

Phosphor Glow Paper

P2-9423



BACKGROUND:

Objects that glow in the dark for an extended period after all sources of excitation are removed are said to be *phosphorescent*. For years, phosphorescent paint has been used to make the numerals and hands of mechanical alarm clocks visible in the dark. Phosphorescent tapes and paints are often used so that signs and markers may be seen in dimly illuminated locations. Nowadays, it is not unusual to see the cozy glow of phosphorescent stars and planets on the ceilings and walls of children's bedrooms. This phosphor glow paper will allow you and your students to explore the many aspects of phosphorescence.

THE PHYSICS OF PHOSPHORESCENCE:

Visible light is produced by either of two processes: incandescence or luminescence. Incandescent light sources are hot, like a standard light bulb filament; luminescent light sources are cool.

Examples of luminescent sources include fluorescent lamps, the fluorescent screens of TV tubes and computer monitors, and phosphorescent materials. Luminescent light sources are often preferred because they are more efficient, producing much less heat than incandescent sources. Luminescence may also result from bioluminescence (fireflies), chemiluminescence (chemical light sticks), and electroluminescence (television screens).

To understand the mechanism responsible for the production of light by luminescent sources one must examine the atom. When an atom absorbs light, an electron moves to a higher energy state. Conversely, when an electron transitions to a lower energy state, light may be emitted. Because atoms have discrete energy levels, the energy absorbed, or emitted, must equal the energy difference between some pair of energy levels. Thus light of only certain wavelengths can be absorbed by or emitted from a given atom.

Fluorescence occurs when the emitted light has a longer wavelength, and therefore less energy, than the light that caused the excitation. This happens when the atom returns to its lowest energy state in stages. Instead of returning to its ground state in one fell swoop, the atom drops via intermediate

excited states. This multiple-step decay process may result in a number of photons, or bundles of light, each with a fraction of the energy of the photon that was absorbed.

The fluorescent lamp uses this principle to produce white light. An electric current passes through a tube containing mercury atoms in the form of a vapor. After being excited by the electric current, the mercury atoms decay to their ground state and in the process emit strong ultraviolet light along with some visible light. The ultraviolet light, whose wavelength is too short to be seen by human eyes, is absorbed by phosphors that line the walls of the tube. These phosphors then “fluoresce,” re-radiating the absorbed energy as visible light.

When the time required for an atom to decay to a lower energy state is quite long, the emission of light is called phosphorescence. (What is meant by quite long? Well some definitions of phosphorescence require that the emission delay be only 10 nanoseconds (10^{-8} s)! However, when most people think of phosphorescence they think of an object glowing for minutes or even hours.)

EXPERIMENTS:

Shadow Formation

Materials: sheet of glow paper, camera flash or other bright light source

1. In a darkened room, place your hand on the photosensitive side of a sheet of glow paper.
2. Illuminate your hand and paper with a camera flash or other bright light. Notice the beautiful green glow after the light source ceases to shine on the paper. This is phosphorescence!
3. With the room lights still off, remove your hand and observe the shadow on the glow paper. Explain why a shadow is produced. Is the shadow sharp? That is, are the edges of the shadow clean or fuzzy? Explain your observation.
4. Keeping the distance between the light source and your hand constant, raise your hand approximately 25 cm above the surface of the paper and once again actuate the flash or other light source. Is a shadow of your hand formed this time? Describe the shadow. Is it as sharp as before or are there regions that are only partially darkened? A totally dark region is called the *umbra*. An area only partially shaded by your hand is referred to as the *penumbra*.
5. Find the relative positions of your hand, light source, and glow paper that produce sharpest shadows and those that produce blurriest shadows.

Stop Action Shadow Formation

Materials: sheet of glow paper, camera flash and small fan

1. In a darkened room, place a small fan between a sheet of glow paper and the flash unit.
2. With the fan blades spinning, actuate the flash. Examine the resulting shadow on the paper. Did the flash “freeze” the motion of the rotating blades?
3. Closely examine the shadow of a single fan blade. Does the blade’s shadow have an umbra? a penumbra? Why do you think a region of partial shadow exists?

Disappearing Shadows

Materials: a black light or bright white light source, sheet of glow paper

1. In a darkened room, place your hand or other object on the glow paper.
2. Illuminate the glow paper with the light source.
3. Remove your hand but do not turn off the light source. Watch the shadow closely. What do you observe? Explain your observation.

Absorbing Science

Materials: sheet of glow paper, bright light source, small colored filters (red, blue, green, cyan, magenta, yellow)

The glow paper produces a greenish light when it is phosphorescing. This means that if the light used to excite the phosphors is less energetic than green light, there will be insufficient energy to produce phosphorescence. That is, red light will not be able to “charge” the glow paper, but green and blue light will.

1. In a darkened room, place the six filters on the surface of the glow paper. It is not necessary that the filters completely cover the glow paper. On the other hand, the filters should not overlap.
2. Illuminate the filter-covered glow paper with bright light.
3. After the light is off, remove the six filters and examine the paper. Can you explain the regions of relative light and dark you see on the paper? It may help to remember that a yellow filter passes both red and green light, a cyan filter passes green and blue light, and a magenta filter passes both red and blue light.

FOR MORE EXPERIMENTS: ...and more information about phosphorescence, visit www.arborsci.com. Once you are there, use the search function to search for part # P2-9423. This will take you directly to Phosphor Glow Paper.

RELATED PRODUCTS:

Color Filters Kit (33-0190). Six 8" x 10" sheets of primary and secondary colors, complete with spectrum graphs and teacher's guide with experiments.

Portable Blacklight (P2-9035). Portable ultraviolet light source.

