Surface Tension

Teacher Handout

Module Overview

Surface tension is the result of forces between molecules in a liquid, called cohesive forces. At the surface of a liquid, the molecules do not have liquid molecules all around them. Therefore these surface molecules interact more strongly with the molecules that are next to them. The strength of the cohesive forces varies, depending on the kind of liquid and any solutes present in the liquid.

After this lab, students will be able to answer questions like: How do some insects walk on water? Could YOU somehow walk on water? What happens to surface tension with the addition of soap to water?

Curriculum Links

Missouri Science Standards

1.B.c. Predict the effects of solvent and solute polarity on solubility ("like dissolves like")

Next Generation Science Standards

HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

Goals

1. To understand the concept of surface tension.
2. To demonstrate that surface tension is a physical property of liquids (i.e. water)
3. To demonstrate that surfactants can reduce the surface tension of a liquid.

Timing

This activity will take about 60 minutes to complete.

Kit Materials (per group of 3 students)

Provided by the Young Scientist Program

Pennies
2 Eyedroppers
2 cups (one water and one for soapy water)
Soap
2 small paperclips
Pepper
A large tin

Kit Materials (per group of 3 students)

Provided by teacher

Paper towels

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Kit Materials for Teacher Demo
Provided by the Young Scientist Program

Candle
Matches Funnel
Soap
Sugar
Tin

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Lesson Design Tool

Course: Teacher:
Week of: Grade Level:

CONTENT AREA:	**DIFFERENTIATED INSTRUCTION/CROSS CONTENT INTEGRATION**
Goals: Big Idea/Concept	*HOW will you teach the content? (groups, strategies, accommodations, variation, etc.)*
At the surface of a liquid, the molecules do not have liquid molecules all around them. Therefore these surface molecules interact more strongly with the molecules that are next to them. The strength of the cohesive forces varies, depending on the kind of liquid and any solutes present in the liquid.	Short lecture on the concept of surface tension in liquids and how surfactants can reduce the surface tension of a liquid. In small groups, perform the four experiments covering the concept of surface tension, the strength of the bonds of the molecules in the liquid at the interface with the air, and the effect of surfactants on surface tension. Demonstrate one experiment which shows the strength of the bonds of the molecules in the liquid at the interface with the air – air from a bubble blowing out a candle. Individually answer questions and discuss as a large group.
Grade Level Expectation/Objective: *(WHAT are you going to teach?)*	
1.B.c. Predict the effects of solvent and solute polarity on solubility (“like dissolves like”) HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.	
Essential Question(s)/DOK: *Higher Order Questions (scaffolded questions to get to Big Idea)*	
Could you walk on water? How do surfactants (soap) get rid of dirt? How would hydrophobic/hydrophilic solvents affect surface tension? Is there a relationship between solubility and surface tension? How does the electrical charge of water molecules (partial negative due to oxygen atoms and partial positive due to hydrogen atoms) contribute to surface tension? Do liquids other than water demonstrate surface tension? Would the forces in the surface liquid molecules of these other liquids be stronger or weaker than water?	

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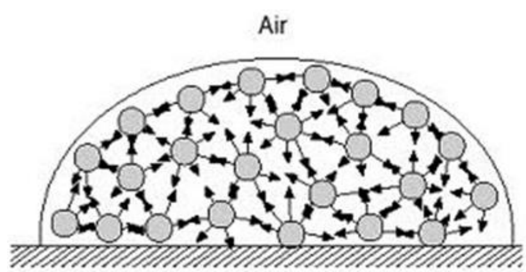
Assessment/Performance Task: *How will students SHOW what they have learned?*		**Teacher Reflections/Student Work Analysis**
Responses on handout/discussion questions		
Vocabulary	**Vocabulary Strategies**	**Reteaching Strategies**
cohesive forces, surface tension, solvent, solute, solubility, surfactant, hydrophobic, hydrophilic, charge/electrical force, bonding, intermolecular force, polar, non-polar		
Technology/Manipulatives		
Pennies, eyedropper, cup, water, soap, paper clips, pepper, candle, matches, funnel		

Background

Surface tension is the result of forces between molecules in a liquid, called cohesive forces. At the surface of a liquid, the molecules do not have liquid molecules all around them. Therefore these surface molecules interact more strongly with the molecules that are next to them. Because the attraction of surface molecules inwards is much stronger than the attraction to air, surface tension is created and the liquid beads up to maintain a liquid-air interface with a minimum surface area, which is a dome.



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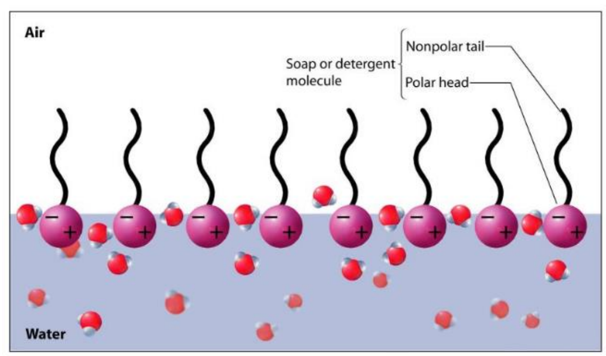
The strength of the cohesive forces varies, depending on the kind of liquid. Water has very strong surface tension, one of water's most important properties. Water molecules hydrogen bond to each other, due to the partial negative charge of the oxygen atoms and the partial positive charge of the hydrogen atoms, making water polar. It is the reason that water collects in drops, but it is also why water can travel up a plant's stem, or get to your cells through the smallest blood vessels. It even allows insects to walk on water! Several insects are able to walk on water, such as the water strider (right). Their legs are shaped to distribute their weight over a large surface area. The strong surface tension of the water can then hold the insects weight and prevent the bug from sinking due to gravity. Even though the relative surface tension of water is relatively strong, the cohesive forces between molecules in a liquid are not powerful. Can large animals, or can you, walk on water?

What is a surfactant? Surfactants are made up of polar parts that are attracted toward (and therefore are soluble in) water (hydrophilic) and other non-polar parts that repel water (hydrophobic). Water-repelling (hydrophobic) molecules are not soluble in water. When surfactants (with both their polar and non-polar parts) are placed in a system of opposing forces (i.e. air-water or oil-water), the hydrophilic groups orient toward the water, and the hydrophobic groups orient away (towards air or oil). This lowers the surface tension because now the water can interact with both other water molecules *and* the water loving portions of the surfactant. This means the molecules of water are no longer forced into a tight cohesion with each other but can spread into a wider area. You can observe this effect by watching the dome structure formed by drops of water on a surface collapse with the addition of a surfactant. In fact, the addition of any polar or ionic solute to water, like table salt, reduces surface tension. Based on the picture on the left, can you explain why?



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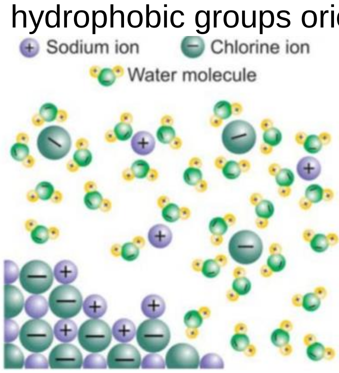

Surfactants have many commercial uses, and depending on the use can be called by many names, including: wetting agents, emulsifying agents, solubilizing agents, detergents or soap. Surfactants also play an important role in the body. For example: phospholipids are a key component in cell membranes, which act as a protective surface against the

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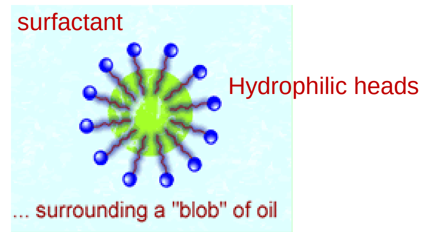
environment. We can observe surfactants at work in everyday life when attempting to combine two not easily mixed liquids such as nonpolar oil and polar water. When these liquids come into contact, they do not bond to each other: resulting in surface tension! However, a surfactant can enable these two liquids to mix more readily. A good example of this is an oil and vinegar salad dressing where the addition of a proper surfactant will lower the tension between the two liquids and allow them to mix: creamy salad dressing contains egg yoke or an artificial surfactant to do just that. Surfactants are also widely used in pharmaceuticals. Surfactants are commonly added to drug suspensions to hinder caking of medications during storage, for reconstitution of powdered forms of medication into water at later use, or as an additive to tablets to aid in the penetration of moisture into the tablet for ready disintegration upon administration.



Experiment #1: Visualizing Surface Tension on a Penny

In this experiment, you will visualize the surface tension of water by dropping water onto a penny with an eyedropper. Soap (a surfactant) will then be added to the water to test if this changes how many drops can be held on the penny.

Materials:

Penny
2 Eyedroppers
1 cup with water
1 cup with soapy water
Paper towels.

Protocol:

1) Take a clean penny and place it on a paper towel.
2) Load your eyedropper with water.
3) Carefully add water to the penny, one drop at a time. Count each drop and observe the shape.
4) After 5 drops, write down how many drops you think can be held on the surface of the penny.
5) Continue dropping water onto the penny until the surface tension can't hold the water together anymore and the bubble collapses.
6) Dry off your penny and repeat the experiment with the soapy water and a different eyedropper. Drop 5 drops, observe the shape, and guess how many drops the penny will now be able to hold.

Challenge: see who can get the most water on the pennies!

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Discussion Questions

1) Were you able to add more or fewer drops to the penny with the soapy water? *The soap is a surfactant, which reduces the surface tension of water. Therefore fewer drops should be added to the penny before the dome collapses.*

2) Were you surprised by how many drops of water the penny could hold?
The penny will probably hold more drops than the students will expect. We were able to place 27 drops on the penny. You may want to record how many drops each student gets, average, and discuss why some students may have gotten very different numbers due to changes in how the experiment was performed.

3) How does surface tension explain how rain comes down in droplets instead of in a sheet?
A rain drop is composed of the maximum number of water molecules that can be held together by attractive inter-molecular cohesive forces. The shape of the drop is caused by the surface tension of the water, which creates a bead- like shape that is distorted by gravity as it falls. In the absence of gravity, the drop would minimize the surface area in order to minimize tension, which would result in a perfectly spherical shape (closer to the shape of the drop of water placed on the surface of a clean penny).

4) Question for thought: Why does the water become a sphere? Why not a triangle or a rectangle?
Think about how the forces are interacting. By minimizing the surface area, the surface tension is reduced. A sphere has the smallest ratio of surface area to volume. A triangle and rectangle would have larger surface areas than the sphere!

Experiment #2: Visualizing the Displacement Required to Break Surface Tension In this experiment, you will see how many pennies can be placed in a cup of water without the cup overflowing.

Materials:

Pennies
Cup
Water
Paper towels

Protocol:

1. Place the cup on a few paper towels. Make sure that it is level.
2. Fill the cup to the rim with water (make sure the water level is as high as possible without spilling over)!
3. Gently drop in one penny and observe any changes in the water.
4. Write down how many pennies you think you can add without the water overflowing.

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5. Continue to gently add pennies one at a time until the water overflows. Be sure to observe the shape of the water surface.

Discussion Questions

1. How many pennies could you add? Was this more or less than you predicted? *Students will probably be surprised by how many pennies they can add to the cup before it overflows. When we added carefully we added over 80 pennies.*

2. What happened to the water in the cup as you added pennies?
The water rises above the cup in an arc due to the surface tension. The curved shape is due to the optimization of surface area to reduce tension, just like in a water drop.

Experiment # 3: The Strength of Surface Tension

In this experiment you will see how surface tension can hold the weight of a paper clip, such that it floats upon the water.

Materials:

1 cup of water
Soap
2 small paper clips
Paper towels

Protocol:

1. Place the cup of water on a paper towel. Take one paper clip and drop it into the cup. Observe if it floats or sinks.
2. Tear off a piece of paper towel that is slightly larger than the size of a paper clip. Place this flat on top of the water.
3. Carefully place the paper clip on the widest side on the piece of paper towel. Once the paper towels get wet, observe if it sinks or floats.
4. Add a drop of soap into the cup of water.

Discussion Questions

1. Is a paper clip more or less dense than water? Will it sink or float?
Paper clips are denser than water and therefore will sink to the bottom of the cup. However, the surface tension is strong enough that an item like a paper clip can be made to float on water.

2. What was different about the paper clip that was dropped into the cup versus the one that floated?
By gently placing the paper clip on its side on top of the water, the force of surface tension is able to keep the paper clip floating. The weight of the paper clip is distributed

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over the largest area possible, so the water's surface tension is able to overcome the weight of the paper clip and makes it float!

3. What happened with the addition of soap?
   The soap is a surfactant that interferes with the water molecules' ability to bind to each other. This lowers the surface tension of the water and results in the paper clip sinking instead of floating.

4. What else might be able to float on water? How about in water with soap? *Many items can float on water but once they become wet they will sink because they are denser than water. Pepper is a good experiment—it will float on water if sprinkled on top. If soap is added, the pepper will sink.*

5. How do some insects walk on water? Could YOU somehow walk on water? *Insects that walk on water are using the same property as the floating paper clip. The large surface area of their feet allows their weight to be distributed in such a way that the water's surface tension can overcome the force of the insect's body, allowing them to float and glide on the water.*

Experiment #4: The Great Effect of Surfactants on Surface Tension This experiment from the 1800's was quite popular, as it shows what seems to be sudden movement caused by no actual observable forces. Using surface tension and surfactants, pepper can be made to move across a bowl of water.

Materials:

Pepper
Soap
A large tin Water

Protocol:

1. Fill the bowl or pan with water
2. Sprinkle the pepper so that it floats evenly on the surface of the water.
3. Put a drop of oil or soap in the center of the pan.
4. Observe what happens!

Discussion Questions

1. What happened to the pepper?
   The pepper will move away from the center of the pan without any additional forces. The force that is moving the fish is caused by the change in surface tension during the addition of soap.

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2. How did this happen?
   The soap or oil causes a drop in surface tension in the middle of the pan. The drop in tension will force the pepper to move to the outer edges of the pan, where the surface tension has not been disrupted by the surfactant.

3. What caused the pepper to stop?
   Once the soap disperses throughout the water, the surface tension will have been lowered across the entire bowl pan. Because the surface tension is now completely reduced and there is no change occurring, the pepper will stop moving.

Teacher **Demo: Putting out a Candle with a Soap Bubble**

Materials:

Candle
Matches
Funnel
Soap

Safety information: As this demo requires use of a flame, only teachers should perform this experiment. Do not inhale the soapy solution when blowing a bubble.

Protocol:

1. Light the candle
2. Coat the large end of the funnel with detergent and carefully tilt it upwards to form a sheet of detergent across the opening
3. Carefully blow a bubble using the small end of the funnel. You should be able to get a large bubble, about 12 inches in diameter.
4. Quickly and carefully place your thumb over the small end of the funnel to prevent the bubble from collapsing.
5. Carefully bring the bubble to the candle. Aim the small end of the funnel toward the flame.
6. Remove your thumb and the surface tension of the bubble will cause it to contract. The air that is forced through the funnel will be enough to put out the candle.

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<u>Discussion Questions</u>

1. How was the air generated?
   Blowing the bubble filled the funnel and the space inside the bubble with air. All the air trapped inside the bubble was released when your thumb was removed and the surface tension of the bubble caused it to contract.

2. What force caused the air to blow out the candle?
   The liquid detergent lowers the surface tension of the liquid enough to allow a bubble to be blown without breaking. When you remove your finger from the funnel the cohesive forces try to return the liquid to its original shape. This results in the bubble collapsing, pushing the air back down the funnel. The amount of force resisted by the surface tension of the liquid detergent and released when you moved your finger was enough to blow out a candle.

3. How else could surface tension be used to generate a directional force, like the air through the funnel? What could this be used for?
   Surface tension is just like other forces at work, such as gravity. By harnessing it in a system like this one, the force that results in surface tension can be used to move the air. Another example of this can be seen in a balloon. When you blow up a balloon, the air accumulating inside creates a force of air filling up the balloon; if the air overcomes the tension, the balloon pops. When the balloon is released, the force of the air pushes back out of the balloon making the balloon fly through the air.

PLEASE FILL OUT OUR SURVEY AND RETURN IT YSP SO WE CAN CONTINUE CREATING AND IMPROVING OUR TEACHING KITS!