Hydrogen Spectrum

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Why: By measuring the wavelengths of light emitted by Hydrogen gas one can deduce the energy levels of the electron in a Hydrogen atom.

What: Using measurements of the apparent positions of the diffracted colors, the angles of diffraction and wavelengths of the light are calculated and hence, when interpreted in terms of photon energy, the Bohr electron energy level formula can be used to deduce a value for the Rydberg constant.

How: A hydrogen gas discharge lamp is viewed with the eye through a diffraction grating.

Equipment

Hydrogen discharge lamp**,** 2 x meter sticks, short ruler, diffraction grating & holder.

Warning: the lamp uses high voltage – don't stick your figures near the sockets at the ends of the bulb!

Procedure

See the laser diffraction experiment for the set up and method to calculate wavelength. The hydrogen lamp is placed at the corner of the L formed by the two rulers. Be careful to ensure the rulers make a 90^o angle and that the Hydrogen bulb is exactly at the corner, otherwise you will introduce systematic errors. (Pro-Tip: If you have room to use a 2-meter ruler with the lamp in the middle of it – to make a T shape - then you can take measurements on both sides. Averaging reduces systematic error from deviation of 90^o).

Looking through the grating straight ahead (N=0), you will see the pinkish glow of the discharge lamp which is a mixture of the colors red, cyan (blue-green), blue, violet.

Looking through the grating at an angle you will see these colors separated into distinct spectral lines (the so-called Balmer series) corresponding to the N=1 (first–order) diffraction spectrum. The violet line is not very intense and so close to the blue that it may be difficult to distinguish it. Even further to the side, you should also be able to see some and perhaps all of these colors repeated in the N=2 (2nd-order) diffraction pattern. The colors in each order N are the same light emitted by the atom but diffracted by different angles θ through the grating.

Take measurements and calculate the wavelengths λ of all the spectral lines you can see, using the method from the laser diffraction laboratory, recording color, order and wavelength. Make independent determinations of each wavelength from both the first ($N = 1$) and second-order ($N = 2$) diffraction if you see both for a certain color. Here is the diffraction equation again

$$N\lambda = d \sin \theta$$

Analysis

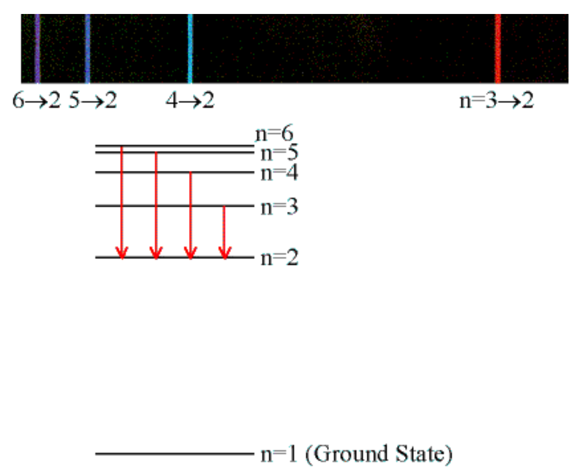
The Bohr formula for the photon wavelength λ emitted when the electron jumps between energy levels labeled by integer quantum numbers n_2 and n_1 is

$$\frac{1}{\lambda} = R \left\{ (1 / n_2)^2 - (1 / n_1)^2 \right\}$$

R is the Rydberg constant (which is made up of fundamental constants like Planck's constant, the electron mass, electron charge, etc.) For emissions in the visible range of wavelengths the final electron level is always $n_2 = 2$. (Jumps to $n_2 = 1$ yield UV light while jumps to $n_2 > 2$ yield IR light). So we are interested in the cases

$$n_1 = 3, 4, 5, 6 \quad ; \quad n_2 = 2$$

You will have to carefully associate which value of n_1 goes with each particular spectral line that you observed. They should be in order, red → 3, cyan → 4, blue → 5, violet → 6, but if a certain line was too hard to detect you have to be careful to skip an integer.



Substitute your calculated wavelength and the corresponding quantum number to get a value for the Rydberg constant R. You should have up to eight R values in all, one for each spectral line and order of diffraction. If the Bohr formula makes sense, all these values should be similar, since R is supposed to be a constant. If they are similar, average them and give an uncertainty. Take care with units - what will be the unit of R compared to the unit used for your wavelengths?

Results

Color	***N* (order)**	***x***	***Y***	θ	λ

Calculate the Rydberg constant from each of the spectral lines you saw and then average.

Wavelength λ	**Initial level** n_1	**Rydberg constant R**
		$R_{av} \pm \Delta R$

Conclusions

Summarize the key things you *learnt from your data*, quoting data to support your conclusions. For example, you could discuss:

- Which color is diffracted more, red or blue? Hence which wavelengths are diffracted more, short or long?
- Which produces a shorter wavelength of light, a larger or smaller electron transition?
- Is your value for R consistent with the known precise value R = 109,737 cm^{-1} (is it within your error range)?
- Atoms can also *absorb* light by electrons jumping to a higher energy level. Imagine you are observing a rainbow through hydrogen gas. What do you think the *absorption* spectrum of hydrogen would look like? (You may want to sketch it).
- Suggest your primary sources of error in determining R