Light − A Tool to Study Atoms

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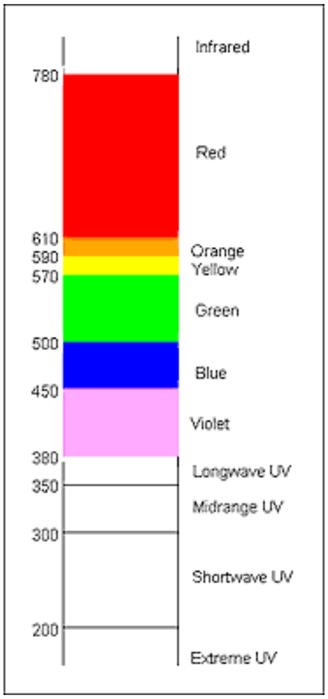


You may find it more beneficial to view this diagram on your computer where it will be in color.

Just what is Light?

Visible light is a form of electromagnetic radiation, EMR. Other forms of electromagnetic radiation are like light in many ways; they are just at different wavelengths that the human eye cannot see. Since wavelength is what makes the difference between colors in visible light, you might say other wavelengths of electromagnetic radiations are "invisible colors of light". Radio, infrared, visible light, ultraviolet, X-rays, and gamma rays are all forms of electromagnetic radiation.

Chemists use light, in all of its many forms as a tool to poke and probe atoms to learn more about the structure and arrangements of protons and electrons.

The Dual Nature of Light – Is it a wave or is it a particle?

Physics experiments over the past hundred years or so have demonstrated that light has a dual nature. In many instances, it is appropriate to represent light as a "particle," thinking of light as discrete "packets" of energy that we call photons. Now in this way of thinking, not all photons are created equal, at least in terms of how much energy they contain. Each photon of X-ray light contains a lot of energy in comparison with a visible or radio photon. It is this "energy content per photon" that is one of the distinguishing characteristics of the different "types" of light described above. Even though it is not strictly correct, you can think of a beam of light as a collection of little "light bullets" all strung together in a row.

The other way of representing light is as a wave. This is somewhat more difficult for most people to understand, but perhaps an analogy with sound waves will be useful. When you play a high note and a low note on the piano, they both produce sound, but the main thing that is different between the two notes is the frequency of the vibrating string producing the sound waves − the faster the vibration the higher the pitch of the note. If we now shift our focus to the sound waves themselves instead of the vibrating string, we would find that the higher pitched notes have shorter wavelengths, or distances between each successive wave. Likewise (and restricting ourselves to optical light for the moment), blue light and red light are both just light, but the blue light has a higher frequency of vibration (or a shorter wavelength) than the red light.

Two Ways to Create Light

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 that is emitted from from thermal radiation (heat energy). If you heat something to a high enough temperature, it will begin to glow is it radiates visible light. When you stuck a paperclip in the Bunsen burner, the metal became hot enough to begin to glow "red hot," that is incandescence. The tungsten filament of an "old fashioned" incandescent light bulb is heated very hot, the filament glows brightly "white hot" by the same means, as you constructed in NE&E. A flame is nothing more than hot glowing gases. The sun and stars glow by incandescence because nuclear fusion generates heat which causes the ball of gas to radiate light.

Luminescence is "cold light", light from energy *other* than heat, 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 as the electron gives back the energy in the form of light, the electron falls back to its "ground" state. Thus luminescence is the energy caused by the movement of electrons.

Varieties of Luminescence

There are several varieties of luminescence, each named according to what the source of energy is, or what the trigger for the luminescence is. You can read about other types of luminescence on the other side of this note sheet.

Fluorescence is one type of luminescence in which the trigger-energy is supplied by ultraviolet light. Inside fluorescent bulbs, mercury vapor generates ultraviolet light (UV) which strikes the white coating of the tube causing luminescence. Improved phosphor coatings in the past twenty years have made fluorescent lights give off a more "natural" white light. Part of the light in natural sunlight is UV. Also UV can be generated by a "black light" or UV lights. Certain substances absorb UV and re-emit the energy as visible light, such as the bright colors emitted by the "day-glo" or "neon-bright" colors of certain paints or fabrics

Are those laundry whites really any whiter?

Laundry detergents enhance their whitening power with an additive chemical. The laundry additives are chemicals that absorb ultraviolet light (present in sunlight and many indoor lighting fixtures as well) and emit the energy back out as visible blue light. This blue light masks any yellowing of the cloth due to age, and makes the cloth seem brighter and whiter than it would otherwise naturally appear to the eye. Your clothes are not really any cleaner than they would be if you used a detergent without brightening agents, but they *appear* to be cleaner when using a detergent with whitening agents.

The Varieties of Luminescence – Describing the trigger that causes the luminescence.

<u>Chemiluminescence</u> is luminescence in which the energy is supplied by chemical reactions. Those glow-in-the-dark plastic tubes that you snap to activate are examples of chemiluminescence.

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

<u>Electroluminescence</u> is luminescence caused by electric current or electron beams; this is how tubed-television pictures are formed. (As shown below, perhaps you've seen them in old movies!) Other examples of electroluminescence are the spectral tubes we looked at in class, "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.

<u>Radioluminescence</u> is luminescence caused by nuclear radiation. Older glow-in-the-dark clock dials often used 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.

<u>Phosphorescence</u> 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" after some time passes; 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 when the light source is gone, thus "glow in the dark".

<u>Triboluminescence</u> 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. Or hammering wint-o-green lifesavers. Try it: get some wintogreen lifesavers and head to the basement at night with a hammer. Wait a few moments in the dark so your eyes "dark–adapt" and you'll get a better view – then kneel down on the floor so you can see sideways under the hammer as you gently tap the lifesavers into powder – You'll get a brief greenish flash.

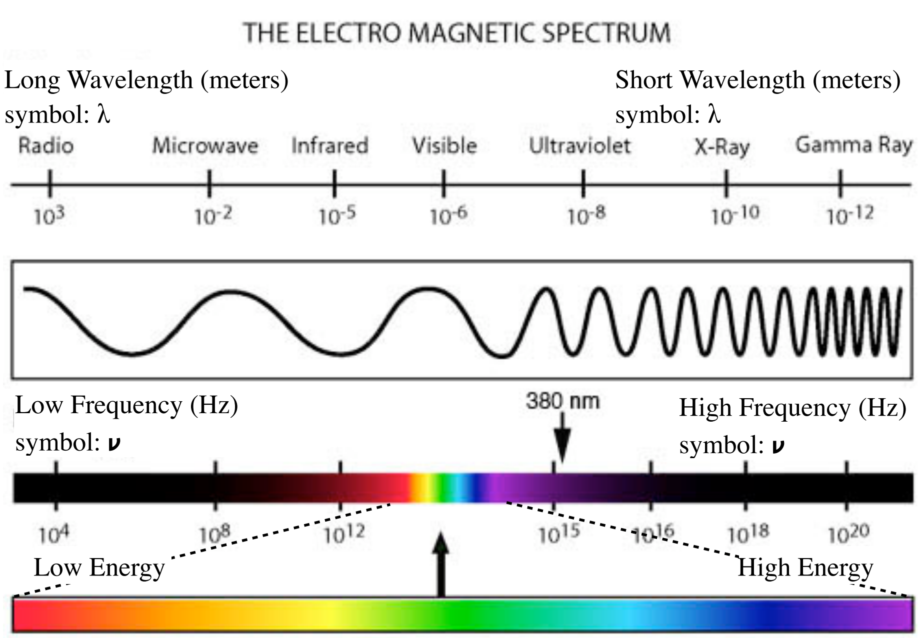
A wee bit more about UV light

Ultraviolet is closest to and just shorter than purple visible light in wavelength. Ultraviolet can be subdivided according to wavelength.

Shorter wavelengths of UV cause sunburn and is mostly stopped by clear glass, which is why you can't get sunburned through your car windshield, only with your arm out the window.

Still shorter wavelength UV (higher energy) is stopped in the upper atmosphere of the earth by the ozone layer. This is important because this high energy light would be very damaging to both our skin and eyes.

Even more extreme ultraviolet is also emitted by the sun, but is completely stopped in the upper atmosphere. In fact it is this extreme UV that actually forms the ozone layer by causing the atmosphere's oxygen to convert from O_2 to O_3. It is this resulting high ozone layer that stops some of the sun's UV light as described in the previous paragraph.



Old TV's were very big because the technology was not the same as today's flat screens