16. Properties of Water

Driving Questions

Explore the properties of water and use the molecular structure of water to explain these properties.

- Why is water the only substance that naturally exists as a solid, liquid, and a gas on Earth?
- Does water behave the same on all surfaces? Why or why not?
- How does the volume of ice compare to the volume of liquid water? Is this unusual? Why?
- How are the properties of water important to processes on Earth such as physical erosion and the hydrologic cycle?

Background

Solid iron sinks in liquid iron. Solid lead sinks in liquid lead. Nearly all substances in their solid state sink when placed in their own liquid. This occurs because the atoms or molecules making up these substances are closer together in the solid state than in the liquid state. Is this true for water? No, ice floats in water because ice is less dense than water.

The properties of water seem normal to us because water is all around us. What other chemical substance can you think of that exists as a solid, liquid and a gas at the temperatures and pressures found on Earth? Couldn't think of anything, right? Water is the only substance that naturally exists in all three states on Earth. Water is unique.

These strange behaviors of water enable life to exist on Earth. They also are responsible for many of the processes on Earth such as physical erosion and the hydrologic cycle. All this strange behavior of water can be explained by the molecular structure of water.

Water is a polar molecule because it has a partially positive side and partially negative side. These two different sides attract to each other (opposites attract). In water this is a special type of intermolecular attraction called hydrogen bonding. This hydrogen bonding explains why solid ice is less dense than liquid water, why water can exist in all three states on Earth, and why water is attracted to and easily mixes with some substances (like salt), but is repelled away from and refuses to mix with other substances (like oil).

Materials and Equipment

For each student or group:

- Temperature Sensor
- Beaker, 600-mL
- Beaker, 100-mL
- Utility clamp
- Ring stand
- Hot pads or mittens
- Hot plate
- Crushed ice, 300 mL
- Eye dropper or disposable pipet
- Paper towel
- Wax paper
- Foam tray
- Other materials to test
- Water, 50 mL

Safety

Add these important safety precautions to your normal laboratory procedures:

- Do not touch the hot plate or hot glassware.
- Do not allow the temperature sensor's wires to touch the hotplate at any time.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Part 1 – Phase change of water

Set Up

1. ☐ Start a new experiment on the data collection system.
2. ☐ Connect a stainless steel temperature sensor to the data collection system.
3. ☐ Display Temperature on the y-axis of a graph with Time on the x-axis.
4. ☐ Attach a utility clamp to a ring stand, and securely tighten a stainless steel temperature sensor to the utility clamp.
5. ☐ Plug in the hotplate and turn it on to its highest setting.

   CAUTION: Ensure that papers and wires do not touch the hot plate.
6. ☐ Fill the 600-mL beaker with crushed ice to approximately 300 mL.
7. ☐ Place the beaker with crushed ice onto the hot plate.

8. ☐ Lower the stainless steel temperature sensor into the ice, positioning the tip of the sensor approximately 2 cm below the surface of the ice. Make sure the sensor does not touch the bottom or the sides of the beaker.

Collect Data

9. ☐ Start data recording.

10. ☐ Adjust the scale of the graph as needed.

11. ☐ Collect data until the water has been boiling for 10 minutes. Be sure that the tip of the sensor is always under the ice or the water. You may have to adjust its position as the experiment continues.

12. ☐ What changes do you expect to happen that may cause the volume of ice and water in the beaker to decrease as the beaker is heated?

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13. ☐ Record the elapsed time when each of the changes listed in Table 1 occurred.

Table 1: Phase changes

Change	**Elapsed Time (s)**
Ice started melting	
The last piece of ice melted	
Water started boiling	

14. ☐ Describe the characteristics (in regard to volume and shape) of ice that make it a solid.

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15. ☐ What is hydrogen bonding and how does it explain the properties of ice listed above?

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16. ☐ Describe the characteristics of water that make it a liquid. Explain how hydrogen bonding is involved.

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17. ☐ Describe the characteristics of water vapor that make it a gas. Explain whether or not hydrogen bonding occurs.

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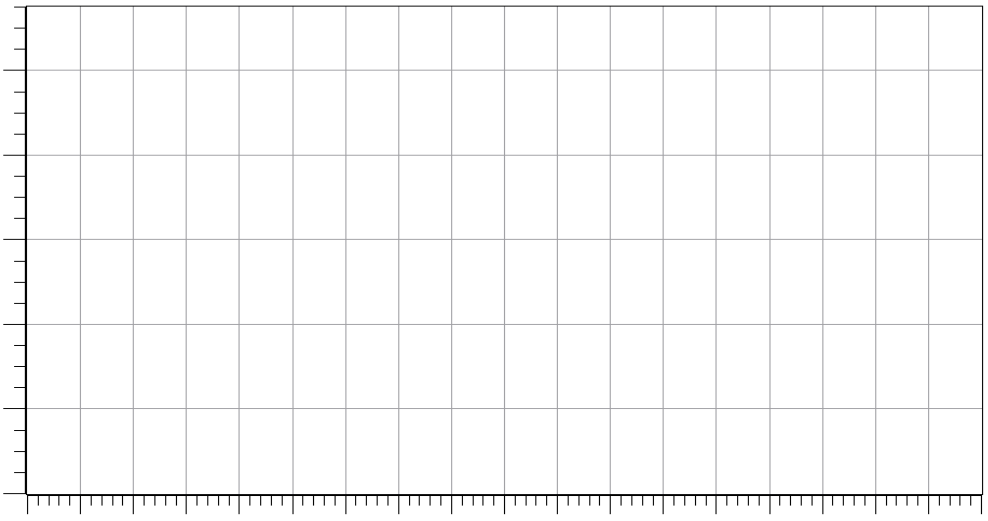
18. ☐ When the water has been boiling for approximately 10 minutes, stop data recording.

19. ☐ Save your experiment and clean up according to your teacher's instructions.

Analyze Data

20. ☐ Print or sketch a graph of Temperature versus Time where heat is added to allow ice to change to water and then to water vapor. Label the overall graph, the x-axis, the y-axis, and include units on the axes.



21. ☐ Label the items below on your temperature versus time graph above.

    a. Ice alone

    b. Ice and water

    c. Water only

    d. Water and Water Vapor

    e. Melting

    f. Boiling

22. ☐ In this lab, what was added to the ice in order to make it melt and then make the water boil? On Earth, what causes these processes to occur?

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23. ☐ What needs to happen for the reverse process to occur (water vapor to turn to water, and water to change to ice? Does this occur on earth? Explain.

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Part 2 – Waters behavior on different surfaces

24. ☐ Fill a 100-mL beaker with approximately 50 mL of water.

25. ☐ Place 10 drops of water on a piece of wax paper.

26. ☐ Slightly lift the edges of the wax paper and slowly move the water from side to side. Record your observation in Table 2.

Table 2: Behavior of water on known surfaces

Surface	Molecular Structure	Observations
Wax paper	Non- polar	
Foam food tray	Non-polar	
Paper towel	Polar	
Untreated wood	Polar	

27. ☐ Repeat the process for a foam food tray, a paper towel, and an untreated piece of wood:

   a. Place 10 drops of water on the surface.

   b. Slightly life the edges of the surface and slowly move the water from side to side.

   c. Record your observation in Table 2.

28. ☐ How does water behave when placed on non-polar surfaces? Explain using the terms cohesion, adhesion, and hydrogen bonding.

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29. ☐ How does water behave when placed on polar surfaces? Explain using the terms cohesion, adhesion, and hydrogen bonding.

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30. ☐ How does the polarity of water affect the behavior of water on different surfaces? Provide evidence to support your answer.

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31. ☐ Pick 5 different surfaces and predict the polarity of these surfaces. Record the name of each surface and your prediction in Table 3.

Table 3: Determining the polarity of unknown surfaces

Surface	Polarity Prediction	Observations	Polarity

32. ☐ Test each of your surfaces to determine how water behaves on each and record your observation in Table 3.

33. ☐ Use your results to determine the polarity of each surface. Record your answers in Table 3.

34. ☐ Were your predictions correct? Explain why or why not.

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35. ☐ Clean up according to your teacher's instructions.

Part 3 – Volume of ice versus water

Complete the following steps to design an experiment to determine how the volume of ice compares to the volume of water (with equal mass).

36. ☐ How do you think the volume of ice compares to that of water? What physical evidence do you have to support your prediction?

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37. ☐ Explain your prediction using what you know about the molecular structure of water. The following terms should be used in your explanation: hydrogen bonds, crystal structure, and water molecule.

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38. ☐ Explain how you plan to test your prediction.

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39. ☐ Write a procedure for the plan you described.

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40. ☐ If time permits your teacher may allow you to perform your experiment.

Analysis Questions

1. **List two behaviors of water you observed in this lab and explain how hydrogen bonding is involved in each.**

2. **List one behavior of water that you experimented with in this lab and explain why it is unique compared to other chemicals on Earth.**

3. **Explain how one (or more) of the properties you observed in this lab is involved in a physical process on Earth.**

Synthesis Questions

Use available resources to help you answer the following questions.

1. **Are changes of state physical or chemical changes? How do you know?**

2. **How can the cohesive forces between water molecules be reduced? Why might this be necessary?**

3. **Does it take more energy for ice to melt or for water to evaporate? Why is this important on Earth?**