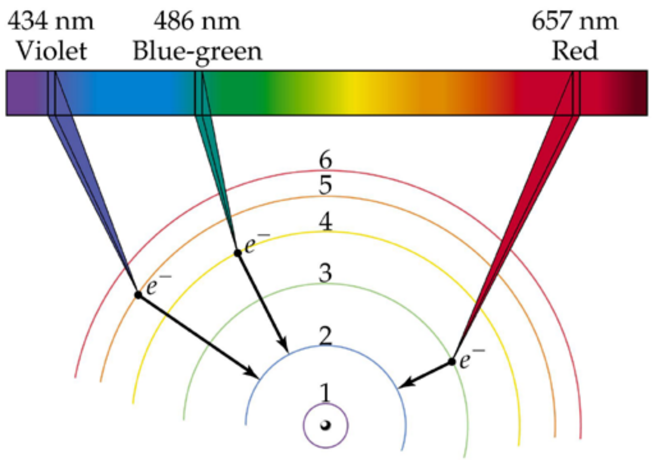
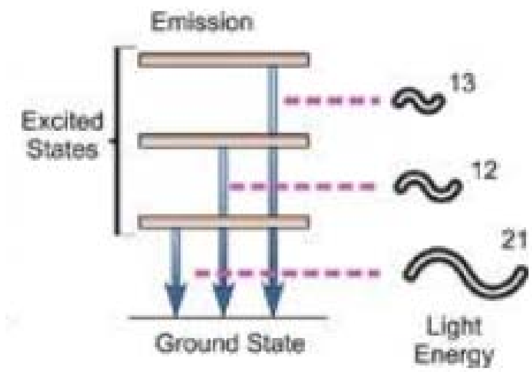
PHYS 1040 - General Physics II Lab
The Balmer Series for Hydrogen Source

Purpose: The purpose of this experiment is to analyze the emission of light from a hydrogen source and measure and the wavelengths of the Balmer series of visible emission lines from the hydrogen source. Further compare the experimental results with calculated wavelengths using the Bohr atom model.





Theory:

Light is an electromagnetic wave travelling as particles or photons that carry packets of energy. Energy of a single photons is given as:

$$E_{photon} = hf \qquad or \qquad E_{photon} = \frac{hc}{\lambda}$$

h = Planck's constant = 6.63×10^{-34} J-s

c = speed of light = 3×10^{8} m/s

f = frequency of the wave

λ = wavelength of the wave

Electrons exist in well defined, discrete energy levels around the nucleus within an atom. By heating, colliding with energetic particles, electrons jump into a higher energy state, called excitation. When the electron jumps from upper energy state to a lower energy state (called emission) the atom emits some energy in the form of a photon.

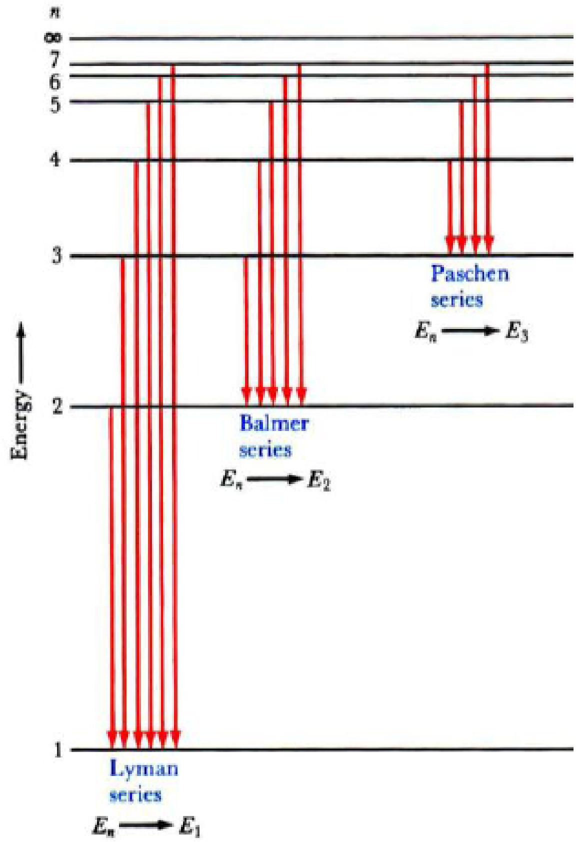
Energy emitted depends on the transition levels. This implies the wavelength of the emitted photon will be different in each case, depending on the characteristics of the atoms in the sample. Electronic structure of the atoms can be revealed by the atomic spectrum that is constituted by those wavelengths.

The energy of the photon emitted will be equal to the difference between the energy levels.

$$E_{photon} = E_{upper} - E_{lower} = \Delta E$$

and $$\Delta E = \frac{hc}{\lambda}$$

The hydrogen atom is the simplest atom, with only one proton and one electron. The Balmer Series are the set of spectral lines emitted from Hydrogen atoms that are created by the transition of electrons from higher energy levels to lower energy levels.



In a hydrogen atom, the energy of an electron on a particular level is given as:

$$E_n = \frac{-13.6}{n^2}\ (in\ eV) \quad where \quad n = 1, 2, 3\ldots etc$$

For the electrons that are transitioning from upper levels of n_{upper} = *3,4,5,6 etc.* to lower level of $n_{lower} = 2$, the series of these emitted photons are called Balmer series in the visible part of the EM spectrum.

In this lab we will analyze the visible spectrum that are emitted by the hydrogen atom (Balmer series).

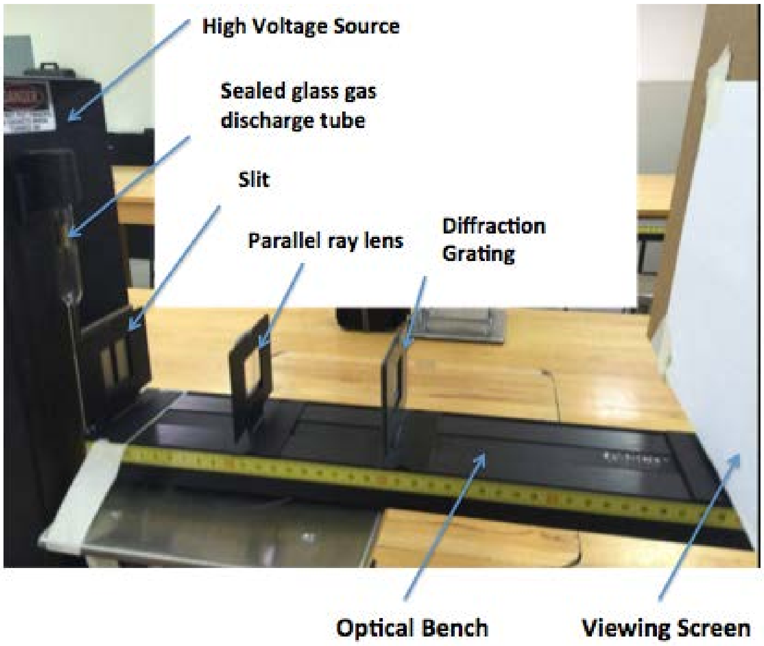
CHECKPOINT 1:

Discuss the following questions with your group and write your expectations and answers.

1) What is the energy of a photon of blue light (λ = 450 nm)? Express this in the units of eV and Joules.
2) Calculate the energy of hydrogen atom for the levels *n = 2, 3, 4, and 5*.
3) Calculate the wavelength $(\lambda_{calculated})$ of the emitted light by hydrogen atom for the following transitions and list the corresponding color -
   (a) n_{upper} = 3 to n_{lower} = 2
   (b) n_{upper} = 4 to n_{lower} = 2
   (c) n_{upper} = 5 to n_{lower} = 2
4) Explain in words the relationship between ΔE and λ.

Show your TA your expectations before proceeding.

Equipment:



- **Glass tube connected to high voltage:** Serves as a light source. When the high voltage is applied across the tube, the electrons in the gas will be first excited to higher states and emit characteristic radiation as they fall back to lower energy states, leading to the emission of line spectrum.
- **Parallel Ray Lens:** After passing through the slit the light will fall into a plano-convex lens which is used to focus the light to acquire a collimated and well-defined light beam. It must be placed such that the curved side of the lens should be towards the source.
- **Diffraction Grating:** An optical component with large number of parallel, closely spaced slits, which disperse the light so that a "rainbow" of light is created beyond the grating (spreading out as in a prism).
- **Optical Bench:** Provides the platform to mount the source, slit, parallel ray lens, diffracting grating and viewing screen.

The position of slit, lens and the diffraction grating can be adjusted to obtain sharper bright light bands of the emission line spectrum that are projected onto the screen.

Experiment:

Part 1 - Conduct the experiment using Helium Source to obtain a calibration curve.

Plan your experiment for the measurements with Helium source.

- You need to create a data table in your lab notebook, deciding on number of columns to be included in the table. Record all the data you take, even though some data may not be within the expected value.
- Perform the experiment to measure the position of each spectral line of the Helium Source.
- The known value of the wavelengths for helium source are listed below –

Violet – 402 nm	**Yellow – 587 nm**
Blue - 447 nm	**Orange – 600 nm**
Green – 501 nm	**Red – 667 nm**

- In your lab notebook, plot a graph of *position of the line (R) vs. wavelength (λ).* This gives the calibration curve for Helium source.

CHECKPOINT 2:

- Analyze the spectral lines you see on the screen for various colors. How many different colors could you see?
- Why does the emission spectrum of helium have a distinct line spectrum instead of a continuous one?

Show your TA your experimental data and calibration curve before proceeding.

Part 2 - Conduct the experiment using Hydrogen Source.

Plan your experiment for measurements of spectral lines with Hydrogen Source.

- Carefully change the glass tube to hydrogen (careful, it will be hot! And try not to touch the ends!)
- Create a table in your lab notebook to record all the data you take.
- Perform the experiment to measure and record the position of each observed spectral line of the Hydrogen Source.

CHECKPOINT 3 :

- Using the calibration curve (from part-1 with Helium source), determine the wavelength of *each* observed spectral line ($\lambda_{measure}$) and tabulate your results for.
- For *each spectral line*, how does $\lambda_{measure}$ compares with $\lambda_{calculated}$ (from checkpoint 1)?
- List all the reasons for the errors and what could be done to minimize them?

Show your TA your experimental data and analysis for the part-2 of the experiment.

Part 3 - Observations – with an unknown source.

- What is your observation about the spectral lines of an unknown source? Is it possible to determine the wavelengths of these spectral lines? If so how? Explain.

CHECKPOINT 4 :

- Show your TA all the experimental data, analysis, and graphs for all parts of the experiment.
- Explain to the TA whether the measured data support your expectations.