Molecular Attraction

Organizing Topic Investigating Water

Overview Students examine water's unique properties of adhesion, cohesion, surface tension, and capillarity.

Related Standards of Learning 6.5b

Objectives

The students should be able to
- comprehend the adhesive and cohesive properties of water.

Materials needed

- Overhead projector
- Petri dishes
- Water
- Pepper
- Detergent
- Blue and red food coloring
- Rubbing alcohol
- Toothpicks
- Eyedroppers
- Pennies
- Beakers
- Paper towels
- Plastic film canisters
- Paper clips
- Plastic cups
- Forks
- Wax paper
- Glass slides
- Chromatography paper or paper towels
- 50-mL graduated cylinders
- Wet erase markers
- Metric rulers
- Stopwatches
- Copies of the attached handouts

Instructional activity

Content/Teacher Notes

Although a water molecule has an overall neutral charge, one of water's unique properties is that one side of the molecule is slightly negative (oxygen) and the other is slightly positive (hydrogen). This polarity of water molecules causes them to attract each other like little magnets: the slightly positive side is attracted to the slightly negative side of an adjacent water molecule. This attraction of one water molecule to another is called *cohesion,* which is the reason water molecules "stick together" and form a "skin" at the surface known as *surface tension.* Surface tension enables water to support small objects, such as water bugs, and it also allows water to form drops and bubbles. A drop of water falling from a faucet will stretch itself very thin before it finally falls. Once it falls, it immediately forms the shape of a sphere.

Water molecules also stick to molecules of other substances. The attraction of water molecules to other substances, like grass or glass, is called *adhesion.* It is adhesion that causes water's surface to rise near a container's walls; if there were no opposing forces, the water would creep up the walls higher and higher until it overflowed the container. However, in most cases, cohesion causes the formation of a "bridge" in the liquid. The various forces — adhesion between water and glass, cohesion between water molecules, and the force of gravity on the water — work in opposition until equilibrium is reached. It is these forces that lead to the concave *meniscus* in a graduated cylinder or test tube.

Capillarity is also the result of a combination of adhesion and cohesion, but one in which adhesion overcomes gravity and cohesion. *Capillary action* is the phenomenon in which the surface of a liquid is elevated or depressed where it comes in contact with a solid. When a glass tube is placed in water, the water rises in the tube, just as water rises in a piece of paper when a portion of it is placed in water. In such cases, water's adhesion to the glass and paper overcomes gravity and its own cohesion. Water moves to the tops of tall trees against the force of gravity due to capillary action.

This lesson involves four lab activities that can be conducted on four separate days or on one day at four lab stations through which pairs of students rotate.

Introduction

1. Lead a class discussion about how some insects can walk on water. How is this possible? Also, ask the students to explain how water can rise to the tops of tall trees when there is no "pumping mechanism" in a tree.
2. Place a petri dish with water on the overhead projector. Sprinkle some pepper on the surface of the water, and discuss the reason that it stays on the surface and evenly distributes across the surface. *(Surface tension, due to the cohesive hydrogen bonds among water molecules, holds the pepper on the surface.)* Very carefully add one drop of detergent to the center of the dish. Ask students to make observations and to explain what happened. *(The pepper moved to sides of the container because the detergent disrupted the hydrogen bonds that cause the surface tension.)*
3. Tell students that they will do other activities like this one to discover the unique properties of water.

Procedure

Activity 1: It's in the Liquid

1. This is a good activity for students to do first. Properties covered in this activity include adhesion, cohesion, and surface tension.
2. Prepare the blue liquid (water with blue food coloring) and the red liquid (rubbing alcohol with red food coloring).
3. Distribute a copy of the "It's in the Liquid" handout to each pair of students, and have them follow the directions.

Activity 2: Molecular Attraction

1. Properties covered in this activity include cohesion and surface tension. Students will predict and count how many drops of water a penny can hold before overflowing.
2. Give a copy of the "Molecular Attraction" handout to each pair of students, and have them follow the directions.

Activity 3: It's All Over

1. Properties covered in this series of quick activities include adhesion, cohesion, and surface tension.
2. Provide a copy of the "It's All Over" handout to each pair of students, and have them follow the directions.

Activity 4: Climbing Trees

1. In this activity, students will observe the capillary action of water in absorbent paper.
2. Prepare 10 x ½ inch paper strips, using chromatography paper or paper towels.
3. Distribute a copy of the "Climbing Trees" handout to each pair of students, and have them follow the directions.

Observations and Conclusions

1. Discuss with students the reasons that these properties of water are essential to life processes. *(Capillary action of water, with cohesion and adhesion, helps water reach the tops of trees and helps carry blood throughout organisms.)*
2. Have students complete all activity pages. Discuss adhesion, cohesion, capillary action, and surface tension, and have students draw pictures illustrating these terms.

Sample assessment

- Assess the completed activity pages.
- Have students explain the difference between adhesion and cohesion and give an example of each.

Follow-up/extension

- Allow students to do the above activities with other substances, such as soapy water, syrup, vegetable oil, and salt water.

Resources

- *Natural Resource Education Guide: Virginia's Water Resources. Virginia Naturally.* http://www.vanaturally.com/guide/water.html.
- *Virginia Naturally: Sixth Grade Science Resources.* http://www.vanaturally.com/sixthgrade/homepage.html. Resource for the sixth-grade water standards.
- *"Virginia Water Central." Virginia Water Resources Research Center.* Virginia Tech. http://www.vwrrc.vt.edu/central/virginia.htm. Offers online back issues of the *Virginia Water Central* newsletter. Current issues can be found at the Research Center's homepage (see below).
- *Virginia Water Resources Research Center.* Virginia Tech. http://www.vwrrc.vt.edu/.
- *Water Resources Management Programs.* Virginia Department of Environmental Quality. http://www.deq.virginia.gov/waterresources/.
- *Water Resources of the United States.* U.S. Geological Survey. http://water.usgs.gov/.

It's in the Liquid

Names: ____________________________ **Date:** ______________ **Class:** _____

Materials

Blue liquid, red liquid, toothpicks, two eyedroppers, petri dish

Procedure

1. Place a dime-size drop of the blue liquid in the petri dish. Use a toothpick to move it around. Record observations.

   ____

   ____

2. How can you explain this? What inferences can be made based on your observations?

   ____

   ____

3. Place a dime-size drop of the red liquid in the petri dish. *Do not* allow the red and blue liquids to touch. Use another toothpick to move the red liquid around. Record observations. ________

   ____

4. How can you explain this? What inferences can be made based on your observations?

   ____

   ____

5. Allow the drops of blue and red liquids to mix in the petri dish. Observe the liquids as they mix, and record observations. ____

   ____

6. How can you explain this? What inferences can be made based on your observations?

   ____

   ____

Inferences

7. The blue liquid stayed in a drop shape because ________________________________.
8. The blue liquid followed the toothpick because ________________________________.
9. The red liquid spread out because ____.
10. The red liquid did not follow the toothpick because ____________________________.
11. When the liquids mixed, the blue liquid spread out because _____________________

    ____.
12. When the liquids mixed, they fizzed because __________________________________.

About the Liquids

Word Bank
cohesion
surface tension
beads up
plastic
toothpick
broken
stick together
break apart

13. Fill in the blanks below, using the word bank at right.

    The blue liquid is water and blue food coloring. Water is a very special liquid with special properties. Water molecules are strongly attracted to each other. This attraction is called *cohesion.* The water molecules like to stick together, and they attract each other the most at the surface. This is called *surface tension.* Water has extremely high surface tension. The reason it hurts when you do a belly flop into a swimming pool is because of ________________________________. Although water molecules like to ________________________________, there are some things to which they don't like to stick. One of these things is plastic. When water is placed on plastic, it ___________________. The water follows the toothpick around because water likes to stick to the _________________ more than to the _________________. Water's attraction to other substances is called *adhesion.* When other substances, such as soap or rubbing alcohol, are mixed with water, the water molecules cannot stick together as well. The red liquid is rubbing alcohol and red food coloring, which causes the water molecules to ______________________________. The water and alcohol would not follow the toothpick because the alcohol disrupted the water's ____________________. When the red and blue liquids were mixed, the surface tension of the water was __________________. That prevented the purple drop of water and alcohol from following the toothpick.

In Your Own Words

14. Explain in your own words what happened with the blue and red liquids.

____

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____

Molecular Attraction

Names: ______________________ Date: ___________ Class: ____

Materials

Penny, beaker of plain water, detergent, eyedropper, paper towel, metric ruler

Procedure

1. Make sure the eyedropper is clean.
2. Predict how many drops of water will fit on the surface of a penny before it overflows.

	Number of drops on clean, dry penny	Number of drops on detergent penny
Name: ___________		
Name: ___________		
Average:		

3. Practice *slowly* dropping water *one drop at a time* from the eyedropper onto the paper towel. Pay attention to how hard you squeeze the dropper. When you have perfected this technique, go to the next step.
4. Place the penny on a dry area of the paper towel. Slowly and carefully drop one drop of water onto the penny. Observe the penny closely from the side, and draw a picture in the appropriate space below of the penny viewed from the side with one drop on it.
5. Continue dropping one drop at a time *(Keep careful count of each drop!)* until the penny is half full. Record this number, and draw a picture of the way this looks.
6. Continue dropping one drop at a time until the water overflows. Count each drop until the water almost overflows, and record this number. Draw a picture of the way the water looked just before overflowing.

Dry Penny			Detergent Penny		
One drop	Half full: ____ drops	Near overflow: ____ drops	One drop	Half full: ____ drops	Near overflow: ____ drops

7. Dry off the penny. Repeat step 6 for two more trials, varying the side of the penny used, and record data in the table below. Find the average number of drops for the three trials, and record.
8. Again, dry off the penny. Use your finger to spread one small drop of detergent across the surface of the dry penny. Repeat step 6 for three trials, and find the average number.

Coin	Number of Drops Near Overflow			
	Trial 1	Trial 2	Trial 3	Average
Dry Penny				
Detergent Penny				

Reflection on the Dry Penny

1. Did the number of drops change when using the "heads" side versus the "tails" side? _____
2. Did the size of the drops change during the experiment? _____
3. Did the same person do each trial? _____
4. Did the height and speed of the drop stay the same with each trial? _____
5. Were your trials consistent? _____ Explain why or why not.

____

____

6. Were your predictions close? _____ Explain why or why not.

____

____

7. Why did the water form a dome on the penny? Use cohesion and surface tension to explain your answer.

____

____

8. What caused the drops that spilled over the side of the penny?

____

____

Reflection on the Detergent Penny

1. Did the detergent make a difference? _____ Describe the effects of the detergent.

____

____

2. What does the detergent do to the water to have this effect?

____

____

Extension

1. Do the same experiment with different coins, or use different liquids, such as soapy water, salt water, vegetable oil, syrup, or other liquids. How do those results compare with the data collected from plain water?________________________________ Are there any differences? _____ Why?

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It's All Over

Names: _________________________ **Date:** ____________ **Class:** ____

Materials

Two plastic film canisters, eyedropper, paper clips, paper towel, plastic cups, fork, petri dish, toothpick, wax paper, glass slide

Procedure

Part A

1. Fill a plastic film canister to the brim with water. How many paper clips do you think you could add before it overflows? ______
2. Carefully add paper clips, counting each one.
3. How many paper clips did you add before the water overflowed? ______
4. What property of water allows you to add paper clips? _______________________

Part B

5. Fill a plastic film canister to the brim with water. How many more drops of water do you think you could add before it overflows? ______
6. Carefully add drops of water, counting each one.
7. How many drops of water did you add before the water overflowed? ______
8. What property of water allows you to add drops? _________________________

Part C

9. How many paper clips do you think you'll be able to rest on top of the water? ______
10. Using a steady hand, see if you can get a paper clip to rest on the surface of the water in such a way that it does not sink. If this doesn't work, try placing the paper clip on the prongs of a fork and gently lowering it onto the water. This may take several tries.
11. How many paper clips could you rest on the surface of the water? ______
12. What property of water allows a paper clip to rest on its surface? ____________________

Part D

13. What will a drop of water look like on a piece of wax paper? Draw it.

____

14. What will a drop of water look like on a glass slide? Draw it.

____

15. Place several drops of water on each surface, and draw the results.

_________________________ _________________________

wax paper glass

16. Compare the results. Record your observations.

____

____

17. What property of water would explain the results? ________________________

Part E

18. Place three drops of water near each other, but not touching, on a piece of wax paper.
19. Use a toothpick to gently push the water drops toward each other.
20. What did you observe? ____
21. What property of water caused the drops to be attracted to each other? ________________
22. Using the toothpick, try to separate the water drops.
23. What property of water keeps the water together? ________________________

Part F

24. Fill the eyedropper with water.
25. Place as many *separate* drops of water as will fit on the petri dish.
26. Quickly turn the dish over so that the drops are hanging.
27. Using a toothpick, move the drops of water together. Record your observations.

____

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28. What property of water kept the drops from falling and allowed you to move the drops with the toothpick? ____________________________
29. What property of water attracted the drops to each other? __________________________

Part G

30. Use the word bank at right to fill in the blanks below.

Word Bank
adhesion
cohesion
surface tension

Water molecules have an attraction to each other, which is called _________________________. This attraction is due to the fact that each molecule has a positive side and a negative side (polarity). The positive, or hydrogen, side of the molecule attracts the negative, or oxygen, side of another molecule. The attraction is similar to the attraction between a magnet and a paper clip, and it causes the molecules to stick together. This attraction is especially strong at the surface of the water: because the molecules at the surface have nothing above them to which to be attracted, they are attracted even more to the water molecules at their sides and below them. The pulling between molecules forms a "skin" over the water, which we call _______________________________. Water molecules also stick to molecules of other substances. The attraction of water molecules to other substances, like grass or glass, is called ____________________________. This force causes water to adhere to the walls of a glass container and causes the water's surface to rise near the container's walls.

Climbing Trees

Names: __________________________ Date: _____________ Class: _____

How long do you think it would take for water to climb a strip of absorbent paper that is 1.5 cm wide? Estimate how long it would take to climb 4 cm up the strip: _____ minutes.

Materials

Paper strips, water, 50-mL graduated cylinder, wet erase markers, metric ruler, stopwatch

Procedure

1. Put a paper strip into the graduated cylinder so that one end reaches the bottom of the cylinder and the other end hangs over the top.
2. Use the marker to put a small spot of ink 4 cm from the bottom of the paper strip. Put additional spots every 4 cm along the strip all way to the other end. Let the ink dry.
3. Put 10 mL of water into the graduated cylinder.
4. Place the paper strip in the cylinder so that the bottom end is immersed in the water but the first ink spot is just above the surface of the water. Fold the top of the paper over the top of the cylinder.
5. Start the stopwatch.
6. Record observations every 5 minutes.

Time (minutes)	Distance (cm)
0	
5	
10	
15	
20	
25	
30	

7. If the water reaches the top of the paper, remove the paper and let it dry.

Reflection

1. How did the ink change?

____

____

2. Water's ability to climb upward against the force of gravity is called *capillarity.* With adhesion and cohesion, capillarity allows trees and other plants to absorb water and nutrients through their roots and distribute them throughout the entire plant. When moving through roots, water molecules cling, or adhere, to the inside of the root and move upward. As the first molecules move up, others follow due to the attraction of cohesion.