Surface Tension: Liquids Stick Together
Teacher Version

In this lab you will learn about properties of liquids, specifically cohesion, adhesion, and surface tension. These principles will be demonstrated by adding drops of different liquids to pennies to determine the strength of molecular attraction.

California Science Content Standards:

- 2. Chemical Bonds: Biological, chemical, and physical properties of matter result from the ability of atoms to form bonds from electro-static forces between electrons and protons and between atoms and molecules.
- 2a. Students know atoms combine to form molecules by sharing electrons to form covalent or metallic bonds or by exchanging electrons to form ionic bonds.
- 2d. Students know the atoms and molecules in liquids move in a random pattern relative to one another because the intermolecular forces are too weak to hold the atoms or molecules in a solid form.
- **2h. Students know how to identify solids and liquids held together by van der Waals forces or hydrogen bonding and relate these forces to volatility and boiling/melting point temperatures.

Prerequisites:

- Students will be asked to create mixtures, place droplets of liquid onto a penny, count droplets, and write numbers and basic observations.
- Advanced students will follow the same procedure, but their mathematical calculations will focus on statistical methods and will be more complex; a calculator is required for advanced students.
- There are no mobility limitations with this lab nor are any particularly special materials required.

Key Concepts:

- **Cohesion** is the attraction of molecules among its own kind; i.e. between two water molecules. Because of cohesion, water and other liquids form thin films and drops. This is why water bugs can walk on water, and why a carefully placed paper clip will float.
- **Adhesion** is the attraction between different substances; i.e. between a water molecule and a copper molecule. Adhesion powers a certain process that allows water molecules to move upward through a narrow tube. The attraction of water to the walls of a tube sucks the water up more strongly than gravity pulls it down (i.e. water moving up a plant's roots).
- **Surface tension** is a property of a liquid that allows them to resist external forces. It combines the concepts of cohesion and adhesion. Surface tension is caused by a strong attraction between the molecules (cohesion) that cause them to link together and remain uniform, even when placed on differing surfaces (adhesion). When the molecules possess weak positive interactions, as is the case with rubbing alcohol, surface tension will be small compared to other liquids.

- **Hydrophobic** or "water-fearing" molecules are molecules that do not like to be near water. Water molecules have a **dipole**, meaning that one side of the molecule has a slightly positive charge and one part has a slightly negative charge.

Introductory Mini-Lecture

Have you ever wondered why small, bubble-like droplets appear on the table when you spill your water? Have you noticed the little spots of oil amongst water on the street after a rainy day? The explanation for these observations lies in principles of liquid: cohesion, adhesion, and surface tension.

In any solid or liquid substance, molecules will be attracted to each other due to the presence of **intermolecular forces**. These forces depend on the distribution of **electrons**, very small, negatively charged particles. Movement of electrons changes the attraction between molecules, so you can think of them as behaving like magnets. Certain parts of a molecule will be attracted to other parts of different molecules and will cause them to stick together. Since all of the molecules are the same, this attraction will be very strong. A water droplet on a desk, for example, is made of many tiny water molecules that are attracted to each other. This is called **cohesion**. Molecules can also be attracted to molecules from different substances. The same water droplet on a desk will also be attracted to molecules in the desk. This is called **adhesion**.

Today, we will examine adhesion by placing drops of different mixtures onto pennies. As we add more drops of each liquid, we will start to see cohesion taking place. The more drops we can add to a penny, the stronger the interaction between molecules and, hence, the greater the surface tension.

Additional considerations:

- To demonstrate cohesion, it is useful to show attraction using magnets.
- To demonstrate adhesion, it is useful to place droplets of liquids on a common surface (desk).
- During the lab, the measurements (number of drops on a penny before spilling) may be affected by the cleanliness of the penny. You can either clean all pennies before beginning *or* pose this question to students to have them contemplate results that may not have been what they predicted.

Complete List of Materials

- Pennies *(at least 3 per student/group, need to be very clean)*
- Water
- Soap *(dishwashing detergent works best)*
- Rubbing Alcohol
- Dropper
- Paper towels
- Calculator *(1 per student/group, required for advanced lab only)*
- Milk *(non-fat milk works best)*
- Food coloring *(non-gel food coloring works better)*
- Toothpick
- Bowl

Part 1 - Drops of Water on a Penny

(Adapted from www. middleschoolscience.com)

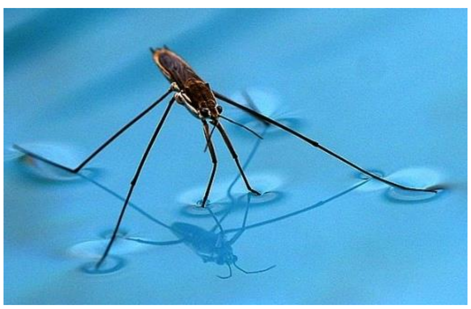
In this portion of the lab you will determine which liquid has the highest surface tension: water, soapy water, or rubbing alcohol. In order to do this, you will determine the number of droplets that can fit onto a penny without spilling over for each liquid. The liquid that can fit the most droplets onto the penny has the highest surface tension, because it can hold onto itself the tightest!

Q1. Using your own words, define surface tension.

Surface tension is a property of a liquid that can be either a strong or weak attraction between molecules.

Q2. List two examples of surface tension that you have observed in your own life:

There are many different examples of surface tension in everyday life, but here are a few examples:



www.boards.na.leagueoflegends.com

Water Striders

http://marketismic.files.wordpress.com/2011/02/drop.jpg

Dew Drops

www.learnnc.org

Mercury has a much higher surface tension than water, which is why spilled mercury will spontaneously form small balls that roll around. NEVER handle mercury without gloves, as it is a highly toxic material.

www.catholiclane.com

Bubbles! Soap must be added to water to create bubbles, because it lowers the surface tension of the liquid.

Q3. Make a prediction: the penny will hold the greatest number of drops when I use…

(a) clean water
(b) soapy water
(c) rubbing alcohol

ANSWERS WILL VARY. Ideally, the student may be able to predict that the number of droplets will have the relationship rubbing alcohol < soapy water < clean water.

Q4. Approximately how many drops of clean water do you think the penny will hold?

(a) 10 drops
(b) 40 drops
(c) 100 drops

ANSWERS WILL VARY

Procedure:

1. **Fill a dropper** with water.

2. **Place the penny**, heads up, on top of a paper towel.

3. **Hold your dropper** about 1-inch above the penny and **add drops of water** to the surface of the penny until it overflows.

4. *Record the number of drops of water* the surface of the penny can hold in the table on the next page under the column labeled "Run 1."

5. **Repeat** steps 2-4 two more times and record your results for "Run 2" and "Run 3."

6. **Repeat** the experiment (steps 2-6) for rubbing alcohol and then soapy water. Be sure to rinse and dry the penny thoroughly between experiments! You should also clean the droppers if you are reusing them.

7. *Add the number of droplets of water the penny held for Run 1, Run 2, and Run 3 and write this total in the column labeled "Sum of Runs."*

8. *Divide this number by three, the number of runs performed, and record this number in the column labeled "Average."* This is the average number of drops the penny held for your three runs.

9. **Repeat** this process with the results from soapy water and rubbing alcohol.

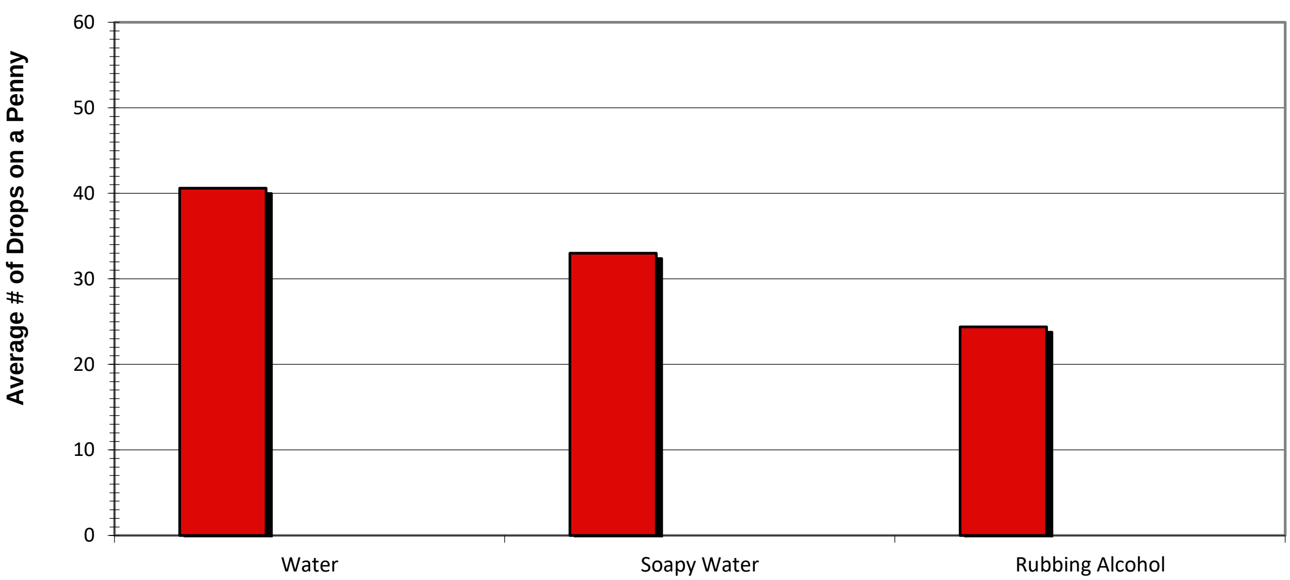
10. *Plot* the average number of droplets for each liquid using the bar graph provided on the next page.

Data Table 1: Drops of liquid on a penny.

Name of Liquid	Number of Droplets			Sum of Runs	Average = Sum of Runs / Number of Runs
	Run 1	Run 2	Run 3		
Water	37	42	44	123	41.0
Soapy Water	33	34	33	100	31.7
Rubbing Alcohol	29	22	23	74	24.7

Record your data in the table below and calculate the average for each liquid.

Values provided in the table were attained from a "test run" of the experiment, and are provided to indicate the range of values you might expect to see during the experiment. Student results will vary. The order of rubbing alcohol and soapy water will depend on how much soap you add to the water.



Q5. Were your predictions from the beginning of the lab correct?

(a) Yes
(b) No

Q6. How were your predictions different from your experimental results?

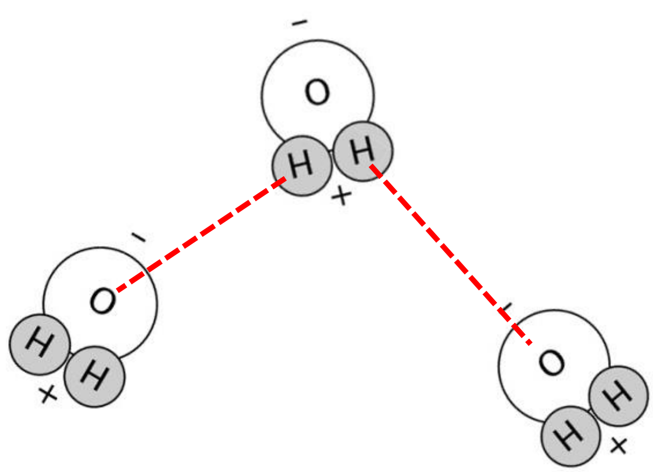
Q7. Which liquid do you think has the strongest molecular interactions? In other words, which liquid can hold onto itself the tightest?

(a) clean water
(b) soapy water
(c) rubbing alcohol

Q8. The surface tension of water is 72.8 millinewtons per meter and the surface tension of rubbing alcohol is 23.0 millinewtons per meter. The higher the number, the stronger the molecular interactions between the liquid molecules. Do these values match what you would have expected given your experimental results?

(a) Yes *(hopefully)*
(b) No

Q9. Below is a cartoon depicting three water molecules. Draw lines to indicate how you think the molecules "bond" or interact with one another.



Part II: Tie Dye Milk

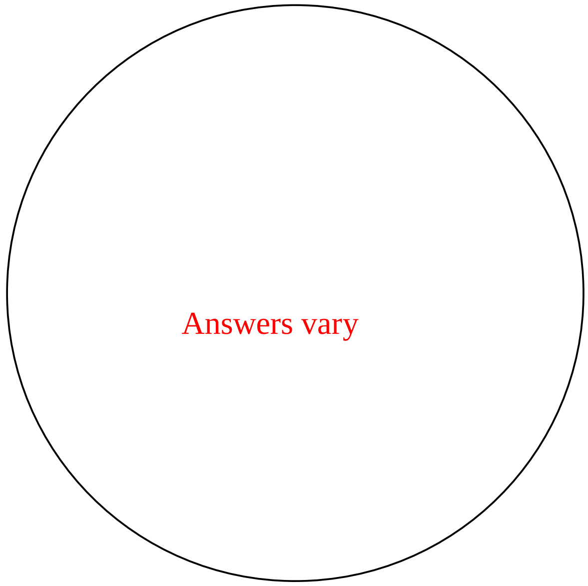
In this portion of the lab you will alter the ***surface tension*** of milk by adding a very small amount of dishwashing liquid to it. Milk produced by cows is mostly water (87.7%), but it also contains protein (3.4%), fat (3.6%), sugar (4.6%), and minerals (0.7%). When you add dishwashing liquid to the milk, the soap molecules move to the surface of the milk. They prefer the surface of the milk because they are ***hydrophobic*** or “water-fearing” and they can interact with air molecules at the surface versus being surrounded by water molecules in the bulk liquid. The soap molecules have to squeeze between the water molecules to gain access to the surface of the liquid. When the soap molecules get in between two water molecules, they decrease the water’s ability to hold onto itself. This in turn causes the ***surface tension*** of the milk to decrease. To visualize the change in surface tension you will first add food coloring to the milk to create a design of your choosing. Then watch what happens you add soap using a toothpick!

Procedure:

1. **Fill** bowl ¾ full with milk.
2. **Place** a few droplets of food coloring into the milk (have fun making your design!).
3. *Draw a picture* of the design you made in the space provided below.

Answers vary

4. **Dip one end** of the toothpick into dishwashing soap.
5. **Lightly touch** the soapy end of the toothpick to the milk surface.
6. *Draw a picture* of the design you made after you touched the surface of the milk with the soapy toothpick in the space provided on the next page.



Q10. Describe what happened when you touched the surface of the milk with the soapy end of the toothpick.

When students touch the soapy toothpick to the surface of the milk, they will see a very rapid movement of the milk outward. The food coloring helps students visualize this movement.

Q11. What do you think is happening to the ***surface tension*** *of the milk when you add the dishwashing soap?*

When the soap is added to the surface of the milk it will spread along the surface and cause a rapid decrease in surface tension, which is what causes the observed reaction. I have heard it likened to the popping of a balloon, where you are "poking a hole" in the "skin" of the milk.

Q12. If you repeat the experiment using the same milk does it work as well as the first time you did it?

(a) Yes
(b) No

Q13. Why do you think this is?

You should get the same result if you repeat the experiment. However, the effect will be less dramatic with successive trials as the surface becomes saturated with soap molecules.