# USE OF THE CAMERA LUCIDA IN CRYSTAL DRAWING*

WALLACE M. AND JOSEPHINE W. McNABB
*Chemistry Department, University of Pennsylvania, Philadelphia, Pa.*

## INTRODUCTION

In publications referring to the use of the gnomonic projection of V. Goldschmidt (1) for the drawing of crystals, no mention has been made of the application of the camera lucida in conjunction with this method. In the construction of a drawing of an ideal crystal the dimensions may be made to correspond to the symmetry of the class to which the particular crystal belongs. However, if a drawing is desired which will reproduce the actual distortion of a typical crystal, the personal judgment of the individual worker must be relied upon to portray the exact condition, and therefore the accuracy of the drawing may vary in each case. The camera lucida attached to a stereoscopic microscope focused on the crystal in a certain position, as herein described, permits a tracing to be made of the edges between the various faces on the crystal, and with this sketch used as the basis for the orthogonal drawing as it is made from the gnomonic projection, errors due to judgment of the individual are entirely eliminated.

## DIRECTIONS FOR USE OF THE CAMERA LUCIDA

In the orthogonal projection, as it is constructed from the gnomonic projection, all edges appear parallel that are parallel on the crystal when the position of the eye is considered to be at infinity and vertically above the crystal. These conditions are also fulfilled in a camera lucida drawing when the crystal is brought in the following position. The crystal to be drawn is mounted on white paper and held so that the lower end is embedded in a small amount of wax. It is placed on the stage of a binocular microscope and the crystal is moved into a position so that its vertical axis coincides in direction with the focal field of the right tube of the microscope, the camera lucida being attached to this tube. This position may be determined by observing the crystal, none of the prism sides should be visible if they are all parallel to the axis of the focal field, and only the top faces of the crystal, as they will appear later in

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the orthogonal drawing, will be seen. The camera lucida must be adjusted so that the angle through which the image is reflected to the drawing board is 90°. (The tubes of the stereoscopic microscope are slightly inclined, but this inclination is not sufficient to distort the image, within the limits of magnification conveniently used, as may be demonstrated by actual measurement of camera lucida tracings of divisions of a stage micrometer placed in different positions on the microscope stage.)

The top and bottom portions of the crystal are sketched separately. It is necessary to remount the crystal to sketch the bottom. Of the two drawings, one is reversed, the other is superimposed in the proper position, and they are held up against a window pane where the bottom faces may be drawn in with dotted lines, thus producing a perspective drawing. The last drawing is then placed in the correct position beside the gnomonic projection, the position being determined by the direction of the edges between corresponding faces and poles. The direction of the edge between two faces in an orthogonal projection is at right angles to the zone line containing the poles of the faces in a gnomonic projection. Each edge of the camera lucida drawing of the crystal is checked and any slight errors made in drawing the lines are corrected; the direction as indicated by the gnomonic projection being considered more accurate. If a small face on the crystal has been inadvertently omitted in making the camera lucida sketch, the drawing will fail to check with the gnomonic projection. Thus the final drawings must contain all faces as they appear on the actual crystal. It is necessary to make a camera lucida drawing only of the top and bottom of the crystal, as the proportions in the parallel perspective drawing follow from the orthogonal plan. However, the length of one prism edge must be marked off, using the camera lucida, if the correct length of the crystal is desired in the parallel perspective drawing. Details of the standard procedure used in making drawings from the gnomonic projection are given by Porter (2).

The size of the crystals to which this combination method may be applied is dependent upon the degree of magnification necessary to give a drawing of proper dimensions. Drawings should be large enough to avoid crowding of the orthogonal plan and thus prevent inaccuracy in the construction of the parallel perspective drawing. Magnifications up to 160 diameters are found to give accurate camera lucida drawings. Above this magnification there is a certain amount of distortion. The method may be applied to crystals from about 0.1 mm. to 1 mm. diameter, a range which includes most artificial crystals.

## Crystal Drawings Demonstrating the Use of the Camera Lucida in Conjunction with the Gnomonic Projection

A gonomonic projection was constructed from average values obtained from the measurement on a two-circle goniometer of 15 crystals of potassium sulphate (Table 1). This was used to check

Table 1.

Potassium Sulphate

Averages obtained from measurement of 15 crystals.

| No. | Form | Symbol | Angles measured | | Angles calculated | |
|---|---|---|---|---|---|---|
| | | | $\phi$ | $\rho$ | $\phi$ | $\rho$ |
| 1, 2 | *b* | 011 | 0°05′ | 29°49′ | 0°00′ | 29°49′ |
| 3, 4, 5, 6 | *c* | 111 | 53°24′ | 43°50′ | 53°42′ | 44°04′ |
| 7, 8, 9, 10 | *d* | 211 | 69°36′ | 58°44′ | 70°15′ | 58°54′ |
| 11, 12 | *e* | 031 | 0°01′ | 59°48′ | 0°00′ | 59°49′ |
| 13 | *a* | 001 | — | 0°00′ | — | 0°00′ |
| 14, 21, 26 | *f* | 120 | 33°25′ | 90°00′ | 43°15′ | 90°00′ |
| 15 | *g* | 11–20–0 | 36°13′ | " | 37°32′ | " |
| 16, 18, 23, 25 | *h* | 110 | 53°57′ | " | 53°42′ | " |
| 17, 24 | *i* | 100 | 89°59′ | " | 90°00′ | " |
| 19 | *j* | 580 | 40°23′ | " | 40°24′ | " |
| 20, 28 | *k* | 010 | 0°03′ | " | 0°00′ | " |
| 22 | *l* | 340 | 45°34′ | " | 45°37′ | " |
| 27 | *m* | 140 | 19°52′ | " | 18°48′ | " |
| 29 | *n* | 380 | 28°41′ | " | 27°03′ | " |

$p_0=0.7802; q_0=0.5731; a:b:c=0.7346:1:0.5731.$
Groth (6) gives 0.7418 : 1 : 0.5727.

a camera lucida drawing of a typical crystal, in constructing the drawings shown in figure 1. In figure 1 the crystal is magnified 107 diameters, the greatest diameter being 0.45 mm. This demonstrates the use of the method as applied to a crystal with a considerable number of faces.

Artificial crystals of oxalato-tetrammine-cobalti-chloride, prepared by Dr. H. A. Altsentzer, using the method of Jörgensen (3), were recrystallized from water in order to obtain crystals suitable for measurement. The crystals are ruby red in color, belong to the rhombic bipyramidal class and apparently are isomorphous with the oxalato-tetrammine-cobalti-nitrate as described by Jaeger (4). In development they approach very closely the tetragonal system.

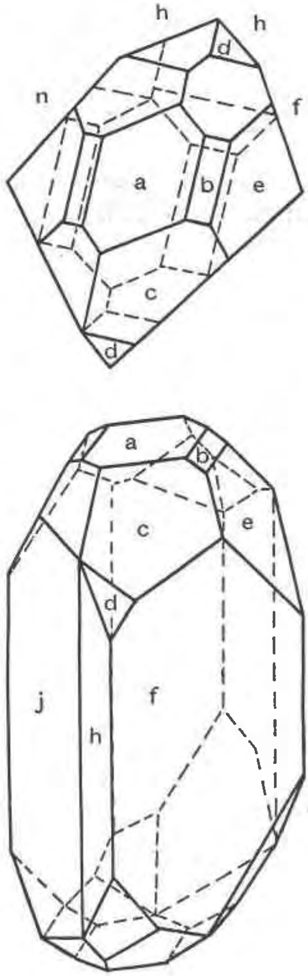


Fig. 1. Potassium sulphate.

Table 2.
Oxalato-Tetrammine-Cobalti-Chloride
Averages obtained from measurement of 12 crystals.

| No. | Form | Symbol | Angles measured $\phi$ | Angles measured $\rho$ | Angles calculated $\phi$ | Angles calculated $\rho$ |
|---|---|---|---|---|---|---|
| 1, 2 | *a* | 011 | 0°13′ | 32°44′ | 0°00′ | 32°41′ |
| 3, 4 | *c* | 101 | 89°59′ | 44°52′ | 90°00′ | 44°53′ |
| 5, 8 | *d* | 010 | 0°03′ | 90°01′ | 0°00′ | 90°00′ |
| 6, 7, 9, 10 | *e* | 110 | 57°06′ | 90°01′ | 57°09′ | 90°00′ |

$p_0=0.9963; q_0=0.6428; a:b:c=0.6458:1:0.6428.$

Average results of measurements obtained from 12 crystals are given in table 2. A gnomonic projection of these results was made on a printed chart (Porter, Oxford Univ. Press) and used in conjunction with the camera lucida drawing. Figure 2 gives an accurate reproduction of a typical crystal. The upper sketch consists of the camera lucida drawings of the top and bottom which are superimposed and then checked with the gnomonic projection. The

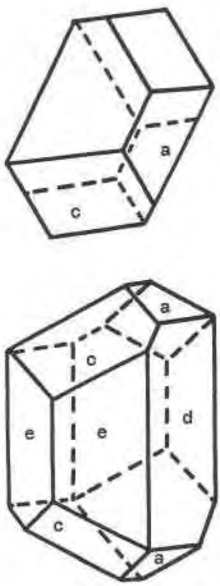


FIG. 2. Oxalato-tetrammine-cobalti-chloride.

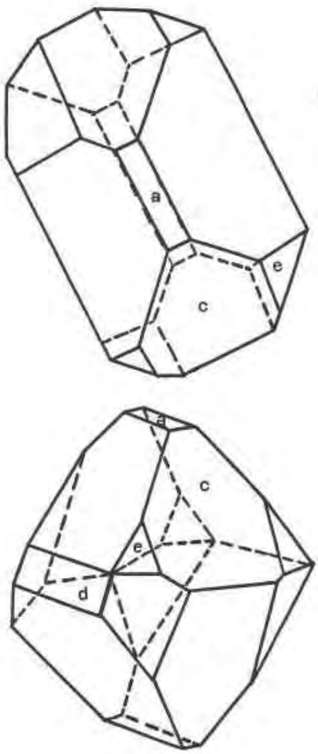


FIG. 3. Hexammine-cobalti-perchlorate.

lower drawing of figure 2 is a parallel perspective made from the above orthogonal plan with the aid of the gnomonic projection. The crystal is magnified 107 diameters in the drawing, the actual size of the crystal being 0.34 mm. at the greatest diameter.

Hexamine-cobalti-perchlorate was prepared by the method used by Wyckoff, Hendricks and McCutcheon (5) who determined its $x$-ray pattern. Average results of the measurement of 12 crystals are given in table 3. The crystals are isometric, amber colored, and show combinations of the cube, octahedron and dodecahedron.

TABLE 3.

HEXAMMINE-COBALTI-PERCHLORATE

Averages obtained from measurement of 12 crystals.

| No. | Form | Symbol | Angles measured | | Angles calculated | |
|---|---|---|---|---|---|---|
| | | | $\phi$ | $\rho$ | $\phi$ | $\rho$ |
| 1 | *a* | 001 | — | 0°00′ | — | 0°00′ |
| 2, 3, 4, 5 | *b* | 112 | 45°05′ | 35°19′ | 45°00′ | 35°16′ |
| 6, 7, 8, 9 | *c* | 111 | 45°00′ | 54°42′ | 45°00′ | 54°44′ |
| 10, 12 | *e* | 021 | 0°02′ | 63°26′ | 0°00′ | 63°26′ |
| 11, 13 | *e* | 201 | 89°59′ | 63°26′ | 90°00′ | 63°26′ |
| 14, 15, 16, 17 | *d* | 110 | 44°59′ | 90°03′ | 45°00′ | 90°00′ |

$a:b:c = 1:1:1$

Figure 3 is a drawing of a typical crystal using the camera lucida and gnomonic projection. The crystal is magnified 54 diameters, the actual size of the crystal being 0.93 mm. at the greatest diameter.

## SUMMARY

A method for drawing typical crystals accurately is described. The method combines the use of the camera lucida and the gnomonic projection; a camera lucida drawing being used as the basis of the orthogonal plan.

The method is especially applicable to artificial crystals, the size conveniently used being about 0.1 mm. to 1 mm. in diameter.

Oxalato-tetrammine-cobalti-chloride crystals are ruby red and belong to the rhombic bipyramidal class. The axial ratio is: $a:b:c = 0.6458:1:0.6428$.

Hexammine-cobalti-perchlorate crystals are amber colored and isometric. Combinations observed were: cube, octahedron and dodecahedron.

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