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Introduction

As defined by Chemistry, the Central Science, line spectra are the examination of “the light emitted by electrically excited atoms” (Brown et al. 2015, p. 213). This examination indicated that “there are only certain energy levels that are allowed for electrons in atoms,” explaining the concept of particular energy levels, or order sets (Brown et al. 2015, p. 213). These photon emissions provide pattern-like information that allow scientists to understand wavelength and color associated with the different orbitals. Line spectra can be observed in real life applications, such as at laser lightshows. At these exciting events, the specific energy emissions provide a range of different laser light colors. To better understand wavelengths, the following equation can be used to find precise wavelengths of spectral lines observed from diffraction gratings:

$$\lambda = \frac{a \sin \theta}{n}$$

In this equation λ equals the wavelength of light being emitted, a is the distance between lines on the diffraction grating, θ is the angle of diffraction, and n is the spectrum order line. In this lab, the a value is equal to 300 lines per mm.

Background

Before completing this atomic emission spectra lab, hypotheses were created regarding the results. The first hypothesis predicted that 2 different elements would have different wavelengths. This hypothesis was formed by understanding that elements have different emissions when in an excited state because “each type of element has a unique energy shell or energy level system” (Volland 2005). The second hypothesis predicted that 1st and 2nd orders of a given element would have slightly different wavelengths.

Procedure

To complete this lab, a careful procedure was followed. A hydrogen bulb was placed inside the lamp, and aligned with the incoming light source on the spectrometer. The diffraction grating was equal to 300 lines per mm. The shutter was adjusted to be a thin line so that this 0^{th} order line was in the viewing scope. For hydrogen, the eyepiece was set to 0 ˚ so that data could be collected. After finding the first initial color, the viewing scope was moved to the left until the next colored line was seen. This next colored line began the 1^{st} order spectrum. We continued to scan to the left until a pattern of colors was identified. Once a color repeated, the 2^{nd} order set began with a similar pattern of colors. A similar procedure was repeated with Mercury, after waiting for Hydrogen bulb to cool and replacing the lamp with the Mercury bulb. After looking through the eyepiece on the Telescope, the first color discovered at position of 0˚. Then, we continued to scan to the left to begin the 1^{st} order line, and discovered the 2^{nd} order line once colors repeated.

Results

As shown by Table 1, Hydrogen's first angle recorded was equal to 0˚ with a line color of red. The 1^{st} line spectrum began with the color violet, found at an angle of 7.5˚. This violet color produced an experimental wavelength of 4.35 E-7 m, a theoretical wavelength of 4.34 E-7 m, and an experimental energy of 4.5503E-19 J (Purdue University). After scanning to the left, teal was found at an angle of 8.6˚, and red was found at an angle of 11.5˚. Teal produced an experimental wavelength of 4.93 E-7 m, a theoretical wavelength of 4.93 E-7 m, and an experimental energy of 4.01497E-19 J (Purdue University). Red created an experimental wavelength of 6.65E-7 m, a theoretical wavelength of 6.56E-7 m, and an experimental energy of 2.97651E-19 J (Purdue University). The 2^{nd} order set contained similar colors, following the pattern violet, teal, and red located at 15˚, 17˚, and 23˚ respectively. These colors had experimental wavelengths of 4.31E-7 m, 4.87E-7 m, and 6.51E-7 m respectively. Violet, teal, and red produced experimental energies of 4.59253E-19 J, 4.06444E-19 J, and 3.04052E-19 J respectively. Due to forgetting to record the last value, the red angle of 23˚ was borrowed from a different group. This other group had identical numbers for all other Hydrogen angles.

As shown by Table 2, Mercury's first color discovered was green with a 0^{th} order line and an angle of 0˚. The first order spectrum was composed of purple, green, and yellow at locations of 7.5˚, 9.5˚, and 10˚. Purple produced an experimental wavelength of 4.35 E-7 m, theoretical wavelength of 4.35E-7 m, and an experimental energy of 4.5503E-19 J (Nave). Green created an experimental wavelength of 5.5E-7 m, theoretical wavelength of 5.46E-7 m, and an experimental energy of 3.59887E-19 J (Nave). Yellow yielded an experimental wavelength of 5.79 E-7 m, theoretical wavelength of 5.79E-7 m, and an experimental energy of 3.41862E-19 J (Nave). The 2^{nd} order line was found to be the colors purple, green and yellow at locations of 15.25˚, 19.4˚, and 20.5˚. These colors produced experimental wavelengths of 4.38E-7 m, 5.54E-7 m, and 5.84E-7 m, respectively. Purple yielded an experimental energy of 4.51913E-19 J, green yielded an experimental energy of 3.57289E-19 J, and yellow yielded an experimental energy of 3.38935E-19 J.

Table 1: Color, Angle, Experimental Wavelength, Theoretical Wavelength, and Experimental Energy of the Emission Spectrum of Hydrogen

Hydrogen						
Order	Color	Measured Angle (Degrees)	Experimental Wavelength (mm)	Experimental Wavelength (m)	Theoretical Wavelength(m)	Experimental Energy (J)
1	Violet	7.5	0.000435	0.000000435	0.000000434	4.5503E-19
1	Teal	8.5	0.000493	0.000000493	0.000000486	4.01497E-19
1	Red	11.5	0.000665	0.000000665	0.000000656	2.97651E-19
2	Violet	15	0.000431	0.000000431	-	4.59253E-19
2	Teal	17	0.000487	0.000000487	-	4.06444E-19
2	Red	23	0.000651	0.000000651	-	3.04052E-19

Table 2: Color, Angle, Experimental Wavelength, Theoretical Wavelength, and Experimental Energy of the Emission Spectrum of Mercury

Mercury						
Order	Color	Measured Angle (Degrees)	Experimental Wavelength (mm)	Experimental Wavelength (m)	Theoretical Wavelength(m)	Experimental Energy (J)
1	Purple	7.5	0.000435	0.000000435	0.000000435	4.5503E-19
1	Green	9.5	0.00055	0.00000055	0.000000546	3.59887E-19
1	Yellow	10	0.000579	0.000000579	0.000000579	3.41862E-19
2	Purple	15.25	0.000438	0.000000438	-	4.51913E-19
2	Green	19.4	0.000554	0.000000554	-	3.57289E-19
2	Yellow	20.5	0.000584	0.000000584	-	3.38935E-19

Discussion & Analysis

When reviewing the data, it can be observed from Table 1 and Table 2 that the experimental data are very close to the theoretical data for both Hydrogen and Mercury. When comparing the wavelength of Hydrogen, the 1st order violet experimental wavelength is greater than the theoretical wavelength by 1E-9 m. The 1st order teal experimental wavelength is greater by 7E-9 m, and the 1st order red experimental wavelength is greater by 9E-9 m. Similar to Hydrogen, the experimental and theoretical wavelengths of Mercury are similar. For the 1st order purple and yellow colors, the values are identical. The 1st order green value has a higher experimental wavelength, differing by only 9E-9 m. As a result, it can be observed that while the theoretical and experimental wavelengths are not identical, they are extremely close. Some causes of error for this difference may be a result of de-calibration of the Spectrometer, light infiltrations from nearby experiments, or de-calibration of the main spectral line.

After running any experiment, it is crucial to re-examine the hypothesis to understand how the initial predictions compare with the experimental results. Initially, it was predicted that 2 different elements would have different wavelengths. While the values of Hydrogen's 1st order violet and Mercury's 1st order purple were the same with an experimental wavelength of 4.35E-7 m, all other values were different. As a result, it can be correctly concluded that different elements have different wavelengths because of individual energy systems associated with a single element. The other hypothesis that predicted that similar colors of different orders should have different wavelengths and energies was incorrect. In this lab, Hydrogen the smallest difference between experimental wavelengths of the same color was 4E-9 m, while Mercury received a minimal difference of 3E-9 m. The differences between wavelengths of the same color in different orders should have been 0 m. The initial incorrect hypothesis should be revised to state that the first and second orders of a given element should have identical wavelengths and energies.

References

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Experiment: Atomic Emission Spectra

Hydrogen a: 1/1300 lines/mm

n:0 color angle λ

Red 0° (1/1300) sin 0 / 0 = 0 mm → 0 m

n:1

Violet 7.5° (1/1300) sin 7.5 / 1 = 4.35x10^-4 mm → 4.35x10^-7 m

Teal 8.5° (1/1300) sin 8.5 / 1 = 4.93x10^-4 mm → 4.93x10^-7 m

Red 11.5° (1/1300) sin (11.5) / 1 = 6.65x10^-4 mm → 6.65x10^-7 m

n:2

Violet 15° (1/1300) sin (15) / 2 = 4.31x10^-4 mm → 4.31x10^-7 m

Teal 17° (1/1300) sin (17) / 2 = 4.87x10^-4 mm → 4.87x10^-7 m

Red 23° (1/1300) sin 23 / 2 = 6.51x10^-4 mm → 6.51x10^-7 m

* borrowed value from other group → had identical angles

Mercury

n:0 color angle λ

Green 0° (1/1300) sin 0 / 0 = 0 mm → 0 m

n:1

Purple 7.5° (1/1300) sin (7.5) / 1 = 4.35x10^-4 mm → 4.35x10^-7 m

Green 9.5° (1/1300) sin (9.5) / 1 = 5.5x10^-4 mm → 5.5x10^-7 m

Yellow 10° (1/1300) sin (10) / 1 = 5.79x10^-4 mm → 5.79x10^-7 m

n:2

Purple 15.25° (1/1300) sin (15.25) / 2 = 4.38x10^-4 mm → 4.38x10^-7 m

Green 19.4° (1/1300) sin (19.4) / 2 = 5.54x10^-4 mm → 5.54x10^-7 m

Yellow 20.5° (1/1300) sin (20.5) / 2 = 5.84x10^-4 mm → 5.84x10^-7 m

$E_{photon}: \frac{hc}{\lambda}$

$E_{photon}: \frac{(6.62 \times 10^{-34}\ Js)(2.99 \times 10^{8}\ m/s)}{\lambda\ (m)}$

<u>Hydrogen</u>

E_{photon} @ n: 1, violet $= \frac{(6.62 \times 10^{-34}\ Js)(2.99 \times 10^{8}\ m/s)}{(4.35 \times 10^{-7}\ m)}$

$E_{photon}: 4.5503 \times 10^{-19}\ J$ ✓