Chemistry CP

Name:

Lab: The Effect of a Solute on Freezing Point

Period:

Pure water freezes at 0^oC at standard atmospheric pressure. At this point, the vapor pressures of liquid water and solid water are the same. If there is a nonvolatile compound dissolved in the water, however, the solution will not freeze until the temperature is lower than 0^oC. Only at a lower temperature will the vapor pressure of the solid equal the lowered vapor pressure of the liquid. Freezing point lowering, like the boiling point elevation, is a colligative property, meaning that it is dependent only on the concentration of solute particles, not on their nature.

How far the freezing point of any solution is lowered depends on what the solvent is and the ratio of solute particles to solvent particles. Therefore, in studying freezing point depression, the concentration of the solution is always expressed as molality, m, which is the number of moles of solute per kilogram of solvent. Molality is not affected by temperature, which makes it useful in these kinds of experiments.

$$m = \frac{moles\ of\ solute}{kg\ of\ solvent}$$

Colligative properties are affected by the total number of solute particles in solution. Nonelectrolytes, or covalently bonded substances, do not dissociate in solution and therefore the molality is unaffected.
In this experiment, you will observe the effect of a non-electrolyte solute on the freezing point of water.

Objectives

- Determine the freezing point of a pure solvent
- Observe the freezing point depression of a solution
- Determine the effect of solute concentration on the freezing point of a solvent.

Materials

LabQuest interface	Distilled water
Coarse grained salt	Foam cup
Temperature Probe	Sucrose, $C_{12}H_{22}O_{11}$
ring stand	Ice
400 mL beaker	18 × 150 mm test tubes
Paper towels	Utility clamp
Tap water	Balance, sensitive

Roles

Project Manager ______________________________

Materials Manager ______________________________

Safety Manager ______________________________

SAFETY ALERT

Wear chemical splash goggles.

PROCEDURE

1. Connect a Temperature Probe to Channel 1 of the LabQuest. Connect the LabQuest to a computer, if desired.
2. Set up the data collection in a timed run for 10 seconds per sample and 60 samples.

Part I Determine the Freezing Temperature of Pure Distilled Water

1. Prepare an ice bath in a foam cup with ice, table salt and a small amount of tap water. Place the cup in a beaker to give it more stability. The ice bath should be deep enough so that it is above the level of the distilled water in the test tube but well below the top.
2. Transfer about 10 mL of distilled water into a test tube. (You do not need to record the precise volume). Place the test tube in the ice-water bath. Take care not to let any of the salt or ice from the ice bath get into the sample of distilled water.
3. Insert the Temperature Probe into the distilled water in the test tube. Fasten the utility clamp to the ring stand so the test tube is in the ice bath, as shown in figure 1.
4. Select START to begin data collection.
5. Data collection can be stopped when there is a clear plateau, and then a further decrease in temperature.
6. When data collection is complete, use a warm water bath to melt the ice enough to safely remove the temperature probe. Carefully wipe any excess liquid from the probe with a paper towel or tissue.
7. The freezing temperature can be determined by finding the mean temperature in the portion of the graph with nearly constant temperature. Select the region of the graph with nearly constant temperature and find the mean temperature. Record this value.
8. Store the data from this run.

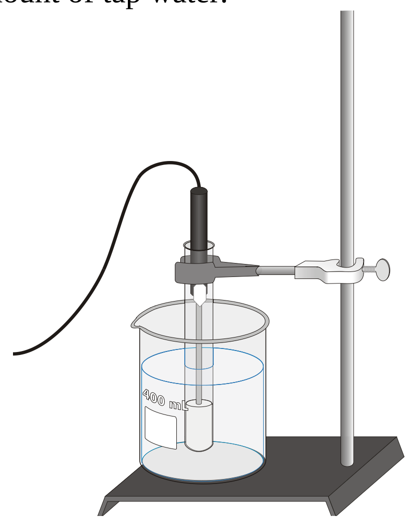
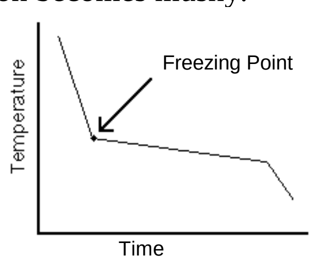


Figure 1

Part II Determine the freezing point of a solution of distilled water and sucrose

9. Mass a clean, dry test tube on a sensitive balance and record this value in your data table.
10. Add about 10 mL of distilled water to the test tube and precisely find the mass of the test tube with the water. Record this value in your data table.
11. Transfer about 1 gram of sugar into the test tube. Find the mass of the test tube with the water and the sugar. Record this value in your data table.
12. Place the test tube in the ice bath—you can reuse the ice bath if you pour out some of the water and add additional ice and salt. Repeat steps 3-6 to record the temperature vs. time data as the mixture freezes. Stop the run when the solution is practically all solidified. Supercooling is common, but the freezing point can be recognized by the relatively constant temperature as the solution becomes mushy.

Figure 2



13. The freezing point of the distilled water- sugar solution can be determined by finding the temperature at which the mixture initially started to freeze. Unlike pure distilled water, the mixture results in a gradual linear decrease in temperature during freezing. If supercooling occurred, the freezing point can be found from extrapolating the gradual linear decrease during freezing back to where it crosses the line showing the initial temperature decrease before freezing (as shown in Figure 2).
14. When data collection is complete, use a warm water bath to melt the substances enough to safely remove the Temperature Probe. Discard all solutions in the sink.
15. Optional: Print a graph showing both runs. (Hint: Load the LoggerPro software on your computer. Then, save your data from the Labquest onto a USB drive so you can do your data analysis later.)

Sources:

Randall, Jack. *Advanced Chemistry with Vernier*, 2004 (Vernier Software and Technology).
Vonderbrink, Sally Ann. *Laboratory Experiments for Advanced Placement Chemistry*, 2001 (Flinn Scientific, Inc.)

DATA TABLE

Freezing temperature of pure water (°C) (Part I)	
Mass of test tube, water and sugar (g)	
Mass of test tube and water (g)	
Mass of empty test tube (g)	
Mass of distilled water (g)	
Mass of sugar (g)	
Freezing point of the sugar-distilled water mixture (°C)	
Freezing point depression for mixture (Δt)	

Calculations: (Show all your work!)

1. Convert total grams of sucrose, $C_{12}H_{22}O_{11}$, to the number of moles of sucrose.

2. Calculate the mass of water you started Part II with, in grams, and convert to kilograms.

3. Divide the moles of sucrose by the kilograms of water. (This is the molality of the sucrose solution)

4. Use the equation $\Delta t = k_{fp} \frac{moles\ sucrose}{kg\ water}$ to find the experimental k_{fp}, the freezing point depression constant for water. Include units with your answer.

5. Calculate the percent error of your freezing point depression constant. The accepted value for the freezing point of water is 1.86°C•kg/mol.

Analyze and Apply Questions

1. The following errors occurred when the above experiment was carried out. How would each affect the observed freezing point depression? (too large, too small, no effect)? Explain your answers.
   a. The thermometer used actually read 1.4^{o}C too high throughout the experiment.

   b. Some of the solvent spilled before the solute was added.

   c. Some of the solute was spilled after it was weighted and before it was added to the solvent.

   d. Some of the solution was spilled after the solute and solvent were mixed but before the freezing point was determined.