The Hydrogen Spectrum & Energy Levels
Spring 2018

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

      | Line Color   | Angle (left), $\theta_{\text{left}}$ | Angle (right), $\theta_{\text{right}}$ | Average Angle, $\theta$ | Wavelength, $\lambda$ (nm) |
      |--------------|-------------------------------------|----------------------------------------|--------------------------|-----------------------------|
      | Violet       |                                     |                                        |                          |                             |
      | Blue-Green   |                                     |                                        |                          |                             |
      | Red          |                                     |                                        |                          |                             |
      | Yellow       |                                     |                                        |                          | 589.3                       |
      | Sodium       |                                     |                                        |                          |                             |

   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 0th 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 report the angle $\theta$ indicated by the pointer (you should estimate angles to 0.1°). 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 $\theta$ for the three hydrogen lines visible on the right side.
   g. Calculate the average $\theta$ for each hydrogen line observed.
h. The spectrometer must now be calibrated: place the spectrometer in front of the sodium bulb in the lab and measure the angle $\theta$ for the yellow line that appears to the left and right of center. *Don’t measure the yellow, 0th order image of the sodium bulb!*

2. Calculating wavelengths:
   a. The ratio of every first-order spectral line to its angle is exactly the same (when observed through the same grating with spacing $d$), so we can use this to calculate the wavelengths of the four hydrogen lines. Calculate the hydrogen wavelengths using the ratio below with the wavelength of the yellow line of sodium ($\lambda_{Na} = 589.3 \ nm$) and your measured angles, and record in your table. **Be sure to use 4 significant figures!**

   \[ \frac{\lambda_n}{\theta_n} = \frac{\lambda_{Na}}{\theta_{Na}} \]

3. Calculating theoretical energy levels and wavelengths:
   a. Construct a large (at least half the page) energy level diagram (as shown below) and calculate the theoretical energy levels for $n = 1$ to $n = 6$ using $E_n = \frac{-13.61 \ eV}{n^2}$. The units are electron volts (where $1 \ eV = 1.602 \times 10^{-19} \ J$). Write the energy of each level, in electron volts, on the diagram.

   ![Energy Level Diagram]

   b. Calculate the wavelengths for all eight transitions shown, using:

   \[ \lambda = \frac{1240 \ eV \cdot nm}{E_{Upper \ Level} - E_{Lower \ Level}} = \frac{1240 \ eV \cdot nm}{\Delta E} \]

   (If $\Delta E$ is in $eV$, then $\lambda$ 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 (3b) above. Write the colors on the energy level diagram.
   b. Calculate the percent difference between your measured and calculated values of the wavelength of each line.

**Discussion**
- Restate your results: the measured and actual wavelengths, and their % difference.
- Discuss your results. What were some sources of error?

PLEASE TURN OFF THE FLASHLIGHT AND HYDROGEN BULB WHEN FINISHED!