F44 Zeeman Spectroscopy

Short Report

Nils Schmitt Timo Kleinbek

Conducted in August 2018
Supervisor: Srinivas, Hemkumar

The Zeeman effect is an atomic physics phenomenon that describes how spectral lines of an element are split when the magnetic moment of the atom is coupled to an external magnetic field. The aim of this experiment was to observe the normal Zeeman effect in cadmium and then to investigate the splitting of the spectral lines as a function of the magnetic field strength. In a second part of the experiment we determine the wavelength of the red cadmium line by using a Czerny Turner spectrometer. We also had to determine the spectral line of an unknown element, which unfortunately was not possible because we could not resolve it. In our measurement we determined only the wavelength $\lambda_{\mathrm{Cd}} = (643.8 \pm 2.9)\,\mathrm{nm}$. In addition, the Bohr magneton μ_{B} could be calculated from both test parts, for which we obtained $\mu_{\mathrm{B}} = (10.3 \pm 0.5) \times 10^{-24}\,\mathrm{J/T}$.

Contents

1. Introduction

The Zeeman effect was studied first in 1896 by the Dutch physicist Peter Zeeman when he observed the widening of the yellow D-lines of burning sodium between strong magnets. Later he found out that the widening of the lines was actually a division in up to 15 components.
The spectral lines of an element arise when an electron emits a photon at the transition between

different energy levels, which wavelength depends on the energy difference of the energy levels. If a strong external magnetic field is applied, individual energy levels are changed by coupling the magnetic moment of the electron with the external magnetic field, which leads to a splitting of the spectral lines. A distinction is made between the normal Zeeman effect observed in the experiment and the anomalous Zeeman effect. These differ in the total spin $\vec{S}$ of the electron, which is $\vec{S} = 0$ at the normal Zeeman effect and $\vec{S} \neq 0$ at the anomalous Zeeman effect.

2. Theoretical Basics

Normal Zeeman effect

To understand the basics of the Zeeman effect, we first assume that the magnetic moment of an electron I can be sufficiently described by Bohr's atomic model. According to this model, the electron orbits the atomic nucleus as point mass m_e with velocity v and charge e at a distance r_{B}, the Bohr radius.
Using this approximation, the magnetic moment

$$\vec{\mu}_l = \frac{evr}{2} \cdot \vec{n} \tag{1}$$

is obtained.
Thus $\vec{n}$ is the normal vector, perpendicular to the disk on which the electron moves. You can easily see that the magnetic moment resembles the angular momentum of the electron

$$\vec{L} = \vec{r} \times \vec{p} = m_e r v \cdot \vec{n}. \tag{2}$$

3. Measurements Log and Evaluation

4. Discussion

References

[1] Wolfgang Demtröder. *Experimentalphysik 3. Atome, Moleküle und Festkörper.* ger. 5. Aufl. 2016. Springer-Lehrbuch. Berlin, Heidelberg: Springer Spektrum, 2016, Online–Ressource (XXI, 588 S. 740 Abb. in Farbe, online resource). ISBN: 978-3-662-49094-5. DOI: 10.1007/978-3-662-49094-5. URL: http://dx.doi.org/10.1007/978-3-662-49094-5.