An accessory to the polarizing microscope for the optical examination of crystals.

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QUALITATIVE studies of the optical properties of crystals under the polarizing microscope and refractive index measurements by immersion methods are made on slides placed upon the microscope stage. These procedures have the disadvantage that the crystals have a fixed orientation. Quantitative properties, such as optic axial angles, are measured on an accessory to the microscope, such as the universal stage, which although allowing rotation of the crystal necessitates auxiliary stereographic projection and is often considered laborious in operation and is not widely employed.

The single instrument to be described overcomes some of these limitations, yet is simple in construction and easy to operate. In the study of individual crystal grains or small sections of aggregates in liquid or solid mounts it may be used for work covering qualitative observations and measurements of principal refractive indices, optic axial angles, orientation, and essential optical properties. Stereographic projection is avoided. The crystal rotates freely to give any desired orientation during observations.

The device is used in conjunction with a polarizing microscope and consists essentially of a glass sphere, base-plate, disk, and markers, as shown in the diagram (fig. 1).

The crystal grain under observation is mounted at the centre of the sphere, A, of about 2·5 cm. in diameter, formed of two segments of optical glass of a chosen refractive index, which are readily detached and reassembled. This feature is achieved by cementing a thin, flat metal ring to the plane surface of each segment, the ring of one segment being an accurate fit within that of the other. When the segments are placed together they form a true sphere and the outer metal ring constitutes part of the spherical surface. The plane surfaces of the two segments are separated by a space of about 0·5 mm. within which the crystal is mounted. The sphere rotates freely on a three-point support, of hardened, polished steel balls in a central opening, B, in the

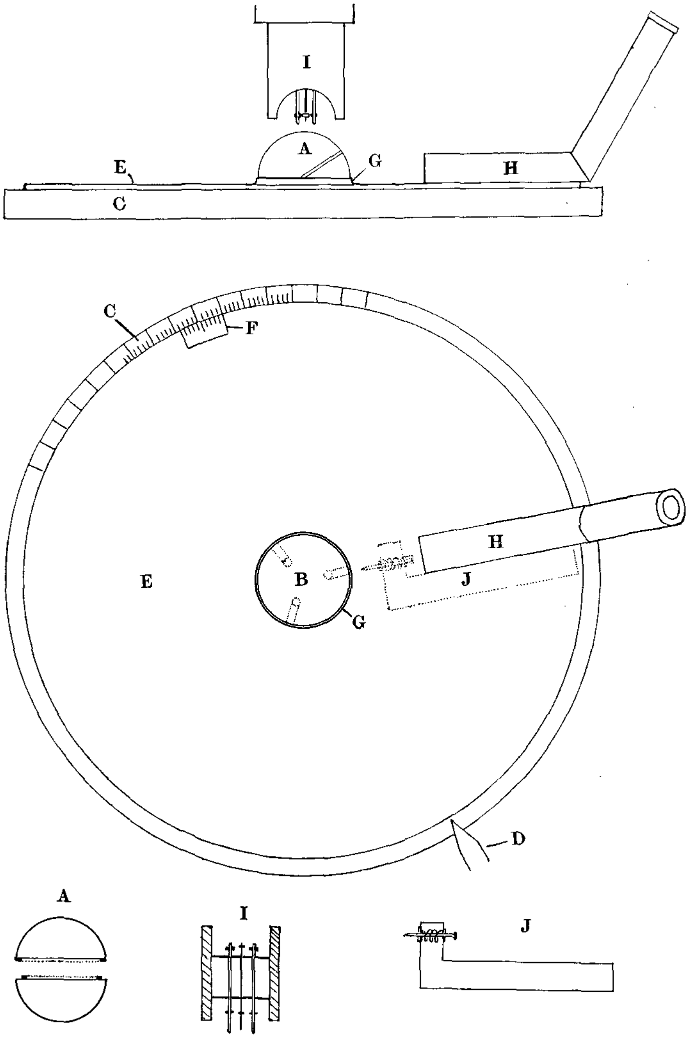

FIG. 1. Accessory to polarizing microscope.
A sphere, B central opening, C base-plate, D fixed reference pointer, E disk, F vernier, G collar, H reading microscope, I objective marker, J horizontal marker.

base-plate, C, the outer rim of which is marked with a scale of degrees and is fixed to and rotates with the microscope stage. Base-plate rotations are read on the rim against a fixed reference pointer, D. The disk, E, is set into and revolves upon the base-plate and its angular movements are read by means of a vernier, F, against the scale of the base-plate. The disk has a circular central opening bordered by a collar, G, the rim of which defines the horizontal *great circle or equator* of the sphere. The pole of this great circle lies on the axis of the microscope and is coincident with the cross-hairs. The disk is fitted with a small horizontal reading microscope, H, provided with cross-hairs adjusted to the equator of the sphere.

The microscope stage itself may be used as the base-plate if suitably modified to take the disk and the sphere supports.

The objective marker, I, which, when in use, occupies the position of the microscope objective, operates on lowering the tube. Vertical needles, tipped with pigment, contact the sphere and rise in their guides. A mark of microscopic dimension is thus made on the sphere at its pole lying at the intersection of the cross hairs, between two dots, easily located by the naked eye, which serve to indicate by their alignment the vibration directions within the crystal.

The horizontal marker, J, moves on the disk, against a slide on the reading microscope. It carries a spring-loaded needle, which operates through a notch in the collar of the disk. It is used to plot points, coincident with the cross-hairs of the reading microscope, on the equator of the sphere, at known angular distances apart, corresponding with vernier readings.

The base-plate, once fixed and centred, need not be detached. For conventional slide studies, sphere and disk only need to be removed.

Crystal material for study as grains or aggregates is mounted in the sphere on or between cover-glasses, in liquid or solid media. When principal refractive indices and other optical properties are to be determined at one time, mobile immersion liquids are used. For this purpose scattered grains are caused to adhere lightly to a cover-glass by a thin film of adhesive. The cover-glass is then attached to the plane surface of one hemisphere by means of a viscous medium, sufficiently mobile to allow it to be moved laterally and thus permit a grain to be selected and centred for study. A cover-glass is attached to the opposite hemisphere, a minimum of chosen liquid is applied to the grains, and the segments are then assembled. The choice of media is of course influenced by solubility relationships, and the refractive index of all the materials comprising the mount must be taken into account if total reflection effects are to be avoided. The immersion medium is held by surface tension at the central area of the sphere, the construction of which allows the liquid to be changed without disturbing the selected grain.

Specimens for study must have clearance in the space provided between the cover-glasses.

A low-power condenser of appropriate focal length, adjustable in height below the stage, provides parallel or convergent light. The Bertrand lens, fitted with an iris diaphragm, should be capable of being focused in the tube. For conoscopic observation without the ocular a loosely-fitting cap, drilled with a central pin-hole, gives improved definition. Strong illumination is necessary, especially when working with small grains. The lamp should be fitted with an iris diaphragm so that the image of the source shows as a circular patch of illumination at the centre of the sphere, and may be adjusted in size by the diaphragm, and limited to the area of the centred crystal under observation.

For qualitative work the convergent phenomena and other optical characters of the crystal may be studied for any desired orientation by revolving the sphere in its seating and by rotating the base-plate, or by a combination of both. For quantitative observations, points of emergence of optical directions in the interference figure, such as the optic axes, are adjusted to the cross-hairs of the microscope and the objective marker is brought into operation to plot the corresponding points on the sphere, which, with its inscribed angular relationships and other data, and the crystal at its centre, represents a model of the indicatrix of the crystal.

In measurements carried out on the sphere, only simple great circle and polar relationships are involved. Thus, when the sphere is manipulated to bring the optic axial plane, indicated by the two plotted optic axial points, to the equator (defined by the collar of the disk) an axis of the indicatrix emerges at the pole of the sphere, coinciding with the cross-hairs of the microscope and this may be plotted on the sphere.

In order to measure the angle between two plotted points the sphere is adjusted to bring them on to the equator. The angular separation of the points is given by the difference in vernier readings when the cross-hairs of the reading microscope are moved from one point to the other. A reference line on the collar may be used instead of the reading microscope when approximate measurements are needed.

Points may be plotted and angles set off upon the sphere along its equator using the horizontal marker. In addition, small angles on great circles between points on the sphere may be measured utilizing a micrometer ocular, the divisions of which are calibrated in terms of degrees on the sphere. These angles may be set off and plotted by the objective marker. Refractive index corrections necessitated by refraction effects of the glass may therefore be carried out on the sphere itself without recourse to stereographic projection. Points of emergence of optical directions, such as optic axes and indicatrix axes, once plotted, are available to indicate positions for refractive index observations by the immersion technique.

The mobility of the sphere is an advantage in the total-reflection method for the estimation of the refractive indices of liquids and platy crystals mounted in the sphere. The illumination boundary, corresponding to the vibration direction concerned, is adjusted to the cross-hairs of the microscope, and the critical angle plotted on the sphere and measured along the equator.

For demonstration, and as an aid in locating optical directions, the interference figure may be seen by normal vision when projected on to a ground glass screen held at the position of sharpest definition. By rotation of the sphere the phenomena may be located and brought into any desired position.

The sphere may be reversed to obtain the mean of two sets of readings, to improve accuracy in quantitative work.