

## Temperature and the Rate of Chemical Reactions

### Purpose:

The purpose of this lab is for students to investigate the effect of temperature on the rate of a chemical reaction.

### Key Science Topics:

- Kinetic Molecular Theory of Heat
- Energy transformation (e.g., chemical energy to light {or radiant} energy)
- Electron energy levels, absorption and emission
- Fluorescence

### Grade Level:

- Physical Science, Grades 6-9

### Student Prior Knowledge:

- Students should be able to define the Kinetic Molecular Theory of Heat.
- Students should be familiar with the Bohr model of the atom and electron energy levels.
- While it would be helpful if students were familiar with electron energy levels and absorption/emission of photons, this activity could be used to introduce that concept.

### Materials:

Each lab group should have the following:

- Three beakers labeled A, B, and C
- Thermometer
- Three glow sticks that are the same size, brand, and color
- Hot, room temperature, and cold water

I have used mini glow sticks up to the regular-sized glow sticks. Be sure to have extra on hand as some glow sticks will not react. After Halloween is a good time to stock up on glow sticks at a bargain price. Science supply stores (especially on-line) and party stores are good sources as well.

This may also be done as a teacher demo and have students record the data.

### Suggestions:

I usually use this lab as an introduction to atomic spectra—a challenging topic for middle school, high school and college students. This lab is a good review of how the Bohr model; while it is an incomplete description of the atom, is a good model for explaining electron energy levels.

To explain electron energy levels, I use the standard climbing on a chair, then a lab table method. While standing on the ground, I explain that I am on the ground state. If I absorb just

the right amount of energy, I will then have enough energy to hop up onto the chair. I then stand on the chair and ask my students if that required energy. Yes. Then I describe that if I absorb yet another packet of energy, I can move up to the second level. Or, I can hop down to the ground state and give off energy. If I hop down to the ground state, I emit a packet of energy which is a photon, or particle of light. I also mention that I can [theoretically, at least] go from the ground state directly up to the table (2<sup>nd</sup> level). I can also jump directly from the table to the ground state and bypass the first state entirely [theoretically speaking again].

**Further Reading:**

For further information on how glow sticks work, please visit the following sites:

“How Do Lightsticks Work? Learn About Chemiluminescence”

<http://chemistry.about.com/od/howthingsworkfaqs/a/howlightsticks.htm>

“Glow Stick”

[http://en.wikipedia.org/wiki/Glow\\_stick](http://en.wikipedia.org/wiki/Glow_stick)

“How Lightsticks Work”

<http://science.howstuffworks.com/innovation/everyday-innovations/light-stick1.htm>

**Common Core Standards**

Insert applicable common core standards here.

**Next Generation Science Standards**

Insert applicable NGSS here.

Student Handout

## Temperature and the Rate of Chemical Reactions

Name: \_\_\_\_\_

Date: \_\_\_\_\_

Pre-lab question: What does the Kinetic-Molecular Theory state?

Purpose:

For this lab, we are going to be taking some qualitative data. Qualitative data describes a *quality* of an object or event. You may have been asked in a survey to select a number that described how well you liked a particular item; that is an example of qualitative data. In this lab, since we can't measure the brightness of a glow stick, we are going to rank how bright it is with "1" being brightest and "3" being the dimmest. We are also going to rank how quickly the glow stick reached its maximum brightness with "1" being the quickest and "3" being the slowest.

Materials:

- Three (3) glass beakers:
  - Fill Beaker A with 200mL of cold water
  - Fill Beaker B 200mL of room temperature water
  - Fill Beaker C with 200mL of hot water.
- Three glow sticks that are the same size, brand, and color.
- Thermometer

Procedure:

1. Record the water temperature of each beaker in the table below.
2. If your glow sticks are in a package, remove them from the package, but do not break them yet!
3. Once everyone has recorded the water temperature of the beakers, the teacher will turn out the lights.
4. Once the lights are out, break the three glow sticks at the same time and immediately place one glow stick in each cup.
5. Observe how bright each glow stick is and how quickly it reached maximum brightness.
6. Rank the glow sticks based on their brightness and how quickly they reach maximum brightness and record in Table 1 below:

**Table 1:**

Beaker	Water Temperature, °C	Brightness ("1" = Brightest, "3" = Dimmest)	How quickly glow stick reached maximum "glow" ("1" = Quickest, "3" Slowest)
A			
B			
C			

Questions:

1. Which beaker contained the brightest glow stick?
2. What was the water temperature in that beaker?
3. Which beaker contained the glow stick that reached maximum brightness first?
4. What was the water temperature in that beaker?
5. How does the water temperature affect the rate of the chemical reaction occurring in a glow stick? Explain this result using your knowledge of the Kinetic Molecular Theory of Heat.
6. What evidence do you have that a chemical reaction took place?

## Post-lab Discussion: How a glow stick works

Glow sticks convert \_\_\_\_\_ energy to \_\_\_\_\_ energy. Inside the glow stick is a liquid called \_\_\_\_\_ which is mixed with a \_\_\_\_\_ dye. Also inside the glow stick is thin glass vial containing \_\_\_\_\_. To start the chemical reaction, snap the glow stick. This starts a two-step process. First, the hydrogen peroxide and the phenyl oxalate ester combine to give off \_\_\_\_\_ in the form of \_\_\_\_\_. This light is in the \_\_\_\_\_ region of the spectrum, so we cannot detect it with our eyes. This is the right \_\_\_\_\_ to be absorbed by the fluorescent dye. The \_\_\_\_\_ in the molecules of the fluorescent dye absorb the excess \_\_\_\_\_ and become, what scientists call, “\_\_\_\_\_.” That means the electrons were bumped up to a higher \_\_\_\_\_. When there is not enough energy for the electrons to remain in that energy level, they drop back down to a lower energy level and give off \_\_\_\_\_. The color of that visible light is determined by the \_\_\_\_\_ of the fluorescent dye.

Have you ever noticed how your white clothing or even your teeth glow under a \_\_\_\_\_? Some laundry detergents and whitening tooth pastes contain chemicals known as “\_\_\_\_\_.” Unlike glow sticks, they do not require the initial \_\_\_\_\_. Instead, these brighteners absorb ultraviolet light from black lights or even the \_\_\_\_\_. This ultraviolet light bumps the electrons up to a higher energy level. The electrons then drop down to a lower energy level, giving off visible light that is \_\_\_\_\_ or \_\_\_\_\_. Our eyes interpret this as really bright white clothing or white teeth.

## Temperature and the Rate of Chemical Reactions

Name:                     Key                    

Date: \_\_\_\_\_

Pre-lab question: What does the Kinetic-Molecular Theory state?

*The Kinetic Molecular Theory of Heat states that molecules in a fluid increase their speed increases as temperature increases.*

Purpose:

*The purpose of this lab is to determine the effect of temperature on the rate of a chemical reaction.*

For this lab, we are going to be taking some qualitative data. Qualitative data describes a *quality* of an object or event. You may have been asked in a survey to select a number that described how well you liked a particular item; that is an example of qualitative data. In this lab, since we can't measure the brightness of a glow stick, we are going to rank how bright it is with "1" being brightest and "3" being the dimmest. We are also going to rank how quickly the glow stick reached its maximum brightness with "1" being the quickest and "3" being the slowest.

Materials:

- Three (3) glass beakers:
  - Fill Beaker A with 200mL of cold water
  - Fill Beaker B 200mL of room temperature water
  - Fill Beaker C with 200mL of hot water.
- Three glow sticks that are the same size, brand, and color.
- Thermometer

Procedure:

7. Record the water temperature of each beaker in the table below.
8. If your glow sticks are in a package, remove them from the package, but do not break them yet!
9. Once everyone has recorded the water temperature of the beakers, the teacher will turn out the lights.
10. Once the lights are out, break the three glow sticks at the same time and immediately place one glow stick in each cup.
11. Observe how bright each glow stick is and how quickly it reached maximum brightness.
12. Rank the glow sticks based on their brightness and how quickly they reach maximum brightness and record in Table 1 below:

**Table 1:**

Beaker	Water Temperature, °C	Brightness ("1" = Brightest, "3" = Dimmest)	How quickly glow stick reached maximum "glow" ("1" = Quickest, "3" Slowest)
A	5°C	3	3
B	20°C	2	2
C	66°C	1	1

Questions:

7. Which beaker contained the brightest glow stick?

*Beaker C*

8. What was the water temperature in that beaker?

*Hot water (T=66°C)*

9. Which beaker contained the glow stick that reached maximum brightness first?

*Beaker C*

10. What was the water temperature in that beaker?

*Hot water (T=66°C)*

11. How does the water temperature affect the rate of the chemical reaction occurring in a glow stick? Explain this result using your knowledge of the Kinetic Molecular Theory of Heat.

*The glow stick in the hot water had a faster reaction rate. The Kinetic Molecular Theory of Heat states that particles in a fluid increase their speed as temperature increases. The hot water has faster moving particles than the cold and room temperature water. These fast-moving particles collide with the glow stick, transferring energy. This causes the liquid particles in the glow stick to move quicker, increasing the rate of the chemical reaction.*

12. What evidence do you have that a chemical reaction took place?

*Emission of light is one of the six indicators of a chemical reaction.*

### Post-lab Discussion: How a glow stick works

Glow sticks convert chemical energy to light energy. Inside the glow stick is a liquid called phenyl oxalate ester mixed with a fluorescent dye. Also inside the glow stick is a thin glass vial containing hydrogen peroxide. To start the chemical reaction, snap the glow stick. This starts a two-step process. First, the hydrogen peroxide and the phenyl oxalate ester combine to give off energy in the form of light. This light is in the ultraviolet region of the spectrum, so we cannot detect it with our eyes. This is the right wavelength to be absorbed by the fluorescent dye. The electrons in the molecules of the fluorescent dye absorb the excess energy and become, what scientists call, "excited." That means the electrons were bumped up to a higher energy level. When there is not enough energy for the electrons to remain in that energy level, they drop back down to a lower energy level and give off visible light. The color of that visible light is determined by the color of the fluorescent dye.

Have you ever noticed how your white clothing or even your teeth glow under a black light? Some laundry detergents and whitening tooth pastes contain chemicals known as "brighteners." Unlike glow sticks, they do not require the initial chemical reaction. Instead, these brighteners absorb ultraviolet light from black lights or even the sun. This ultraviolet light bumps the electrons up to a higher energy level. The electrons then drop down to a lower energy level, giving off visible light that is blue or white. Our eyes interpret this as really bright white clothing or white teeth.