Experiment #7: The Hydrogen Spectrum

Objective:
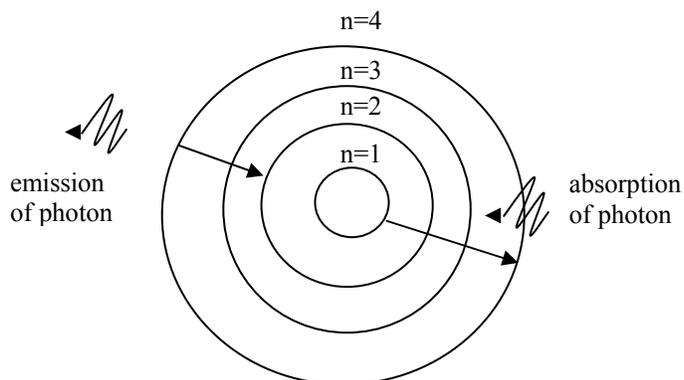To measure the visible spectral lines of atomic hydrogen

Textbook Reference: pp 276-277, 284-287

Introduction:

The nucleus of the atom contains protons and neutrons. Atoms also possess electrons, which are located outside the nucleus. In a neutral atom there is the same number of electrons as protons. For example, the silver atom has 47 protons and 47 electrons. An electron is a negatively charged particle with a mass that's about 1800 times smaller than that of the proton or the neutron. Protons are positively charged and neutrons are neutral.

The arrangement of the electrons in an atom is called its electronic structure. For simplicity, let's consider the simplest of the atoms, hydrogen. There is only one proton and one electron in a hydrogen atom. We can't see electrons in an atom so we have to study them indirectly. One piece of evidence about the arrangement of electrons is the electromagnetic spectrum. For example, the spectrum of hydrogen is an important piece of evidence that light interacts with matter through the absorption and emission of discrete packets of energy, called quanta. We now call these quanta "photons." The figure to the right shows a representation of how we can think of the interaction of photons with hydrogen atoms. When a photon is absorbed by a hydrogen atom the energy of the photon is absorbed and the electron in the atom is promoted to a higher energy level. Likewise, when the electron in the atom moves to a lower energy level it emits a photon with an energy equal to the difference between the two energy levels. These energy levels are said to be quantized, meaning that there are a limited number of energy levels possible. In the figure above both emission and absorption are shown. On the left side of the figure an electron moves from the n = 4 energy level to the n = 2 energy level. When it does a photon is emitted from the atom with an energy equal to the difference between n = 4 and n = 2. On the right side of the figure the absorption of a photon by an atom is represented. When the photon is absorbed by the atom the electron is promoted from the n = 1 energy level to the n = 4 level. For this to take place the energy of the photon must match the energy difference between the n = 1 and n = 4 levels.

The hydrogen atom is most stable when the electron is in the lowest energy level (n = 1). This level is often called the ground state. If a sample of hydrogen atoms is heated electrons can be promoted to higher energy levels (n = 2, 3, 4,...). When the electrons move back to lower energy levels photons will be emitted. Because only specific energy levels are possible, only specific wavelengths of light will be produced. The result is what's called an emission line spectrum or a bright line spectrum. Each line (wavelength or color) is associated with the transition of the electron from one energy level to another. In this experiment we will heat a large collection of hydrogen atoms so that the electrons are promoted to higher energy levels. When the electrons spontaneously drop down to lower energy levels they emit photons. We can then measure the wavelengths of these photons using a device called a Bunsen spectroscope.
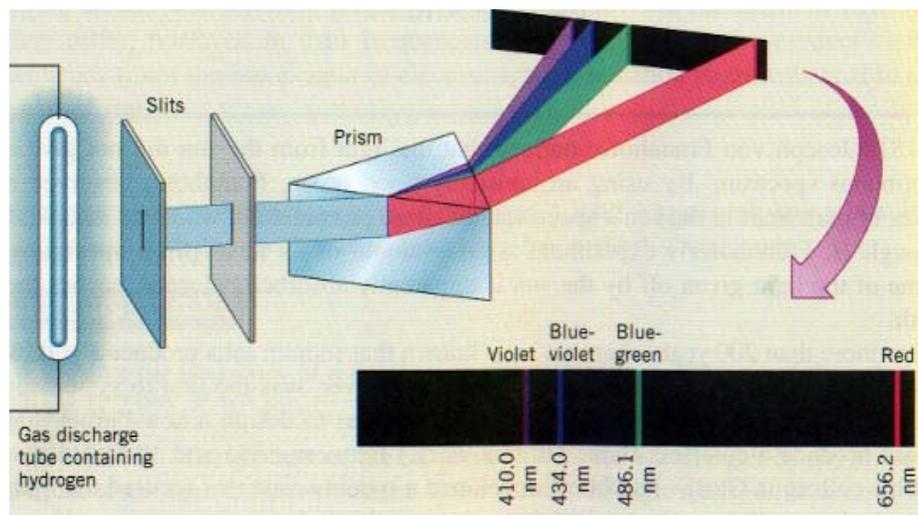
Procedure:

SAFETY PRECAUTIONS

The glass tubes are fragile and should be handled with care.

Students work in groups of two to three. Each student acquires one set of data for hydrogen.

Measuring the lines of the hydrogen spectrum

The visible portion of the hydrogen spectrum consists of four lines, as shown in the figure below.

However, only three of these lines are clearly visible using the spectroscope.   Your instructor will demonstrate how to use the spectroscope. Record the angle and color for each of the three lines in the spectrum. Then calculate the sine of the angle. To find the wavelength corresponding to each line, you will use a calibration curve. The wavelength is on the y-axis and sine θ is on the x-axis. For each value of sine θ, find the value on the x-axis; draw a vertical line up to the calibration curve and then a horizontal line to the y-axis. This will give you the corresponding wavelength value.

Color	Angle (θ)	Sine θ	Wavelength (nm)
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Calculation of the spectrum of hydrogen

We can also calculate the wavelengths of the photons emitted by hydrogen using the Rydberg equation:

$$\lambda = \frac{91.15 \text{ nm}}{\left(\frac{1}{2^2} - \frac{1}{n^2}\right)}$$

where n can be 3, 4, 5, 6, 7, 8,...
You should calculate λ for n = 3 through n= 6 and enter your values into the data table below.

Then find a % difference for each line using the following equation:

$$\% \text{ difference} = \frac{|\text{measured value - calculated value}|}{\text{calculated value}} \times 100$$

n	λ (nm) measured	λ (nm) calculated	% difference
3	_____	_____	_____
4	_____	_____	_____
5	_____	_____	_____
6	not measured	_____	

Helium Calibration Curve

Wavelength (nm)

Sine (angle)