A LIGHT OF A DIFFERNT COLOR

By Brian Rohrig

A piece of white cloth is placed underneath a strange-looking purplish light. It glows brilliantly. White powder placed underneath this same light emanates a brilliant radiance. A beaker of green fluid glows with a supernatural hue. Is this the stuff of science fiction? Hardly. The above phenomena are all a result of a special type of light known as a black light.

UV connection

The black light gets its name because it emits a type of light that you cannot see. Actually, most types of light, or electromagnetic radiation, are invisible to the naked eye (see figure opposite page). Our eyes can detect only a tiny sliver of the entire electromagnetic spectrum, appropriately referred to as the "visible" region. A black light gives off radiation in the form of ultraviolet (UV) light. Because most sources of UV light emit violet light along with the UV light, the luminosity given off by a black light source appears to be violet. However, the actual UV light that is emitted is invisible to the naked eye.

For convenience purposes, UV light is often divided into three categories: UVA, UVB, and UVC. A black light makes use of UVA radiation—the longest UV light wavelength and very close in frequency to visible violet light. Of the three types of UV light, UVA carries the least amount of energy per photon, small packets in which light carries its energy. UVA is thus considered the least harmful to humans. However, care should be taken never to look directly at a black light, because prolonged exposure can be harmful to the eyes.

Other types of UV light have shorter wavelengths and thus have higher frequencies. They carry more energy per photon and can cause greater harm to living things. UVB light is responsible for sunburns, which have been linked to skin cancer and eye damage. Tanning salons use primarily UVB radiation. UVC light is used to sterilize surfaces and medical instruments. Because these rays are so energetic, they can kill bacteria and viruses. Some schools sterilize safety goggles with special cabinets that use UVC radiation.

Fluorescence

Certain objects, when placed under a black light, appear different than under an ordinary white light. They may appear to be brighter or emit a completely different color altogether. Specialized pigments within these substances have the amazing ability to absorb energy of one wavelength and then reemit it as energy of a different wavelength. This absorption of UV light and emission as visible light is known as fluorescence.

In the simplest case where fluorescence occurs in atoms, a black light emits photons of energy that are absorbed by electrons of the atom. These electrons are initially in the ground state, which is the lowest possible energy level that the electrons can occupy. However, upon absorbing a photon of UV energy, these electrons jump up to a higher energy level. This higher energy level is known as the excited state. However, this excited state is extremely unstable and only temporary. The electrons quickly return to the ground state, but as they do, they "stop off" at intermediate energy levels. With each stop, they have a choice between dissipating their excess energy as heat or emitting a photon of light. Because the total energy they absorbed all at once is now being emitted in more than one step—or dissipated as heat—each emitted photon has only a fraction of the energy of the initial UV light that was emitted. These lower energy photons also have a lower frequency—in the visible region of the spectrum, not the UV region.

Most fluorescent objects actually contain fluorescent pigments that are complex molecular substances. Fluorescence in these molecules is a more complex process that involves both the vibration of the molecule and changes in the electronic configuration.

Because of fluorescence, substances often appear to be a different color under a black light. The wavelengths of the emitted black light may not correspond to the substance's color because the substance absorbs the light. The incident light from a black light is invisible to us, but a fluorescent pigment emits visible light. Thus, we see more light coming out of a fluorescent object than out of other nearby ordinary objects; hence, the glow. Because these electrons rapidly fall back to the ground state, once a black light is removed from a fluorescent object, the object instantly ceases to fluoresce.

A typical fluorescent lamp operates under this same principle; therefore, its name. The fluorescent lamp emits short-wave UV light, which is absorbed by white fluorescent powders known as phosphors, lining the inside of the fluorescent tube. As the UV light strikes these phosphors, it is emitted as the white,

When you crush a Wint-O-Green Lifesaver, it gives off a burst of blue light. You can see this demonstration of triboluminescence only if you first let your eyes adapt to a dark room.

visible light that you see. Without this phosphor coating, the lamp would emit harmful short-wave UV light.

Phosphorescence

A property closely related to fluorescence is that of phosphorescence, the property of "glowing in the dark". Phosphorescent substances continue to glow after a light source is removed, whereas fluorescent substances do not. Objects that glow in the dark do so because they contain molecules that have the ability to absorb energy quickly and then emit it slowly. This is because the excited electrons remain so for a period of time before gradually falling back to ground state. Once all of the electrons fall back to ground state, the substance ceases to glow. That is why objects that glow in the dark must be frequently "charged up" with an outside light source to reexcite the electrons. Glow-in-the-dark objects appear brilliant under black light, because UV light is more than sufficient to excite these substances.

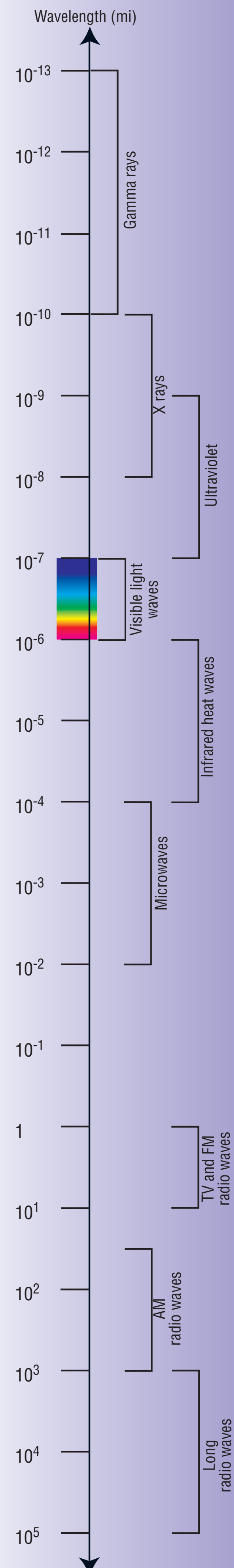
Triboluminescence

Another closely related phenomenon is triboluminescence. To demonstrate triboluminescence, go to a completely dark room with a Wint-O-Green Lifesaver and a pair of pliers. If you crush the Lifesaver with the pliers, it will give off sparks of bluish light, which is a result of breaking the sugar crystals in the candies. The crystals tend to break along planes containing positive charges on one side and negative charges on the other. These negative charges result from excess electrons, and the positive charges, from a deficiency of electrons. When a crystal is broken, the negative charges try to bridge this gap between the two planes. These electrons primarily emit energy in the form of UV light. Because Lifesavers are fluorescent, they have the ability to absorb this UV light and emit it as visible light. Thus, the light you see when a Wint-O-Green Lifesaver is crushed is primarily this absorbed UV light—emitted as visible light.

Fluorescent uses

Many household substances will fluoresce brilliantly when placed under a black light. There are fluorescent markers, paints, and crayons. Most white copy paper is fluorescent. Many stamps, stickers, and labels glow beautifully under a black light. Black light-sensitive posters, jewelry, and clothing are available in specialty shops. You can even buy fluorescent toothpaste, shampoo, lipstick, and fingernail polish. If you go to an amusement park, you will likely get your hand marked with a fluorescent stamp, barely visible to the naked eye yet highly visible under a black light. The newly designed U.S. paper currency contains anti-counterfeiting strips that are only visible under a black light.

Fluorescence is used to make new and old clothes appear brighter. Most laundry detergents—liquid and powder—fluoresce very brightly because of fluorescers that are added to them, comprising up to 1% of the total formulation. This is how laundry detergent advertisements can truthfully promise to get your clothes "whiter than white". Although new clothing is manufactured with the fluorescers already intact, the concentration decreases with washing and wearing. Washing with detergents will restore these



The electromagnetic spectrum is composed of electromagnetic radiation over a wide range of wavelengths. The visible and near-visible UV spectrums are only a small fraction of the entire spectrum.

When placed under a black light, hands covered in Glo Germ oil glow a brilliant orange.

Using plenty of soap and a scrub brush—hands are washed.

After being washed, they are placed under a black light again.

It is evident where they were not washed properly—most commonly missed areas are around the fingernails and between the fingers.

fluorescers. Because all clothing contains residual detergent, some types of clothing may appear to be especially brilliant in bright sunshine, which is more than 10% UV light.

Many liquids are also fluorescent. Antifreeze appears bright green under a black light, and quinine, found in tonic water, is highly fluorescent. Pouring the tonic water under a black light can create an interesting effect. If salt is added to the tonic water, its fluorescence will decrease, because the chloride ion will react with the quinine molecule to reduce the movement of its electrons between levels. Its ability to release energy as light, rather than heat, will be reduced. One can say that the fluorescence will be "quenched".

Fluorescence in the workplace

Substances exhibiting fluorescence under a black light have many practical uses. For example, a solution of fluorescein, one of the most highly fluorescent substances in the world, can be used to detect a scratch on the cornea of the eye. A few drops of a very dilute solution are placed in the eye, and when viewed under a black light, this highly fluorescent substance will adhere to a scratch on the cornea, making it easier to see.

Forensic scientists often use black lights at a crime scene to test for evidence of a crime. Many types of bodily fluids are highly fluorescent. Semen, for example, can be detected under a black light, which may help determine whether a rape has taken place. The cleanliness of restroom facilities can also be checked with a black light, because urine contains highly fluorescent compounds (see How Well Do You Wash Your Hands?).

Fluorescence is an important tool that geologists use in mineral identification. Many minerals that appear unimpressive under ordinary white light exhibit spectacular displays of color under UV light. Some common fluorescent minerals are fluorite, quartz, sodalite, and willemite.

Experiment with other household products, and you will be amazed at the many substances all around you that display vivid fluorescence under black light.

How Well Do You Wash Your Hands?

A commercially available substance, known as Glo Germ, is an excellent example of a practical use of black light. It is available in liquid form as a bright orange, oil-based substance. A small amount is squirted on the hands and then rubbed around thoroughly. When placed under a black light, the hands glow a brilliant orange. After washing, the hands are again placed under a black light, and it is evident where they were not washed properly. The hands are then scrubbed again until all traces of the Glo Germ are no longer visible under the black light. The most commonly missed areas are around the fingernails, the forearms, and between the fingers. Medical personnel are often trained in proper handwashing technique using this method.

Glo Germ is also available as a white powder. Under a black light, the powder is highly fluorescent. A small amount of powder is placed on the hands, and everything the hands touch is likewise contaminated. It is easy to see how "germs" can be so easily transmitted. Just one student with the Glo Germ powder on his or her hands can "infect" an entire class by shaking hands with another student who, in turn, passes the Glo Germ onto someone else.

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