THE CRYSTALLOGRAPHY OF POTASSIUM TETRATHIONATE.

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ABSTRACT.

Analyzed artificial crystals of potassium tetrathionate have been investigated and their geometrical elements and optical constants have been determined; also, the dimensions of their structural unit cell and their space-group.

INTRODUCTION.

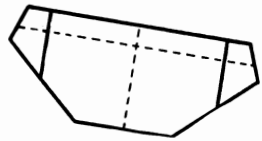
An attempt to correlate observations of the optical properties and angles of potassium tetrathionate crystals studied under the microscope, with the recorded properties of older crystals, brought to light discrepancies. This led to a reinvestigation of the crystallography of potassium tetrathionate, also to an X-ray determination of the unit cell dimensions and space-group. The crystals utilized by us were from several batches prepared by Dr. E. T. Allen in the Geophysical Laboratory. The method of preparation was as follows: To a sample of Wackenroder's solution (a mixture of thionic acids obtained by saturating sulphurous acid with hydrogen sulphide) potassium acetate was added and the liquid allowed to crystallize. The highest yield of tetrathionate was obtained from the middle fraction. This was separated from the lighter sulphate and pentathionate by a heavy liquid, bromoform and xylol, and finally recrystallized at room temperature from water containing several per cent of acetic acid. The chemical formula of the compound was checked by Doctor Allen as follows: 0.3009 g. of the compound was changed to K_2SO_4 and weighed; K_2SO_4 equivalent to 0.3017 g. of $K_2S_4O_6$ was found; 0.1023 g. of the compound was oxidized and the H_2SO_4 formed was precipitated as $BaSO_4$ and weighed; $BaSO_4$ equivalent to 0.1022 g. of $K_2S_4O_6$ was found.

MORPHOLOGY.

Crystals of potassium tetrathionate were pictured by C. F. Rammelsberg[1] as monoclinic prisms terminated by pyramids;

[1] These were erroneously supposed to be potassium pentathionate. Handbuch d. kryst.-physik. Chem., Wilhelm Engelmann, Leipzig, Abt. 1, pp. 495-496, 1881.

they were described by H. Baker[2] as hemimorphic orthorhombic prisms terminated at one end by a pyramid and at the other by a pinacoid; and described and pictured by A. Fock[3] as domatic monoclinic prisms with different upper and lower terminations. The crystals prepared by Doctor Allen resemble



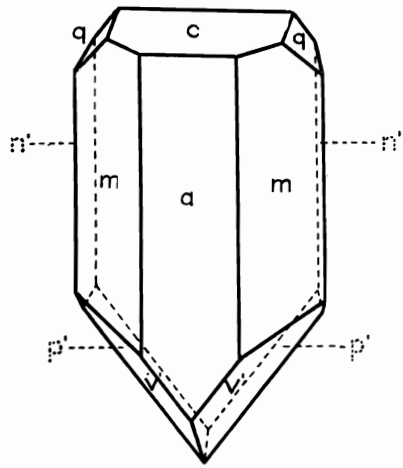


Fig. 1. Crystal of potassium tetrathionate measured on reflection goniometer.

those described by Fock. They have corresponding faces on both sides of a plane of symmetry; however, not all of the faces required by an axis of symmetry are present, and the two faces of a pair required by an axis of symmetry are usually different in size or appearance if both are present. Figure 1 is a drawing of one of the simplest crystals.

[2] J. Chem. Soc., 43, 354, 1883, in article by S. Shaw.
[3] Z. Kryst. Mineral., 19, 236-239, 1891. (Some details of the drawing are incorrect.)

The forms observed by us are[4] $a\{100\}$, $a'\{\bar{1}00\}$, $b\{010\}$, $c\{001\}$, $l'\{\bar{5}10\}$, $m\{320\}$, $m'\{\bar{3}20\}$, $n\{120\}$, $n'\{\bar{1}20\}$, $o\{\bar{2}11\}$, $o'\{21\bar{1}\}$, $p\{111\}$, $p'\{\bar{1}1\bar{1}\}$, $q\{011\}$, $q'\{01\bar{1}\}$, $r\{124\}$, $v\{\bar{1}11\}$, $v'\{11\bar{1}\}$. The form complementary to a is a', etc.

Crystals were always prismatic to tabular with one end pyramidal and the other either entirely basal, or with the base diminished in the presence of a dome and pyramids. The front or the back pedion usually rested on the bottom of the crystallizing dish, in which case that face was large and the neighboring faces were narrow. If the surface of the liquid barely covered the crystals, both pedions were large, otherwise prism faces were large. In tufted groups crystals attached by the basal end grew much longer than those in the reverse position. In such groups, from a solution saturated with potassium sulphate and containing acetic acid, the front pedion was narrow and smooth, the back pedion indistinctly broad and rounded by stepping off toward the prism $\{\bar{5}10\}$; but in pure water solution the smooth front pedion was much wider than the back pedion together with the adjacent faces of $\{\bar{5}10\}$. The front form complementary to $\{\bar{5}10\}$ has not been observed. Both front and back pedions were present on all crystals. The side pinacoid was absent or exceedingly narrow. The prisms m and m' were both present and wide unless the crystals were very flat, and they appeared equally smooth and bright; the faces of prism n gave multiple signals from minute convexities, and under similar conditions were wider than the bright faces of prism n'. o' was usually absent, but when present it was minutely but distinctly striated parallel to a, while o was smooth or only obscurely striated. v' and p' terminated the lower end of the crystals, sometimes accompanied by q' or o'. r was observed only as an upper front form. Crystals dissolved in pure water and recrystallized under a capillary film of solution were flat and elongated and pointed similarly at both ends like holohedral orthorhombic crystals.

The numerical values of the geometrical elements were calculated from measurements made on a Goldschmidt two-circle goniometer. The angles for a small number of rather poor faces were not used. The coordinates, x' and y', of the gnomonic face-pole of each of the other faces (x'/y' for prisms) were computed for each face and then combined to obtain the values of the projection elements, according to the method

[4] The correspondence of the letters used by the different authors to designate the forms is given in Table III.

TABLE I.

Measured and calculated phi and rho angles of potassium tetrathionate.†

Letter	Symbol Gdt.	Symbol Miller	Calculated ϕ	Calculated ρ	Measured ϕ	Measured ρ	Number of faces used	Limits ϕ	Limits ρ
a	$\infty 0$	100	90°00′	90°00′	90°00′	.....	11	89°53′- 90°06′	.....
b	0∞	010	0°00′	90°00′	0°06′	.....	1	.....	.....
c	0	001	90°00′	14°01′	90°59′	14°00′	1*	.....	.....
l′	$\bar{5}\infty$	$\bar{5}10$	—74°55′	90°00′	—74°18′	.....	4	—73°25′- —75°55′	.....
m	$\frac{3}{2}\infty$	320	48°04′	90°00′	48°00′	.....	27	47°41′- 48°09′	.....
n	$\infty 2$	120	20°22′	90°00′	20°13′	.....	17	19°13′- 20°30′	.....
q	01	011	11°11′	52°08′	11°13′	51°59′	14	10°56′- 11°46′	51°00′-52°15′
p	11	111	43°14′	60°00′	43°05′	59°56′	15	41°57′- 43°45′	59°40′-60°08′
o	$\bar{2}1$	$\bar{2}11$	—52°09′	64°04′	—52°32′	64°08′	4	—52°18′- —52°56′	63°58′-64°19′
r	$\frac{1}{2}\frac{1}{2}$	124	37°29′	38°29′	37°12′	38°35′	1	.....	.....
v	$\bar{1}1$	$\bar{1}11$	—28°34′	55°09′	—28°35′	55°10′	12	—28°23′- —28°47′	54°50′-55°20′

† Where both hemi-forms of a complementary pair were observed they have been included together in this table.
* A large but rough face on most crystals.

explained by V. Goldschmidt.[5] The values of p_o' and q_o' obtained from the terminal faces were considered equally reliable and both were adjusted by means of the average value of p_o/q_o obtained from all these terminal faces and prisms, the sum $(p_o' + q_o')$ obtained from the terminal faces thus remaining unchanged. The polar and linear elements were then calculated from the projection elements. All calculations were carried out to the nearest tenth of a minute. In the tabulations the angles were finally rounded off to the nearest minute.

Some of the limits of the measurements as recorded in Table I indicate considerable imperfection in the crystals, but as T. V. Barker[6] has stated: "An important feature, peculiar to the Goldschmidt 'polar elements,' is that they are adapted to the derivation of very accurate constants, for all the measured angles can be taken into account." Thus the calculated and the averaged measured angles are but a few minutes apart.

The earlier measurements by Rammelsberg[1] and by Fock[3] were made on one-circle goniometers, which fact must be considered in relation to the accuracy of the elements[7] calculated by them, and the interchanges of angles, and other inconsistencies in their publications.

Our geometrical elements are compared with those of Rammelsberg and of Fock in Table II. Those of Rammels-

TABLE II.

Linear and polar elements of potassium tetrathionate.

Tunell, Merwin, and Ksanda

$a:b:c = 1.3885:1:1.2615$, $\beta = 104°01'$,
$p_o:q_o:r_o = 0.9085:1.2240:1$, $\mu = 75°59'$,
$p_o' = 0.9364$, $q_o' = 1.2615$, $x_o' = 0.2495$.

Fock

$a:b:c = 1.3952:1:1.2666$, $\beta = 104°16'$. (Recalculated by Tunell, Merwin, and Ksanda from the three angles taken by Fock as fundamental, namely, $q:q$ [Fock's letters] $= 101°40'$, $m:a = 42°02'$, and $c:a = 75°44'$.)

Rammelsberg

$a:b:c = 1.4099:1:1.2641$, $\beta = 104°32'$. (Recalculated by Tunell, Merwin, and Ksanda from the three angles taken by Rammelsberg as fundamental, namely, $o:o$ [Rammelsberg's letters] $= 67°48'$, $o':o' = 78°22'$, and $o' = 53°40'$.)

[5] Z. Kryst. Mineral., 30, 272-294, 1898.

[6] Graphical and Tabular Methods in Crystallography, Thomas Murby and Company, London, p. 94, 1922.

[7] Barker's opinion (see Op. cit., p. 16), that the readings of two-circle goniometry are more faithful to the crystal in its entirety than those of one-circle goniometry seems to us to be justified.

berg are not entirely consistent with his three fundamental angles. The values recalculated by us from these angles are: $a' : b' : c' = 0.9285 : 1 : 1.2641$, $a'c' = 78° 28'$. The values given by Rammelsberg are: $a' : b' : c' = 0.9285 : 1 : 1.264$, $a'c' = 78° 45'$. Fock recalculated Rammelsberg's values as: $a' : b' : c' = 0.9285 : 1 : 1.2642$, $a'c' = 78° 28'$. Thirteen of the angles calculated by Rammelsberg are also in error by a few minutes. They are listed here with his letters, and with the letters of Tunell, Merwin, and Ksanda: *oo'* or *op'*, *mm* or *vv*, *m'm'* or *qq*, *mm'* or *vq*, *mm'* or *vq'*, $^3p\,^3p$ or *nn*, *a* or *an*, *p* or $mn, \frac{r'}{3}$ *a* or *ca*, *m* or *a'v*, *m'* or *aq*, *om* or *ov*, *o'm'* or *pq*. The values of these calculated angles with the arithmetical errors corrected are given in Table V. Rammelsberg's assignment of symbols was consistent.

The values calculated by us from Fock's three fundamental angles are: $a'' : b'' : c'' = 0.93014 : 1 : 1.26664$, $a''c'' = 75° 44'$, the values given by Fock are $a'' : b'' : c'' = 0.93017 : 1 : 1.26664$, $a''c'' = 75° 44'$. Fock selected as his basal pinacoid the face designated by Rammelsberg as $\frac{r'}{3}$. Fock says: "Die Aufstellung der Krystalle wurde aus leicht ersichtlichen Gründen etwas anders gewählt. Das Hemidoma $c\{\bar{1}03\}$ wurde zur Basis {001}, die prismatischen Formen dagegen unverändert beibehalten." Fock selected as his three fundamental angles the measured angles: $am = 42° 02'$, $ac = 75° 44'$, $qq = 101° 40'$. In accordance with the quotation given above, he assigned Miller indices to these forms as follows (Fock's letters): *a*, {100}; *m*, {110}; *c*, {001}; *q*, {011}. This assignment of course determines the indices of all the other forms. Fock's derivations of the Miller indices of his three pyramids, *o*, *p*, and *v* (Fock's letters), are all erroneous. For these forms he gave the indices: *o*, $\{\bar{1}11\}$; *v*, $\{\bar{1}33\}$; *p*, {111}; the correct indices of these forms with Fock's choice of axes and unit forms are: *o*, $\{\bar{4}33\}$; *v*, $\{\bar{2}33\}$; *p*, {233}. Fock's calculated angles, *oo*, *pp*, *vv*, *ao*, *av*, *ap*, are also in error; the correct values of these calculated angles are given in Table V. In addition to the mistakes already mentioned, Fock interchanged his measured angle *oo* with his measured angle *pp*, and likewise his measured angle *ao* with his measured angle *ap*.

In his paper Fock quoted Rammelsberg's measured angles and corrected some mistakes in Rammelsberg's computations.

However, Fock interchanged Rammelsberg's measured angles *oo* and *pp* (Fock's letters), but the remainder of Rammelsberg's measured angles quoted by Fock are given correctly. Fock recalculated part of Rammelsberg's calculated angles. The values recalculated by Fock for the following calculated angles are correct to ± 1′ (Fock's letters) : *vv*, *qq*, *am*, *ca*, *ao*, *av*, *aq*; but for the angle *an* there is an error of several minutes. The large discrepancy between the values of *oo* as measured and published by Rammelsberg and as measured by Fock, and likewise between the values of *pp*, *ao*, and *ap*, measured by Rammelsberg and by Fock (cf. the writers' Table V), is due to the fact that Fock interchanged his measured angles relating to *o* and *p* which in his drawing, and according to his Miller symbols, are an upper back or lower front pyramid and an upper front or lower back pyramid respectively. Such an interchange of angles and wrong assignment of indices are much less likely to occur with the use of the two-circle goniometer and the gnomonic projection than with the use of the one-circle goniometer and stereographic projection.

The correspondence of the forms observed by Rammelsberg, by Fock, and by us is shown in Table III. Our choice of axes and unit forms is not entirely the same as that of Rammelsberg or that of Fock. The transformation matrices are assembled in Table IV.

TABLE III.

Correlation of the letters used by the various authors.

Tunell, Merwin, and Ksanda	Fock	Rammelsberg
a & *a*′	*a*	*a*
b		
c	*c*	$r'/_3$
l′		
m & *m*′	*m*	*p*
n & *n*′		$3p$
q & *q*′	*q*	*m*′
p & *p*′	*p*	*o*′
o & *o*′	*o*	*o*
r		
v & *v*′	*v*	*m*

DETERMINATION OF THE STRUCTURAL UNIT CELL AND SPACE-GROUP.

X-ray analysis shows that the morphological ratio of *a* to *b* must be doubled for structural purposes but confirms the

TABLE IV.

Transformation matrices.*

From \ To	Rammelsberg 1881	Fock 1891	Tunell, Merwin, and Ksanda (Morphological) 1938	Tunell, Merwin, and Ksanda (Structural) 1938
Rammelsberg	1 0 0 0 1 0 0 0 1	$\bar{1}$ 0 $\frac{1}{3}$ 0 $\bar{1}$ 0 0 0 1	$\frac{3}{2}$ 0 $\frac{1}{2}$ 0 $\bar{1}$ 0 0 0 1	3 0 0 0 1 0 0 0 1
Fock	$\bar{1}$ 0 $\frac{1}{3}$ 0 $\bar{1}$ 0 0 0 1	1 0 0 0 1 0 0 0 1	$\frac{3}{2}$ 0 0 0 1 0 0 0 1	$\bar{3}$ 0 $\bar{1}$ 0 $\bar{1}$ 0 0 0 1
Tunell, Merwin, and Ksanda (Morphological)	$\frac{2}{3}$ 0 $\frac{1}{3}$ 0 $\bar{1}$ 0 0 0 1	$\frac{2}{3}$ 0 0 0 1 0 0 0 1	1 0 0 0 1 0 0 0 1	$\bar{2}$ 0 $\bar{1}$ 0 $\bar{1}$ 0 0 0 1
Tunell, Merwin, and Ksanda (Structural)	$\frac{1}{3}$ 0 0 0 1 0 0 0 1	$\bar{1}$ 0 $\frac{1}{3}$ 0 $\bar{1}$ 0 0 0 1	$\frac{1}{2}$ 0 $\frac{1}{2}$ 0 $\bar{1}$ 0 0 0 1	1 0 0 0 1 0 0 0 1

* For the method of using these transformation matrices, see Barker, T. V.: Systematic Crystallography, Thomas Murby & Co., London, pp. 32--34, 1930; or Donnay, J. D. H.: Am. Mineral., 22, 621-624, 1937; for the reason for the fractional form see Peacock, M. A.: Am. Mineral., 23, 38, 1938.

morphological ratio of *c* to *b*. While the X-ray results would permit the same choice of the base as that made in Fock's and in our morphological study, this choice would not give a unit cell in which the glide directions are oriented in conformity with the conventions of the *International Tables for the Determination of Crystal Structures.* Therefore for the sake of conformity with the conventions of those tables, the plane chosen by Rammelsberg as his base was taken as 001 in the röntgenographic study. The unit cell dimensions and systematically missing spectra were determined by means of rotation and Weissenberg photographs taken with the crystals rotating about the *c*- and *b*-axes.[8] Equator and first and second layer-line

[8] The crystals of potassium tetrathionate are mostly elongated parallel to the *c*-axis. In order to obtain a suitable specimen for rotation about the *b*-axis, a crystal was severed roughly parallel to the base, and one end with suitable faces for orientation was utilized. The cutting of the crystal in a definite direction was readily accomplished by means of a small apparatus described by F. E. Wright (Min. Mag., 23, 157-158, 1932). In using this

TABLE V.

Interfacial angles of potassium tetrathionate.

Interfacial angles		Rammelsberg		Fock		
		Measured#	Recalculated†	Measured	Recalculated†	Tunell, Merwin, & Ksanda Calculated
oo¶	$\bar{2}11 \wedge \bar{2}\bar{1}1$	67°48′	*	78°31′§	67°17′	66°59′
pp	$111 \wedge 1\bar{1}1$	78°22′	*	67°50′§	78°19′	78°14′
op	$\bar{2}11 \wedge 111$	81°05′	81°00′			81°37′
op′	$\bar{2}11 \wedge \bar{1}1\bar{1}$	56°30′	56°43′			56°36′
vv	$\bar{1}11 \wedge \bar{1}\bar{1}1$	92°45′	92°53′	92°19′	92°35′	92°14′
qq	$011 \wedge 0\bar{1}1$	101°38′	101°29′	101°40′	*	101°31′
vq	$\bar{1}11 \wedge 011$	32°00′	31°37′			31°55′
vq′	$\bar{1}11 \wedge 01\bar{1}$		74°18′			74°29′
mm	$320 \wedge 3\bar{2}0$	84°18′	84°36′			83°51′
ma	$320 \wedge 100$	42°15′	42°18′	42°02′	*	41°56′
nn	$120 \wedge 1\bar{2}0$		139°45′			139°17′
na	$120 \wedge 100$	70°06′	69°53′			69°38′
mn	$320 \wedge 120$	28°07′	27°35′			27°43′
ca	$001 \wedge 100$	75°25′	75°28′	75°44′	*	75°59′
a′o	$\bar{1}00 \wedge \bar{2}11$	45°30′	45°20′	53°36′‡	44°54′	44°46′
a′v	$\bar{1}00 \wedge \bar{1}11$	67°20′	67°31′	67°08′	67°05′	66°54′
ap	$100 \wedge 111$	53°40′	*	45°03′‡	53°34′	53°37′
aq	$100 \wedge 011$	80°48′	80°52′	81°07′	81°03′	81°11′
ov	$\bar{2}11 \wedge \bar{1}11$	21°45′	22°11′			22°08′
pq	$111 \wedge 011$	27°16′	27°12′			27°34′
m′q	$\bar{3}20 \wedge 011$			66°13′	66°12′	66°12′
mq	$320 \wedge 011$			50°41′	50°36′	50°51′

¶ Letters of Tunell, Merwin, and Ksanda.

The angles in this column are the supplements of the measured angles reported by Rammelsberg.

†Recalculated by Tunell, Merwin, and Ksanda from the three measured angles chosen as fundamental by Rammelsberg or by Fock respectively. The fundamental angles are indicated by asterisks.

§, ‡ The angles in each of these pairs must have been interchanged by Fock.

Weissenberg resolutions were made about the *c*-axis, and an equator Weissenberg resolution was made about the *b*-axis. The unit cell dimensions, all determined by purely röntgenographic measurements are: $a_0 = 22.05$ Å, $b_0 = 7.99$ Å, $c_0 = 10.09$ Å, all $\pm$ 0.02 Å, $\beta = 102° 05′ \pm 15′$. Diffraction effects

apparatus the present writers have found it extremely helpful to support the crystal on a thin layer of plasticine. Even very brittle crystals such as calaverite, which, without the supporting layer of plasticine, fly to bits at the touch of the cutting blade, can be cut in desired directions when so supported.

were obtained from the following planes: *g*00, 0*g*0, 00*g*, 0*gu*, 0*gg*, *g*0*g*, *uu*0, *gg*0, *uuu*, *uug*, *ggu*, *ggg*, where *g* denotes any even number and *u* denotes any odd number. No diffraction effects were obtained from the following, although representatives of each were in a position to diffract during the exposures of the Weissenberg photographs: *u*00, 0*u*0, 00*u*, 0*uu*, 0*ug*, *u*0*u*, *u*0*g*, *g*0*u*, ug0, *gu*0, *ugu*, *ugg*, *guu*, *gug*. These missing spectra are characteristic of the space-groups C_{2h}^6 — *C*2/*c* and C_s^4—*Cc*. As already mentioned, the morphology of the potassium tetrathionate crystals affords a strong indication that they belong to the crystal class C_s — *m*. That the symmetry of potassium tetrathionate is lower than holohedral was conclusively established by tests for pyroelectric and piezoelectric effects, both of which were proved to be present.[9] Potassium tetrathionate therefore belongs to the space-group C_s^4 — *Cc*.

The density of potassium tetrathionate was determined to be 2.296 by Hertlein,[10] using a flotation method. The unit cell accordingly contains 8 molecules of $K_2S_4O_6$, the density calculated from the X-ray measurements on this assumption being 2.296, in exact agreement with the measured density.

A comparison of the axial ratios obtained from the röntgenographic measurements with those obtained from the morphological measurements is given in Table VI.

TABLE VI.

Crystallographic elements referred to the structural axes.

a	:*b*:	*c*	*β*	
2.760	1	1.263	102°05′	Tunell, Merwin, and Ksanda (röntgenographic)
2.7581	1	1.2615	102°20′	Tunell, Merwin, and Ksanda (morphological)
2.7656	1	1.2666	102°05′	Fock* (morphological)
2.7855	1	1.2641	101°32′	Rammelsberg* (morphological)

* Recalculated by Tunell, Merwin, and Ksanda.

In order to facilitate future identification of potassium tetrathionate by the X-ray powder method, the planar spacings and relative intensities of the lines in a powder photograph taken with Cu-radiation filtered through nickel foil are recorded in Table VII.

[9] The authors are indebted to Messrs. S. B. Hendricks and M. E. Jefferson of the U. S. Department of Agriculture, Bureau of Chemistry and Soils, for their kindness in testing the crystals for pyro- and piezoelectric effects.

[10] Hertlein, H.: Z. phys. Chem., 19, 297, 1896.

TABLE VII.

Planar spacings and relative intensities of the X-ray diffraction lines of $K_2S_4O_6$ from a powder spectrum taken with filtered Cu-K radiation.

Line	Intensity observed*	*d/n*
1	2	9.48
2	3	6.21
3	3	5.80
4	5	5.387
5	3	4.946
6	4	4.436
7	3	4.005
8	1	3.830
9	3	3.607
10	10	3.371
11	7	3.173
12	7	3.095
13	8	2.921
14	6	2.694
15	4	2.529
16	2	2.454
17	4	2.391
18	3	2.299
19	1	2.267
20	6	2.158
21	4	2.097
22	2	2.029
23	4	1.947
24	5	1.908
25	4	1.819
26	5	1.801
27	4	1.777
28	3	1.717
29	4	1.678
30	3	1.634
31	5	1.594
32	2	1.550
33	3	1.518
34	1	1.492
35	4	1.453
36	6	1.415
37	1	1.361
38	1	1.344
39	4	1.328
40	5	1.290
41	1	1.264
42	5	1.247
43	5	1.227
44	3	1.196
45	2	1.172
46	3	1.149
47	2	1.130
48	3	1.113
49	4	1.080
50	5	.990
51	3	.946
52	4	.898

* Estimated intensities of the diffraction lines are based on a scale of ten, where ten represents the intensity of the strongest line.

CLEAVAGE, REFRACTIVE INDICES, DISPERSION, OPTICAL ORIENTATION.

The monoclinic crystals, elongated parallel to the c-axis, have a perfect cleavage parallel to 100. The optic axial plane is 010; $\gamma \wedge c = 33°_{C}$ and $34°_{F}$ in the obtuse angle β. $2V$, positive, $= 66°_{C}$ and $69°_{F}$. An optic axis emerges in air $38\frac{1}{2}°_{C}$ and $36°_{F}$ from the normal to the cleavage, in the obtuse angle β.[11]

TABLE VIII.

Dispersion of refractive indices.*

	α	β	γ
	±.0002	±.0002	±.0002
404 Hg	1.6160	1.6370	(1.6791)
G'	1.6089	1.6285	1.6695
436 Hg	1.6085	1.6281	1.6690
F	1.5999	1.6180	1.6575
501 He	1.5979	1.6156	1.6548
546 Hg	1.5931	1.6098	1.6483
588 He	1.5897	1.6058	1.6436
D	1.5896	1.6057	1.6435
C	1.5856	1.6009	1.6382
668 He	1.5849	1.6001	1.6374
706 He	1.5832	1.5981	1.6352

* Measurements for helium and mercury lines by minimum deviation. Interpolated for the letters and for the value in parentheses.

[11] According to Fock, about 48° in the acute angle between the a- and c-axes (designated by Fock the acute angle β).