

## Turning on the Light

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In this Activity, students investigate the luminescent properties of common items. After making observations, they use a flowchart to categorize the luminescent items as fluorescent, phosphorescent, or triboluminescent.

### Background

Fluorescence, phosphorescence, and triboluminescence are the emission of light from substances that have been excited. Because these processes occur without heating the substance, the light emitted is described as "cold light". *Fluorescence* is emission of longer-wavelength light immediately after excitation by shorter-wavelength light. An example is the fluorescence of chlorophyll, a green pigment in plants. Chlorophyll absorbs blue and UV light from the sun and emits a bright red fluorescence. *Phosphorescence* happens much more slowly, and can often be observed minutes or hours after excitation. Phosphorescence only occurs in some substances; it requires an excited state electron to change its spin, a process that is very difficult to do. *Triboluminescence* is the emission of light from a substance when it is strained or cracked. A more thorough treatment of these processes is in an accompanying article in this issue (1).



photo by J. J. Jacobsen & E. K. Jacobsen

### Integrating the Activity into Your Curriculum

This Activity allows students to see directly emission of light as a result of electron transitions. The Activity could be used as an introduction to atomic structure. It also illustrates the concepts of energy transformation and conservation; it could be useful during a discussion of photosynthesis in an AP Biology class.

### About the Activity

Fluorescent and phosphorescent materials such as paints, crayons, markers, and stickers can be purchased in craft or discount stores. Fluorescent mineral samples such as fluorite can be purchased from a science supply vendor such as Edmund Scientific (2). Rubbing two hand-sized quartz crystals could also be used to illustrate triboluminescence (3). Larger denominations of U.S. paper currency may exhibit fluorescence. UV black lights may be purchased from a gift store such as Spencer's or from an online vendor (4). Extra care should be taken not to shine UV light directly into the eyes. For the chlorophyll observations, denatured alcohol can be substituted for isopropyl alcohol. A refrigerated chlorophyll stock solution retains its properties for several weeks. Instructors may wish to experiment with making the Activity more quantitative by having students use light meters to measure the light intensity of the various items. A table of typical observations and several photos are available in this issue of *JCE Online*.<sup>W</sup>



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### Answers to Questions

1. Items that emit light without heat are luminescent. This should include most, if not all, of the items on the Student Activity. Fluorescent items include the chlorophyll solution, fluorescent markers/crayons/paints/stickers, white clothing and paper, tonic water, and rocks containing the mineral fluorite. Phosphorescent items are usually labeled "glow-in-the-dark" and may include toys and art items. Wintergreen-flavored hard candies are triboluminescent.
2. All three are processes in which light is emitted from a substance without heat. They differ in the way the substance is excited. When light is used to excite an electron in a substance, and then the sample emits light immediately, we call the process fluorescence. Phosphorescence also involves using light to excite a substance, but there is a delay before light is emitted. Triboluminescence appears in a substance excited by the mechanical action of breaking or striking.
3. White light and UV light are each associated with different wavelengths and energies of light.
4. The source of the energy is whatever does the crushing. It is a transfer of energy from your hand to the pliers (crushing the candy) into light energy.

### References, Additional Related Activities, and Demonstrations

1. O'Hara, Patricia B.; Engelson, Carol; St. Peter, Wayne. Turning on the Light: Lessons from Luminescence. *J. Chem. Educ.* 2005, 82, 49–52.
  2. Edmund Scientific. <http://scientificsonline.com>; 800/728–6999; #3053593, 3 lbs. fluorescent mineral rocks, \$16.95.
  3. Experiments with rocks and minerals. <http://rockhoundingar.com/quartz/experiments.html>
  4. <http://technika.com/Sperls330006.htm>; pen lamp: UV / Laser / White Light #330006, \$26.
- (All sites accessed Oct 2004)

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## Turning on the Light

Have you ever watched the pulses of light from fireflies? This light has much in common with “lightsticks”, in which two substances are mixed in a sealed plastic tube after an inner membrane is cracked. Fireflies and lightsticks both emit a light that glows without heat. This “cold light” is called *luminescence*. Luminescent processes include bioluminescence (fireflies), chemiluminescence (lightsticks), triboluminescence, fluorescence, and phosphorescence; the relationships among these processes are shown in the flow chart. Emission of light occurs when electrons in the substance move from higher energy levels (excited states) to lower energy levels. The electrons can be excited by an outside source such as light of certain wavelengths. The energy of the emitted light is always less than the energy of the light that excites the electrons. In this Activity, you will “turn on the light” as you investigate the luminescence properties of common substances.

### Try This

You will need: fresh or frozen spinach, isopropyl alcohol (70%), tablespoon, small container, test tube, knife and cutting board or blender, wintergreen-flavored hard candy, plastic bag, pliers, UV black light, lamp with incandescent bulb, a room that can be darkened, and several of the items listed in step 3.

### Preparation

1. Prepare a table with five columns labeled: Item, White Light, White Light Off, UV Light, UV Light Off, Luminescent/Non-luminescent, Type of Luminescence.
2. Chop 2–3 leaves of fresh or frozen spinach with a knife or blender. Scrape into a small container. Add 2 tablespoons (30 mL) of 70% isopropyl alcohol and mix thoroughly. Fill a test tube with this chlorophyll solution.
3. Obtain several of these: glow-in-the-dark or fluorescent toys or markers, crayons, paints and stickers; white clothing and paper; tonic water; rocks containing the mineral fluorite.

### Observations

Write the name of each item you will observe under “Item” in the table from step 1. Include the solution from step 2 and the items from step 3. Make the observations in a darkened room. Observations for columns 2–5 should describe the color and intensity (C/I) of any light emitted from the items, such as “blue-green/bright” or “red/dim”. Note whether the light is steady or fading. When following steps 4–7 for the solution from step 2, observe the solution from different angles (straight on, perpendicular, etc.). Record whether the angle of observation changes what you observe.

4. In a darkened room, expose each item to a lighted incandescent bulb for ~15 s. Observe and record in column 2 the color and intensity (C/I) of any light emitted from each item.
5. Turn off the white light. In the darkened room, observe and record in column 3 the C/I of any light emitted from each item.
6. In the darkened room, expose each item to a UV black light. Observe and record in column 4 the C/I of any light emitted from the items.
7. Turn off the UV black light. In the darkened room, observe and record in column 5 the C/I of any light emitted from each item.
8. Obtain a wintergreen-flavored hard candy, plastic bag, and a pliers. In a darkened room, place the candy between the jaws of the pliers. Hold the plastic bag around the pliers and candy to catch any candy shards. Use the pliers to crush the candy. Observe the candy as it is crushed. Record in column 3 the C/I of any emitted light.

### Questions

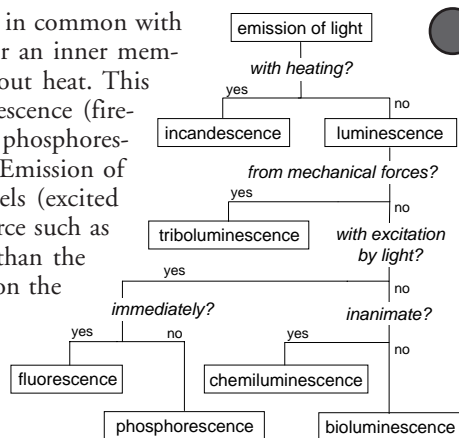
1. Using the flowchart above, label in column 6 each of the items you observed as luminescent or non-luminescent. Label in column 7 each luminescent item as fluorescent, phosphorescent, or triboluminescent. Explain your answers.
2. How are fluorescence, phosphorescence, and triboluminescence similar? How are they different?
3. Why do white light and UV light interact differently with the same material?
4. If you observed light when wintergreen hard candies were crushed, what is the source of energy for this light?

### Information from the World Wide Web (accessed Oct 2004)

Bioluminescence. <http://www.sdnbm.org/kids/lightsalive/biolum3.html>; <http://www.biolum.org/>

How does glow-in-the-dark stuff work? <http://science.howstuffworks.com/question388.htm>

Chemical of the week: chlorophyll. <http://scifun.chem.wisc.edu/chemweek/CHLRPHYL/Chlrphyl.html>



**Be Safe!** Observe manufacturer's procedures for use of the UV black light, including any necessary eye protection.



photo by J. Jacobson & E. K. Jacobson