ON THE CRYSTAL STRUCTURE OF CRYOLITHIONITE

BY

HANS CLAUSEN

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WITH 4 FIGURES IN THE TEXT

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Among the minerals of the cryolite-group, cryolithionite occupies an exceptional position, as this mineral crystallises in the cubic system and has a well-defined chemical composition. For this reason it may be expected that the crystal structure of this mineral can comparatively easily be determined. Also other minerals showing cubic symmetry have been mentioned[1], but they occur in such small quantities that a chemical analysis can not be undertaken. The cryolite itself crystallises in the monoclinic system, although with pseudocubic symmetry, and as the chemical composition of this mineral (Na_3AlF_6) shows a great analogy in relation to that of the cryolithionite ($Li_3Na_3Al_2F_{12}$), a determination of the structure of the last mentioned mineral will not only be of interest in itself, but in addition such a determination of the structure will probably be of great value for an investigation concerning the structure of the cryolite.

Cryolithionite was first found at Ivigtut and has been described by N. V. Ussing[2]. Cryolithionite from this locality does not show crystal faces suitable for measurement, but on the other hand it may be cleaved very plainly along the faces of the dodecahedron. Later on O. B. Bøggild[1] has described crystals of cryolithionite from Ural, and as limiting faces he found the planes belonging to the dodecahedron and the icositetrahedron (211).

In the X-ray investigations of the structure, partly the method with powdered material and partly the Laue-method have been used. The material for the investigation has been delivered by Universitetets mineralogiske Museum, for which I wish to express my gratitude to the director, Professor O. B. Bøggild.

The first of the X-ray diagrams were taken in Oslo at Mineralogisk Institut and here I want to express my best thanks to the director, Professor, Dr. V. M. Goldschmidt for the use of his apparatus and also for his excellent instruction in the methods of structure-investigations.

During the work at the closer interpretation of the X-ray photographs (which were made here in Copenhagen) it appeared expedient to make some new, more accurate oriented photographs, and I am greatly indebted to Professor, Dr. Niels Bohr because he has enabled me to do this by placing the necessary apparatus at my disposal at Universitetets Institut for teoretisk Fysik. The later photographs, however, have only confirmed the results obtained from the first diagrams, which were made in Oslo. I am also very much indepted to Professor, Dr. H. M. Hansen

with whom I have discussed some of the problems relating to the conditions of reflection.

In Table I the data from a powder-photograph obtained by means of copper K-radiation are given (Fig. 1). A tube with "hot cathode" and "Lindemann-window" was used. 32 lines were observed on the photograph, which had a diameter of 56.70 mm. From the difference between the squares of the sinus for neighbouring lines, it appears that $q = h^2 + k^2 + l^2$ has those values which are characteristic of the simple cubic lattice Γ_c; the length a_o of the edge of the unit cube is about 6.03 Å. The values q are mainly even numbers, but in spite of this, a_o cannot have the double length. This can be seen for instance from lines no. 11 and 12, where both of the line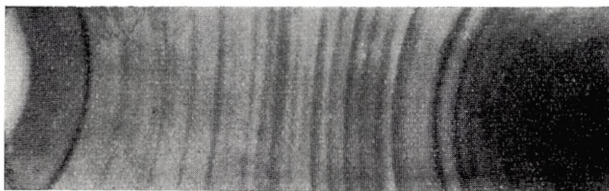s are strong. Furthermore, if the edge of the unit cube has double the size, this last mentioned line should be given by $q = 7$, a value which is impossible as well as $q = 15$ (line no. 21). By looking over the variations within the factor X to the different lines, it will be seen that when q is greater than 30, neither the value of q nor the indices of the reflecting plane

Fig. 1. Reproduction of one half of the powder-photograph.

can be determined with certainty. $q = 38$ for no. 25 may after all be taken for granted, as this line shows great intensity just like the form (611) where $q = 38$ on the Laue-photograph (Table II). Altogether there is no great variation in X. The striking deviation for lines no. 6, 7 and 8, where q has been found to be 6, 8 and 9 respectively, is however noteworthy. But $8 \cdot X$ has too small a value, while both $6 \cdot X$ and $9 \cdot X$ are too great. The last mentioned two values may, however, be explained by the fact that lines no. 6 and 8 may be in part derived from intermingled cryolite. Cryolithionite is never quite free from that mineral[2] and cryolite produces strong lines on a powder-photo, these lines having a glancing-angle only a little greater. Something similar applies to lines no. 2 and 4, whereby comparisons of the intensities to these lines are but of little value. But as regards line no. 7 such an interpretation is not possible, and the cause for the deviation of this line is unknown at present.

The weight of a "chemical molecule" of cryolithionite is: $2Al + 3Li + 3Na + 12F = 372$. The density was found by USSING to be $2.777 - 2.778$. With these values the number of "chemical molecules" in the unit cube where $a_o = 6.03$ Å will be

$$n = \frac{2.78 \cdot 6.03^3 \cdot 10^{\div 24}}{372 \cdot 1.65 \cdot 10^{\div 24}} = 0.994, \quad \text{or} \quad n = 1.$$

The problem will now be how to place the atoms or rather the ions in such a manner that the conditions of symmetry may agree with the properties of symmetry shown by a cubic crystal which for lattice of translation has the simple

cubic lattice Γ_c. There must consequently be 2 sets of 3 equivalent points (Li^+ and Na^+), 2 sets with one point only (Al^{+++}) and finally either 2 sets with 6 equivalent points each or one set of 12 equivalent points ($F^{\div}$).

Selection of a space-group. According to R. W. G. Wyckoff's tables [3] it is only possible simultaneously to place 2 sets each with 1 point and 2 sets with 3 equivalent points in the following space-groups for all of which the lattice of translation is Γ_c: $T^1, T_h^1, T_d^1, O^1, O_h^1$. Of these, however, it is necessary to exclude the first two, as a Laue-photo parallel to (001) does not show indications of hemihedry, and consequently only the three last mentioned groups remain. But it must be remembered that the cryolithionite from Ural has the icositetrahedron developed as a natural face, a fact which is not reconcilable with the conditions of symmetry shown by T^d, where the planes of symmetry parallel to the cube-planes are missing. Consequently it is to be expected that cryolithionite crystallises either in O or in O^h.

The coordinates for the metals according to Wyckoff's tables are the following:

$$Al^{+++}: (1a) \text{ and } (1b)$$
$$Li^+: (3a) \text{ or } (3b)$$
$$Na^+: (3b) \text{ or } (3a)$$

$$(1a): 000; \quad (1b): \tfrac{1}{2}\tfrac{1}{2}\tfrac{1}{2}.$$
$$(3a): \tfrac{1}{2}\tfrac{1}{2}0; \ \tfrac{1}{2}0\tfrac{1}{2}; \ 0\tfrac{1}{2}\tfrac{1}{2}. \quad (3b): \tfrac{1}{2}00; \ 0\tfrac{1}{2}0; \ 00\tfrac{1}{2}.$$

The coordinates for $F^{\div}$. In O^1 and in O_h^1 there are only two ways in which the fluorine-ions may be placed so that each of the $6F^{\div}$ are equivalent, viz. $(6a)$ and $(6d)$. — — (Wyckoff in his tables for O^1 in addition to $(6a)$ and $(6d)$ also gives the sets $(6b)$ and $(6c)$; accordingly there are not 2 but 4 possibilities in which the $F^{\div}$ may be grouped. These 4 sets of 6 equivalent positions are only possible in T_h^1, but in O^1 $(6b)$ and $(6c)$ in a lump are indentical with the set $(12f)$ which should therefore be added in the place of $(6b)$ and $(6c)$ on page 132 in Wyckoff's paper amid "Twelve equivalent positions". This correction similarly is to be applied in the synopsis on page 177 for O^1. — The same correction should also be applied in H. Mark: Die Verwendung der Röntgenstrahlen in Chemie und Technik. Leipzig 1926. Tabelle 52) — —.

With 12 equivalent $F^{\div}$ there will be 3 sets of coordinates. namely $(12f)$, $(12m)$ or $(12n)$ for O^1 as well as O_h^1.

Each one of these sets of coordinates for the fluorine-ions contains one unknown parameter as also appears from the following values for the coordinates:

$$(6a): u00; \ 0u0; \ 00u; \ \bar{u}00; \ 0\bar{u}0; \ 00\bar{u}.$$
$$(6d): \tfrac{1}{2}u\tfrac{1}{2}; \ \tfrac{1}{2}\tfrac{1}{2}u; \ u\tfrac{1}{2}\tfrac{1}{2}; \ \tfrac{1}{2}\bar{u}\tfrac{1}{2}; \ \tfrac{1}{2}\tfrac{1}{2}\bar{u}; \ \bar{u}\tfrac{1}{2}\tfrac{1}{2}.$$
$$(12f): \tfrac{1}{2}u0; \ 0\tfrac{1}{2}u; \ u0\tfrac{1}{2}; \ \tfrac{1}{2}\bar{u}0; \ 0\tfrac{1}{2}\bar{u}; \ \bar{u}0\tfrac{1}{2};$$
$$0u\tfrac{1}{2}; \ \tfrac{1}{2}0u; \ u\tfrac{1}{2}0; \ 0\bar{u}\tfrac{1}{2}; \ \tfrac{1}{2}0\bar{u}; \ \bar{u}\tfrac{1}{2}0.$$

$(12\,m) : u\,\bar{u}\,0; \quad u\,u\,0; \quad \bar{u}\,\bar{u}\,0; \quad \bar{u}\,u\,0;$

$0\,u\,\bar{u}; \quad 0\,u\,u; \quad 0\,\bar{u}\,\bar{u}; \quad 0\,\bar{u}\,u;$

$\bar{u}\,0\,u; \quad u\,0\,u; \quad \bar{u}\,0\,\bar{u}; \quad u\,0\,\bar{u}.$

$(12\,n)$ totally corresponds to $(12\,m)$, so long as 0 is replaced by $\frac{1}{2}$ (Therefore it makes no difference whether $(12\,m)$ or $(12\,n)$ is applied, as for Li^{+} $(3\,a)$ or $(3\,b)$ may be used ad libitum).

Selection of the set of coordinates for $F^{\div}$ and determination of the value of the variable parameter u. By inserting the indices of the different planes into the sets of coordinates which specify the places of the ions in the unit cube, it is possible to calculate the intensity with which each of the planes reflects. In comparing the calculated intensities with those observed, one can investigate which of the sets of coordinates and which of the values of the parameter best gives the intensities observed, and by this means the positions of the fluorine-ions may consequently be found.

A general view of the reflecting power of the different planes is most distinctly obtained from a Laue-photo. Therefore a preparation was cut with a face as far as possible parallel to a cube-face; there was a difficulty in producing such a cut, the exterior parts of the cryolithionite at the limits to the surrounding cryolite being very irregularly built, for which reason a Laue-photo does not show points but an "asteriated" system of reflexes. The external parts just mentioned are characterised by being traversed with parting-planes which are parallel to the cube-faces. From the interior parts, a cut was however obtained which, though a little oblique, produced a Laue-photo rich in points. In the usual manner this was converted into the gnomonic projection from which the indices of the reflecting planes may easily be obtained. As the cut was somewhat too oblique with regard to (001), viz. about $10°$, later on (here in Copenhagen) a better cut was made which deviated only
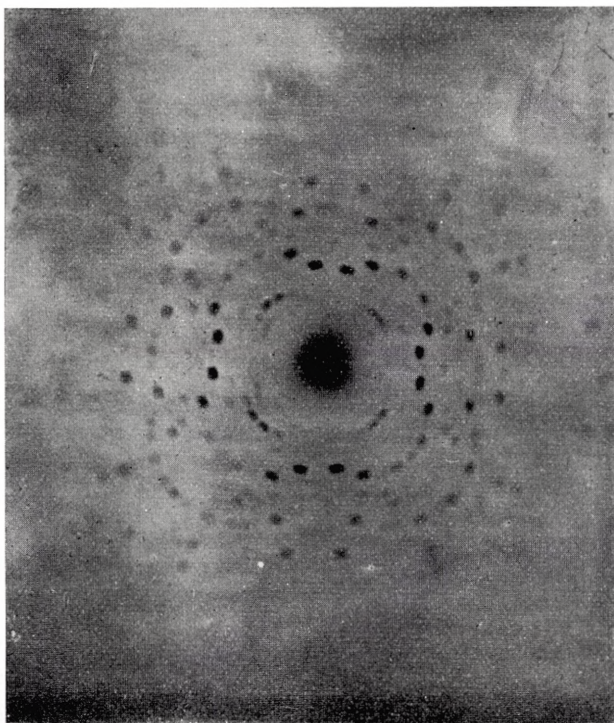

Fig. 2. Reproduction of the Laue-photograph very near (001); the distance from the crystal to the photographic plate was 3.92 cm.

about 2° from the said plane. This cut was placed in the Laue-camera on the crystal holder which is composed of the sleds from a goniometer. By this means an oblique cut can be transferred to any symmetrical position desired. The symmetry of the cut in relation to the incident X-ray beam may then be verified by taking a photo after the adjustment. The photographic plate is mounted on a sledge in such a way that the direction of the incident beam is perpendicular to the plate; by moving the sledge, the distance from crystal to photographic plate can be varied. The size of the displacement can be read on a scale, and thus the distance from crystal to plate can be determined by taking two or more photographs, oriented identically, but with the sledge moved a known distance. A Laue-diagram (Fig. 2), obtained in this manner, showed in all reflections from 45 different forms, among which the following are especially adapted for comparisons of the intensities:

q	hkl	Intens.	$n \cdot \lambda$
26	501	sv	0.43
30	521	st	0.38—0.44
38	611	stst	0.3
46	631	sv	0.25
62	651	m-st	0.25
62	732	sv	0.38

The intensities are classified as strong (st), medium (m) and weak (sv); $n \cdot \lambda$ indicates the wave-length of the reflected X-rays, as n denotes the order of the reflection (in the table above n certainly equals one).

If we provisionally assume that the fluorine ions are grouped in accordance with ($6a$) and ($6d$), u may theoretically be of any value between 0 and 0.5. It may, however, be expected that the F-ions are closer to Al^{+++} than to the ions of the alkali-metals. It means that in ($6a$) u is smaller than $\frac{1}{4}$, and in ($6d$) greater than $\frac{1}{4}$. For the sake of convenience only the value of u in ($6a$) is specified, since $u_{(6d)} = \frac{1}{2} \div u_{(6a)}$.

The forms referred to above having all one even and two odd indices, all reflect with amplitude: $2Al \div 1Li \div 1Na + xF$. As regards sign and magnitude x depends on the indices of the reflecting plane. Assuming that the reflecting power of an ion or an atom is proportional to the number of electrons, the amplitude of the planes mentioned will be: $8 + xF$ ($F = 10$).

A general view of the values of the fluorine-amplitude for different values of $u_{(6a)}$, for the planes (501), (521) and (611), is given in the following table.

$u =$	0.16	0.18	0.20	0.23	0.25	0.27	0.30
(501)	3.690	4.470	4.618	3.426	2.000	0.574	$\div$ 0.618
(521)	0.838	1.195	1.000	$\div$ 0.511	$\div$ 2.000	$\div$ 3.363	$\div$ 4.236
(611)	4.080	3.456	1.854	$\div$ 0.957	$\div$ 2.000	$\div$ 1.959	$\div$ 0.618

From these values it will be seen that only if u is about 0.27, is the structural factor for (501) considerably smaller than that for (611). But with this value of u the

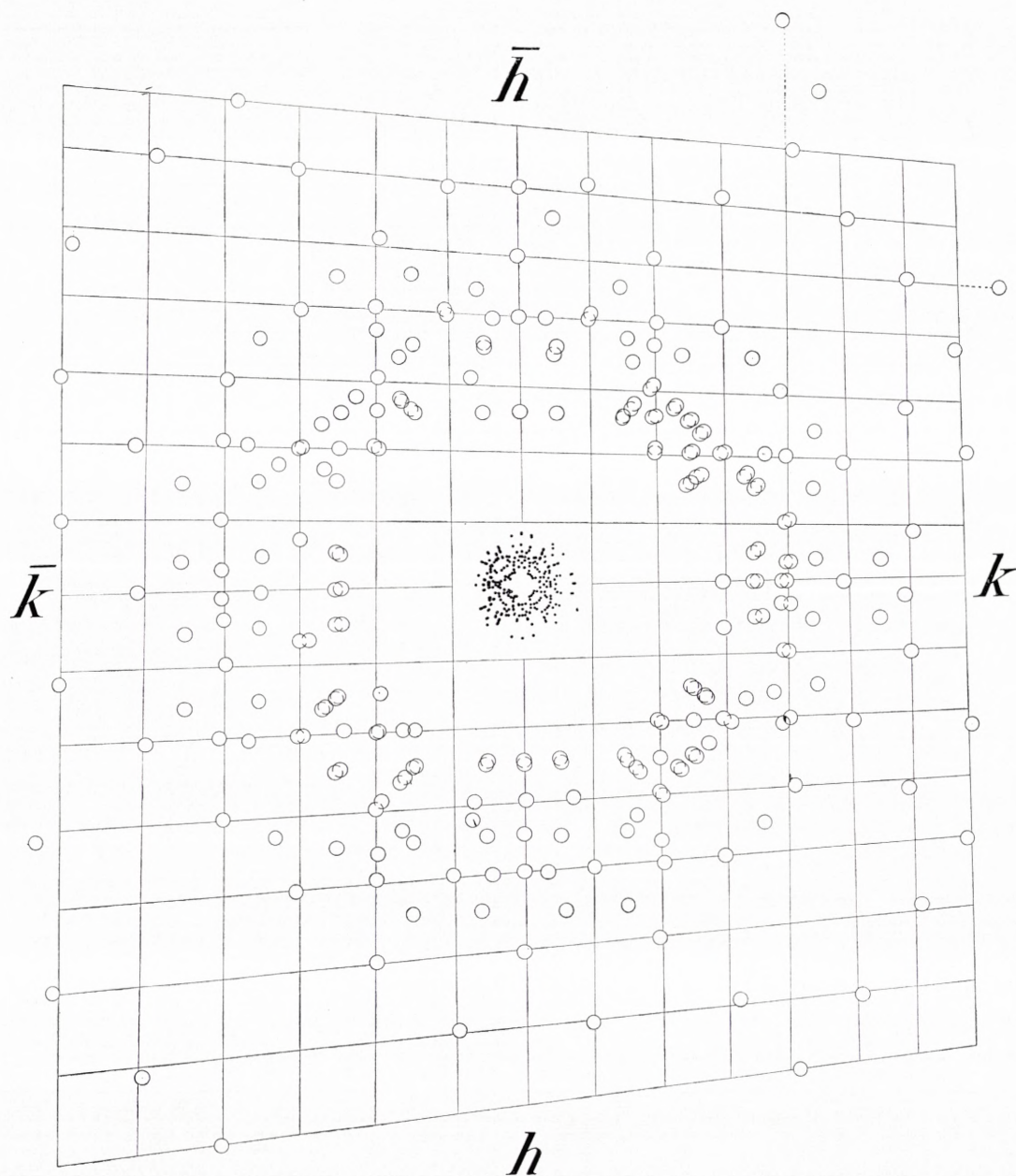Fig. 3. The points of the Laue-photograph (in the middle) and their gnominic projection.

structural factor for (611) becomes too small compared with that of (521). Other values of u lead to intensities of (501) which are larger or of the same order of magnitude as the intensity of the strongly reflecting (611). Neither does a combination of (6 a) and (6 d) with mutually different values of u lead to a result in agreement

with the observed facts. In this case too (501) reflects with the same or greater intensity than (611). Consequently there is no possibility of placing the fluorine-ions in the coordinates $(6a)$ and $(6d)$.

The arrangements with 12 equivalent positions.

In $(12f)$ it is most likely that the $F^{\div}$ are placed pretty near the middle of the line joining Li^+ and Na^+. Compared to the intensities of the Laue-spots $u = \frac{1}{4}$ gives intensities which are absurd, since a range of planes gives an amplitude of the value $8 + 4F$, and hence the intensities of these planes will be inversely proportional to $q = h^2 + k^2 + l^2$. Assuming for a moment that the above supposition is correct, the result will be that planes (651) and (732) reflect with the same intensity, both of them, however, weaker than for instance (631). The fluorine-amplitude for (501) is moreover independent of u since it is always $\div 4F$. This,

Fig. 4.

The dependence of the fluorine-amplitude on $u_{(12m)}$ for planes (501), (521) and (611).

however, is not the case for (611), where the F-amplitude decreases if u deviates from $\frac{1}{4}$.

It is thus impossible on the basis of $(12f)$ to obtain reasonable relations between the intensities for different reflecting planes. Hence the fluorine-ions in cryolithionite cannot be placed in accordance to $(12f)$.

In the group of coordinates $(12m)$ the fluorine-ions are arranged in planes parallel to the cube faces. If the fluorine-ions are placed approximately at equal distances from the two Al^{+++} in the unite cube, u becomes 0.375. Planes (611), (521) and (501) are especially suited for a preliminary investigation of what values u may attain. The fluorine-amplitude of (611) must be larger than that of (521) which again is larger than that of (501). According to the Laue-photograph it is to be
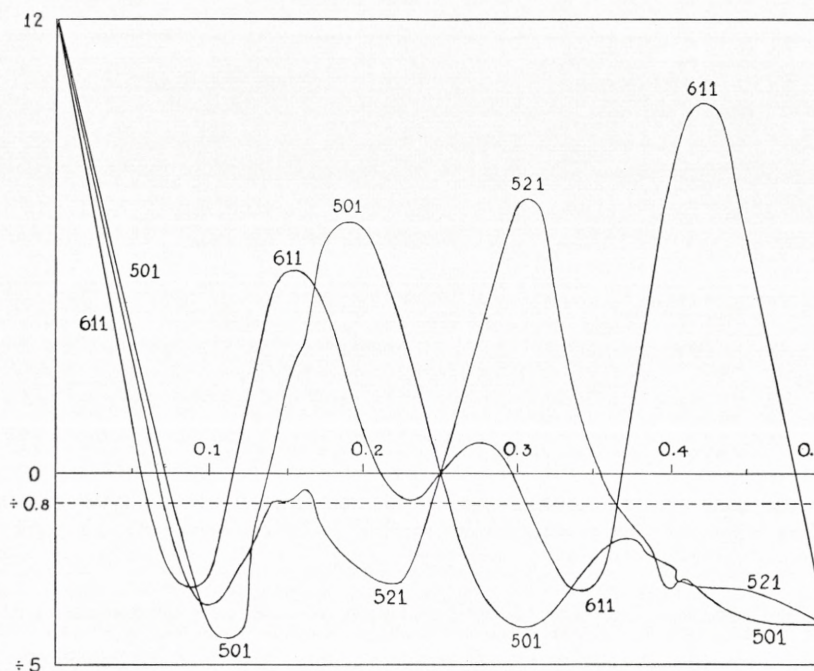
expected that the differences between these amplitudes should be rather great. The relations between these amplitudes are most clearly described graphically. In the diagram (Fig. 4) u is the abscissa and the fluorine-amplitude the ordinate. The effect of the amplitude of the metal-ions is shown by the dotted line at $\div 0.8$, which thus becomes the zero line for the determination of the total amplitudes. It is seen from the course of the curves that the total amplitude is only larger for (611) than for (501) if u has the following values: between 0.13 and 0.16; about 0.26; between 0.36 and 0.46.

In the case of $u = 0.26$, however, the total amplitude of (521) is considerably larger than that of (611); and between 0.13 and 0.16 the total amplitude of (521) is only larger than that of (501) at 0.13. Between 0.36 and 0.46 it is only for values of u between 0.39 and 0.41 that the total amplitude of (521) becomes larger than that of (501). Accordingly it is only possible to place the fluorine-ions in the group $(12\,m)$ if u either has a value of about 0.13 or if its value is between 0.39 and 0.41.

A calculation of the fluorine-amplitudes of the three planes just mentioned will show that we obtain the best agreement with our experiment when we put u equal to 0.13 or very near to 0.395. The fluorine-amplitudes and the intensities calculated therefrom are given in the following table.

hkl	Int.	$u = 0.13$		$u = 0.305$	
		F.-Amp.	Intens.	F.-Ampl.	Intens.
501	sv	$\div 1.223$	0.69	$\div 2.332$	9.04
521	st	$\div 1.634$	2.3	$\div 2.925$	15.04
611	stst	$+ 2.900$	36.0	$+ 6.825$	153.2
631	sv	$\div 2.175$	4.11	$\div 0.179$	0.84
651	m-st	$\div 1.537$	0.88	$\div 3.663$	13.2
732	sv	$\div 2.621$	5.36	$+ 0.618$	3.25

It will be seen that in both cases the intensity of (611) is very much larger than that of (521). In the case of $u = 0.395$, however, the intensity of the latter is not very different from the intensity of (501), a fact which does not agree with the observations. The value $u = 0.13$ is not better, however, as it leads to absurd intensities for (651) and (732).

For the purpose of obtaining a more accurate determination of u the intensities of the powder-photograph were considered. It is observed that the forms (110) and (100) II order give strong lines, whereas only a very weak and questionable line is found for (111).

As in the cases of the forms discussed above the structural factor for the form (110) is: $2\,Al \div 1\,Li \div 1\,Na + xF$. In the case of (111), however, the structural factor is: $0\,Al \pm 3\,Li \mp 3\,Na + xF$, where a positive value for Li corresponds to the set of coordinates $(3\,a)$ and a negative value to the set of coordinates $(3\,b)$. Values of fluorine-amplitudes obtained from $u = 0.13$ and $u = 0.395$ respectively are given

in the following table. The intensities given in the table are calculated from the amplitudes, taking in consideration the statistical weight which has to be given to the two forms in the powder-diagram.

hkl	Int.	$u = 0.13$		$u = 0.395$	
		F.-Ampl.	Intens.	F.-Ampl.	Intens.
110	st	$+6.930$	17940	$\div 3.824$	2750
111	?	$+5.623$	1387	$+7.492$	3460

As seen from the table, it is only possible to interpret the intensities of the powder-diagram on the assumption that Li^+ is arranged according to $(3a)$ and Na^+ according to $(3b)$. Furthermore it will be seen that only $u = 0.13$, but not $u = 0.395$, gives intensities in qualitative agreement with the experimental values. As found above, however, $u = 0.13$ is not in agreement with the intensities of the Laue-spots. Consequently the fluorine ions can not be arranged in accordance with the set of coordinates $(12\,m)$. It is therefore necessary to investigate whether some other arrangement of the 12 fluorine ions will lead to conformity between calculated and observed intensities.

The group T_d^1 was disregarded during the discussion of the possible structure of the cryolithionite because the icositetrahedron is observed on the crystals from Ural (pag. 5). If the cryolithionite actually crystallises in the hexacistetrahedral class, a simultaneous appearance of both the positive and the negative triacistetrahedron will result in an apparent icositetrahedron. This being the case, we should expect a difference in the appearance of the positive and the negative faces as to lustre and size. Such facts, however, were not observed on the above crystals from Ural. It must be borne in mind, however, that these crystals are very small, the dimensions being of the order $1/3$ mm.

The holohedric appearance of the crystals from Ural can also be explained by the fact that the apparently homogeneous crystal consists of numerous thin twins of which the one set belongs to the positive triacistetrahedron and that, alternating with these, there is another set, which belongs to the negative triacistetrahedron. As the three-fold axes are polar in the hexacistetrahedral class, the axes in the twin complex just described, will be in opposite directions in two neighbouring individuals. If the lamellae are very thin, the complex may, however, appear externally as if the symmetry was holohedric. Under such circumstances it is also to be expected, that the etching figures show holohedric symmetry, as they virtually do in the case of cryolithionite. The etching figures were produced by diluted sulphuric acid on the cleavage faces of the cryolithionite, and in this manner rhombic etching figures appeared. In these figures symmetry was obvious about the longer of the diagonals as also about the shorter one of (110), a fact, which suggests that the crystals of cryolithionite possess holohedral symmetry.

The appearance of the Laue photograph may possibly countenance the idea that the structure of the cryolithionite is not quite uniform throughout. All of the

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reflections in the Laue photograph are not single spots, but many of the planes produce distinct double spots. It may be thought that the cause for such a "regular irregularity" is that the orientation of the two sets of crystal-individuals in relation to each other is not exactly uniform throughout the whole of the complex.

Other crystals than cryolithionite also produce double spots on a Laue photograph. Here especially a paper of M. L. GARRABOIS[4] should be brought into notice; in this paper there are reproductions of Laue photographs along the cleavage rhombohedron of dolomite and from the face (100) as well as from that of ($\overline{1}00$).

The difference between the two sorts of faces obviously appears from the etching figures. Parts of an apparently homogeneous cleavage face, however, were also found, with a belt consisting of the one sort of etching figures bordering on a belt of those of the other sort. Here, evidently, two crystal individuals with their 3-fold axes parallel but in opposite directions adjoin each other. A Laue-photograph from this bound (loc. cit. Pl. II, Fig. 3) shows holohedral symmetry in contrast to a Laue photograph along e i t h e r (100) o r ($\overline{1}00$), both of them being obviously asymmetrical. But while the asymmetrical photographs, produced by single crystals, show single spots, the reflections are double spots in the holohedrecal looking photograph. Taken as a whole, the formation of twins evidently produces a very exiguous disarrangement in the structure of the complex, which disarrangement especially appears plainly when an X-ray investigation of the crystal is made.

If it be provisionally assumed that cryolithionite crystallises in T^d, and consequently in T_d^1, then the coordinates of the fluorine-ions can be $(12f)$ or $(12g)$. In this case only $(12g)$ is fit for the purpose, as $(12f)$ has previously been found unfit (pag. 9). In $(12g)$ there are two unknown parameters, u and v; the coordinates of $(12g)$ are given below:

$$uuv; \quad u\overline{u}\overline{v}; \quad \overline{u}u\overline{v}; \quad \overline{u}\overline{u}v;$$
$$vuu; \quad \overline{v}u\overline{u}; \quad \overline{v}\overline{u}u; \quad v\overline{u}\overline{u};$$
$$uvu; \quad \overline{u}\overline{v}u; \quad u\overline{v}\overline{u}; \quad \overline{u}v\overline{u}.$$

Since nothing is known about the values of the two parameters in $(12g)$, an attempt was made to get some information on the subject from the data of the dimensions of the ions, as they are found from other crystals. In this way it is possible to estimate the placings of the fluorine-ions. Using the "radii of the ions" found by V. M. GOLDSCHMIDT and others, the minimum distances in the cryolithionite are as follows:

$$Al^{+++} - F^{\div} : 0.57 + 1.33 = 1.90 \, \mathring{A} \ (= 0.315 \text{ units of cryolithionite})$$
$$Na^+ - F^{\div} : 0.98 + 1.33 = 2.31 \ - \ (= 0.383 \qquad - \qquad)$$
$$Li^+ - F^{\div} : 0.78 + 1.33 = 2.11 \ - \ (= 0.350 \qquad - \qquad)$$
$$F^{\div} - F^{\div} : 1.33 + 1.33 = 2.66 \ - \ (= 0.441 \qquad - \qquad)$$

With the coordinates of $(12g)$ the fluorine ions lie parallel to a plane of the tetrahedron, and consequently the minimum distance from a fluorine ion to

the nearest 3-fold axis is equal to $^2/_3$ of the perpendicular in an equilateral triangle of which the side is 0.441 (= 2.66 Å); accordingly the distance is 0.225. In that case it is necessary that u is at least about 0.3 (for this value of u the fluorine-ions come so near to the sodium (or the lithium) ions, that the two sorts of ions will encroach on each other).

From calculations based on the fluorine grouping $(12g)$ it appeared that the aspect of the Laue photograph is in accordance with arrangement $(12g)$, when u is about 0.32 and v is about 0.05; also when $u = 0.33$ and $v = 0.03$ the calculated intensities and the observed ones are reconcilable.

But in the case of the powder photograph the values just mentioned of u and v in $(12g)$ lead to quite wrong consequences, as the reflections from (110) in relation to that of (111) do not at all correspond to what was observed in the photograph.

With the grouping $(12g)$ the fluorine amplitude contains pure real numbers as far as (110) is concerned. But in the case of the planes having $q = 3$ the fluorine amplitude contains both real numbers and imaginary values. Calculations show that when the real part of the flourine amplitude is about 20—28, the imaginary part will always be of such a value that the intensity of (111) can never be very small in comparison to the intensity of (110).

Note 1. The fluorine amplitude of the positive form (hkl) can be written as $\bar{F}(a+ib)$; and as to the negative form $(\bar{h}\bar{k}\bar{l})$ the fluorine amplitude will be $\bar{F}(a \div ib)$. There is a possibility that the imaginary part of the fluorine-amplitude may be abolished if, by the reflection, an interaction might be imagined between planes belonging to the positive form and those of the negative form. Consequently under such circumstances it is not necessary to pay any regard to the imaginary part of the fluorine-amplitude. The values $u = 0.32, v = 0.05$ and $u = 0.33, v = 0.03$ respectively may, according to the above suppositions, be in accordance with the intensities observed in the powder-photograph.

The circumstances mentioned in Note 1 may apply if the crystals of cryolithionite are actually constructed of such fine twin lamellae along the plane (100) that the finely devided material used for the powder-photograph will contain parts with an apparent holohedral symmetry. Supposing that the circumstances mentioned in Note 1 actually apply, the missing reflection of (111) in the powder-photograph is caused by the formation of twins.

Note 2. In case the cryolithionite is constructed of positive and negative individuals of crystals alternatively, which may be designated as individual I and individual II respectively, they will stand in a mirror image relation with regard to the plane of symmetry missing in T^d.

If II is translated a distance a_0 parallel to the edge of the cube, itself of length

a_o, and is then rotated $90°$ about an edge of the cube, _II_ will be brought into a position so as to cover individual _I_. By a mere translation there will be no difference between the points without a variable parameter (the positions of the metalions) of _I_ and _II_ if ions are found on the said points only. But in the case dealt with here, the points of _I_ and _II_ are not equivalent in such a manner that a simple translation will make them coincide point to point as they are surrounded in a different manner by the fluorine-ions. Consequently, it may be justifiable to say that the translation a_o to the points of individual _I_ adds $2Al + 3Li + 3Na + 12F$ from individual _II_. The $12 F^{\div}$ of _II_ are placed in the four not occupied octants of individual _II_.

As in the investigations of the structure the only point is to express the relations between the intensities, but not the absolute values of the same, it may be said that the effect of the translation a_o as to _I_ is only that the imaginary parts of the fluorine-amplitude are abolished by the total amplitude.

On applying the above considerations to the twin complex of the cryolithionite, which may be imagined formed of positive and negative individuals of crystals alternatively, the calculations of the total amplitudes of various planes show that the amplitudes will be 8 times larger than the real part of the total amplitude of the corresponding plane in the single individual. The imaginary part of the fluorine-amplitude of the single individual quite disappears from the amplitude expression of the complex of twins. But as only the relations of the intensities are of interest it is sufficient to calculate the structural factor of the individual and disregard the imaginary part of the fluorine-amplitude just abolished by the formation of twins.

As mentioned above, the values $u = 0.32$, $v = 0.05$ and also $u = 0.33$, $v = 0.03$ in $(12g)$ might explain the appearance of the powder-photograph if the imaginary part of the fluorine-amplitude may be disregarded, as seems justified by a formation of twins like the one mentioned above. The examples given in Table III will illustrate the dependency of the fluorine-amplitudes on u and v.

If we accept the presence of fine twin lamellae, it must however, be investigated whether there is a possibility for the space-group T_h^1 although the Lauephotograph shows no hemihedry. The lamellae being sufficiently fine, a repeated formation of twins along the plane of the dodecahedron will result in the whole complex showing holohedral symmetry. From calculations it was proved that the intensities m a y be explained by the fluorine-grouping $(6a)$ and $(6b)$ in which u equals 0.17 and 0.27 respectively. — — $((6b)$ is identical whit the top line of $(12f)$ on page 5) — —.

Taking it for granted that cryolithionite is constructed of exceedingly fine twin-crystals, its structure may consequently be explained on the basis of either the space-group T_d^1 or T_h^1. It is difficult to say which of the two possibilities is the correct one. A comparison with the Laue-photograph of cryolite results in T_d^1 being

considered the better. It is, however, only the great analogy as regards the chemical composition, and moreover the fact that the cryolite is very nearly cubic and actually becomes so when heated to about 570° C that justifies such a comparison between cryolite and cryolithionite.

G. MENZER has arrived at an entirely different result[5] concerning the structure of cryolithionite, having found that the length of the edge of the unit is almost double the value I have arrived at. MENZER consequently finds that the unit contains 8 "chemical molecules" which he supposes to be placed in accordance with the space-group O_h^{10}. He has arrived at this result from a certain analogy between cryolithionite and garnet as regards the chemical composition.

When explaining the powder-photograph (page 4) I mentioned that if the purest cryolithionite was employed the reflections observed would prove that the unit contains one "chemical molecule", and the length of its edge is $a_o = 6.03$ Å, even if the reflections of the powder-photograph chiefly represent planes for which q are even numbers.

I therefore hold that no great importance can be attached to MENZER's determination of the structure of cryolithionite, which is only made from a powder-photograph, which is not a good basis for intensity comparisons. MENZER's further step, the statement of the numerical values for three variable parameters, must therefore be considered entirely insignificant.

When labouring at determining the crystal structure of a substance one has to face several facts, each of which is instrumental in lessening the certainty of the determination. The very existence of a variable parameter signifies an uncertainty, which, naturally, is considerably increased if not one, but two (or three) variable parameters occur at the same time. And owing to our deficient knowledge of the real power of reflexion of the ions a further uncertainty appears. Inter alia, it should no doubt be considered that the ions are not formed as a point, but are of finite extent, so that the size of the glancing angle influences the power of reflexion. TOM. BARTH for instance has tried to use the numerical corrections as to the final extent of the ions for Sodium fluoride[6], starting from the real ion radii as estimated by H. G. GRIMM[7]. These corrections, however, do not lead to values which, as regards the substance in question, are more conformable to the intensity relations than the intensities arrived at by supposing the power of reflection proportional to the total numbers of electrons. As regards cryolithionite I have therefore introduced no such correction, especially as it would obviously yield no better conformity to the most simple sets of coordinates for $F^{\div}$, $(6a)$ & $(6d)$, $(12f)$ and $(12m)$.

Of course, the supposition that cryolithionite is constructed of twin lamellae in itself signifies a new uncertainty, which does not become less by our having to deal with two variable parameters at the same time.

If we consider the purely geometrical problem of placing 12 points within a cube, in such a way that the symmetry shall fulfil the claims of the cubic system, and the corners and center of the cube and also the middle of edges and planes

are set with other points (respectively Al^{+++} and Na^+ and Li^+), and the various dimensions of the points (the ionradii) are taken into consideration, I think that the grouping $(12\,m)$ will prove the best solution. Next, $(6\,a)$ & $(6\,d)$ will follow as no. 2, while $(12\,f)$ is an inferior solution. From a geometrical point of view $(6\,a)$ & $(6\,b)$ and $(12\,g)$ are by no means better solutions. But if we consider that the ions are certainly not stiff spheres, but can be deformed so as to be "polarised" it is probable that even the two last mentioned ways of placing the fluorine-ions are the most space-saving methods. As mentioned before (pag. 14), of these two ways $(12\,g)$ is probably the one which virtually underlies the crystal structure of cryolithionite.

Table 1. The results of the measurement of the powder-photograph (Fig. 1); in the second column the intensity observed is stated. NB. beside a line signifies that the line may partly be due to an intermixture of cryolite.

Nr.	Intens.	Glancing angle θ	$10^4 \cdot sin^2 \theta$	q	$X \cdot 10^5$		
1	st	10° 24′	325.8	2	1629		
NB. 2	?	12° 52′	495.9	3	1652		
3	st	14° 48′	652.5	4	1632		
NB. 4	m	16° 39′	821.1	5	1643		
5	svsv	17° 22′	890.9				
NB. 6	m-st	18° 58′	1056	6	1760		
7	st	20° 36′	1238	8	1546		
NB. 8	stst	23° 9′	1546	9	1718		
9	svsv	23° 44′	1620	10	1620		
10	?	25° 23′	1838	11	1670		
11	m-st	27° 37′	2149	13	1653		
12	st	28° 33′	2285	14	1632		
13	sv	30° 44′	2612	16	1634		
14	sv	32° 53′	2947	18	1636		
15	st	34° 54′	3273	20	1637		
16	sv	36° 56′	3611	22	1642		
17	st	38° 59′	3958	24	1649		
18	svsv	40° 27′	4209	26	1619		
19	svsv	41° 58′	4471	27	1655		
20	sv	43° 41′	4771	29	1645		
21	sv	44° 23′	4894	30	1631		
22	svsv	45° 57′	5166	32	1615		
23	svsv	47° 38′	5460	34	1606	or	33·1655
24	?	50° 7′	5888	36	1636		
25	st	51° 52′	6186	38	1629		
26	m	55° 20′	6764	42	1611	or	41·1650
27	svsv	57° 36′	7129	44	1620	or	43·1658
28	svsv	58° 43′	7305				
29	svsv	59° 51′	7478	46	1625	or	45·1662
30	svsv	62° 20′	7845	48	1635	or	49·1602
31	sv	64° 21′	8124	50	1625	or	49·1659
32	stst	69° 31′	8774	54	1625	or	53·1655

Table II. Here each of the points of the Laue-photograph is stated with its number, the intensity observed, the distance c from the center of the photograph, indices ($h\,k\,l$) of the reflecting plane, and the sum of $h^2+k^2+l^2$. Further, for some of the planes the wave lengths of the reflected X-rays have been stated by $n\cdot\lambda$. A bracket outside one or two points signifies double points.

Nr.	Intens.	c Central dist.	$h\,k\,l$	$h^2+k^2+l^2$	$n\cdot\lambda$	Nr.	Intens.	c Central dist.	$h\,k\,l$	$h^2+k^2+l^2$	$n\cdot\lambda$
{ 40	sv	3.30	221	9	1.375	{ 19	m	2.15	141	18	
{ 41	sv	3.20	»	»		{ 20	m	2.20	»	»	0.719
{ 106	sv	3.05	$2\overline{2}1$	»		64	m	2.00	411	»	
{ 107	sv	3.00	»	»	1.285	{ 86	m	1.95	$41\overline{1}$	»	
{ 167	sv (m)	3.10	$\overline{2}21$	»		131	m	1.90	$\overline{1}41$	»	0.635
{ 168	sv	3.20	»	»		148	m	1.90	$\overline{1}\overline{4}1$	»	
{ 231	sv	3.40	$\overline{2}21$	»	1.4	{ 187	m	2.05	$\overline{4}11$	»	
{ 232	sv	3.30	»	»		{ 188	m	2.10	»	»	
						{ 206	m	2.10	$\overline{4}\overline{1}1$	»	
7	sv sv (sv)	3.15	031	10	1.262	{ 207	m	2.15	»	»	
74	sv sv	2.85	301	»	1.208	{ 263	m	2.15	$\overline{1}41$	»	
						{ 264	m	2.20	»	»	
{ 34	sv-m	2.50	231	14							
{ 35	sv-m	2.40	»	»		{ 26	sv	1.95	241	21	
{ 50	m	2.35	321	»		{ 28	sv	2.10	»	»	
{ 51	m	2.40	»	»		59	sv	1.85	421	»	
{ 98	m	2.30	$3\overline{2}1$	»		91	sv	1.75	$42\overline{1}$	»	
{ 99	m	2.20	»	»	0.815	123	sv	1.70	$\overline{2}41$	»	0.535
{ 114	m	2.20	$2\overline{3}1$	»		153	sv	1.75	$\overline{2}\overline{4}1$	»	
{ 115	m	2.25	»	»		179	sv	1.85	$\overline{4}\overline{2}1$	»	
{ 159	sv	2.35	$\overline{2}\overline{3}1$	»		215	sv	1.975	$\overline{4}21$	»	
{ 160	sv	2.30	»	»		255	sv	2.00	$\overline{2}41$	»	0.615
173	m	2.375	$\overline{3}\overline{2}1$	»							
{ 222	sv	2.575	$\overline{3}21$	»	1.017	2	sv	1.80	051	26	0.504
{ 223	sv	2.50	»	»		71	sv	1.55	501	»	
{ 243	sv	2.55	$\overline{2}31$	»		136	sv	1.50	$05\overline{1}$	»	0.428
{ 244	sv	2.50	»	»		197	sv	1.75	$\overline{5}01$	»	
						36	m	1.70	341	26	
72	sv	2.05	401	17		49	m	1.70	431	»	
{ 3	sv	2.25	041	»		101	m	1.50	$43\overline{1}$	»	0.428
{ 4	sv	2.30	»	»	0.766	113	·m	1.50	$34\overline{1}$	»	
{ 137	sv	1.95	$04\overline{1}$	»	0.670	161	m	1.60	$\overline{3}\overline{4}1$	»	
196	sv	2.20	$\overline{4}01$	»		172	m	1.65	$\overline{4}31$	»	

Table II (continued).

Left half:

Nr.	Intens.	c Central dist.	$h\,k\,l$	$h^2+k^2+l^2$	$n\cdot\lambda$
225	sv	1.775	$\bar{4}31$	26	
241	sv	1.80	$\bar{3}41$	»	0.504
{ 75	sv	3.60	502	29	
{ 76	sv	3.70	»	»	
{ 139	sv	3.50	$0\bar{5}2$	»	0.798
{ 140	sv	3.65	»	»	
{ 195	sv	3.80	$\bar{5}02$	»	0.838
{ 104	svsv	3.60	$4\bar{3}2$	29	0.820
{ 112	svsv	3.65	$3\bar{4}2$	»	
23	st	1.60	251	30	
62	st	1.50	521	»	
{ 66	sv	3.55	512	»	
{ 67	sv	3.65	»	»	
{ 82	sv	3.50	$5\bar{1}2$	»	
{ 83	sv	3.60	»	»	
88	st	1.40	$5\bar{2}1$	»	
125	st	1.40	$2\bar{5}1$	»	0.375
{ 129	sv	3.40	$1\bar{5}2$	»	0.769
{ 130	sv	3.55	»	»	
{ 145	sv	3.45	$\bar{1}\bar{5}2$	»	
{ 146	sv	3.55	»	»	
150	st	1.40	$\bar{2}\bar{5}1$	»	
184	st	1.525	$\bar{5}\bar{2}1$	»	
{ 205	sv	3.70	$\bar{5}\bar{1}2$	»	0.811
{ 204	sv	3.75	$\bar{5}12$	»	
209	st	1.625	$\bar{5}21$	»	
260	st	1.675	$\bar{2}51$	»	0.422
1	svsv	1.50	061	37	0.362
198	svsv	1.425	$\bar{6}01$	»	0.346
15	st	1.45	161	38	
70	st	1.30	611	»	
81	st	1.25	$61\bar{1}$	»	
132	st	1.20	$16\bar{1}$	»	0.29

Right half:

Nr.	Intens.	c Central dist.	$h\,k\,l$	$h^2+k^2+l^2$	$n\cdot\lambda$
143	st	1.20	$\bar{1}\bar{6}1$	38	
190	st	1.40	$\bar{6}11$	»	
203	st	1.40	$\bar{6}11$	»	
267	st	1.45	$\bar{1}61$	»	0.344
{ 30	sv	3.20	352	38	
{ 31	sv	3.125	»	»	
{ 54	sv	3.00	532	»	
{ 55	sv	3.15	»	»	
{ 94	sv	2.95	$53\bar{2}$	»	
{ 95	sv	2.90	»	»	
{ 118	sv	2.85	$35\bar{2}$	»	
{ 119	sv	2.90	»	»	
{ 157	sv	2.95	$3\bar{5}2$	»	
{ 176	sv (m)	3.00	$\bar{5}\bar{3}2$	»	
{ 177	sv	3.10	»	»	
{ 218	sv	3.25	$\bar{5}32$	»	
{ 219	sv	3.20	»	»	
{ 246	sv	3.30	$\bar{3}52$	»	
{ 247	sv	3.20	»	»	
18	svsv	3.05	162	41	
39	svsv	2.80	452	45	
48	svsv	2.75	542	»	
111	svsv	2.65	$45\bar{2}$	»	0.526
163	sv (sv)	2.70	$4\bar{5}2$	»	
169	svsv	2.70	$5\bar{4}2$	»	
{ 226	sv	2.90	$\bar{5}42$	»	
{ 227	sv	2.85	»	»	
{ 238	sv	2.90	$\bar{4}52$	»	0.562
{ 239	sv	2.85	»	»	
25	sv	1.30	361	46	
58	svsv	1.20	631	»	
122	sv	1.05	$63\bar{1}$	»	0.232
155	svsv	1.10	$\bar{3}\bar{6}1$	»	

13*

Table II (continued).

Nr.	Intens.	c Central dist.	h k l	$h^2+k^2+l^2$	$n \cdot \lambda$	Nr.	Intens.	c Central dist.	h k l	$h^2+k^2+l^2$	$n \cdot \lambda$
182	sv sv	1.20	$\bar{6}\bar{3}1$	46		171	m	1.00	$\bar{6}\bar{5}1$	62	
212	sv	1.30	$\bar{6}31$	»	0.2835	230	st	1.15	$\bar{6}51$	»	0.217
						240	st	1.15	$\bar{5}61$	»	
127	sv sv	2.45	$26\bar{3}$	49		61	sv	2.20	732	62	0.388
						89	sv	2.10	$73\bar{2}$	»	
5	sv sv	2.60	072	53	0.478	124	sv	2.05	$37\bar{2}$	»	
6	sv sv (sv)	2.65	»	»		151	sv	2.10	$\bar{3}\bar{7}2$	»	
73	sv sv	2.40	702	»		183	sv	2.25	$\bar{7}\bar{3}2$	»	
138	sv sv	2.30	$07\bar{2}$	»	0.434	258	sv	2.35	$\bar{3}\bar{7}2$	»	
						259	sv	2.40	»	»	
13	m	2.50	172	54		29	sv	1.10	471	66	
14	m	2.60	»	»	0.474	56	sv	1.00	741	»	
21	sv sv	1.20	271	»	0.2422	92	sv sv	0.875	$74\bar{1}$	»	0.1625
68	m	2.35	712	»		181	sv	1.00	$\bar{7}\bar{4}1$	»	
80	m	2.35	$71\bar{2}$	»		217	sv	1.10	$\bar{7}41$	»	
134	m	2.25	$17\bar{2}$	»		250	st	1.15	$\bar{4}71$	»	0.2104
144	m	2.30	$\bar{1}\bar{7}2$	»	0.430						
192	m	2.45	$\bar{7}12$	»		57	sv	2.00	742	69	
193	m	2.50	»	»		93	sv	1.90	$74\bar{2}$	»	
201	m	2.50	$\bar{7}\bar{1}2$	»		216	m	2.15	$\bar{7}42$	»	
202	m	2.60	»	»		77	sv	2.00	$81\bar{2}$	69	
262	sv sv	1.225	$\bar{2}71$	»	0.2465	78	sv	2.00	812	»	
265	m	2.625	$\bar{1}72$	»		135	sv	1.95	$18\bar{2}$	»	0.332
266	m	2.55	»	»		270	sv sv	2.20	$\bar{1}82$	»	0.367
42	m	2.50	552	54		271	sv sv	2.25	»	»	
43	m	2.45	»	»		103	sv sv	3.40	$65\bar{3}$	70	
108	m	2.30	$55\bar{2}$	»							
109	m	2.25	»	»		224	sv sv	2.10	$\bar{7}52$	78	
166	m	2.40	$\bar{5}\bar{5}2$	»		100	sv sv	1.80	$75\bar{2}$	»	
233	m	2.60	$\bar{5}52$	»							
234	m	2.55	»	»		12	sv sv	2.00	192	86	
37	m	1.10	561	62		69	sv sv	1.75	912	»	
45	m	1.05	651	»		79	sv sv	1.75	$91\bar{2}$	»	
102	m (sv)	0.90	$65\bar{1}$	»	0.172	133	sv sv	1.70	$19\bar{2}$	»	0.2640
110	m	0.90	$\bar{5}61$	»		142	sv sv	1.70	$\bar{1}92$	»	
162	m	1.00	$\bar{5}61$	»							

Table II (continued).

Left table:

Nr.	Intens.	c Central dist.	$h\,k\,l$	$h^2+k^2+l^2$	$n\cdot\lambda$
191	sv sv	1.95	$\overline{9}\,\overline{1}\,2$	86	
269	sv sv	2.00	$\overline{1}\,9\,2$	»	0.303
211	sv (sv)	0.975	$\overline{8}\,5\,1$	90	
245	sv	1.00	$\overline{5}\,8\,1$	»	
22	sv	1.85	$3\,9\,2$	94	
63	sv sv	1.70	$9\,3\,2$	»	0.2635
65	sv sv	2.80	$9\,2\,3$	»	
84	sv sv	2.75	$9\,\overline{2}\,3$	»	
87	sv	1.65	$9\,3\,\overline{2}$	»	
126	sv	1.60	$3\,9\,\overline{2}$	» ·	
128	sv (sv)	2.70	$\overline{2}\,9\,3$	»	
147	sv sv	2.75	$\overline{2}\,\overline{9}\,3$	»	
149	sv	1.625	$\overline{3}\,\overline{9}\,2$	»	
186	sv sv	1.75	$\overline{9}\,\overline{3}\,2$	»	
189	sv sv	2.90	$\overline{9}\,\overline{2}\,3$	»	
208	sv	1.85	$\overline{9}\,3\,2$	»	
261	sv	1.90	$\overline{3}\,9\,2$	»	
{ 52	sv	2.75	$8\,5\,3$	98	
{ 53	sv	2.85	»	»	
{ 96	sv	2.70	$8\,\overline{5}\,3$	»	0.362
{ 97	sv	2.60	»	»	
{ 116	sv	2.60	$\overline{5}\,8\,3$	»	
{ 117	sv	2.65	»	»	
{ 174	sv (m)	2.75	$\overline{8}\,\overline{5}\,3$	»	
{ 175	sv	2.80	»	»	
{ 220	sv	3.00	$\overline{8}\,5\,3$	»	
{ 221	sv	2.90	»	»	
{ 248	sv	3.05	$\overline{5}\,8\,3$	»	
{ 249	sv	2.95	»	»	
210	sv	0.90	$\overline{9}\,4\,1(?)$	98	0.1370
44	sv	1.70	$7\,7\,2$	102	
165	sv	1.60	$\overline{7}\,7\,2$	»	0.2295
235	sv (sv)	1.80	$\overline{7}\,\overline{7}\,2$	»	

Right table:

Nr.	Intens.	c Central dist.	$h\,k\,l$	$h^2+k^2+l^2$	$n\cdot\lambda$
180	sv sv	1.60	$\overline{9}\,\overline{5}\,2$	110	
251	sv sv	1.75	$\overline{5}\,9\,2$	»	
{ 46	sv	2.45	$8\,7\,3(?)$	122	
{ 47	sv	2.50	»	»	
164	sv sv	2.35	$\overline{7}\,\overline{8}\,3$	»	
{ 228	sv	2.60	$\overline{8}\,7\,3$	»	
{ 229	sv	2.55	»	»	
{ 236	sv	2.60	$\overline{7}\,8\,3$	»	
{ 237	sv	2.55	»	»	
170	sv	2.40	$\overline{8}\,\overline{7}\,3$	»	
268	sv sv	1.60	$\overline{1}\,1\,1\,2$	126	
11	sv sv	1.60	$1\,1\,1\,2$	»	
199	sv sv	1.55	$\overline{1}\,\overline{1}\,1\,2$	»	
27	sv	2.40	$5\,10\,3$	134	0.276
60	sv sv	2.30	$10\,5\,3$	»	
90	sv sv	2.15	$10\,\overline{5}\,3$	»	
152	sv	2.20	$\overline{5}\,10\,3$	»	
185	sv	2.30	$\overline{10}\,\overline{5}\,3$	»	
214	sv	2.40	$\overline{10}\,5\,3$	»	
{ 253	sv	2.40	$\overline{5}\,\overline{10}\,3$	»	
{ 254	sv	2.45	»	»	
{ 9	sv sv	2.20	$1\,12\,3(?)$	154	
{ 10	sv sv	2.30	»	»	
141	sv	1.95	$\overline{1}\,\overline{1}2\,3$	»	
213	sv	2.35	$\overline{1}\overline{1}\,5\,3$	155	
194	sv sv	2.20	$\overline{1}\overline{2}\,\overline{1}\,4(?)$	161	
200	sv sv	2.20	$\overline{1}\overline{2}\,1\,4(?)$	»	
121	sv	1.85	$6\,\overline{1}\overline{1}\,3$	166	0.2045
154	sv	1.90	$\overline{6}\,\overline{1}\overline{1}\,3(?)$	»	
178	sv (m)	2.00	$\overline{1}\overline{1}\,\overline{6}\,3(?)$	»	
{ 252	sv	2.15	$\overline{6}\,11\,3(?)$	»	
85	sv sv	2.50	$13\,\overline{3}4\,(?)$	194	

Table III. The dependence of the fluorine-amplitude on u & v in $(12g)$ for a series of planes.

hkl	0.28; 0.17	0.30; 0.17	0.31; 0.17	0.32; 0.05	0.33; 0.03	0.33; 0.09	0.4; 0.02
110	÷ 0.582	÷ 0.8088	÷ 0.877	÷ 2.514	÷ 2.857	÷ 2.326	÷ 3.804
111	0.203 ÷ i...		0.783 ÷ i 9.091	2.069 ÷ i 3.036	+ 2.795 ÷ i 1.697	2.351 ÷ i 4.937	6.668 ÷ i 0.520
501	÷ 1.394	÷ 1.417	÷ 1.298	÷ 1.700	÷ 2.310	0.980	÷ 1.885
521	1.534 ÷ i 2.362	1.485 ÷ i 1.809		2.472 + i 3.605	2.897 + i 2.177	0.556 + i 0.475	÷ 2.717 + i 1.314
611	0.447 + i 5.747	0.021 ÷ i 5.888	÷ 0.366 + i 4.589	÷ 3.063 ÷ i 5.273	÷ 3.361 ÷ i 2.634	÷ 4.047 + i 1.331	7.104 ÷ i 3.026
631	÷ 1.157 ÷ i 2.486	÷ 0.145 ÷ i 2.032	0.726 ÷ i 1.132	2.861 + i 2.119	1.457 + i 0.429		
651	1.453 ÷ i 1.610	0.407 ÷ i 2.927		÷ 3.123 + i 3.2913	÷ 2.624 + i 2.845	÷ 1.249 ÷ i 0.787	
732	2.469 ÷ i 1.842	0.246 ÷ i 0.207		1.554 + i 0.699	÷ 1.2321 + i 1.563		

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