EXPERIMENT C1: FREEZING POINT DEPRESSION

Learning Outcomes

Upon completion of this lab, the student will be able to:

1) Relate freezing point depression to molality of the solution.
2) Measure the freezing point depression constant for water.

Introduction

Properties of a solution that only depend on the amount of solute in the solution and are independent of the chemical identity of the solute are referred to as *Colligative Properties.* Examples of colligative properties include: 1) boiling point elevation 2) freezing point depression 3) lowering of vapor pressure and 4) osmotic pressure.

In this experiment the freezing point depression of water due to the presence of a solute will be studied.

When solutes such as salt or glucose are added to water, the freezing point of water decreases. The extent to which the freezing point is lowered or depressed depends on the amount of the solute that is added. The amount of solute in the solution is measured in terms of molality. Molality (m) is defined as the moles of solute per kilogram of the solvent. Molality is used instead of molarity in these instances, as the volume of the solvent changes slightly with variations in temperature while mass does not. This allows for consistency over a range of temperatures without additional calculations to account for thermal expansion of solvents.

Therefore, the depression in the freezing point, ΔT_f; is proportional to the molality, *m*, of the solution.

$$\Delta T_f \propto m$$

$$\Delta T_f = K_f \bullet m$$

In the above equation K_f, the proportionality constant, is referred to as the freezing point depression constant. The freezing point depression constant for water is 1.86 °C/*m*. This value will be confirmed experimentally.

Experimental Design

In this experiment, different amounts of a non-volatile and non-ionic solute, glycerol, will be added to water. The freezing point of water will be measured for each amount of glycerol added. A plot of the molality vs. the freezing point depression will be used to determine the freezing point depression constant.

Reagents and Supplies

Glycerol, rock salt, thermometer

(See posted Material Safety Data Sheets)

Procedure

*note: As this experiment relies on having an accurate amount of solute dissolved in solution, clean glassware is very important. Any other potential solutes in the test tubes will affect the measured freezing point.

1. Place an empty beaker on the electronic balance and tare the balance.

2. Place a large empty test tube inside the beaker in step 1 and record the mass.

3. Add about 1 gram of glycerol into the test tube from step 2 and record the mass. Use a dropper to add the glycerol. Glycerol is highly viscous and may not flow easily in and out of the dropper. Care must be taken to avoid glycerol spills on the balance pan. In case of spills, use paper towels to immediately clean the glycerol and discard the paper towel in the trash container.

4. Add about 12 grams of deionized water to the test tube from step 3 and record the total mass. Mix well, making sure that the glycerol is completely dissolved before beginning the cooling process. (Look for the absence of mixing lines)

5. Repeat steps 1 through 4 with the following amounts of glycerol.

Test Tube	Water (grams)	Glycerol (grams)
0	12	0
1	12	1.0
2	12	1.4
3	12	1.8
4	12	2.4
5	12	3.0
6	12	3.8
7	12	4.5
8	12	5.2

6. Determine the freezing point of water in each of the test tube using the following method.

    a. Clamp the test tube containing the water/glycerol solution.

    b. Prepare a cold water bath by combining water, rock salt, and ice in the following proportion in a 600-mL beaker: 5% water, 25% rock salt, and 70% ice. Stir with a metal spatula. The temperature of the bath should be at least −8°C.

    c. Place the test tube inside containing the water/glycerol solution in the cold water bath. Make sure that the solution inside the test tube is completely submerged into the ice mixture.

d. Place a thermometer inside the test tube and vigorously stir the contents, taking care to avoid breaking the test tube.

e. When the mixture becomes a thick slurry, remove the test tube from the ice bath. (If ice adheres to the edge of the test tube, remove the test tube from the ice bath and warm it in our hands briefly until the ice can be broken up into the liquid in the test tube)

f. Remove the test tube from ice bath and begin stirring to melt the ice crystals. Dip the test tube into a room temperature water bath immediately in order to facilitate melting. Do not leave the test tube inside the room temperature bath as this might lead to artificially high melting points.

g. Stir the contents of the test tube gently, using the thermometer. Record the temperature at which the last crystal has melted. This is the melting point (NOTE: this is the same as the freezing point).

h. Repeat this process once for each test tube. The measured freezing points should agree within +/- 0.3 °C.

7. Once the freezing points of the water in all the test tubes have been measured, discard the solutions as directed by the instructor.

Data Table

NOTE: Normal freezing point of water = 0°C

ΔT_f = freezing point of pure water –freezing point of solution

Test Tube	**Mass of Empty Test Tube (grams)**	**Mass of Test Tube + Glycerol (grams)**	**Mass of Test Tube + Water + Glycerol (grams)**	**ΔT_f (°C)**
0				
1				
2				
3				
4				
5				
6				
7				
8				

Data Analysis

Mass of glycerol= (Mass of test tube + glycerol) – (Mass of empty test tube)

Mass of water= (Mass of test tube + water + glycerol) – (Mass test tube + glycerol)

Molar mass of glycerol = 92.1 g/mol

$$\text{Molality} = \frac{\text{moles of glycerol}}{\text{Mass of solvent (kg)}}$$

Test Tube	**Mass of water (grams)**	**Mass of water (kg)**	**Mass of glycerol (grams)**	**Moles of glycerol**	**Molality**	**ΔT_f (°C)**
1						
2						
3						
4						
5						
6						
7						
8						

Data Analysis

Plot a graph of molality (x-axis) vs. ΔT_f (y-axis).
Obtain the equation of the best-fit line. Be sure to set the y-intercept to zero.
The slope of this line is the K_f.

The experimental value of the freezing point depression constant for water =

% error in the measurement =