Contributors

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Intended Audience

<table>
<thead>
<tr>
<th>K-4</th>
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</thead>
<tbody>
<tr>
<td>5-8</td>
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<td>9-12</td>
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Intended Audience

<table>
<thead>
<tr>
<th>Classroom Setting</th>
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<tbody>
<tr>
<td>Requires special equipment</td>
<td>X</td>
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<tr>
<td>Uses hands-on manipulatives</td>
<td>X</td>
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<tr>
<td>Requires mathematical skills</td>
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<tr>
<td>Can be performed individually</td>
<td>X</td>
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<tr>
<td>Requires group work</td>
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<tr>
<td>Requires more than one (45 min class) period</td>
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<tr>
<td>Appropriate for special needs student</td>
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Introduction

Description

Students will explore the nature of bioluminescence using chemiluminescent reactions.

Abstract

Students will explore the concept of chemiluminescence and relate it to the concept of bioluminescence by creating glowing slime, examining the effect of temperature on glow sticks, and observing a demonstration with luminol. They will be able to explain how bioluminescence is a chemical reaction, how living organisms emit light, and why this is beneficial to various organisms.

Core Themes Addressed

<table>
<thead>
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<tr>
<td>The Cell</td>
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<tr>
<td>Molecular Basis of Heredity</td>
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<tr>
<td>Biological Evolution</td>
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<tr>
<td>Interdependence of Organisms</td>
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<tr>
<td>Matter, Energy, and Organization in Living Systems</td>
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<tr>
<td>Other – Chemical Reactions</td>
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Keywords

Chemiluminescence, light, reactions,

Learning Objectives

By completing this activity, students will be able to:

1. Define bioluminescence and chemiluminescence
2. Distinguish between bioluminescence and chemiluminescence
3. Give examples of sources of bioluminescence

National Science Education Standards Addressed

Teaching Standard A: Science as inquiry

- Through conducting their own experiment, students are learning how to ask and answer valuable questions pertinent to the experiment at hand

Teaching Standard B: Physical Science

- Bioluminescence involves multiple chemical reactions, as well as, conservation of energy and increase in disorder

Bioluminescence – Page 2
Teaching Standard C: Life Science

- Bioluminescence involves understanding reactions within the cell through matter, energy, and organization in living organisms

Teaching Standard E: Science and Technology

- This lab allows students to make their own bioluminescent model through mixing reagents and actually visualizing the end product
Student Prior Knowledge

Students should have the following prior knowledge before completing this activity:

1. Understand the basics of chemical reactions
2. Be able to make objective and subjective observations
3. Be able to take measurements using the metric system
4. Be introduced to the concept of light and the electromagnetic spectrum

A powerpoint on [Bioluminescence](#) can be given to cover these basic concepts.

Teacher Background Information

Bioluminescence is an interesting property exhibited by a number of organisms. Plants, animals, fungi, and even bacteria have species that will bioluminesce. Bioluminescence itself is simply a chemiluminescent reaction that occurs inside a living organism. This means that the reaction that occurs gives off energy in the form of light; although unlike other light producing reactions, a chemiluminescent reaction loses none of its energy in the form of heat. This is why bioluminescence is sometimes referred to as ‘cold light’. In all cases bioluminescence is the result of an enzyme called luciferase oxidizing a protein called a luciferin. There are many different types of luciferin and many different types of luciferase, and they produce many different types of bioluminescence. From red to purple, the different colors that organisms can emit run the gamut of the visible light spectrum, and the color of light emitted is dependent on the amount of energy released by the reaction. The amount of energy released is in turn dependent on the type of luciferin and luciferase involved. Most organisms that bioluminesce can be found in the ocean, where different types of bioluminescence is used in many different life strategies. Some animals use it to catch prey, some use it to hide from predators, and some use it to find a mate. In many instances an organism might use bioluminescence for any combination of those three purposes, or all three.

Class Time

This activity will require a minimum of one 90 minute class period

1. Make luminescent slime – 25 min
2. Worksheet questions – 10 min
3. Glo-Germ demonstration – 10 min
4. Glow stick reaction rate/temperature test – 15 min
5. Worksheet questions – 10 min
6. Luminol demonstration – 10 min

Teacher Preparation Time

This lesson will require approximately 15 minutes of preparation time.

1. Prepare lab stations – 5 min
2. “Contaminate” lab area with Glo-germ – 5 min
3. Prepare two stock solutions for luminol demo – 5 min

Safety Precautions

The luminol demonstration requires that a solution be made using NaOH pellets and bleach, so exercise care when preparing the stock solutions.

Materials and Equipment

Per Lab Group (4 students/group)
1. 100 ml Polyvinyl Acetate (PVA) Solution (1 part Elmer's clear glue, 3 parts water)
2. 10 ml Luminescent Reagent (Luminescent Paint)
3. 1.25 g Sodium Borate (Borax)
4. Ziploc bag
5. 2 Glow sticks
6. 2 250 ml Beakers
7. Ice water
8. Warm water
9. Thermometer

Per Class
1. Electronic balances
2. Weigh boats
3. 2 1000 ml volumetric flasks
4. 1 2000 ml beaker
5. 0.4 Luminol
6. 4 g NaOH pellets
7. 100 ml household bleach (5% available chlorine. Sodium hypochlorate, NOT hydrogen peroxide)

Methods

Making Slime
1. Mix 100 ml of your PVA solution in your Ziploc bag with 10 ml of luminescent reagent. Mix well.
2. Suspend 1.25 g of Sodium Borate in 35 ml of water. Mix well.
3. Add your saturated Sodium Borate solution to your Ziploc bag and mix well.
4. When all groups are ready the instructor will turn off the lights. Record your observations.

Glo-germ demo
1. Spread the glo-germ powder on the students' work area
2. When ready turn off the lights and examine the students with a small black light to see who has been ‘contaminated’

Glow Stick Reaction Rates
1. Get a beaker with ice water and a beaker with warm water from the instructor
2. Record the temperature in each beaker and the ambient temperature in the table below
3. Crack the glass rod in each glowstick by bending them
4. Place one glowstick in the warm beaker and one glowstick in the cold beaker.
5. When all groups are ready the instructor will turn off the lights. Record your observations

Luminol Demonstration
1. Mix 100 ml bleach in 900 ml water in one flask
2. Dissolve 0.4 g luminol and 4 g NaOH pellets in 1 L water in the other flask
3. Turn off the lights, then slowly pour each flask simultaneously into the beaker

Tips/Suggestions

Slime Notes
- Any glowing paint can be used for the ‘luminescent reagent’. This can usually be found at a craft store
- If there is little direct sunlight in the room, the paint may not glow very well. You can allow the students to expose the slime to sunlight first, bring the students into a completely dark room for the luminescence observations (we used the storage room), or shine the black light from the glow germ demonstration onto the slime so it will glow better
- It may take a lot of mixing to get the two solutions to mix together properly to make the slime. If the borax wasn’t dissolved before adding or if the glue wasn’t mixed well with the water, it took some groups almost 30 min of mixing to get the solution to turn into slime
- It helps if the students use disposable cups to measure out the PVA (elmer’s glue). Have them pour 100 ml from a graduated cylinder into the disposable cup, mark the level with a pen or pencil, and then pour the PVA into the cup up to that line. Otherwise you may end up with very messy graduate cylinders

Glo Germ Notes
- It’s fun to sabotage the students work area without their knowledge prior to the lab, and this can also be used as a tool to help reinforce the idea of maintaining proper lab safety with regards to potential contamination
**Glow Stick Notes**

- It helps if the two glow sticks given to each group are of the same color, otherwise students may have a problem mistaking light intensity for color intensity.
- The effect of temperature on the glow sticks is much more visible if the classroom lights are turned off.
- Have all of the groups prepare their beakers and take their temperature measurements before handing out the glow sticks. This way you can turn off the lights and all groups can crack their glow sticks at the same time.

**Luminol Notes**

- You can pour them both through spiraling tubing or a condenser for dramatic effect.
- You can have the students take the temperature of the solutions before and after the experiment to show that there is no temperature increase because of the reaction.
- Luminol waste is safe to be washed down the drain.

**References**

- Adapted from [http://www.wisegeek.com/what-is-bioluminescence.htm](http://www.wisegeek.com/what-is-bioluminescence.htm), explanation of bioluminescence, accessed 10/2/11
- Adapted from [http://www.wisegeek.com/what-are-glow-sticks.htm](http://www.wisegeek.com/what-are-glow-sticks.htm), explanation of glow sticks, accessed 10/2/11
- Adapted from [http://www.practicalchemistry.org/experiments/chemiluminescence-cold-light,62,EX.html](http://www.practicalchemistry.org/experiments/chemiluminescence-cold-light,62,EX.html), instructions for luminol reaction, accessed 10/2/11

**Answers to Student Worksheet - Bioluminescence**

**Part 1 - Bioluminescent Slime**

1. The slime glowed the color of the paint that was put in.
2. Color of paint and approximate wavelength that corresponds to it (~625 nm for orange, ~525 nm for green, ~ 630 for pink).
3. The two liquids became a thick slime.
4. No, because the ‘slime’ is not alive and therefore the light emitted is chemiluminescence.

**Part 2 - Reaction Rate With Glow Sticks**

1. The warm water resulted in more light being emitted, the cold water resulted in the least light being emitted.
2. Yes, the warmer the solution, the more light is emitted.
3. Temperature increases the rate of the reaction occurring.
4. Yes, because there is light being emitted as a result of a chemical reaction that does not give off heat.
5. Refraction.
Student Background Knowledge

Bioluminescence is when a living organism can produce its own light. When an electron of an atom is excited by the input of energy it can jump to a higher orbital shell. Once the electron cannot maintain enough energy to stay in that higher orbital shell it falls back down to a lower energy shell and the remainder of the energy that was there is released as light. Most light sources we are familiar with, such as the sun, utilize thermal energy to excite electrons and therefore they emit a lot of energy as heat and only a small portion as light. In bioluminescence the electrons are excited by chemical processes, meaning no energy is lost as heat. Instead all of the energy that is released is in the form of light. This lack of heat release is why bioluminescence is referred to as 'cold light'.

Glow sticks utilize a chemical process known as chemiluminescence in order to generate their light. If a chemical reaction is chemiluminescent, that means that it is a reaction that generates light. The reaction causes electrons in the chemicals involved to become excited and jump to a higher energy level. When the electrons fall back down to their normal energy levels, the energy that was lost is released as light.

Usually glow sticks utilize hydrogen peroxide (H₂O₂), phenyl oxalate ester (C₁₄H₁₀O₄), and fluorescent dye. The hydrogen peroxide is usually contained in a small glass vial suspended in the phenyl oxalate, which is why glow sticks must be bent in order to make them glow. This bending causes the glass vial to break, the hydrogen peroxide to be released, and the reaction that causes chemiluminescence to begin.

There are a number of factors that affect how long a glow stick will be able to maintain its glow. One key factor is the rate at which the reaction occurs. The faster the reaction, the faster the starting reagents are depleted, the less time the glow stick will stay glowing. In order to demonstrate this, today we will be looking at the effect of warm, cold, and room temperature environments on the reaction rate of a glowstick.

Vocabulary

Bioluminescence: The process by which living organisms emit light. This process loses no energy in the form of heat.

Chemiluminescence: A chemical reaction that results in the emission of light. This process loses no energy in the form of heat.
Materials Checklist

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>100 ml PVA</td>
<td>Solution (1 part Elmer's clear glue, 3 parts water)</td>
</tr>
<tr>
<td>10 ml Luminous</td>
<td>Reagent (Luminescent Paint)</td>
</tr>
<tr>
<td>1.25 Sodium</td>
<td>Borate (Borax)</td>
</tr>
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<td>Ziploc bag</td>
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<tr>
<td>2 Glow sticks</td>
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<tr>
<td>2 250 ml Beakers</td>
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<tr>
<td>Ice water</td>
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<tr>
<td>Warm water</td>
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</tbody>
</table>

Procedure

Part 1

1. Mix 100 ml of your PVA solution in your Ziploc bag with 10 ml of luminescent reagent. Mix well.
2. Suspend 1.25 g of Sodium Borate in 35 ml of water. Mix well.
3. Add your saturated Sodium Borate solution to your Ziploc bag and mix well.
4. The instructor will turn off the lights when all groups are ready. Record your observations

Part 2

1. Get a beaker with ice water and a beaker with warm water from the instructor
2. Record the temperature in each beaker and the ambient temperature in the table below
3. Crack the glass rod in each glowstick by bending them
4. Place one glowstick in the warm beaker and one glowstick in the cold beaker.
5. When all groups are ready the instructor will turn off the lights. Record your observation
Student Worksheet

Bioluminescence

Part 1: Bioluminescent Slime

1. What happened when the lights were turned off?

2. What color of light was emitted? Based on that, about what wavelength was the light emitted?

3. What happened when you mixed all of the reagents together in the bag?

4. Would you say that the light emitted was a result of bioluminescence? Why or why not?
Part 2: Reaction Rates With Glow Sticks

Observations

<table>
<thead>
<tr>
<th>Glow Stick Treatment</th>
<th>Temperature (°C)</th>
<th>Light Intensity (Low, Medium, High)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold Water</td>
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</tbody>
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Questions

1. Which treatment resulted in the greatest amount of light being emitted? The least?

2. Did the treatments affect the rate of reaction inside the glow stick? Explain.

3. What can you conclude about the effect of temperature on reaction rate of this reaction?

4. Would you say the reaction in glow sticks is a chemiluminescent reaction? Why or why not?

5. What effect occurs on the light emitted by the glowsticks that causes it 'bend' when it hits the water?