

# Hydrogen Spectrum

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## Calculations

By noting that the Rydberg constant  $R$  is directly proportional to reduced mass of the hydrogen (or deuterium) atom, a relationship can be established between the difference in deuterium and hydrogen frequencies, for the longest wavelength emission in the visible range, to the mass ratio of deuterium to hydrogen  $M_H/M_D$  (represented by  $x$ ):

Use algebraic manipulation of the above equation to obtain an expression for  $x$ .

$$x = \frac{f_D m_e}{M_H \left( \frac{f_D - f_H - f_H^* m_e}{M_H} \right)}$$

## Analysis

The following figures show the graphs of the data collected using the techniques detailed earlier in this report. The first figure shows a plot of detected emission intensity (plotted as log scale) vs wavelength...

*Table 1: Wavelength vs  $1/2^2 - 1/n^2$  for hydrogen lamp regression statistics*

Regression Statistics	
Multiple R	0.9970276
R Square	0.994064034
Adjusted R Square	0.991096051
Standard error	40509.93987
Observations	4

*Table 2: Wavelength vs  $1/2^2 - 1/n^2$  for hydrogen lamp regression coefficients*

	Coefficients	Standard error
Intercept	-105791.5925	122317.56
0.2295911837	11640415.89	636051.1071

Using the difference in the frequencies of photon emission corresponding to these peaks, determine the mass ratio of deuterium to hydrogen.

Sure, here's a restructured and rephrased version of your lab report:

#### 1. \*Analysis of the Rydberg Constant and Comparison to Accepted Value\*:

From the averaged hydrogen spectra produced by collisions, we plotted the inverse of the peak wavelengths ( $1/m$ ) against the  $\frac{1}{n_l^2} - \frac{1}{n_u^2}$  term from the Rydberg equation (where  $n_l = 2$ ). The obtained slope corresponds to an experimental Rydberg constant ( $R$ ) of  $11640415.8896174 \pm 636051.107077189 \frac{1}{m}$ . This value, compared to the accepted Rydberg constant of  $10973731.56816 \frac{1}{m}$ , yields a relatively minor discrepancy of 6.08%. This suggests the experiment was successfully executed despite the minor deviation.

#### 2. \*Assessment of Deuterium to Hydrogen Mass Ratio and Comparison to Accepted Value\*:

Our experimentally derived mass ratio for deuterium to hydrogen ( $\frac{m_D}{m_h}$ ) stands at 0.691832, deviating from the accepted ratio of 0.500248 by 38.3%. Despite this substantial discrepancy, indicative of possible errors in data collection, the experimentally determined ratio nonetheless underscores the distinct mass difference between hydrogen and deuterium.

### 3. \*Evaluation of Quantum Effects on Spectral Line Broadening\*:

We employed the Heisenberg Uncertainty Principle to quantify the impact of quantum effects on the broadening of the spectral line with the highest wavelength. This involved examining the uncertainty in energy ( $\Delta E$ ) above the ground state energy of the light wave and the uncertainty in the lifetime ( $\Delta t$ ) of that energy state. By relating these uncertainties to the frequency and consequently the wavelength of the spectral line

$$\Delta E \Delta t \leq \hbar$$

$$E = \frac{hc}{\lambda}$$

we arrived at a new relationship incorporating quantum uncertainty

$$\Delta E \sim h \Delta f \sim \frac{hc}{\Delta \lambda}$$

Given the assumed brief lifetimes of hydrogen's excited states, we combined these uncertainties to establish an uncertainty in the hydrogen wavelength

$$\Delta \lambda \sim \frac{hc}{\Delta E} \sim \frac{hc}{\hbar} \Delta t \sim 2\pi c \Delta t$$

$$\Delta \lambda = \frac{\Delta E}{hc} \lambda^2 = \frac{\lambda^2}{2\pi c \Delta \tau}$$

Our analysis suggests that quantum effects contribute minimally to peak broadening, with factors such as the Doppler effect or thermal broadening due to lamp operation exerting a more substantial influence.

### 4. \*Exploration of Selection Rules and Their Influence on Observed Spectral Lines\*:

Selection rules govern the permissible transitions between energy states for atomic or molecular electrons. The primary rule stipulates that an electron's spin must remain constant during transitions. Further, in a molecule with a center of symmetry, transitions within a set of p orbitals

are disallowed, prohibiting transitions where angular momentum equals zero. These rules, known as the "spin rule" and the "orbital rule", respectively, dictate the spectral lines that can be observed during atomic spectroscopy  $\Delta l = \pm 1$ .

##### 5. \*Discussion of Potential Error Sources in the Experiment\*:

The procedure of recording emission spectra is inherently prone to errors. The most common source of error is the improper use or handling of the equipment, such as smudging the hydrogen bulb's glass. These can disrupt the light detection process and introduce irregularities in the spectral lines. Furthermore, improper device usage, like oversaturating the detector due to close proximity to the lamp or misdirection of the device, can skew the results. Provided the spectrometer operates correctly and the lamp contains only hydrogen, the main potential error sources are tied to equipment use. Overall, the experiment's simplicity reduces the likelihood of systematic or unusual random errors.