Atomic Line Spectra

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Contents

1 Introduction

1.1 Purpose

Observe the atomic line spectrum of hydrogen. Compare the differences between calculating the emission wavelengths from the angle of diffraction using a Gaertner-Peck spectroscope to determining them from intensity peaks collected by an Ocean Optics Emission Spectrometer to literature values. Observe the difference between the emission spectrum of hydrogen and another element, krypton.

1.2 References

Shields, G. C.; and Kash, M. M. Experiment in quantization: atomic line spectrum *Journal of Chemical Education* **1992** *69(4)*, 329-331. DOI:10.1021/ed069p329

McQuarrie, D. A.; Simon, J. D. *Physical Chemistry: A Molecular Approach*; University Science Books: Sausalito, CA, 1997.

The Atomic Spectrum of Hydrogen https://chem.libretexts.org/@go/page/33907

Wiser, D.; *Atomic Line Spectra*; Lake Forest College: Lake Forest, IL, 2025; pp 1.

Logger Pro, Vernier.

1.3 Safety Information

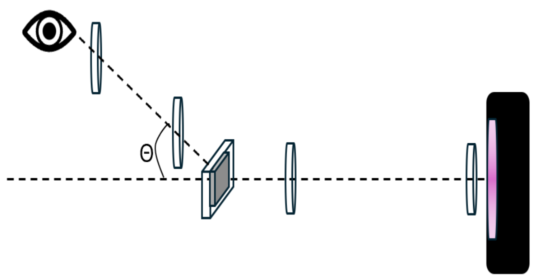
Hot glass looks the same as cool glass, proceed with caution when changing discharge tubes.

2 Methods

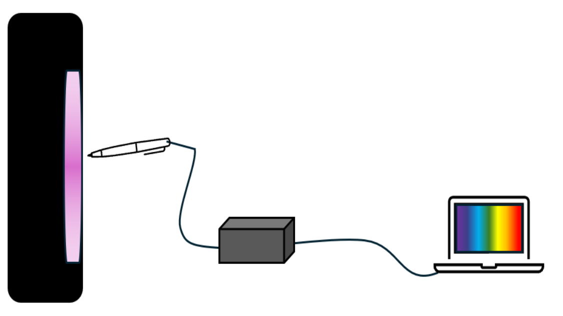
A hydrogen discharge tube was supplied with 115V from an Electro-technic Products. Inc. Model SP200 Spectrum Tube Power Supply. The emission was observed by eye using a Gaertner Scientific Spectroscope (Fig. 1a). The wavelength (λ) was calculated using the equation:

$$n\lambda = dsin\theta \tag{1}$$

The order of diffraction (n) was 1. The grating spacing (d) was 600 lines/mm. The difference between the non-diffracted line and the diffracted line (θ) was the difference between 180° and the angle of diffraction measured in degrees and minutes.



(a)



(b)

Figure 1: Cartoon depictions of (a) Gaertner-Peck Spectroscope and (b) Ocean Optics Emission Spectrometer.

The emission spectrum was also recorded with an Ocean Optics emission spectrometer USB2000UV/Vis version 2.41.3 (Fig 1b). Intensities were collected over a wavelength range of 400 nm to 700 nm over a period of 16 ms. Samples were not averaged or smoothed and there was no intensity correction. The distance between the probe and the discharge tube was manually adjusted until all peaks were comparable, with an intensity between 0 and 1.

The emission of Krypton was also observed with both methods, although no quantitative data was recorded.

3 Results/Data

3.1 Gaertner-Peck Spectroscope

The hydrogen emission spectrum had 4 distinct lines (Fig. 2): red, blue-green, blue, and violet. The red line was very clear, whereas the violet line was more difficult to observe.

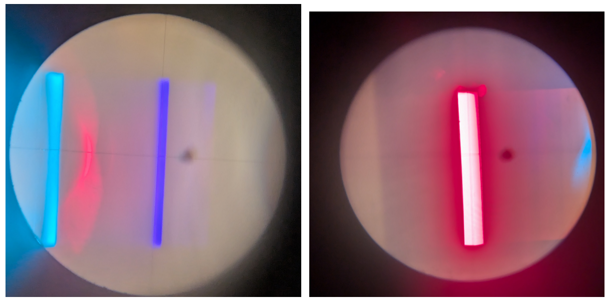


Figure 2: Lines of hydrogen emission spectrum visible through a Gaertner-Peck Spectroscope. The blue-green line appeared light blue on camera and the violet line is barlely visible to the right of the blue line.

The angle of diffraction (Table 1) was calculated from the center of each emission line. The total angle was measured in degrees and minutes where 60 minutes were equivalent to one degree. The angle of diffraction was plugged into Eq. 1 and an experimental wavelength value was solved for (Table 2). Each group member, myself and Julia, individually measured the degrees and calculated the wavelength. The final calculated angle was the average our results.

Table 1: Angle of diffraction measurements from the Gaertner-Peck Spectroscope.

Angle	Time (min)	Total Angle
164	31	164.52
162	42	162.70
156	52	156.87
165	25	165.42

Table 2: Comparison between calculated wavelength values from Gaertner-Peck spectroscope measurements and literature values from The Atomic Spectrum of Hydrogen.

Color	λ Calculated (nm)	λ (nm)	% Error
Violet	421	410	2
Blue	445	434	2
Blue-Green	497	486	2
Red	661	656	3

3.2 Ocean Optics Emission Spectrometer

LoggerPro identified peaks at wavelengths of 408.7 nm, 432.7 nm, 484.8 nm, and 655.4 nm from the Ocean Optics spectrometer (Fig. 3). The peak at 655.4 nm was larger than any other peaks. As the wavelength decreased, so did the intensity of the peaks. These measured values were compared with literature values (Table 3) and resulted in a lower percent error than the previously calculated values.

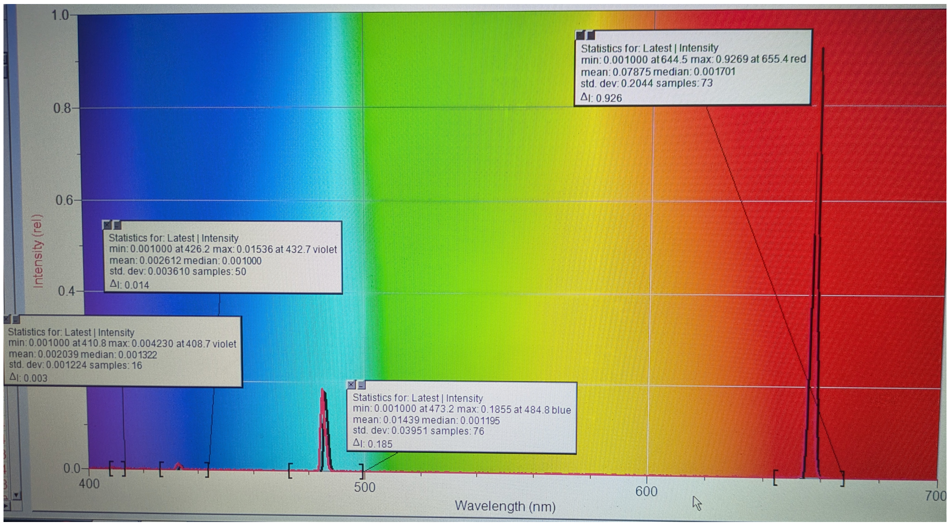


Figure 3: Emission spectrum of hydrogen captured by Ocean Optics Emission Spectrometer and plotted by LoggerPro.

Table 3: Comparison between measured wavelength values from Ocean Optics emission spectrometer and literature values from The Atomic Spectrum of Hydrogen.

Color	λ Measured (nm)	λ (nm)	% Error
Violet	408.7	410	0.3
Blue	432.7	434	0.3
Blue-Green	484.8	486	0.3
Red	661	655.4	0.09

3.3 Rydberg Constant Calculation

The energy level transition (Fig. 4) was calculated using the Balmer series equation:

$$\frac{1}{\lambda} = R_H(\frac{1}{2^2} - \frac{1}{n_2^2}) \tag{2}$$

The transition from n=6 to n=2 emitted a violet light. The transition from n=5 to n=2 emitted a blue light. The transition from n=4 to n=2 emitted a blue-green light. The transition from n=3 to n=2 emitted a red light. The red light was the most prominent because it had the lowest energy transition.

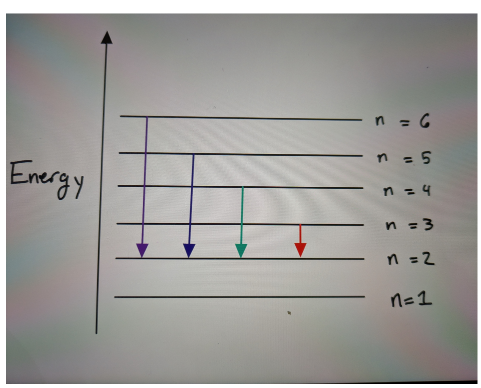


Figure 4: Energy level diagram of the emission spectrum of hydrogen.

The wavenumber vs. $1/n_2^2$ was plotted to show a linear relationship where the slope of the line was equivalent to Rydberg's constant (Fig. 5). The Rydberg constant calculated from the Gaertner-Peck spectroscope data was 109,648 m^{-1} and the constant calculated from the Ocean Optics spectrometer data was 109,662 m^{-1}. These values have an error of 0.03% and 0.02% respectively when compared to the literature value of 109,690 m^{-1} from McQuarrie and Simon. There was a 0.01% difference between the two calculated values.

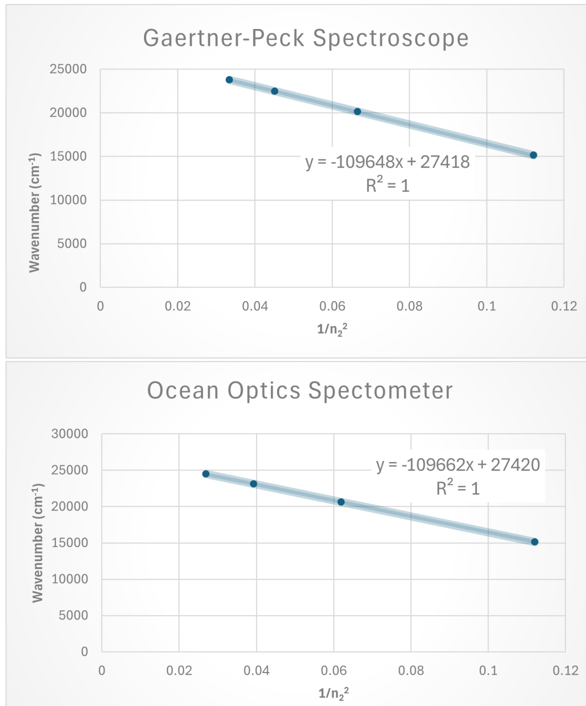


Figure 5: Graphs of wavenumber vs $\frac{1}{n_2^2}$ from Gaertner-Peck spectroscope data (top) and the Ocean Optics spectrometer data (bottom) made in Excel.

3.4 Emission of Krypton

The emission of krypton was much brighter than the emission of hydrogen. The column had no visible color and appeared to be white (Fig. 6). Viewing through the Gaertner-Peck spectroscope we were able to observe three distinct lines (Fig.7), one green, one orange, and one purple. The Ocean Optics emission spectrometer data (Fig. 8) showed that there should have been a series of violet lines, however we were unable to see any.

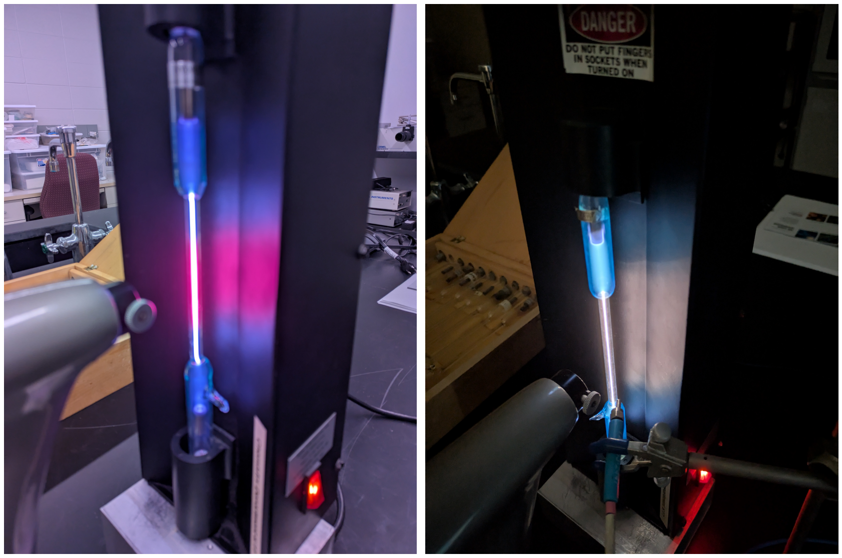


Figure 6: Discharge tubes of hydrogen (left) and krypton (right). The light emitted from the hydrogen tube appears blue and red while the krypton tube appear white.

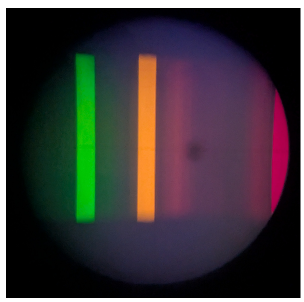


Figure 7: Lines of krypton emission spectrum visible through a Gaertner-Peck Spectroscope. The most distinct lines were green, orange, and red.

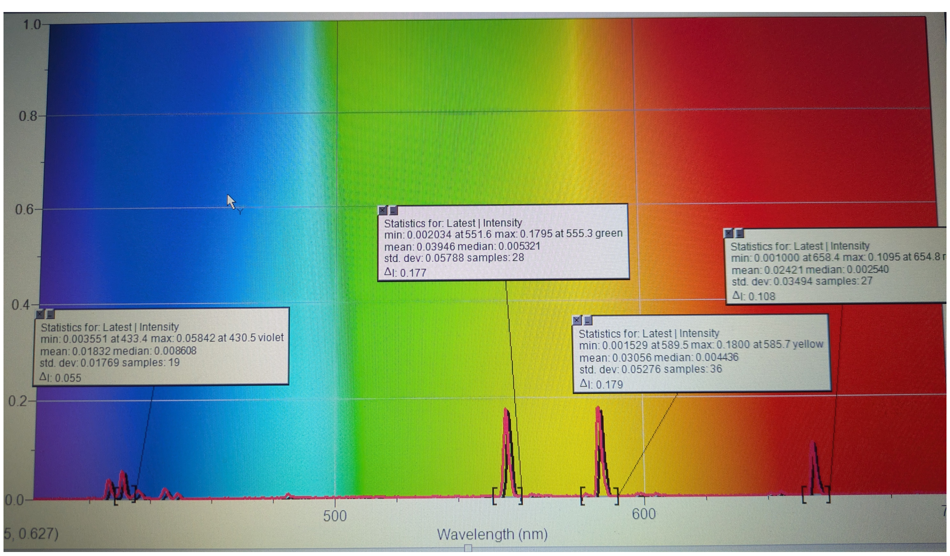


Figure 8: Emission spectrum of kypton captured by Ocean Optics Emission Spectrometer and plotted by LoggerPro.

4 Conclusion

The hydrogen emission spectrum has 4 distinct wavelengths: red, blue-green, blue, and violet. The red wavelength has the highest intensity as it is the most emitted because it represents the lowest energy transition. The violet wavelength is the least emitted because represents the highest energy transition. It is also more difficult to see because the photoreceptors in the human eye that detect blue and purple are less sensitive than those that detect red.

The photoreceptor of a spectrometer is more sensitive so it is more easily able to detect the blue and violet wavelengths. When comparing experimental values to literature values, the measurements from the spectrometer has a lower percent error.

The value of the Rydberg constant can be calculated from the emission spectrum. Comparing the experimental data to the literature value shows a less than 0.05% error.