

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 mercury 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 mercury is placed in an electric discharge tube and a high voltage is placed across the tube. The excited mercury emission looks almost white, 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, but the human eye can't see it.

After using the mercury data to find the line spacing of the grating, you will then examine the spectrum of hydrogen and measure the wavelengths of the visible part of this spectrum.

Procedure

1. Determining the grating spacing using known Mercury lines

In this part of the experiment you will observe three different spectral lines of excited mercury vapor and measure the angle of diffraction of each line. The relationship between the wavelength, the grating spacing and the diffraction angle is

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

where n is the order of diffraction (you can only see the first order, so $n = 1$), λ is the wavelength of the spectral line, and θ is the angle of diffraction. The three spectral lines have wavelengths of 578, 546 and 436 nm. You will measure the diffraction angle of each line and then you can calculate the value of the grating spacing, d , in nm. You should study the diagram of the equipment and the experimental procedure for making the measurements before you begin this part of the experiment.

2. Determining the Wavelengths of Hydrogen Line Spectra

In this part of the experiment you will use the grating spacing determined in part 1 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 the same as in part 1. From the observed hydrogen spectra you can calculate the Rydberg constant, R_H .

The emission spectra you will observe are in the visible part of the electromagnetic 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,

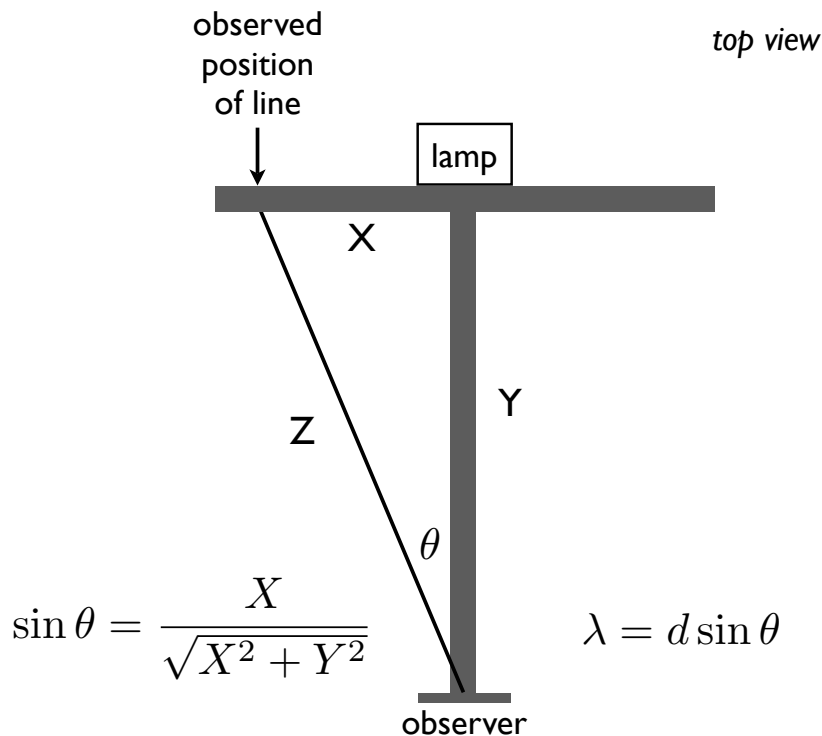
$$E = hf = \frac{hc}{\lambda}$$

since $\lambda f = c$. The constant h is called Planck's constant, 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.

Experimental Setup for the Observation of Mercury Discharge Line Spectra



Safety: You should not look directly at the mercury discharge coming from the slit in 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 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 mercury 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 of mercury 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 yellow, green and violet 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 $\sin \theta$ and then d should be calculated from the X_{average} , Y and λ values and entered in the table.
7. Calculate an average value for d .

Part 2

1. Now replace the mercury lamp with the hydrogen lamp *after turning the lamp power off*. The bulbs are fragile, be careful!
2. Repeat steps 4 and 5 from part 1, and fill in the table below.
3. Use your data, including the value of d found in part 1, to calculate the wavelength λ for each spectral line.
4. Also calculate the energy of the photons emitted in the corresponding transition.

Equations (*remember to use consistent units for distance!*)

$$\lambda = d \sin \theta \quad f \lambda = c \quad E = hf = \frac{hc}{\lambda}$$
$$\frac{1}{\lambda} = R_H \left(\frac{1}{2^2} - \frac{1}{n^2} \right)$$

Worksheets and calculations for Mercury spectra

Yellow Mercury line

observer	d (m)	Y (m)	X _{left} (m)	X _{right} (m)	sin θ	λ	d
1						578 nm	
2							
average							

Green Mercury line

observer	d (m)	Y (m)	X _{left} (m)	X _{right} (m)	sin θ	λ	d
1						546 nm	
2							
average							

Violet Mercury line

observer	d (m)	Y (m)	X _{left} (m)	X _{right} (m)	sin θ	λ	d
1						436 nm	
2							
average							

Average value for d _____

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								

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 data give for the Rydberg constant R_H ?