

■ Experiment

12

Freezing Point Depression



Objectives

- To determine the freezing point depression constant of water.
- To observe the relationship between sugar concentration and freezing point.
- To compare the freezing points of sugar and salt solutions of the *same concentration*.

In the Lab

- Students will work in pairs.
- Bring a paper copy of your rough draft to lab for the report review. The *final* version will be submitted electronically. Paper copies of the final report will **not** be accepted.
- Students will write a full lab report for this experiment.

Waste

- All solutions may be poured in the drain.
- Excess solids may be disposed of in the trash can.

Safety

- Wear goggles at all times.
- Do not handle dry ice with your bare hands.

Colligative properties are those that depend on the number of dissolved particles present in a solution, rather than the identity of the particles. These include boiling point and freezing point. As the concentration of particles in a solution increases, the boiling point increases and the freezing point decreases. In other words, the more particles, the bigger the change from the normal freezing and boiling points of the pure solvent. The relationship for the freezing point is shown in the equation

$$\Delta T = iK_f m$$

where ΔT is the change in temperature from the original freezing point, i is the van't Hoff factor, K_f is the freezing point depression constant for the solvent, and m is the *molality* of the solution. Molality is defined as the moles of solute per kilogram of solvent. Remember that we use *molality* instead of *molarity* because the mass of the solvent will not change with temperature.

In this experiment, you will design a procedure to determine the freezing point depression constant of water by measuring the freezing points of multiple sugar solutions. To explore the effects of the van't Hoff factor, you will also need to prepare a sodium chloride solution for comparison.

Safe Handling of Dry Ice

The temperature of dry ice is -78.5°C (-109°F), so it must be handled with care. Exposure to the skin can result in both skin injuries (feels similar to a burn) and frostbite (begins as pain or blisters but long-term contact can result in freezing of muscles, tendons, vessels, and nerves, which can lead to permanent loss of use of that area of the body). Use tongs, insulated gloves, or scoop to transfer dry ice from one container to another.

Since dry ice sublimates at room temperature, CO_2 gas is being given off. Do not intentionally breathe the CO_2 gas. If you start to have difficulty breathing, leave the area immediately. To minimize the amount of CO_2 gas evolved, take only what you need.

- Do *not* touch dry ice with bare hands.
- Do *not* eat dry ice. If ingested, seek medical attention immediately.

- Do *not* place dry ice in air-tight containers, as CO_2 gas is constantly evolving from the solid, which can result in high pressures inside an air-tight container.
- Use dry ice in a ventilated area.

Dry Ice Bath

This experiment uses a dry ice-saturated NaCl solution to create a bath with a temperature of approximately -20°C . You should prepare *all of your experimental sugar and salt solutions* first, *before* preparing the ice bath.

1. Prepare a saturated NaCl solution by mixing 50–60 g NaCl in 200 mL of water. The exact mass and volume are not important for this solution.
2. In a 400 mL beaker, obtain approximately 150 mL of dry ice pellets. Use a scoop or tongs to handle the dry ice.
3. Slowly pour the NaCl over the dry ice, stirring until the temperature is fairly constant (-18 to 25°C).
4. Remove the temperature probe from the ice bath and rinse it thoroughly.

Freezing Point Depression Data

The freezing point of water shows the initial cooling of the water, the freezing of the water, and then the further cooling of the ice (see Figure 12.1). Remember that a pure substance cannot change temperature and phase at the same time, which explains the flat region in the middle of the graph. To determine the freezing point, you can draw lines to extrapolate both the initial drop and the flat region. The point at which these two intersect is the freezing point. To draw lines in Chem21, click on the graph and hold the mouse button down to draw the line, and release the button to end the line. You can draw multiple lines on the graph. To redraw the lines, resize your browser window to erase the current lines.

Figure 12.2 shows the freezing point depression curve of a sugar solution. As you can see, the data follows the same trends, but there are also distinct differences for a solution vs. a pure substance. One can still extrapolate lines from the two linear regions to determine the freezing point of the solution. Place the mouse button on the intersection of the two lines, and look at the coordinates

in the upper left corner of the graph (see the red box in Figure 12.2). The coordinates shown on the graph are for the nearest point on the line, which may or may not be where the two lines intersect. Use the coordinates from the upper left corner to determine the freezing point of the solution.

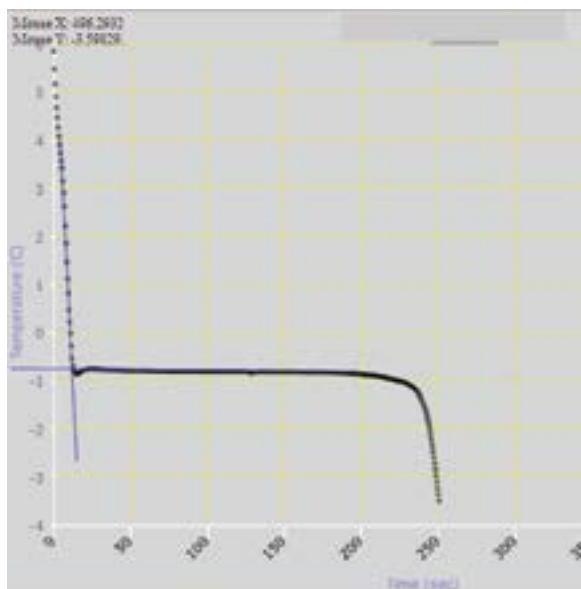


Figure 12.1. Freezing point depression curve of water.

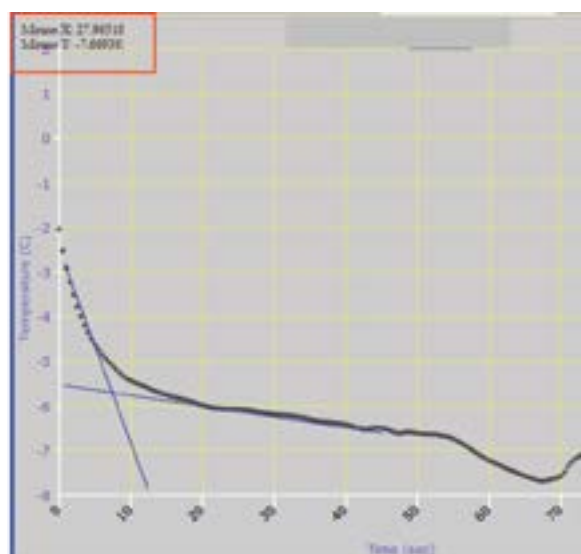


Figure 12.2. Freezing point depression curve of sugar solution.

Tips for Procedure

- Calibrate the temperature probe before beginning your trials in an ice bath.
- The freezing point of water can vary depending on the conditions of the room and the purity of the water. You should determine the freezing point of water first.
- Remember that ΔT is the change in temperature from the pure solvent to the solution.
- Measure the freezing point of at least four sugar solutions of varying concentrations. Your maximum concentration should be less than 2 g per 5 mL of water.
- Prepare approximately 25 mL of each solution. Use approximately 5 mL of solution for each trial.
- Record the exact masses of the solute and the solvent for each solution.
- The concentration of the salt solution should equal the **molality** of one of the sugar solutions.
- Complete your sugar solution measurement in order of increasing molality.
- Rinse and dry the temperature probe between each trial.
- Always use tongs or scoop to transfer dry ice.
- You may need to remake the dry ice bath during your experiment.

Procedure

You must write the procedure and prepare your lab notebook *before* coming to lab to do the experiment. Make sure that you will collect the data necessary to complete the data analysis questions. It's better to have too much information and not need it, than to need something and not have it.

Details about collecting data with MeasureNet are in Chapter 4.

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Suggested Materials

salt (NaCl)

sucrose (table sugar, $C_{12}H_{22}O_{11}$)

250 mL Erlenmeyer flask

MeasureNet

temperature probe

other glassware and equipment, as needed

6" test tubes

wash bottle

lint-free tissues

Data Analysis

1. Determine the concentration of each sugar solution in g/mL and molality.
2. Determine the individual and average values of the freezing point depression constant, K_f , based on the data calculated for each solution.
3. Use the graph to determine the value of the freezing point depression constant, K_f . Hint: Look at the units for K_f and the units of the values being graphed.
4. Determine the percent error for both experimental values of K_f compared to the accepted value for K_f . You will need to look up and reference your source for the accepted value of K_f .
5. Determine the concentration of your salt solution in g/mL and molality.
6. Using the K_f value from the graph, determine the theoretical freezing point of your salt solution.
7. Compare the change in freezing point for the NaCl and sugar solutions of the same concentration. Explain the similarity or difference between the two values.

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