EXPERIMENT 11

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PHY 115L

INTRODUCTION

In this experiment I sought to learn how to perform diffraction grating spectroscopy. Using the method of normally incident diffraction, I determined the wavelength of the sodium D2 spectral line based on diffraction angles measured for both first and second order fringes. I then set out to again measure the wavelength of the sodium D2 line, this time using the method of minimum deviation, to compare to the reported wavelength of the sodium D1 and D2 spectral lines. In analyzing these phenomena, I aimed to use the high precision of the instrument to robustly validate the theory behind diffraction and diffraction grating spectroscopy. Finally, I sought to identify an unknown gas species through qualitative observation and measurement of its emission spectrum.

RESULTS

Measurement of Wavelength of Sodium D2 Line:

In this section, I used a spectrometer and a diffraction grating of 600 lines/mm to measure the wavelength of the sodium D2 spectral line produced from the sodium lamp. Specifically, I used the method of first- and second-order normal incidence, in which I lined up the normal angle of incidence by eye with the help of a protractor, to determine the angle of diffraction and from this, the wavelength of the line. My measurements and results are as follow, with tables 1 and 2 showing the measurements and calculations, respectively. I also compared my results with the reported wavelength of the D2 line.

Table

|  |  |  |
| --- | --- | --- |
| Order | θ (°) | |
| 1 | 20.47 | 0.03 |
| -1 | 20.52 | 0.03 |
| Average first-order | 20.49 | 0.03 |
| 2 | 45.00 | 0.03 |
| -2 | 44.53 | 0.03 |
| Average second-order | 44.77 | 0.03 |

Table

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | λ (nm) | | λ (Å) | |
| Calculated from first-order | 583.5 | 0.7 | 5835 | 7 |
| Calculated from second-order | 586.9 | 0.4 | 5869 | 4 |
| Reported | 588.995 |  | 5889.95 |  |

These results agree closely with the known wavelength, with the wavelength calculated from the second-order fringes being more accurate than that calculated from the first-order fringes. Also, the uncertainties calculated here is predominantly based on the precision of the spectrometer, so they understate the true error in the calculated wavelengths, since this method contains noise from the fact that I had to line up the spectrometer by hand such that the incident light was normal to it. In practice, the first- and second-order calculated results were within 55 Å and 29 Å, respectively, of the true wavelength, limited by the method and not the spectrometer. One advantage of the second-order measurement is that the second-order fringes have a larger diffraction angle and therefore measuring them results in a smaller relative uncertainty. However, the first-order measurement has the advantage that the first order peaks were slightly brighter and therefore easier to spot consistently.

Method of Minimum Deviation:

I again sought to measure the wavelength of the sodium D2 spectral line, but this time using the more accurate method of minimum deviation, in which I no longer had to rely on the normal incidence of the light onto the spectrometer. Instead, I tilted the grating until I observed the diffracted spectrum move the least and only then measured the diffraction angle of the brighter first-order fringe. I measured this diffraction angle at the position of minimum deviation to be . From this measurement, I calculated the wavelength of the D2 line to be (). This is within about 37 Å of the reported wavelength, 588.995nm (5889.95 Å). This result is surprisingly closer to (within 31 Å of) the reported wavelength of the D1 line, 589.592nm (5895.92 Å).

The precision of the measurement didn't allow me to compare the result for D2 to that of D1 since the uncertainty from the measuring instrument again understated the error from the method. Though theoretically this method should have been more accurate than the method of normally incident light since it doesn’t rely on lining up the apparatus by eye, I found that in practice the exact position of minimum deviation was difficult to assess objectively and again was limited by the eye.

Identification of Unknown Gas Species:

I now turned by attention to a gas lamp, lamp # 1, containing an unknown gas which I identified by observing its emission spectrum. I first qualitatively observed that the light emitted was a distinctive shade of light pink. I also saw that there was a relatively dim violet line and a slightly brighter blue line just outside it. Further out, there were a couple brighter green lines. The brightest line was an orange one of roughly 600nm.

I next measured a few spectral lines using the method of normally incident light for first-order fringes. I compiled the measurements and calculated wavelengths of these lines to compare to the reported wavelengths. I also tabulated my qualitative assessment of the lines’ relative intensities so that I could compare them to the reported intensities.

In comparing my quantitative and qualitative analyses of the spectrum to a graph of the spectrum and tabulated values of the spectrum for various elements, I concluded that the gas species in the lamp was helium. To confirm these results, table 3 shows the reported wavelengths of the spectral lines which I measured, and figure 1 shows the emission spectrum of helium which closely matches my observations.

Table

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Line | θ (°) | | Observed λ (nm) | | Observed λ (Å) | | Observed intensity\* | Reported λ (nm) | Reported λ (Å) | Reported intensity |
| Violet | 15.50 | 0.03 | 445 | 1 | 4450 | 10 | Very dim | 447.1 | 4471 | 25 |
| Blue | 16.32 | 0.03 | 468 | 1 | 4680 | 10 | Dim | 471.3 | 4713 | 30 |
| Darker green | 17.15 | 0.03 | 491 | 1 | 4910 | 10 | Bright | 492.2 | 4922 | 20 |
| Lighter green | 17.50 | 0.03 | 501 | 1 | 5010 | 10 | Bright | 501.6 | 5016 | 100 |
| Orange\* |  |  | 600\* | 30\* | 6000\* | 300\* | Very bright | 587.6 | 5876 | 500 |
| \*data not measured, estimated from qualitative observation | | | | | | | | | | |

Helium Emission Spectrum



Figure

The wavelength of the four lines which I measured agreed closely with the reported wavelengths of the corresponding 4 lines in helium, and the same qualitative observations of intensity and color match what is shown in the graph of helium’s emission spectrum. Most noticeably, helium has a very intense orange band at around 590nm, which matched the very bright line I observed. From this evaluation, I am confident that the gas in lamp # 1 was in fact helium.

SUMMARY

I successfully learned to use a spectrometer while studying diffraction grating spectroscopy in this experiment. I also succeeded in measuring the wavelength of the sodium D2 spectral line to the desired accuracy using the method of first- and second-order normal incidence. I then was able to repeat this measurement with the more precise method of minimum deviation, albeit with only marginally improved accuracy. All my measurements were accurate enough that I could clearly see that the theory behind grating diffraction was valid. I then used the spectrometer to analyze the emission spectrum of an unknown gas species in a lamp and was able to identify the gas as helium to a high degree of certainty through both qualitative observation and measurement. In doing so, I was able to fulfill each of the objectives outlined in the introduction. A question for a future experiment could be how similar the measurements end up being in the case of absorption spectroscopy instead of emission spectroscopy.