ART. IV.—*A Simple Model for Illustrating the Symmetry of Crystals*; by ALEXANDER H. PHILLIPS.

For several years past I have been using in my class work a model, of very simple construction, to illustrate the symmetry of the various types of crystals. It has been very helpful and

FIG. 1.

most effective in simplifying some of the points in crystallography, which have always seemed most difficult for the ordinary student to grasp without a demonstration.

The model as shown in the figure is constructed of a horizontal disk of tin, representing the plane of the lateral axes or the equator, in the equatorial types. At right angles to this disk and at right angles to each other are two semicircular disks; these three planes divide space in the northern hemisphere into the usual four quadrants, as in those systems in which the axes are at right angles and represent the axial or diametral planes, the intersections of which will represent the axes $a : b : c$. At the center of the model a socket is cut in the

stand and holes in the disks, large enough to allow easy motion to a lead ball, of an inch and a half in diameter, which forms a universal joint; into this lead sphere a knitting needle of proper size is set in the direction of the radius and upon the end a small card, P, is placed which represents the position and inclination of the crystal face under consideration. The lead ball being so much heavier than the needle, the pole may be placed in any position whatever within the quadrant and remain stationary.

At *b*, the vertical disk is not soldered to the equatorial disk, but a slot is cut wide enough to allow the pole to pass to the right back quadrant. The pole thus, in the prism zone, has a range of 180 degrees and any face in this zone may be represented by the pole. There is a similar slot at *c*, which allows the pole to pass from the right to the left front quadrants, allowing a range of 180 degrees in each dome zone. The only quadrant not accessible to the pole is the back left. The right front quadrant is lined with mirrors, which represent planes of symmetry; by placing the pole in the required position any crystal face is represented, and if wished, a card may be cut and placed in the mirrors, when the exact shape of the form will be reflected. The model in the figure represents the holohedral orthorhombic class; with the pole in any position within the quadrant, not in contact with a mirror, will represent a pyramid, as the eight reflected poles may be counted, representing the eight possible faces of the form. When the pole is moved in contact with one of the mirrors (the lead ball should be placed a little eccentric in favor of the octant in which the mirrors are placed to permit of this), it will be seen that two poles will be in contact, indicating that two faces of the most general form, the pyramid, will coincide, yielding a form of four faces, a dome or prism, according to the position of the pole.

When the pole is placed in any one of the three angles of the octant, it will be seen that four of the eight poles of the pyramid coincide forming the pinacoids of two faces, which are also shown as fixed in forms, as there is but one position for the pole in the angle.

For the tetragonal system an intermediate mirror may be placed at 45 degrees to the one containing the crystallographical axes; the ditetragonal pyramid will be reflected by the mirrors, when a card is placed between them, as in the figure, and 16 poles may be counted. For the hexagonal system the intermediate mirror is placed at 30 degrees, when 24 reflections may be counted. For the isometric system three pieces of tin are cut and soldered at their intersection, the trigonal axis of the system, so as to divide the octant symmetri-

cally into eight similar triangles, representing the six diagonal planes of symmetry of the system, three of which are represented in an octant. If when this set of three planes is placed in the octant, one of the six triangular spaces is lined with mirrors and the pole placed within it, 48 reflections may be counted or the hexoctahedron is illustrated. The remaining six forms may be represented by placing the pole in the six possible positions, the three sides and the three angles of the triangle.

If desired, the disks may be graduated and marked off in degrees, when any particular dome or prism may be illustrated.

The model is also most convenient for illustrating the method of the two-circle goniometer, as the equatorial disk represents the vertical circle of the instrument and the vertical disk of the model the meridian of reference. The relation of the two angles measured on the instrument, to the pole of the face, is simply shown in the model, as one corresponds to the longitude and the other to the complement of the latitude.

In the gnomonic projection the plane of projection would be tangent to the two vertical disks of the model at c , and the intersections of these two disks with this plane would be the lines along which the two angular coördinates x and y of any face is measured; the face being represented by the point of intersection of the pole with this tangent plane. The trigonometrical relations of the coördinates x and y , the point representing the face and the two angles measured on the goniometer, cannot be more simply demonstrated than by this model.

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