

THE BALMER SPECTRUM OF HYDROGEN

There are two primary relationships that you need to know about light:

$$c = \lambda f \quad \text{and} \quad E_{\text{photon}} = hf = h\left(\frac{c}{\lambda}\right)$$

where:

λ = the wavelength of light (in meters).

f = the frequency of light (in Hertz which are cycles/second).

c = speed of light

$$c = 2.998 \times 10^8 \text{ meters/second}$$

h = Planck's constant

$$h = 6.6256 \times 10^{-34} \text{ Joules}\cdot\text{second}$$

PHOTON ABSORPTION AND EMISSION BY ATOMS:

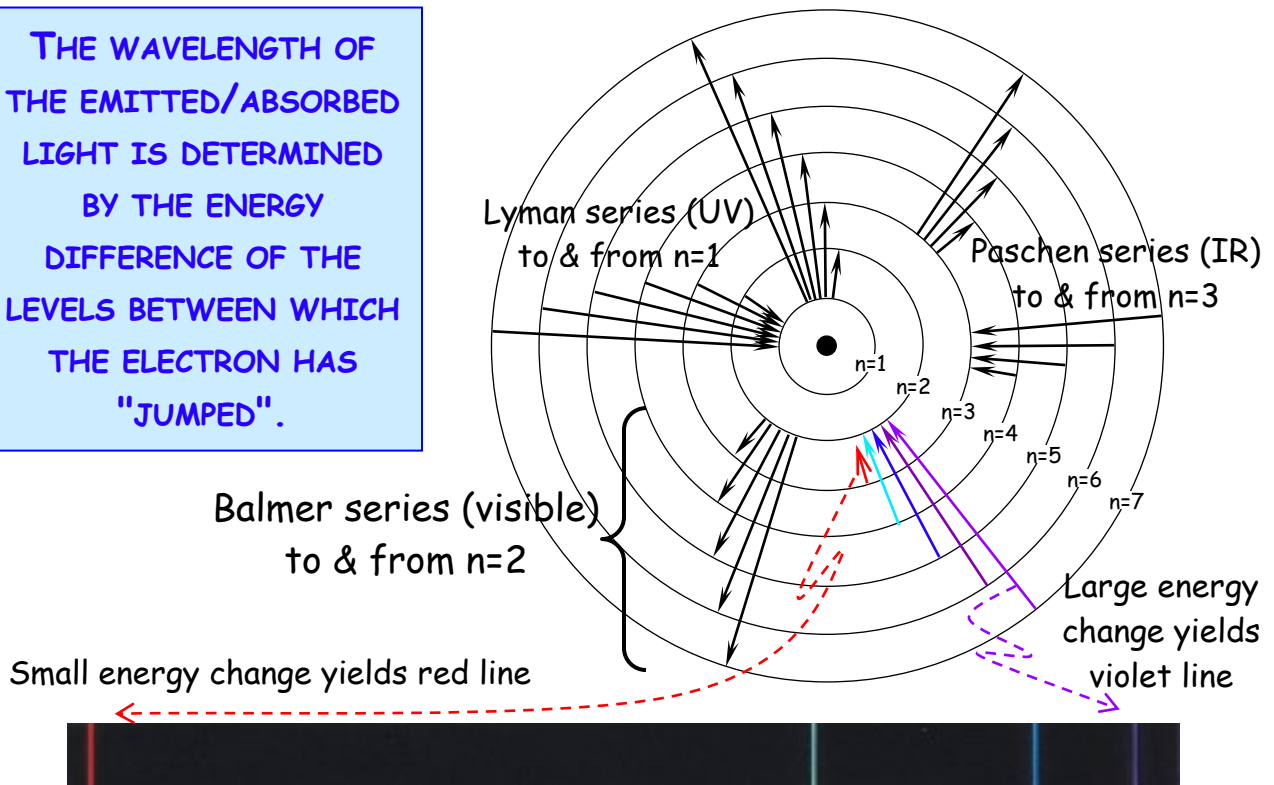
In atoms, the electrons are arranged in energy levels determined by the number of protons in the nucleus. To change energy level, an electron must absorb or emit a photon of an energy exactly equal to the difference in the energy between the two levels. Thus

$$E_{\text{photon}} = E_{\text{upper Level}} - E_{\text{lower Level}}$$

The energy of the photon shown above then gives

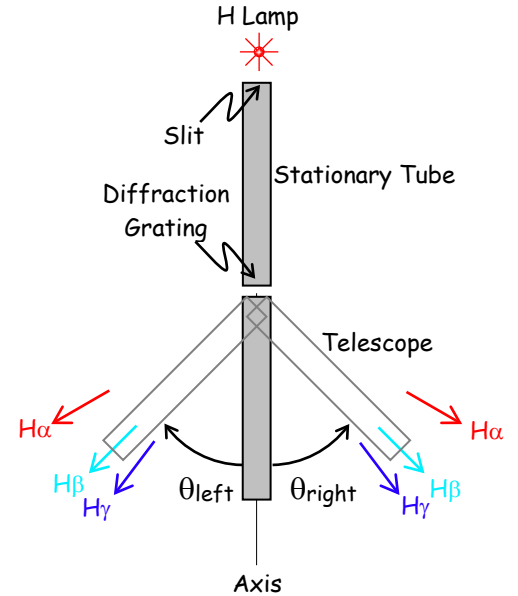
$$\frac{hc}{\lambda} = E_{\text{upper Level}} - E_{\text{lower Level}} \quad \text{or} \quad \lambda = \frac{hc}{E_{\text{upper Level}} - E_{\text{lower Level}}}$$

THE WAVELENGTH OF THE EMITTED/ABSORBED LIGHT IS DETERMINED BY THE ENERGY DIFFERENCE OF THE LEVELS BETWEEN WHICH THE ELECTRON HAS "JUMPED".



THE EXPERIMENT: MEASURING WAVELENGTH, CALCULATING ENERGY

Use a spectroscope to observe and note the positions of the Balmer lines of hydrogen. Measure the angles to within 0.5° on the left and right sides of the axis and average the values. Then take the sin of each average angle.



a)¹⁸ Find each of the three Balmer lines on both sides of the stationary tube by swinging the telescope left and right. Center the crosshair on each line and record the angles, average and sine of the average.

LINE	COLOR	ANGLE (θ)			sin(θ _{average})
		left	right	average	
H _α	Red			15.7°	0.271
H _β	Teal			17.7°	0.304
H _γ	Violet			14.8°	0.255

b) The relationship for the H_α (red) line and any other line is:

$$\frac{\lambda_{\text{any line}}}{\sin \theta_{\text{any line}}} = \frac{\lambda_{\text{red line}}}{\sin \theta_{\text{red line}}} \xrightarrow[\text{magic of algebra...}]{\text{through the}} \lambda_{\text{any line}} = \left(\frac{\lambda_{\text{red line}}}{\sin \theta_{\text{red line}}} \right) \sin \theta_{\text{any line}}$$

where $\lambda_{\text{red}} = 656.3 \text{ nm}$.

c)¹⁰ Use your measurements of $\sin \langle \theta \rangle$ and the wavelength of the red line to complete the following table. BE SURE TO USE THE "WAVELENGTH (METERS)" VALUES TO CALCULATE THE "PHOTON ENERGY"! (1 NANOMETER = 10⁻⁹METER)

LINE	COLOR	TRANSITION LEVELS	WAVELENGTH (λ)	WAVELENGTH (λ)	PHOTON ENERGY (E=hc/λ)
H _α	Red	n=3 to n=2	656.3 nm	656.3 × 10 ⁻⁹ m	<u>3.027</u> × 10 ⁻¹⁹ Joules
H _β	Teal	n=4 to n=2	486.1 nm	<u>486.1</u> × 10 ⁻⁹ m	<u>4.087</u> × 10 ⁻¹⁹ Joules
H _γ	Violet	n=5 to n=2	434.1 nm	<u>434.1</u> × 10 ⁻⁹ m	<u>4.577</u> × 10 ⁻¹⁹ Joules

d)² Compare these values the standard values below and discuss the accuracy of your measurements. How could your measurements be improved?

LINE	COLOR	λ (nm)	E (10 ⁻¹⁹ J)
H _α	Red	656.3	3.03
H _β	Teal	486.1	4.09
H _γ	Violet	434.0	4.58

Considering how crummy the little spectroscopes are, it's amazing that we can get within 10 or 20 nm ... that's 10 or 20 millionths of a meter! Wow!

Getting spectroscopes that were well crafted with a more precise and well-aligned angle scale or a digital readout would improve the results.