Experiment 2

Properties of Water

Introduction

Water (H_2O) is the most abundant compound on Earth's surface and the life on the Earth is possible only because it's unique properties. Have you ever wondered how anti-freeze works? Do you know what makes ice melt on the side walk when you sprinkle salt on it? Have you seen how homemade ice cream is made- by mixing rock salt with ice to freeze the ice cream mix? When a solute such as sucrose or sodium chloride dissolves in a solvent such as water, the melting/freezing point of the solution is altered. In this experiment we'll investigate the effect on the freezing point of water upon addition of NaCl and sucrose.

Safety

You must wear safety goggles. Dispose of all waste materials in the appropriate waste containers as directed by your instructor. Thermometers should be handled carefully.

Objectives

In part A, you will determine the freezing point of a pure liquid. In parts B and C you will do series of experiments to observe and measure the effect that the amount of a solute dissolved in a solvent has on the freezing point of a solution.

Concepts

You have learned that a solution is composed of solute plus solvent. You know the term *molarity*- moles of solute per liter of solution. Because the volume of the liquid changes when the temperature changes, you need to determine the *molality* of the solution. The units of molality are moles of solute per kilogram of solvent.

Materials

Laboratory Balance	Beakers (600 mL, 100 mL)
Glass rod	Graduated cylinder
Test tube	Temperature Probe
Wire stirrer	Ring stand
Rubber stopper 2-hole with slit	

Procedure

Part A - The freezing point of a pure liquid

You will work in groups of four to perform this activity.

Add approximately 15 mL of deionized water to the 18 x 150 mm (3/4-inch) test tube. Assemble the apparatus as shown below (Figure I), with the test tube containing the water immersed in the ice-rock salt mixture. (For best results use mostly ice & salt with just a little water.) The test tube should be inserted deeply enough that the entire water sample is below the level of the ice-rock salt level in the beaker. Stir both the water and the ice-rock salt solution continuously. Record the temperature every 10 seconds until you reach the freezing point. The lowest constant temperature observed is the freezing point of the water. When the temperature reaches a constant value, read it to the nearest 0.5 °C. Record the freezing point of pure water. Remove the test tube from the beaker. Dispose of the water sample and dry the test tube for later use.

NOTE: The solution may cool below the true equilibrium freezing point because there are no nucleation sites for solidification to occur. This is called supercooling. Stir the solution rapidly and the temperature will increase to the equilibrium freezing point and remain constant. (See Figure II - next page).

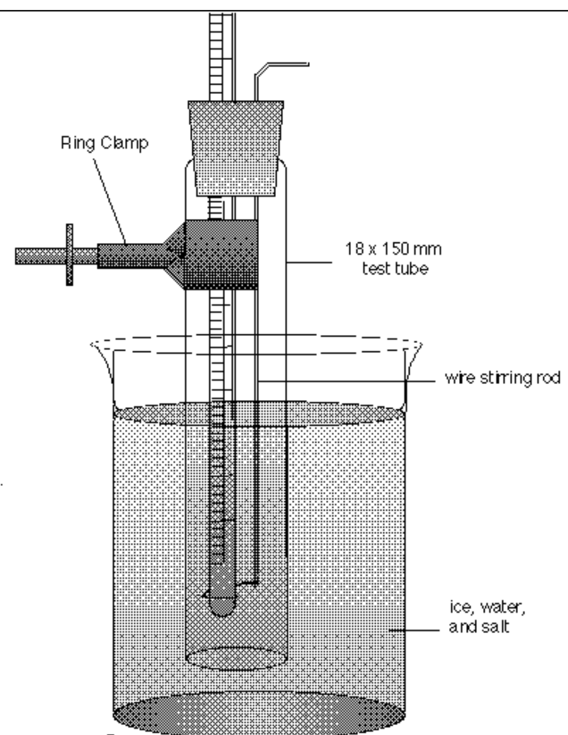

Figure I.

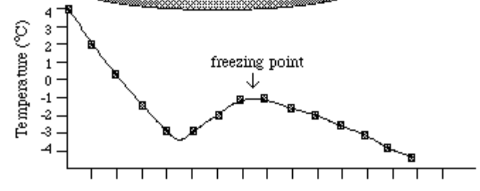

Figure II.

Part B - The freezing point of sucrose solutions

Weigh a clean, dry 18 x 150 mm test tube, supported in a 100 mL beaker, using the laboratory balance and record the mass below. Add between 15 and 16 mL of deionized water to the test tube. Record the mass of the water+test tube+beaker. Carefully add about 2.0-2.4 g of sucrose ($C_{12}H_{22}O_{11}$) to the test tube and record the mass of sucrose+water+test tube+beaker. After all of the sucrose has dissolved, assemble the apparatus with the test tube containing the solution immersed in the ice-rock salt mixture. The test tube should be inserted deeply enough that the entire solution sample is below the level of the ice-rock salt level in the beaker. Stir both the sucrose solution in the test tube and the ice-rock salt solution continuously. Record the temperature every 10 seconds until you reach the freezing point. The lowest constant temperature observed is the freezing point. Record the freezing point of this solution. Watch for supercooling!

Repeat the procedure above using about 4.0-4.8 g of sucrose. Record your data and observed freezing point.

Part B- Analysis

1. Calculate the molality of the sucrose solutions.
2. Calculate change in freezing point of the solutions in both cases compared to the freezing point of pure water.
3. How did the freezing point change with change in the molality of the sucrose solution? Complete the following table.

	Molality of Sucrose Solution (m)	Change in Freezing Point (ΔT)
1		
2		

4. Write a mathematical proportionality statement based on your data in table.

   (In order to make a proportionality into an equality, we need to incorporate a constant into the equation. (For example, if a variable *a* is directly proportional to another variable *b*, we can write $a \propto b$. To convert the proportionality statement to an equation we write $a = kb$, where k is a proportionality constant.) We need an equation relating the molality of the solution to its change in freezing point. We will call the required constant, k_f, the freezing point constant. Write the equation obtained by including k_f in your proportionality statement. So that all answers in the class will be consistent, be sure to place the constant on the "molality side" of the equation.)

5. Calculate the magnitude of the freezing point depression constant based on your data. (Be sure to include the correct units for the constant.)

Part C - The freezing point of sodium chloride solutions

Weigh a clean, dry 18 x 150 mm test tube, supported in a 100 mL beaker, using the laboratory balance and record the mass in the data sheet. Add between 15 and 16 mL of deionized water to the test tube. Record the mass of the water+test tube+beaker on the data sheet. Carefully add about 0.4-0.6 g of sodium chloride to the test tube and record the mass of sodium chloride+water+test tube+beaker. After all of the sodium chloride has dissolved, assemble the apparatus with the test tube containing the solution immersed in the ice-rock salt mixture. The test tube should be inserted deeply enough that the entire solution sample is below the level of the ice-rock salt level in the beaker. Stir both the salt solution in the test tube and the ice-rock salt solution continuously. Record the temperature every 10 seconds until you reach the freezing point. The lowest constant temperature observed is the freezing point. Record the freezing point of this solution. Watch for supercooling!

Repeat the procedure above using about 0.8-1.2 g of sodium chloride. Record your data and observed freezing point below.

Part C- Analysis

1. Calculate the molality of the NaCl solutions.
2. Calculate change in freezing point of the solutions in both cases compared to the freezing point of pure water.
3. How did the freezing point change with change in the molality of the NaCl solution? Complete the following table.

	Molality of NaCl Solution (m)	Change in Freezing Point (ΔT)
1		
2		

4. Write a mathematical proportionality statement based on your data in table.
5. Calculate the magnitude of the freezing point depression constant based on your data. (Be sure to include the correct units for the constant.)
6. Knowing what happens when sucrose & NaCl dissolves in water, how can you account in the different freezing depressions that you observed when sucrose and NaCl are added to water?

Post-Laboratory Questions

1. Write a chemical equation which describes what happens when the following substances are added to water.
   (a) $C_2H_4(OH)_2$*(l)*
   (b) $Ca(NO_3)_2$*(s)*

2. Complete the following table.

Substance	Molar Mass	Mass of Solute	Mass of Water	Ideal Freezing Point °C	Molality of Solution
Sugar	342	122.0 g	_____	_____	0.32
Potassium Iodide	166	_____	140 g	_____	0.090
Ethylene Glycol	_____	1.5 g	25.0 g	−1.80	_____
Calcium nitrate	164	_____	1000 g	-4.30	_____
Urea	60	_____	610 g	-3.46	_____

3. Calculate the boiling point of each of the solutions in Problem #2.
4. Freezing point depression is often used to experimentally determine the molecular mass of a solute, but boiling point elevation is rarely used. Considering the calculations you have just performed in questions #2 and #3, explain why this is so.
5. A solution of 0.684 g of chlorous acid, $HClO_2$, in 100 g of water freezes at -0.24 °C. Would you classify $HClO_2$ as a nonelectrolyte, a weak electrolyte, or a strong electrolyte?