ART. XXXVII.—*A method of Giving and of Measuring the angles of Crystals, for the determination of species, by the use of the Reflecting Goniometer; by JOHN M. BLAKE.*

It seems desirable that more general use should be made of angular measurements of crystals for the purpose of determining species, than the ordinary methods of measurement and comparison will allow.

The time and study required to understand the various forms of symbols adopted by different authors, and then to locate the planes on the given crystal before making the measurements, make the pursuit of the subject in this way a difficult matter, even to those who have spent considerable time in the study.

Now it is possible to describe a crystal, giving measurements which will locate every plane occurring upon it, without the use

of symbols having reference to any system of crystallization. By thus making the measurement of a crystal, simply a mechanical operation, this description will be sufficient to determine again the same species, so far as it can be done by angular measurement of the planes.

The method consists in taking advantage of the existence of certain natural laws, which determine the arrangement of the planes upon a crystal into zones; and noting the angular distance of each plane in a zone, from one of them fixed upon as the starting point; this to be done by simply giving the goniometer-reading for each plane; and, further, binding all of the measured zones together by noting a sufficient number of their points of intersection.

Since a zone is a number of planes making parallel intersections with each other, if we adjust any two of the planes for measurement, we have at the same time adjusted all, and can readily go on and record the reading of the instrument for each plane.

We thus preserve the relative position of the planes, which gives the measurements a value which cannot be attained by the ordinary method of separate measurements, for the location of which we have to depend upon our knowledge of certain symbols.

It can be seen that there is thus a saving of labor, and of space in recording, if we consider that the object in view is to get a *complete* measurement of a crystal.

This measurement of zones may be carried to an extent which convenience will determine for each species. Four or five zones will often include nearly all the planes on a crystal, perhaps all that would be actually needed for the determination of species. To bring in the remainder, to complete the description, it may be best to make separate measurements; or to give only portions of zones, where to give the complete zone would be an unnecessary repetition of what had already been well noted.

To show what can be done by this method, suppose in the case of sulphate of copper, ($\text{CuOSO}_4 + 5\text{HO}$) each plane to have its opposite, there will be more than twenty-eight planes upon a complete crystal.

All of these planes can be brought into three zones intersecting in a common plane (*b*, of Rammelsberg).

It will be necessary to add a fourth zone, crossing the others, to bind them together and make the description complete. The species, sulphate of copper, is selected, because it belongs to the triclinic system of crystallization, and therefore it might be considered more difficult of description than the average of species, and the remeasurement of a crystal for comparison, an op-

eration requiring considerable patience, to say the least; but by the use of this method it becomes in either case a comparatively easy operation.

If, from the description, the angle be required between any two planes lying in one of the measured zones, it can be readily obtained by subtraction. But if the planes do not both lie in one of the measured zones the angle can be found by means of spherical trigonometry, without taking into consideration symbols or axes.

The prismatic zone in elongated crystals would be the first to measure, because best developed.

We can start with the zero of the instrument opposite the largest plane if we have no other guide.

The other zones may be taken in the order in which they appear best developed. Some order is desirable to facilitate the use of the description for future comparisons.

In using the description for determining species, after measuring the most obvious zones on the crystal, we can plot them on paper and turn the protractor until the readings coincide with the description.

The plotting is necessary only when there is difficulty in making the comparison, on account of the zero of the instrument not having been brought opposite the plane used in the description.

When we have found a coincidence of readings for a zone we have determined all the planes in the zone; also the symbols, if given in the description.

In this way, with a description in this form, we can speedily determine all of the given planes which occur upon the crystal before us; also if there are any new planes.

Care should be taken not to confound right and left hemihedrism, or similar non-superposable forms, which is liable to be done if we do not note the relative position of at least three planes, not in one zone. In case a drawing is given, this will not be necessary.

The use of this method gives us a great advantage in detecting and measuring accurately very small planes and cleavages, which, were it not for the fact that they come into the zones, could not be adjusted for measurement on account of the feeble reflection which they give.

Note.—Direct sunlight is of great value in detecting and measuring small planes: the light may be tempered by means of smoked glass.

For convenience in approximate adjustment when using a Wollaston's goniometer of the usual form, and to make it possible to measure entirely around a crystal, it will be found an advantage to mount the crystal at the extremity of a lead wire, of three or four centimeters in length, and for most crystals one millimeter in diameter.

A method for the rapid and easy adjustment of a crystal for measure-

ment, in the Wollaston goniometer is, first, to bring one plane parallel to the motion of the joint between the two L's, so that motion of this joint will not affect the reflected image, and then to use for adjusting this plane only the motion of the rod carrying the crystal, while, for adjusting the other plane, motion of the joint only is to be used. By observing these points, from two to four movements only will be required to obtain perfect adjustment; while if we neglect them there are certain positions in which the planes may lie with reference to the adjusting motions, which will make the adjustment a tedious operation.

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