THE BALMER SERIES

Objective

To study the spectrum of hydrogen and compare the observations to Balmer's formula.

Equipment

Mercury discharge tube, hydrogen discharge tube, incandescent lamp, spectrometer with diffraction grating.

Background

The Bohr model of the atom explains that bound electrons can only have discrete energy levels. If an electron falls from an excited state(n_i) to a lower state(n_f) it will emit an photon with a quantized amount of energy, also called a quanta. This quanta of energy gives the photon a set amount of energy which is described as follows,

$$\Delta E = h\nu = \frac{hc}{\lambda}, \tag{1}$$

where ΔE is the quanta of energy, h is Planck's constant, c is the speed of light, ν is the frequency of light(Hz), and λ is the wavelength(m). So when light is emitted from an atom it will have a set wavelength which is related to the energy and color. The reverse is true for when an atom absorbs energy, i.e. an atom can only absorb photons with a specific wavelength.

The first to experimentally describe this was Johann Balmer when he observed that hydrogen gas only emitted select wavelengths of visible light. He subsequently formalized this discovery into the Balmer formula which was eventually generalized into the Rydberg formula,

$$\frac{1}{\lambda} = R_H\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right), \tag{2}$$

where λ is the wavelength, R_H is the Rydberg constant for hydrogen(1.097×10^7 m^{-1} or 1.097×10^{-2} nm^{-1}), n_i is the initial quantum number and n_f is the final quantum number where n_f equals 2 for the Balmer Series. The Rydberg formula works for all hydrogen-like atoms with a slight modification, i.e. $R_H \Rightarrow R_H Z^2$ with Z being the number of protons.

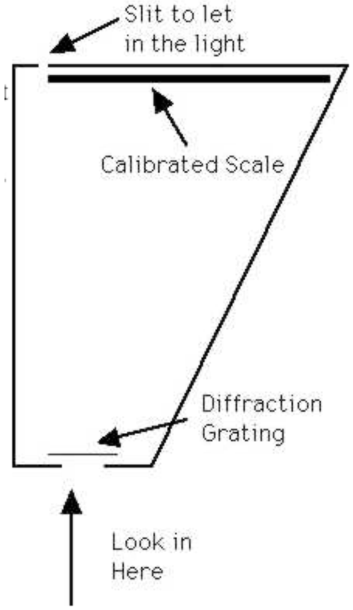

Figure 1: Spectroscope Diagram: The larger numbers are in units of nanometers(nm) and the smaller is in electron-Volts(eV).

Other spectral lines do exist which are: Lyman Series(n_f=1), Paschen Series(n_f=3), Brackett Series(n_f=4), and others. For reference read Halliday and Resnick, Section 39-8 and 39-9.

Outline

Step 0: For this lab you will prepare an individual data sheet. Please write your last name and first name on this paper.

Step 1: To use the spectroscope, position your eye at the eyepiece and point the "line-up slot", as shown in Figure 1, at your source. Without moving your head or the spectroscope, look to the side using your eyes only. There should appear several lines on the scale. This scale has been marked with the corresponding wavelength(nm) for each particular spectral line.

Step 2: Look at the incandescent light source using the spectroscope and record **the range of wavelengths and colors** you see. Record your data and observation in your data sheet.

Step 3: Next, analyze the mercury source with the spectroscope and record the line spectra(**wavelength and color**). If you do not observe lines at 436 nm, 546 nm and 577 nm for the mercury source, consult your lab instructor for assistance in calibrating the spectroscope. You should be able to see **four** distinct lines!! Record your data and observation in your data sheet.

Step 4: Do not continue unless you have done Step 3!! With a properly calibrated instrument, observe the hydrogen source. For each visible line present, record the wavelength, the color, and the quantum number of the final state. Look up the initial quantum numbers from Table 1. Record your data and observation in your data sheet.

Individual data sheet

Record all your data(step 1 to 4).

Graphs and Diagrams

For the Hydrogen source, plot one over the wavelength, $1/\lambda$, versus $1/n_i^2$, where n_i is the principle quantum number of the initial state (see Table 1 below).

Questions and Calculations

1. Calculate the Rydberg constant from your graph and compare it with the accepted value.
2. **Show** that the principle quantum number of the final state(n_f=2) is consistent with your data by using the y-intercept. **Note:** showing is not just stating the y-intercept value.
3. What do you see when looking at the incandescent light? How might an incandescent light bulb work differently than the discharge lamps?
4. You observe discrete lines when you look at the hydrogen or mercury source. How would this be different if the electrons in an atom obeyed classical mechanics?
5. How much energy do the emitted photons have for both the hydrogen and mercury light sources?
6. Why can we only visually see the Balmer Series? Are other light spectrums(Lyman Series, Paschen Series, Brackett Series, etc.) being emitted? Explain.

Table 1: Balmer Series(n_f=2) Look up Table for Hydrogen

n_i	3	4	5	6	7	8	9	∞
Name	H-α	H-β	H-γ	H-δ	H-ϵ	H-ζ	H-η	Balmer Break
Wavelength(nm)	656.3	486.1	434	410	397	388	383.5	364.6