Things That Glow In The Dark

Classroom Activities That Explore Spectra and Fluorescence

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Special Guest: Dr. Rusty Lansford, Senior Scientist and Instructor, Caltech

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Exploring Spectra

(by Paul Doherty and Linda Shore)

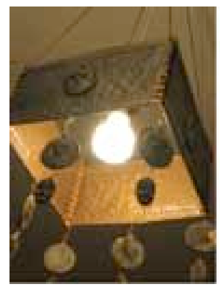
Using a spectrometer

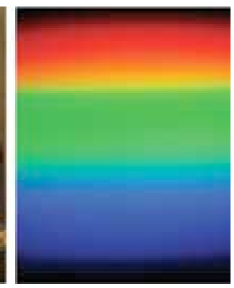
The project Star spectrometer can be used to look at the spectra of many different sources. It is available from Learning Technologies, for under $20. Learning Technologies, Inc., 59 Walden St., Cambridge, MA 02140

You can also build your own spectroscope.
http://www.exo.net/~pauld/activities/CDspectrometer/cdspectrometer.html

Incandescent light

An incandescent light has a continuous spectrum with all visible colors present. There are no bright lines and no dark lines in the spectrum. This is one of the most important spectra, a blackbody spectrum emitted by a hot object. The blackbody spectrum is a function of temperature, cooler objects emit redder light, hotter objects white or even bluish light.





Fluorescent light

The spectrum of a fluorescent light has bright lines and a continuous spectrum. The bright lines come from mercury gas inside the tube while the continuous spectrum comes from the phosphor coating lining the interior of the tube.

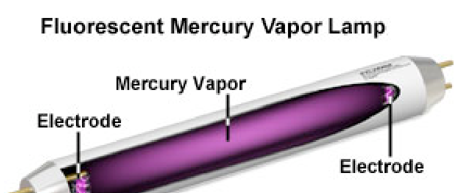
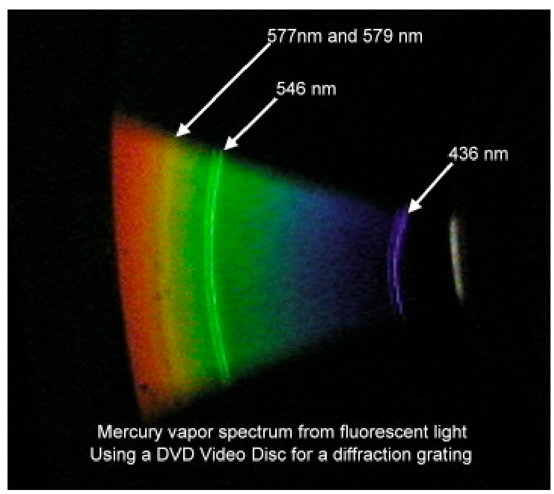
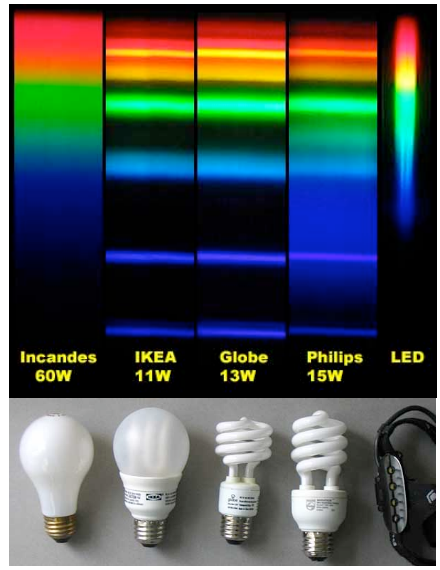


Figure 5



Mercury vapor spectrum from fluorescent light
Using a DVD Video Disc for a diffraction grating

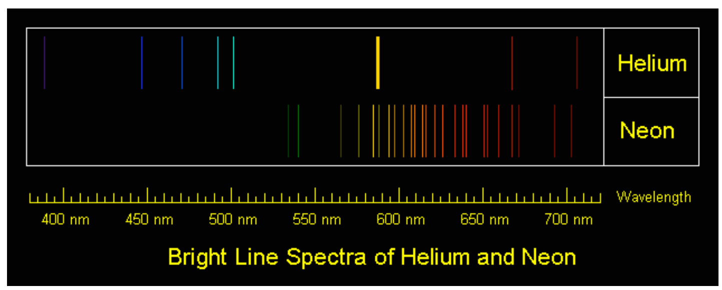
CLF Light



There is a new kind of fluorescent called a CFL (compact fluorescent lamp). These are highly energy efficient light bulbs that are replacing the more energy wasting incandescent bulbs (that generate lots of heat). In the photo to the right, the three CFL are the Ikea, Globe, and Philips bulbs.

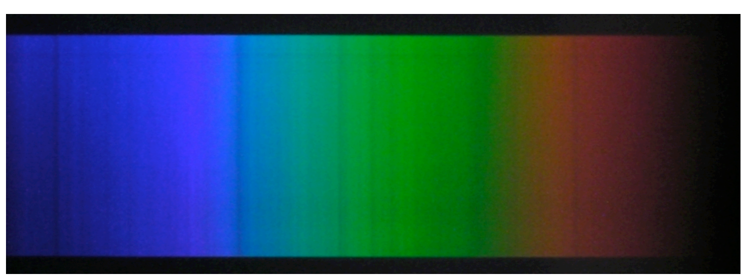
There are two main parts in a CFL: the gas-filled tube and the electrical ballast. Electrical current from the ballast flows through the gas, causing excited electrons to emit ultraviolet light. The ultraviolet light then excites a white phosphor coating on the inside of the tube. This luminescent coating emits visible light as the ultraviolet light energy absorbed is released.

Neon light



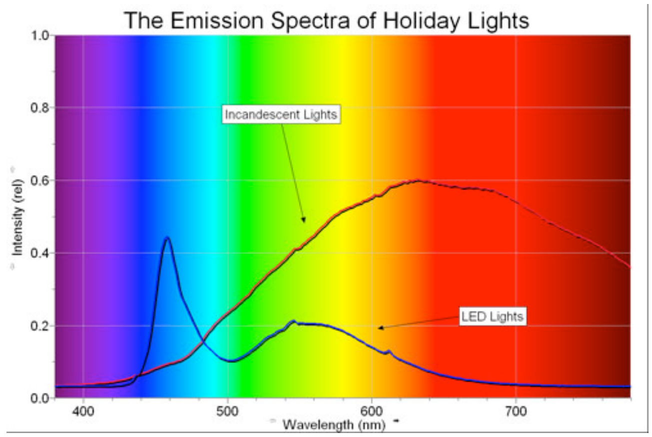
The simplest source of a neon light is a night light which says 1/4 watt on the package. These night lights have neon lights inside them. You can also find neon lights in the windows of businesses. Warning: even though they are called neon lights the lights do not necessarily contain neon gas. Some contain argon or other gasses to produce different colors. *The red ones contain neon*. The spectrum of the neon light has several bright lines. The red lines are very bright. The line used by helium neon lasers, 632.8 nm wavelength, does not appear in the spectrum of a neon tube. It is too dim relative to the other lines. The lines of light are produced when electrons in an excited state decays into a lower energy state. The change in energy of the electron between these two states is precise and results in the emission of light with a narrow range of energies, a spectral line.

Sunlight – NEVER LOOK DIRECTLY AT THE SUN! Even with a spectrometer!



Look indirectly at sunlight by looking at a white surface in the sun. White paper works well. The solar spectrum is a continuous spectrum of an incandescent gas. Look closely and you will see fine dark lines crossing the solar spectrum. These fine lines are Fraunhofer lines. The dark lines are produced by gas above the surface of the sun that absorbs some of the incandescent light from the sun below. Each of these lines is produced by one atom or ion. However several lines may be produced by one atom. Two lines close together in the yellow are a famous pair of sodium lines.

Light emitting diodes, LEDs



These come in many colors from red, orange, yellow and green to blue. In light emitting diodes electrons in a higher energy conduction band drop into holes in a lower energy band. The energy lost by the electrons is emitted as light. Thus there is usually one brightest color of light that appears as a line in the spectrum of the LED. In addition to the bright line there is usually also a dimmer, continuous emission of lower energy light. This lower energy light is produced when electrons decay to or from impurity states between the main energy bands. In a solid the well-defined energy states of electrons that would appear in atoms of a gas are spread into energy bands.

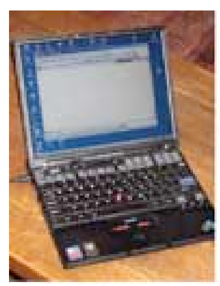
Street lights

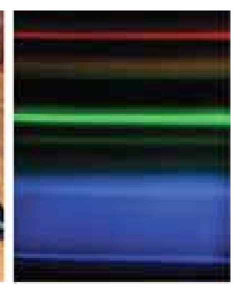
Mercury Vapor Looks bluish; has many bright lines of mercury. Looks similar to the spectrum of fluorescents.

Low Pressure sodium Looks orange; has narrow yellow lines of sodium vapor.

High pressure sodium Looks yellow; has broad bands of light.

Computer Screen





Look at a white screen on a computer. Notice the bright spectral emission bands. Compare the spectral bands on a liquid crystal display screen to those on a cathode ray tube display.

Using Just Diffraction Grating

You can also look at lights through a diffraction grating without using a spectrometer. Just hold the grating in front of your eyes and look through it at a light. This only works for lights which appear to be small points of light or narrow lines of light that line up with the lines in the diffraction grating. The diffraction grating spreads the light right and left when its lines are vertical. So look at a vertical line of light with the diffraction grating lines also vertical, i.e. the spectrum to the right and left. Look at horizontal lines with the diffraction grating horizontal, i.e. with the spectra above and below the light. Place the diffraction grating in a plastic page protector to protect it from scratches and fingerprints.

Candle Flame

A candle across the room works well. You will see the continuous spectrum of the incandescent carbon particles in the flame.

Stars

Few stars are bright enough to trigger the color sensitive cones of your eyes. However those that are such as Sirius in the winter and Vega in the summer will have a continuous incandescent spectrum. If you look at stars through a telescope you will gather more light and be able to see their colors better. Hold the diffraction grating in front of a small telescope or behind the eyepiece of a large one.

Lightning

Lightning usually makes bright vertical lines. So hold the lines of the diffraction grating vertical to spread the spectra to the sides. Look at lightning and you will see the continuous spectrum from hot incandescent gas plus spectral lines from excited atmospheric gasses.

Lasers

Never shine a laser beam into your eye! However, you can project a laser dot on a wall and look at the dot through a diffraction grating. You will see just one dot of light spread to either side of the original dot representing the single color of light produced by the laser. You can also shine the laser through the diffraction grating at a distant white screen or wall. Once again a single dot of light will be diffracted to each side. Each single dot represents the single color produced by the laser.

Luminescence
From http://www.uvminerals.org/luminese.htm

Light is a form of energy. To create light, another form of energy must be supplied. There are two common ways for this to occur, incandescence and luminescence.

Incandescence is light from heat energy. If you heat something to a high enough temperature, it will begin to glow. When an electric stove's heater or metal in a flame begin to glow "red hot", that is incandescence. When the tungsten filament of an ordinary incandescent light bulb is heated still hotter, it glows brightly "white hot" by the same means. The sun and stars glow by incandescence.

Luminescence is "cold light", light from other sources of energy, which can take place at normal and lower temperatures. In luminescence, some energy source kicks an electron of an atom out of its "ground" (lowest-energy) state into an "excited" (higher-energy) state; then the electron gives back the energy in the form of light so it can fall back to its "ground" state.

If you lift a rock, your muscles are supplying energy to raise the rock to a higher-energy position. If you then drop the rock, the energy you supplied is released, some of it in the form of sound, as it drops back to its original low-energy position. It is somewhat the same with luminescence, with electrical attraction replacing gravity, the atomic nucleus replacing the earth, an electron replacing the rock, and light replacing the sound.

There are several varieties of luminescence, each named according to what the source of energy is, or what the trigger for the luminescence is.

Fluorescence and **Photoluminescence** are luminescence where the energy is supplied by electromagnetic radiation (rays such as light, which will be discussed later); photoluminescence is generally taken to mean luminesce from any electromagnetic radiation, while fluorescence is often used only for luminescence caused by ultraviolet, although it may be used for other photoluminescences also. Fluorescence is seen in fluorescent lights, amusement park and movie special effects, the redness of rubies in sunlight, "day-glo" or "neon" colors, and in emission nebulae seen with telescopes in the night sky. Bleaches enhance their whitening power with a white fluorescent material.

Photoluminescence should not be confused with reflection, refraction, or scattering of light, which cause most of the colors you see in daylight or bright artificial lighting. Photoluminescence is distinguished in that the light is absorbed for a significant time, and generally produces light of a frequency that is lower than, but otherwise independent of, the frequency of the absorbed light.

Chemiluminescence is luminescence where the energy is supplied by chemical reactions. Those glow-in-the-dark plastic tubes sold in amusement parks are examples of chemiluminescence.

Bioluminescence is luminescence caused by chemical reactions in living things; it is a form of chemiluminescence. Fireflies glow by bioluminescence.

Electroluminescence is luminescence caused by electric current. **Cathodoluminescence** is electroluminescence caused by electron beams; this is how television pictures are formed. Other examples of electroluminescence are neon lights, the auroras, and lightning flashes. This should not be mistaken for what occurs with the ordinary incandescent electric lights, in which the electricity is used to produce heat, and it is the heat that in turn produces light.

Radioluminescence is luminescence caused by nuclear radiation. Older glow-in-the-dark clock dials often used a paint with a radioactive material (typically a radium compound) and a radioluminescent material. The term may be used to refer to luminescence caused by X-rays, also called photoluminescence.

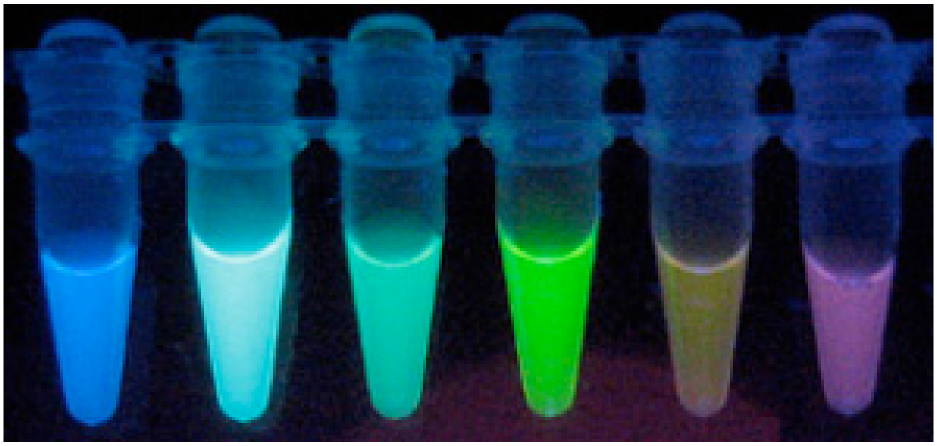
Phosphorescence is delayed luminescence or "afterglow". When an electron is kicked into a high-energy state, it may get trapped there for some time (as if you lifted that rock, then set it on a table). In some cases, the electrons escape the trap in time; in other cases they remain trapped until some trigger gets them unstuck (like the rock will remain on the table until something bumps it). Many glow-in-the-dark products, especially toys for children, involve substances that receive energy from light, and emit the energy again as light later.

Triboluminescence is phosphorescence that is triggered by mechanical action or electroluminescence excited by electricity generated by mechanical action. Some minerals glow when hit or scratched, as you can see by banging two quartz pebbles together in the dark.

Thermoluminescence is phosphorescence triggered by temperatures above a certain point. This should not be confused with incandescence, which occurs at higher temperatures; in thermoluminescence, heat is not the primary source of the energy, only the trigger for the release of energy that originally came from another source. It may be that all phosphorescences have a minimum temperature; but many have a minimum triggering temperature below normal temperatures and are not normally thought of as thermoluminescences.

Optically stimulated luminescence is phosphorescence triggered by visible light or infrared. In this case red or infrared light is only a trigger for release of previously stored energy.

Photograph taken from purified fluorescent proteins excited by ultraviolet light.



From left to right; blue fluorescent protein (BFP), cyan fluorescent protein (CFP), green fluorescent protein (GFP), yellow fluorescent protein (YFP), monomeric Kushibara Orange (mKO) and mCherry. mKO from Kawasara et al. (2004), mCherry from Shaner et al. (2004).