Introduction to Astronomy	**Laboratory Exercise #3**
Name ___________________________	Date _______________
Partners _________________________	Section _____________

Atoms and Line Spectra

Purpose:
To relate color and line spectra to specific elements and to recognize the value of spectroscopy in astronomical measurements.

Equipment:

Spectrometer	Tape	2 Rulers
Diffraction Grating	High Voltage Source	Spectral Tubes

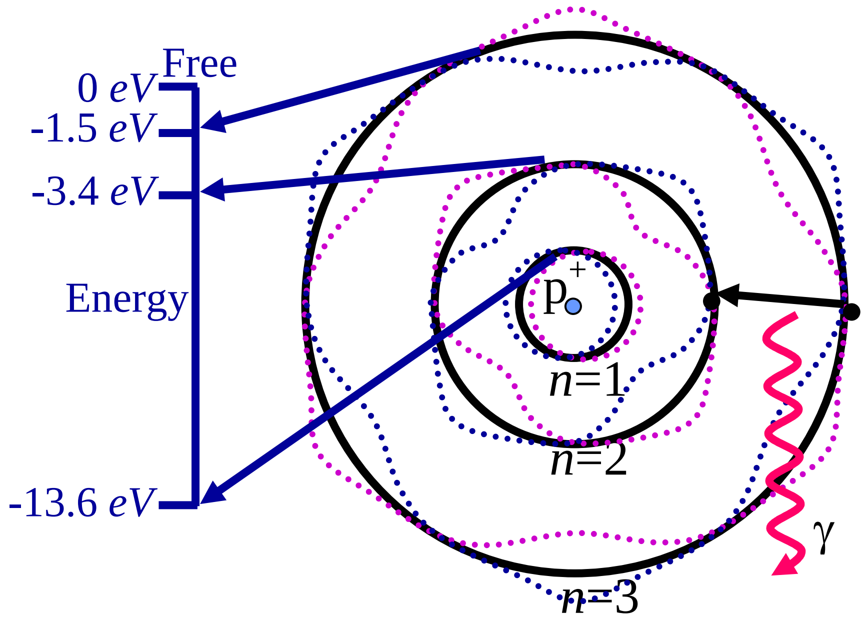
Background:
There is a relationship between color and wavelength of light. In addition due to the particle nature of light each wavelength is associated with a set energy contained in the wave of light. This ‘particle’ of light is called a photon. Because light is an electromagnetic wave it interacts with charged particles. For our lab we are interested in the interaction of electrons and light waves. Although the electromagnetic spectrum ranges from radio waves to gamma rays, we will focus on visible light since our eyes can detect this portion of the spectrum directly.

The relationship between energy and wavelength is given below where wavelength, λ, is measured in meters and energy, E, is measured in joules. The two constants in the formula are the speed of light, $c = 3.0 \times 10^{8}\ m/s$, and Planck’s constant, $h = 6.63 \times 10^{-34}\ J{\cdot}s$.

$$E = hc / \lambda$$

Atoms are composed of protons (positive charge), neutrons (no net charge) and electrons (negative charge). The protons and neutrons comprise the nucleus of the atom while the electrons form a cloud around the nucleus. Electrons are attracted to the protons due to the fact that opposite charges attract each other. If an electron is removed from an atom, it will require energy to overcome the attraction between the electron and the nucleus. The energy needed to remove an electron from an atom comes from photons of light which are absorbed in the process. If an electron is captured by a nucleus, it will give off energy which results in a photon of light being emitted.

The average distance between an electron and the nucleus can also be changed by absorbing and emitting light. Since an electron behaves like a wave, it can not occupy every possible distance from the nucleus. Only those distances where the circumference of the orbit is a multiple of the electron’s wavelength are allowed.



For the Hydrogen atom the possible energy levels are labeled as n = 1, 2, 3, … and the associated energy is given by the equation

$$E_n = \frac{-13.6eV}{n^2}$$

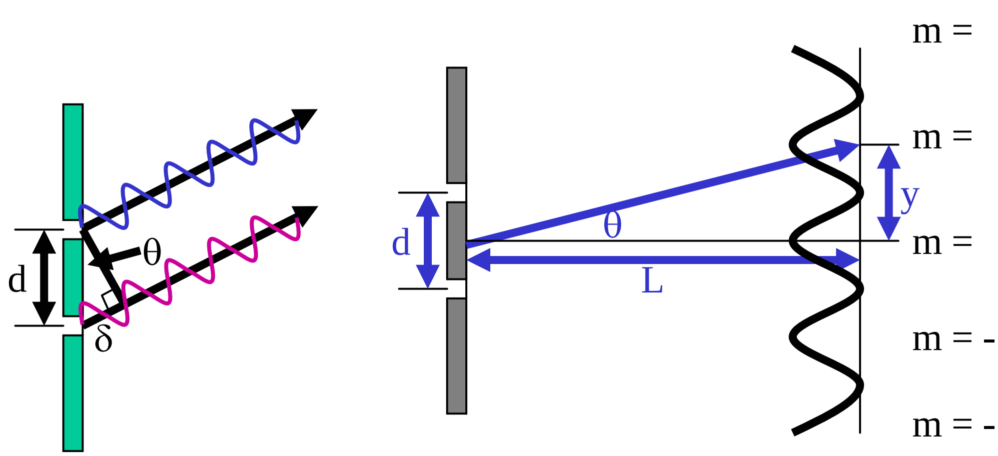
where $1\ eV = 1.6 \times 10^{-19}\ J$.

Jumping from a higher energy level to a lower energy level will result in the emission of a photon. Combining the formulas presented above the wavelength of this photon can be calculated with the formula

$$\lambda = \frac{hc}{\Delta E} = 90\frac{m^2 n^2}{n^2 - m^2} \qquad \text{(Equation 1)}$$

where the answer is in nanometers

Diffraction Gratings:
A diffraction grating consists of closely spaced lines etched in the surface of a slide. The etched lines cause the light to spread out from the location of the line due to diffraction. As the light spreads out from each of the lines, they waves constructively and destructively interfere. The location for waves interfering constructively depends on the wavelength. As a result, the light traveling through the diffraction grating froms a spectrum of color where red is spread the least and violet is spread the most. The location of constructive interference can be determined by trigonometry from the following diagram.



$\delta = d\sin\theta = m\lambda \qquad (m = 0, \pm 1, \pm 2, ...) \qquad \sin\theta \cong \frac{y}{L}$

If you choose the first set of spectral lines, the value of *m* is *1*. Combining these two equations gives

$$\lambda = \frac{yd}{L} \qquad \text{(Equation 2)}$$

Diffraction gratings are rated in lines per *mm*. The slit distance, *d*, is then the reciprocal of this value after *mm* have been converted to *m*. This is given by the following formula

$$d = \frac{1}{1000N}$$

Exercise:

Part 1: Spectrum of Hydrogen (Theory)

Calculate the different wavelengths of light emitted by a Hydrogen atom using equation 1. The values of m and n can be 1, 2, 3, …. Once you calculate the wavelength determine the color of light or the range of the electromagnetic spectrum assocated with this change in the electron's orbit.

m	n	Wavelength (nm)	EM
1	2		
1	3		
1	4		
1	5		
2	3		
2	4		
2	5		
3	4		
3	5		
4	5		

Part 2: Spectrum of Hydrogen (Measured)

Tape one ruler to a second to form a ‘T’ shape. When placing the base of the ‘T’ near your eye, you should be able to read the markings on the ruler making to the top of the ‘T’. Tape the diffraction grading to the base of the ‘T’ in such a way that you can look through the grating and see the top portion of the T. Look through the diffraction grating at the Hydrogen spectral tube. While looking through the diffraction grating, record the locations of the three visible spectral lines. Calculate the wavelength given that the slit spacing of the diffraction grating is 600 lines/mm.

L =________________ $d = \dfrac{1}{1000N}$ = ___________

y (m)	λ (m)	λ (nm)

Part 3: Spectra of other Atoms

While using diffraction grating glasses, draw the location of the spectral lines for 3 different elements. Try to accurately represent the location and number of lines present.

Element Name = _____________________

Violet Blue Green Yellow Orange Red

Element Name = _____________________

Violet Blue Green Yellow Orange Red

Element Name = ____________________

Violet Blue Green Yellow Orange Red

Questions:

1. Did the wavelengths in part 2 correspond to any of the wavelength calculated in part 1 of the lab? If so, which transitions resulted in the lines observed. (Use n and m numbers to describe the transition.)

2. Of the spectra observed in part 3, which element was easiest to illustrate and why?

3. What information can be gathered by observing the spectra of our sun or of other stars?