18.7 HYDROGEN SPECTRUM

Even before Bohr's theory, Ritz and Rydberg showed that the lines of hydrogen spectrum could be expressed by a general equation of the form

$$\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \quad (18.10)$$

where λ represents the wavelength of the spectral lines, R represents the Rydberg constant and n_1 and n_2 are integers.

The formation of various series in the hydrogen spectrum is shown by energy level diagram in Fig. 18.4.

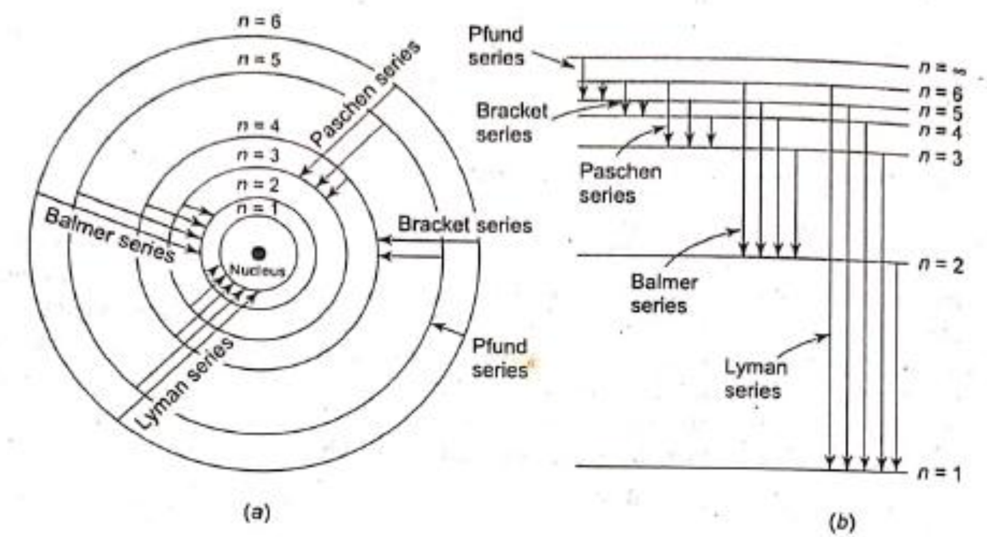

Fig. 18.4

Various series and their positions in the electromagnetic spectrum are given in the table below.

S.No.	Series observed	Value of n_1	Value of n_2	Position in the spectrum
1.	Lyman	1	2, 3, 4, ...	Ultraviolet
2.	Balmer	2	3, 4, 5, ...	Visible
3.	Paschen	3	4, 5, 6, ...	Infra-red
4.	Brackett	4	5, 6, 7, ...	Infra-red
5.	Pfund	5	6, 7, 8, ...	Infra-red

Experiment 18.1: To find the wavelengths of the spectral lines of hydrogen and hence to determine the value of Rydberg's constant.

Apparatus: Hydrogen discharge lamp with a suitable transformer, spectrometer with collimator and telescope, a plane transmission grating and spirit level.

Theory: The spectrum of hydrogen is obtained with the help of the hydrogen discharge tube, the spectrometer and the diffraction grating. If $(a + b)$ is the grating element which is the distance between two grating lines, the wavelength λ of the line of the spectrum is given by

$$n\lambda = (a + b) \sin \theta$$

where n is the order of the spectrum and θ is the angle of diffraction.

For the lines of the Balmer's series (the only series in the visible range),

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right) \qquad (18.11)$$

For H_α line (red), $n = 3$

For H_β line (blue), $n = 4$

For H_γ line (blue-violet), $n = 5$

For H_δ line (violet), $n = 6$

The wavelengths of these lines are, measured with the help of a diffraction grating. Substituting the values of the wavelengths of these lines and the corresponding values of n in Eqn. (18.11) the value of the Rydberg constant R can be obtained.

Procedure

1. Focus the eyepiece on cross-wires and focus the telescope and collimator for parallel light as discussed in chapter 12. Level the table with a spirit level. Do all the adjustments with sodium light.
2. Replace the sodium light by hydrogen discharge lamp. Place the grating perpendicular to the light coming from the collimator. The light should fall on the back of the grating, i.e., on the side not having the rulings.
3. See the direct image of the slit. Turn the telescope to left till the first order spectrum is obtained. Coincide the vertical cross-wire with the centre of the H_α line. Note down the readings of the scale on both the verniers. Move the telescope to the right and get the 1st order spectrum again. Coincide the vertical cross-wire with the centre of the H_α line. Note down again the readings of the scale on both the verniers. The difference of the readings gives 2θ for H_α line.
4. Similarly, note the readings of the verniers by setting the cross-wire on the other lines as well.
5. Repeat the observations for the lines in the second order spectrum.

Observations

Least count of the spectrometer = ...
Number of lines per inch on the grating, N = ...

$$\therefore \text{ the grating constant, } (a+b) = \frac{2.54}{N} = \dots \text{ cm.}$$

Spectral line	Order of spectrum	Vernier	Telescope reading		Angle of Diffraction		
			Left	Right	2θ	θ	Mean
H_α	I[st]	V_1 V_2					θ_1
	II[nd]	V_1 V_2					θ_2
H_β							
H_γ							
H_δ							

Calculations

$$\bar{\nu} = \frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$$

For red H_α line corresponding to $n = 3$

For I[st] order spectrum

$$\lambda = (a+b)\sin\theta_1$$
$$= \dots \text{ cm} = \dots \text{ m}$$

For II[nd] order spectrum

$$\lambda = \frac{(a+b)\sin\theta_2}{2}$$
$$= \dots \text{ cm} = \dots \text{ m}$$

Mean λ for H_α line = ... cm = ... m.

$$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right]$$

or $$R = \frac{36}{5} \times \frac{1}{\lambda} = \dots \text{ m}^{-1}$$

Similarly calculate λ and hence R for other lines and calculate the mean value of R.

Result : The wavelenth of Hydrogen Spectrum

Precautions and error

Conclusion