Atomic Spectra

PH 116

Your Name

Your Partner's Names

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Introduction

The spectrum is the entire range over which some measurable property of a physical system of phenomenon can vary. Systems that have spectrums include sound frequency, electromagnetic radiation wavelength, and the mass of specific kinds of particles. Every element has a series of spectral lines. No two elements have the same spectral line. These spectral lines can be seen by ionizing the element and then sending the emitted photons through a prism or diffraction grating. This experiment allows the experimenter to see spectral lines of two different elements, mercury and hydrogen. The spectral lines of the elements look like a series of reflections of the element's ionized source in different, specific colors.

Procedure and Data

A spectrometer is used to measure the angular position of the different order diffraction gratings. This was done for a mercury light source and a hydrogen light source.

The mercury light was used first. The light was set as close as possible to the spectrometer, without touching it, and then adjusted until the maximum amount of light is seen through the eyepiece on the opposite end of the spectrometer. Once this was done, the diffraction grating was placed on the center of the spectrometer. The eyepiece was then swept side to side to find the spectral lines. The first order diffraction line for mercury was violet. The angle between the light source and the violet line was measured and found to be 15º.

The mercury light was then removed and replaced with a hydrogen light source. The same basic procedure was followed for setup. The placement of the light was adjusted until the maximum of light was seen through the eyepiece of the spectrometer. The diffraction grating was then added so that the spectral lines could be seen (figure 1). For the hydrogen light, angles for the first three orders of spectral lines were recorded. The first order line was a violet line at 15º, the second order line was a turquoise line at 17º, and the third order line was a red line at 23º. All angles were measure from the light source as seen in the spectrometer. Using the following equation, the wavelength of each of the spectral lines can be calculated.

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$$

Where R is the Rydberg constant, equivalent to $1.09\text{x}10^{-7}$ m^{-1}, and n is the order of the diffraction line. These values came out as 661 nm for the violet line, 489 nm for the turquoise line, and 437 nm for the red line.

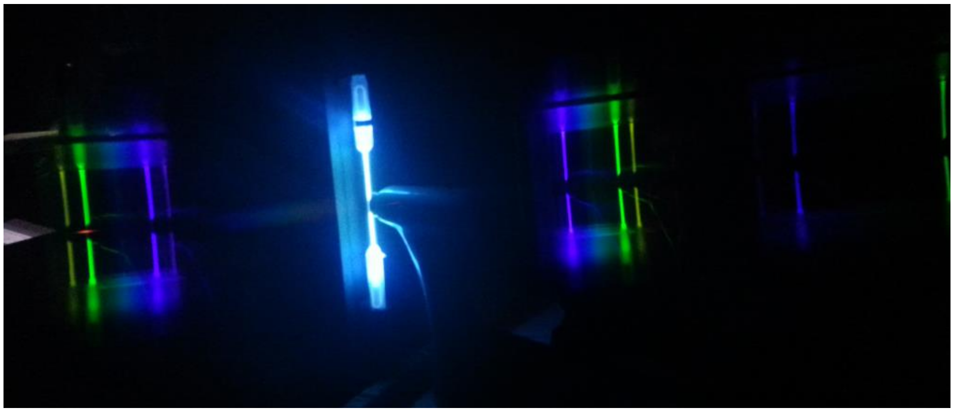

Figure 1-Hydrogen Light Source as Seen Through a Diffraction Grating*

*Figure 1 was taken by placing the diffraction grating against the camera lens and aiming it towards the hydrogen light source.

Results

All elements have a distinct spectral line. This experiment focused on the spectral lines of a mercury light source and a hydrogen light source. The spectral lines of elements can be seen by ionizing the element, causing it to release photons, then sending those photons through a diffraction grating. Images similar to that of figure 1 will be seen for each element. However, different elements will have lines of different color, spacing, or patterning as those of the hydrogen lamp. A spectrometer can be used to find the angular position of the visible spectral lines. In the case of the hydrogen lamp, the first three orders of spectral lines were measured. Using the given equation and the order of each spectral line, the wavelength of each line can be found.

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$$

Because this equation was developed using the Balmer series, the order of the diffraction lines found cannot be less than three. If they are, the equation will return a negative wavelength. For the purposes of this experiment, although told to find the first through third diffraction lines, n=3-5 was used. For example, the first order diffraction line found was a violet line and 15º from the light source. To find the wavelength, a value of n = 3 was plugged into the given equation along with the value of the Rydberg constant ($R = 1.09\text{x}10^{-7}\ m^{-1}$). This returned a value of $6.61\text{x}10^{-7}$ m or 661 nm. After doing some researching on the internet, it was found that the violet spectral in the hydrogen spectrum is about 670 nm. By comparing the other two values with those found on the internet, this was found to be true for all three values. This should lead the experimenter to believe that the violet, turquoise, and red lines are actually the third, fourth, and fifth order diffraction lines.

Chapter 9

Atomic Spectra

9.1 A Brief History

A spectral line of an element is the same as a human fingerprint. No two elements share the same series of spectral lines therefore if we chose to look at a star we could, in theory, determine the individual elements which made up the star. Ionizing an elemental gas will allow it to emit photons. Sending these photons through a prism or diffraction grating will separate the colors. Cataloguing the angular displacement of these lines will give the elemental signature.

9.2 Notes

1. This experiment will be done in the dark because the spectral lines are incredibly difficult to see. Allow your eyes to adjust before valiantly trying to find phantom spectral lines.

9.3 Definitions

1. *Spectra*-The entire range over which some measurable property of a physical system or phenomenon can vary, such as the frequency of sound, the wavelength of electromagnetic radiation, or the mass of specific kinds of particles.[1] [1]Definitions were provided by *The American Heritage Science Dictionary*

9.4 Laboratory Objectives

By the end of today's exercise you will understand that each element produces a different series of spectral lines and how we may observe these.

9.5 Equipment

Spectrometer, Transmission Diffraction Grating, Grating Holder, Mercury Light Source, Hydrogen Discharge Tube, and a Power Supply

9.6 In Class Lecture

1. The TA will give a brief overview of spectral lines and also a demonstration on how to set up the apparatus and pro-tips on where to look for spectral lines.

9.7 Procedure

1. Set up the Mercury lamp such that the light passes through the entrance slit of the collimator on the spectrometer. Adjust the eyepiece of the spectrometer such that you can view directly down the passage of the slit. Adjust the position of the source and the size of the slit to get maximum light while maintaining a knife edge narrow slit.

2. Once the light passing through has been optimized, place the given diffraction grating on the center of the spectrometer. Swing the eye piece to either side to find what is called the "first order" diffraction line; which consequently should be green. Record the angular position using the angle marks located on the bottom of the device.

   θ: 15 ° violet

3. Rotate to the opposite and equal angle to observe the "other" first order diffraction line. This part of the experiment is similar to experiment you completed in chapter 27 involving the double slits.

4. Now turn off the Mercury lamp and replace it with the Hydrogen Lamp. Find three spectral lines and their respective colors.

   First Order: 3
   θ_1: 15 ° Color: RED

   Second Order: 4
   θ_2: 17 ° Color: turquoise

   Third Order: 5
   θ_3: 23 ° Color: VIOLET

5. All of the lines that you observed are a part of the Balmer series. Calculate the wavelength associated for each color using a formula derived from your coursework:

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right) \quad (9.1)$$

where λ is the wavelength, R is the Rydberg Constant(1.09×10^7 m^{-1}), 2^2 is intrinsic of the Balmer series, and n is the order of the diffraction line.

λ_1: 661 nm λ_2: 489 nm λ_3: 437 nm

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

6.61×10^{-7} m $= \lambda$

661 nm