**ATOMIC SPECTRA**

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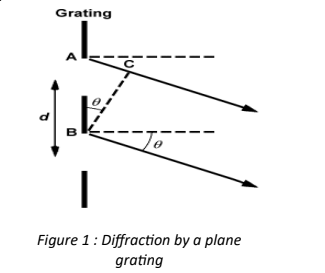
Date of the Experiment: 28.02.19

Report Submission Date: 07.03.19

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**Introduction**

A visible spectrum is obtained by separating light into its wavelength components. These spectrums can be discrete or continuous. The continuous spectrum does not a have a beginning or an end and the colours come one after another continuously. On the other hand, discrete spectrum has certain colour lines and besides that it is mostly dark. Discrete spectrums are produced by the help of the hot gas discharges of single element and is unique to each element. In this experiment, we looked at the discrete spectrum of sodium element and observed its fine structure.

One of the methods can be used for separating the light into its wavelengths and produce a spectrum is to use a transmission diffraction grating. Transmission grating is a piece of transparent material that usually has more than thousands of slits per cm. In Figure 1 we see the rays falling on the grating. Even though some of them continue their way unaffected some portion is deviated. When the phase difference between these rays equals to the wavelength or integer multiples of it then the rays interfere constructively, and the light is observed. The path difference is calculated by **.**

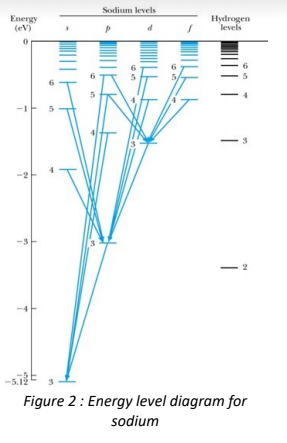
The condition for constructive interference is

Here, n is the order number.

For being able to distinguish closely placed images grating needs to have a high resolving power. The resolving power determines the ability of the grating to which extent it can resolve an image and is calculated by where n is the order number and N is the total number of rulings.

The equation above is valid when the grating is placed perpendicular to the lamp, however when the grating makes an angle of θd with the lamp we consider the additional path difference and use the following equation

Placing the grating at an angle with respect to the lamp helps us for observing the fine structure of sodium which happens due to internal Zeeman effect. The electron configuration of Na at the ground state is as 1s22s22p63s1 which means it has 1 valence electron at the outer shell. This electron sees a potential same as the hydrogen case when it’s far away from the nucleus. When closer, this electron also experiences the potential(C) generated by the other electrons at the nucleus and therefore the total potential of . So, the situation becomes more complex as the same n correspond to several levels due to l which makes the electron transitions possible between different states when the selection rules are satisfied.

The Rydberg formula that is used for hydrogen spectrum is not valid for sodium due to its complexity and is modified into the following form

Here is called the quantum defects and its proportional to inverse of l. and are the principal quantum states of final and initial states, respectively. R is the Rydberg’s constant.

The valance electron of sodium makes transitions between 3p and 3s levels with two possible angular momentum values which are j=3/2 and j=1/2. This splitting occurs because of the orientation directions and is called the internal Zeeman effect .

The possible transitions for sodium is indicated in Figure 2.

**Experimental Details**

Figure 3. Spectrometer
The setup consists of a sodium lamp, a spectrometer, a voltage source and a diffraction grating. The spectrometer consists of a collimator, support table and a telescope placed on a movable arm. The voltage source is used for exciting the sodium atoms in the tube. The light coming from the lamp falls onto the collimator. Collimator collimates the light rays, so they leave the other end of the collimator as parallel rays. The parallel rays then get diffracted by the grating which is located on the support table perpendicular to the grating and separated into its wavelengths. Therefore, we see the different wavelength of light separately by the help of the telescope and identify their position by the help of the circular scale.

Telescope

Collimator

Figure 3. Spectrometer

**Measurement & Data Analysis**

Analysis, calculations and interpretation of the experimental data.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Color of the observed line** | **Angular position of image left θL** | **Angular position of image right θR** | **Average angular pos. of image** | **sinθ** | **Wavelength**  **λ(Ǻ)** | **Theoretical values** | **Percentage error (%)** | **Δλ** |
| **Violet** | 163.75˚ | 195.82 ˚ | 16.035 ˚ | 0.279864 | 4603.56 | 4668.5 | 1.391025 | 590.57 |
| **Blue-green** | 162.18 ˚ | 197.33 ˚ | 17.575 ˚ | 0.306742 | 5032.367 | 5153.6 | 2.352394 | 592.24 |
| **Green** | 159.58 ˚ | 199.88 ˚ | 20.15 ˚ | 0.351684 | 5741.091 | 5688.2 | 0.92984 | 595.30 |
| **Yellow** | 158.82 ˚ | 200.65 ˚ | 20.915 ˚ | 0.365036 | 5949.474 | 5889.9 | 1.01146 | 596.26 |
| **Red** | 157.78 ˚ | 201.58 ˚ | 21.9 ˚ | 0.382227 | 6216.217 | 6154 | 1.011 | 597.54 |

For the first part n=1, , d=16666Ǻ

For violet:

Using ,

Ǻ

Error is calculated with the formula

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Color observed** | **Order [n]** | **Θd1** | **Θd2** | **Θd1’** | **Θd2’** | **sin Θd1’** | **sin Θd2’** | **Λ1 (Ǻ)** | **Λ2 (Ǻ)** | **Experimental Δλ=λ2-λ1 (Ǻ)** | **Theoretical (Δλ) (Ǻ)** | **Percentage error of Δλ** |
| **Red** | 2 | 225.05° | 225.08° | 15.22 | 15.25 | 0.265639 | 0.266163 | 6354.13 | 6358.34 | 4.209812 | 6.5 | 64.8 |
|  | 3 | 247.9° | 248.13° | 38.07 | 38.3 | 0.664447 | 0.668461 | 6203.218 | 6220.747 | 17.52863 | 6.5 | 269.7 |
| **Yellow** | 2 | 223.17° | 223.23° | 13.33 | 13.4 | 0.232652 | 0.233874 | 6087.751 | 6097.656 | 9.904963 | 6 | 165.1 |
|  | 3 | 244.68° | 244.78° | 34.85 | 34.95 | 0.608248 | 0.609993 | 5952.152 | 5960.104 | 7.9521 | 6 | 32.5 |
| **Green** | 2 | 221.75° | 221.78° | 11.92 | 11.95 | 0.208043 | 0.208567 | 5887.646 | 5891.915 | 4.268831 | 5.6 | 76.2 |
|  | 3 | 242.68° | 242.87° | 32.85 | 33.03 | 0.573341 | 0.576482 | 5791.111 | 5805.758 | 14.64692 | 5.6 | 261.6 |

**For red n=2**

4.209812

**Results and Discussion**

We have repeated the atomic spectra experiment with Na and observed its spectrum and fine structure. We confirmed that Na has a discrete spectrum visible to human eye and the wavelengths of these spectrum lines can be found with the help of spectrometry.

We also observed the splitting of the emission lines due to the spin-orbit interaction (or internal Zeeman effect) which was only possible after rotating the grating by 30. We confirmed that the lines we observed in the first part were not a single line but two closely spaced lines as we rotated the grating. The calculations made after the experiment clarifies the fact that there’s a direct relationship between angles, wavelengths, and the orders of the images.

The first part of the experiment was successfully done as our errors are within the range of 5% which confirms the accuracy of spectrometry.

However, in the second part the error is much more than tolerable which can be due to a few factors. Firstly, the slight misreading in the circular scalar can result in greater error in the calculations and we might have misread it. As the lines are very close, we might have not arranged the position of the crosshair exactly which resulted in such an error. Another reason for not being able to place the crosshair might be due to the light coming from as the room was not completely dark. Additionally, the angle that we rotated the grating might not exactly be 30 degrees which resulted in further errors. Furthermore, parallax error might have happened while reading the Vernier scale.

But overall, we achieved our purpose by observations and calculations. Even though there were errors in the second part we still could still beautifully observe the splitting.