**Main Idea**

Generally due to some kind of incident light, it is possible for atomic electrons to jump from their ground energy state up an excited state. This is because, when one of said electrons has light incident upon it, energy is transferred. If the transferred energy is at least equal to the energy difference between the atom’s energy states, this results in the electron’s excitation.

Since nature hates having energy and always wants to return to some equilibrium, these excited electrons will then relax back to either some lower energy state or their ground state, thus releasing the energy that had it in its more excited state. When this happens, the energy is released in the form of a photon, equal in energy to the energy difference between the states the electron relaxed between.

The Balmer series is a set of relaxed photon wavelengths that is present when measuring released photons from hydrogen from an excited state, back down to their first excited state. It is of particular interest since it corresponds to the spectrum of visible light.

In this experiment, we specifically, were most interested in the first four photons in the Balmer series, since each photon becomes more difficult to detect the higher the energy and lower the wavelength, till it reaches its ionization wavelength.

The composition of a given atom determines the difference of energy between states, which in turn affects the wavelengths and energies of these released photons. To explore this, we looked at two comparable atoms: a deuterium atom and a hydrogen atom, which have a single proton and neutron in the nucleus and an orbiting electron and a single proton and single orbiting electron respectively.

**Instrumentation and Data Collection**

The device we used was a monochromator, which as the name suggests, helps us to analyze specific wavelengths of light emitted from a source.

First light passes through a lens where it is focused into an entrance slit. From the entrance slit, the light becomes incident on a collimating lens, where a specific range of the light’s spectrum is directed towards a diffraction grating. The diffraction grating is made of a large number of closely spaced groves that act as an array of tiny prisms. As light hits the grating, it is diffracted at different angles, separating it into various spectral components. The angle of diffraction depends on the wavelengths, with longer wavelengths diffracted at smaller angles and shorter wavelengths at larger angles. The diffraction grating also allowed us to select for specific wavelengths by rotating to adjust the angle at which the incident light interacts with the grooves. After the diffracting grating, the light is directed towards a focusing mirror where it then leaves through an exit slit as a monochromatic beam where it is picked up by a spectrometer which reads the wavelengths.

While taking the data for each specific wavelengths, we also took data on the weather in order to find the index of refraction so that we could adjust the detected wavelengths and compare them with the published Balmer series wavelengths.

**Data Analysis**

We used a linearized version of the Ryberg equation to find the particular Rydberg constant for each nucleus. The Rydberg constant of each nucleus was determined in some part by its reduced electron mass. From each of the two plots and best fit equations, we were able to get Rydberg constants very close to the values we got in the prelab write up. However, when trying to solve for the ratio of the reduced electron mass, we ended up getting values greater than one, which is obviously incorrect. The source of this error seems to be in our data collection as well as in our analysis. If we were to perform more repetitions for each wavelength length, as well as take a weighted average across several points for each peak, we probably could have substantially improved our results.

**Special Topic**

In modern art analysis, aspects of quantum physics are able to be used to determine the age, techniques, and materials used in the creation of a piece. One of the most commonly used methods is x-ray analysis, in which spectroscopy is used to perform an analysis of pigment.

In this analysis, an x-ray photon source is put above a sample, where the incident gamma rays will interact with the sample material, exciting the atomic electrons. The material will then release photons as it relaxes back down to a lower state. Due to the nature of quantum mechanics, these photons will be released with set energy levels, corresponding to the difference of energy between energy states. Since the difference between these energy states is determined in part by the nucleus of the atom, measurement of these photon energies can be used to trace backwards to determine the type of atoms which make up the material, and ultimately which material(s) makes up the sample.

S – Sulfur

Ca – Calcium

Ti – Titanium

Fe – Iron

Zn - Zinc

After determining the atomic makeup of a sample, we can then reference a chart like the one here. This specific chart is a list of pigments that were made from naturally available materials, commonly found in pre 1800 oil paintings.