PLATE 17.

TABLE SHOWING THE SYMMETRY OF CRYSTALS

PREPARED BY J.E. POGUE – 1915.

Axes of symmetry: ⬢ Hexagonal; ■ Tetragonal; ▲ Trigonal; ⬬ Binary

System	Class (32 in all, 18 important)	Center of Symmetry	Planes of Symmetry: Axial: Vertical	Planes of Symmetry: Axial: Horiz'tal	Planes of Symmetry: Diagonal	Axes of Symmetry	Symmetry of Crystallographic Axes: a-Axis	b-Axis	c-Axis
Isometric	Normal	1	2	1	6	3 ■ 4 ▲ 6 ⬬	■	■	■
	Pyritohedral	1	2	1		3 ⬬ 4 ▲	⬬	⬬	⬬
	Tetrahedral	0			6	3 ⬬ 4 ▲	⬬	⬬	⬬
Tetragonal	Normal	1	2	1	2	1 ■ 4 ⬬	⬬	⬬	■
	Sphenoidal	0			2	3 ⬬	⬬	⬬	⬬
	Tri-Pyramidal	1		1		1 ■			■
Hexagonal	Normal	1	3	1	3	1 ⬢ 6 ⬬	⬬		⬢
	Tri-Pyramidal	1		1		1 ⬢			⬢
	Hemimorphic	0	3		3	1 ⬢			⬢
Trigonal	Normal	1			3	1 ▲ 3 ⬬	⬬		▲
	Hemimorphic	0			3	1 ▲			▲
	Tri-Rhombohedral	1				1 ▲			▲
	Trapezohedral	0				1 ▲ 3 ⬬	⬬		
Orthorhombic	Normal	1	2	1		3 ⬬	⬬	⬬	⬬
	Hemimorphic	0	2			1 ⬬			⬬
	Sphenoidal	0				3 ⬬	⬬	⬬	⬬
Monoclinic	Normal	1	1			1 ⬬		⬬	
Triclinic	Normal	1							

TABLE OF SYMMETRY FOR THE MORE IMPORTANT CRYSTAL CLASSES.

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A LABORATORY METHOD OF TEACHING ELEMENTARY CRYSTALLOGRAPHY

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IN spite of its apparent complexity, elementary crystallography is fundamentally simple, and may be successfully presented to college sophomores if taken up gradually and in a logical way. In connection with a course in elementary mineralogy given by the writer at Northwestern University from 1914 to 1917 the plan outlined in the following pages was found to be practical and satisfactory. It is published in the hope that it may be found useful to others called upon to teach the subject.

Twelve lecture periods of fifty minutes each, and twelve two hour laboratory periods, were devoted to crystallography in the writer's course. The laboratory was provided with a set of wooden crystal models and a collection of well developed natural crystals; and a quantity of report blanks, headed as shown below, but with type about twice as large as that here used, the whole sheet being about 9 by 11 inches.[1]

CRYSTALLOGRAPHY REPORT

Tray............ Name.............................

No.	SYMMETRY								SYSTEM	CLASS	FORMS	
	Center	PLANES			AXES						Symbol	NAME
		Axial		Diagonal	Faces	Edges	Vertices					
		Vertical	Horizontal									

[1] This blank was modeled after that used by Dr. Edgar T. Wherry at Lehigh University.

Each student is required to have a note book, ruler, pencil, piece of cross-section paper, piece of cardboard, and a suitable elementary text-book. To each is furnished, also, a blue-print of the table of symmetry (see frontispiece), and mimeographed copies of the two sets of directions, given herewith. Students who conscientiously followed these directions were able at the close of the course to work out almost any crystallographic form and axial ratio of reasonably simple relationships.

DIRECTIONS FOR WORKING OUT AN UNKNOWN MODEL OR CRYSTAL

(Practice with known models and then with unknown models until these directions are thoroly understood.)

I. Work out the complete symmetry of the unknown, listing your findings on a report blank. Make your examination as follows (referring to textbook for definitions):

(*a*) Look for a center of symmetry. If present, every face, edge, and vertex has an *opposite, similar* one.

(*b*) Examine *each* face, edge, and vertex in turn to see if an axis of symmetry passes thru it. Your eye quickly detects an axis of symmetry if you look directly at the point of its emergence. To determine the character of an axis of symmetry, look squarely at it and either (1) note whether faces, edges, and points are disposed about it in pairs, threes, fours, or sixes, or (2) rotate the model upon this axis and observe how many times the appearance repeats during one revolution.

(*c*) With a piece of cardboard, note how many planes can be found that will divide the model into two halves, each of which is the *mirror-image* of the other. List these planes according to whether they are vertical, horizontal, or diagonal when the model stands oriented.

Note 1.—You can train yourself to show great facility in determining symmetry. In many cases, the eye catches the symmetry instantaneously.

Note 2.—Be careful not to count some of the elements of symmetry twice.

II. Refer to *Table of Symmetry*. Consider the total symmetry as listed for the unknown and locate its place in the table. This gives the crystal system and class of the unknown.

III. Orient the unknown. This may best be done by observing

(*a*) The position in the unknown of axes that correspond in symmetry to the symmetry of the crystallographic axes (the symmetries of the crystallographic axes are shown in the *Table of Symmetry*).

(*b*) The position of vertical planes of symmetry when such are also axial planes; *i. e.*, pass thru two axes.

(*c*) The position of a horizontal plane of symmetry, if present. Such a plane passes thru the horizontal crystallographic axes.

(*d*) The elongation of the unknown gives a clue to its orientation; for crystals are usually elongated along the c-axis.

Note 1.—Some crystals (isometric) are not elongated (are equi-dimensional).

Note 2.—Some crystals are elongated at right angles to the c-axis.

IV. Determine the forms present on the unknown, giving the name and symbol for each, as follows:

(*a*) Hold the model oriented.

Example: If isometric, the *c*-axis must be vertical, the *a*-axis pointing toward observer, and the *b*-axis at right angles to observer.

(*b*) Take up the largest and most prominent form first. Examine its face that lies nearest to your right (such a face will yield indices without minus signs). Note the slope of this face toward the imaginary crystallographic axes (extended if necessary). The intercepts of the face on the axes give the cutting-ratio or parameters of the face. Convert these parameters into indices. If necessary look in the book to see what form corresponds to the indices found.

Note 1.—If the form is complicated it may be necessary to lay a thin piece of cardboard on the face and note its inclination.

Note. 2—It is often advantageous to hold the model, *oriented and centered*, over cross-section paper upon which a plan of the crystallographic axes has been drawn. Then the cutting-ratio of the face may be determined graphically *on two axes at the same time* either by means of a piece of cardboard (see Note 1) or by laying a pencil on the paper so as to parallel the slope of the face and then rolling the pencil until it cuts one of the two axes at unity.

Note 3.—A simple form may often be determined by merely noting the number, shape, or disposition of its faces.

Note 4.—Remember that unless the unknown belongs to the isometric system, its axes are not all similar in length. Make allowance for this in estimating the parameters of a given face.

Note 5.—Of several forms the simplest is always assumed to be the *unit* form (the form whose cutting lengths, as shown in the indices, are unity, 1; for example, (111) is a unit pyramid; (221) is not.

Note 6.—Very complicated forms can only be approximately determined by these methods.

(*c*) Take up the form next in prominence and proceed as under (*b*).

Note 1.—Each form is to be treated as if it occurred alone; the presence of other forms does not affect its relations to the crystallographic axes.

Note 2.—When three or more faces intersect in parallel lines these faces are said to occur in a *zone*. Look for zonal arrangement of faces; all faces in the same zone have a simple relation one to the other.

Example: Tetragonal	prism	2d order	—(100).
"	pyramid	" "	—(101).
"	base		—(001).

(*d*) Take up the form third in prominence, and so on until all the forms are determined.

V. Observe that the Trigonal System of the *Table of Symmetry* is the Rhombohedral class of the Hexagonal System as given in some textbooks.

(*To be concluded*)