Phys 4910 Spectroscopy
Laboratory Assignment 7

IMPORTANT: In this laboratory you will be using a cadmium lamp. Please be extra careful when using this lamp. Under no circumstances should you touch the lamp itself.

- The lamp itself, when at its operating temperature is ***very hot***. Touching it when hot will most certainly result in burning yourself.
- You can damage the quartz envelope of the lamp even when cold. Leaving a fingerprint on the quartz will result in irreversible scarring of the quartz when it is next turned on. In the event that you do inadvertently touch the quartz envelope immediately unplug the power supply from the wall and the lamp from the power supply. (The lamp cable first unscrews from the power supply and then pulls out.) Then notify either myself or Phil Rojas as soon as possible.

NOTE: if you arrive at the apparatus and find the lamp is unplugged, please do not plug it in and turn it on. That is our indication that there is a serious problem which needs to be corrected first.

Introduction

The objective of this assignment is to measure the wavelengths of the red emission lines of cadmium. Concurrently you will be asked to calibrate your spectrum against a known spectrum, in this case neon.

Calibration

When trying to measure wavelengths accurately it is always risky to rely on equipment calibration, unless you have calibrated it yourself and are sure of its accuracy. We can use the monochromator calibration to identify known lines, as you did in lab assignment 1 with the lines of helium and neon.

However, when the lines are not tabulated the instrument calibration is simply not good enough to determine unknown wavelengths. In that case a preferred method is to calibrate an unknown spectrum against a known spectrum, whose lines are recorded *at the same time*.

Assignment

You are given two lamps, a cadmium lamp (note safety instructions at top of page) and a neon lamp. You will need to record two spectra

- the spectrum of cadmium alone
- the spectrum of cadmium and neon

1. Select and record your entrance slit width
2. Place the cadmium lamp in front of the entrance slit, and adjust its position if necessary. (Note safety instructions at top of page)
3. Turn the lamp on, and leave for at least five minutes to warm up. This is required to attain an operating temperature with a sufficiently high vapor pressure of cadmium in the lamp. During this time you should notice that the lamp changes color. This is an indication that the cadmium is being evaporated into the lamp.
4. When the lamp is warm, record the spectrum from 550 nm to 700 nm.
5. Leaving the cadmium lamp in place, place the neon lamp directly behind it, and record the spectrum again.
6. Check that the second spectrum has more lines in it than the first spectrum. These extra lines are neon lines from the second lamp. They need not be very strong, just recognizable. If you cannot see them, then adjust the position of the neon lamp, and take the spectrum again.
7. Please make sure the cadmium lamp is turned off when you finish.

Analysis

By comparing the two spectra you should be able to decide which lines belong to the (unknown) cadmium spectrum, and which belong to the (known) neon calibration spectrum. Once you have made that identification the spectrum of cadmium alone can be discarded.

1. Load the cadmium+neon spectrum into Excel.
2. For each of the neon lines (or at least the 8-10 strongest lines) record the row number corresponding to the center of the peak.
3. Do the same in a separate list for the cadmium lines.
4. You can now delete the column of wavelengths if you like. These are from the WinSpec program, and we are not going to rely on them.
5. Use the neon lines to calibrate your spectrum (see next section). Use a linear fit as default, a quadratic fit also if that improves your results. (The difference is likely to be small unless you have an error in your assignment of neon lines.)
6. From the calibration determine the wavelengths of the cadmium lines.
7. Estimate your uncertainty in the measured wavelengths (see below).
8. Compare your Cd wavelengths with those in the CRC handbook, and compute differences. Compare the differences to your uncertainties.

Calibration

You should by this stage have

- a data table containing row number and wavelength of the neon lines in your spectrum
- a list of row numbers for the cadmium lines in your spectrum

The determination of the unknown cadmium wavelengths is a two step process. It relies on there being a predictable relationship between the row number (x) and wavelength (λ) for the spectrum

$$\lambda = a_0 + a_1 x + a_2 x^2 + a_3 x^2 + \ldots\ldots = \Sigma_i a_i x^i$$

where the sum is from i=0 to i=N, the highest power in the series. In practice a linear fit (N=1) should be sufficient. It might be worth also trying a quadratic fit (N=2) to see if the accuracy of your results improve (see below).

1. Using the data table for the neon lines, find the coefficients a_0 and a_1 (linear fit) or a_0, a_1, and a_2 (quadratic fit) using a regression procedure. Excel has this capability, or alternatively I have added to the computer in N136 a program (Polyfit) which will perform the fit for you. Your data should fit the regression curve fairly closely. Having one or more calibration lines well away from the regression curve indicates a mis-assignment of one or more lines.
2. Once the regression coefficients have been determined, use the equation above to calculate the wavelength for each of the cadmium lines.

Uncertainties

The uncertainty in any one measured wavelength depends on three factors

1. How accurately you can pick out the centers of the neon calibration lines.
2. How uniform is the scan rate of the monochromator.
3. How accurately you can pick out the centers of the cadmium lines.

The first two can be accounted for by calculating the uncertainties in the calibration fit parameters. For the equation

$$\lambda = a_0 + a_1 x + a_2 x^2 + a_3 x^2 + \ldots\ldots = \Sigma_i a_i x^i$$

each of the coefficients a_i has an uncertainty σ_i. In the case of a linear fit these uncertainties can be obtained from the linear regression routine in Excel. (It is also possible to find them in the case of a quadratic fit.)

For the last item in the list above, you measured that as the (half) width of the line in the previous laboratory exercise. Assume it is the same for all the lines (usually a good assumption), equal to the ½(δλ) you measured earlier for the same slit width that you used in this laboratory exercise.

For each wavelength you should calculate an uncertainty from the calibration uncertainties, assuming that your measurements are perfect (call that σ_1) and one from your measurement uncertainty, assuming the calibration is perfect (call it σ_2). The total uncertainty in your measurement is then given by

$$\sigma^2 = \sigma_1^2 + \sigma_2^2$$

Report

Your report should have the following

1. The combined cadmium + neon spectrum. Indicate which lines are due to cadmium, and which are due to neon. In the case of the latter, give the wavelengths also.
2. The data of row number vs wavelength for the neon lines, and the fit coefficients that you calculated.
3. The data of row number for the cadmium lines, the wavelengths that you calculated from the calibration, the uncertainties, and the differences between your calculated wavelengths and the known wavelengths
4. A discussion of the accuracy of your measurements, when compared to your uncertainties.