. Again heat your hot water bath. Return the test tube with the PDB to the water bath. This time stop heating the test tube when the temperature is 10 degrees above the apparent freezing point of the pure PDB.
2. Carefully weigh out 1.00 g of unknown and pour it into the test tube with the PDB. Record the mass of unknown in your data table under Run #2.
3. Do Run #2 in the same manner as you did Run #1. The material may not get as hard this time.
4. Make a note of the apparent freezing point temperature of the PDB/unknown mixture.

PART IIIC: Data Recording - PDB and 1 gram Unknown

1. Again heat your hot water bath. Return the test tube with the mixture from Part IIIB to the water bath. This time stop heating the test tube when the temperature is 10 degrees above the apparent freezing point of the last mixture.
2. Carefully weigh out a second 1.00 g of unknown and pour it into the bottom of the test tube with the mixture. Record the combined mass of unknown in your data table under Run #3.
 - Note: This should be about 2.00 g.
3. Do Run #3 in the same manner as you did the last two runs. The material may appear like a solid slush at the end.
4. Clean up and dispose of your chemicals as directed.

Analyzing the Data

1. Click the Graph display to make it active. The Graph display will show all three runs of data.
2. Rescale the graph to fit the data.
 - NOTE: Drag-and-drop data runs from the Summary list to the Graph display in *DataStudio*. Select each run of data separately by clicking on the DATA menu button in the Graph display in *ScienceWorkshop*.
3. Use a printed copy of your Graph display to determine the freezing point for each run as discussed in the 'How to Determine the Freezing Point' section.
4. Use the Graph's data analysis tools to determine the freezing point depression, ΔT_f , for Run #2 (PDB plus 1 g of unknown) and Run #3 (PDB plus 2 g of unknown).
 - Hint: Use the Smart Tool in *DataStudio* or the Smart Cursor in *ScienceWorkshop*.

Calculations

1. Use the freezing point depression and the value of K_f for PDB to calculate the molality, m , of the solutions for Run #2 and Run #3.
2. Use the molality and the mass of the unknown to calculate the number of moles of unknown (“solute”) used in Run #2 and Run #3. (Remember that the molality of a solution equals the number of moles of solute per kilogram of solvent.)
3. Use the mass of the unknown and the number of moles of unknown (“solute”) to determine the experimental value for the molar mass of the unknown for Run #2 and Run #3.
4. Calculate the average experimental molar mass for the unknown.
5. If your teacher gives you the actual value for the molar mass, then determine your percent difference.

Formulas

Record your results in the Lab Report section.

Lab Report - Activity C25: Molar Mass Determination by Freezing Point Depression

What Do You Think?

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Data Table and Calculations

	Run #1	Run #2	Run #
	PDB	1 g of unknown	2 g of unknown
Mass PDB (solvent)	kg	kg	kg
Mass unknown (solute)	--	g	kg
Freezing point, T	°C	°C	°C
Freezing point depression, ΔT_f	--	°C	°C
Molality, m, of solute	--	mol/kg	mol/kg
Moles of unknown (solute)	--	mol	mol
Molar mass of unknown	--	kg/mol	kg/mol

Average molar mass	kg/mol
Actual molar mass of unknown	kg/mol
Percent difference	%

Question

1. What is the percent difference between your measured value and the accepted value for the molar mass of the unknown substance?

