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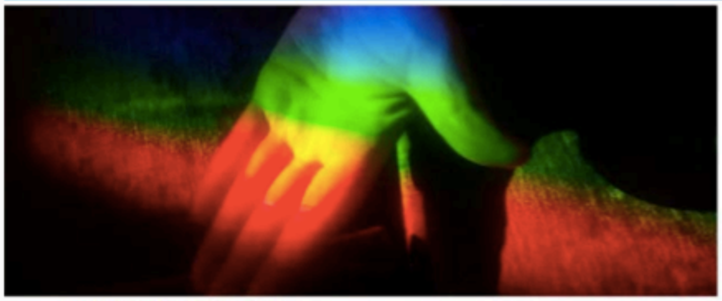

OPTICS MAGIC
with Judy & Nancy

#OpticsAtHome
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LET'S WONDER

Spooky Light: Fluorescence and Phosphorescence

WHAT ARE FLUORESCENCE AND PHOSPHORESCENCE? HOW DO THEY WORK?

MATERIALS

Activity 1 – Fluorescence

- An ultraviolet light. This can be a keychain UV-LED, or a UV-LED flashlight or a currency checker. A 405 nm violet laser pointer works too.
- Some materials to check: try laundry detergent, olive oil, soy sauce (or other fermented liquid), neon markers or even clothing, wet tea leaves, and tonic water- be creative!

Activity 2 – Phosphorescence

- The UV light from Activity 1
- A red LED light (laser pointer, keychain, finger light, etc). Other color LEDs can be used as well (including white)
- Glow in the dark material- a toy, stickers, paper, anything that continues to glow once light is removed

Where to find materials: Several internet stores sell UV flashlights, also called hand-held black lights. Hunters use these to track animals (urine is fluorescent!) so you may find them in a sporting goods store. They are also marketed as currency checkers and for curing nail gels. For serious study of fluorescent minerals you need a short wavelength and long wavelength UV light. Some minerals fluoresce under only shortwave length or long wavelength. The short wavelength lights are more expensive and not n ecessary for this activity. If you buy a laser pointer online be sure it is from a reputable source. Some internet stores sell laser pointers with power much higher than the legal limit. Red LEDs and laser pointers are also fairly easy to find on the internet. LED finger lights are very inexpensive and good for optics experiments that need different color lights.

Educational Innovations is a good source in the US for inexpensive science supplies, including a variety of phosphorescent (glow in the dark) materials. Dollar stores often have glow in the dark stickers.

SAFETY:

Inexpensive ultraviolet LED lights are usually 395 nm, barely into the UV range (usually given as 10 nm to 400 nm). Also, compared to sunlight the amount of UV they produce is miniscule. Nonetheless, it's not a good idea to stare into the light (or any light, for that matter). 365 nm flashlights are also within the UVA range but they produce much less visible light than 395 nm, so it's not evident that you are being exposed to UV. These should be used by children only with adult supervision. The Avon® Derma Spec lamp (290-320 nm) is in the UVB range. The lamp is quite dim however, and it shuts off after 12 seconds of use. Like the 365 nm light, these should not be used by children.

PARENT AND TEACHER NOTES:

The lesson begins by observing fluorescence and phosphorescence before explaining how they work. The long lifetime (or "metastable") energy state that explains phosphorescence is important for explaining how a laser works.

ACTIVITY 1 – FLUORESCENCE

Test the sample materials for fluorescence in a room that is fairly dark. If you cannot darken the room sufficiently, put the materials inside a deep box to shade them from as much light as possible. Shine the UV light on the materials and observe and record any differences in appearances when the light is on compared to when it is off. Does the glow last after the light is removed or does it stop immediately? If you have other color lights try shining them on the material. Does anything happen?

Visible light is produced when electrons in atoms are excited to a high-energy (*excited*) level and then return to a lower energy level. Electrons can be excited in a number of ways, for example, when an atom absorbs light or is subjected to a high voltage. In fluorescence a material is excited by light and gives off the extra energy quickly, usually as light of a longer wavelength (lower energy).

The ultraviolet light waves used in this exploration have higher frequency and higher energy than visible light. The rule is that the shorter the wavelength of light, the higher the photon energy. Fluorescent materials absorb the high-energy photons of UV light and give off less energetic photons of visible light. The fluorescent glow starts immediately when the light is turned on and stops as soon as the light is removed.

The light bulbs we call fluorescents work in the same way: UV light generated inside the lamp excites a special coating on the inner surface of the glass. The coating materials are chosen to provide the overall shade of white light desired- "warm white", "daylight", etc. by fluorescence.

Application: Besides energy efficient light bulbs, fluorescence has many applications in medicine, various sensors and the study of gems and minerals.

ACTIVITY 2 – PHOSPHORESCENCE

In a darkened room (it does not need to be completely dark), place the glow-in-the-dark material on a table. What do you think will happen if you shine each of the light sources you have on the material? (Lights can include a red laser or LED, the UV light, other color or white LEDs) Write down your predictions. Test your predictions by shining each of the lights onto the material. Record which lights make the material glow. How long does the material glow after the light is removed? Were there any surprises?

The photons of red light don't have enough energy to activate phosphorescence, but violet/UV photons do. Blue (and sometimes green) usually excites it as well, which is why white light works. Remember that in fluorescence electrons are excited to energy levels where they lose their energy almost immediately. That's why the glow stops when the light is turned off. But phosphorescent materials have energy levels where electrons can stay for a while before giving off the extra energy as light. That is, the material is still giving off light as electrons lose their extra energy even after the UV light is turned off. We call these long-lifetime states "metastable". They are essential for explaining how a laser works, too.

MORE WAYS TO PRODUCE LIGHT

- Chemiluminescence is light produced as a result of a chemical reaction. This is how light sticks work. Two chemicals are mixed together when the outer container is twisted, breaking the inner, thin-walled glass containers of chemicals. The color of the light depends on the chemicals used. You can demonstrate the effect of heat on the chemical reaction by breaking two glow sticks at the same time and putting one in hot water and one in ice water. The warmer one will glow brighter, but for a shorter time.

- Triboluminescence is produced by mechanical action – crushing, scratching or rubbing certain materials. Crushing sugar crystals can produce a tiny flash of UV light as electrical charges in the crystals are separated. If you crush a hard wintergreen flavored candy (for example, a Wint-o-Green Lifesaver®) the UV light produced by triboluminescence causes the wintergreen oil molecules to fluoresce. You can see this visible fluorescence by breaking the candy with pliers in a very dark room. What does the light emission look like? What color is it?

RESOURCES

A video of the lesson's activities is available on the pblprojects YouTube channel
https://youtu.be/Z6o8HB15ME4

All about UV flashlights, including safety:
https://www.waveformlighting.com/tech/everything-you-need-to-know-about-uv-flashlights