Atomic Spectroscopy

Garcia, Jorge A. Lane, Ryan C. Miller, Patrick C.

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1 Purpose

The purpose of this experiment is to demonstrate the emission lines of the electromagnetic spectrum for different elements. Diffraction is the key physical concept in this experiment, since an element will emit light it's light as a combination of its different spectral lines, and it must be diffracted into its components in order to observe them individually. The only controled quantity is that of the diffraction grating, while measured quantities during the experiment are that of the angles at which emission lines are seen. From these quantities, the wavelength of said emission lines will be determined and an approximation of the Rydberg constant can be achieved.

2 Apparatus and Method

3 Procedure

The procedure was replicated for three different samples. After setting the discharge tube in front of the slit, it is important to align the telescope to the center of the telescope pivot, so it is perpendicular to the parallel beam. This allows for the identification of the central emission line, which will be used as the reference point to find the rest of the lines. The telescope will then be moved to find a new line, and recording of the angle indicated on the base is necessary. This measured angle has at the very least an uncertainty of 0.1 degrees from pure instrumental limitations.

The first run was done with Mercury for calibration purposes and ensuring proper use of the equipment, as the tube has a longer lifetime than that of Hydrogen. Hydrogen will be used to approximate the Rydberg constant. Finally, the spectrum of an unknown source will be used, with the objective of identifying it.

4 Data and Uncertainties

Each member in the team did 2 sets of measurements, one for the left-side lines and another for the right-side. The angle at which the undiffracted light is seen was not set to 0 degrees, and such all measurements were shifted, so only the change in angle from the center line is taken into account. The 6 measurements for each of the lines are then averaged, in order to reach a mean value for the angle at which the color is observed. The standard deviation of the mean is then:

$$\Delta\theta = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(\theta_i - \bar{\theta})^2} \tag{1}$$

With N being the number of measurements, θ_i the ith measurement for an angle, and $th\bar{e}ta$ the mean value of that angle. Calculation of the mean and error of the angles for each emission line was done in Python.

Shown in Table 1 is the average measurements for the Mercury discharge tube. The uncertainty in the mean of each of the angles was lower than 0.1 degrees, so our uncertainty in these measurements must be intrument dominated.

Mercury (Hg)			
Degree Shift:	139.4		
Color	θ	$\Delta\theta$	**Order**
Violet	15.1	0.1	First
Green	19.2	0.1	First
Yellow	20.3	0.1	First
Orange	20.4	0.1	First

Table 1: Average Measurements for Hg

For the measurements of Hydrogen emission lines (Table 2), the human error was larger than for the previous measurements. This is possibly due to the lower intensity of the emission lines, making them harder to be seen. Another detail with this discharge tube is the sudden appearance of a blue emission line, which hadn't been seen near the Cyan line. This means this linedax

Hydrogen (H)			
Degree Shift:	139.4		
Color	θ	$\Delta\theta$	**Order**
Violet	15.1	0.1	First
Cyan	17.0	0.2	First
Red	23.3	0.2	First
Blue	35.75	0.3	Second

Table 2: Average Measurements for H

The most problems occured with the Unknown Sample A. The emission lines were too faint to be accurately measured, even after attempts of darkening the room. Because of these difficulties and lack of time to take more measurements, our data is very imprecise. This especially can be seen in the last two angles.

5 Analysis and Uncertainties

Knowing the angle at which an emission line is seen, and given the spacing of the diffraction grating lines, the wavelengths can be calculated as:

$$dsin\theta = m\lambda$$
$$\lambda = \frac{dsin\theta}{m} \tag{2}$$

Unknown Sample A			
Degree Shift:		139.4	
Color	θ	$\Delta\theta$	**Order**
1	14.4	0.2	First
2	14.4	0.3	First
3	15.5	0.1	First
4	17.7	2.1	First
5	23.2	5.3	First

Table 3: Average Measurements for Unknown Sample A

Accordingly, when calculating the wavelength, the error from the angle of the emission line propagates as follows:

$$\Delta\lambda = \frac{1}{m}\sqrt{sin^2\theta(\Delta d)^2 + d^2cos^2\theta(\Delta\theta)^2} \tag{3}$$

The results were then calculated in Python using Equations 2 and 3.

Mercury (Hg)		
Color	λ (nm)	$\Delta\lambda$ (nm)
Violet	434.6	2.8
Green	548.6	2.7
Yellow	577.8	2.7
Orange	581.4	2.7

Table 4: Determined wavelengths and $sin\theta$ for Hg

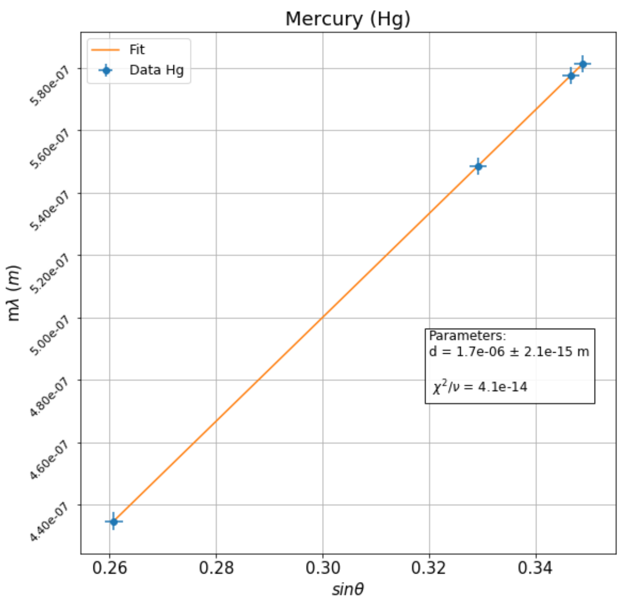

Figure 1: Plot of Mercury's $sin\theta$ against $m\lambda$

Hydrogen (H)		
Color	λ (nm)	$\Delta\lambda$ (nm)
Violet	435.1	3.5
Blue	486.8	3.1
Cyan	487.3	4.8
Red	657.9	4.0

Table 5: Determined wavelengths for H

Hydrogen Balmer Series					
	n_i				
		3	4	5	6
n_f	2	32	42	52	62

Table 6: Expected wavelength for electron transitions of H

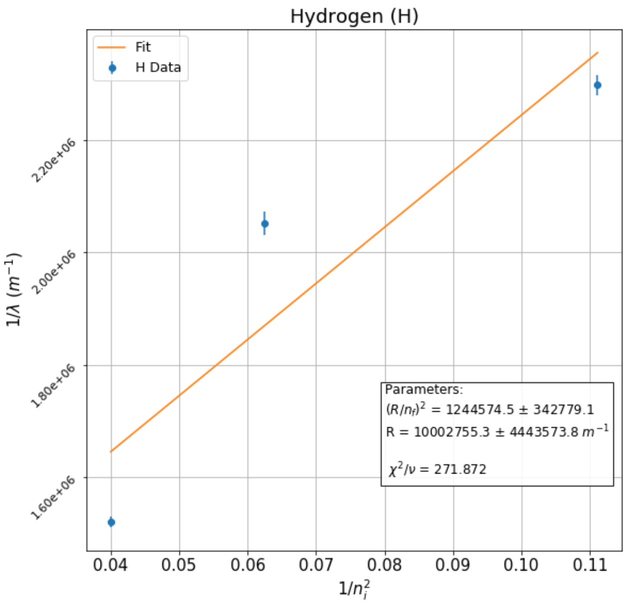

Figure 2: Plot of Hydrogen's $\frac{1}{n^2}$ against $\frac{1}{\lambda}$

Unknown Sample A		
Color	λ (nm)	$\Delta\lambda$ (nm)
1	415.9	4.2
2	415.9	7.0
3	445.4	3.2
4	506.7	5.8
5	655.2	1.2

Table 7: Determined wavelengths for Unknown Sample A

6 Results

7 Conclusions