**EXPERIMENT: THE WAVELENGTH OF LIGHT MEASURED WITH A DIFFRACTION GRATING**

[Equipment list: Student Spectrometer with Telescope and Vernier Scale, Mercury Light Source, 600 lines/mm Diffraction Grating]

**Overview:**

A diffraction grating consists of a glass plate on which closely spaced grooves have been ruled with a diamond. You will be using a replica grating, in which the groove pattern from an original grating has been pressed into gelatin placed on a second plate of glass.

**WARNING: THE GRATING SURFACE IS DELICATE AND EVEN LIGHTLY TOUCHING IT WITH A FINGER PRODUCES HARMFUL FINGERPRINTS WHICH CANNOT BE REMOVED! DO NOT TRY TO CLEAN THE GRATING SURFACE!!!!!**

A grating may be considered as a large number of parallel slits with a common spacing d between adjacent slits. In this experiment it will be illuminated with parallel light normal to the grating surface (see figure 1). Spectral lines, each corresponding to a definite wavelength, λ, are observed through a telescope focused at infinity. The vertical cross hair of this telescope is centered on light which leaves the grating as parallel rays at an angle θ to the normal. An image of the slit will of course be observed through the telescope when θ = 0 (called the “zero order” or “central maximum”). Due to diffraction of the light passing through the narrow slits, however, light leaving the grating may also be seen at other angles.

Diffraction Grating

Collimator

Slit

Source

Bench

Ө

Telescope

Eye

figure 1

At a given angle (see figure 2), there is an optical path difference δ = d sin θ between rays from consecutive grooves (here d = .001667 mm, since there are 600 lines/mm). When this path difference is a multiple of a wavelength which is present in the source, the amplitudes of the rays from all of the slits will add up. We call this constructive interference, and it corresponds to a bright spectral line at this angle θ. This may be written δ = pλ or:

pλ = d sin θ (1)

where the order number p = 0, + 1, + 2, ....

3pλ

2pλ

pλ

d

Ө

Ө

figure 2

Most light sources produce many different wavelengths. For each order a bright line will appear for each of these wavelengths at an angle given by equation 1. This spectrum is repeated for every possible order number p, being more spread out (greater dispersion) for larger p. The order number may be determined by counting from the zero order and by a little common sense and attention to color where orders overlap.

**CAUTION:** The mercury source produces considerable ultraviolet light. If you look at it for very long you may wake up tomorrow morning with a gritty feeling in your eyes‑‑most uncomfortable. Glass stops this UV, such as eyeglass lenses, spectroscope optics, etc. If you don't wear glasses, avoid looking at the mercury source‑‑looking at the spectrum through the spectrometer is safe, however.

175°15’

175°49’

**PROCEDURE:** Measure the angle θ from the undeviated (and extremely bright) central image. The central image (Central Maximum) angular position must first be measured first with the telescope. Adjust the light source to give you the brightest image, close down the slit to yield a thin sharp line not much wider than the cross hair, and adjust the eyepiece to give the best focus. The main scale reads in degrees and halves of degrees; the Vernier scale reads in minutes of arc (up to 30 minutes and 60 minutes). Record the angular positions on the Excel worksheet in degrees (minutes of arc should be converted to degrees). Calculate the “Angle measured from Central Maximum” by taking the absolute value of the difference between the Central Maximum angle and the photon emission angle.

Measure the position of the bright blue line for the first and second orders on either side of the central maximum. For, say, the first order blue, average the angles θ to either side and calculate the wavelength from equation (1). To calculate another value for the wavelength of the blue line use the data for this line in the second order and use equation (1) again. These two values for the wavelength should agree closely, average them to obtain your best value for this wavelength.

Repeat the process for the green line.

According to Einstein, a photon with wavelength λ will have an energy E = hf or E = hc/λ where h is Plank's constant and c is the velocity of light. Expressed in electron volts E = hc/eλ where e is the charge on an electron. This combination of constants hc/e has the numerical value:

12.4 x 103 Å⋅eV,

so the energy of a photon (in electron volts) of wavelength λ is

12.4 x 103 Å⋅eV

λ

Calculate the energies of the green and blue photons in electron volts from the average wavelengths calculated above.

These photon energies must correspond to differences between allowed energies of the mercury atom. Listed in Table 1 on the Excel worksheet are a few of the lowest allowed energies of the mercury atom. The labels identifying the levels are spectroscopic designations, which describe the quantum numbers associated with each level. For this experiment, we are not going to be concerned with the meaning of these designations, but only using them to give us something to designate each level.

To identify the transition associated with each wavelength, we simply search for a difference between two of the levels that agrees with the calculated photon energy. Since there are many differences between seven numbers, we prefer to use a shortcut. For, say, the blue photon we first add its energy to the energy of the first or lowest mercury level. If this sum agrees with another of the mercury energy levels, then we have found the two levels involved in the transition. If not, then add the photon energy to the second energy level and see if this sum agrees with another level. Repeat until you have clearly determined which two levels are responsible for the blue photon, and state your results as "The blue photon corresponds to a transition between the and levels of mercury". Indicate how well the energies agree by comparing the sum (lower level energy plus photon energy) with the listed energy for the upper level.

Repeat this entire process for the green photon.

**Results:**

**As part of your discussion in the Results section of your lab report, make a statement such as the on below, one statement for the blue photon, and one statement for the green photon.**

The blue photon corresponds to a transition between the \_\_\_\_\_\_\_\_\_\_\_\_\_ and the \_\_\_\_\_\_\_\_\_\_\_\_\_ levels of Mercury.

**Also in the Results section of your lab report, discuss how well the sum of the energies compared to the listed energy for the upper level. Use the following percent difference equation to discuss this.**

**Questions for Further Discussion**

1. Could we resolve the spectra without use of a telescope? If so, why are we able to resolve it?

2. The manufacturer of the grating quotes the number of lines/mm of the grating. For **one of your spectra lines**, how many lines/mm would the manufacturer’s value have to be in error to result in a 20 Å error in wavelength? Let N equal the number of lines/mm such that d = 1/N. Use an uncertainty analysis equation to determine this answer. The (sin θ) should be considered a constant since it has nothing to do with how the manufacturer made the grating, but with the telescope used in the experiment.

3. The grating is mounted on one side of the glass plate. Which side is it mounted with respect to the telescope and is it important to have it this way? Light normal to a glass plate passes through un-refracted. However, light striking a glass plate at an angle other than 0° will refract upon **entering** the glass plate. Think “Snell’s Law” when answering this question.