Citation:

F.M.Jaeger, On the Symmetry of the Röntgenpatterns Obtained by means of Systems Composed of Crystalline Lamellae and on the Structure of Pseudo-Symmetrical Crystals, in:
KNAW, Proceedings, 22 II, 1920, Amsterdam, 1920, pp. 815-830

Chemistry. — *"On the Symmetry of the* RÖNTGEN*patterns Obtained by means of Systems Composed of Crystalline Lamellae, and on the Structure of Pseudo-Symmetrical Crystals".* By Prof. F. M. JAEGER.

(Communicated at the meeting of April 23, 1920)

§ 1. It is well known how SOHNCKE [1]) and MALLARD [2]), as a consequence of experiments formerly executed by NÖRREMBERG and VON REUSCH, have first tried to account for the optical properties of uniaxial, circularly-polarizing crystals, by the supposition that all such crystals are in reality only apparently higher-symmetrical intergrowths of very numerous, extremely thin, and often submicroscopical, crystalline lamellae of lower crystallographical symmetry. In many cases this supposition has afterwards been confirmed by experience; and just in the same way as in the experiment executed in 1869 by VON REUSCH, who demonstrated in a more or less perfect way the possibility of imitating the behaviour of uniaxial crystals endowed with rotatory power in the direction of their optical axis, by means of a number of *mica*-lamellae, regularly piled-up clock-wise or oppositely, while crossing under the same fixed angle, — thus the behaviour of such pseudo-symmetrical crystals, built up from microscopical lamellae, also appeared to approach the more closely to that of true tetragonal, trigonal, and hexagonal crystals, as the composing lamellae were thinner and more numerous. The complexes thus obtained are either dextro-, or laevo-gyratory, be it that the piling-up of the successive lamellae has occurred clockwise or in the opposed direction. During the investigations of HAGA and myself about the specific symmetry of the RÖNTGENpatterns obtained by diffraction of RÖNTGENrays in plane parallel plates of optically uniaxial crystals [3]), we had occasion to study also some pseudo-symmetrical crystals of this kind, which were characterised by more or less evident optical anomalies; and, while some of them, — e.g. the pseudo-tetragonal *strychnine-sulphate,* — gave RÖNTGENpatterns of so perfect a symmetry, that they could not be distinguished from those obtained with real tetragonal crystals, — we also found with some other crystals of this kind (racemic *triethylenediamine-cobalti-*

[1]) L. SOHNCKE, Zeits. f. Kryst. u. Miner, **19**, 529, (1899).
[2]) E. MALLARD, Ann. des Mines, (7), **19**, 256 (1881); *Traité de Cristallographie,* **II**. 262—304, (1881), H. POINCARÉ, *Théorie mathém. de la Lumière,* **II**, 275, (1892).
[3]) Cf. i.a.: H. HAGA and F. M. JAEGER, Proceed. Royal Acad. of Sciences, Amsterdam, **17**; 1204, (1915); **18**, 558, 1355, (1916).

bromide (+ 3 H_2O), *benzile, apophyllite,* etc.), patterns, showing only a single plane of symmetry, and having, therefore, really the aspect of the patterns commonly obtained with monoclinic crystals, if cut parallel to a plane of their orthodiagonal-zône. On that occasion we also emphasized, that the cause of this abnormal behaviour might probably be ascribed to an imperfect orientation of the lamellae in one of the directions of intergrowths, these for the rest being equivalent. This imperfect orientation might then consist of either a slight rotation of the lamellae about one of their axes in the special direction mentioned above, or of a twinning of some of these lamellae. In all cases, however, it appeared necessary to make the supposition, that those particulars should have occurred more frequently in one of the directions of intergrowth, than in each of the others.

As it was our purpose to obtain a more exact insight into the real behaviour of such pseudo-symmetrical crystals composed of intergrown lamellae, with respect to the phenomenon of the diffraction of transmitted RÖNTGENrays, we have undertaken the study of the specific symmetry of the RÖNTGENpatterns, which could be obtained by means of systems of regularly piled-up *mica*-lamellae, in its dependency on the special structure of the used *mica*-complexes.

The results obtained, which are reviewed in the following pages, have in the first place shown some pecularities, pointing to a close analogy with the anomalies formerly found by us in the case of real pseudo-symmetrical crystals; on the other hand, however, the experience gained must necessarily lead to the conclusion that the views of SOHNCKE and MALLARD, — at least in so far, as *tetragonal* crystals endowed with circular polarisation be considered — cannot yet be considered to give a final explanation of the phenomena observed in these cases.

The RÖNTGENpatterns used here, have all been obtained in the Physical Laboratory of the University of Groningen by my colleague HAGA, to whom I wish once more here to offer my sincere thanks for his kind and expert help during this investigation.

§ 2. In these experiments, thin cleavage-lamellae of *muscovite*: $KH_2Al(SiO_4)_3$ were continually made use of. As is wellknown, this mineral has monoclinic-prismatic symmetry, with the parameters: $a:b:c: = 0.577: 1:2,217$ and $= 84°55'$. This symmetry, however, very closely approaches a hexagonal one, the prism-angle of *muscovite* being 120°11′. A perfect cleavage occurs parallel to {001}, the preparation of very thin lamellae being thus extraordinarily facilitated. In this *mica*-species the optical axial plane is perpendicular to the crystallographical plane of symmetry (010); moreover, the first bisector is almost perpendicular to the plane of cleavage, while the dispersion ($\varrho > v$) also, differs only unappreciably from that of a rhombic crystal. The mineral is strongly birefringent (about: 0,038), with negative character.

In first instance now, the RÖNTGENpattern of a single lamella ($d = 0.32$ mm.) was obtained, as reproduced in fig 1 of Plate I; a stereographical projection of this beautiful and rich diffraction-image is given, moreover, in the diagram 1 of the text. It manifests the ordinary bilateral symmetry of the monoclinic crystals parallel to {001} or {100}; on more detailed examination, three directions may, moreover, be clearly discerned in it, which include angles of almost 60° with each other, and which are closely related to the hexagonal "radiation-figure" of this *mica*-species, obtained by pressure with a sharp object. The direction of the optical axial plane may also be discerned in it without much difficulty; it is indicated by a row of numerous smaller spots, situated perpendicularly to the plane of symmetry of the diffraction-pattern.

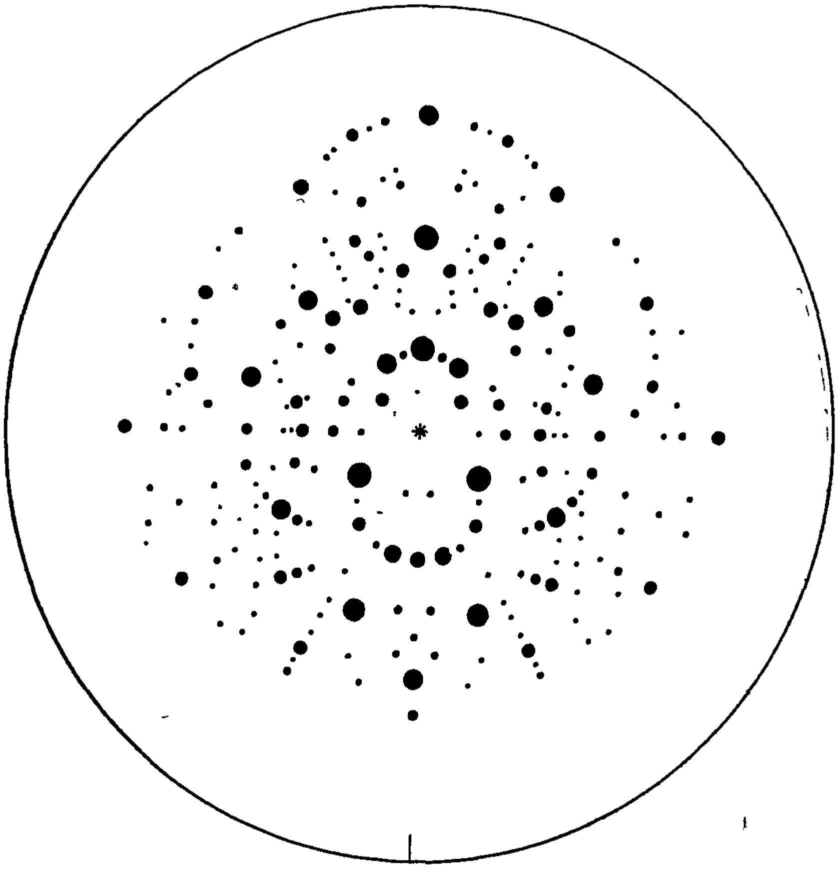

Fig. 1. Stereographical projection of the RÖNTGENpattern of a single *Muscovite*-lamella, parallel to {001}.

§ **3**. In the second place we investigated the behaviour of four preparations, these being dextro-, respectively laevogyratory *mica*-piles consisting of *muscovite*-lamellae crossing at 45° or 60°. The composing lamellae were cut from a *muscovite*-crystal in such a way, that their longer side was parallel to the optical axial plane of the mineral, their shorter edge thus being parallel to its plane of crystallographical symmetry. The central part of the complexes composed of hexagonally arranged lamellae, manifested in convergent polarized light between crossed nichols the almost perfect axial image of a uniaxial crystal endowed with circular polarisation; in the interference-image of the dextro- or laevogyratory complexes built up by lamellae crossing under 45°, there appeared only a single dark beam interrupted in the central part of the image, while also the coloured rings showed a somewhat elliptical distortion with a slight spiral constriction in the immediate vicinity of the dark beam. For the rest, the optical properties of the preparation appeared to vary quite continuously in all azimuths, being almost the same in all directions. The RÖNTGENpatterns obtained are reproduced in fig. 2 and 3 of Plate I, in the right position with respect to that

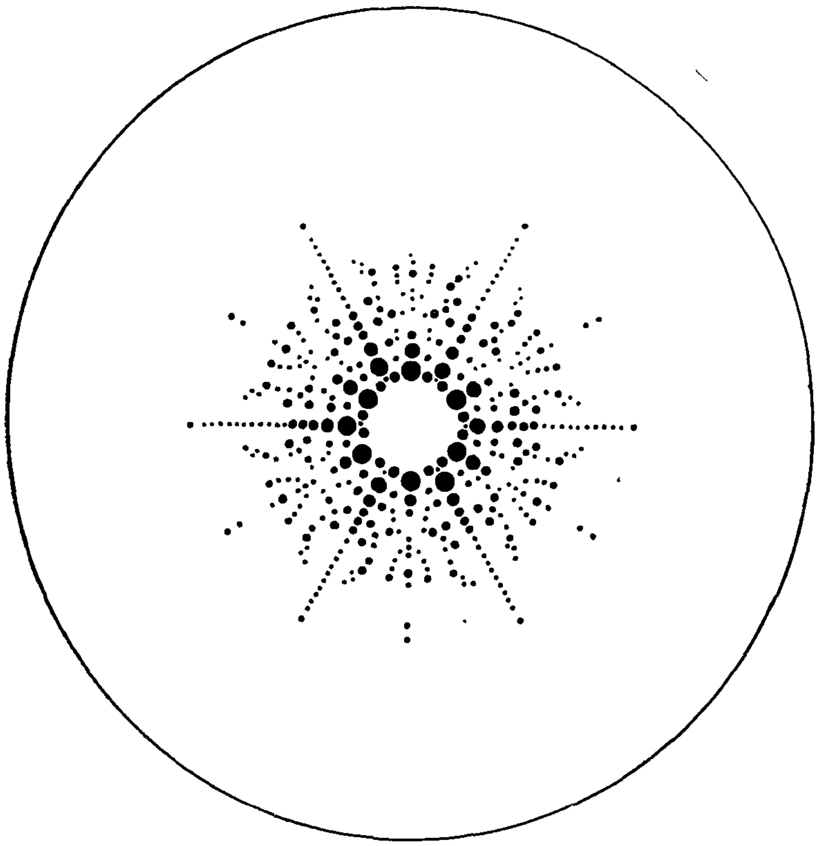

Fig. 2*a*. Stereographical Projection of the normal Diffraction-pattern of a dextro or laevogyratory Complex of *Muscovite*-lamellae, crossing at 60°.

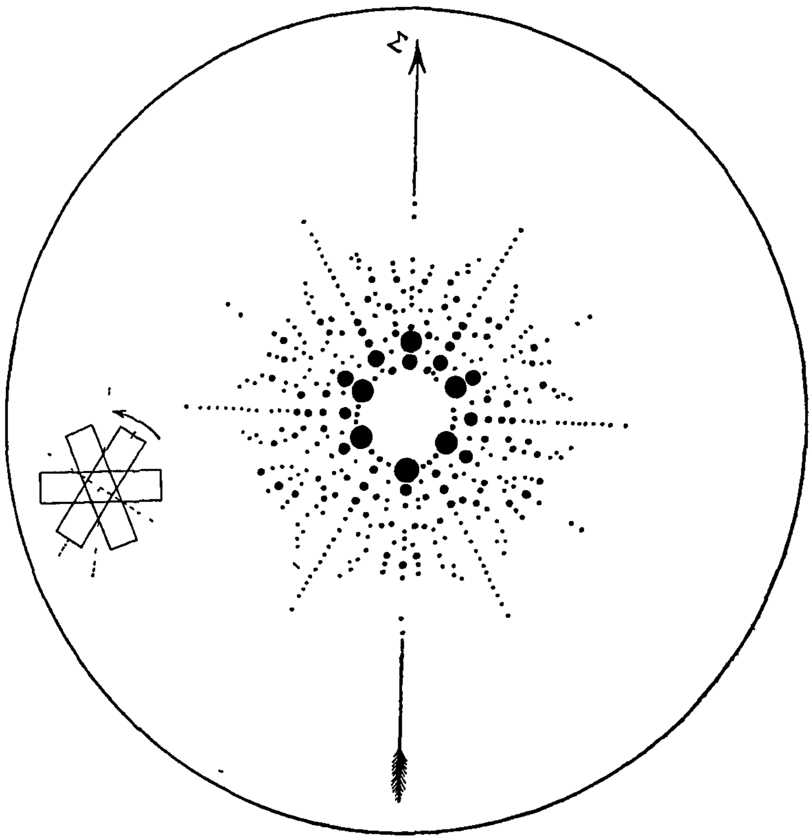

Fig. 2*b*. Stereographical Projection of the abnormal Diffraction-pattern of a dextro- or laevogyratory Complex of *Muscovite*-lamellae, crossing at 60°.

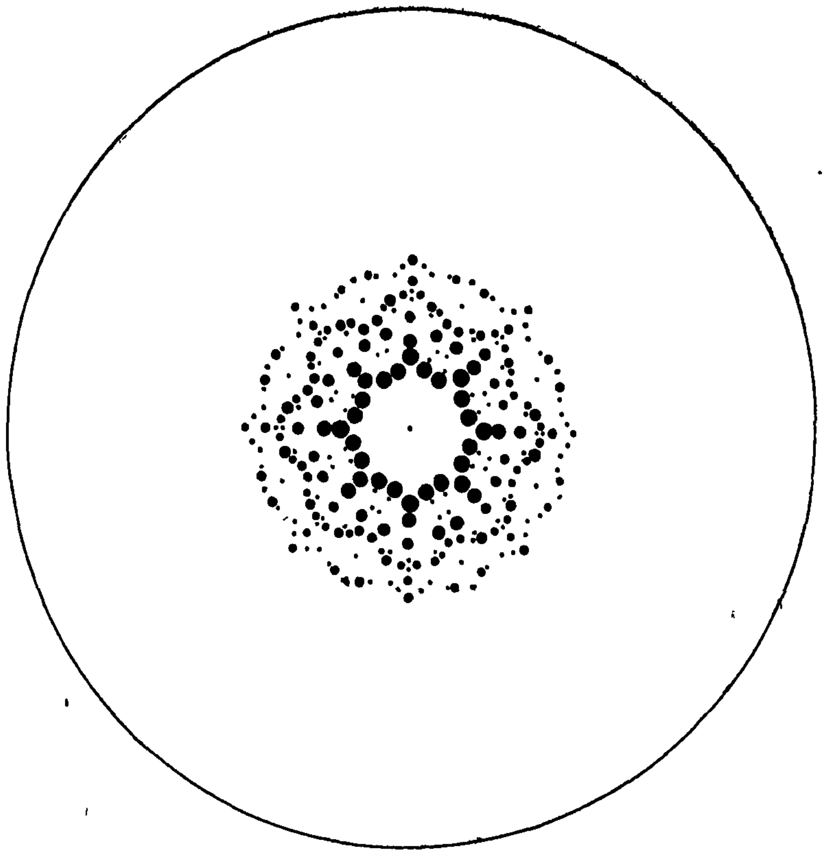

Fig. 3*a*. Stereographical Projection of the normal Diffraction-image of a dextro- or laevogyratory Complex of *Muscovite*-lamellae. crossing at 45°.

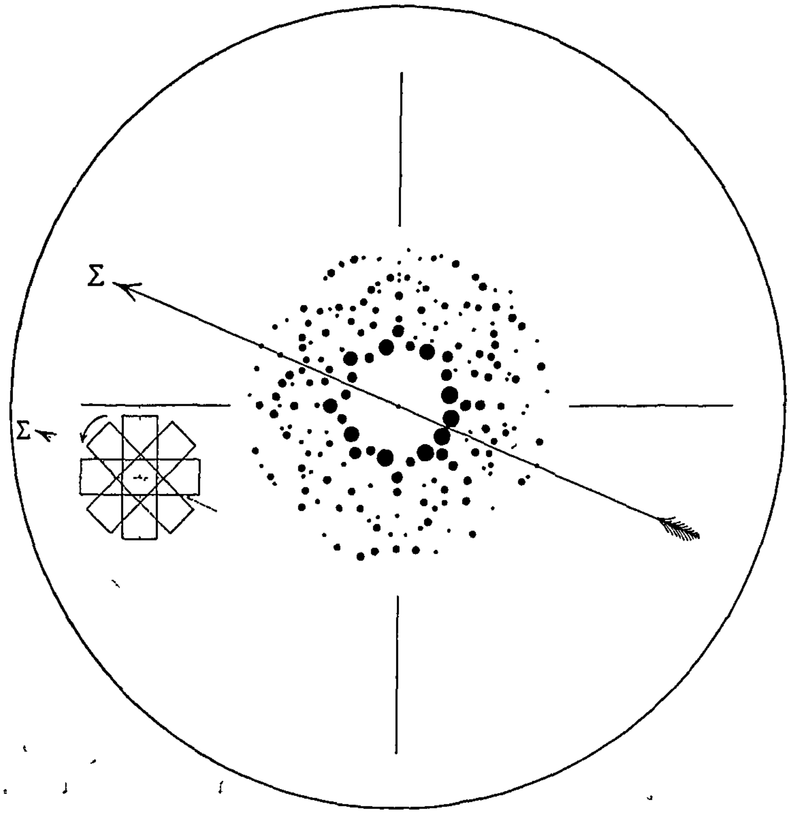

Fig. 3*b*. Stereographical Projection of the abnormal Diffraction-image of a dextro- or laevogyratory Complex of *Muscovite*-lamellae, crossing at 45°.

of fig. 1 of this plate, while the text-figures 2*a* and 2*b*, respectively 3*a* and 3*b*, represent stereographical projections, immediately relating to these diffraction-images. In all experiments the time of exposure of the photographic plates was two hours.

Secondly, we can remark, that the normal RONTGEN-images of fig. 2*a* and 3*a* show a perfect *hexagonal*, respectively *octogonal* symmetry, evidently consisting of a pattern repeated *six*, respectively *eight* times, the structure of which is, however, in the hexagonal image clearly *different* from that in the octogonal image, although the absorption of the RÖNTGENrays in these very thin lamellae plays only an insignificant part. Evidently the character of the composing patterns is here dependent in some way or other on the special way in which the secondary waves, emerging from the upper lamella, are modified by their passage through the next following lamella; and from this experience it seems, that this influence varies with the magnitude of the crossing-angle of two subsequent lamellae [1]).

[1]) On the modifications of a primary RÖNTGEN-pattern, if a secondary ray of it passes through a second and identically orientated crystalplate of the same sub-

The character of the whole pattern as that of an original figure repeated regularly a number of times, equal to the number of lamellae contained in a full turn of 360° (here, therefore 6 or 8), — was observed in all cases of normal diffraction-images; it can be considered as the *normal* character of the diffraction-patterns of such complex systems of lamellae.

Basing ourselves upon the experience gained in these and other cases, we may, therefore, safely enunciate as a general rule: *If the central part of a regular complex of crystalline lamellae, cut perpendicular to a plane of symmetry of the crystals, and crossing at angles* $\alpha = \frac{2\pi}{n}$, *be radiated through by* RÖNTGEN*rays, then the normal diffraction-pattern thus obtained, will exhibit an axis of n-fold symmetry, showing, therefore the image of an original pattern repeated n-times. The diffraction-image of the dextro- and laevogyratory complexes of this kind are always identical.*

§ 4. From what has been said, it must be concluded directly, that pseudo-*tetragonal*, circularly polarizing crystals can *not* be considered as built up in the way supposed by MALLARD, namely, if they do not consist of a substance, the molecules of which are themselves endowed with rotatory power. For it may be easily foreseen, that even in the case where the composing lamellae possessed *no* symmetry-plane whatever, the final diffraction-image will at least show an axis of *octogonal* symmetry, the eight planes of symmetry in fig. 3*a* then having disappeared. In this most general case of lamellae crossing at 45°, therefore, the pattern should all the same show an *octogonal* symmetry-axis, which, however, is *impossible* in crystallography, and which, in agreement with this fact, was never found by us in any diffraction-image of real or apparent tetragonal crystals. The RÖNTGENpatterns of any optically-inactive, pseudo-tetragonal crystal-species [1]), or those of optically-inactive, pseudo-tetragonal crystals

stance, conf. the paper of R. GLOCKER, Ann. der Physik, (4) **47**, 337, (1915). We have now started the systematical investigation of the phenomenon stated in the above, according to which the special character of the diffraction-image of such crossed lamellae varies with the angle φ, at which subsequent lamellae cross. From the fact, that the text figures 2—7 are drawn on the same scale as fig. 1, it will immediately be clear, that there can be *not* a mere superposition of images here, as e. g. a considerable number of the outer spots of fig. 1 have completely disappeared, even in so simple a case as that of fig. 4.

1) Conf. the pattern of *strychnine-sulphate*, in: F. M. JAEGER, *Lectures on the Principle of Symmetry and its Application in all natural Sciences*, 2nd Edition, Amsterdam, (1920), p. 194, 195. However, in this case the molecules of the substance have a rotatory power in solution also.

such as *potassium-ferrocyanide,* always manifested in their most complete and undisturbed form an axis of *four*fold symmetry at the highest, and the same appeared to be the case with all true tetragonal crystals hitherto investigated. But in such complexes of lamellae, an axis of *four*fold symmetry of the diffraction-image results only, when the composing subsequent lamellae include an angle of 90°, instead of 45°, as could be demonstrated e.g. by the pattern reproduced in fig. 4, obtained with a system of *muscovite*-lamellae, carefully arranged at 90°.

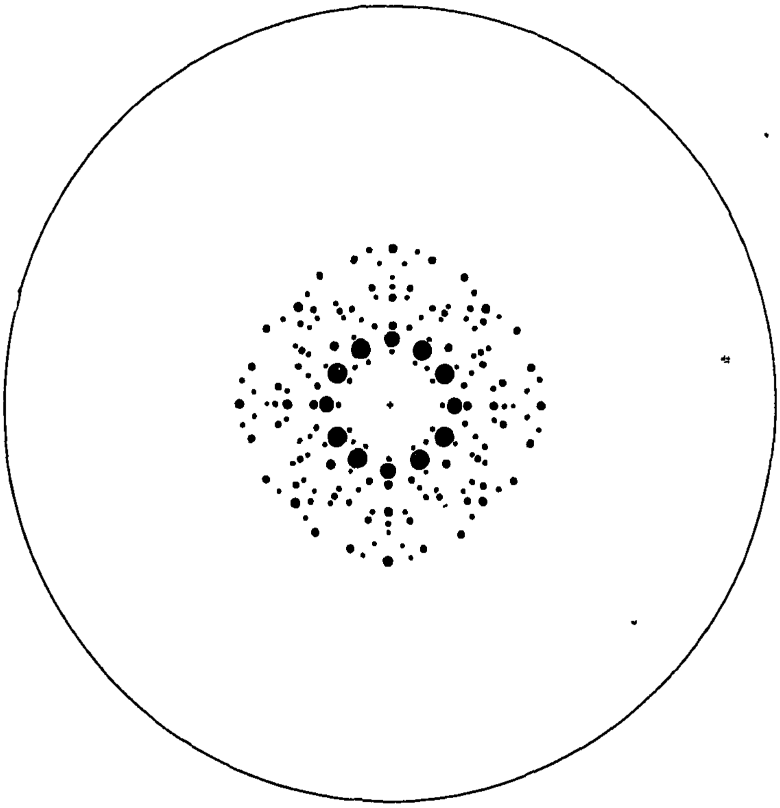

Fig. 4. Stereographical Projection of the RÖNTGEN-pattern of a Complex of *Muscovite*-lamellae crossing at 90°.

It must be concluded, therefore, that, if pseudo-tetragonal crystals be of the nature of polysynthetical intergrowths at all, the composing lamellae cannot cross at other angles than 90°. But from the mathematical theory of optical superposition [1]) it follows necessarily, — and the early experiments of NÖRREMBERG and others are in full agreement with this conclusion, — that such systems of lamellae

[1]) In 1906, at my request, professor LORENTZ was kind enough to develop once more the theory of the optical phenomena in systems of regularly piled-up lamellae. His results agree, although not quantitatively, yet in their principal features with those obtained by MALLARD and others.

crossing under angles of 90° will *never* manifest an optical rotation.
The supposition made by MALLARD is, therefore, only allowable for pseudo-tetragonal crystals *without* optical rotation, and there is no possibility to explain the special behaviour of real pseudo-tetragonal crystals endowed with rotatory power in this way, at least in those cases, where the molecules of the crystallised substance do not possess a molecular rotation of their own. It will be necessary to look for a special explanation in all cases concerning this kind of objects, as e.g. in that of the pseudo-tetragonal *ethylenediamine-sulphate,* etc.

§ 5. On closer examination of the original photographic plates of the patterns obtained with the hexagonal and octogonal complexes, which correspond with the projection-figures $2a$ and $3a$, it became evident that, although the situation of the spots on the plates completely agreed with that of the normal images in fig. $2a$ and $3a$, yet a distinct and rigorously determined abnormal distribution of their *intensities* was present, in such a way, that equivalent spots in the images did *not* possess the same intensity. Especially in the immediate vicinity of the centre, where very intensive spots were situated, the said phenomenon manifested itself most clearly. A more detailed study taught us, that this distribution of the intensities in the two images was, as drawn in the figures $2b$ and $3b$, i, e. *symmetrical with respect to only a single plane.* By special experiments it could be proved, that these anomalies did not depend on the position of the preparation with respect to the plane of the anticathode, or generally, to that of the luminous source: for on turning the preparation from its original position through 45° e.g., the plane of symmetry E in the images appeared to have turned also through the same angle on the new photograms. The cause of the said abnormalities must, therefore, be ascribed to the preparations themselves; and the close analogy of these anomalies with those formerly observed by us in real pseudo-symmetrical crystals, must be obvious, as also in those cases we observed a bilateral symmetry of the pattern, instead of the expected one, as was e.g. demonstrated with *rac. triethylenediamine-cobalti-bromide* and other preparations. The chief difference between these cases is, that in the preparations formerly studied, a number of spots were lacking altogether, their intensities being reduced to zero. Thus the bilateral symmetry of the patterns came there to expression in a higher degree, than was the case in our photograms which were obtained with objects, composed of a much smaller number of superimposed lamellae.

That it must be special properties of the preparations, that are the cause of such anomalies, becomes also evident from the fact, that the pseudo-symmetrical substances showing them, under favourable circumstances may occur in such well developed individuals, as to give perfectly *un*disturbed RÖNTGEN-patterns: thus e.g. with *potassium-ferrocyanide* in most cases certainly only bilaterally symmetrical images were obtained[1]), but occasionally there were found also perfect tetragonal patterns. And while *we* obtained an only bilaterally symmetrical RÖNTGEN-pattern with an apparently irreproachable individual of *benitoite* [2]) cut perpendicular to its optical axis, RINNE [3]) afterwards was able to obtain a quite normal trigonal diffraction-image of the same mineral.

Moreover, it was found that the direction of the single plane of symmetry in the RÖNTGENpattern was completely analogous in the two cases studied in the above: *its situation being in that of the hexagonal complex, as well as in that of the octogonal one, coinciding with the bisector of one of the angles of two subsequent lamellae of the mica-piles.* As the optical and microscopical investigation of the preparations did not reveal any abnormality in these directions, the only possible conclusion was, that the cause of this phenomenon must be attributed to some peculiarity in the lamellar arrangement.

In the case of the preparations with lamellae crossing at 60°, the explanation of the phenomenon may be given in the simplest way as follows.

The preparation of such *mica*-piles was hitherto executed only with the purpose of demonstrating the *optical* effects of such complexes: the apparent uniaxiality and the rotation of the plane of polarisation of the incident rays. Because of the fact that the optical orientation of each lamella does not differ appreciably from that of a rhombic crystal cut perpendicularly to its first bisector, it could be considered hitherto of no interest to the prepairer of such *mica*-piles, whether he piled up these lamellae in the same position as they were cut from the original crystal, or whether he turned them accidentally through 180° about an axis perpendicular to the plane of the lamella. For the final optical effect of the preparation will not be affected in the slightest degree by this turning. However, such a change of right and left, of the anterior or posterior part

[1]) The plane of symmetry being in these and other cases often parallel to the direction of the composing lamellae, contrary to what was observed here.

[2]) F. M. JAEGER and H. HAGA, Proceed. Acad. of Sciences Amsterdam. **17**, 1204 (1915).

[3]) F. RINNE, Miner. Centralblatt, (1919), p. 193.

of the lamellae, etc., is by no means indifferent any longer, if the distribution of the intensities of the spots in the diffraction-image by RÖNTGEN-rays be considered. For the *muscovite*-crystal has under all circumstances a true "monoclinic" molecular structure; the intensities of the diffraction-spots of a lamella parallel to {001} e.g., will, therefore, always be *different* to the left or to the right of the optical axial plane, while they will appear the same to the right or to the left of the plane of crystallographical symmetry. It must thus be evident, that the interchange of the two sides of a lamella in the way mentioned above, must really be of influence with respect to the special symmetry, which will be manifested in the distribution of the intensities of the diffraction-spots, as they will appear in the photographical image of the lamellar complex as a whole.

If the subsequent lamellae of a hexade are numbered 1 to 6, while the longer side of the lamellae, — as was really the case with our preparations, — is parallel to the direction of the optical axial plane in each lamella, then, if in the piling-up of the lamellae at angles of 60° first the lamellae 1 to 5 be taken in their right position, but N°. 6 be turned now through 180° in its own plane, the thus obtained hexade will give a diffraction-image, in which the intensities of the spots will be no longer distributed symmetrically with respect to six planes of symmetry, but in which *there is only a single plane* of this kind, exactly bisecting the angle between the superimposed pairs of lamellae: (1—4) and (2—5), and, therefore, being perpendicular to the pair: (3—6). By means of schematic figures, in which the distribution of the intensities of the spots, as effected by a single lamella is taken into account, it is possible to deduce systematically the general symmetry-character of the final distribution of intensities in the diffraction-image resulting from the complete hexade.

Undoubtedly such a reversion of a lamella will have accidentally occurred during the preparation of the *mica*-piles considered, just because there was no need for the prepairer to draw special attention to avoid such a reversion, and because with regard to his aim he was quite free to fix the subsequent lamellae in those positions, in which they accidentally were presented to him. Of course, there is a fair chance also, that during his work, he turned *two* or *three* lamellae in the way described; and it is necessary, therefore, also to consider the consequences of this for the final character of the diffraction-image, if all possible combinations of lamellae be in this way taken into account. In the case of such hexades, it appears unnecessary, however, to consider any combinations with a number of reversed lamellae greater than *three:* for it will be evident, that an accidental reversion of *four* lamellae, for example, will have the same effect as the turning through 180° of *two* lamellae, of *five* the same as if *one* were reversed, etc. These cases are, therefore, already contained amongst the possibilities formerly deduced in turning one, two, or three lamellae respectively.

A closer examination now taught us, that in the case of six *muscovite*-lamellae crossing at 60°, *three* kinds of diffraction-images might be produced: with respect to the intensities of the spots *normal* patterns (N); or such as are symmetrical with respect to a single plane bisecting the angle between two subsequent lamellae (diagonally-symmetrical; D); or finally such of the same symmetry, but in which the symmetry-plane now coincides with the direction of the lamellae themselves (lamellar-symmetrical; L). If *one* of the six lamellae be turned, there are *six* possibilities; if *two* be reversed, *fifteen* cases must be considered; and if *three* lamellae be turned through 180°, *twenty* possible combinations must be accounted for. In the first mentioned six cases only images with the bilateral symmetry D appear to be possible, as we found it just now in the case of fig. 2*b*; in the case of two reversed lamellae, we may find *three* combinations of pure *hexagonal*, normal symmetry, *six* combinations of diagonally-symmetrical character D, and *six* of lamellar symmetry L. In the last mentioned case of three reversed lamellae, we may find *two* possible combinations of normal character, here, however, not with hexagonal, but with *trigonal* symmetry; and *eighteen* combinations, corresponding to diagonally symmetrical diffraction-images D:

A Review of the Possible Types of Intensity-Distribution in the Diffraction-Patterns, Obtained by means of Mica-Complexes with Lamellae Crossing at 60°.

	If one lamella be turned:	If two lamellae be turned:	If three lamellae be turned:
Number of possible combinations:	6	15	20
Normal images:	0.	3 (hexag.).	2 (trigon.).
Asymmetrical Images:	0.	0.	0.
Diag. symm. Images:	6.	6.	18.
Lamell. symm. Images:	0.	6.	0.

From this it appears, that a *mica*-complex piled-up arbitrarily and without special care, with lamellae crossing at 60°, will *never* produce a completely asymmetrical diffraction-pattern; and that there is an appreciably fair chance that the symmetry of it will be diagonally-symmetrical, as found in the case of fig. 2*b*; it is no wonder, that we just now met with *this* symmetry in the case of the preparation investigated in the above.

In the same way it is possible to deduce the possibilities to be expected, if the composing lamellae cross at 45°. However, because in such *mica*-piles there are always lamellae present perpendicular to, or coinciding with the geometrical symmetry-plane in one of the eight lamellae, the case of fig. 3*b* will never result from the reversion of a single lamella but only a lamellar symmetry *L* of the intensities can be produced thereby. A general review of the possible cases can be given as follows [1]):

A Review of the Possible Types of Intensity-Distribution in the Diffraction-Patterns, Obtained by Mica-Complexes with Lamellae Crossing at 45°.

	If one lamella be turned:	If two lamellae be turned:	If three lamellae be turned:	If four lamellae be turned:
Number of possible Combinations:	8	28	56	70
Normal images:	0.	4 (octogon.).	0.	6 (octogon.).
Asymmetrical Images:	0.	0.	16.	0.
Diag. Symm. Images:	0.	16.	0.	48.
Lamell. Symm. Images:	8.	8.	40.	16.

If only *two* lamellae be turned, there is an appreciable chance of a diagonally-symmetrical image, as found in fig. 3*b*; but if *four* lamellae be accidentally reversed, this chance is extremely great. For the rest, there are about equal probabilities for the bilaterally-symmetrical images *D* and *L*, both of which were observed formerly in the case of natural pseudo-symmetrical crystals.

§ **6**. A number of *mica*-piles were, moreover, prepared, in which the right orientation of the *muscovite*-lamellae was rigorously checked by comparison with their true position in a single *muscovite*-crystal [2]). First a dextro-, and a laevogyratory combination, in which the

[1]) My assistant Dr. A. Šimek was kind enough to check the number of these possible combinations systematically. I wish to express my best thanks to him here once more for the trouble he has given himself in this matter.

[2]) This crystal my colleague Prof. Bonnema most kindly gave me for this purpose from the mineralogical collection of the University.

lamellae were crossed at 120°, while attention was given to prevent a rotation of them through 180° about an axis perpendicular to the plane of cleavage. In these and the following preparations, the longer sides of the lamellae were always parallel to the geometrical plane of symmetry of the *muscovite*-crystal, contrary to what occurred in the *mica*-piles studied before. A normal image with a trigonal axis and three planes of symmetry passing through it, could be expected here beforehand. Because of the not wholly irreproachable material available, the patterns obtained were not suited for photographical reproduction; but notwithstanding this, it was possible to confirm the exactness of this prediction completely. A schematical projection of these patterns, which also in this case appeared to be identical for the dextro-, and laevogyratory complexes, is reproduced in fig. 5.

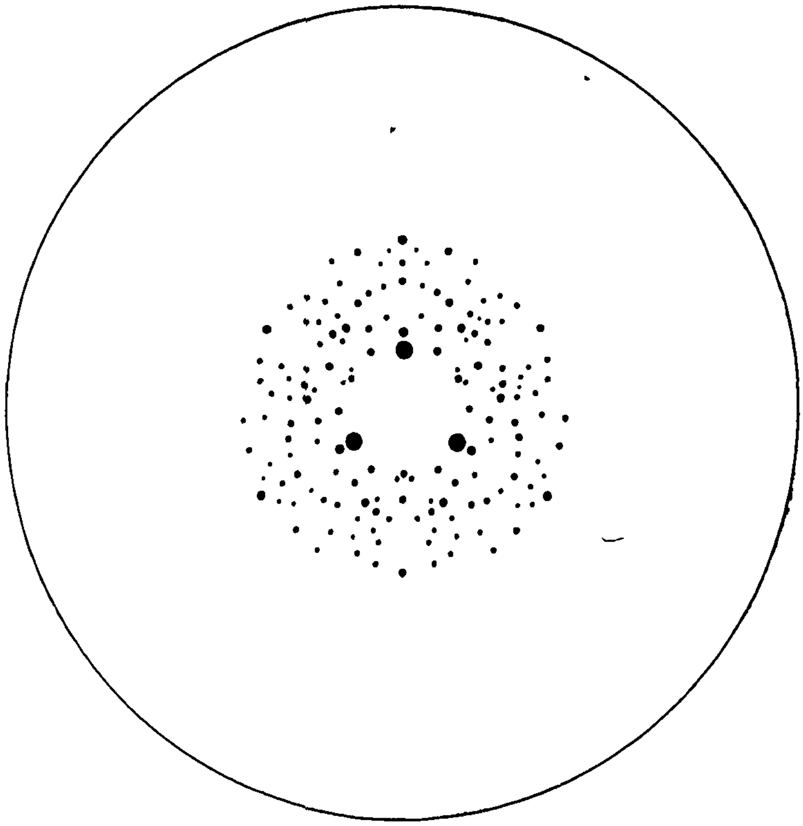

Fig. 5. Stereographical Projection (schematical) of the RÖNTGENpattern of dextro and laevogyratory *Mica*-piles, with Lamellae crossing at 120°.

Finally in fig. 6 the stereographical projection is reproduced (schematically) of two diffraction-images, obtained by two different *muscovite*-piles. In the first complex the lamellae crossed at 60°, and a rotation of the lamellae was carefully prevented; in the second preparation, however, the subsequent lamellae included angles of 120°, but each following lamella was turned with respect to the preceding through 180° about an axis perpendicular to its plane of cleavage. It will be easily understood that in this way the symmetry of the intensity-distribution in the two patterns must be essentially the same; it is remarkable, moreover, that also the patterns themselves appeared identical, notwithstanding the fact, that the sequence of

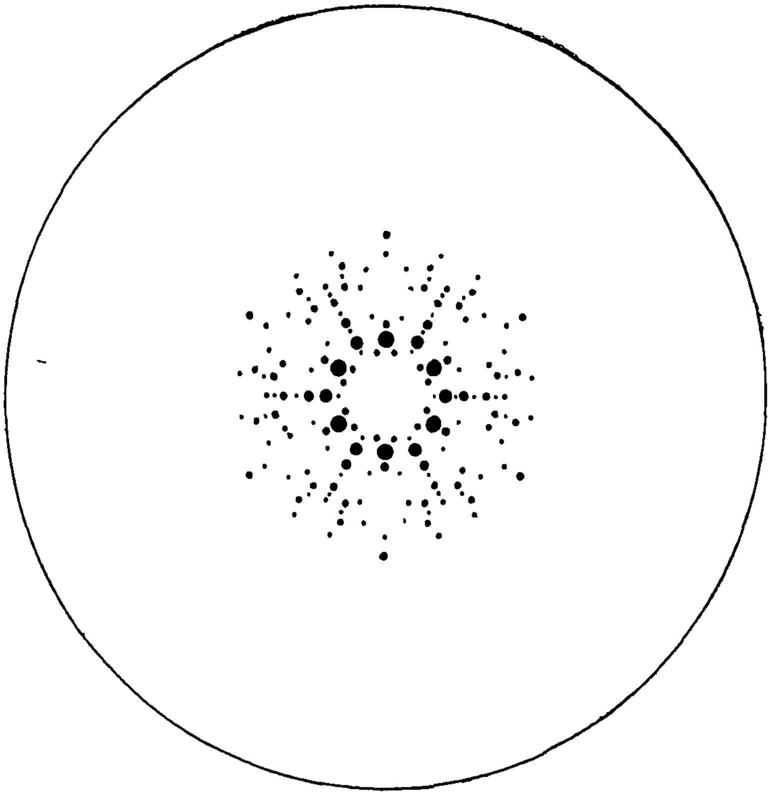

Fig. 6. Stereographical Projection (schematical) of the RÖNTGENpatterns of two *Mica* piles, the Lamellae of which crossed at angles of 60° and 120° respectively, with a partial reversion of some of them.

subsequent lamellae was different in the two *mica*-piles: both diffraction-images show a senary axis and six planes of symmetry passing through it.

§ 7. Regarding the results obtained in the above, hardly any doubt can remain as to the principal justification of our former view, according to which the observed abnormalities in the RÖNTGENpatterns of pseudo-symmetrical uniaxial crystals are in reality caused by a simple reversion of the position of the composing lamellae. Rotations of this kind may, for example, occur in some cases of *twin*-formation between those lamellae, if the axis of rotation or twinning be only no *real* symmetry-element of the crystallographical structure of the lamellae; at best it may be an axis of pseudo-symmetry of this structure. It is, therefore, by no means improbable, that finally *submicroscopical twinformation* between the lamellar units, composing the pseudo-symmetrical crystal, has to be considered as the primary cause of the anomalies formerly observed in the RÖNTGEN-diffraction-images of such crystals.

But then the question arises, why such a twinning-process happens oftener in one principal direction of intergrowth, than in the other equivalent ones? This question must arise, however, because in such crystals one has to deal *not* with a relatively *small* number of super-imposed lamellae in each direction, but with an *extremely great* number of them. It might be supposed that there were special influences during the growth of the crystal from its mother-liquor, which caused such a directing and preferential action in this respect: but it is at the moment difficult to guess, of what nature those influences really may be. Perhaps a factor of some importance therein may have been the *heat-effect* during the crystallisation, which causes convection-, and concentration-currents to appear in the environing liquor, corresponding in their turn to greater or smaller changes of the viscosity of the solution in those directions. It is well known, that the degree of viscosity of a medium plays an important rôle with respect to the occurrence of twins, and generally in such a way, that an increase of the viscosity appears most favourable to the occurrence of twin-formations. It is not improbable that influences of this kind may in the end appear to favour also the twinning of the very thin submicroscopical lamellae, of which the crystal is built up in one special direction.

Perhaps systematical investigations on the phenomena of crystallisation of such pseudo-symmetrical crystals under variable, but well-determined external circumstances, may in not too distant a future bring us better evidence on this subject.

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Groningen, April 1920.