Another Way to Solve a Chilling Problem…
Liquid Water that is Colder than Ice!

- Loosely adapted from a "Supercooling, Clouds and Precipitation" activity developed by the American Meteorological Society for their Water in the Earth System (WES) Project.
- It is recommend that this activity be done by the students. If you wish, have them try it twice with the second attempt being a competitive event!

Time Required

40-80 minutes with 10-15 minutes prep time to gather materials

Objectives

Demonstrate that the physical properties of a substance may be changed by introducing other substances. Demonstrate one of many methods of refrigeration.

National Science Education Standards

Standard B: Conservation of Energy and the Increase in Disorder
Everything tends to become less organized and less orderly over time. Thus, in all energy transfers, the overall effect is that the energy is spread out uniformly. Examples (of this) are the transfer of energy from hotter to cooler objects by conduction, radiation, or convection and the warming of our surroundings when we burn fuels.

Overview

This activity is a lab that will leave students with a lasting impression. In the video, "Building the Coolest X-ray Satellite", it is apparent that cold temperatures must be reached that cannot be reached simply by packing the X-Ray Spectrometer (XRS) in a common refrigerator or some dry ice. In fact, a high-tech system is used. To illustrate that creative methods can lead to desired, but surprising, results this lab presents a technique for creating super-cooled water. This may be done as a demonstration, but is easily integrated into a class as a lab exercise. It also may be done in a chemistry setting as well as a physics classroom, and is ideal for an independent project for students who are highly motivated.

Materials

- Small, clear containers, such as test tubes (1 per group)
- A large, clean plastic cup or bowl-shaped container, such as a 1000 mL beaker (1 per group)
- Two thermometers
- A stirrer
- Crushed ice or snow
- Salt
- Water

Calibrating the thermometers

Share with students: Calibration on a frequent basis is often necessary to insure the accuracy of any scientific instrument. A common method is using the instrument to measure a quantity that is already known (sometimes called a "standard") and should produce a given reading. If that reading is not seen, then the measuring tool must be adjusted or its readings adjusted.

1. Fill the 1000 mL beaker approximately 2/3 full with crushed ice or snow.
2. Add water to within 1.5 cm of the top.
3. Place both thermometer bulbs well into the middle of the mixture. This will allow for the calibration of each thermometer, as they may not be accurate. The mixture will be at exactly 0° C or 32° F, but the readings on the thermometers may not, thus being in error.
4. Note any differences between the actual temperature of the mixture and the thermometer reading. This is done by taking the reading on the thermometer minus the actual temperature which is known to be 0° C or 32° F.

   $$T_{thermometer} - T_{actual} = T_{cal}$$

   We will refer to this difference, Tcal, as the calibration factor, which must be used to accurately determine the temperature readings from this point on.

Supercooling the Water

1. Create a salt water solution with the ice water slush by adding 20 grams of salt to each 100 mL of water stirring slightly so that the salt becomes evenly distributed.
2. Using one thermometer, note and record the change in temperature on the worksheet. Continue to add salt 10 grams at a time (roughly a total of 200 grams), until not all dissolves upon stirring.
3. Record the temperature after each addition, until it drops to -10° C. Continue to monitor the temperature occasionally (every 2-3 min) until the mixture is saturated with salt.
4. Fill the small container with approximately 10 mL of tap water.
5. Gently place the small container in the mixture so that the liquid levels inside and outside the small container align. If possible, slightly tip the small container.
6. Submerge the second thermometer in the water sample in the small container, and position it so that temperature readings may be obtained without touching or moving the thermometer or the container.
7. Record the starting temperature of the tap water and make observations of temperature every 30 seconds. During or after tabulation, plot temperature vs. time. Note that you have just created liquid water that is existing below 0° C!
   If ice forms or the temperature does not stabilize below 0° C, then repeat steps 4 through 7 again. This will happen rarely, but does happen

This is referred to as super-cooled water, and <u>is one of many refrigeration processes that clever scientists use to keep things cold</u>. It is also a demonstration that liquid, super-cooled water may exist near ice. This process commonly occurs in cloud formation. Students should develop whatever product is normally assigned as a lab write-up.
The XRS contains other examples of refrigeration methods to reduce the temperature of the XRS to 0.06 K, enabling it to detect X-rays with maximum efficiency. These include the use of insulation (as in a thermos), the use of liquid helium and solid neon, and an

adiabatic demagnetization refrigerator (ADR - for more on this innovative technology that has applications well beyond detecting X-rays, please visit: http://imagine.gsfc.nasa.gov/docs/teachers/lessons/xray_spectra/background-adr.html).

Extensions:

1. Research the ADR. Develop a product (flow chart, PowerPoint presentation, paperfold, etc.) that shows the processes present in the working of the ADR. Include important details, such as its life expectancy. The Suzaku Learning Center serves as an excellent source for beginning this research.
2. Note that a physical property of the liquid water, its freezing point, was changed by the addition of another substance, the salt. It may almost seem that we added an impurity to obtain a desired result. This process is commonly used to develop products that we used everyday, and is sometimes referred to as "doping". Do a small amount of searching and find out how and where doping is used.