Homework 2.1

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1 Problem a

The only wavelength range observed in this experiment was near ultra violet and visible range. Roughly 400 nm to 700 nm, therefore the Balmer series is used to identify all of the transitions of the hydrogen emission spectra. The Rydberg equation is used to find the transitions expressed as,

$$\frac{1}{\lambda} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right). \tag{1}$$

Where $R_H = 1.097 * 10^7 m^{-1}$ specifically for hydrogen. solving for n_2

$$n_2 = \sqrt{R_H * \left(\frac{R_H}{4} - \frac{1}{\lambda}\right)^{-1}}.$$

When $\lambda = 4.25 * 10^{-7}m$

$$\frac{1}{4.25 * 10^{-7}m} = R_H * \left(\frac{1}{4} - \frac{1}{n_2^2}\right) = n_2 = \sqrt{R_H * \left(\frac{R_H}{4} - \frac{1}{4.25 * 10^{-7}m}\right)^{-1}} \approx 5eV$$

When $\lambda = 4.88 * 10^{-7}m$

$$\frac{1}{4.88 * 10^{-7}m} = R_H * \left(\frac{1}{4} - \frac{1}{n_2^2}\right) = n_2 = \sqrt{R_H * \left(\frac{R_H}{4} - \frac{1}{4.88 * 10^{-7}m}\right)^{-1}} \approx 4eV$$

When $\lambda = 6.59 * 10^{-7}m$

$$\frac{1}{6.59 * 10^{-7}m} = R_H * \left(\frac{1}{4} - \frac{1}{n_2^2}\right) = n_2 = \sqrt{R_H * \left(\frac{R_H}{4} - \frac{1}{6.59 * 10^{-7}m}\right)^{-1}} \approx 3eV$$

2 Problem b

To calibrate the prism spectrometer the slit letting the light in had to be adjusted to let the most efficient amount of light in. The slit was used to adjust how thick the spectrum lines were. The focusing lens also had to be adjusted so that the visible light spectrum could be observed with no noise. Finally, the the prism had to be adjusted so that it was level, not allowing light to be diffracted in obscene directions. These steps are crucial in order to obtain good data and limit the possible systematic errors when calculation the mass of a neutron compared to a proton. More systematic errors that could have occurred, not necessarily to me, could of been how the machine was set up. This could include how far the light was from the slit, the prism on the table, the level the table on the spectrometer, and the level of the table the spectrometer was on.

3 Problem c

The code in appendix A was use to generate the figure below.

The code that generated the plot was also able to generate the λ values of deuterium, mainly looking at the two λ values of deuterium and hydrogen around 420 nm and 480. The λ values of hydrogen were subtracted from the λ values of deuterium. However, when this was done one of the values was in range but the other value was negative. This means that the λ value of deuterium was observed wrong since the shift was wrong. This is the type of error was described in problem b, there was too much noise picked up off of the prism spectrometer. Thus, since the deuterium bulb had died out, there was really no neutron to be calculated. Therefore, there is no way to determine the mass of a neutron compared to a proton with this data.

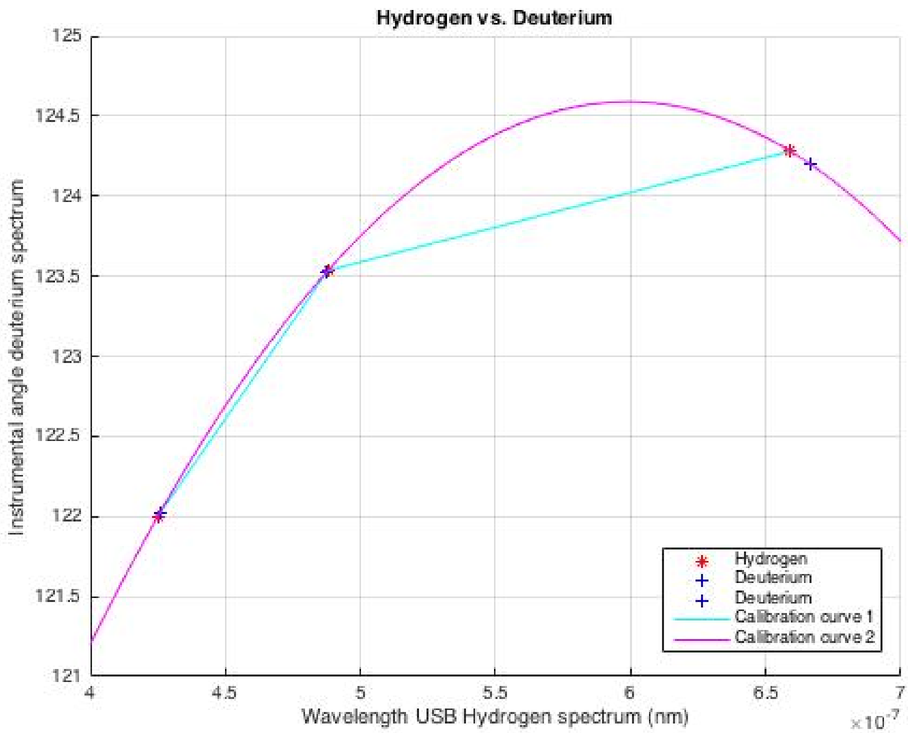

Figure 1: **Calibration curve** : The x axis shows the wavelength of the visible light spectrum in nanometers. The y axis represents the angles measured. The red asterisk are the hydrogen values, the blue pluses are the deuterium values, the cyan line is the lower polynomial calibration curve, and the magenta line is the higher polynomial curve.

4 Problem c (For revised homework)

$$\frac{\lambda_D}{\lambda_H} = \frac{R_D}{R_H} = \left(\frac{1 + \frac{m_e}{2m_p}}{1 + \frac{m_e}{m_p}} \right) = 1 - \frac{m_e}{2m_p}$$

where R_H is Rydberg's constant for hydrogen, R_D is Rydberg's constant for deuterium, m_e is the mass for and electron, and m_p is the mass of a proton. so then,

$$\frac{\lambda_H - \lambda_D}{\lambda_H} = \frac{1 - \frac{M_H}{M_D}}{1 + \frac{M_H}{M_D}}$$

5 Problem d (For revised homework)

The atomic mass of hydrogen is 1.007276, this is simply just the mass of a proton in atomic mass units. Deuterium is just a one proton and one neutron, where the mass of a neutron is 1 atomic mass unit. Thus, the mass of deuterium is just the mass of a proton plus the mass of a neutron, $1.007276 + 1.008867 \approx 2.013553$. So then $\frac{M_H}{M_D}$ must be

$$\frac{M_H}{M_D} = \frac{1.007276}{2.013553} = 0.500248.$$

appendix A

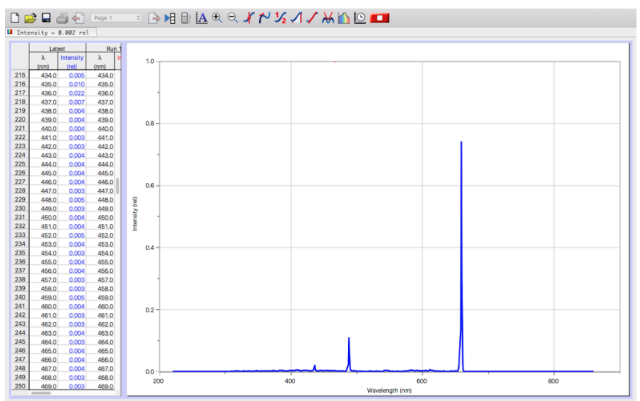

Figure 2: Hydrogen spectrum

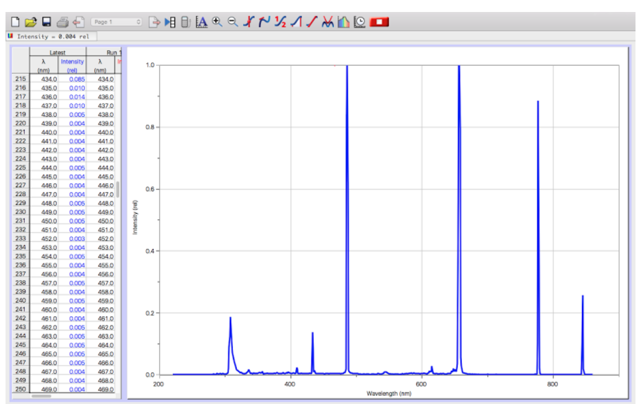

Figure 3: Deuterium spectrum

appendix B

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function homework2_1

X = [4.25E-07 4.88E-07 6.59E-07] %Hydrogen lambda (nm)
Yh = [122.000 123.536 124.28]; %Hydrogen angle
Yd = [122.020 123.525]; %Deuterium angle
Yd2 = [124.2]
P = polyfit(X,Yh,2);
theta = ((X.^2)*P(1))+(X.*P(2))+P(3); %Curve fit
xx = 4E-07 : 1E-09 : 7E-07;
yy = (xx.^2*P(1))+(xx.*P(2))+P(3);
A = P(1);
B = P(2);
C = P(3)-Yd;
C2 = P(3)-Yd2;
quad = ((-1.*B)+sqrt((B.^2)-(4.*(A*C)))./(2*A)
quad2 = ((-1.*B)-sqrt((B.^2)-(4.*(A*C2)))./(2*A);
figure(1); hold on
grid on
plot(X,Yh,'r*','markersize',5)
plot(quad,Yd,'b+','markersize',5)
plot(quad2,Yd2,'b+','markersize',5)
plot(X,theta,'c')
plot(xx,yy,'m')
title('Hydrogen vs. Deuterium')
xlabel('Wavelength USB Hydrogen spectrum (nm)')
ylabel('Instrumental angle deuterium spectrum')
legend('Hydrogen','Deuterium','Deuterium',
'Calibration curve 1','Calibration curve 2', 'Best')
hold off

end
```