

Matter and Motion

Fall 2015

Chemistry Lab 2: Emission Spectrum of Atomic Hydrogen

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Overview

The goal of this lab is to measure and analyze the Balmer series of hydrogen using a homemade spectrometer. You will learn how to make a basic spectrometer as well as a small spectroscope from paper and a CD. You will also observe and record the atomic spectra of several noble gases.

While it is possible to record the emission spectrum of atomic hydrogen using a state of the art spectrometer, it is easy and more economical to use the “homemade” spectrometer. Besides, you get to build and see the “guts” of the spectrometer!

The hydrogen discharge tube is a quartz tube filled with H₂ gas. Two electrodes (an anode and a cathode) are connected to the ends of the tube. When supplied with an electric charge, there is sufficient energy to break down the bond in the H₂ molecules and to generate excited state H atoms.



These excited state H atoms emit energy, **relaxing** down to lower energy states. This excess energy is emitted in the form of light. In this experiment, we will be monitoring the visible light emitted by the excited H atoms. In the Balmer series, the wavelength of the emitted light is related to the principle quantum numbers involved in the transitions by the Rydberg equation:

$$\frac{1}{\lambda} = R \left(\frac{1}{(2)^2} - \frac{1}{n_{\text{initial}}^2} \right) \qquad \text{Equation 1}$$

Visible light is easy to monitor since we can use our eyes as the detector. The function of the diffraction grating is to disperse this emitted light into its respective wavelengths. A grating with approximately 600 grooves/mm is sufficient for this experiment. Gratings with a higher number of grooves/mm provide better resolution, but are more expensive. If we look at the hydrogen discharge tube through the grating, we will see several colored lines; these are the emitted visible light dispersed into different wavelengths by the diffraction grating.

Refer to sections 2.3 and 2.4 of your Chemistry text for further information.

PRE-LAB QUESTIONS

Read the lab carefully then complete the Pre-lab before coming to lab. It should be completed in your chemistry lab notebook.

1. Some of the words in this lab may be new to you. Make a list of any new vocabulary and their definitions.
2. What is a *diffraction grating* and how does it help us measure and analyze the hydrogen spectrum?
3. Describe all of the data/measurements you will take during this lab. Be as specific as possible, i.e, include the units used and the number of times each measurement made.
4. Draw an energy diagram for the energy levels of a hydrogen atom. Include at least 7 energy levels and the five lowest energy transitions in the Balmer series.

EXPERIMENT PROCEDURE

Work in groups of no more than three for this lab.

Part I: Calibration and Recording the Balmer series of Hydrogen

1. Draw a diagram of the spectrometer. Label all components.
2. Record the brand name and the number of lines per millimeter on your diffraction grating.
3. Record the emission spectrum of mercury in the visible region. Record the positions of the mercury (Hg) lines in **millimeters** (on the meter ruler) to the highest number of significant figures possible. Record as many Hg lines as possible since this will improve the accuracy of your data. Mercury emission lines in the visible region are at the follows.

wavelengths (nm)	color
404.6	Violet
435.8	Blue
546.0	Green
576.9	Yellow doublet
579.1	Yellow doublet
695.9	Red

4. Draw a calibration curve (use **Microsoft Excel**) using the mercury data of position on meter stick (in millimeters) versus wavelength. Use Excel to draw a **line of best fit** through the points. Make sure that your graph axes are labeled with names and units. Print your calibration graph with your group names on the graph and attach it in your notebook.
5. Record the emission spectrum of hydrogen (or deuterium) in the visible region. Record the positions of the hydrogen lines in **millimeters** (on the meter ruler) to the highest number of significant figures possible. You must be able to see at least **4** lines (red, blue-green, blue-violet and violet). The violet line may not be easy to observe but it will help your data analysis immensely if you spend time to record this line.

Part II: Emission spectra of various gases

You will be provided with an assortment of gas discharge tubes in the lab. Turn each one on and record the color (naked eye observation) of the gas lamp. Then use a hand-held spectrometer and look at the line spectrum. Record the wavelength and the colors of the spectral lines you observe. Try to be as descriptive as possible (example: **strong** red line at 723 nm, **weak** blue line at 400 nm, **medium** yellow line at 605 nm). Tabulate your data for easy reading. How do these observed lines compare to the hydrogen spectrum?

Part III: Make your own spectroscope

Refer to the handout page for directions on how to make a handheld spectroscope. We have black construction paper for you to use. **If you use a razor blade, then please dispose of it properly in the sharps container.** You can use your spectroscope to observe the spectra from many different light sources, but **DO NOT LOOK AT THE SUN.**

Continue to the Post-lab in class if time allows, or complete it outside of class. It should be done in your lab notebook and turned in at the beginning of class next Tuesday at 9 am.

POST-LAB: Calculations and Analysis

1. Use your calibration curve to determine the wavelengths of the hydrogen lines.
2. Use the energy diagram you drew in the Pre-lab to identify specific transitions with the wavelengths of emitted light you calculated in question (1) of the Post-Lab.
3. Do you believe that your spectral lines have been assigned correctly? Why or why not? How can you be sure?
4. When you are satisfied that you have the right spectral assignment and the right relationship between transition and wavelength, plot your data using an appropriate graph. Consider the Rydberg formula (see Equation 1 in Pre-Lab) when deciding how to graph your results. Make sure this graph is properly labeled and then print it out and attach it to your lab notebook.
5. Obtain the value of the Rydberg constant from your graph. Pay attention to units.
6. Quantum theory predicts that the Rydberg constant (R) can be calculated from:

$$R = \frac{me^4}{8\epsilon_0^2ch^3}$$

Where m = mass of the electron, e = charge of the electron, c = speed of light, h = Planck's constant, ϵ_0 = the permittivity of the vacuum. Obtain these values from your text books and calculate the value of R. Pay attention to units! Write your final answer to 7 significant figures.

7. Compare your experimental value from question 5 with the calculated value from question 10 and perform a percent error calculation:

$$\text{Percent error} = \frac{|\text{measured value} - \text{calculated value}|}{|\text{calculated value}|} \times 100$$

Make sure you are comparing values in the same units!

8. Calculate the ionization energy of hydrogen using your experimental data and compare with published values (cite your sources). Again perform a percent error calculation.