Freezing of Water and Solutions

To survive in (literally) freezing water, Arctic fish produce “antifreeze proteins.” Such materials that lower the freezing point of water are being studied for use in cryopreservation of organs and tissues.[1]
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Introduction

Water is such a common substance that we sometimes forget how interesting it can be. It is one of only a few known substances that is denser as a liquid than as a solid. Have you thought much about the fact that water expands when it freezes? Obviously, this can have bad consequences for pipes and car radiators, which leads us to another interesting fact about water. Did you ever notice that hot water pipes sometimes freeze before cold water pipes? This is because dissolved air in the water acts as an insulator. Less gas can remain dissolved in hot water, so when the water in your hot-water pipes cools down to the same temperature as the water in your cold-water pipes, it is less insulated from dissolved air, and freezes first. It also forms denser ice than the unheated water. This is a good reason to remember to winterize your car’s radiator!

Because water makes up a large portion of the mass of most cells, expansion from freezing can be destructive to living things, as well. Some insects, plants, and animals have developed unique ways of dealing with this potential problem. Go to the sites listed below and discover the interesting applications their adaptations may provide for humans in the future.

Antifreeze proteins in fish may impact human agriculture:


Antifreeze proteins in carrots:

http://www.york.ac.uk/admin/presspr/pressreleases/antifree.htm

Antifreeze in insects:

http://www.technologyreview.com/articles/00/11/prototype11100.asp
**Safety:** Goggles must be worn at all times.

**Ethylene glycol is toxic!** Health hazards (acute and chronic): Moderately toxic by ingestion. Mildly toxic by subcutaneous routes (i.e. under the skin). An experimental carcinogen, tumorigen (tumor-causing) and teratogen (if ingested, etc., during pregnancy, it is capable of causing birth defects). Eye and skin irritant. Targets kidneys, liver, and central nervous system. Use good laboratory techniques to avoid spills and splashes.

**Methanol is toxic and highly flammable!** There should be no open flames in the laboratory during this experiment.

**Pre-lab Assignment:** Please write out the following in your lab notebook. This assignment must be completed before the beginning of lab. You will not be allowed to start the experiment until this assignment has been completed and accepted by your TA.

1) List all of the chemicals you will use for this week’s experiment. For each chemical, list specific safety precaution(s) that must be followed. In order to find specific safety information, please obtain a Materials Safety Data Sheet (MSDS) on the chemical of interest. MSDSs can be found through an internet search (e.g., Google) or from the following website: www.hazard.com Read the MSDS and find specific safety concerns for each chemical.

2) A thought experiment: you’re really bored, so you’ve decided to melt a few things that you found in your kitchen. Placing a pan on a hot burner, you start with an ice cube. Then, after drying the pan, you decide to try table sugar, and finally move on to table salt. Being a good observer, you notice some differences in the behavior of these items. Surf the internet (some suggested sites are linked to this page; be creative) and discover what it reveals about the melting behavior of these substances. Record any structural information that could be used to account for the differences you “observed” in this virtual pre-lab.


http://www.madsci.org/posts/archives/dec98/913733647.Ph.r.html

http://www.chemguide.co.uk/atoms/structures/ionicstruct.html

http://www.webelements.com/compounds/sodium/sodium_chloride.html

In addition to these pre-lab requirements, a short quiz may be given at the beginning of lab based on the material in this lab write-up.
Procedure

Part 1 – Freezing Curve and Melting Curve for Pure Water

1. Obtain a 400 mL beaker in which to make an ice/water/salt bath, along with a test tube to serve as your freezing vessel. Place a small amount of water in the test tube (about 5 mL) and clamp the test tube firmly in place. Into the 400 mL beaker place 25 mL or less of water, and add approximately a cup of crushed ice and ~5 heaping spoonfuls of salt to produce your ice bath. You will be using the temperature probe to examine the freezing point of pure water (and of several solutions).

2. Prepare your computer for data collection by opening “Exp 02” from the Chemistry with Vernier Experiment folder in Logger Pro.

3. When you are ready to begin data collection, click “Collect” and lower your test tube into the ice-water bath. Stir the water gently in the test tube for the first ten minutes, and then let it freeze into the ice without moving it for the final five minutes. (Data collection will automatically stop after 15 minutes.) Determine the freezing point of water from your graph.

4. You can select any portion of your graph by pointing at a desired spot, holding the mouse button down and dragging across the part of the graph you wish to examine in more detail. For water, you can move the mouse pointer to the beginning of the flat part of your graph, depress the mouse button and select the entire phase change region. The mean temperature for this portion of the graph will be displayed in the statistics box if you click on the STAT button. This is the freezing temperature of the water.

5. Now, raise the test tube so that it does not touch the water bath; do not move the probe during this portion of the experiment. Click “Collect” to begin new data collection. After 12 minutes, lower the test tube into a beaker of warm water for the final 3 minutes of the run. From this graph, can you determine the melting point of ice?

6. Repeat the freezing of water once more. Does the second freezing point determination agree with the first?
Part 2 - Freezing Curves for Aqueous Solutions

1. Now that you've had some practice in making freezing and melting curves, add a small amount (~ 0.5 g) of sodium chloride to the water in the test tube. Be sure to get accurate masses for the salt and the water (use 5 g of water, which is ~ 5 mL) in the test tube using the electronic balance. Determine the freezing point of the solution. What effect does sodium chloride have on the freezing point of water?

2. What effect does adding ~0.5 g of ethylene glycol to ~5 g of water have on the freezing point of water? (Note: both ethylene glycol and water should be accurately weighed.) Collect the ethylene glycol solution as directed by your TA when finished with it.

3. Repeat using ~0.5 g of methyl alcohol in ~5 g of water.

What differences in the freezing points did you observe with the salt, ethylene glycol, and methyl alcohol solutions? Compare the freezing points of these solutions on a (g solute/g solvent) and a (mole solute/g solvent) basis. This should be done graphically—and described in the text that accompanies the graph—in the Results section of your report. Speculate about the cause of these differences (in the Discussion section of your report.)

Reference(s)

A brief, individually prepared report *approximately* 2-3 pages in length is due at the beginning of next week’s lab period. It is a **full** report, consisting of **All Sections.** You have practiced each section of a lab report already, and quality work is expected.

The content for each section is briefly reviewed below. There are also example questions you might address. Each section also has a suggested lengths you might consider for this report.

The **Introduction** should provide background information and context that helps the reader understand why your experiment would be important or useful. What is “freezing point,” and what are examples that highlight its importance? For this report, one good paragraph is sufficient.

The **Experimental Procedures** should summarize what you did in the lab with enough detail that someone else could perform the experiment. This could be written text or a flowchart. For this report, you can probably describe what you did in about half a page.

The **Results** section is what happened—your observations and measurements, often with some calculations involved. Your data should be summarized in a table or chart; your data should also be described in the accompanying text in this section. When you repeated the measurement for each solution, how close were the results to one another (i.e., how “repeatable” is this method for measuring freezing point?) Do the different mixture freeze at the same or different temperatures? If they’re different, is there a simple relationship between melting temperature and, say, molar mass? Etc. For this report, the results and a simple description of them should fit on about half a page.

The **Discussion** should interpret and analyze your results within what’s already known about the subject. It’s your opportunity to show you’ve really thought about the experiment and your results. If you describe each solution at the molecular level, would the differences between the solutions allow you to explain any differences in freezing temperature? If the freezing temperature is the same for all solutions, why might this be? How do your results compare to values published elsewhere or available on the internet? Is there an additional, complementary experiment you could perform that would help you make a stronger argument or more confident interpretation? What would you do differently next time? The Discussion should always be the main component of a scientific report. About one page would be appropriate for this short experiment.

The **Conclusions** section is a brief summary of your report: (1) why you did the experiment, (2) a (very short) description of the experiment, (3) your data and (4) what you think they mean / why they make sense, and (5) what you might to do improve the measurement or what you might measure next if this were one in a series of related experiments. Here, one good paragraph is sufficient.

If you have questions about writing the report, please ask your TA!
Glossary

*Freezing point*

*(Melting point)*

the temperature at which the liquid form of a substances converts to the solid form (freezing) or the solid form of a substance converts to the liquid form (melting); for a given pressure, the temperature at which a solid and a liquid are in equilibrium