LINE SPECTRUM OF HYDROGEN

OBJECTIVES FOR THE EXPERIMENT

The student will be able to do the following:

1. Calculate the frequencies and wavelengths for the light emitted in the first five transitions in the Balmer series for hydrogen.
2. Experimentally determine degree of diffraction reading for light sources using a spectroscope.
3. Determine wavelengths from experimental degree of diffraction readings and a graph of degree of diffraction vs. wavelength.
4. Calculate percent error.

BACKGROUND

The purpose of the experiment is to study the Balmer Series of the line spectrum of hydrogen. This is the portion of the line spectrum of hydrogen that lies in the visible range. The wavelengths for this series will be determined in two ways.

1. The actual wavelengths for the first five transitions in the Balmer Series will be calculated using the Rydberg equation and the relationship between frequency and wavelength.

$$\nu = R\left(\frac{1}{4} - \frac{1}{n_{high}^2}\right) \qquad \nu = \text{frequency} \qquad R = 3.289 \times 10^{15}\ s^{-1} \qquad n_{high} = 3,4,5,....$$

$$\lambda = \frac{c}{\nu} \qquad c = \text{speed of light} = 2.9979 \times 10^8\ m/s$$

2. Three or four of the wavelengths for the lines in the hydrogen spectrum will also be determined experimentally using a hydrogen light source and a spectroscope.

The spectroscopes used in the experiment do not register the position of the lines in terms of wavelength but in terms of degree of diffraction. Different diffraction gratings will yield different angles of diffraction, so each spectroscope will give slightly different angles for the same wavelengths. To obtain the wavelengths, we must first set up a calibration graph for your spectroscope so that the degrees can be converted to wavelengths.

The calibration graph is based on the line spectrum of helium. You are given a table of wavelengths, colors, and relative intensities of the lines in the line spectrum of helium. You will view the line spectrum of helium through the spectroscope and record the degree of diffraction of its lines. You will assign the degree readings to specific wavelengths based on color and relative intensity. If the helium lines are assigned correctly, the graph of scale reading (in degrees) versus wavelength (nm) should be close to a straight line. With this graph the scale readings from the hydrogen spectrum can then be converted to wavelengths.

PRELAB ASSIGNMENT

You should complete the preliminary calculations before you come to lab.

a. Using the Rydberg equation, calculate the frequencies for the light emitted for the first five transitions in the Balmer series. Report your answers on your report sheet.
b. Convert the frequencies to wavelengths and report them on the data sheet.

PROCEDURE

1. Check to be sure that the spectroscope is properly zeroed.
   a. Check to see that the locking screw is loose. Turn the viewing arm to 0.0° and lock it in place with the locking screw.
   b. Align the spectrometer to the light source by moving the entire instrument until you see the brightest light.
   c. The left side of the slit should be at the intersection of the two hairlines. If it is not, tell your instructor.
2. Unlock the locking screw and slowly swing the viewing arm to the left. Start measurement of the lines from the red region and move back to the blue and violet regions.
   a. For the helium spectrum, you should see 6 to 9 lines.
   b. For the hydrogen spectrum, you will see 3 to 4 lines: a red line, a blue-green line, and at least one violet line.
3. When the hairline is in the general region of the line you want to measure, tighten the locking screw.
4. Turn the fine adjustment knob to bring the intersection of the hairline to the left edge of the line.
5. With a flashlight, read the angle at the base of the spectrometer to a tenth of a degree with the aid of the Vernier scale, which will be explained in class.
   a. For the helium spectrum, you should try to assign the lines to specific wavelengths. You will do this by matching the colors and relative intensities with the chart given on the report sheet.
   b. For the hydrogen spectrum, record the color and scale reading.
6. Using your data for the helium spectrum, plot a calibration curve of wavelength versus degree of diffraction on the graph paper provided.
   a. Use a sharp pencil and plot your points with an X.
   b. It will probably work best to use the long axis of the paper for the degree reading and the shorter axis for wavelength.
   c. Set the scale on your graph so that each box is associated with an easily read value. For example, each box might be 0.2 degrees and 3 nm, not 0.193 degrees and 2.46 nm.
   d. Set the scale so that you are using a maximum amount of the paper for your graph. You should not start your scales at zero. Start at just below your lowest value and end just above your highest value.
   e. A straight line should be drawn through the points.
   f. If your points do not lie along the line, you may have misread the scale or incorrectly assigned one or more of the helium lines.
      1) For example, you may have assigned the red line at 706.5 nm to the scale reading that should be correlated with the red line at 667.8 nm.
      2) Try different assignments of lines until your points fall close to your best straight line.

g. Label your graph clearly.

7. From the calibration curve and your scale readings for the hydrogen spectrum, determine the wavelength for each hydrogen line. Show on the calibration curve how you did this with dotted lines leading from the y-axis and to the x-axis.
8. Compare your experimental wavelengths for the hydrogen spectrum to the ones you calculated earlier and assign each experimental wavelength to a particular transition in the Balmer series.
9. Calculate the percent error for each wavelength. Watch your significant figures!

NAME ______________________________

REPORT SHEET FOR THE LINE SPECTRUM OF HYDROGEN

HELIUM SPECTRUM

Wavelength	Color	Relative Intensity	Scale Reading
728.1	red	30	
706.5	red	70	
667.8	red	100	
587.6	yellow	1000	
504.8	light green	50	
501.6	light green	100	
492.2	dark green	50	
471.3	blue-green	40	
447.1	blue-violet	100	
443.8	blue-violet	10	
438.8	violet	30	
414.3	violet	15	
412.1	violet	25	
402.6	violet	70	
400.9	violet	10	

OBSERVED LINES FOR HYDROGEN

Color	Scale Reading

CALCULATED AND EXPERIMENTAL WAVELENGTHS FOR HYDROGEN

n_{low}	n_{high}	Calc ν	Calc λ	Expt λ	% Error
2	3				
2	4				
2	5				
2	6				
2	7				

Show your calculations here.