MIDDLE EAST TECHNICAL UNIVERSITY

Atomic Spectra

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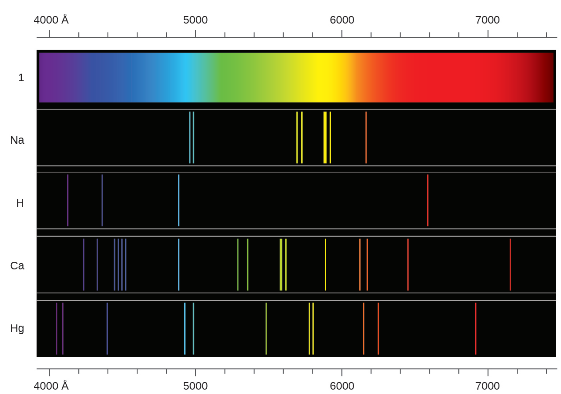

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1 Introduction

1.1 Goal

The main goal of this experiment is to observe the spectral lines of the sodium atom in the visible region to make comments about the physical mechanism of fine structure and verify the theory with experimental data.

1.2 Theory

There are two types of light spectra: Continuous spectrum and discrete spectrum. Continuous spectrum consists of all colors of light and they blend to each other, producing a continuous picture, hence its name. Discrete spectrum consists of only a few colors showing up as lines on the spectrum, not fading into each other, hence its name. The two main physical phenomena we are interested in this experiment, which are diffraction and fine structure.

1.3 Diffraction Mechanism

Diffraction is a useful technique to separate incident light into the wavelength components it is made out of. A transmission diffraction grating was used in this experiment for this exact purpose, separating the wavelengths of incoming light from the sodium discharge tube. The transmission diffraction was achieved by a glass grating with grating spacing that ranges from approximately 1000 nm to 2000 nm.

In general, diffraction mechanism can be written as:

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

where δ is the phase difference, λ is the wavelength, d is the grating spacing, θ is the angle and n is the order number.

Viewing the lamp through constant deviation of the grating, the spectral line splitting can be observed. This splitting is called the fine structure and it proves that the energy levels are not the same for different spin orientations for electrons with the same quantum numbers n, l and m.

1.4 Fine Structure

The fine structure points to the closely-spaced doublet that can be observed when the spectral lines are viewed under very high resolution. The observation of the fine structure was one of the first evidences of the existence of electron spin.

This small splitting of the spectral lines is due to the spin orbit interaction between the electron spin and the orbital angular momentum. The magnetic field caused by the orbital angular momentum interacts differently with different spin orientations of the electron. A schematic showing the fine structure in sodium can be seen below.

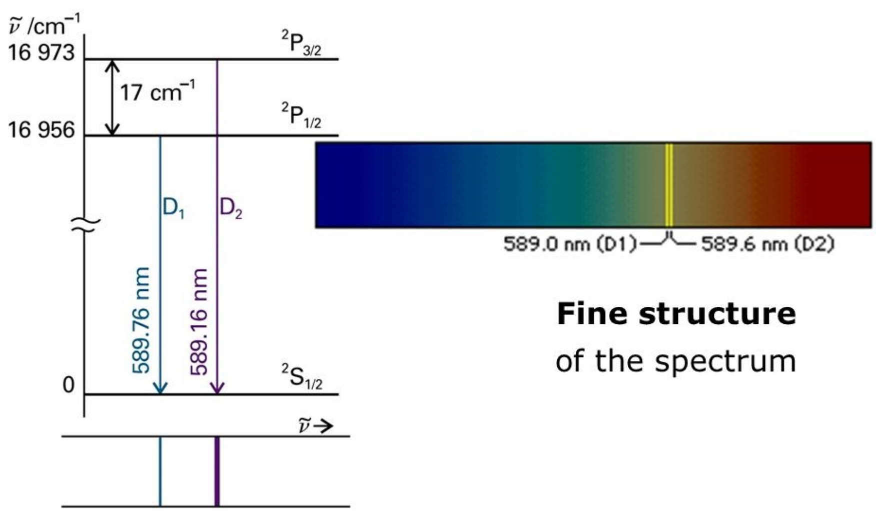

Figure 1: A schematic of fine structure in sodium.

2 Experimental Details

2.1 Equipment

The experiment apparatus consisted of a sodium discharge lamp, a glass grating, a telescope, a power supply for the discharge lamp and a circular scale.

The sodium discharge lamp provided incident light for us to observe the spectral lines, the glass grating was used to perform transmission diffraction to separate the wavelengths of incident light, the telescope was used to look though the discrete spectra of sodium and the circular scale was used to measure the angle of the telescope with respect to the glass grating. The complete apparatus can be seen in the figure below.

Figure 2: The Atomic Spectra experiment apparatus.

2.2 Procedure

The first part of the experiment consisted of adjusting the glass grating perpendicular to the line of sight and recording the angles in which we observe certain spectral lines.

The second part of the experiment consisted of adjusting the glass grating to a sixty degree angle and recording the angles in which fine structure splitting was present.

3 Measurement And Data Analysis

3.1 Presentation Of Data

D1	D2	D3	D4	D5	D6	D7	D8
'Violet'	1	-15.61	16	0.275	4612.07	1.13	52.72
'Green-Blue'	1	-17.5	17.5	0.30	5090.94	1.12	58.05
'Green'	1	-20.03	20.16	0.35	5818.15	2.28	-129.95
'Yellow'	1	-20.91	20.96	0.36	6051.07	2.63	-155.17
'Red'	1	-21.83	21.98	0.38	6316.96	2.53	-156.26

Table 1: Spectral Lines Of Na, First Order Image

For Table 1 above: D1 is the color of the line observed, D2 is the order number, D3 is the angular position of the image from left, D4 is the angular position of the image from right, D5 is the average angular position of the image, D6 is $sin\theta$, D7 is wavelength and D8 is percentage error.

Color	Order	θ_{d1}	θ_{d2}	sinθ_{d1}	sinθ_{d2}	λ_1	λ_2	$\Delta\lambda$,e	$\Delta\lambda$,t
'Green'	2	11.5	11.51	0.20	0.20	5920.14	5922.56	2.41	56.91
'Green'	3	32.69	32.78	0.57	0.57	5870.42	5877.32	6.90	23.28
'Yellow'	2	12.85	12.90	0.22	0.22	6115.11	6122.31	7.20	20.02
'Yellow'	3	34.65	34.75	0.60	0.60	6030.25	6038.34	8.09	34.96
'Red'	2	14.70	14.75	0.25	0.25	6380.56	6387.70	7.14	9.91

Table 2: Spectral Lines Of Na, Higher Order Images

3.2 Calculations

The calculations for the first part of the experiment followed from the relation

$$n\lambda = dsin\theta \tag{2}$$

where n is the order number (which is $n = 1$ for the first part), λ is the wavelength, d is the spacing of the grating material and θ is the measurement angle.

The calculations for the second part of the experiment followed from the relation

$$n\lambda = d(sin\theta_i + sin\theta_d) \tag{3}$$

where θ_i is the angle of incidence (which is thirty degrees for the second part) and θ_d is the angle of diffraction.

All of the calculations were carried out using a Python script to avoid tedious intermediate steps and two significant figures were chosen as the resolution for this experiment.

4 Results And Discussion

4.1 Discussion Of Results

It is clear from the percentage error results that we have successfully identified the wavelengths of the spectral lines of Na atom in the first part. This result shows that sodium has a discrete spectra, i.e. only certain wavelengths/colors can be observed from its diffracted light.

In the second part, we have managed to prove that fine structure exists and it is possible to observe the splitting of spectral lines if we have enough resolving power. We have managed to observe the splitting to the number order of $n = 3$ with our experimental apparatus.

The reason for the difference of atomic spectra for different elements is the fact that they have different numbers of protons, electrons and different electron arrangements. Basically, the amounts of energy resulting from absorption and emission is different for each element.

4.2 Discussion Of Errors

We have lined up a very slim crosshair with the spectral lines and then measured the angle values manually on a Vernier scale mounted on the experiment apparatus. This means that we have used our eyes two times, to line up the crosshair with the spectral lines and to measure the angle values which should produce a lot of error in return. The errors can be significantly lowered just by using a digital scale instead of a manual Vernier scale which is hard to line up and relatively primitive in this day and age.

Contrary to our suspicions though, the actual error values turned out to be shockingly small when we processed the data and calculated the percentage error. The calculated percentage error values can be seen in Table 1 and Table 2.

References

[1] James Blackburn. *Modern Instrumentation For Scientists and Engineers*. Springer-Verlag New York Inc., 2000.

[2] Eugene Hect. *Optics*. Pearson, 2015.

[3] Kenneth Krane. *Modern Physics*. Wiley, 2012.

[4] STScI. Webb space telescope.

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