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ARTICLE

The Cool Blue Light of Luminol

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On TV, you might see police investigators spraying a liquid that glows the colour blue if there is blood present at the crime scene. The chemical luminol causes the glowing. I am going to investigate if the temperature of a room will make this fascinating molecule change its chemical reaction.

INTRODUCTION

What is more fascinating and mysterious than glow-in-the-dark objects? Why do they glow and where does the light come from? It might seem like magic, but there is no magic involved. What is involved is a phenomenon called chemiluminescence, which is how objects use chemical energy to produce light. Chemiluminescence can be used to help solve crimes and is used by forensic scientists to detect blood at crime scenes. This helps make blood visible even if it has been washed away. Using a very special chemical called luminol, all the blood traces that had been hidden glow in the dark.

Understanding how this happens requires understanding how electrons behave in different materials. The 'ground state' is the lowest energy that electrons in a molecule can have and is the normal energy of electrons. Electrons can also absorb energy, for instance in a chemical reaction, and jump up in energy to what we call an 'excited state' (higher energy level). The fundamental premise of the luminol reaction is that enough energy is released to excite the electrons of luminol from their ground state (lowest energy level) to their excited state (higher energy level), as shown in Figure 1. When the electrons lose this energy and fall back down to their low energy/ground state level, this results in the discharge of light. The light particle released (called a photon) is how the electrons lose energy to go back to their original energy level (ground state). A variety of colours of light can be produced depending on the energy difference between the ground state and the excited state of a chemical. For instance, blue light is high energy light, and would represent a big difference in energy (which is the colour luminol glows). On the other hand, red light is low energy light and would represent a small difference in energy between these states.

This process is important for a lot of different applications, including in imaging and chemical sensing. Here, it is very important for understanding how luminol produces chemiluminescence, which in itself has a lot of important applications, including the crime scene detection of blood as discussed. Now that you have a general understanding of how light production occurs, what allows luminol to specifically detect blood?

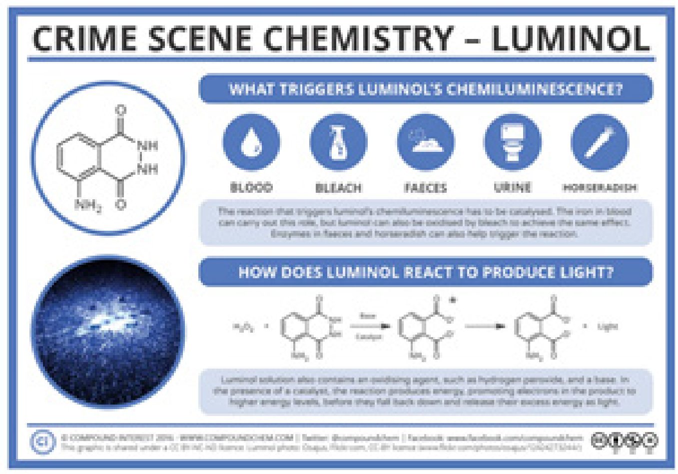


Figure 1. Figure showing what triggers luminol's chemiluminescence and how luminol reacts to produce light [4].

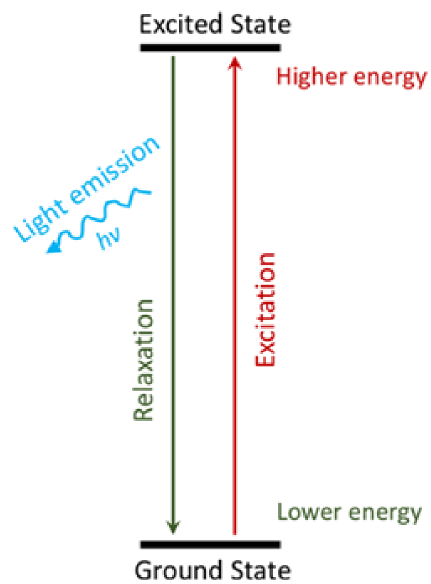
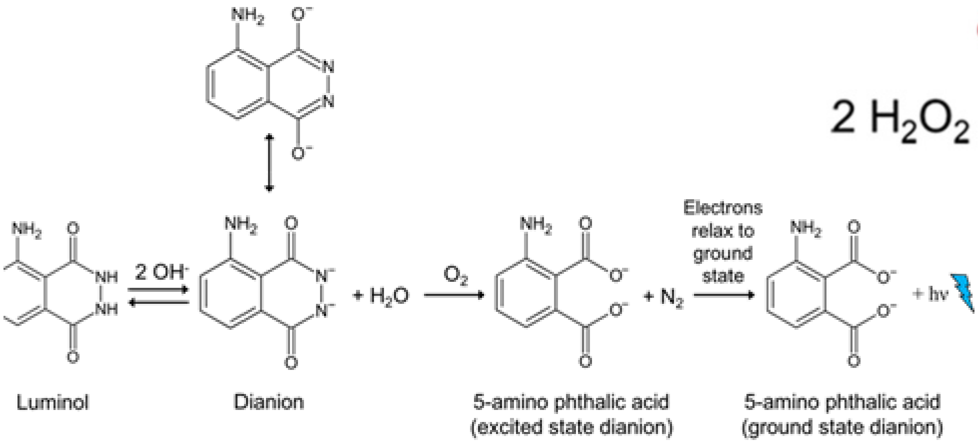


Figure 2. Diagram showing how the excitation of an electron from its ground state (low energy level) to excited state (higher energy level) can result in the emission of light [3].



$$2\,H_2O_2 \xrightarrow{\text{Catalyst (blood)}} 2\,H_2O + O_2$$

Figure 4. The reaction of hydrogen peroxide produced with blood when decomposing [3].

Figure 3. To produce light by luminol, this is the simplified reaction mechanism [3].

The luminol solution contains luminol (C8H7N3O2), hydrogen peroxide (H2O2) and hydroxide ions (OH-). The luminol chemical must first be activated by OH- to form a dianion, which is a compound with two negative charges. Then, H2O2 forms oxygen through reacting with iron in the blood, through the reaction in Figure 4, which reacts with (oxidizes) the luminol dianion and promotes it to its excited state. Usually, oxygen production by H2O2 happens slowly, but the iron in blood works as a catalyst to make this occur a lot more quickly.

Catalysts are chemicals that can increase the speed of a reaction, without being consumed. Iron is found in blood in the form of hemoglobin, which is in our red blood cells and carries oxygen.

My motivation behind this experiment is to understand if investigators or forensic scientist should use luminol in warmer temperatures or colder temperatures to maximize its chemiluminescence. I made my hypothesis based on the rate of reaction: when the temperature increases, molecules move a lot more which increases the average kinetic energy.

Kinetic energy is a form of energy of an object because of its motion. It can be transferred between objects, and turned into other kinds of energy. Also, kinetic energy depends on its motion and mass. With increased temperature this motion increases, which results in the increase in kinetic energy.

Different rates occur for different chemical reactions. Colour change, precipitate formation, energy change, or/and release of gas, are indicators of reactions. Temperature, concentration, use of a catalyst, and particle size are four factors that affect the rate of a chemical reaction. For example, when the temperature increases, a reaction happens at increasing the rate of reaction. When the temperature is higher, the particles frequently collide, with more energy, causing the reaction to be faster.

HYPOTHESIS

If the luminol is placed in both the hot water and ice-cold water, my hypothesis is the luminol in warmer temperatures (the hot water) will have a long-lasting and better reaction then in the ice-cold water.

Figure 5. Diagram of how particles move slower in low temperatures compared to the particles at high temperatures [5].

MATERIALS

The materials needed in this experiment are a Cool Blue Light Experiment Kit, paper plate, Styrofoam cups, liquid measuring cups, kitchen thermometer, hot water (about 50°C), ice, two metal spoons, and a lab notebook. Also, I am measuring the luminescent glow with Google's Science Journal app, which means I need the following materials: glass vial with cap (comes with the experiment kit), pipette, transparent and waterproof plastic bag, and a tablet to record my data.

METHODS

Setting Up Your Materials

1. Read the information booklet from the Cool Blue Light Experiment Kit.

2. Investigate how temperature affects the luminol reaction, then set out two plastic cups that came with the kit. Start with adding one scoop each of luminol and perborate, with two teaspoons of water.

3. Next, add 2-3 scoops of copper sulfate crystals to the provided vial (provided in the science kit) and add about 10-20 mL of

Figure 6. Materials used in this experiment.

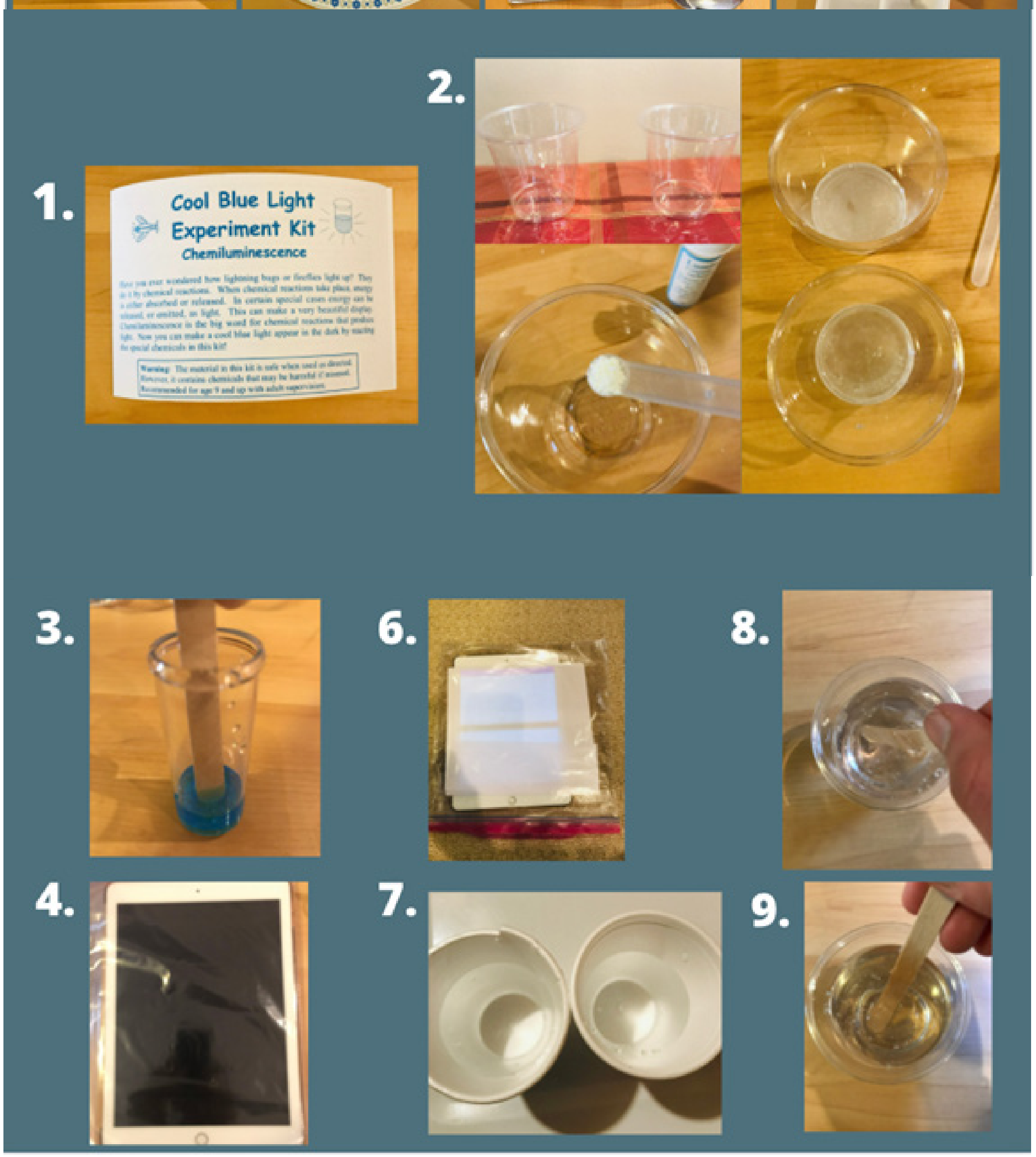


Figure 7. Setting up your materials.

Figure 8. Materials used in luminol experiment. 1) Cool Blue Light Experiment kit, 2) Two plastic cups, luminol, perborate, and water, 3) Vial, copper sulfate crystals, and water, 4) Tablet, and waterproof and transparent plastic bag. 6) Piece of paper and Google's Science Journal app, 7) Styrofoam cups, ice cold water, and hot tap water, 8) Prepared cups (hot water), luminol/perborate mixture, and clean popsicle stick, 9) Prepared cups (ice cold water), luminol/perborate mixture, and clean popsicle stick.

water to prepare the copper sulfate solution. If the crystals are not dissolved add more water.

4. Put a waterproof plastic bag to protect your device from any potential spills. The plastic needs to be transparent, so the light can go through it.

5. Identify the location of the light sensor in your phone and test it if it works as it supposes to.

6. On the display part of your phone, cut a piece of paper and cover it. The display's light can interfere with the measurement of chemiluminescence.

7. In one of the Styrofoam cups add ⅓ cup of ice-cold water, and in the other Styrofoam cups add hot tap water (50°C).

8. In one of the prepared cups add hot water with the luminol/perborate mixture and mix with a clean spoon or popsicle stick until the chemicals are well combined and dissolved.

9. Add ice-cold water to the other cup into the luminol/perborate mixture, and once again mix until completely dissolved.

10. Figure out the temperature of each cup with the solutions and record it in the notebook. The temperature of each cup: Cup 1 (the hot water)-36 Celsius, Cup 2 (the ice water)-13 Celsius

Running the Experiment

11. Move to a dark location when you have your phone and solutions ready. The camera sensor would not pick up the luminol glow if you're in a room full of light.

12. With the display facing forward, lay your phone flat. Open the Science Journal app, start a new experiment, and make sure to label it. Decide on the light sensor and check that they are constant and are not changing.

13. Directly on the top of the light sensor on your phone, place your first cup with the solution. Also, cover the phone's display with a piece of paper (fold the lower part so you can click the play button).

14. Close the door of the room and cover the window to reduce the amount of light in the room. Then, press the button record and add 2 mL of the copper sulfate solution to the cup, and mix for at least 30 seconds.

15. About 1-2 minutes stop the recording.

16. Then with the second cup repeat steps 13-15, use the exact amount of copper sulfate.

17. Two more times repeat the experiment, by following steps 1-16, with fresh/clean materials, and then record the brightness of the luminol reaction in your notebook by using Google's Science Journal app.

VARIABLES

The independent variable in this experiment is the temperatures and the number of copper sulfate crystals. The dependent variable in this experiment is the reaction of the luminol at different times with unlike temperatures. The controlled variable in my experiment is the temperature and the brightness of the room.

RESULTS

According to the chart, it showed that the warmer temperature affects the luminol more. The luminol in the warmer temperatures (the hot water) had a longer-lasting reaction time and a different reaction than the colder temperatures (the ice water). There was a longer-lasting reaction time with the warmer temperatures because when the temperature increases, the reaction rate increases also, causing a brighter glow in the warm water. The chart below shows that luminol had a brighter glow and an increased reaction rate in the warm water than the cold water.

DISCUSSION

I observed that the hot water had a brighter and longer glow, and if I compare that to the ice-cold water, the colder temperature water had a duller and shorter glow. The luminol glowed for longer in the hot water because the higher the temperature, the higher the kinetic energy of molecules inside. The presence of more energy in this reaction means that more electrons are able to be promoted to the excited state, and that this excitation will occur for a longer period of time (as long as there is more energy from the heat available). As long as electrons are being promoted to the excited state, light can be emitted. As extra energy from heat was not provided in the cold water trials, it makes sense that less electrons were promoted to the excited state, and that less light/brightness was observed as a result. In the warm trial, the luminol produced a stronger blue light. This happened because the copper sulphate dissolved in the warm water, and reacted with the luminol, causing it to form a molecule that is in the excited electronic state.

CONCLUSION

In conclusion, my hypothesis was correct. The warmer temperature did in fact affect the luminol more. The data supports my reasoning: the warmer temperature had a longer reaction time and stronger production of blue light. The luminol in the higher temperatures had stronger emission because luminol produces a stronger glow in higher temperatures due to the presence of more kinetic energy. The higher the temperature is, the faster the reaction is, causing the luminol reaction to glow brighter. The lower temperatures had weaker emission because the lower temperatures have a lower kinetic energy of molecules, which creates a less intense reaction. This finding is important because temperature does affect the production of light from luminol. This means that luminol works best in warmer temperature conditions. So, investigators should use luminol in warmer temperatures if they want the glow from luminol to be brighter and long-lasting. Other studies this makes me think of are that happens if I add more perborate than luminol, will this affect the brightness? What happens if I use an alternative of luminol, will there be a different chemical reaction? Also, what other factors can make luminol glow longer so forensic scientists have more time to detect traces of blood at crime scenes?

Table 1. Results from trial 1, showing the brightness of luminol in warm water compared to cold water.

Seconds	Brightness of Warm Water	Brightness of Cold Water
20	-6.32 EV	-3.57 EV
40	-6.32 EV	-4.86 EV
60	-6.32 EV	-5.15 EV

Table 2. Results from trial 2, showing the brightness of luminol in warm water compared to cold water.

Seconds	Brightness of Warm Water	Brightness of Cold Water
20	-4.74 EV	-4.07 EV
40	-4.74 EV	-4.23 EV
60	-4.74 EV	-4.32 EV

Table 3. Results from trial 3, showing the brightness of luminol in warm water compared to cold water.

Seconds	Brightness of Warm Water	Brightness of Cold Water
20	-2.80 EV	-4.62 EV
40	-4.32 EV	-4.74 EV
60	-4.32	-4.86 EV

REFERENCES

Anne Marie Helmenstine, P. (n.d.). *How to use luminol to test to detect blood.* Retrieved March 03, 2021, from https://www.thoughtco.com/luminol-chemiluminescence-test-for-blood-607630

Harris, T. (2020, January 27). *How luminol works.* Retrieved March 03, 2021, from https://science.howstuffworks.com/luminol.htm

Science Buddies. (2020, June 23). *Crime Scene Chemistry-The Cool Blue Light of Luminol: Science Project.* Retrieved July 19, 2021, from https://www.sciencebuddies.org/science-fair-projects/project-ideas/Chem_p078/chemistry/crime-scene-luminol-blood#background

Crime scene *Chemistry – Luminol, Blood & Horseradish.* (2016, October 19). Retrieved July 19, 2021, from https://www.compoundchem.com/2014/10/17/luminol/

Rates of reaction - rates of reaction - national 4 chemistry revision - bbc bitesize. (n.d.). Retrieved August 09, 2021, from https://www.bbc.co.uk/bitesize/guides/z4n82hv/revision/1

ABOUT THE AUTHOR - GURVEEN BAINS

Gurveen Bains is a 15-year-old from London, Ontario, who loves being engaged in everything. She currently attends London Central Secondary School. She has a strong interest in science and loves researching new scientific projects and ideas. She is a passionate student in her school's Social Justice Club, Hosa Club, STEM club, and much more. She participated in the Thames Valley Science and Engineering Fair for this project and was glad to win a bronze award and a special award to Western Engineering Summer Academy. Gurveen was a past contestant in the 2020 Youth Science Canada Fair, where she and her sister, Jasneet, won the Climate Change Resilience Award presented by Intact Financial Corporation and a silver award from TVSEF for the project, Blame The Rain (which is published in the CSFJ, under Volume 3 Issue 6).