

Experiment 1

23 January 2020

Colligative Properties

*Our first
experiment!
Woo-hoo!*

*So, what exactly is a
colligative property, you
may ask. We will find
out today!*

*Colligative... it just sort of
rolls off the tongue... Try
it. Try using it in polite
conversation.*



Objective: To learn how colligative properties affect the rate of evaporation.

Today's experiment is not in the lab manual. Everything you need to know is in this presentation.

In this experiment we will see that the rate of evaporation is lower for solutions that have a dissolved solute. The more solute, the lower the rate of evaporation.

Overview:

1. Colligative properties, vapor pressure lowering and rate of evaporation
2. How to use these pre-lab presentations.
3. Calculation Activity
4. Lab Procedure Activity
5. Your lab report

We will be gathering qualitative, empirical information about solutions. Anybody know what evaporation has to do with vapor pressure?

Info for
Introduction

1. How to use these pre-lab presentations.

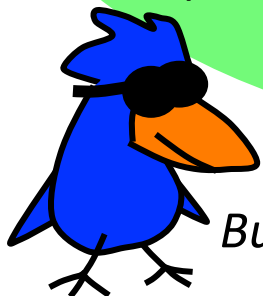
Format of each experiment in the lab manual:

1. Background (or Introduction)
2. Procedure
3. Calculations, Analysis, etc.

Before we get started with Experiment 1, let's buzz a bit about the lab manual and these presentations. Each experiment in the lab manual has three parts as you see in this box. Our pre-lab presentations do the same. We try to provide a simple, more concise alternative to the first section (Background). If this works for you, you can skip the Background section in the lab manual.

Most of the time, we follow the Procedure from the lab manual.

And finally, we take you through the calculations and you should follow along with what we are doing.



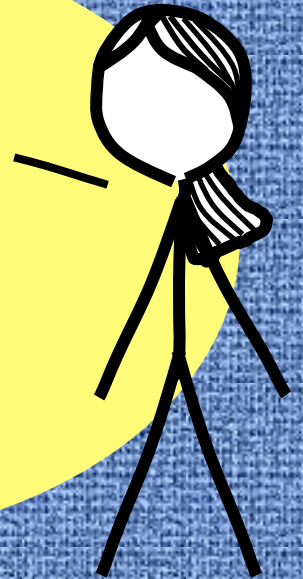
Buzz. Buzz.

1. How to use these pre-lab presentations.



*Each week, we introduce you to the experiment and this should help you write the **Introduction** before coming to lab.*

Slide 2 always lists the objectives. Some of these are the talking points for your Introduction.



Info for Introduction

Looking back to Slide 2 – you can see that we should mention something about vapor pressure lowering and rates of evaporation. Also something about each of the three experiments we will do. As you flip through the presentation, look for these bright yellow signs for more info for your Introduction.

Uh-huh.



1. How to use these pre-lab presentations.

These presentations introduce you to the experiment, so you can usually skip the Background/Introduction section from the lab manual and go straight to the Procedure (once we are in lab). These presentations are tailored to go with Dr Mattson's lectures, using the same vocabulary and approaches you've seen in lecture.

The pre-lab presentations also provide an overview of the procedure followed each week, however, they lack the detail that the lab manual gives.

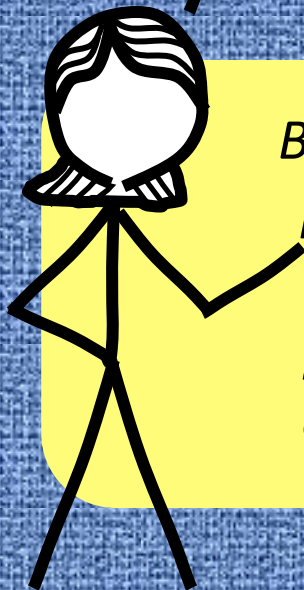
*So we generally follow the **Procedure** section in the lab manual carefully. Usually, word for word.*



1. How to use these pre-lab presentations.



These pre-lab presentations always walk you through the calculations in a way that is easy to follow. (The lab manual expects you will refer back to the lab manual's introduction for this.)



Bring your laptop and have this presentation available during lab. So when it's time to perform the calculations, you can refer to the presentation.

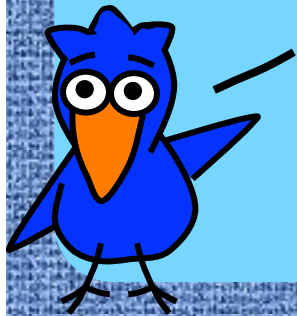


Not every lab will have calculations, but they all have some sort of analysis of how things went.



Let's go!

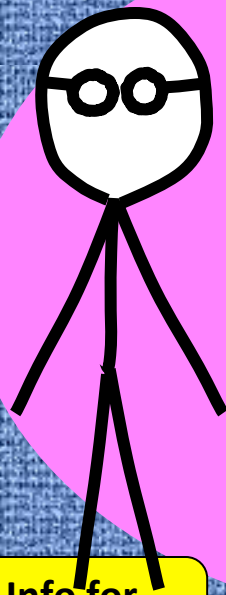
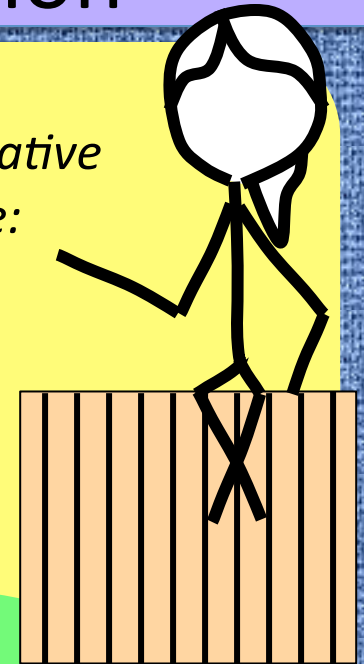
2. Colligative properties, vapor pressure lowering and rate of evaporation



We have been studying colligative properties in class. They all pertain to solutions.

There are four types of colligative properties in all. They are:

- Vapor pressure lowering
- Freezing point lowering
- Boiling point elevation and
- Osmotic Pressure



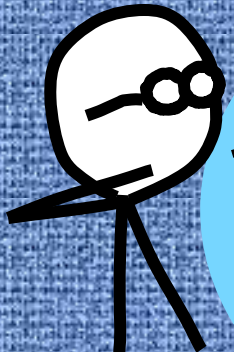
In this experiment we will study the first one – vapor pressure lowering – without actually measuring any vapor pressures.




If a solution has a lower vapor pressure, that means that the intermolecular forces within the solution are stronger and it is harder for the solvent to evaporate. For solutions, this includes the interactions between solvent and solute

Info for
Introduction


2. Colligative properties, vapor pressure lowering and rate of evaporation



Wait. Soooo, if it is harder for the solution to evaporate, molecules will do so more slowly and this will cause a smaller change in temperature?



Yup. It takes a lot of energy to evaporate. We call it ΔH_{vap} . Slow evaporation means the water molecules are interacting strongly with the solute. It takes more energy to break all of those forces – which is what happens when a liquid evaporates.



So lower vapor pressure means larger intermolecular forces. And slower evaporation. And the solution doesn't get as cold.



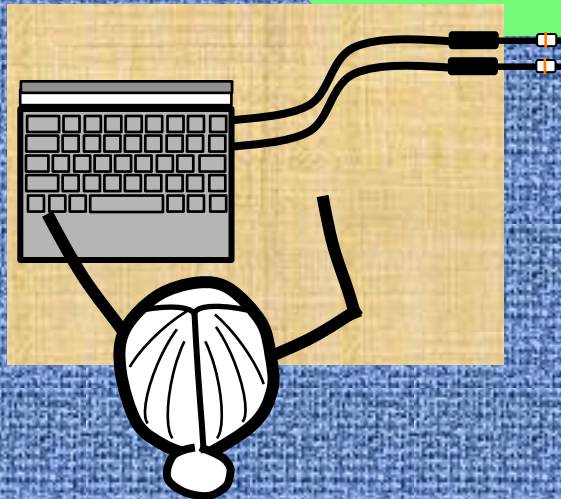
Mercy!

Info for
Introduction

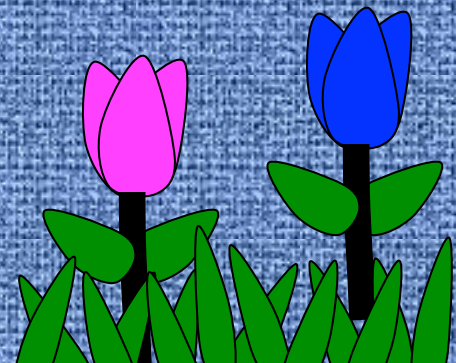
2. Colligative properties, vapor pressure lowering and rate of evaporation

There are two parts to the experiment today. One involves calculations and the other involves using two temperature probes at the same time – like you see me doing below.

You can do these parts in either order. Decide which pair at your station will use the probes first. That pair should go to Slide 16 for the procedure and come back to Slide 10 when you are done. The calculation peeps continue on to the next slide.



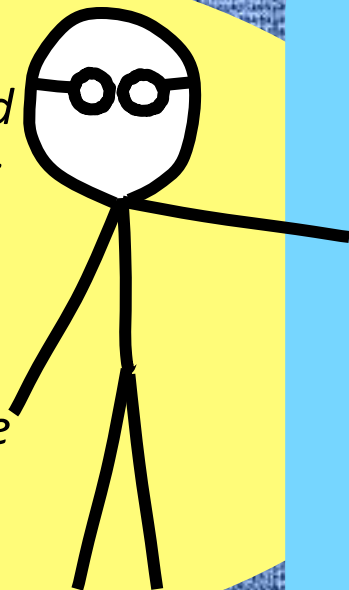
Uh huh.



3. Calculation Activity

15°??? Brrrrr. I'm kind of a warm weather bird.

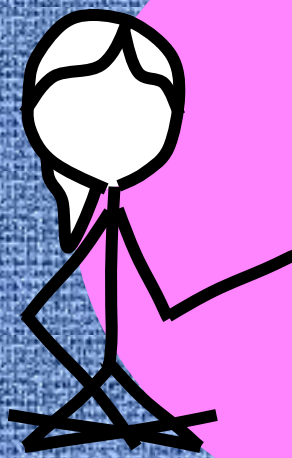
Perfect! Let's get started on the calculations! This table gives the vapor pressure of pure water, P_{water} , at the various temperatures likely to be encountered in lab.



Temperature	P_{water}
15 °C	12.8 mmHg
16	13.6
17	14.5
18	15.5
19	16.5
20	17.5
21	18.7
22	19.8
23	21.1
24	22.4
25	23.8



If we add some non-volatile solute to the water, the vapor pressure will be lowered. The more we add, the lower the vapor pressure drops.



You will use this chart to look up the vapor pressure for pure water later on in lab today when you use LoggerPro.



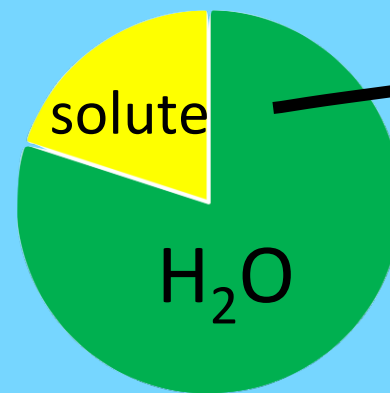
3. Calculation Activity

This formula for vapor pressure lowering tells us that solutions have lower vapor pressures than pure solvents. The X in the equation is the mole fraction of water. Yes, water.

Similar expressions exist for all solvents, not just water. Today we are using water, so all of our discussion will pertain to water.

$$P_{\text{sol'n}} = X_{\text{water}} P_{\text{water}}$$

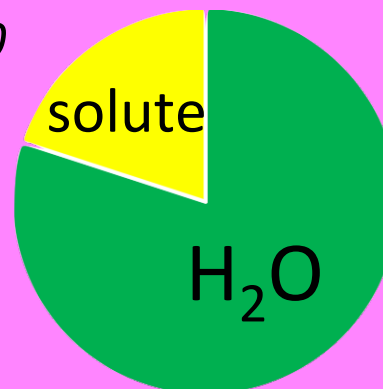
Suppose a solution consists of 4.00 mol water for every 1.00 mol particles. The mole fraction of water would be $4.0 / (4.0 + 1.0)$ or 0.800. Mole fractions are like pies – the pieces add up to 1.000. In this pie, water is the green part.



3. Calculation Activity



Continuing with this example, $X_{\text{water}} = 0.80$
and if the temperature is 20°C , the
normal vapor pressure for pure water,
 P_{water} is 17.8 mmHg.



$$P_{\text{sol'n}} = X_{\text{water}} P_{\text{water}}$$

$$P_{\text{sol'n}} = 0.800 \times 17.5 \text{ mmHg}$$

$$P_{\text{sol'n}} = 14.0 \text{ mmHg}$$

You try this: What is
the vapor pressure of a
solution of 50.0 g urea,
 $\text{CH}_4\text{N}_2\text{O}$, $\text{MM} = 60.0 \text{ g/mol}$
dissolved in 75 g
water at 290 K?



The lower vapor pressure is caused by
increased intermolecular forces between
the solvent and solute. This results in a
lower rate of evaporation.



Include
this work
in your
lab
report.

3. Calculation Activity

Things get a bit weird with solutions of ionic salts. When we figure out X_{water} , we have to consider the number of moles of particles.

$$X_{\text{water}} = \frac{n_{\text{water}}}{n_{\text{water}} + n_{\text{solute}} \times i}$$

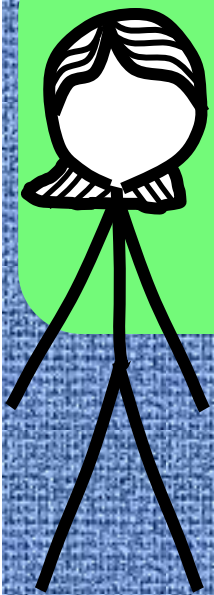

$$P_{\text{sol'n}} = X_{\text{water}} P_{\text{water}}$$

The moles of particles equals the moles of solute times the van Hoff factor, i . This factor expresses the number of particles created by a solute. Non-electrolytes like urea have $i = 1$. Salts with 1:1 ion ratios such as NaCl or NH_4NO_3 make two ions in solution so $i = 2$.

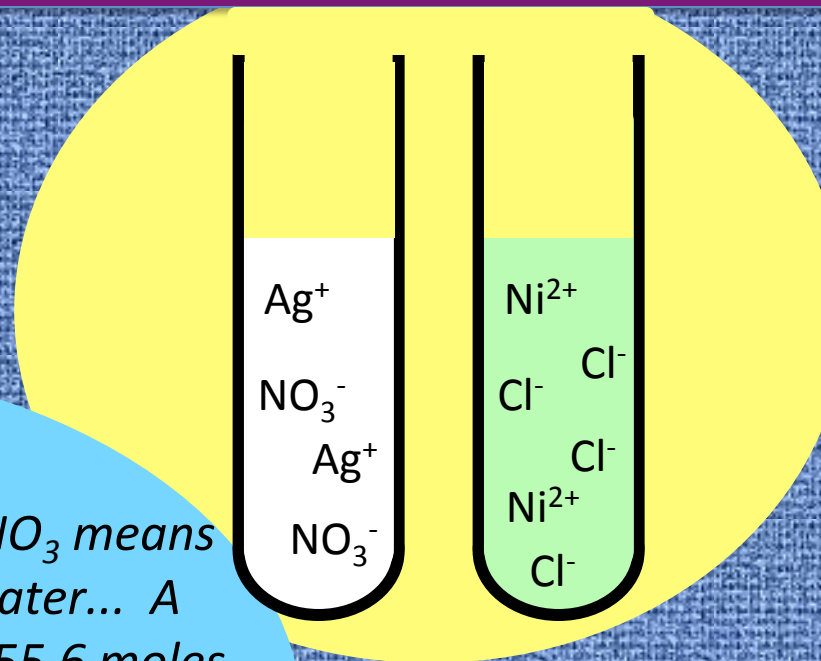
So, you remember that all ionics that dissolve dissociate 100% into ions in water. Right? Tell me you remember this.



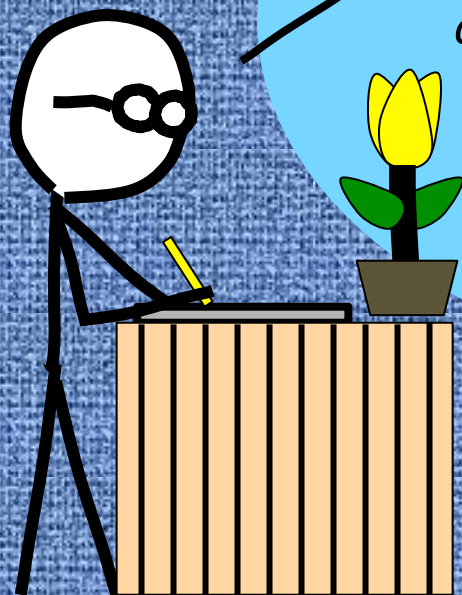
3. Calculation Activity



Let's try a calculation. Here is a question: What is the calculated vapor pressure of a 1.0 molal solution of $\text{AgNO}_3(\text{aq})$ at 19°C ?



Let's see... So 1.0 molal AgNO_3 means 1.0 mol AgNO_3 in 1.0 kg water... A thousand grams of water is 55.6 moles of water... We can't forget that $i = 2$ for this salt... Ok, that makes X_{water} equal to 0.965. Then $P_{\text{sol'n}} = 15.9 \text{ mmHg}$.

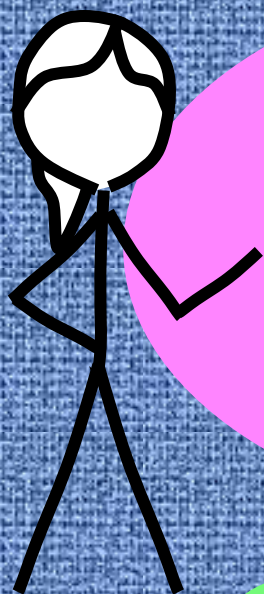


$$X_{\text{water}} = \frac{55.6}{55.6 + 1.0 \times 2} = 0.965$$

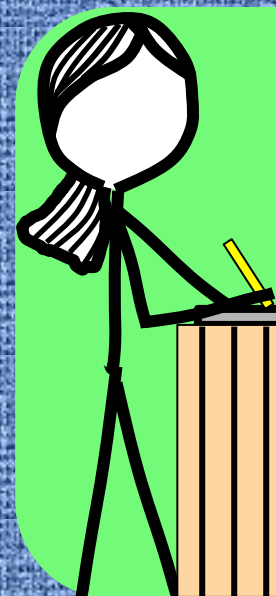
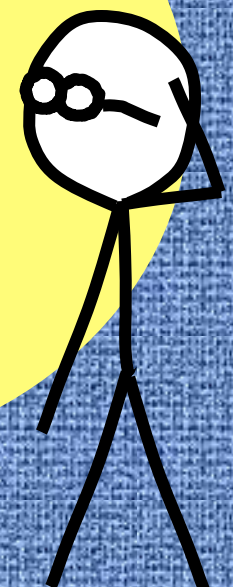
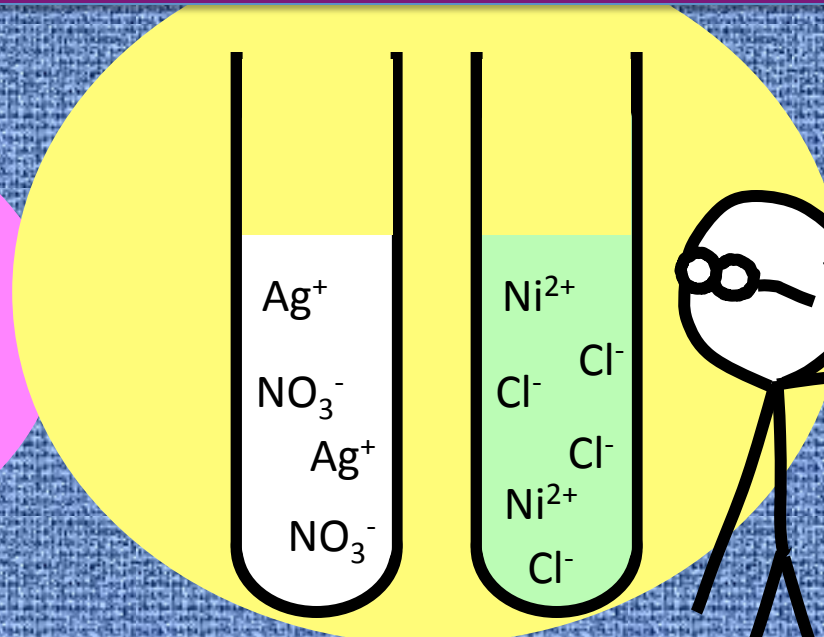
$$P_{\text{sol'n}} = 0.965 \times 16.5 \text{ mmHg} = 15.9 \text{ mmHg}$$



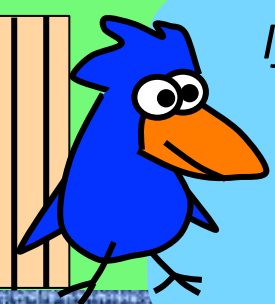
3. Calculation Activity



Now you try one. What is the calculated vapor pressure of a 2.40 molal solution of $\text{NiCl}_2(\text{aq})$ at 22 °C? Include this work in your lab report.



And this one, which is one of the solutions you will use (or already used) today: Calculate the vapor pressure of a 3.0 m $\text{NaCl}(\text{aq})$ solution at the measured temperature of your solution.



If you are doing the calcs first, you can ask others in lab who are doing the data collection what their initial temperature was – or just wait until you measure it yourself.

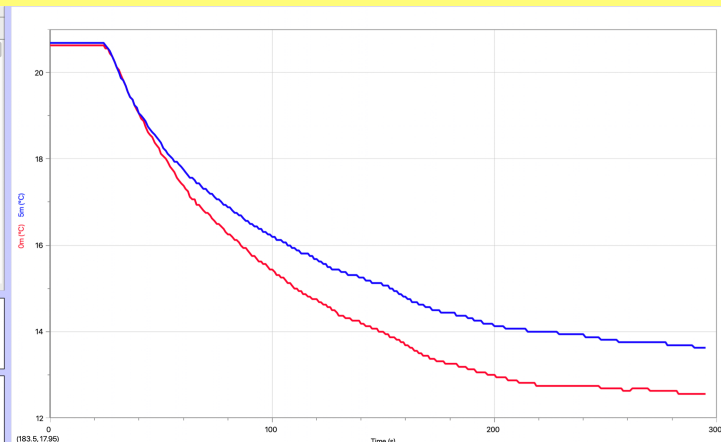
4. Lab Activity Procedure

Now we do the lab experiment!
In the first trial, we will simultaneously measure the temperatures associated with evaporation for pure water vs. 3.0 molal NaCl(aq). It should look something like this.

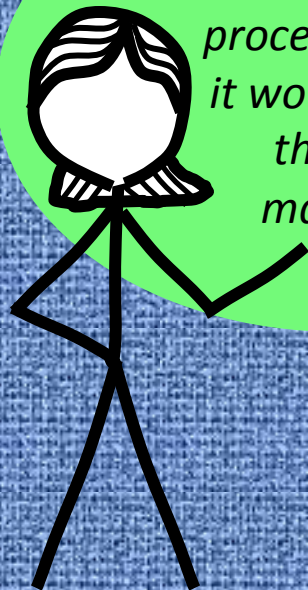


Time (s)	On (°C)	5m (°C)
1	0	20.6
2	1	20.6
3	2	20.6
4	3	20.6
5	4	20.6
6	5	20.6
7	6	20.6
8	7	20.6
9	8	20.6
10	9	20.6
11	10	20.6
12	11	20.6
13	12	20.6
14	13	20.6
15	14	20.6
16	15	20.6
17	16	20.6
18	17	20.6
19	18	20.6
20	19	20.6
21	20	20.6
22	21	20.6

water
3 m



Here is the procedure like it would be in the lab manual.



Step 1. Connect the two temperature probes to the two USB ports on your laptop and then start LoggerPro. Tell your TA or Dr M if the little green light is not on. The ambient temperature should be displayed on the screen.

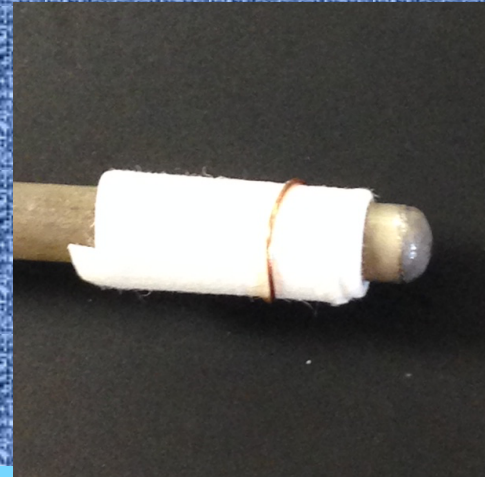
Step 2. Set up data collection in LoggerPro as follows:

- Under the Experiment menu, select Data Collection.
- Choose Time Based for mode.
- Enter **300 seconds** for duration and **1 second per sample**. Make sure that the Sample at Time Zero box is checked.
- Press Done.

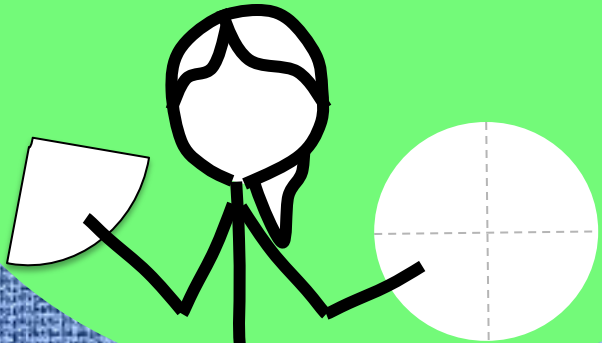
4. Lab Activity Procedure



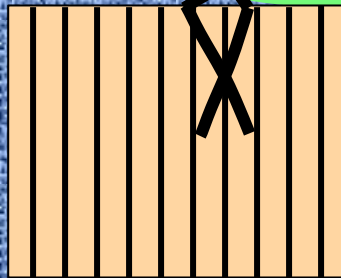
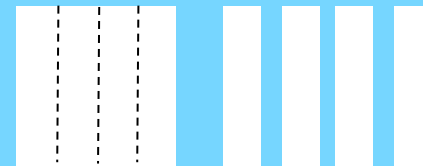
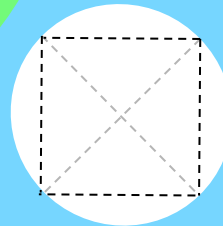
Controlling variables is hugely important. In this experiment, all of the filter paper strips must be the same size or the rate of evaporation will not be comparable.



Start with a filter paper circle and fold it into quarters. Unfold it and note the fold marks.



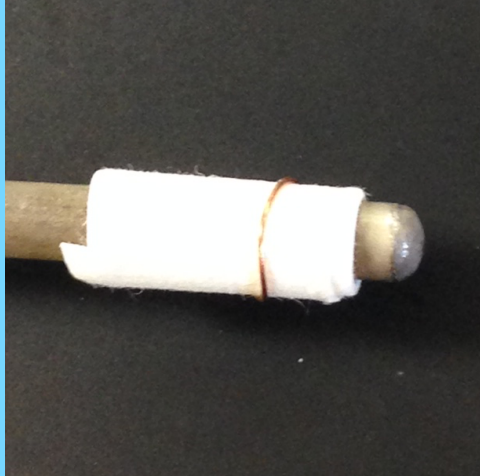
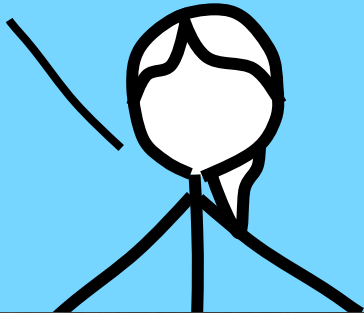
Then cut into a square using the fold mark ends to guide you, and then into four identical strips.



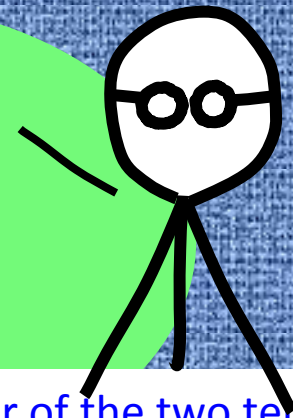
If you need holes punched all over, I can do that!

4. Lab Activity Procedure

Here is how each probe will look when wrapped with filter paper. Try to wrap both probes exactly alike. Use identical sizes of filter paper.



Now we continue on with the procedure like it would be in the lab manual.



Step 3. Wrap the last centimeter of the two temperature probes each with a strip of filter paper secured by a copper wire.

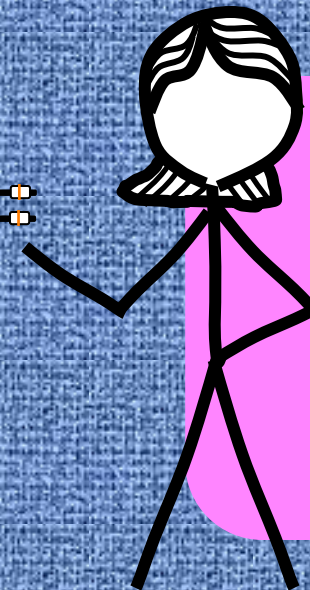
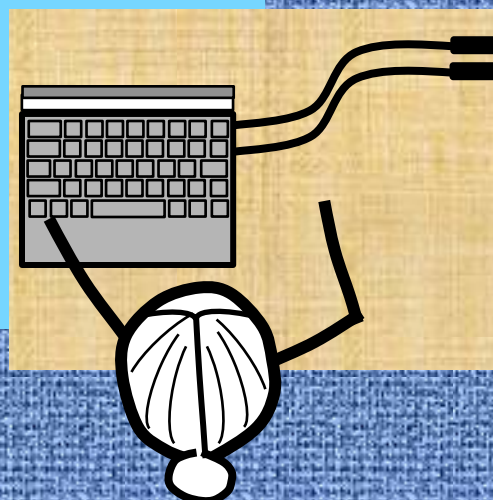
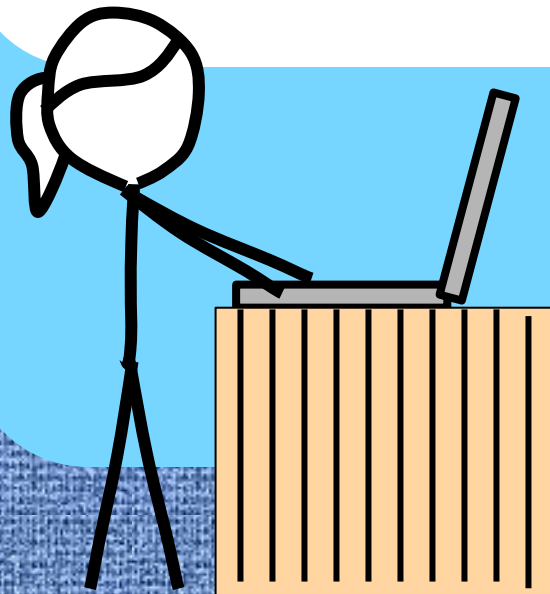
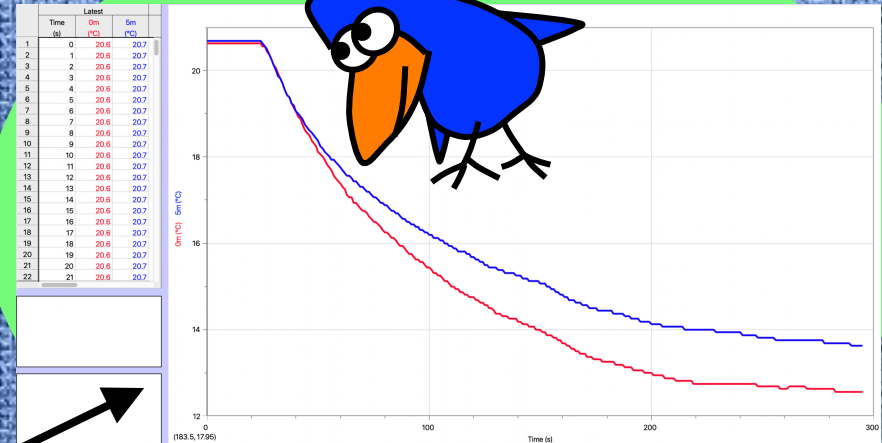
Step 4. Place one of the probes in the bottle of 3.0 *m* NaCl at your station and the other probe in a beaker of distilled water. Soak each for at least 30 seconds (until the filter paper has saturated, and the temperature stabilized). **Hold the bottles!** Make sure the solutions do not tip over.

Step 5. Do **not** remove the probes from the liquids in which they are soaking. Begin data collection by clicking *Collect* (the green arrow) along the top menu bar, or hitting the space bar. Temperature data will start collecting. Do this for about 15 seconds.

4. Lab Activity Procedure

Step 6. After ~15 seconds and a stable value for the initial temperature is evident with the nice flat line, simultaneously remove the two probes from the liquids and place them side-by-side on the edge of the table. Tape them to the edge of the table so that the stainless steel probe parts are not touching the table.

Step 7. Click the *Stop* button to end data collection, or it will stop after 300 s.



See how this minimizes variables? This is good experimental design.

4. Lab Activity Procedure

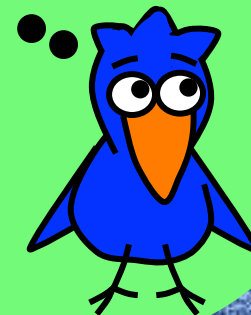
Step 8. To analyze your data, click the *Statistics* button in the toolbar at the top (or select *Statistics* from the *Analyze* menu) and record the maximum and minimum values in your table.

Step 9. Remove the filter paper and place it in the trash.

Step 10. Repeat the experiment with water vs. NaCl(aq) solution of unknown concentration. Use new pieces of filter paper each time.

Step 11. Repeat the experiment with 3 m NaCl(aq) vs. NaCl(aq) solution of unknown concentration. Use new pieces of filter paper.

Nothing.



Woo-hoo! That's it! You should have done three 300 s runs, one with 3 m NaCl vs. pure water another with the NaCl(aq) of unknown concentration vs. pure water, and a final one with 3 molal vs the unknown solution.

That's it for the procedure. Make sure you clean up everything. Now let's look at our graphs.

The procedure today was modified from Experiment 10 of our Chm 204 lab manual from last semester, edited by Dr Jess Gunn and produced by Dr Mark Freitag, both from Creighton Chemistry.

4. Lab Activity Procedure

These are typical cooling curves. Evaporation is endothermic so the temperature drops.

See where the temperature starts to drop? That is when the probes were removed from the liquids and evaporation started. This is $T_{initial}$.

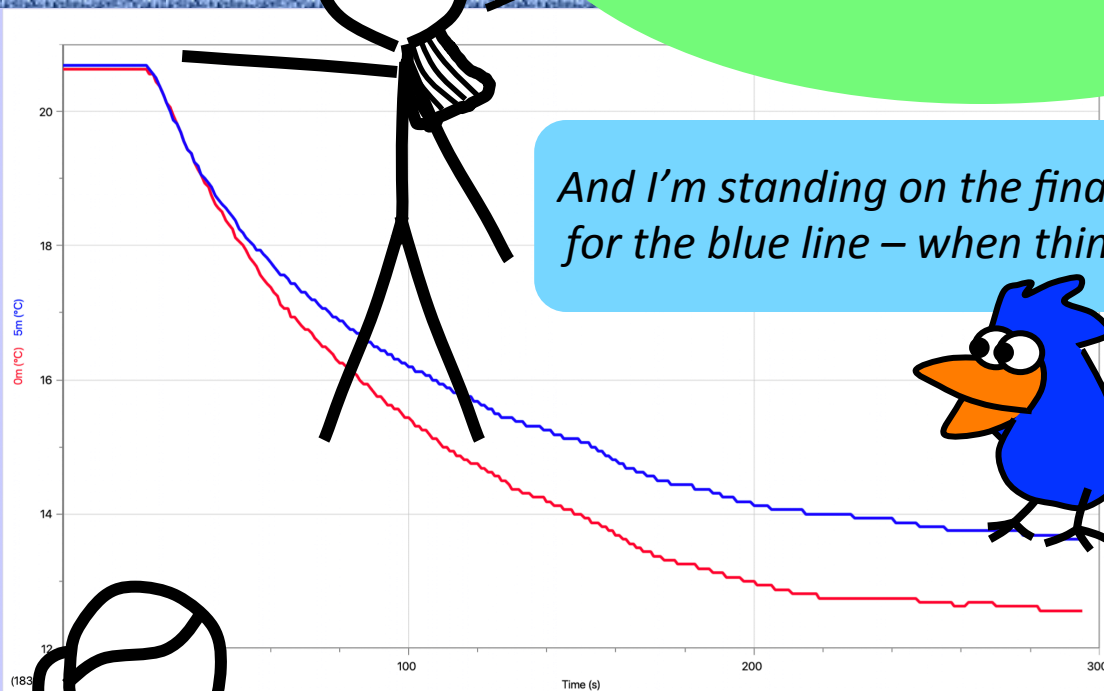
And I'm standing on the final temperature for the blue line – when things flatten off.

Is the blue line water or the NaCl solution? Calculate both ΔT values recalling that $\Delta T = T_{final} - T_{initial}$.

Time (s)	Latest		
	0m (°C)	5m (°C)	
1	0	20.6	20.7
2	1	20.6	20.7
3	2	20.6	20.7
4	3	20.6	20.7
6	4	20.6	20.7
7	5	20.6	20.7
8	6	20.6	20.7
10	7	20.6	20.7
11	8	20.6	20.7
12	9	20.6	20.7
13	10	20.6	20.7
14	11	20.6	20.7
15	12	20.6	20.7
16	13	20.6	20.7
17	14	20.6	20.7
18	15	20.6	20.7
19	16	20.6	20.7
20	17	20.6	20.7
21	18	20.6	20.7
22	19	20.6	20.7
	20	20.6	20.7
	21	20.6	20.7

water

3 m

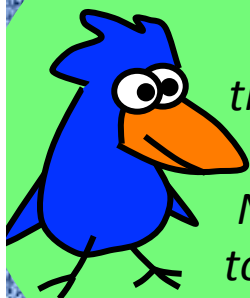


Special thanks to Lydia Johnson and Brooke Chambers for trying this experiment and producing the graphs used here.

5. Your lab report

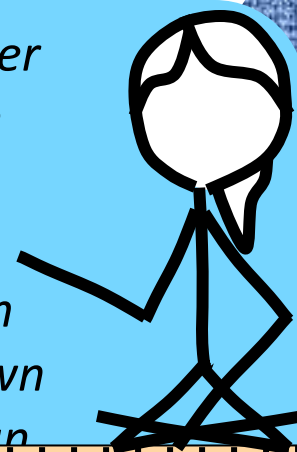


- ① First, the cover page with TA initials.
- ② Trim copy pages from your lab notebook stapled together.
- ③ Attach the graphs from the three experiments (on one page).
- ④ **On-line results** due at the end of class today. **Late submissions are not graded – see the syllabus.**
- ⑤ Turn in lab report **today** or **before** the start of class tomorrow. **Late labs may not be graded – see the syllabus.**



We do not need to dress for a mess for this experiment or for Experiment 2. Next week we return to the lab manual and learn more about Beer's law.

In your discussion, include all of your earlier calculations regarding your 3 m solution and what you calculated for the vapor pressure of that solution. Discuss the temperature curve for water vs. your 3 m solution. Also discuss whether the unknown NaCl solution was more concentrated than 3 m or less concentrated.



Stick people inspired by xkcd cartoons by Randall Munroe (www.xkcd.com)

Chem Lab with the Stick People and Bird was created and produced by Dr. Bruce Mattson, Creighton Chemistry. Enjoy it and share it if you wish.