UOWD
University of Wollongong in Dubai

Lab Experiment: Spectra

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Student Number:	.....	.....	.....	.....

Activity 1: Emission (Bright Line) Spectrum

EQUIPMENT NEEDED

Spectrophotometer System (OS-8539)

or

Spectrophotometer Kit (OS-8537)
Rotary Motion Sensor (CI-6538)
Aperture Bracket (OS-8534)
Mercury Spectral Tube and Power Supply
PASCO Interface
High Sensitivity Light Sensor (CI-6604)
Basic Optics Bench (part of OS-8515)
Rod, 45 cm (ME-8736) (2)
Large Rod Stand (ME-8735) (2)
Data acquisition software

Introduction

The purpose of this activity is to determine the wavelengths of the colors in the spectrum of a mercury vapor light.

Theory

An incandescent source such as a hot solid metal filament produces a continuous spectrum of wavelengths. Light produced by an electric discharge in a rarefied gas of a single element contains a limited number of discrete wavelengths - an emission or "bright line" spectrum. The pattern of colors in an emission spectrum is characteristic of the element. The individual colors appear in the shape of "bright lines" because the light that is separated into the spectrum usually passes through a narrow slit illuminated by the light source.

A grating is a piece of transparent material on which has been ruled a large number of equally spaced parallel lines. The distance between the lines is called the grating line spacing, d.

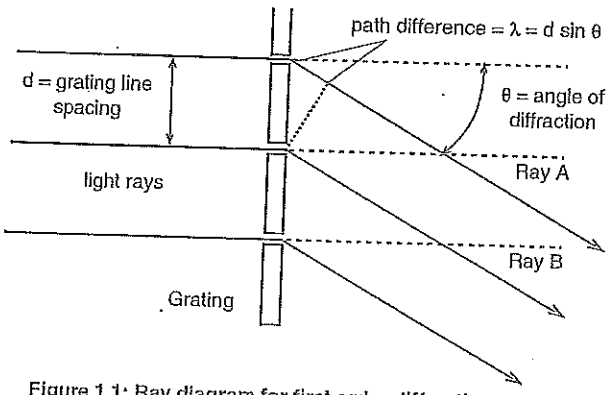


Figure 1.1: Ray diagram for first order diffraction pattern

Light that strikes the transparent material is diffracted by the parallel lines. The diffracted light passes through the grating at all angles relative to the original light path. If diffracted light rays from adjacent lines on the grating interfere and are *in phase*, an image of the light source can be formed. Light rays from adjacent lines will be in phase if the rays differ in path length by an integral number of wavelengths of the light. The first place that an image can be formed is where the path length between two adjacent light rays differs by one wavelength, λ. However, the difference in path length for two adjacent light rays also depends on the grating line spacing, d, and the angle, θ, at which the two light rays were diffracted by the grating.

The relationship between the wavelength of the light, λ, the grating line spacing, d, and diffraction angle, θ, is as follows:

$$\lambda = d \sin \theta$$

In the diagram (Fig. 1.1), the path length for Ray A is one wavelength longer than the path length of Ray B.

Procedure

In this activity, the High Sensitivity Light Sensor measures the relative intensity of colors of light in an emission spectrum produced by light from a mercury vapor light source passing through a grating. The Rotary Motion Sensor measures the angle, θ, of each band or "bright line" of color.

The data acquisition program records and displays the light intensity and the angle. You can use the program's built-in data analysis tools to find the angle for each color, and then you can determine the wavelength, λ, of each color.

Equipment Setup

1. Set up the Spectrophotometer next to a mercury vapor light source as shown (Fig. 1.2). If needed, use the Rod Stand Mounting Clamps, two rods, and two bases to raise the Spectrophotometer to the same level as the opening to the light source. (Refer to the Introduction for more information.)

2. If the light source has a large opening, mask the opening so it transmits a narrow (0.5 to 1.0 cm) beam to the Collimating Slits. Put a cloth hood over the light source and attach the edge of the hood to the plate on the Collimating Slits.

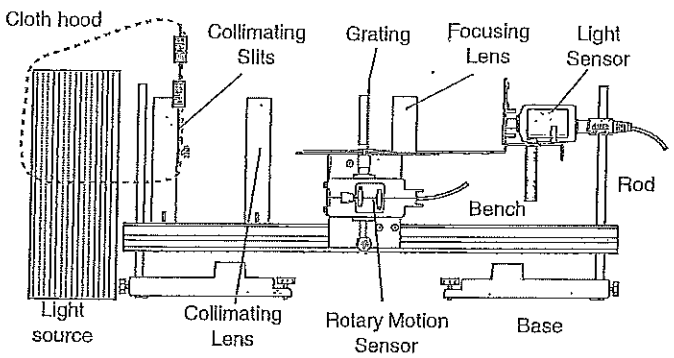


Figure 1.2: Equipment Setup

3. Turn on the light source. Once it is warmed up, adjust the light source, Collimating Slits, Collimating Lens, and Focusing Lens so clear images of the central ray and the first order spectral lines appear on the Aperture Disk and Aperture Screen in front of the High Sensitivity Light Sensor. Turn the Aperture Disk so the smallest slit on the disk is in line with the central ray.

4. Connect the PASCO interface to the computer, and turn on the interface. Start the data acquisition software.

5. Connect the High Sensitivity Light Sensor cable to Analog Channel A. Connect the Rotary Motion Sensor cable to Digital Channels 1 and 2.

Experiment Setup

Select the Sensors, Set the Sample Rate, and Create a Calculation

Refer to the User's Guide for your version of data acquisition software for detailed information on selecting sensors, changing the sample rate, and creating a calculation.

1. In the program, select the Rotary Motion Sensor and connect it to Digital Channels 1 and 2 and select the Light Sensor and connect it to Analog Channel A.

2. In the program, set up the Rotary Motion Sensor for high resolution (1440 Divisions per Rotation) and set the sample rate to 20 Hz, or 20 measurements per second.

3. In the data acquisition program, use the Calculator to create a calculation of Actual Angular Position based on the Angular Position measurement made by the Rotary Motion Sensor and the ratio of the radius of the Spectrophotometer's Degree Plate to the radius of the small post on the Pinion (Fig. 1.3). (Refer to the Set Up section for more information.)

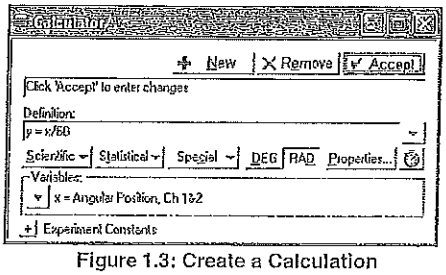


Figure 1.3: Create a Calculation

Select the Display

Refer to the User's Guide for your version of the PASCO data acquisition software for detailed information on displays.

1. Select a Graph display.

2. Set the axes of the Graph display so *Light Intensity* is on the *vertical* axis and *Actual Angular Position* is on the *horizontal* axis.

Prepare to Record Data

Refer to the User's Guide for your version of the PASCO data acquisition software for detailed information on monitoring and recording data.

1. Darken the room. Examine the spectrum closely. Determine which of the two first order spectral patterns is brightest. In the Data Table, list the colors you see in order starting with the color that appears farthest from the central ray.

2. Use the Light Sensor Arm on the Spectrophotometer to turn the Degree Plate until the light sensor is beyond the last line in the brightest first order spectral pattern.

Record Data

1. Set the GAIN select switch on top of the High Sensitivity Light Sensor to 1.

2. Start recording data.

3. Push on the threaded post under the light sensor to slowly and continuously scan the spectrum in one direction. Scan all the way through the first order spectral lines on one side of the central ray, through the central ray itself, and all the way through the first order spectral lines on the other side of the central ray (Fig. 1.4).

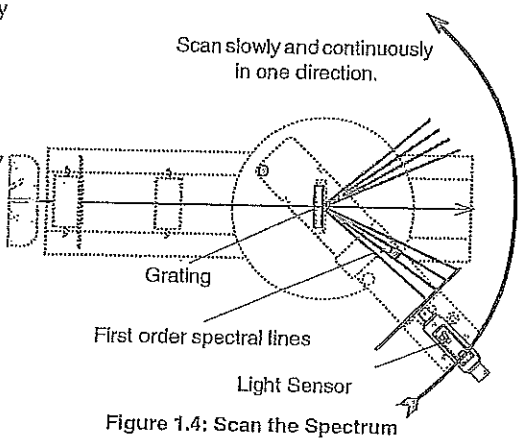


Figure 1.4: Scan the Spectrum

4. Stop recording data.

5. Set the GAIN select switch on top of the light sensor to 10. Put the light sensor back at its starting point. Repeat the data collection procedure.

6. Set the GAIN select switch on top of the light sensor to 100 and repeat the data collection procedure.

Analyze the Data

Refer to the User's Guide for your version of the PASCO data acquisition software for detailed information on using the software for data analysis.

1. Use the Graph display to examine the plot of Light Intensity versus Actual Angular Position for the first run of data (GAIN select switch = 1).

2. Use the built-in analysis tools to determine the angle of the first line in the spectral pattern, and the angle of the matching line in the first order spectral pattern on the other side of the central ray.

3. Determine the difference in angle between the two lines and use one-half of the difference as the angle, θ, to determine the wavelength, λ, of that color. (If you did not calibrate the Diffraction Grating, assume d = 1666 nm.)

4. Repeat the process for the other colors in the first order spectral pattern.

5. Examine the plot of Light Intensity versus Actual Angular Position for your other two runs of data. Look for other lines in the spectral pattern that may be too dim to record when the sensor was set to GAIN = 1.

Data Table

Record your data here:

Color	θ_1	θ_2	$\Delta\theta$	$\theta = \Delta\theta/2\lambda =$ d sin θ

Conclusion

Compare your values for the wavelengths of color in the mercury vapor light spectrum to the accepted values for wavelengths.

Extensions

Repeat the process for a different gaseous element, such as hydrogen or helium.

Activity 2: Absorption (Dark Line) Spectrum

EQUIPMENT NEEDED

Spectrophotometer System (OS-8539)

or

Spectrophotometer Kit (OS-8537)
Rotary Motion Sensor (CI-6538)
Aperture Bracket (OS-8534)

and

Incandescent Light Source, DC, regulated
Rod, 45 cm (ME-8736) (2)
PASCO Interface
High Sensitivity Light Sensor (CI-6604)
Basic Optics Bench (part of OS-8515)
Large Rod Stand (ME-8735) (2)
Colored Liquid Sample (about 5 mL)
Data acquisition software

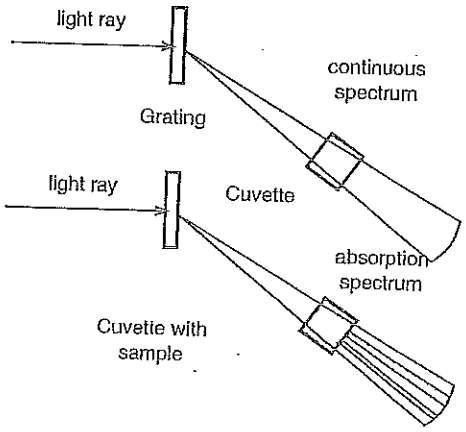
Introduction

The purpose of this activity is to determine the wavelengths of the colors absorbed by a liquid sample.

Theory

One of the most important applications of spectrophotometers is to identify substances by their absorption spectra. For example, it is possible to identify tiny amounts of sodium dissolved in a complicated liquid (such as beer) because sodium has a unique absorption spectrum.

An incandescent source such as a hot solid metal filament produces a continuous spectrum of wavelengths. A substance placed in the path of light from a continuous spectrum source will absorb certain colors from the continuous spectrum. The individual colors that are absorbed appear as gaps or "dark lines" in the otherwise continuous spectrum (Fig. 2.1).



Procedure

In this activity, the High Sensitivity Light Sensor measures the relative intensity of colors of light in an continuous spectrum produced by an incandescent light. Then, the sensor measures the relative intensity of colors of light in an absorption spectrum produced when light from the incandescent source passes through a liquid sample. The Rotary Motion Sensor measures the angle, θ, of each part of the continuous spectrum and then the absorption spectrum.

The data acquisition program records and displays the light intensity and the angle. You can use the program's built-in data analysis tools to find the angle for each "gap" or dark line in the absorption spectrum, and then you can determine the wavelength, λ.

Equipment Setup

1. Set up the Spectrophotometer next to a DC powered incandescent light source as shown. Move the High Sensitivity Light Sensor to the second position on the Light Sensor Arm so there is room for a cuvette between the back of the Aperture Disk and the opening to the sensor. (Refer to the Set Up section for more information.)

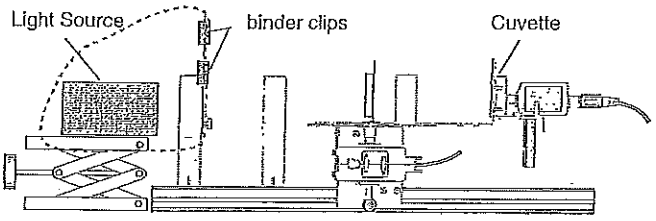


Figure 2.2: Equipment Setup for Absorption Spectrum

2. Put an empty cuvette in front of the High Sensitivity Light Sensor between the sensor and the back of the Aperture Disk. Make sure that the smooth sides of the cuvette are in line with the opening to the sensor (Fig. 2.2).

3. If the light source has a large opening, mask the opening so it transmits a narrow (0.5 to 1.0 cm) beam to the Collimating Slits. Adjust the Collimating Slits slide so the number 2 slit is in line with the light source. Put a cloth hood over the light source and attach the edge of the hood to the plate on the Collimating Slits.

4. Turn on the light source. Once it is warmed up, adjust the light source, Collimating Slits, Collimating Lens, and Focusing Lens so clear images of the central ray and the first order spectral pattern appear on the Aperture Disk and Aperture Screen. Turn the Aperture Disk so the second smallest slit on the disk is in line with the central ray.

5. Connect the PASCO interface to the computer, turn on the interface. Start the data acquisition software.

6. Connect the High Sensitivity Light Sensor cable to Analog Channel A. Connect the Rotary Motion Sensor cable to Digital Channels 1 and 2.

Experiment Setup

Select the Sensors, Set the Sample Rate, and Create a Calculation

Refer to the User's Guide for your version of the data acquisition software for detailed information on selecting sensors, changing the sample rate and sensitivity, and creating a calculation.

1. In the data acquisition program, select the Rotary Motion Sensor and connect it to the interface.

2. In the program, set up the Rotary Motion Sensor for high resolution (1440 Divisions per Rotation) and set the sample rate to 20 Hz, or 20 measurements per second.

3. Set the Sensitivity for the High Sensitivity Light Sensor to 10x.

4. Use the Calculator to create a calculation of Actual Angular Position based on the Angular Position measurement made by the Rotary Motion Sensor and the ratio of the radius of the Spectrophotometer's Degree Plate to the radius of the small post on the Pinion. (Refer to the Introduction for more information.)

Select the Display

Refer to the User's Guide for your version of the data acquisition software for detailed information on displays.

1. Select a Graph display.

2. Set the axes of the Graph display so *Light Intensity* is on the *vertical* axis and *Actual Angular Position* is on the *horizontal* axis.

Prepare to Record Data

Refer to the User's Guide for your version of the data acquisition software for detailed information on displays.

1. Darken the room. Examine the spectrum closely. Determine which of the two first order spectral patterns is brightest.

2. Use the Light Sensor Arm on the Spectrophotometer to turn the Degree Plate until the light sensor is beyond the last color in the brightest first order spectral pattern.

Record Data - Empty Cuvette

1. Set the GAIN select switch on top of the High Sensitivity Light Sensor to 10.

2. Start recording data.

3. Push on the threaded post under the light sensor to slowly and continuously scan the spectrum in one direction. Scan all the way through the first order spectral pattern on one side of the central ray, through the central ray itself, and all the way through the first order spectral pattern on the other side of the central ray.

4. Stop recording data.

Record Data - Cuvette with Liquid Sample

1. Remove the cuvette and fill it three-quarters full with the liquid sample you are testing. Cap the cuvette and replace it in front of the sensor.

2. Start recording data.

3. Push on the threaded post under the light sensor to slowly and continuously scan the spectrum in one direction. Scan all the way through the first order spectral pattern on one side of the central ray, through the central ray itself, and all the way through the first order spectral pattern on the other side of the central ray.

4. Stop recording data.

Analyze the Data

Refer to the User's Guide for your version of the data acquisition software for detailed information on displays.

1. Use the Graph display to compare the plot of Light Intensity versus Actual Angular Position for the first run of data (empty cuvette) to the plot of Light Intensity versus Actual Angular Position for the second run of data (cuvette plus liquid sample).

2. Use the built-in analysis tools of the program to find the angle of the first gap or "dark line" in the absorption spectrum of the liquid sample. Find the angle of the corresponding gap or line in the first order on the other side of the central ray.

3. Determine the difference between the angles and use one-half of the difference as the angle, θ, to determine the wavelength, λ, of that gap or dark line. (If you did not calibrate the Diffraction Grating, assume d = 1666 nm.)

$$\lambda = d \sin \theta$$

4. Repeat the process for the other gaps (if any) in the first order spectral pattern.

Data Table

Record your data here:

"Dark Line"	θ_1	θ_2	$\Delta\theta$	$\theta = \Delta\theta/2$	$\lambda = d \sin \theta$

Questions

1. What color corresponds to the wavelength for each "dark line" in your absorption spectrum?

2. How does the color or colors that are absorbed out of the continuous spectrum compare to the naked eye color of your liquid sample?

Extensions

Repeat the process for a different liquid sample, such as chlorophyll extracted from a spinach leaf.