Hydrogen - Deuterium Shift

Ata Ahmad

Physics Department, University of California, Santa Barbara, CA 93106-9530

(Dated: March 5, 2020)

Abstract

We measure the energy shift between Hydrogen and Deuterium, in the first six Balmer transition lines. This was done through spectroscopy, and specifically the measurement of the wavelength of emitted light from a lamp with a Hydrogen-Deuterium mixture. We found the corresponding shift values:

Transition	Alpha	Beta	Gamma	Delta	Epsilon	Zeta
Shift [Angstroms]	1.80 $\pm$0.07	1.35 $\pm$0.05	1.27 $\pm$0.05	1.20 $\pm$0.05	1.11 $\pm$0.05	1.07 $\pm$0.10

Table 1. All measured transition shifts with standard deviations.

INTRODUCTION

We started by shining light from a lamp of Hydrogen and Deuterium gas through a 30 micron-wide slit into a spectrometer. Through the diffraction grating plate mechanism within the spectrometer, we were able to change the angle of the plate at a constant rate and sweep through certain frequencies of light and would get a doublet signal when passing over certain wavelengths of light emitted by both Hydrogen and Deuterium particles. Measuring the distance in between each doublet's separate peaks gave us the difference in wavelength between photons emitted by Hydrogen and photons emitted by Deuterium.

METHOD

We started at wavelengths higher than the wavelengths in which the doublets would be located at. We then swept down the spectra with a sweeping speed of 5 Angstroms per minute. We used LoggerPro software to create graphs that recorded signal [V] versus time [s]. We did this five times for each Balmer transition line plus a calibration step.

Construction Details

To get units of length rather than time on our x-axis, we calibrated the machine using a Hg lamp. We measured the time differences between the occurrence of peaks. Using the known value of Hg peaks, we derived a conversion factor 0.082 ± 0.003 Angstroms per second to calibrate our x-axis of our graphs from seconds to Angstroms. This gives us uncertainty in our initial source of error, which is the machinery itself.

Measurement Details

While one lab partner handled starting and stopping the recording software, the other partner handled turning on the sweeping mechanism. The machine was run through every trial at the same speed. After having all data plots constructed. We saved all the data in csv files and uploaded them into Matlab for analysis. We used the curve fitting tool and a specialized function to locate the center-line of each peak's fitted parabolic curve. This measurment method brings up another source of error which is the curve fitting. We took note of this by recording standard deviation in each measurement of each peak given by the Matlab software. Examples of hardware, peaks and mid-line locating code are shown below.

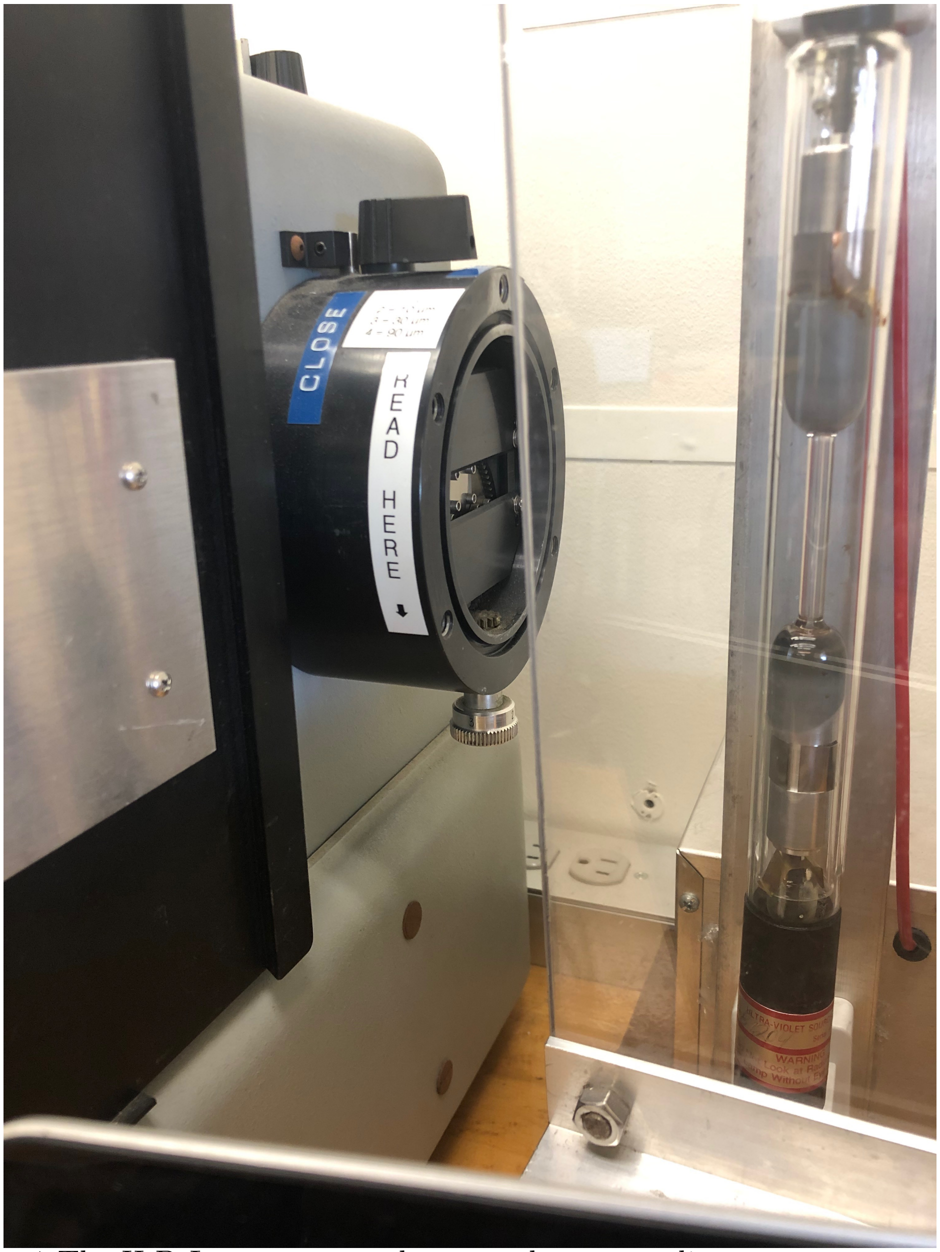

Fig. 1 The H-D Lamp next to the monochromator slit.

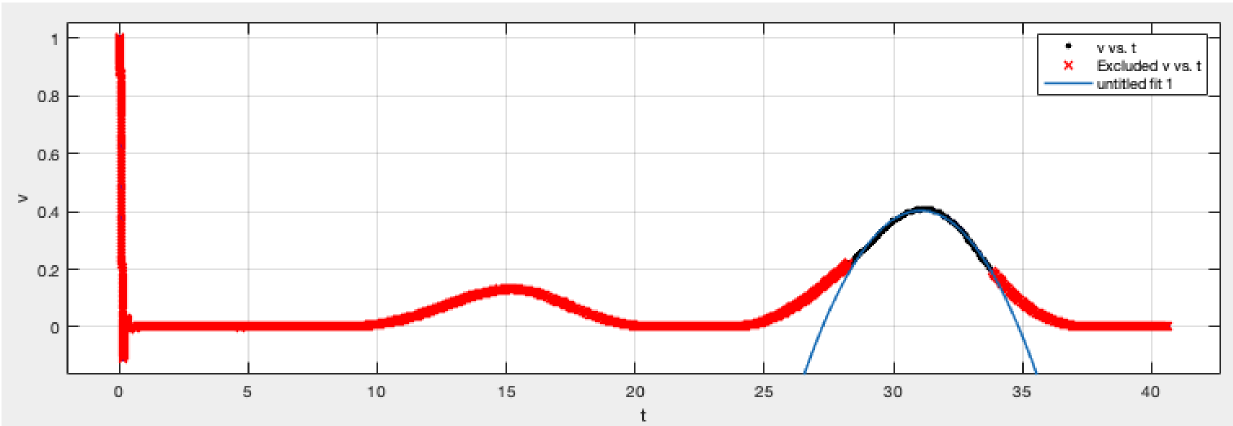

Fig. 2 The curve fitting software used in MatLab.

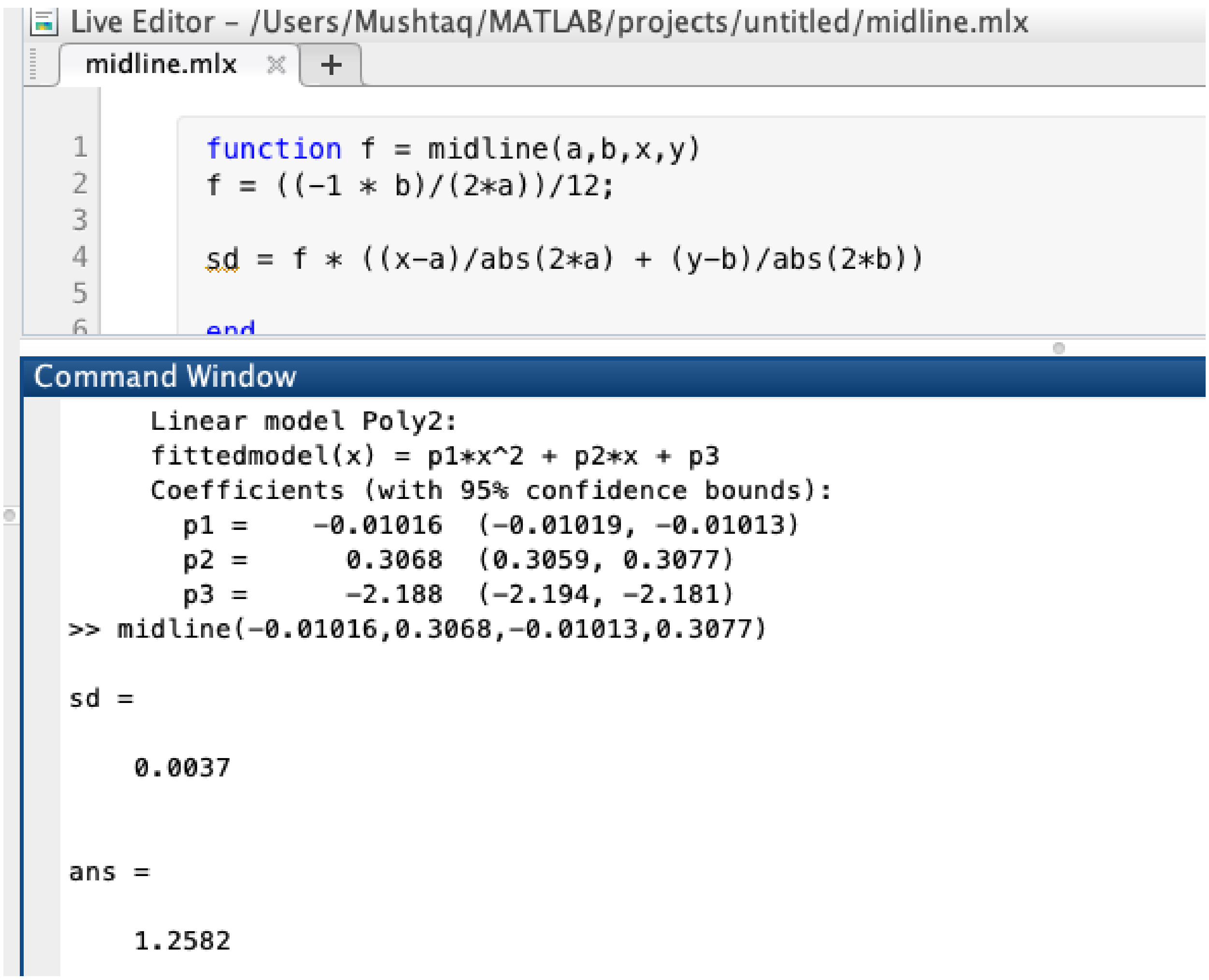

Fig. 3 The code we used to find the x-value of each peak.

RESULTS

The results for each transition along with corresponding error results are given in the following table.

Transition	Alpha	Beta	Gamma	Delta	Epsilon	Zeta
Measured Shift [Angstroms]	1.80 ±0.07	1.35 ±0.05	1.27 ±0.05	1.20 ±0.05	1.11 ±0.05	1.07 ±0.10
True Value	1.783764	1.321307	1.179738	1.114852	1.079067	1.057045
Error [%]	1.13	2.82	7.69	7.84	2.61	1.75

Table 2. All Transition shifts measured, true values and percent errors.

Overall the trend within our data is good because we show less than 3% error in four out of the six shifts in the Balmer series lines we measured. The first account of error was with using the conversion factor that we made. Since it was multiplied into all the data, and the Hg measurements that we ran to derive it, we took the square root of the sum of squares for each fractional error of each transition. Another source of error in our results was the Matlab software generating standard deviations for each individual peak. Since we were only concerned with the difference in peaks, we just summed the fractional uncertainties of both peaks in each run. The biggest error arose when we were measuring the Gamma and Delta series. This is mostly due to the PicoAmmeter, a device that effectively allowed us to 'zoom in' on certain signals via us controlling the range at which it would read at. When we were running the gamma and delta series, we decided not to scale down, in order to get more smooth looking data. such as in the following example of a delta measurement.

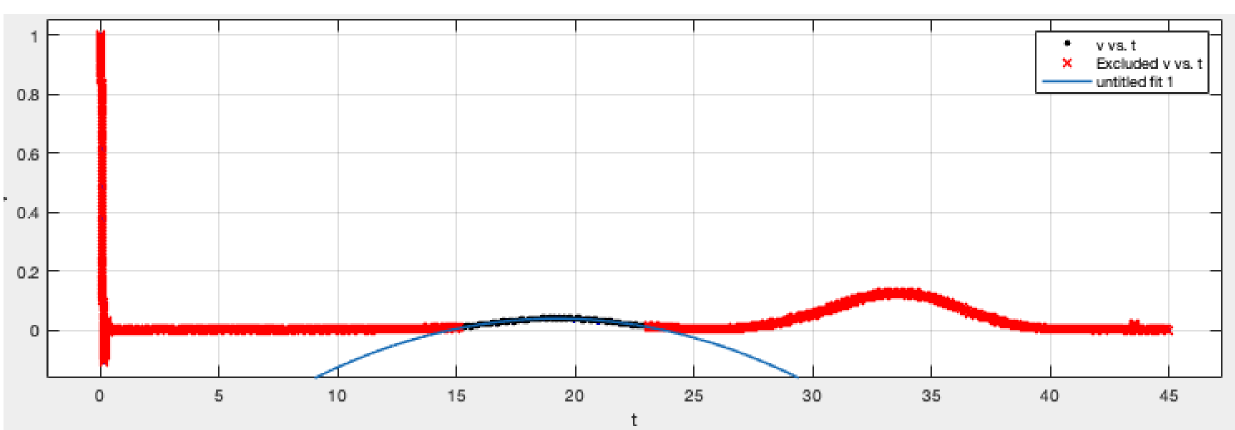

Fig. 4 One of the Delta measurements made. The peaks are not well defined, but the data points don't deviate extremely from the curve fit.

However when we moved onto the epsilon series, the peaks became too indistinguishable from flat lines, that we had to zoom in. This is reflected in the following example of one of our epsilon measurements.

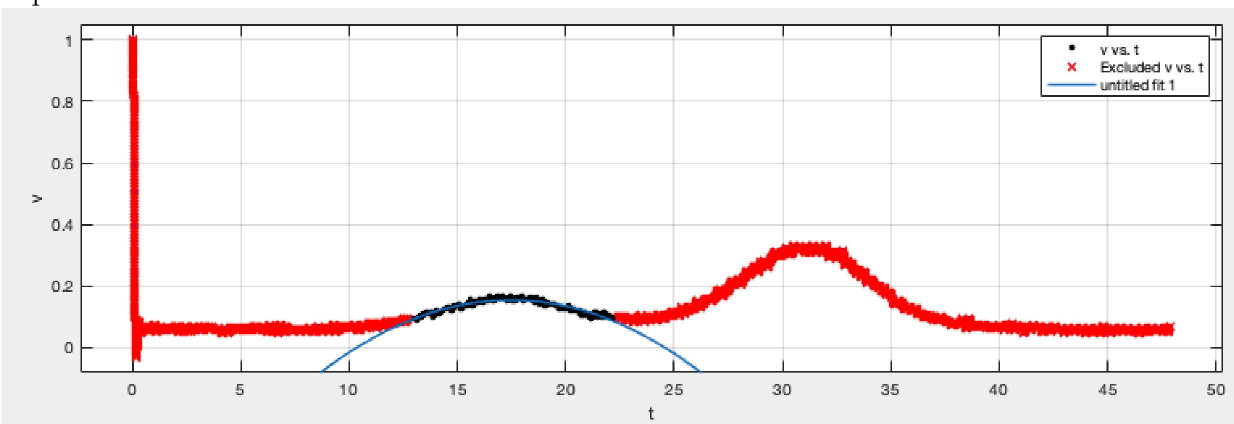

Fig 5. One of the Epsilon measurements made. The data points deviate from the curve fit more, but the peaks are better defined at this PicoAmmeter range.

Even though the data points are more scattered slightly above and below in the curve fit, it still resulted in a more defined vertex of our parabolic fit. This turned into a better result for the Epsilon and Zeta series measurements.

Discussion

If we wanted to get better results, then we should have zoomed in at the start of the gamma series. The gamma and delta series turned out to be much higher in error than any other series, and this is most certainly due to the decision on our part to sacrifice peak height at the expense of small deviations of data from our parabolic curve fit. In hindsight, all of the deviations would have canceled out since all of the deviations at that wavelength were inherently random and would have been smoothed out by the curve fitting tool.