SPECTRAL LINES

(L-10)

Consider the following: You wish to take helium atoms and line them up, row upon row, layer upon layer, until you have a cube one centimeter on a side. To do this, it would take 1,000,000,000,000,000,000,000,000 atoms.

I bring this up for two reasons. First, I want to highlight how incredibly small atoms are. Second, I want to pose a question.

The question? How do we know anything at all about something as small as an atom?

Answer: There are several ways, one of which you are about to experience.

Part A: (background)

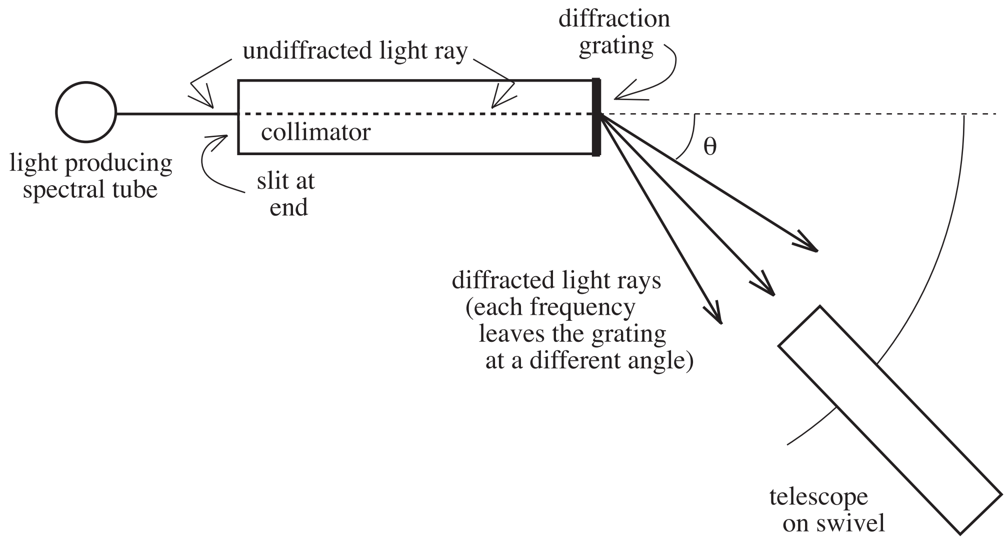
a.) We will be using what are called *spectral tubes* (sometimes called *discharge tubes*) in this lab. A spectral tube is a glass tube in which gas of a particular type is trapped.

b.) We will motivate each spectral tube to glow by passing high-speed electrons through the gas. As the electrons collide with individual gas molecules, the molecules will absorb the energy of collision by throwing one of their own valence electrons into a higher energy orbital (that is, the molecules will *excite*). Once excited, the molecules will then de-excite by cascading down from higher energy orbital to less-high energy orbital until they finally find themselves in their ground state (i.e., their least energetic orbital).

c.) To do this cascading from energy level to energy level, the molecule's electrons must give up energy in the process. As the amount of energy given off with each jump (i.e., the difference in the amount of energy an electron has to lose to make a jump from a higher energy level orbital to a lesser energy orbital) is proportion to the frequency, hence wavelength, of light being emitted, we have a nifty way to learn something about our gas atom's orbital structure.

d.) In short, an excited gas in a spectral tube will give off very specific frequencies of light. As the frequencies of that light are proportional to orbital energy *differences* of the atom, all we have to do is determine the frequencies we see coming out from the gas and we can deduce something about the energy structure of the atom in question.

e.) To determine the frequencies, we will use a *spectroscope*.



f.) The workings of a spectroscope are simple. The light to be analyzed is passed through a collimator so that skew rays may be eliminated. It then strikes either a prism or a diffraction grating, depending upon the type of spectroscope (ours uses a diffraction grating). The effect of the diffraction grating is the heart of the spectroscope, for each frequency that passes through the grating will be re-directed in its own characteristic way. That is, the light of one particular frequency will be bent at an angle θ_1 with the original direction of the ray, whereas the light of a second frequency will be bent at a different angle θ_2. (Note that it is wavelengths that are usually used with spectroscopes, but you know that for light, the relationship between frequency and wavelength is $c = \lambda\nu$).

g.) Given the diffraction angle θ_1, the relationship that gives you the wavelength is

$$\lambda = \frac{d}{n}\sin\theta_1 .$$

where *d* is the distance between grating lines and *n = 1* for our purposes. (For our device, assuming it's a metal device, $d = 5x10^{-6}$ meters.)

h.) Make sure the spectroscope is set up correctly (i.e., the slit is giving enough light, the slit is vertical with spectral lines arranged in the horizontal, the telescope is focused at infinity, the grating is over the pivot bolt, the right-angle eyepiece is displaying a vertical reticule line that matches the slit image, the image is sharp, and the dark cloth covers the gap between the tubes).

Part B: (fun with two or three random elements)

j.) Before we actually start using the spectroscope, there is an alternate way to view spectral lines that is kind of fun. It requires the use of a diffraction grating. I will give you a pair of special plastic glasses, then present several lit spectral tubes (krypton, nitrogen, helium, neon) for your viewing. I'll tell you what is in each tube, then you should list the colors you see along with the number of a particular type of color you see (if you see three shades of red, write "red—3"). We won't be doing any calculations with this data. It's more for fun than anything else. Nevertheless, I will expect you to include your data in your write-up at the appropriate spot.

Part C: (fun with a spectroscope and hydrogen gas)

k.) I will hopefully have at least two spectroscopes set up and directed at a hydrogen discharge tube. Check to be sure the non-deviated light passes through the scope when the angle on the base reads zero. With your telescope oriented so that at the zero degree position, you see a bright slice of colored light, proceed to swivel the scope until you find:

i.) The aqua line. (There should be a violet and blue line before it, but both are hard to see so we will zero in on the aqua line.) Record the angle at which you find the aqua line.

ii.) Continue swiveling until you come upon the red line. Record its angle.

CALCULATIONS

Part B: (spectral combinations)

1.) You used the diffraction glasses to identify the colors associated with several elements provided via discharge tubes.

a.) Make a table. Identify each element, then list the color and number of lines in that color for each element observed.

b.) Some colors appeared dim, some bright. Why were some colors brighter than others? (ten words)

c.) Briefly explain why each element had its own particular set of spectral frequencies (ten words).

Part C: (hydrogen spectra)

2.) For the aqua (greenish-blue) line of hydrogen:

a.) Use the relationship $\lambda = \frac{d}{n} sin\theta_{green}$ to determine the wavelengths of that line (note that "n" and "d" are given in the preamble);

b.) The actual wavelength for the aqua line in hydrogen is 4860 angstroms. Do a % comparison between the determined value from #2a and the actual value. (% comp = difference between the two values divided by the actual value times 100)

c.) How much energy is wrapped up in a photon associated with this wavelength? Answer this in joules remembering that Planck's constant is $6.62x10^{-34}\ J \bullet s$.

d.) What is the solution to #2c in electron volts (1 electron volt equals $1.6x10^{-19}\ J$).

e.) In light of the answers in both 2c and #2d, what can you say about the energy/orbital spacing associated with hydrogen atoms? (just a few words)

3.) For the red line of hydrogen:

a.) Use the relationship $\lambda = \frac{d}{n} sin\theta_{green}$ to determine the wavelengths of that line (note that "n" and "d" are given in the preamble);

b.) The actual wavelength for the red line in hydrogen is 6560 angstroms. Do a % comparison between the determined value from #3a and the actual value.