Colligative Properties – ID: 16153

By Texas Instruments

TEACHER GUIDE

Time required
45 minutes

Topic: Solutions

- *Experimentally determine the relationship between molality and freezing point.*
- *Experimentally determine the freezing-point depression constant for water.*
- *Calculate variations in freezing point due to dissolved substances.*

Activity Overview

In this activity, students explore colligative properties. They begin by collecting data on the freezing point of a solution as the concentration increases. They use these data to experimentally determine the freezing-point depression constant for water. Then, they solve several problems relating to freezing point depression.

Materials

To complete this activity, each student will require the following:

- *TI-Nspire™ technology*
- *Vernier EasyTemp™ temperature probe*
- *250 mL beaker*
- *10 mL graduated cylinder*
- *ice*
- *distilled water*
- *aqueous sucrose solutions (0.10* m*, 0.20* m*, 0.30* m*, 0.40* m*, and 0.50* m*)*
- *test tube*
- *rock salt*
- *copy of student worksheet*
- *pen or pencil*

TI-Nspire Applications

Data & Statistics, Lists & Spreadsheet, Notes, Calculator

Teacher Preparation

Students should be familiar with the concepts of molality and freezing point before conducting this activity.

- *Prepare the sucrose solutions prior to class. Alternatively, purchase pre-mixed sucrose solutions. Solution concentrations other than those listed can be used.*
- *The screenshots on pages 2–6 demonstrate expected student results.*
- ***To download the .tns file, go to education.ti.com/exchange and enter "16153" in the search box.***

Classroom Management

- *This activity is designed to be **student-centered**, with the teacher acting as a facilitator while students work cooperatively. The student worksheet guides students through the main steps of the activity and includes questions to guide their exploration. Students may record their answers to the questions on blank paper or answer in the .tns file using the Notes application.*
- *The ideas contained in the following pages are intended to provide a framework as to how the activity will progress. Suggestions are also provided to help ensure that the objectives for this activity are met.*
- *In some cases, these instructions are specific to those students using TI-Nspire handheld devices, but the activity can easily be done using TI-Nspire computer software.*

The following questions will guide student exploration during this activity:

- How does the concentration of a solute affect the freezing point of a solution?
- How do solutes affect colligative properties?

In this activity, students first observe the freezing points of various aqueous sucrose solutions. They observe that the freezing point decreases as solute concentration increases. They use linear regression to estimate the freezing-point depression constant for water. Then, they use the accepted theoretical freezing-point depression constant to calculate the freezing points of various solutions.

Problem 1 – Data Collection and Analysis

Step 1: First, students make a salt-ice-water mixture in the 250 mL beaker. If you wish, you may give students stirring rods to mix the ice, salt, and water with.

Step 2: Next, students add 2 mL of water to the test tube. This is the solution whose freezing point they will test.

Step 3: Next, students should place the tip of the EasyTemp™ probe in the water in the test tube.

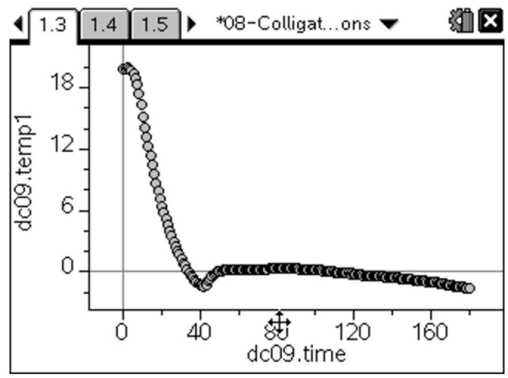
Step 4: Next, students should open the file **08-Colligative_Properties.tns**, read the first two pages, and then connect the temperature probe to their handhelds or computers. A data collection display should appear.

Step 5: Students should begin the temperature sampling and then place the test tube into the beaker of ice water. Ensure that students place the test tube in the beaker such that the water in the test tube is completely surrounded by ice water, but the top of the test tube is still above the top of the ice. It is important that no ice or ice water fall into the water in the test tube.

Step 6: Next, students swirl the test tube in the ice water. For the most accurate results, students should keep the tip of the temperature probe in the center of the water in the test tube.

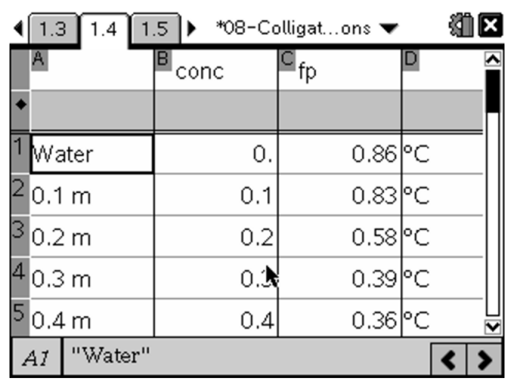
Step 7: Once the water is completely frozen, students should stop the data collection and remove the probe from the test tube. They should empty the test tube and rinse the probe and tube with distilled water.

Step 8: Next, students should examine the temperature data on page 1.3. The data should show a rapid decrease, followed by a relatively level region. If students left the test tube in the beaker after the water was completely frozen, there may also be a region in which the temperature again begins to decrease. The area in which the temperature is level is the freezing point of the water.



TI-Nspire Navigator Opportunity: *Screen Capture*
Screen Capture can be used here to ensure that students have obtained a reasonable data set. Observe student plots and compare them with the desired graph shown above. If students' data sets do not have a clear horizontal region, they should repeat the data collection with a new test tube of water.

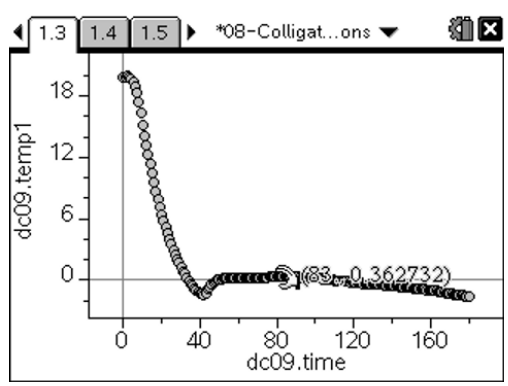
Step 9: Students should click on one of the points in the horizontal region of the graph to estimate the freezing point. The freezing point is the *y*-coordinate of the points in the horizontal region. Students should record the freezing temperature in the *Lists & Spreadsheet* application on page 1.4.



	A	B conc	C fp	D
◆				
1	Water	0.	0.86	°C
2	0.1 m	0.1	0.83	°C
3	0.2 m	0.2	0.58	°C
4	0.3 m	0.3	0.39	°C
5	0.4 m	0.4	0.36	°C

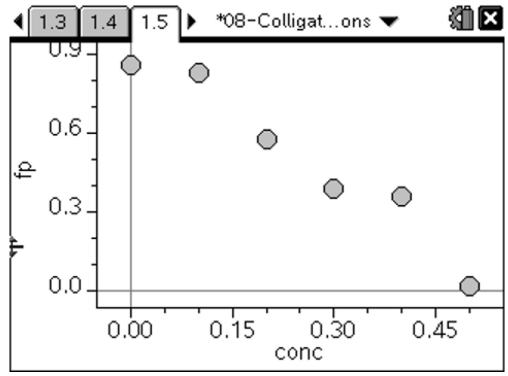
A1 "Water"

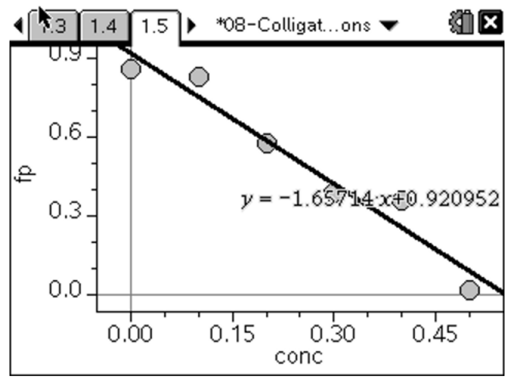
Step 10: Students should repeat the data collection for the five sucrose solutions.



Step 11: After students have recorded the freezing point of each solution, they should graph **fp** vs. **conc** in the *Data & Statistics* application on page 1.5. They should use the **Linear Regression** tool to determine the best-fit line for the data.

Step 12: Next, students should answer questions 1–6.





Q1. What is the best-fit equation for the data?

A. *Students' answers will vary.*

Q2. What do *x* and *y* represent?

A. x *is concentration, and* y *is freezing point*

Q3. What is the slope? What does the slope represent?

A. *The slope of the equation is the freezing-point depression constant for water. Students' exact slopes will vary; the theoretical value is –1.86 °C/*m*.*

Q4. The units for the slope are

A. $\frac{^{o}C}{m}$

Q5. Use your best-fit equation to calculate the freezing point of a 0.25 *m* sucrose solution.

A. *Students' answers will depend on the exact equations they determine. The theoretical freezing point is –0.465 °C.*

Q6. Use your best-fit equation to calculate the molality of a sucrose solution with a freezing point of –2.50 °C.

A. *Students' answers will depend on the exact equations they determine. The theoretical molality is 1.34* m*.*

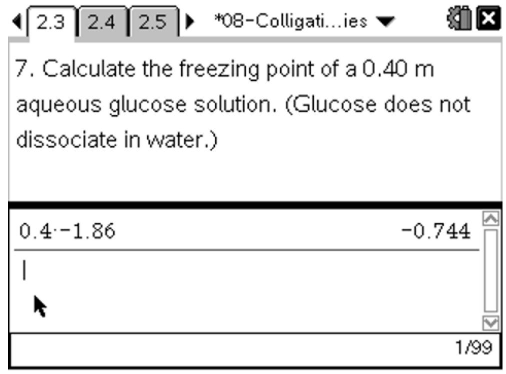
Problem 2 – Problem Solving

Step 1: Next, students should move to page 2.1 and read the text there. They should also read the text in Step 1 of the student worksheet.

Step 2: Next, students should review the problem on page 2.2 and then answer questions 7–10.

Q7. Calculate the freezing point of a 0.40 *m* aqueous glucose solution. (Glucose does not dissociate in water.)

A. *Using the theoretical freezing-point depression constant of –1.86 °C/*m*, the total freezing point depression is (–1.86 °C/*m*)(0.40* m*) = –0.74 °C. Therefore, the freezing point of this solution should be –0.74 °C.*

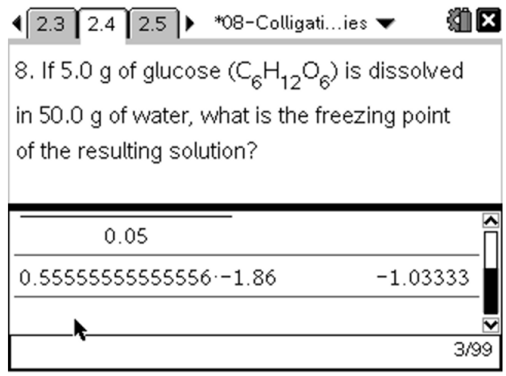


Q8. If 5.0 g of glucose ($C_6H_{12}O_6$) is dissolved in 50.0 g of water, what is the freezing point of the resulting solution?

A. *The molecular weight of glucose is 180 g/mol. Therefore, 5.0 g of glucose is 0.028 mol glucose. The molalty of the solution is*

$$\frac{0.028\ mol}{0.0500\ kg} = 0.556\ \text{m}.$$

*Therefore, the freezing point depression is (–1.86 °C/*m*)(0.556* m*) = –1.03 °C, and the freezing point is –1.03 °C.*

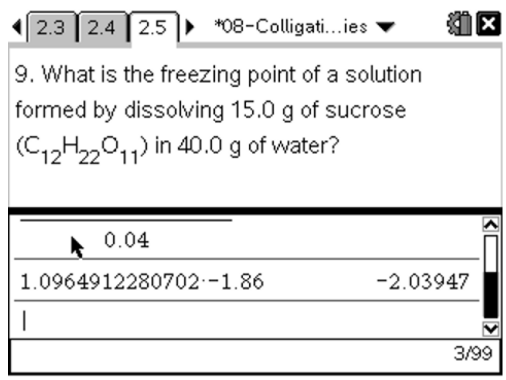


Q9. What is the freezing point of a solution formed by dissolving 15.0 g of sucrose ($C_{12}H_{22}O_{11}$) in 40.0 g of water?

A. *The molecular weight of sucrose is 342 g/mol. Therefore, 15.0 g of sucrose is 0.044 mol sucrose. The molalty of the solution is*

$$\frac{0.044\ mol}{0.040\ kg} = 1.10\ \text{m}.$$

*Therefore, the freezing point depression is (–1.86 °C/*m*)(1.10* m*) = –2.04 °C, and the freezing point is –2.04 °C.*



Q10. How many moles of glucose must be dissolved in 50.0 g of water to decrease the freezing point of the water to –0.50 °C?

A. *First, calculate the molality of the solution:*

$$\frac{-0.50\ °C}{-1.86\ °C\ /\ \text{m}} = 0.27\ \text{m}.$$

A 0.27 m *solution contains (0.27)(0.0500) = 0.013 mol glucose per 50.0 g water.*