

## WARNING NOTICE

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### Chemiluminescence What's inside of a light stick anyway?



Photo taken at MIT 150<sup>th</sup> Celebration Open House Under the Dome April 30, 2011  
Courtesy of Nathan Sanders. Used with permission.

#### Abstract

Three plastic cups containing solutions are poured simultaneously into three other plastic cups containing solutions and chemical reactions occur producing different colors in each of the cups that glow in the dark.

## Materials

5 red light sticks	scissors
5 green light sticks	knife
5 blue light sticks	gloves
6 plastic cups	goggles

## Safety

Wear gloves and safety goggles when handling the chemicals in a light stick.  $H_2O_2$  is a strong oxidizing agent that can cause burns. The fluorescent dyes should be considered toxic and not be ingested. Caution! Never ever try to open a glow stick up with your mouth. When opening a glow stick and breaking the glass vial inside make sure you wear safety goggles to prevent shards of glass or chemicals from reaching the eye.

## Procedure

Create two solutions from each of the three colors of light sticks as follows:

Solution 1:

Using a knife cut the top off the plastic light sticks and carefully pour out the solutions into plastic cups. Pour all the red light stick solutions into the same cup and so on for the blue and green. Carefully remove the inner glass vials and reserve for Solution 2.

Solution 2:

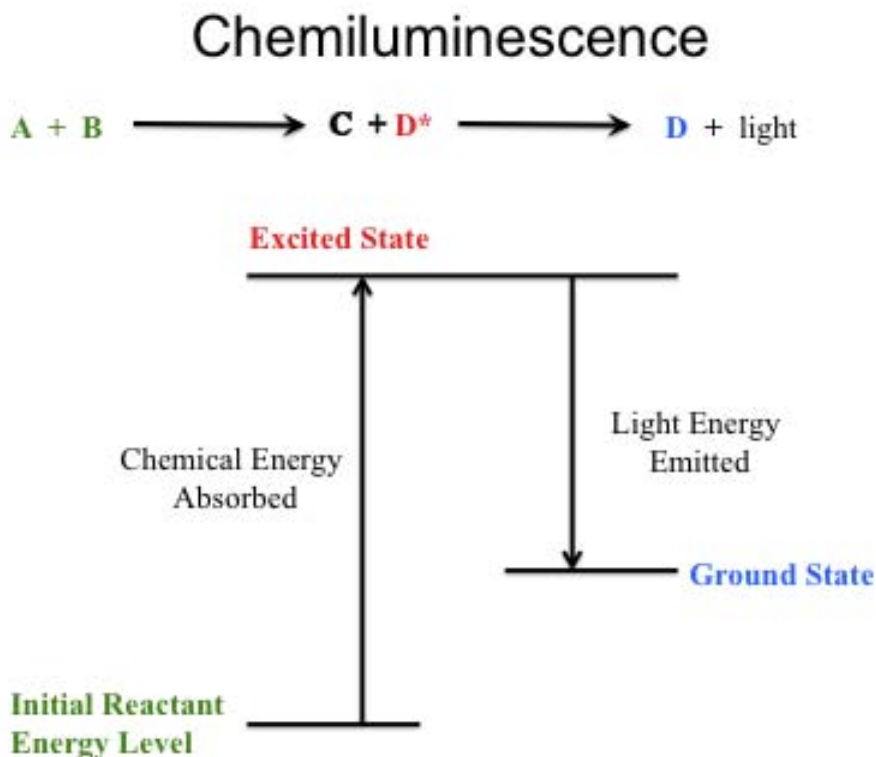
Using a pair of scissors snip open the glass vials that you removed from the opened light sticks and pour those solutions into the other three cups.

Get three volunteers to come up give each one-cup containing solution 1 and one cup containing solution 2. The solutions are then poured together resulting in a chemical reaction resulting in different colors of light that glow in the dark.

## Discussion

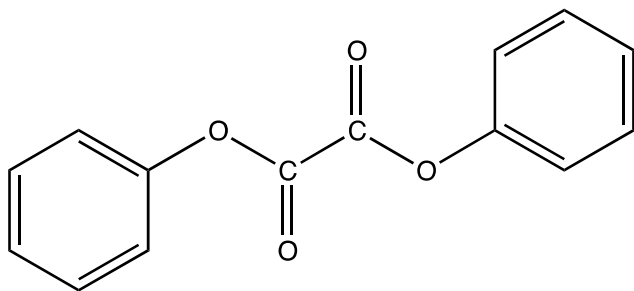
This is a classic reaction where energy is released in the form of light without heat. In Chemiluminescence, two molecules react together to create a third excited intermediate molecule. This molecule finally relaxes back to the ground state with

the release of a photon of light at a frequency, which we can see in the visible range of the electromagnetic spectrum. A general scheme for Chemiluminescence is shown below:

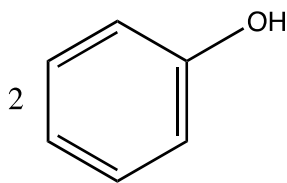
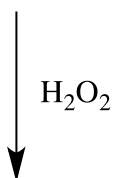


In our case, each light stick contains three chemicals. The chemical in the inner glass vial Solution 2 is  $H_2O_2$ . The chemicals inside of the plastic light stick that were poured out into Solution 1 consists of Cyalume a Phenyl Oxalate Ester plus a fluorescent dye molecule. When the  $H_2O_2$  in Solution 2 is poured into Solution 1 a chemical reaction occurs that produces energy. The energy produced is transferred to the dye molecule, which gets excited and converts the energy into light. Depending on what type of dye is present you will get different colors of light given off.

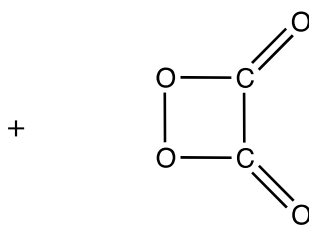
The general reaction scheme for the reaction inside of a light stick is shown below:



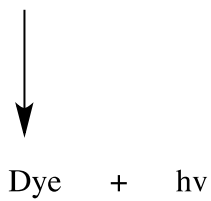
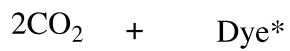
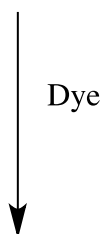
Cyalume (Phenyl Oxalate Ester)



Phenol



1,2-dioxetanedione (Peroxyacid Ester)



When the two solutions are mixed the hydrogen peroxide oxidizes the phenyl oxalate ester, which produces phenol plus an unstable compound called 1,2-dioxetanedione. This unstable ester breaks apart releasing energy and CO<sub>2</sub>. The energy gets transferred to the dye molecule causing the electrons to jump to higher levels, when they relax and fall back down, energy is released in the form of light.

## **Disposal**

The contents of the reaction and any leftover solutions should be combined into a properly labeled waste bottle and disposed of properly in labeled waste containers.

## **References**

Michael M. Rauhut, *Acc. Chem. Res.* **1969**, 2(3), pp. 80-87.

Elizabeth Wilson, *Chemical and Engineering News*, **1999**, 77(3), p 65.

Edwin A Chandross, *Tetrahedron Letters* **1963**, 4(12) pp. 761-765.

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