Soap Film Demonstrations

Hydrogen Bonding

FLINN SCIENTIFIC CHEM FAX!

Introduction

Soap films and bubbles are easy and accessible ways to explore such phenomena as surface tension and intermolecular forces, geometric forms and minimal surface structures, gas diffusion, light interference patterns and electrostatic forces. They're also just plain fun.

Concepts

- Electrostatic forces
- Hydrogen bonding
- Intermolecular forces
- Surface tension

Materials

Dishwashing soap (Dawn® is recommended)
Water, tap
Balloon
Bubble wand
Bucket
Graduated cylinder, 50-mL
Plastic soda bottle, 2-L
Scissors
Stirring rod
Wire coat hanger
Wool cloth

Safety Precautions

Take care when cutting the plastic soda bottle; the edges may be sharp. Bubbles break with a fair amount of force; keep them away from your face. The bubble solution will make the floor or pavement slippery; it is advisable to put down newspapers, towels or floor mats.

Preparation

To make one liter of bubble solution, pour 50 mL of dishwashing liquid in a large container. Add to this 950 mL of tap water. The mixture should be stirred, not shaken, otherwise excessive amounts of suds will be produced. *Note:* For larger structures up to four liters of solution may be needed in order to completely submerge the structures—it may be best to prepare the solution in a bucket or other larger container.

The Hula Bubble

Procedure

1. Cut away and discard the cylindrical mid-section of a 2-L soda bottle (the part that the label usually wraps around, see Figure 1).
2. Trim another centimeter off the bottom of the top section so that it can slide down into the base (see Figures 2 and 3).
3. Fill the bottom section (the base) with soapy water to within about 1 cm of the rim (see Figure 2).
4. Place the top section down into the base and move it around to fully wet the rim with the soapy water (see Figure 3).
5. Ask students to predict what shape film will be formed when the top section is gradually lifted upward. Since soap films tend to achieve minimal surface area, and the shortest distance

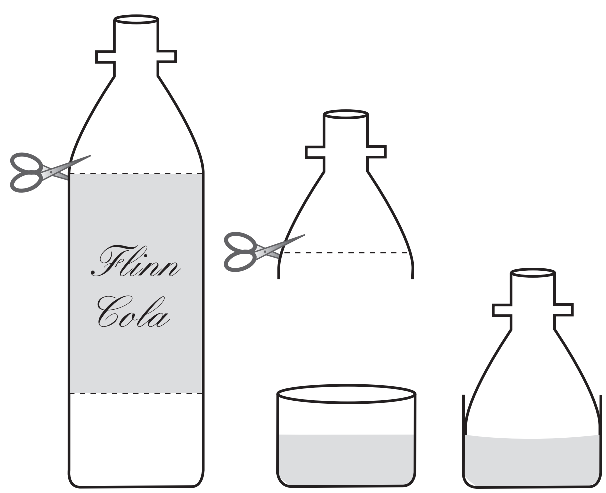

Figure 1. Figure 2. Figure 3.

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between two points is a straight line, it would make sense that the film naturally would be cylindrical.

6. Slowly lift the top section and show that the actual shape preferred by the stretched soap film is not a cylinder at all. Instead the film pinches inward toward the center to form a beautiful curved shape known as a *catanoid* (see Figure 4). *Note:* A catanary is the name of the curve generated when a slack chain is held up by its two ends. When this is turned on its side and then rotated about a vertical axis, concave side outward, it produces a catanoid.
7. If the top is lifted too high, the catanoid pinches off in the middle, and if it does not break in the process, the soap film divides into two films, one dome shaped film on the base and one flat film across the rim of the top section. This latter film quickly climbs up inside the top-section toward the mouth (see Figure 5), since this enables an even smaller and therefore more stable configuration.

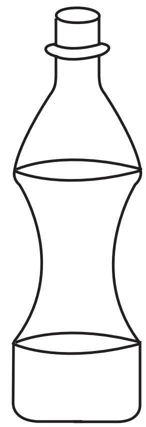
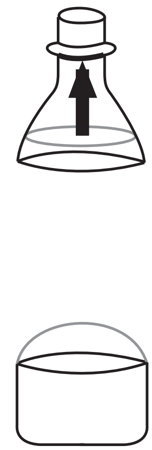


Figure 4. **Figure 5.** **Figure 6.**

8. Although the catanoid is actually the minimal surface structure that connects the two circular rims, a cylindrical film can be made by simply increasing the pressure inside the bottle. This can be done by gently blowing from a distance of 10–15 cm onto the mouth of the bottle as the top section is lifted from the base, see Figure 6). With some practice, a beautiful, tall cylindrical film can be formed. It will begin to pinch off in the middle, however, if the top is not covered with the palm of one's hand to prevent the air from escaping (see Figure 7).
9. There is a limit, however, as to how tall this cylinder can be. If one tries to lift the top section too high, the cylindrical film starts to distort into a bowling pin shape—bulging at the bottom and pinching off at the top (see Figure 8). This shape, like the catanoid, will pinch off completely if the top is lifted too high (see Figure 9).

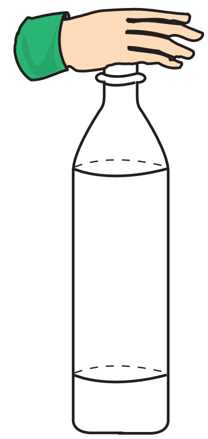
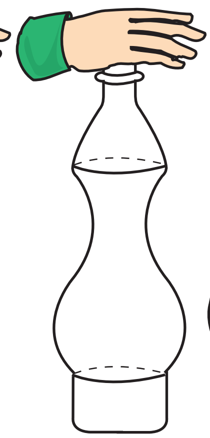
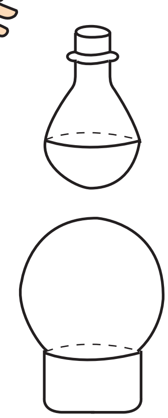

Figure 7. **Figure 8.** **Figure 9.**

Discussion

Water molecules form hydrogen bonds between each other. Intermolecular forces of attraction cause molecules to adhere to one another and make interior molecules more stable than surface molecules. In liquids, this gives rise to an effect called surface tension, in which a liquid is most stable when it has the smallest surface area. Thus, liquid films always tend to be as small as possible. Nowhere is this more evident than in soap films. The same forces that pull a small droplet of water into a perfectly spherical shape also act to make a soap film always assume the smallest shape possible. Since water molecules are highly attracted to one another, the more molecules arranged in close proximity, the more energetically stable the molecules are as a group. Thus interior molecules which are completely surrounded by other molecules provide for greater stability than do surface molecules which are only partially surrounded (see Figure 10). Thus, any configuration that has more interior molecules than surface molecules will be more stable (lower energy) and therefore favored.

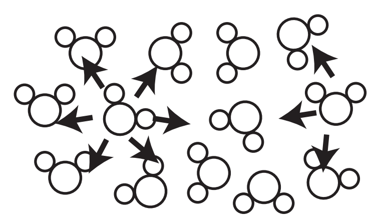

Figure 10.

When pressure is increased inside the bottle as in steps 8 and 9, a cylinder shaped is achieved. Boys (see *Reference*) points out that the maximum height for a stable cylinder is precisely three diameters. Though he offers no mathematical proof of this, and indeed it would require calculus to do so, empirical evidence does seem to support this claim. Boys also points out that this phenomenon is at play when a small stream of water leaks from a faucet—the cylindrical shape becomes unstable after a short distance and breaks up into droplets.

So, why is this activity nicknamed the "Hula Bubble"? Once a tall (but not too tall) cylindrical film is established, and the mouth of the bottle capped off with the palm of one's hand, the top section can be given a gentle swirl and the entire film resonates and undulates much like a hula dancer!

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The Electrostatic Bubble

Procedure

1. Inflate a balloon and tie it closed.
2. Charge one side of the balloon by rubbing it against some wool or someone's hair.
3. Use a bubble wand to blow a fist-sized bubble into the air.
4. As the bubble starts to descend, bring the charged balloon a few centimeters above it and suspend the bubble in air—caught between gravitational force pulling downward and electrostatic attraction pulling upward. *Note:* This might require some practice (see the following *Tips* section).

Tips

- If the balloon is not close enough to the bubble, the bubble will fall. If the balloon gets too close, it will cause the bubble to pop. Suspending the bubble is not so much a matter of holding the balloon steadily in the perfect position, as it is making quick minute adjustments in the balloon's position in response to the bubble's movement. For this reason, larger bubbles are easier to suspend than smaller ones, since the larger ones respond more slowly, allowing more time to make adjustments in the balloon position.
- After dipping the bubble wand in the soap solution, the first one or two bubbles blown tend to be too heavy to suspend; they fall quickly since they usually contain an excess of soapy water. Wait for a bubble that falls slowly.

Discussion

When an electrostatically charged object is brought near a neutrally charged object, the former can induce a polarity in the latter, resulting in an attraction between the two. This effect demonstrates the same principle as the old stream-of-water-deflected-by-a-charged-comb demonstration—mainly that an electrostatic field has an attractive force on water. This attractive force is not due to the polar nature of the water molecule as is often claimed, for indeed a nonpolar substance can also show an attraction if the field is strong enough. Instead the attraction is due to the induced polarity brought on by the field—the same reason a charged balloon will be attracted to a wall. The congregation of electrons on the charged balloon repels the electrons in the wall, leaving it more positively charged near its surface, hence the attraction (see Figure 11).

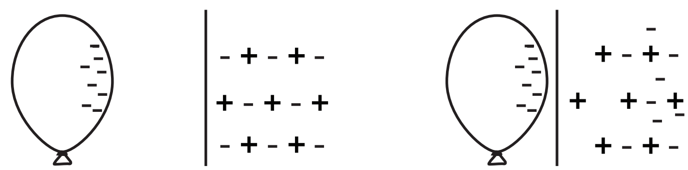

Figure 11.

The suspended bubble demonstration can also be used as a prop when explaining Millikan's famous oil drop experiment. Millikan adjusted an electric field to cause a variety of falling oil droplets to levitate, and from this information, he estimated the actual charge on an individual electron.

Figure 12.

One more application of the electrostatic bubble demonstration might be found in astronomy to illustrate by analogy how the strong gravitational field of a planet or a star can cause an approaching object, such as a meteor or a comet to be torn apart. Indeed, when the bubble gets too close to the charged balloon, one can see its shape distort sharply as it pops toward the balloon (see Figure 12).

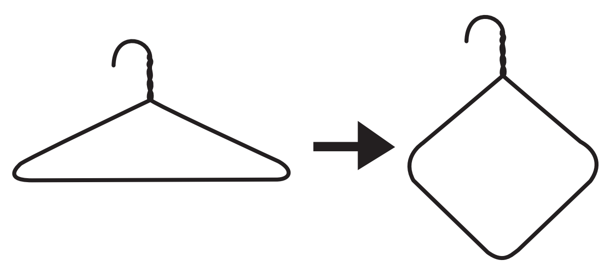

Figure 13.

The Bubble Trampoline

Procedure

1. Bend a wire coat hanger triangle into more of a square (see Figure 13).
2. Hold the hanger by the top hook and dip the hanger into a bucket or basin of soapy water.
3. Lift the hanger vertically out of the bucket to establish a film across its frame.

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4. Use a bubble wand to blow a fist-sized bubble with your free hand.
5. As the bubble starts to descend, bounce it back up into the air with the large flat film on the coat hanger (see Figure 14). As the soap film is brought up from beneath, it tends to bulge downward due to the air it is encountering. This catches the bubble, and as then as the film is stopped, the bulge inverts itself to bounce the bubble quite dramatically upward. This gives a very convincing simulation of a trampoline.

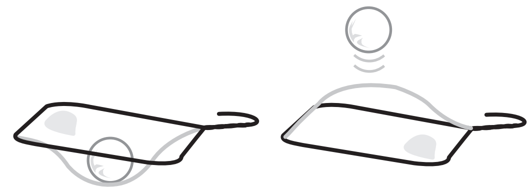

Figure 14.

Tips

- With some practice and good timing, one can make the bubble bounce quite high. Try "juggling" two or more bubbles at the same time!
- It is worth pointing out that although they appear to bounce against one another, the two soap films in fact never come in contact. As Boys points out, electrostatic negative charges are distributed over their surfaces which repel and keep the two soap films from touching.

Disposal

The bubble solution may be flushed down the drain with excess water according to Flinn Suggested Disposal Method #26b.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Content Standards: Grades 5–8
Content Standard B: Physical Science, properties and changes of properties in matter, motions and forces
Content Standards: Grades 9–12
Content Standard B: Physical Science, structure and properties of matter, motions and forces

Reference

Boys, C. V. *Soap Bubbles and the Forces which Mold Them;* Doubleday: New York, 1959.

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Soap Film Demonstrations* activity, presented by Bob Becker, is available in *Hydrogen Bonding*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Soap Film Demonstrations* are available from Flinn Scientific, Inc.

Catalog No.	Description
C0241	Cleaner, Dishwashing
AP1900	Balloons, 12''Round, Latex, Pkg/20
AP6009	Bucket, Ultility Pail, 4.7 L

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

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