Determination of the optic axial angle of biaxial crystals in parallel polarized light.

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IT will in the first place be assumed for the sake of simplicity that the crystal to be investigated is immersed in a liquid having a refractive index as nearly as possible equal to the intermediate refractive index (β), so that light travelling along the optic axis[1] is not appreciably refracted on entering or leaving the crystal.

The observation is made in parallel light between crossed nicols, which are rotated together till a position of extinction is reached, when the directions of vibration of the nicols will be parallel to those in the crystal. If the latter be now rotated on an axis parallel to one of these directions, it will in general show light throughout the revolution, except in the original position and that opposite to it. Occasionally, however, it will remain dark throughout; in that case the axis of rotation is the bisectrix of an optic axial angle. Sometimes, on the other hand, it will remain dark except in four positions opposite to each other in pairs; the axis of rotation is then the optic normal, and the plane in which the rotation takes place the optic axial plane. The four positions correspond to the two optic axes; and a determination of the angles between these positions would give the acute and obtuse optic axial angles, but the observation is not a very satisfactory one.

If the crystal be now returned to its original position, and the nicols rotated through 45°, the crystal will become light. With the nicols in this position it is easy to ascertain by means of a gypsum-plate or quartz-wedge whether the axis of rotation be parallel to the vibrations of the slow or fast wave-surface, in other words, whether it be positive or negative.

If the crystal be now rotated as before, it will, if the axis of rotation be either a bisectrix or optic normal, remain light through the entire revolution; but, if the sign of the axis of rotation be observed, a differ-

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[1] Or, to use more accurate language, light whose wave-surface is at right angles to a binormal.

ence will be noted in the two cases. If the axis of rotation be a bisectrix, the sign of the axis of rotation will remain the same throughout, and though the relative retardation between the two wave-surfaces will vary from point to point, it will never be zero. If, on the other hand, the axis of rotation be the optic normal, its optical sign will change four times during a revolution at positions corresponding to the optic axes; and at these positions the relative retardation will be zero.

The angles between these positions are the optic axial angles, and the sign of the axis of rotation in the interval between any two optic axes is the same as that of the bisectrix of the angle between them.

The exact points where the relative retardation is zero may be determined by inserting either a gypsum-plate showing a sensitive tint—preferably the red of the first order—or a double quartz-wedge such as is described on p. 91 of the present volume. The wedge should be placed in the focus of the eye-piece. If the plate be used, the position of an optic axis is marked by the appearance of the characteristic tint, while in the case of the wedge it is indicated by the exact coincidence of the bands on the two sides of the wedge. If the light used be strictly parallel, the quartz-wedge will give results equal, if not superior, to those given by the methods in which convergent light is employed. For the most accurate work mono-chromatic light should, I need not say, be used.

If the crystal substance is not immersed in a liquid of the required refractive index, it should have one or more pairs of parallel plane surfaces, and the refractive index between it and the medium in which it lies should be such as to allow of the emergence of two optic axes whose apparent positions may be determined in the manner described above. Thence their true positions and the angle between them may be calculated in the usual manner.

The principal advantage of the method described in this paper is that it can be employed in the case of minerals occurring in a thin section of a rock. In strongly convergent light this can only be turned through a comparatively small angle, but in parallel light under a low power it can be rotated to any required extent.

It is preferable to employ a microscope in which both nicols revolve together. With it should be used a stage-goniometer or 'Universal-Drehapparat[1],' which allows of two rotations, one about an axis at right angles to the axis of the microscope, and the second about an axis at

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[1] The 'Universal-Drehapparat' designed by C. Klein is well suited for use with this method; see H. Rosenbusch, 'Mikroskopische Physiographie der Mineralien und Gesteine,' vol. i, part 1, 4th edition, by E. A. Wülfing, 1904, pp. 204–205.

right angles to that of the first as well as to the plane of the glass slip supporting the thin section. It should be fitted with an arrangement for holding the glass slip, so that any desired portion of the section may be retained at the centre of rotation. The glass slip should be of less than the usual size. Though not absolutely necessary, it is very desirable to employ some form which allows of immersion in liquid. Instruments in which glass hemispheres are employed instead of immersion are unsuitable, as these interfere with the parallelism of the light.

The rock slide must be searched to find a crystal cut at right angles to the optic axial plane and which allows the emergence of two optic axes in the medium employed. This search may be carried out in parallel light by looking for a section which gives, on rotation about the axis at right angles to the axis of the microscope, the phenomena described above as characteristic of a rotation on the optic normal; but it will usually be more convenient in the first place to use convergent light, when the symmetrical 'pendulum movement' of the dark brush or 'isogyre', will, as F. Becke[1] has shown, indicate a section cut at right angles to the optic axial plane, and thus one suitable for further examination in parallel light for finding the positions of emergence of the optic axes.

In conclusion, I have only to add that it is to E. S. Fedorov[2] that we owe the principle of the examination of the optical characters of a crystal by rotation in different directions in parallel polarized light, of which principle the method described in this paper is only a special development.

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[1] F. Becke, 'Die Skiodromen,' Min. petr. Mitt. (Tschermak), 1905, vol. xxiv, pp. 1–34.

[2] Zeits. Kryst. Min., 1893, vol. xxii, p. 229; 1896, xxvi, p 225; 1896, xxvii, p. 337; 1898, xxix, p. 604.