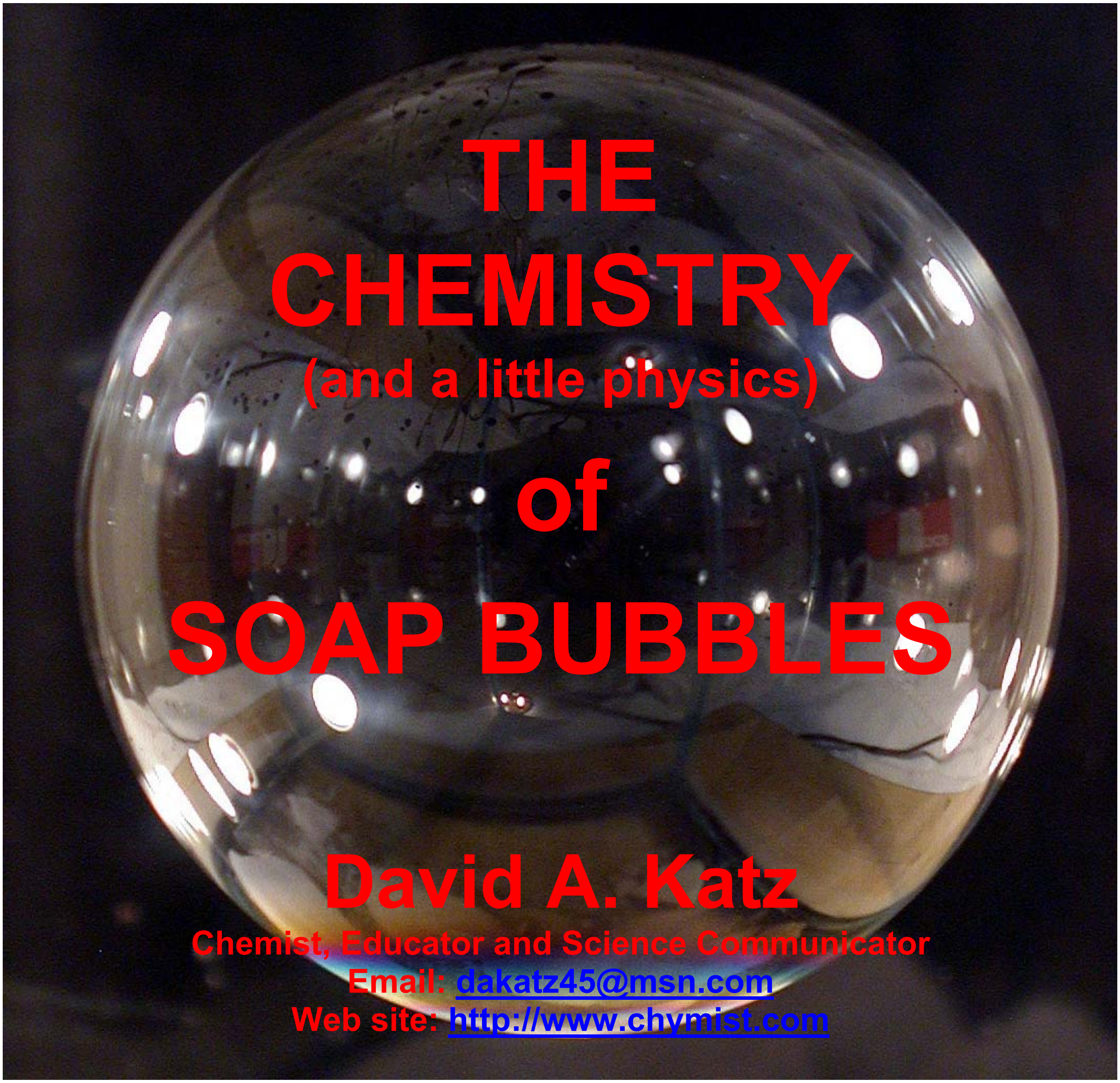


THE CHEMISTRY
(and a little physics)
of
SOAP BUBBLES

David A. Katz
Chemist, Educator and Science Communicator
Email: dakatz45@msn.com
Web site: http://www.chymist.com

The Chemistry
(and a little physics)
of
Soap Bubbles

David A. Katz
Chemist, Educator, Science Communicator, and Consultant
5003 Canby Drive
Wilmington, DE 19808, USA
Email: dakatz45@msn.com

The Behavior of Soap Bubbles

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 13). 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.

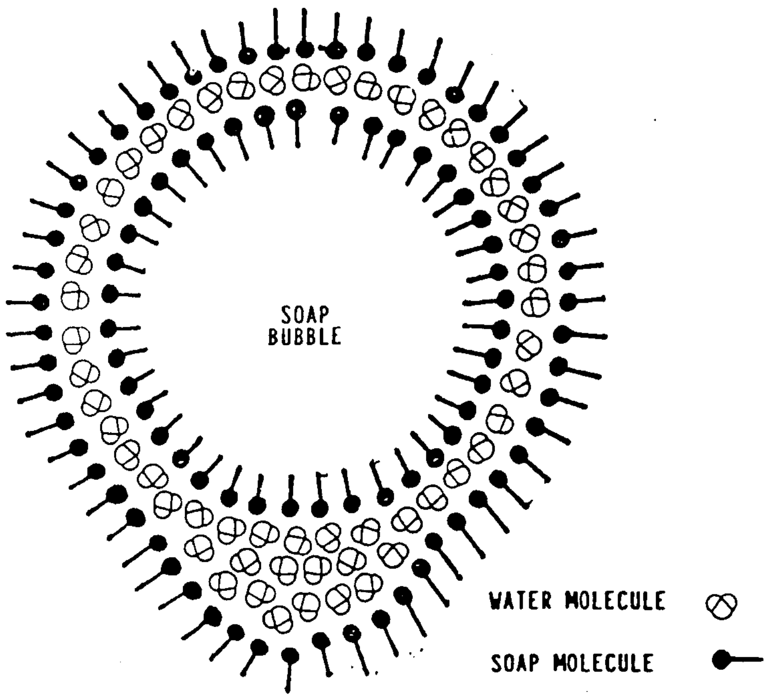


Figure 13. Schematic diagram of a soap bubble

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 14) 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 waves 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)

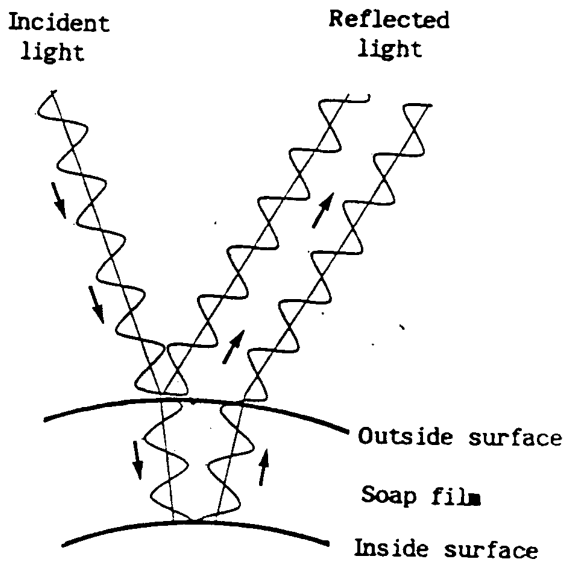


Figure 14. Interference between light waves reflected from the outside and inside surfaces of a soap film.

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
Pan or tray to hold the soap 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?

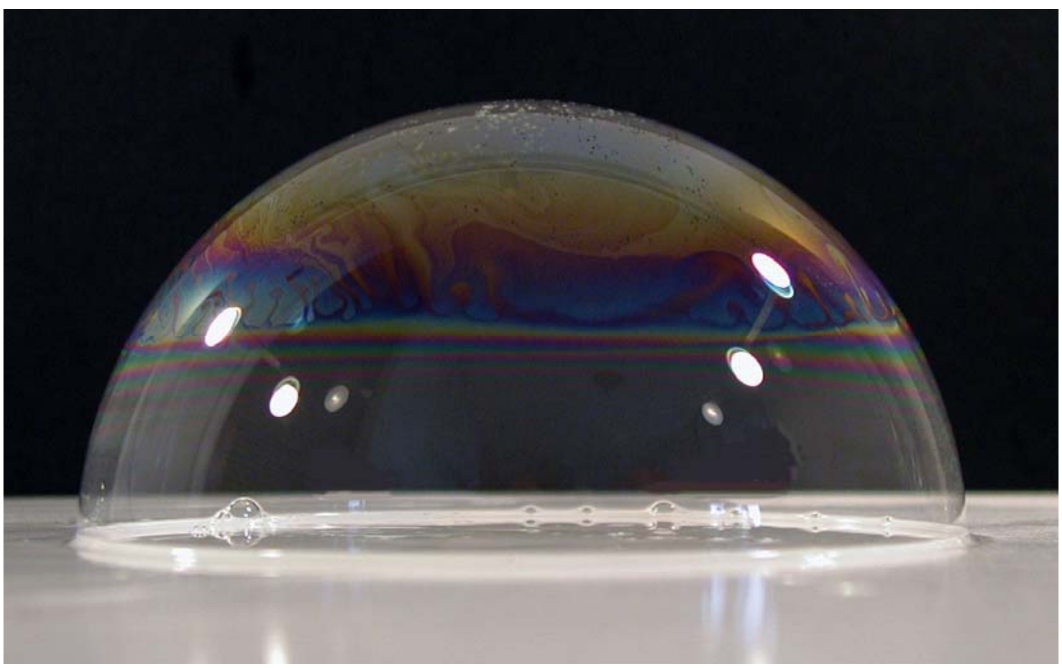
Experiment 7. Observing Colors in a Soap Bubble

Materials needed
Soda straws
Soap bubble solution
Container to hold the soap solution
Plastic sheet or tablecloth

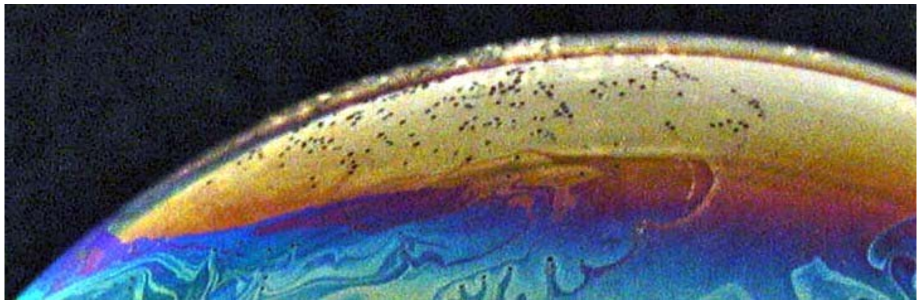
Procedure
Spread some soap solution on a clean waterproof surface, such as a Formica tabletop or a table covered with a plastic tablecloth, to wet an area about 20 to 30 cm (about 8 to 12 inches) in diameter.

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. (See photo below.)



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 longs as a surface or your skin is wet, even with water, soap bubbles generally will not break when they contact that surface. (See Experiment 8.)

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. (See Experiments 9 and 10.)

Bubble Basketball

Play bubble basketball with a tabletop basketball game. (See Experiment 11.)

Experiment 8. Catching soap bubbles

Materials needed
Small bubble loop
Soap bubble solution

Procedure
Dip one hand into some soap bubble solution. Let the excess solution drip off your hand.

Blow some bubbles using the bubble loop.

Gently catch some bubbles.

Will this work if your hand is wet with plain water?

Experiment 9. 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 10. 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 11. Bubble basketball

Materials needed

Small bubble loop
Soap bubble solution
Cloth gloves, prewashed in detergent or wet with bubble solution and allowed to dry.
Small basketball hoop. Look for "wastepaper" basket basketball sets – these fit over the top of a door or on the side of a wastebasket. Wash the netting material for the hoop with detergent or wet it with soap bubble solution and allow it to dry.

Procedure

Put on one or two gloves.

Blow some bubbles using the bubble loop.

Gently bring your gloved hand up to the bubbles and give them a gentle push. You should be able to gently "dribble" the bubble into the air from the glove. Bounce the bubble toward the basketball hoop for a two-point score!

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 12 and 13)

If you want to blow a bubble inside a bubble, see Experiment 14.

Experiment 12. Put your hand through a soap film

Materials needed

A large bubble loop or the string and soda straw shown in Figure 1.
Soap bubble solution
Pan or tray to hold soap bubble solution

Procedure

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

Dip your finger, or hand, in soap solution. Stick you 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 13. Put someone inside a soap bubble

Materials needed and preparation

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 ½ inch copper tubing and connect it to the T-fitting using a 3/8 to ½ 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 (91 cm) pieces of 2 x 4 inch wood, arranged so that the frame will make a pool which is about 4 inches deep. Place 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, has a support under the center to keep it from sagging, 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.

You will need approximately 5 gallons (20 liters) of soap 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.

Safety precautions

Make sure any stand used to hold a person is strong enough to hold an adult. Rubber feet or skids should be used to retard the stand sliding across the bubble pool.

Help people to get onto and off of the stand in the bubble pool. Warn them to move slowly to prevent slipping.

Bubble solution will splash on the floor around the bubble pool. The entire area around the bubble pool should be covered with indoor-outdoor type carpet or some type of non-slip, but absorbent, surface. Rubber mats may become slippery when covered with bubble solution.

It is advisable to have people wearing safety glasses, when being placed in a bubble, to keep the solution from splashing into their eyes.

Procedure
Add soap bubble solution to the bubble 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.

When the giant bubble covers the individual, have them blow into the side of the giant bubble.

Experiment 14. Blow a bubble inside a bubble

Materials needed
A large bubble loop about 8 inches (20 cm) in diameter
Soap bubble solution (use the 10% solution)
Pan or tray for the bubble solution
Safety glasses

Safety precautions
Wear safety glasses to keep soap bubble solution from splashing in the eyes.

This is an outdoor activity as soap bubble solution will splash on walls, floors, and furniture indoors. Do not attempt this procedure indoors unless the area is prepared for soap bubble activities.

Procedure
Make a large bubble with the bubble loop by moving the loop in an upward direction. If done correctly, the bubble will be above your head.

As the bubble falls, blow upward into the bottom of the bubble using a medium-strong, but short, breath of air. If successful, a small bubble will be formed inside the large bubble. This procedure takes some practice to achieve results.

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, use a sheet of plastic such as :Plexiglas, or cover a table with a plastic sheet or tablecloth.

To make tabletop bubbles, spread some bubble solution onto the table or surface, and, then, using a soda straw, dipped in soap solution gently blow hemispherical, or dome shaped, bubbles. You can blow bubbles of different sizes, bubbles inside of bubbles, bubble colonies, and more. (See Figure 13 and Experiment 15)

Experiment 13. Tabletop Bubbles

Materials needed
Waterproof tabletop or surface for soap bubbles
Soda straws
Soap bubble solution
Newspapers or other absorbent material
Safety glasses (recommended)

Safety Precautions
Wear safety glasses to keep soap bubble solution from splashing in the eyes.

Put newspapers or other absorbent material around the work area in case of spills.

Procedure
Spread some bubble solution onto the table or surface 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. This may take some practice to get the proper technique.

Try blowing bubbles of different sizes. Allow them to sit undisturbed. What changes do you observe in the bubbles?

To blow bubbles inside of bubbles, dip the soda straw into soap solution, insert it into a tabletop bubble, and blow a bubble. If the outer bubble keep breaking, make sure the outer surface of the soda straw is wet with soap solution. How many concentric bubbles can you make?

To make bubble colonies or clusters, just blow bubbles around the existing bubbles. Can you blow bubbles on top of bubble clusters? Can you observe any geometric shapes in the bubble clusters?

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 14)

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.

Experiment 14. 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.

Youngsters may not understand how to calculate an average value, however, if all the measured diameters of the soap bubbles are recorded on a chalkboard or sheet of paper and placed in numerical order, a central, or average, value can be determined.

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 15. 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 (-78.5º 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. (See Figure 16) 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 fog-filled bubble. Look for the colored rings in the bubble. (See Figure 17)

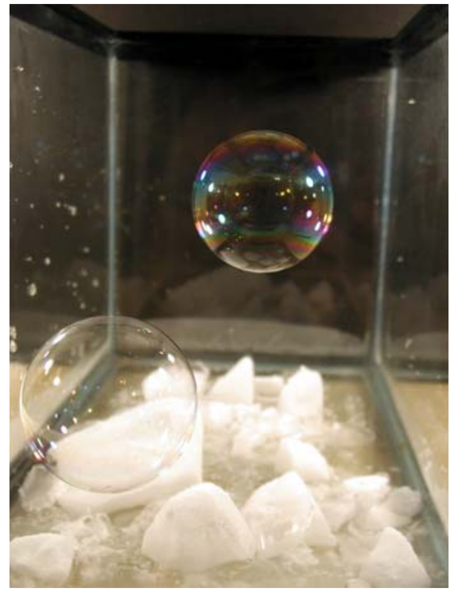
Figure 16. Bucket and light for illuminated soap bubble.

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.

What happens to the fog when the bubble breaks?

Figure 17. Illuminated fog-filled bubble

Experiment 16. 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 (-78.5º 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. (Note: This is to protect the glass or plastic from damage due to the cold temperature of the dry ice.)

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.

Some bubbles will freeze and may settle on the surface of a dry ice chunk. Sometimes the frozen bubbles collapse leaving a frozen hemisphere.

Did you observe any floating bubbles with no top half? Occasionally, most of the water in a floating bubble will drain from the top of the bubble to the bottom without the bubble breaking. The top half of the bubble becomes so thin, it may be difficult to see it in certain light conditions. Look closely, from several different angles to observe the upper half of the bubble.