LIGHT YOUR CANDY

LIGHT YOUR CANDY

By Linda M. Sweeting

Would you like to really amaze your friends? Gather some sugar cubes, wintergreen candies, and adhesive tape, and take them (along with your friends) into a room with no windows, such as a closet or bathroom. Turn out the lights and wait about five or 10 minutes. During that period, your eyes will begin to adapt to the darkness, and you may begin to be able to see a little of your surroundings. Take two sugar cubes and strike one against the other as if you were trying to strike a match. If your eyes are sufficiently adapted to the dark, you will see a bluish white glow from the sugar cubes when you strike them.

Now for the candy. The best way to see the candy is in your mouth. Keeping your mouth open, place the candy between your teeth and (unless your dentist forbids it) bite down and crush the candy. Your friend will see blue light coming from your mouth. If a friend is not available, use a mirror. If you don't see anything, try again, being careful not to let the candy get wet. The flash of light from the candy is usually brighter than the one from the sugar cube. The tape? Watch closely while you quickly pull a few inches of it from the roll.

Figure 1. **When you crush a Wint-O-Green Lifesaver it gives off a burst of blue light. You can see this demonstration of triboluminescence only if you first let your eyes adapt to a dark room.**

Rubbing for light

This fascinating phenomenon has been known for centuries and has several names: triboluminescence (from the Greek *tribein*, to rub), mechanoluminescence, and fractoluminescence. The last part of the name, luminescence, means "light emission." Once you break the names down, they aren't so mysterious: we have light emission from rubbing, mechanical action, or fracture. I've been studying this phenomenon for several years, with help from undergraduate students and other professional scientists.

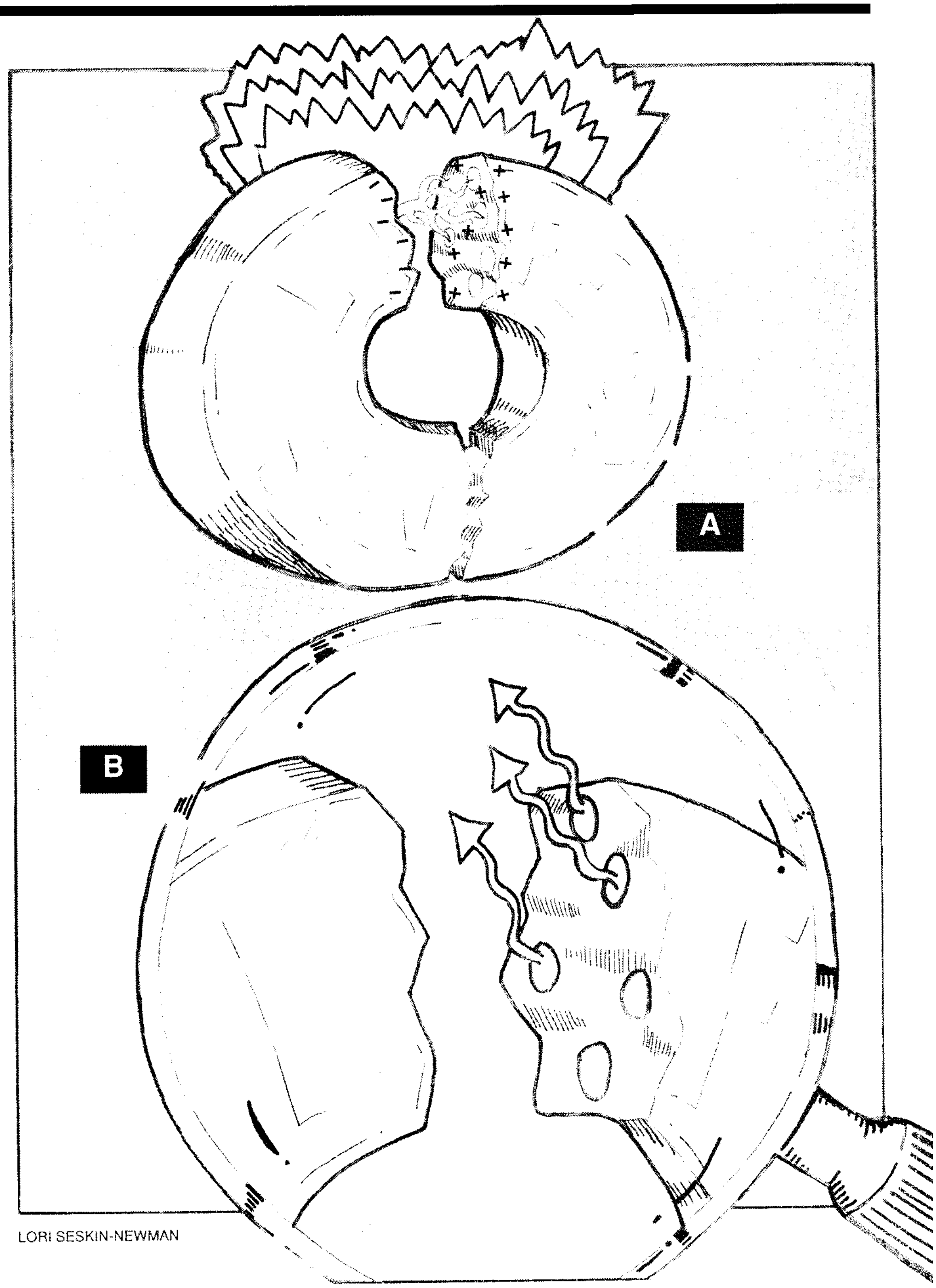
To understand triboluminescence, let's look at how atoms and molecules emit light, a phenomenon that was first explained by Niels Bohr. If you supply a lot of energy to atoms, for example by heating them in a flame or by passing electricity through them, they emit light of a color that is characteristic of the kind of atom. If the spectrum of the light is examined to determine the primary colors that compose the light, it is found to consist of sharp, colored lines, that is, very specific wavelengths. Bohr explained these sharp lines by proposing that electrons in atoms have only certain allowed potential energies, just as you are allowed to have only certain energies and positions when you are standing on stairs. You can have potential energy when standing on stair two, more potential energy when on stair three, but you can't have the energy that's midway between these because there is no stair 2 1/2. After electrons are transported up the energy "stairs" by heat or electricity, they are able to go back to the lowest energy (the ground floor) by steps. As they cascade down the steps, the energy they lose is released as light whose color is determined by the size of the step.

Molecules behave the same way except that the steps are closer together and wiggling (like a rope ladder) and so they emit many colored lines that are so close together that we often cannot separate them readily into individual colors. Our eyes are able to see only a small fraction of the light that atoms and molecules emit, namely, that between violet (big, high-energy steps) and red (smaller steps). Light we cannot see is called ultraviolet (the high-energy emissions that cause sunburn) and infrared (that we can detect as heat).

Lightning in your mouth

Where does the light from sugar and candy come from? The first clue is in the spectrum of the light from sugar — it is exactly the same as the spectrum of lightning. Lightning is simply an electrical current (electrons) passing through air, exciting (giving energy to) the nitrogen molecules of the air. It appears that triboluminescence is lightning on a very small scale. When a sugar crystal is cracked into two pieces, each has an electrical charge, one positive and the other negative (Figure 2A). When there is a big enough charge accumulation (voltage), the electrons jump through the air, colliding with and exciting the nitrogen molecules.

Most of the light emitted by the nitrogen in the air is ultraviolet, at an energy too high for our eyes to detect; thus the emission appears faint. But why is the emission from the candy so much brighter? In addition to the sugar (sucrose) in candy, flavoring has been added. Some flavorings are themselves luminescent. Given enough energy, wintergreen molecules will emit light too, and their emission is mostly in the visible region of the spectrum (Figure 2B). Because they are not in the air but in the candy, they are probably excited not by the electrons, but by the ultraviolet part of the lightning emission. We know that the ultraviolet lightning is responsible because some of it is absorbed (see box **Wintergreen light**).



LORI SESKIN-NEWMAN

Figure 2. **When a Wint-O-Green Lifesaver is cracked open (A), there is an unequal division of electrons, and positive charge accumulates on one piece, negative charge on the other. Soon an electric spark jumps between them and excites the nitrogen molecules in the air, causing the molecules to emit ultraviolet light (part of the lightning represented in A by the branched line). The candy contains wintergreen flavor molecules (circles); some of them absorb part of the ultraviolet energy. The energized wintergreen molecules (colored circles) release the energy (B) as visible blue light (arrows). Most of the light that you see is this blue light emitted by the wintergreen, which explains why you get more light from crushing a wintergreen candy than a plain sugar candy.**

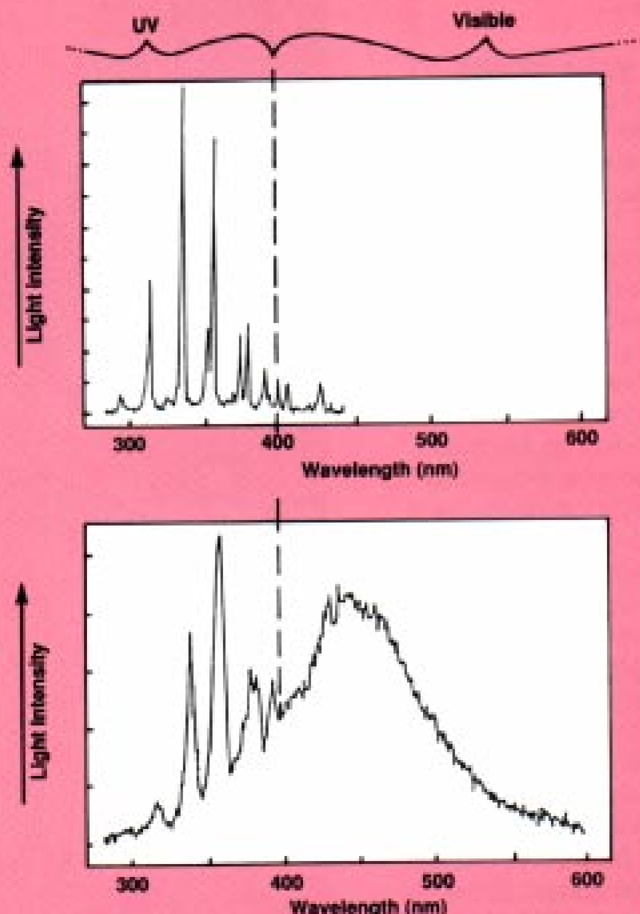
Still in the dark

We are still trying to explain why all materials are not triboluminescent. For example, most transparent sugar candies are not, nor are candies made with artificial sweeteners such as saccharin or aspartame. Because of the unsymmetrical way some molecules pack when they crystallize, their crystals naturally separate charges when you break them—a phenomenon known as piezoelectric-

Wintergreen light

The light emitted by an ordinary sugar candy (top spectrum) has the color of lightning because in both cases the light is given off by nitrogen molecules in the air that have been excited by electricity. This light is mostly invisible because it is in the ultraviolet (UV) part of the spectrum (the series of lines with wavelengths less than 400 nm).

The light emitted by a Wint-O-Green Lifesaver™ (bottom spectrum) appears brighter than that of plain sugar candy because the wintergreen flavoring molecules emit light in the visible part of the spectrum (the wintergreen emission is the broad band between 400 nm and 500 nm). Moreover, wintergreen absorbs best the wavelengths less than 340 nm, and has partially absorbed the UV emission lines in this region. The wintergreen has reduced the ultraviolet emission that we cannot see and increased the visible emission that we can see, thus making the light appear brighter.



ity. A larger fraction of piezoelectric crystals are triboluminescent than of highly symmetrical crystals, but there are well-documented examples of symmetrical crystals that are triboluminescent and unsymmetrical crystals that are not. Only a few scientists are working on this problem, but they have discovered that impurities, disorder, and defects in the crystals may be the source of the triboluminescence, presumably because these variations allow charge separation to occur. While scientists are working on the theory, you can do your own experiments by testing different types of tapes and candies. But, of course, the more you learn about triboluminescence, the more you'll be in the dark!

Linda M. Sweeting *teaches chemistry at Towson State University, Towson, MD, which is also the home of the Editorial Office of* Chem Matters *magazine.*

Dr. Sweeting extends thanks to Patrick Moy, Laksman Phadke, and John Zipper of EG&G PAR of Princeton, NJ, for assisting us in using their diode array detector, OMA3 optical multichannel analyzer, and spectrometer. Towson State University student Reginald F. Pippin III assisted with these experiments.

References

Sweeting, L. M.; Rheingold, A. L. *J. Am. Chem. Soc.* **1987**, *109*, 2652-58.

Sweeting, L. M. In *Spectroscopic Characterization of Minerals and Their Surfaces*; Coyne, L. M.; McKeever, S.W.S.; Blake, D. F., Eds.; American Chemical Society Symposium Series 415: Washington, DC, 1990; pp. 245-60.