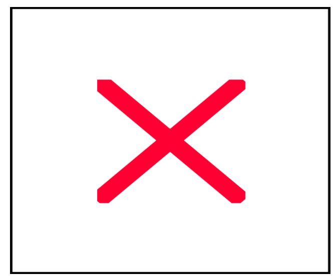
Name ____________________ Class _____________ Date _________

Activity C26: Molal Freezing Point Depression Constant, K_f (Temperature Sensor)

Concept	*DataStudio*	*ScienceWorkshop (Mac)*	*ScienceWorkshop* (Win)
Freezing point	C26 Freeze Point.DS	C26 Depression Constant	C26_DEPR.SWS

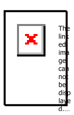
Equipment Needed	**Qty**	**Chemicals and Consumables**	**Qty**
Temperature Sensor (CI-6505A)	1	Ice, crushed (from deionized water)	150 g
Balance (SE-8723)	1	Lid (for Styrofoam cup)	1
Beaker, 500 mL	1	Rubber band	1
Calorimeter *	1	Sodium chloride, NaCl, solid	100 g
Graduated cylinder, 100 mL	1	Styrofoam cup	2
Stir rod	1	Water	100 mL
Test tube	1	Water, deionized	50 mL
Protective gear	PS	Weighing paper	1

(*The calorimeter is made from two small Styrofoam cups nested one inside the other. Please see the diagram.)



What do you think?

Freezing a milk/cream mixture makes ice cream. The freezing usually takes place in an ice cream maker that has an inner and outer lining. The milk/cream mixture is placed into the inner container and ice, water and salt are placed in the outer container. The ice used in the outer container is initially at zero degrees Celsius. Water and salt are then added to this ice and the resulting mixture is used to "freeze" the milk/cream into ice cream. Milk and cream require a temperature colder than zero degrees Celsius to be turned into ice cream. Just how does this "freezing" temperature come about?



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

Background

Pure substances have characteristic boiling point temperatures and freezing point temperatures if the atmospheric pressure is constant. If a pure substance is contaminated with another, the boiling and freezing point temperatures are changed.

Changes in the physical properties of a substance are referred to as *colligative* properties. Each substance changes to a different degree. For every mole of contaminating substance, the dissolving substance's melting point will be depressed by a specific amount. This amount is known as the Molal Freezing Point Depression Constant or K_f. The presence of a non-volatile solute in a solution lowers the freezing point of a substance. A non-volatile substance is one, which is not boiled away when a solution is heated.

For example, when sodium chloride is dissolved in ice water, the molecule of the salt dissolves to form two ions for every molecule of salt.

$$\mathbf{NaCl_{(s)} \text{ ======> } Na^{+}{}_{(aq)} + Cl^{-}{}_{(aq)}}$$

The effect on the freezing point of water with sodium chloride is double what it would be if the molecule stayed together and acted as a single unit. The number of particles influences the freezing point of a solid, not just the mass of material, dissolved.

SAFETY REMINDERS

- Wear protective gear while handling chemicals.
- Follow directions for using the equipment.
- Dispose of all chemicals and solutions properly.

For You To Do

This activity has two parts:

Part A - Observation

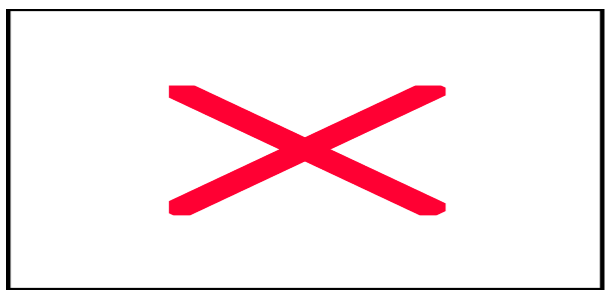
Place a test tube of water into a beaker containing ice, water and salt. Stir the ice/water/salt mixture and observe what happens to the ice in the test tube. Use a Temperature Sensor and either *DataStudio* or *ScienceWorkshop* to record the temperature of the water in the test tube.

Part B – Measurement

Use a Temperature Sensor to measure the change in the freezing point of a common substance, water, and to use these measurements to determine the value of the Molal Freezing Point Depression Constant K_f.

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;

DataStudio	*ScienceWorkshop (Mac)*	*ScienceWorkshop* (Win)
C26 Freeze Point.DS	C26 Depression Constant	C26_DEPR.SWS

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook
- The *ScienceWorkshop* document has a Graph display of the Temperature versus Time.
- Data recording is set so there is one measurement per second.

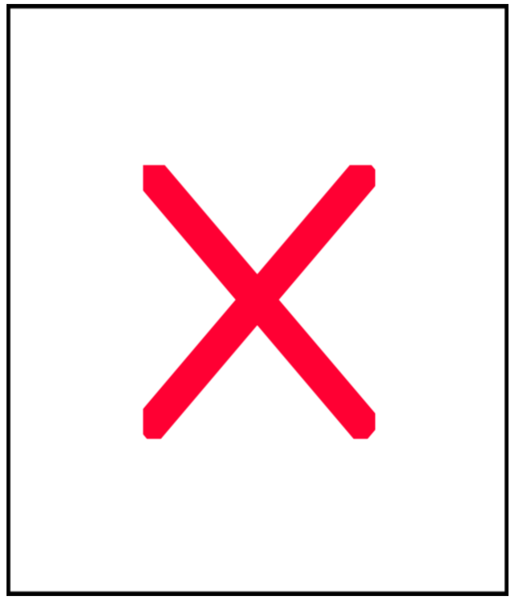
PART II: Sensor Calibration

This is an activity where it is good to calibrate the Temperature Sensor, since an actual freezing point is being measured and not just a change in temperature. The calibration procedure is simple. (Refer to the Temperature Sensor instruction sheet or the *DataStudio* On-Line Help file or the *ScienceWorkshop* User’s Guide.)

Name ____________________ Class _____________ Date _________

PART IIA: Equipment Setup - Observation

- Put about 100 grams of ice, 50 mL of water, and a couple of teaspoons of table salt into a



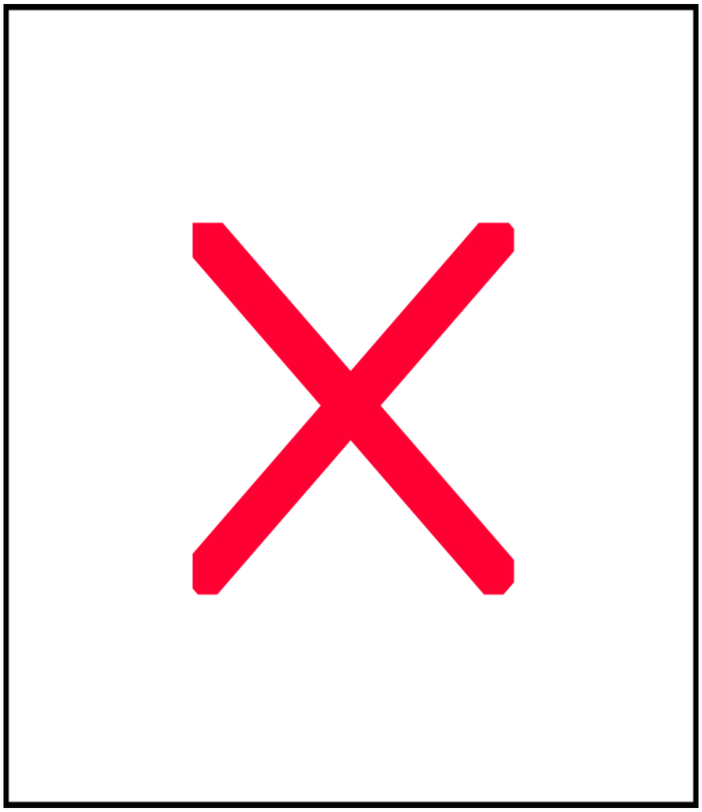
  beaker. Stir the mixture to dissolve the ice.
- Put water into a test tube. Place a Temperature Sensor into the water.
- Place the test tube into the ice/water/salt mixture in the beaker.
- Start recording the temperature of the water in the test tube.
- Continue to measure the temperature of the water in the test tube until it stops decreasing.
- Observe the contents of the test tube throughout the activity.

Questions About The Observation (Optional)

- Does a phase change occur for the water in the test tube?
- Can you determine the freezing point of water in this activity?
- Can ice be colder than zero degrees Celsius?

PART IIB: Equipment Setup - Measurement

1. Weigh one Styrofoam cup and record the weight of the cup.
2. Make a calorimeter by placing a rubber band about the middle of the Styrofoam cup. Nest this cup inside another cup of the same dimension.
3. Use a 1/4" paper punch to make a hole in the lid of the inside cup.
4. Put 50 mL of water and 50 g of ice in the inside cup.
5. Carefully measure 2.9 g of sodium chloride. Add the salt to the ice/water mixture.
6. Put the lid on the cup. Place the Temperature Sensor in the hole in the lid.



PART III: Data Recording

1. Start recording data.
2. Gently swirl the calorimeter to help the salt dissolve until the reaction is complete.
3. Stop the data recording after approximately 90 seconds (1.5 minutes).
4. Remove any remaining chunks of ice from the inner cup. Weigh the inner cup with the remaining water and record the total weight of the cup plus water.

Name ____________________ Class _____________ Date _________

Analyzing the Data

1. Use the Graph analysis tools to determine the maximum temperature (maximum 'y') and minimum temperature (minimum 'y').

- Hint: Use the Smart Tool in *DataStudio* or the Smart Cursor in *ScienceWorkshop*.

2. Record the maximum temperature and the minimum temperature.

Calculations

1. Calculate the change in temperature and record it.

2. Calculate the mass of the water remaining in the cup after the salt dissolved.

3. Calculate the number of moles of solute (salt).

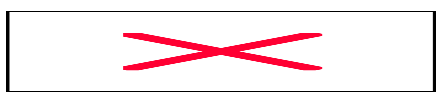
4. Determine the molality of the ice/water/salt mixture.

5. Calculate the Molal Freezing Point Depression Constant, K_f.

6. Compare your value for the Molal Freezing Point Depression Constant, K_f, to the accepted value.

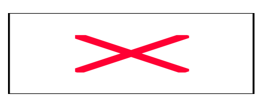
- Note: A mass of 2.9 g sodium chloride is equal to 0.05 moles of sodium chloride, or 0.1 moles of dissolved ions.

- The molality of a solution is equal to the moles of solute divided by the weight (in kg) of solvent.



- The Molal Freezing Point Depression Constant formula is:

Δ freezing temperature of water = m (molality) x K_f



Record your results in the Lab Report section.

Name ____________________ Class ______________ Date _________

Lab Report - Activity C26: Molal Freezing Point Depression Constant, K_f

What do you think?

Freezing a milk/cream mixture makes ice cream. The freezing usually takes place in an ice cream maker that has an inner and outer lining. The milk/cream mixture is placed into the inner container and ice, water and salt are placed in the outer container. The ice used in the outer container is initially at zero degrees Celsius. Water and salt are then added to this ice and the resulting mixture is used to "freeze" the milk/cream into ice cream. Milk and cream require a temperature colder than zero degrees Celsius to be turned into ice cream. Just how does this "freezing" temperature come about?

Data Table

Mass of empty cup	kg
Mass of cup plus water	kg
Mass of water used	kg
Minimum Temperature	˚C
Maximum Temperature	˚C
Change in Temperature	˚C

1. Calculate the number of moles of solute (salt).

2. Determine the molality of the ice/water/salt mixture.

3. Calculate the Molal Freezing Point Depression Constant, K_f.

Questions

1. If ionic solutions, like sodium chloride, form ions and effect the freezing point so much more than non-ionic solutions, like ethylene glycol (Zerex™), why are non-ionic materials used in cars?

2. Why is calcium chloride ($CaCl_2$) more effective as an anti-icing material than sodium chloride (NaCl)?

3. What is your value of Kf? How does this compare with the accepted value for Kf? (The accepted value of Kf for water is 1.86 ˚C kg/mol.)

Questions About the Observation (Optional)

- Does a phase change occur for the water in the test tube?
- Can you determine the freezing point of water in this activity?
- Can ice be colder than zero degrees Celsius?