

# Lab 11

## Spectrum of Hydrogen

### What You Need To Know:

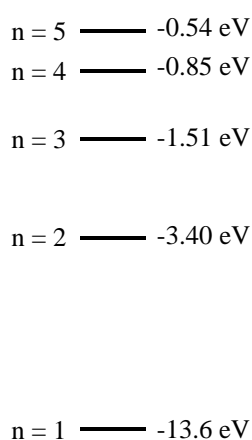


FIGURE 1  
Energy levels for a  
hydrogen atom.

**The Physics** 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 or energy levels. For example, an electron in the ground state ( $n = 1$ ) of a hydrogen atom has an energy of  $-13.6$  eV. An eV is a unit of energy called an *electron volt*. See **Figure 1**. The next energy the electron could have is for the 1<sup>st</sup> 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.

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  $1.89$  eV 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 only be 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,  $\theta$ , using a spectroscope. From this data you can calculate the wavelength of the light using the following equation ...

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

$\lambda$  is the wavelength (in nanometers, nm)  
 $d$  is the distance between grooves on the grating (in nm)  
 $\theta$  is the angle of refraction (in degrees)

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

$$\frac{1}{\lambda} = R \left( \frac{1}{n_F^2} - \frac{1}{n_I^2} \right)$$

$\lambda$  is the wavelength (in nm)  
 $R$  is Rydberg's constant,  $0.011 \text{ nm}^{-1}$   
 $n_F$  is the lower energy level  
 $n_I$  is the higher energy level

**The Equipment** There are two pieces of equipment you will be using today: a power supply with a discharge tube and a spectroscope. See **Figure 2** on the next page.

The power supply will apply a voltage across a discharge tube. The tube 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 Reflection and Refraction lab.] Light will enter the spectroscope through a slit at the end of the 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 last week's lab, Interference and Diffraction. 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  $\theta$ . See **Figure 2**. This will allow you to focus on different colors, which are refracted through the grating at different angles.

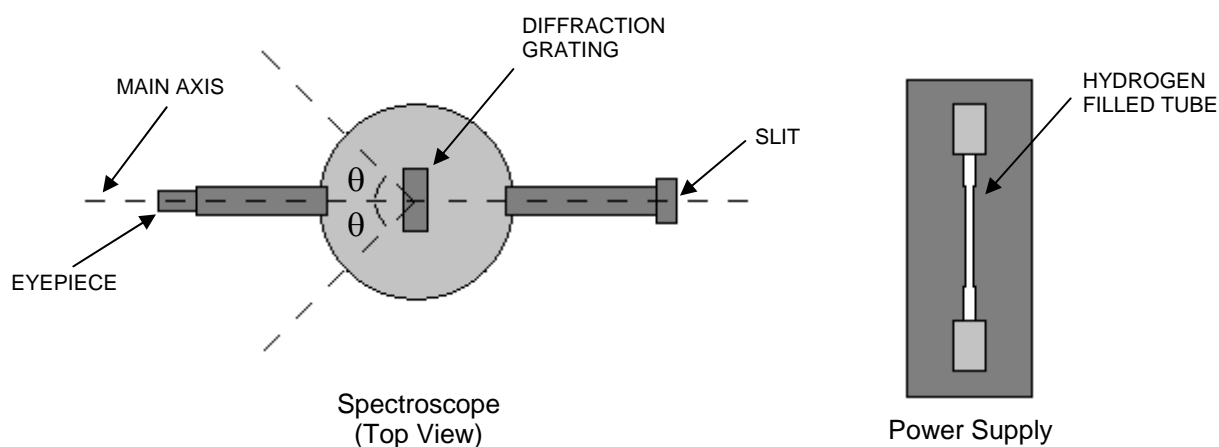


FIGURE 2 - Lab equipment

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

### What You Need To Do:

**Calibration** The first part of the lab deals with measuring the slit spacing,  $d$ , for the diffraction grating. 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. Decrease the slit width so that you get just a thin line of light. If the line seems blurry you can focus it by rotating the ring on 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.

Swing the eyepiece off to the **right** side (about  $20^\circ$ ). This corresponds to  $\theta_R$ . Look for two bright yellow lines that are **very** close together. In fact, they will look like they are the same line. This is the sodium doublet. Align the crosshair in the eye-

piece so that it is in the middle of the doublet. Read the angle,  $\theta_R$ , off the scale that is to the **right side of the eyepiece**. Your TA will explain how to use the vernier scale. Now swing the eyepiece over to the **left** side (about  $20^\circ$ ). This corresponds to  $\theta_L$ . Repeat the procedure to find angle  $\theta_L$ . **NOTE:** Make sure you use the scale that is to the **right side of the eyepiece** even when finding  $\theta_L$ .

## EQUATIONS

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

$$\frac{1}{\lambda} = R \left( \frac{1}{n_F^2} - \frac{1}{n_I^2} \right)$$

$$R = 0.011 \text{ nm}^{-1}$$

Calculate the refraction angle by using the equation,  $\theta = (\theta_L - \theta_R)/2$ . Using this method will give you a more accurate reading for  $\theta$ . Now, using your  $\theta$  and the fact that we know the sodium doublet wavelength is **589.295 nm**, calculate the slit spacing, **d**. You will be using this value for the rest of the lab.

Color	$n_F$	$n_I$	$\theta_R$	$\theta_L$	$\theta$	$\lambda_\theta$	$\lambda_{n,n}$	% error
Red								
Turquoise								
Violet								

CHART

**Spectrum of Hydrogen** Replace the sodium lamp with the hydrogen tube power supply. 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 **Chart**.

The first line you will be looking for is red. This corresponds to electrons jumping from the  $n_I = 3$  energy level to the  $n_F = 2$  level. (Recall that the Balmer series has jumps from any level to  $n_F = 2$ .) Follow the same procedure you did above to find  $\theta$ . However, now you will be using this value and your slit spacing, **d**, to find the wavelength,  $\lambda_\theta$ , of your light. Repeat this procedure for each of the other colors. Turquoise light is emitted for electron jumps from  $n_I = 4$  to  $n_F = 2$ . Violet light is emitted for electron jumps from  $n_I = 5$  to  $n_F = 2$ . Place all of the values in the **Chart**.

Use Balmer's Formula to calculate the wavelength for each color of light,  $\lambda_{n,n}$ . Place these values in the **Chart**.

Compare, by calculating a percent error, the two wavelengths. 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** If you move the eyepiece farther than the red line, you will see a repeat set of colors. What is this extra set of colors? **HINT:** Think about last week's lab.

### What You Need To Turn In:

Turn in your calculations for the slit spacing. Show all of your other calculations for the wavelengths for each color.