Experiment 2

Radiation in the Visible Spectrum

Emission spectra can be a unique fingerprint of an atom or molecule. The photon energies and wavelengths are directly related to the allowed quantum energy states of the system.

In the following experiments we will examine the radiation given off by sources radiating in the visible region. We will be using a spectrometer produced by Ocean Optics. Light enters the spectrometer via a fiber optic cable. Inside the spectrometer a diffraction grating diffracts the different frequencies onto a CCD. The CCD basically "counts" the photons according to wavelength. The data is transferred via a usb port to a PC. The Ocean Optics software displays the spectrum as counts versus wavelength.

We will examine the spectra given off by the following sources: incandescent light filament, hydrogen, helium, various light emitting diodes and a laser pointer. You will also be given an unknown gas discharge tube and will need to identify the gas via its spectral emissions

Pre Lab

1) Obtain a spectrum for hydrogen, mercury, sodium and neon gas emissions. The spectrum must contain an accurate listing of major emission lines (in nm), not simply a color photo of the emission.
2) Make yourself familiar with the manual for the spectrometer and the software. These are available via the following links:
http://www.oceanoptics.com/technical/hr4000.pdf
http://www.oceanoptics.com/technical/SpectraSuite.pdf

These documents are also available on Black Board.

3) How does the Ocean Optics spectrometer work? In your answer list its three main components and describe what each component does.
4) You will have to make sure the spectrometer is calibrated. Explain what calibrate means in this case and suggest how to test whether the spectrometer is calibrated.

Data collection

Note1: For each measurement, you must first take a dark spectrum scan.
After you take a dark spectrum scan, you can take as many measurement scans as needed. However, if you change any sampling variable (integration time, averaging, smoothing, angle, temperature, fiber size, etc.), you must store new dark spectrum scan.

Note 2: All data obtained should be saved in excel form and submitted as part of the lab report

Part A : Atomic and Molecular spectra:

I) Mercury/Argon spectrum (Callibration)

1. Data collection: Record and save the spectra for the mercury tube .
   Using the Ocean Optics spectrometer observe the spectra of your gas discharge tube by placing it in the power supply (switched OFF, of course, when the tubes are installed or removed).
   To operate the Ocean Optics software, double click the icon 'Ocean Optics Spectrometer' on the desktop. In the menu displayed, click 'Go' to start data acquisition. You may start with the initial parameters of integrating time (100ms) and Average (1). Read the manual and find suitable parameters to obtain smooth curves. Save the data on Excel spread sheet for data analysis.

2. Qualitative assessment: Describe (in words) the nature of the spectrum. (e.g. is it continuous or discrete). Did you observe any radiation bellow around 300 nm from the discharge tubes? If not why not?

3. Compare the spectrum you have observed to the 'known' spectrum from a physics reference. Make a chart for each gas showing your recorded wavelength, the accepted wavelength for this line, and the % error in your observation (the difference between your reading and the accepted reading ratio over the accepted value).
4. You may have noticed in the "known" spectrum from a physics reference that Mercury has an emission line at 253.7 nm, did you observe this line? If not why not?
5. Describe the purpose of this measurement (Part A I, hint: look at the title of this section)

II) Hydrogen Spectrum

In this experiment we will examine the radiation given off by a hydrogen discharge tube.

1. Data collection: Record and save the spectra for the hydrogen tube.

2. Qualitative assessment: Describe (in words) the nature of the spectrum . (e.g. is it continuous or discrete).

3. Print out the graph of the spectrum (from excel) and on the graph write down the atomic transition that is producing each peak. For example 3p→3s.

4. Identify as many peaks from the Balmer series as you can. Make a data table of these wavelengths and the corresponding photon energies (in eV). Make a graph of $1/\lambda$ versus $1/n_i^{\ 2}$, where n_i is the "quantum number" of the initial state. The Balmer equation is:

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

Where n_f is the quantum number of the final state.

5. From the slope of the graph, determine the Rydberg constant R

6. From the intercept of the vertical axis, and your value of R, determine n_f which is the quantum number of the final state.

7. Do the values you obtained for R and n_f agree with those stated in the literature? What are some of the reasons that they might be a little bit different?

III) Molecular Spectrum

1. Data Collection: Collect and save the spectrum from 2 discharge lamps containing molecular gas.
2. Qualitative Assessment: Describe (in words) the nature of the spectra. How is this spectrum different from the spectra you obtained in part I and II? What could be the reason for the difference?

Part B: Incandescent Light source:
Our Incandescent light source will be tungsten filament.

1. Data Collection: Record and save the spectra for the light bulb when it is operating at its " normal" brightness.
2. Qualitative Assessment: Describe (in words) the nature of the spectrum. (e.g. is it continuous or discrete). Do you notice any unusual features? Do you think is representative of a perfect "black body" radiation? Why or why not.

3. From the spectrum, estimate the temperature of the filament. This can be done by modeling the filament as a " black body" radiator. In this case, the Wien displacement law kT= 0.2014 hc/λ_{max}. From your spectra estimate as best as you can what λ_{max} is. Is your result close to what listed in the literature as the temperature of a light bulb?

4. Reduce the voltage across the filament, and repeat Part 3 above. Is λ_{max} the same, less, or greater as in part 3? Is your observation consistent with the change in temperature?

Part C: LED spectrum

In this experiment we will examine the radiation given of by different Light Emitting Diodes (LED).

1. Data collection: For each LED, you will slowly increase the voltage across it. For each step in voltage, you will also record the current through the LED. Keep recording voltages and currents until the LED lights up. Do not put too much voltage, as you might damage the LED. The goal of this exercise is to determine at which voltage the diode starts conducting. The charge of an electron, e, times this starting voltage should be equal to the energy of the photon that is emitted.

2. When the LED is producing light, record and save a spectrum with the spectrometer.

3. Qualitative Assessment: Describe (in words) the nature of the spectrum. (e.g. is it continuous or discrete).

4. For each LED, determine the wavelength that has the most counts. This is the characteristic wavelength of the LED. Estimate the Full Width at Half Maximum (FWHM) of the peak in nanometers. This is the range of wavelength for which the counts drop to 1/2 the maximum value to the left and right of the peak.

5. If you examine the graph of current versus voltage for each LED, you will be able to estimate the voltage at which the current starts. This starting voltage times the charge of the electron should equal the energy of the photons emitted. That is $eV = hc/\lambda$

6. Make a graph of voltage V versus $1/\lambda$ for each LED. Do your data lie in a straight line? If so find the slope of the line. Does it agree with the literature value?

Part D: Laser spectrum

In this experiment we will examine the radiation given of by a diode laser.
1. Data Collection: Collect and save the spectrum from a laser pointer. BE CAREFUL NOT TO HAVE TOO MUCH LIGHT INTENSITY GOING INTO THE FIBER. For the laser, you will need to put the cloth provided over the laser light to diffuse the light before it enters the optical fiber.

2. Qualitative Assessment: Describe (in words) the nature of the spectrum. (e.g. is it continuous or discrete).

3. Quantitative Assessment: Print out a graph of the spectrum (from Excel). From the text file, determine the wavelength of the peak(s) and estimate the width of the peak(s).

Part E: Florescent lamp

In this experiment we will examine the radiation given of by the florescent lights in the classroom.

1. Data Collection: Collect and save the spectrum from the florescent lights in the room.
2. What are the main wavelengths (three) present in the spectrum? Are they approximately the same intensity? What colors do these wavelengths correspond to? Why do you think the florescent light manufacturer designed the light to give the spectrum it does.

Part F: Identification of Unknown Gases:

Install the tube with the 'mystery' gas, compare to known spectra and identify the gas. Include a paragraph describing your rational for identifying it (e.g. # of lines, wavelengths, error justification..). Repeat this section for 2 mystery gases.