Meteorology 101 Laboratory - Cloud Physics, Supercooling Water

Most clouds you see are made of tiny droplets of liquid water bathed in air with a relative humidity of 100%. As water condenses, it releases heat which warms the air next to the droplet. As water freezes it again releases heat. Once ice forms in a cloud, water vapor will condense on the ice before it does on liquid drops releasing still more heat which can make a cloud grow rapidly. Summer Thundershowers are a prime example of this rapid growth.

In this laboratory we will be investigating the supercooling of a fairly large sample of water as it freezes and then trying to extend the results to smaller scale samples, droplets of water.

In overview, the procedure of the first part is to make a refrigerator to cool a sample of water, put the sample in the refrigerator, and then graph the temperature every ten seconds as the water cools and freezes. (It is easiest to plot the temperatures directly on the graph paper.)

To begin, you will need a refrigerator to cool a test tube of water. When you want to melt the ice on your sidewalk, you put salt on it. The salt gets wet and the ions mix with the surface of ice. This lowers the freezing temperature of the mixture. A cup full of shaved ice with a liberal mix of normal table salt makes a very good refrigerator for this experiment as the temperature of the mixture can be brought below 20 degrees Fahrenheit (-7 deg C). You can use this "refrigerator" to reduce the temperature of a sample of "pure" tap water and find the temperature at which the water freezes.

Fill a styrofoam cup about three quarters full of finely broken ice. Then add about three teaspoons of salt. Then add a little water and stir (not with the thermometer). Use the thermometer to find the temperature of the ice-salt-water mixture. Stir (with the stirrer) to obtain a temperature of the mix about 16 degrees F (-8 deg C).

Put about 2 centimeters of tap water in a test tube. Rinse the thermometer and put the thermometer in water in the test tube. Take the temperature of the water. Plot the initial temperature on the graph. Then put the test tube and thermometer well into the ice salt mixture so you can read the temperature without moving anything.

Read the temperature every ten seconds and record it directly on the graph. Record the time at which the water freezes. (You can look down the test tube and see the crystals.) Continue recording the temperature for 30 seconds after the water freezes.

Draw a line through the points on the graph.

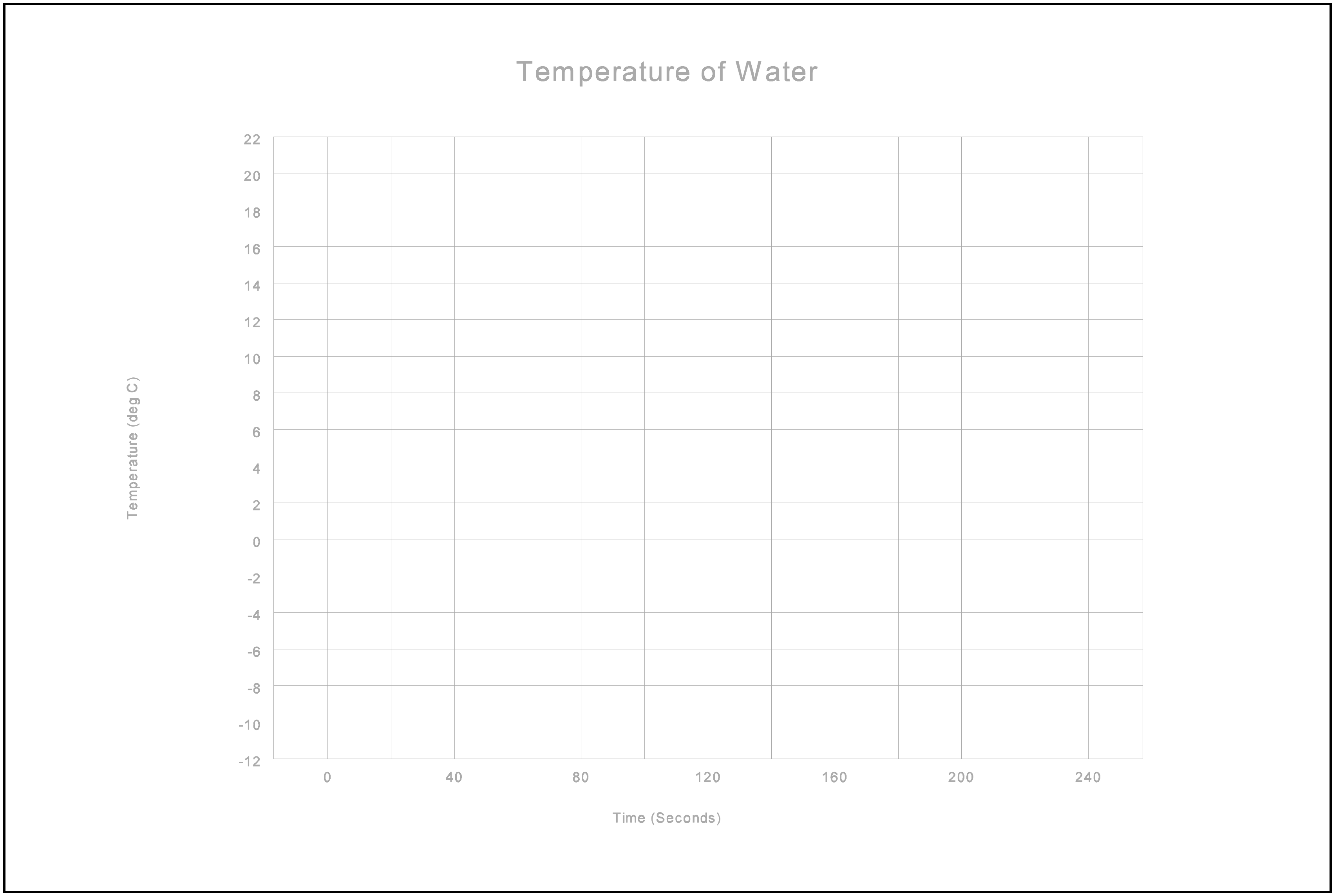
Question 1 - Is there a discontinuity in the temperature-time graph where the water froze?

Question 2 - If so, where did the heat come from to warm the sample?

Question 3 - If not, as the temperature approached 0.0 degrees Celsius, did the slope of the curve change any?

Question 4 - Describe the curvature of the lines on both sides of the 0.0 degrees Celsius point.

Question 5 - Describe in a short paragraph what happened.



Graph - Temperature of Water Sample vs. Time

Cloud Physics - Part 2

The second part of this experiment is to investigate the question "Does the size of the droplet matter as to the temperature at which it freezes?"

Remove the test tube and set it aside. (The thermometer can easily break if you try to pull it out so just let the ice melt.) Gently stir the ice-salt mixture again to cool it. When your thermometer is free of ice, check the temperature of the mix to see if it is still around -8 degrees C or lower.

Flatten a small piece (2 cm by 2 cm) of aluminum foil so there are no wrinkles in it. Now, lay it on the salt water surface so the aluminum foil is cooled all the way across, with no bubbles or gaps under it. Spray some small water droplets on it and mentally divide them into two categories, large and small. The small ones should be smaller than the size of the period at the end of this sentence.

Question 6 - Which freeze first, the large ones or the small ones? Record your results by putting your and your partners initial on the table on the blackboard.

Question 7 - Fill in the table below by putting your and your classmates initials in the appropriate column.

Small drops froze first	Large drops froze first

This is truly an experiment and there are no "wrong" results, however, the results have to be explained.

Question 8 - Please explain the results in the table.

Notes for Instructors

Materials Needed:

Per Group
- Styrofoam cup
- Test tube
- Stirrer (preferably wood or metal)
- Thermometer (avoid mercury thermometers if possible)
- Swatch of aluminum foil

General
- Shaved or crushed ice
- Table salt, 1-2 big boxes per class
- Paper Towels
- You may want to know where the mop is

I use this experiment to illustrate the source of energy for cumulus clouds, especially the big summer thundershowers which reach up to where the air temperature is almost -50 degrees C. The heat released by the water in the test tube is the same type of heat which drives the clouds, although most of the heat comes from vapor deposition on snowflakes above the freezing level.

In the first part, where the students are cooling the water in the test tube, caution them not to jar the test tube or even wiggle the thermometer in the test tube. If they do, the water won't supercool; however, their graph will probably still show a tendency of the temperature to be constant around zero and then to drop off once all of the water has frozen. This too is evidence of the release of the latent heat of freezing.

Occasionally, one group will not be able to get the water to freeze even though the temperature is below zero. (You can generally see the ice by looking down the axis of the test tube.) If that happens, make a big deal, pull the test tube smoothly out of the bath and snap it with your finger. The ice should grow across the test tube. Quickly return the test tube to them and have them record the temperature, put the test tube back in the water and resume the graphing for another minute.

Occasionally a quick student will point out that the thermometer is resting on the bottom of the test tube and probably is giving a false reading. This is true; however, thermometer bulbs are pretty big and is measuring the average temperature of the water and glass around the bulb. The absolute value is not as important as the rise of temperature when the ice forms, or the plateau of the graph as the temperature drops across the zero celsius point.

The second part of the experiment is an attempt to show another important process. It is a true experiment and you should have as many setups as possible. The ice-water-salt bath should be as cold as possible consistent with the student being able to cool the aluminum foil nearly uniformly.

I have found that it doesn't matter if the student wets the foil from a tap and then puts the foil on the ice or splatters water on top of the cold foil with a wet finger. Statistically, there appears to be no difference - the somewhat surprising result that the large drops freeze first - seems to be case.

This part is a statistical experiment. Some groups will find the small ones freeze first. If they finish after most of the others, they may be reluctant to put their results on the board. Point out that they are correct, that data are data, and even results which go against the rest should be reported.

The existence of one or more freezing nuclei (clay minerals in dust are excellent freezing nuclei) in a drop appears to be the explanation for these results. The drops supercool almost on contact, so volume to surface area is not a factor. Rather, the larger drops have more chance of containing a freezing nucleus within them. This is apparently also the case in clouds.

This laboratory experiment, and it is a true experiment, can get messy. But it is one of the more popular ones and seems to be worth the effort. Inspiration for this lab came from the IPS “The freezing of butter”, some research which went on at Penn State in the early 1970's and a demonstration of cloud seeding in Ira Geer’s Meteo. 101 class.

Henry W. Robinson,
Montgomery College, Germantown, MD