Cool Blue Light Experiment Kit
Chemiluminescence

Have you ever wondered how lightning bugs or fireflies light up? They do it by chemical reactions. When chemical reactions take place, energy is either absorbed or released. In certain special cases energy can be released, or emitted, as light. This can make a very beautiful display. Chemiluminescence is the big word for chemical reactions that produce light. Now you can make a cool blue light appear in the dark by reacting the special chemicals in this kit!

Caution! The Cool Blue Light Experiment Kit is safe when used as directed. However, anything can be dangerous when used in the wrong way. Always use any chemicals, including household chemicals, with care.

Wear safety glasses when using the chemicals in this kit.

Keep the chemicals away from infants and young children.
Do not eat or taste any of the chemicals in this kit.
However, if any chemical gets on the the skin or in the eyes or mouth, the best first aid is to wash with lots of water.
If swallowed, drink a glass of water or milk and call a physician or the Poison Control Center.

Always ask permission to use any household materials.
Work on a newspaper or paper towel to make clean up easier.
Keep the caps on the vials when not in use.
The luminol mixture should be stored away from light.
Read the directions carefully. Never experiment with something you know nothing about.
Experiment with small amounts of materials. It will be less dangerous and easier to control than large amounts; and you will conserve your resources.

When finished with an experiment, pour the liquid down the sink and run the water for half a minute.
Wash with water, any cups and spoons that you used.
Wash your hands and put away your materials when finished.

Chemistry is fun, but always experiment carefully!

Now let's get ready to make some cool, amazing and illuminating reactions.
Experiment 1 Cool Blue Light
You will need a dark room to see the reaction, but a lighted area to do the experiment. Take a plastic cup and add 2 teaspoons of water. You will use the water to make a solution. Chemists call a mixture of something dissolved in something else a solution. A solution also means an answer to a problem. Words can be confusing, so it is a good idea to use a dictionary if you have any question about words.

Add one small scoop of the luminol mixture and one small scoop of the perborate mixture to the cup with water. Use the wooden stick to take out a few small crystals of copper sulfate and add it to the cup. Take the cup to a dark room and observe.

You should begin to see beautiful blue light coming from where the copper sulfate is dissolving and reacting with the luminol. Swirl the cup gently to help it mix. The light is a "cool" light. That is, the solution is not hot. It is also "cool" in the sense that it is very good and interesting. The light will continue to be emitted, or given off, from the mixture for several minutes, until one of the reactants, or ingredients is used up. The used solution can either be washed down the sink with water, or saved to use in experiment 5.

Experiment 2 The Instant Ready Light
This is a variation of experiment 1 that will make it easy to do the experiment anytime you want to. Variation means a change in the form. You will prepare a mixture that will produce light, just by adding water.

Take the large, clear vial and make sure that it is dry. Add one small scoop of the luminol mixture and one small scoop of the perborate mixture and a few crystals of copper sulfate. Put the cap on the vial.

This mixture is now ready to make the light anywhere, anytime you want. It should stay fresh and ready for quite a while. When you want to make it light up, just add water. When you add water, the water dissolves the ingredients and that allows them to come closer together and start the reaction. A solution is necessary for the reaction.

What’s happening?
The word for these experiments is chemiluminescence. It means light from chemical reactions and is pronounced "chem- e - lu - min - s - cents". Chemiluminescence is also what causes fireflies to glow and "light sticks" to light up. The light in the firefly comes from an organ in the skin of the abdomen section called the lantern. Just before a firefly flashes, two chemicals are released, or secreted, in the lantern. In commercial "light sticks", there are two solutions, one is in a glass tube. To activate or start the chemical reaction, the glass tube is broken and the two solutions mix, react and glow.

Emitted Light
When a lamp is turned on, the light bulb gets hot, hot enough to burn. When a match or a candle is lit, heat and light are produced during the chemical reaction of combustion or burning. This is called incandescence, light produced by heat. Many things, such as wood and paper, will burn and give off heat and light.

But the cool light that you made is different. Luminescence is the emission of visible light without heat. It is sometimes called "cold light". "Lumin" is the latin word for light. Studying parts of words helps us to figure out other words; for example, illuminate means to light up.

Bioluminescence is a special type of chemiluminescence that happens in some living organisms, such as fire flies. "Bio" is the prefix meaning living. There are certain bacteria, fungi, sea animals, and insects that make special chemical compounds in special cells in their body that can produce light. Foxfire is the name for light-producing fungi on decaying wood. Some jelly fish when touched, expel or give off a solution that glows when it comes in contact with sea water. Chemiluminescence from this experiment kit or from fireflies involve the same general reactions, but different chemical compounds.

Glow in the dark objects involve another type of luminescence called phosphorescence. Those objects must absorb light energy from another source such as a lamp or sun light, they then release that energy as a glow for some time. Fluorescence is similar, but its glow is for a very, very short time. For example, when a fluorescent overhead light is switched off, the light also goes out. Other examples are fluorescent paint that glows under a black light or ultra-violet light.
Experiment 3 Practice With the Dropper
This is just a simple exercise to practice using the dropper, or pipet, that you will use in the next experiment. Practice using the dropper so that you can squeeze out one drop of a liquid at a time. The word pipet, pronounced "pie-pet", came from the French word for little pipe. Take the pipet and place it in a cup of water. Put the dropper tip in the liquid and squeeze slightly. Notice that air bubbles come out. Keep the dropper in the liquid while you release the bulb. Notice that the liquid moves up into the dropper. Squeezing the air out creates a vacuum (or empty space). Releasing the bulb allows the liquid to move into the empty space. Lift the dropper with the liquid in it, and hold it over the cup. Squeeze so that one drop comes out at a time.

Experiment 4 The Bright Bleach Light
Caution! Ask for permission and help from a responsible adult to do this experiment. You will need a very small amount of liquid bleach such as "Clorox". Bleach is very reactive. That means that it will combine and change in chemical reactions very quickly, with lots of energy. That also makes it very dangerous.

Pour a very small amount of liquid bleach into an old plastic cup. Then take one of the cups from this kit and half fill it with water. Then use the dropper, or pipet, and add one drop of bleach to the cup with water. Use the stirring stick and gently stir to mix the water and drop of bleach. This will be called the dilute bleach solution. Dilute means watered-down or less concentrated. The regular bleach solution is about a 5% sodium hypochlorite solution. Your dilute bleach solution is now about 0.005%.

If you have the left over reaction mixture from experiment 1 or experiment 2 take it and add 1 drop of the dilute bleach solution. It should make a very bright blue light. This will be bright enough to see without going to a dark room. Add more of the bleach solution until the light stops appearing. The bleach is very reactive and makes the light very bright, but it is used up quickly and will not last as long as the light in experiment 1. There generally is some luminol left over in the reaction mixture and that is what reacts with the bleach. Luminol is not very soluble in water. That means, there will be some small particles of luminol not dissolved.

If you do not have any of the left over reaction mixture or want to make some more luminol solution to react with bleach, try this experiment. Put one small scoop of the luminol mixture and two teaspoons of water in a cup. Then add a drop of bleach. What happens? Notice that this did not need any of the perborate mixture or copper sulfate.

Experiment 5 The oxidizer
In experiment 1, luminol, perborate and copper sulfate were reacted to give the eerie glow. In experiment 4, we saw how luminol and bleach could make the light. Now we will try to substitute or change another of the ingredients. This will help us figure out how the reaction works. Scientists know that perborates form hydrogen peroxide in water. Let's use hydrogen peroxide in place of the perborate mixture. Caution! Ask permission and help from a responsible adult for this experiment. You will need a small amount of hydrogen peroxide. Hydrogen peroxide is commonly found in medicine cabinets and is sold in drug stores.

Pour a little hydrogen peroxide into one of the plastic cups. Into a second cup, add 1 small scoop of the luminol mixture, a few crystals of copper sulfate and 2 teaspoons of water. Swirl to mix. This will be the luminol/copper sulfate solution. Use the dropper and add 2 drops of hydrogen peroxide to the luminol/copper sulfate solution. Take it to a dark room and observe. What happens? Add a few more drops of the hydrogen peroxide. How does the glow compare to the other experiments?

Hydrogen peroxide forms oxygen. You may have noticed the bubbles that form when hydrogen peroxide is put on a cut. Those bubbles are oxygen. The oxygen reacts with luminol producing the blue light. Chemists say that the luminol is oxidized. Any substance that can act like oxygen is called an oxidizer. Bleach in the last experiment is an oxidizer. Oxygen is a high energy molecule that can supply the energy for the quantum leap. At the right is the safety symbol for an oxidizer. It is very important for safety. Oxidizers can support combustion, like oxygen. Do not store oxidizers near combustible material, or something that can burn, that could start a fire.

Hydrogen peroxide is one of the ingredients in commercial "lightsticks". Light sticks also contain a compound called an oxalate ester that reacts with the hydrogen peroxide and provides chemical energy. A fluorescent dye glows when it absorbs that energy. Light sticks use a variety of different fluorescent dyes to give the different glowing colors.
Experiment 6  Bleaching Powders Can Light It Up!

Caution: Ask for permission and help from a responsible adult to do this experiment. You will need small amounts of cleaning powders or color safe bleach such as "Clorox II"® that have bleaching agents in them.

Make more luminol/copper sulfate solution as in experiment 5 (one small scoop of the luminol mixture, a very few crystals of copper sulfate and 2 teaspoons of water). Add a small dash of the cleaning powder to an old cup and use the stirring stick to add a small amount of the cleaning powder to the luminol/copper sulfate solution. Go to a dark room and observe.

The bleaching powder cleaners contain oxidizers, and they oxidize the luminol to make the chemiluminescence. The perborate mixture in this kit is actually Clorox II®. Read the ingredient labels on packages when in the grocery store cleaning supply section.

Swimming pool chlorinators that contain calcium hypochlorite are very strong oxidizers and bleaching agents. And they will light up luminol. They are also very dangerous and corrosive. Freshly treated swimming pool water may also oxidize luminol.

Experiment 7  Dirty Copper

In experiment 1, you used a copper sulfate crystal. Now you can try another source for the copper: a penny. But for this experiment to work, the penny must be slightly corroded. We will tell why, later.

Find a penny that has some green color on it.

Put two teaspoons of water in a cup. Add 1 scoop of luminol and 1 scoop of perborate mixtures and swirl gently to mix. Place the dirty (corroded) penny in the solution. Take the cup into a dark place and watch. You should see the blue glowing light. It may take longer for it to appear than in experiment 1, and it may not be as bright.

The copper acts as an activator or catalyst in this experiment. A catalyst speeds up something; gets it started more quickly. However, the copper must be in the form of copper ions.

Pennies are made of the metal copper. Pennies made since 1983 are made of a mixture (alloy) of copper and zinc. These are cheaper to make, but they also corrode easier than the older pennies. But for our experiment we want the more corroded penny. Copper metal, which is orange or brown colored, is in a chemically different state than the copper ions in copper salts, such as copper sulfate, which is blue or green colored. They are Cu++, cupric ions. Perhaps you have seen a "gold" ring that turned green. The ring actually has copper in it, and corrodes forming blue-green copper salts.

Experiment 8  The Hemoglobin Detector

Luminol is used by forensic scientists to detect blood. Forensic science is the study of objects found at a crime scene. The word forensic refers to legal debate. Thus, lawyers use forensic evidence in the courtroom.

Detect means to discover something that is hidden. Often a tiny spot of blood may not be visible, but crime lab investigators can spray a luminol solution and in the dark any blood stains with glow with blue light. Red blood cells contain hemoglobin which is responsible for carrying oxygen in the body. Hemoglobin contains iron which reacts with luminol, just like copper. The iron is in the positive two charge form called the ferrous ion, Fe++. You will need a source of blood. The blood on a piece of a meat tray container will work. You will not needed much, just a trace will work best. Add one scoop of the luminol and perborate mixtures and two teaspoons of water to a cup. Then put a small spot of beef blood that is on a piece of paper towel, or plastic meat wrapper in the cup. Swirl it gently and take it to a dark place and look. What happens?
Experiment 9 Hot and Cold Factors
The rate of a reaction is how fast things change. The rate depends on several factors. For example, if you are cooking soup, temperature is an important factor. Generally, the hotter the pot, the quicker it is done. Up to a point, too hot and it burns. Stirring and the size of the ingredients also affect the rate. Small pieces will cook faster than large pieces. Stirring distributes the heat better. Here is an experiment to show the effect of temperature on the cool blue reaction. You will do the experiment twice, at the same time, one with cold water and one with hot tap water. Always try to do each trial exactly the same, except for the difference that you are looking at, temperature in this case.

Set up 2 cups. Add 1 scoop of the luminol and perborate mixtures, and a few copper sulfate crystals to each cup. Then run the cold water faucet for a few minutes to get a cup of cold water, or add a little ice to some water. Run the hot water for a few minutes and get a separate cup of hot water. Then add 2 teaspooons of the cold water to one of the mixtures and add 2 teaspoons of hot water to the other mixture. Take both to a dark place and observe any differences.

![Diagram showing the experiment setup with cold and hot water cups with luminol, perborate, and copper sulfate mixtures.]

The reaction with hot water should be quicker and brighter, but go out sooner than the cold water reaction. Chemists can control the rates of reaction like this. Kinetics is the study of rates.

Experiment 10 Other Factors
The brightness and duration of the cool blue light will depend on several factors, or variables, such as the solvent, the amount and type of oxidizers and activators and pH. A solvent is the substance that the reactants, are dissolved in. In our experiments, water is the solvent. pH is a measure of the acidity or alkalinity of the solution. Chemists have found that a pH of 11 is best, or optimum, for this reaction. Here are two things that you can try to see how pH affects the reaction. You will need a small amount of baking soda and vinegar.

Set up 2 cups. One will be a control. A control allows an experimenter to observe how changing one thing affects the experiment. Any differences can be compared. Add 2 small scoops of baking soda to one cup only. Then add all the ingredients as in experiment 1, to each cup. Take both to a dark place and observe any differences.

![Diagram showing the experiment setup with a control and a mixture with 2 small scoops of baking soda.]

The cup with the baking soda will not be as bright at first, but should last longer. Baking soda is sodium bicarbonate and it forms a buffer with sodium carbonate, which is in the luminol mixture. Buffers help maintain a constant pH. Another thing to try is to add a drop of vinegar to the cool blue light. The light will go out. Vinegar is an acid and it quenches, or stops the reaction. Swirling the mixture may start the light again. Note that this one will not be a very exciting experiment.
The Chemistry of Luminol
The chemical name for luminol is 5-amino-2,3-dihydrophthalazine-1,4-dione. It is also known as 3-aminophthalhydrazide. Its molecular structure looks complicated and that is one reason that its name is complicated. The molecular structure is:

\[
\text{N-H} \begin{array}{c}
\text{N-H} \\
\text{O} \\
\text{O} \\
\text{O} \\
\text{N-H} \\
\text{N-H}
\end{array}
\]

The name luminol is the common name, it was given to show its property of producing light. The other names are systematic names based on the structure. Every different chemical compound has its own name that can tell a chemist what the structure is. The chemical formula of luminol is \( \text{C}_8\text{H}_7\text{N}_3\text{O}_2 \).

The perborate mixture is a mixture of sodium perborate, \( \text{NaBO}_3\cdot\text{H}_2\text{O} \), and sodium carbonate, \( \text{Na}_2\text{CO}_3 \). Sodium carbonate is a base and sodium perborate is the oxidizer. Copper, in the form of \( \text{Cu}^{++} \), is the activator, or catalyst. The reaction is complicated, but we will show some of it.

\[
\begin{align*}
\text{NH}_2\text{O} & \quad \text{Na}_2\text{CO}_3 \\
\text{N-H} & \quad 2 \text{NaBO}_3\cdot\text{H}_2\text{O} \\
\text{O} & \quad \text{N}_2 \\
\text{O} & \quad \text{H}_2\text{CO}_3 \\
\text{O} & \quad 2 \text{NaBO}_2 \\
\text{O} & \quad \text{H}_2\text{O}
\end{align*}
\]

The Quantum Leap
It is the electrons in atoms that make a quantum leap that produce the cool blue light. All things are made of matter. Matter is made of chemical compounds called molecules, which are made of atoms, which are made of protons, neutrons and electrons. In chemiluminescence, a chemical reaction releases energy that is absorbed by electrons in molecules, such as luminol. The electron jumps to a higher level and is said to be in an excited state. As the electron returns to the lower ground state, it releases the energy as a photon of light that is the glow that we see. The amount of energy is called a quantum.

The electrons must either jump to or fall back from one quantum level to another quantum level and this is the quantum leap. Some things glow in the dark after light shines on them. "Glow-in-the-dark" paint must absorb light energy from the sun or a lamp to glow. It also involves electrons, excited states, photons and quantum leaps.

Excited States
Everything exists in its lowest energy state naturally. For example, a ball on a hill will naturally roll down because the hill is a higher state than the bottom of the hill. To move the ball up the hill, energy must be added. Electrons follow the same laws of energy. But for electrons, the hills are the orbitals that they move in around the nucleus of the atom. Chemists and physicists use energy diagrams to help show the energy differences.

The arrows represent electrons. Electrons are spinning negative charges and they can spin in 2 directions, what we call clockwise and counter-clockwise. This is a more complicated picture than the orbits shown on page 17.

When the electron absorbs energy, from a chemical reaction, it can jump up to a higher quantum level. That is the excited state. But nothing stays in the excited state for long, including humans. The electron falls back to its ground state and gives the energy back as a photon, or quantum of light energy. That is the blue glow that we can see. Lightning in the sky during storms is due to the excited states of nitrogen and oxygen in the air emitting light.

Max Planck and Albert Einstein, were two of the famous physicists who worked on this theory. Planck's equation, \( E = h \nu \), relates the energy of the quantum jump (\( E \)) to the frequency, or color, of the emitted light (\( \nu \)).
Lightning Bugs
Fireflies are commonly called lightning bugs. They appear in the summer, and are a special treat to see light up in the evening. They are members of the beetle family and have blue wings and an orange colored head with two dark spots. You may be able to find them in the day when they are resting on a leaf. The larva of the firefly is called a glowworm. They are also luminescent and emit light. Larva is the young form of an insect before it changes into an adult. A caterpillar is the larva of a butterfly or moth.

It is not known for sure what the purpose is, or why they have a light emitting organ (called the lantern). It may be to attract each other or communicate. The males flash brighter. But, the light also attracts predators that may eat or collect the lightning bugs. Some entomologists (scientists that study insects) have observed that different patterns in the flashes of light are emitted by different species or kinds of fireflies. The firefly controls the flashing by regulating or adjusting the amount of air that gets to the lantern, something like the way we breathe. It is oxygen (O₂) in the air that reacts with the substance called luciferin that is made in certain cells of the firefly.

All chemical reactions in living things need an energy source and an enzyme. Enzymes are very large and complicated molecules that can hold the other substances together in the right way so that they can react quickly. Enzymes are catalysts that speed up reactions in living cells. The enzyme in the firefly reaction is called luciferase because it reacts on luciferin. The energy in cells for chemical reactions is stored in a high energy molecule called ATP or adenosine triphosphate.

\[
\text{luciferase} \quad \text{luciferin} + O_2 + \text{ATP} \rightarrow \text{light}
\]

Experiment 11 Sugar Light
One last experiment to show that many strange and wonderful, and simple phenomena are all around, but sometimes hard to see. Phenomena means an observable fact or event. We must be observant, have the right conditions and also be lucky.

You will need an old small clear drinking glass, a bowl and a teaspoon of sugar. The sugar must be granulated and not powdered sugar. Put the sugar in the bowl and take it and the glass into a dark room. Rub, grind and crush the sugar crystals with the bottom of the glass. You will be able to see small flashes of light coming from where the sugar crystals are crushed. Try this with a wintergreen lifesaver. Go to a dark room. Look in a mirror and bite on the lifesaver.

When pressure or friction is applied to a crystal, light is produced. This phenomena is called triboluminescence. Tribo is from the Greek work for friction. One theory is that crushing the crystal causes separation of positive and negative electrical charges. This is a piezoelectric effect (piezo meaning squeeze or press). The charges recombine forming a tiny lightning bolt. Scientists are looking for uses or applications of these phenomena.

Science is fun, fundamental and amazing, but always to remember to experiment carefully!

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