Concepts in Physics
Lab 5: Line Spectra

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Introduction

When a low pressure gas in a glass tube is excited by the input of a large amount of energy, the atoms or molecules that make up the gas become excited. When the molecules return to their unexcited state, they give of a just few particular frequencies (colors) of light. The particular frequencies of light emitted by a particular gas are called its *emission spectrum,* which acts like a "fingerprint" for that gas because it can help a scientist uniquely identify that gas.

Incandescent light, on the other hand, is the kind of light you get from a filament in an ordinary light bulb. With incandescent light, the colors you get depend not on the substance, but only on the temperature of the substance. While the emission spectrum of an excited gas consists of a number of discrete frequencies (colors) of light, the spectrum of an incandescent light consists of a broad, continuous band of frequencies.

During this experiment you will make use of a device known as a diffraction grating spectrometer. A diffraction grating splits a single beam of light into the many colors which it contains. The spectrometer is just a device for extracting quantitative information from the spectrum, such as the wavelength of the various lines in the spectrum. The device you will use is similar to the experimental apparatus used by spectroscopists for almost two centuries to study the line spectra of the elements. These line spectra played a crucial role in the development of the atomic theory of matter and quantum mechanics.

Activity 1: The Experiment

There are a number of different tasks you have to perform; in sequence, these are:

- First you must set up and calibrate the spectrometer. I will help you with this.

    1. Focus the telescope on something far away.
    2. Focus the cross-hairs.
    3. Adjust the collimator until the slit is in focus.
    4. See that the light from the slit is going through the telescope and the collimator and then directly to your eye without bending.

- Now that the spectrometer is aligned, read the angle that the telescope makes on the scale and record it below in Table 1. This will be your "zero angle" for future reference. From this point on, do not make any changes to the spectrometer except to rotate the telescope arm. Do not adjust the the telescope arm or the collimator arm. If the cross hairs are out of focus, it is OK to adjust the eyepiece to bring them back into focus.
- Put a spectrum tube containing mercury (Hg) in a spectrum tube power supply and turn it on. The tube will glow with a bluish light. Return the telescope to a position directly opposite the collimator tube and adjust the position of the light source until the vertical line you see is as bright as it can get.
- Rotate the telescope arm counterclockwise very slowly while looking through the telescope eyepiece. As you turn the telescope arm through the angles you should see bright, colored bars of light appear and disappear. These are the same lines of the line spectrum of mercury that you can observe by looking at the lamp with a diffraction grating near your eye.
- Center the crosshairs on the single green line and note the angle from the Vernier scale for this line. Calculate the difference between this

angle and the "zero angle" and record this difference in the appropriate column in Table 1.

- Now swing the telescope arm clockwise, back past the "zero angle" point, and continue moving it clockwise until the spectral lines reappear in the telescope eyepiece. Center the cross hairs again on the yellow line and note the angle from the Vernier scale for this line. Calculate the difference between this angle and the "zero angle" and record this difference as well in Table 1.
- Calculate the average of your two angles and put this value in the third column of Table 1. This average angle is also called the *deviation angle.*
- Now you will need to make use of the diffraction grating formula,

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

where λ is the wavelength of the light, θ is the deviation angle, and d is the number of lines per nm (1 nm = 10^{-9} m) of the diffraction grating. Use this formula with the value for the wavelength of the green line of mercury and your measured average angle to calculate the value of d. Record this number above Table 1.

- Now that the spectrometer is calibrated and you have seen how it is used, and you know the value of d, you can begin to make wavelength measurements for the other spectrum lines of mercury. Just as you did above for the green line, record the deviation angles for the other visible lines of mercury in Table 1, take their average value, and using the equation above and your knowledge of d calculate the wavelengths of these lines. Record these wavelengths in Table 1.
- Turn off the spectrum tube power supply and replace the tube containing mercury with a tube containing a different gas. Repeat this procedure for measuring the unknown wavelengths of spectral lines for this new gas, and record your measurements for at least five spectral lines in Table 2.

Complete Table 1 and 2 and hand them in.

Activity 2: Questions

Also hand in answers to the following:

- How close were your wavelength measurements to the accepted values of wavelengths for the various gases, as listed in the last table? What factors do you think might have contributed to any differences, and how might they have affected your measurements?
- For what practical purpose do you suppose this experimental technique might be used? Spectroscopic techniques of the kind you applied in this lab are routinely used by scientists, by government, and in business. Can you think of any examples where or how they might be applied?

(1) Gas: Mercury (Hg)			d (nm):	
Color	θ **(cw)**	θ **(ccw)**	θ **(avg)**	λ **(nm)**
Green				546

(2) Gas:				
Color	θ **(cw)**	θ **(ccw)**	θ **(avg)**	λ **(nm)**

Note: "cw" means the clockwise angle, and "ccw" the counterclockwise angle. These values should be close to one another!

Color	**Accepted λ (nm)**			
	Helium	**Mercury**	**Neon**	**Krypton**
Purple	439	405		423
Purple	447	436		432
Purple				437
Purple				446
Purple				450
Blue	469	492		
Blue	492			
Green	502	546	534	557
Green			540	
Yellow	588	577	585	587
Yellow		579	588	
Yellow			603	
Orange		607		
Red	668		616	646
Red			627	
Red			638	
Red			640	
Red			651	
Red			660	

Don't be overly literal-minded about the colors. A line listed as yellow might look somewhat like orange to you, a purple line may be more bluish in your judgment etc.