The crystallography of Vogtite, an anorthic metasilicate of iron, calcium, manganese, and magnesium, from acid steel-furnace slags.

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THE substance was met with in the course of work on steel-furnace slags, a general account of which has been communicated to the Iron and Steel Institute.[1] These slags were for the most part melts consisting principally of the three oxides FeO, MnO, and SiO_2, and yielded the silicates fayalite and rhodonite. The small amount of calcium silicate usually present is held in isomorphous solid solution in these silicates, but when the amount of lime exceeds about eight per cent. a new silicate appears, which does not seem to belong to any of the known mineral groups. A specimen was obtained from a slag of rather low silica content in which this substance had crystallized first in long blades radiating from the sides of the slag-ball; by the withdrawal of the mother-liquor, cavities had been formed which contained terminated crystals, and from these it has been possible to determine the crystallographic and optical properties of the material.

Analysis.—The two analyses quoted below are by Mr. J. H. Whiteley (loc. cit.). The silicate was separated magnetically after a slight roasting, and the ferric oxide is therefore to be treated as originally in the ferrous state. The amount of ferric oxide present in the slag itself is small and is mainly in the form of magnetite in the interstitial glass.

[1] 'The acid hearth and slag,' by J. H. Whiteley and A. F. Hallimond (read May 10, 1919).

	Slag.	Separated crystals.	Equivalent ratios.
SiO_2 ...	47·9 ...	47·4 ...	0·790
Al_2O_3 ...	1·72 ...	0·15	
Fe_2O_3 ...	1·2 ...	2·7 } ...	0·257
FeO ...	20·85 ...	15·95 }	
MnO ...	10·8 ...	12·95 ...	0·182
CaO ...	13·0 ...	15·1 ...	0·270
MgO ...	3·89 ...	5·26 ...	0·131
TiO_2 ...	0·58 ...	0·10	
Total ...	99·4 ...	99·61	
Sp. gr. ...	... ...	3·39	

The composition approximates to the metasilicate ratio, and it is interesting to note that while the FeO has diminished in the crystals the other three basic oxides have slightly increased. The deviation from metasilicate ratio is rather greater than would be expected for the material analysed, and it seems possible that solution of non-isomorphous compounds may occur.

Optical properties.—When free from included glass the crystals are transparent and pale amber-yellow in colour. They show little or no pleochroism and have nearly straight extinction. On crushing, flakes on the two cleavages *M* and *m* are obtained, and in both an optic axis can be seen at a short distance from the centre of the field. The axial plane is nearly normal to the zone of elongation and the crystals are optically negative. By immersion in a mixture of monobromonaphthalene and methylene iodide the refractive index β was found to be 1·701 for sodium-light. On the Hutchinson universal apparatus, by immersion in the same liquid, the axial angle was measured as $2V_D = 65\frac{1}{2}^\circ$. The optic axis, which is nearly normal to the cleavage *m*, shows but little dispersion, but that emerging through *M* is very noticeably coloured; the brush is displaced obliquely for blue light and the axial angle is less than that for yellow. A small flake was mounted on the stage goniometer and rotated in the mixture with refractive index equal to β. The position of the two optic axes having been observed, the flake was set so that the acute bisectrix was nearly coincident with the axis of the microscope. The extinction was found to be 5°. When the obtuse bisectrix was in the axis, the extinction was straight. These results, together with the extinction on *mM* in fully developed crystals, indicate that the position of the third mean line is that shown in the stereogram

(fig. 1); the acute and obtuse bisectrices lie very nearly in the equatorial plane in the positions shown.

Cross-sections of these crystals are almost impossible to prepare, but in a section of a closely similar slag from a Scottish steel-works it was found possible to measure the birefringence $\gamma - \alpha = 0{\cdot}018$.

Crystallography.—Four elongated crystals, of the habit shown in fig. 2 and about 2 mm. in width, were found to give moderately good readings. The observations on these are summarized in the following table:—

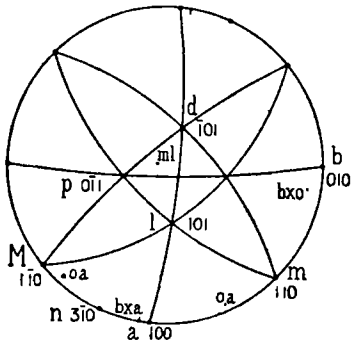

FIG. 1.—Stereographic projection of the crystal-forms of Vogtite.

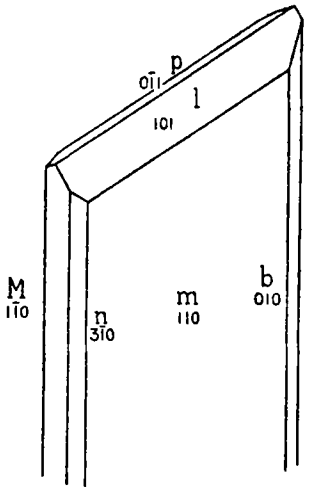

FIG. 2.—Crystal of Vogtite.

Angle.	*mb*	*m'M*	*mn*	*ml*	*m'p*	*m'M* (cleavage)	[*mM*]:[*mp*]
No. of readings	4	4	1	2	3	1	4
Highest	44°40′	84°54′		60° 1′	75°46′		62°10′
Lowest	44 30	84 49		59 18	74 21		62 0
Mean	44 3$\frac{1}{2}$	84 50$\frac{1}{2}$	69°53′	59 39$\frac{1}{2}$	75 30	85°12′	62 6$\frac{1}{2}$
Calculated	*	*	69 34$\frac{1}{2}$	*	*	—	*

Anorthic, $a : b : c = 1{\cdot}093 : 1 : 0{\cdot}729$; $\alpha = 99° 37'$, $\beta = 99° 21'$, $\gamma = 83° 53'$.

Forms: $b\{010\}$, $m\{110\}$, $M\{1\bar{1}0\}$, $p\{0\bar{1}1\}$, $l\{101\}$, $n\{3\bar{1}0\}$.

The readings for the angle between the zones $[mM]$ and $[mp]$ were measured on the microscope, the faces l and p being unsuitable for the measurement of a cross-zone on the goniometer. The cleavages M and m are perfect; the cross-cleavage, if present at all, is very steep, and the flakes of the crushed crystals are extremely sharp.

A substance having the same angles as those here given has been described by C. Hlawatsch,[1] who proposed for it the name vogtite in honour of J. H. L. Vogt. The composition could not be ascertained and the source of the slag was not known. The cleavages given are not in accordance with those observed for the material now described, and there are minor differences in the physical properties, but the agreement between the angles is very close, and there is no doubt that the substances are members of the same isomorphous group. The crystals exhibit marked pseudo-tetragonal symmetry, and for this reason a setting has been chosen which differs from that of Hlawatsch. The following table shows the forms and angles in both settings:—

Forms.		Angles.	
Hlawatsch.	A. F. H.	Hlawatsch.	A. F. H.
a (100)	*m (110)	$a:m$ 50° 18·7′	$m:a$ 50° 10½′
m (110)	a (100)	$a:M$ 44 21·9	$m:b$ 44 34½
*t (120)	[t (2$\bar{1}$0)]	$m:M$ 94 40·6	$a:b$ 94 45
*b (010)	*M (1$\bar{1}$0)	$a:b$ 95 30	$m:M$ 95 9½
*M (1$\bar{1}$0)	b (010)	$b:d$ 64 47·3	—
e (0$\bar{1}$1)	p' (01$\bar{1}$)	$a:d$ 81 10·2	—
d (011)	[d' (10$\bar{1}$)]	$b':e$ 61 33·9	—
—	n (3$\bar{1}$0)	$a:e$ 75 26·1	$m:p'$ 75 30
—	l (101)	$[aM]:[ac]$ 62 1	$[mb]:[mp]$ 62 6½
		—	$m:l$ 59 39½
		—	$a:l$ 50 41

* cleavage-form.

It is probable that vogtite will prove to be the commonest silicate in those slags of the acid process to which lime has been added. No natural

[1] C. Hlawatsch, 'Eine trikline, rhodonitähnliche Schlacke.' Zeits. Kryst. Min., 1907, vol. xlii, pp. 590–593.

occurrence of the substance would seem to have been recorded,[1] but since the conditions of formation are very similar to those which yield rhodonite, the formation of this mineral also might be expected in a rock of suitable composition.

[1] Two anorthic minerals resembling rhodonite have recently been described, namely pyroxmangite (W. E. Ford and W. M. Bradley, Amer. Journ. Sci., 1913, ser. 4, vol. xxxvi, p. 169), and sobralite (J. Palmgren, Bull. Geol. Inst. Univ. Upsala, 1917, vol. xiv, p. 173). These are considerably denser than vogtite, and the optical schemes given by Palmgren have nothing in common with that for this substance.