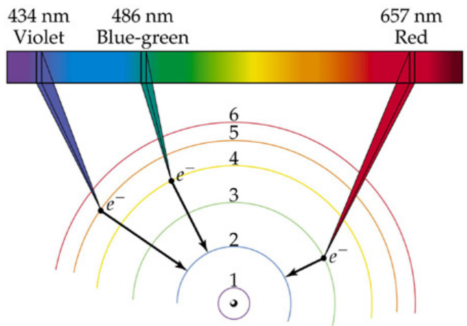
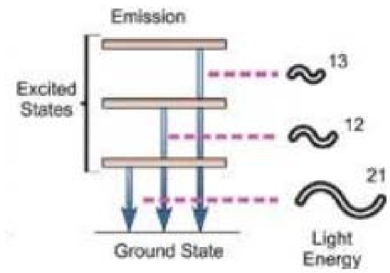
PHYS 1040 - General Physics II Lab
The Balmer Series for Hydrogen Source

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:

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

h = Planck's constant = 6.63 x 10^{-34} J-s c = speed of light = 3 x 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.

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

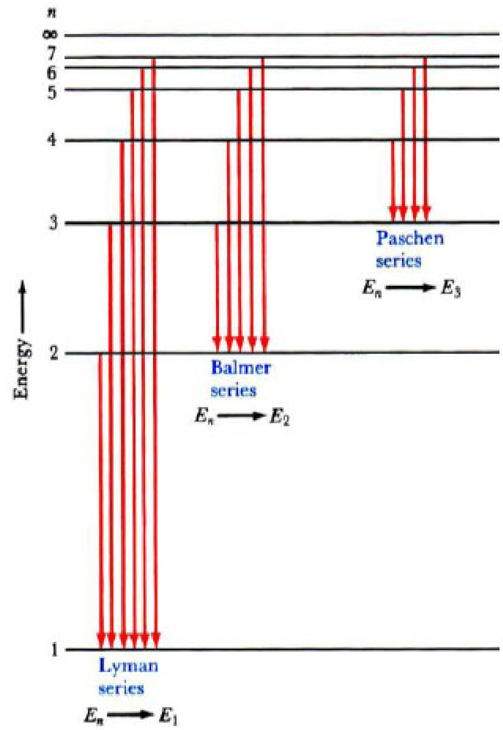
$$and \qquad \Delta E = \frac{hc}{\lambda}$$

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:

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

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).

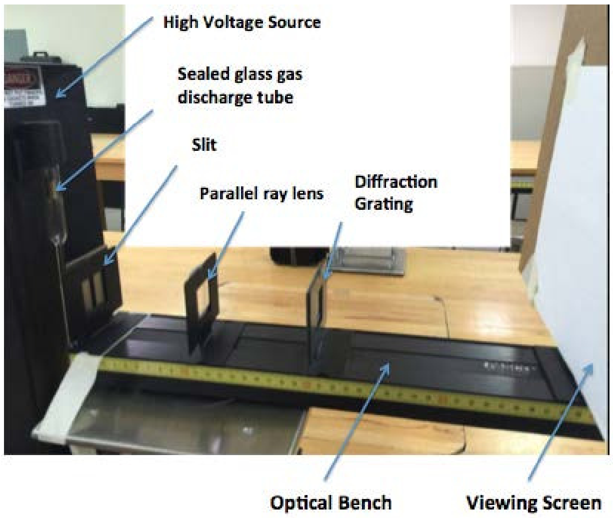
CHECKPOINT 1:

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

1) Which of the following electron transitions between two energy states in the hydrogen atom corresponds to the emission of a photon with the longest wavelength in visible spectrum?
   (a) 5 → 2 (b) 4 → 2 (c) 3 → 2
2) Explain in words the relationship between ΔE and λ.
3) Calculate the energy (in eV and Joules) of hydrogen atom for the levels *n = 2, 3, 4, and 5*.
4) 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 $n_{lower} = 2$

Show your TA your expectations and calculations 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.
  NOTE: It must be placed such that the curved side of the lens should be towards the source.
- **Diffraction Grating:** Diffraction grating is an optical component with many slits (openings). These slits are very closely spaced and hence they produce on a screen a series of sharp, bright spectral lines of a given light source.
- **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 (known wavelengths for spectral lines) 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 and record the *position (R)* of each observed spectral line of the Helium Source.
- **NOTE**: Note the position of the grating and the screen.
- 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 (x-axis) vs. wavelength, λ (y-axis).* 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 with Hydrogen Source.

**** Check with your TA to change the source to Hydrogen ****

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

- Change the source to hydrogen (ask your TA for help).
- Create a table in your lab notebook to record all the data you take.
- **NOTE:** Keep the location of grating and screen same as in part-1.
- Perform the experiment to measure and record the *position (R)* 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 *each spectral line*, how does $\lambda_{measure}$ compares with $\lambda_{calculated}$ (checkpoint 1 – question 4)?
- Determine the percentage difference.
- 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.

Unknown source.

- You are given an unknown source, which produces spectral lines. Is it possible to determine the wavelengths of these spectral lines? If so how? Explain in words.

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.

LAB REPORT – due one week after the lab.

The procedure you followed should be clearly written and all the analysis should be included. You can include the computer plotted graphs showing the trend-line with display equations. Make sure you address the questions posed at the beginning of this handout, your expectations before conducting the experiment and use to your experimental data to support your conclusions. Your conclusion should indicate whether or not you were able to confirm your expectations.