Day in the Dark Demonstrations with Jamie Benigna

Introduction

Use this lively presentation with a multitude of related and exciting demonstrations to explore the basic principles of light absorption and emission. An unforgettable lesson plan for fluorescence, phosphorescence, and chemiluminescence!

Concepts

- Atomic structure
- Fluorescence
- Phosphorescence
- Chemiluminescence
- Energy levels
- Excited States

Connecting to the National Standards

These demonstrations relate to the following National Science Education Standards (1996)

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Constancy, change, and measurement
Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, properties and changes of properties in matter, transfer of energy
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure of atoms, structure and properties of matter, interactions of energy and matter
Content Standard F: Science in Personal and Social Perspectives, natural and human-induced hazards, science and technology in local, national, and global challenges

Master Materials List

	Demonstration				
	Excited States	Permanent Excitation	Fluorescence	Phosphorescence	Chemiluminescence
Chemicals					
Antifreeze			~400 mL		
Clorox 2, powder form					64 g*
Detergent, Vaseline			1 box		
Fluorescein			> 0.05g**		
Hydrogen Peroxide, H_2O_2, 3%					15 mL†
Irradiated Salt, NaCl		10 g			
Luminol					0.3 g*†
Potassium ferricyanide, $K_3Fe(CN)_6$					4.7 g*†
Sodium Hydroxide solution, NaOH, 5%					50 mL†
Sunscreen, transparent spray				1 bottle	
Toothpaste, Whitening				1 tube	
Water, distilled or deionized				700 mL	2400 mL
Water, tap, warm (~70 °C)					400 mL
Water, tap, cold (~10 °C)					400 mL
Tonic Water			1 L**		

Apparatus					
Beaker, 100-mL			1		
Beaker, 400-mL			1		4–5
Card, black, 8½″ × 11″				2 sheets‡	
Depression era glass			1 piece		
Envelope, 5″ × 11″				1‡	
Erlenmeyer flask, 2-L					1
Fluorescent paints, crayons, or dyes			3–7**		
Fluorescent and non-fluorescent highlighters			3–7		
Foam spheres or plastic lids, colored (red, orange, yellow, green, and blue)	5–8				
Funnel, large					1
"Glow-in-the-dark" items (e.g., stars, solar system stickers, t-shirts, watch faces, etc.)				Several samples	
Graduated cylinder, 50-mL					1
Hot plate		1			
LED, miniature, high energy (blue) and low energy (yellow or red)				2–3	2–3
Light sticks					2–3
Magnetic stirrer and stir bar			1 *(optional)*		1
Phosphorescent Vinyl sheets				2–3	
Ring stand and ring					1
State driver's license or credit card			1		
Step stools or set of chairs at different heights	5–8				
Stirring rod			1		
Theater gel, red square, 1″ × 1½″				1‡	
Theater gel, orange square, 1″ × 1½″				1‡	
Theater gel, yellow square, 1″ × 1½″				1‡	
Theater gel, green square, 1″ × 1½″				1‡	
Theater gel, blue square, 1″ × 1½″				1‡	
Theater gel, violet square, 1″ × 1½″				1‡	
US bill, above $5			1		
Ultraviolet detecting beads			1 bag *(optional)*		
Ultraviolet lamp, long- and short-wave			1	1 *(optional)*	
Visor goggles, or UV-protective safety goggles			1	1 *(optional)*	

** Materials available in the Instant Light Kit, AP9118*
† Materials available in the Cool Light—Chemiluminescence Kit, AP8672
‡ Materials assembled in the Energy in Photons kit, AP4576
***Materials available in the Fluorescent Dye Kit, AP4848*

Preparation

The room will need to be darkened to demonstrate the "-escence" activities. Cover the windows to block all sources of light except those found inside the classroom. Select a student volunteer to flip the light switch during the demonstrations.

Background

In 1865, J. C. Maxwell showed that visible light is a form of electromagnetic radiation. All forms of electromagnetic radiation consist of oscillating electric and magnetic fields travelling at a constant speed, the speed of light, 2.998 x 108 m/s. Other familiar forms of electromagnetic radiation include microwave radiation from a microwave oven, X-rays, the infrared radiation in heat from a fire, and radio waves. Together, all forms of electromagnetic radiation make up the electromagnetic spectrum.

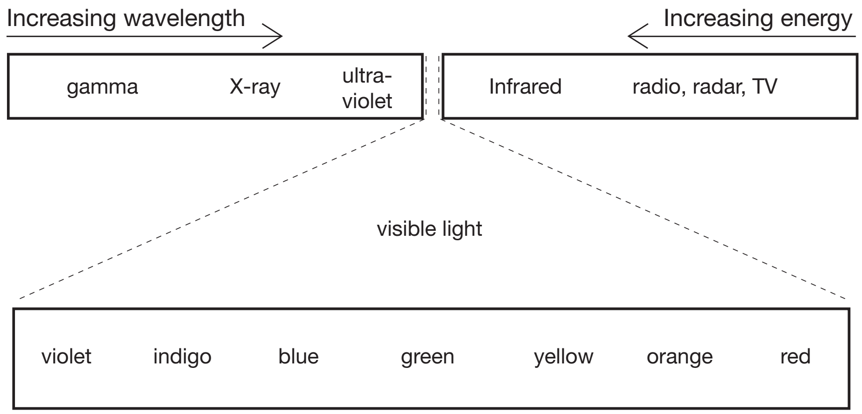

Figure 1.

The visible portion of the electromagnetic spectrum is only a small part of the entire spectrum. It spans the wavelength region from about 400 to 700 nm. We see light of 400 nm as violet and 700 nm as red. Because wavelength is inversely proportional to energy according to the equation E = hc/l, violet light is higher energy light than red light. The color of light we see with the human eye varies from red to violet (low to high energy) according to the familiar phrase ROY G BIV: red, orange, yellow, green, blue, indigo, violet. As the color of the light changes, so does the amount of energy it possesses. White light, like that from normal classroom lights, contains all of the colors in the visible spectrum. A typical black light (such as Flinn Catalog No. AP9030) gives off UVA light. UVA is ultraviolet light in the wavelength range from approximately 320 to 400 nm; therefore, it is higher energy light than visible light. The human eye cannot see ultraviolet light. Therefore, a substance that gives off ultraviolet light (and does not also give off visible light) will appear clear or colorless. The black light gives off higher energy light than the normal classroom lights. Because the light from a black light can be seen with the human eye, it clearly must give off some wavelengths of visible light in addition to the UVA wavelengths it gives off. These additional wavelengths are in the low 400's, so the black light appears purple to the human eye.

Demonstration 1. Excited States

Introduction

Help students learn the Bohr Theory and the basic concepts of energy levels, ground states, and excited states by performing this energetic demonstration.

Concepts

- Energy levels
- Ground states
- Excited states
- Photon emission

Materials

Foam balls or plastic lids, 5–8*

Step stool or set of chairs at different heights

**Foam balls or plastic lids will be used to simulate photons and the loss of energy when an electron drops from an excited state to a lower energy state.*

Safety Precautions

Clear away all items from the "landing area." Be careful when jumping off the chairs or step stools. To avoid possible injury to students or damage to equipment, use only soft and flexible "photons" and gently throw them up into the air.

Procedure

1. Demonstrate the definition of quantized electron energy levels by first standing on the floor *(ground state)*, and then stepping onto a chair or the first step of a step stool *(first excited state)*. The electron in the excited state is at a higher potential energy compared to the ground state. Energy must be added to "climb" from a lower energy state to a higher energy state. *(In this analogy, the potential energy is due to gravity.)*
2. Explain that there are no *stable* energy levels between the ground state and the first excited state.
3. Jump down to the floor to simulate an electron dropping back down to the ground state. Again, note that there are no stable energy levels between the first excited state and the ground state. Discuss the fact that energy is lost or released when an electron drops from a higher energy, excited state to the lower energy ground state.
4. If possible, step onto a higher chair or onto the second step on a step stool to demonstrate the second excited state.
5. Jump down to either the "first excited state" or the "ground state." Note that both options are possible, but that different amounts of energy will be lost when an electron drops from the second excited state to the first excited state compared to when it drops from the second excited state to the ground state.
6. Ask students to imagine what this process would look like at the subatomic level. What happens to the energy that is lost in the process? *(The loss of energy when an electron drops from a higher energy level to a lower energy level may be observed as light emission, as in flame tests.)*
7. Leap onto the chair and shout, "I'm so excited!"
8. Pull the "photons" from your pocket and, as you jump back down to the floor, toss a "photon" out into the classroom over the heads of the students.
9. Repeat the process of climbing from the ground state to excited states, jumping back down, and releasing photons until the supply of photons has been exhausted.

Tips

- This demonstration can be enhanced by use of the song "I'm So Excited" by the Pointer Sisters when demonstrating being in an "excited state". This provides enthusiasm for the concepts. Many students will recognize the song and relate the science concepts to the demonstration. The abstract ideas of electrons, energy levels, and photons have suddenly become concrete and even entertaining to the students. The entertainment factor is quite refreshing—quantum mechanics often causes students much frustration as they attempt to comprehend abstract concepts that seem so far removed from their daily lives.
- Use soft or lightweight "photons." Nerf™ balls or plastic lids to margarine or other plastic containers work well.
- A step stool with two or three steps works great. Two chairs of different heights or a chair and a lab bench will also work. Use your imagination but always stay within your physical limitations.
- If possible, toss the "photon" as you are in the air to symbolize that the photon is emitted as the electron drops to a lower energy state.
- To demonstrate different excited states and the different possible energy transitions, use different colored foam balls to represent photons of different energy (color and wavelength) that may be emitted.

Discussion

Introduce the Bohr theory of the atom and the concepts of ground states, excited states, and photons. There are four fundamental concepts: (1) Energy is quantized. (2) Electrons that are closer to the nucleus are generally lower in energy than electrons that are farther away from the nucleus. (3) Energy is required to promote an electron from a lower energy level to a higher energy level. (4) Energy is released (often in the form of light) when an electron drops from a higher energy level to a lower energy level.

Demonstration 2. Permanent Excitation

Introduction

When ordinary table salt is irradiated, it turns brown due to "color centers" (defects) in the excited-state crystal structure. When the irradiated salt is heated on a hot plate, it gives off flashes of light and turns white as the excited-state crystal returns to the ground state. The thermal fluorescence of irradiated table salt is used to illustrate crystal defects.

Concepts

- Irradiation
- Excited state
- Crystal structure
- Fluorescence

Materials

Irradiated salt, NaCl ~10g

Hot plate

Safety Precautions

Irradiated salt is not radioactive nor is it more hazardous than normal table salt. However, it should be treated as a laboratory chemical and not consumed. A "hot" hot plate looks exactly like a cold hot plate! To avoid burns, place a HOT sign next to the hot plate before the demonstration and also afterwards to warn students and other teachers that the hot plate is indeed hot. Wear chemical splash goggles, chemical resistant gloves, and a chemical resistant apron. Wash hands thoroughly with soap and water before leaving the lab. Please review current Material Safety Data Sheet for additional safety, handling, and disposal information.

Procedure

1. Turn on the hot plate to its highest setting beforehand so that it will be hot at the time of the demonstration.
2. Show a sample of the irradiated table salt, which is orange-brown in color.
3. With the room darkened, sprinkle the irradiated salt sample on the hot surface of the hot plate. Have students observe with their sense of sight and sense of hearing. The heated salt sparkles, and a sizzling sound may be detected.
4. Turn on the lights and note the color of the salt sample, which is now white.

Disposal

The salt may be flushed down the drain with water according to Flinn Suggested Disposal Method #26b.

Discussion

When sodium chloride is irradiated with high doses of gamma radiation, defects in the crystal structure are formed. These defects cause the salt to appear orange-brown in color. The radiation also provides the necessary energy to excite electrons within the crystal structure. These electrons are trapped in the crystal defects. The irradiated salt crystals exist in a stable, albeit excited state, and will remain in this "potential energy well" until additional energy is added. When energy is added to the stable excited state in the form of heat, the electrons obtain sufficient energy to get out of the energy well and return to the ground state. When the electrons return to their ground state, energy is emitted in the form of light. This is thermal fluorescence. The heating also decreases the rigidity of the crystal lattice, allowing the salt crystals to revert to their original, defect-free state, which is white in color. The salt is not radioactive. A discussion of irradiated foods can ensue.

The concepts involved in this demonstration can also be related to devices used to detect radiation exposure in radiation workers. Thermoluminescent dosimeters (TCD) contain LiF (rather than NaCl), which "stores energy" when exposed to ionizing radiation. The LiF is then heated to release its stored energy and the amount of energy that is released is measured with a lightsensitive instrument (e.g., a photomultiplier tube). The amount of light released corresponds to the energy that was deposited in the LiF salt as the ionizing radiation passed through the material.

Demonstration 3. Fluorescence

Introduction

Wow your students with all the everyday items that glow under ultraviolet light.

Concepts

- Fluorescence
- Ultraviolet light

Materials

Distilled or deionized water, 300 mL
Beaker, small, 100 mL, 1
Beaker, medium, 400- or 600 mL, 1
Petri dishes, to fit medium and small beakers, plastic or glass, 2
Stirring rod or magnetic stirring plate and stir bar
Transparent sunscreen spray
Ultraviolet-detecting beads
UV lamp, long- and short-wave
Visor goggles, or UV-protective safety goggles

Fluorescent materials

Antifreeze (contains fluorescein)
Vaseline petroleum jelly
Fluorescein, < 0.05 g*
Fluorescent and non-fluorescent highlighters
Fluorescent paints, crayons, or dyes*
Toothpaste, whitening
Water, tonic, 1 L*
Detergent containers and regular food containers
Depression era glass
State drivers' licenses or credit cards
U.S. bill above $5

**Materials available in Fluorescent Dye Kit, AP4848.*

Safety Precautions

Dye solutions will easily stain hands and clothing; avoid all contact with skin and clothing. Ultraviolet light may damage the eyes and cause cataracts. Do not look directly at the UV light source. Do not hold the lamp close to your eyes. Wear UV-protective safety glasses or goggles during the demonstration.

Preparation

Preparing a fluorescein solution: In the medium, 400- or 600 mL beaker, place a tiny amount (< 0.05 g) of fluroescein dye with 300 mL of distilled or deionized water and stir to dissolve.

Procedure

Part A. Fluorescent everyday objects

1. Demonstrate fluorescence in everyday objects by holding them under fluorescent light. Some suggestions include:
   - Vaseline petroleum jelly
   - State driver's license or credit card
   - US bill above $5
   - Depression era glass
   - Tonic water (contains Quinine)
   - Antifreeze (contains Fluorescein)

Part B. Ultraviolet Advertising and Cleaning

2. Put a detergent container under the UV lamp and show its vivid fluorescence.
3. Put a food can (generic brand is best) under the UV lamp and show its distinctive lack of fluorescence.
4. Demonstrate that detergent itself is fluorescent. UV-sensitive compounds were added to detergents to make "whites whiter and brights brighter."

Part C. Fluorescent Highlighters

5. Demonstrate that some highlighters are fluorescent
6. Turn lights on and off to show differing colors

Part D. Sunscreen's UV protection

7. Obtain the fluorescein solution, small beaker, transparent sunscreen, and the petri dish.
8. Carefully balance the beaker with the fluorescein solution on top of the UV lamp. Turn off the lights, turn on the lamp, and demonstrate the fluorescing properties of fluorescein.
9. Turn the lights back on, remove the beaker, and set it down.
10. Spray the transparent sunscreen onto the petri dish, and set the fluorescein beaker inside the petri dish.
11. Once again, carefully balance the fluorescein beaker atop the UV lamp, and with the lights out, demonstrate the dramatic reduction in fluorescence.
12. *Optional:* For added effect, pour a small amount (~50 mL) of the fluorescein into the smaller beaker, and set it right next to the medium beaker, to demonstrate the difference in fluorescence.

Tip

- Depression era glass can be found in many flea markets. It is a bright green color, a result of the uranium oxides

Discussion

Fluorescence is different from other types of luminescence in that is it restricted to phenomena in which the time interval between absorption and emission of energy is extremely short. Therefore, fluorescence only occurs in the presence of the exciting source. This is different from phosphorescence, which continues after the exciting source has been removed. When a light source is shined on a material, a photon is absorbed. The energy from the photon is transferred to an electron that makes a transition to an excited electronic state. From this excited electronic state, the electron naturally wants to relax back down to the ground state. When it relaxes back down to the ground state, it emits a photon (symbolized by the squiggly arrow in figure 2 below). This relaxation may occur in a single step or in a series of steps. If it occurs in a single step, the emitted photon will be the same wavelength as the exciting photon. If the relaxation occurs in a series of steps emitting a photon along the way, the emitted photon will have a greater wavelength (lower energy) than the exciting photon.

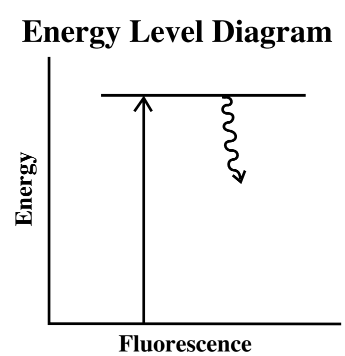

Figure 2.

If the emitted photon's wavelength is in the visible portion of the spectrum, we observe a colorful, glowing effect. Emission of this form is termed fluorescence. This process is practically instantaneous so the fluorescence is observed as soon as the exciting source is present, and it disappears as soon as the exciting source is removed. The fluorescent glow is brighter than the color of the solution seen under normal fluorescent lights because light is being emitted from the solution, not just transmitted through it.

Many everyday objects contain fluorescent material. Tonic water contains quinine, which fluoresces. Antifreeze contains fluorescein, a pH indicator which fluoresces. Advertising takes advantage of the subconscious human response to UV-sensitive dyes: people want their clothes "vivid," and the fluorescent dyes give people that impression.

Demonstration 4. Phosphorescence

Materials

LEDs, miniature, high energy (blue) and low energy (yellow or red)

Visor goggles, or UV-protective safety goggles

UV lamp, long- and short-wave (optional)

Energy in Photons Demonstrator Card (available in the "Energy in Photons" kit, AP4576)

Black card, 8½″ × 11″, 2

Envelope for storing, 5″ × 11″

Theater gel, red square, 1″ × 1½″

Theater gel, orange square, 1″ × 1½″

Theater gel, yellow square, 1″ × 1½″

Theater gel, green square, 1″ × 1½″

Theater gel, blue square, 1″ × 1½″

Theater gel, purple square, 1″ × 1½″

Phosphorescent vinyl sheet

Phosphorescent materials

"Glow-in-the-dark" stars, solar system stickers, several

"Glow-in-the-dark" periodic table t-shirt

"Glow-in-the-dark" watch face

Phosphorescent Vinyl sheets, 2

Safety Precautions

Ultraviolet light may damage the eyes and cause cataracts. Do not look directly at the UV light source. Do not hold the lamp close to your eyes. Wear UV-protective safety glasses or goggles during the demonstration.

Preparation

To create the Energy in Photons Demonstrator Card:

1. Cut one of the black cards in half, 4¼″ × 11″, creating the half sheet cover card. Set aside for step 8.
2. Fold the other black card in half, "hot dog" style, 4¼″ × 11″, and crease it.
3. With a ruler, measure and mark five evenly-spaced divisions every ~1¾″, dividing the top half of the card into 6 rectangles of equal width.
4. In each rectangle, vertically center and cut a circle with about a 1″ diameter.
5. Cut a 1″ × 10½″ strip from the Phosphorescent Vinyl sheet.
6. Remove the backing from one Phosphorescent Vinyl strip sheet. Open the card and attach the strip down the center of the non-holed half of the 6-holed card. *Note:* There will be about 1⅜″ both above and below the strip after centering. The strip must be attached so that when the card is closed, the phosphorescent vinyl strip is showing beneath the 6 holes and no black is showing.
7. Obtain the 6 colored theater gels. Open the card and tape the colored filter squares over the 6 holes, following the order of lowest energy to highest—red to orange to yellow to green to blue to violet. *Note:* When taping, be sure that no tape is showing through the circles.
8. Place the half sheet cover card over the phosphorescent vinyl strip. Close the folded card and place in an envelope for storage, or until ready to use.

Procedure

1. Irradiate any phosphorescent material with the UV lamp to show that it emits photons even after irradiation. *Note:* For these demonstrations, a UV lamp is not necessary--classroom lights will also cause the materials to phosphoresce.
2. With the lights darkened, remove the Phosphorescent Vinyl sheet from its envelope.
3. Place an object, such as your hand, over the sheet, and illuminate it for 5-10 seconds using the UV lamp.
4. Turn off the UV lamp and remove the object, showing the sheet phosphorescing around the object's outline.
5. *Optional:* Obtain the LED lights and shine them on the phosphorescent sheet, drawing a pattern. Demonstrate that a lower energy light, such as a red LED, will not cause the sheet to phosphoresce, whereas a blue LED will.
6. Energy in Photons Demonstrator Card:

   a. Remove the cardboard insert from the folded Energy in Photons demonstrator card, and illuminate the colored circles with the classroom lights, or a bright overhead light, for 10–15 seconds.

   b. Dim the lights and open the card, showing the phosphorescent strip and noting where the phosphorescent strip glows, and noting the corresponding color filters. *Note:* Only the violet and blue filters should allow light through with high enough energy to allow for phosphorescence.

   c. Place the black cover card back inside the folded Demonstrator Card and turn on the lights once more, placing the Energy in Photons Demonstrator Card back in its storage envelope.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. The materials can be stored and reused year after year. However, if desired, dispose of the sheets and materials in the trash according to Flinn Suggested Disposal Method #26a.

Tips

- The phosphorescent vinyl sheet has an adhesive backing and can be used as phosphorescent tape.
- The phosphorescent vinyl sheet can easily be cut into letters, shapes, or smaller pieces with scissors.
- Store the phosphorescent vinyl sheet in a dark envelope or some other container that protects it from light. This will lengthen the life of the phosphorescent material in the sheet.

Discussion

Phosphorescence, commonly known under the name “glow-in-the-dark,” is different from the other types of luminescence in that light continues to be emitted even after the exciting source has been removed. This is sometimes referred to as the “afterglow.” In this demonstration, the exciting source is the UV light source, but it can also be the lights in your classroom. The vinyl sheet glows even after the lights have been turned off (removal of the exciting source), so it can be classified as a phosphorescent material.

Why does a phosphorescent material continue to glow even after the exciting source has been removed? This can be explained by looking at an energy level diagram for the phosphorescent material (Figure 3).

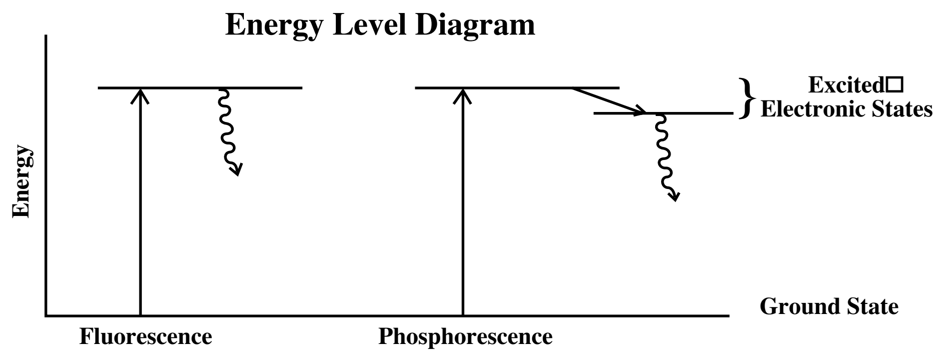

Figure 3.

In both phosphorescence and fluorescence, a light source is shined on the material, and a photon is absorbed. The energy from the photon is transferred to an electron that makes a transition to an excited electronic state. From this excited electronic state, the electron naturally wants to relax back down to its ground state. When the electron relaxes, it does not necessarily return to the ground state in a single step. The relaxation pathway varies, and is different depending on whether the material is fluorescing or phosphorescing.

In phosphorescence, the excited electron first makes a slow transition to another excited state very close in energy to the initial excited state. From this second excited state, the electron then relaxes down to a state lower in energy, emitting a photon in the process. The characteristic afterglow of phosphorescence is due to the delayed emission that occurs because the transition between the first two excited states is slow.

Demonstration 5. Chemiluminescence

Materials

Beakers, 400-mL, 4–5	Magnetic stirrer and stir bar
Beakers, 1-L, 2	Water, tap, cold (~10 °C)
Light sticks, 2–3	Water, tap, warm (~70 °C)
*Instant Light Crystals materials**	
Clorox 2,® powder form, 64 g	Water, distilled or deionized, 400 mL
Luminol, 0.2 g	Beakers, 400-mL, 2–3
Potassium ferricyanide, $K_3Fe(CN)_6$, 4 g	Magnetic stirrer and stir bar
*A Toast to Chemistry materials***	
Hydrogen peroxide, H2O2, 3%, 15 mL	Beakers, 1-L, 2
Luminol, 0.1 g	Erlenmeyer flask, 2-L
Potassium ferricyanide, K3Fe(CN)6, 0.7 g	Funnel, large
Sodium hydroxide solution, NaOH, 5%, 50 mL	Graduated cylinder, 50-mL
Water, distilled or deionized, 2000 mL	Ring stand and ring

**Available as a kit, "Instant Light," AP9118*
***Available as a kit, "Cool Light", AP8627*

Safety Precautions

Sodium hydroxide solution is corrosive, very dangerous to eyes, and skin burns are possible. Much heat is evolved when sodium hydroxide is added to water. Potassium ferricyanide will emit poisonous fumes of hydrogen cyanide if heated or placed in contact with concentrated acids. Hydrogen peroxide is an oxidizer and skin and eye irritant. Clorox 2 powder may be irritating to mucous membranes. Ultraviolet light may damage the eyes and cause cataracts. Wear chemical splash goggles, chemical-resistant gloves and a chemical resistant apron. Wash hands thoroughly with soap and water before leaving the lab. Please review current Material Safety Data Sheet for additional safety, handling, and disposal information.

Preparation

Prepare Instant Light crystals:

1. Mix the dry ingredients thoroughly in a 400-mL beaker, but do not grind! Note: Try mixing the luminol and potassium ferricyanide together first and then add the Clorox 2 with frequent stirring.
2. Pour the dry mixture from one beaker to another beaker to ensure a homogenous mixture. Note: Do this in an operating fume hood to reduce airborne dust.

Prepare "A Toast to Chemistry" solutions

3. Prepare Solution A by adding 0.1 g of luminol and 50 mL of 5% sodium hydroxide solution to approximately 800 mL of distilled or deionized (DI) water. Stir to dissolve the luminol. Once dissolved, dilute this solution to a final volume of 1000 mL with DI water.
4. Prepare Solution B by adding 0.7 g of potassium ferricyanide and 15 mL of 3% hydrogen peroxide to approximately 800 mL of DI water. Stir to dissolve the potassium ferricyanide. Once dissolved, dilute this solution to a final volume of 1000 mL with DI water.
5. Set up the demonstration container(s) as desired. A sample flask and funnel is shown in Figure 4. (Shirley, please add diagram from Publication 91331, or IN8627—it's the same diagram so whatever's more convenient)
6. See *Tips* section for other set-up ideas.

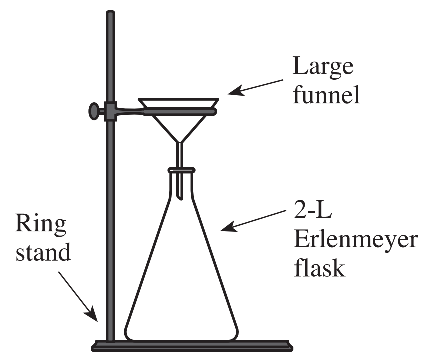

Figure 4.

Lightsticks

7. Obtain two 400 mL beakers. Fill one with hot tap water (~70 °C), and the other with cold tap water Note: Use ice to help bring the temperature down
8. Place two uncracked light sticks in each bath, and allow to sit for several minutes before moving on to the demonstration.

Procedure

Part A. Lightsticks

1. Crack a lightstick at room temperature to demonstrate chemiluminescence.
2. To show the effect of temperature on reaction rate, crack the two light sticks in the hot and cold water baths.

Part B. Instant Light Crystals

3. Fill a beaker with distilled or deionized water, and place the beaker on a magnetic stirrer. The size of the beaker and the amount of water is up to you.
4. Turn off the lights in your classroom.
5. Add some Instant Light crystals to the water. About two teaspoons for every 200 mL water works well.
6. The blue chemiluminescent glow will begin instantly and last for several minutes.

Part C. Chemiluminescence: A Toast to Chemistry

7. Turn down the lights. The room should be as dark as possible.
8. Simultaneously, pour Solution A and Solution B into the large funnel or desired container(s). As the two solutions mix, chemiluminescence begins.
9. As the reaction progresses, it can be enhanced by adding small amounts of potassium ferricyanide and 5–10 mL of 5% sodium hydroxide solution into the flask.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. Allow the Instant Light solution to fully react (stir for 15 minutes) and then flush down the drain with excess water according to Flinn Suggested Disposal Method #26b. The Toast to Chemistry Solutions A & B may be flushed down the drain with an excess of water according to Flinn Suggested Disposal Method #26b.

Tips

- Clorox 2 is a commercial product. Due to formulation variations of the Clorox 2, actual times of the chemiluminescent glow may vary greatly from one batch to another. The glow should last from 90 seconds to 5 minutes depending on the formulation.
- Adding a small amount of a fluorescent dye along with the luminol will produce different colors of light. Try small amounts (0.005 g) of disodium fluorescein (yellowish green) or Rhodamine B (red).
- Use hot or cold water to see how temperature affects the kinetics of the chemiluminescent reaction.
- Sprinkle Instant Light crystals on a wet towel; they will light up like stars.
- The demonstration “A Toast to Chemistry” is especially appealing if it is set up so the students can see the mixture moving. Use two funnels and clear Tygon tubing to pour the two solutions through a “Y” connector into a long coiled tube (see Figure 5). This type of apparatus gives a large surface area for light to be emitted as well as providing a flowing effect along with the luminescence—increasing the overall visual impact.

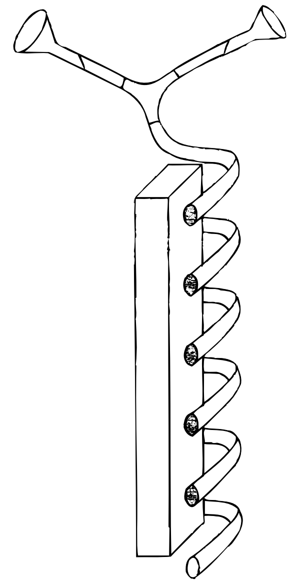

Figure 5.

- Another means of displaying luminol’s luminescence is to take the two solutions (A and B in “A Toast to Chemistry”), place them in spray bottles, and spray them at each other creating a luminescent cloud. The key to this procedure is to get the solutions into as fine a mist as possible. *Caution:* Do not spray the solutions toward anyone or in a manner in which they can be easily inhaled.
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- Use only distilled or deionized water when preparing the solutions. Hard water and softened water contain high concentrations of ions (such as chloride ions) that may interfere with the excited state of the luminol and prevent chemi luminescence.

Discussion

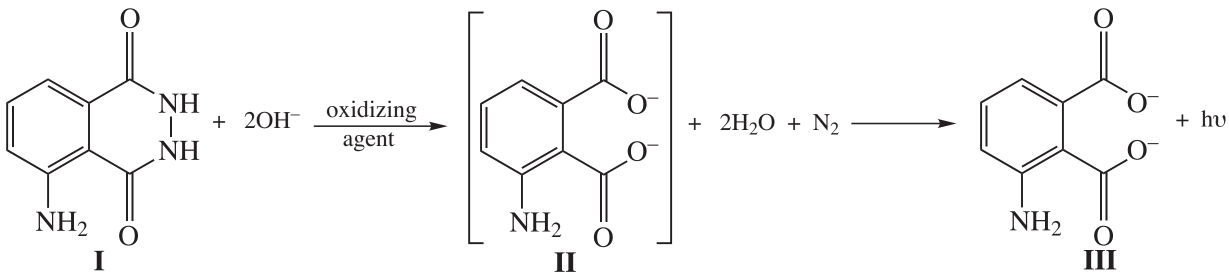
Chemiluminescence is defined as the production or emission of light that accompanies a chemical reaction. Light emission results from the conversion of chemical energy into light energy due to changes in the composition of a chemiluminescent material. The oxidation of luminol (3-aminophthalhydrazide) in this demonstration is another well-known example of chemiluminescence.

The light-producing chemical reactions of luminol were discovered by H. O. Albrecht in 1928. Since that time numerous procedures have been developed to produce light using luminol. Experiments have shown that the following “ingredients” are necessary for luminol to exhibit chemiluminescence—a basic (alkaline) pH, an oxidizing agent, and a catalyst. In this demonstration, the oxidizing agent is Clorox 2, which also maintains the basic pH needed, and the catalyst is the iron(III) cation in potassium ferricyanide.

Oxidation of luminol and the resulting chemiluminscence occurs in the following sequence of reactions

1. Chlorox 2 acts as a base and converts luminol (structure I) into a dianion.
2. Chlorox 2 oxidizes the dianion form of luminol to aminophthalate ion (structure II), which is produced in an excited electronic state (electrons not occupying their lowest energy orbital).

3. The excited aminophthalate ion decays to a lower energy ground state and gives off light in the process (structure III). The emitted light has a wavelength of 425 nm, which is in the blue region of the visible spectrum.



Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Day In the Dark Demonstrations with Jamie Benigna* activity, presented by Jamie Benigna, is part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Day In the Dark Demonstrations with Jamie Benigna* are available from Flinn Scientific, Inc.

Materials required to perform this activity are available in the *Fluorescent Dye Kit*, the *Instant Light Kit*, the *Cool Light—Chemiluminescence Kit*, *Fluorescent Liquids*, and *Energy In Photons Kit* available from Flinn Scientific. Materials may also be purchased separately.

Catalog No.	Description
AP4576	Energy in Photons Kit
AP4848	Fluorescent Dye Kit
AP6018	Fluorescent Liquids
AP9118	Instant Light Kit
E0023	Eosin Y Solution, 1%, 100 mL
E0007	Ethyl Alcohol, 95%, 500 mL
F0043	Fluorescein, 25g
H0009	Hydrogen Peroxide, 3%, 473 mL
L0031	Luminol, 1 g
P0272	Phosphorescent Flash Paint, 200 mL
P0050	Potassium Ferricyanide, 100 g
R0014	Rhodamine B Solution, 1%, 20 mL
AP6613	Sodium Chloride, Irradiated, 100 g
S0074	Sodium Hydroxide, Reagent, 100 g
AP6393	Chalk, Fluorescent Pastels, Box of 12
AP1362	Flinn Visor Goggles
AP5725	Ultraviolet Lamp, Long Wave/Short Wave
AP9030	Ultraviolet Lamp, 18″
AP4794	Phosphorescent Vinyl Sheet
AP1443	Light Stick, Green
AP2066	Light Stick, Red
AP2067	Light Stick, Blue
AP2068	Light Stick, Yellow
AP2069	Light Stick, Orange
FB1554	Sun Print Paper
FB1147	Ultraviolet Detecting Beads
AP6365	Atomic and Electron Structure, Flinn ChemTopic™ Labs, Volume 3

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