Phys 4910 Spectroscopy
D lines of the Alkali Metals

Introduction

The alkali metals, including hydrogen, are one electron atoms in that each consists of a number of closed sub-shells and a single electron.

Z	Element	Configuration
1	Hydrogen	$n\ell$
3	Lithium	$1s^2\, n\ell$
11	Sodium	$1s^2\ 2s^s\ 2p^6\ n\ell$
19	Potassium	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ n\ell$
37	Rubidium	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ n\ell$
55	Cesium	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 5s^2\ 5p^6\ n\ell$

The ground term is a ns ^{2}S term[1], which only has the one level with J=½. The first excited term is the np ^{2}P term, with two levels corresponding to J=½ and J=3/2. The resonance D lines are then the transition np ^{2}P → ns ^{2}S, and are doubled because of the two upper ^{2}P levels.

The difference in wavelength of the D lines is determined by the magnitude of the spin-orbit coupling (fine structure) which is responsible for the splitting of the ^{2}P term into two levels. For hydrogen the spin-orbit coupling is very small, and the 1216 Å Lyman α line is split into two lines only 0.00054 Å apart. However as the number of electrons increases (equal to the atomic number Z) the relative importance of the spin orbit interaction becomes much larger, and the D lines become further and further apart.

In this project you will identify the D lines of the alkali metals lithium through rubidium, measure their wavelengths, and use the results to measure the strength of the spin orbit coupling, and its dependence on the principal quantum number n.

Assignment

For the most part these spectra can be recorded using the diode array as the detector, which is simpler and quicker than using the photomultiplier (PMT). You will need to use the PMT to measure the splitting of the D lines of lithium, which are too close together for the diode array to resolve.

There are a series of hollow cathode lamps in N136, including lamps for Li, Na, K, and Rb.

1 n=1 for hydrogen, 2 for lithium, 3 for sodium, 4 for potassium, 5 for rubidium, and 6 for cesium

Each uses neon as the buffer gas. You can use the neon lines which are produced simultaneously with the alkali metal lines to calibrate your spectra.

1. For each element record the spectrum of neon + alkali metal. Uses the ranges
    1. 600 nm to 700 nm for lithium
    2. 550 nm to 700 nm for sodium
    3. 700 nm to 900 nm for potassium
    4. 700 nm to 900 nm for rubidium
2. You already have neon spectra to compare with the first two for calibration. You will also need a neon spectrum from 700 nm to 900 nm for comparison with the last two.
3. For each one identify the D lines (they should be obvious if you compare with a pure neon spectrum)
4. Calibrate each spectrum against the known neon lines, and then deduce the wavelengths of the two alkali metal lines.
5. For the case of lithium, take a second spectrum using the PMT at high resolution, that is with a slit width as small as possible. You should include the two closest neon lines in your spectrum also to provide a wavelength scale.
    1. Using the monochromator control, set the Diverter to side.
    2. Use a PMT voltage of about 750 V
    3. Set the monochromator to wavelength of the D lines (measured from your full lithium spectrum) and adjust the wavelength slightly for maximum current on the electrometer.
    4. Decrease the slit width until the electrometer signal goes away, then increase slightly again to get a measurable current.
    5. Scan from just below the smaller neon wavelength to just above the higher neon wavelength.
    6. Using the two neon lines to establish the scale of your spectrum, determine the wavelength difference of the two lithium lines.

Report

It is now time to start putting together the main structure of a research paper. A full report consists of the following

- Abstract
- Introduction
- Experimental apparatus and method
    - A brief description of the method should include any relevant (bit not trivial) details of the apparatus. For example you would probably include the fact that you used a Roper Spectra Pro 760 monochromator, but not describe how the monochromator works.
    - Include any relevant details, such as the slit widths that you used.
    - Since you will be switching from the diode area to the PMT you should definitely

mention this, and why.
    - Mention that you calibrated against the neon spectrum.
- Data
    - A sample graph is optional, but not obligatory
    - Tabulate the lines you measured, including any uncertainties
- Analysis
    - Correction for the refractive index of air.
    - Calculation of energy splitting
    - Comparison with theory
- Conclusion