SPECTROSCOPY AND ATOMIC STRUCTURE

10

OBJECTIVES

After completing this exercise the student should be able to:

1. use a spectroscope to measure the wavelengths of emission-lines produced by a discharge tube.
2. identify unknown gases by comparison of their spectra to known emission-line sources.
3. draw a scale model of a hydrogen atom from measurements of the Balmer emission-lines observed with a laboratory spectroscope.

STUDENT MATERIALS

pencil
compass
mm scale
calculator

LAB MATERIALS

student spectroscopes
spectral emission tubes, including hydrogen
transformers for tubes
a light with electrical socket and lab jacks

Set up ten stations. Each station should be labeled. Station 1 should have a light bulb. Station 2 should have a hydrogen emission tube. Stations 3 through 10 can have assorted emission tubes. All stations need a spectroscope. Stations 2 through 10 need spectral tube transformers. Some stations may need lab jacks to adjust the tube heights to match the spectroscope heights.

STUDENT REQUIREMENTS

Each student is to do individual work, without a lab partner. Turn in answers to the questions, **Table I**, **Fig. 1**, and **Fig. 2**.

INTRODUCTION

Astronomers must obtain most of their information about the stars from observations of the small amount of light received from each star. One of the most useful astronomical instruments is the spectroscope or spectrograph. These use a prism or diffraction grating to spread light into its rainbow of colors. Spectra can be divided into three major groups which depend upon the origin of the spectra. These groups are described by Kirchhoff's Laws of spectral analysis given below:

1st Law: continuous spectrum is produced by a hot, glowing solid.

2nd Law: bright line or emission spectrum is produced from a hot, rarefied gas.

3rd Law: dark line or absorption spectrum is produced when the light from a continuous spectral source passes through a cooler, less-dense gas.

A line spectrum (emission or absorption) can be used to determine the element(s) that are producing the spectrum. The lines are related to the electron orbitals of each element. Since these orbitals are different for each of the elements, the spectral lines act like a set of fingerprints which will identify the element producing them.

In this exercise you will identify several unknown gases by observing their emission-line spectra. Also you will measure the wavelengths of hydrogen emission-lines and use these measurements to construct a model of the hydrogen atom.

PROCEDURE

Spectra

Around the lab room several numbered stations have been set up. Each station has a light source and a spectroscope.

1. At **Station 1** observe the spectrum of an incandescent light bulb, and answer questions 1, 2, and 3 on page 10-3. Move to **Station 2**.

2. Observe the spectrum of the hydrogen gas discharge tube. Sketch the position of each emission line on the scale drawn in **Fig. 2**. Use the spectroscope's scale to determine the wavelength of each line in angstroms, $\mathring{A}$, and record the results in **Table I**.

3. Proceed to each of the stations and sketch the emission-line spectra of each unknown gas in **Fig. 2**. Be sure the station number matches the number of your sketch.

4. Compare your sketches to the standard emission-line spectra in **Fig. 3**. Write the name of each gas in the blank to the right of each sketch in **Fig. 2**.

The Hydrogen Atom

In this lab you viewed a hydrogen emission-line spectrum. This spectrum was produced by applying an electric current to hydrogen gas trapped inside the tube. When the electrons were excited they jumped back and forth between several discrete energy levels or orbits. Because the electrons can only orbit the atoms at particular distances or energy levels, they must give up exactly the energy difference between any two levels in order to drop from a higher orbit down to a lower orbit. The energy is lost in the form of emitted light, which has the correct wavelength (color) for the energy which the electron loses. If this process is repeated many times an emission-line spectrum can be observed.

The hydrogen spectrum observed in lab is called the Balmer Series. Balmer lines are produced when electron transitions are down to or up from the second-smallest orbit. The radii of this orbit and those above it can be calculated from

$$\mathbf{r_n} \approx \frac{\lambda}{(0.473)\lambda - 1630} \qquad \mathbf{(1)}$$

where $\mathbf{r_n}$ ($\mathbf{n = 2,3,4...}$) represents the orbital radii of orbits 2,3,4 etc., and λ is the wavelength of the corresponding emission-line in angstroms. The red, blue-green, and violet emission lines observed in the spectroscope came from an electron moving from a high orbit, $\mathbf{r_n}$, down to $\mathbf{r_2}$ as given below:

red	$r_3 \longrightarrow r_2$
blue-green	$r_4 \longrightarrow r_2$
violet	$r_5 \longrightarrow r_2$

1. Use equation **(1)** and your measured values of each emission line in **Table I** to calculate the radius in $\mathring{A}$ units of the 3rd, 4th, and 5th electron orbits for hydrogen. Record your answers in the column labeled "$\mathbf{r_n}$ **in** $\mathring{A}$" of **Table I**.

2. On **Fig. 1** make a scale drawing of the electron orbits for a hydrogen atom for n = 3, 4, and 5. Use a scale of 1 $\mathring{A}$ = 1 cm. The orbit corresponding to n = 2 has already been drawn to scale and has a radius of 2.1 $\mathring{A}$.

3. On your drawing use arrows to indicate the three electron transitions from levels n = 3, 4, and 5 to level n = 2. Label each arrow with the corresponding color emitted (red, blue-green, violet).

Clean up your lab area and turn in the answers to the questions, **Fig. 1**, **Table I**, and **Fig. 2**.

NAME: ______________________________

SECTION: ______________________________

QUESTIONS

1. Is the spectrum of the light bulb continuous, emission line or absorption line?

2. From Kirchhoff's Laws, describe what causes a light bulb to glow.

3. What is the approximate wavelength of the red light?______________ *Å*

   The blue light? ____________ *Å*

TABLE I

Hydrogen Balmer Series

line color	n	λ in Å	R_n in Å
red	3		
blue-green	4		
violet	5		

NAME: ______________________________

SECTION: ______________________________

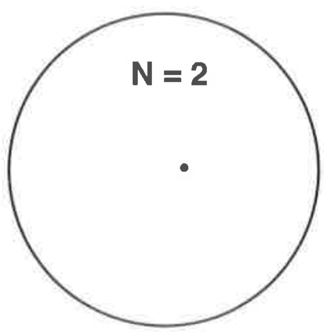

Fig. 1: Scale drawing of the hydrogen atom. Scale is 1Å = 1 cm.

NAME: ____________________

SECTION: ____________________

Station No.	Spectrum	Gas Name
1.	: : I : : : : I : : : : I : : : : I : : 4000 5000 6000 7000	
2.	: : I : : : : I : : : : I : : : : I : : 4000 5000 6000 7000	
3.	: : I : : : : I : : : : I : : : : I : : 4000 5000 6000 7000	
4.	: : I : : : : I : : : : I : : : : I : : 4000 5000 6000 7000	
5.	: : I : : : : I : : : : I : : : : I : : 4000 5000 6000 7000	
6.	: : I : : : : I : : : : I : : : : I : : 4000 5000 6000 7000	
7.	: : I : : : : I : : : : I : : : : I : : 4000 5000 6000 7000	
8.	: : I : : : : I : : : : I : : : : I : : 4000 5000 6000 7000	
9.	: : I : : : : I : : : : I : : : : I : : 4000 5000 6000 7000	
10.	: : I : : : : I : : : : I : : : : I : : 4000 5000 6000 7000	
	violet blue green yellow red	

Fig. 2: The spectra of a light bulb, hydrogen, and several unknowns.

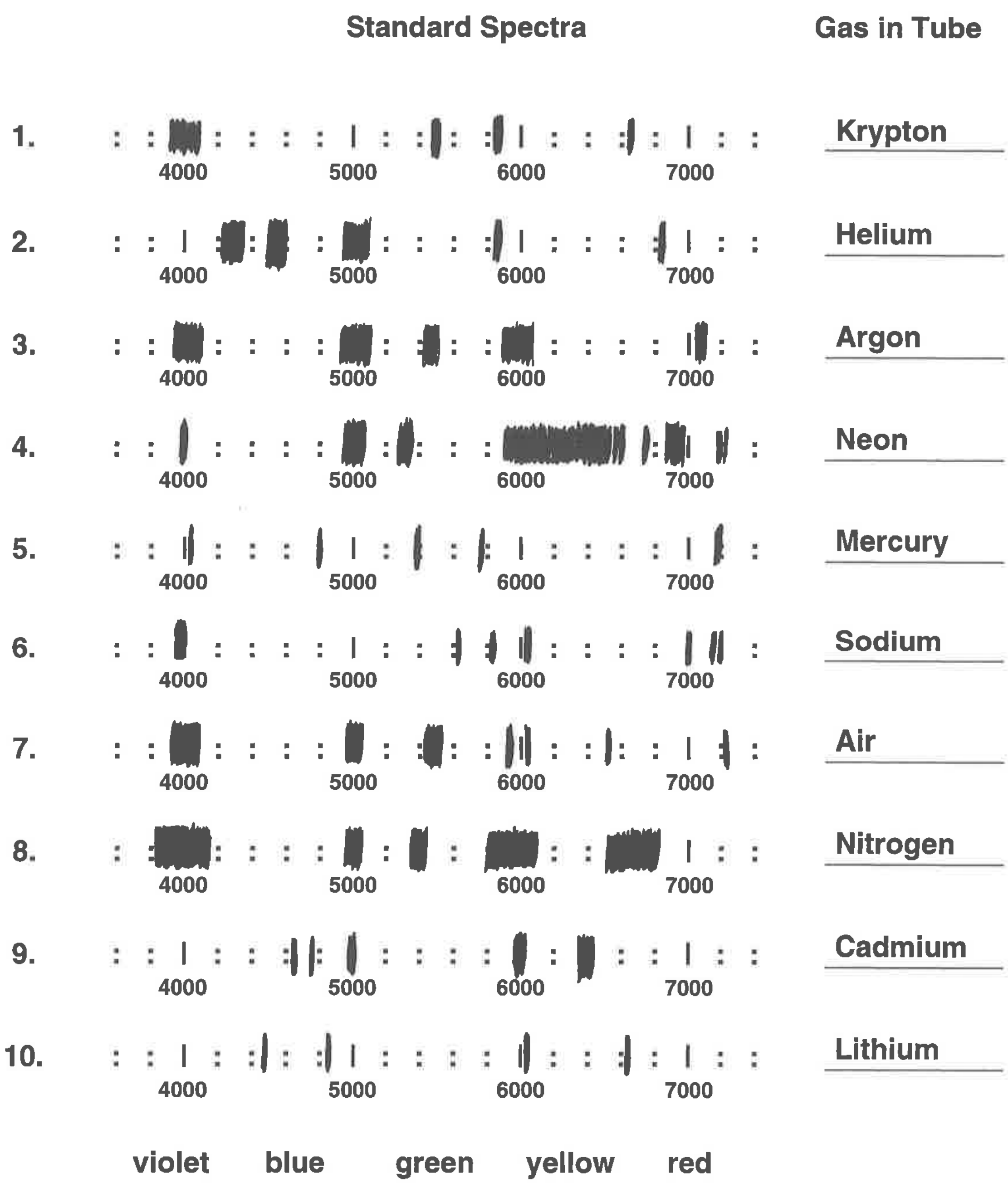

Fig. 3: Standard emission-line spectra for several gas discharge tubes.