On Rathite and its variety, Wiltshireite.

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Introduction.

THE main portion of this memoir as far as it relates to wiltshireite was in the Editor's hands in January, 1911; but before it was sent by him to press I learnt that Mr. R. H. Solly had, at the Anniversary Meeting of the Mineralogical Society in 1903, described an unnamed crystal, which, from the statement made to the Society on March 21, 1911, and published in the 'Mineralogical Magazine' (1911, vol. xvi, p. 121), is undoubtedly the same substance as that named by me in August, 1910, wiltshireite.[1] In the statement of March, 1911, Mr. Solly pointed out the striking relation of the crystals of wiltshireite to those of rathite; and suggested that the latter is oblique and not orthorhombic, as described in this Magazine (1901, vol. xiii, pp. 77–85). I consequently postponed publication until I could examine such crystals of rathite as were available. With this object I appealed to Professor Baumhauer for the loan of his standard crystal of rathite, described in Groth's 'Zeitschrift' (1896, vol. xxvi, pp. 593–602); and he with great courtesy at once sent it to me. I beg leave here to thank him for his kindness. The account of my examination of this crystal is given under viii; but I may here state that the terminal faces, though poor and probably compound, are easily referable to similarly placed faces of wiltshireite; and that the crystal is to be regarded as a complex twin with (100) and (101) of wiltshireite as twin-faces. My examination of the several rathite crystals confirms Mr. Solly's inference that rathite is oblique. For convenience, the name wiltshireite is retained in this paper to distinguish the comparatively simple crystals such as that described by me in August, 1910, from the more complex twins to which Professor Baumhauer's crystal is referred. I may state that I found no true cleavage; but I got a good parting parallel to (100), which I believe to be due to twin-lamellation parallel to this face.

[1] Phil. Mag., 1910, ser. 6, vol. xx, pp. 474–475.

Wiltshireite.

System, Oblique: $a:b:c = 1{\cdot}5869:1:1{\cdot}0698$; $\beta = 79° 16'$.

Forms observed; those marked with a ? being doubtful. A large number of them are indicated on the stereogram, fig. 1.

$A(100)$, $C(001)$, (501)?, (401)?, $h(301)$, $t(201)$, $\zeta(302)$, $d(101)$, $\phi(102)$, $w(\bar{1}02)$, $u(20\bar{3})$, $z(\bar{1}01)$, $\chi(\bar{3}02)$, $y(\bar{2}01)$, $k^*(522)$?, $\delta(211)$, $e(322)$, $g(111)$, $\tau(344)$, $\sigma(122)$, $n(011)$, $o(\bar{1}22)$, $p(\bar{1}11)$, $x(\bar{3}22)$, $\lambda(\bar{2}11)$, $\kappa(\bar{5}22)$, $i(\bar{3}11)$, $\mu(31\bar{2})$, $\eta(52\bar{4})$, $\pi(21\bar{2})$, $\epsilon(32\bar{4})$, $\Delta(11\bar{2})$, $\gamma(012)$, $\Sigma(112)$, $\theta(510)$, $\rho(920)$, (410), $l(310)$, $\psi(520)$, $r(210)$, (740), $s(820)$, (540), (650), $m(110)$, $\omega(340)$, $f(120)$, $a(250)$.

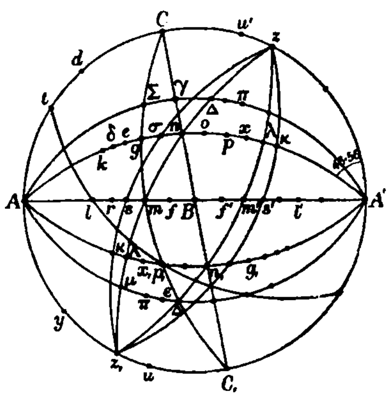

FIG. 1. Stereogram of Wiltshireite.

The crystals which I have examined are described below.

Crystal i.—The first, on which the note in the 'Philosophical Magazine' of September, 1910, is based, is rich in faces; but most of the end ones have two or more separate portions which reflect the light simultaneously, or very nearly so. The crystal is about 5 mm. long by 1·5 mm. across, and may to some extent be compared to a pile of minute needles with ends loaded with facets. Several faces give two images, coming probably from separated portions of a face, i. e. from the facets on different rods. The separation of the images is specially noticeable in measuring the zones $[Bpz]$ and $[BnC]$; when the images from each face are separated by some $10'$ to $14'$. When the zone $[Agp] = [01\bar{1}]$ was perceived, it and the homologous zone were both measured; and, as shown by the table of angles, they give trustworthy readings. To eliminate as far as possible the uncertainty arising from faces giving two images, a number of *cross-zones*, e. g. such as $[110, 10\bar{1}]$, were measured;

and the angle $pAC = 46° 56'$ was determined from nine triangles, the poles forming them being those of the faces which had given the best readings. This angle is nearly the complement of the angle (100) : (101) $= 43° 5\frac{1}{2}'$ given by Mr. Solly in his memoir on rathite (this Magazine, vol. xiii, p. 79).

The presence of minute facets which lie in zones [100, 012] was perceived at an early period; and, as far as possible, their position in the cross-zones was determined. They are, as a rule, much smaller than facets of the series (hll) and give very faint images. They were of service in settling the character of crystal ii.

The prism-faces are uneven and are, so to speak, built up of portions of several rods. They are free from the oblique striae characteristic of rathite crystals; but give poor direct readings. They are somewhat tarnished, and have a brown tint; and the lustre, though metallic, is much as if the crystals had been rubbed with oil. The end facets are very white and bright.

The crystal lies in a cavity in dolomite at the bottom of which is a crystal of sartorite, proved by measurement of its prism-zone. Only that end which I have selected as the positive end of OZ is sufficiently exposed for measurement; and the face y $(20\bar{1})$ in its true place was only observed after my note had been sent to the 'Philosophical Magazine'. The face giving the angle $40° 11'$, and for which the symbol (302) was suggested in that note, lies between (100) and (001). The evidence supplied by the set of crystals of the accuracy and constancy of the angles of wiltshireite, and also in crystal iv of twinning with (100) as twin-face, makes it fairly certain that the face in question is y in twin-orientation. At the time I had no data on which an explanation of the discrepancy could be based. Later on, when the presence of y and twinning with (100) as twin-face had been established, such an explanation became obvious. It may be here pointed out that an angle of $40° 14'$ to $40° 30'$ measured in a pinakoid-zone from the conspicuous pinakoid is common to all the lead sulpharsenites except jordanite. It is further probable, as pointed out by Mr. Solly, that the face to which the symbol (522) has been assigned is the face $(31\bar{1})$ in twin-orientation on the same lamella as y; for $(100) : (31\bar{1}) = 38° 4'$. The divergence of the observed angle from the computed one is then $3'$ instead of $34'$. The face $(31\bar{1})$ has only been observed in its true place on crystal iii.

Crystal ii.—This crystal is smaller than i, and is implanted in an apparently regular orientation on a plate of one of the lead sulpharsenites which I am inclined to think is rathite; but the angles on it which I have measured do not enable me to determine this with certainty. Some of its faces reflect the light simultaneously with faces of wiltshireite, and the (100) of the latter is parallel to the large face of the underlying plate. The end facets on ii which are best exposed are those which meet OZ at its negative end. The lustre is like that of i.

Crystal iii.—This was broken in an attempt to clear some of the dolomite out of the way: its broken end is nearly spherical and gives very fair readings. The fracture is conchoidal, and seems inconsistent with a cleavage. Such fracture surfaces parallel to (100) as have been observed at broken places on this and other crystals seem to be due to twin-lamellation parallel to (100). The small top shows in a striking way one of the peculiarities of the crystals; for the facets are not in all directions bounded by definite edges, but are like those seen on round grains of olivine extracted from the Pallas meteoric iron. The measured fragment has a minute crystal of sartorite attached to it; and there is reason to think that the zones [010] of the two crystals coincide, but the faces (100) of the two are at 12° 57′ to one another.

Crystal iv.—This is a very minute isolated fragment differing from the preceding crystals in the freshness of its colour and lustre; and in this respect it resembles Professor Baumhauer's crystal of rathite. It shows fine striation parallel to (100) on the faces (101), (102) and (122); striae due probably to twin-lamellae with (100) as twin-face. They cause an unusual disturbance of the angles in the zones [100, 111]. For in one of them the face $\sigma(122)$ gives two images; the better one making an angle of 69° 45′ with (100), the poorer one the correct angle 70° 2′ given in the table. In the second zone $g_{,}(1\bar{1}1)$ is ill-developed, and gives a blurred bar of light and not a definite image; the angle $Ag_{,}$ being 58° 39′. In the zone $[gdg_{,}]$ the angle gd is 38° 15′, $g_{,}d$ 39° 29′, both very appreciably different from the computed angle 38° 50′. Two of the {120} faces show also oblique striae such as are characteristic of rathite; so that this crystal may perhaps be better regarded as a good crystal of the latter rather than one of the simple form.

Crystal v.—This is an isolated group of two or three slender rods of wiltshireite deposited on a relatively large crystal of rathite in nearly parallel orientation with a face (100) in common. The faces of wiltshireite are fresher and brighter than those of rathite; and the group may be compared with one of redruthite in which a number of small crystals are deposited on a tabular altered crystal of earlier formation. The end faces of wiltshireite are $(20\bar{1})$, (111), and $\sigma(122)$ or $p(\bar{1}11)$.

Independently of probable twinning with (100) as twin-face, certainty as to the last face being σ or p is unattainable; for the (100) faces of the group give three images, the extreme ones being nearly $1\frac{1}{4}°$ apart. The prism-faces l, r, s, m, f were identified in a zone common to wiltshireite and rathite. On the rathite crystal two zones [010] and [01$\bar{1}$] are perceived, the faces in the latter forming fairly long ridges with re-entrant angles. The angles measured in these two zones were poor, but they seem to prove the presence of (302) in one zone, and of (011) in simple and twin orientation in the other. Further, the angle between the prism-zone and [01$\bar{1}$] was found to be 43° 30′.

Other crystals having the distinctive colour and oily appearance of the first three specimens have been observed implanted on, or mixed up with, other lead sulpharsenites, especially sartorite; but they have broken ends, which leave their character doubtful, for the prism-zone is too uncertain to be relied upon.

Rathite.

From the table of angles and the description of the crystals vi–viii it will be seen that they can be regarded as twins of the simple crystal of wiltshireite; and consequently rathite is oblique and not prismatic.

Crystal vi.—This is a tarnished characteristic crystal of rathite, though it shows no oblique striae on the prism-faces. In the zone [01$\bar{1}$] fairly large faces e, g, σ, n, o, and p occur; in [011] two slightly developed faces are inclined to (100) at 59° 48′ and 70° 28′, so that it is doubtful whether they are g and σ, or x and p in twin-orientation. Further in the prism-zone an image at 90° 50′ to (100) was observed, which is possibly due to numerous ridges combining to simulate (010).

Crystal vii.—Fig. 2 is a fairly accurate sketch of the best rathite crystal (No. 2885) in the Cambridge collection. It is about 8 mm. long by 2 mm. wide and 2 thick; and is still attached to a small piece of dolomite which prevents complete measurement, and the left side in the sketch is that best exposed. Owing to the crystal's development the negative end of OZ is uppermost. The prism-faces f, r, s, &c. are, save on the central portion marked by $\underline{A}$ and $\underline{y}$, finely striated in an oblique direction which seems to coincide with the trace of a plane parallel to (101). Across the portions marked A and A_0 of the large pinakoid there are less numerous, but very strongly developed, lines perpendicular to the prism-edges. On the part A these lines are interrupted on the right by three or four fine lines parallel to the prism-edges; but a few of them reappear near the right-hand edge. On A_0 they seem to extend from side to side. These striae on pinakoid and prisms accord with the view that they are due to twin-lamination with (101) for twin-face. Mr. Solly (this Magazine, vol. xiii, pp. 80 and 88) gives the twin-face as (074), which by the table given further on is strictly (17·0·16) of wiltshireite, though his approximate determination fits well enough with (101). On the portion marked $\underline{A}$ there are no such transverse lamellar markings, but only very fine lines parallel to the prism-edges. At the place marked by a stroke-and-dot line there is a small re-entrant angle. Measurement of the zone $[Ay]$ gave for Ay and for $A\underline{y}$ the same angle 40° 25′; for $A\underline{A}$ 1° 59′, and for $y\underline{y}$ 78° 54′. Subtracting the last from 2 × 40° 25′, we have 1° 56′ for the re-entrant angle. Now a possible face ($\bar{1}04$) on wiltshireite is inclined to (100) at an angle of 88° 58′; and twinning about the normal to this face gives 2° 4′ as the re-entrant angle between the twinned pinakoids 100 and ($\bar{1}00$). The twinned portion indicated by $\underline{A}$ and $\underline{y}$ does not extend the whole thickness; and the prism-faces near $\underline{A}$ are free from the oblique striae which are seen at the two ends of the crystal. There is a fine crack across the crystal, where the flaw is marked on A_0, and this portion of the face is inclined at an angle of about 14′ to that marked A.

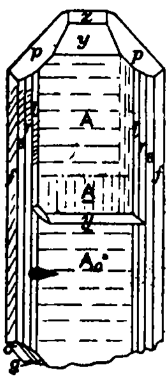

FIG. 2.—Rathite (Crystal vii).

The faces p were covered with a layer of dull earthy galena or soot-like matter, and the other hemipyramids were likewise very dull. Glass-plates were first gummed to the two large p faces, and approximate readings obtained from them. Afterwards the hemipyramids were all gently rubbed and fresh readings taken. The angles found afford satisfactory evidence that the faces are the same as p, o, σ, g, and e of wiltshireite.

Crystal viii.—Fig. 3, the cliché of which has been kindly supplied by Professor von Groth, is the idealized plan given by Professor Baumhauer of his standard crystal of rathite described in Groth's 'Zeitschrift', vol. xxvi, p. 593 et seq. The pinakoid labelled (001) is my (100); and both faces are throughout their length deeply grooved perpendicular to the prism-edges in a way characteristic of twin-lamellae. One of its faces gives two images—one yellowish, one white—inclined to one another at an angle of 11′; and my impression is that the yellow image (denoted by A) is the more trustworthy, and the readings in the zones [100, 001] and [100, 111] are taken from it. The parallel face A, gives a number of close images separated by a few minutes, and a mean value has been taken. Again, with one exception, the pinakoids at the two ends (Baumhauer's brachydomes) give more than one image. Of his form {045} there are three faces, for which he adopts the angle (001) : (045) = 40° 14.5′; whilst he points out the differences which exist in the measured values. Reading from the yellow image *A*, I get at one end *Ay* = 40° 1′ (a good angle); and at the other end 40° 16′ and 40° 37′, the latter face being striated and giving two images. The third of the faces is also striated, and makes with *A*, an angle of 40° 12′. Following *y*, the first of the above faces, there are three others in direct succession; the first making with *A* an angle of 49° 9′ and 49° 35′: it may be treated as a composite face, partly *d* (101) and partly χ (30$\bar{2}$), one being in twin-orientation. The second face is poor and makes with *A* the angle 64° 34′. This differs a good deal from *Az* = 63° 36′, but no simple indices can be obtained to accord closely with the reading. The third face, which I take to be (001), is fairly large, and gives a good angle 79° 56′.

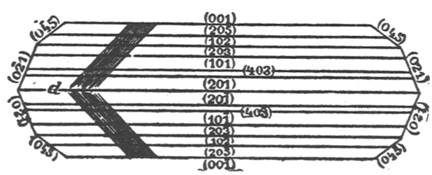

FIG. 8.—Baumhauer's crystal of Rathite (Crystal viii).

Hemipyramids, which I take to be *e* (322), *g* (111), and σ (122), are present on one side of one end; and at the other end there is a poor face parallel to σ. The angles given in the table are read from the yellow image *A*. It will be observed that they differ somewhat from the corresponding angles of wiltshireite, but not more so than happens with complex twins of other minerals, and more especially as the faces may be composite ones. Thus the face *e* to which I assign the symbol (322) may be λ (21$\bar{1}$) in twin-orientation; for the measured angle 50° 46′ is midway between *Ae* = 50° 14′, and *A*λ = 51° 4′. Measurement of cross-zones did not give satisfactory results, but served one good purpose. For in measuring [*md*] I perceived that the striae on one of the faces *m* were parallel (or nearly so) to the vertical wire, whilst on the opposite face they were nearly parallel to the horizontal wire. Again, on one of the large composite faces *f* (120), the striae on different laths are nearly at right angles to one another. By the aid of a two-circle goniometer I found the angle between the zones [010] and [01$\bar{1}$] to be 46° 53′, which agrees well with the 46° 56′ of wiltshireite. Again the angle between the zones [$01\bar{1}$] and [001] was found to be 42° 57′; and computation of this angle from the triangles $Af\sigma$ and $Am\gamma$ gives the same value.

If it be now accepted that the system of rathite is oblique, and that the variations in its angles from those of wiltshireite (regarded as its simple form) are due to the disturbance produced by complex twinning, we can compare my results with those of Professor Baumhauer and Mr. Solly in their memoirs (already cited) by supposing that the pinakoid {010} of the former and {001} of the latter are replaced by {$\bar{1}04$} of wiltshireite. The formulae of transformation of their symbols are the following (unaffected indices being those of wiltshireite):

Mr. Solly $h_{,} = 3k,\ k_{,} = 4h + l,\ l_{,} = 3l.$

Professor Baumhauer $h_{,,} = 20k,\ k_{,,} = 28l,\ l_{,,} = 5\,(4h + l).$

Lewis.	Solly.	Baumhauer.		
*100	010	001		
*010	100	100		
*$\bar{1}04$	001	010		
120	320	201		
*110	340	101		
$hk0$	$3k{\cdot}4h{\cdot}0$	$k0h$		
*$20\bar{1}$	$07\bar{3}$	$0\bar{4}5$		
302	073	045		
17·0·16	074	—		
101	053	0·28·25	nearly	0·11·10
$30\bar{2}$	$05\bar{3}$	$0{\cdot}\overline{28}{\cdot}25$	,,	$0{\cdot}\overline{11}{\cdot}10$
$10\bar{1}$	$01\bar{1}$	$0{\cdot}\overline{28}{\cdot}15$	,,	$0\bar{2}1$
$20\bar{3}$	$05\bar{9}$	$0{\cdot}\overline{34}{\cdot}25$	,,	$0{\cdot}\overline{17}{\cdot}5$
**$50\bar{9}$	0·11·27	$0{\cdot}\overline{252}{\cdot}55$	,,	$0{\cdot}\overline{14}{\cdot}3$, or $0\bar{9}2$
001	013	0·28·5		
$10\bar{2}$	$01\bar{3}$	$0{\cdot}\overline{28}{\cdot}5$		
$11\bar{1}$	$11\bar{1}$	$20{\cdot}\overline{28}{\cdot}15$		
111	353	20·28·25		
$32\bar{2}$	$35\bar{3}$	$20{\cdot}\overline{28}{\cdot}25$		

The faces which serve as basis of the transformation are those starred. The symbol ($50\bar{9}$) is not that of an observed face; but is that of a possible one making with (100) an angle of 79° 9′. Computation of the angles corresponding to the symbols in the two last columns will not agree exactly with those given by Messrs. Solly and Baumhauer; for the angles will be those of wiltshireite. In Mr. Solly's memoir (this Magazine, vol. xiii, p. 73) the table of his and Baumhauer's symbols does not in all cases give the true equivalents, but only near approximations with simple indices. Thus Solly's (190) is Baumhauer's (4·0·27) and not as stated (107); and Baumhauer's (045) should be (094), although in my transformation it is, as given by Mr. Solly, taken as (073).

Table of Angles observed on Wiltshireite and Rathite.

Forms.	Indices.	Computed.	Wiltshireite. Observed means.				Rathite. Observed means.		
			Crystal i.	Crystal ii.	Crystal iii.	Crystals iv & v.	Crystal vi.	Crystal vii.	Crystal viii.
						Crystal iv.			
	100:501	15° 46′		15°16′					
	401	18 46		18 25					
Ah	301	23 59					23° 40′		
At	201	32 38	32°36′			32° 14′	32 32		
*A*ζ	302	39 22				39 19			
Ad	101	48 47½	48 47			48 47	48 48		
	405	58 27							
*A*φ	102	61 57				61 52	61 47		
AC	001	79 16	79 15			80 41	79 21		79°56½′
*A*ψ	$\bar{1}04$	88 58							
Aw	$\bar{1}02$	98 44							
Au	$\bar{2}03$	105 0	104 12	104 51					
Az	$\bar{1}01$	116 24½	116 33	116 29	116°24′				
*A*χ	$\bar{3}02$	130 1							
Ay	$\bar{2}01$	139 47½	139 46		138 56		139 42	139°31′	139 48
	$\bar{3}01$	151 51							
*A*θ	100:510	17 19	17 48	17 39	17 10			17 37	
*A*ρ	920	19 6			19 7			19 17	19 59
	410	21 18				21 24		21 51	21 21
	720	24 1						24 35	
Al	310	27 28	28 17	27 15	27 28		27 14	27 46	27 54
	520	31 57	31 52		31 50		32 15	32 27	32 14
Ar	210	37 56	38 35		37 57		38 14	38 24	38 24
	740	41 42			41 44				41 19
As	320	46 6		46 3	46 4	46 4	46 24	46 28	46 34½
	540	51 17					51 20	51 40	51 46
Am	110	57 19		57 8	57 32	57 22	57 21	57 39	57 46
*A*ω	340	64 18	64 15						
Af	120	72 13		72 14	72 18	72 12	72 19	72 29	72 30
*A*α	250	75 37			75 49				76 18
	140	80 53						80 22	81 4
Ak	100:522	37 33	38 7?						
*A*δ	211	43 9	43 7						
Ae	322	50 14	50 7			50 12	50 7		50 46
Ag	111	59 7	59 10		59 5	59 2	58 58		59 29
	344	64 19				64 21			
*A*σ	122	70 1	70 0		69 54	70 2	70 7		70 15
An	011	82 37½	82 38		82 36		82 29		
Ao	$\bar{1}22$	96 0	96 2		96 1		95 47		
Ap	$\bar{1}11$	108 44	108 39		108 46		108 50		
Ax	$\bar{3}22$	119 50			119 48				
*A*λ	$\bar{2}11$	128 56	128 58		129 8				
*A*κ	$\bar{5}22$	136 11	136 2		136 11				
Ai	$\bar{3}11$	141 56			142 0				

Table of Angles (continued).

Forms.	Indices.	Computed.	Wiltshireite. Observed means.				Rathite. Observed means.		
			Crystal i.	Crystal ii.	Crystal iii.	Crystals iv & v.	Crystal vi.	Crystal vii.	Crystal viii.
$A\mu$	100:31$\bar{2}$	53 29			53 33				
$A\eta$	52$\bar{4}$	59 29			59 21				
$A\pi$	21$\bar{2}$	66 21			66 20				
$A\epsilon$	32$\bar{4}$	74 0			74 7				
$A\Delta$	11$\bar{2}$	82 17			81 57				
$A\gamma$	01$\bar{2}$	99 29			98 51				
xn	$\bar{1}$01:011	56 40			56 36				
mn	110:011	47 14	47 17		47 20				
$m\Delta$	$\bar{1}$12	71 17							
$m\lambda$	21$\bar{1}$	35 9		35 3	35 9				
$m\mu$	31$\bar{2}$	50 10		50 4	49 57				
$mx_{,}$	10$\bar{1}$	76 6		75 59	75 56				
$f\sigma$	120:122	40 42	40 37						40 39
$C\sigma$	001:122	46 2	45 47						46 26
Cf	120	86 44	86 34						87 5
$Cf_{,}$	$\bar{1}$20	93 16							93 2
$s\kappa$	320:52$\bar{2}$	30 8		29 51	30 8				
$s\sigma$	122	42 58	42 54		42 54				
sx	$\bar{1}$01	107 57	107 50	108 7	108 2				
σx	122:$\bar{1}$01	64 59	64 55		65 5				
						Crystal v.			
yi	20$\bar{1}$:31$\bar{1}$	36 28			36 16				
ym	110	65 39			65 10				
mp	110:$\bar{1}$11	65 52			65 55	65° 34′			
$p\mu$	$\bar{1}$11:$\bar{3}$12	24 13			24 8				
py	$\bar{2}$01	48 29			48 49	48 13			
mg	110:111	36 24½			36 26				36 28
$m\Sigma$	112	53 56			54 22				
mC	001	84 14	84 19						84 40
$mp_{,}$	11$\bar{1}$	40 54	40 50		40 25				
$m\Delta$	11$\bar{2}$	62 14	62 19		61 47				
$C_{,}\Delta$	00$\bar{1}$:11$\bar{2}$	83 32	83 26						
$p\pi$	$\bar{1}$11:$\bar{2}$12	18 10½	18 14*		18 7				
πx	$\bar{2}$12:$\bar{1}$01	25 36	25 28		25 37				
px	$\bar{1}$11:$\bar{1}$01	48 46½	48 45		48 44				
$pp_{,}$	$\bar{1}$11:$\bar{1}\bar{1}$1	87 38	87 29		87 31				
nC	011:001	46 26	46 29*						
γC	012:001	27 48½							
$nn_{,}$	011:0$\bar{1}$1	92 52	92 52						

* As pointed out in the description of crystal i, these angles are a selection amongst a number of possible values.