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HALLIMONDITE, A NEW URANIUM MINERAL FROM THE MICHAEL MINE NEAR REICHENBACH (BLACK FOREST, GERMANY)

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ABSTRACT

Hallimondite is a new lead uranyl arsenate mineral found at the Michael Mine near Reichenbach in the Black Forest. It forms small yellow crystals and coatings in cavities and fractures of quartz and is associated with hügelite and mimetite.

Crystals of hallimondite have triclinic symmetry. They are tabular and more or less elongated along the *c*-axis. Observed forms: a {100}, b {010}, c {001}, m {110}, n {610}, k {011}, q {018}, p {111}. No distinct cleavage, fracture conchoidal, color yellow, streak pale yellow, luster subadamantine, hardness probably like that of parsonsite $2\frac{1}{2}$–3, G meas. (synthetic hallimondite) 6.39, calc. 6.40; no fluorescence; optically biaxial (+), 2V near 80°, $r > v$, α 1.882 ± 0.005, γ 1.915 ± 0.005, weak pleochroism.

Unit-cell dimensions were determined from calibrated Weissenberg photographs: *a* 7.123, *b* 10.469, *c* 6.844 Å, α 100°34′, β 94°48′, γ 91°16′, $a:b:c = 0.6804:1:0.6537$, space group probably $P\bar{1}$, Z = 2. Partly indexed powder patterns are listed both for natural and synthetic hallimondite. Strongest lines (natural): 4.42(6), 3.42(10), 3.03(6), 2.85 Å (8). The formula $Pb_2(UO_2)(AsO_4)_2$ was derived from synthetic material. For natural material the results of microchemical and spectrochemical analyses are given. The DTA curve of synthetic hallimondite shows a distinct endothermic effect at 940° C.

Hallimondite is the arsenate analogue of the lead uranyl phosphate mineral parsonsite.

INTRODUCTION

The new species described herein was discovered among the secondary minerals of the Michael Mine which in olden times exploited a lead-zinc vein near Reichenbach in the Black Forest (east of Lahr). The author has already given a short preliminary description of the new mineral in an article dealing with the secondary mineral paragenesis of this vein (Walenta, 1961). In addition to hallimondite a number of other uncommon secondary minerals occur at this locality: hügelite (arsenate analogue of the lead uranyl phosphate dumontite), widenmannite (lead uranyl carbonate), weilerite (member of the beudantite-crandallite series with barium and aluminum as cations) and a new as yet unnamed lead-zinc arsenate. The name hallimondite is for Dr. Arthur F. Hallimond, London, to whom we owe major contributions to the knowledge of secondary uranium minerals.[1]

The discovery of hallimondite was made by the author in the course of a new investigation of the mineral hügelite. Small yellow crystals associated with hügelite could not be identified with any known mineral and proved to be a distinct species. The hallimondite-bearing specimens of hügelite were found by Goldbach, a mineral collector, before the first world war. On the original label the locality is given as Reichenbach near Lahr. The mineral association proves that the samples originated from the Michael Mine. Attempts to find new samples of hallimondite in the area of the Michael Mine in recent years were unsuccessful.

The author thanks the Deutsche Forschungsgemeinschaft for supporting this study. Thanks are also due to Professor Dr. Weil, University of Strasbourg, who procured the original specimens of hügelite.

MODE OF OCCURRENCE

Hallimondite is found as small crystals and fine-grained coatings in cavities and fractures of quartz. The quartz is gray and white in color and more or less dense ("hornstone"). It contains inclusions of barite and galena. Hügelite and mimetite are associated with hallimondite. Earthy mimetite in places coats hallimondite aggregates, thus proving that hallimondite is older. On the other hand hallimondite evidently was formed later than hügelite, for in one specimen crystals of hallimondite were found as an incrustation on hügelite (Fig. 2).

In some cases oriented intergrowths were observed between hallimondite and hügelite. Intergrown crystals of the two minerals have the *c*-axis in common.

The formation of hallimondite and hügelite is due to the action of arseniferous and uraniferous waters on galena. The arsenic acid has been derived by oxidation of native arsenic which is rather abundant in the Michael vein. The source of uranium is not exactly known, as no primary uranium minerals occur in the vein. Probably the uranium has been derived from the wall rock (Walenta and Wimmenauer, 1961).

CRYSTALLOGRAPHY

Crystals of hallimondite, though small, are usually well-developed. Their length does not exceed 0.4 mm. They are flattened on {110} and {100} and more or less elongated along the *c*-axis. Some crystals are double-terminated; generally, however, they are attached by one end of the *c*-axis. Observed forms are: a {100}, b {010}, c {001}, m {110},

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[1] The name hallimondite has been approved by the Commission on New Minerals and Mineral Names, I.M.A.

Table 1. Angle Table for Hallimondite

Triclinic

$a:b:c=0.6804:1:0.6537$; α 100°34′, β 94°48′, γ 91°16′
$p_0:q_0:r_0=0.9448:0.6516:1$; λ 79°17′, μ 84°53′, ν 87°48′
p'_0 0.9650, q'_0 0.6655; x'_0 0.0839, y'_0 0.1899

Forms	ϕ	ρ	A	B	C
c 001	23°49′	11°44′	84°53′	79°17′	—
b 010	0°00′	90°00′	87°48′	—	79°17′
a 100	87°48′	90°00′	—	87°48′	84°53′
m 110	53°56′	90°00′	33°52′	53°56′	79°52
n 610	81°17′	90°00′	6°31′	81°17′	83°43′
k 011	5°36′	40°41′	84°56′	49°32′	29°45′
q 018	17° 4′	15°57′	84°48′	74°46′	4°31′
p 111	49°35′	54° 1′	50°32′	58°22′	43°39′

n {610}, k {011}, q {018} and p {111} (Table 1 and Fig. 5). Figures 1 to 4 show the characteristic habit and form development of the crystals.

The largest faces are {110} and {100}. {010} and the six-sided base {001} are of medium size, {011} and {111} are small. The base is striated parallel to the intersection with {010}. This striation is caused by the development of narrow vicinal faces—according to angle measurement under the microscope {018}—which alternate with sections of {001} (oscillating faces). A similar striation can be observed on {100} parallel the *c*-axis. As in case of the base it is due to the development of oscillating

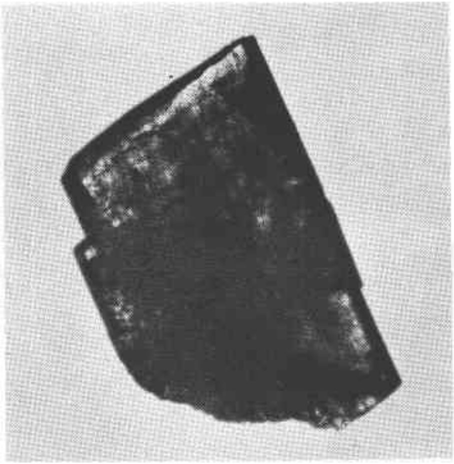

Fig. 1. Hallimondite crystal of typical habit embedded in xylene. Michael Mine. Magnification about 135×.

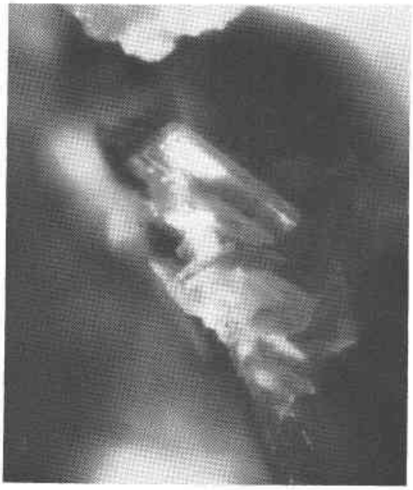

FIG. 2. Hallimondite crystals on hügelite. Michael Mine. Magnification about 60×.

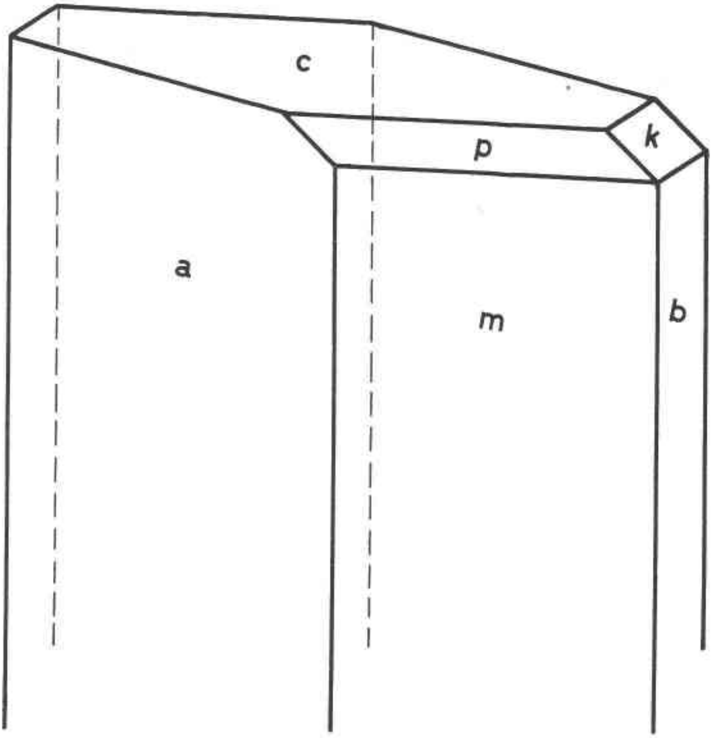

FIG. 3. Morphological development of hallimondite crystal, slightly idealized. Combination a {100}, b {010}, c {001}, m {110}, k {011}, p {111}.

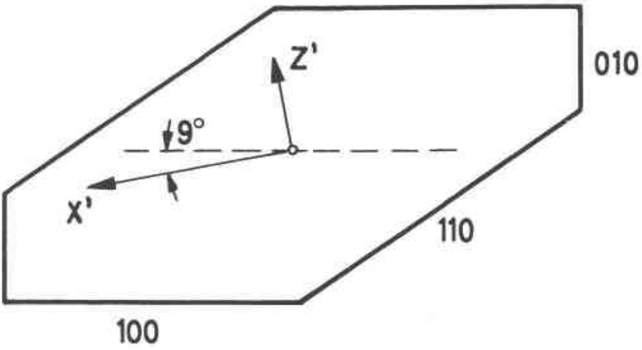

FIG. 4. Basal section of hallimondite crystal (with optical orientation).

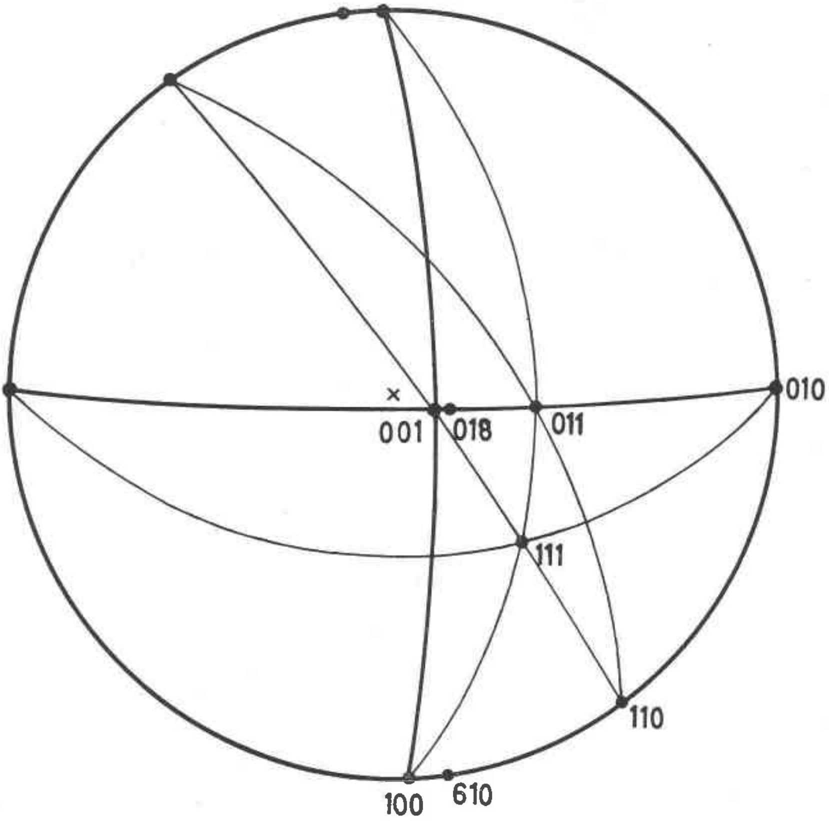

FIG. 5. Hallimondite. Stereogram.

vicinal faces. Angle measurements—giving angle values of about 6° between the vicinal faces and {100}—prove the faces to be {610}.

The angles given in Table 1 are not based on direct angle measurements, but on the more accurate results of the *x*-ray study. Direct measurements carried out by means of a two-circle reflecting goniometer and also under the microscope with the aid of the universal stage were not always satisfactory in view of the smallness of the faces. Their accuracy, however, was sufficient for identification of the faces, even of the small vicinal faces mentioned above.

Direct angle measurements were also used for a first preliminary calculation of axial ratios. The axial ratio b:c=1:0.6552 derived from these measurements agrees well with that obtained by the *x*-ray study (1:0.6537). In case of the a:b-ratio, however, the agreement was less satisfactory.

PHYSICAL AND OPTICAL PROPERTIES

Crystals of hallimondite do not show any distinct cleavage. The fracture is conchoidal. The color is yellow, markedly different from the more orange and brownish yellow color of hügelite. The streak is pale yellow. The luster of the transparent to translucent crystals is subadamantine. The hardness is low and probably identical with that of parsonsite ($2\frac{1}{2}$–3). The specific gravity of natural crystals could not be determined with accuracy because of the small amount of material available for study. The measured specific gravity of synthetic crystals is 6.39, which agrees well with the calculated value of 6.40. Hallimondite does not show any fluorescence in short-wave or long-wave ultra-violet light.

Optical data are:

α 1.882 ± 0.005
γ 1.915 ± 0.005
biaxial positive, 2V large (near 80°), $r > v$
Extinction angles: on (100) $Z' \wedge c$ 11°
(010) $X' \wedge c$ 11°
(001) $X' \wedge b$ 9°

Crystals of hallimondite appear pale yellow under the microscope. They show a weak pleochroism: X pale yellow, Z nearly colorless (absorption $X > Z$). Owing to the dispersion, extinction is not sharp when nicols are crossed and anomalous blue and brown interference colors can be observed. The values of the extinction angles show that the optic plane is closest to the {001} plane (Figs. 4, 6). These values, however, are not wholly uniform. Sometimes substantial variations in extinction angles can be observed even within an individual crystal.

X-RAY DATA

The unit-cell dimensions of hallimondite were derived from calibrated Weissenberg photographs taken about the three axes a, b and c. Potassium chloride and in one case copper were used as internal standards (a KCl 6.2929$_4$ Å, Hambling, 1953; a Cu 3.6153 Å, Barett, 1953). In the following table the results of the single crystal x-ray study are summarized. Limits of error are assumed to be 0.15% for the unit-cell edges and 10′ for the unit-cell angles.

direct lattice	a 7.123, b 10.469, c 6.844 Å α 100°34′ β 94°48′, γ 91°16′ $a:b:c = 0.6804:1:0.6537$
reciprocal lattice	a^* 0.1410, b^* 0.0972, c^* 0.1492 Å^{-1} α^* 79°17′, β^* 84°53′, γ^* 87°48′

The unit lengths were taken in the order $c < a < b$ according to the rule now generally adopted. This choice makes c the repeat distance along the marked prismatic zone. The form development of the crystals implies that they have a center of symmetry. Therefore, it is assumed that the space group is $P\bar{1}$.

Calculation of the specific gravity from above data (giving a cell volume of 499.6 Å^3) and the formula $Pb_2(UO_2)_2(AsO_4)_2$ with $Z = 2$ yields a value of 6.40.

Table 2 gives x-ray powder data both for natural and synthetic hallimondite (d-spacings in Å with estimated intensities from $\frac{1}{2}$ to 10). The photographs were taken with FeKα radiation and Mn filter using a camera of 57.3 mm in diameter. The d-spacings are corrected for film shrinkage. In addition the Hadding correction was applied to compensate for sample thickness.

The powder patterns of natural and synthetic hallimondite are nearly identical. The powder photograph of synthetic hallimondite, however, is somewhat sharper and contains more measurable lines. If the powder data are compared closely, also some small differences in d-spacings can be observed. Generally, the d-spacing of natural hallimondite are slightly larger. Though the differences are at least in part within error limits of line measurement, their general tendency may be real.

The calculated d-spacings with indices given in Table 2 are derived from the unit-cell dimensions of natural hallimondite determined by the Weissenberg method. The calculated values agree closely with the measured d-spacings.

TABLE 2. *X*-RAY POWDER DATA FOR NATURAL AND SYNTHETIC HALLIMONDITE

Hallimondite Michael Mine				Hallimondite synthetic	
d (observed)	I	d (calculated)[1]	hkl	d (observed)	I
10.24	2	10.284	010	10.43	2
7.09	3	7.092	100	7.09	1
6.19	2	6.163	$01\bar{1}$	6.19	3 diff.
5.93	1	5.946	$1\bar{1}0$	5.93	3 diff.
5.13	1	5.190; 5.142; 5.103	$011; 020; 10\bar{1}$	5.13	1 diff.
4.83	1/2	4.794	$11\bar{1}$	4.85	1/2
4.42	6	4.377	$\bar{1}11$	4.41	5
4.26	5	4.241	$1\bar{2}0$	4.24	4
4.09	1/2	4.089	120	4.07	2
3.76	1/2	3.757; 3.756	$1\bar{2}1; 021$	3.73	1
3.42	10 diff.	3.432; 3.428; 3.393	$\bar{1}21; 030; 2\bar{1}0$	3.40	10
3.33	5 diff.	3.351; 3.313; 3.312	$002; 210; 03\bar{1}$	3.30	3
3.22	3	3.217	121	3.21	3
3.13	1/2	3.144; 3.140; 3.134	$11\bar{2}; 10\bar{2}; 1\bar{3}0$	3.13	2
3.08	1/2	3.082; 3.057	$02\bar{2}; \bar{2}11$	3.07	2
3.03	6	3.041; 3.025; 3.024; 3.009	$130; 201; 012; 13\bar{1}$	3.01	4
2.94	1/2	2.961; 2.930	$1\bar{1}2; 102$	2.93	1
2.85	8	2.868; 2.845	220; 031	2.84	9
2.73	1	2.751; 2.706	$2\bar{2}1; \bar{1}31$	2.71	2
2.66	1	2.656	$03\bar{2}$	2.64	1
2.60	2	2.595; 2.579	022; 131	2.58	2
2.54	1	2.552; 2.545; 2.521	$20\bar{2}; 21\bar{2}; 13\bar{2}$	2.54	1/2
2.35	2	2.364; 2.356	$300.\ 2\bar{1}2$	2.35	2
		2.323; 2.299	$3\bar{1}0; \bar{2}31$	2.31	2
2.26	1	2.272; 2.264; 2.261; 2.252; 2.252	$01\bar{3}; 041; 2\bar{2}2; 31\bar{1}; 04\bar{2}$	2.26	2
2.20	1/2	2.204; 2.203; 2.200; 2.198; 2.189; 2.187	$02\bar{3}; 212; 032; \bar{1}41; \bar{2}22; 10\bar{3}$	2.20	1
2.15	3	2.165; 2.163; 2.153; 2.149; 2.147	$3\bar{1}1; 14\bar{2}; \bar{1}32; 12\bar{3}; 231$	2.14	4
2.09	1	2.103; 2.085; 2.083; 2.083; 2.078; 2.078; 2.075	$013; 2\bar{3}2; 311; 2\bar{4}1; 103.\ 05\bar{1}; \bar{3}21$	2.08	1
2.03	1/2	2.045; 2.018	$240; 30\bar{2}$	2.03	1
1.966	2			1.970	2 diff.
1.916	1/2			1.910	1/2
1.893	2			1.887	4
1.866	1/2			1.862	1
				1.840	1
1.818	1/2			1.812	1
1.740	3			1.736	6 diff.
1.725	1				
1.698	3			1.696	5
				1.677	1
1.650	1/2			1.656	1
				1.641	1
				1.620	1
1.587	1			1.585	2 diff.
1.539	1			1.540	2
1.499	1/2			1.496	2
				1.467	1/2
				1.456	1/2
				1.447	1/2

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[1] d-spacings are calculated from unit-cell data.

Table 2—(*continued*)

Hallimondite Michael Mine				Hallimondite synthetic	
d (observed)	I	d (calculated)$_1$	hkl	d (observed)	I
				1.430	1/2
				1.408	1
				1.393	1
				1.375	2
				1.359	1
				1.342	1
1.316	1/2 diff.			1.315	3
				1.303	1 diff.
				1.282	1 diff.
				1.271	1/2 diff.
				1.254	2 diff.
				1.240	1/2 diff.
				1.220	2 diff.
				1.204	3 diff.
1.196	1/2 diff.			1.188	1
				1.181	1
1.176	1/2 diff.			1.174	1
				1.162	3
				1.145	1/2 diff.
				1.133	2
				1.121	2
				1.112	1 diff.
				1.106	1/2
				1.099	2
				1.075	1 diff.
				1.066	1
				1.050	1/2
				1.043	1/2
				1.036	1
				1.033	2
				1.028	2
				1.024	2
				1.017	1
				1.014	2
				1.009	3
				1.006	2
				1.003	1/2
				0.994	1 diff.
				0.988	6
				0.985	1
				0.981	1/2
				0.979	2

CHEMICAL COMPOSITION

The mineral is easily soluble in HNO_3 1:1. A microchemical analysis gave Pb, U and As as major constituents. The spectrographic analysis of a hallimondite sample somewhat contaminated with quartz, which kindly was carried out by Dr. Pfeilsticker, Chemisches Untersuchungsamt der Stadt Stuttgart, confirmed the above result. P could not be detected with certainty, if present it occurs only in trace amounts. In addition to the major constituents the spectrographic analysis indicated the presence of Ba, Si, Fe, Cu, Ca and Sr in small amounts or traces. Though, in view of the presence of impurities, it cannot be said with certainty whether all of these elements are constituents of hallimondite, it is probable that at least part of the detected bivalent cations are incorporated in the hallimondite structure where they substitute for Pb^{++}. Due to the small amount of material available for study a quantitative chemical analysis could not be made.

SYNTHESIS

Hallimondite was synthesized by reacting solutions of lead acetate or nitrate, uranyl nitrate, and arsenic acid and then heating the precipitate, either in contact with the mother liquid or with pure water, in pressure vessels at temperatures ranging from 150° to 180° C. Arsenic acid was used in equivalent amounts or in excess. Under these conditions precipitation took place in the acid range (pH 2–5).

The procedure did not always give an entirely pure product. Frequently, in addition to hallimondite, lead uranospinite formed in square or rectangular tabular crystals. Increasing the amount of arsenic acid reduced or suppressed the formation of this compound. However, if arsenic acid was present in considerable excess, another byproduct, the acid lead arsenate, schultenite ($PbHAsO_4$), formed in thin tabular crystals. On the other hand, hügelite was sometimes obtained as byproduct if the amount of arsenic acid was reduced and precipitation took place at about pH 5. The best results were achieved taking a lead acetate: uranyl nitrate: arsenic acid (AsO_4) molar ratio of 2:1:4 (or 5) and not of 2:1:2 as demanded by the formula. Ross (1956) who prepared parsonsite, the phosphate analogue of hallimondite, states that this phase, too, forms in the acid range (pH 2–6).

Synthetic hallimondite obtained by the above method forms tabular crystals of yellow color which in some cases almost reach the size of natural crystals. The largest crystal observed had a length of about 0.3 mm. The crystals resemble natural ones in habit (Fig. 7). Closer inspection, however, reveals that at least part of the crystals, unlike natural ones, are flattened on $\{010\}$ and elongated along the *a*-axis. One crystal, investigated on the universal stage under the microscope, showed in the marked prismatic zone of the *a*-axis in addition to $\{010\}$, $\{011\}$ and $\{001\}$ a number of faces, *i.e.* $\{0\bar{1}1\}$, $\{0\bar{4}3\}$ and $\{0\bar{2}1\}$, not observed among the forms of natural crystals. $\{0\bar{4}3\}$ is exceedingly narrow. $\{0\bar{2}1\}$ and $\{011\}$ also are very narrow, whereas $\{0\bar{1}1\}$ and $\{001\}$ are somewhat larger.

The specific gravity of synthetic hallimondite was determined by means of a pycnometer. The measured value of 6.39 agrees closely with that calculated from *x*-ray data (Table 2). The optical properties of synthetic crystals have also been checked. They were found not to be entirely identical with those of natural ones. Whereas the α value of synthetic crystals (1.880±0.005) is virtually the same as that of natural hallimondite (1.882±0.005), the value of γ is markedly greater (1.939±0.005) as compared to 1.915±0.005 for the natural mineral). This means that the birefringence of the synthetic compound considerably surpasses that of natural crystals. Also the pleochroism of synthetic crystals seems to be somewhat more distinct than that of natural ones.

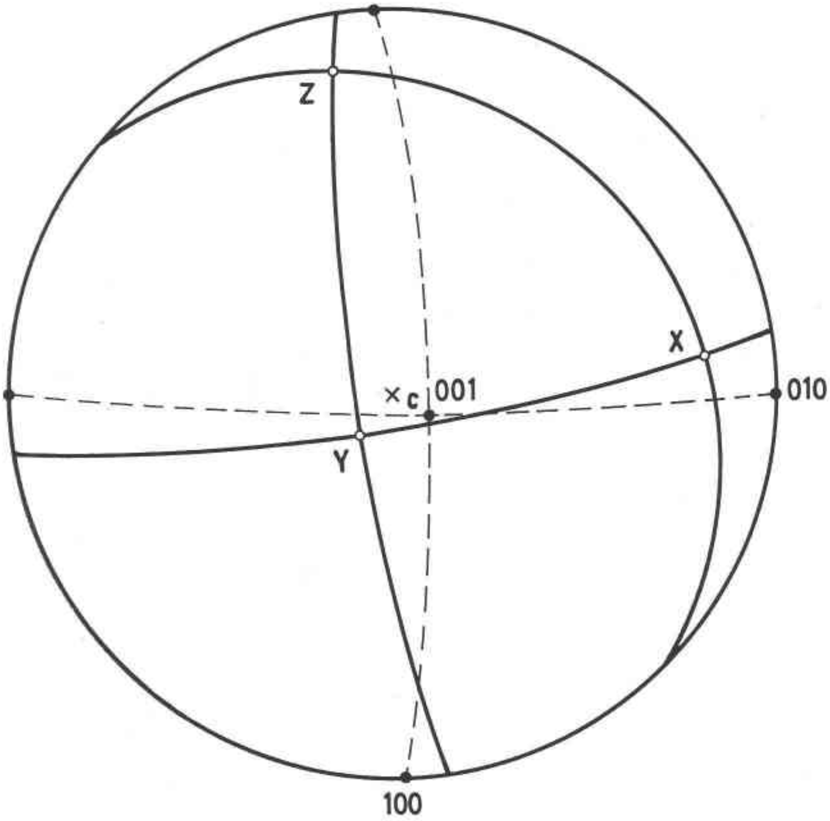

Fig. 6. Hallimondite. Stereogram showing optical orientation.

The exact cause of the difference in optical behavior of synthetic and natural hallimondite crystals is not known, but there is a possible explanation for it. Natural hallimondite, though a secondary mineral, probably is not of very recent formation. The radioactivity of uranium and its decay products, therefore, may have caused lattice disorders in natural hallimondite crystals and reduced their birefringence in the course of time.

Radiation damage in natural hallimondite crystals may also explain the observation that the powder pattern of natural hallimondite is poorer in quality than that of the synthetic compound. It is possible that they also caused the small differences in d-spacings of natural and synthetic hallimondite. The general tendency of the differences implies that the unit cell of natural hallimondite is slightly larger than that of the synthetic product as is to be expected if the natural mineral had been exposed to radioactivity for a long period. On the other hand small differences in unit-cell dimensions might also be due to isomorphous substitution. Among the elements detected by spectrographic analysis as possible minor constituents of natural hallimondite, Ba has a larger ionic radius than Pb. Hence partial substitution of Ba for Pb in hallimondite would lead to a somewhat larger unit cell. The question of Ba-Pb substitution in hallimondite was also experimentally investigated. Attempts were made to synthesize a pure barium hallimondite by the method used for the synthesis of the lead compound. These attempts, however, failed. In all cases the product obtained was $Ba(UO_2)_2(AsO_4)_2 \cdot nH_2O$ (heinrichite) and not the barium analogue of hallimondite. Evidently, a pure barium analogue does not exist and if there is any substitution of Ba for Pb in hallimondite, the extent of it is limited.

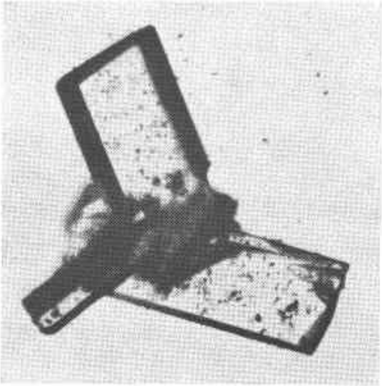

FIG. 7. Intergrown crystals of synthetic hallimondite embedded in Canada balsam. Magnification about 150×.

Below the results of a chemical analysis of synthetic hallimondite are cited (1). The analysis was carried out by the Laboratory Dr. Fresenius, Wiesbaden (Fresenius and Schneider analysts). The second column (2) gives the theoretical weight percentages for the composition $Pb_2(UO_2)(AsO_4)_2$.

	(1)	(2)
PbO	45.9%	46.39%
UO_3	28.1%	29.73%
As_2O_5	26.5%	23.88%
total	100.5%	

Weight loss determinations after heating a sample of synthetic hallimondite at different temperatures (up to 600° C.) showed that the compound does not contain an appreciable amount of water.

Though there is no ideal agreement between the results of the analysis and the theoretical composition for $Pb_2(UO_2)(AsO_4)_2$, the deviations are not great enough to warrant a modification of the formula. The PbO-value fits rather well the theoretical weight percentage for PbO, whereas in case of UO_3 and As_2O_5 the differences are somewhat greater.

THERMAL BEHAVIOR OF SYNTHETIC HALLIMONDITE

Synthetic hallimondite becomes orange to brownish yellow when strongly heated. Upon cooling it regains the original yellow color. The optical properties are not influenced by strong heating. One sample heated to redness for about 15 minutes did not show any noticeable change in optical behavior when investigated upon cooling.

The DTA curve of synthetic hallimondite heated to about 1000° C. shows an endothermic effect at a temperature of about 940° C. A powder photograph taken of the sample after heating does not show any fundamental changes in comparison to the pattern of unheated hallimondite. The heated sample had turned into a compact mass and when investigated under the microscope crystal forms could no longer be observed among the fine-grained aggregates. Evidently, the registered endothermic effect is due to fusion of the substance. The heating experiments prove, the same as the results of the weight loss determinations, that hallimondite does not contain any water of crystallization.

It may be mentioned that the optical properties of strongly heated natural hallimondite crystals were also checked and found to be the same as those of unheated crystals.

COMPARISON OF HALLIMONDITE AND PARSONSITE

In Table 3 some properties of hallimondite and parsonsite are compared. The symmetry of parsonsite was assumed to be monoclinic until now, although Frondel (1958, p. 233) states that the possibility of triclinic symmetry cannot be ruled out. In view of the established triclinic symmetry of hallimondite, there can be hardly any doubt that parsonsite also is triclinic. The formula of parsonsite was determined by Bignand (1955) to be $Pb_2(UO_2)(PO_4)_2$ in agreement with the anhydrous nature of hallimondite, and not as formerly assumed $Pb_2(UO_2)(PO_4)_2 \cdot 2H_2O$.

The data show that the indices of refraction and the specific gravity of parsonsite are smaller than those of hallimondite as is to be expected if P substitutes for As. The ionic radius of P^{5+} being smaller than that of As^{5+}, it is also to be expected that the unit-cell edges of parsonsite will be smaller than those of hallimondite. Though the data for parsonsite determined by Frondel are incomplete, a comparison of the d-spacings 100 and 010 as well as the *c*-values shows that this is indeed the case. It may be inferred from the values that the differences in unit-cell edges are greatest in the direction of the *a*-axis.

TABLE 3. COMPARISON OF DATA FOR HALLIMONDITE AND PARSONSITE

Hallimondite (natural) $Pb_2(UO_2)(AsO_4)_2$	Parsonsite[1] $Pb_2(UO_2)(PO_4)_2$
Triclinic	Monoclinic or triclinic
a 7.123 Å — d_{100} 7.092 Å	d_{100} 6.77 Å
b 10.469 Å — d_{010} 10.284 Å	d_{010} 10.21 Å
c 6.844 Å — d_{001} 6.701 Å	*c* 6.8 Å
α 100°34′, β 94°48′, γ 91°16′	
α 1.882	α 1.85 (1.795–1.870)
γ 1.915	γ 1.86 (1.815–1.890)
Biaxial positive	Biaxial negative
G 6.40 (calc.)	G 5.71–5.75

[1] Data for parsonite according to Frondel (1950, 1958), Bignand (1955), Chervet and Branche (1955).

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