Experiment 6 Worksheet/Lab Report

**Author: Ricci Lam**

**Date: 11/22/16**

**TA Name: Matthew Du**

**DUE DATE: Expt 6 is finished Nov 21-22. This worksheet is due 24-hours after your section ends.**

## This worksheet will be submitted as a digital document on Ted. It is highly recommended that you complete it using your laptop during lab. Or, you may fill it out by hand, and then transfer the data to a digital version. If you decide to fill it out by hand, do not make errors during the transfer process. We will rely only on the digital version for grading purposes.

**ACCURACY (10 points for accuracy)**

UNKNOWN NUMBER: #117 IDENTITY OF UNKNOWN: Strontium Salt, Sodium Chloride

# INTRODUCTION (0 points, Not required)

The interaction of light and matter can yield important information about the matter or atoms under study. This is the basis of atomic spectroscopy. After the characterization of the visible emission spectrum of excited hydrogen gas by J.J. Balmer in 1885, it was soon realized that every element in the periodic table had a similar, though unique emission spectrum when excited in the gas state by electrical, thermal or other means. Because each element has a unique emission spectrum, the emission spectrum can be thought of as an unambiguous "fingerprint" for each element. Indeed, this technique is often used in cosmology and astronomy to identify the elements present in interstellar gas clouds and the like. This is but one example where the known emission spectra of the elements are used to identify an unknown sample.

In the specific case of hydrogen, its simple one-electron system makes the determination of the energies involved in the transitions between different energy levels relatively simple. The energy is related to the wavelength of the emitted light as shown in Equation 1:

(1)

where Plank's constant is equal to and the speed of light is equal to . The energy of the emitted light reflects the energy of the transition between excited and ground states; these states are characterized by the principal quantum number , where is an integer (). This transition energy can be calculated using the Rydberg equation, shown in Equation 2:

(2)

where 1312.75 kJ/mol is the Rydberg constant and is equal to the ionization energy of hydrogen, and and represent the final and initial levels that characterize the excited and ground states.

# EXPERIMENTAL (0 points, Not required)

**RESULTS (Total = 70 points)**

**Part I. Spectroscope Calibration**

Before use, the spectroscope (**spectroscope #: \_\_\_\_\_\_3\_\_**) must be calibrated. The known lines in the emission spectrum of mercury provided the data for the calibration curve so that the scale reading on the spectroscope could be correlated to wavelength. These results are shown in Table 1:

## Table 1. Calibration of Spectroscope by Mercury Lamp

|  |  |  |
| --- | --- | --- |
| **Known wavelength (nm)** | **Visible Color** | **Scale Reading** |
| 579.0 | Yellow | 5.75 |
| 546.1 | Green | 5.55 |
| 435.8 | Blue-Violet | 4.45 |
| 404.7 | Violet-UV | 4.35 |

*\* If you are not able to see the 404.7-nm line, record “Not visible” in the corresponding “Scale Reading” cell.*

The calibration curve for the spectroscope is generated by plotting the known wavelength on the x-axis, with a scale of **400-800 nm** vs. the "scale reading" on the y-axis with a scale of **4.0-8.0**. The data are fit to a line, and any measured wavelength () from this spectroscope corresponds to the corrected wavelength via the equation:

Insert the calibration curve below:

# Part II. Calculations for Hydrogen Spectra

Rearranging Equations #1 and #2, we determine that the wavelength of emitted light is related to the electronic transition in the hydrogen atom via Equation #3:

(3)

where is the speed of light, and are the final and initial levels, respectively, and RH is the Rydberg constant ().

Using Equation #3, the expected wavelengths of a large portion of the emission spectrum for hydrogen can be calculated, as shown in Table 2:

## Table 2. Calculated Emission Spectrum of Hydrogen

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ***nf*** | ***ni*** | ***Wavelength(nm)*** | ***Spectral Region\****  *(UV, VIS, IR...)* | ***Should this emission line be seen? (circle one)*** | |
| 1 | 2 | 121.5 | Ultraviolet | YES | NO |
| 1 | 3 | 102.5 | Ultraviolet | YES | NO |
| 1 | 4 | 97.2 | Ultraviolet | YES | NO |
| 1 | 5 | 94.9 | Ultraviolet | YES | NO |
| 1 | 6 | 93.7 | Ultraviolet | YES | NO |
| 2 | 3 | 656.1 | Visible | YES | NO |
| 2 | 4 | 486 | Visible | YES | NO |
| 2 | 5 | 433.9 | Visible | YES | NO |
| 2 | 6 | 410.1 | Visible | YES | NO |
| 3 | 4 | 1875 | Infrared | YES | NO |
| 3 | 5 | 1281 | Infrared | YES | NO |
| 3 | 6 | 109.3 | Ultraviolet | YES | NO |
| 4 | 5 | 405 | Visible | YES | NO |
| 4 | 6 | 262.4 | Ultraviolet | YES | NO |
| 5 | 6 | 745.6 | Infrared | YES | NO |

\* Spectral regions are characterized on Figure 6-1 in the lab Manual (Experiment 6).

Calculation - In the space below, show a detailed calculation for one of the wavelengths values reported in Table 2:

= 6.56 x 10-7 m

The actual results of the atomic spectrum for hydrogen from the spectroscope were then compared to the theoretical values from Table 2. The calibrated emission spectrum for hydrogen gas excited in a discharge lamp is shown in Table 3:

## Table 3. Emission Spectrum for Hydrogen

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Observed Color** | **Scale Reading** | **Corrected wavelength (nm)** | **Actual Value** | **Light Band Intensity\*** |
| **Red** | 6.65 | 679.7 | **656.3 nm** | Bright |
| **Blue** | 4.95 | 482.0 | **486.1 nm** | Bright |
| **Blue-Violet** | 4.43 | 421.6 | **434.0 nm** | Bright |
| **Violet-UV** | 4.22 | 397.2 | **410.2 nm\*\*** | Very faint |

\*Light Band Intensity: use an adjective such as very faint, faint, medium, bright, etc.

*\*\* If you are not able to see the 410.2-nm line, record “Not visible” in the corresponding “Scale Reading” cell.*

Calculation - In the blank space provided below, show a calculation for how you determined one of the corrected wavelengths values reported in Table 3:

= 679.7 nm

If Equation #3 is rearranged to solve for the energy levels, we obtain:

(4)

Using Equation 4, the visible emission spectrum of hydrogen was related to the energy levels, as shown in Table 4 (it was assumed that *nf* = 2 as is the case of the Balmer series).

## Table 4. Atomic Energy States for Hydrogen

|  |  |  |
| --- | --- | --- |
| **Corrected Wavelength (nm)** |  | **\*** |
| 679.7 | **2** | 3 |
| 482.0 | **2** | 4 |
| 421.6 | **2** | 5 |
| 397.2 | **2** | 7 |

*\*Note: ni values that were close to whole integer values were rounded to the integer values.*

Calculation - In the space below, show a detailed calculation for one of the ni values reported in Table 4:

🡪 3

***Part III. Calculations for Helium Spectra***

The calibrated emission spectrum for helium gas excited in a discharge lamp is in Table 5:

## Table 5. Emission Spectrum for Helium

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Observed Color** | **Scale Reading** | **Corrected Wavelength (nm)** | **Actual Value** | **Light Band Intensity\*** |
| **Red** | 7.25 | 749.5 | **706.5 nm** | Faint |
| **Red** | 6.70 | 685.5 | **667.8 nm** | Medium |
| **Yellow** | 5.95 | 598.3 | **587.6 nm** | Bright |
| **Green** | 5.10 | 499.5 | **501.6 nm** | Medium |
| **Green** | 5.05 | 493.7 | **492.1 nm** | Faint |
| **Indigo** | 4.78 | 462.3 | **471.3 nm** | Faint |
| **Violet** | 4.55 | 435.5 | **447.1 nm** | Medium |

\*Light Band Intensity: use an adjective such as very faint, faint, medium, bright, very bright, etc.

Calculation - In the space below, show a detailed calculation for one of the corrected wavelength values reported in Table 5

= 749.5 nm

Using Equation 4, the relationship of the visible emission spectrum of helium to the energy levels was attempted, as shown in Table 6 (it was assumed that *nf* = 2).

## Table 6. Atomic Energy States for Helium (based on RH = 3.29 × 1015 Hz)

|  |  |  |
| --- | --- | --- |
| **Corrected Wavelength (nm)** |  | **\*** |
| 749.5 | **2** | 3 (2.79) |
| 685.5 | **2** | 3 (2.92) |
| 598.3 | **2** | 3 (3.20) |
| 499.5 | **2** | 4(3.85) |
| 493.7 | **2** | 4 (3.92) |
| 462.3 | **2** | 4 (4.35) |
| 435.5 | **2** | 5 (4.97) |

*\*Note: ni values reported in Table 6 are shown to 2-3 significant figures.*

Calculation - In the space below, show a detailed calculation for one of the ni values reported in Table 6:

🡪 3

The ionization energy of helium is actually 2373 kJ/mol (as opposed to 1312.75 kJ/mol for hydrogen). Using this ionization energy value leads to a modified Rydberg constant for helium that should be equal to , yielding Equation #5:

(5)

Equation #5 was used to calculate the energy levels of the helium atom (assuming

***nf* = 3**. If one assumes that *nf* = 2, the resulting values are all *ni* < 3), as shown in Table 7.

## Table 7. Atomic Energy States for Helium (based on RH = 5.94 × 1015 Hz)

|  |  |  |
| --- | --- | --- |
| **Corrected Wavelength (nm)** |  | **\*** |
| 749.5 | **3** | 5 (4.78) |
| 685.5 | **3** | 5 (5.17) |
| 598.3 | **3** | 6 (6.11) |
| 499.5 | **3** | 10 (10.0) |
| 493.7 | **3** | 11 (10.7) |
| 462.3 | **3** | 23 (23.1) |
| 435.5 | **3** | ∞ |

*\* Note: ni values reported in Table 7 are shown to 2-3 significant figures.*

Calculation - In the space below, show a detailed calculation for one of the ni values reported in Table 7:

🡪 5

**Comparison of hydrogen spectrum vs. helium spectrum**

A comparison of the hydrogen and helium spectra is provided below (e.g., difference in the emission lines for hydrogen and helium, difference in the equation used to relate their emission spectrum to the energy levels). The maximum length is 300 words.

Hydrogen and helium have very different emission spectrums, primarily caused by the fact that hydrogen only has one electron, so it is limited in the ways in which it can emit its light and from its electron. The light of helium, on the other hand, can be emitted in a large number of ways because of the fact that it has two electrons, creating more possible combinations for a larger number of bands that can be used to distinguish it from other elements. The difference in the emission spectrum formula is caused by the fact that helium is heavier, and therefore, has a higher ionization constant, driving up the value of the Rydberg Constant and increasing the amount of energy it takes to raise the electrons off of the base orbital into higher orbitals. The fact that there are smaller gaps in between the wavelengths in the helium emission spectrum is indicative that the orbitals are higher, because higher orbitals means that there are smaller gaps in the orbitals, causing the photons emitted upon deionization to have lost less energy, meaning that the electrons will emit redder light. That is also the exact reason that the hydrogen emission spectrum is wider spread. The drop from other energy levels to level 2 is greater than the drop to level 3, meaning that there will be more violet shifted light and the emission line will be more spread out in comparison to the line for helium.

# Part IV. Comparison of Alkali and Alkaline Earth Spectra

A comparison of the alkali and alkaline earth atomic spectra follows:

## Table 8. Emission Spectrum for Alkali and Alkaline Earth Metals

Note: To describe the “Intensity of Light Bands” in the table below, use an adjective such as very faint, faint, medium, bright, very bright, etc.

# Group I's:

**Lithium (Li+)** Overall Flame Color: Red

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Color of Bands | Red | Yellow orange |  |  |  |  |
| Intensity of Bands | Bright | bright |  |  |  |  |
| Scale Readings | 6.9 | 6 |  |  |  |  |

**Sodium (Na+)** Overall Flame Color: Orange

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Color of Bands | Orange |  |  |  |  |  |
| Intensity of Bands | Bright |  |  |  |  |  |
| Scale Readings | 6 |  |  |  |  |  |

# Group II's:

**Calcium (Ca2+)** Overall Flame Color: Orange

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Color of Bands | Green | Orange | red |  |  |  |
| Intensity of Bands | Medium | Medium | Medium |  |  |  |
| Scale Readings | 5.6 | 6 | 6.8 |  |  |  |

**Strontium (Sr2+)** Overall Flame Color: Red

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Color of Bands | 4.6 | 5.9 | 6.1 | 6.5 | 6.4 | 6.3 |
| Intensity of Bands | Bright | Medium | Brignth | Bright | Bright | Bright |
| Scale Readings | Blue | Yellow | orange | Red | Red | red |
|  |  |  |  |  |  |  |

**Strontium had a massive band of red, only the brightest bands of red were recorded**

**Part V. Identification of Unknown**

Results from the emission spectrum of the unknown number\_117\_\_\_\_\_are shown in Table 9:

## Table 9. Emission Spectrum for Unknown Sample

**Unknown Sample** Overall Flame Color: Orange/red tinge

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Color of Bands | Yellow | Orange | Red |  |  |  |
| Intensity of Bands | Bright | Bright | Bright |  |  |  |
| Scale Readings | 6.0 | 6.2 | 6.7 |  |  |  |

The unknown sample contains the following **two metals\***:\_\_Strontium, Sodium\_\_\_\_\_\_\_\_

The Flame burned an orange with red tinge when the salt was first added to the flame. the red faded over the course of several seconds and the orange persisted. A mixture of the suspected unknowns was prepared and compared, with the known and the unknown producing the exact same bands. The other salts were eliminated based on the process of elimination. The absence of green indicated the absence of calcium and the characteristic wide red band with a blue band identified strontium. When mixed together, lithium and strontium created a constant red flame. The only one possible left was the mmixture of strontium and sodium, which created one very bright red band within the large number of bands of red of Strontium

**\*It is recommended that you prepare a mixture of the two metals using the known samples in Part IV and confirm that the emission spectrum and flame color of this known mixture is consistent with your unknown.**

**DISCUSSION (10 points)** Write a brief discussion (< 500 words) to conclude this experiment.

The use of emission spectra is important to identifying chemicals in real life. One application of this is the use of emission spectra to analyze the atmospheres of different planets and stars to identify the different chemicals and the chemical compositions of their atmospheres. In this lab, electricity was run through glass tubes with different gasses inside so that different emission spectra could be observed. This helped to understand ionization energy and its role in contributing to the colors of different chemicals. The use of the spectroscope allowed for the quantifying of different wavelengths observed. The spectroscope was first calibrated with the use of a tube filled with mercury, of which the wavelengths of its emission spectrum were already known. This was then applied to create a calibration curve from which later measurements were compared to so as to generate accurate maps of the emission spectra of different elements, including hydrogen and helium. The calibrated spectroscope allowed for different emission spectra to be compared to the original calibration curve for accurate readings of the emission spectra. The calibrated readings can be back-calculated to the original calibration curve to produce a set of wavelengths that can be used to identify the different ionized materials.

In the second portion of the lab, the spectroscope was employed again, this time to qualitatively analyze different emission spectra of known alkali and alkaline earth metal salts when they were burned to create ionization. The spectra of the different metals were observed and the color bands recorded. The color bands that were recorded were then used to decipher the composition of an unknown in which a color band was observed. The color bands generally showed different qualities based on the composition, including addition, which made coinciding bands brighter than when the metal spectra were observed individually, and interference, in which some bands ended up being cancelled out.one source of error that was noted in this lab was the fact that certain identified bands may have been originally part of the background flame. This was generally not a problem as it was observed that many of the visible bands were in the red and orange range while