5 Experimental Procedures

The experimental setup is illustrated in Figure 2. Make the room as dark as possible.

1) Set up the apparatus following Fig. 2 by placing related components onto the rail and doing proper alignment. Note: it is suggested to use the 1-D translation carrier to hold the adjustable slit in order to adjust the slit position in horizontal direction.

2) Move the condenser lens (f50 mm) back and forth along the rail to image the line-style light (i.e. tube) of the Hydrogen-deuterium lamp onto the front surface of the slit. Move the lamp housing left and right to bring the image of the light line overlapping with the slit (also rotate the slit to be parallel to light line in vertical direction).

3) Move the collimating lens (f100 mm) back and forth to achieve a collimated beam along the central axis of the rail. If the collimated beam does not coincide to the central line of the rail, coordinately shift the slit or/and the lamp housing horizontally to implement.

4) Mount the grating onto the post on the rotation stage, let the surface plane of the grating align to the central line of the disk. Rotate the stage to let the collimated beam illuminate onto the grating surface perpendicularly. Lock the rotation stage using the fixing screw of the carrier.

5) Adjust the height of the telescope. Look into the eyepiece, if the vertical reference line of the telescope is not parallel to the image of the light line, rotate the telescope tube (need to loosen the pressing screw of the telescope holder), and rotate the arm of the rotation stage to find spectral lines, clear spectral lines should be observed. Note: Since the telescope is ready to receive collimated light beam (minor focusing adjustment for the eyepiece is allowed), if the observed spectral lines are not clear, it means the incident beam is not perfect collimated. In this case, carefully move the collimating lens back and forth and at the same time, observe the spectral lines in the eyepiece till clear lines are achieved.

6) Measure diffraction angles of hydrogen spectral lines of Balmer series. Since line H_δ (410 nm) is not sensitive to eye, it may not be seen. Only H_α, H_β and H_γ three lines are measured. Since there is chromatic aberration in the system, it needs to slightly adjust focus for different spectral lines. Data are recorded in Table 4.

Table 4 Angular positions of diffracted spectral lines

Spectral lines	-1^{st} order	0^{th} order	1^{st} order
H_α (red)			
H_β (tourqoise)			
H_γ (blue)			

Since the grating might not be located exactly in the center of the rotation stage, i.e., there is a decenter error, this will cause reading error for angle measurement. To eliminate this error, rotate the stage 180°, and repeat the above measurements. Data are recorded in Table 5:

Table 5 Angular positions of diffracted spectral lines after stage rotated by 180°

Spectral lines	-1st order	0th order	1st order
H_α (red)			
H_β (tourqoise)			
H_γ (blue)			

7) Take an average of the 4 angle values of each spectral line. Calculate wavelengths of spectral lines H_α, H_β, and H_γ using grating equation. Results are given in Table 6.

Table 6 Calculated wavelengths based on diffraction angles

Spectral lines	Average angle (°)	Wavelength in air (nm)
H_α (red)		
H_β (tourqoise)		
H_γ (blue)		

8) Convert wavelength in air to wavelength in vacuum using Table 2. Use formula $R_H = \dfrac{1}{\lambda(\frac{1}{4} - \frac{1}{n^2})}$ to calculate Rydberg constant, given in Table 7.

Table 7 Calculated Rydberg constant

Spectral lines	H_γ	H_β	H_α
Wavelength in vacuum (nm)			
n	5	4	3
Rydberg constant (10^7 m^{-1})			

9) Calculate the average of Rydberg constant in above table $\overline{R_H} = \frac{1}{3}(R_{H_\alpha} + R_{H_\beta} + R_{H_\gamma})$.

10) Calculate the experimental value of universal Rydberg constant R_∞:

$$R_\infty = \overline{R_H}(1 + m/M), \text{ with } m = 9.109 \times 10^{-31} kg, \quad M_H = 1.673 \times 10^{-27} kg.$$

The recognized value of R_∞ is 10973731.568549(83)/m. Compare it with the experimental value and get experimental error.

6 Examples of Data Recording and Processing

1) Measure diffraction angles of hydrogen spectral lines of Balmer series: H_α, H_β and H_γ. Data are recorded in the table below.

Spectral lines	-1st order	0th order	1st order
H_α (red)	22.8	0.1	23.2
H_β (tourqoise)	16.6		17.0
H_γ (blue)	14.8		15.1

Turn 180° of the rotation stage, measure again.

Spectral lines	-1st order	0th order	1st order
H_α (red)	23.2	0.0	23.3
H_β (tourqoise)	17.0		17.0
H_γ (blue)	15.1		15.1

2) Take an average of the 4 angle values of each spectral line. Calculate wavelengths of spectral lines H_α, H_β, and H_γ using grating equation. Results are given in the table below.

Spectral lines	Average angle (°)	Wavelength in air (nm)
H_α (red) (nm)	(22.8+23.2+23.3+23.3)/4=23.15	655.2
H_β (tourqoise) (nm)	(16.6+17.0+17.1+17.0)/4=16.925	485.2
H_γ (blue) (nm)	(14.8+15.1+15.2+15.1)/4=15.05	432.8

3) Convert wavelength in air to wavelength in vacuum using Table 2. Use formula $R_H = \frac{1}{\lambda(\frac{1}{4}-\frac{1}{n^2})}$ to calculate Rydberg constant, given in Table below.

Calculated Rydberg constant

Spectral lines	H_γ	H_β	H_α
Wavelength in vacuum (nm)	433.0	485.3	655.3
n	5	4	3
Rydberg constant (10^7 m^{-1})	1.09975	1.09898	1.09873

4) Calculate the average of Rydberg constant in above table $\overline{R_H} = \frac{1}{3}(R_{H_\alpha} + R_{H_\beta} + R_{H_\gamma})$=1.09915 ($\times 10^7$ m^{-1}).

5) Calculate the experimental value of universal Rydberg constant R_{∞} :

$R_{\infty} = \overline{R_H}(1 + m/M)$, with $m = 9.109 \times 10^{-31} kg$, $M_H = 1.673 \times 10^{-27} kg$.

$R_{\infty} = 1.09969$ ($\times 10^7$ m^{-1}).

The recognized value of R_{∞} is 10973731.568549(83)/m. Compare it with the experimental value and get experimental error.