Chemiluminescence

Topic

The strength of *chemiluminescence* varies with temperature, pH, and concentration of reactants.

Introduction

Chemiluminescence is a chemical reaction that yields light without producing heat. In a chemiluminescent reaction, chemical energy is converted into light energy. Light sticks rely on a chemiluminescent reaction that begins when two chemical solutions are mixed by bending the stick. Several types of animals, including fireflies and some types of fish, carry out luminescent reactions to signal members of their own species.

Chemists use light-producing reactions for a variety of purposes. As any fan of crime drama knows, forensic scientists spray luminol on surfaces to detect blood. Luminol is a chemical that luminesces when it combines with *hemoglobin*, an iron-containing protein in blood. Luminol can be used to reveal blood splatter as well as bloody fingerprints and shoeprints that are invisible to the naked eye. To get the best results, a forensic scientist must understand the chemistry behind this reaction. In this experiment, you will find out how variation in temperature, pH, and concentration of reactants effects reactions with luminol.

Time Required

30 minutes for part 1
55 minutes for part 2

Materials

- 25 milliliters (ml) of liquid chlorine bleach
- 0.12 grams (g) of luminol
- 2 beakers (200 to 300 ml)

- large beaker (300 ml or larger)
- graduated cylinder
- electronic scale or triple-beam balance
- weighing boat
- ice bath
- hot water bath
- stirring rod
- thermometer
- vinegar
- access to a room that can be darkened
- access to distilled water

Safety Note **Bleach is very reactive and should be handled with care. During the experiment, wear safety goggles, gloves, and a lab apron. Please review and follow the safety guidelines.**

Procedure: Part 1

1. Pour 125 ml of distilled water in a beaker.
2. Use the electronic scale or balance to weigh 0.6 g of luminol. Carefully pour the luminol into the beaker of distilled water. Gently mix with a stirring rod.
3. Pour 110 ml of distilled water in another beaker.
4. Measure 12 ml of bleach in the graduated cylinder. Pour the bleach into the second beaker of distilled water.
5. Place the solutions in the ice bath for 10 minutes (min).
6. Place a thermometer in each solution. After 10 min, find the temperature of each solution and record that temperature in your science notebook.
7. Darken the room. Pour the two solutions together into the large beaker. Observe the mixture and record your observations in your science notebook.

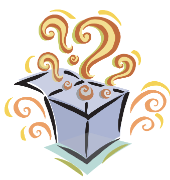
Procedure: Part 2

1. Your job is to design and perform an experiment in which you vary one of the controls (temperature, pH, or concentration of reactants) of the reaction of luminol with bleach.
2. You can use any of the supplies provided by your teacher, but you will not need to use all of them.
3. Before you conduct your experiment, decide exactly what you are going to do. Write the steps you plan to take (your experimental procedure) and the materials you plan to use (materials list) on the data table. Show your procedure and materials list to the teacher. If you get teacher approval, proceed with your experiment. If not, modify your work and show it to your teacher again.
4. Once you have teacher approval, assemble the materials you need and begin your procedure.
5. Collect your results on a data table of your own design.

Data Table
Your experimental procedure
Your materials list
Teacher's approval

Analysis

1. Describe the appearance of powdered luminol mixed with distilled water.
2. Describe the appearance of bleach mixed with distilled water.
3. How did the two solutions look when you mixed them?
4. What control, temperature, pH, or concentration of reactants, did you decide to vary?
5. How did varying one of the controls alter the results of the experiment?



What's Going On?

Criminalists mix luminol powder, $C_8H_7O_3N_3$, with a liquid such as hydrogen peroxide, then place the mixture in a spray bottle. Hydrogen peroxide and luminol serve as reactants in a chemical reaction, but they need a *catalyst* to act strongly. The iron in hemoglobin, a blood protein, is one material that can catalyze this reaction. For this reason, a luminol solution can be used to detect unseen blood. To search for blood, the criminalist sprays a mist of the luminol mixture on the area where blood is suspected. Iron in the blood accelerates the reaction between luminol and hydrogen peroxide, causing a blue luminescence. In this oxidation reaction, luminol loses nitrogen and hydrogen atoms and gains oxygen atoms, producing a compound called 3 aminophthalate, which exists in a high-energy state because its oxygen electrons have been moved to higher energy levels. When the electrons falls back to their normal, or ground, state, they give off energy in the form of light. The colder the solution, the longer the glowing color lasts because molecules in a cold solution move slower than those in a warm solution. The reaction occurs better in a basic solution than a neutral or acidic one, and it gives more dramatic results when the reactants are concentrated than when they are dilute.

Want to Know More?

See Our Findings.

OUR FINDINGS

CHEMILUMINESCENCE

Suggestion for class discussion: Ask students to name some things that glow in the dark. Help students understand the differences in types of luminescence. In fluorescence, atoms that are excited by ultraviolet light release the energy as visible light. The glow disappears as soon as the ultraviolet light is removed. Phosphorescence is similar, but the glow continues for a while after the light source is removed. Chemoluminescence occurs when two substances react and one of the products is light. In bioluminescence, this reaction takes place in a living thing.

Analysis

1. Answers will vary, but the mixture does not glow.
2. The mixture resembles water.
3. When mixed, the two solutions produce a faint blue glow.
4. Answers will vary.
5. Answers will vary. Generally, students will get a stronger reaction, and more light, by concentrating reacts and working in a neutral or basic environment.

SAFETY PRECAUTIONS

Review Before Starting Any Experiment

Each experiment includes special safety precautions that are relevant to that particular project. These do not include all the basic safety precautions that are necessary whenever you are working on a scientific experiment. For this reason, it is absolutely necessary that you read and remain mindful of the General Safety Precautions that follow. Experimental science can be dangerous, and good laboratory procedure always includes following basic safety rules. Things can happen very quickly while you are performing an experiment. Materials can spill, break, or even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following the basic safety guidelines during the entire experiment, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual experiments. For one reason, we want you to take very seriously every safety precaution that is printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical.

Read the safety precautions here and at the beginning of each experiment before performing each lab activity. It is difficult to remember a long set of general rules. By rereading these general precautions every time you set up an experiment, you will be reminding yourself that lab safety is critically important. In addition, use your good judgment and pay close attention when performing potentially dangerous procedures. Just because the book does not say “Be careful with hot liquids” or “Don’t cut yourself with a knife” does not mean that you can be careless when boiling water or using a knife to punch holes in plastic bottles. Notes in the text are special precautions to which you must pay special attention.

GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge, or taking an unnecessary risk can be avoided by practicing safety procedures and being alert while conducting experiments. Be sure to check the individual experiments in this book for additional safety regulations and adult supervision requirements. If you will be working in a lab, do not work alone. When you are working off-site, keep in groups with a minimum of three students per groups, and follow school rules and state legal requirements for the number of supervisors required. Ask an adult supervisor with basic training in first aid to carry a small first-aid kit. Make sure everyone knows where this person will be during the experiment.

PREPARING

- Clear all surfaces before beginning experiments.
- Read the instructions before you start.
- Know the hazards of the experiments and anticipate dangers.

PROTECTING YOURSELF

- Follow the directions step by step.
- Do only one experiment at a time.
- Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eyewash, and first-aid kit.
- Make sure there is adequate ventilation.
- Do not horseplay.
- Keep floor and workspace neat, clean, and dry.
- Clean up spills immediately.
- If glassware breaks, do not clean it up; ask for teacher assistance.
- Tie back long hair.
- Never eat, drink, or smoke in the laboratory or workspace.
- Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult.

USING EQUIPMENT WITH CARE

- Set up apparatus far from the edge of the desk.
- Use knives or other sharp-pointed instruments with care.

- Pull plugs, not cords, when removing electrical plugs.
- Clean glassware before and after use.
- Check glassware for scratches, cracks, and sharp edges.
- Clean up broken glassware immediately.
- Do not use reflected sunlight to illuminate your microscope.
- Do not touch metal conductors.
- Use alcohol-filled thermometers, not mercury-filled thermometers.

USING CHEMICALS

- Never taste or inhale chemicals.
- Label all bottles and apparatus containing chemicals.
- Read labels carefully.
- Avoid chemical contact with skin and eyes (wear safety glasses, lab apron, and gloves).
- Do not touch chemical solutions.
- Wash hands before and after using solutions.
- Wipe up spills thoroughly.

HEATING SUBSTANCES

- Wear safety glasses, apron, and gloves when boiling water.
- Keep your face away from test tubes and beakers.
- Use test tubes, beakers, and other glassware made of Pyrex™ glass.
- Never leave apparatus unattended.
- Use safety tongs and heat-resistant gloves.
- If your laboratory does not have heat-proof workbenches, put your Bunsen burner on a heat-proof mat before lighting it.
- Take care when lighting your Bunsen burner; light it with the airhole closed, and use a Bunsen burner lighter in preference to wooden matches.

- Turn off hot plates, Bunsen burners, and gas when you are done.
- Keep flammable substances away from flames and other sources of heat.
- Have a fire extinguisher on hand.

FINISHING UP

- Thoroughly clean your work area and any glassware used.
- Wash your hands.
- Be careful not to return chemicals or contaminated reagents to the wrong containers.
- Do not dispose of materials in the sink unless instructed to do so.
- Clean up all residues and put them in proper containers for disposal.
- Dispose of all chemicals according to all local, state, and federal laws.

BE SAFETY CONSCIOUS AT ALL TIMES!