Spectrum of Hydrogen

Physics 227 Lab

Introduction

In today's lab you will be dealing with an area of physics called quantum mechanics. The only quantum mechanical idea that you will be using today is that electrons in an atom can exist only with specific energies of energy levels. For example, an electron in the ground state (n = 1) of a hydrogen atom has an energy of -13.6eV. An eV is a unit of energy called an electron volt. See Figure 1. The next energy the electron could have is for the 1st excited state (n = 2) with -3.40 eV, but it could not have an energy in between the two values because there are no possible energy levels in between. Therefore, we say that the energy of the electron is quantized.

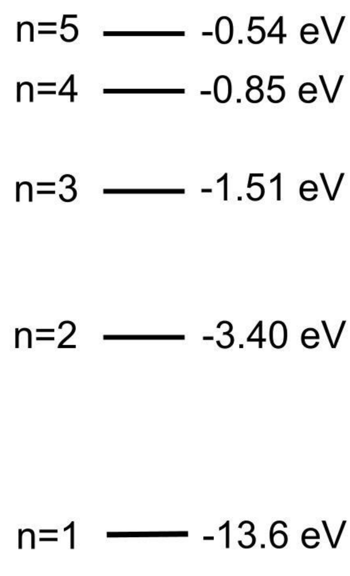

FIGURE 1
Energy levels for a hydrogen atom.

Electrons can be made to jump up an energy level by giving them energy. When the electron returns to the energy level where it started, it releases energy in the form of light. The light will be of a particular color depending on how much energy the electron releases. For example, an electron jumping from n = 3 to n = 2 will release 1.89eV of energy and the color of the emitted light will be red. Other jumps can be a variety of other colors. If every atom has its own set of distinct energy levels, then every atom has its own set of colors as well. You can think of this set of colors as the atom's fingerprint.

In today's lab you will be examining the Balmer Series of jumps in a hydrogen atom. The Balmer Series is a collection of jumps that can start at any level greater than n = 2 and end at n = 2. You will be only concerning yourself with jumps beginning at energy levels n = 3, 4, and 5. So, you will be looking at 3 colors: red, turquoise, and violet. For each of these colors you will measure a refraction angle using a spectroscope. From this data you can calculate the wavelength of the light using the following equation ...

$$d\ sin\theta \ = m\lambda$$

Where m is the order of the diffraction. (peak number from the interference and diffraction lab)

You will then compare this wavelength to the calculated value using the following equation called Balmer's formula ...

$$\frac{1}{\lambda_n} = R\left(\frac{1}{n_{final}^2} - \frac{1}{n_{initial}^2}\right)$$

The *n* values here are the numbers assigned to the energy levels on the previous page, from where the electron starts to where it ends

R is Rydberg's constant given by

$$R = 1.097 \times 10^7 \frac{1}{meters}$$

The Equipment

There are two pieces of equipment you will be using today: a carousel of gases or a power supply with a discharge tube, and a spectroscope. See Figure 2.

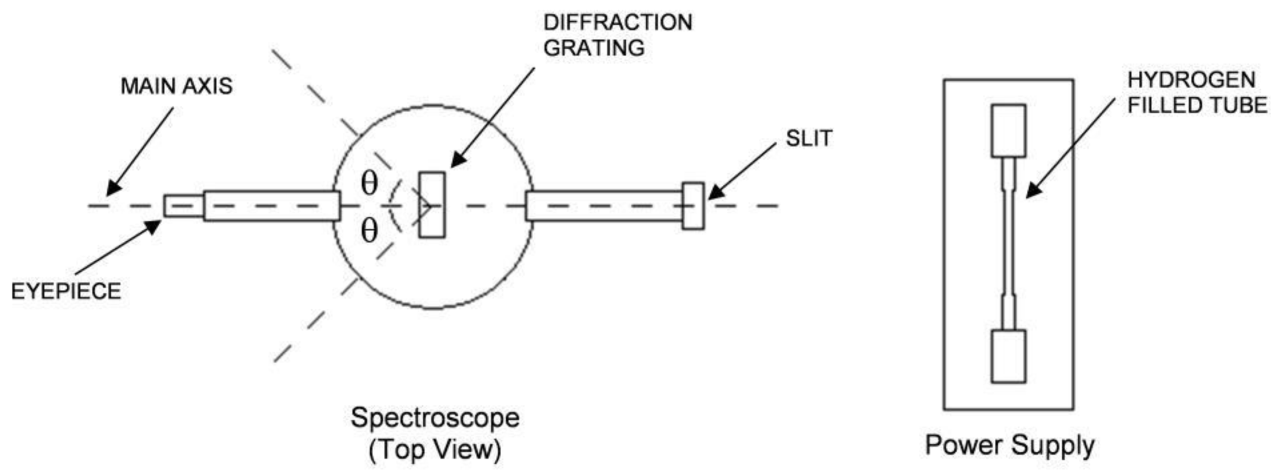

FIGURE 2 - Lab equipment

The power supply will apply a voltage across a discharge tube in the carousel. The tube labelled 1 is filled with hydrogen gas that will be stimulated by this voltage. This will cause electrons in the gas to jump to higher energy levels and in turn drop back down, emitting light. You will use the spectroscope to separate out the light into its component colors. (Like you saw in the prism during the Reflection and Refraction lab). Light will enter the spectroscope through a slit at the end of the right side scope. The light will then refract through a diffraction grating. A diffraction grating is a piece of plastic that has thousands of very small slits. The slits cause incident light to make fringes, just like in the Interference and Diffraction lab. The light will then enter the eyepiece through which you look into to see the fringes. The eyepiece can be moved from side to side through an angle. See Figure 2. This will allow you to focus on different colors, which are refracted through the grating at different angles.

WARNING: Do not remove or touch the hydrogen filled tube. It is attached to a high voltage and it is also very hot.

Procedure:

Part I: d Calibration with Sodium

The first part of the lab deals with measuring the slit spacing, **d**, for the diffraction grating.

A.) For this part you will not be using the power supply shown above. There should be another power supply on the table that has a sodium lamp attached to it. Turn on the lamp and align it in front of the slit. Align the eyepiece so that it is along the main axis. In looking through the eyepiece, you should see a line of yellow light.

B.) The Spectrometer should be focused for you already, but if it isn't call your Instructor over to help. If the line seems blurry you can focus it by rotating the ring on top of the eyepiece. Now, move the sodium lamp left or right in small amounts in order to find the brightest possible position for the lamp. If the light is still not very bright then try putting the black velvet cloth over the spectroscope.

C.) Swing the eyepiece to the right side (about 20°), this corresponds to θ_R. Look for two bright yellow lines that are very close together. In fact, they will look like they are the same line just slightly thicker than what you'll see later. This is the sodium doublet. Align the crosshair in the eyepiece so that it is in the middle of the doublet.

D.) Read the angle, θ_R, from the scale on the right side, be sure from here on that you read all angles from this same side. Your instructor will explain how to use the Vernier scale. Now swing the eyepiece over to the left side (about 20°), this corresponds to θ_L. Repeat the procedure to find angle θ_L. NOTE: Make sure you use the scale that is to the right side of the eyepiece even when nding $_L$.

E.) Calculate the center angle by using the equation,

$$\theta_{avg} = \frac{\theta_L + \theta_R}{2}$$

F.) Then finally calculate θ by taking the difference between your θ_R and θ_{avg}.

$$\theta = \theta_{avg} - \theta_R$$

G.) Using this method will give you a more accurate reading for θ. Now, using your θ and the fact that we know the sodium doublet wavelength(for the yellow sodium line) is 589.295nm, calculate the diffraction grating's spacing, d. You will be using this value for the rest of the lab.

Part II: Spectrum of Hydrogen

Color	n_{final}	$n_{initial}$	θ_R	θ_L	θ_{avg}	θ	λ_θ	λ_n	*% error*
Red	2	3							
Cyan	2	4							
Violet	2	5							

A.) Replace the sodium lamp with the carousel and be sure to set it on with the tube labelled 1. (Or the hydrogen lamps) Align it in the same way that you did for the sodium lamp. Make sure that the line is thin, in focus, and as bright as possible. Make a copy of the above table.

B.) The first line you will be looking for is a red line which is farthest from the center (it should have the largest theta). This line corresponds to electrons jumping from the n = 3 energy level to the n = 2 level. (Recall that the Balmer series has jumps from any level to n = 2). Follow the same procedure as you did in part 1 to find θ_L .

C.) Now you will be using this value and your slit spacing, d from part 1, to find the wavelength, of your light. Repeat this procedure for each of the colors in the chart. Turquoise light is emitted for electron jumps from n = 4 to n = 2. Violet light is emitted for electron jumps from n = 5 to n = 2. Place all values in the chart.

D.) Use Balmer's Formula to calculate the wavelength for each color of light, λ_n.Place these values in the chart.

E.) Compare the two wavelengths by calculating a percent error between them. This is a very accurate lab; your percent error should not be over 5%. If it is, then go back and retake your data. Be more precise in taking your data.

Question 1

If you move the eyepiece to an angle beyond the red line, you will see a repeated set of colors. What is this extra set of colors? HINT: Think about the lab on interference and diffraction.

Question 2

a) Would you expect to see these same color lines from different light sources?

If you have a carousel of light sources look at two other sources and answer the following.

b) Do you see the same 3 distinct lines that you saw in hydrogen?
c) What colors do you see for each of the two sources?
d) Observe Air if you haven't already done so, number 6, is this what you would expect to see? Explain

Use the table on the right to determine which gas you are looking at.

#	Gas
1	H
2	He
3	Ne
4	Ar
5	N
6	Air
7	CO_2