Experiment
2

Freezing-Point Depression

Freezing temperature, the temperature at which a substance turns from liquid to solid, is a characteristic physical property. In this experiment, the freezing point depression constant for water will be experimentally determined by measuring the freezing point for various water/glycerol solutions.

When a solute is dissolved in a solvent, the freezing temperature is lowered in proportion to the number of moles of solute added. This property, known as freezing-point depression, is a *colligative property*; that is, it depends on the ratio of solute to solvent particles, not on the nature of the substance itself. The equation that shows this relationship for a dilute solution is:

$$\Delta T = K_f \bullet m \qquad \textbf{\textit{(Equation 1)}}$$

where ΔT is the change in the freezing point of the solution (compared to the pure solvent),

K_f is the freezing point depression constant for a particular solvent, and

m is the molality of the solution.

Thus, a plot of the change in freezing point versus the molality of all various water/glycerol solutions should yield a straight line with a slope of K_f.

where ΔT is the freezing point depression, K_f is the freezing point depression constant for a particular solvent (1.86°C/m for water), and *m* is the molality of the solution (in mol solute/kg solvent).

In this experiment, you will first find the freezing temperature of the pure solvent, water, H_2O. You will then add a known mass of glycerol solute, $C_3H_5(OH)_3$, to a known mass of water, and determine the lowering of the freezing temperature of the solution, ΔT. Finally, you make a graph ΔT vs molality of all solutions to get the freezing point depression constant, K_f.

Alternatively, if the freezing point depression constant, K_f, is given or known, the freezing point data, ΔT, can be used to determine the molar mass (MM, g/mol) of an unknown in solution. First, you determine the molality of a solution from the experimental freezing point depression data for the solution and the given K_f.for the solvent, using *Equation 1*. Once you obtain the molality of the solution, you can calculate the molar mass of the solute from the solution molality, and the solvent and the solute masses, using *Equation 2*.

molality = (moles of solute) / (kilograms of solvent)

molality = (grams of solute / MM of solute) / (kilograms of solvent)

MM of solute = (grams of solute) / (molality) • (kilograms of solute) ***(Equation 2)***

OBJECTIVES

In this experiment, you will

- Determine the freezing temperature of pure water.
- Determine the freezing temperature of various water/glycerol solutions.
- Examine the freezing curves for each.
- Determine the freezing point depression constant k_f.
- Calculate the experimental molecular weight of glycerol. (Optional)
- Compare it to the accepted molecular weight for glycerol. (Optional)

MATERIALS

Check out from the Stockroom:
Freezing Point Depression Vernier kit

- Vernier Lab*Pro* interface box
- Power cord for Lab*Pro* interface
- USB cable for Lab*Pro* interface
- Ethernet cable
- Vernier Temperature Probe

Check out from your instructor:

- Laptop computer

Found in the lab or your locker:

- Ring stand
- 3" and 5"O-rings
- Analytical balance
- 250mL and 600mL beakers
- 18 x 150 test tubes
- Stirring rod

Reagents

- Rock salt
- Glycerol
- Deionized water

PROCEDURE

Part I: Preparation of solutions:

Use the following table 1 as a guide to prepare various glycerol/water solutions. An accuracy of a few percent is sufficient because of the error in measuring ΔT. Record the mass of water (g) and water/glycerol (g):

1. Label nine 18 x 150mm test tubes according to the table 1.

Table 1 – Composition of water-glycerol solutions

Trial	Water (g)	Water/glycerol (g)	Glycerol (g)	Molality	ΔT
1	12	12.0	0.0		
2	12	13.0	1.0		
3	12	13.4	1.4		
4	12	13.8	1.8		
5	12	14.4	2.4		
6	12	15.0	3.0		
7	12	15.8	3.8		
8	12	16.5	4.5		
9	12	17.2	5.2		

2. Place a 250mL beaker on the balance top and tare it to zero. This beaker is used to hold test tube during the weighing of each water/glycerol solution.

3. Place a 18 x 150mm test tubes in the pre-tared beaker and tare it to zero. Add about 12mL of water to pre-tared test tube, weigh and record the mass of water. Then add glycerol until the weight corresponds to about the amount of glycerol shown in the table 1, weigh accurately and record the mass of water/glycerol mixture.

4. Stir the water/glycerol mixture thoroughly. Repeat steps 3 and 4 for the remaining solutions.

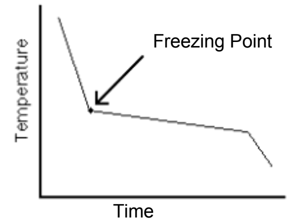
Part II: Determination of the freezing point:

1. Setting up the equipment:
   a. Connect the temperature probe to the Lab*Pro* interface box through channel 1 (refer to Appendix 1)
   b. Connect the Lab*Pro* interface box to the power outlet with the power cord. The Lab*Pro* will beep to indicate it is ready.
   c. Connect the Lab*Pro* interface box to the laptop computer using the USB cable (refer to Appendix 1). The USB ports are found in the back of the laptop on the right hand side when the screen is facing you.
2. Prepare the ice-salt-water bath:

   Fill rock salt/water/ice mixture into a 600mL beaker with about 25% rock salt, 25% water and 50% ice. **Important:** Stir enough to dissolve most of the salt.
3. Prepare the computer for data collection by opening the file "Lab 2 Freezing Point Depression" from the *CHEMISTRY1B VERNIER desktop* folder.
4. When everything is ready, click Collect to begin data collection. Then lower the test tube into the ice-salt-water bath. Make sure the level of solution in the test tube is below the level of ice-salt-water bath. Place the Vernier temperature probe into the test tube. With a very slight up and down motion of the Temperature Probe, **continuously stir the solution during the cooling.** Hold the top of the probe and *not* its wire.
5. Click Stop to stop data collection when the cooling curve shows nearly constant temperature. On the displayed graph, analyze the flat part of the curve to determine the freezing temperature of water:
   a. Move the mouse pointer to the beginning of the graph's flat part. Press the mouse button and hold it down as you drag across the flat part to *select* only the points in the plateau.
   b. Click on the Statistics button, STAT. The mean temperature value for the selected data is listed in the statistics box on the graph. Record this value as the freezing temperature in your data table.
   c. To remove the statistics box, click on the upper-left corner of the box.
6. Repeat steps 4 and 5 for the remaining solutions.

   Note: After clicking Collect to begin data collection of the next solution, you must select **Store Latest Run** from the Experiment menu to store your previous run data.

When you stop data collection, click on the Examine button, . To determine the freezing point of the water-glycerol solution, you need to determine the temperature at which the mixture initially started to freeze. Unlike pure water, cooling a mixture of water and glycerol results in a gradual linear decrease in temperature during the time period when freezing takes place. As you move the mouse cursor across the graph, the temperature (y) and time (x) data points are displayed in the examine box on the graph. Locate the initial freezing temperature of the solution, as shown here. Record the freezing point in your data table.



7. Hide a curve to display only your choice of curves during data analysis or processing:
   a. Move the mouse pointer to vertical axis (y-axis) and double click to access the *Graph Options* menu.
   b. Select the *Axes Options* and uncheck the Temperature box of the curve you want to hide.
   c. Click Done.

8. Recycle the excess rock salt in your beaker:
   a. Decant as much water-ice-salt solution as possible
   b. Pour the excess rock salt back to the large container labeled "Used Rock Salt" near the large sink in your lab.

9. Dispose solutions as instructed by the instructor.

OBSERVATIONS

PROCESSING THE DATA

A. DETERMINATION OF THE FREEZING POINT DEPRESSION CONSTANT, K_f :

1. Determine the difference in freezing temperatures, ΔT, between the pure water (T_1) and the mixture of water and glycerol (T_2). Use the formula, $\Delta T = T_2 - T_1$.
2. Show the plot of temperature (Celsius) versus time (s) for one or two typical solutions.
3. Calculate the molality (m), in mol/kg, of the solutions made (using the formula, $\Delta T = K_f \cdot m$ (K_f = 1.86°C/m for water)).
4. Plot ΔT versus the molality for all the solutions. Calculate the slope of the best fitted straight line to get the value of K_f. Compare the K_f value obtained experimentally with the literature value of K_f = 1.86°C/m for water and calculate the percent error.

B. DETERMINATION OF MOLECULAR MASS OF GLYCEROL:(Optional)

1. Selecting your choice of a solution from trial 2-9 in Table 1, perform the experiment for the freezing point determination in the same manner as described in Part I and Part II to:

   a) Determine $\Delta T = T_2 - T_1$

b) Calculate the experimentally *molality* of the solute, glycerol, in mol/kg (using ***Equation 1***, where K_f = 1.86°C/m for water).

c) Calculate the molar mass of the solute, glycerol, using ***Equation 2***.

2. Repeat the step 1for two other solutions in Table 1.

3. Take the average of the three calculated molar masses of glycerol and compare it with the theoretical value from its formula, $C_3H_5(OH)_3$.

4. Calculate the percent error.

EXTENSION

Here is another method that can be used to determine the freezing temperature from your data. With a graph of the data displayed, use this procedure:

1. Move the mouse pointer to the initial part of the cooling curve, where the temperature has an initial rapid decrease (before freezing occurred). Press the mouse button and hold it down as you drag across the linear region of this steep temperature decrease.
2. Click on the Linear Fit button, .
3. Now press the mouse button and drag over the next linear region of the curve (the gently sloping section of the curve where freezing took place). Press the mouse button and hold it down as you drag only this linear region of the curve.
4. Click again. The graph should now have two regression lines displayed.
5. Choose Interpolate from the Analyze menu. Move the mouse pointer left to the point where the two regression lines intersect. When the small circles on each cursor line overlap each other at the intersection, the temperatures shown in either examine box should be equal to the freezing temperature for the water-glycerol mixture.

DATA AND CALCULATIONS

Mass of water	g
Mass of glycerol	g
Freezing temperature of pure water	°C
Freezing point of the water-glycerol mixture	°C

Freezing temperature depression, ΔT	°C
Molality, *m*	mol/kg

Moles of glycerol	mol
Molecular weight of glycerol (experimental)	g/mol
Molecular weight of glycerol (theoretical)	g/mol
Percent error	%