Observing the Normal Zeeman Effect and Estimating e/m for Orbital Electrons

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1 Introduction

The Zeeman effect was first observed in 1896 by the Dutch physicist Pieter Zeeman. Although at first there was no clear explaination for the results, the experiment was a cornerstone in proving the existence of electron Spin and magentic moments.

The Zeeman effect is the splitting of spectral lines in the presence of a magnetic field. The effect is caused by the interaction of the magnetic field with the magnetic moment of the electron.

It is important to point out that the Zeeman effect does not occur in all cases. For example, a simple case where it does not occur is in the ground state of the Helium atom, where the electrons are paired and the total magnetic moment is zero, as both atoms occupy the 1s orbital, and have opposite spin (remember also that the s orbitals do not have any orbital angular momentum, becuase the only possible l quantum number is l=0).

In this experiment, we will be using a Hg-Cd lamp to observe the Zeeman effect.

The electron for Mercury (Hg) is given by: 1s$^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1 04p^6 5s^2 4d^1 05p^6 6s^2 4f^1 45d^1 0, whilethecon$
$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1 04p^6 5s^2 4d^1 0$.

All of the orbitals of these are filled, the spin magnetic moments inside the orbitals will cancel out, and we can safely ignore the effect of spin in spectral line separation. The report will then be scoped to the **Normal Zeeman Effect**.

In order to set the foundation for the experiment, we will have to go back to electromagnetism. We can consider the electron as a point charge, with a charge of $-e$, and a mass of m_e travlling around the charged nuclus.

A torque given by $\tau = \vec{\mu} \times \vec{B}$ will be applied to the electron, where $\vec{\mu}$ is the magnetic moment of the electron, and is given by $\vec{\mu} = \gamma \vec{L}$, where $\gamma = -\frac{e}{2m_e}$ is the gyromagnetic ratio, and $\vec{L}$ is the orbital angular momentum of the electron.

Given this information, we can now calculate the energy shift of the electron in the presence of a magnetic field.

$$\Delta E = -\vec{\mu} \cdot \vec{B} = -\gamma \vec{L} \cdot \vec{B} = -\gamma L_z B \quad (1)$$

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 4
	595 ± 0.5	604 ± 0.5	600 ± 0.5	588 ± 0.5	601 ± 0.5

Table 1: Magnetic Field Intensity in mT

	Without Field	With Field	
Trial	Line Position	Upper edge position	Lower edge position
1	3.61	3.67	3.60
2	3.44	3.55	3.46
3	3.29	3.40	3.34
4	3.15	3.27	3.18
5	3.03	3.14	3.06
6	2.90	3.00	2.94

Table 2: Raw Data for Part 1

Where L_z is the z component of the orbital angular momentum (assuming the field B is applied in the z direction). We also know that $L_z = m_l\hbar$, where m_l is the magnetic quantum number, and $\hbar$ is the reduced Planck constant. We can rewite the above expression as:

$$\Delta y = -\gamma m_l \hbar B \tag{2}$$

According to this, and keeping in mind that m_l can take intager values from $-l$ to l, we can see that the energy levels of the electron are spaced by $\Delta E = \gamma\hbar B$. This is the energy difference between the Zeeman levels.

2 Method

method

3 Results

After adjusting the magnet poles, several measurments of the magnetic filed intensity were taken using the Gauss meter. The results are shown in the table below.

These measurments result in an average value of: $B = 598 \pm 0.22$ mT.

The field current and pole positions were not changed throughout the experiment, so we assume the magnetic field intensity to be constant.

3.1 Part 1: Observing the Zeeman split perpendicularly to the magnetic field

4 Conclusion

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