Mouth Lightning **Primary Audience: All Ages**

Description: Participants will make observations about triboluminescence using Wintergreen Lifesavers.

Keywords: Triboluminescence, Bioluminescence, Cold Light

Concepts:
- Light can be produced without heat.
- Light produced without heat is called "cold light"
- Cold light can be produced by crushing certain materials.
- Some materials can absorb ultraviolet light, which we cannot see, and reemit it as light waves we can see.

Materials:
- Wintergreen Lifesavers
- Pliers (optional)
- Sugar Cubes (optional)

Instructions:
For this experiment, I'm going to give you some candy. Since the candy is part of the experiment, I want you to promise me that you won't eat the candy until I explain how to do the experiment. Okay?? Great! Each of you will get two pieces of candy. One to use in while you are in this workshop and one to take home, so you can do this experiment again after you get home!

Be certain you give this bit of information before *you hand out the candy!*

Does everyone have two pieces of candy now? Then you need to put one in your carrying bag, and carefully hold on to the other one for just a little while longer.

Don't put it in your mouth just yet, because if it gets wet, the experiment won't work. If you hands are sweaty, hold the candy between your thumb and forefinger, like this.

When we get ready to do this experiment, you are going to put the candy in your mouth just a little to the side, with the widest part of the candy between your teeth, like this.

Demonstrate how to place the candy in your mouth.

If any of you are wearing braces on your teeth, of if you are diabetic; there are some pliers in the bin which you can use instead of putting the candy in your mouth. You will need to place the candy between the jaws of the pliers just like you would put it in your mouth.

Hold up a pair of pliers and show how to put the candy in the pliers.

You need to work in pairs again for this activity, so sit facing your partner.

For this experiment to be successful, we have to darken the room and let our eyes adjust to the darkness. Please remain facing your partner while we let our eyes adjust to the dark.

If we had a whole lot of time, we would give our eyes about three minutes to adjust, but since that's a long time to sit in the dark, we are going to wait just about one minute.

While we are waiting, let me tell you a little about a couple of unusual ways light can be emitted from objects.

The type of light we are investigating in this experiment is called "cold light" because the light that is produced does not produce heat.

Perhaps you have seen pictures of fish that produce light as they swim in the very deep parts of the ocean. Where else have you seen cold light produced by a living creature? Right! Fireflies, as they flash their signals on summer nights. This is bioluminescent light. It is produced as a result of chemical processes in the tissues of these creatures' bodies.

Another type of cold light is produced when some substances are rubbed, crushed or broken. This is known as triboluminescence. When sugar, quartz and mica crystals are crushed, and when adhesive tape is pulled quickly off the tape dispenser, tiny bolts of light will result.

Still another type of cold light results when certain materials absorb very short wave lengths and then emit them as longer wave lengths. This process is called photoluminescence.

Okay. Do you think our eyes are adjusted to the dark now? Great. Let's get ready to do our experiment.

Turn out the lights.

It's a little hard to see into our own mouths, so you will need to watch your partner's mouth, and your partner will need to watch yours, to see how this experiment works.

When I say "ready," I want you to put the candy in your mouths just as I showed you, with the candy upright between your teeth, and then, when I say "go," I want you to crush the candy between your teeth, or between the pliers.

Okay. Ready? Go! Wow! What happened?

Wintergreen candies are both **triboluminescent** and **photoluminescent**. When the sugar in the candy is crushed, it emits tiny bluewhite bolts of light at the same wavelength as lightning, this is triboluminescence. The wintergreen in the candy absorbs ultraviolet light (which we can't see) from the cracked candy and reemits a bright, bluegreen light which we can see. This is photoluminescence.
Turn the light back on.

Possible Interactive Questions:

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What's Going On?
For several decades people have been playing in the dark with triboluminescence using wintergreen-flavored Lifesavers candy. The idea is to break the hard, donut-shaped candy in the dark. Usually a person looks in a mirror or peers into a partner's mouth while crunching the candy to see the resulting blue sparks.
Triboluminescence is light produced while striking or rubbing two pieces of a special material together. It is basically light from friction, as the term comes from the Greek tribein, meaning "to rub," and the Latin prefix lumin, meaning "light". In general, luminescence occurs when energy is input into atoms from heat, friction, electricity, or other sources. The electrons in the atom absorb this energy. When the electrons return to their usual state, the energy is released in the form of light.

The spectrum of the light produced from the triboluminescence of sugar (sucrose) is the same as the spectrum of lightning. Lightning originates from a flow of electrons passing through air, exciting the electrons of nitrogen molecules (the primary component of air), which emit blue light as they release their energy. Triboluminescence of sugar can be thought of as lightning on a very small scale. When a sugar crystal is stressed, the positive and negative charges in the crystal are separated, generating an electric potential. When enough charge has accumulated, the electrons jump across a fracture in the crystal, colliding with and exciting electrons in the nitrogen molecules. Most of the light emitted by the nitrogen in the air is ultraviolet, but a small fraction is in the visible region. To most people the emission appears bluish-white; although some people discern a blue-green color (human color vision in the dark is not very good).

The emission from wintergreen candy is much brighter than that of sucrose alone because wintergreen flavor (methyl salicylate) is fluorescent. Methyl salicylate absorbs ultraviolet light in the same spectral region as the lightning emissions generated by the sugar. The methyl salicylate electrons become excited and emit blue light. Much more of the wintergreen emission than the original sugar emission is in the visible region of

the spectrum, so wintergreen light seems brighter than sucrose light.

Triboluminescence is related to piezoelectricity. Piezoelectric materials generate an electrical voltage from separation of positive and negative charges when they are squeezed or stretched. Piezoelectric materials generally have an asymmetric (irregular) shape. Sucrose molecules and crystals are asymmetric. An asymmetric molecule changes its ability to hold electrons when squeezed or stretched, thus altering its electric charge distribution. Asymmetric, piezoelectric materials are more likely to be triboluminescent than symmetric substances. However, about a third of known triboluminescent materials are not piezoelectric and some piezoelectric materials are not triboluminescent. Therefore, an additional characteristic must determine triboluminescence. Impurities, disorder, and defects are also common in triboluminescent materials. These irregularities, or localized asymmetries, also allow for electrical charge to collect. The exact reasons why particular materials show triboluminescence can be different for different materials, but it is probable that crystal structure and impurities are primary determinants of whether or not a material is triboluminescent.

Wint-O-Green Lifesavers aren't the only candies that exhibit triboluminescence. Regular sugar cubes will work, as will just about any opaque candy made with sugar (sucrose). Transparent candy or candy made using artificial sweeteners will not work. Most adhesive tapes also emit light when they are ripped away. Amblygonite, calcite, feldspar, fluorite, lepidolite, mica, pectolite, quartz, and sphalerite are all minerals known to exhibit triboluminescence when struck, rubbed, or scratched. Triboluminescence varies widely from one mineral sample to another, such that it might be unobservable. Sphalerite and quartz specimens that are translucent rather than transparent, with small fractures throughout the rock, are the most reliable.
There are several ways to observe triboluminescence at home. If you have wintergreen-flavored Lifesavers handy, get in a very dark room and crush the candy with pliers or a mortar and pestle. Chewing the candy while watching yourself in a mirror will work, but the moisture from saliva will lessen or eliminate the effect. Rubbing two sugar cubes or pieces of quartz or rose quartz in the dark will also work. Scratching quartz with a steel pin may also demonstrate the effect. Also, sticking/unsticking most adhesive tapes will display triboluminescence.

For the most part, triboluminescence is an interesting effect with few practical applications. However, understanding its mechanisms may help explain other types of luminescence, including bioluminescence in bacteria and earthquake lights. Triboluminescent coatings could be used in remote sensing applications to signal mechanical failure. One reference states that research is underway to apply triboluminescent flashes to sense automobile crashes and inflate air bags.[1]

Further Exploration:

1. Try using other materials to see if they produce a cold light when rubbed together or cracked. Can sugar cubes do the same?

Relevant Ohio Science Content Standards:

- Physical Science K-2: B. Recognize that light, sound, and objects move in different ways.
    - 2.3: Explore with flashlights and shadows that light travels in a straight line until it strikes an object.
- Physical Sciences 3-5: F. Describe the properties of light and sound energy.
    - 5.5: Explore and summarize observations of the transmission, bending (refraction) and reflection of light.
- Physical Science 9-10: G. Demonstrate that waves (e.g., sound, seismic, water and light) have energy and waves can transfer energy when they interact with matter.
    - 9.18: Demonstrate that electromagnetic radiation is a form of energy. Recognize that light acts as a wave. Show that visible light is a part of the electromagnetic spectrum (e.g., radio waves, microwaves, infrared, viable light, ultraviolet, X-rays, and gamma rays).
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[1] How Stuff Works.com