

Lab 4

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We compared the visible spectra of He to that of H (Balmer series) to see the effects of Singlet-Triplet splitting and electron shielding. By subtracting the energy emissions of He to H, we witness reoccurring differences of 0.22eV and -0.03eV. That showed us that the He nucleus acts like H under some circumstances. The two differences are there because splitting is noticeable in the 2p orbital.

I. INTRODUCTION

In the simple Bohr model of an atom, the nucleus is surrounded by electrons that occupy different energy levels corresponding to a number called the principle quantum number n . In this model, an electron transitioning from a higher energy state to a lower one obeys the equation

$$\Delta E = -13.6\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)eV$$

But it turns out that the energy structure is finer than what the above equation describes. The energy of an electron depends to its total angular momentum which includes the orbital angular momentum and the spin angular momentum. The spin angular momentum is an intrinsic property of the electron and can take on values of $\pm\frac{1}{2}$. These values are measured along the azimuth axis, which is the axis of the orbital angular momentum. We witness the effects of spin angular momentum in the phenomena called singlet-triplet splitting by comparing the spectra of He to the spectra of H. We are able to compare the 2 spectra because it happens that in the d orbitals, one of the protons experiences shielding.

A. Theory

Since we are examining the He spectra, we note that we are talking about a 2 electron system. For orbitals that can contain more than 2 electrons, for example p orbital, we can have the possible electron configurations: $|\uparrow\uparrow\rangle$, $|\uparrow\downarrow\rangle$, $|\downarrow\uparrow\rangle$, or $|\downarrow\downarrow\rangle$. The singlet state is when the electron pair are in opposite directions and the triplet state is when they're in the same direction. Therefore the magnitude of total spin angular momentum in the singlet and triplet states are 0 and 1, respectively.

One of the electrons in the He atom can shield the attraction of one of the protons and therefore make the nucleus look like the H nucleus. Under those circumstances, since the potential that a valence electron experiences is that from one proton, we should see energy transitions from He similar to that of H.

We use our spectrometer to collect intensity

readings in the visible spectra. Therefore we compare our transition energies to that of the Balmer series, i.e. $n_f = 2$.

II. MATERIALS AND METHODS

We collect emission data for H and He using a HR4000 Spectrometer. According to the manufacturer, the resolution is as good as 0.025nm (FWHM). It's operation range is 200-1100nm. The emissions come from excited tubes of H and He gas.

A. Calibration

The spectroscopy software gives us emissions data in terms of wavelength. We determine how far off the software's values are by comparing the photopeak wavelengths given by the software to known values. This is done by taking the average of the differences of each wavelength.

B. Data Collection

Data collection is straightforward. We can record the data by clicking on the peaks seen on the screen or saving data to a file to be opened in Excel. The parameter we vary in data collection is the "integration time". This is the duration of time the software collects counts before refreshing. Our integration times ranged from 60ms to 8s. Longer integration times are used to zoom in on small peaks. Notice in Fig 2, that the highest peaks flatten out due to saturation for a long integration time.

The large peaks were clearly easy to identify. For the smaller peaks, we used Excel to open the numerical file saved from Oceanview and marked where we thought peaks were.

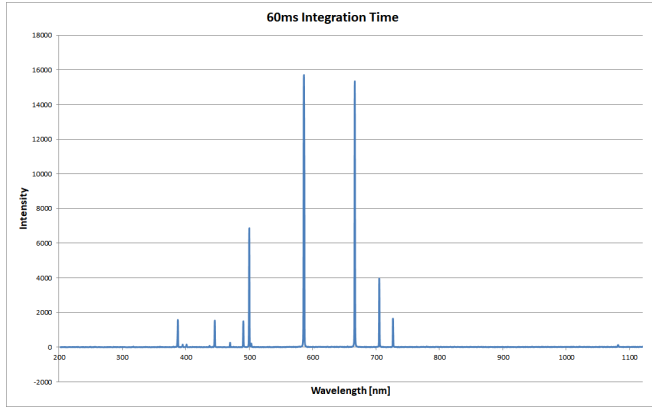


FIG. 1: He - 60ms integration time

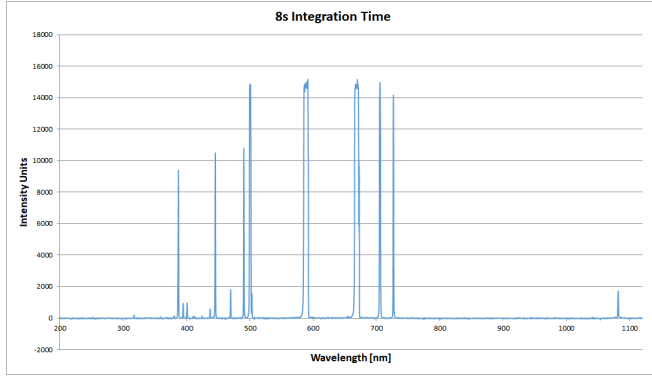


FIG. 2: He - 8s integration time

III. DATA

We initially collected data for H in terms of pixels, not wavelength. We tabulated the pixel number and known wavelengths then used Excel to get a best fit line equation $\lambda = 0.2595p + 202.89$, Table I. We then plugged the pixel into this equation to get a predicted wavelength. Our average residual was 0.33nm. However, later in the experiment when we were sharing peaks as a class, it turned out that we were consistently off by 1-2nm, Table II.

Pixel #	True Wavelength (nm)	Predicted Wavelength	Difference
750	397.01	397.52	0.50
799	410.17	410.23	0.06
890	434.05	433.85	0.20
1089	486.13	485.49	0.64
1748	656.28	656.50	0.22

TABLE I: H Calibration

Table II shows the peaks we were able to extract compared to peaks listed in class. As stated before, we were off by

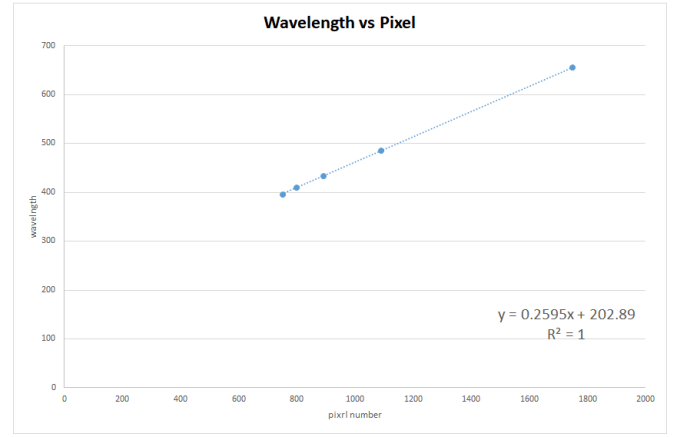


FIG. 3: H Calibration

Us	Class	
317.455	318.9	1.445
359.998	361.4	1.402
369.278	370.5	1.222
380.666	382.0	1.334
387.544	388.9	1.356
395.210	396.3	1.090
410.785	412.2	1.415
413.159	414.6	1.441
437.383	438.0	0.617
445.793	447.2	1.407
469.926	471.1	1.174
490.855	491.5	0.645
501.300	501.4	0.100
-	402.6	-
587.995	587.6	-0.395
669.914	668.0	-1.914
705.587	706.5	0.913
726.908	728.1	1.192

TABLE II: He Peaks

IV. DISCUSSION

Repeated values of differences between He and H transitions are boldfaced in Table III. These reoccurring differences suggest that some energy transitions in He are the same as in H, to the accuracy of our spectrometer. One way this could happen is if the attracting potential from one of the protons is cancelled by the repulsive potential of one of the valence electrons.

The differences can be understood if we consider the transitions into the 2p orbital; $n_f = 2$ because we are comparing to the Balmer series and the p orbital because it is the minimum orbital that splitting can occur. We can assume that the shielding electron is in the 1s ground state. 1s being closest to the nucleus, the valence electrons in the higher states see the potential as the same from one proton. Also, since energy is higher at larger n_i 's, the splitting effect there should not be as noticeable as at the lower n 's. Therefore we can assume the splitting effect to be at the $n_f = 2$ level. This can

	λ_H	397.01	410.17	434.05	486.13	656.28
λ_{He}	energy [eV]	3.12	3.02	2.86	2.55	1.89
318.90	3.89	0.77	0.87	1.03	1.34	2.00
361.40	3.43	0.31	0.41	0.57	0.88	1.54
370.50	3.35	0.22	0.32	0.49	0.80	1.46
382.00	3.25	0.12	0.22	0.39	0.70	1.36
388.90	3.19	0.07	0.17	0.33	0.64	1.30
396.30	3.13	0.01	0.11	0.27	0.58	1.24
402.60	3.08	-0.04	0.06	0.22	0.53	1.19
412.20	3.01	-0.12	-0.01	0.15	0.46	1.12
414.60	2.99	-0.13	-0.03	0.13	0.44	1.10
438.00	2.83	-0.29	-0.19	-0.03	0.28	0.94
447.20	2.77	-0.35	-0.25	-0.08	0.22	0.88
471.10	2.63	-0.49	-0.39	-0.22	0.08	0.74
491.50	2.52	-0.60	-0.50	-0.33	-0.03	0.63
501.40	2.47	-0.65	-0.55	-0.38	-0.08	0.58
587.60	2.11	-1.01	-0.91	-0.75	-0.44	0.22
668.00	1.86	-1.27	-1.17	-1.00	-0.69	-0.03
706.50	1.76	-1.37	-1.27	-1.10	-0.80	-0.13
728.10	1.70	-1.42	-1.32	-1.15	-0.85	-0.19

TABLE III: Comparison Matrix

explain the reoccurring differences we notice. As for the value's of the difference itself 0.22 and 0.03, we can say that the splitting levels of He at 2p are shifted from 2p of H by those values. The shift in energy levels is because the nuclei are different and therefore have different energy bands.