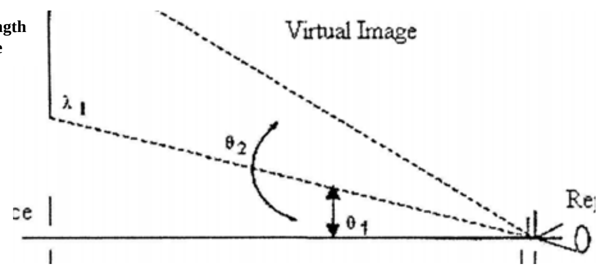
AP LAB 17
ATOMIC SPECTROSCOPY

- Simple Spectroscopy
- Energy Levels
Useful Constants:
Planck's constant h = 6.626 x 10^{-34} J s
Speed of light c = 2.998 x 10^{8} m/s
Rydberg constant $\mathbf{R_H}$ **=** 2.18 x 10^{-18} **J**
Useful Equations:
Energy, E, and Frequency, v, of Electromagnetic Radiation
E = hv
Speed, c, of Electromagnetic radiation of wavelength, l
c = lv

INTRODUCTION
In this experiment the spectral lines of hydrogen are observed and the wavelengths at which they occur are measured using a precision grating spectroscope. The lines of hydrogen are correlated in a spectral series and the exact energy levels between which the electrons fall is calculated.
In the experiment you will also examine the bright line spectra of various elements that will demonstrate the fact that each element has its own unique spectrum. Qualitatively this information will be used to determine an unknown substance.
The important features of experimental spectroscopy may be summarized in the following way. The passage of a strong electric discharge through a sample of a gaseous element at low pressure usually produces light. If this light is made to pass through a slit onto a diffraction grating (or prism) the light is broken up into its component frequencies that may be observed using an optical system and measured in terms of the angle through which the light component has been diffracted. The process may be visualized in terms of the following diagram:
It is known from the theory of diffraction that when the angle of incidence is **900** the wavelength of the diffracted light is given by the equation. n l= d sin q where l= wavelength of light
d = grating space q = diffraction angle n = spectrum order = 1 l_1 = d sin q l_2 = d sin q

Wavelength Scale



Light Source Slit

Repli Diffrac Grati

Figure 1

The wavelength, l or its reciprocal, the wavenumber is used to characterize the variety of spectral lines that are observed emanating from an electric *v* discharge through a gas of an element. Each element produces a characteristic set of spectral lines, each with a unique wavelength. The measured wavelengths can be related to the atomic structure and the particular electronic transitions responsible for each of the lines can be estimated.

The interaction between the theory and this experiment is illustrated as follows:

The energy of photons emitted by excited atoms corresponds to energy differences between energy levels in the atom. For example, an electron falling from the second to the first energy level in the hydrogen atom emits a photon having 16.3 x 10^{-19} joules of energy. This implies that an electron in the first energy level in the hydrogen atom has 16.3 x 10^{-19} joules less energy than an electron in the second energy level in that atom.
The equation relating energy levels in the hydrogen atom to the wavelengths or frequency of the spectral lines has been arrived at both experimentally and theoretically and takes the form:

$\nu = \frac{1}{\lambda} = \frac{R_H}{hc}\left(\frac{1}{n_x^2} - \frac{1}{n_y^2}\right)$ Rydberg Equation (Equation 2.)

by substituting R_H = 2.179 x 10^{-18}J, *h* = 6.626 x 10^{-34} Js, and c = 2.998 x 10^{8} m/s, you will find that

$\frac{R_H}{hc} = 1.097 \times 10^7\ /m$ Therefore, substituting in the Rydberg Equation:

$\nu = \frac{1}{\lambda} = \frac{1.097 \times 10^7}{m}\left(\frac{1}{n_x^2} - \frac{1}{n_y^2}\right)$ we may

where **V** is the wave number of the spectral line; *2* is the wavelength of the spectral line; 9.12 x 10^{6}cm is a single constant; n and n are the principal quantum numbers for the energy levels in the atom between which the electron falls; n_x is the lower and n_y the higher quantum number.
By substituting the wavelength (in cm) of the measured lines in the hydrogen spectra into this equation it will give us a number equal to

$$\frac{1}{n_x^2} - \frac{1}{n_y^2}$$

From this number it will be possible to calculate the exact energy levels between which the electron falls in emitting the photons that give rise to that particular spectral line.

Example:
Suppose l = 1.21 x 10^{-5} cm then $\frac{1}{n_x^2} - \frac{1}{n_y^2} = \frac{9.12 \times 10^{-6}}{1.21 \times 10^{-5}} = 0.75$

Consequently:
n_x must be 1 and n_y must be 2 since $\frac{1}{1^2} - \frac{1}{2^2} = \frac{1}{1} - \frac{1}{4} = \frac{3}{4} = .75$

Thus the electron must have undergone a transition from n = 2 to n = 1 to produce this spectral line.

After determining the wavelengths of the observable spectral lines in the hydrogen spectrum you will make the calculation just described. On completing your calculations you will then produce an energy-level diagram showing the relative positions of the various energy levels for the atom as indicated by the spectral lines.

Construction of such a diagram for hydrogen requires knowledge that the lines in the visible spectrum of hydrogen correspond to transitions in which the electron is falling to the same energy level in each case. If the base line of a piece of graph paper represents this energy level, the various other levels can be represented in their correct relative positions on the graph using the values calculated for the energy of the respective spectral lines. These values correspond to the differences in energy between the respective energy levels and the reference energy.

SAFETY AND ENVIRONMENTAL CONCERNS

Extreme care must be taken when working with the Spectroscope;

CAUTION: HIGH VOLTAGES.

Power Supply 220 volts are used in the electrical discharge unit which will produce a lethal shock hazard if not handled properly.

Gaseous discharge tubes are under pressure, handle with caution. When changing gaseous discharge tubes, the tubes must have cooled sufficiently, and the power supply must be in the **OFF** position and unplugged.

EXPERIMENTAL PROCEDURE

Instructions regarding the use of the spcctroscopes will be provided at the time of the exercise. BE EXTREMELY CAUTIOUS OF THE ELECTRICAL DISCHARGE UNIT THAT IS A LETHAL SHOCK HAZARD.

Start by passing an electrical discharge through the hydrogen tube and examine its spectra with the spectroscope.

Read the wavelengths (in nano meters) of all observable lines using the illuminated scale. Compare the wavelengths of other lines in the observed hydrogen spectrum with the known wavelengths as indicated in the literature values given. You will notice that if the instrument is not reading the exact literature values, that all lines are misplaced in the same direction.

Each instrument is supplied with both known and unknown tubes in addition to the hydrogen spectral tube. Record the wavelengths of the lines observed from each spectral tube. Using the literature values given, identify the unknown elements based on their characteristic emission spectra.

NOTE: Use caution when changing the tubes. Always turn the power supply off before replacement of tubes. To avoid burns, wait a few minutes after turning the power off before touching the hot tube.

RESULTS AND CALCULATIONS

1. Record the colors and the wavelengths of the fundamental lines observed in the hydrogen and other assigned spectral tubes.
2. Record the letter on your unknown tubes. Based on the observable wavelengths and the literature values given, determine the element in your tubes.
3. Calculate the energy of the photons in the hydrogen lines in kilojoules and in kilojoules per mole of photons.
4. Calculate using the Rydberg Equation the electron transitions that cause each of the spectral lines in the hydrogen spectra. (2 must be in cm)
5. Construct a partial energy level diagram for the hydrogen atom. Using the values for the hydrogen atom spectral photons plot an energy level diagram using the instructions described in the introduction.