Lighten up your lesson: Matter, optics,

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Have you ever taken the time to really think about a soap bubble? If not, we think you are in for a fun-filled surprise. Soap bubbles can be used to teach scientific principles such as phases of matter and the reflection of light. The study of soap bubbles addresses the National Science Education Standards for grades 5–8 related to the properties and changes of properties in matter (NRC 1996).

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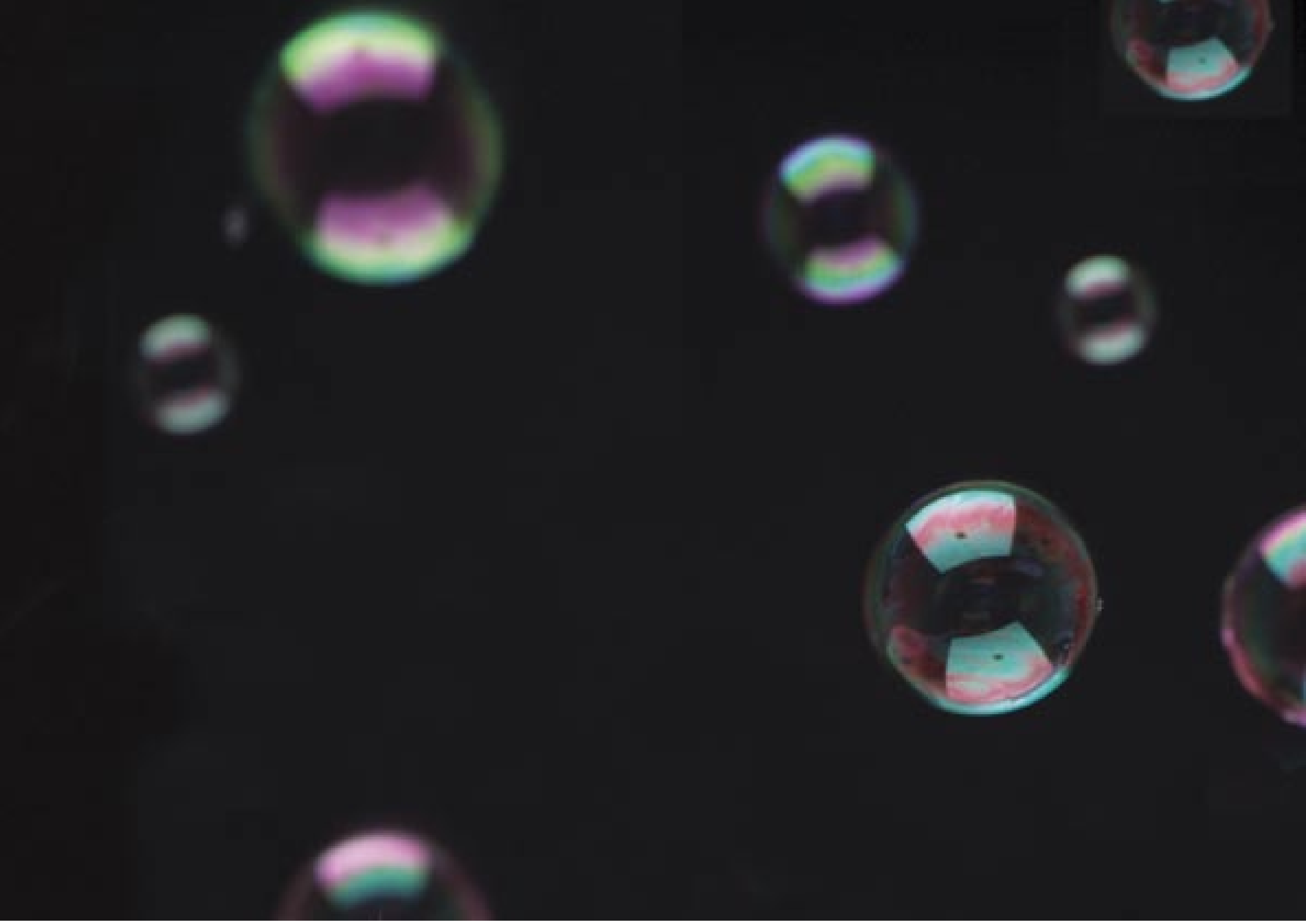

and bubbles

Soap bubbles matter

As we all know, a soap bubble is filled with air, but how should a bubble's shell be classified? In other words, is a soap bubble's shell made of a liquid, a solid, or something else entirely? Begin with a class discussion on this topic to really get your students thinking about what makes a liquid a liquid and a solid a solid. Have them brainstorm ideas and guide them with such questions as "What do rocks, metals, and other solid objects all have in common?" Write down their observations on a chart for everyone to see. This discussion should lead your students to notice many different traits of matter, such as the fact that solids maintain a definite size and shape. The reason that solids maintain their size and shape is that the particles in a solid are tightly packed together and are not free to move. The particles in a liquid are not as tightly packed together as the particles in a solid. Although they maintain a definite size, liquids take on the shape of any container into which they are poured.

After discussing the basic properties of liquids and solids with your students, have some volunteers blow bubbles around the classroom while everyone answers the bubble observation questions (see page 40). A bubble maker such as the Gazillion Bubble Giggler (*www.amazon.com*, $7.99) can produce large quantities of bubbles. However, a variety of less expensive bubble solutions

Bubble observation questions

1. What do the soap bubbles look like? Size? Shape? Other characteristics?
2. How do the bubbles behave? What do they do when they are first blown? Just before they pop? While they are floating or sitting still?
3. Consider a bubble's outer shell—the soapy film that creates the bubble. How is it like a liquid? How is it like a solid? How is it different from liquids and solids? What is it after it pops?

Color observation questions

Look at the soap bubbles near a window or other good source of light. View them from several different angles and pay careful attention to the rainbow patterns and colored bands that cover each bubble's surface.

1. Which colors do you see? Are there any colors missing?
2. Why do you think soap bubbles reflect these different colors?
3. Which colors are brightest when the bubbles are first blown?
4. Which colors still remain just before the bubbles pop?
5. Why do you think that the colors change with bubble thickness?
6. Do different regions reflect different colors? If so, why?
7. Pick a single point on a bubble's surface. Does it stay the same color when you view it from different angles? If not, why do you think this is the case?

Take home questions

1. What is the definition of *iridescence*?
2. Can you provide examples of iridescent phenomena found in our everyday lives?

come equipped with wands and also work well. Students can also use varying sizes of wands to see the effect of wand size on bubble shape and color. To avoid a mess, this activity can be performed outside, or you may wish to place newspapers on the floor to prevent slippery spills. One benefit to performing this activity indoors is that, after wiping down the classroom, all of the desktops are clean! Be sure to have your students wear safety goggles as bubble solution can be an eye irritant.

In the context of the previous discussion and the students' observations, talk about the specific nature of soap bubbles with your students. In particular, focus on the soapy shell that surrounds the internal pocket of air. Ask students whether they believe that the shell is a liquid, a solid, or something else. For example, in a liquid, molecules are free to change orientation and position. It might, therefore, be tempting to say that a soap bubble is a liquid because moving swirling patterns cover its surface, it comes from a liquid solution, and it feels wet (and pops!) when you touch it. On the other hand, it might be tempting to say that a soap bubble is a solid. Unlike liquids, solids maintain a definite shape because their molecules are fixed in terms of both position and orientation. For example, a pearl will maintain its shape without any outside help. In contrast, if you want a liquid to hold the same shape as a pearl, you must either freeze it or pour it into a round container. Consistent with solids and in contrast to liquids, a soap bubble possesses a definite shape of its own—in this case, a sphere. Write down the reasons for and against each idea as a class.

Revealing the truth

In actuality, a soap bubble cannot properly be classified as either a liquid or a solid. Rather, it belongs to a unique and extremely important, often-neglected phase of matter known as liquid crystal. Although the notion may seem paradoxical, the term *liquid crystal* itself is really quite informative. For example, when we ask students what they think is meant by liquid crystal, we almost always get one or more of the following answers: a crystal that is made out of liquid, a liquid that is made out of crystals, a liquid-like crystal, or a crystal-like liquid. However, after providing one of these answers, students often appear puzzled. How can something be both liquid-like and crystal-like at the same time?

The answer resides in the fact that the intermolecular forces in liquid crystals are both weak enough to allow flexibility of molecular movement (liquids), yet strong enough to lend a degree of structural order (solids). In other words, the molecules in a liquid crystal are free to move around (translate), but must maintain a common orientation with respect to their neighbors. This possession of fluid-like properties by a structurally ordered substance has lead scientists to classify liquid crystal as a unique state of matter that exists somewhere between a liquid and a solid (Collins 1990).

Students can research the answer to this and many other questions, such as, "What are the current applications for liquid crystals?" and, "What are potential future applications for liquid crystals?" (see Resources). Additionally, consider having students research today's practical applications of liquid crystal technology, including the development of advanced polymers and the production of flat-screen televisions and display panels for computers, digital cameras, cellular phones, iPods, and similar devices. You may also be familiar with liquid crystals in the form of mood rings, thermometers, and paints that change color as a function of heat. In such products, we are able to observe nanoscale alterations in a liquid crystal's underlying molecular structure by discerning perceptible color changes with the naked eye. Scientists are currently exploiting the unique color changing properties of liquid crystals in the form of chemical and biological sensors that have been specially tuned to respond to particular agents. Additionally, biology is filled with examples of liquid crystalline materials, including such macromolecules as proteins, lipids, and deoxyribonucleic acid (DNA). In fact, the unique combination of structural order and fluidity that is present in liquid crystals is integral to life as we know it.

Iridescence

In addition to introducing the exciting world of liquid crystals, soap bubbles serve as a fun and familiar example of iridescence. While volunteers blow bubbles again, have students answer the color observation questions (see page 40). The iridescent colors that decorate a soap-bubble's surface illustrate the fact that sunlight consists of all the colors of the rainbow. Additionally, this colorful display can be used to teach about light wave interference.

Incoming light reflects off both the inner and outer surfaces of a bubble's soapy shell. These reflected light waves, in turn, either sum together (constructively interfere) or cancel one another out (destructively interfere). The net degree to which reflected light waves constructively or destructively interfere is determined, in part, by a bubble's thickness. If a given wavelength is reflected off the inner and outer surfaces of a bubble's shell in phase with itself or another wavelength of visible light, it will constructively interfere and produce brilliant color. In contrast, light waves that are reflected out of phase will destructively interfere and result in muted or absent color.

Again, consider having students research the examples of iridescent phenomena that appear all around us (see Resources). For instance, iridescence can be observed in cloud formations and oil slicks. It can also be seen in butterfly wings, peacock feathers, beetle shells, certain types of algae, and the interior of seashells. Perhaps most strikingly, as noted by Isaac Newton, subtle changes in viewing angle can drastically alter which, if any, colors appear on an iridescent surface. Try it! One intriguing hypothesis about biological iridescent surfaces, such as beetle shells and butterfly wings, is that they function to help animals evade potential predators by creating visual confusion (Platt 1996).

Additional notes and resources

Both of these exercises can be flexible in terms of time and complexity. For example, you may choose to devote additional time to teaching about the molecular structure of liquid crystals, electromagnetic radiation and the visible spectrum. You may also incorporate this activity into review sessions concerning the different states of matter or the fundamentals of optics. Additionally, instead of purchasing a commercial brand of bubble solution, you can easily and inexpensively make your own (see Resources). This is especially useful if you plan to combine these exercises with additional bubble activities or generate human-sized bubbles. ■

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Resources

Bubblesphere (background, formulae, activities, etc.)—*bubbles.org*

Liquid crystals—*www.lci.kent.edu/lc.html, www.elis.rug.ac.be/ELISgroups/lcd/lc/lc1.html*

Nobel Prize website—*nobelprize.org/physics/educational/liquid_crystals/history/index.html*

Light and optics—*acept.la.asu.edu/PiN/rdg/readings.shtml*

Iridescence in nature—*www.mpm.edu/collect/insect.html, www.mbari.org/staff/conn/botany/reds/iridaea/iridesc.htm, newton.ex.ac.uk/research/emag/butterflies/iridesc-text.htm, www.meteoros.de/iris/irise.htm*

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