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The birefringence patterns of crystal spheres

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The preparation of polished spheres of crystalline solids is an ancient art, and indeed it is not uncommon to find large spheres of quartz as exhibits in natural history museums. Using appropriate techniques, it is possible to prepare spheres with different materials and of any desired size, even as small as half a centimetre in diameter. A spherical shape is evidently the most appropriate for a crystal to possess if we wish to observe or exhibit the variation of its optical properties with the direction of propagation of light over the entire possible range. Hence, a collection of such spheres is a useful acquisition for a crystallographic museum.

We may mention here as an example the case of the well known pleochroic mineral iolite. Holding a polished sphere of this crystal so that it can be turned round and viewed against an extended source of light with a magnifier, Brewster's brushes can be seen around each of the two optic axes in the rear of the sphere. More generally, we place a crystal between a polariser and an analyser, viz., two sheets of polaroid, and view it against an extended source of light. An arrangement should be provided for holding the sphere and altering its setting as desired. The birefringent pattern then seen in various settings shows at once whether the crystal is uniaxial or biaxial, whether the birefringence is weak or strong, whether the material is or is not optically active, and in the case of a biaxial crystal, what the angle between the optic axes is and how their positions vary with the wavelength of the light.

The plates accompanying the present paper illustrate some typical examples of such birefringent patterns. Plates I and II refer to the case of quartz in different settings, plate III to beryl, plate IV to calcite, plate V to topaz, and plate VI to the case of iolite already mentioned. The spheres used in this study were prepared at this Institute by Mr J Padmanabhan who also photographed the birefringence patterns, using for this purpose the monochromatic illumination furnished by a sodium vapour lamp. The principal difficulty encountered in the work was that of obtaining material for preparing the spheres which besides being of adequate size had also the requisite degree of optical perfection. Any imperfections inevitably show up in the birefringence patterns. This is evident, for example, from the slight irregularities noticeable in the figures recorded for beryl and topaz in plates III and V respectively.

By way of explanation of the observed effects, we may remark that a beam of light incident on a sphere and traversing it along a diameter would be brought to a focus at a point outside the sphere and at a distance from it depending upon the refractive index. Since there are two refractive indices for any given direction of propagation within a crystal, the positions of the two foci would be different except in the special cases when the direction of propagation within the crystal coincides with an axis of single-wave velocity. Hence, in all directions other than these axes the optical paths would be different for the two indices and interferences can therefore arise. The convergence of the light beams produced by the sphere would result in these interferences appearing in good focus on the surface of a sphere concentric with the crystal sphere but of larger diameter. Hence, when the sphere is rotated, the pattern would rotate with it, and its appearance as seen in any given direction would alter progressively.

With white light, the interferences in the vicinity of the axes of single wave-velocity exhibit colours. They are very fine in the case of calcite (plate IV) but can be readily seen through a magnifier. These rings can also be seen with a magnifier in the case of topaz but not visible in the photographs of low magnification reproduced in plate V. As seen through a magnifier, they appear unsymmetrically located with respect to the optic axes, evidently as the result of the dispersion of these axes.

Of a different nature are the circular or elliptic interference rings observed with the various crystals in directions very remote from the axes of single-wave velocity (see figures 5 and 6 in plate I, figures 3, 4, 5 and 6 in plate II, figures 5 and 6 in plate III and figures 7 and 8 in plate V). These interferences are only seen in monochromatic light and hence correspond to large differences of path between the two sets of waves which overlap.

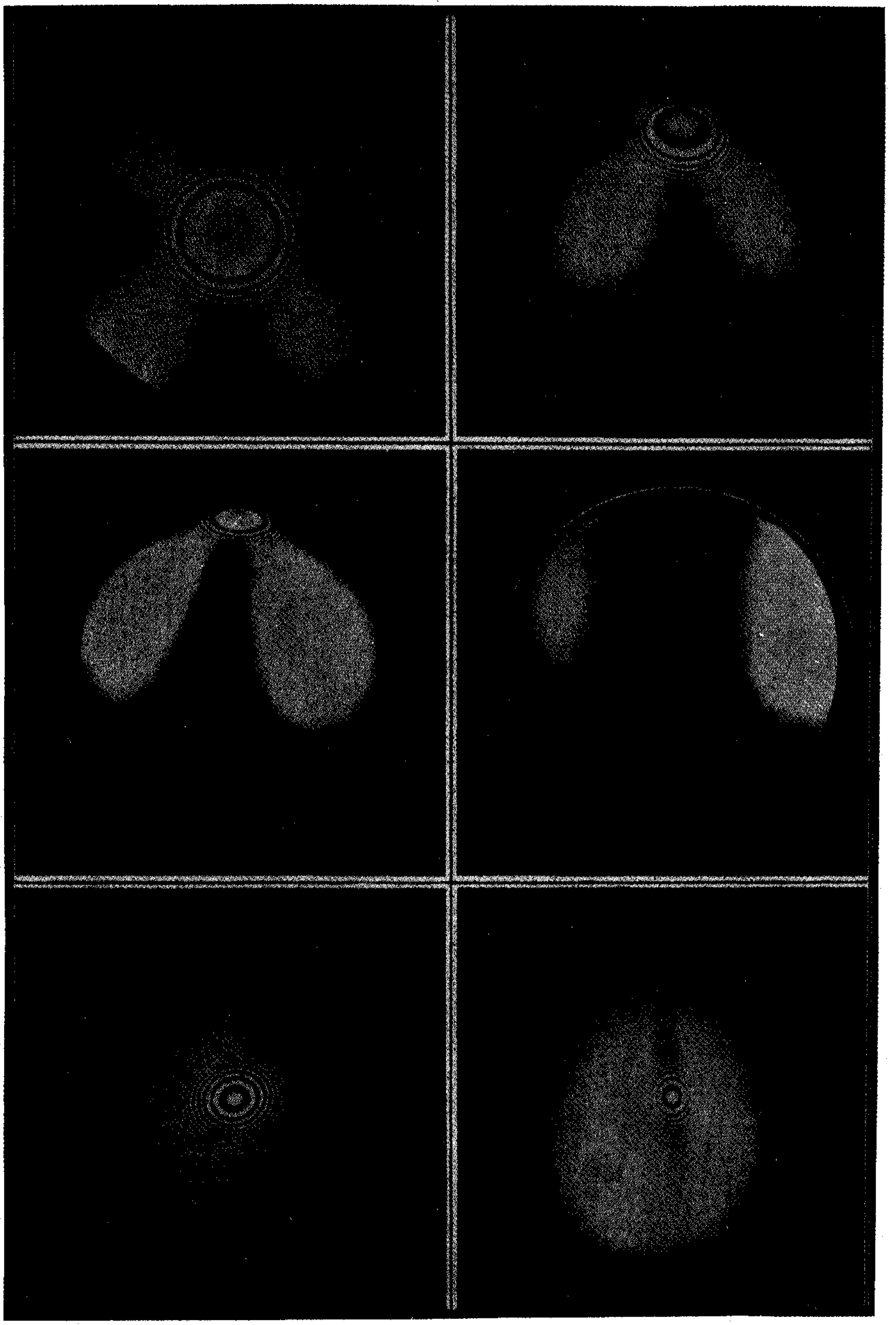
Figure 4 in plate II is of special interest. It was recorded when the optic axis of the quartz sphere was set accurately parallel to the vibration direction of the polariser, the analyser also being accurately crossed with respect to it. It will be seen that the rings have not vanished even in this critical setting, but are faintly visible. Their visibility may be ascribed to the non-extinction of the transmitted light consequent on the optical activity of quartz in a direction transverse to the optic axis.

Figure 1 in plate VI represents Brewster's brushes as exhibited by iolite without any polariser or analyser. Similar brushes running parallel to them are also seen in the vicinity of the other axis of single-wave velocity. The other figures in plate VI exhibit the effects of introducing either a polariser or an analyser, or both between the source of light and the eye of the observer.

Summary

Light from an extended source traversing a sphere reaches foci lying on a concentric spherical surface of a larger radius determined by the refractive index. Hence, if the incident light be polarised and the sphere is viewed through an analyser, the interferences arising from the birefringence of the material are focussed by the sphere itself on such concentric surface and rotate with the sphere when the latter is rotated. Photographs of such patterns in typical cases are reproduced.

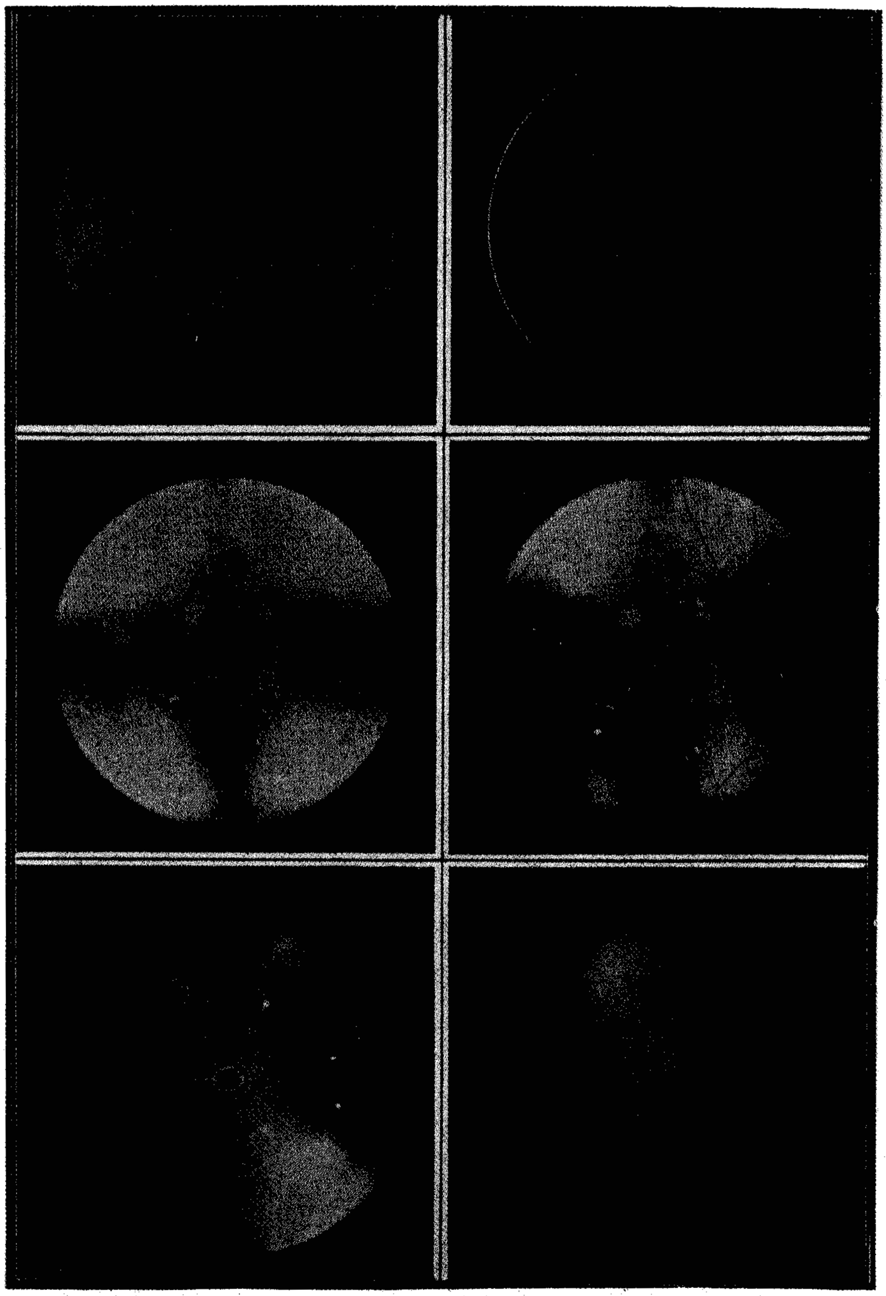
(1) (2) (3) (4) (5) (6)



Figures 1–6. Birefringence patterns of quartz sphere.

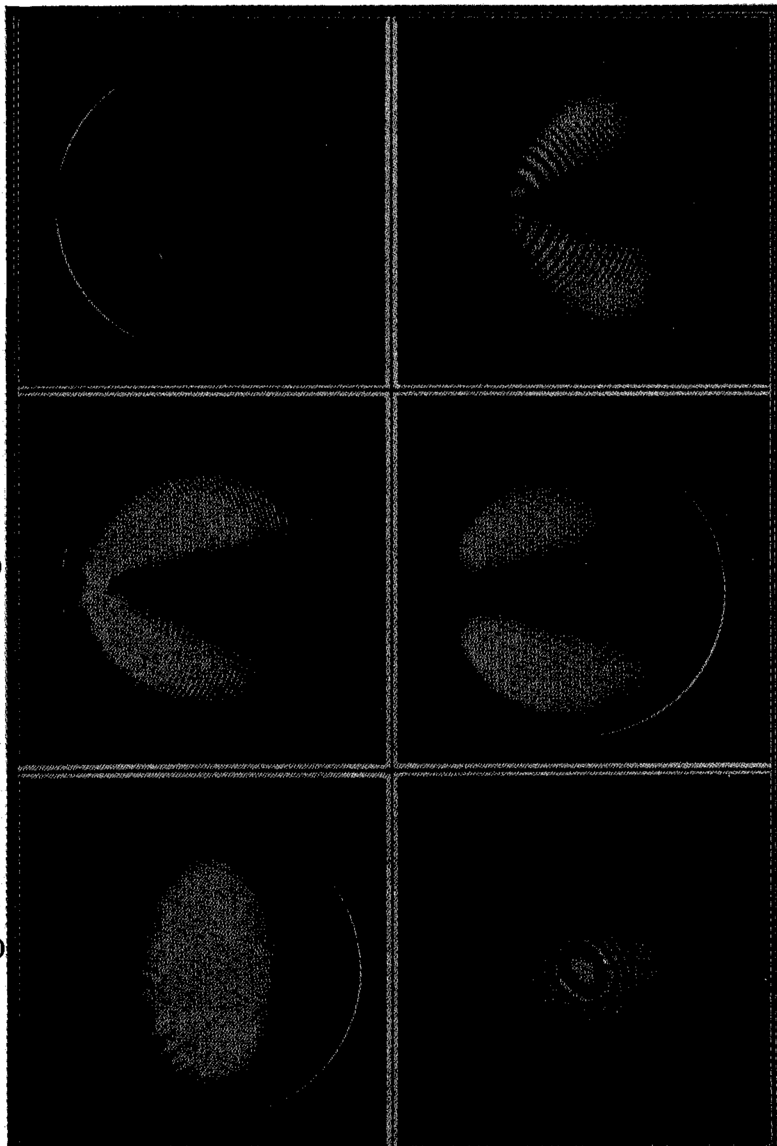
Plate I

(1) (2) (3) (4) (5) (6)



Figures 1–6. Birefringence patterns of quartz sphere.

Plate II

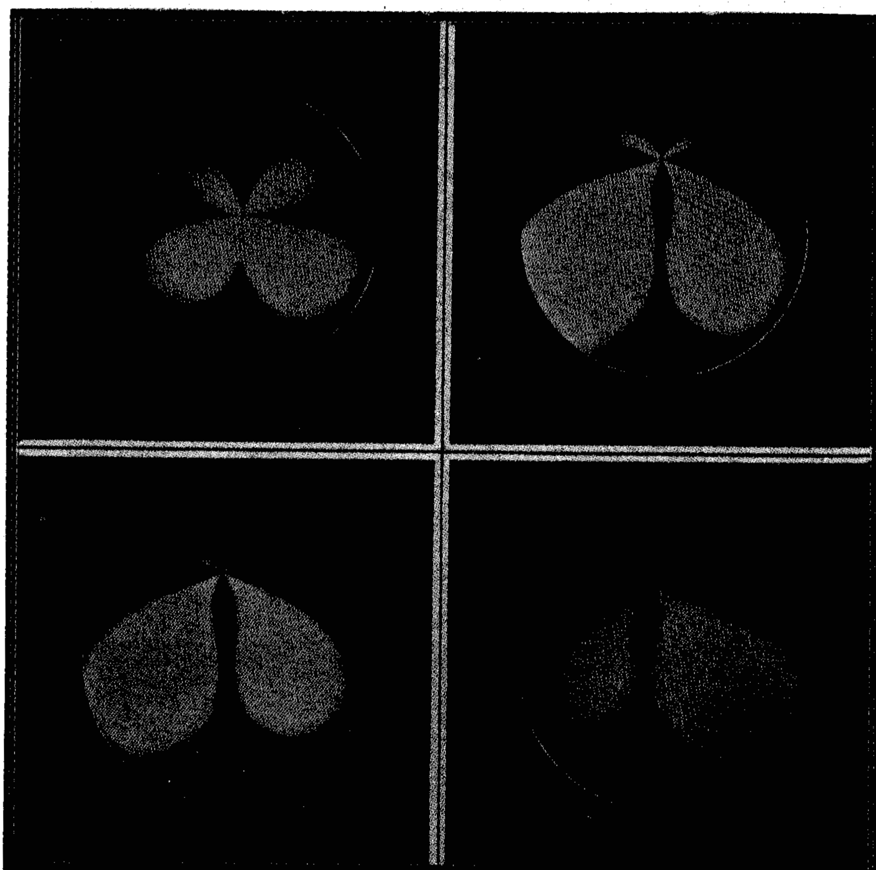


(1) (2) (3) (4) (5) (6)

Figures 1–6. Birefringence patterns of beryl sphere.

Plate III

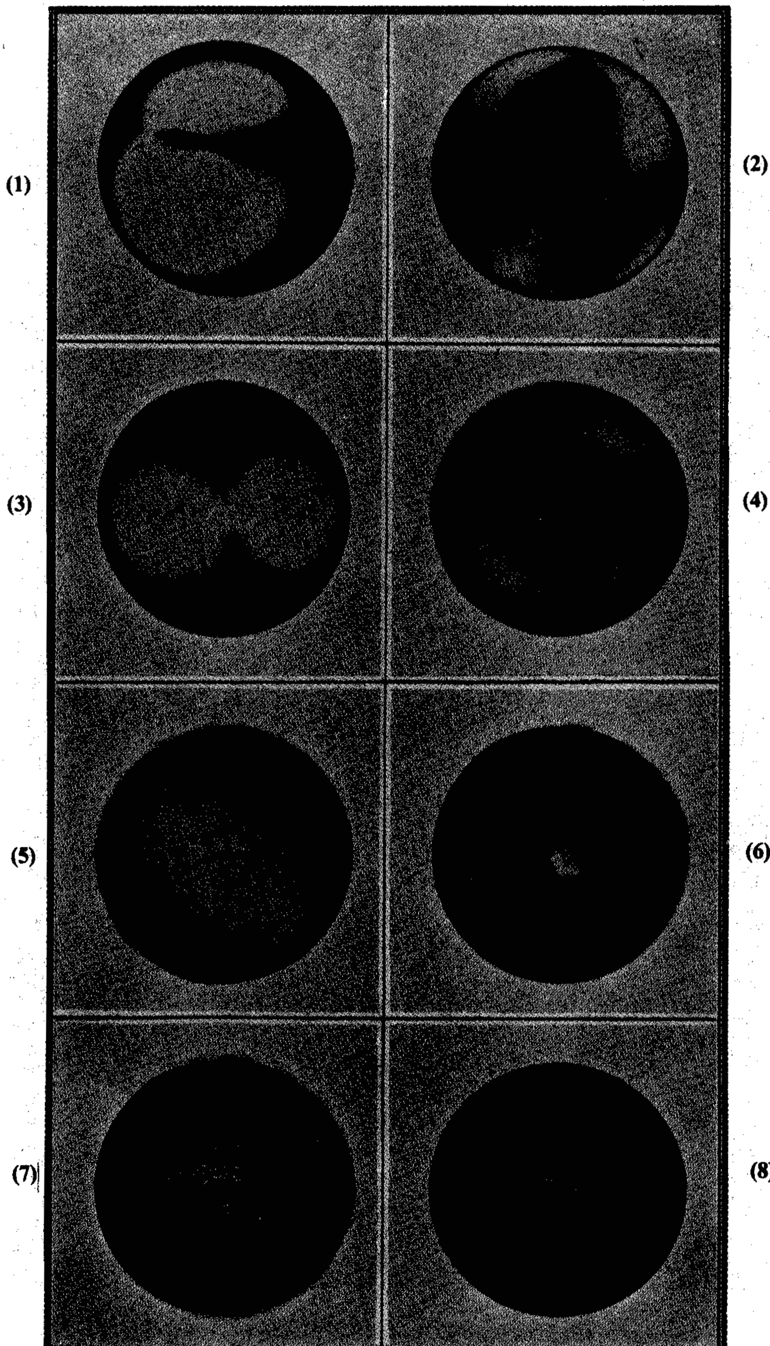
(1) (2)



(3) (4)

Figures 1–6. Birefringence patterns of calcite sphere.

Plate IV



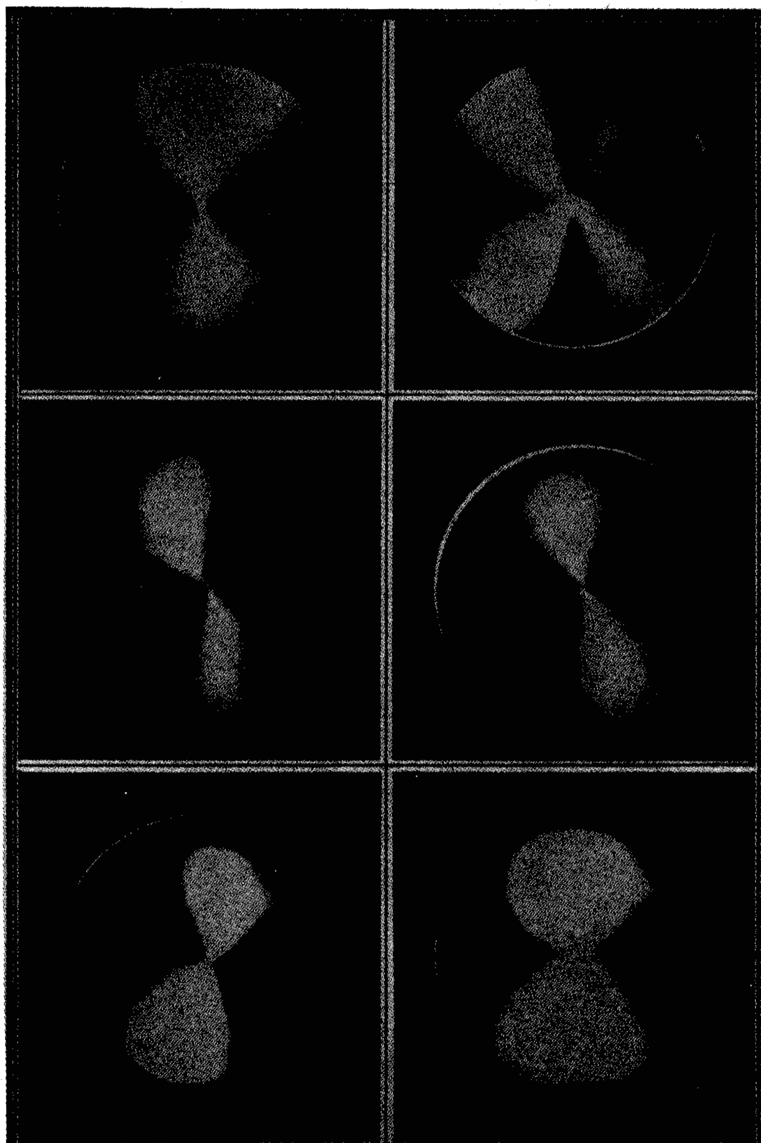
Figures 1–8. Birefringence patterns of topaz sphere.

Plate V

(1) (2)

(3) (4)

(5) (6)



Figures 1–6. Birefringence patterns of iolite sphere.

Plate VI