Molecular Attraction

Strand	Matter	
Topic	Investigating adhesion, cohesion, and capillary action	
Primary SOL	6.5	The student will investigate and understand the unique properties and characteristics of water and its roles in the natural and human-made environment. Key concepts include b) the properties of water in all three phases.
Related SOL	6.1	The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which f) one variable is manipulated over time, using many repeated trials; g) data are collected, recorded, analyzed, and reported using metric measurements and tools.

Background Information

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 a sphere-like shape due to cohesion.

Water molecules also stick to molecules of other substances. The attraction of water molecules to other substances, such as 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 or teams of students rotate.

Materials

- Goggles
- 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

Vocabulary

adhesion, capillary action, cohesion, gravity, molecule, surface tension

Student/Teacher Actions (what students and teachers should be doing to facilitate learning)

Introduction

1. Lead a class discussion about how some insects can walk on water. Ask how this is possible. Also, ask students to explain how water can rise to the tops of tall trees when there is no "pumping mechanism" in a tree.
2. Display a petri dish with water. 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 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

Adhesion, Cohesion, Surface Tension

1. Prepare the blue liquid (water with blue food coloring) and the red liquid (rubbing alcohol with red food coloring).
2. Distribute a copy of the attached It’s In the Liquid handout to each pair of students, and have them follow the directions. Make sure they wear goggles when working with rubbing alcohol.

Cohesion, Surface Tension

1. Tell students that they 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 complete it.

Adhesion, Cohesion, Surface Tension

1. Provide a copy of the It’s All Over handout to each pair of students, and have them complete it.

Capillary Action

1. Prepare 10 x ½ inch paper strips, using chromatography paper or paper towels.
2. Distribute a copy of the attached Climbing Trees handout to each pair of students, and have them complete it.

Observations and Conclusions

1. Following the completion of all activity pages, discuss adhesion, cohesion, capillary action, and surface tension.
2. Discuss 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.)*

Assessment

- **Questions**
  - What is the difference between adhesion and cohesion?
  - What role does molecular attraction play in adhesion and cohesion?
- **Journal/Writing Prompts**
  - Describe examples of adhesion, cohesion, and capillary action.
  - Explain how adhesion, cohesion, and capillary action affect and improve your life.
- **Other**
  - Have students draw pictures illustrating these terms.
  - Assess the completed activity pages.

Extensions and Connections (for all students)

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

Strategies for Differentiation

- Conduct the hands-on experimental activities in cooperative learning groups, assigning roles (supply manager, recorder, leader, and illustrator) to students as appropriate to their readiness and learning profiles.
- Have student role-play, linking arms, to demonstrate <u>co</u>hesion (e.g., link with a “<u>co</u>worker” who is wearing the same color shirt), and <u>ad</u>hesion (“<u>ad</u>d a friend” who is wearing a different color shirt).
- Take students to a local pond to look for examples of surface tension which may include bugs or leaves.
- Give students magnets, and ask them to put two of them together to represent cohesion. Have students put magnets on a metal surface to represent adhesion.
- Give students sticky notes, and ask them to put two notes together to represent cohesion. Have students place sticky notes on various objects in the classroom to represent adhesion.
- Use video clips to explain molecular attraction.

It's In the Liquid

Name: ______________________________ Date: ____________ Class: ______________________

Materials

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

Safety Precautions

When using alcohol, you must wear goggles!

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

1. The blue liquid stayed in a drop shape because _____________________________________.
2. The blue liquid followed the toothpick because _____________________________________.
3. The red liquid spreads out because ____.
4. The red liquid did not follow the toothpick because __________________________________.
5. When the liquids mixed, the blue liquid spreads out because __________________________.
6. When the liquids mixed, they fizzed because ____.

About the Liquids

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.

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

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

The reason it hurts when you do a belly flop into a swimming pool is because of ______________________________. Although water molecules _____________________________, there are some things to which they don't stick as well. One of these things is plastic. When water is placed on plastic, it _________________. The water follows the toothpick around because water sticks better to the _______________ 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

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

Molecular Attraction

Name: _____________________________ Date: ___________ Class: _____________________

Materials

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

Procedure

1. Predict how many drops of water will fit on the surface of a penny before it overflows.

	Number of drops on clean penny	**Number of drops on detergent penny**
Name: __________		
Name: __________		
Average:		

2. Make sure eyedropper is clean. 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 to get just one drop. When you have perfected this technique, go to the next step.
3. Place a clean, dry 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.

Clean Penny			**Detergent Penny**		
One drop	**Half full: ____ drops**	**Full: ____ drops**	**One drop**	**Half full: ____ drops**	**Full: ____ drops**

4. 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.
5. Continue dropping one drop at a time until the water overflows. Subtract 1 from your total number of counted drops, and record this number as the number for a full penny. Draw a picture of the way the water looked when full before it overflowed.
6. Dry off the penny. Repeat step 5 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.

Coin	**Number of Drops for Full**			
	Trial 1	**Trial 2**	**Trial 3**	**Average**
Clean Penny				
Detergent Penny				

7. Dry off the penny. Use your finger to spread one small drop of detergent across the surface of the penny. Use the detergent-coated penny to repeat steps 3–6.

Reflection Questions on the Clean Penny

1. Did the size of the drops change during the experiment? _____
2. Did the same person do each trial? _____
3. Did the height and speed of the drop stay the same with each trial? _____

4. Did the number of drops change when using the "heads" side versus the "tails" side? _____
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 Questions 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 when using plain water?
2. Are there any differences? _____ Why?

It's All Over

Name: ____________________________ Date: ___________ Class: _____________________

Materials

Two small clear cups, eyedropper, small paper clips, paper towel, fork, petri dish, toothpick, wax paper, glass slide

Procedure

Part A

1. Fill a small clear cup 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 small clear cup 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.

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.
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, such as 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

Name: ______________________________ Date: ____________ Class: ______________________

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 cohesion among them.

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

Strip of paper (made from chromatography paper or paper towel), water, 50-ml graduated cylinder, wet-erase marker, metric ruler, stopwatch

Procedure

1. Use the marker to put a small spot of ink 4 cm from the bottom of a paper strip. Put additional spots every 4 cm along the strip all way to the other end. Let the ink dry.
2. Put 10 ml of water into the 50-ml graduated cylinder.
3. Place the strip of paper 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 edge of the cylinder.
4. Start the stopwatch.
5. Record observations every 5 minutes.

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

Reflection Questions

1. How did the ink change?
2. What was the final height of the water after 30 min.? __________
3. Did the water reach the top of the strip? _______ If the water reached the top, how long did it take? __________
4. Did the water climb up the strip at the same rate throughout the 30 min.? _______ If not, when did it climb quickly? _______________ When did it climb slowly? ________________
5. What could be the reason for the different rates of climb near the bottom and near the top of the strip?