CRYSTALLOGRAPHY OF CAESIUM MOLYBDO-TELLURATES

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Summary

Caesium molybdo-tellurate crystals are of two types: (1) equant, biaxial positive, (2) tabular, biaxial negative. Both types are triclinic, apparently holohedral.

The positive salt has the following axial elements: $a:b:c=0.9498:1:0.6059$, $\alpha=96°41'$, $\beta=102°1'$, $\gamma=101°31'$. Variable habit. Refractive indices: $n_\alpha=1.709$, $n_\beta=1.716$, $n_\gamma=1.797$. $2V=34°$. $r<v$, weak.

The negative salt has the axial elements: $a:b:c=0.9365:1:0.7989$, $\alpha=93°45'$, $\beta=94°8'$, $\gamma=88°21'$. Constant habit, tabular on $\{1\bar{1}0\}$. Refractive indices: $n_\alpha=1.669$, $n_\beta=1.734$, $n_\gamma=1.738$. $2V=30°$. $r>v$, strong.

The two types of crystals show a tendency towards homeomorphism.

The Barker classification angles are given.

Introduction

The present paper is part of the crystallographic study of a series of alkaline molybdo-tellurates.[1] The chemical study of these compounds is being carried on by Professors V. M. Meloche (Wisconsin) and S. R. Wood (Oklahoma Agricultural and Mechanical College). Their results will appear in the *Journal of the American Chemical Society.*

Our thanks are due to Dr. Wood, who prepared the crystals necessary for this investigation. The batch of crystals that he sent us were recrystallized from their aqueous solution and we found that two distinct crystal species were thus obtained. Both belong to the triclinic system but they differ in optical character and crystal habit. One type is biaxial positive, with rather equant crystals; the other is biaxial negative, with crystals showing a thin tabular habit. In our preparations crystals of the first type largely predominate.

First Type of Crystals: Equant, Biaxial Positive

General

This first type of crystals separates fairly easily from an aqueous solution, along with crystals of the second type.

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[1] Previous papers: Haüy-Bravais lattice and other crystallographic data for sodium molybdo-tellurate: *Am. Mineral.*, vol. **18**, pp. 227–47, 1933. Angles paramétriques de Barker dans une série cristalline homéomorphe: *Annales Soc. géol. Belgique*, vol. **57**, B 39–52, 1933. Ammonium and potassium molybdo-tellurates, two homeomorphous orthorhombic substances: *Proc. Nat. Acad. Sci.*, vol. **20**, pp. 327–35, 1934. Crystallography of lithium molybdo-tellurate: *Am. Mineral.*, vol. **21**, pp. 125–27, 1936. Crystallography of ammonium molybdo-ditellurate: *Am. Mineral.*, vol. **21**, pp. 250–57, 1936.

The crystals are small, averaging 1 to 2 millimeters in their greatest dimension. They are colorless, translucent to transparent, usually well developed, with fairly plane faces and splendent vitreous to adamantine luster. No cleavage, parting, or twinning was observed. The crystals are brittle, with uneven fracture.

Form

The crystal system is triclinic, the class apparently holohedral (pinacoidal) $C_i = \bar{1}$.

Axial elements: $\breve{a}:\bar{b}:\acute{c} = 0.9498:1:0.6059$, $\alpha = 96°41'$, $\beta = 102°1'$, $\gamma = 101°31'$; $A(010:001) = 80°30'$, $B(001:100)\,76°14'$, $C(100:010) = 76°40'$.
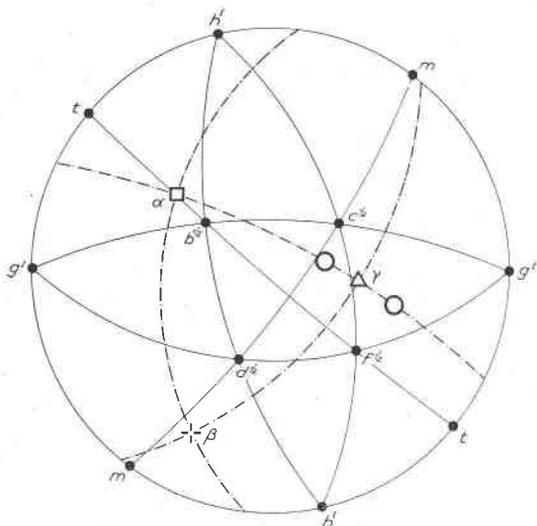
FIG. 1. Stereographic projection of the first type of crystals (biaxial positive).

Eight crystal forms[2] have been observed: $m\{1\bar{1}0\}$, $t\{110\}$, $b^{1/2}\{\bar{1}1\bar{1}\}$, $c^{1/2}\{\bar{1}11\}$, $g^1\{010\}$, $f^{1/2}\{111\}$, $d^{1/2}\{1\bar{1}1\}$, and $h^1\{100\}$. Of these the first six are always present, $d^{1/2}$ is common, h^1 is rather rare. On many crystals the two parallel faces of the same form are unequally developed (for instance: $c^{1/2}$, t, g^1); on some, one of the two is missing altogether (forms $d^{1/2}$ and h^1, especially the latter). The form g^1 shows faint striations parallel to the vertical edge [001].

Three form combinations have been encountered: (1) the first six forms alone; (2) the same with $d^{1/2}$; (3) the same with $d^{1/2}$ and h^1.

A stereographic projection is given in Fig. 1.

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[2] The Lévy form-notation is used in conjunction with the Miller symbols.

Habit

The crystal habit is very variable, hence the insuperable difficulty to list the forms according to decreasing importance. In a general way, the crystals are always more or less equidimensional, somewhat flattened or elongated in different directions. A few crystals are briefly described in order to illustrate the variability of the habit.

(1) Slightly flattened on $m\{110\}$, somewhat elongated along the edge $mt[001]$. Decreasing importance[3] of faces: $\overline{1}10 \cdot (1\overline{1}0 \cdot 110) \cdot \overline{1}1\overline{1} \cdot (11\overline{1} \cdot \overline{1}11$
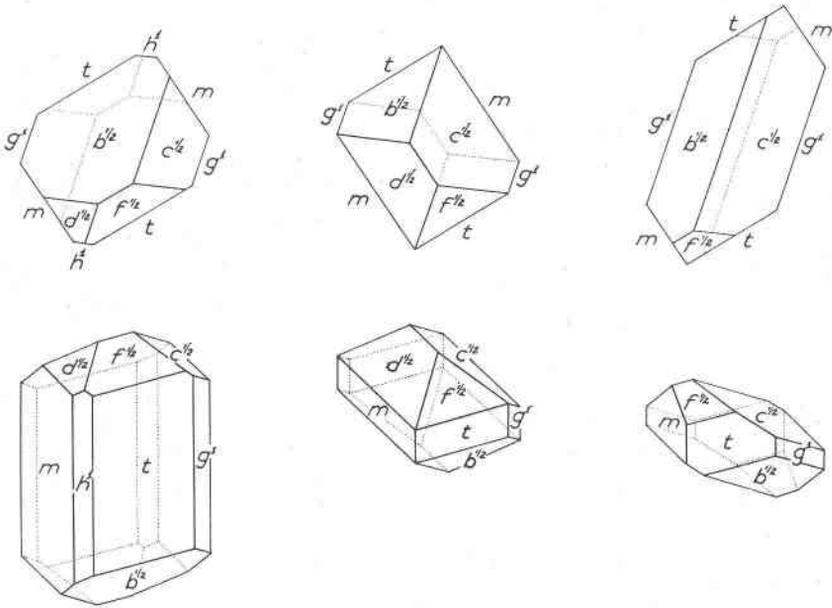
Fig. 2. Some of the habits observed on crystals of the first type (biaxial positive). Orthographic projection, 20° rotation, 20° tilt.

$\cdot 0\overline{1}0 \cdot \overline{1}\overline{1}0) \cdot (111 \cdot \overline{1}\overline{1}1 \cdot \overline{1}11) \cdot 100 \cdot 010 \cdot \overline{1}1\overline{1} \cdot \overline{1}11$. Missing: $\overline{1}00$. The face $m(\overline{1}10)$ is hopper-shaped.

(2) Thick tabular on $c^{1/2}\{\overline{1}11\}$, elongated parallel to the edge $g^1c^{1/2}$ [101]. Decreasing importance of faces: $(\overline{1}11 \cdot 1\overline{1}1) \cdot (\overline{1}\overline{1}1 \cdot 11\overline{1}) \cdot (110 \cdot \overline{1}\overline{1}0)$ $\cdot \overline{1}10 \cdot (1\overline{1}0 \cdot 0\overline{1}0 \cdot 010) \cdot \overline{1}1\overline{1} \cdot 111$. The face $c^{1/2}$ (1$\overline{1}$1) is hopper-shaped.

(3) Very slightly flattened on $g^1\{010\}$, somewhat elongated parallel to the edge $mt[001]$. Decreasing importance of faces: $010 \cdot \overline{1}11 \cdot 1\overline{1}0 \cdot \overline{1}1\overline{1} \cdot 0\overline{1}0$ $\cdot 11\overline{1} \cdot 110 \cdot \overline{1}11 \cdot \overline{1}\overline{1}0 \cdot 110 \cdot (100 \cdot \overline{1}00 \cdot 1\overline{1}1 \cdot \overline{1}\overline{1}1 \cdot 111)$. Missing, $11\overline{1}$.

(4) Very slightly flattened on $t\{110\}$. Decreasing importance of faces:

$\overline{1}10\cdot110\cdot1\overline{1}0\cdot11\overline{1}\cdot\overline{1}11\cdot010\cdot1\overline{1}\overline{1}\cdot\overline{1}11\cdot\overline{1}10\cdot0\overline{1}0\cdot\overline{1}1\overline{1}\cdot1\overline{1}1\cdot\overline{1}1\overline{1}\cdot111\cdot100.$
Missing: $\overline{1}00$. The face $t(\overline{1}10)$ is hopper-shaped.

(5) "Octahedral" habit. Decreasing importance of faces: $(\overline{1}1\overline{1}\cdot1\overline{1}1$ $\cdot1\overline{1}\overline{1}\cdot\overline{1}11)\cdot(11\overline{1}\cdot\overline{1}1\overline{1}\cdot\overline{1}\overline{1}\overline{1}\cdot111)\cdot(1\overline{1}0\cdot1\overline{1}0)\cdot(\overline{1}10\cdot110)\cdot(0\overline{1}0\cdot010)$.

Some of the habits are illustrated by the crystal drawings in Fig. 2.

It should be pointed out that whenever a face is hopper-shaped, the crystal is slightly flattened on that face. The skeletal development may affect any face on which the crystal happens to lie at the bottom of the beaker during growth. It may then be safely inferred that the observed variations of the habit are accidental, in the sense that they are due to the conditions of crystallization. The mere fact that a growing crystal happens to lie on one rather than another face may apparently be sufficient cause to alter the habit that the Law of Bravais would normally require.

Measurements and calculations

Five crystals have been measured on the non-modified one-circle Wollaston goniometer. Although the signal images reflected by the faces were, on the whole, rather distinct, the series of readings are quite widespread (about 40′, as much as 1° in a few cases) and, at best, mediocre.

Only one 4-plane zone is present (g^1mh^1t). The interfacial angles in that zone are among the best obtained. We have followed the method advocated by T. V. Barker[4] for the mutual adjustment of fundamental angles. The angles g^1t (010:110) and g^1m (010:1$\overline{1}$0) have been adjusted by means of the angle g^1h^1 (010:100). These two adjusted values, together with the other three best interfacial angles, were adopted as fundamental.

The calculations were made by the usual methods of spherical trigonometry. The setting adopted for the description of the crystals was arrived at by applying the rules of the Barker method.[5] Since no one setting seemed to be particularly indicated from the morphological point of view, we thought it best to adopt the setting that fits the Barker determinative scheme.

A comparison of measured and calculated angles will be found in Table 1. For each series of measurements, the probable error is given so that the reliability of the mean value can be estimated. The accuracy of the axial elements is discussed later.

[4] Barker, T. V., *Graphical and tabular methods in crystallography*, p. 100, London, Thomas Murby and Co., **1922**.

[5] Barker, T. V., *Systematic crystallography*, London, Thomas Murby and Co., **1930**.

TABLE 1. EQUANT, BIAXIAL POSITIVE CRYSTALS
COMPARISON BETWEEN MEASURED AND CALCULATED ANGLES

$\check{a}:\bar{b}:\check{c}=0.9498:1:0.6059$, $\alpha=96°41'$, $\beta=102°1'$, $\gamma=101°31'$. (Axial elements derived from five crystals)

Number of readings	Probable error	Lévy	Angle Miller	Barker	Measured (mean)	Computed
21	13.8′	g^1t	010:110	bm	39°58′	**39°51′
16	10.9′	g^1m	010:1$\bar{1}$0	bM	126°11′	**125°55
7	8.4′	g^1h^1	010:100	ba	†76°47′	76°40′
18	9.7′	$g^1c^{\frac{1}{2}}$	010:$\bar{1}$11	bp	*59°30′	—
17	11.4′	$g^1b^{\frac{1}{2}}$	010:$\bar{1}\bar{1}$1	bP	*119°12′	—
10	18.2′	$m\,c^{\frac{1}{2}}$	1$\bar{1}$0:$\bar{1}$11	Mp	126° 1′	125°20′
8	23.7′	$m\,d^{\frac{1}{2}}$	1$\bar{1}$0:1$\bar{1}$1	MO	49°55′	49°41′
18	18.4′	$t\,b^{\frac{1}{2}}$	110:$\bar{1}\bar{1}$1	mP	*126°50′	—
12	25.6′	$t\,f^{\frac{1}{2}}$	110:111	mo	38° 7′	37°55
4	15.9′	$t\,c^{\frac{1}{2}}$	110:$\bar{1}$11	mp	80°20′	80°21′
1	—	$t\,d^{\frac{1}{2}}$	110:1$\bar{1}$1	mO	76°–77°	76°13′
1	—	$b^{\frac{1}{2}}d^{\frac{1}{2}}$	$\bar{1}\bar{1}$1:1$\bar{1}$1	PO	61°47′	61°43′

N.B.—The five values marked with either one or two asterisks (* or **) are chosen as fundamental angles. The two values marked with two asterisks (**) are values adjusted by means of the measured angle marked with a dagger (†).

Barker classification angles

The parametral angles necessary in order to identify this substance according to the Barker determinative method have been computed. The Barker form letters are as follows: c(001), r(101), a(100), m(110), b(010), q(011), o(111).

The different combinations of forms observed lead to several solutions.

(1) Two combinations lead to the same setting and orientation.
Transformation: none.
Forms: 1$\bar{1}$0·110·$\bar{1}$11·$\bar{1}$11·010·111·1$\bar{1}$1; 100.
Angles:
cr = 28°33′, ra = 47°41′, **am = 36°49′**, mb = 39°51′, bq = 52°2′, qc = 28°28′.

Remarks: The order of decreasing importance is difficult to ascertain for the first six forms. The forms that precede a semi-colon (or the final period) in the above list are observed combinations.

(2) The combinations of the first six forms leads to one and the same setting with two possible different orientations. This is due to the fact that two angles, which must be compared in order to find the correct orientation, are within 1° of each other (37°55′ and 37°7′). In such a case,

they are to be considered equal, and two entries are consequently worked out.[6] The latter are as follows:

(2a) Transformation: Old to new $= \overline{1}10/\overline{1}10/00\overline{2}$.
    New to old $= \overline{1}10/\overline{1}10/00\overline{1}$.

Forms:
$$\frac{\text{Old:} \quad 1\overline{1}0 \cdot 110 \cdot \overline{1}\overline{1}1 \cdot \overline{1}11 \cdot 010 \cdot 111.}{\text{New:} \quad 0\overline{1}0 \cdot \overline{1}00 \cdot 10\overline{1} \cdot 01\overline{1} \cdot \overline{1}10 \cdot \overline{1}01.}$$

Angles:
cr $= 37°7'$, ra $= 37°55'$, **am $= 36°49'$**, mb $= 49°15'$, bq $= 49°41'$, qc $= 36°19'$.

(2b) Transformation: Old to new $= 002/1\overline{1}0/110$.
    New to old $= 011/0\overline{1}1/100$.

Forms:
$$\frac{\text{Old:} \quad 1\overline{1}0 \cdot 110 \cdot \overline{1}\overline{1}1 \cdot \overline{1}11 \cdot 010 \cdot 111.}{\text{New:} \quad 010 \cdot 001 \cdot 10\overline{1} \cdot 1\overline{1}0 \cdot 0\overline{1}1 \cdot 101.}$$

† Angles:
cr $= 37°55'$, ra $= 37°7'$, **am $= 36°19'$**, mb $= 49°41'$, bq $= 49°15'$, qc $= 36°49'$.

Optical properties

The refractive indices, obtained by the immersion method, are: $n_\alpha = 1.709 \pm 0.003$, $n_\beta = 1.716 \pm 0.002$, $n_\gamma = 1.797 \pm 0.005$. The crystals are biaxial positive. The optic angle $2V = 34°$ (measured on universal stage); the value of $2V$ calculated from the indices is also $34°$. Dispersion: $r < v$, weak.

The optical orientation is difficult to determine. The three axes of the index ellipsoid can be located by measurements on the Fedorov universal stage, but even the smallest crystals that can be handled give too high a retardation to ascertain which is which. Many crystals obtained by recrystallization on a glass slip lie on a face of the form $b^{1/2}\{\overline{1}11\}$, as can be shown by measuring the plane angles between edges. Such preparations are thin enough to permit recognition of the three axes of the indicatrix on the universal stage.

The optic angle $2V$ is measured on fragments of crystals. The elements of the index ellipsoid are plotted on a stereographic projection and their coordinates (longitudes ϕ and colatitudes ρ) are thus determined

[6] In accordance with the general rule proposed by Mr. R. C. Spiller (Oxford University) for the compilation of the Barker determinative index (unpublished memorandum, private communication). It seems desirable that, in the Index, some typographical sign (a dagger, e.g.) precede the list of angles of every additional entry (such as 2b), in which CR is larger than RA, contrary to the usual convention. This would attract the attention of the chemist who is using the Index and would indicate to him that he is dealing with a "freak" entry, not a misprint as he might well think on noticing that CR is greater than RA!

graphically. Longitudes are counted clockwise from the plane normal to $g^1(010)$, taken as zero meridian. The results are as follows:

	ϕ	ρ
α	$218\frac{1}{2}°$	$54°$
β	$116°$	$74°$
γ	$6°$	$41°$
O.A. 1	$15\frac{1}{2}°$	$56\frac{1}{2}°$
O.A. 2	$350\frac{1}{2}°$	$26°$

Remarks on the accuracy of the axial elements

The poor agreement obtained between measured and calculated angles raises the question of the accuracy of the axial elements.

In our calculations we have used as fundamental angles the weighted average of all the readings obtained from five different crystals. Should these crystals belong to an isomorphous series and have slight differences in composition, it is obvious that better agreement would be reached between measured and calculated angles if each crystal were computed separately. We have, therefore, repeated the calculations for the crystal that seemed to yield the most satisfactory measurements.

The results are as follows:

Forms present: $m\{1\bar{1}0\}$, $t\{110\}$, $b^{1/2}\{\bar{1}\bar{1}1\}$, $c^{1/2}\{\bar{1}11\}$, $f^{1/2}\{111\}$, $d^{1/2}\{1\bar{1}1\}$, $g^1\{010\}$, $h^1\{100\}$.

Axial elements: $\breve{a}:\bar{b}:\breve{c}=0.9523:1:0.6092$, $\alpha=96°44'$, $\beta=101°56'$, $\gamma=101°9'$.

Comparison between measured and calculated angles will be found in Table 2.

The agreement is not much better than with the elements calculated from 5 crystals, as a comparison of Tables 1 and 2 will show. It does not seem likely that we are dealing here with crystals of an isomorphous series. The unsatisfactory results obtained can safely be ascribed to the imperfection of the crystals measured.

From the two sets of axial elements calculated here, it can be seen that not more than two decimal places are reliable in the axial ratios (0.95:1:0.61) and that the interaxial angles may be in error by almost half a degree.

The tedious recalculation of the axial elements from fundamental angles obtained from one crystal only, at any rate, has had the merit of emphasizing this point.

$\breve{a}:\bar{b}:\overset{.}{c}=0.9523:1:6092$, $\alpha=96°44'$, $\beta=101°56'$, $\gamma=101°9'$. (Axial elements derived from one crystal only)

Number of readings	Angle		Measured (mean)	Calculated
	Lévy	Miller		
4	g^1t	010:110	*39°59′	—
4	g^1m	010:1̄10	*126°14′	—
2	g^1h^1	010:100	76°58′	77°3′
4	$g^1c^{\frac{1}{2}}$	010:1̄11	*59°19′	—
4	$g^1b^{\frac{1}{2}}$	010:1̄1̄1	*119° 9′	—
4	$m\ c^{\frac{1}{2}}$	1̄10:1̄11	126° 7′	125°37′
2	$m\ d^{\frac{1}{2}}$	1̄10:1̄1̄1	49°51′	49°34′
4	$t\ b^{\frac{1}{2}}$	110:1̄1̄1	*126°53′	—
3	$t f^{\frac{1}{2}}$	110:111	38°22′	37°58′
2	$c^{\frac{1}{2}}d^{\frac{1}{2}}$	1̄11:11̄1	76°16′	76° 3′
2	$b^{\frac{1}{2}}f^{\frac{1}{2}}$	1̄1̄1:111	88°25′	88°55′

N.B.—The angles marked with an asterisk (*) are chosen as fundamental.

SECOND TYPE OF CRYSTALS: TABULAR, BIAXIAL NEGATIVE

General

The second type of crystals separates from an aqueous solution along with crystals of the first type, described in the foregoing sections. We have obtained no batch consisting of only one type of crystals.

The crystals of the second type are slightly larger than those of the first type; their greatest dimension averages 3 millimeters, ranging from 0.5 to 5 millimeters. They are clear, colorless, transparent, usually well developed with fairly plane faces showing good vitreous luster. No cleavage, parting, or twinning. The crystals are fragile, their fracture is irregular.

Form

The crystal system is triclinic; the class, apparently holohedral (pinacoidal) $C_i=\bar{1}$.

Axial elements: $\breve{a}:\bar{b}:\overset{.}{c}=0.9365:1:0.7989$, $\alpha=93°45'$, $\beta=94°8'$, $\gamma=88°21'$; $A=86°22'$, $B=85°58'$, $C=91°23'$.

Seven crystal forms have been observed: $m\{1\bar{1}0\}$, $a^1\{\bar{1}01\}$, $h^1\{100\}$, $i^1\{011\}$, $t\{110\}$, $e^1\{0\bar{1}1\}$, and $^2h\{3\bar{1}0\}$. Of these the forms m, a^1, h^1, and i^1 are always present; t and e^1 are also always observed, but one of the

two faces of the form is missing on several of the crystals examined; the form ^2h has been detected (with one face missing) on one crystal only. Two form combinations can thus be recorded: $m\ a^1\ h^1\ i^1\ t\ e^1$, with or without ^2h. The form m is striated parallel with the edge mt [001].

A stereographic projection is given in Fig. 3.
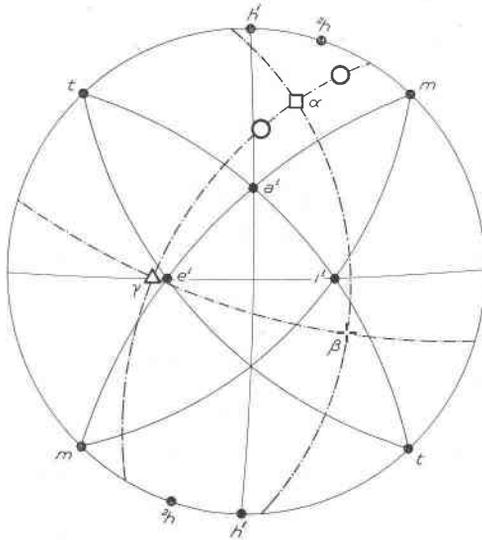
FIG. 3. Sterographic projection of the second type of crystals (biaxial negative).

The Federov symbol for crystals of the second type was kindly determined for us by Mr. W. J. van Weerden (Rijks-Universiteit te Groningen, Holland). It is as follows:

$$4\ o;\ +5\tfrac{1}{2}\ 4$$
$$50\quad 0$$
$$-\tfrac{1}{2}$$

The following transformation enables one to pass from the setting adopted in this paper to the Fedorov setting:

$$\overline{1}00/0\overline{1}0/001.$$

The face symbols in the Fedorov setting are thus obtained by changing the sign of the first two indices in our face symbols.

Habit

The crystal habit is very constant, thin tabular on $m\{1\overline{1}0\}$. The plates are somewhat more elongated along the edge $ma^1[111]$ than along the

edge $mt[001]$. The order of forms, listed according to decreasing size is as follows: m a^1 $(h^1 i^1)$ t e^1; ^2h. The form m is much larger than all others; the forms h^1, i^1, and perhaps t, look equally important; e^1 is a narrow form; ^2h is seen as a rare line-face.

One crystal drawing suffices to illustrate the habit and is shown in Fig. 4.
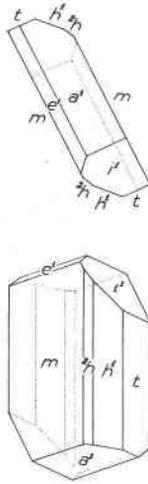
Fig. 4. The constant habit of crystals of the second type (biaxial negative). Orthographic projection, 20° rotation, 20° tilt.

The largest form m generally has one face hopper-shaped as the crystal tends to lie on it during growth.

Measurements and calculations

Half a dozen crystals have been measured on the one-circle goniometer. The readings were, on the whole, unsatisfactory; the reflected signals being often multiple or faint. The series of readings were even more widespread than in the first type of crystals (over one degree). The mean error for the best series was 2.8′ (angle $a^1 i^1$); three series of readings gave a mean error of 7′ or 7.5′ ($m i^1$, mt, $h^1 t$). The probable errors are given in Table 2; they range from 10′ to half a degree.

The Barker setting obtained from the most common form combination (m a^1 h^1 i^1 t e^1) has been adopted for the purpose of crystal description.

Measured and calculated angles show poor agreement (see Table 3).

TABLE 3. TABULAR, BIAXIAL NEGATIVE CRYSTALS
COMPARISON BETWEEN MEASURED AND CALCULATED ANGLES
$\breve{a}:\bar{b}:\bar{c}=0.9365:1:0.7989$, $\alpha=93°45'$, $\beta=94°8'$, $\gamma=88°21'$.

Number of readings	Probable error	Angle			Measured (mean)	Computed
		Lévy	Miller	Barker		
14	12.4′	$m\,e^1$	$1\bar{1}0:0\bar{1}1$	MQ	*63° 7′	—
17	29.8′	$m\,a^1$	$1\bar{1}0:\bar{1}01$	MR	*119°19′	—
11	16.0′	$m\,t$	$1\bar{1}0:110$	Mm	*86°13′	—
17	25.7′	$m\,h^1$	$1\bar{1}0:100$	Ma	41°38′	42°27′
10	22.5′	$h^1\,t$	$100:110$	am	44°36′	43°45′
2	—	$m\,{}^2h$	$\bar{1}10:\bar{3}10$	—	25°31′	25°15′
12	27.1′	$m\,i^1$	$\bar{1}10:011$	M′q	*65°36′	—
10	10.0′	a^1i^1	$\bar{1}01:011$	Rq	*52°54′	—
2	—	h^1a^1	$\bar{1}00:\bar{1}01$	a′R	50°28′	51°56′
3	—	$t\,a^1$	$\bar{1}\bar{1}0:\bar{1}01$	m′R	65° 9′	65°48′
1	—	h^1i^1	$100:011$	aq	88°18′	87°47′

N.B.—The five angles marked (*) are chosen as fundamental.

Barker classification angles

Two entries in the Barker determinative Index are necessary, one for each form combination.

(1) Transformation: none.

Forms: $1\bar{1}0\cdot\bar{1}01\cdot100\cdot011\cdot100\cdot0\bar{1}1$.

Angles:

cr = 38°43′, ra = 47°15′, **am = 43°45′**, mb = 47°38′, bq = 49°14′, qc = 37°8′.

(2) Transformation: Old to new $=0\bar{2}0/00\bar{2}/111$.

New to old $=112/\bar{1}00/0\bar{1}0$.

Forms:

$$\frac{\text{Old:}\quad 1\bar{1}0\cdot\bar{1}01\cdot100\cdot011\cdot110\cdot0\bar{1}1;\,3\bar{1}0.}{\text{New:}\quad 100\cdot0\bar{1}0\cdot001\cdot\bar{1}\bar{1}1\cdot\bar{1}01\cdot1\bar{1}0;\,101.}$$

Angles:

cr = 17°12′, ra = 25°15′, **am = 31°32′**, mb = 29°9′, bq = 30°3′, qc = 21°53′.

Remark: The forms are listed in the order of decreasing importance.

Optical properties

The refractive indices, obtained by the immersion method, are: $n_\alpha=1.669\pm0.001$, $n_\beta=1.734\pm0.002$, $n_\gamma=1.738\pm0.001$. The crystals are biaxial negative. The optic angle, measured on the Fedorov stage, is $2V=30°$; calculated from the indices, the value of 2V is 27°. Dispersion: $r>v$, strong.

Optical orientation.—Measurements on the Fedorov universal stage

enabled us to locate the position of γ, β, and both optic axes. We give the orientation by means of longitudes and colatitudes, measured from the stereographic projection (Fig. 3). The zero meridian is taken normal to the dominant face $m(\bar{1}10)$. Longitudes are measured clockwise.

	ϕ	ρ
α	$333\frac{1}{2}°$	$72°$
β	$77\frac{1}{2}°$	$52°$
γ	$222\frac{1}{2}°$	$42\frac{1}{2}°$
O.A.1	$323°$	$61°$
O.A.2	$342\frac{1}{2}°$	$84°$

Since the crystal habit is very constant, thin tabular on $m\{1\bar{1}0\}$, the optical appearance of this face is a good determinative character of the species. An excellent interference figure is obtained in convergent light; one of the optic axes emerges on the edge of the field, the face $m(1\bar{1}0)$ being oblique to an optic axis. The angle between the normal to m and the optic axis is *ca.* 35° (estimated) in air; hence a true value of 19°. The same angle, read on the stereographic projection, is equal to $18\frac{1}{2}°$; the check is thus quite close. The isogyre of the interference figure is fringed with red on the convex side, with blue on the concave, showing the strong dispersion of the optic axes. Small crystals, mounted with wax on match sticks, can be held in various orientations under the microscope; other types of triclinic dispersion can thus be obtained, all of which are devoid of symmetry.

COMPARISON AS TO HOMEOMORPHISM

The two salts show a tendency to homeomorphism as can be seen from the superposition of the two stereographic projections (Fig. 5).

This rough similarity could be emphasized by changing the crystallographic setting of one salt in order to give the same symbols to corresponding faces, for instance by means of the transformation $\bar{1}10/\bar{1}10/00\bar{2}$ applied to the positive salt.[7] The face symbols of the positive crystals are then changed as follows:

Old: $0\bar{1}0 \cdot \bar{1}10 \cdot \bar{1}00 \cdot 110 \cdot \bar{1}1\bar{1} \cdot \bar{1}1\bar{1} \cdot 11\bar{1} \cdot 1\bar{1}\bar{1}$.

New: $1\bar{1}0 \cdot 100 \cdot 110 \cdot 010 \cdot 101 \cdot 011 \cdot \bar{1}01 \cdot 0\bar{1}1$.

The new symbols are used in Fig. 5.

Although this crystallographic resemblance is very crude, it is worth mentioning in view of the presumed chemical similarity of the two substances.

[7] The transformation $\bar{1}10/\bar{1}10/00\bar{1}$, applied to the negative salt, would serve the purpose just as well.
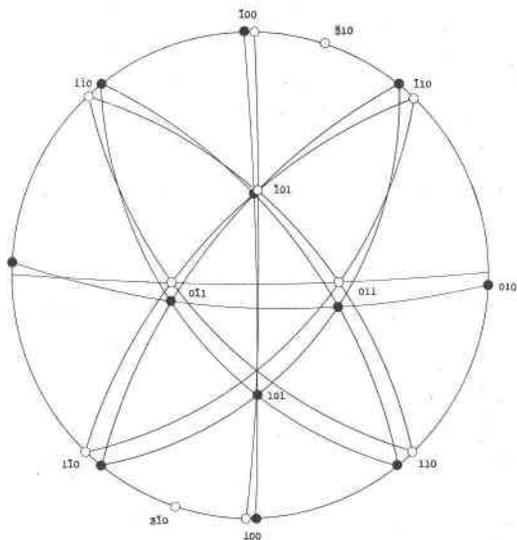
FIG. 5. Comparison as to homeomorphism. The projection of the negative salt (circles) is that of Fig. 3; the projection of the positive salt (black spots) is obtained from that of Fig. 1 by applying the transformation: Old to New $= \overline{1}10/\overline{1}10/00\overline{2}$.