The Hydrogen Spectrum & Energy Levels
Spring 2024

Introduction

In this experiment you will use a diffraction grating to measure the wavelengths of three visible lines emitted by hydrogen, and from those results determine the allowed energy levels of the hydrogen electron (*Note that a fourth line is produced in the hydrogen spectrum at visible wavelengths, but you won't be able to see it during today's experiment*). You should be able to measure the wavelength of each line to within 1 or 2%!

Experiment

1. *Measuring the diffraction angle for Hydrogen and Sodium lines:*

a. Your instructor will explain the operation and initial setup of the spectrometer, as shown in **Figure 1**.

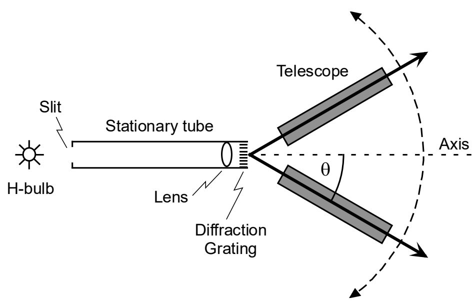

Figure 1: The spectrometer

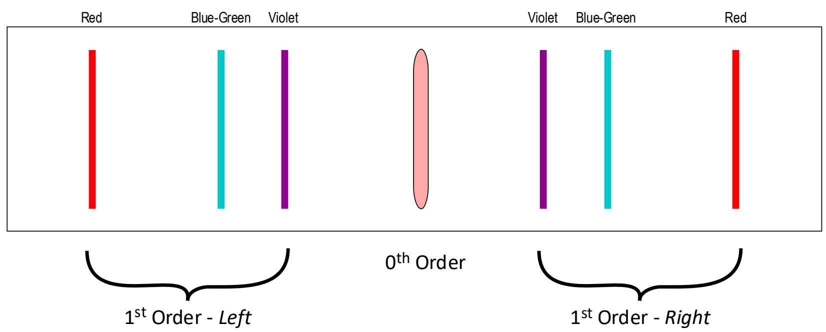

Figure 2: The view of hydrogen spectral lines through spectrometer eyepiece

b. Create a data table in your journal as follows:

Line Color	*Angle (left),* θ_{left}	*Angle (right),* θ_{right}	*Average Angle,* θ	*Wavelength,* λ (nm)
Violet				
Blue-Green				
Red				
Yellow *(in Sodium)*				**589.3**

c. When the room lights have been turned off, look through the telescope, which should be in a straight line with the stationary tube facing the hydrogen bulb. At the center you will see a pink line; this is the 0^{th} order image of the hydrogen bulb (**Figure 2**).

d. Move the telescope by pushing on the pointer. Swing the telescope *left* of center until the crosshair is lined up with the first hydrogen line you see (the violet line in **Figure 2**). When this line is centered, record in your journal the angle θ indicated by the pointer (<u>you should estimate angles to 0.1°</u>). Have your partner check the angle as well.

e. Continue moving the telescope to the left to record the angle for the blue-green and red lines.

f. Move the telescope so that it is again lined up directly with the stationary tube. Now swing the telescope *right* of center and repeat the measurements of θ for the three hydrogen lines visible on the right side.

g. Calculate the average θ for each hydrogen line observed.

h. The spectrometer must now be calibrated so that we know the relationship between measured angle and wavelength. *Carefully* carry your spectrometer to one of the sodium bulbs and place it on the platform. Measure the angle θ of the yellow line that appears to the left and right of center. *<u>Don't measure the **bright** yellow, 0^{th} order image of the sodium bulb when the spectrometer is pointing directly at the sodium bulb!</u>*

2. *Calculating wavelengths:*

We will use *Eqn. 1* to calculate the wavelength, λ of each spectral line observed in hydrogen. Recall that m is the order of the image, d is the grating spacing and θ is the measured angle:

$$m\lambda = d\sin\theta \qquad (Eqn.\ 1)$$

a. First, we need to calculate the value of the grating spacing, d. Solve *Eqn. 1* for d using the wavelength of the yellow line of sodium (λ_{Na} = 589.3 *nm*) and your measured angle for the sodium line (what is the value of m here?) Calculate d to one-tenth of a *nanometer*. Check with your instructor that you have a reasonable value for d.

b. Now use your calculated value of d and *Eqn. 1* to calculate the wavelength of each hydrogen line observed. **Be sure to calculate the wavelengths with 4 significant figures!**

3. *Calculating theoretical energy levels and wavelengths:*

a. Construct a *LARGE* (at least half the page) and NEAT (use a ruler!) energy level diagram (**Figure 3**) in your journal and calculate the theoretical energy levels (in *electron volts*) for n = 1 to n = 6 using *Eqn. 2*:

$$E_n = \frac{-13.61(eV)}{n^2} \qquad (Eqn.\ 2)$$

b. Write the energy of each level, calculated to one-thousandth of an *eV*, on the right side of **Figure 3**.

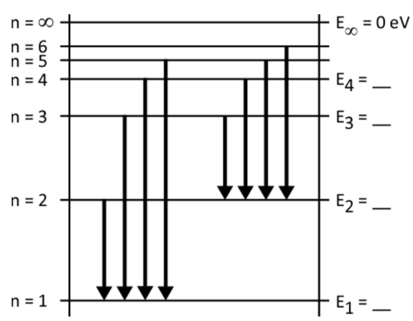

Figure 3: The energy level diagram for hydrogen. The *transition* of an electron from a higher to lower energy level – resulting in the emission of a photon – is represented by each arrow. Two *series* of transitions are shown, with one series ending at energy level n = 1 and the other at n = 2. Note that only the first six energy levels are shown, but there are actually an infinite number of levels.

c. Calculate the wavelengths for *all eight* transitions shown in **Figure 3**, using *Eqn. 3*:

$$\lambda = \frac{1240\,(eV\cdot nm)}{E_{Upper\ Level} - E_{Lower\ Level}} = \frac{1240\,(eV\cdot nm)}{\Delta E} \qquad (Eqn.\ 3)$$

(If ΔE is in *eV*, then λ has units of *nm*). Write these wavelengths next to each transition on the diagram.

4. *Identify the transitions from your measured colors:*

a. Identify the series and the individual transitions for each line observed by comparing your measured wavelengths with those found in step (3c) above. Write the colors on the energy level diagram.

b. Calculate the percent difference between your measured and calculated values of the wavelength for each line.

Discussion

- Restate your results: the measured and actual wavelengths, and their % difference.
- Briefly discuss your results. What difficulties did you encounter when collecting your data?

PLEASE TURN OFF THE FLASHLIGHT AND HYDROGEN BULB WHEN FINISHED!