



## Freezing and Melting of Water

The cooling and warming behavior of water is investigated. With the use of technology, water temperature data is collected, graphed and analyzed. The freezing and melting points of water are determined and compared.

### Hypothesis

The freezing and melting points of a substance may be determined by observing the warming and cooling behavior of that substance.

### Primary Learning Outcomes

At the end of this lesson, students will be able to:

- Be familiarized with data collection using the Vernier LabPro and TI calculator
- Be familiarized with the use of the Vernier LabPro temperature probe
- Collect, graph, display and make inferences from data
- Determine the freezing and melting point of water using temperature readings of cooling and warming water samples

### Assessed GPS

**SCSh2.** Students will use standard safety practices for all classroom laboratory and field investigations.

- a. Follow correct procedures for use of scientific apparatus.

**SCSh3.** Students will identify and investigate problems scientifically.

- c. Collect, organize and record appropriate data.
- d. Graphically compare and analyze data points and/or summary statistics.
- e. Develop reasonable conclusions based on data collected.
- f. Evaluate whether conclusions are reasonable by reviewing the process and checking against other available information.

**SCSh4.** Students will use tools and instruments for observing, measuring, and manipulating scientific equipment and materials.

- a. Develop and use systematic procedures for recording and organizing information.
- b. Use technology to produce tables and graphs.
- c. Use technology to develop, test, and revise experimental or mathematical models.

**SCSh5.** Students will demonstrate the computation and estimation skills necessary for analyzing data and developing reasonable scientific explanations.

- b. Consider possible effects of measurement errors on calculations.
- c. Recognize the relationship between accuracy and precision.
- d. Express appropriate numbers of significant figures for calculated data, using scientific notation where appropriate.

**SC6.** Students will understand the effects motion of atoms and molecules in chemical and physical processes.

- Compare and contrast atomic/molecular motion in solids, liquids, gases, and plasmas.
- Collect data and calculate the amount of heat given off or taken in by chemical or physical processes.
- Analyzing (both conceptually and quantitatively) flow of energy during change of state (phase).

### **Duration**

90 minutes

### **Materials and Equipment**

400-mL beaker  
10-mL graduated cylinder  
test tube  
salt  
ice  
water  
ring stand  
utility clamp

### **Technology Connection**

Vernier LabPro interface  
TI Graphing Calculator  
Vernier DataMate program  
Vernier Temperature Probe

### **Procedures**

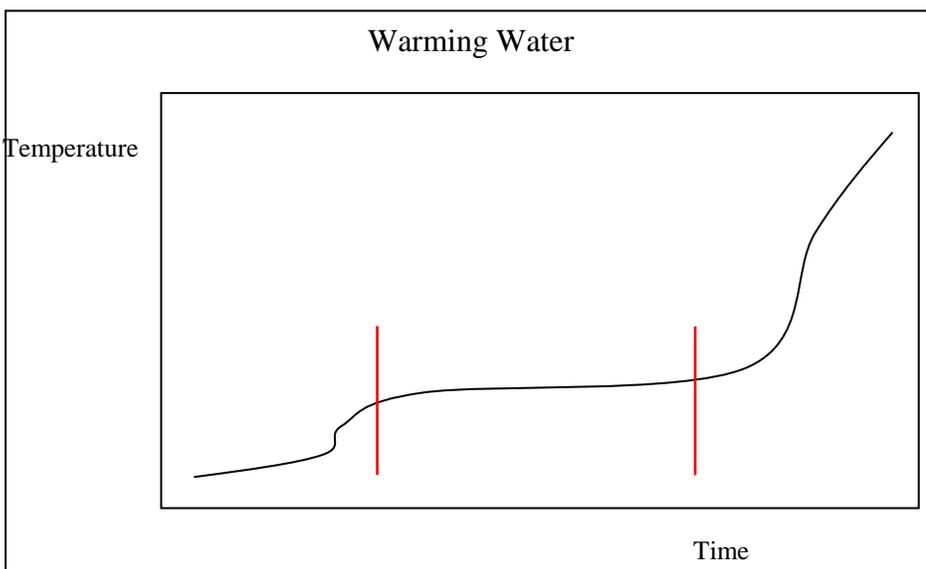
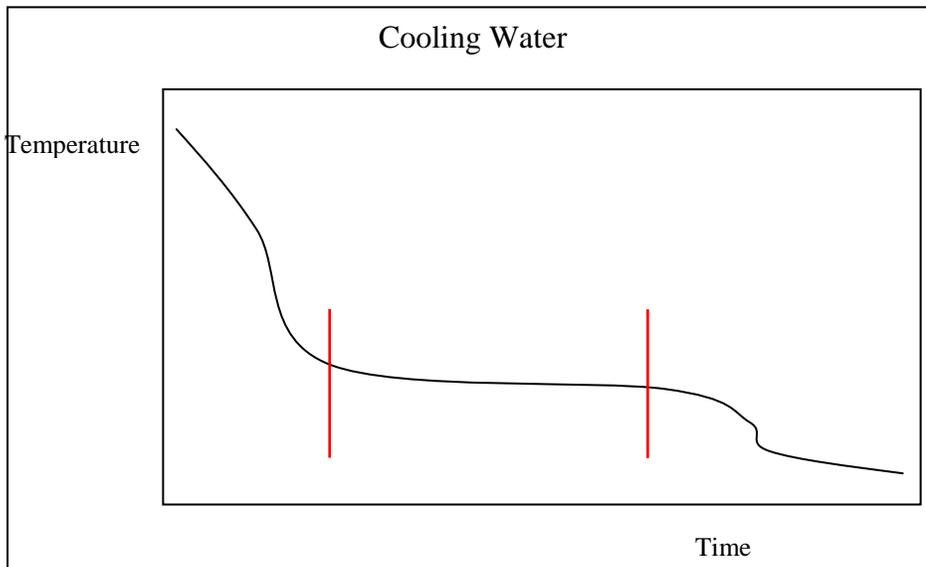
#### **Step 1: Introduction/Motivation, 20 minutes**

If necessary, prep temperature probes, including calibration as outlined in the manual accompanying temperature probes.

Put some ice cubes in a beaker containing warm water for the students to see. Elicit responses as to what is “really” happening (emphasis on the molecular level). Lead a discussion as to what happens to molecules of H<sub>2</sub>O in a given phase when in contact with other H<sub>2</sub>O molecules in a different phase (e.g., water vapor and ice, water and water vapor, water and ice).

Molecules of a substance exhibit increasing **disorder** as phase changes from solid to liquid to gas. As disorder increases, so does the frequency of molecules of a substance colliding with each other and with their surroundings. Thus, the **kinetic energy** of molecules in a substance increases as disorder increases. Conversely, the **potential energy** of the molecules in a substance increases as the **tendency** of molecules to become disordered increases.

Irrespective of the method of temperature observation (e.g., thermometer, temperature probe attached to electronic data collection device, etc.), graphs of temperature vs. time for water that is warming and for water that is cooling will have a characteristic appearance:



Draw these graphs on the board for students to see and record. In both graphs, there is a region (bounded by the red bars) that represents the phase change of the water. In these intervals, there is no kinetic energy. However, potential energy is either increasing (as in the case during melting) or decreasing (as in the case during freezing) in these intervals.

In this activity, students will record the cooling and warming of water for 15 minutes each using the LabPro with attached temperature probe. Using their calculators and the Vernier DATAMATE program, students will then select the region shown above as bounded by the red bars and take the mean of the range of values spanning this interval. These two mean values are to be interpreted as the freezing and melting points of water, respectively.

Given this information as well as prior knowledge about the properties of water, ask students to share and record their hypotheses regarding the following:

- What is the freezing point of water? the melting point?
- Why would temperature stay stable for a given time as seen in the graphs (above, drawn on the board)?

Show students what the setup is supposed to look like, including initialization and preparation of the probe, LabPro device, and calculator. Refer to the student activity handout for visual. Have students look over the student activity handout to anticipate the sequence of data entry and button combinations on the TI calculators. Ask if there are any questions about the procedure (5 minutes max).

### **Step 2: Activity, 50 minutes**

Students will break up into groups and conduct activity “Freezing and Melting of Water” as outlined in student activity handout.

Recommendations:

- It is recommended that 20 x 150 mm, 25 x 150 mm or 18 x 150 mm test tubes be used. Water samples of 5 mL work and 5 teaspoons of salt are recommended.
- Students whose solutions are slow to reach the 0°C plateau at the start of Trial 1 or slow to drop below 0°C near the end of the trial may not have added enough salt or used adequate stirring to dissolve it.
- Many samples will supercool. Stirring will bring the super-cooled water to the melting temperature plateau.
- Remind students to collect data for the entire 15 minutes of each trial. If data collection is prematurely stopped, students will not be able to see both graphs simultaneously as described in Step 16 of the student activity handout.

### **Step 3: Review, 20 minutes**

Gather students as a class and discuss results, answers to the review questions given at the end of the student handout, and any problems or questions with the procedure. A brief mention should be made of the concepts of **precision** (repeatability of results) and **accuracy** (proximity to the “true” value) if there is an issue with the calculated freezing and melting points of water not being 32°F/0°C.

### **Assessment**

Completed student worksheets will be collected and graded.

Student understanding of activity components may be assessed by unit examination.

Student affect and work ethic may be assessed by affect/ethic rubric.

### **References**

Holmquist, D.D., Randall, J. & Volz, D. (2000). Chemistry with Calculators. pp. 1-1 – 1-T3. Vernier Software & Technology: Beaverton, Oregon.

## Freezing and Melting of Water

Freezing temperature, the temperature at which a substance turns from liquid to solid, and melting temperature, the temperature at which a substance turns from a solid to a liquid, are characteristic physical properties. In this experiment, the cooling and warming behavior of a familiar substance, water, will be investigated. By examining graphs of the data, the freezing and melting temperatures of water will be determined and compared.

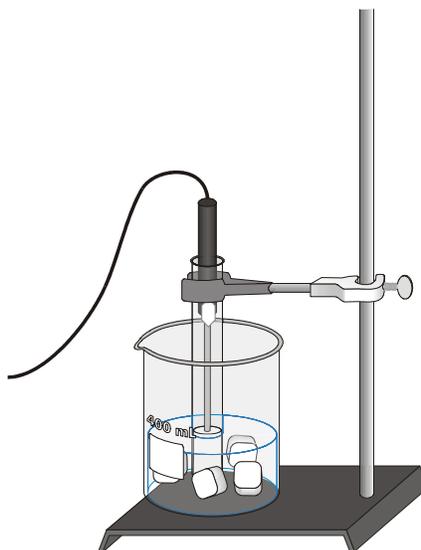


Figure 1

## MATERIALS

LabPro or CBL 2 interface  
TI Graphing Calculator  
DataMate program  
Temperature Probe  
ring stand  
utility clamp

400-mL beaker  
10-mL graduated cylinder  
test tube  
salt  
ice  
water

## PROCEDURE

### Part I Freezing

1. Put about 100 mL of water and 6 ice cubes into a 400-mL beaker.
2. Put 5 mL of water into a test tube and use a utility clamp to fasten the test tube to a ring stand. The test tube should be situated above the water bath. Place the Temperature Probe into the water inside the test tube.
3. Plug the Temperature Probe into Channel 1 of the LabPro or CBL 2 interface. Use the link cable to connect the TI Graphing Calculator to the interface. Firmly press in the cable ends.
4. Turn on the calculator and start the DATAMATE program. Press **CLEAR** to reset the program.
5. Set up the calculator and interface for the Temperature Probe.

- a. Select SETUP from the main screen.
  - b. If the calculator displays a Temperature Probe in CH 1, proceed directly to Step 6. If it does not, continue with this step to set up your sensor manually.
  - c. Press  to select CH 1.
  - d. Select TEMPERATURE from the SELECT SENSOR menu.
  - e. Select the Temperature Probe you are using (in °C) from the TEMPERATURE menu.
6. Set up the data-collection mode.
- a. To select MODE, press  once and press .
  - b. Select TIME GRAPH from the SELECT MODE menu.
  - c. Select CHANGE TIME SETTINGS from the TIME GRAPH SETTINGS menu.
  - d. Enter "10" as the time between samples in seconds.
  - e. Enter "90" as the number of samples. The length of the data collection will be 15 minutes.
  - f. Select OK to return to the setup screen.
  - g. Select OK again to return to the main screen.
7. When everything is ready, select START to begin collecting data. Lower the test tube into the ice-water bath.
8. Soon after lowering the test tube, add 5 spoons of salt to the beaker and stir with a stirring rod. Continue to stir the ice-water bath throughout the remainder of Part I.
9. Slightly, but continuously, move the Temperature Probe during the first 10 minutes of Part I. Be careful to keep the probe in, and not above, the ice as it forms. When 10 minutes have gone by, stop moving the probe and allow it to freeze into the ice. Add more ice cubes to the beaker as the original ice cubes get smaller.
10. Data collection will stop after 15 minutes. Keep the test tube *submerged* in the ice-water bath until Step 13.
11. Analyze the flat part of the graph to determine the freezing temperature of water. To do this:
- a. Press  to return to the main screen, then select ANALYZE.
  - b. Select STATISTICS from the ANALYZE OPTIONS menu.
  - c. Use  to move the cursor to the beginning of the flat section of the curve. Press  to select the left boundary of the flat section.
  - d. Move the cursor to the end of the flat section of the graph, and press  to select the right boundary of the flat section. The program will now calculate and display the statistics for the data between the two boundaries.
  - e. Record the MEAN value as the freezing temperature in your data table (round to the nearest 0.1°C).
  - f. Press  to return to the ANALYZE OPTIONS menu, then select RETURN TO MAIN SCREEN.
12. Store the data from the first run so that it can be used later. To do this:
- a. Select TOOLS from the main screen.
  - b. Select STORE LATEST RUN from the TOOLS MENU.

## Part II Melting

13. Choose START to begin data collection, then raise the test tube and fasten it in a position above the ice-water bath. Do not move the Temperature Probe during Part II.
14. Dispose of the ice water as directed by your teacher. Obtain 250 mL of warm tap water in the beaker. When 12 minutes have passed, lower the test tube and its contents into this warm-water bath.
15. Data collection will stop after 15 minutes. Analyze the flat part of the graph to determine the melting temperature of water. To do this:
  - a. Press  to return to the main screen, then select ANALYZE.
  - b. Select STATISTICS from the ANALYZE OPTIONS menu.
  - c. Use  to move the cursor to the beginning of the flat section of the curve. Press  to select the left boundary of the flat section.
  - d. Move the cursor to the end of the flat section of the graph, and press  to select the right boundary of the flat section. The program will now calculate and display the statistics for the data between the two boundaries.
  - e. Record the MEAN value as the freezing temperature in your data table (round to the nearest 0.1°C).
  - f. Press  to return to the ANALYZE OPTIONS menu, then select RETURN TO MAIN SCREEN.
16. A good way to compare the freezing and melting curves is to view both sets of data on one graph.
  - a. Select GRAPH from the main screen, then press .
  - b. Select MORE, then select L2 AND L3 VS L1 from the MORE GRAPHS menu.
  - c. Both temperature runs should now be displayed on the same graph. Each point of Part I (freezing) is plotted with a box, and each point of Part II (melting) is plotted with a dot.
17. Print a graph of temperature vs. time (with two curves displayed). Label each curve as “freezing of water” or “melting of ice.”

Name \_\_\_\_\_

## Data Table and Review Questions

### DATA TABLE

Freezing temperature of water	°C
Melting temperature of water	°C

### PROCESSING THE DATA

1. What happened to the water temperature during freezing? During melting?
2. According to your data and graph, what is the freezing temperature of water? The melting temperature? Express your answers to the nearest 0.1°C.
3. How does the freezing temperature of water compare to its melting temperature?
4. Tell if the *kinetic energy* of the water in the test tube increases, decreases, or remains the same in each of these time segments during the experiment when:
  - a. the temperature is changing at the beginning and end of Part I
  - b. the temperature remains constant in Part I
  - c. the temperature is changing at the beginning and end of Part II
  - d. the temperature remains constant in Part II
5. In those parts of Question 4 in which there was no kinetic energy change, tell if *potential energy* increased or decreased.