Experiment
3

Freezing and Melting of Water

Freezing temperature is the temperature at which a substance turns from a liquid to a solid. Melting temperature is the temperature at which a substance turns from a solid to a liquid. Freezing temperature and melting temperature are characteristic properties of a pure substance. In this experiment, you will determine and compare the freezing and melting temperatures of water.

OBJECTIVES

In this experiment, you will

- use a TI Graphing Calculator, a LabPro or CBL 2 interface, and a Temperature Probe to measure temperature
- record data
- make a graph of the data
- analyze your data and graphs to determine the freezing and melting temperatures of water
- determine the relationship between the freezing and melting temperatures of water
- apply the concepts studied in a new situation

MATERIALS

LabPro or CBL 2 interface
TI Graphing Calculator
DataMate program
Temperature Probe
ring stand
utility clamp
test tube
400-mL beaker
water
10-mL graduated cylinder
ice
salt
stirring rod

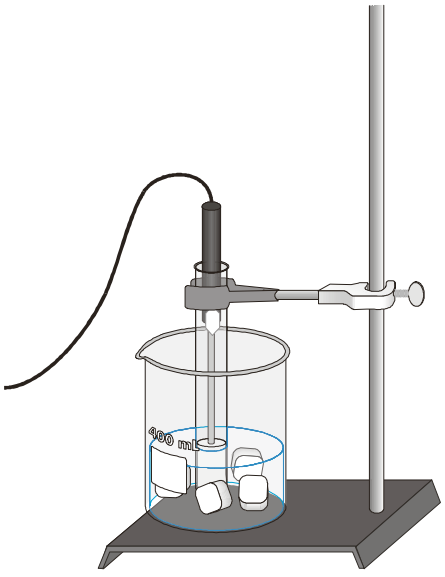


Figure 1

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 situated above the water bath. Place a 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 correct Temperature Probe.
   a. Select SETUP from the main screen.
   b. If the calculator displays the correct 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 [ENTER] to select CH 1.
   d. Select TEMPERATURE from the SELECT SENSOR menu.
   e. Select the correct Temperature Probe (in °C) from the TEMPERATURE menu.

6. Set up the data-collection mode.
   a. To select MODE, press [▲] once and press [ENTER].
   b. Select TIME GRAPH from the SELECT MODE menu.
   c. Select CHANGE TIME SETTINGS from the TIME GRAPH SETTINGS screen.
   d. Enter "30" as the time between samples, in seconds.
   e. Enter "30" as the number of samples. (The experiment length 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 data collection. Note: It will take 30 seconds for the graph to appear with the first data point plotted.

8. When a graph appears on the calculator screen, lower the test tube into the ice-water bath.

9. 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.

10. 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.

11. Data collection will stop after 15 minutes. **IMPORTANT:** Keep the test tube *submerged* in the ice-water bath until Step 14 below.

12. When data collection is complete, a graph of temperature *vs*. time will be displayed. As you move the cursor right or left, the time (X) and temperature (Y) values of each data point are

displayed below the graph. Record the temperature values in your data table (round to the nearest 0.1°C).

13. (Optional) Print a graph of temperature *vs*. time.

14. Press ENTER to return to the main screen.

Part II Melting

15. Select START to collect another set of data.

16. Raise the test tube and fasten it in a position above the ice-water bath. Do not move the Temperature Probe during Part II.

17. 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.

18. When data collection is complete, a graph of temperature *vs*. time will be displayed. As you move the cursor right or left, the time (X) and temperature (Y) values of each data point are displayed below the graph. Record the temperature values in your data table (round to the nearest 0.1°C).

19. (Optional) Print a graph of temperature *vs*. time.

20. Press ENTER to return to the main screen.

DATA

Part I Freezing

Time (s)	Temp (°C)	Time (s)	Temp (°C)	Time (s)	Temp (°C)	Time (s)	Temp (°C)
0	_____	240	_____	480	_____	720	_____
30	_____	270	_____	510	_____	750	_____
60	_____	300	_____	540	_____	780	_____
90	_____	330	_____	570	_____	810	_____
120	_____	360	_____	600	_____	840	_____
150	_____	390	_____	630	_____	870	_____
180	_____	420	_____	660	_____	900	_____
210	_____	450	_____	690	_____		

Part II Melting

Time (s)	Temp (°C)	Time (s)	Temp (°C)	Time (s)	Temp (°C)	Time (s)	Temp (°C)
0	_____	240	_____	480	_____	720	_____
30	_____	270	_____	510	_____	750	_____
60	_____	300	_____	540	_____	780	_____
90	_____	330	_____	570	_____	810	_____
120	_____	360	_____	600	_____	840	_____
150	_____	390	_____	630	_____	870	_____
180	_____	420	_____	660	_____	900	_____
210	_____	450	_____	690	_____		

OBSERVATIONS

PROCESSING THE DATA

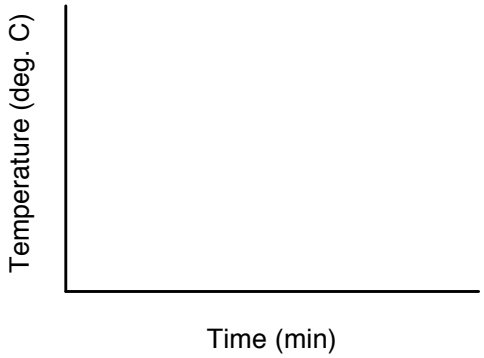
1. What happened to the water temperature during freezing? During melting?

2. According to your data and graph, what is the freezing temperature of water? The melting temperature?

3. How does the freezing temperature of water compare to its melting temperature?

4. Phenyl salicylate has a freezing temperature of 41.5°C. In the space to the right, sketch and label a freezing curve for phenyl salicylate. Be sure to indicate the freezing temperature on the graph.

5. Using another color, draw a melting curve for phenyl salicylate on the same graph. Indicate the melting temperature on the curve.



EXTENSIONS

1. Explore the graphing capabilities of the calculator and display both the melting and freezing curves on the same graph.

2. Modify the procedure to study the freezing and melting temperatures of another substance suggested by your teacher.

TEACHER INFORMATION

Freezing and Melting of Water

1. This entire experiment requires a full 45-50 minute period. Students should have done Experiments 1 and 2 before this one. Be sure to prelab this experiment well, especially if it is one of the first *Physical Science with Calculator* experiments to be done by your students. As the Sample Results on the next page show, this procedure can give excellent results.
2. The stored calibration for the Stainless Steel Temperature Probe or Direct-Connect Probe works well for this experiment—the freezing and melting temperatures of water should be within ± 0.2°C of 0°C using these calibrations.
3. Size 20 X 150 mm test tubes work well. Sizes 25 X 150 mm and 18 X 150 mm work, too.
4. A water sample size of 5 mL works well. Larger samples will take more time than is provided in this procedure.
5. We suggest that you have a computer with a printer setup with the TI-Graph Link software and cable for the graph printing. In *Appendix B*, you will find instructions for using Macintosh and Windows versions of TI-Graph Link to transfer and print graphs.
6. Graphing data by hand is an alternative to the graph printing procedure outlined above.
7. As a third alternative, you may elect to use Vernier Graphical Analysis program (for Macintosh or Windows) along with the a graph-link cable[1]. Graphical Analysis software has a file option for importing data lists from all of the TI Graphing Calculators supported in this book (TI-73, 83, 83 Plus, 86, 89, 92, and 92 Plus). See *Appendix D* for more information about using Graphical Analysis software with TI Graphing Calculators.
8. Some possible substances for use in a modified version of this experiment are:

   Palmitic acid (Hexadecanoic acid) (m.p. = 63°C)

   Lauric acid (Dodecanoic acid) (m.p. = 44°C)

   tert-Butanol (2-Methyl-2-Propanol) (m.p. = 25.5°C)
9. Stirring during Part I gives more constant freezing temperature readings and delays the drop of temperature below freezing temperature. No stirring, in contrast, gives more constant temperature readings during Part II.
10. 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.

ANSWERS TO QUESTIONS

1. The water temperature stayed constant at 0°C during freezing and melting.

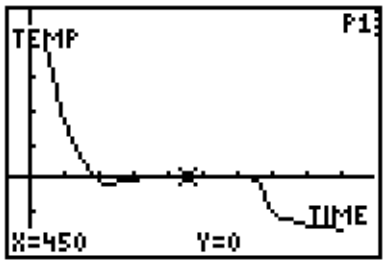
---

[1] This feature is supported only when using the *gray* TI Graph Link cable (or the gray Graph Link Cable sold by Vernier). The *black* TI-Graph Link (Windows PC only) cable is not currently supported in Graphical Analysis for Windows software.

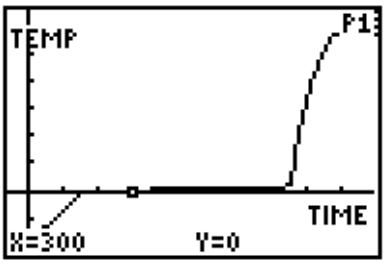
2. The expected value is 0°C for both the freezing and melting temperatures, but answers will vary slightly. (You might want to compile class averages or construct histograms of student results.)
3. The freezing and melting temperatures of water are the same.
4. The freezing curve for phenyl salicylate looks similar to the freezing curve for water below. The plateau should be at 41.5°C, phenyl salicylate's freezing temperature.
5. The melting curve for phenyl salicylate looks similar to the melting curve for water below. This plateau should also be at 41.5°C, phenyl salicylate's melting temperature.

SAMPLE RESULTS

Time (s)	Temperature Part I (°C)	Temperature Part II (°C)	Time (s)	Temperature Part I (°C)	Temperature Part II (°C)
30	22.0	-7.2	480	0.0	0.3
60	15.7	-5.7	510	0.0	0.3
90	9.7	-4.2	540	0.0	0.3
120	5.4	-2.1	570	0.3	0.3
150	2.4	-0.3	600	0.0	0.3
180	0.9	-0.3	630	0.0	0.3
210	-0.9	0.0	660	-0.9	0.3
240	-1.2	0.0	690	-4.5	0.3
270	-0.6	0.0	720	-6.0	0.3
300	-0.3	0.0	750	-6.3	1.2
330	0.0	0.0	780	-6.9	11.1
360	0.0	0.3	810	-7.2	19.2
390	0.0	0.3	840	-7.5	24.6
420	0.0	0.3	870	-7.5	27.7
450	0.0	0.3	900	-7.8	29.0



Part I: Freezing Water



Part II: Melting of Water