Helium Spectrum Analysis

In this experiment we will measure the wavelengths emitted by hydrogen and helium with our Ocean Optics spectrometer. We will use the hydrogen spectrum to calibrate the spectrometer. Then, we will be able to obtain accurate measurements of the helium spectrum. After collecting the Helium spectrum data, we will compare the helium wavelengths to those of hydrogen to help us identify the transitions.

Methods

Data will be collected using our Ocean Optics spectrometer using appropriate collection times. If you are satisfied with the spectrum, then save it in the course directory.
The optical spectrum data is fundamentally different than the nuclear gamma spectrum data. In the case of the gamma detector, the photoelectric effect was the method of detection and allowed us to *count* the photons. For the optical spectrometer, a diffraction grating uses interference effects to separate the different wavelengths. The detector measures the intensity (classical) of the radiation. We are not counting photons with the optical spectrometer. The intensity in each" channel" is not an integer, and does not necessarily obey Poisson statistics. The shape of the peaks are not necessarily Gaussian.

Wavelength Calibration

Take and save a hydrogen spectrum. The wavelengths of the Balmer series transitions are listed in the table below in order of their intensity. Use the table below to obtain a "calibration equation" between "channel number" and wavelength. To get an idea of the uncertainty of the energy calibration, you can examine the residues of the standards from the fit .

Transition ($n_i \rightarrow n_f$)	Wavelength (nm)
$3 \rightarrow 2$	656.28
$4 \rightarrow 2$	486.13
$5 \rightarrow 2$	434.05
$6 \rightarrow 2$	410.17
$7 \rightarrow 2$	397.01

Helium Analysis

Take and save helium spectra using a short collection time, for peaks with a large intensity. Then take and save helium spectra using a long collection time for peaks with small intensities. Measure the channel number of the peaks. Use your calibration equation to determine the wavelengths of the radiation.

An interesting way to analyze the data is to calculate all possible differences in energy between the helium and the hydrogen specrum lines. The energy of a photon is $E = hf = hc/\lambda$. In units of $eV-nm$, $hc = 1240\ eV-nm$. The energy differences can be calculated using the following spreadsheet approach. The hydrogen wavelengths are entered in the first row of the spreadsheet according to their initial principal quantum number, n_i. The helium wavelengths are entered in the first column of the spreadsheet according to their relative intensity. Then fill the spreadsheet with the energy differences ΔE_{ji} between all combinations of the emitted photons of hydrogen and helium by entering the following formula in the spreadsheet:

$$\begin{aligned}\Delta E_{ji} &= \frac{hc}{\lambda_j(He)} - \frac{hc}{\lambda_i(H)} \\ &= 1240\left(\frac{1}{\lambda_j(He)} - \frac{1}{\lambda_i(H)}\right)\ eV\end{aligned}$$

where $\lambda_j(He)$ is the helium wavelength (in nm) in the $j^{l}th$ row, and $\lambda_i(H)$ is the hydrogen wavelength (in nm) in the $i^{l}th$ column. Note that j is not the index for the $j^{l}th$ energy level of helium. Examine the array for any patterns and check if there are common values of energy differences. After everyone has made the spreadsheet, we will discuss our results in lab.

Make sure your lab report for Experiment 6 includes:

1. The data for the hydrogen spectra, which includes the "channel number" corresponding to the hydrogen wavelengths. Turn in the calibration graph, and the calibration equation that relates wavelength to "channel number". Determine the uncertainty and discuss in detail how you estimated the uncertainties

2. The data for the helium spectra, which includes the "channel number" and the corresponding wavelength of the peaks from your calibration graph.

3. Your spreadsheet for all the energy difference combinations ΔE_{ji} of the hydrogen and helium emission lines.

4. Discussion of your analysis of the data. You should be able to identify many transitions, and determine a singlet-triplet splitting in helium. Label the transition in as many Helium lines as you can using *just your data*. Each spectral line should be labelled in the form: $6d \rightarrow 2p$(*singlet*), $6d \rightarrow 2p$(*triplet*), etc. Discuss how one can determine the singlet-triplet splitting from the data.

Questions: No questions for this experiment.