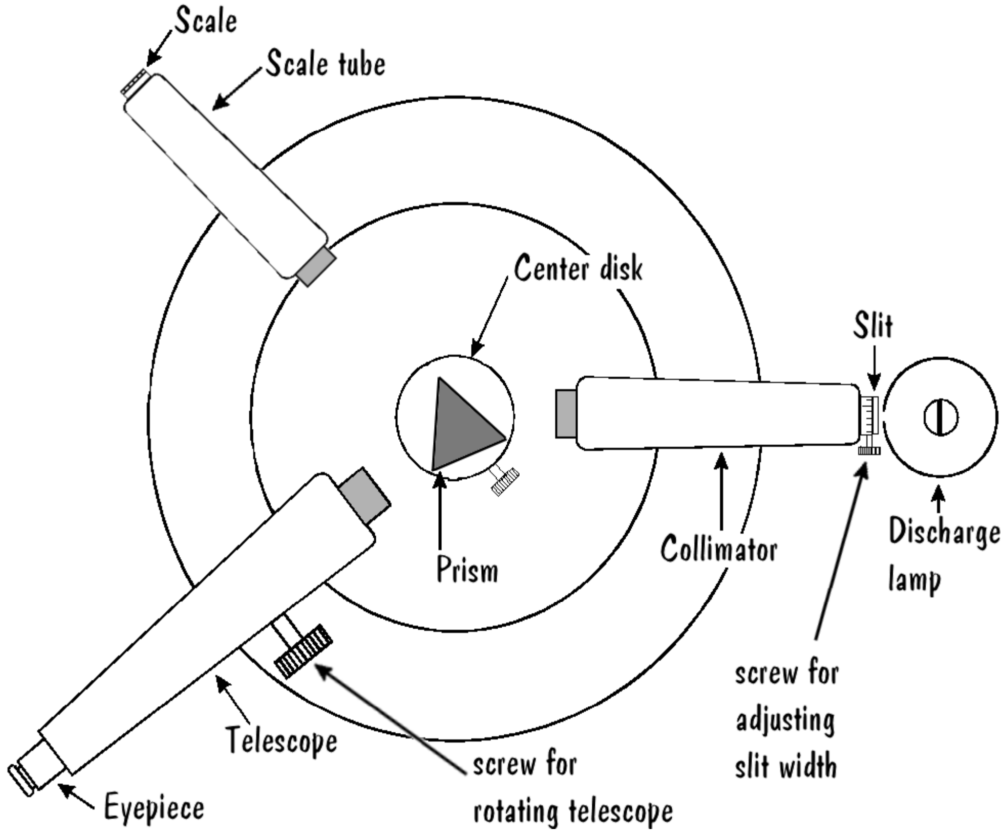
The Spectroscope

APPARATUS

1. Spectroscope
2. Mercury arc
3. Sodium Lamp
4. Geissler tubes with high voltage unit
5. Desk lamp
6. Filters

INTRODUCTION

This exercise will permit the student to study the spectroscope and to use it to examine the spectra of several light sources. The spectroscope used here consists of a collimator, a prism, a telescope, and a scale tube. The collimator is a tube having at one end a fine slit of adjustable width and at the other a converging lens. Because the slit-to-lens distance is equal to the focal length of the lens, light which diverges from the slit will become parallel upon passing through the lens. A parallel beam entering the telescope is imaged into the focal plane. The optics of the scale tube is identical with that of the collimator. The relation and function of each part is shown in the following figure.



Suppose that the collimator slit is illuminated with monochromatic light. The rays leaving the collimator are parallel and remain so through the prism though their direction is changed. (They all have the same angle of incidence and wavelength within the prism). Therefore, these rays will be brought to a focus in the focal plane of the telescope and form there a real image of the slit. If a source which contains several colors is used, several images of different color will appear, each an image of the slit formed by one constituent of the light. In order to see all these images it will be necessary to rotate the telescope by means of the knurled knob. When the outer end of the scale tube is illuminated by white light, this light is rendered parallel by the scale tube lens and reflected from the face of the prism into the telescope, so that a real image of the scale is formed in the focal plane of the telescope, coinciding with the spectrum observed. Thus the position (in arbitrary units) of the line of the spectrum can be read off directly.

PROCEDURE

Part I: The Mercury Spectrum

Place the mercury arc in front of the slit, the lamp in front of the scale tube, and look through the telescope. If necessary, slide the telescope tube in or out until the scale appears sharp. Leave the telescope tube in this position. If the slit is not in focus move the slit tube in or out until it appears sharp. If you have difficulty in making these two adjustments consult your instructor. You should see the following lines:

Color	Wavelength
Bright Violet	404.7 nm
Violet	407.8 nm
Blue	435.8 nm
Dull Green	491.6 nm
Bright Green	546.1 nm
Yellow	577.0 nm
Yellow	579.1 nm

Before you note the positions of the lines on the scale, make the slit very narrow. If you have difficulty in finding some of these lines, widen the slit, and after locating the lines make the slit narrow again. (Why?).

Part II: The Sodium Spectrum

Set up the Sodium lamp in front of the slit. If your instrument is in very good adjustment you can see two lines very close together. These lines are of wavelength 589.0 nm and 589.6 nm, but for our purposes we shall consider them as a single line of wavelength 589.3 nm. Note that the yellow line of sodium does not fall at the same position on the scale as either of the yellow mercury lines. ”Yellow” is simply a region in the spectrum. Within that region may lie several lines, all of different wavelength but nevertheless all "yellow". Similar statements could he made about every spectral color.

Part III: The Helium Spectrum and the Calibration Curve

You should find the following helium lines and probably some other fainter ones:

Color	Wavelength
Blue	447.1 nm
Blue	471.3 nm
Blue green	492.2 nm
Green	504.8 nm
Yellow	587.6 nm
Red	667.8 nm
Red, faint	706.5 nm

from your results with sodium, mercury, and helium, plot a curve showing the relationship between arbitrary scale numbers as x and wavelengths in nanometers as y. This is called a "Calibration Curve" for your instrument.

Part IV: The Hydrogen Spectrum

Examine the hydrogen spectrum, record the positions of the three visible lines of the hydrogen atom. These are the red H_α, the blue-green H_β, and the violet H_γ line. The background is due to the hydrogen molecule.

Using your calibration curve from part III, determine the wavelength of each of these lines. Compare these wavelengths with those tabulated. (H_γ: 434.0 nm, H_β: 486.1 nm, H_α: 656.3 nm)

Part V: The Neon Spectrum.

Look at the spectrum of neon. Make no attempt to record the positions of all the lines. How many red lines do you observe?

Part VI: The Continuous Spectrum

Examine the spectrum of the light from a tungsten lamp. From your calibration curve, determine the range of the visible spectrum in nanometers.

Part VII: Absorption Spectra

Place each of the filters between the tungsten lamp and determine the limits (in nanometers) of each absorption band.

Part VIII: Spectral Series

In 1884 the Swiss mathematician Johann Balmer discovered that the wavelengths of the four visible lines of the Hydrogen spectrum could be represented by the formula:

$$\lambda = 364.56 \text{ nm} \frac{m^2}{m^2 - 4} \qquad \text{where m} \;=\; 3,\; 4,\; 5,\; \text{or } 6.$$

In 1889 Johannes Rydberg recast Balmer's formula in a new form by introducing the "wave number" $k = 1/\lambda$:

$$k = R\left(\frac{1}{4} - \frac{1}{m^2}\right), \qquad \text{where } R = 0.0109678 \text{ nm}^{-1} \text{ and n } = \; 3,\; 4,\; 5\; ...$$

Rydberg had shown that a similar formula applies to many series in several different elements with the same value for R. It has therefore come to be called the "Rydberg Constant". In 1913 Niels Bohr derived this formula from theoretical considerations.

Convert the measured Hydrogen wavelengths into wave numbers and calculate the value of R from each of them. Compare your mean value with the standard value.