

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.

OBJECTIVES

In this experiment, you will

- Collect temperature data during the freezing and melting of water.
- Analyze graphs to determine the freezing and melting temperatures of water.
- Determine the relationship between the freezing and melting temperatures of water.

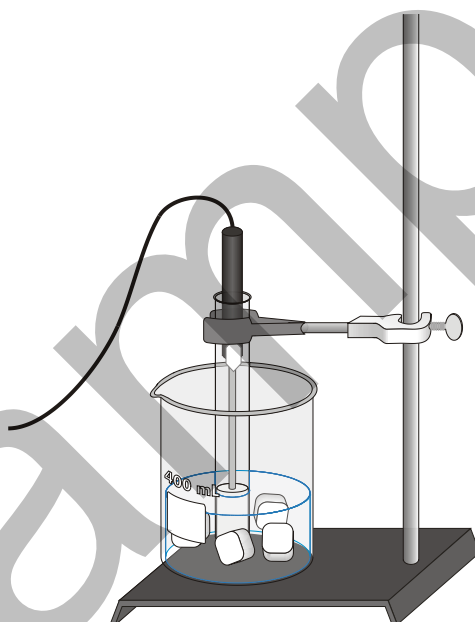


Figure 1

MATERIALS

computer
Vernier computer interface
LoggerPro
Temperature Probe
ring stand
utility clamp
test tube

400 mL beaker
water
10 mL graduated cylinder
ice
salt
stirring rod

PROCEDURE

Part I: Freezing

1. Fill a 400 mL beaker 1/3 full with ice, then add 100 mL of water.
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 clamped above the water bath. Place a Temperature Probe into the water inside the test tube.
3. Connect the probe to the computer interface. Prepare the computer for data collection by opening the file "02 Freeze Melt Water" from the *Chemistry with Vernier* folder of *LoggerPro*.
4. When everything is ready, click to begin data collection. Then lower the test tube into the ice-water bath.
5. 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 during Part I. **Important:** Stir enough to dissolve the salt.
6. Slightly, but continuously, move the 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.
7. When 15 minutes have passed, data collection will stop. Keep the test tube *submerged* in the ice-water bath until Step 10.
8. On the displayed graph, analyze the flat part of the curve to determine the freezing temperature of water:
 - a. Move the mouse pointer to the beginning of the graph's flat part. Press the mouse button and hold it down as you drag across the flat part to *select* it.
 - b. Click on the Statistics button, . The mean temperature value for the selected data is listed in the statistics box on the graph. Record this value as the freezing temperature in your data table.
 - c. To remove the statistics box, click on the upper-left corner of the box.

Part II: Melting

9. Prepare the computer for data collection. From the Experiment menu, choose Store Latest Run. This stores the data so it can be used later. To hide the curve of your first data run, click the Temperature vertical-axis label of the graph, click More, and uncheck the Run 1 Temperature box. Click .
10. Click 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.
11. 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.
12. When 15 minutes have passed, data collection will stop.

13. On the displayed graph, analyze the flat part of the curve to determine the melting temperature of water:
 - a. Move the mouse pointer to the beginning of the graph's flat part. Press the mouse button and hold it down as you drag across the flat part to *select* it.
 - b. Click the Statistics button, . The mean temperature value for the selected data is listed in the statistics box on the graph. Record this value as the melting temperature in your data table.
 - c. To remove the statistics box, click on the upper-left corner of the box.
14. To print a graph of temperature vs. time showing both data runs:
 - a. Click the Temperature vertical-axis label of the graph. To display both temperature runs, click More, and check the Run 1 Temperature and Latest Temperature boxes. Click .
 - b. Label both curves by choosing Text Annotation from the Insert menu, and typing "Freezing Curve" (or "Melting Curve") in the edit box. Then drag each box to a position near its respective curve. Adjust the orientation of the arrowhead by clicking and dragging to the desired position.
 - c. Print a copy of the graph. Enter your name(s) and the number of copies of the graph you want.

OBSERVATIONS

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.
 - a. when the temperature is changing at the beginning and end of Part I
 - b. when the temperature remains constant in Part I
 - c. when the temperature is changing at the beginning and end of Part II
 - d. when 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.

TEACHER INFORMATION

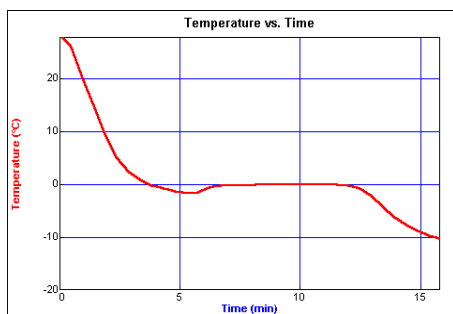
Freezing and Melting of Water

1. The student pages with complete instructions for data collection using LabQuest App, Logger Pro (computers), and EasyData or DataMate (calculators) can be found on the CD that accompanies this book. See *Appendix A* for more information.
2. This entire experiment requires a full 45–50 minute period. Students should have done Experiment 1 before this one. Be sure to go over this experiment well with your students, especially if it is one of the first computer-interfaced experiments they have done. As the Sample Results below show, this procedure can give excellent results.
3. The stored calibration for all Vernier Temperature Probes works well for this experiment—the freezing and melting temperatures of water should be within $\pm 0.2^{\circ}\text{C}$ of 0°C using these calibrations.
4. Test tubes size 20×150 mm work well. Sizes 25×150 mm and 18×150 mm work, too.
5. A water sample size of 5 mL works well. Larger samples will take more time than is recommended in this procedure.
6. As shown in the first graph in the Sample Results, many of the samples will supercool. Stirring will bring the super-cooled water to the melting temperature plateau.
7. If you are using calculators and EasyData for data collection, remind students to collect data for the entire 15 minutes. If they stop data collection early, they will not be able to view both graphs simultaneously.

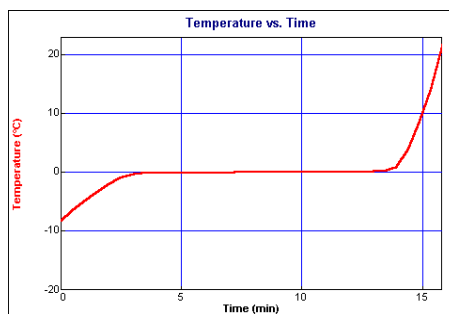
ANSWERS TO QUESTIONS

1. The water temperature stayed constant near 0°C during freezing and melting.
2. The expected value is 0°C for both the freezing and melting temperatures, but answers will vary slightly.
3. The freezing and melting temperatures of water are the same.
4.
 - a. Average kinetic energy decreases with the temperature decrease at the beginning and end of Part I.
 - b. Since there is no temperature change during freezing, average kinetic energy remains constant.
 - c. Average kinetic energy increases with the temperature increase at the beginning and end of Part II.
 - d. Since there is no temperature change during melting, average kinetic energy is constant.
5.
 - b. Potential energy decreased during freezing
 - d. Potential energy increased during melting.

SAMPLE DATA



Part I: Freezing Water



Part II: Melting Water