Practical 8

SPIN-ORBITAL INTERACTION

AND

FINE STRUCTURE OF RADIATION SPECTRA

EXPERIMENTAL SETUP

The instrument for the spectral decomposition of the investigated radiation is a reflective diffraction grating. The lattice is a glass plate covered with a reflective metal layer with a large number of parallel strokes (in this setup - 600 strokes per millimeter). The angle φ_m, which determines the direction to the maxima of the *m-th* order, is related to the period of the grating d and the angle of incidence of light on the grating φ_0 (fig. 8.1) by the condition:

$$(\sin\varphi_0 - \sin\varphi_m)d = m\lambda . \quad (1)$$

This formula allows you to determine the wavelengths in the emission spectrum from the values of φ_0 and φ_m. These angles are measured using a goniometer.

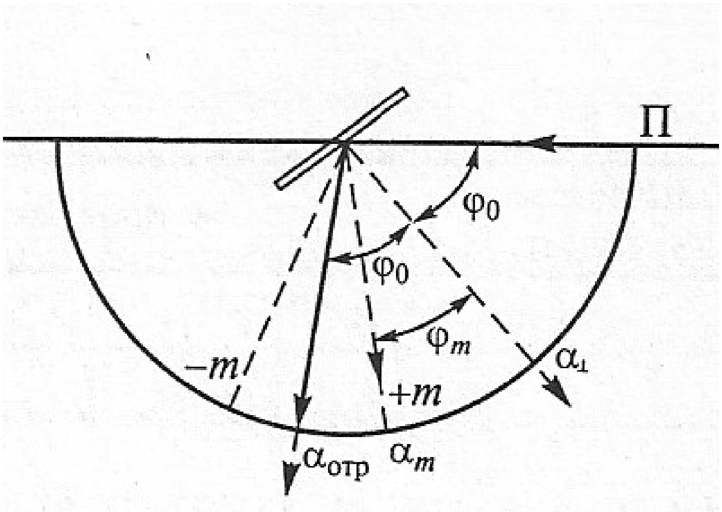

fig. 8.1

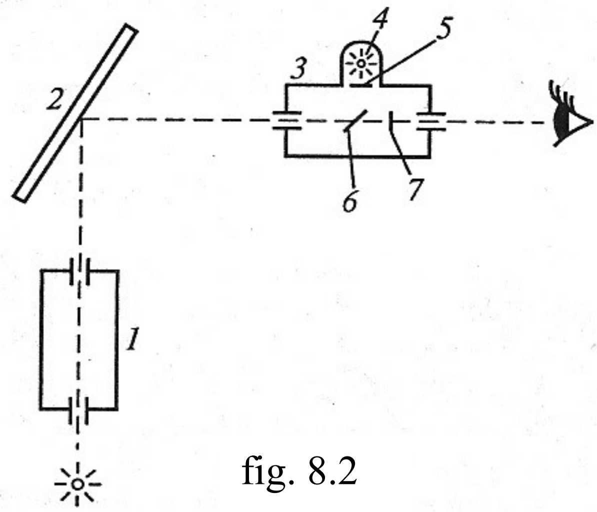

fig. 8.2

The optical scheme of the goniometer with the grating is shown in Figure 8.2. The figure shows the collimator *1*, in the front focal plane of which there is a narrow slit, the grid *2* and the telescope *3*, in the focal plane of the lens of which an image of the entrance slit of the collimator is formed. If the light contains several wavelengths, then a series of images of the slit corresponding to these wavelengths (line spectrum) appears.

The light source *4* illuminates the translucent cross on the plate *5*. The rays passing through it are reflected from the translucent mirror *6* and leave the tube. The image of plate *5* in the mirror appears in the focal plane of the lens and the light beam emerging from it will be parallel. Reflected from the flat face of the object, the beam returns to the tube and in the focal plane of the eyepiece forms an image of a cross. If the object's face is perpendicular to the axis of the tube, then the image of the cross will align with the sighting cross located in plane *7*.

Scheme of the goniometer is shown in fig. 8.3, and fig. 8.4 gives its photograph.

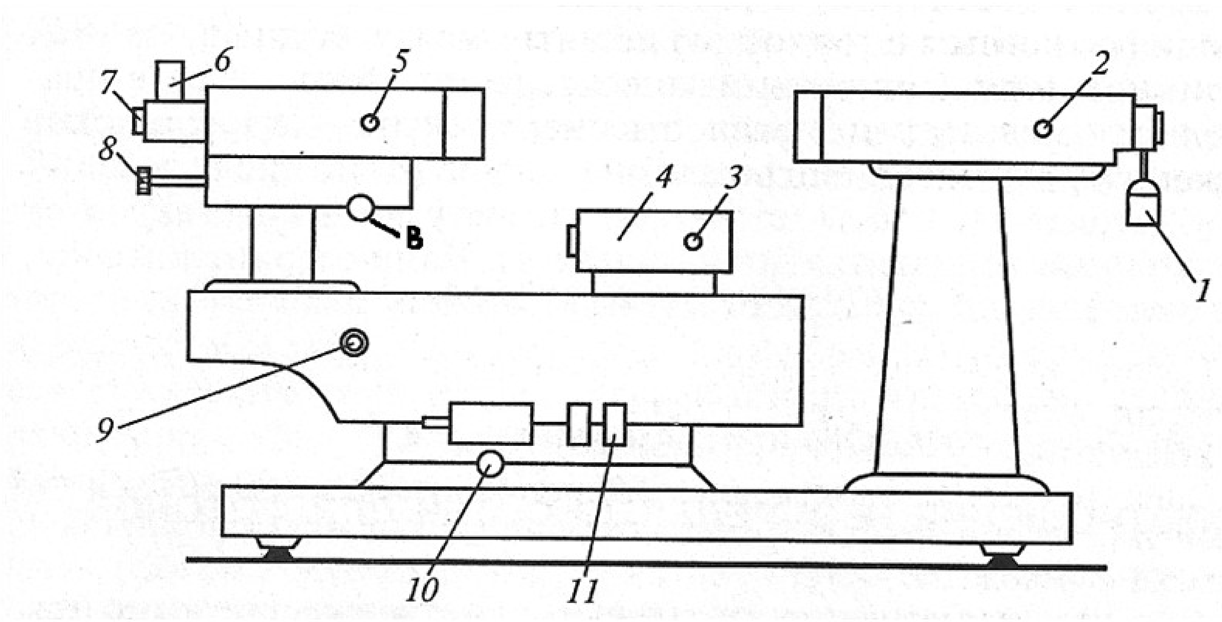

fig. 8.3

1 is a micrometer that adjusts the width of the entrance slit of the collimator, *2* is the focusing screw of the collimator, *3* is the object table, the slope of which is regulated by two screws, *4, 5* is the focusing screw of the telescope, **B** is the autocollimator illuminator, *7* is the eyepiece of the tube, *8* is a magnifying glass, through which the count is made on the scale of the limb inside the device, *9* is the hand-wheel of the optical micrometer.

fig. 8.4

Figure 8.5 shows what the field of view of a reading microscope looks like. In the left window there are images of diametrically opposite parts of the limb and a vertical index for counting degrees, in the right window - dividing the scale of an optical micrometer and a horizontal index for counting minutes and seconds.

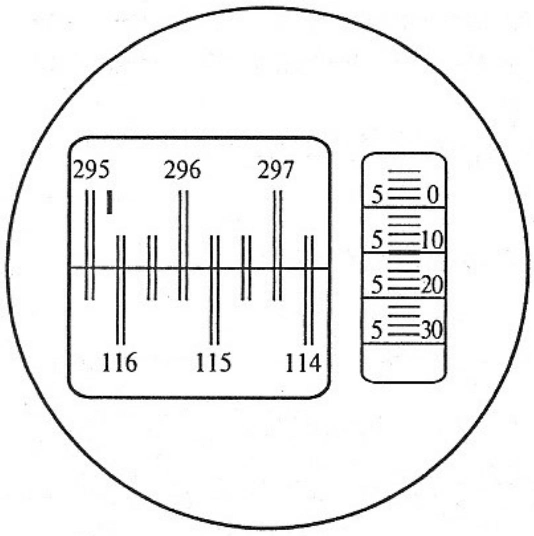

fig. 8.5

To measure the angle on the limb, you need to rotate the handwheel 9 of the optical micrometer (look at fig. 8.3-8.4) so that the upper and lower images of the limb strokes in the left window are exactly aligned.

The number of degrees is determined by the visible nearest left of the vertical index figure. Tens of minutes are counted according to the number of divisions of the left scale, located between the top risk and the bottom digitized stroke, which differs from the top one by 180^0.

The units of minutes are counted on the micrometer scale in the right window along the left row of numbers, and tens of seconds in the same window along the right row of numbers.

The number of seconds is equal to the number of divisions between the marks corresponding to the countdown of tens of seconds and a fixed horizontal index.

For example, the position shown in figure 8.5 corresponds to the countdown 295^0 45’10’’.

MEASUREMENT AND DATA PROCESSING

1. Turn on the radiation source being investigated (sodium lamp).
2. Loosen the locking screw 10 (fig. 8.3.), Turn the telescope and make sure that at certain positions you can observe diffraction maxima of zero- (specularly reflected light), 1^{st}- and 2^{nd}- orders (at the selected angle of incidence maximum of the 1^{st} order will be visible to the right of the maximum of the zero order, the maximum of the 2nd order to the right of the maximum of the 1st order).
3. Measure the angle of incidence φ_0 .

$\varphi_0 = \alpha_{ref} - \alpha_{\perp}$, где α_{ref} и $\alpha_{\perp}$ – the goniometer readings corresponding to these angles can be determined using the telescope's autocollimation setup.

To determine $\alpha_{\perp}$, it is necessary to install the tube so that its axis is perpendicular to the plane of the lattice. To do this, rotate the tube until a second image of the cross appears in its field of view, due to the reflection of a beam of light coming out of the tube from the plane of the grid (fig.8.7a). Using screw 11 and screw B (it is located under screw 5), achieve an exact coincidence of the cross image with the crosshair itself (fig.8.7b). Secure the locking screw 10 and determine the value of $\alpha_{\perp}$ on the scales of the goniometer.

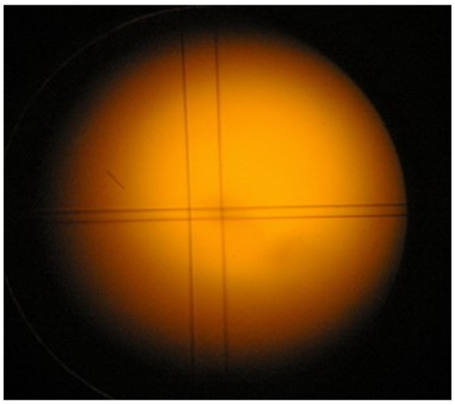

fig. 8.7a

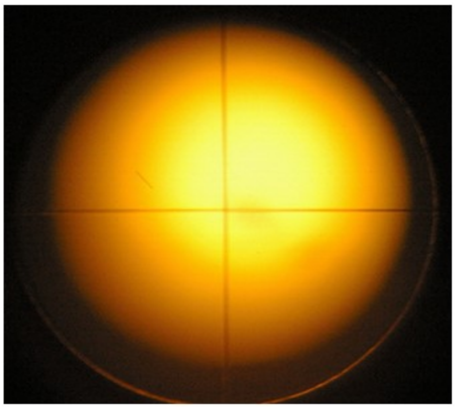

fig. 8.7b

Then move the tube (pre-loosening the screw 10) to the position corresponding to the specularly reflected beam, and, having aligned the cross of the threads with the image of the line, count the value α_{ref}.

After loosening the locking screw 10, return the tube to its original position and remove the countdown again $\alpha_{\perp}$, then find α_{ref}.

Repeat this operation at least five times, then calculate the average value of $\alpha_{\perp}$ and α_{ref} complete up to a second.

4. Turn the tube to the right until you see a doublet line in view - first-order spectrum (fig. 8.8).

Combining the vertical of the crosshair with the image of the first component of the doublet, and then the second, find, as described above, the corresponding angles and two values $\alpha_1^{*}\ \alpha_1^{**}$.

Repeat these measurements five times and find the average for each component. Make similar measurements for the lines in the spectrum of the 2nd order.

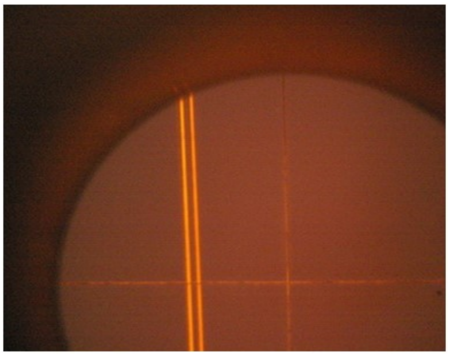

fig. 8.8

5. Using the obtained average values, calculate the angles $\varphi_0 = \alpha_{ref} - \alpha_{\perp}$, $\varphi_1 = \alpha_1 - \alpha_{\perp}$ Calculate the sine values of these angles with six significant digits.

6. Using formula (1), calculate the desired wavelength with an accuracy of 1 A.

T a s k 1 . **Measurement of the wavelengths of the two yellow lines of the Na doublet in the spectrum of the 1st and 2nd orders.**

Using the above method, obtain the values of the wavelengths of sodium doublet with an accuracy of 0.5A. The lattice constant is taken to five significant digits. The results of measurements and calculations are listed in tables 1.2 and 3.

Table 1

Zero order						
	α_{ref}	$\alpha_{ref.av.}$	$\alpha_{\perp}$	$\alpha_{\perp\, av.}$	φ_0	$\sin\varphi_0$
1.						
2.						
3.						
4.						
5.						

Table 2

1st order										
α_1^*	α_1^* av.	α_1^{**}	α_1^{**} av.	φ_1^*	φ_1^{**}	$\sin\varphi_1^*$	$\sin\varphi_1^{**}$	**λ*, Å**	**λ**, Å**	**Δλ, Å**

Table 3

2nd order										
α_2^*	α_2^* cp.	α_2^{**}	α_2^{**} cp.	φ_2^*	φ_2^{**}	$\sin\varphi_2^*$	$\sin\varphi_2^{**}$	**λ*, Å**	**λ**, Å**	**Δλ, Å**

T a s k 2. **Determination of the difference of the energy levels of sodium doublet.**

Find the difference between the energy levels of sodium doublet in electron-volts

QUESTIONS

1. List all quantum numbers describing the state of an electron in an atom, specify their possible values.
2. What is spin? What experiments confirm the presence of the electron spin? What is the spin gyromagnetic ratio?
3. Determine the number of different states corresponding to one value of the main quantum number n.
4. What caused the fine structure of the energy levels of the atom? What levels do not have a fine structure?
5. Why does the fine structure constant α play an important role in quantum theory? What does she characterize? Make sure that α is dimensionless.
6. Give examples and designate on the scheme the transitions allowed by the selection rules belonging to the main series, the sharp series and the diffuse series of the Na atom.
7. Transitions between which states correspond to the line of sodium doublet observed in the work?
8. Evaluate the resolution of the instrument, necessary for observing the yellow doublet of the Na line.