2023

Balmer series

Balmer Series

Hydrogen Spectra

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Safety Measures

1. Here we discussed about Balmer series but the Lyman series also present in lamp which can't detect with spectrometer which is in deep UV range; So don' t look directly in to lamp. It will damage your eyes.
2. It is best that you
3. work in low light dust free atmosphere.
4. Lamps are powered by high voltage and they get hot. Don't touch the tube anywhere.
5. Experiment needs to be done in low light and dust free environment.
6. Lamp tubes are fragile, handle them with care.
7. Don't keep the lamps on for a longer time. (< 30 secs is ideal).
8. The spectra analyser shouldn't be on run for more than 1 minute.
9. The operating voltage for Hg lamp is 2500kv and for H lamp it's 3000kV. Never turn the power to maximum.

Experiment

To determine the wavelength of Balmer series in the visible region from hydrogen emission spectrum.

To determine the RYDBERG constant.

Theory

Hydrogen atom in a discharge lamp emit a series of lines in the visible part of the spectrum. The series is called Balmer series after the Swiss teacher Johann Balmer who, in 1885, found by trail and error a formula to describe the wavelength of these lines. This formula is given by

$$\frac{1}{\lambda} = R\ [\frac{1}{2^2} - \frac{1}{n^2}]$$

Where n are integers, 3, 4, 5…… up to infinity and R is a constant now called the Rydberg constant.

Then in 1889, Johannes Robert Rydberg found several series of spectra that would fit a more general relationship, similar to Balmer`s empirical formula. This general relation is known as Rydberg formula and is given by

$$\frac{1}{\lambda} = R\left[\frac{1}{{n_f}^2} - \frac{1}{{n_i}^2}\right]; n_i > n_f$$

where n_i and n_f are integers, 1, 2, 3, 4……. Up to infinity, with $n_i > n_f$. for the Hydrogen atom, n_i =2 corresponds to Balmer series. In the SI units; R = 1.097 x 10^7 m^{-1}.

Balmer Series – Spectral lines

Name of Line	$\mathbf{n_f}$	$\mathbf{n_i}$	**Symbol**	**Wavelength (nm)**
Balmer Alpha	2	3	$\mathbf{H_\alpha}$	656.28
Balmer Beta	2	4	$\mathbf{H_\beta}$	486.13
Balmer Gamma	2	5	$\mathbf{H_\gamma}$	434.05
Balmer Delta	2	6	$\mathbf{H_\delta}$	410.17

Spectrometer calibration using Hg lamp

Every element emits a characteristic spectrum of its own. To find the wavelength of light emitted usually the spectrum of a standard source is measured and compared. The unknown wavelength is determined by using Hartmann equations. The wavelength of the prominent lines in any spectrum of is studied by using the Hartmann’s formula,

$$\lambda(d) = \lambda_0 + \frac{C}{d \sim d_0}$$

where λ0, C and d0 are Hartmann’s constants that must be evaluated experimentally. This is done by substituting the distances d of three known lines (in the mercury spectrum) from an arbitrary point and their wavelengths λ in the above equation and solving the three equations. If we could find three lines with scale readings d1, d2 and d3 corresponding to known wavelengths λ1, λ2 and λ3 respectively, then we can find Hartmann’s constants using the following relations,

$$A = (\lambda_2 - \lambda_1) / (\lambda_3 - \lambda_1)$$

$$B = (d_2 - d_1) / (d_3 -, d_1)$$

$$\lambda_0 = \{(A \times \lambda_3) - (B \times \lambda_2)\} / (A - B)$$

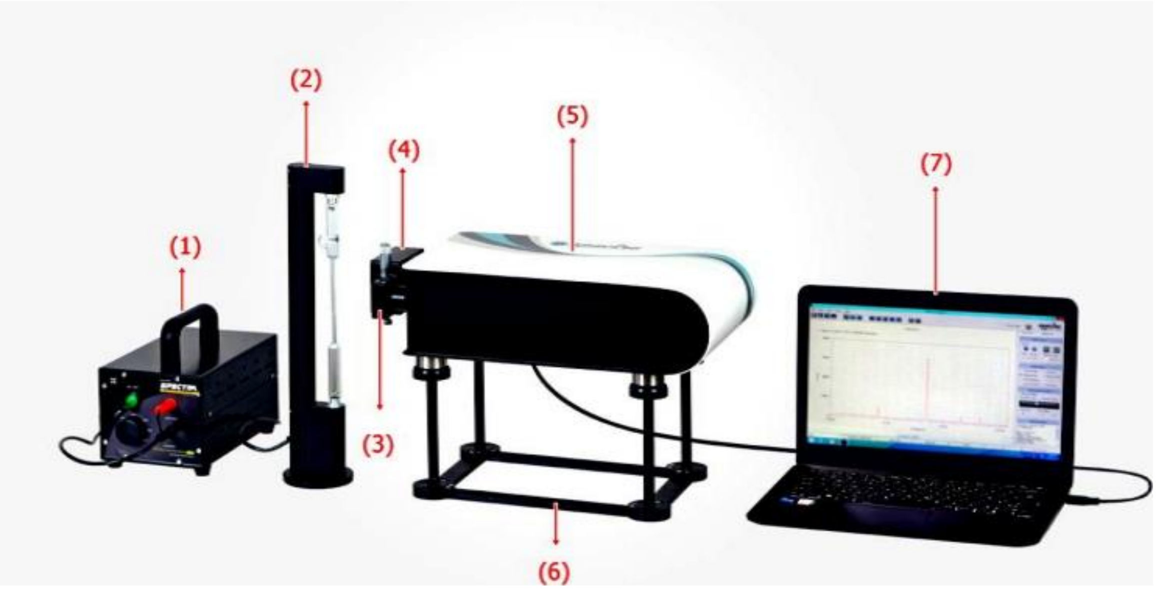
$$d_0 = \{(B \times d_3) - (A \times d_2)\} / (B - A)$$

$$C = \{(\lambda_2 - \lambda_1) \times (d_0 - d_1) \times (d_0 - d_2)\} / (d_2 - d_1)$$

The wavelength of the prominent lines in any spectrum is studied by using Hartmann`s formula,

$$\lambda(d) = \lambda_0 + \frac{C}{d_0 - d}$$

Parts Listing



1. High Voltage Power Supply
2. Mercury/Hydrogen Discharge Tube with Lamp House
3. Adjustable Slit
4. CCD
5. Constant Deviation Spectrometer
6. Stand for Spectrometer

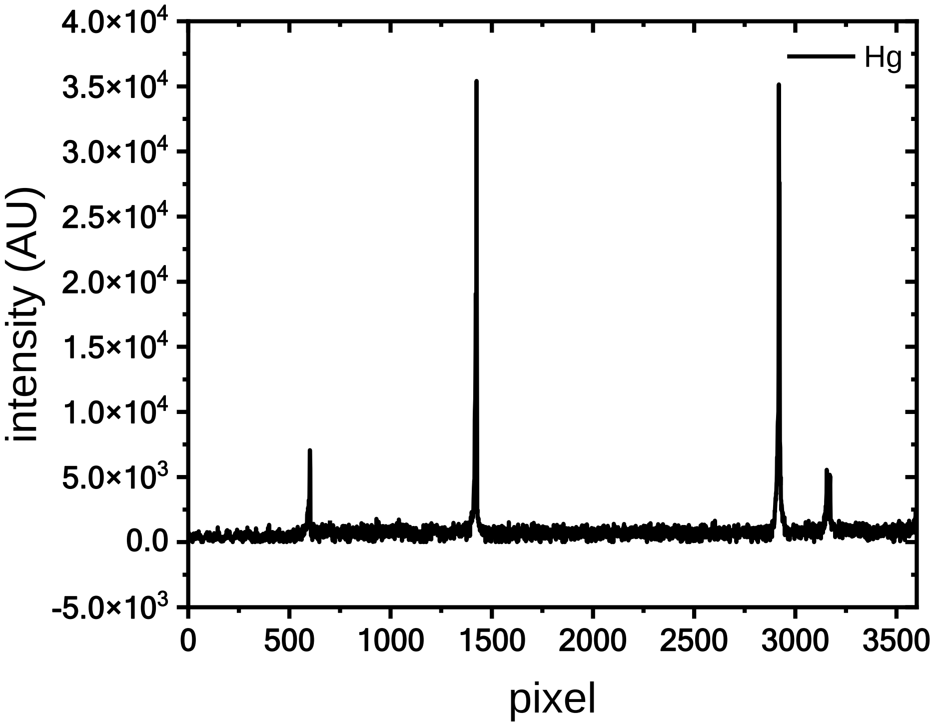
Procedure

1. Place the constant deviation spectrometer om the stand and keep it on a rigid table.
2. Connect the spectrometer to the computer by USB cable.
3. Open the HOLMARC spectra analyser in the computer.
4. Login as user.
5. Switch on the mercury lamp and place it in front of the slit of the spectrometer.
6. To observe the spectrum of Mercury, click on the run icon, to start live spectrum view.
7. Adjust the slit width using the micrometer screw provided to get precise sharp spectral lines.
8. You will see a live plot with X -axis having pixel values and Y – axis having intensity. Once you obtain sharp good resolved spectral lines, click on the stop icon and then click on the ‘acquire single spectrum’ icon to capture the current spectrum.

9. Find the pixel values of the peaks, obtained by zooming the graphs and drag a rectangle around the point whose values need to be measured.
10. Using the values obtained and the known wavelengths find the Hartmann's constant. Take any three known wavelengths to find the Hartmann's constant.

Known Wavelength (nm)	Corresponding Pixel values (X-axis)
λ_1 =	D_1 =
λ_2 =	D_2 =
λ_3 =	D_3 =
λ_4 =	D_4 =

Hg Spectra



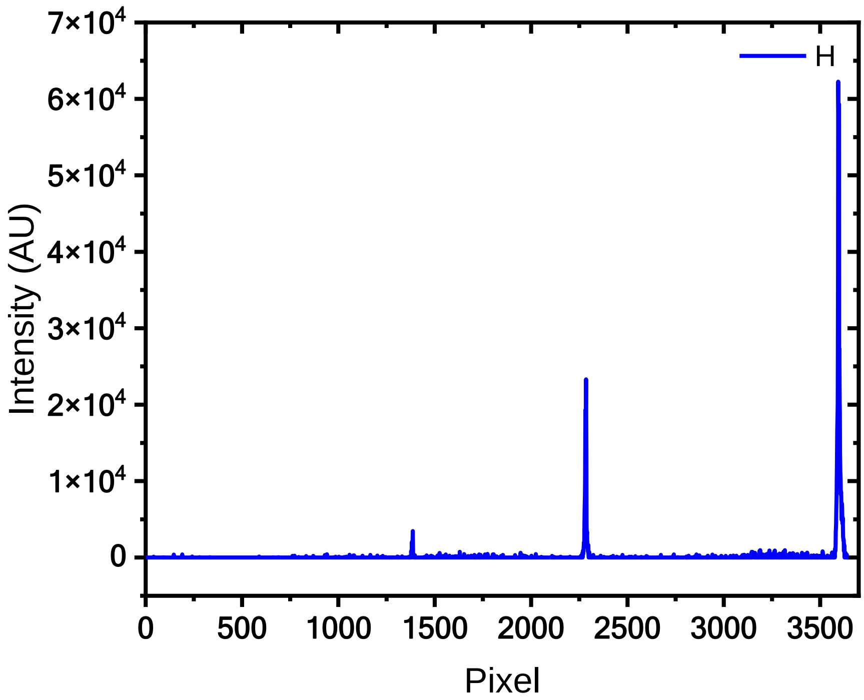
Wavelengths of hydrogen spectrum – Balmer series

1. To find the wavelength of emission spectra of certain materials replace the mercury source with hydrogen discharge tube and its power supply.
2. To observe the discrete spectrum of Hydrogen click on the play icon, to start live spectrum view.

3. Adjust the slit width using the micrometer screw provided to get precise sharp spectral lines.
4. Once you obtain the sharp good resolved spectral lines, click the stop icon and then click on the ‘acquired single spectrum’ icon to capture the current spectrum.
5. Find the pixel values of the peaks obtained by zooming the graph.
6. Using the pixel values in the given below equation we can obtain the corresponding wavelengths.

$$\lambda(d) = \lambda_0 + \frac{C}{d_0 - d}$$

Hydrogen Spectra



d (pixel values)	Calculated wavelength $\lambda(d) = \lambda_0 + \frac{C}{d_0 - d}$

Determination of Rydberg Constant

From Balmer series formula we can find out the Rydberg constant value

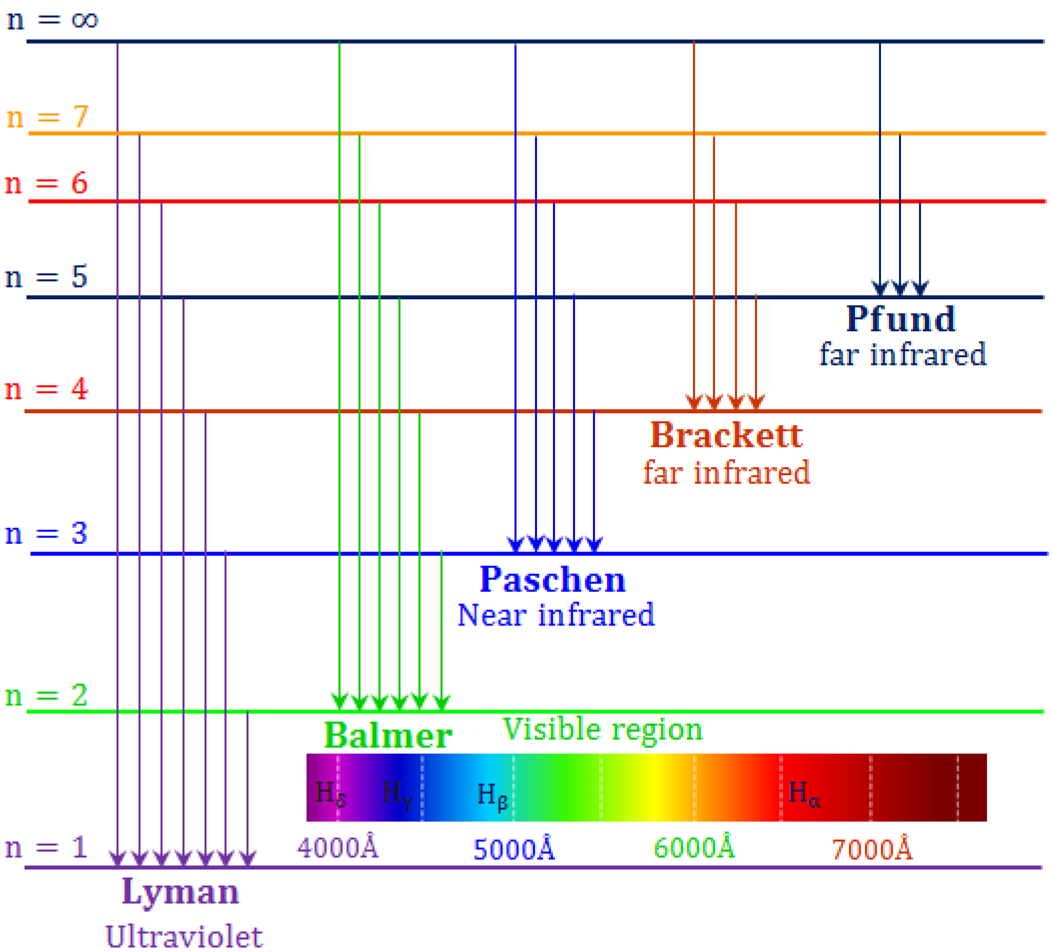
$$\boldsymbol{R = \frac{1}{\lambda}/[\frac{1}{2^2} - \frac{1}{n^2}]}$$

Wavelength (nm)	n	n^2	$R = \frac{1}{\lambda}/[\frac{1}{2^2} - \frac{1}{n^2}]$

Average Rydberg constant, R = _____ m^{-1}.

Appendix _ 1

Hydrogen Spectra



Energy levels of the Hydrogen atom with some of the transitions between them that give rise to the spectral lines indicated.

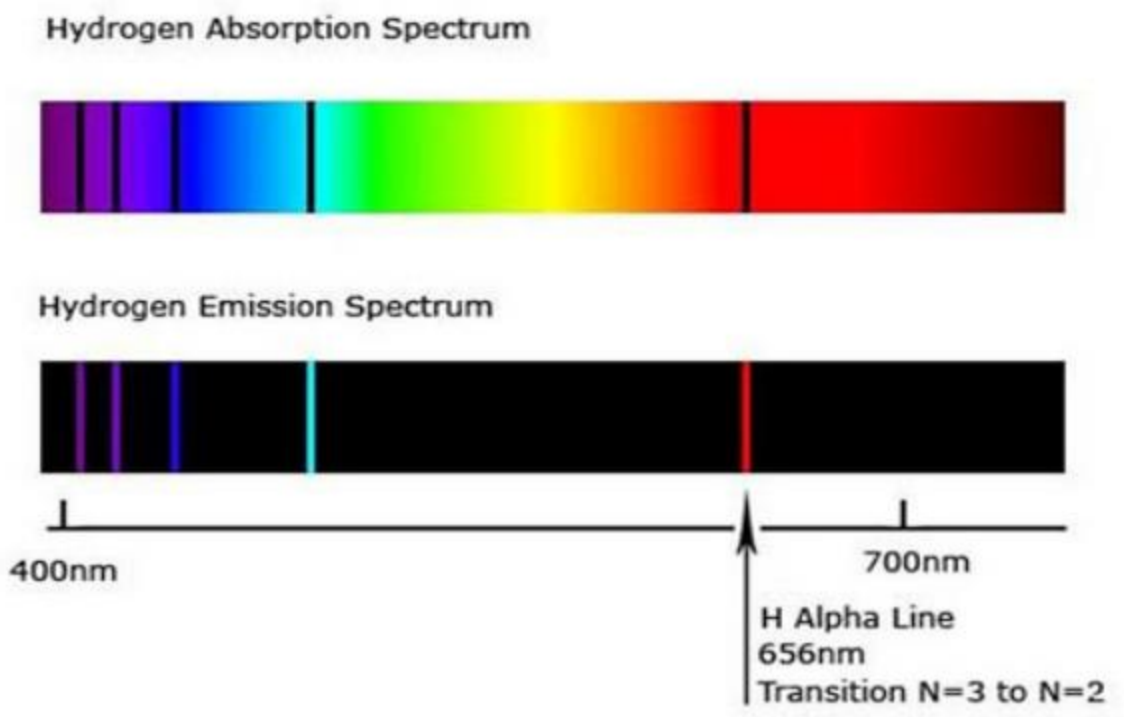
The prominent Balmer lines are follows

H_α line –The de-excitation of electron from quantum number n=3 to n=2; which have emission line 656.2nm

H_β line –The de-excitation of electron from quantum number n=4 to n=2; which have emission line 486.1nm

H_γ line –The de-excitation of electron from quantum number n=5 to n=2; which have emission line 434nm.

Hδ line –The de-excitation of electron from quantum number n=6 to n=2; which have emission line 410nm.



Appendix-2

Components included with specifications

Constant deviation spectrometer

Prism type	:	Pellin Broca prism
Design	:	constant deviation 120F
Spectrometer input	:	micrometer controlled slit (1 Rev : 0.25mm, 1 Div : 0.005mm)
Spectrometer output	:	CCD Electronic output through USB connected to a PC
Wavelength range	:	400 – 800 nm
Wavelength accuracy	:	±2nm

CCD Camera

CCD detector	:	sensitive linear array 0-3647 pixels
Pixel Size	:	800 x 200 micron

A/D Resolution	:	16 bits
Exposure time	:	0.1 – 6500 ms
Frame Rate	:	138 scan/sec
Compatibility	:	Any windows platform OS
Interface	:	USB 2.0

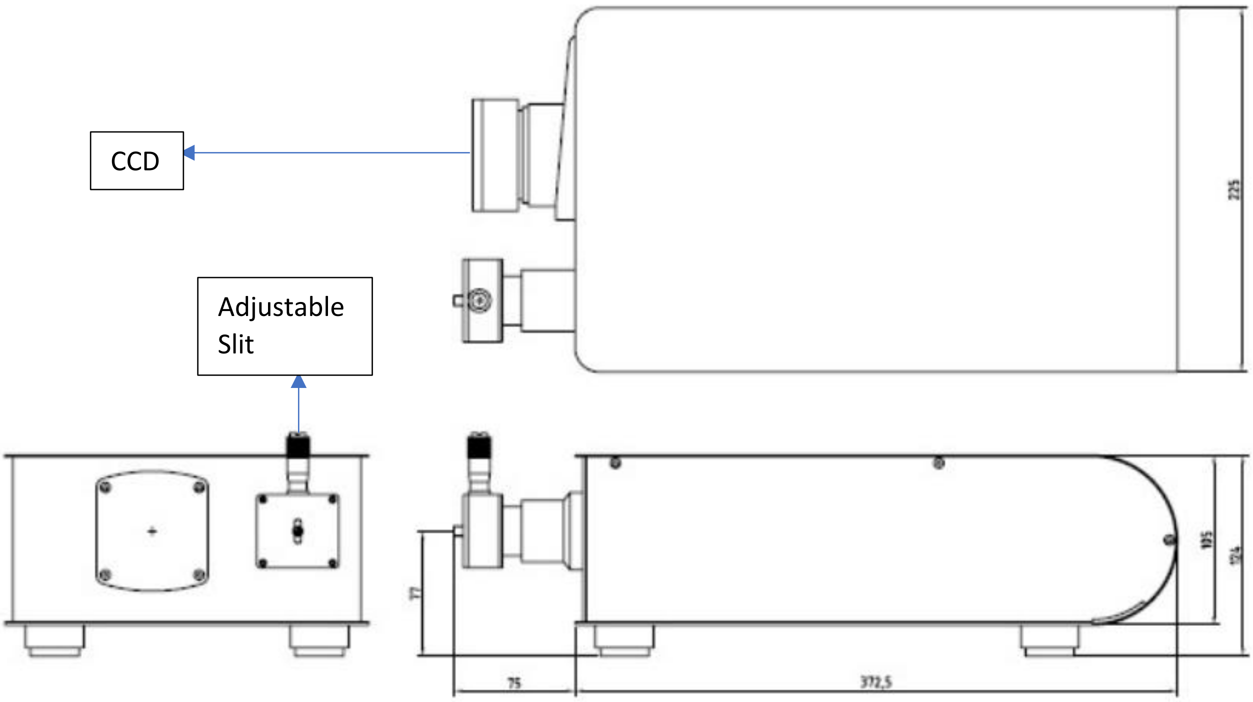
Discharge source with power supply

Discharge Tube	:	Mercury and Hydrogen
Power Supply	:	0-4000 V (variable)

Appendix – 3

Spectrometer

Mechanical drawing



Optical drawing