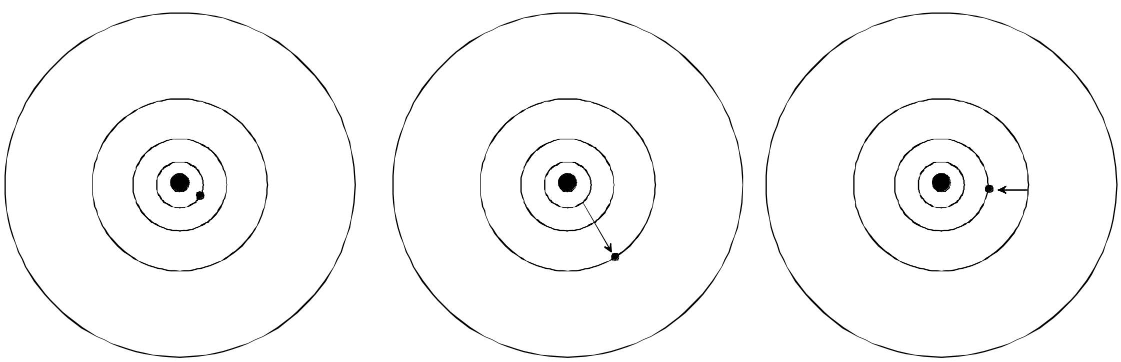
1 Atomic Spectra

Purpose

To examine the atomic spectra from several light sources and understand their importance to astronomy.

Introduction

When looking at light from the Sun and fluorescent sources within our home, we are looking at a combination of actual "wavelengths" or "spectra" of distinct light colors produced through atomic emission of photons by energetic electrons. When energy, in the form of electricity, is introduced to a gas or filament, the gas or filament will heat. For example, when you turn 'on' a light bulb electricity is the energy introduced to the filament, heating it. The electrons within the gas or filament will become "excited" or in other words "they want to move from where they are to a higher energy level". In order to move to a higher "level", they need energy. They will "absorb" energy provided through heatings and subsequent atomic collisions in "unique" or "discrete" amounts according to the nature of atomic systems and move to a higher specific energy "level" or "shell". The electron will then decay (or fall back) from the higher state returning to the original or an intermediate position, **this will produce what is known as an <u>emission line</u> which we will view**. Look at the diagrams in figure 1 for the complete cycle. This will go on continuously while energy is provided to the gas source tube given in lab or the fluorescent tube at home. Thus, atomic photon emission will be seen.



Electron in ground state or lowest energy state. Electron in second excited state after absorption of photon. Electron in lower excited state after photon emission.

Figure 1.1: Three stages of the Atomic Emission Process

When an electron "absorbs" the energy needed to advance to a higher energy level and reemits the energy in a random direction, the process is called atomic "absorption." Here a specific amount of energy is needed which in turn corresponds to a specific wavelength of the photon (i.e. light). Thus, when looking at a spectra of emissions from a distant star, one may not be seeing every emission line being output by the star since in our line of sight some of the wavelengths may have been absorbed and reemitted in random direction not along our line of sight. Since matter exist between the star and the viewer on earth, some of the star's emission lines may be "absorbed" by other matter that exist in space, or the atmosphere of Earth itself.

Stars are distant from us and therefore, matter exists between the source, the star and the viewer, the astronomer on Earth. When these astronomers take spectral data, how can they be sure the results are what is actually emitting from star? They can't, but with much data and what is known about star formation, they can now learn not just about the star, but the matter between the observer and the star. The matter is absorbing various emission lines. Once they have identified the lines from the star, using their knowledge of atomic spectra, they can then identify the matter's make up between the star and them since they know which lines are being "absorbed". Thus, absorption and emission of spectra from light sources plays an important role in astronomy.

When all of the "emission lines" produced by a light source are combined together, they produce light which does not show inherently each color. Tools must be used to separate the visible light into its "spectral lines" or distinct light colors. In this experiment we will look at light emission from elemental gases, as well as an incandescent light source subjected to various voltages which will vary the wattage of light produced by the bulb.

Separation of the spectral lines can be done in a number of methods. We see light separated into components after a rainstorm through droplets of moisture in the sky producing a rainbow. A rainbow serves to demonstrate that the sunlight we see is actually made up of the colors of the rainbow and that it has been separated or "deflected" by the atmosphere, much like a prism will separate incandescent light.

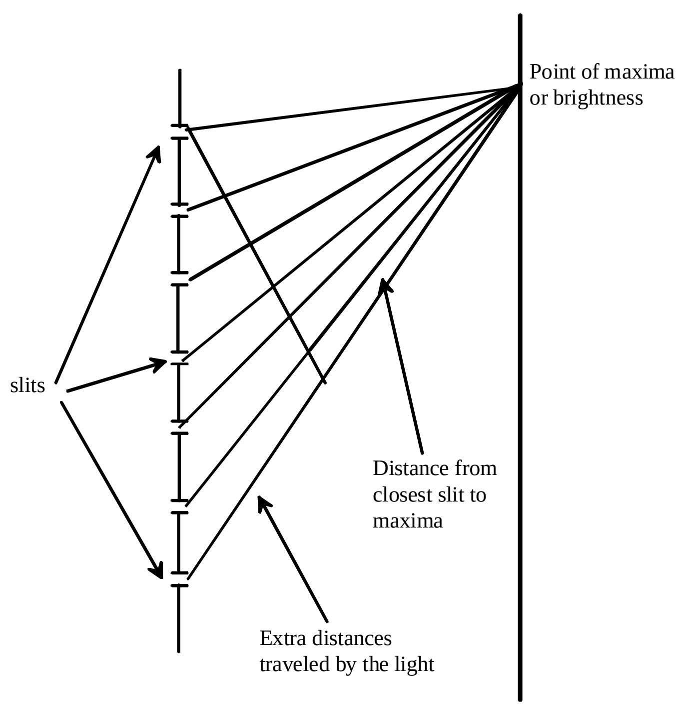


Figure 1.2: Diffraction of Emission Spectra into constituent Colors

What's going on with the light? Well, when the combined light travels through a prism or droplet of water, the different wavelengths or colors of light will be "deflected" at different angles which depend uniquely on the deflecting surface and the "wavelength" of the light. Since the "combined" light is made up of numerous wavelengths, we can separate the light if the deflecting surface is adequate to create large enough angles of deflection so that our eyes see unique colored bands or a continuous band of various colors of light.

In today's lab we will be able to look through a hand-held spectrometer which will separate the light into its color spectra. This device uses a "diffraction grating" to separate the light. The grating has thousands of scratches or "slits" which the light travels through and then is reflected onto the wavelength chart within the spectrometer. Through each slit the light travels an extra distance dependent upon the position of the slit and therefore through different angles Θ_i to appear at the same point on a screen.

If this angle matches the unique angles that correspond to unique wavelengths of light, a brightness or maxima of light will appear on the screen. thus, separating the wavelengths for viewing. It in not necessary in today's experiment to use a mathematical equation or measure the angle or the distance "d" since the wavelength chart within your spectrometer gives the final wavelength value for each "line or band" that is viewed. By reading the number from the bottom of the chart, one can get the wavelengths of the light emitted by the various elements used in lab.

1. *Thought question:* Since each element has a unique combination of electrons in their various orbital "levels" or "shells," would it be expected or not expected that the emission lines of each element should be identical or unique? Could these elements have some lines which are the same and yet the total spectra not the same?

All questions are to be answered in the Laboratory Problems section of this chapter and turned in to your instructor to be graded.

Procedure: Part1

- To get an idea of what the bands of light will look like, select a gas tube and place it in your power supply making sure it is in properly. Turn of the power supply and view the spectra through the diffraction glasses. You should see bands of light, these are the spectral lines. Now that you know what the bands of light should look like, proceed to calibrating your spectrometer so that you may take measurements.

- Calibrate your spectrometer as stated on the top of the device. (Make sure to place the slit of the spectrometer on a white surface which will reflect the fluorescent light.) View the fluorescent lights in the lab room. You will see a continuous spectra (a band of "rainbow light") with bright lines (like in #1) within the band of light. The bright green emission line is the 546 nm "wavelength" . Make note if the bright green line is not at 546 nm. as it should be for subsequent measurements. View the other lines seen and record all emission lines from the fluorescent source. Compare to the lines given on top of the spectrometer for fluorescent sources. Since the fluorescent tube is filled with mercury vapor, check with the spectral chart the emissions lines which should be seen.

- Choose three gas tubes from those provided and view their spectra. Write down the various emission lines viewed for each element and compare to the lines given on the Spectral Chart provided in the lab room. Are any lines missing from your data when compared to the chart? Why might this be?

Hint: If the separation of the light is dependent upon the angle the light goes through and the distance between slits on the grating...talk about these limiting factors and how that could impact the system.

Laboratory Questions and Data

These pages to be turned in to your instructor.

1. *Thought question:* Since each element has a unique combination of electrons in their various orbital "levels" or "shells," would it be expected or not expected that the emission lines of each element should be identical or unique? Could these elements have some lines which are the same and yet the total spectra not the same?

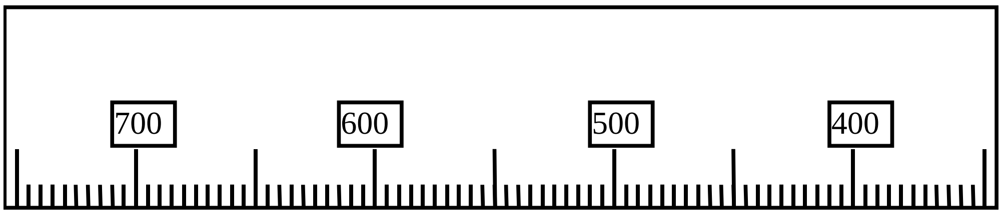
Fluorescent Tube Data

Wavelength Given on Spectrometer (nm)	Wavelength Viewed (nm)	Wavelength Color
405		
436		
546		
577		
579		

Instructions: Draw lines viewed at the appropriate wavelength for each element viewed. Note the color and wavelength of any line seen on the spectra chart for the element but not seen through the spectrometer. (thus, missing)

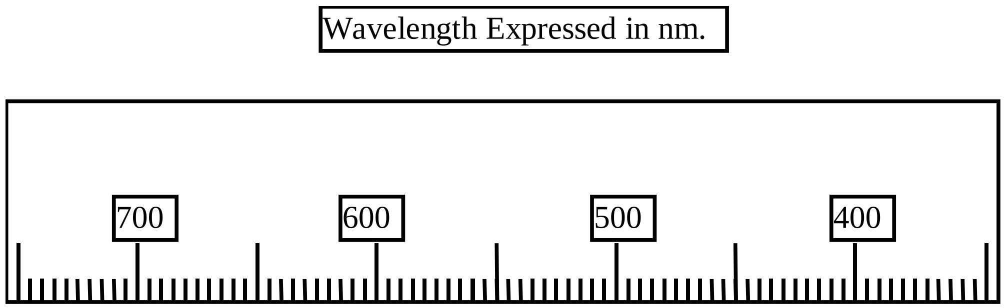
2. **Element**: ________________

Wavelength Expressed in nm.



Missing Lines from Spectral Chart		**Additional Lines not on Spectral Chart**	
Wavelength	Color	Wavelength	Color

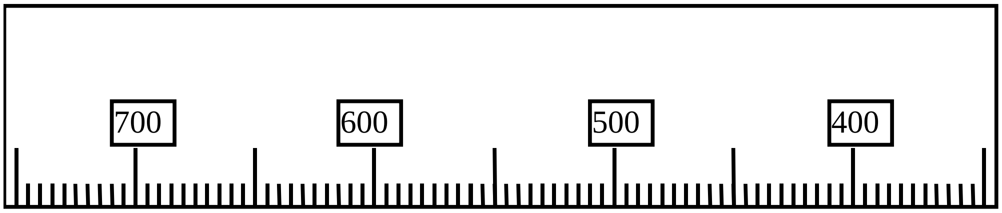
3. **Element**: ________________



Missing Lines from Spectral Chart		**Additional Lines not on Spectral Chart**	
Wavelength	Color	Wavelength	Color

4. **Element**: ________________

Wavelength Expressed in nm.



Missing Lines from Spectral Chart		**Additional Lines not on Spectral Chart**	
Wavelength	Color	Wavelength	Color

5. Conclusion: Be sure to address how this cataloging of elements is helpful to astronomers as you see it here.