*Red silver minerals from the Binnenthal, Switzerland.*

*On their Crystallographical Characters.*

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*And on their Chemical Composition.*

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F OR many years past Mr. R. H. Solly has been accustomed to spend each succeeding summer in the quest of mineral specimens in the neighbourhood of the village of Binn, Switzerland, particularly of those occurring in the white crystalline dolomite of the Lengenbach quarry, and his patient energy has been rewarded by the discovery, not only of material which has thrown fresh light on previously known minerals, but also of specimens which on examination proved to represent species new to science. Especially important was the discovery in 1903 of small, and often minute, blood-red crystals which differed both in colour and in streak from realgar, a common mineral in the quarry. From goniometrical measurement of a few crystals suitable to the purpose, Mr. Solly concluded that they belonged to two distinct species, both of which were new, and he accordingly assigned[1] to them the names hutchinsonite, after Dr. Arthur Hutchinson, Demonstrator of Mineralogy in the Uni-

[1] Min. Mag., 1905, vol. xiv, pp. 72, 74.

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versity of Cambridge, and smithite, after one of the authors of this paper.
Upon hearing of this discovery, Dr. C. O. Trechmann courteously sent to
Mr. Solly a specimen, purchased by the former in 1902, on which he
had noticed a few small red crystals. These proved on examination
to differ in morphological characters from the crystals of both the
previous species, and belonged, therefore, to a third new species, for
which Mr. Solly proposed[1] the name trechmannite after the owner of
the specimen.

In the following summer (1904) Mr. Solly carefully scrutinized every
specimen that came into his hands, and was successful in finding more
hutchinsonite and smithite, and also a single, well-developed crystal of
trechmannite[2] springing from a crystal of tennantite ('binnite'). The
search in 1905 was comparatively barren as regards the first two species,
but yielded a fine crystal of trechmannite[3], which again was situated on
tennantite ; and again, during the summer of last year, some fine crystals
of trechmannite have come to light, but scarcely any hutchinsonite and
smithite were encountered.

The best of the specimens collected by Mr. Solly, together with the
actual crystals measured by him, have been acquired by the Trustees of
the British Museum, and in accordance with his wishes the investigation
of the red minerals has been continued by the authors. In the case of
the first two of the species described in the present paper, the investiga-
tion may be considered fairly complete; but it has still not been found
possible to collect a sufficient amount of the third, and the rarest of
these red minerals, trechmannite, for a satisfactory determination of the
chemical composition.

## I. HUTCHINSONITE.

This mineral has especial interest because it contains a considerable
amount, nearly 20 per cent., of the rare element thallium[4], which had
previously been known as an essential constituent in only two minerals,
crookesite, in which it was first found, and lorandite. Although it
occurs in smaller crystals than is the case with either of its companion
species it is, at any rate so far as can be judged from the specimens
which have hitherto been found, comparatively speaking, quite as
common and plentiful as smithite ; nevertheless, owing to its intimate

[1] Loc. cit., p. 75.
[2] Loc. cit., p. 75.
[3] Min. Mag., 1906, vol. xiv, p. 189.
[4] The discovery was announced by Dr. Prior in a letter to 'Nature', April 6,
1905, vol. lxxi, p. 534.

association with sartorite, or other sulpharsenite of lead, the selection of pure material for a trustworthy determination of the chemical composition proved a matter of extreme difficulty, and, as will be seen below, the whole amount of material collected for the purpose was very small.

## 1. *Morphological Characters.*

The crystals are of two different types. In the first case the mineral is found in radiating tufts of tiny needles, less than 0·1 mm. in section and less than 1 mm. in length, situated in little cavities in the dolomite. A peculiar feature of these needles added still further to the difficulty of collecting material for analysis. Both the colour and the streak varied considerably: some of the needles were a rich red in hue and gave a vermilion streak; while others, on the contrary, were much deeper in colour with a decidedly brownish tinge, and gave a deep cherry-red streak. On the other hand, the angles measured in the prism-zone, in which alone on these minute crystals were trustworthy observations obtainable, were identical within the limits of error, and both kinds display the characteristic form $g$ (140). Such similarity in form and such divergence in colour seemed difficult to reconcile, and accordingly in the selection of material for analysis care was taken to keep the two kinds apart. In the second case the mineral occurs in thicker crystals, usually about 0·4 mm. in length and 0·2 mm. in section, coating crystals of sartorite and rathite. When situated on the prism-faces, the crystals of hutchinsonite are arranged in parallel position, so that their prism-edge is parallel to that of the sartorite or rathite. Somewhat shorter crystals have been deposited without any definite orientation on the terminal faces of the same crystals; and similar, but far smaller, crystals are found irregularly placed on crystals of smithite. When deposited on a crystal of a sulpharsenite of lead, the hutchinsonite forms a skin so thin that it is impossible to separate the two minerals, and in consequence a crystal of hutchinsonite removed for measurement may appear nearly black in colour and almost opaque. It may be remarked that frequently the black minerals without definite crystalline form, which are embedded in the dolomite, merge into some red mineral—probably hutchinsonite—as may be detected by scratching the surface.

In addition to the minerals on which it is actually deposited, sartorite, rathite, and smithite, the minerals associated with hutchinsonite are blende, iron-pyrites, realgar, and orpiment.

The habit of the crystals is invariably prismatic, and the dome- and

pyramid-faces are rarely developed so largely as those in the prism-zone. Indeed, in the case of the minute needles the terminal faces are so infinitesimal in size that no determination of their positions was possible. The illustrations (figs. 1–4) represent actual crystals, all of which were intimately associated with sartorite and rathite. That depicted in fig. 2 was removed from a prism-face of sartorite. The crystal shown in fig. 4 is remarkable for the large number of dome- and pyramid-faces present.
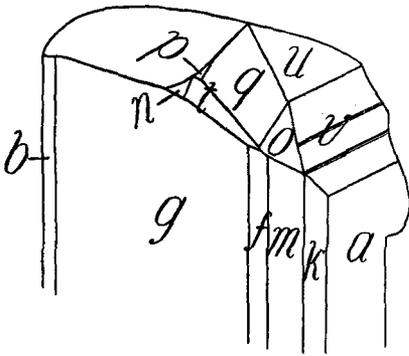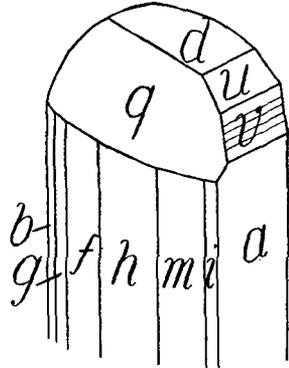


Fig. 1.                    Fig. 2.

Crystals of Hutchinsonite.

The crystal illustrated in fig. 1 calls for particular note, because it alone of all the crystals examined provided any opportunity for the determination of the optical characters. Fig. 3 shows a curiously shaped crystal.

Hutchinsonite crystals are almost invariably characterized by the predominance of the form $g\{140\}$ in the prism-zone. It will be remarked how very close are certain angles in the prism- and dome-zones, e. g. :—(100):(320)=47° 27′ and (100):(201)=47° 16′; (100):(340)=65° 21′ and (100):(101)=65° 12½′. There is, however, no marked approximation to tetragonal symmetry. The parametral plane adopted is different from Mr. Solly's, his (111) corresponding to (211), and in general his ($hkl$) to ($2h.k.l$). This slight modification effects some simplification in the indices of the forms as a whole.

All the crystals were measured on the three-circle goniometer from the face $a(100)$, which was on all of them well developed, as origin, and the measurements made on the fourteen best crystals are summarized in table I. They were all small in size, and the largest did not exceed

## TABLE I (HUTCHINSONITE).
### Measurements from a = (100).
Orthorhombic; $a:b:c = 1.6343:1:0.7549$.

| Form. | Indices. | Calculated Values. | | Observed Means. | | Number. | Limits of Observations. | |
|---|---|---|---|---|---|---|---|---|
| | | Azimuth. | Distance. | Azimuth. | Distance. | | Azimuth. | Distance. |
| c | 001 | * | * | 90° 0′ | 90° 0′ | 3 | ...  90° 15′ | ... 90° 29′ |
| U | 102 | ,, | 77° 0′ | ,, ,, | 77 3 | 3 | ... ... | 76° 59′— 77 9 |
| V | 304 | ,, | 70 53½ | ,, ,, | 70 40 | 1 | | |
| d | 101 | ,, | 65 12½ | ,, ,, | 65 12 | 12 | ... ... | 64 42 — 65 30 |
| W | 302 | ,, | 55 17 | ,, ,, | 55 24 | 1 | | |
| u | 201 | ,, | * | ,, ,, | 47 16 | 12 | ... ... | 47 10 — 47 22 |
| X | 703 | ,, | 42 51 | ,, ,, | 42 35 | 1 | | |
| v | 301 | ,, | 35 49 | ,, ,, | 35 42 | 11 | ... ... | 35 0 — 36 16 |
| w | 401 | ,, | 28 25½ | ,, ,, | 28 35 | 3 | ... ... | 28 33 — 28 39 |
| Y | 501 | ,, | 23 25 | ,, ,, | 23 34 | 1 | | |
| Z | 601 | ,, | 19 50½ | ,, ,, | 20 0 | 1 | | |
| θ | 825 | 73° 12′ | 54 43½ | 72 51 | 54 17 | 1 | | |
| e | 012 | 69 19 | 90 0 | 69 21 | 90 1 | 1 | 69° 19′— 69 23 | |
| x | 524 | ,, ,, | 61 37 | ,, ,, | 61 40 | 2 | ,, ,, ,, ,, | ... 61 40 |
| C | 312 | ,, ,, | 57 2½ | ,, ,, | 57 20 | 1 | ,, ,, ,, ,, | |
| O | 144 | * | 84 44 | 52 57 | 84 45 | 1 | 52 39 — 53 6 | |
| r | 122 | ,, | 79 33 | ,, ,, | 79 34 | 8 | ,, ,, ,, ,, | 79 0 — 79 51 |
| p | 111 | ,, | 69 46 | ,, ,, | 69 36 | 10 | ,, ,, ,, ,, | 69 15 — 69 56 |
| q | 322 | ,, | 61 3½ | ,, ,, | 61 6 | 11 | ,, ,, ,, ,, | 60 42 — 61 25 |
| o | 211 | ,, | 53 36 | ,, ,, | 53 38 | 10 | ,, ,, ,, ,, | 53 21 — 54 0 |
| P | 522 | ,, | 47 20 | ,, ,, | 47 16 | 1 | ,, ,, ,, ,, | |
| Q | 311 | ,, | 42 7 | ,, ,, | 42 15 | 1 | ,, ,, ,, ,, | |
| R | 411 | ,, | 34 8½ | ,, ,, | 34 10 | 1 | ,, ,, ,, ,, | |
| A | 332 | 41 27 | 65 22 | 41 12 | 65 25 | 1 | | |
| s | 142 | 33 31 | 82 44 | 33 25 | 82 15 | 4 | 33 0 — 33 40 | 81 40 — 82 44 |
| n | 121 | ,, ,, | 75 41½ | ,, ,, | 75 38 | 5 | ,, ,, ,, ,, | 75 15 — 75 56 |
| t | 342 | ,, ,, | 69 4 | ,, ,, | 68 50 | 3 | ,, ,, ,, ,, | 68 32 — 69 1 |
| N | 221 | ,, ,, | 62 58 | ,, ,, | 62 52 | 2 | ,, ,, ,, ,, | 62 49, 62 55 |
| T | 742 | ,, ,, | 48 14½ | ,, ,, | 48 14 | 1 | ,, ,, ,, ,, | |
| b | 010 | * | * | 0 0 | 90 0 | 11 | ... ... | ... 90 27 |
| g | 140 | ,, | 81 18 | ,, ,, | 81 24 | 20 | ... ... | 81 7 — 81 57 |
| K | 250 | ,, | 76 15 | ,, ,, | 76 24 | 1 | | |
| f | 120 | ,, | 72 59½ | ,, ,, | 73 2 | 9 | ... ... | 72 52 — 73 6 |
| h | 340 | ,, | 65 21 | ,, ,, | 65 22 | 17 | ... ... | 64 16 — 65 46 |
| m | 110 | ,, | 58 32 | ,, ,, | 58 33 | 13 | ... ... | 58 0 — 59 16 |
| i | 540 | ,, | 52 35½ | ,, ,, | 52 30 | 11 | ... ... | 52 11 — 53 3 |
| k | 320 | ,, | 47 27 | ,, ,, | 47 14 | 10 | ... ... | 46 52 — 47 32 |
| l | 740 | ,. | 43 2½ | ,, ,, | 42 50 | 7 | ... ... | 42 18 — 43 7 |
| F | 210 | ,, | 39 23 | ,, ,, | 39 0½ | 2 | ... ... | 39 0, 39 1 |
| G | 730 | ,, | 35 0½ | ,, ,, | 34 59 | 1 | | |
| H | 830 | ,, | 31 30 | ,, ,, | 30 59 | 1 | | |
| a | 100 | ,, | * | ,, ,, | 0 0 | 19 | | |

1 mm. in the longest direction. Of the forty-two forms observed, twenty-four, viz. *a, b, c, G, F, l, k, i, m, h, f, g, Y, w, v, u, W, d, U, Q, o, q, p* and *r*, were given by Mr. Solly. The two forms (011) and (850), equivalent to (011) and (16·5·0) according to the parameters adopted in this paper, which were observed by him, have not been noticed on any of the crystals. The means of the observed values agree very closely with Mr. Solly's determinations.

In the prism-zone the forms $a\{100\}$, $k\{320\}$, $m\{110\}$, $h\{340\}$, $f\{120\}$, and particularly $g\{140\}$, are well developed; $b\{010\}$ is common, but small.

In the dome-zone the more prominent forms are $v\{301\}$, $u\{201\}$, and $d\{101\}$.
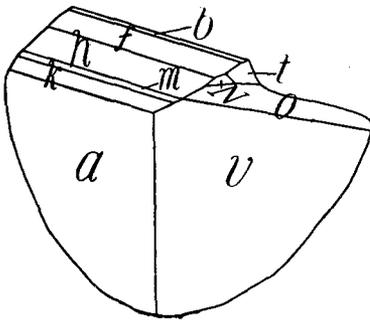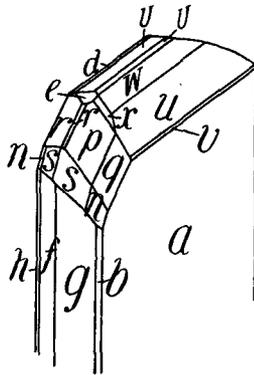


Fig. 3.                              Fig. 4.

Crystals of Hutchinsonite.

In the principal pyramid-zone ⌊100,011⌋ the common and largest faces are those of the forms $o\{211\}$, $q\{322\}$, $p\{111\}$, and $r\{122\}$.

In the zone [100,021] the largest faces are those of the forms $t\{342\}$, $n\{121\}$, and $s\{142\}$ (cf. figs. 1, 3, and 4).

The face $\theta(825)$ is peculiar. It was only once observed, and in that case formed the only terminal face of the crystal. The natural supposition is that it is produced by some flat surface, which limited the growth of the crystal in that direction; on the other hand, it gives an unusually brilliant and distinct reflexion of the object-slit, which is not the case with pseudomorphous faces.

The remaining faces were quite minute, but gave measurable reflexions when the intensity of the image relative to the field of the telescope had been increased to the utmost.

There is a good cleavage parallel to $a$(100), but it cannot compare with the highly perfect cleavage of smithite.

Table II comprises the coordinates of the principal forms referred to the other faces of symmetry, $b$(010) and $c$(001), as origins.

TABLE II  (HUTCHINSONITE).

*Calculated coordinates of the principal forms with respect to*
$$b = (010) \; and \; c = (001) \; as \; origins.$$

$b = (010).$

| Form. | Indices. | Azimuth. | Distance. |
|---|---|---|---|
| U | 102 | 77° 0′ | 90° 0′ |
| r | 122 | ,, ,, | 53 40 |
| s | 142 | ,, ,, | 34 13 |
| d | 101 | 65 12½ | 90 0 |
| p | 111 | ,, ,, | 55 35 |
| n | 121 | ,, ,, | 36 7 |
| W | 302 | 55 17 | 90 0 |
| q | 322 | ,, ,, | 58 11 |
| t | 342 | ,, ,, | 38 51½ |
| u | 201 | 47 16 | 90 0 |
| o | 211 | ,, ,, | 60 53 |
| N | 221 | ,, ,, | 41 54 |
| v | 301 | 35 49 | 90 0 |
| Q | 311 | ,, ,, | 66 10 |
| w | 401 | 28 25½ | 90 0 |
| a | 100 | 0 0 | 90 0 |
| F | 210 | ,, ,, | 50 37 |
| l | 740 | ,, ,, | 46 57½ |
| k | 320 | ,. ,, | 42 33 |
| i | 540 | ,, ,, | 37 24½ |
| m | 110 | ,, ,, | 31 28 |
| h | 340 | ,, ,, | 24 39 |
| f | 120 | ,, ,, | 17 0½ |
| g | 140 | ,, ,, | 8 42 |

$c = (001).$

| Form. | Indices. | Azimuth. | Distance. |
|---|---|---|---|
| b | 010 | 90° 0′ | 90° 0′ |
| g | 140 | 81 18 | 90 0 |
| s | 142 | ,, ,, | 33 13½ |
| f | 120 | 72 59½ | 90 0 |
| n | 121 | ,, ,, | 68 28 |
| r | 122 | ,, ,, | 51 43 |
| h | 340 | 65 21 | 90 0 |
| t | 342 | ,, ,, | 31 3 |
| m | 110 | 58 32 | 90 0 |
| N | 221 | ,, ,, | 66 8½ |
| p | 111 | ,, ,, | 48 30 |
| i | 540 | 52 35½ | 90 0 |
| k | 320 | 47 27 | 90 0 |
| q | 322 | ,, ,, | 44 18 |
| l | 740 | 43 2½ | 90 0 |
| F | 210 | 39 23 | 90 0 |
| o | 211 | ,, ,, | 39 54½ |
| Q | 311 | 28 35 | 32 22 |
| a | 100 | 0 0 | 90 0 |
| w | 401 | ,, ,, | 61 34½ |
| v | 301 | ,, ,, | 54 11 |
| u | 201 | ,, ,, | 42 44 |
| d | 101 | ,, ,, | 24 47½ |
| U | 102 | ,, ,, | 13 0 |

## 2. *Optical Characters.*

As might be anticipated from the colour of the crystals, the violet end of the spectrum is strongly absorbed, and, indeed, very little beyond the yellow is transmitted. Pleochroism is just discernible, but more by a slight variation in the intensity rather than in the hue of the transmitted light. The lustre is adamantine.

If a crystal be illuminated by monochromatic light and viewed between crossed nicols in the direction perpendicular to $b(010)$, the resulting interference-figure is of the usual kind given by a biaxial crystal in the direction of the acute bisectrix. In red light the 'eyes' are visible in the field of view, but in sodium-light they cannot be seen, even if the plate be immersed in oil. The plane of the optic axes is parallel to $a(100)$, and the usual test with a quartz-wedge reveals the double refraction as negative.

The crystal depicted in fig. 1 was mounted on the ordinary instrument for the measurement of the angle between the optic axes and dipped into pure methylene iodide, which was contained in a trough fitted with parallel glass sides. The angles between the optic axes in the oil were as follows :—

For C, 2H $=35°$ 19', and for D, 2H $=71°$ 58', where C and D are the Fraunhofer lines in the red and yellow portions respectively of the solar spectrum. As the wave-length of the illuminating light diminishes, the angle rapidly increases, and, since at the same time the intensity of the transmitted light markedly falls off, trustworthy observations in the green were found impracticable. The refractive indices of the liquid at the temperature, 18° C., of the observations are for C, 1·731, and for D, 1·740. From these values we find that $2E_r = 63°$ 22', and that in sodium-light the optic axes are internally reflected.

The same crystal was mounted on a goniometer, and it was found that light could traverse the prism formed of the large face $g(140)$ shown in the figure, and a small face of the same form lying at the back. The values corresponding to the position for minimum deviation furnish two of the principal indices. The refracted images lie very near together, and that experiencing the greater deviation is noticeably more strongly absorbed.

|  | Line C. | | Line D. | |
|---|---|---|---|---|
| Angle of minimum deviation . . | 37° 38' | 37° 50' | 39° 56' | 40° 5' |
| Plane of polarization at right angles to | $a(100)$ | $c(001)$ | $a(100)$ | $c(001)$ |
| Corresponding refractive index . . | 3·063 | 3·073 | 3·176 | 3·188 |
| By calculation we have 2V . . | 19° 44' | | 37° 34' | |
| And thence the third index . . | 2·779 | | 3·078 | |

The optical constants for the lines C and D of the solar spectrum are then as follows :—

| | Direction at right angles to | | | |
|---|---|---|---|---|
| | $a(100)$. | $b(010)$. | $c(001)$. | 2V. |
| Line C . | . 3·063 | 2·779 | 3·073 | 19° 44′ |
| „ D . | . 3·176 | 3·078 | 3·188 | 37° 34′ |

The particular prism-angle was 17° 20′. Since an error of 2′ in its determination would involve an error of 3 units in the third place of decimals, probably the values given above for the first and third of the refractive indices may be considered accurate to that place. But it is otherwise with the second refractive index : an error of 1 unit in the third place of one of the other indices involves an error of 6 units in the third place of decimals in the case of the yellow light, and as much as 2 units in the second place of decimals in the other case.

It will be noticed that the values are slightly higher than those of the principal indices of proustite.

### 3. *Chemical Composition.*

The first analysis was made on the more definitely crystallized variety of hutchinsonite, which is transparent and deep-red in colour, and gives a brilliant scarlet streak. The material consisted mainly of measured crystals, but included some fragments which showed no crystal-faces. These fragments were deep-red and transparent and exhibited no perfect cleavage like that of smithite, but the possibility that some of them may have been trechmannite is not absolutely precluded. The crystals and fragments when broken up and examined under the lens were found to be not absolutely pure, but to contain needle-like inclusions and adhering minute fragments of black minerals. These impurities were detected by means of their black or chocolate-brown streaks, and were separated under the lens as far as possible, but traces of them were doubtless present in the material analysed.

The total amount of this variety of hutchinsonite, i. e. with scarlet streak, available for analysis was only about 18 milligrams. The analysis of so small a quantity of material, though intended primarily for the qualitative determination of the constituents, was conducted as . carefully as possible by quantitative methods, and the percentage numbers thus obtained are given under I, although obviously not much reliance can be placed upon them. The mineral was decomposed in chlorine, and a separation thus at once effected between the volatile

and the non-volatile chlorides.   Decomposition took place readily in the
cold, so that quite gentle heating sufficed to drive off completely the
volatile chlorides.   In the solution of the latter, only sulphur and
arsenic were found.   The sulphur was determined by precipitation as
sulphate with barium chloride; and the arsenic by precipitation as
sulphide.   The latter was weighed and then oxidized by nitric acid.
The total sulphur in the precipitated sulphide of arsenic was determined
by precipitating the resulting sulphuric acid by barium chloride.

The non-volatile chlorides were found to consist of silver, lead, and thal-
lium.   The amount of chloride of silver left after treatment with nitric acid
and water was comparatively small; the lead was precipitated and weighed
as sulphate; and the thallium was separated as sulphide by precipitation
with ammonium sulphide in alkaline solution, and then converted into
sulphate.   The solution gave a yellow precipitate with potassium iodide,
and a brilliant green colour to the Bunsen-flame, showing in the spectro-
scope the characteristic green line.   The percentage of thallium given
below is that determined by deducting the chlorides of silver and lead
from the weight of the non-volatile chlorides.

Two determinations of specific gravity, made with a 3 cc. pyknometer,
on 27 milligrams gave the numbers 4·6 and 4·7 respectively.

The second analysis (the result of which is given under II) was made
on the other variety of hutchinsonite, which occurs in minute, deep-red
needles and has a deep cherry-red streak quite distinct from the scarlet
streak of the first variety.

Of this second variety of hutchinsonite a somewhat larger amount of
material (about 66 milligrams) was available for analysis.   The minute
tufts of needles detached from the dolomite were not absolutely pure.
On separating the needles under the lens a little iron-pyrites in minute
crystals and small fragments of a mineral giving a black streak were
seen to be present.   It spite of every care to remove these impurities,
it is probable that traces of them were still present in the material
analysed, but it is hardly conceivable that they could be in sufficient
amount to account for the lead obtained in the analysis.   In this
analysis the same methods were employed as in the preceding one,
except that the arsenic was precipitated by magnesia mixture.   The
solution of the volatile chlorides contained sulphur and arsenic and
a little antimony; the non-volatile chlorides included copper, besides
silver, lead, and thallium.

A determination of specific gravity made with a 3 cc. pyknometer on
0·0732 gram gave the number 4·6.

The results of the two analyses are as follows:—

|  | I. | II. |
|---|---|---|
| Ag . . . | 9 | 2 |
| Tl . . . | 25 | 18 |
| Pb . . . | $12\frac{1}{2}$ | 16 |
| Cu . . . | — | 3 |
| Fe . . . | — | $0\frac{1}{2}$ |
| As . . . | $30\frac{1}{2}$ | $29\frac{1}{2}$ |
| Sb . . . | — | 2 |
| S . . . | 26 | $26\frac{1}{2}$ |
|  | 103 | $97\frac{1}{2}$ |

In analysis I, weight of material used = 0.0184 gram; weight of AgCl = 0.0022; $PbSO_4 = 0.0034$; $BaSO_4 = 0.0349$; As + S = 0.0102; $BaSO_4$ from As + S = 0.0333; $AgCl + PbCl_2 + TlCl = 0.0107$; TlCl (by diff.) = 0.0053 gram.

In analysis II, weight of material used = 0.0664 gram; weight of AgCl = 0.0016; $PbSO_4 = 0.0153$; CuO = 0.0025; $Mg_2As_2O_7 = 0.0406$; $Fe_2O_3 = 0.0005$; $SbO_4 = 0.0015$; $BaSO_4 = 0.1286$; $AgCl + PbCl_2 + CuCl_2 + Fe_2Cl_6 + TlCl = .0350$; TlCl (by diff.) = 0.0142 gram.

The most probable formula suggested by the results of the analyses is $(Tl,Ag,Cu)_2S.As_2S_3 + PbS.As_2S_3$; but, considering the small amount of material dealt with and the somewhat unsatisfactory condition as regards freedom from impurities, the formula can only be regarded as provisional until larger amounts of material are available for analysis.

That hutchinsonite may be a double salt, as suggested by the formula, is probable, since it shows so little relationship crystallographically to either smithite $(Ag_2S.As_2S_3)$, lorandite $(Tl_2S.As_2S_3)$, or miargyrite $(Ag_2S.Sb_2S_3)$.

#### 4. *Summary of Characters of Hutchinsonite.*

Orthorhombic; $a:b:c = 1.6343:1:0.7549$. Crystals, prismatic in habit. Cleavage, $a$ (100) good. Fracture, conchoidal. Brittle. Hardness, $1\frac{1}{2}$–2. Specific gravity, 4.6. Lustre, adamantine. Colour and streak, scarlet-vermilion to deep cherry-red. Transparent to translucent. Optic axial plane parallel to $a$ (100), acute bisectrix perpendicular to $b$ (010); double refraction, negative and fairly strong. Pleochroism, weak. Composition, $(Tl,Ag,Cu)_2S.As_2S_3 + PbS.As_2S_3$.

#### II. SMITHITE.

The investigation of this species, to which Mr. Solly gave the name smithite, presented on the whole far less difficulty than was experienced

in the case of hutchinsonite. Comparatively large fragments were obtained and no ambiguity, such as arose owing to the diversity in the coloration of the latter species, was encountered. The highly perfect cleavage and the characteristic interference-figure visible through the cleavage-face in convergent, monochromatic light provided an easy and satisfactory means of discriminating the species. It was, therefore, possible to collect an amount of pure material sufficient for a trustworthy determination of the chemical composition.

### 1. *Morphological Characters.*

Smithite is found usually in cleavage-fragments, which are sometimes as much as 3 mm. in length and 1 mm. in thickness, and well-formed crystals are uncommon. The finest crystal which has as yet come to light is shown in fig. 5; the approximately circular contour as seen in the drawing represents a diameter of nearly 1 mm. on the actual crystal. It lies in contact with a similar, but slightly inferior, crystal on a lump of sartorite. The crystals almost imperceptibly pass into the sartorite at the back, and no sharp division can be drawn between the red and the black minerals. These crystals were almost the first of the



Fig. 5.                Fig. 6.
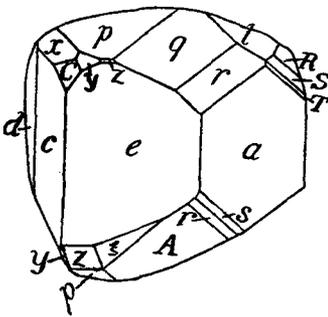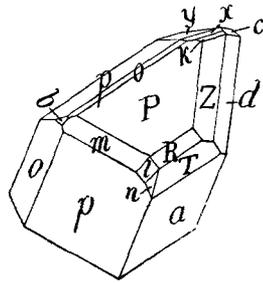Crystals of Smithite.

red minerals to be discovered by Mr. Solly. Both were measured by him and the results of his measurements are recorded in his paper[1]. The crystal depicted in fig. 6 is much smaller and measures only 0·5 mm. in the greatest diameter. Several faces have been omitted on account of their smallness of size. The crystal was observed on a large cleavage-

[1] Loc. cit., p. 74.

fragment of smithite found in 1904, which provided the material used in the chemical analysis. The crystal is of interest for several reasons. The habit is peculiar, and the development is unusually complete ; the zone [ac] is inconspicuous and what is to all appearance the prism is really the principal pyramid-zone [ap]. No fewer than eight forms are represented, none of which have been observed on any other crystal ; among them are the forms with complex symbols $\theta$ (759), $G$ (0·1·10), $H$ (3·1·10), and $\beta$ (10·0·1). The rare zone [ab] too is well represented.

The ordinary appearance of the crystals of smithite is suggestive of a hexagonal crystal in which the basal plane is largely developed, due to the fact that the azimuthal angle (62° 56′) between the principal zones intersecting in the prominent cleavage-face approximates to 60° so far as the eye can judge. One cleavage-fragment had on the edge an irregular arrangement of small crystals of a deeper red, which proved on examination to be hutchinsonite. Another cleavage-fragment contained a number of small, opaque needles ; one of them was with difficulty isolated, and the measurements in the prism-zone, which alone were possible, are in fair agreement with those required for stibnite.

The colour of smithite is a scarlet-vermilion, exactly like that of proustite, and the powder has the same hue. On prolonged exposure to strong sunlight the colour changes to an orange-red. Smithite is lighter in colour and more transparent than is usually the case with hutchinsonite. The associated minerals are sartorite, rathite, blende, iron-pyrites, realgar, orpiment, and hutchinsonite.

The three-circle goniometer was employed for the determination of the positions of the faces on all the measured crystals, and the cleavage-face, which was always conspicuous and gave a brilliant reflexion, was selected as origin. The measurements made on the best crystals, eight in number, are summarized in table III. Altogether fifty-seven forms have been observed, of which sixteen, viz. $a$, $c$, $e$, $d$, $s$, $r$, $q$, $B$, $p$, $\pi$, $o$, $T$, $S$, $Q$, $P$, $\rho$, have already been recorded by Mr. Solly[1]. The constants deduced by him, viz. $a : b : c = 2\cdot2309 : 1 : 1\cdot9657$ ; $\beta = 101° 12\frac{1}{2}′$ (78° 47$\frac{1}{2}$′), differ little from those given below.

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[1] The form given by him as (2̄12) should be (122̄).

## TABLE III  (SMITHITE).

*Measurements from* a = (100).

$$a : b : c = 2·2206 : 1 : 1·9570; \quad \beta = 101° 12′.$$

| Form. | Indices. | Calculated values. | | Observed Means. | | Number. | Limits of Observations. | |
|---|---|---|---|---|---|---|---|---|
| | | Azimuth. | Distance. | Azimuth. | Distance. | | Azimuth. | Distance. |
| b | 010 | * | * | 90° 0′ | 90° 0′ | 2 | ... 90° 14′ | ... 90° 5′ |
| μ | 140 | ,, | 83° 27′ | ,, ,, | 83 38 | 1 | | |
| w | 130 | ,, | 81 18 | ,, ,, | 81 37 | 1 | | |
| v | 120 | ,, | 77 4 | ,, ,, | 77 18 | 2 | ... ... | 77° 5′, 77 31 |
| m | 110 | ,, | 65 20½ | ,, ,, | 65 44 | 1 | | |
| l | 320 | ,, | 55 27 | ,, ,, | 55 17 | 4 | ... ... | 55 5 −55 40 |
| n | 210 | ,, | 47 26½ | ,, ,, | 47 16 | 2 | ... ... | 46 57, 47 35 |
| ν | 520 | ,, | 41 4 | ,, ,, | 40 55 | 1 | | |
| J | 44Ī | 82° 43′ | −66 46 | 83 23 | −65 50 | 1 | | |
| D | 121 | 71 10 | 70 31 | 71 40 | 70 30 | 1 | | |
| U | 61Ī | * | −22 55 | 62 56 | −22 52 | 1 | 62° 38′ −63 11 | |
| T | 51Ī | ,, | −27 6 | ,, ,, | −27 2 | 4 | ... ... | 27 0 −27 4 |
| S | 41Ī | ,, | −32 54½ | ,, ,, | −32 50 | 4 | ... ... | 32 48 −32 53 |
| R | 31Ī | :, | −41 21 | ,, ,, | −41 14 | 2 | ... ... | 41 13, 41 15 |
| Q | 21Ī | ,, | −53 58 | ,, ,, | −54 2 | 6 | ... ... | 53 55 −54 15 |
| P | 11Ī | ,, | −72 19 | ,, ,, | −72 14 | 2 | ... ... | 72 11, 72 17 |
| σ | 344 | ,, | −77 47 | ,, ,, | −77 56 | 1 | | |
| τ | 233 | ,, | −79 40 | ,, ,, | −79 31 | 1 | | |
| ρ | 122̄ | ,, | −83 28½ | ,, ,, | −83 24 | 1 | | |
| o | 011 | ,, | 84 51 | ,, ,, | 84 50 | 2 | ... ... | 84 45, 84 55 |
| π | 355 | ,, | 71 27½ | ,, ,, | 71 25 | 1 | | |
| p | 111 | ,, | 63 29 | ,, ,, | 63 22½ | 5 | ... ... | 63 16 −63 26 |
| B | 322 | ,, | 54 53 | ,, ,, | 54 47 | 3 | ... ... | 54 45 −54 51 |
| q | 211 | ,, | 47 46 | ,, ,, | 47 34 | 8 | ... ... | 47 20 −47 46 |
| a | 15.7.7 | ,, | 45 59 | ,, ,, | 45 58 | 2 | ... ... | 45 56, 46 0 |
| A | 522 | ,, | 41 57½ | ,, ,, | 41 53 | 1 | | |
| r | 311 | ,, | 37 13 | ,, ,, | 37 6 | 5 | ... ... | 36 54 −37 10 |
| s | 411 | ,, | 30 6 | ,, ,, | 30 4 | 3 | ... ... | 30 1 −30 9 |
| t | 511 | ,, | 25 6½ | ,, ,, | 25 10 | 1 | | |
| θ | 759 | 47 23½ | 58 44½ | 48 13 | 58 46 | 1 | | |
| Ξ | 413 | 33 7 | −50 3 | 32 59 | −50 26 | 1 | 32 55 −33 3 | |
| Z | 313 | ,, ,, | −59 35½ | ,, ,, | −59 35 | 2 | ... ... | 59 31, 59 39 |
| k | 013 | ,, ,, | 80 35 | ,, ,, | 80 45 | 1 | | |
| x | 113 | ,, ,, | 67 23 | ,, ,, | 67 24 | 3 | ... ... | 67 20 −67 28 |
| y | 213 | ,, ,, | 56 16½ | ,, ,, | 56 16 | 4 | ... ... | 56 14 −56 20 |
| z | 313 | ,, ,, | 47 26 | ,, ,, | 47 28 | 3 | ... ... | 47 26 −47 32 |
| ξ | 413 | ,, ,, | 40 32 | ,, ,, | 40 26 | 2 | ... ... | 40 21, 40 31 |

TABLE III—*continued.*

| Form. | Indices. | Calculated values. | | Observed Means. | | Number. | Limits of Observations. | |
|---|---|---|---|---|---|---|---|---|
| | | Azimuth. | Distance. | Azimuth. | Distance. | | Azimuth. | Distance. |
| O | 21̄4 | 26 4 | −77 17 | 26 20 | −77 14 | 2 | 25 50, 26 50 | 76 50, 77 38 |
| C | 215 | 21 22½ | 62 34 | 21 15 | 62 40 | 2 | 21 10, 21 20 | 62 30, 62 50 |
| G | 0·1·10 | 11 4 | 79 0 | 11 0 | 78 58 | 2 | 10 45 −11 15 | 78 56, 79 0 |
| H | 3·1·10 | ,, ,, | 65 21 | ,, ,, | 66 0 | 1 | | |
| j | 40̄1 | * | −16 27 | 0 0 | −16 23 | 1 | | |
| κ | 11·0·3 | ,, | −17 53½ | ,, ,, | −17 45 | 1 | | |
| γ | 502 | ,, | −26 1 | ,, :, | −25 37 | 1 | | |
| i | 20̄1 | ,, | −32 1 | ,, ,, | −31 58 | 1 | | |
| δ | 503 | ,, | −37 31½ | ,, ,, | −37 26 | 1 | | |
| λ | 403 | ,, | −45 0 | ,, ,, | −44 53 | 2 | ... ... | 44 20, 45 26 |
| d | 10̄1 | ,, | * | ,, ,, | −54 59 | 9 | ... ... | 54 53 −55 6 |
| c | 001 | ,, | * | ,, ,, | 78 48 | 10 | ... ... | 78 37 −79 0 |
| ε | 308 | ,, | 61 51 | ,, ,, | 62 8 | 1 | | |
| h | 102 | ,, | 57 5 | ,, ,, | 57 6 | 3 | ... ... | 57 6 −57 6 |
| ζ | 505 | ,,, | 53 36 | ,, ,, | 53 43 | 1 | | |
| e | 101 | ,, | 42 22 | ,, ,, | 42 26 | 5 | ... ... | 42 18 −42 35 |
| g | 301 | ,, | 19 4 | ,, ,, | 19 5 | 1 | | |
| η | 501 | ,, | 14 46 | ,, ,, | 14 25 | 1 | | |
| β | 10·0·1 | ,, | 6 36 | ,, ,, | 6 53 | 1 | | |
| α | 100 | ,, | * | ,, ,, | 0 0 | 14 | | |

Of the forms given above, the most prominent are $a$ (100), $e$ (101), $c$ (001), and $d$ (1̄01) in the prism-zone, and $q$ (211), $p$ (111), $P$ (1̄11), and $Q$ (2̄11) in the principal pyramid-zone. The forms $h$ (102), $r$ (311), $R$ (3̄11), and $l$ (320) are occasionally represented by relatively large faces; but the remainder are quite small and often very minute.

There is a highly perfect cleavage parallel to $a$ (100), which, as has been pointed out, provides a ready means of discriminating this species from hutchinsonite and trechmannite. The glistening of the cleavage-face readily catches the eye, and will reveal the existence of a thin skin of smithite on a lead sulpharsenite, which might otherwise have escaped detection.

In table IV are given the calculated coordinates of the principal forms with reference to the face of symmetry, $b$ (010), as origin.

TABLE IV (Smithite).

*Calculated Coordinates of the principal forms referred to* b = (010) *as origin.*

| Form. | Indices. | Azimuth. | Distance. |
|-------|----------|----------|-----------|
| $Q$ | $\bar{2}11$ | $-32°\ 1\frac{1}{2}'$ | $43°\ 56\frac{1}{2}'$ |
| $d$ | $\bar{1}01$ | $-54\ 59$ | $90\ \ 0$ |
| $Z$ | $313$ | $,,\ \ ,,$ | $61\ 53$ |
| $P$ | $\bar{1}11$ | $,,\ \ ,,$ | $31\ 57\frac{1}{2}$ |
| $c$ | $001$ | $78\ 48$ | $90\ \ 0$ |
| $x$ | $113$ | $63\ 33$ | $59\ 43$ |
| $h$ | $102$ | $57\ \ 5$ | $90\ \ 0$ |
| $y$ | $213$ | $51\ 27$ | $62\ 58\frac{1}{2}$ |
| $e$ | $101$ | $42\ 22$ | $90\ \ 0$ |
| $z$ | $313$ | $,,\ \ ,,$ | $66\ 16$ |
| $p$ | $111$ | $,,\ \ ,,$ | $37\ 10$ |
| $q$ | $211$ | $26\ 37\frac{1}{2}$ | $48\ 45$ |
| $r$ | $311$ | $19\ \ 4$ | $57\ 24\frac{1}{2}$ |
| $a$ | $100$ | $0\ \ 0$ | $90\ \ 0$ |
| $l$ | $320$ | $,,\ \ ,,$ | $34\ 33$ |
| $m$ | $110$ | $,,\ \ ,,$ | $24\ 39\frac{1}{2}$ |
| $v$ | $120$ | $,,\ \ ,,$ | $12\ 56$ |

2. *Optical Characters.*

As in the case of hutchinsonite, very little of the violet end of the spectrum beyond the yellow is transmitted, and there is some indication of pleochroism. The lustre is adamantine.

If a cleavage-plate, which is parallel to *a* (100), be viewed in mono-chromatic, convergent light between crossed nicols a system of inter-ference rings slightly out of centre may be seen ; no rings are visible in white light. The figure is such as would be given by a biaxial crystal in the direction of one of the bisectrices, but no 'eyes' are visible,

even in red light. A plate was mounted on an axial-angle instrument and it was found that the centre of the figure is inclined at an angle of 21° in air, equivalent to 6½° in the crystal, for sodium-light, and at an angle of 13° in air, equivalent to 4° in the crystal, for red (C) light, with the normal to $a$ (100) in the obtuse angle (100 : 00$\bar{1}$). Even when the plate is dipped into pure methylene iodide the ' eyes ' are invisible for any colour, however far the plate be rotated; but the curvature of the rings increases considerably and they become nearly circular in form. It is probable, therefore, that the optic axes were only just internally reflected, in which case the angle between the optic axes within the crystal for sodium-light would be about 65°. At any rate, there seems no doubt that it is the acute bisectrix which is so nearly at right angles to $a$ (100), and the plane of the optic axes is therefore parallel to $b$ (010). The usual test by means of a quartz-wedge shows that the character of the double-refraction is negative.

Unfortunately, none of the crystals of smithite examined were favourably enough developed for the determination of the principal indices of refraction; indeed, it rarely happens that any zone extends completely round a crystal. Further, they are too small or too thin to permit of the grinding of artificial faces for the purpose. It was possible on the crystal shown in fig. 6 to observe the light refracted through the prism formed by faces of the forms $o$ (011) and $p$ (111), and the measurements of the angles of minimum deviation lead to the values 3·18 and 3·36 for sodium-light, whence is obtained 3·27 as an approximate value for the mean refractivity, slightly higher than that found for hutchinsonite.

## 3. Chemical Composition.

For the analysis of smithite much more satisfactory material was available than in the case of hutchinsonite. It consisted of a fairly large cleavage-fragment of the mineral, part of which was perfectly pure and free from inclusions. A preliminary analysis was made on about 50 milligrams of less pure material containing minute, dark, needle-like inclusions. The mineral was decomposed in chlorine and the analysis was conducted by the same methods as in the case of hutchinsonite. The result of this preliminary analysis, made on 0·0502 gram, was as follows:—Ag, 40; Pb, 1; Cu, 2; As, 25½; S, 26½; total, 95·0 per cent.

For the second analysis, made on perfectly pure material, as much as a decigram was available. The result was as follows:—

z

|       |     |      |     | Atomic ratios. |     | Calc. for $AgAsS_2$. |
|-------|-----|------|-----|----------------|-----|------|
| Ag    | ... | 43.9 | ... | 0.407          | ... | 43.69 |
| As    | ... | 28.9 | ... | 0.385          | ... | 30.36 |
| Sb    | ... | 0.4  | ... | —              | ... | —     |
| S     | ... | 26.0 | ... | 0.812          | ... | 25.95 |
|       |     | 99.2 |     |                |     | 100.00 |

Weight of material used = 0.1076 gram ; weight of AgCl = 0.0626 ; BaSO$_4$ = 0.2037 ; Mg$_2$As$_2$O$_7$ = 0.0643 ; SbO$_2$ = 0.0005 gram.

Specific gravity, as determined with a 3 cc. pyknometer on 0.1128 gram of pure material, = 4.88.

The numbers obtained agree very closely with the simple formula $AgAsS_2$ or $Ag_2S.As_2S_3$.

### 4. *Summary of Characters of Smithite.*

Monoclinic; $a : b : c = 2.2206 : 1 : 1.9570$ ; $\beta = 101° 12'$. Crystals, hexagonal in habit, tabular and occasionally modified. Cleavage, $a$ (100), highly perfect. Fracture, conchoidal. Brittle. Hardness, 1½–2. Specific gravity, 4.88. Lustre, adamantine. Colour and streak, scarlet-vermilion, altering to orange-red on exposure. Transparent. Optic axial plane parallel to $b$ (010) ; acute bisectrix inclined at 6½° (Na) and 4° (Li) to normal to $a$ (100) in the obtuse angle (100 : 00$\bar{1}$) ; 2E about 65°. Double refraction, negative and fairly strong. Pleochroism, weak. Mean refractive power, 3.27 approximately. Composition, $Ag_2S.As_2S_3$ = $AgAsS_2$.

### III. Trechmannite.

Of these red minerals, by far the rarest, at the present time, is the third species, to which the name trechmannite has been assigned by Mr. Solly. In consequence, it has not been possible to carry out the investigation of its characters to the same completion as in the case of the two companion species just considered ; and, moreover, so little material could be spared for analysis, that even a complete qualitative determination of the chemical composition was impracticable. As has already been stated at the beginning of this paper, the discovery of this new mineral was made by Mr. Solly on an examination of the specimen placed at his disposal by Dr. Trechmann ; none of the crystals on it, however, were sufficiently well developed for a satisfactory

determination of the morphological characters. In 1904 a single good crystal (fig. 7) with dull, but plane, faces was found; in the following year (1905) a pair of brilliant crystals in nearly parallel position, the larger of which is illustrated in fig. 8, came to light; and finally, last summer Mr. Solly secured five specimens, on each of which were a few small, well-developed crystals.

The satisfactory discrimination of trechmannite from the lighter-coloured variety of hutchinsonite requires the crystal to have a sufficient number of faces for the recognition on goniometrical examination of some characteristic angle. If, however, the crystal be intimately associated with tennantite ('binnite') it is in all probability trech-mannite.


### 1. *Morphological Characters.*

Trechmannite has a remarkable predilection for the black and metallic-looking tennantite ('binnite') characteristic of this locality, and, indeed, all the good crystals which have been observed were found springing from this mineral. The crystals are always small, and, as will be pointed out in further detail below, they are frequently corroded in parts.
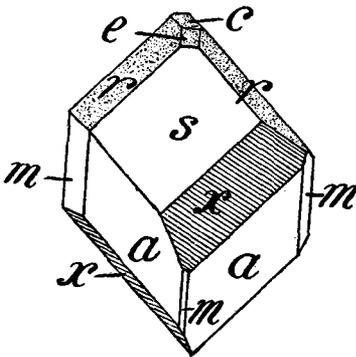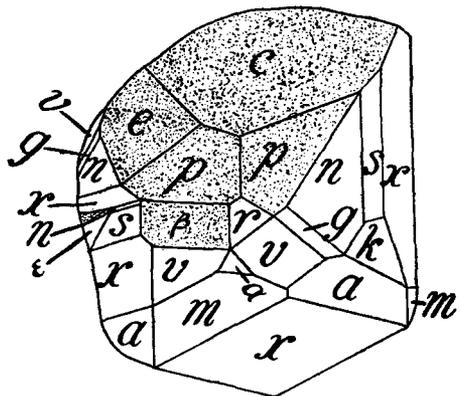


Fig. 7.        Fig. 8.

Crystals of Trechmannite.

For the determination of the morphological constants the measurements made on the five best crystals observed were alone utilized.

Crystal 1 (fig. 7) was found by Mr. Solly[1] and has already been described by him. Part of the crystal of tennantite ('binnite') on which it was found had to be cut away in order to complete the measurements. It is the largest crystal as yet found and measures 1 mm. in the greatest diameter; the remaining crystals do not exceed 0·7 mm. All the faces are dull, but mostly give distinct reflexions of the object-slit with the exception of those (c, e, and r) stippled in the drawing, which were so much corroded that no measurements were possible. The edges between the faces are, however, so distinct as to leave no doubt regarding the identification of the faces. Each face of the rhombohedron of the third order, x, is striated parallel to its intersection with that face of the contiguous form which makes the smaller angle with it.

Crystal 2 (fig. 8) is the larger of a pair in nearly parallel position, which were found in 1905 and have likewise been measured by Mr. Solly.[2] The second individual lies to the right, when viewed as depicted in the figure. Here again, certain faces (c, e, p, and β) are corroded, and no trustworthy measurements of them were possible. It is curious that the faces closely adjoining are bright, even up to the edge or edges separating them from those corroded. On the left the crystal is broken and certain faces (x and n) are repeated on either side; a re-entrant angle is, of course, formed where the faces n and x on opposite sides meet. The crystal is most irregularly developed and the prism is by no means the most conspicuous zone.

Crystal 3 (fig. 9) was found last summer; a small crystal of iron-pyrites is partially embedded in it at the back. Again, certain faces (p, r, and η) are corroded, and in this case the edges bounding them are indistinct, so that the identification of them is uncertain. The crystal is, moreover, broken at the top. The prism-zone is unusually conspicuous, and the faces of the form a are striated parallel to the edge of the prominent zone [azxsn]. These striae, together with the considerable development of faces below as well as above the prism-zone, reveal clearly the nature of the symmetry, to which we recur below.

Crystal 4 (fig. 10) also was found last summer. It surpasses all that have yet been observed as regards the brilliancy of the reflexions and the number of the faces present; in all thirty-nine distinct faces were observed, many of which are too minute to be reproduced in the

[1] Loc. cit., p. 75.
[2] Loc. cit., p. 189.

drawing. There are no signs of corrosion. The stippling in the figure represents a gap in the crystal, on both sides of which appears a face of the form *c*.
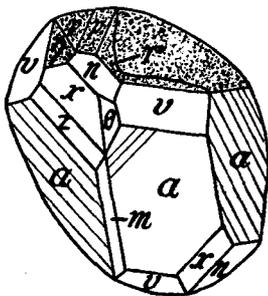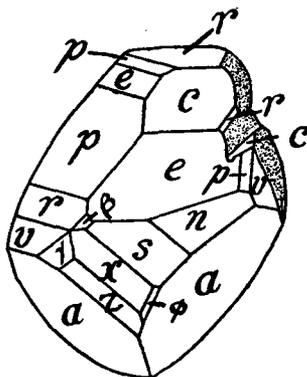


Fig. 9.                              Fig. 10.

Crystals of Trechmannite.

Crystal 5, likewise found last summer, is very imperfect and pos-. sesses few faces other than those in the prism-zone. The faces of the form *a* are striated parallel to the prism-edge.

The illustrations represent as faithfully as possible the actual crystals.

The colour of trechmannite is a scarlet-vermilion, and that of its streak is the same. There is a good cleavage parallel to *r* (100), and Mr. Solly [1] has noticed another perpendicular to the edge of the prism-zone. The associated minerals are, in addition to tennantite ('binnite'), seligmannite, blende, iron-pyrites, and a colourless to light-greenish mica (fuchsite).

Trechmannite belongs to the hexagonal-alternating, or diplohedral, class of the rhombohedral system [2], which includes such important species as ilmenite and phenacite. A study of fig. 9 shows clearly that the crystal possesses a centre of symmetry and a trigonal axis, which together are equivalent to a hexagonal-alternating axis, but is devoid of planes of symmetry and digonal axes. The zone [*azxsn*] is always prominent, and the form *x* is one of the most conspicuous (cf. figs. 7 and 8).

[1] Loc. cit., p. 75.
[2] The symmetry was at first incorrectly stated (Nature, 1905, vol. lxxi, p. 574) to be that of quartz on the examination of an incompletely developed crystal, and was so given by Mr. Solly, loc. cit., p. 190.

TABLE V (TRECHMANNITE).

*Measurements from* c = (111) = (0001).

Rhombohedral, diplohedral; $a:c = 1:0.6530$.

| Form. | Indices Rhombohedral. | Indices Hexagonal. | Calculated Values Azimuth. | Calculated Values Distance. | Observed Means Azimuth. | Observed Means Distance. | Number. | Limits of Observations Azimuth. | Limits of Observations Distance. |
|---|---|---|---|---|---|---|---|---|---|
| c | 111 | 0001 | ···° 0′ | 0° 0′ | ···° 0′ | ···° ··0 | 4 | | |
| m | 211 | 1010 | 0° 0′ | 90 0 | 0° 0′ | 90° 0 | 11 | | |
| F | 321 | 1450 | 10 53½ | ,, ,, | 10 11 | ,, ,, | 1 | | |
| d | 725 | 1340 | 13 54 | ,, ,, | 13 23 | ,, ,, | 1 | | |
| D | 413 | 2570 | 16 6 | ,, ,, | 16 10 | ,, ,, | 3 | 16° 0′ – 16° 19′ | |
| a | 101 | 1120 | 30 0 | ,, ,, | 30 0 | ,, ,, | 13 | 30 15 | |
| H | 122 | 1015 | 0 0 | 8 34¼ | 0 0 | 9 0 | 1 | | |
| G | 133 | 2027 | ,, | 12 39½ | ,, | 12 10 | 1 | | |
| e | 011 | 1012 | ,, | 20 39½ | ,, | 20 41 | 3 | | 20° 36′ – 20° 48′ |
| s | 111 | 2021 | ,, | 56 33 | ,, | 56 28½ | 11 | | 56 24 – 56 37 |
| φ | 322 | 5051 | ,, | 75 9 | ,, | 75 27 | 1 | | |
| r | 100 | 1011 | ,, | 37 1 | ,, | 37 2 | 5 | | 36 57 – 37 11 |
| a | 311 | 4041 | ,, | 71 39½ | ,, | 71 38½ | 2 | | 71 37, 71 40 |
| θ | 17.12.14 | 2.29.31.9 | 3 19 | 68 20 | 3 8 | 68 15 | 1 | | |
| k | 765 | 1.12.13.4 | 3 58½ | 67 8 | 4 1 | 66 55 | 1 | | |
| λ | 656 | 1.11.12.5 | 4 18½ | 60 6 | 4 38 | 60 19 | 1 | | |
| n | 232 | 1453 | 10 53½ | 49 2 | 10 59 | 49 3 | 9 | 10 37 – 11 4 | 48 58 – 49 9 |
| x | 212 | 1341 | 13 54 | 69 48½ | 13 58 | 69 50 | 14 | 13 48 – 14 9 | 69 45 – 69 59 |
| ν | 531 | 2681 | ,, ,, | 79 35 | 13 57 | 79 32 | 1 | | |
| δ | 037 | 4.9.13.4 | 17 29 | 65 18 | 17 40 | 65 13 | 1 | | |
| ε | 8.5.11 | 6.13.19.8 | 18 9 | 57 42 | 18 13 | 57 44 | 1 | | |
| v | 210 | 1231 | 19 6½ | 63 22½ | 19 8 | 63 25 | 13 | 18 58 – 19 15 | 63 16 – 63 36 |

| Form. | Rhombo-hedral. | Hexa-gonal. | Azimuth. | Distance. | Azimuth. | Distance. | Number. | Azimuth. | Distance. |
|---|---|---|---|---|---|---|---|---|---|
| z | 313 | 2461 | 19 6½ | 75 56 | 19 7 | 75 56 | 4 | 18 54 — 19 12 | 75 40 — 76 10 |
| g | 325 | 3684 | 21 47 | 52 50½ | 21 56 | 52 55½ | 2 | 21 53, 21 59 | 52 50, 53 1 |
| ζ | 14.10.1 | 3651 | ,, ,, | 79 16 | 21 39 | 79 28½ | 2 | 21 38, 21 40 | 79 20, 79 27 |
| η | 124 | 2355 | 23 25 | 33 19 | 23 30 | 33 10 | 1 | | |
| β | 4ī1 | 2954 | ,, ,, | 39 24½ | 23 14 | 39 22 | 1 | | |
| χ | 430 | 3471 | 25 17 | 77 42 | | | | | |
| γ | 5ī1 | 4552 | 26 19½ | 71 14½ | 26 9 | 71 40 | 1 | | 23 29 — 23 55 |
| ρ | 012 | 1123 | 30 0 | 23 31½ | 30 0 | 23 40 | 4 | 30 4 | |

## TABLE VI (TRECHMANNITE.)

Measurements from a = (ī01) = (ī011).

| Form. | Indices. | | Calculated Values. | | Observed Means. | | Number. | Limits of Observations. | |
|---|---|---|---|---|---|---|---|---|---|
| | Rhombo-hedral. | Hexa-gonal. | Azimuth. | Distance. | Azimuth. | Distance. | | Azimuth. | Distance. |
| z | 313 | 2461 | * | 17 43½' | 52° 59' | 17° 39½' | 5 | 52° 52' ~ 53° 4' | 17° 33' — 17° 40' |
| x | 212 | 1341 | ,, | 25 37 | ,, ,, | 25 33 | 12 | ... | 25 3 — 25 47 |
| s | 111 | 2021 | ,, | 43 48 | ,, ,, | 43 44 | 12 | ... | 43 11 — 43 58 |
| n | 232 | 1453 | ,, | 55 11 | ,, ,, | 55 9 | 5 | ... | 55 0 — 55 20 |
| r | 010 | 10ī1 | ,, | * | ,, ,, | 90 0 | 5 | ... | 90 — 90 5 |
| c | 111 | 0001 | 90° 0' | 90 0 | | | | | |
| X | 304 | 3471 | 69 20½ | 18 9½ | 69 18½ | 12 52½ | 2 | 69 7 ~ 69 29 | 12 45 — 13 0 |
| v | 102 | 1231 | ,, ,, | 28 37 | ,, ,, | 28 36 | 4 | ... | 28 30 — 28 43 |
| r | 001 | 10ī1 | ,, ,, | 58 34½ | ,, ,, | 58 32 | 4 | ... | 58 29 — 58 38 |
| p | 102 | 1123 | ,, ,, | 78 29 | ,, ,, | 78 24 | 4 | ... | 78 15 — 78 38 |
| e | 101 | 10ī2 | ,, ,, | * | ,, ,, | 90 0 | 2 | ... | 90 — 90 3 |

All four crystals were measured on the three-circle goniometer from the face $c=(111)=(0001)$ as origin, and in the three cases where this face was corroded the crystals were set up by means of the prism-zone. In table V are given the means of the observed values and the calculated values of the coordinates. The latter values have been computed from the mean of the azimuths of the prominent zone $[azxsn]$, viz. 52° 59′ (see table VI). The axial ratio thus determined, $a:c=1:0.6530$, differs little from that deduced by Mr. Solly from his measurements, viz. $a:c=1:0.6556$.

In all, thirty forms have been observed, of which seven, viz. $c$, $r$, $x$, $z$, $a$, $m$, $d$, were noted by Mr. Solly ; the form $f=\{32\bar{5}\}=\{17\bar{8}0\}$ recorded by him has not been noticed.

Further, on all four crystals, measurements were made of the faces in the two prominent zones intersecting in $a=(\bar{1}01)=(11\bar{2}0)$ from this pole as origin, and the means of the observations together with the corresponding calculated values are given in table VI.

The characters of the various forms are as follows :—

$c=\{111\}=\{0001\}$    usually small and frequently corroded.

$m=\{\bar{2}11\}=\{10\bar{1}0\}$    common, but small.

$a=\{\bar{1}01\}=\{11\bar{2}0\}$    common and large ; striated on one crystal parallel to the edge of the zone $[azxsn]$ and on another parallel to the prism-edge.

$r=\{100\}=\{10\bar{1}1\}$    common, but small ; sometimes corroded : a cleavage parallel to it.

$e=\{011\}=\{10\bar{1}2\}$    small : sometimes corroded.

$p=\pi\{012\}=\{11\bar{2}3\}$    not common, but occasionally large : sometimes corroded : the companion form $p_i=\pi\{021\}$ is also present.

$v=\pi\{2\bar{1}0\}=\{12\bar{3}1\}$    common, but small : the companion form $v_i=\pi\{20\bar{1}\}$ is also present.

$x=\pi\{\bar{2}12\}=\{13\bar{4}1\}$    common, and often very prominent : sometimes striated parallel to the intersection with the nearest face of the form $m$.

$z=\pi\{313\}=\{24\bar{6}1\}$    common, but small.

$n=\pi\{\bar{2}32\}=\{14\bar{5}3\}$    common, and fairly large.

The remaining forms were in all cases rare : on crystal 2 (fig. 8) $g=\pi\{32\bar{5}\}$ is represented by two faces, $k=\pi\{765\}$ by one, $a=\pi\{3\bar{1}\bar{1}\}$ by two, $\beta=\pi\{4\bar{1}1\}$ by one corroded, and $\epsilon=\pi\{\bar{8}\cdot5\cdot11\}$ by one, all of which faces are quite distinct though small ; $\theta=\pi\{\bar{1}7\cdot12\cdot14\}$ appears as a definite face on crystal 3 (fig. 9) ; one of the corroded faces probably belongs to the

form $\eta$, but for reasons given above there is some uncertainty. $\beta = \pi\{4\bar{1}1\}$ and $\gamma = \pi\{5\bar{4}1\}$ are each represented by one small, but distinct face on crystal 4 (fig. 10). Finally $V = \pi\{531\}$ and $\eta = \pi\{\bar{1}24\}$ are each represented by one small, but distinct face on crystal 5. The outstanding forms appeared as most minute faces. $\chi = \pi\{4\bar{3}0\}$ gave so faint a reflexion that approximate measurements in the zone $[avre]$ alone were possible (see table VI).

## 2. *Optical Characters.*

As in the case of the previous species, very little above the red end of the spectrum is transmitted, and there is again some faint indication of pleochroism. The lustre is adamantine.

None of the crystals observed were suitably shaped for a determination of the optical constants, and the information obtained is very meagre. The mineral is highly refracting. On crushing up a small crystal, a splinter was seen which showed when viewed in convergent light between crossed nicols an indistinct uniaxial figure with negative double refraction.

## 3. *Chemical Composition.*

Qualitative tests made on a small fragment indicated the presence of silver and arsenic, and the absence of thallium. We may reasonably assume, therefore, that trechmannite is a sulpharsenite of silver.

## 4. *Summary of Characters of Trechmannite.*

Rhombohedral, diplohedral; $a:c = 1:0.6530$. Crystals, prismatic in habit often irregular; sometimes corroded in parts. Cleavage, $r$ good, $c$ distinct. Fracture, conchoidal. Brittle. Hardness, $1\frac{1}{2}$–2. Lustre, adamantine. Colour and streak, scarlet-vermilion. Transparent to translucent. Double refraction, fairly strong; negative. Pleochroism, weak. Composition, probably a sulpharsenite of silver.

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The formula found for smithite at once suggests that some obvious relation should subsist between its morphological characters and those of miargyrite, the corresponding sulphantimonite, such as obtains in the case of proustite and pyrargyrite; but, though both smithite and miargyrite are monoclinic in symmetry, there is no accord between the interfacial angles. Again, hutchinsonite contains thallium, but its morphological characters bear no resemblance to those of lorandite, the sulpharsenite of thallium. Finally, all three of the red minerals discussed in this paper differ completely from one another in their crystalline characters.

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