Atomic Spectra

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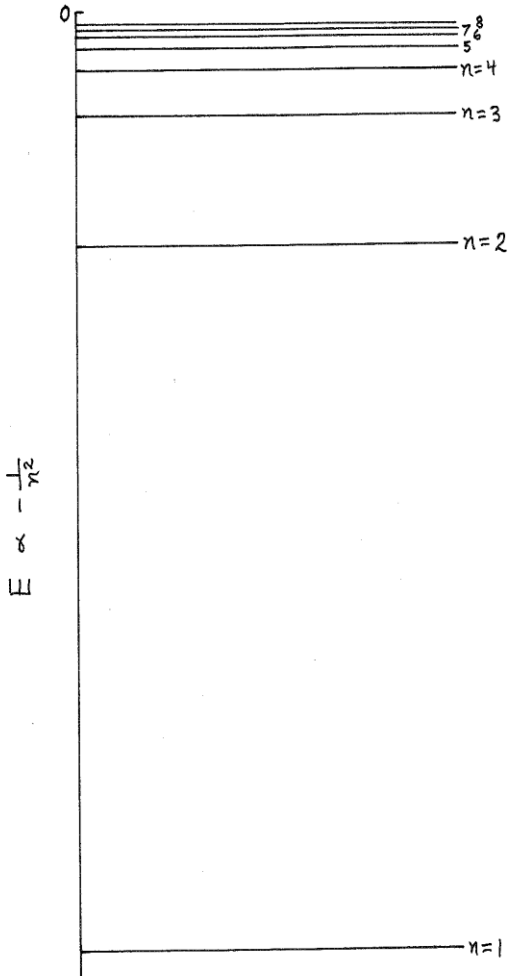
Introduction
When electricity passes through a tungsten wire in an incandescent light bulb, the light output is essentially a smooth continuous spectrum, as seen in Figures 8-7 and 8-11 in Petrucci *et al.* [1] or in the first figure at https://en.wikipedia.org/wiki/Black-body_radiation. But when electromagnetic radiation is absorbed or emitted by individual atoms, a discontinuous spectrum is observed as seen in Figures 8-9 and 8-10 in Petrucci *et al.* or at http://www2.ifa.hawaii.edu/newsletters/article.cfm?a=517. These discontinuous spectra are called atomic spectra. Since the original recording of these spectra were done on photographic plates, scientists saw a series of lines, and so these spectra are also called line spectra. These line spectra are the most direct evidence for the quantization of energy in atoms.[2]

The only way to explain line spectra is to assume that only certain energy levels are available to electrons in an atom. In the case of a hydrogen atom, we have the following diagram according to the Bohr model.



In the ground state, hydrogen's one electron is in the n=1 energy level. There are an infinite number of excited states, where the electron can be in the n=2 energy level or n=3 energy level or any higher level.

Hydrogen in the elemental state exists as a diatomic molecule. But if we put a low pressure of hydrogen gas into an evacuated tube and pass a current through the gas, the molecules break into atoms, and the presence of the electric current excites the electrons into a variety of excited states. The electrons in the excited states relax to lower energy levels, giving off electromagnetic radiation. Eventually the electrons will fall to the ground state, but the process may occur in only one step or it may take many steps. In the laboratory we will just be observing the steps, or transitions, which give off light in the visible spectrum, but ultraviolet and infrared radiation are also given off as electrons fall to lower energy levels. The line spectra that we observe are unique for each element.

Another method to obtain electrons of atoms in excited states is by flame tests. Typically we put a compound containing a metal cation into a flame. Heat from the flame breaks down the compound, producing gaseous metal atoms with at least one electron in an excited state. Electrons in excited states relax to lower energy levels, eventually reaching the ground state which is the lowest possible energy level. These energy transitions are unique to each element.

Experimental

I. Arc emission using arc lamps filled with pure H_2 or pure He or pure Ne or pure Ar or pure Hg
Caution: The H_2 arc lamp can be on no longer than 30 seconds and then it must be off for at least 30 seconds. The other arc lamps should be turned off when not being used.

1. Observe and record the colors of the gases in each of the arc lamps.

2. Observe each lamp through the spectroscope provided. Hold the spectroscope flat and place you eye near the small rectangle on the narrow end of the spectroscope. Point the spectroscope so that the narrow slit on the wide end is pointing directly toward the lamp. On the inside of the box, you should see numbers which are shorthand for 400, 500, 600, and 700 nm. While holding the spectroscope steady, move your head slightly to the left until you see lines of color which are the line spectra. Record the view with colored lines and numbers for the hydrogen arc lamp and one other gas.

II. Flame emission for aqueous solutions of LiCl, NaCl, KCl, $CaCl_2$, and $CuCl_2$

1. Dip a clean cotton tip applicator swab into one of the solutions listed. Put the wet tip into the flame of a Bunsen burner. (Avoid burning the wooden shaft.) Observe the color of the flame and record.

2. With help of a classmate, try using a spectroscope and see if you can observe the line spectra for any of the metals. If so, note which metal allowed you to see a line spectra. You probably will not be able to detect line spectra for most of these solutions since the arc lamps provide a more consistent source of excited atoms and therefore a higher intensity.

References:

1. Petrucci, R. H.; Harwood, W. S.; Herring, F. G.; and Madura, J. D. *General Chemistry: Principles and Modern Applications*, 9th ed.; Pearson Prentice Hall: Upper Saddle River, NJ, 2007, 283-285 or
Petrucci, R. H.; Herring, F. G.; Madura, J. D.; and Bissonnette, C. *General Chemistry: Principles and Modern Applications*, 10th ed.; Pearson Canada: Toronto, Ontario, 2011, 300-302.

2. Atkins, P. W. *Physical Chemistry*, 5th ed.; W. H. Freeman & Co., New York, 1994, 360-365.