Experiment Activity 1: Spectral Lines: Understanding the Wave-Like Nature of Light

Problem 1. Understanding the Experimental Setup: Mercury Gas

Consider and answer the following questions:

(a.) Printed on the diffraction grating, you will find the number of *lines/mm* the grating contains. Use this information to determine the separation distance between the slits of the grating.

1 μm, 1000/mm

(b.) What is the role of the adjustable slit? Why is it adjusted as narrowly as possible?

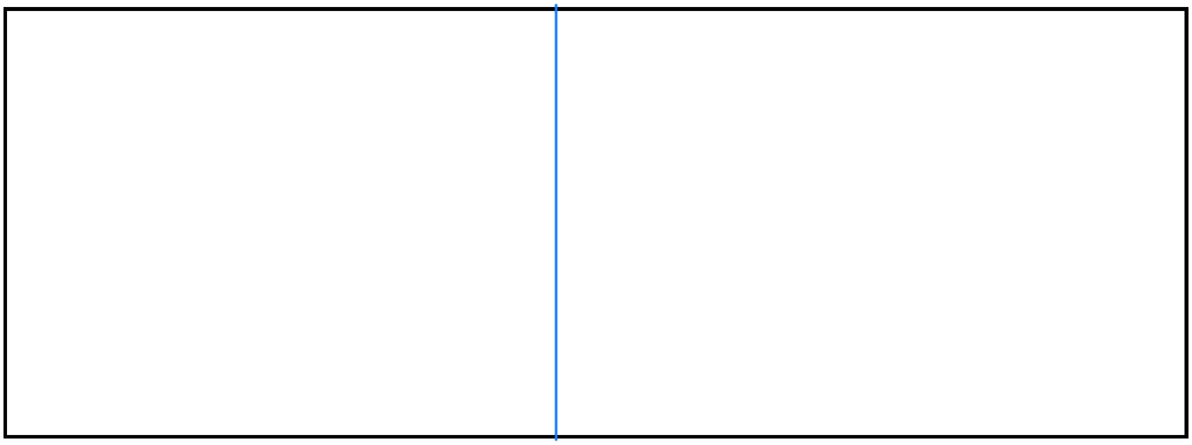
Focus in on the light from the mercury tube and block out ambient light.

(c.) With the mercury gas tube in place in the lamp base/power supply, observe the spectral lines with your analogue grating spectrometer. In the box below, sketch the lines and colors you see.

Purple @ 20°

Green @ 30°

Red @ 35°



(d.) What color is the emission from the mercury lamp? Is it what you would have expected from the combination of colors of the individual lines that you observed?

Blueish White

Problem 2. Finding $\delta\lambda$

Derive an expression for the uncertainty in the wavelength, $\delta\lambda$, that you get from computing λ from your measured values of θ_m using the equation $d\sin\theta_m = m\lambda$. (Remember your rules for uncertainty propagation.) Note that $\frac{d\sin\theta}{d\theta} = \cos\theta$ only if θ is expressed in radians!

Problem 3. Measuring the Emission Spectrum of Mercury: Data Collection

Record your observations/measurements of the $m = 1$ mercury spectrum here (Don't forget units!): rel. to 180°

Spectral Line Color	$\theta_R \pm \delta\theta_R$	$\theta_L \pm \delta\theta_L$	$\theta_1 \pm \delta\theta_1$	$\lambda_1 \pm \delta\lambda_1$
Purple	210	160		
Green	220	150		
Red	225	145		

Did you find any second or higher order spectral lines? If so, record those observations/measurements here:

m	Spectral Line Color	$\theta_R \pm \delta\theta_R$	$\theta_L \pm \delta\theta_L$	$\theta_m \pm \delta\theta_m$	$\lambda_m \pm \delta\lambda_m$

If you observed $m = 2$ and/or higher-order spectral lines, combine all corresponding ($m = 1$ and all $m \geq 2$) wavelengths and report the combined wavelengths for each spectral line:

Spectral Line Color	$\lambda \pm \delta\lambda$

Problem 4. Comparing Mercury Spectral Lines With Well Known Values

Given the data you recorded in the previous problem, compare your wavelength measurements for each spectral line with those in the NIST Atomic Spectra Database, which you can find at `http://physics.nist.gov/PhysRefData/ASD/lines_form.html`. You will have to search the database and find the relevant sets of wavelengths, using your own measurements as a guide.

Do your values agree with values in the NIST database? Check by computing the discrepancy and fractional/percent error between the relevant NIST wavelength values and your measured wavelength values. *Don't simply answer "yes" or "no": show your calculations which check agreement!*

Enough space should be given in the table below to examine several prospective NIST wavelength values that may match your own. Show all work and clearly indicate those you think are the correct matches for each spectral line color. (If you still need more room for calculations, make them on a separate piece of paper and attach it to your submission.)

Pro Tip: The NIST database contains an overwhelmingly large amount of spectral line data. So, limit your database search to wavelengths in the visible range of the electromagnetic spectrum (approximately 380 nm to 700 nm).

Your Wavelengths	NIST Wavelengths	Agreement? (Show Work to Justify!)

Problem 5. Measuring the Emission Spectrum of an Unknown Gas: Data Collection

Record your observations/measurements of the $m = 1$ unknown gas spectrum here:

Spectral Line Color	$\theta_R \pm \delta\theta_R$	$\theta_L \pm \delta\theta_L$	$\theta_1 \pm \delta\theta_1$	$\lambda_1 \pm \delta\lambda_1$
Red	180°	180°		
Green	210°	150°		
Yellow/Orange/Red	220°-225°	140°-135°		

Did you find any second or higher order spectral lines? If so, record those observations/measurements here:

m	Spectral Line Color	$\theta_R \pm \delta\theta_R$	$\theta_L \pm \delta\theta_L$	$\theta_m \pm \delta\theta_m$	$\lambda_m \pm \delta\lambda_m$

If you observed $m = 2$ and/or higher-order spectral lines, combine all corresponding ($m = 1$ and all $m \geq 2$) wavelengths and report the combined wavelengths for each spectral line:

Spectral Line Color	$\lambda \pm \delta\lambda$

Problem 6. Identifying an Unknown Element Quantitatively

Using the data you recorded in the previous problem, identify the unknown elemental gas by comparing your wavelength measurements for each spectral line with those in the NIST Atomic Spectra Database (`http://physics.nist.gov/PhysRefData/ASD/lines_form.html`). This should be done similarly to Problem 4, except now you do not know ahead of time what the gas in the tube is composed of. You will therefore have to compare your results with several possible matches in the NIST database. Use the table below (and partition it as needed by possible element matches or however you see fit) to help identify the unknown gas you were given.

Once you have come to a conclusion, state the name of the element you identified in the box below, and explain how you came to that conclusion.

Pro Tip: Consider, for example, the following to help you narrow down and guide your database search:

- What color light is emitted?
- How does the spectrum compare to spectra displayed on the Spectrum Chart provided in the classroom?
- What other tools can you use to help identify the gas?

Your Wavelengths	NIST Wavelengths	Agreement? (Show Work to Justify!)

Your Wavelengths	NIST Wavelengths	Agreement? (Show Work to Justify!)

Design Considerations

Problem 7. Improving the Experiment

How might you change the experimental setup or environment to help better identify the unknown gas?