THE HYDROGEN-ATOM SPECTRUM

Another piece of strange behavior observed at about the same time is the so-called "line spectrum" of the hydrogen atom. You are already familiar with the fact that a prism can be used to **disperse** (separate) the colors of **white light** (like light from the sun or a light bulb) into its component colors: Red, Orange, Yellow, Green, Blue, Indigo and Violet (**ROYGBIV**). The rainbow that results from dispersion by a prism is called the **spectrum** of the sun.

We know that our sun is made up of many elements, everything, in fact, from hydrogen (most abundant) to Iron (0.003% of all atoms in the sun). Although sunlight consists of more of some colors and less of others, we refer to its light as **white light** because it contains all colors visible to humans. However, if we look at the emission spectrum of only hot, glowing hydrogen gas (e.g. by putting H_2 gas in a fluorescent bulb), dispersing it with a prism in just the same way, we see a completely different result (figure below). Now instead of a rainbow, we see only four distinct "lines" or "bands" of colored light with nothing in between - thus the term "line spectrum."

The two spectra below show absorption by and emission from an ensemble of hydrogen atoms.

In the top panel, we see that when white light is shined on a sample of hydrogen gas, the H absorbs certain **discrete** wavelengths of light, leaving the rest to pass through the prism and be dispersed into colors. The black bands represent missing light - light that has been absorbed by the hydrogen.

In the lower panel, Hydrogen gas has been **excited** with electricity in a kind of fluorescent tube, and passed through the prism. The light emanating from the excited hydrogen atoms consists of only four discrete color bands, red, cyan, blue and violet. The wavelengths of the colors are given (in nanometers), and form a characteristic *fingerprint* of Hydrogen.

The actual emission spectrum of the sun (and anything else) is also really a line spectrum, but because there are so many different types of atoms in the sun, and because all have much more dense and complex line spectra than H(which is the simplest atom) they overlap and blur together to give our familiar rainbow.

The color spectra of different stars are different because each star has a unique composition.

What does this mean? There is really only one explanation for the existence of line spectra.

Think about emission: In order to maintain the **law of conservation of energy**, if an electron in an atom is to "relax" from a state of higher kinetic energy (the energy of motion) to a lower one, it must get rid of that energy somehow. It does so by **radiating** that energy away, usually in the form of one particular color of visible light. If the electrons in an atom could have any kinetic energy at all, we would expect a continuous spectrum - a rainbow. That we see a *discrete* spectrum is evidence that electrons can't just have any energy. They can only take on **discrete energies**, with nothing in between.

Energy Levels of Hydrogen

The diagram below explains the H-atom emission spectrum. It contains a bit more information than you need right now, but just concentrate on the middle set of arrows that goes with the visible emission spectrum (hydrogen also has emission lines in the invisible infrared and ultraviolet regions of the spectrum).

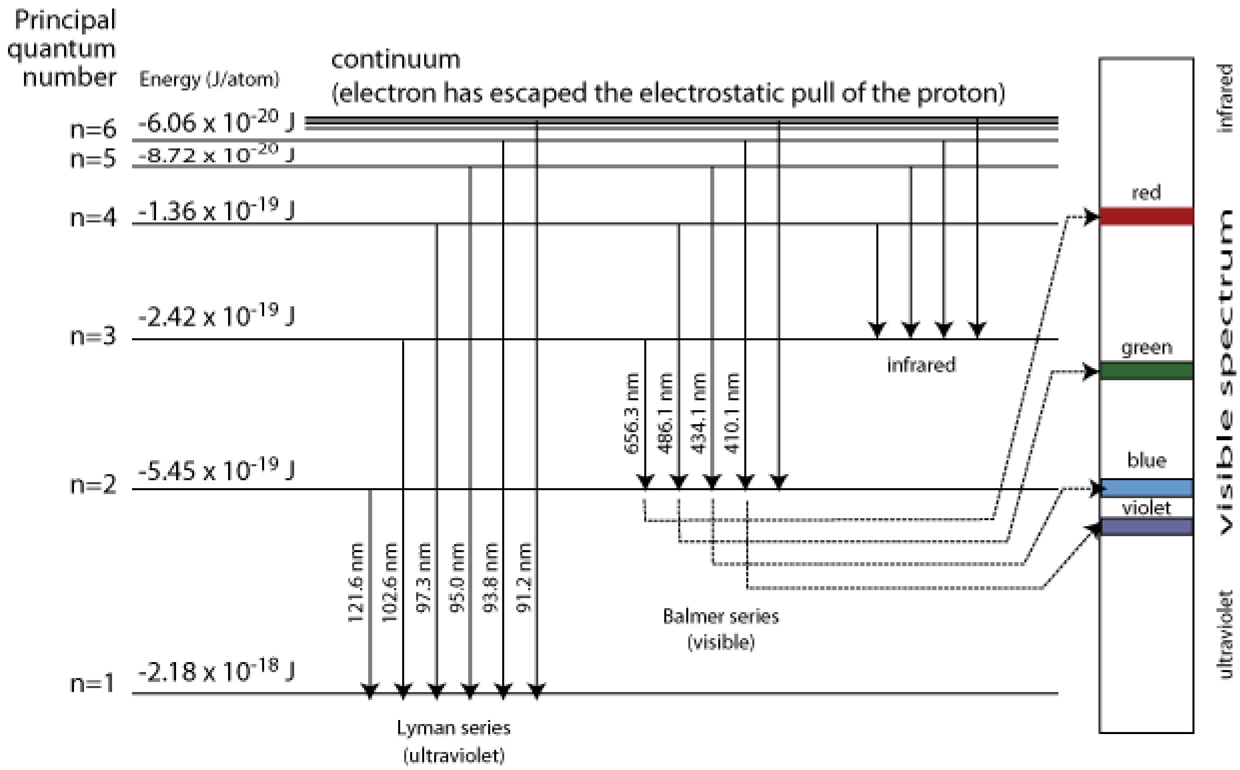
We assume that electricity excites the electron in an H atom to one of the "**excited states**" - higher energy levels than the **ground state** or lowest energy level.

When those excited electrons **relax**, they **emit** light that exactly equals the difference between the two energy levels that define the **transition**.

This must be so because energy must be conserved — neither created out of nothing, nor destroyed. You can see that the visible line spectrum represents transitions from excited states to the second-highest energy level. The spectra of larger atoms are proportionally more complicated.

The absorption spectrum is just the reverse. The electron in a ground-state hydrogen atom absorbs certain energies of light in order to achieve an excited state.

The idea that the energies of electrons in atoms are discrete and not continuous is another example of the non-classical (not like objects we're used to seeing) and unexpected behavior of electrons that begged for a non-classical explanation.



Analogy: Pick any two speeds of a thrown baseball, like 60 mph and 80 mph. The same baseball could be throwin with an infinite variety of speeds in between 60 and 80 mph. In fact, give me two speeds and I can find one in between. 68.005 mph is between 68.01 and 68.02 mph, and so on. Because speed is proportional to kinetic energy (KE = $^1/_2$ mv^2), we say that a baseball can have a **continuum** of kenetic energies.

This just isn't true for electrons bound to atoms. There is no more continuum. Electrons can have one energy or another, but no energy in between. Electrons in atoms can have only **discrete** levels of kinetic energy.

Source: http://www.drcruzan.com/Chemistry_Electrons.html