STUDENT ACTIVITY GUIDE

How does water form droplets on surfaces?

The challenge

If you've ever stared out a window on a rainy day, you've probably noticed the rain forming rounded droplets on the glass. You may have seen water "bead up" when you spilled some on a counter or watched a drop of water slowly form into a blob at the lip of a leaky faucet. It turns out that not all liquids behave this way, so what makes water special?

Why does water form droplets instead of spreading out in an even sheet? What aspects of molecular structure cause water to have this property? In this activity, you'll investigate several liquids, including water, and use your knowledge of molecular polarity to develop an explanation.

By the end of this activity, I will be able to…

- explain how molecular structure affects the strength of intermolecular forces and the behavior of a liquid in a charged field
- collect and analyze data on certain properties of liquids and use these data to make inferences about the relative strengths of the liquids' intermolecular forces
- make predictions about certain properties of liquids (surface tension and boiling point) based on the relative strengths of their intermolecular forces

Setting the stage

Electrical forces between particles are responsible for the structure and interactions of matter. Some of these forces create covalent bonds between atoms ***within*** molecules, which are called _____________________________ forces, and some create attractions ***between*** different molecules, which are called _____________________________ forces. It is useful to remember that opposite charges attract and like charges repel.

The strength of intermolecular forces in a substance can be used to explain many of its properties, such as melting point, vapor pressure, boiling point, and surface tension.

By comparing the structures of molecules in different substances, we can make inferences about the relative strengths of their intermolecular forces and predict how their properties will compare. And by observing how their properties compare, we can make inferences about the relative strengths of their intermolecular forces.

Molecules may contain polar and/or nonpolar covalent bonds. Bond polarity is determined by the difference in electronegativity between atoms in the bond.

- Electronegativity is the measure of an atom's ability to _____________________________ electrons in a bond.
- A bond where the difference in electronegativity between the atoms is greater than 0.5 is considered (circle one) **polar/nonpolar**.
- A bond where the difference in electronegativity between the atoms is less than 0.5 is considered (circle one) **polar/nonpolar**.

Since atoms in a polar bond have different levels of attraction for their shared electrons, these electrons will spend more time closer to the (circle one) **more/less** electronegative atom.

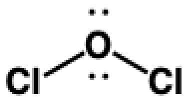
As a result, the more electronegative atom will have a partial _____________________________ charge and the less electronegative atom will have a partial _____________________________ charge. This separation of charge is the **dipole moment** of the bond.

We use lowercase delta signs (δ- and δ+) to indicate partial charges on the atoms. The dipole moment of a bond can also be shown using arrow notation like this (where the arrow points in the direction of the more electronegative element): 

Use the electronegativity values in the table below to draw bond dipole moments on the molecules using arrows or delta signs.

H—Cl

F—Br

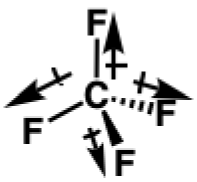


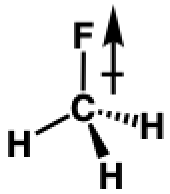
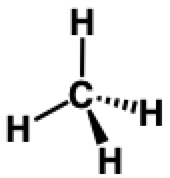
Element	Electronegativity
H	2.1
C	2.5
O	3.5
F	4.0
Cl	3.0
Br	2.8

But, having polar bonds is not enough for a *molecule* to be polar.

- Molecules are polar if charge distribution is ______________________________ because individual bond dipoles do not cancel out.
- Molecules are nonpolar if charge distribution is ______________________________ because bonds are nonpolar *or* because individual dipoles cancel out.

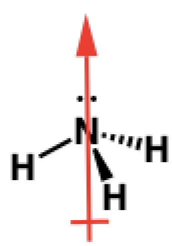
Fill in the table below to indicate if the ***molecule*** is polar or nonpolar.

Molecule	Polar or nonpolar?
	

When a molecule is polar, we can add up all the individual bond dipole moments to draw one overall ***molecular dipole moment***. For example, in the ammonia molecule below, there are three bond dipoles. In each N-H bond, the dipole arrow points toward the more electronegative N atom, indicating that it has a partial negative charge and the H atom has a partial positive charge:

When we add up these bond dipoles, we get one arrow pointing toward the N atom. This shows that the overall charge distribution in the molecule is uneven, and the molecule is polar:



Now that you've reviewed how the structure of a molecule affects its polarity, let's investigate how this uneven distribution of charge can be used to explain some of the fundamental properties of substances that we observe every day. Why ***does*** water form droplets on surfaces?

Let's get started!

Materials

- 1 plastic drinking straw
- 1 piece of fabric/clothing to rub on the straw to transfer charge (fleece, wool and felt work well)
- 3 plastic cups with a small hole in the bottom labeled 1-3
- 3 cups or beakers containing separate liquids labeled 1-3 with the liquids' names
- 3 empty cups or beakers labeled 1-3
- 3 pennies
- 3 droppers
- 3 paper clips

Investigation (Part 1): Liquids with a charged "wand"

1. Gather the three cups labeled #1. There should be one empty cup, one empty cup with a small hole in the bottom, and one cup containing a liquid.
2. Place the empty cup on a table. One team member should hold the cup with the small hole in the bottom about half a meter ***directly above*** the cup on the table.
3. Another team member should hold the drinking straw at one end and rub the piece of fabric over it to create a static electric charge on the "wand."
    - ***Tip***: Be careful not to let the straw touch anything once you have charged it. Continue holding it at the end without changing hands.
4. Once the straw is charged, the team member holding the cup with the small hole should carefully pour liquid #1 into the cup. A narrow, steady stream of liquid should flow through the hole down into the empty cup on the table.
    - ***Tip:*** Pour very slowly at first to make sure the cups are lined up and the liquid is flowing smoothly.
    - ***Tip:*** If you have a third team member, have that person pour or hold the cup on the table steady.

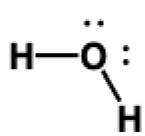
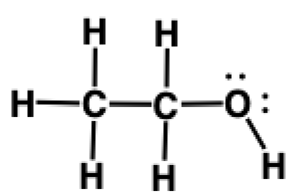
5. When there is a steady stream of liquid flowing down, bring the charged straw close to the stream ***without touching it***. Move the straw up and down alongside the liquid stream (without touching it). Observe the liquid's behavior and record your observations in the table below.
    - ***Tip:*** If the straw does touch the liquid stream, carefully dry it off with a paper towel, return the liquid to its original cup, and begin the process again.
6. Trade roles with your teammates and repeat steps 2-5 until each team member has a chance to charge the straw and observe the liquid's behavior closely.
7. When you are done observing liquid #1, set those cups aside, wipe up any spills, gather the three cups labeled #2, and carry out steps 2-6 for liquid #2.
8. Repeat the whole process for liquid #3. Make sure to record your observations in the table below for each liquid.

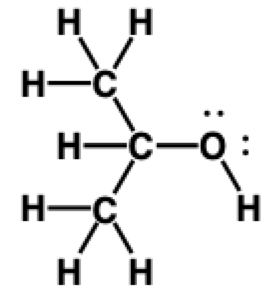
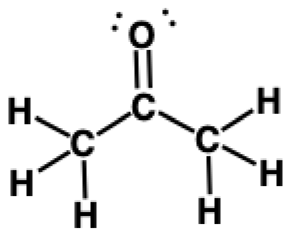
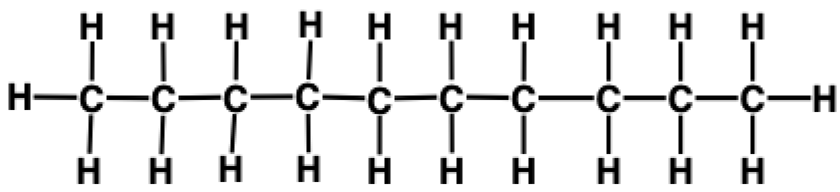
Cup #	**Name of liquid (from the cup label)**	**Behavior of liquid with the charged wand (Did the liquid stream move?)**
1		
2		
3		

Follow-up questions (Part 1)

1. Some of the liquids were affected by the charged wand and some were not. Based on your observations, which liquids contain polar molecules? Explain your thinking.

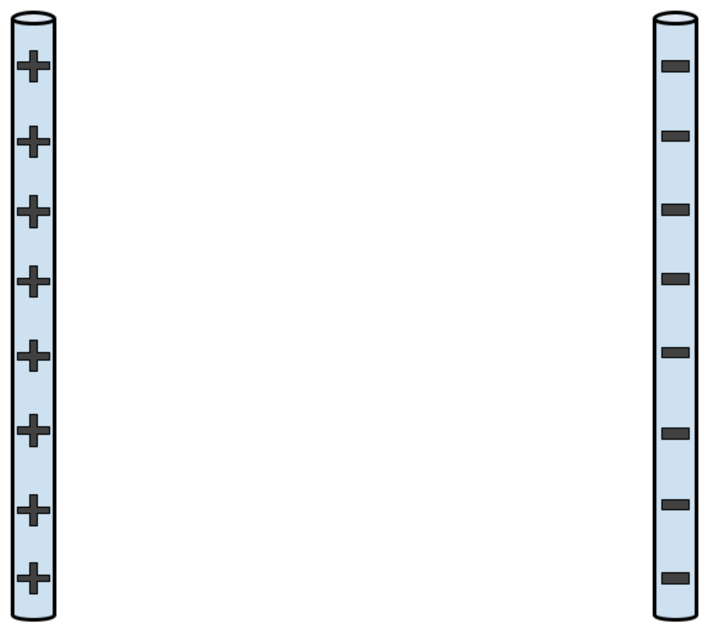
2. Given the molecular structures below, find those that correspond to the liquids you tested. For each of the liquids you tested, draw the appropriate bond dipoles and a molecular dipole moment (if any exist). You may want to refer to the table of electronegativity values in the *Setting the stage* section.

Water	
Ethyl alcohol	

Isopropyl alcohol	
Acetone	
Mineral oil	

3. Can you determine from this investigation if the wand is positively or negatively charged? Explain.

4. In the space below, you will see a positively charged wand on the left and a negatively charged wand on the right. Sketch a model to show how the molecules in one of the polar liquids could attract to the positively charged wand. Then sketch a model to show how molecules of the **same** liquid could attract to the negatively charged wand.



Investigation (Part 2): Drops on a penny

1. Place a penny heads or tails side up on top of a paper towel on a flat surface. (You can choose heads or tails, but be consistent every time!)

2. Starting with liquid #1, use a dropper to carefully place drops of the liquid from the cup onto the surface of the penny.

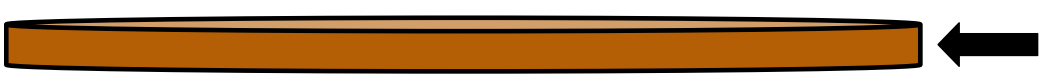
3. Count the number of drops you can add to the penny's surface before the liquid slides off the penny and onto the paper towel. Use the table below to record the number of drops you were able to add ***before*** the liquid slid off the penny.
4. Dry off the penny, and repeat the process for a second trial. This time, while you are adding drops, position yourself so that the penny is at eye level. Observe the shape of the drops from the side, and add a sketch of your observations to the table.
5. Dry off the penny, and repeat the process for a third trial.
6. Using a new penny and a new dropper for each liquid, complete steps 1-5 for liquids #2 and 3.
7. When you have finished recording all your data, carefully wipe up any spills and dispose of wet paper towels.

Cup #	Name of liquid (from the cup label)	# of drops (trial 1)	# of drops (trial 2)	# of drops (trial 3)	# of drops (avg)	Sketch of drop from the side
1						
2						
3						

Follow-up questions (Part 2)

1. Use your data for the number of drops of each liquid that fit on the penny to rank the three liquids in terms of the strength of their intermolecular forces from ***weakest to strongest***. Explain your reasoning.

2. Sketch a model to show how the molecules in the water drops interact to stick together on top of the penny in the drawing below.



Side view of penny

Khan Academy

Investigation (Part 3): Make predictions

Surface tension is a property that allows a liquid to resist a force pressing down on its surface. Now that you have collected and analyzed data and created models for some behaviors of three liquids, let's consider what you think will happen if you gently place a paperclip on the surface of each liquid. Will the paperclip float on the surface, or will it sink?

Record your predictions in the table below.

Cup #	Name of liquid (from the cup label)	Prediction (Will the paperclip float or sink?)
1		
2		
3		

Explain how you made your predictions.

Let's test your predictions!

Take a paperclip and bend one end slightly upward, as shown in the photo to the right. This will allow you to place the paperclip very gently on the surface of the liquid without touching the liquid with your hand.

Test each liquid with a different paperclip.

Tip: Hold the paperclip by the bent end and try to keep the paperclip completely parallel to the surface of the liquid as you place it.

Did the experimental results agree with your predictions? Explain.

How does the strength of the intermolecular forces in the liquids relate to whether or not the paperclip floats?

Boiling point is another physical property of a substance that is related to the strength of its intermolecular forces. Based on what you have learned so far, predict the relative boiling points of the **polar** liquids that you tested.

Predicted ranking from ***lowest to highest*** boiling point:

Explain how you made your predictions.

Use an online or print resource to look up the actual boiling points of the liquids. Was your predicted order correct?

Keep creating!

We've seen that the strong intermolecular forces in water contribute to its high surface tension. Use your understanding of intermolecular forces to create a digital or paper poster explaining with words and pictures why water droplets are spherical, or nearly spherical. (On the International Space Station, they are completely spherical! Why do you think this is?) Brainstorm and research other phenomena that are related to water's strong intermolecular forces, and include these in your poster.

More creative activities!

Below are some ideas for how you can use your creativity and your understanding of intermolecular forces to generate new ideas and solutions.

- How does adding salt to water affect the strength of intermolecular forces in the liquid? Repeat the drops on a penny experiment using water with different amounts of salt dissolved in it. Keep the volume of water constant and add increasing amounts of salt. Plot a graph showing the amount of salt vs the number of drops that fit on the surface of a penny. What relationship do you see? What does it tell you about the effect of dissolved salt on the strength of intermolecular forces in the salt water solution? Use Adobe InDesign or markers and paper to create a poster that includes your experimental design, your graphical analysis, and your experimental conclusions.

- Water striders are insects that are able to walk on top of water by taking advantage of the liquid's high surface tension. Do some research to discover how a water strider's body structure and motion allow it to stay on the water's surface without sinking and to move across the surface at a rate of 100 body lengths per second! Design an interactive exhibit for a science center that can teach other people about what you learned.

- Have you ever wondered how dish soap works to help clean a sinkful of dirty pots and pans? Dish soaps contain *surfactants*, which are molecules that have a polar part and a nonpolar part. This dual nature enables them to decrease the surface tension of water and facilitate the mixing of nonpolar substances, like grease and oil, with water. Do some research to learn more about surfactants and create a model showing how surfactant molecules interact with water and oil molecules to aid the process of cleaning dishes.