EXPERIMENT 10: PROPERTIES OF WATER

Pre–Lab Questions:

> The following preparatory questions should be answered before coming to class. They are intended to introduce you to several ideas important to aspects of the experiment. <u>You must turn-in your work to your instructor before you will be allowed to begin the experiment.</u> Be sure to bring a calculator and paper to laboratory.

1. Calculate the molality of glucose in a solution prepared by mixing 1.258 g $C_6H_{12}O_6$ in 14.0 mL of water.

2. Briefly discuss the term *freezing point depression*.

3. (a) Complete the table.

Exp. #	Mass of $C_6H_{12}O_6$	Moles of $C_6H_{12}O_6$	Mass of H_2O	Volume of solution	Molality of solution	Molarity of solution	Density of solution
1	1.600 g		15.50 g	16.52 mL			
2	1.160 g		15.50 g	16.21 mL			
3	0.798 g		15.50 g	15.98 mL			
4	0.465 g		15.50 g	15.78 mL			
5	0.310 g		15.50 g	15.68 mL			

3. (b) Why are molarity and molality more nearly equal for dilute solutions than for concentrated solutions?

3.   (c)   Under what conditions will molarity and molality of a solution be equal? Explain.

4.   Why is it desirable to express concentration as molality rather than molarity when performing experiments in which the temperature changes?

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EQUIPMENT:

laboratory balance...................... 1	ring stand 1
beaker, 100 mL 1	rubber stopper, 2-hole with slit 1
beaker,600 mL 1	thermometer, ˚C........................ 1
glass rod 1	test tube, 18x150 mm 2
graduated cylinder, 25 or 50 mL..... 1	utility clamp............................ 1
paper towels........................several	wire stirrer............................ 1

It is suggested that students work in groups of two while collecting the experimental data.

The apparatus to be used in the following experiments is illustrated in Figure I (next page). The apparatus consists of an 18 x 150 mm test tube which will hold the solution whose freezing point is to be determined. The test tube is fitted with the two-holed rubber stopper. A thermometer is carefully inserted into the split hole of the rubber stopper and the wire stirrer is inserted through the other hole. A ring clamp is used to hold the test tube assembly, which is immersed in a ice/water/salt bath in a 600 mL beaker. A glass stirring rod is used to stir the ice/water/salt solution, while the wire stirrer is used mix the solution in the test tube. If you have any questions about the apparatus consult with your instructor.

Part I: The Freezing Point of a Pure Liquid

Add approximately 15 mL of deionized water to the 18 x 150 mm (3/4-inch) test tube. Assemble the apparatus, 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. Watch the mercury level in the thermometer drop. The lowest constant temperature observed is the freezing point of the water. When the temperature reaches a constant value, read the thermometer to the nearest 0.5 ˚C. 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).

Obs. #1   Freezing Point of Pure Water   _____

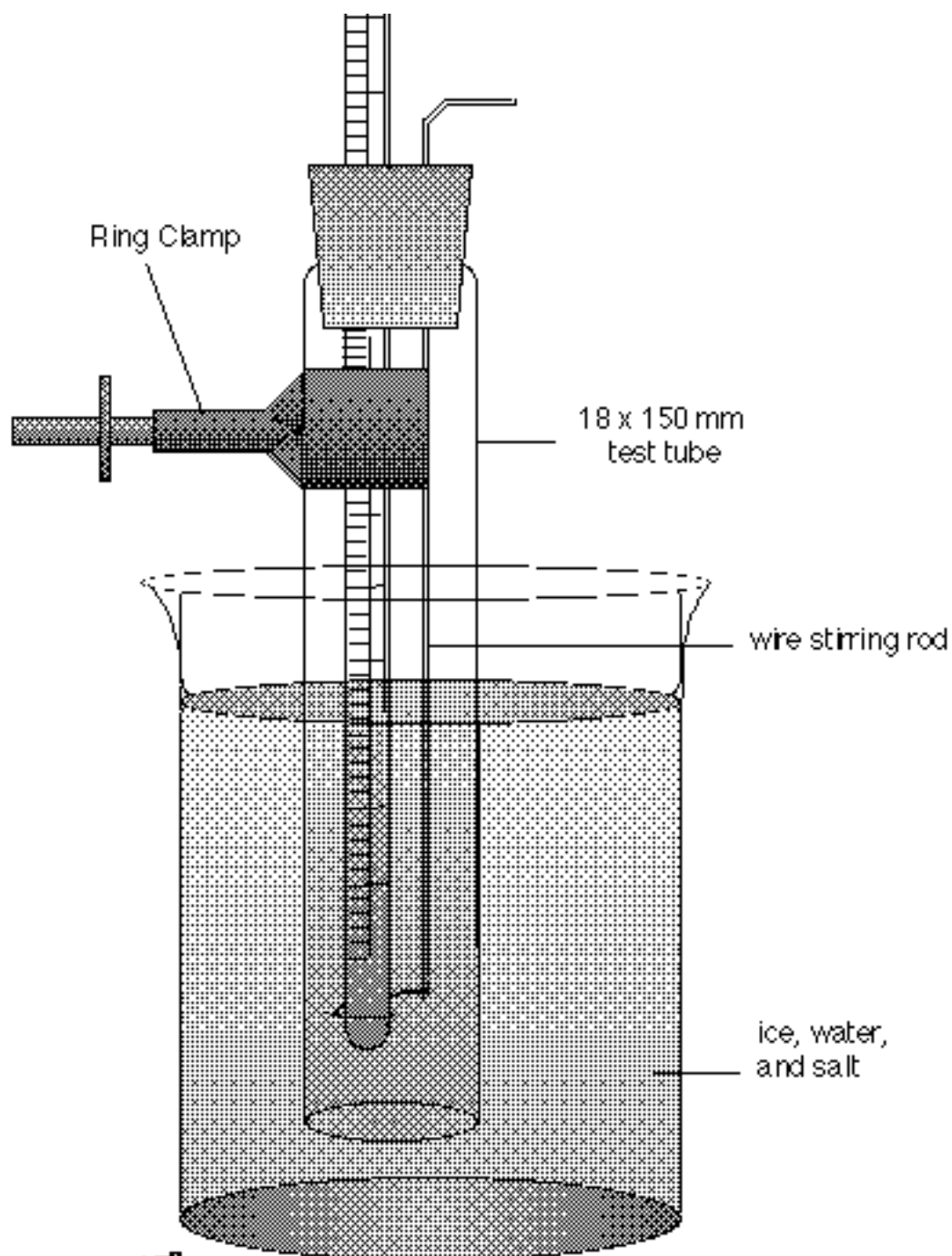Remove the test tube from the beaker. Dispose of the water sample and dry the test tube for later use.

Ring Clamp

18 x 150 mm
test tube

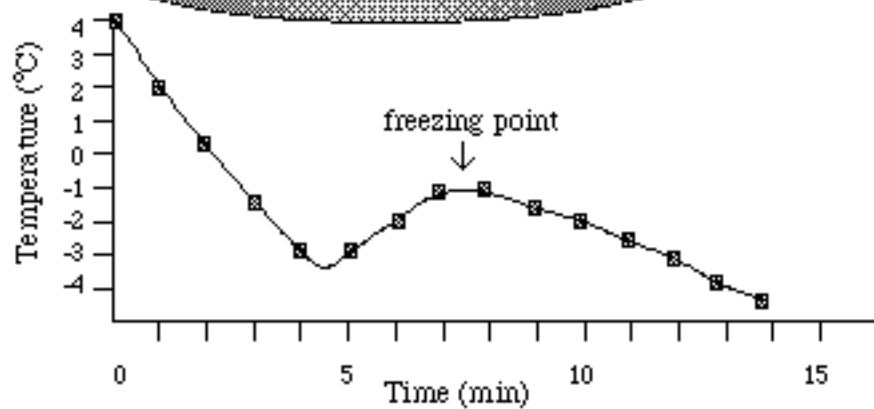wire stirring rod

Figure I.

ice, water,
and salt

Figure II.

Part II: 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 below (Note: This mass is entered twice for ease of calculations). Carefully add about 2.2 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. Measure the freezing point of this solution and record the temperature. Watch for supercooling!

Mass: sucrose + H_2O
+ test tube + beaker   _____

Mass: H_2O + test tube
+ beaker   _____

Mass of sucrose   _____

Mass: H_2O + test tube
+ beaker   _____

Mass: test tube + beaker _____

Mass of water   _____

Calculate the molality of the sucrose solution.

Calc. #1

Obs. #2   Freezing Point of the Solution _____

Obs. #3   Change in Freezing Point of Solution _____ (Obs #1 - Obs #2)

Repeat the procedure above using about 4.4 g of sucrose. Record your data and observed freezing point below.

Mass: sucrose + H_2O
+ test tube + beaker   _____

Mass: H_2O + test tube
+ beaker   _____

Mass of sucrose   _____

Mass: H_2O + test tube
+ beaker   _____

Mass: test tube + beaker _____

Mass of water   _____

Calculate the molality of the sucrose solution.

Calc. #2

Obs. #4   Freezing Point of the Solution _____

Obs. #5   Change in Freezing Point of the Solution _____ (Obs #1 - Obs #4)

Complete the following table.

Table I.

	Molality of sucrose solution (m)	Change in freezing point (ΔT)
Experiment #1		
Experiment #2		

How did the freezing point change with change in the molality of the sucrose solution?

Expl. #1

Write a mathematical proportionality statement based on your data in Table I.

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

Calc #3

Part III: 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 0.5 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. Measure the freezing point of this solution and record the temperature. Watch for supercooling!

Mass: $NaCl + H_2O$
+ test tube + beaker _____

Mass: H_2O + test tube
+ beaker _____

Mass of NaCl _____

Mass: H_2O + test tube
+ beaker _____

Mass: test tube + beaker _____

Mass of water _____

Calculate the molality of the sodium chloride solution.

Calc. #4

Obs. #6 Freezing Point of the Solution _____

Obs. #7 Change in Freezing Point of the Solution _____

Repeat the procedure above using about 1.0 g of sodium chloride . Record your data and observed freezing point below.

Mass: $NaCl + H_2O$
+ test tube + beaker _____

Mass: H_2O + test tube
+ beaker _____

Mass of NaCl _____

Mass: H_2O + test tube
+ beaker _____

Mass: test tube + beaker _____

Mass of water _____

Calculate the molality of the sodium chloride solution.

Calc. #5

Obs. #8 Freezing Point of the Solution _____

Obs. #9 Change in Freezing Point of the Solution _____

Complete the data Table.

Table II.

	Molality of sucrose solution (m)	Change in freezing point (ΔT)
Experiment #1		
Experiment #2		

How did the freezing point change with change in the molality of the sodium chloride solution?

Expl. #2

Write a mathematical proportionality statement based on your data in Table I.

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

Calc #6

Is there any difference between the constant obtained from Part II (sucrose solution) and the constant obtained in Part III (sodium chloride solution)? If so, how do they differ?

Expl. #3

What would you have to do to the constant from Part III to get close to the constant from Part II?

Expl. #4

Write the chemical equation for what occurs when sucrose is added to water.

Equ. #1

Write the chemical equation for what occurs when sodium chloride is added to water.

Equ. #2

For every mole of sucrose that dissolves, how many moles of 'particles' (sucrose molecules) are in solution?

Expl. #5

For every mole of sodium chloride that dissolves, how many moles of 'particles' (ions) are in solution?

Expl. #6

The equation " $T = K_f m$" describes the freezing point depression of a solvent due to the addition of a nonvolatile solute. The freezing point constant, K_f, for a given solvent is constant and independent of the identity of the nonvolatile solute particles. In other words, the freezing point constant has to be the same in Part II and Part III of the experiment because water is the solvent in both parts. Explain the reason for the difference in the values obtained in Calc. #3 and Calc. #6.

Expl. #7

If the freezing point constant, K_f, is constant, on what does the freezing point of an aqueous solution of a nonvolatile solute depend?

Expl. #8

Post-Laboratory Questions

These problems are to be turned in with the laboratory write-up. SHOW ALL CALCULATIONS.

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) $Ca(NO_3)_2{}_{(s)}$
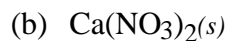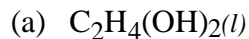
2. Complete the following table.

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?