1.0 Introduction

Colligative properties are properties of solutions that depend only on the number of solute particles in the solution and not on their chemical identity or properties. As far as colligative properties are concerned a particle is a particle, and the more particles available whether ions or molecules, large or small, the more the property is affected. Common colligative properties include freezing point depression (melting point depression), boiling point elevation and osmotic pressure.

The relationship that has been measured for freezing point depression can be expressed as:

$$\Delta T_f = i \times K_f \times m$$

ΔT_f is the freezing point depression since there is always a lowering of the freezing point of a solution with solute added, K_f is a constant that is unique for each solvent. For water this constant is 1.86 °C/m but it is different for other solvents. m is the molality of the solution and is equivalent to the moles of solute per kg of solvent. Notice how it differs from its close relative molarity which is moles of solute per liter of solution. Also, molality is per kg of the solvent only, not the mass of solution. The final factor in the relationship is i which is called the van't Hoff factor. This indicates the extent of dissociation for strong electrolytes. For a two particle electrolyte which completely dissociated this factor would be 2. In practice it is found that most salts do not completely ionize in solution even when expected to do so. Often for a salt MX(aq) an i value from 1.2 – 1.9 can be measured. This i factor can be calculated from the ratio of the ΔT_f observed / ΔT_f predicted. Thus, if a ΔT_f is calculated to be -1.4 °C but a value of -2.1 °C is actually measured the i value would be calculated to be 1.5. It can be deduced at this point that the substance producing this freezing point lowering consists of two ions which are about 50% dissociated in solution.

In this lab 3 unknown solids will be dissolved in water and the freezing point depressions will be measured. The van't Hoff factor for each will be calculated based on the expected and observed freezing point depressions. From this information you will deduce the number of ions in the compound formula.

2.0 Procedure

Take a 600 mL beaker and add a small layer of rock salt, followed by a layer of ice and continue filling the beaker with these alternating layers of rock salt and ice. Once the beaker is nearly full, wet these salt-ice layers with water. The resulting salt-ice bath should not have too much water added and water may have to be decanted if too much of the ice melts. The bath should have a temperature of at least -10 °C.

MeasureNet Task: Setup for Temperature-Time Measurements

Your Actions:		MeasureNet Response:
Press: **MAIN MENU**		**LCD:** Shows Function Choices
Press: **F2 –** Temperature		**LCD:** Shows More Temperature Choices
Press: **F1 –** Temp v Time		**LCD:** Shows SELECT OPTION screen
Press: **SETUP**		**LCD:** Asks New Acquisition or Replot
Press: **F1** for New Acquisition		**LCD:** Shows MIN MAX Temp & Time Values

MeasureNet Task: Setup for Temperature-Time Measurements (CONTINUED)

Your Actions:		MeasureNet Response:
Set: MAX Temp = 5 & MIN Temp = -15 using Keypad and arrow keys		**LCD:** Shows Y MAX 5 and Y MIN -15
Set: Max Time = 800 seconds		**LCD:** Shows X MAX 800
Press: **DISPLAY** to accept all values		**LCD:** Shows the Temp Time Measurement screen

Fill a large test tube about half full of dionized water and immerse the test tube in the cold bath. Insert the MeasureNet temperature probe and begin stirring with the wire stirrer. Stirring with an up and down action must be continuous in order to distribute the temperature evenly. When the temperature drops to about 4°C, press the **START/STOP** button to begin collecting the data. You can watch the data on the MeasureNet screen as the graph is completed. Continue the run until the mixture is completely solid or the temperature remains constant a couple of minutes, then press **START/STOP**. This run determines the freezing point of pure water, to calibrate your temperature probe.

MeasureNet Task: Save the Data File

Your Actions:		MeasureNet Response:
Press: **FILE OPTIONS**		**LCD:** Shows Function Choices
Press: **F3 –** SAVE		**LCD:** Asks Enter File Number
Respond “181” on Keypad & Press **ENTER** (Lab 18 File 1)		**LCD:** Shows saving data & Asks SELECT a FUNCTION (Choose what to do next)

Once the pure water file is saved, weigh your clean, dry test tube, standing in a small beaker, to the milligram. Add about 20 mL deionized water to the tube, and reweigh. Finally, add approximately 2.0 grams of an unknown, and reweigh. All masses should be recorded. Completely dissolve the unknown. Stirring with the stirring wire might be helpful. Check to be sure the temperature of your ice bath is about at or below −10°C. If not, decant some water and add more ice and/or salt to lower its temperature.

Lower the test tube into the ice bath, insert the temperature probe, press **DISPLAY** to return to the temperature measurement screen, *begin stirring* and when the temperature gets to about 4 ºC press **START/STOP** to take the time–temperature data as before. Take readings until the mixture is solid or freezing and the temperature has remained constant for several minutes. Be sure you have enough ice and salt in your cold bath before you begin this run. You may press **START/STOP** to stop taking data before 800 seconds or the MeasureNet station will stop and beep when it reaches 800 seconds.

MeasureNet Task: Save the Data File

Your Actions:		MeasureNet Response:
Press: **FILE OPTIONS**		**LCD:** Shows Function Choices
Press: **F3 –** SAVE		**LCD:** Asks Enter File Number
Respond "182" on Keypad & Press **ENTER** (Lab 18 File 2)		**LCD:** Shows saving data & Asks SELECT a FUNCTION (Choose what to do next)

After saving the file, melt the frozen mixture and clean the tube and repeat this procedure for the other two unknowns. Each time use approximately 2 grams of the unknown. Once the data has been recorded for the unknowns save them as file **"183"** (lab 18 file 3) and **"184"** (lab 18 file 4). Now you should have recorded the freezing curves for pure water and the three unknowns.

3.0 MeasureNet Data Entries

Once you have completed the freezing curve for unknowns and saved the data files, you should save the mass data in a manual entry file.

MeasureNet Task: Manual Data Entry

Your Actions:		MeasureNet Response:
Press: **MAIN MENU**		**LCD:** Shows Function Choices
Press: **F7 –** OTHER		**LCD:** Shows More Function Choices
Press: **F3 –** MANUAL ENTRY		**LCD:** Shows 2 columns for data
Use Keypad and **ENTER** key to enter data in columns		**LCD:** Shows Data as Entered

Enter values for the Unknown ID #, unknown molar mass (from the bottle), mass of the tube, mass of the tube & water and the mass of the tube & water & unknown. Enter all the data for the three unknowns in a single column leaving the second column blank. Make sure you enter the unknowns in the same order as their freezing curves so you can match the data. Finally, save this file as **"185"** using the save procedure above.

4.0 Before You Leave

The unknowns may be washed down the sink. Clean your tube and empty the ice bath as directed. Wipe down your work area and you can be on your way.

5.0 Calculations and Spreadsheet

When you get the master file **"Lab18ColligativeProp.csv"** all of the data for your station will be included so you can easily use the "XY Scatter" plot type to graph each freezing curve. For each sample find the ΔT value for the freezing point determination. For each unknown's mass data calculate the solution molality using molar masses that were given on the bottle for each unknown. Using these molality values calculate the expected ΔT value for each unknown. Water has a K_f = 1.86 °C/m.

When you have the calculated ΔT values use them and your experimental values to calculate a van't Hoff constant for each of the unknowns. Once you have determined the constants predict how many ions or particles are in each of the unknown formulas.

6.0 Report Sheet

Data for Unknown freezing point determinations:

Unknown ID	1	2	3
Mass tube			
Mass tube & H_2O			
Mass tube & H_2O & unk			

Final Results

Unknown	1	2	3
Mass of unknown			
Mass of H_2O			
Molality of unknown			
ΔT calc			
ΔT (graph)			
van't Hoff factor			
Predicted ion number			