



CHEMISTRY IN THE TOY STORE™

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by

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A look at some toys which utilize chemicals, chemical reactions or unique properties of materials which can be found in toy, magic or novelty stores.

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PART I: The Science of Soap Bubbles

One of the most common items found in toy stores are soap bubbles. These are usually accompanied by small plastic wands, a bubble pipe, or more complicated type of apparatus such as bubble trumpets, bubble airplanes, bubble lawn mowers, and more. Some companies have been producing large bubble loops with many smaller loops inside or one large loop or concentric loops for making small bubbles in a larger bubble. A large bubble loop can easily be made by threading string through two plastic soda straws (see Figure 1) or by bending a wire coat hanger into a loop. (Note: Plastic coated coat hangers will not rust as rapidly as regular metal coat hangers.) Wrapping some string around the wire hanger will allow it to hold more soap solution, making larger bubbles.

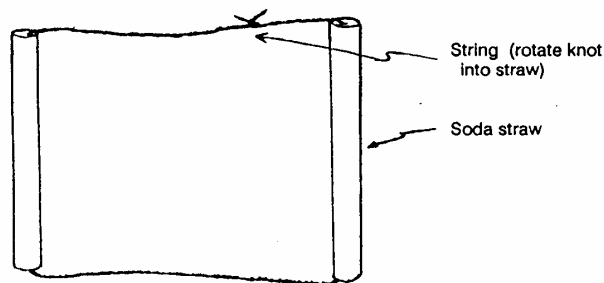


Figure 1. A bubble loop constructed from string and soda straws.

The bubble solutions commonly available in the toy store are dilute soap or detergent solutions that are good for making small bubbles, but not particularly effective for producing strong soap films or large bubbles. A better solution can be made at home.

There are many recipes for preparing soap solutions. A simple solution for making soap bubbles or films can easily be prepared by mixing a soap such as Ivory[®] or Ivory[®] powdered detergent or a detergent such as Tide[®] in some distilled or deionized water. A general purpose solution using liquid dishwashing detergent is:

- 5% liquid dishwashing detergent such as Dawn[®] or Joy[®], by volume.
 - 92% water (distilled or deionized)
 - 3% glycerin (available at drug stores)
- (Note: If an "ultra" detergent is used, decrease the amount to 3% and increase the water to 95%)

The soap mixture should always be stirred, not shaken, otherwise excessive amounts of suds are produced. Do not use a low suds or "controlled suds" detergent and, also, avoid detergents containing bleach and fabric softeners.

Stronger bubbles are made by increasing the amount of detergent and/or glycerin in small amounts. A solution that is good for making stronger, longer lasting bubbles consists of:

- 10% liquid dishwashing detergent such as Dawn[®] or Joy[®], by volume.
 - 84% water (distilled or deionized)
 - 6% glycerin (available at drug stores)
- (Note: If an "ultra" detergent is used, decrease the amount to 7% and increase the water to 87%)

Generally, it was found that when the detergent concentration exceeds 12% (by volume) the bubbles do not last as long. Also, a greater concentration of glycerin will not usually make longer lasting bubbles.

The glycerin is used to strengthen the soap film. Sugar can also be added but it is best to use it in the form of a sugar syrup, made by heating equal volumes of sugar and water, since solid sugar does not dissolve readily. White Karo syrup (corn syrup or dextrose syrup) also works well. If you intend to store the soap solution for a long period of time, generally, it is best to use glycerin as solutions containing sugar or Karo syrup may become moldy.

A recipe for "super bubbles" (supplied by Fred Juergens, Dept. of Chemistry, University of Wisconsin-Madison) calls for:

4 parts glycerin by volume
2 parts liquid Joy[®]
1 part white Karo[®] Syrup.

All parts are measured by volume. There is no water added to this solution. This produces a thick solution that will be difficult to clean up. These "super bubbles" should only be used outdoors.

Variables will depend on the purity of materials as well as the brand of soap or detergent used. Distilled water is essential to prevent interference from dissolved metal ions, although detergents will not be affected as much as a soap such as Ivory[®] (Metal ions in the water are responsible for producing the soap "scum" that forms a ring around the tub.). If the solution does not seem to work well, let it sit for a few days to a week. Aging improves the characteristics of soap solutions. Super-bubbles may even bounce on a clean, smooth floor. A note of caution, these bubbles break with a fair amount of force, keep them away from your face. Also, the solutions will make the floor or ground slippery, wear rubber soled shoes or sneakers and be careful to avoid falling. Indoors, a piece of indoor/outdoor carpet protects the floor and can prevent slipping.

A soap or detergent molecule consists of a long slender nonpolar hydrocarbon chain (consisting of hydrogen and carbon) with a highly polar oxygen-rich group attached to one end (see Figure 2). Water molecules, consisting of hydrogen and oxygen arranged in a bent or angular arrangement (see Figure 4), are polar (think of a polar substance acting like a little magnet). In a soap, the nonpolar hydrocarbon end is hydrophobic, which means it moves away or separates from water like the salad oil in a vinegar and oil salad dressing. The polar oxygen-rich end is hydrophilic, which means it is attracted to water and will try to dissolve in it. When soap molecules are added to water, some form clusters, called micelles, in the body of the solution where the nonpolar ends are in the middle of the cluster and the polar ends are on the outside. (See Figure 5) These micelles are important to the cleaning properties of soaps and detergents. Many of the soap molecules tend to migrate to the surface and orient themselves so that their polar ends are pointed toward the water and the nonpolar ends are sticking out. The surface of the water is covered with a nonpolar layer which drastically reduces the surface tension of the water and adds stabilizing elastic properties to the liquid surface along with an increase in total surface area. (The total surface area is increased as a result of the non-polar ends of the soap molecules sticking out of the surface.) This is accompanied by an increase in the surface energy (or surface tension) of the solution (but still less than the surface tension of pure water – see Experiment 2). These surface molecules are important in making soap bubbles. When a plastic or wire loop or frame is placed in the solution and then withdrawn, the water tends to drain from the inside of the raised surface, making the surface begin to collapse on itself forming a multilayered film that forms a soap bubble. (In essence, the ends of the soap molecules fall over and become tangled like pieces of spaghetti to form the surface film. The layers consist of soap molecules on the inner and outer surfaces with a water and/or water-glycerin layer in the middle. See the soap bubble diagram in Figure 7.) The soap limits the minimum thickness of the soap film to the length of two soap molecules stacked end to end. Moderately thick films, such as these, are self-healing with respect to small punctures. That is, escaping air bubbles that burst through the surface do not cause the film to break. Also, small objects may pierce a soap film and be removed without it breaking, as long as the objects have a coating of water or soap solution and are not totally dry.

Experiment 1. Determining the Best Formula for a Soap Bubble Solution

Materials needed

Liquid dishwashing detergent
Distilled or deionized water (from grocery or drug store)
Soda straws
Containers to hold soap solutions
Glycerin (available from drug store)
Meter stick or tape measure
Timer, or stopwatch
Table with waterproof top or plastic tablecloth

Procedure

Start with liquid dishwashing detergent and distilled or deionized water. Make a series of solutions such as 2% detergent by volume, 4%, 6%, 8%, and so on up to a maximum value of no more than 20%.

Select one soap solution. Spread some of the solution on a clean waterproof surface such as a Formica tabletop or a table covered with a plastic tablecloth to wet an area about 40 to 50 cm (about 15 to 20 inches) in diameter. Dip a soda straw into the solution, touch it to the wet surface, and gently blow a hemispherical (or dome shaped) bubble. Do this several times to get the largest bubble possible. Use a meter stick or tape measure to measure the size of the largest bubble. (When the bubble breaks, it leaves a ring of suds that is a record of the bubble's diameter.) Record the size of the bubble. Repeat this process several times and determine the average size of the bubbles you could blow from that particular solution.

Repeat the bubble blowing procedure for each soap solution you prepared.

You want to use the concentration of detergent that consistently makes the largest bubbles.

Once you find the concentration of detergent that makes the largest bubble, make several solutions adding glycerin in the concentrations of 2% by volume, 4%, 6%, and so on up to a maximum value of no more than 12 to 15%.

Repeat the bubble blowing procedure that you used for the detergent solutions, but this time, try to blow large bubbles approximately the same size each time. Use a watch with a second hand, a stopwatch, or a timer to determine how long the bubble lasts. You want to determine the concentration of glycerin that produces the longest lasting bubbles.

The best solution produces the largest and longest lasting bubbles.

Experiment 2. Comparing the Surface Tension of Water vs. a Soap Solution

Materials needed

Two pennies or other small coins
 Eyedropper
 Water
 Dishwashing detergent

Procedure

Obtain two clean pennies, an eyedropper, some water and some dishwashing detergent.

Count the number of drops of water you can place on a penny.

Add a drop of the dishwashing detergent to the water and stir gently to mix. Count the number or drops of the soap solution you can place on a penny.

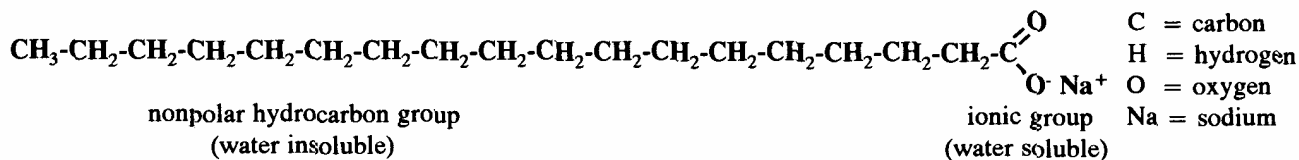


Figure 2. Sodium stearate, a typical soap

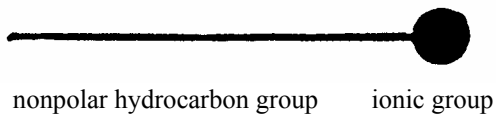


Figure 3. A shorthand notation for a soap molecule.

Soap films can come together at only two angles. If there are three films that meet along a common edge, the angles between them are 120°. If there are four films that meet at a point, the angles between them are 109° (see Figure 6). If there are more soap films, then they will rearrange themselves so that there are never more than three films in contact along an edge or four films in contact at any one point. (See Experiment 3)

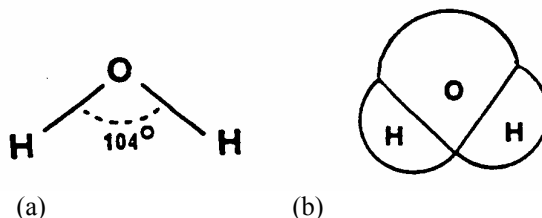


Figure 4. A water molecule showing (a) arrangement of the atoms and (b) the shape of a water molecule

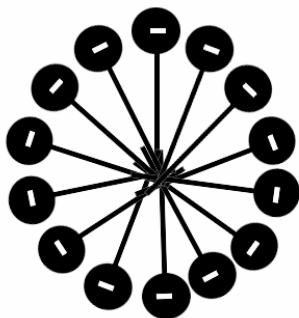


Figure 5. A micelle

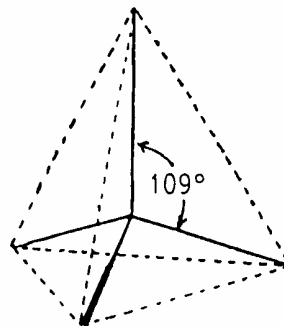
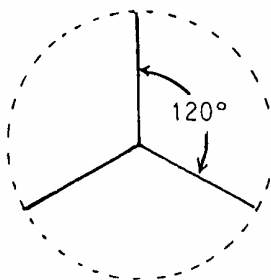


Figure 6. Angles formed by soap films.

Experiment 3. Observing the Angles formed by Soap Films

Materials needed

- Wire frames: a triangular prism and a tetrahedron
- Soap bubble solution
- Bucket or container to hold bubble solution and allow dipping of frames

Procedure

Obtain two wire frames, a triangular prism and a tetrahedron (See Figure 9) and a container of soap bubble solution large enough to hold the frames. (Frames can be made from copper wire by twisting or soldering them together at the angles.) Dip each frame into the soap solution and withdraw it. Observe the angles between the soap films in the frames.

A soap bubble is round (or spherical) since the surface of the soap film which forms it will try to contract to take up the smallest surface area. In nature, the volume with the smallest surface area is a sphere. (See Experiment 4)

Experiment 4. Observing Surface Tension in a Soap Film or Understanding Why a Soap Bubble is Spherical.

Materials needed

- Bubble loop made from string and soda straws
- Soap bubble solution
- Container for soap bubble solution

Procedure

Obtain a bubble loop made from string and soda straws (See Figure 1). Hold it by one straw so that the soda straws are positioned horizontal to the ground and the string forms the left and right sides of the square or rectangle. Note the shape of the bubble loop.

Dip the loop into some soap solution and hold it up the same way as before. How does the soap film in the loop affect its shape? What happens when you break the soap film?

Experiment 5. Observing Surface Tension in a Soap Bubble

Materials needed

Soap bubble wand
Soap bubble solution

Procedure

Obtain a small bubble wand with a loop on one end. Dip the wand into some soap solution and blow a medium to large bubble. Catch the bubble on the loop of the wand. Insert a dry finger into the loop to poke a hole in the soap film. What happens to the soap bubble?

One reason a bubble breaks is that it hits something dry. The other reason is a result of the water in the walls of the bubble draining to the bottom of the bubble. The water, in the bottom of the bubble produces a small bump on the bottom and will drip from the bubble. (see Figure 6). One can observe water dripping from the bottom of a large bubble. (See Experiment 6) When the top of the bubble becomes too thin to support the total mass of the bubble, it breaks. The addition of glycerin, or other viscous material like Karo[®] syrup, adds strength to a bubble since this material does not drain out of the soap film readily making the upper part of the soap bubble stronger.

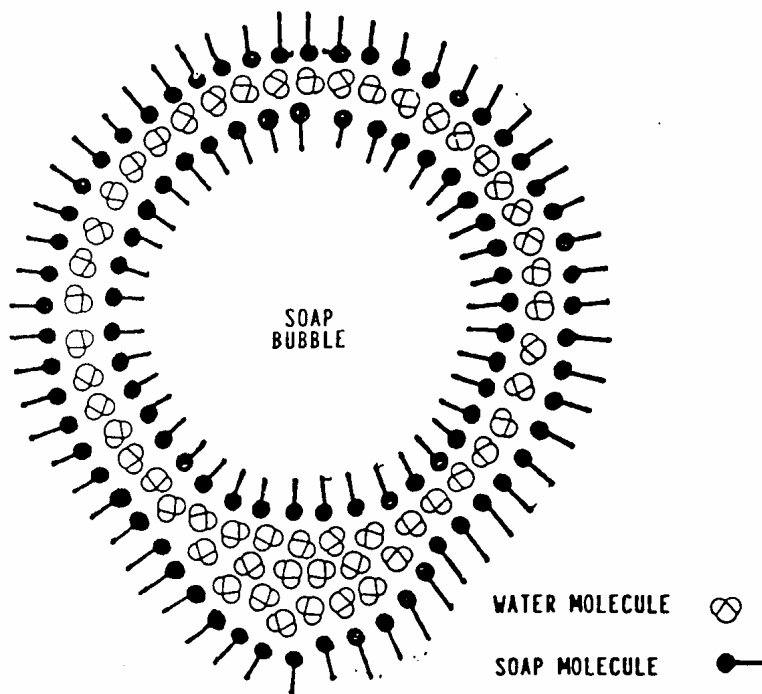


Figure 7. Schematic diagram of a soap bubble

Experiment 6. Observing the Water Draining From a Soap Bubble

Materials needed

Large bubble loop 15 to 20 cm (6 to 8 inches) in diameter
Soap bubble solution

Procedure

Obtain a large bubble loop, approximately 15 to 20 cm (6 to 8 inches) in diameter. Dip it in soap solution and make a large bubble. Observe the shape of the bubble as it falls through the air. Does water drip from the bottom of the bubble?

The swirling colors observed in a soap bubble are a result of thin film interference and the changing thickness of the film due to the draining liquid. (See Figure 8) The color is not affected by the addition of coloring agents, such as food colors, when used in normal concentrations. Although a bubble is transparent, like glass, some light is reflected off the outside surface of the soap film. Some light is also reflected off the inside surface of the film. When the two reflected light waves meet, they may be in phase (the waves aligned peak to peak and trough to trough) or out of phase (not aligned). In phase light waves produce the same color as the incoming light (e.g., white light) making the color appear brighter. This is called constructive interference. Out of phase light waves produce interference effects which we see as color. If the light wave are out of phase so that the peak of one wave is aligned with the trough of the reflected wave, then the light cancels itself out and no color is seen. This is called destructive interference. As the thickness of the soap film changes, the distance the light travels changes, and the different interference effects give different colors. When just about all the water is drained out of the upper part of the soap bubble, the wall becomes so thin that the light reflected from the top surface cancels itself out (when light is reflected, all peaks become troughs) and dark spots appear in the soap film. The swirling effects are a result of the uneven thickness in the soap film as the water drains out. (See Experiment 7)

Experiment 7. Observing Colors in a Soap Bubble

Spread some soap solution on a clean waterproof surface, such as a Formica tabletop or a table covered with a plastic tablecloth, to wet an area about 20 to 30 cm (about 8 to 12 inches) in diameter.

Dip a soda straw into the soap solution, touch it to the wet surface, and gently blow a hemispherical (or dome shaped) bubble.

Watch the soap bubble as the water drains toward the bottom of the bubble. How do the colors change? Do the colors stabilize?

Watch the top of the bubble. When the top of the soap film is close to its minimum thickness, it will be some multiple of half the wavelength of the reflected light. The light from the two surfaces, the inside and the outside, will cancel (destructive interference) making parts of the bubble film look black.

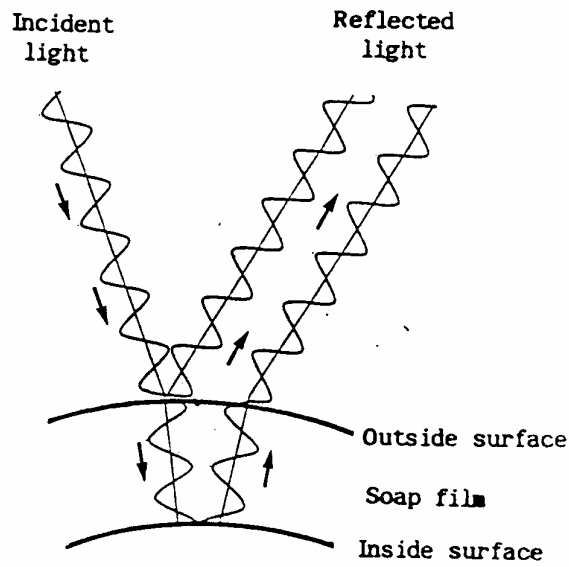


Figure 8. Interference between light waves reflected from the outside and inside surfaces of a soap film.

Soap Bubble Activities

There are many activities that can be performed with soap bubbles. The simplest is making bubbles with a loop, wand, or home-made frame. You can buy a bubble trumpet, or use a household funnel. A soda straw, or an empty cardboard tube from toilet tissue, paper towels, aluminum foil, or plastic wrap can be used to blow bubbles, although the cardboard tubes tend to disintegrate after they become wet. You can even blow bubbles from your hand by making a circle from your thumb and forefinger. See what household items you can use to blow bubbles.

Catch a Bubble

You can catch a bubble or put your finger, hand, or even an arm through a soap film without breaking it by first spreading the soap solution over the skin surface. As long as a surface or your skin is wet, even with water, soap bubbles generally will not break when they contact that surface.

Bouncing Bubbles

You can bounce a bubble off your shirt sleeve once the shirt has been washed in detergent. There will be small amounts of detergent that remain in your clothing that will prevent the bubble from breaking.

Putting Objects Through or Inside a Soap Bubble

When using a large bubble loop, one can easily put a bubble around an object or a person. If soap solution is spread over the skin surface, a person can place a finger, hand or even an arm through a soap film or soap bubble without breaking it. With a big enough loop, and enough soap solution, one could walk through a soap film and stand inside a large bubble. (See Experiments 10 and 11)

Experiment 8. Demonstrating that soap or detergent is in your clothes

Materials needed

Ultraviolet lamp, long wave
Container of detergent

Procedure

In a darkened room, place an ultraviolet lamp near your clothes (light colors or whites work best). Note how your clothes fluoresce (i.e., glow with a blue color). The fluorescence is due to optical brighteners from the laundry detergent. Do you recall the TV commercials stating that detergents make your clothes “whiter and brighter”? What you are seeing is the “brighter” aspect of the detergent. Although detergents clean your clothes, they leave a residue behind that may give the clothes a yellow or gray color. Before the use of optical brighteners, people used a material called laundry bluing. Laundry bluing was a solution of Prussian Blue, a blue dye that covered up the yellow or gray from the detergent residue. The problem was that laundry bluing had to be added to the rinse cycle and one had to watch the washing machine for that cycle to start. Also, if spilled, laundry bluing would leave permanent stains. Optical brighteners were a welcome improvement to the detergents. In sunlight or under fluorescent lights, both sources of ultraviolet light, the brightener in the clothes is glowing. You do not see it consciously, but are aware of it subconsciously and your clothes appear to be brighter. Thus, if there is optical brightener in your clothes, there is also some detergent residue.

Place the ultraviolet lamp near the detergent. It also fluoresces.

Place the ultraviolet lamp next to the label of the detergent container. Does the label, or parts of it fluoresce? What you are seeing is some subliminal advertising. That is, the label glows to your subconscious under the fluorescent lights in the market making you notice that detergent and, hopefully, to the manufacturer, you will pick up that container and purchase the detergent.

Experiment 9. Bounce a bubble off your shirt sleeve

Materials needed

Small bubble loop
Soap bubble solution

Procedure

Blow some bubbles using the bubble loop. Gently bring your arm up to the bubbles and give them a gentle push. If your shirt has been washed in detergent, the bubbles should bounce off your shirt sleeve.

Experiment 10. Put your hand through a soap film

Use a large bubble loop or the string and soda straw shown in Figure 1.

Dip the loop in soap solution and hold it in a vertical position.

Dip your finger, or hand, in soap solution. Stick your finger, or hand through the soap film. What happens? How far can you insert your finger or hand through the film? What happens if your finger or hand is wet with water only?

Experiment 11. Put someone inside a soap bubble

Construct a large bubble loop approximately 30 inches (76 cm) in diameter. The loop can be made from different materials such as curved plastic pipe or 3/8 inch diameter copper tubing. (Copper tubing is preferred by the author.)

To make a 30 inch loop from the copper tubing. Solder the loop together using a T-fitting. Fashion a handle from 1/2 inch copper tubing and connect it to the T-fitting using a 3/8 to 1/2 inch adapter. Solder all joints. Wrap the handle with plastic or foam tape so it does not become too slippery to hold when it gets wet.

Wrap string around the large bubble loop. This will allow it to hold more soap solution for large bubbles.

For the bubble pool, you can use a small wading pool, or make a pool by making a square frame from 4 36-inch pieces of 2 x 4 inch wood and placing 4 or 6 mil heavy plastic sheeting inside the frame. (The plastic sheeting is available from hardware stores and home centers.) Tuck the ends of the plastic under the frame. It is recommended that the bubble pool be set up on a large piece of indoor-outdoor type carpeting as the area around the bubble pool will become very slippery due to a coating of soap from bursting bubbles.

Provide a stand to place in the center of the pool. Make sure it is strong enough to hold an adult and that it has no sharp edges that can cut into the bubble pool. Small utility stands (one step high) can be found in home centers, or use a heavy plastic milk crate.

Add soap bubble solution (use the solution described on page 2: 10% liquid dishwashing detergent such as Dawn® or Joy®, 84% water, and 6% glycerin, or the adjusted version for ultra-type detergent) to the pool and place the stand in the center. Put the loop in the pool. Help someone to step SLOWLY onto the stand as the stand can slide across the pool.

Lift the loop around the person. Practice will help you determine the proper method and speed.

Indoor Activities with Soap Bubbles

Although bubbles are mainly an outdoors activity, there are many activities that can be done indoors.

Tabletop Bubbles

To do this you will need a table with a Formica or plastic laminate top. You can substitute vinyl floor tiles, taped together with a waterproof tape from the back side or cover a table with a plastic sheet or tablecloth. Put newspapers around the work area in case of spills.

To make tabletop bubbles, spread some bubble solution onto the table to wet an area about 35 to 50 cm (about 15 to 20 inches) in diameter. Take a straw, dip it into some soap solution, then touch the straw to the soapy surface and gently blow a hemispherical (or dome shaped) bubble. You can blow bubbles of different sizes, bubbles inside of bubbles, bubble colonies, and more.

If you want to see how large a bubble you can blow, continue to blow a tabletop bubble until it pops. You will observe that there is a ring of soap suds left by the bubble. You can use a meter stick, or other measuring device, to measure the diameter of the ring. This is the size of the bubble. Record the sizes of the bubbles and determine the average sized bubble. (Soap bubbles are an excellent means of teaching measurement skills. See Experiment 12)

Try mixing up different concentrations of soap solutions (as described in Experiment 1). Make up small batches of soap solutions with soap concentrations such as 2%, 4%, 6%, 8%, 10%, 12%, etc. Record the sizes of the bubbles and determine the average size bubble blown from each solution. Construct a graph of average bubble size versus soap concentration. Which concentration of soap makes the largest bubbles?

Repeat your studies of the largest soap bubble with different brands of soap. Record your results. Construct a graph of average bubble size versus the brand of soap used. Determine which brand makes the largest bubbles.

If you want to make long lasting bubbles, try varying the concentration of glycerin in your soap solution. Make small batches of soap solutions containing 2%, 4%, 6%, etc... glycerin, up to a concentration equal to that of the soap. Try to blow large bubbles approximately the same size bubble each time. Use a watch with a second hand, a stopwatch, or timer to see how long the bubble lasts. Record your results. Construct a graph of average time the bubble lasts versus the amount of glycerin used. Which solution makes the longest lasting bubbles?

Other bubble solutions for making long lasting bubbles can be made by adding gelatin (use unflavored gelatin) or agar to the mixture. Addition of a polyvinyl alcohol solution can also prolong the life of a bubble. Try concentrations of 2%, 4%, 6% and 8%. (Above about 8% concentration, polyvinyl alcohol solutions can be very thick.)

To see the color fringes in a bubble, blow a tabletop bubble in a brightly lit area and watch it as the water drains to the lower portion of the bubble. How many rings of color do you observe? What is the order of the rings of color? Are the colors always in the same order? Does the top of the bubble become colorless? Does it become black?

To see different bubble shapes, blow clusters of bubbles. Look at the shapes of the bubbles that are located between other bubbles.

To put an object into a tabletop bubble, wet the object with some soap solution and place it inside the bubble. For example, take a small plastic car, dip it in bubble solution and the roll it into the bubble.

Experiment 12. Using soap bubbles to teach measurement skills

You can teach measurement skills to youngsters as long as they can count simple objects.

Instead of using a meter stick or other “standard” measuring device, the diameter of the soap bubble can be measured using a string of pop beads, unifix cubes, or similar objects. It is best to make the string of beads alternating colors to minimize counting errors.

After the soap bubble breaks, just lay the string of beads across the circle of soap suds and have the youngster count the number of beads. The only difference between using a standard measuring device and a string of beads is that the units of measurement are beads instead of centimeters or inches.

Experiment 13. Color fringes in an illuminated soap bubble

Materials needed

Plastic bucket with a smooth top edge
Waterproof lantern or flashlight
Soap bubble solution
Cloth large enough to span the top of the bucket
Water
Dry ice

Safety Precautions

Dry ice (solid carbon dioxide) is very cold (-78.5°C) and can cause burns to the skin which are similar to frostbite. Wear heavy gloves and handle dry ice with tongs. In the event of a burn, obtain medical assistance.

Procedure

Add water to the bucket to a depth of about 2.5 cm (1 inch). Turn on the lantern or flashlight and stand it in the bucket with the light shining up. Place a few chunks of dry ice into the bucket. Note that a fog forms in the bucket.

Roll or fold the cloth into a narrow strip. Dip the cloth in some bubble solution. Pull the cloth over the top of the bucket to make a soap film over the entire top of the bucket. Dim the room lights and watch the bubble. Look for the colored rings in the bubble.

This procedure can be repeated several times until soap solution, which drips into the water, will start producing lots of soap suds, filling the bucket.

Experiment 14. Floating Soap Bubbles

Materials Needed

Large aquarium or plastic cube (Plexiglas or similar) with clear cover (plastic recommended). (Note: The author utilizes a 24-inch cube, constructed from Plexiglas, with an 8-inch square cut-out, centered at the top of one side, and a Plexiglas cover.)

Soap bubble solution

Foam insulation sheets (expanded polystyrene or equivalent) to cover bottom of container.

Soap bubble loop

Dry ice

Optional: Vermiculite

Safety Precautions

Dry ice (solid carbon dioxide) is very cold (-78.5°C) and can cause burns to the skin which are similar to frostbite. Wear heavy gloves and handle dry ice with tongs. In the event of a burn, obtain medical assistance.

Procedure

Cover the bottom of the aquarium or plastic cube with foam insulation sheets.

Add chunks of dry ice to the container. If desired, the dry ice can be hidden by covering it with vermiculite. Cover the container and allow it to sit for about 5 minutes to build up a concentration of carbon dioxide gas.

Blow bubbles into the container. (If it is a large bubble cube, blow bubbles through the cut-out. If it is an aquarium, partially remove the cover.)

What happens to the bubbles in the container?

Watch the bubbles in the container. Do they change in any way?

Do any of the bubbles freeze?

Observations/Explanations

Carbon dioxide is heavier than air. As a result, in a closed container, there will be a layer of carbon dioxide at the bottom of the container. When a soap bubble is blown into the container, it is filled with air, and, as a result, it will float on the carbon dioxide.

The floating bubbles will slowly increase in size as carbon dioxide diffuses through the bubble film into the bubble. This makes the bubble heavier and it will slowly settle toward the bottom of the container.

Investigations with Soap Films and Frames

Some experiments with soap solutions, other than blowing bubbles, can be performed with different shaped wire frames dipped into soap solution. These frames can be purchased in kits, ready made, or they can be made by bending and twisting together stiff wire, such as a heavy gauge copper wire. (Stiff pipe cleaners can be used, but some tested by the author tended to sag when wet with the soap solution.) More permanent frames are made by soldering the wire together. Some shapes that can be used are shown in Figure 9.

To demonstrate the surface tension of a soap film (in addition to the method in Experiments 4 and 5, take a piece of thin string or thread, tie it into a loop, dip it in soap solution, and gently lay it on a soap film on a large simple loop. Using a dry toothpick, touch the soap film in the center of the string loop. What happens?

Using a loop within a loop, dip it into a soap solution to get a soap film in both loops. Use a dry toothpick or a dry finger and touch the soap film inside the center loop. What happens?

Using a planar rectangle with a movable side, slide the side close to the bottom and dip it into a soap solution. Make sure your hands are soapy. Can you move the side up and down stretching and compressing the soap film? How much can the soap film be stretched?

Dip a cubic frame into a soap solution. What happens to the soap films on the cube? How many soap films are in contact at any one point? Can you measure the angles between the films? Dip the cube about half way into the soap solution and withdraw it to put a bubble into the middle of the frame. Describe the bubble in the center of the frame.

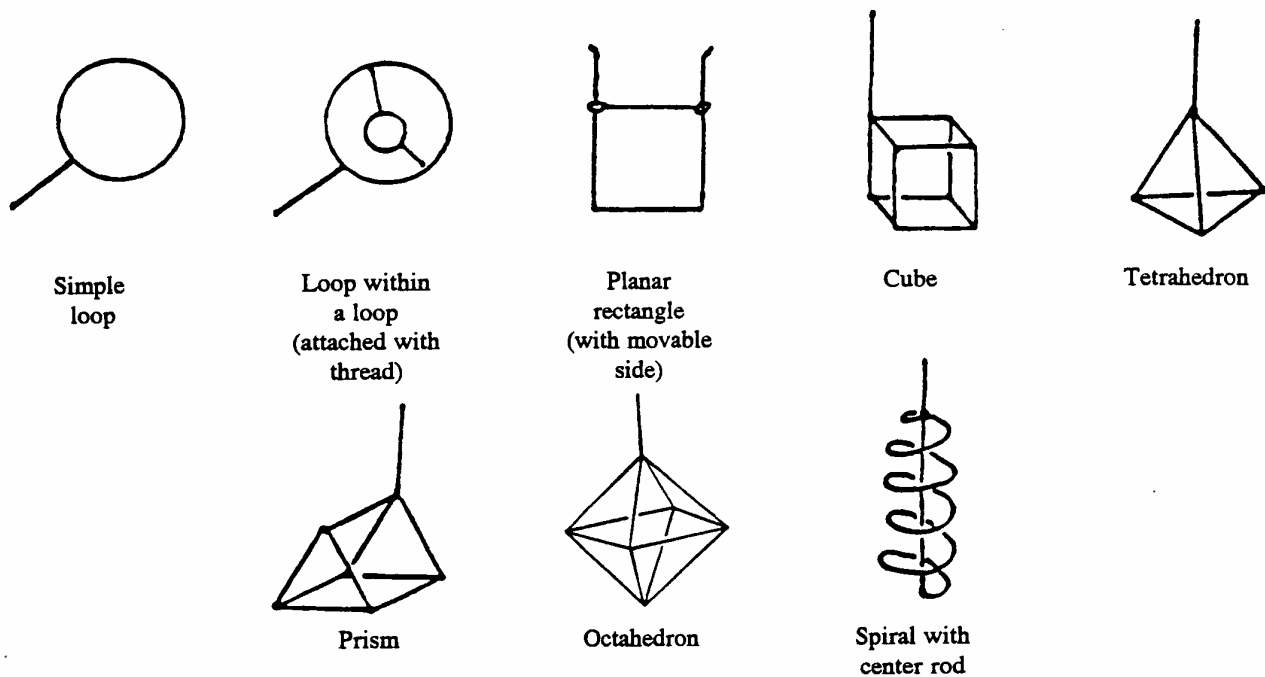


Figure 9. Different shaped wire frames for experimenting with soap films.

Dip a tetrahedral frame into a soap solution. What happens to the soap films on the tetrahedron? How many soap films are in contact at any one point? Can you measure the angles between the films? Dip the tetrahedron about half way into the soap solution and withdraw it to put a bubble into the middle of the frame. Describe the bubble.

Dip a triangular prism frame into a soap solution. What happens to the soap films on the prism? How many soap films are in contact at any one point? Can you measure the angles between the films? Dip the prism about half way into the soap solution and withdraw it to put a bubble into the middle of the frame. Describe the bubble.

Dip an octahedron frame into a soap solution. What happens to the soap films on the octahedron? How many soap films are in contact at any one point? Can you measure the angles between the films? Dip the octahedron about half way into the soap solution and withdraw it to put a bubble into the middle of the frame. Describe any bubbles that form in the center of the octahedron. Repeat your investigations putting bubbles inside the octahedron.

Dip a spiral frame into a soap solution. Describe the soap film that forms.

You can do further investigations by constructing different shaped frames using stiff wire. Use your imagination to come up with different shaped frames.

If you want to make frames more complex than those shown in Figure 9, then a different construction set is needed. One such set, tested by the author, is Zome System. This is a set of small spherical connectors, called nodes, and connecting rods that allows one to construct many geometric shapes from cubes to octahedrons, decahedrons, dodecahedrons, and more. Shapes which, in the past, were too tedious to construct by joining and welding heavy wire are now possible with this construction system.

Cleaning Up

Soap solution can be reused if it is not dirty or contaminated with any metal ions, particularly iron (or rust). It gets better with age. Save the soap solution in an air tight plastic bottle or container. The 2-Liter bottles from soft drinks work well, so do 2 ½ gallon plastic gasoline containers. (5 gallon containers get too heavy) Remember to remove any labels from the containers and put a new label on the container that says "Soap Solution". You may also want to put the formula used to make the soap solution on the label along with the date it was made.

Remove excess bubble solution from the surface by using a squeegee to scrape it into a bucket or tray. (A squeegee works best, but paper towels will also work.) Do not add water. Then sprinkle a small amount of vinegar on the area to cut any remaining soap film. Wipe the surface dry with paper towels. If the surface is still soapy, repeat the procedure.

Bubbles Bibliography

Books

Barber, Jacqueline, **Bubble-ology**, Great Explorations in Math and Science (GEMS), Lawrence Hall of Science, University of California, Berkeley, 1986.

A teacher's guide of activities with bubbles for grades 6-9. Devise bubble blowing devices, test to see which soap makes the best bubbles, and make long lasting bubbles. Each activity lists all materials needed, skills developed, themes, and complete directions from preparation to clean-up.

Boys, C. V., **Soap Bubbles**, Dover, 1959.

A reprint of the 1911 edition. Everything you wanted to know about soap bubbles and surface tension. Many simple experiments and demonstrations are explained along with excellent engravings.

Cassidy, John, with Stein, David, **The Unbelievable Bubble Book**, Klutz Press, 1987.

This book accompanies David Stein's *Bubble Thing*. Includes recipes for bubbles, methods for making large bubbles, troubleshooting, homemade bubble machines, and additional bubble lore. Also included are articles on Bubble People.

Faverty, Richard, with Javna, John, **Professor Bubbles' Official Bubble Handbook**, Greenleaf Publishers, 1987.

Information about bubbles, bubble wands, and other bubble toys. Includes recipes for bubble solutions and instructions for all kinds of bubble tricks.

Isenberg, Cyril, **The Science of Soap Films and Soap Bubbles**, Dover, 1992.

Good discussions of the molecular basis for soap bubbles. A more mathematical treatment of soap bubbles and films than Boys' book with some excellent color plates.

Noddy, Tom, **Tom Noddy's Bubble Magic**, Running Press, 1988.

Using commercial "bubble juice", Tom Noddy explains how to do many bubble tricks such as caterpillar bubbles, a bubble carousel, and more. Brief explanations of what bubbles are and why they behave as they do.

Rämme, Göram, **Soap Bubbles in Art and Education**, Science Culture Technology Publishing, Singapore, 1998.

A well illustrated book, with many excellent photographs, which is a collection of papers published by the author. Covers topics such as bursting bubbles, colors of soap films, soap film models, modeling the atom with soap bubbles, and more.

Stevens, Peter S., **Patterns in Nature**, Little, Brown and Co., 1974.

Chapter 7 of this book examines the mathematics of soap bubbles. Well illustrated and readable.

Zubrowski, Bernie, **Bubbles**, Little, Brown and Company, 1979.

Activities with bubbles including very big bubbles, soap-film curves, geometric shapes, domes, bubble building blocks, and more. Does not give specific recipes, but encourages experimenting with making bubble solutions.

Articles

Almgren, Frederick J. Jr. and Taylor, Jean E., "*The Geometry of Soap Films and Soap Bubbles*", **Scientific American**, **235**, 82 (July 1976).

A semi-technical article on the mathematics of bubbles. Well illustrated.

Katz, David A., "*Chemistry in the Toy Store*", **1988 Yearbook of Science and the Future, Encyclopedia Britannica, 1988**, 154.

Soap bubbles lead off this article on the science behind many toys.

Kuehner, A. L., "*Long-Lived Soap Bubbles*", **Journal of Chemical Education, 35**, 337 (July 1958).

A recipe for making a soap that will produce soap bubbles that can last for many months in a jar or other closed environment. This recipe requires handling some hazardous material. A chemistry laboratory is required.

Strong, C. L., "*How to blow soap bubbles that last for months and even years*" in *The Amateur Scientist*, **Scientific American, 220**, 128 (May 1969).

A discussion of the work of Dr. A. V. Grosse and his long lived bubbles. A laboratory is needed to prepare some of his solutions.

Bubble Materials

Your local toy store, science and nature stores, and also Science Museum shops are resources for bubble materials. These items are seasonal, that is, any of them may not be available in your area during colder months. You will find many items such as bubble guns, bubble mowers, a bubble bee, bubble airplanes, and more. These items change from year to year. Use discretion in purchasing bubble items, most items do not make large bubbles and do not work as they are expected.

Some items that can be used to make large bubbles are:

A set of two 18 cm diameter bubble wands consisting of a large single loop and one filled with smaller loops and a small plastic pan is available under the name Mickey's (Mouse) Million Giant Bubbles, manufactured by Chemtoy Corp. A variation of that set includes a large loop filled with smaller heart shaped loops

A concentric loop for making bubbles in a bubble is available under the name Giant Bubbles, manufactured by Hedstrom

David Stein's Bubble Thing[®] for giant bubbles six feet long or larger. It should come with Cassidy's **The Unbelievable Bubble Book**.

The Bubble Trumpet which is a long narrow funnel. Good for making a chain or medium-large bubbles.

Kubic Bubbles. Some years ago, this author obtained a set of plastic coated, wire bubble frames consisting of a cube, tetrahedron, octahedron, triangular prism, and helix (screw thread), sold under the name Kubic Bubbles, from The Exploratorium Store in San Francisco, CA . The price for the set was \$30.00 (U.S.). It appears that this well made and sturdy set is no longer available. Currently, the Kubic Bubbles set consisting of plastic tubes and angle fittings which allows one to construct four geometric bubble frames is available from some scientific supply companies under the name Kubic Bubbles.

Zome System, a set of spherical connectors, called nodes, and connecting rods that allow one to construct almost any geometric shaped frame. The company maintains lesson plans for teachers and families on their web site: www.zomesystem.com