

**Teacher’s Guide**

 **What Are Glow Sticks, And What Is the Chemical Reaction That Makes Them Light Up?**

***October 2022***

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Activate students’ prior knowledge and engage them before they read the article.

[***Reading Comprehension Questions***](#_heading=h.3znysh7) ***3***

These questions are designed to help students read the article (and graphics) carefully. They can help the teacher assess how well students understand the content and help direct the need for follow-up discussions and/or activities. You’ll find the questions ordered in increasing difficulty.

[***Graphic Organizer***](#_heading=h.9f8azrtnp6p5) ***5***

Thishelps students locate and analyze information from the article. Students should use their own words and not copy entire sentences from the article. Encourage the use of bullet points.

[***Answers***](#_heading=h.djipzn7z1r1b) ***6***

Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.

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Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article

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# Anticipation Guide

**Directions: *Before reading the article*,** in the first column, write “A” or “D,” indicating your **A**greement or **D**isagreement with each statement. Complete the activity in the box.

As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. The glass vial inside a glow stick contains water. |
|  |  | 2. Scientists have identified the high-energy intermediate compound in glow sticks. |
|  |  | 3. Light is emitted when a photon moves to a higher energy state. |
|  |  | 4. An anion is negatively charged. |
|  |  | 5. Energy is released when chemical bonds form. |
|  |  | 6. The U.S. government market for glow sticks is greater than that for the consumer novelty market. |
|  |  | 7. Different glow stick colors are produced by using different esters. |
|  |  | 8. The chemicals used in glow sticks have not changed since the discovery in the 1960s. |
|  |  | 9. Glow sticks work only at comfortable temperatures (10-30 °C). |
|  |  | 10. A catalyst can change the length of time of chemiluminescence. |

# Student ReadingComprehension Questions

**Directions**: Use the article to answer the questions below.

Reading Comprehension Questions.

1. What causes the signature “snap” that starts the process of chemiluminescence and a glow stick illuminating light?
2. Briefly summarize the sequence of steps/reactions that take place inside a glow stick to produce light.
3. The article mentions how glow sticks are not only used for novelty purposes at parties. The U.S. government spends approximately $35 million dollar a year on glow stick type technology. Why is glow stick technology and chemiluminescence important to the U.S. Government?
4. Explain how glow sticks have become safer since their invention in 1962.
5. How can the lifetime (amount of time a glow stick produces light) of a glow stick be controlled?

**Connecting Concepts**

1. What is a chemical catalyst? Explain how a catalyst increases the rate of a chemical reaction.
2. The article discusses that energy is required to break chemical bonds to start a reaction process and energy is produced when new, product bonds form. The breaking and forming of bonds in a chemical process can result in an endothermic process or exothermic process. Define both of those terms and give a real world example of each type of process.
3. Draw a reaction energy diagram for an exothermic process, you may research an example of a reaction energy diagram using online resources if needed. Define activation energy and indicate how the activation energy can be found on the diagram. The article discusses a reaction intermediate in the process of chemiluminescence. Label where reaction intermediates are found on your reaction energy diagram.
4. Light is just one form of electromagnetic radiation caused by the exciting and relaxing of electrons. Draw a simple sketch of the electromagnetic spectrum. Be sure to include the following forms of electromagnetic radiation; gamma, infrared, ultraviolet, visible, x-ray, microwave, radio.
5. What are some common chemicals found in fluorescent dyes? (Additional research may be required)

**Student Reading Comprehension Questions, cont.**

**Questions for Further Learning**

***Write your answers on another piece of paper if needed.***

1. Fictional scenario: The glow stick market has hit an all time law. Sales are down and the CEO of the largest glow stick company has reached out to you, to develop a new and exciting product using glow stick technology to revitalize the market and increase sales. Design a new product using glow stick technology. Explain the uses for the product and draw a sketch of the prototype.
2. Create a “Chemistry of Glow Sticks” infographic or poster using the information learned in the article.

# Graphic Organizer

**Directions**: As you read, complete the graphic organizer below to describe the chemistry of glow sticks (chemiluminescence).

|  |
| --- |
| **Glow Stick Chemistry** |
| How and when discovered |   |   |
| Reactants |   |   |
| Catalyst |   |   |
| Possible intermediate(s) |   |   |
| Products |   |   |
| Safety innovations |   |   |
| Other innovations |   |   |

**Summary:** On the back of this sheet, write three new things you learned about glow sticks, and why you want to remember them (three sentences total).

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. What causes the signature “snap” that starts the process of chemiluminescence and a glow stick illuminating light?

A walled vial filled with hydrogen peroxide breaks starting the chemiluminescence process.

1. Briefly summarize the sequence of steps/reactions that take place inside a glow stick to produce light. Hydrogen peroxide reacts with oxalate ester to form an high energy reaction intermediate, possibly 1-2 dioxetanedione. The intermediate accepts electrons from the fluorescent dye, which causes electrons in the dye to move to an excited state. Light is released as electrons return to a relaxed state.
2. The article mentions how glow sticks are not only used for novelty purposes at parties. The U.S. government spends approximately $35 million dollar a year on glow stick type technology. Why is glow stick technology and chemiluminescence important to the U.S. Government?

The U.S military uses glow stick technology in training exercises and field ops. Glow stick technology is also used in search and rescue missions for location marking purposes.

1. Explain how glow sticks have become safer since their invention in 1962.

Toxic oxalate esters have been replaced with safer compounds such as phthalates and butyl benzoate.

1. How can the lifetime (amount of time a glow stick produces light) of a glow stick be controlled?

The lifespan of a glow stick can be controlled by adjusting the salicylate catalyst concentration.

**Connecting Concepts**

1. What is a chemical catalyst? Explain how a catalyst increases the rate of a chemical reaction.

A catalyst is a substance that increases the rate of chemical reaction by providing an alternate mechanism for the reaction with a lower energy of activation which is the energy required to break the reactant bonds. The catalyst is not consumed during the process.

1. The article discusses that energy is required to break chemical bonds to start a reaction process and energy is produced when new, product bonds form. The breaking and forming of bonds in a chemical process can result in an endothermic process or exothermic process. Define both of those terms and give a real world example of each type of process.

An endothermic reaction is a reaction that absorbs heat from the surroundings. In an endothermic process, more energy is required to break reactant bonds than is produced by the formation of product bonds. An example of an endothermic process is water evaporating.

An exothermic reaction is a reaction that releases heat into the surrounding from the reaction. In an exothermic reaction, more energy is produced by the formation of product bonds than is put in to break reactant bonds. An example of exothermic reaction is mixing a strong acid and water.

1. Draw a reaction energy diagram for an exothermic process, you may research an example of a reaction energy diagram using online resources if needed. Define activation energy and indicate how the activation energy can be found on the diagram. The article discusses a reaction intermediate in the process of chemiluminescence. Label where reaction intermediates are found on your reaction energy diagram.

The energy diagram should have the reactant energy higher than the resulting product energy, which is present in an exothermic process. The activation energy is the energy required to break reactant bonds and can be seen on the diagram as the distance between the reactant energy and the peak of the graph. Reaction intermediates are present at the point when reactant bonds are breaking and new product bonds are forming, which is represented by the peak of the graph.

1. Light is just one form of electromagnetic radiation caused by the exciting and relaxing of electrons. Draw a simple sketch of the electromagnetic spectrum. Be sure to include the following forms of electromagnetic radiation; gamma, infrared, ultraviolet, visible, x-ray, microwave, radio.

Students can use online research to complete the spectrum.

1. What are some common chemicals found in fluorescent dyes? (Additional research may be required)

Answers may vary. Example: sulfonated cyanines

1. Fictional scenario: The glow stick market has hit an all time law. Sales are down and the CEO of the largest glow stick company has reached out to you, to develop a new and exciting product using glow stick technology to revitalize the market and increase sales. Design a new product using glow stick technology. Explain the uses for the product and draw a sketch of the prototype.

Answers will vary

1. Create a “Chemistry of Glow Sticks” infographic or poster using the information learned in the article. Answers will vary

**Graphic Organizer Rubric**

If you use the Graphic Organizer to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

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# Additional Resources and Teaching Strategies

**Additional Resources**

* **Labs and demos**
	+ [Activation Energy Lab](https://teachchemistry.org/classroom-resources/determination-of-the-activation-energy-of-a-lightstick)
* **Simulations**
	+ [Reaction Rate Simulation](https://teachchemistry.org/classroom-resources/reaction-rates-simulation)
* **Lessons and lesson plans**

* + [Light and Electromagnetic Radiation](https://teachchemistry.org/classroom-resources/understanding-light-and-color)

* **Projects and extension activities**

* + [Thermochemistry Infographic](https://teachchemistry.org/classroom-resources/thermochemistry-infographic)

**Teaching Strategies**

Consider the following tips and strategies for incorporating this article into your classroom:

* **Alternative to Anticipation Guide:** Before reading, ask students how they think glow sticks work, including what chemicals are involved, as well as how they are used. Their initial ideas can be collected electronically via Jamboard, Padlet, or similar technology.
	+ As they read, students can find information to confirm or refute their original ideas.
	+ After they read, ask students what they learned about glow sticks.
* After students have read and discussed the article, ask students what questions they still have about glow sticks or the chemical reactions involved.
* Since the article is in the first issue of the school year, this is a good opportunity to investigate the effect of temperature on chemical reactions using this simple activity:<https://www.acs.org/content/acs/en/education/outreach/celebrating-chemistry-editions/2021-ncw/slow-the-glow.html>

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# Chemistry Concepts and Standards

**Connections to Chemistry Concepts**

The following chemistry concepts are highlighted in this article:

* Activation energy
* Bond energy
* Molecular structure

**Correlations to Next Generation Science Standards**

This article relates to the following performance expectations and dimensions of the NGSS:

**HS-PS1-4.** Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends on the changes in total bond energy.

**HS-ETS1-2.** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

**Disciplinary Core Ideas:**

* PS.1.A: Structure and Properties of Matter
* PS.1.B: Chemical Reactions
* ETS1.B: Developing Possible Solutions

**Crosscutting Concepts:**

* Cause and effect
* Energy and matter: flows, cycles, and conservation
* Systems and system models

**Science and Engineering Practices:**

* Asking questions (for science) and defining problems (for engineering)

**Nature of Science:**

* Science is a human endeavor.

See how *ChemMatters* correlates to the[**Common Core State Standards** online](https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/teachers-guide.html).