Observation of Atomic Spectra

Introduction

In this experiment you will observe and measure the wavelengths of different colors of light emitted by atoms. You will first observe light emitted from excited hydrogen atoms.

When gases are placed in a tube and subjected to a high-voltage electric discharge, the electrons in the atoms can be excited to higher energy levels within the atoms; when they return to their original levels electromagnetic radiation is emitted. Some of this radiation may be in a wavelength region that is visible to the human eye.

In this experiment a vapor (such as mercury or hydrogen) is placed in an electric discharge tube and a high voltage is placed across the tube. The excited emission may look almost white or have a characteristic color depending on the vapor inside, but it is in reality composed of a number of different colors or wavelengths of visible light. You will use a diffraction grating to allow you to separate the different wavelengths in the visible region. There is also some emission in the ultraviolet region, corresponding to higher energy transitions, as well as emission in the infrared region, but the human eye cannot see these transitions.

After determining the emitted wavelengths from hydrogen, you should compare your data to the predictions of the Bohr model to determine which atomic transitions you are exciting in the gas discharge lamp (e.g., do you observe transitions from n=4 to n=2, or from n=3 to n=1?). Once you have completed the measurement and analysis for a hydrogen lamp, you should try another vapor (such as Hg, He, Ar, etc). Can your data for the more complex atoms be explained in the same manner as the hydrogen spectra? Find a reference spectra for your lamp online and compare your results.

Procedure

1. Determining the Wavelengths of Hydrogen Line Spectra

In this part of the experiment you will use the known grating spacing d and the measured angle of three lines of the hydrogen spectrum to determine the wavelength and energy of the photons associated with these spectral lines. You should also **draw an energy level diagram** to show which energy levels of the hydrogen atom are related to the emission of these lines. The experimental procedure for determining the diffraction angles is just as in our last experiment. From the observed hydrogen spectra you can also calculate the Rydberg constant, R_H.

The emission spectra you will observe are in the visible part of the spectrum. The relationship between the frequency (f) and the wavelength (λ) of electromagnetic radiation is

$$\lambda f = c$$

where c is the speed of light in a vacuum ($c = 3.0 \times 10^8$ m/s).

After you determine the wavelength of three of the hydrogen emission lines, you will be able to also calculate the frequency of the radiation. You can then calculate the energy (E) associated with the different colors of light by using the relationship

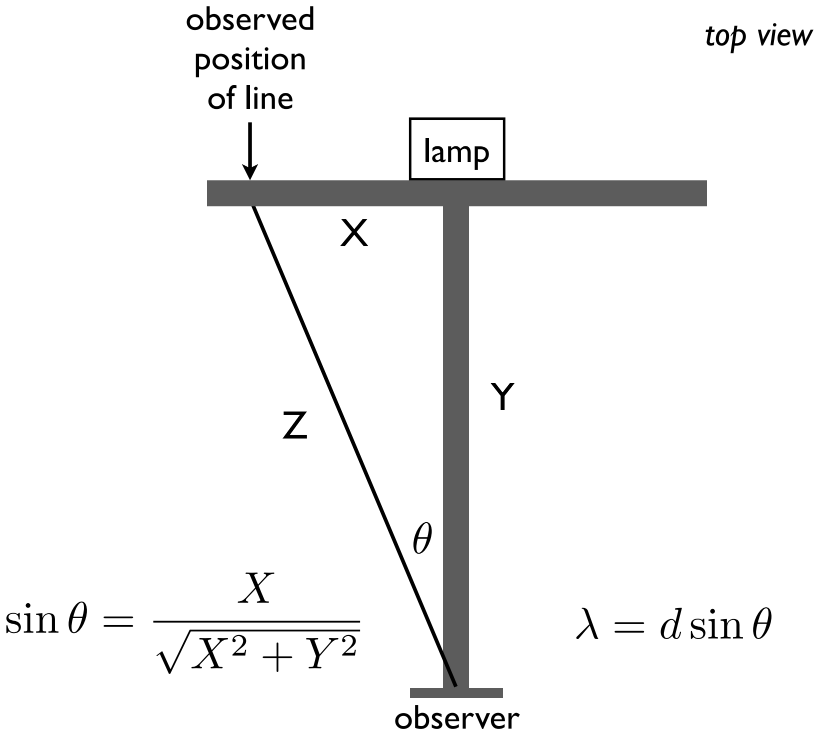
$$E = hf = hc/\lambda$$

since $\lambda f = c$. The constant h is called Plancks constant, which you measured last time and the value of h is 6.63×10^{-34} Joule-seconds, so your energy will be expressed in Joules. Use the conversion

$$1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$$

to convert your energies to eV. If you wish to use electron volts for energy (convenient!), it is useful to note that hc = 1240 eV-nm.

Experimental Setup for the Observation of Discharge Lamp Line Spectra



$$\sin\theta = \frac{X}{\sqrt{X^2 + Y^2}}$$

$$\lambda = d\sin\theta$$

Safety: You should not stare directly at the discharge coming from the mercury lamp. When you observe the spectra, you will be looking at an angle to the slit, but you should not stare directly at the slit. The bulb may also be very, very hot; take care in removing it. Never touch the bulb or attempt to remove it without first turning off the power.

The figure above illustrates the basic setup - use two meter sticks to measure the distances X and Y, thereby determining the angle θ. From the angle θ, and the diffraction spacing *d* you will determine, you can determine the wavelength of the emitted lines using the procedure below.

Part 1

1. Set the meter sticks on the end table at the base of the lamp. Be sure the two are exactly perpendicular to each other and that the stick is balanced at its 50 cm mark.
2. Put the grating on its support and place it on the optical bench so that it is about 100 cm from the mercury discharge tube. The top of the grating is marked on the grating, and it should be positioned so that the top is highest above the optical bench.
3. The lamp should be positioned as close as possible to the other end of the optical bench.
4. One lab partner will view the emission spectrum by looking through the diffraction grating and observing the yellow, green and violet lines at a position on either side of the mercury lamp. The other partner will stand behind the mercury lamp and move a pencil along the meter stick to the position described by the observer. Record the position where the yellow, green or blue image appears. This procedure should be repeated for each of the visible lines by *at least two* of the partners, and the spectral lines should be measured on both sides of the lamp position. Thus there should be two measurements of each spectral line by each observer.
5. The measured values should be entered in the data table and all the X values for each spectral line should be averaged.
6. The value of sin θ should be calculated from the $X_{average}$, Y and d values and entered in the table.
7. Calculate the wavelength, frequency, and photon energy.

Part 2

1. Now replace the hydrogen lamp with a different lamp *after turning the lamp power off.* The bulbs are fragile, be careful! The bulb may also be **very hot**.
2. Repeat steps 4 and 5 from part 1, and fill in the table below.
3. Calculate the wavelength λ and frequency f for each spectral line.
4. Also calculate the energy of the photons emitted in the corresponding transition.
5. Find a reference spectra for your lamp online (e.g., google for the emission spectra of your element). Take care, the field of spectroscopy is littered with many different (and marginally insane) units of measurements.

Worksheets and calculations for Hydrogen spectrum

First Hydrogen line

observer	d (m)	Y (m)	X_{left}	X_{right}	sin θ	λ_{calc}	λ_{acc}	% error
1								
2					f_{calc}	E (J)	E (eV)	
average								

Second Hydrogen line

observer	d (m)	Y (m)	X_{left}	X_{right}	sin θ	λ_{calc}	λ_{acc}	% error
1								
2					f_{calc}	E (J)	E (eV)	
average								

Third Hydrogen line

observer	d (m)	Y (m)	X_{left}	X_{right}	sin θ	λ_{calc}	λ_{acc}	% error
1								
2					f_{calc}	E (J)	E (eV)	
average								

Worksheets and calculations for second spectrum; ELEMENT = __________

First line

observer	d (m)	Y (m)	X_{left}	X_{right}	sin θ	λ_{calc}	λ_{acc}	% error
1								
2					f_{calc}	E (J)	E (eV)	
average								

Second line

observer	d (m)	Y (m)	X_{left}	X_{right}	sin θ	λ_{calc}	λ_{acc}	% error
1								
2					f_{calc}	E (J)	E (eV)	
average								

Third line

observer	d (m)	Y (m)	X_{left}	X_{right}	sin θ	λ_{calc}	λ_{acc}	% error
1								
2					f_{calc}	E (J)	E (eV)	
average								

Fourth line (if applicable)

observer	d (m)	Y (m)	X_{left}	X_{right}	sin θ	λ_{calc}	λ_{acc}	% error
1								
2					f_{calc}	E (J)	E (eV)	
average								

Questions

1. How do your measured wavelength values of the hydrogen spectrum compare to the accepted values? To what can you attribute any discrepancies?

2. What transitions (initial and final values of the principal quantum number n) in the hydrogen atom do the lines you observed today correspond to? Draw an energy level diagram for hydrogen to indicate these transitions.

3. What value does your hydrogen data give for the Rydberg constant R_H?

4. Can your data for the more the second lamp (a more complex atom) be explained in the same manner as the hydrogen spectra? Why or why not?

5. Find a reference spectra for your second lamp online and compare your results.