Chemiluminescence — A Toast to Chemistry

Chemiluminescence

Introduction

Chemiluminescence demonstrations are popular with students and teachers alike. This activity demonstrates basic chemiluminescence using luminol.

Concepts

- Chemiluminescence
- Oxidation–reduction
- Catalyst

Materials (for one demonstration)

Hydrogen peroxide, H_2O_2, 3%, 15 mL
Luminol, 0.1 g
Potassium ferricyanide, $K_3Fe(CN)_6$, 0.7 g
Sodium hydroxide solution, NaOH, 5%, 50 mL
Water, distilled or deionized, 2000 mL
Beakers, 1-L, 2
Erlenmeyer flask, 2-L
Funnel, large
Graduated cylinder, 50-mL
Ring stand and ring

Safety Precautions

Please review current Material Safety Data Sheets for additional safety, handling, and disposal information. Hydrogen peroxide is an oxidizer and skin and eye irritant. 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. If heated to decomposition or in contact with concentrated acids, potassium ferricyanide may evolve poisonous hydrogen cyanide fumes. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron.

Preparation

1. 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.
2. 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.
3. Set up the demonstration container(s) as desired. A sample flask and funnel is shown in Figure 1.
4. See *Tips* section for other set-up ideas.

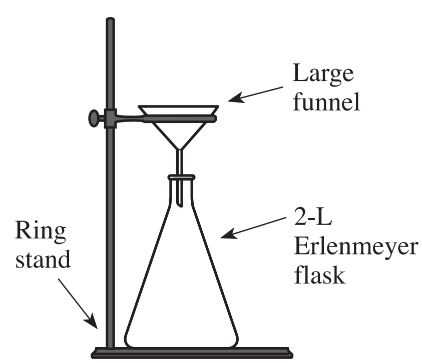


Figure 1.

Procedure

1. Turn down the lights. The room should be as dark as possible.
2. Pour Solution A and Solution B into the large funnel or desired container(s) simultaneously. As the two solutions mix, chemiluminescence begins.
3. 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

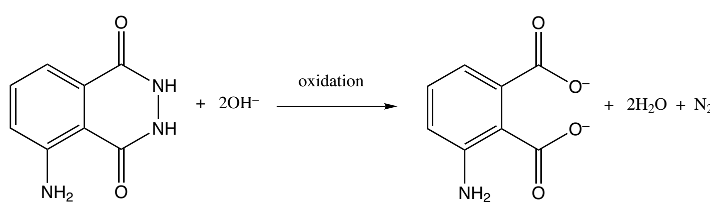
Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. The resulting solutions may be disposed of according to Flinn Suggested Disposal Method #26b.

Tips

- The *Cool Light—Demonstration Kit* (Catalog No. AP8627) is available from Flinn Scientific and contains enough chemicals to perform the demonstration seven times: 1 g of luminol, 5 g of potassium ferricyanide, 500 mL of 5% sodium hydroxide, and 500 mL of 3% hydrogen peroxide.
- This demonstration is especially appealing if it is set up so the students can see the mixture moving through glasses, such as used by Kathleen Dombrink in the video, or by spiraling clear plastic tubing. To use spiraling clear tubing, simply fol low the directions for setup at the end of these instructions. 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.
- Another means of displaying luminol's luminescence is to take the two solutions (A and B above), 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.
- Use only distilled or deionized water when preparing the solutions. Hard water and softened water contain high con centrations of ions (such as chloride ions) that may interfere with the excited state of the luminol and prevent chemiluminescence.

Discussion

Over the past several centuries there has been great expansion in the knowledge about materials, organic and inorganic, that produce light (luminescence). There are at least six different classifications of light-producing systems that have been observed. One of these is known as chemiluminescence; light produced through a chemical reaction, whether in a gas or in solution. The energy for light emission comes from a chemical reaction, usually involving considerable change in the composition of the chemiluminescent material. The appearance of colors when different metal salts are placed in the flame of a Bunsen burner are examples of a variation of chemiluminescence known as pyroluminescence. One of the long-standing classic models of a chemiluminescent reaction is the glow of solid phosphorus in air. This is an oxidation reaction in which light is produced and some heat. Out of a wide variety of "cool light" demonstrations, where little or no heat is produced, the use of luminol (3-aminophthalhydrazide) has been one of the most popular.



I II

Luminol was discovered to be luminescent by Albrecht in 1928. Since that time numerous procedures have been developed that produce light using luminol. Experimentation has demonstrated that for luminol to luminesce, an oxidizing agent, an alkaline pH, and some type of catalyst (such as copper or iron compounds) are required. This procedure gives just that condition. Sodium hydroxide acts as a base and converts luminol into a dianion that is oxidized by hydrogen peroxide to an aminophthalate ion. The aminophthalate is found in an excited state that will decay to a lower energy state through chemiluminescence and one of the products is the emission of light. This light has a wavelength of 425 nm, which is in the blue zone of the visible spectrum.

The chemiluminescence demonstration has value not only for the obvious reason of demonstrating chemiluminescence, but it can also be used to show the effects of a catalyst, the effect of pH on a reaction, the effect of temperature on a reaction, and how reaction rates are affected by concentration.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation

Content Standards: Grades 5–8

Content Standard B: Physical Science, properties and changes of properties in matter, transfer of energy

Content Standards: Grades 9–12

Content Standard B: Physical Science, structure and properties of matter, chemical reactions, interactions of energy and matter

Answers to Worksheet Questions

1. Describe what happened in this demonstration.

   Two solutions were poured through a large funnel simultaneously. The mixture of the two solutions began to glow.

2. Oxidation is necessary for luminol to luminesce. The chemicals used in this experiment were 5% sodium hydroxide, 3% hydrogen peroxide, and potassium ferricyanide. Which of these do you think served as the oxidizing agent?

   Hydrogen peroxide was the oxidizing agent in this demonstration.

3. In chemiluminescence, a molecule in an "excited" state (i.e., electrons are at a high energy level) is produced. The electrons in the molecule then must return to their stable state (i.e., lower energy level. Explain how this is linked to the production of light.

   When an electron drops to a lower energy level, energy must be released. This energy is released in the form of light.

4. Define chemiluminescence. Give an example of chemiluminescence found in nature.

   Chemiluminescence is a process in which light is produced through a chemical reactions. An example of this that is found in nature is the firefly.

Acknowledgment

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References

Harvey, E. N., *A History of Luminescence.* The American Philosophical Society: Philadelphia, PA, 1957; p 5.

Huntress, E. H.; Stanley, L. N.; Parker, A. S., *J. Chem. Educ.*, **1934,** *11*, 145.

Shakhashiri, B. Z. *Chemical Demonstrations: A Handbook for Teachers of Chemistry*, Vol. 1; University of Wisconsin: Madison, 1985; p 189.

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Chemiluminescence—A Toast to Chemistry* activity, presented by Kathleen Dombrink, is available in *Chemiluminescence*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Chemiluminescence—A Toast to Chemistry* are available from Flinn Scientific, Inc.

Materials required to perform this activity are available in the *Cool Light—Chemical Demonstration Kit* available from Flinn Scientific. Materials may also be purchased separately.

Catalog No.	Description
AP8627	Cool Light—Chemical Demonstration Kit
L0078	Luminol, 5 g
S0074	Sodium Hydroxide, 100 g
P0050	Potassium Ferricyanide, 100 g
H0009	Hydrogen Peroxide, 3%, 500 mL

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Chemiluminescence — A Toast to Chemistry Worksheet

Discussion Questions

1. Describe what happened in this demonstration.

2. Oxidation is necessary for luminol to luminesce. The chemicals used in this experiment were 5% sodium hydroxide, 3% hydrogen peroxide, and potassium ferricyanide. Which of these do you think served as the oxidizing agent?

3. In chemiluminescence, a molecule in an "excited" state (i.e. electrons are at a high energy level) is produced. The electrons in the molecule then must return to their stable state (i.e. lower energy level. Explain how this is linked to the production of light.

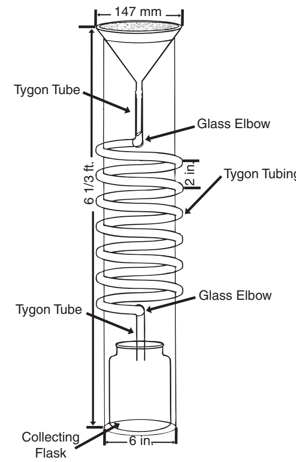
4. Define chemiluminescence. Give an example of chemiluminescence found in nature.

HOW TO. . .

Make Your Own "Cool Light" Spiral Apparatus

Materials

Glass Funnel (large enough to sit in the opening of the Plexiglas tube)
Clear plastic (Tygon®) tubing
Long Plexiglas® tube
2 Glass elbows or glass tubing with bends
Collecting vessel
Electric drill



The "Cool Light" spiral can easily be scaled down to suit readily available equipment

1. Attach to the funnel stem a small piece of plastic tubing, a glass elbow and the long plastic tubing you will use for the "spiral". Place this setup down into the Plexiglas tube.
2. Drill a hole in the Plexiglas tube just below the height of the glass elbow connected to the funnel stem. Thread the long plastic tubing through this hole from the inside out.
3. Spiral the tubing around the Plexiglas tube.
4. Drill a hole in the Plexiglas tube 1) above the height of your collecting vessel. Feed the spiraled tubing through the hole and attach it to a glass elbow and a small piece of plastic tubing. If the tubing does not stay tightly spiraled, a small amount of quick-drying glue can be used to keep it in place.
5. Select a collecting vessel (e.g. battery jar, beaker) large enough to contain all the chemiluminescent liquid used in the demonstration. (In this case, the vessel must be larger than two liters.) The Plexiglas tube must fit over the collecting vessel. Insert the plastic tubing into your collecting vessel.
6. If your spiral is tall, we urge you to build some sort of support stand or attach it to a ring stand for stability. You don't want the apparatus to tip over.
7. Once the spiral is set up, dim the lights and pour your favorite chemiluminescent solution through it. Your students will love it!