



Procedure

Materials

Chemicals

- Solid sodium chloride, NaCl
- Deionized water in a wash bottle
- Unknown compound A
- Unknown compound B
- Crushed ice
- Saturated sodium chloride (NaCl) solution

Equipment

- Test tubes (4)
- 100 mL beakers (2)
- Disposable 1 mL plastic pipette (1)
- Styrofoam coffee cups (2)
- Ring stand

Instrumentation

- Digital device for collecting temperature versus time data
- Temperature probes compatible with digital data collector (2)

PART A Getting Ready

- 1 Prepare a waste container.
- 2 Label your four test tubes 1, 2, 3, and 4.
- 3 Label one of your 100 mL beakers DI Water, and obtain about 60 mL of deionized water in the beaker.
- 4 Use the following steps to prepare Test Tube 1 for analysis. This test tube will contain only the solvent, water.
 - a Place Test Tube 1 into your empty 100 mL beaker.
 - b Place the beaker and test tube on a balance, and zero the balance.
 - c While the beaker and test tube are still on the balance, use a plastic pipette to transfer deionized water from your beaker labeled DI Water until the mass reads ~ 4.000 g.
 - d Record the mass of water in Table 14.2 on the data sheet, page 457.
- 5 Prepare Test Tube 2 for analysis according to the steps below. NaCl will be used as the solute in this test tube.
 - a Measure ~ 0.234 g of NaCl and add it to Test Tube 2. Record the actual mass of NaCl in Table 14.2.
 - b Repeat steps 4a–d to add ~ 4.000 g of deionized water to Test Tube 2. Record this mass of water in Table 14.2.
 - c Mix the solution with a stir rod until the NaCl is completely dissolved.
 - d After mixing, rinse the stir rod off with deionized water into your waste container.
- 6 Repeat step 5 for Test Tubes 3 and 4. Unknown A will be the solute in Test Tube 3, and Unknown B will be the solute in Test Tube 4.
- 7 Attach the iron ring to your ring stand so the ring is a few inches from the countertop.
- 8 Label your temperature probes 1 and 2 (Fig. 14.7).
- 9 Insert the temperature probes into the appropriate ports on your digital data collector.

Note

In steps 4–6, try to measure a mass of water that is close to 4.000 grams, but it is okay if it is not exactly equal to 4.000 grams. Similarly, the mass of solute you add in steps 5–6 should be close to 0.234 grams, but does not have to be exactly equal to 0.234 grams.

- 10 Prepare a -6°C cooling bath using the following steps:
- Stack your two Styrofoam cups together. Fill the inner cup 1/3 full of crushed ice.
 - Add just enough saturated NaCl solution to the cup to make a slush, and stir with your glass rod.
 - Place the cooling bath into the iron ring. Adjust the height of the ring as needed so the Styrofoam cups are resting on the counter, but are protected from being accidentally knocked over (Fig. 14.8).
 - Place Temperature Probe 1 into the cooling bath. If the temperature is higher than -6°C , add a bit more ice, re-stir, and measure the temperature again.



Note

There should always be a significant amount of ice in your cooling bath. Make sure to add more ice as needed throughout the activity.

PART B Measuring the Freezing Point of Water

- 1 Initiate data acquisition on the digital data collector.
- 2 Place Temperature Probe 2 into Test Tube 1. Make sure the probe is below the water level.
- 3 Place Test Tube 1 into the cooling bath.
- 4 Mix the deionized water gently with the probe. The temperature should fall below the freezing point (supercooling) and then rapidly rise to the freezing point as ice starts to form.
- 5 Stop the data acquisition when you are satisfied that you have a reasonably stable freezing temperature. Save the data file.

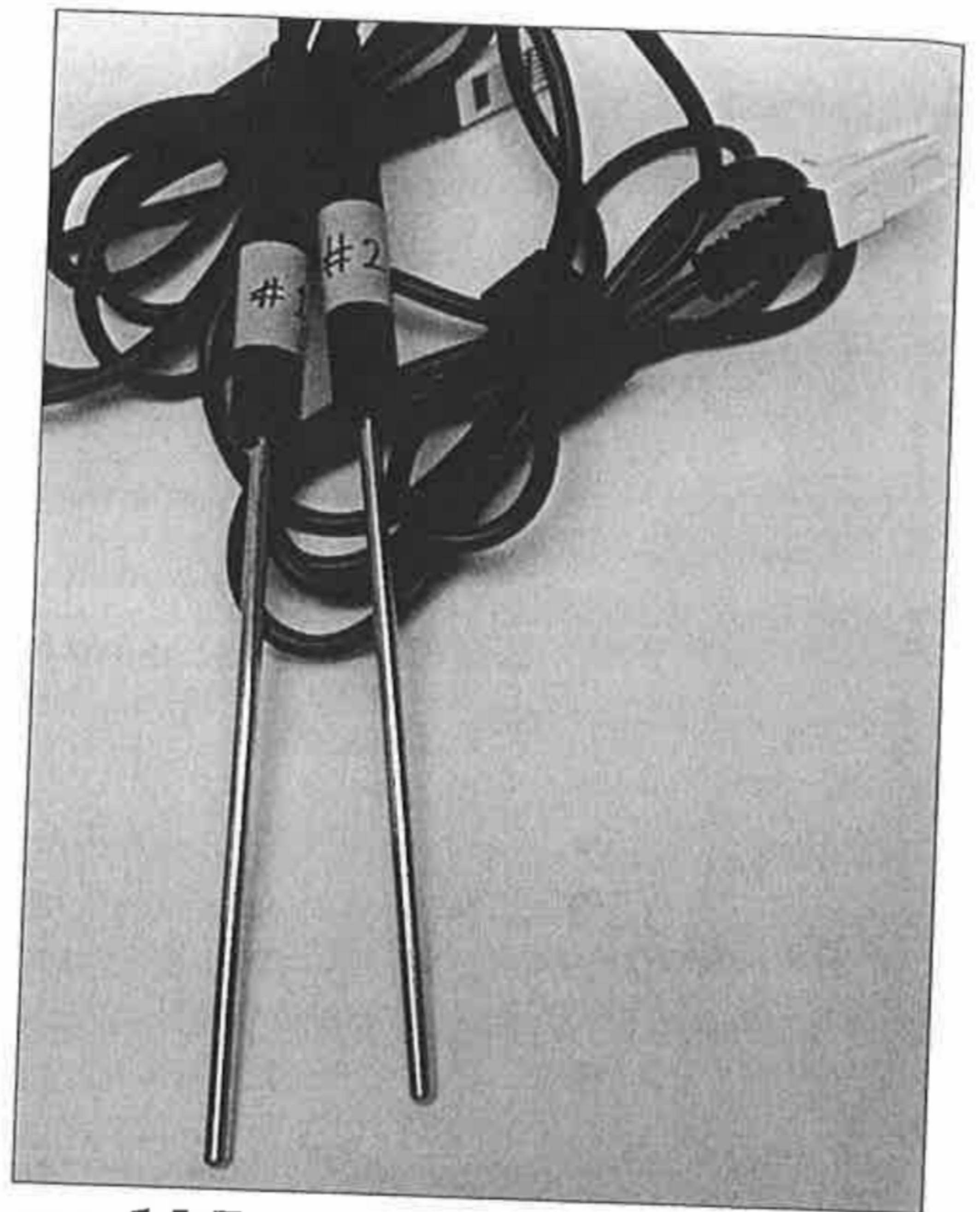


FIGURE 14.7 Label the temperature probes at the base so the label is visible during the experiment.

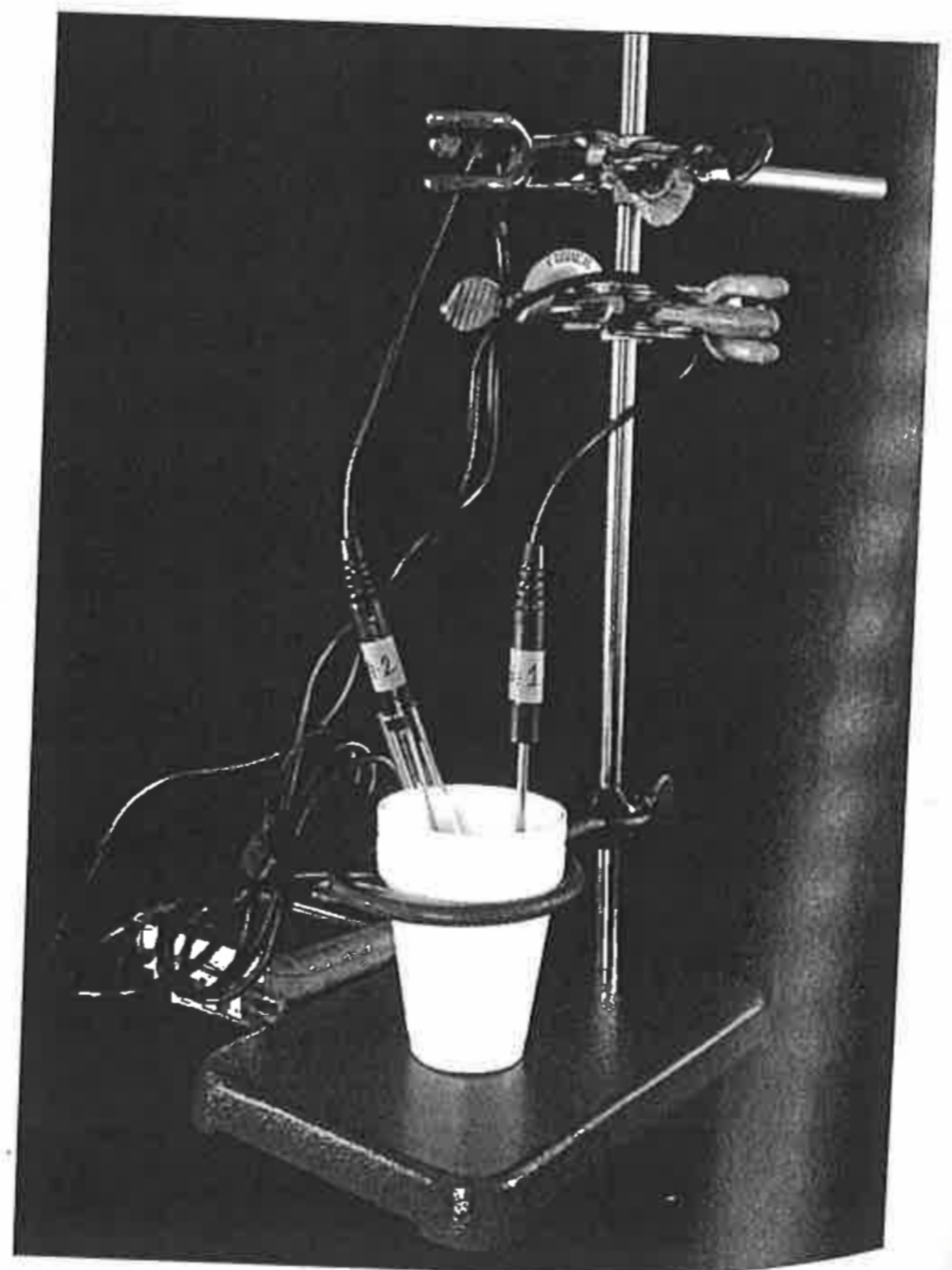


FIGURE 14.8 Finalized experimental apparatus.

Reflect: Since you were not instructed to calibrate the thermometer probes, the freezing point of water you measure may not be exactly 0°C . Do you think that using an uncalibrated thermometer in this lab will introduce error in your data analysis? Why or why not? (*Hint:* Consider Equation 2.)

- 7 Identify the freezing temperature of the water in the data collector display. Record the temperature in Table 14.2 on the data sheet, page 457.

PART C Measuring the Freezing Point of Aqueous Solutions

- 1 Begin with Test Tube 2. The cooling bath must be near or below -8°C to observe the freezing point of the NaCl solution, so check the temperature of your cooling bath before you proceed. Prepare a new cooling bath if necessary.
- 2 Initiate data acquisition on the digital data collector.
- 3 Place Temperature Probe 2 into Test Tube 2. Make sure the probe is below the solution level.
- 4 Place Test Tube 2 into the cooling bath.
- 5 Mix the solution gently with the probe. You will observe supercooling that may persist for several minutes, followed by a temperature rise as ice forms, and then a temperature drop as the solution gradually becomes more concentrated from the freezing process.
- 6 Continue recording data on the digital data collector until you have a long enough trace to clearly identify the first freezing point.
- 7 Stop data acquisition, and save the data file.
- 8 Use the cursor in the data collector display to identify the first freezing temperature. Record the temperature in Table 14.2 on the data sheet, page 457.
- 9 Rinse the temperature probe with deionized water into the waste container.
- 10 Repeat steps 1–9 for Test Tubes 3 and 4. A cooling bath around -6°C is sufficient for these compounds.

DATA SHEET 14.1

Name _____

Section _____

Date _____

Data Analysis and Calculations

PARTS B AND C Measuring the Freezing Points of Water and Aqueous Solutions

TABLE 14.2 Laboratory Data for Determining Freezing Point of Water and Three Different Solutions

Test Tube	Solute	Mass of Deionized Water (g)	Mass of Solute (g)	Freezing Point (°C)
1	None	4.0g		0°C
2	NaCl	4.0g	0.249g	-3°C
3	Unknown A	4.0g	0.234g	-1°C
4	Unknown B	4.0g	0.234g	-10°C

- 1** Use the following steps to determine the molar mass of the solutes in Test Tubes 2, 3, and 4. Record the results of your calculations in Table 14.3. Include sample calculations for Test Tube 2 and Test Tube 3.
- a** Calculate the freezing point depression for each solution relative to pure water using Equation 2. Record your results in Table 14.5 in addition to Table 14.3.

Sample Calculation for Test Tube 2:

Sample Calculation for Test Tube 3:

- b** Solve Equation 1 for molality. Show your work in the space provided.

- c** Determine the molality of each solution using your rearranged version of Equation 1.

Sample Calculation for Test Tube 2:

Sample Calculation for Test Tube 3:

- d** Calculate the molar mass of the solute in each solution. Record your results in Table 14.4 in addition to Table 14.3.

Sample Calculation for Test Tube 2:

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Sample Calculation for Test Tube 3:

DATA SHEET 14.1

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- e Identify Unknowns A and B as urea or glucose, and record your answers in Table 14.3.

TABLE 14.3 Laboratory Data for Determining Molality and Solute Molar Mass for Each Solution

Freezing Point Depression Constant for H₂O: _____

Test Tube	Solute	Freezing Point Depression (°C)	Solute Molality (m)	Solute Molar Mass (g/mol)
2	NaCl			
3	Unknown A			
4	Unknown B			

Based on my results, I conclude the following:
 Unknown A is _____
 Unknown B is _____

- 2 Determine the percent error of the solute molar masses you determined experimentally from the actual molar mass of each solute and record your results in Table 14.4. Show a sample calculation for your sodium chloride solution.

Sample Calculation:

TABLE 14.4 Comparison of the Actual Molar Mass to the Measured Molar Mass of Each Solute

Solute	Actual Molar Mass (g/mol)	Measured Molar Mass (g/mol)	Percent Error
Sodium Chloride			
Urea			
Glucose			

3 Use the following steps to determine the percent error of the freezing point depressions you determined experimentally from the expected freezing point depression for each solute, and record your results in Table 14.5. Show sample calculations for your sodium chloride solution.

- a** Use the actual molar mass of each solute to determine the expected molality of 0.234 g of each solute in 4.00×10^{-3} kg of water.

Sample Calculation:

- b** Determine the expected freezing point depression for a solution with this molality.

Sample Calculation:

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- c** Determine the percent error of the freezing point depressions you determined experimentally from the expected freezing point depression for each solute.

Sample Calculation:

DATA SHEET 14.1

(continued)

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TABLE 14.5 Comparison of Expected Freezing Point Depression to Measured Freezing Point Depression for Each Solute

Solute	Expected Molality of 0.234 g Solute in 4.00×10^{-3} kg Water (m)	Expected Freezing Point Depression (°C)	Measured Freezing Point Depression (°C)	Percent Error
Sodium Chloride				
Urea				
Glucose				

- 4 Use Excel to plot the freezing curves for each of the four runs. Label your axes appropriately (see Appendix A.5), and label the freezing point depression liquid phase, freezing phase, supercooling temperature, freezing point temperature, and solid phase (if present), as shown in Figures 14.4 and 14.5.

Post-Lab Questions

- 1 In this lab activity, you observed the phenomenon of supercooling. Why does a supercooled liquid *increase* in temperature as it starts to freeze? Why doesn't it just stay at the supercooled temperature as it freezes? (*Hint:* Think about the enthalpy of the phase change.)

2 Assume that when you were transferring the mass of sodium chloride you measured to Test Tube 2, a small amount remained on the weighing paper, so the actual mass of NaCl you added to the tube was a bit smaller than the mass you thought you transferred. Describe how this error would affect each of the following values.

a The freezing point depression that you measured.

b The molality that you calculated from your measurement of the freezing point depression.

c The molar mass of NaCl that you calculated from the molality that you determined.

d The actual molality of the solution.

e The expected freezing point depression.

3 Describe how a minor error at the beginning of an experiment can affect your final results.

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a Consider the procedure you performed in this lab activity. What is one other possible measurement error a student could make?

b Following the framework in question 2, describe how this error would propagate through the subsequent measurements and data analysis in the experiment.
