

Exercise 7: The hydrogen spectrum

Purpose: You will use a calibrated spectroscope (with a diffraction grating) to measure the different discrete wavelengths of light which are emitted from a hydrogen gas discharge tube. In addition, you will calculate the predicted wavelengths of hydrogen gas emissions from the Bohr atomic energy equation. Finally, you will decide if the spectroscope is truly well-calibrated.

Procedure: Work in pairs. Each pair should select a **spectroscope** (one of the blue or black rhomboidal boxes).

Look through the round eyepiece on the narrow side of the rhombus-shaped spectroscope; you should be able to see a vertical **slit** on the far side through the **eyepiece**. You should also see some calibration marks to the right.

1. What **quantity** will you be measuring with the spectroscope? What are the **units** of the spectroscope? Also, write the **color** of the spectroscope you are using.

Turn on a **hydrogen gas discharge tube** (you may need to dim the room lights to see the emission lines effectively through the spectroscope). Align the slit so that you can see the vertical gas discharge tube through it. Out of the corner of your eye, you should see a set of *three* bright lines of different colors superimposed on the calibration area.

2. Record the values of each color in the "Data and Predictions" table on the page 3.

Prediction: 3. The Bohr equation is given as: $E_n = -R_H/n^2$. E_n is the energy of the n th quantum level, R_H is the Rydberg constant = 2.179×10^{-18} J and n is the principal quantum number.

Fill in the following table for the energies of quantum levels $n = 1$ through 5.

Quantum level (n)	1	2	3	4	5
Energy (J)					

4. a. What seems to be the **limiting** value of the energy? (In other words, as n tends towards infinity, what happens to the energy)

b. Why are all the energy values in your table **negative**? In other words, what does the limiting value of the atom's energy (you calculated in part a) represent?

5. a. Suppose an electron starts off at quantum level $n = 1$ and suddenly "jumps" to $n = 2$. I will symbolize this event as " $1 \rightarrow 2$ ". What is the **change in energy** (in joules) that the electron experiences? You *could* use the other formula given in the textbook, but I think you can do this as a simple *subtraction* problem. (Hint: ΔE (change in energy) = $E_{\text{ending level}} - E_{\text{starting level}}$)

b. What **sign** did you end up with for your change in energy? Does this mean that energy was required or that energy was released? In other words, would light be **absorbed** or would light be **emitted**?

c. Since you are trying to figure out what wavelengths of light hydrogen emits, will you be looking for electrons "jumping" from high n numbers to low n numbers or the other way around?

6. a. To make the electron "jump" from $2 \rightarrow 1$, what **wavelength** light would you get? Recall that $E = hc/\lambda$. Do a little algebraic manipulation so that λ is the unknown. Perform the calculation (don't forget units!). What **part** of the EM spectrum is this? Could you **see** this transition happen, either by absorption or emission of **visible** light?

b. So what sort of energy light would you expect from electron transitions $3 \rightarrow 1$, $4 \rightarrow 1$, etc.? Can any of these be responsible for the hydrogen gas emissions?

c. Can quantum level $n = 1$ be involved at all with the hydrogen gas emissions?

7. Try the next level of transition: $3 \rightarrow 2$. What is the energy difference? What wavelength light does this correspond to?

8. Then try $4 \rightarrow 2$, $5 \rightarrow 2$, $6 \rightarrow 2$. Place the transitions and their calculated wavelengths in the appropriate cells in the data and prediction table.

Data and prediction table:

Color	Measured wavelength	Calculated wavelength	Transition

Analysis: Compare the measured and calculated wavelengths for each color.

9. Is there a **systematic** error between your data and your predictions? What then can you conclude about your spectroscope?

10. To what **precision** should you read your spectroscope? Will this account for any **random** error between your data and your predictions?