Surface Tension Demonstration

Properties of Liquids

Introduction

Surface tension is a force—a force powerful enough to prevent water from spilling out of an open jar when it is turned upside-down! A fine mesh screen hidden inside the lid of the jar provides hundreds of tiny surface tension "membranes" that, in addition to air pressure, will support the weight of the water.

Concepts

- Surface Tension
- Cohesion
- Air pressure
- Properties of water

Materials

Jar with screw-on ring lid
Laminated card
Screen
Liquid detergent (optional)
Plastic tub or bucket
Water, tap

Safety Precautions

Although this activity is considered nonhazardous, please observe all normal laboratory safety guidelines.

Procedure

1. Place the screen inside the lid of the jar, and screw the lid tightly onto the jar.
2. Pour tap water through the screen until the jar is about three-quarters full.
3. Place a laminated card over the top of the jar and hold the card down tightly with one hand. *The water will form an adhesive seal with the laminated paper.*
4. Quickly invert the jar 180° over a sink or other container, such as a plastic tub or bucket.
5. While holding the jar steady, remove your hand from the laminated card. *The card will remain in place over the mouth of the jar! The water forms a tight adhesive seal and external air pressure holds the card in place.*

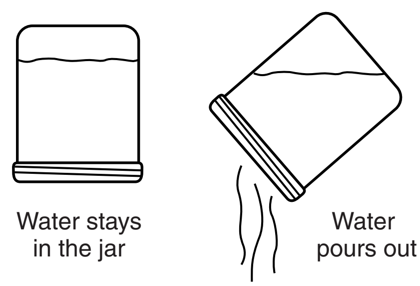


Figure 1.

6. Carefully slide the card out from under the jar with one hand while holding the jar steady with the other hand. *A little water may spill out, but most of the water will stay in the jar! The mesh screen provides a surface for the formation of hundreds of tiny surface-tension "membranes" that, in addition to air pressure, will support the weight of the water.*
7. Tilt the jar a few degrees to allow air to enter the jar. The water will immediately spill out of the jar—gravity still works!
8. *(Optional)* After performing the demonstration once for the students, ask for a student volunteer to repeat the demonstration. Dip a finger into detergent that is hidden from view and inconspicuously run the finger over the screen after the jar has been filled with water. *When the student inverts the jar, the laminated card may stick for a short time due to the counter-force of air pressure acting on the outside of the card. When the card is removed, however, the water will rush out. The detergent interferes with the hydrogen-bonding network in water, which drastically reduces the surface tension of water and modifies its adhesive properties.*
9. Alternatively, you may show students that the demonstration will work without the laminated card, simply by covering the jar mouth with your hand and then quickly removing it.

Publication No. 91067
061616

Disposal

None required—save all materials for future use.

Tips

- If the jar is inverted while the screen is uncovered, all of the water will pour out.
- To make the demo more dramatic, do not allow students to see the screen before inverting the jar—let them think the mouth of the jar is open. Alternatively, do the demonstration over a student's arm if they do not mind getting wet in the event that the surface tension is broken.
- Experiment with different materials in place of the screen. Be creative—try a larger mesh material, such as the type from a produce bag, a fine mesh with smaller openings than the screen included in the kit, cloth, aluminum foil with holes, filter paper, etc.
- Test whether the demonstration will work with different amounts of water in the jar. Fill the jar completely, add only enough water to cover the screen, etc.

Discussion

There are two main questions in this demonstration. What force(s) hold the laminated card in place under the inverted jar (step 5)? What force(s) prevent the water from spilling out when the card is removed (step 6)? In order to understand why this demonstration works, it helps to know also when the demonstration will not work! The demonstration does not work, for example, with alcohols, even though their properties are similar to water. The demonstration also does not work if the air pressure
outside the jar is reduced (by placing the inverted jar inside a bell jar and applying a vacuum).

Water is a unique liquid—the surface tension of water is substantially greater than that of alcohols and other liquids. Surface tension is a net attractive force that tends to "pull" adjacent surface molecules inward toward the rest of the liquid. Surface tension is a result of uneven attractive forces experienced by molecules at the surface of a liquid versus those in the rest of the liquid. Molecules in the liquid are bound to neighboring molecules all around them. Molecules at the surface, however, have no neighboring molecules above them. Because the forces acting on the surface molecules are not balanced in all directions, the surface molecules are drawn inward toward the rest of the liquid.

When the jar is first inverted, a small amount of water probably leaks out from the jar. This creates a slight partial vacuum in the space above the water in the jar. The water in the jar also forms a tight adhesive "seal" with the card—in addition to forming strong intermolecular cohesive forces with other water molecules, water also forms strong adhesive forces to many other molecules or materials. External air pressure, acting in all directions, applies a net upward force on the card and the water and prevents the water from spilling out of the jar.

When the card is removed, the surface tension of water provides an additional force keeping the water in the inverted jar. The high surface tension of water arises because of strong hydrogen bonding among water molecules. As an analogy, the surface tension of water may be thought of as an invisible, "elastic" film that expands as needed to counteract the force of gravity and prevent the water from spilling out of the jar. The numerous tiny holes in the mesh screen provide a larger total surface area for the formation of thousands of invisible surface membranes.

When the jar is tilted, the forces become off-balanced and there is no longer a greater pressure on the outside of the jar. The surface tension "breaks" and the water spills out of the jar.

Acknowledgment

Special thanks to Patrick Funk, Pickerington High School, Pickerington OH, for providing the idea and the instructions for this activity to Flinn Scientific.

Reference

Floating water experiment http://www.stevespanglerscience.com (accessed June 30, 2004)

Answers to Worksheet Questions

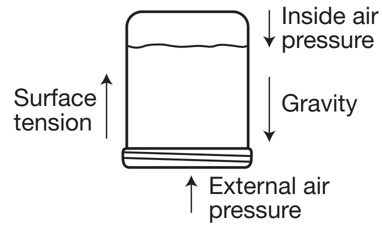
1. Draw a sketch of the inverted jar filled with water. Use arrows to show the direction of the following forces acting on the water: Gravity, external air pressure, pressure of air inside the jar, and surface tension.

2. When the jar is inverted with the card in place, a small amount of water leaks out of the jar. Assuming that the card prevents air from entering the jar, how does the air pressure inside the jar change when water leaks out?

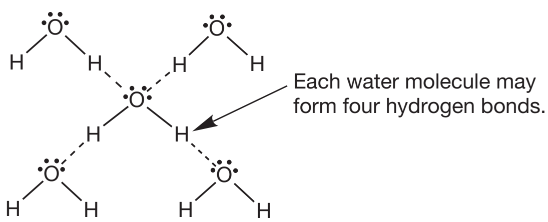
   The air pressure inside the jar decreases, creating a partial vacuum.

3. If there is even a trace of soap or detergent in the water in the jar, the demonstration will not work. What effect does soap have on the surface tension of water? How does this relate to how soaps work?

   Adding soap or detergent drastically reduces the surface tension of water by interfering with hydrogen bonding among water molecules. One way that soaps work is by improving the "wettability" of surfaces (skin, clothing, etc.). Water's extremely high surface tension prevents it from spreading out across and penetrating into a material. Soap lowers the surface tension of water and helps it diffuse into the pores on these surfaces.



4. Draw the structure of a water molecule and show by means of a diagram the hydrogen bonds between water molecules. How many hydrogen bonds does each water molecule form?



Flinn Scientific Best Practices for Teaching Chemistry Video Series

A video of the *Surface Tension Demonstration* activity, presented by Bob Lewis, is available in *Properties of Liquids* and in *Discrepant Event—Physical Properties*, part of the Flinn Scientific Best Practices for Teaching Chemistry Video Series.

Materials for *Surface Tension Demonstration* are available from Flinn Scientific, Inc.

Surface Tension Demonstration Worksheet

1. Draw a sketch of the inverted jar filled with water. Use arrows to show the direction of the following forces acting on the water: Gravity, external air pressure, pressure of air inside the jar, and surface tension.

2. When the jar is inverted with the card in place, a small amount of water leaks out of the jar. Assuming that the card prevents air from entering the jar, how does the air pressure inside the jar change when water leaks out?

3. If there is even a trace of soap or detergent in the water in the jar, the demonstration will not work. What effect does soap have on the surface tension of water? How does this relate to how soaps work?

4. Draw the structure of a water molecule and show by means of a diagram the hydrogen bonds between water molecules. How many hydrogen bonds does each water molecule form?