Determination of Molar Mass by Freezing Point Depression

Freezing point depression is one of the colligative properties, properties that depend on the concentration (number of particles) and not the identity of a solute. One of the uses of colligative properties is to determine the molar mass of an unknown substance. We will use freezing point depression to do this.

Materials:

Two insulated cups
One wire mesh screen
One liquid unknown
One solid unknown
Ice

Equation:

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

Step One: Accurately determine the freezing point of water (K_f = 1.86).

Weigh two empty insulated cups on an analytical balance and label cup one and cup two. Prepare a mixture of water and ice in **cup one** using deionized water. Use a lot of ice so that it doesn't all melt even after stirring for a few minutes. In fact it is important that there always be some ice present in the mixture during this entire experiment. The mixture should occupy about ½ to ¾ of the cup's volume. Stir this ice water mixture very well and record the lowest temperature you observe. This is necessary to properly calibrate your thermometer. While the freezing point of water is well established at 0.0 °C a thermometer may not be calibrated precisely. Record this value in your laboratory notebook.

Step Two: Liquid unknown

We will begin with an assumption that the molar mass of the liquid unknown is somewhere around 50g/mole. Determine approximately how many grams of unknown liquid you will need to add to 100 grams of water to end up with a 2 molal solution. This is a theoretical calculation based on an approximation that there is about 100 grams of water in the cup. Do this calculation in your laboratory notebook.

Determine the mass of your **cup one + ice + water** mixture used in step one on the **analytical balance**. Carefully add the amount of liquid unknown to the ice + water mixture that you estimated in the previous calculation. Add this liquid carefully by pouring it down a clean glass rod. Record the mass of this ice + water + liquid unknown mixture. Gently stir and record the lowest temperature observed. You should be able to observe a freezing point depression of at least 4 degrees Celsius. If you don't see this much decrease in the freezing point add more unknown liquid. As soon as you have observed a decrease in the freezing point of 4 degrees or greater record this temperature and the mass of cup one + water + ice + unknown liquid. Quickly

pour the mixture through a screen **cup two** to separate the ice and determine the mass of the water + unknown liquid + cup two. You now have all the data you need for **trial one**. Do **NOT** throw your solution away yet. It will be used in the next step!

For **trial two** you will begin with the mixture you just weighed in cup two. Add some more ice and water to this mixture. The amount of water and ice added doesn't matter as long as there is ice visible and the cup isn't over flowing. This additional water will decrease the molality of the solution. Measure the freezing point again. As before, pour the mixture through a **screen back into cup one**. Determine the mass of the water + unknown liquid + cup one. This data will be used for **trial two**. This solution is more dilute so the freezing point should not be as low at the one observed for trial one. Finish this experiment by calculating the average molar mass of your unknown liquid.

Step Three: Unknown solid

Rinse and dry your two cups. Rinse and dry your screen. You will use them again. You do not need to weigh them as you already did this in Step One. The same procedure will be used with the unknown solid but with one important change. The solid will be dissolved into a small amount of water to make an unknown "liquid". Use approximately the same mass of solid as the mass of unknown liquid you used in Step Two. Use the analytical balance to determine the exact mass of the solid in a clean small beaker. Add deionized water to the solid until it dissolves (about 20 grams should be enough). Determine the mass of the solid + water + beaker. This is important because the amount of water you use to dissolve the solid needs to be included in the total mass of the solvent. You now have a "liquid" unknown. Begin with a fresh ice + water mixture in cup one and follow the same steps as before. When you have completed the procedure you will have data for two trials.

Report

Report your average molar mass for your unknown liquid. You will then be given the identity of your unknown liquid. Calculate the percent error and report it.

Report your average molar mass for your unknown solid. Assume that i=1 for this calculation. You will then be given the identity of your unknown solid and the theoretical value of *i* for your unknown. Use this information to determine the molar mass and the percent error in your determination.