Name Solution

THE BALMER SPECTRUM OF HYDROGEN

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

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

where:

λ = the wavelength of light (in meters).

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

c = speed of light **$c = 2.998 \times 10^{8}$ meters/second**

h = Planck's constant **$h = 6.6256 \times 10^{-34}$ Joules·second**

PHOTON ABSORPTION AND EMISSION BY ATOMS:

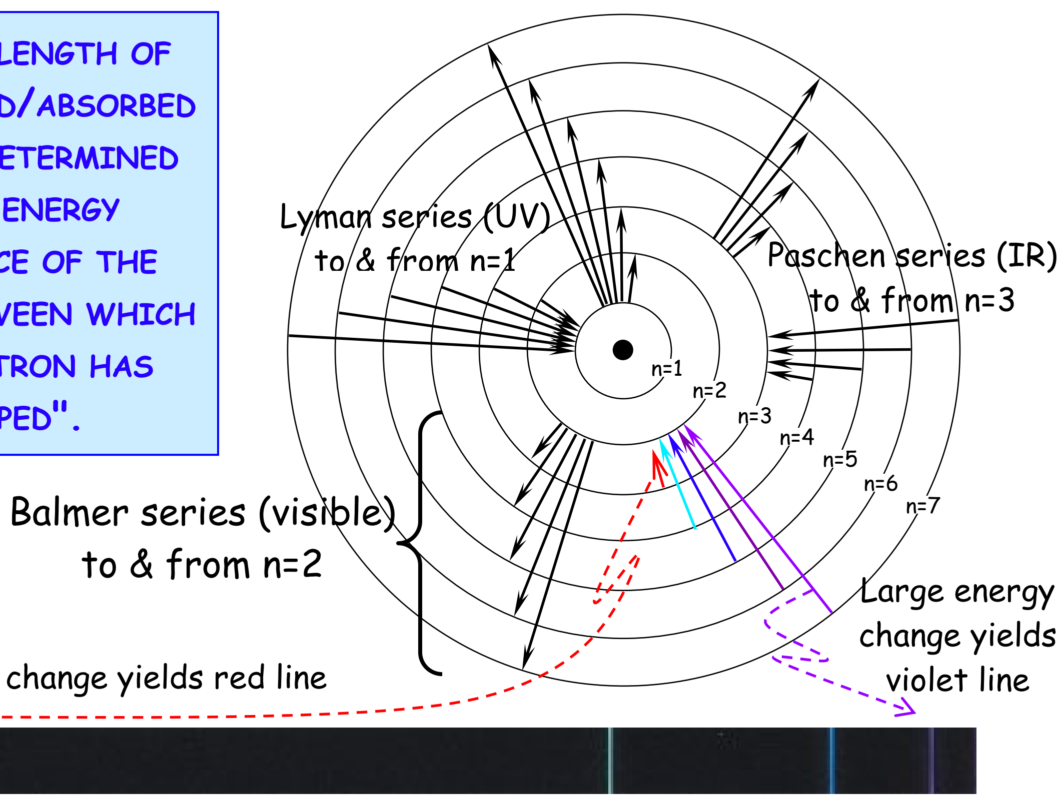
In atoms, the electrons are arranged in energy levels determined by the number of protons in the nucleus. To change energy level, an electron must absorb or emit a photon of an energy exactly equal to the difference in the energy between the two levels. Thus

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

The energy of the photon shown above then gives

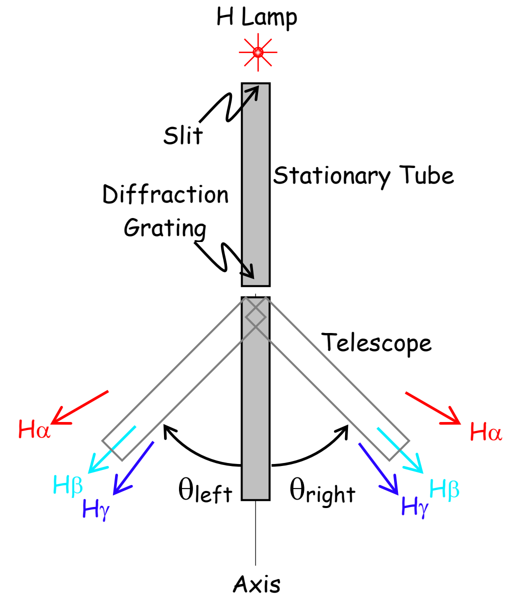
$$\frac{hc}{\lambda} = E_{upper\ Level} - E_{lower\ Level} \quad \text{or} \quad \lambda = \frac{hc}{E_{upper\ Level} - E_{lower\ Level}}$$

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) left	Angle (θ) right	Angle (θ) average	$\sin(\theta_{average})$
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 Hα (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 λ_{red} = 656.3 nm.

c)[10] Use your measurements of sin<θ> 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^{-9} METER)

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 x 10^{-9} m	3.027 x 10^{-19} Joules
H_β	Teal	n=4 to n=2	486.1 nm	486.1 x 10^{-9} m	4.087 x 10^{-19} Joules
H_γ	Violet	n=5 to n=2	434.1 nm	434.1 x 10^{-9} m	4.577 x 10^{-19} Joules

↳ *Change nm to meters* ⤴ ↳ *Use λ in meters to calculate energy!* ⤴

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.