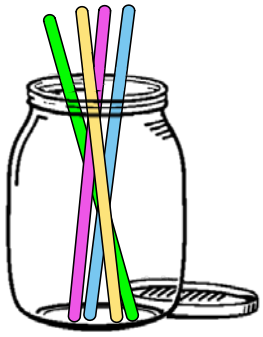
Glow Sticks

Cartoon of Experiment Setup



Time Required:

- ☒ 0-30 minutes
- ☐ 30-60 minutes
- ☐ 60-120 minutes (1-2 hours)
- ☐ 120-180 minutes (2-3 hours)
- ☐ 180-240 minutes (3-4 hours)
- ☐ > 4 hours

Materials Needed:

- Three glow sticks
- Two cups of ice
- Two cups of hot water (~ 110 °F (43 °C))
- Two four cup measuring cups

Optional Materials:

- Glow sticks of different colors
- Stopwatch

Concepts:

- ☒ Kinetics
- ☒ Chemical Equilibrium

Parental Supervision:

- ☒ Recommended for children under 5
- ☒ Recommended for children under 12
- ☐ Highly recommended for children under 12
- ☐ Recommended for children under 18
- ☐ Adults Only

Age Recommendation:

- ☒ 0-3
- ☒ 3-8
- ☒ 8-12
- ☒ 12-18
- ☒ Above 18

Location of Experiment:

- ☒ Indoors
- ☒ Outdoors

Is Heat Needed?

- ☐ Microwave
- ☐ Stove Top/Oven
- ☐ Refrigerator

☒ Freezer

Safety:

According to the manufacturer, the mixture of the two components of glow sticks are nontoxic either to the skin or through ingestion and the mixture is not irritating to the eyes. In the event of a rupture of the plastic container, wash thoroughly with water. The solution in the glow stick will stain clothing and soften or mar paint and varnish.

Procedure:

1. Remove the plastic tube from the foil wrapper and bend the plastic tube slightly to break the thin tube inside and shake.
2. The glow stick should start to glow immediately after the tube inside the glow stick is broken.
3. To examine the effect of temperature on light intensity, one of the glow sticks can be immersed into a container containing ice water (or placed in the freezer).
4. The intensity of this glow stick should decrease.
5. Place the third glow stick in the container with hot water. The temperature must not exceed 160 °F (70 °C) to avoid melting the plastic tube.
6. The intensity of this glow stick should increase.

Optional:

1. The glow sticks can be cycled between cooling and heating to observe how temperature can influence a chemical reaction.
2. The effect of color on the glow stick intensity, when cooled or heated, can also be examined by repeating steps 1-6 with different color glow sticks.
3. A stopwatch can be used to measure the length of the glow of the glow stick when heated.

Clean Up:

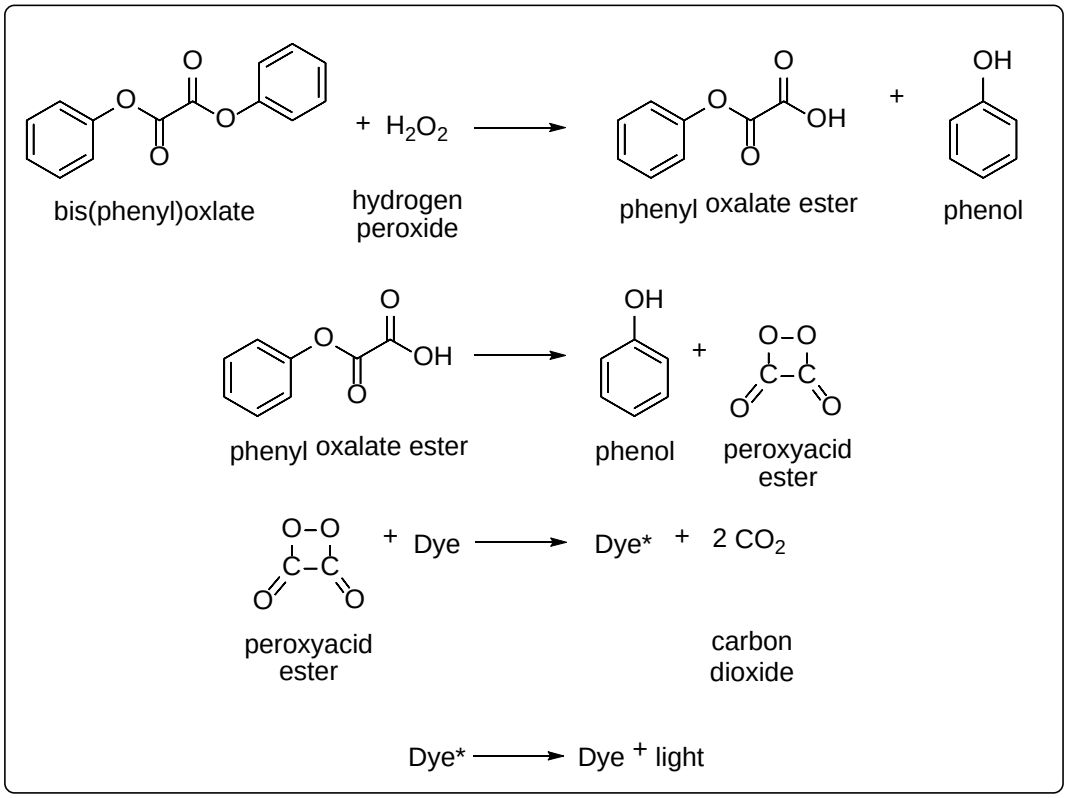
Upon completion of the experiment, the glow stick can be placed in the trash can and can be disposed of in the same manner as conventional household waste. No special waste handling is needed.

What is going on?

Glow sticks are wrapped in an airtight foil wrapper, due to the sensitivity to humidity. If the wrapper is punctured and the glow stick is not used within a few days, the light emission will be reduced. If the glow stick is left in the damaged wrapper for an extended period of time, it may be become completely deactivated. If the foil wrapper is not damaged, glow sticks can have a shelf life of up to 4 years.

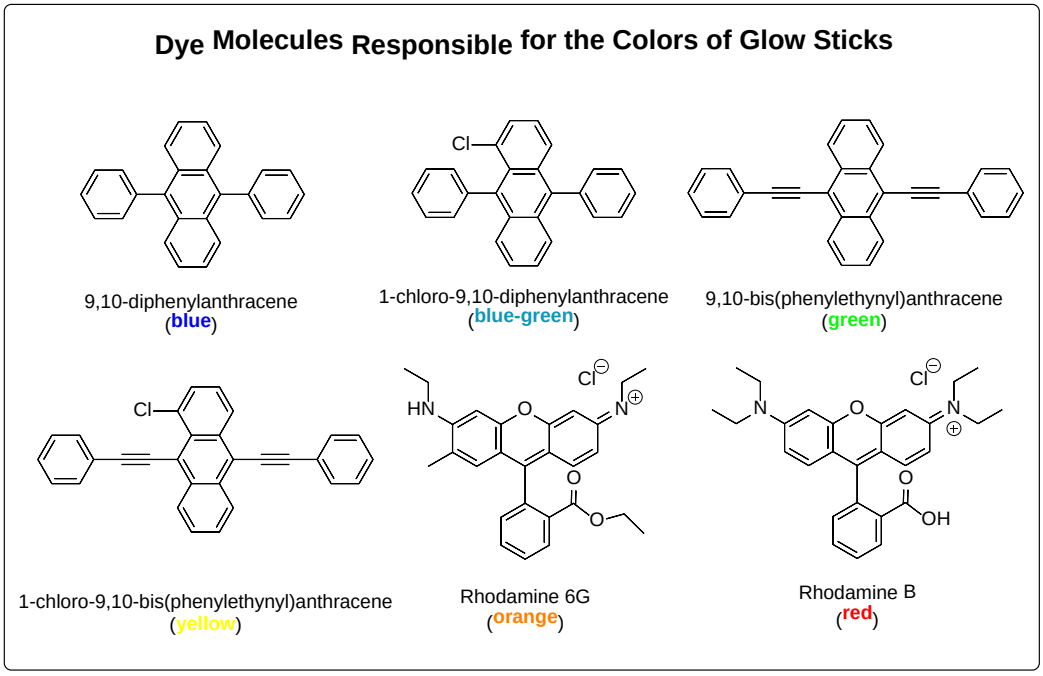
The glow stick can be placed in the freezer to see how long the glow stick can retain its glow upon warming to room temperature. There have been reports of a glow stick still being able to demonstrate a faint glow even after remaining in a home freezer for over six months.

Glow sticks work by having a dilute (~ 0.5 %) hydrogen peroxide (H_2O_2) solution in a thin glass tube. This glass tube is surrounded by a solution containing a bis(phenyl)oxalate and a fluorescent dye, often 9,10-bis(phenylethynyl)anthracene for green glow sticks. When the ampule is broken, the H_2O_2 reacts with the oxalate ester to generate a phenyl oxalate ester and phenol.



The phenyl oxalate ester then decomposes (breaks apart) into a second molecule of phenol and a peroxyacid ester. This peroxyacid ester is a very unstable molecule. As you can see, the peroxyacid ester is two carbon dioxide molecule connected together.

As the reaction proceeds, the unstable peroxyacid ester decomposes to two carbon dioxide molecules and transfers energy to a dye molecule. The energy transfer to the dye molecule causes the dye molecule to become excited to a higher energy state. This higher energy state is not very stable, and visible light is emitted as the dye molecule relaxes to the lower energy ground state. Pictures of the dye molecules that are used to generate glow sticks of different colors are seen below.



Questions and Discussion

1. Why does the light intensity increase with an increase in temperature and decrease when cooled?

   Answer: When the glow stick is heated, the reaction occurs at a faster rate resulting in a more intense glow stick, as more dye molecules are being excited. When the glow stick is cooled, the reaction slows down, resulting in less dye molecules being excited leading to a less intense glow stick.

2. Why does the glow stick last longer when cooled and glow for a shorter time period when heated?

   Answer: Cooling the glow stick causes for the reaction to occur at a slower rate. The slower reaction causes for the reaction between bis(phenyl)oxalate and hydrogen peroxide to occur over a longer period of time, leading to the glow stick glowing longer, but less intense. The opposite phenomenon is observed upon heating the glow stick. When the glow stick is heated, the reaction between bis(phenyl)oxalate and hydrogen peroxide goes faster, resulting in the glow disappearing in a shorter time period, but with a more intense glow.

3. This reaction is irreversible. What does that mean?

   Answer: When a reaction is irreversible it only occurs in one direction.