Chemistry 150

Please have the following pages ready **before** class on Wednesday, February 14. As usual, please write an **abstract** and **paper-clip** it to the front of your individual writeup. The abstract and the carbon-copy pages of the write-up is due in class on **Wednesday, February 28.**

This lab takes advantage of the fact that **colligative properties** of solutions depend only on the number of moles of solute in a solution and not the nature of the solute. This enables us to determine the number of moles of an unknown material and thus determine its molar mass.

The temperature difference between the freezing point of a pure solvent and a solution made with that solvent is proportional to the concentration of solute. The units of concentration used in this experiment are moles of solute per kg of solvent also called **molality**. By not having a volume term in the concentration expression we avoid any problems that might arise with volume changes caused by changes in temperature.

In brief terms, the experiment works like this: You melt a pure material then allow it to cool and solidify while recording its temperature. This gives you its freezing point. Next you add a known mass of an **unknown material** (and, in this lab, you will have a choice of one of three unknowns) to the pure material and make a solution. Again you allow it to cool and record its temperature. The difference in freezing points of the pure material and the solution is directly proportional to the number of moles of solute in the solution. You don't know what the solute is but you do know its mass, and from your experiment, the number of moles. Thus you know its molar mass, in principle.

To be sure, you add some more of the unknown material (a measured mass, of course) to the remelted solution and, once again, you allow it to cool and record its freezing point.

The change in freezing points and the concentration in molality (symbolized by $\underline{m}$)are related by the following equation:

$$\Delta T_f = K_f \underline{m}$$

K_f is called the **freezing point depression constant**, and it is constant for a given solvent. Once this is known for a given solvent that solvent can be used as a measuring tool to determine molar mass. We will use the value of $K_f = 8.40°C/\underline{m}$ for t-butanol.

In order to simplify the experiment you will be given the freezing point depression constant for your solvent. You could determine it on your own but it is difficult to get accurate results from this experiment and it is bad enough using just one set of lousy data. The solvent used in this experiment is **tertiary butyl alcohol** also called tert-butanol or t-butanol or 2-methyl-2-propanol. It has a freezing point close to room temperature and is relatively safe and odor free in comparison to naphthalene, which is traditionally used in this type of experiment.

Section 11.7 of the text will be quite helpful in preparing for this experiment.

Oh, and one other complication: you are going to write up the **procedure** as you do the experiment. Exercise 6 and your own observation skills will be invaluable as you write down the steps as you perform them.

Lab 4: Determination of molar mass by freezing point depression

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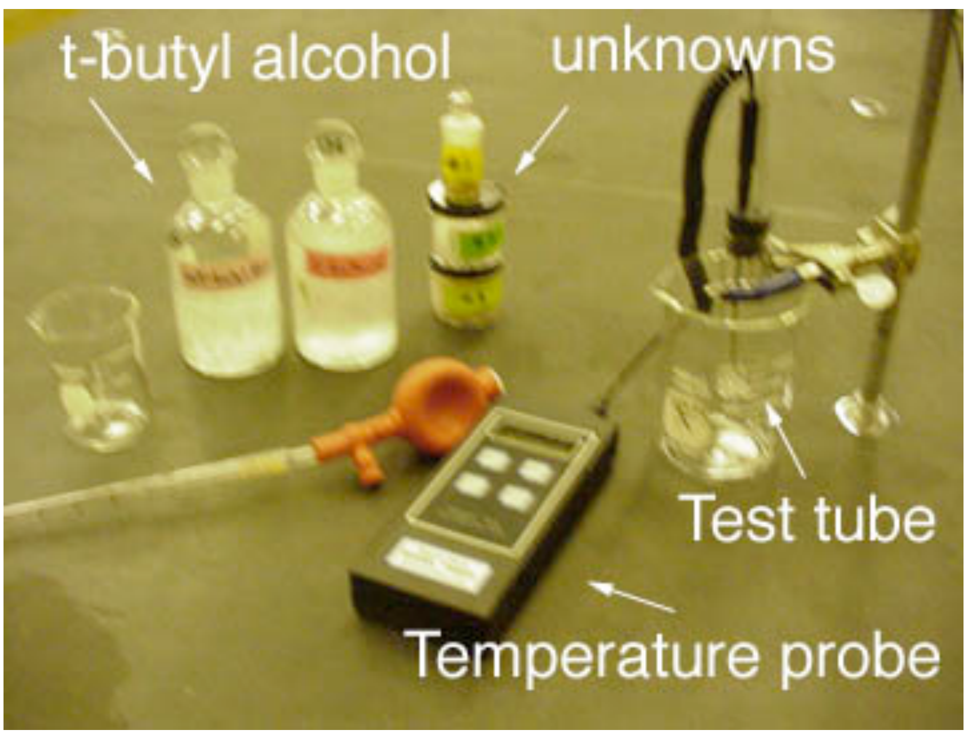
Part 1. Purpose

This should be fairly evident from the preceding introduction. Summarize it into a sentence.

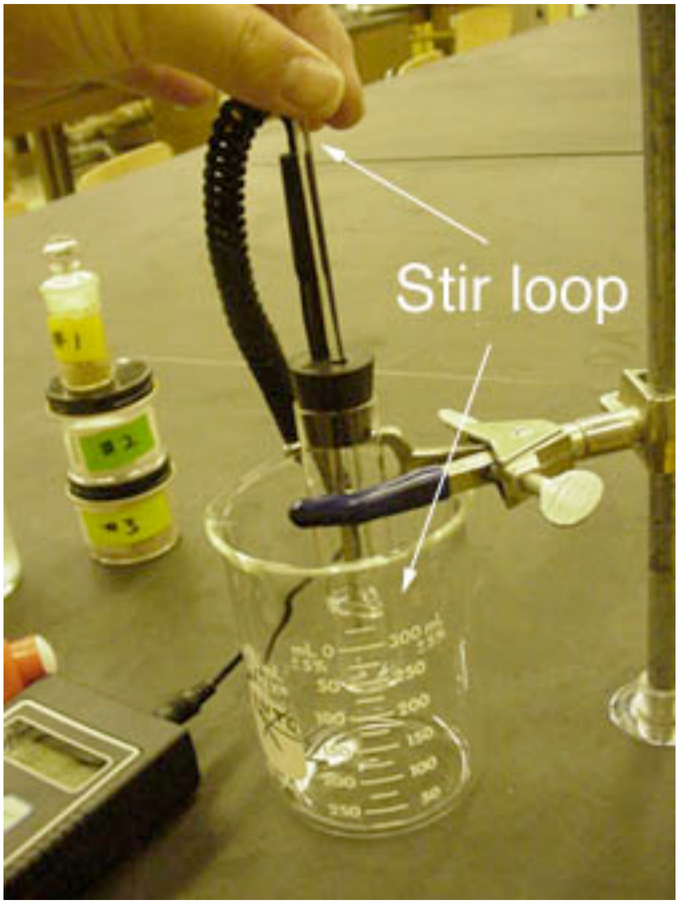
Part 2. Materials and methods

Chemicals list: t-butanol and 3 unknown organic substances

Sketch and label the various pieces of equipment. This picture may be helpful, though you will be using the LabPro datalogger and temperature probe connected to the laptop, rather than a stand-alone probe. Note that the beaker will be full of ice water. It isn't in the photo, so that you could see what was inside.



Here's a close-up view of the test tube:



You don't have to stir vigorously, but you do want to make sure that the solution or solvent is of uniform temperature throughout the tube (crystals will of course begin to form at the test tube walls otherwise).

Part 3. Procedure

Using exercise 6 to guide you, write down every single thing you do during this lab in a series of numbered steps. Notice that you should use the past tense as you write these steps down. Explicitly state the criterion you used to determine that you had "enough" data.

Safety issues: t-butanol and some of the unknowns are quite pungent. If you get any material on yourself, **immediately** wash it off with soap and water.

Waste disposal: All materials in this lab are to be treated as organic waste; nothing should go down the sink. Please use the beakers in the hoods to get rid of waste.

Part 4. Original data and preliminary analysis

You should be able to figure out (from exercise 6, if nothing else) what data you need to collect. Of course, you should write down unknown numbers, unknown identities, and freezing point depression constants in this section. Table format is necessary to keep the different trials organized.

Part 5. Calculated results

Show the molar mass determination calculation for your unknown solute, from the freezing point depression all the way to the molar mass.

Plot the time (x-axis) versus temperature (y-axis) data in order to obtain the freezing points; you may do it by hand, by Excel or by printing out the graph from LabPro. These graphs are called **cooling curves**. Do separate graphs (or overlays) for each freezing point. you will show the solution freezing points by adding the necessary lines by hand (see exercise 6).

Part 6. Group results

Write your group's solute mass and temperature change for each trial on the overhead (cluster these with the other groups using the same unknown solute).

Plot solute mass (x-axis) versus temperature change (y-axis). Clearly title the graph and label the axes (complete with units). Calculate a best-fit line equation (you may draw the line if you wish) and a correlation coefficient. Note: you must have at least five points on the graph for these calculations to be meaningful.

Calculate the mean and standard deviation (do the usual outlier analysis) of the molar masses for all groups that used your unknown (you do not need to include the data of the groups who did not use your unknown).

Comment on outliers, if any, including your own value.

Part 7. Questions

1. a. Explain why it is the freezing point depression of a solvent **does not** depend on the identity of the solute.

b. Explain why it is the freezing point depression of a solvent **does** depend on the concentration of the solute.

You may combine a and b into a single answer.

2. Occasionally, a phenomenon called **supercooling** occurs in the cooling curve. Given its name, explain how you recognize supercooling when it occurs on the cooling curve. Did this happen in your case? Would supercooling make determining the freezing point easier or more difficult? What can you do about it, then?

3. Calculate the **percent error** between your calculated molar mass and the actual molar mass. Did you have a **systematic** error? If so, name its most likely source.

4. In the plot of solute mass versus temperature change, what quantity is proportional the slope of the best-fit line? In principle, then, what should the correlation coefficient have been?

5. Calculate how much your molar mass would have changed if your freezing temperature was off by 0.5°C. Do the calculation for both 0.5°C higher than you obtained and 0.5°C lower than you obtained. Was it worthwhile to use the digital thermometers, which have an uncertainty of 0.1°C, rather than the alcohol thermometers, which have an uncertainty of 0.5°C, in terms of precision of the final number?

Part 8. Conclusion

First sentence: "The average molar mass of ("unknown identity") was __________ g/mol, determined by the freezing point depression of t-butanol."

Explain how much percent error you had off of the actual molar mass (question 3) and whether you had a systematic error or not. Suggest methods to minimize the systematic error.

How confident are you of your results? In other words, was this a good experimental setup? Question 5 may help here. If your results were not very good, suggest (beyond fixing the systematic errors) other changes that might result in better numbers.

Abstract

In the standard abstract format and in a hundred words or less, state the overall class result for your unknown, and the experimental method by which that value was obtained. Assess the accuracy (% error off the true value) and the precision (the standard deviation) of the result and what sources of error may have affected each.