Phys 4910 Spectroscopy
Laboratory Assignment 5
Measuring the spin-orbit coupling in sodium and potassium

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 ^2S term[1], which only has the one level with J=½. The first excited term is the np ^2P term, with two levels corresponding to J=½ and J=3/2. The resonance D lines are then the transition np $^2P \rightarrow$ ns ^2S, and are doubled because of the two upper ^2P 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 ^2P 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 laboratory unit you will identify the D lines of the alkali metals sodium and potassium, measure their wavelengths, and use the results to measure the strength of the spin orbit coupling.

Assignment

There are a series of hollow cathode lamps in N136, including lamps for all the alkali metals, including Na and K. 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
   a. 550 nm to 700 nm for sodium
   b. 600 nm to 900 nm for potassium
2. You already have neon spectra to compare with the first two for calibration.

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

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.

Report

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

- Abstract
  - Write this last. Look at your conclusions and use the abstract to tell the reader this is what you plan to do and what the results are.
- Introduction
  - Here you should discuss (briefly) what spin orbit coupling is. Give citations to texts (including on line sites) that explain the topic in more detail.
- 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.
    - Mention that you calibrated against the neon spectrum.
- Data
  - This time we don't need to talk about the neon spectrum, or the calibration details. They are standard and can be taken as known.
  - A sample spectrum is optional, but not obligatory. If you do include it mark the lines which you identified as the D lines.
  - Report the wavelengths of the D lines for each element, including uncertainties.
- Analysis
  - In this section use the wavelengths to calculate the energies of the np ^2P levels.
  - Report the results of the experiment, as defined in the title.
  - Discuss any random or systematic errors which you might have encountered, and that have not been accounted for.
- Conclusion
  - Briefly summarize what you did and your conclusions.