

Splitting of sodium D-lines using diffraction grating

Objective: Measurement of the wavelength separation of sodium D-lines using a diffraction grating and to calculate the angular dispersive power of the grating.

Apparatus: Spectrometer, prism, diffraction grating, sodium lamp with power supply.

Theory

The sodium spectrum is dominated by the bright doublet known as the sodium D-lines at 589.0 and 589.6 nanometers as shown in Fig. 1. Using an appropriate diffraction grating the wavelength separation of these two lines can be determined. A schematic for diffraction of sodium light (Na-D lines) with a plane transmission grating is shown in Fig. 2.

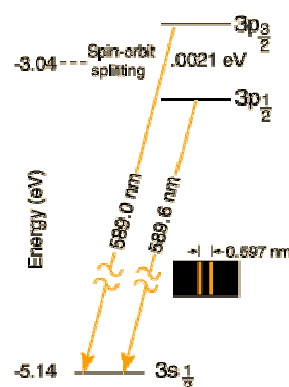


Figure 1: Sodium D-lines

Diffraction Grating:

An arrangement consisting of a large number of parallel slits of the same width and separated by equal opaque spaces is known as diffraction grating. It is usually made by ruling equidistant, extremely close fine grooves with a diamond point on an optically plane glass plate. A photographic replica of a plate made in this way is often used as a commercial transmission grating.

For N parallel slits, each with a width e and separated by an opaque space of width b , the diffraction pattern consists of diffraction modulated interference fringes. The quantity $(e+b)$ is called the grating element and $N (= 1/(e+b))$ is the number of slits per unit length, which could typically be 300 to 12000 lines per inch. For a large number of slits, the diffraction pattern consists of extremely sharp (practically narrow lines) principal maxima, together with weak secondary maxima in between the principal maxima. The various principal maxima are called orders.

For polychromatic incident light falling normally on a plane transmission grating the

principal maxima for each spectral wavelength are given by

$$(e+b) \sin\theta = \pm m\lambda \quad (1)$$

Where m is the order of principal maximum and θ is the angle of diffraction.

Angular dispersive power:

The angular dispersive power of the grating is defined as the rate of change of angle of diffraction with the change in wavelength. It is obtained by differentiating Eqn. 1 and is given by

$$\frac{d\theta}{d\lambda} = \frac{m}{(e+b)\cos\theta} \quad (2)$$

Experimental setup:

The actual experimental set up is shown in Fig. 3.

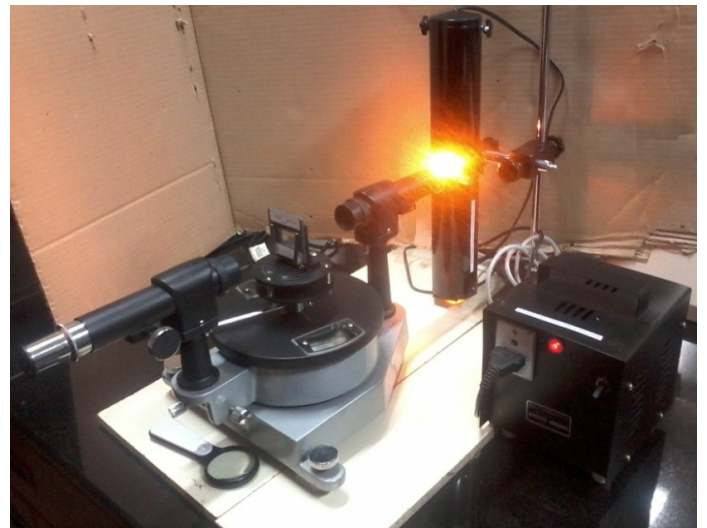
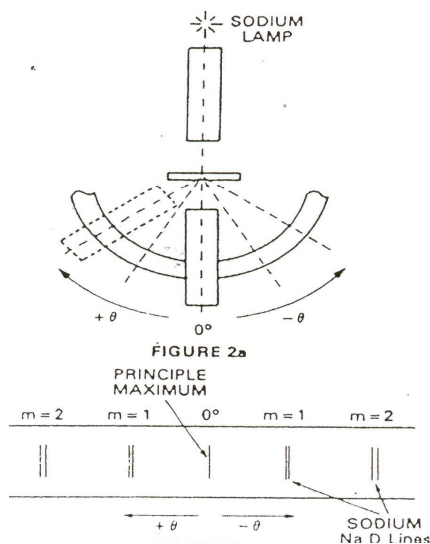


Figure 2: Schematic for diffraction of sodium Na-D lines

Figure 3: Experimental set up

Procedure :

1. Follow the support manual for spectrometer provided in the appendix for basic adjustment of spectrometer. Determine the vernier constant of the spectrometer.
2. Now remove the prism from the turntable. The next step is to adjust the grating on the turntable so that its lines are vertical, i.e. parallel to the axis of rotation or the turntable. Moreover, the light from the collimator should fall normally on the grating.

To achieve this, the telescope is brought directly in line with the collimator so that the centre of the direct image of the slit falls on the intersection of the cross-wires (without mounting the grating). In this setting of the telescope, its vernier reading is noted; let it be ϕ .

3. The telescope is now turned through 90° from this position in either direction so that the reading of the vernier becomes $(\phi+90^\circ)$ or $(\phi-90^\circ)$. Now the axis of telescope is at right angles to the direction of rays of light emerging from the collimator. The telescope is clamped in this position.
4. The grating of known grating element is then mounted on the grating holder, which is fixed on the turntable in such a way that the ruled surface of the grating is perpendicular to the line joining two of the leveling screws (say Q and R).
5. The table is now rotated in the proper direction till the reflected image of the slit from the grating surface coincides with the intersection of the cross-wires of the telescope.
6. By the help of two leveling screws (Q and R), perpendicular to which grating is fixed on the table, the image is adjusted to be symmetrical on the horizontal cross-wires. The plane of the grating, in this setting, makes an angle of 45° with the incident rays as well as with the telescope axis.
7. The reading of vernier is now taken and with its help, the turntable is rotated through 45° from this position so that the ruled surface becomes exactly normal to the incident rays. The turntable is now firmly clamped.
8. The final adjustment is to set the lines of the grating exactly parallel to the axis of rotation of the telescope. The telescope is rotated and adjusted to view the first order diffraction pattern. The third leveling screw (P) of the prism table is now worked to get the fringes (spectral lines) symmetrically positioned with respect to the horizontal cross-wire.
9. If this adjustment is perfect, the centers of all the spectral lines on either side of the direct one will be found to lie on the intersection of the cross-wires as the telescope is turned to view them one after another. The rulings on the grating are now parallel to the axis rotation of the telescope. The grating spectrometer is now fully ready to make the measurements. Do not disturb any of the setting of the spectrometer henceforth throughout the experiment.

10. Look through the telescope to notice the first or second order (whichever you see is completely resolved) D lines of sodium. That means you will see two yellow lines on both sides of the direct image (which is a single line) of the slit at the center. Note down the positions of the cross wire for each line on one side using the two verniers on the spectrometer. Use a torch, if needed, to read the verniers. Repeat the above step by turning the telescope to the other side too. Determine the diffraction angle, α , for all the two spectral lines.
11. Take two sets of reading for each D-line and calculate the corresponding wavelength λ_1 and λ_2 using Eq. 1.

Observation

Number of lines on grating = ----- Grating element = ----- Order, m = ----

Sodium Doublet	Left side						Right side						Vernier 1 20(deg)	Vernier 2 20(deg)	Avg. θ (deg)	λ
	Vernier 1(deg)			Vernier 2(deg)			Vernier 1(deg)			Vernier2(deg)						
	MSR	VSR	TOTAL	MSR	VSR	TOTAL	MSR	VSR	TOTAL	MSR	VSR	TOTAL				
D1															$\theta_1 =$	$\lambda_1 =$
D2															$\theta_2 =$	$\lambda_2 =$

Results:

1. Calculate λ_1 and λ_2 and the uncertainty of the result.
2. Calculate the difference $\lambda_2 \sim \lambda_1$ and compare with the literature value.
3. Calculate the angular dispersive power.

Precautions:

1. Once the collimator and the telescope are adjusted for parallel rays, their focusing should not be disturbed throughout the experiment.
2. Once the grating is properly adjusted on the turntable it should be locked.
3. While taking measurements at different positions of the telescope. It must always be in locked condition.
4. While rotating the telescope arm if the vernier crosses over 0° (360°) on the circular main scale take the angular difference appropriately.

References:

1. B.L. Worsnop and H.T. Flint, Advanced Practical physics for Students
2. B.K. Mathur, Introduction to Geometrical and Physical Optics