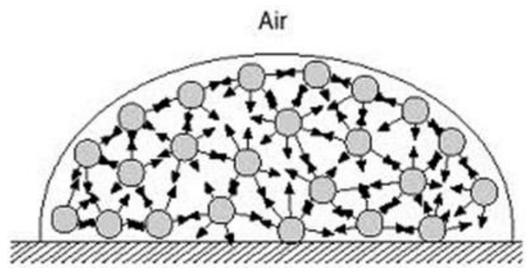
Surface Tension

Student Handout

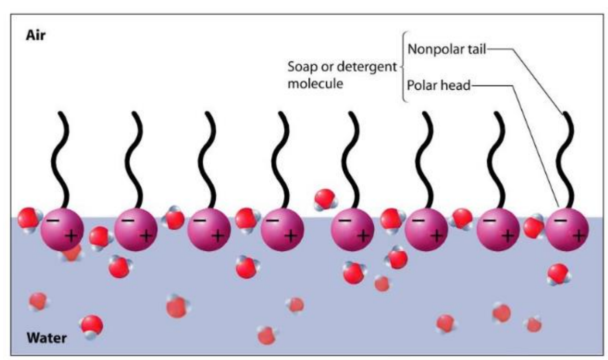
Background

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.



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



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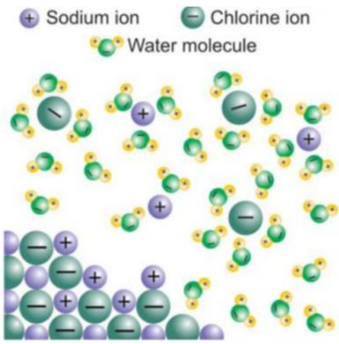
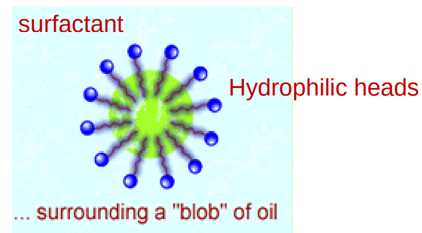


Surface Tension

Student Handout

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?

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 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.



<u>Experiment #1: Visualizing Surface Tension on a Penny</u>

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.

<u>Materials:</u>

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

<u>Protocol:</u>

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.

Surface Tension

Student Handout

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!

Discussion Questions

1) Were you able to add more or fewer drops to the penny with the soapy water?

2) Were you surprised by how many drops of water the penny could hold?

3) How does surface tension explain how rain comes down in droplets instead of in a sheet?

4) Question for thought: Why does the water become a sphere? Why not a triangle or a rectangle?

Surface Tension

Student Handout

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.
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?

2. What happened to the water in the cup as you added pennies?

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

Surface Tension

Student Handout

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?

2. What was different about the paper clip that was dropped into the cup versus the one that floated?

3. What happened with the addition of soap?

4. What else might be able to float on water? How about in water with soap?

Surface Tension

Student Handout

5. How do some insects walk on water? Could YOU somehow walk on 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?

2. How did this happen?

Surface Tension
Student Handout

3. What caused the pepper to stop?

***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.

Funding provided by The Leon Lowenstein Foundation

Discussion Questions

1. How was the air generated?

2. What force caused the air to blow out the 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?