2. See Teeple, *Industrial Devel. of Searles Lake Brines, Am. Chem. Soc. Monog.*, no. 49, New York (1929).
3. Burke, *J. Ind. Eng. Chem.*, **13**, 249 (1921).
4. Schroeder, Berk, Partridge, and Gabriel, *J. Am. Chem. Soc.*, **58**, 846 (1936); Kracek and Ksanda, *J. Phys. Chem.*, **34**, 1741 (1930).

UNNAMED MINERAL. *Schaller* (*Am. Min.*, **25**, 213, 1940).
A scaly white mineral resembling alunogen in appearance and properties, found with halotrichite, siderotil, and szomolnokite in the Tintic Standard mine, Dividend, Utah. Soluble in cold water. Does not lose H_2O on heating at 105°. Composition said to be $2Al_2O_3 \cdot 4SO_3 \cdot P_2O_5 \cdot 24H_2O$.

Habit. Thick tabular {001}.

Twinning. Pseudo-hexagonal twins on {110} analogous to aragonite have been observed on both natural[3] and artificial crystals.

Phys. Cleavage {001} and {010} distinct. G. 2.74 (artif.);[4] 2.735 (calc.). Transparent. Color bright canary-yellow.

Opt.[5]

ORIENTATION		n	
X	b	1.687	Biaxial negative (−).
Y	a	1.722	$2V$ 52°.
Z	c	1.731	$r > v$, weak.

Chem. Potassium chromate, K_2CrO_4. Complete analyses are lacking.[6]

Tests. Easily soluble in water.

Occur. From nitrate deposits in the Tocopilla pampa associated with lopezite and dietzeite, and from other nitrate deposits, especially in the so-called *caliche azufrado*, in Atacama, Tarapacá, and Antofagasta provinces, Chile.

Artif. A well-known artificial product, easily obtained in crystals from water solution.

Name. From the locality in Tarapacá province, Chile.

Ref.

1. Mitscherlich, *Ann. Phys.*, **18**, 169 (1830), quoted in Brendler, *Zs. Kr.*, **58**, 445 (1923). Forms also noted in Brendler.
2. Zachariasen and Ziegler, *Zs. Kr.*, **80**, 164 (1931), by Laue and oscillation methods on artificial crystals.
3. Brendler (1923).
4. Gossner, *Zs. Kr.*, **39**, 166 (1904), on artificial crystals by the suspension method.
5. Larsen and Berman (192, 1934) on artificial crystals.
6. The natural material was proved by Brendler (1923) by chemical tests and morphology to be identical with the artificial salt.

TYPE 2. $A_2(X_2O_7)$

35.2.1 **LOPEZITE** [$K_2(Cr_2O_7)$]. *Bandy* (*Am. Min.*, **22**, 929, 1937).

Cryst.[1] Morphological data are lacking for the natural material. Artificial crystals are triclinic; pinacoidal—$\bar{1}$.

$$a:b:c = 0.5575:1:0.5511; \qquad \alpha\ 98°00', \beta\ 90°51', \gamma\ 96°13'$$

$$p_0:q_0:r_0 = 0.9847:0.5543:1; \qquad \lambda\ 81°51\tfrac{1}{2}', \mu\ 88°15\tfrac{1}{2}', \nu\ 83°36'$$

$$p_0'\ 0.9948,\ q_0'\ 0.5600,\ x_0'\ 0.0148,\ y_0'\ 0.1431$$

Common forms:	Less common:	Rare or uncertain:			
c 001	m 110	ν 150	v 041	w $0\bar{5}2$	o $1\bar{1}1$
b 010	M $1\bar{1}0$	x $2\bar{1}0$	κ $0\bar{1}2$	r 101	π $\bar{1}11$
a 100	t 011	l 021	k $0\bar{2}1$	ρ $\bar{1}01$	ω $\bar{1}\bar{1}1$
q $0\bar{1}1$					

often arranged in interpenetrating groups; usually flattened {010} with a rhombohedral outline.

Phys. Indistinctly cleavable in three directions.[4] Fracture uneven. Brittle. H. $3\frac{1}{2}$. G. 2.929 (artif.).[3] Luster vitreous. Color pale yellowish white; the pure artificial salt is white. Translucent.

Opt. In transmitted light, colorless.

	n(Na)[5]	
X	1.587	Biaxial positive (+).
Y	~1.615	$2V$ large.
Z	1.640	$r > v$, weak.

In {010} sections an extinction direction makes an angle of 23° with the edge with {$10\bar{1}$}, and in {001} sections, an angle of 30° with the edge with {010}.

Chem. Calcium acid phosphate, $CaH(PO_4)$. CaO 41.21, P_2O_5 52.18, H_2O 6.61, total 100.00. Analyses of pure natural material are lacking.[6]

Occur. From the Islands of Moneta and Mona, in the Caribbean Sea about 40 miles from the port of Mayaguez, Puerto Rico. The mineral occurs with gypsum in a phosphate-rock deposit in limestone underlying a bed of bird guano. Also found with whitlockite on Los Monges Islands in the Caribbean Sea off the Gulf of Maracaibo, Venezuela (*glaubapatite* pt.) [7] and with apatite and newberyite on Ascension Island in the South Atlantic. In a cave deposit of phosphates at Gunong Jerneh, Malaya.

Alter. Finely divided monetite takes up water from the atmosphere and forms brushite.

Artif.[8] Obtained in crystals by heating precipitated $CaHPO_4 \cdot 2H_2O$ with water in a closed tube at 150°, by slow inter-diffusion of Na_2HPO_4 and $CaCl_2$ solutions and in numerous other ways.

Name. From the locality.

Ref.

1. Angles and unit of de Schulten, *Bull. soc. min.*, **27**, 120 (1904), on artificial crystals. Transformation: de Schulten to new orientation, 001/010/$\bar{1}$00.
2. de Schulten (1904).
3. de Schulten, *Bull. soc. min.*, **24**, 332 (1901).
4. Larsen and Berman (111, 1934); Dana in Shepard (1882) mentions only an apparent cleavage {001}.
5. Hill and Hendricks, *Ind. Eng. Chem.*, **38**, 440 (1936).
6. Analyses of mixtures with gypsum are cited by Shepard (1882) and Willbourn, *J. Malayan Branch Roy. Asiatic Soc.*, **3**, Pt. 3, 57 (1925).
7. Shown to be identical with monetite by Frondel, *Am. Min.*, **28**, 215 (1943).
8. Mellor (**3**, 881, 1923); de Schulten, *Bull. soc. min.*, **24**, 323 (1901), **26**, 15 (1903); Hill and Hendricks (1936).

37.1.2 **SCHULTENITE.** [$PbH(AsO_4)$]. *Spencer* (*Min. Mag.*, **21**, 149, 1926).

Cryst.[1] Monoclinic; prismatic—$2/m$.

$a:b:c = 0.8649:1:0.7201$; $\beta\ 95°23\frac{1}{2}'$; $p_0:q_0:r_0 = 0.8326:0.7169:1$

$r_2:p_2:q_2 = 1.3949:1.1614:1$; $\mu\ 84°36\frac{1}{2}'$; $p_0'\ 0.8363$, $q_0'\ 0.7201$, $x_0'\ 0.0944$

77 AB_3X_7 TYPE

7711	Coronadite	$MnPbMn_6O_{14}$
7712	Hollandite	$MnBaMn_6O_{14}$
7713	Cesarolite	$PbMn_3O_7 \cdot H_2O$

Ref.

1. See Evans (203, 1939).
2. Dana (1892).

711 **DELAFOSSITE** [$CuFeO_2$]. *Friedel* (*C. R.*, 77, 211, 1873).

Cryst. Hexagonal — *R*; scalenohedral — $\bar{3}\ 2/m$.[1]

$$a : c = 1 : 1.945;^2 \qquad p_0 : r_0 = 2.246 : 1$$

Forms:[3]

		ϕ	ρ	M	A_2
c 0001	111	.....	0°00′	90°00′	90°00′
m $10\bar{1}0$	$2\bar{1}\bar{1}$	30°00′	90 00	60 00	90 00
r $10\bar{1}1$	100	30 00	66 00	62 49½	90 00

Structure cell.[4] Space group $R\bar{3}m$; a_{rh} 5.96, α 29°26′; a_0 3.02, c_0 17.10; $a_0 : c_0 = 1 : 5.66$; contains $CuFeO_2$ in the rhombohedral unit.

Habit. Crystals tabular {0001} to equant, with {0001} and {$10\bar{1}1$} as dominant forms. As botryoidal crusts.

Twinning. Contact twins on {0001} have been observed.[3]

Phys. Cleavage {$10\bar{1}0$} imperfect.[5] Brittle. H. 5½.[6] G. 5.41;[7] 5.52 (calc. for artificial material). Luster metallic. Color and streak black. Opaque. Weakly magnetic. In polished section[8] rose brown-white in color, with strong anisotropism. Pleochroism distinct: *O* light golden brown, *E* darker rose-brown.

Chem. Copper iron oxide, $CuFeO_2$.

Anal.

	1	2	3	4
Cu	41.99	42.14	41.32	40.68
Fe	36.88	33.56	37.26	37.91
O	21.13	[19.74]	[21.21]	[21.41]
Rem.	.....	3.52	0.21	......
Total	100.00	98.96	100.00	100.00
G.	5.52	5.07		

1. $CuFeO_2$. 2. Ekaterinburg, Siberia. Rem. is Al_2O_3 3.52.[9] 3. Bisbee, Ariz. Rem. is insol. 0.21 (hematite). Average of two analyses.[10] 4. Salmon, Id. Recalc. to elements from oxide values. Original analyses recalc. to 100.00 after deduction of insol. 30.94 and sol. SiO_2 0.70.[11]

Tests. Easily fusible. Becomes magnetic on heating. Readily soluble in HCl and H_2SO_4, but insoluble in HNO_3.

Occur. Originally found on clay from the region of Ekaterinburg, Siberia. Reported as a secondary mineral from the Copreasa mine, Sonoripa district, Sonora, Mexico; from the Cartagenera mine, near Pedroso, Sevilla, Spain; from Pfaffenreuth, Oberpfalz, Germany. In the United States in large amounts at Bisbee, Arizona, as crystals and as botryoidal

Occur. Found with montgomeryite, wardite, millisite, and crandallite in variscite nodules at Fairfield, Utah County, Utah.

Name. After George L. English (1864–1944), American mineral dealer and collector.

Ref.

1. From x-ray Laue photograph of a cleavage flake by Larsen, *Am. Min.*, **27**, 296 (1942).
2. Shannon analysis in Larsen and Shannon (1930).

TYPE 7. $A_3(XO_4)_2Z_q \cdot xH_2O$

42.7.1 **LEGRANDITE** [$Zn_{14}(OH)(AsO_4)_9 \cdot 12H_2O$]. *Drugman* and *Hey* (*Min. Mag.*, **23**, 175, 1932).

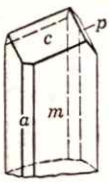
Cryst.[1] Monoclinic

$a{:}b{:}c = 1.6076{:}1{:}1.2886$; $\beta\ 104°25'$; $p_0{:}q_0{:}r_0 = 0.8016{:}1.2480{:}1$

$r_2{:}p_2{:}q_2 = 0.8013{:}0.6422{:}1$; $\mu\ 75°35'$; $p_0'\ 0.8276$, $q_0'\ 1.2886$, $x_0'\ 0.2571$

Forms:

	ϕ	ρ	ϕ_2	$\rho_2 = B$	C	A
c 001	0°00′	14°25′	75°35′	90°00′	.....	75°35′
a 100	90 00	90 00	0 00	90 00	75°35′	.....
m 110	32 43	90 00	0 00	32 43	82 17	57 17
p $\bar{1}11$	−23 53	35 38½	119 42½	41 47	61 25½	109 17



Structure cell.[2] a_0 12.70 kX, b_0 7.90, c_0 10.18; β 75°35′; $a_0{:}b_0{:}c_0 = 1.607{:}1{:}1.288$. Cell contents $Zn_{14}(OH)(AsO_4)_9 \cdot 12H_2O$.

Habit. Radiating aggregates of crystals prismatic [001].

Phys. Cleavage {100}, fair.[3] H. ~5[3]. G. 4.01 ± 0.05; 4.00 (calc.). Colorless to canary-yellow. Transparent.

Opt. In transmitted light, colorless to pale yellow.

ORIENTATION	n(Na)[4]	n[3]	PLEOCHROISM	
X b	1.675 ± 0.005	1.702	Colorless to yellow	Biaxial positive (+).
Y	1.690 ± 0.005	1.709	Colorless to yellow	$2V$ 36°±.
$Z \wedge c$ +36° to 40°	1.735 ± 0.005	1.741	Yellow	$r < v$, distinct.

Chem. A hydrated basic zinc arsenate, $Zn_{14}(OH)(AsO_4)_9 \cdot 12H_2O$.

Anal.

	1	2
ZnO	47.49	46.68
MnO		0.05
Fe_2O_3		2.14
As_2O_5	43.11	42.02
H_2O	9.40	9.36
Total	100.00	100.25
G.		4.01

1. $Zn_{14}(OH)(AsO_4)_9 \cdot 12H_2O$. 2. Lampazos, Mexico.[5] Total iron determined as Fe_2O_3.

Occur. Found with siderite, mimetite (?), and pyrite on massive sphalerite from the Flor de Peña mine, Lampazos, Nuevo Leon, Mexico.

Name. After Mr. Legrand, a Belgian mine manager, who collected the only known specimen.

Ref.

1. Only approximate morphological measurements could be obtained, owing to the poor quality of the crystals and the elements are here computed from the x-ray data.
2. Bannister in Drugman and Hey (1932).
3. Berman, priv. comm. (1933).
4. Drugman and Hey (1932).
5. Hey analysis in Drugman and Hey (1932).

42.7.2 **BERAUNITE** [$Fe''Fe_4'''(PO_4)_3(OH)_5 \cdot 3H_2O$ (?)]. *Breithaupt* (136, 1841; *B. H. Ztg.*, 402, 1853). Eleonorite *Nies* (*Ber. Oberhess. Ges.*, **19**, 111, 1880); *Streng* (*Jb. Min.*, I, 102, 1881). Dufreniberaunite *Wherry* (*Proc. U. S. Nat. Mus.*, **47**, 509, 1914).

Cryst.[1] Monoclinic.

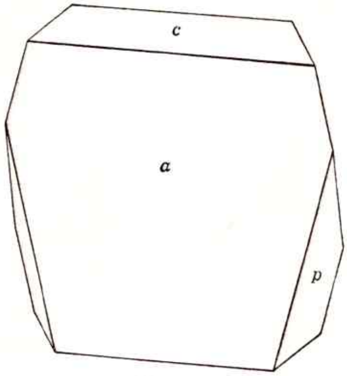
$a:b:c = 2.7550:1:4.0157$; $\beta\ 131°27'$; $p_0:q_0:r_0 = 1.4576:3.0099:1$

$r_2:p_2:q_2 = 0.3322:0.4843:1$; $\mu\ 48°33'$; $p_0'\ 1.9447, q_0'\ 4.0157, x_0'\ 0.8832$

Forms:

	ϕ	ρ	ϕ_2	$\rho_2 = B$	C	A
c 001	90°00′	41°27′	131°27′	90°00′	.....	48°33′
a 100	90 00	90 00	0 00	90 00	48°33′	.....
f 111	35 09	78 29½	19 28½	36 45½	58 28	55 39
p $\bar{1}$11	−14 48½	76 28	136 42½	19 57½	89 22½	104 23

Habit. Tabular {100} and more or less elongated [010]; {100} striated [010]. Crystals rare and small. Usually as radiated foliated globules and



Giessen.

crusts, or as radial-fibrous aggregates; as discoidal concretions with a coarse-fibrous structure.

Twinning. On {100}, sometimes as interpenetration twins.

Cleavage {010} distinct. Fracture conchoidal. Brittle. H. $3\frac{1}{2}$–4. G. 2.39. Luster vitreous to pearly. Color bright blue to blue-gray. Strongly pleochroic.

Chem. Apparently a hydrated silicate-phosphate of beryllium, aluminum, and calcium. An average of two microchemical analyses gave:[1] CaO 3.22, BeO 8.74, Fe_2O_3 0.29, Al_2O_3 21.35, P_2O_5 33.80, SiO_2 9.25, H_2O 23.45, total 100.10.

Tests. Decomposed by acids.

Occur. Found as a few small crystals in a quartz-wolframite vein in the Sadisdorf copper mine near Schmiedeberg, Saxony, Germany.

Name. After Friedrich Kolbeck (1860–1943), German mineralogist, of the Mining Academy at Freiberg.

Ref.

1. Thurnwald and Benedetti-Pichler, *Mikrochem.*, **11**, 200 (1932).

47 VANADIUM OXYSALTS

TYPE 1. MISCELLANEOUS

CARNOTITE AND TYUYAMUNITE

	a_0	b_0	c_0	β
Carnotite, $K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$	6.59 Å	8.40	10.43	104°12′
Tyuyamunite, $Ca(UO_2)_2(VO_4)_2 \cdot nH_2O$	19.41	8.26	10.40	90

Synthetic $K(UO_2)(VO_4)$ appears to be the anhydrous prototype of one of the several minerals at present included under the name carnotite. The synthetic compound has a layer structure[1] consisting of sheets of the composition $(UO_2VO_4)_n^-$ interlaminated parallel {001} with sheets of K ions. Linear uranyl ions, $(UO_2)^{++}$, are present as in autunite and all other known oxysalts containing U^6; in carnotite these are coordinated with (VO_4) groups. The layer structure offers an explanation of the ready base exchange and variable water content of carnotite. Tyuyamunite probably has a related layer structure with the metal-oxygen sheets bonded together by Ca ions; it may be likened to the brittle micas.

Ref.

1. Sundberg and Sillén, *Ark. Kemi*, **1,** no. 42, 337 (1949).

47.1.1 **CARNOTITE** $[K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O]$. *Friedel* and *Cumenge* (*C.R.*, **128,** 532, 1899; *Bull. soc. min.*, **22,** 26, 1899).

Orthorhombic or monoclinic? As a powder or loosely coherent microcrystalline aggregates, sometimes compact; disseminated; rarely as crusts of imperfect platy crystals flattened {001}. Microscopic crystals[1] are flattened {001} and rhomboidal {110}, also lath-like [010] with {100} and {110} or {120}; (110) ∧ (1$\bar{1}$0) ~78°.

Structure cell.[8] Artificial anhydrous $K(UO_2)(VO_4)$ is monoclinic with the space group $P2_1/c$. a_0 6.590Å, b_0 8.403, c_0 10.430; β 104°12′; $a_0:b_0:c_0 = 0.784:1:1.242$. Cell contents $K_4(UO_2)_4(VO_4)_4$. G. 5.03 (calc.). X-ray powder study indicates that this substance is isostructural with some natural (hydrated) material referred to carnotite.

Phys. Cleavage {001} perfect. Luster dull or earthy, also pearly or silky when coarsely crystalline. Color bright yellow to lemon-yellow, also greenish yellow.

Opt.

ORIENTATION	*n* (Long Park, Colorado)[2]	*n*(Na) (anal. 2)[3]	PLEOCHROISM	
X c	1.750		Nearly colorless	Biaxial negative (−).
Y b	1.925	2.06	Canary-yellow	
Z a	1.950	2.08	Canary-yellow	
$2V$	~40°	~50°		

The indices of refraction vary with the water content, increasing as the amount of water present decreases.

ium, and an unidentified hydrous silicate of vanadium, aluminum, and potassium.

Name. In allusion to its relation to hewettite.

Ref.

1. A partial study of the dehydration phenomena is given in the original paper.
2. Hillebrand analysis.

47.1.20 **FERNANDINITE** [$CaO \cdot V_2O_4 \cdot 5V_2O_5 \cdot 14H_2O$]. *Schaller* (*J. Washington Ac. Sc.*, **5**, 7, 1915; Dana, App. III, 29, 1915).

Massive, cryptocrystalline to fibrous; rarely in rectangular plates. Color dull green.

Opt. In transmitted light, light green to dark olive-green to brownish green and nearly opaque. Birefringence strong. Mean index of refraction [1] about 2.05. Not pleochroic.

Chem. A hydrated calcium vanadyl vanadate, probably $CaO \cdot V_2O_4 \cdot 5V_2O_5 \cdot 14H_2O$.

Anal.

	1	2
CaO	4.05	3.83
MoO_3		1.58
V_2O_4	11.99	11.63
V_2O_5	65.73	63.33
H_2O	18.23	18.07
Rem.		1.56
Total	100.00	100.00

1. $CaO \cdot V_2O_4 \cdot 5V_2O_5 \cdot 14H_2O$. 2. Minasragra. Rem. is K_2O 0.59, MgO 0.07, Fe_2O_3 0.90. Recalculated to 100 after deducting insol. 12.18 per cent.

Tests. Easily soluble in acids to a green solution; sufficiently soluble in cold water to give a yellow solution.

Occur. Found in the vanadium deposit at Minasragra, near Cerro de Pasco, Peru.

Name. After Eulagio E. Fernandini, a former owner of the deposit.

Ref.

1. Larsen (74, 1921).

Occur. Found in placer concentrates containing cassiterite and wolframite at Mt. Misobo, Kalima district, Maniema, Belgian Congo; also associated with ferberite in quartz veins. Also found at Ruanda, Kifuruwe region, in the Belgian Congo.

Alter. Apparently replaced by ferberite in the vein occurrences.

Name. After Raymond Anthoine, Belgian mining engineer.

Ref.

1. Gastelier analysis in Varlamoff (1947).
2. Analysis by Laboratoire de Panda (Congo Belge) in Varlamoff, who cites additional analyses.

PATERAITE. *Haidinger* (*Jb. Geol. Bundesanst.*, 7, 196, 1856). A supposed cobalt molybdate, found admixed with pyrite and bismuthinite in the Elias mine, Joachimsthal, Bohemia. Massive; color black, but probably due to sulfidic impurities. The only available analysis [1] is on very impure material. Easily fusible, and soluble in acids. Needs verification. Named after A. Patera, who first examined the mineral.

Ref.

1. Laube, *Jb. Geol. Bundesanst.*, 14, 303 (1864); also cited in Dana (991, 1892).

1 NATIVE ELEMENTS

11 METALS

111 GOLD GROUP

1111 Gold
1112 Maldonite
1113 Silver
1114 Copper
1115 Lead

---

112 Mercury
113 Moschellandsbergite
114 Gold amalgam
115 Potarite

---

116 PLATINUM GROUP

1161 Platinum
1162 Palladium
1163 Platiniridium
1164 Aurosmiridium

1165 Iridosmine
1166 Siserskite
1167 Allopalladium

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117 IRON GROUP AND METEORITES

1171 Iron
1172 Nickel-iron

1173 Cohenite
1174 Moissanite
1175 Osbornite
1176 Schreibersite
1177 Siderazot

---

118 Tantalum
119 Tin
11·10 Zinc

---

12 SEMI-METALS AND NON-METALS

121 ARSENIC GROUP

1211 Arsenic
1212 Arsenolamprite
1213 Allemontite
1214 Antimony
1215 Bismuth

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122 TELLURIUM GROUP

1221 Selenium
1222 Selen-tellurium
1223 Tellurium

123	SULFUR GROUP	
1231	Sulfur	
1232	β-Sulfur	
1233	γ-Sulfur	
124	CARBON GROUP	
1241	Diamond	
1242	Graphite	

111 GOLD GROUP

1111	Gold	Au
1112	Maldonite	Au_2Bi
1113	Silver	Ag
1114	Copper	Cu
1115	Lead	Pb

These native metals are isometric, hexoctahedral — $4/m\ \bar{3}\ 2/m$. They are alike in structure (copper type), the atoms lying at the points of a face-centered cubic lattice. This structure conforms to the space group $Fm3m$; the unit cell contains 4 atoms. The cubic cell edges for the pure metals compare as follows.

	Cu	Au	Ag	Pb
a_0	3.6077	4.0699	4.0772	4.9396

Although differing somewhat in crystal habit, all the members of the group show twinning on {111} and a strong tendency to form dendritic and arborescent crystal groups. They are also similar in their physical properties (hardness, malleability, ductility, and conductivity of heat and electricity.)

The variations in the compositions of the native metals correspond in a measure to the different degrees of mutual solubility of the end members in the artificial binary systems. Gold and silver are most nearly alike; they form a continuous series with a minimum cell edge at 20 per cent Ag[1] (*electrum*). Gold and copper show complete mutual solubility.[2] Silver and copper, on the other hand, are practically mutually insoluble.[3] Gold and silver form continuous series with palladium,[4] the gold-palladium series being represented by *porpezite*. Gold will take some rhodium into solid solution, much less than the reported rhodium content of rhodite; silver will not hold rhodium in solid solution.[5] Gold takes mercury up to 16.5 per cent at 90° (mercurian gold); silver will dissolve up to 45 per cent of mercury[6] (mercurian silver). Gold dissolves less than 0.2 per cent of bismuth;[7] some of the reported natural bismuthian gold appears to be an intermetallic compound, Au_2Bi (*maldonite*). Silver will dissolve about 5 per cent of antimony[8] (antimonian silver), and about 7 per cent of arsenic[9] (arsenian silver). Copper takes about 4 per cent of arsenic.[10]

Ref.

1. Sachs and Weerts, *Zs. Phys.*, **60**, 481 (1930).
2. Vegard and Kloster, *Zs. Kr.*, **89**, 560 (1934); *Strukturber.*, 504, 1913–28 and 615, 1928–32.

Little is as yet known of the controlling principles in the structures of the sulfosalts so that a more elaborate classification than that used here is of doubtful value. The investigation of the crystal structure of these complex minerals offers a fruitful field of study.

Most sulfides (and sulfosalts) are opaque and, in addition, they are nearly always intimately intermixed. These two characteristics, not nearly so common in other classes of minerals, serve to increase the difficulties of investigation, and consequently the descriptive mineralogy of the sulfides and sulfosalts is less well known than that of most other minerals. A considerable number of the sulfides and sulfosalts still have no universally accepted chemical formula. In others the amount of substitution of certain minor elements is not known (the problem of nickelian pyrite is an example). Adequate crystallographic discussions of such minerals as *sartorite* are not yet available, chiefly because we do not know whether the crystals examined are individuals or twins, and how they are twinned or aggregated. The reflecting microscope has helped to solve the difficulty of opacity, but the quantitative data obtained from a reflecting surface is not, at this time, nearly so useful as that which can be obtained by the standard methods applied to nonopaque minerals. In order to obtain pure samples for chemical analysis of many sulfides, it is necessary to extract material under the reflecting microscope. This is an arduous and well nigh impossible task when analytical quantities for macroanalysis are required. Further clarification of the chemistry of certain sulfides and sulfosalts must therefore be accomplished by micromethods.

2 SULFIDES

21 A_mX_n TYPE WITH $m : n > 3 : 1$

211	TETRADYMITE GROUP	
2111	Tellurobismuthite	Bi_2Te_3
2112	Tetradymite	Bi_2Te_2S
2113	Gruenlingite	Bi_4TeS_3
2114	Joseite	Bi_3TeS
2115	Wehrlite	Bi_3Te_2 ?
212	Nagyagite	$Pb_5Au(TeSb)_4S_{5-8}$?
213	COPPER ARSENIDE GROUP	
2131	Algodonite	Cu_6As
2132	Domeykite	Cu_3As
2133	Horsfordite	Cu_5Sb
2134	Cocinerite	Cu_4AgS

22 A_3X TYPE

221	Dyscrasite	Ag_3Sb
222	Stibiopalladinite	Pd_3Sb

23 A_2X TYPE

231	ARGENTITE GROUP	
2311	Argentite	Ag_2S
2312	Aguilarite	$Ag_2(Se, S)$
2313	Naumannite	Ag_2Se
2314	Digenite	$Cu_{2-x}S$
2315	Berzelianite	Cu_2Se
2316	Crookesite	$(Cu, Tl, Ag)_2Se$
2317	Eucairite	$CuAgSe$
2318	Hessite	Ag_2Te
2319	Petzite	Ag_3AuTe_2

232	CHALCOCITE GROUP	
2321	Chalcocite	Cu_2S
2322	Stromeyerite	$AgCuS$
2323	Acanthite	Ag_2S

24 A_3X_2 TYPE

241	Maucherite	$Ni_{11}As_8$
242	Umangite	Cu_3Se_2
243	Bornite	Cu_5FeS_4

25 A_4X_3 TYPE

251	Dimorphite	As_4S_3
252	Rickardite	Cu_4Te_3
253	Weissite	Cu_5Te_3

26 AX TYPE

261	GALENA GROUP	
2611	Galena	PbS
2612	Clausthalite	$PbSe$
2613	Altaite	$PbTe$
2614	Alabandite	MnS
2615	Oldhamite	CaS

262	SPHALERITE GROUP	
2621	Sphalerite	ZnS
2622	Metacinnabar	$(Hg,Fe,Zn)S$
2623	Tiemannite	$HgSe$
2624	Coloradoite	$HgTe$

263	CHALCOPYRITE GROUP	
2631	Chalcopyrite	$Cu_2Fe_2S_4$
2632	Stannite	Cu_2FeSnS_4

264	WURTZITE GROUP	
2641	Wurtzite	ZnS
2642	Greenockite	CdS
2643	Voltzite	Zn_5S_4O

265	NICCOLITE GROUP	
2651	Pyrrhotite	$Fe_{1-x}S$
2652	Valleriite	
2653	Niccolite	$NiAs$
2654	Breithauptite	$NiSb$
2655	Millerite	NiS
2656	Pentlandite	$(Fe,Ni)_9S_8$
266	Cubanite	$CuFe_2S_3$
267	Sternbergite	$AgFe_2S_3$
268	COVELLITE GROUP	
2681	Covellite	CuS
2682	Klockmannite	$CuSe$
269	Cinnabar	HgS
26·10	Realgar	AsS
26·11	Cooperite	PtS
26·12	Braggite	$(Pt,Pd,Ni)S$
26·13	Herzenbergite	SnS
26·14·1	Empressite	$AgTe$
26·14·2	Muthmannite	$(Ag,Au)Te$

27 A_3X_4 TYPE

271	LINNAEITE SERIES	
2711	Linnaeite	Co_3S_4
2712	Siegenite	$(Co,Ni)_3S_4$
2713	Carrollite	Co_2CuS_4
2714	Violarite	Ni_2FeS_4
2715	Polydymite	Ni_3S_4
272	Daubreelite	Cr_2FeS_4
273	Badenite	$(Co,Ni,Fe)_3(As,Bi)_4$?

28 A_2X_3 TYPE

281	Orpiment	As_2S_3
282	STIBNITE GROUP	
2821	Stibnite	Sb_2S_3
2822	Bismuthinite	Bi_2S_3
2823	Guanajuatite	Bi_2Se_3
283	Kermesite	Sb_2S_2O

29 AX_2 TYPE

291	PYRITE GROUP	
2911	Pyrite	FeS_2
2912	Bravoite	$(Ni,Fe)S_2$
2913	Laurite	RuS_2
2914	Sperrylite	$PtAs_2$
2915	Hauerite	MnS_2
2916	Penroseite	$(Ni,Cu,Pb)Se_2$

292	COBALTITE GROUP	
2921	Cobaltite	$CoAsS$
2922	Gersdorffite	$NiAsS$
2923	Ullmannite	$NiSbS$
293	LOELLINGITE GROUP	
2931	Loellingite	$FeAs_2$
2932	Safflorite	$(Co,Fe)As_2$
2933	Rammelsbergite	$NiAs_2$
2934	Pararammelsbergite	$NiAs_2$
294	Marcasite	FeS_2
295	ARSENOPYRITE GROUP	
2951	Arsenopyrite	$FeAsS$
2952	Glaucodot	$(Co,Fe)AsS$
2953	Gudmundite	$FeSbS$
2954	Wolfachite	$Ni(As,Sb)S$?
2955	Lautite	$CuAsS$
296	MOLYBDENITE GROUP	
2961	Molybdenite	MoS_2
2962	Tungstenite	WS_2
297	KRENNERITE GROUP	
2971	Krennerite	$AuTe_2$
2972	Calaverite	$AuTe_2$
2973	Sylvanite	$(Ag,Au)Te_2$
298	Melonite	$NiTe_2$
299	Parkerite	NiS_2 ?

2·10 AX_3 TYPE

2·10·1	SKUTTERUDITE SERIES	
2·10·11	Skutterudite	$(Co,Ni)As_3$
2·10·12	Smaltite	$(Co,Ni)As_{3-x}$
2·10·13	Nickel-Skutterudite	$(Ni,Co)As_3$
2·10·14	Chloanthite	$(Ni,Co)As_{3-x}$
2·10·2	Niggliite	$PtTe_3$?

211 TETRADYMITE GROUP

RHOMBOHEDRAL

			G.	a_0	c_0	$\frac{c_0}{a_0}$
2111	Tellurobismuthite	Bi_2Te_3	7.65	4.24	11.10	2.618
2112	Tetradymite	Bi_2Te_2S	7.3	4.32	30.01	6.946
2113	Gruenlingite	Bi_4TeS_3	8.08	....	.....	.....
2114	Joseite	Bi_3TeS	8.18	....	.....	.....
2115	Wehrlite	Bi_3Te_2 ?		....	.....	.....

The members of the tetradymite group possess a perfect basal cleavage, a lamellar habit and many of the properties of metals. The structure of tetradymite[1] is of the layered type, with successive planes composed entirely

36 $A_2B_2X_5$ TYPE WITH $A : B \sim 1 : 1$

361	Dufrenoysite	$Pb_2As_2S_5$
3621	Cosalite	$Pb_2Bi_2S_5$
3622	Kobellite	$Pb_2(Bi,Sb)_2S_5$
363	Franckeite	$Pb_5Sn_3Sb_2S_{14}$
364	Fizelyite	$Pb_5Ag_2Sb_8S_{18}$
365	Ramdohrite	$Pb_3Ag_2Sb_6S_{13}$
366	Wittite	$Pb_5Bi_6(S,Se)_{14}$
367	Jamesonite	$Pb_4FeSb_6S_{14}$
368	Rathite	$Pb_{13}As_{18}S_{40}$

37 $A_2B_3X_6$ TYPE WITH $A + B : X \sim 5 : 6$

371	ANDORITE GROUP	
3711	Andorite	$PbAgSb_3S_6$
3712	Lindstromite	$PbCuBi_3S_6$
372	Baumhauerite	$Pb_4As_6S_{13}$
373	Liveingite	$Pb_5As_8S_{17}$
374	PLAGIONITE GROUP	
3741	Fuloppite	$Pb_3Sb_8S_{15}$
3742	Plagionite	$Pb_5Sb_8S_{17}$
3743	Heteromorphite	$Pb_7Sb_8S_{19}$
3744	Semseyite	$Pb_9Sb_8S_{21}$

38 AB_2X_4 TYPE WITH $A : B \sim 1 : 2$

381	Hutchinsonite	$(Pb,Tl)_2(Cu,Ag)As_5S_{10}$
382	Rezbanyite	$Pb_3Cu_2Bi_{10}S_{19}$
383	Galenobismutite	$PbBi_2S_4$
384	Weibullite	$PbBi_2(S,Se)_4$
385	Platynite	$PbBi_2(Se,S)_3$
386	Chiviatite	$Pb_3Bi_8S_{15}$
387	Alaskaite	$Pb(Ag,Cu)_2Bi_4S_8$?
388	Zinkenite	$Pb_6Sb_{14}S_{27}$
389	Sartorite	$PbAs_2S_4$
38·10	Berthierite	$FeSb_2S_4$
38·11	Cylindrite	$Pb_3Sn_4Sb_2S_{14}$
38·12	Gladite	$PbCuBi_5S_9$
38·13	Vrbaite	$TlAs_2SbS_5$

39 AB_4X_7 TYPE

391	Livingstonite	$HgSb_4S_7$

4 SIMPLE OXIDES

41 A_2X TYPE

411	Cuprite	Cu_2O
413	Water	H_2O

42 AX TYPE

421	PERICLASE GROUP	
4211	Periclase	MgO
4212	Bunsenite	NiO
4213	Manganosite	MnO
4214	Cadmium oxide	CdO
4215	Lime	CaO
422	ZINCITE GROUP	
4221	Zincite	ZnO
4222	Bromellite	BeO
423	Tenorite	CuO
424	Paramelaconite	$Cu^{2}_{1-2x}Cu^{1}_{2x}O_{1-x}$
425	Montroydite	HgO
426	Litharge	PbO
427	Massicot	PbO

43 A_3X_4 TYPE

431	Minium	Pb_3O_4

44 A_2X_3 TYPE

441	HEMATITE GROUP	
4411	Corundum	Al_2O_3
4412	Hematite	Fe_2O_3
	Ilmenite series	
4413	Ilmenite	$FeTiO_3$
4414	Geikielite	$MgTiO_3$
4415	Pyrophanite	$MnTiO_3$
4416	Senaite	$(Fe,Mn,Pb)TiO_3$
442	ARSENOLITE GROUP	
4421	Arsenolite	As_2O_3
4422	Senarmontite	Sb_2O_3
443	Claudetite	As_2O_3
444	Valentinite	Sb_2O_3
445	Bixbyite	$(Mn,Fe)_2O_3$
446	Braunite	$(Mn,Si)_2O_3$

45 AX_2 TYPE

451	RUTILE GROUP	
4511	Rutile	TiO_2
4512	Pyrolusite	MnO_2
4513	Wad	
4514	Todorokite	
4515	Cassiterite	SnO_2
4516	Plattnerite	PbO_2
452	Anatase	TiO_2
453	Brookite	TiO_2
454	Tellurite	TeO_2
455	Selenolite	SeO_2
456	Cervantite	Sb_2O_4?
457	Stibiconite	$Sb_3O_6(OH)$?
447	Bismite	Bi_2O_3
448	Sillenite	Bi_2O_3

46 A_mX_n TYPE

461	Vanoxite	$V_4V_2O_{13}\cdot 8H_2O$?
462	Corvusite	$V_2V_{12}O_{34}\cdot nH_2O$
463	Ilsemannite	$Mo_3O_8\cdot nH_2O$?
464	Russellite	$(Bi_2W)O_3$
465	Tungstite	$WO_3\cdot H_2O$?

Ref.

1. See Evans (168, 1939).
2. Tunell, Posnjak, and Ksanda, *Zs. Kr.*, **90**, 120 (1935).
3. Goldschmidt, *Vidensk. Skr. Oslo, Mat.-Nat. Kl.*, 1, 17 (1926).

411 **CUPRITE** [Cu_2O]. Aes caldarium rubro-fuscum *Germ.* Lebererzkupfer *Agricola* (334, 1546A; 462, 1546B). Minera cupri calciformis pura et indurata, colore rubro, vulgo Kupferglas, Kupfer Lebererz *Cronstedt* (173, 1758). Cuprum tessulatum nudum *Linnaeus* (176, tab. viii, 1756); Cuprum cryst. octaëdrum *Linnaeus* (1768). Octahedral Copper Ore, Red Glassy Copper Ore *Hill* (1771). Mine rouge de cuivre *Sage* (1772). Mine de cuivre vitreuse rouge *de Lisle* (1772, 1783). Rothes Kupferglas *Pallas* (*Nord. Beiträge*, **5**, 283, 1793). Rothkupfererz *Germ.* Cuivre oxidulé *Fr.* Oxydulated Copper.Ziguéline *Beudant* (**2**, 713, 1832). Ruberite *Chapman* (63, 1843). Cuprit *Haidinger* (548, 1845). Kupferoxydul, Kupferroth, Kupferbraun *Hausmann* (370, 1847). Ruby Copper.

Ziegelerz = Tile Ore; Kupferlebererz; Hepatinerz. Ziguelina *Ital.* Ziegelite. Haarförmiges Rothkupfererz. Cuivre oxidulé capillaire *Haüy.* Kupferblüthe *Hausmann.* Capillary Red Oxide of Copper. Chalkotrichit *Glocker* (369, 1839). Plush Copper Ore.

Vanadic Ocher, Vanadic Acid *Teschemacher* (*Am. J. Sc.*, **11**, 233, 1851). Cuprocuprite pt. *Vernadsky* (**1** [3], 416, 1910).

Cryst. Isometric; gyroidal — 4 3 2.[1]

Forms:[2]

a 001	*δ* 016	*f* 013	*n* 112	*χ* 334	*r* 233	*F* 689
d 011	*η* 015	*e* 012	*σ* 335	*q* 133	*D* 245	*G* 10·12·13
o 111	*h* 014	*m* 113	*β* 223	*p* 122	*E* 467	

Structure cell.[3] Space group *Pn3m*; a_0 4.252 ± 0.002; contains Cu_4O_2.

OXIDES CONTAINING URANIUM, THORIUM, AND ZIRCONIUM

Uraninite and thorianite have the fluorite structure and baddeleyite has a distorted fluorite structure.[1] The other minerals containing uranium are more complex and structural studies of them have not, as yet, been made. Since the other uranium minerals of this class are usually derived by alteration from uraninite, they are hydrous. The lead contained in most of them is probably radiogenic, and its role in the composition is not clear.

Gummite is a convenient name for indeterminate alteration products of uraninite, some of which are non-crystalline with variable water content. Some substances now placed with gummite may prove, upon investigation, to be valid mineral species.

The alteration products of uraninite are all brilliantly colored, mostly in orange and yellow. They possess a perfect cleavage in the basal plane (as here taken) and the acute bisectrix is usually normal to that cleavage. (These features of cleavage and optical orientation are common to most minerals containing considerable amounts of uranium).

5 OXIDES CONTAINING URANIUM (ALSO THORIUM AND ZIRCONIUM)

511	Baddeleyite	ZrO_2
512	URANINITE GROUP	
5121	Uraninite	UO_2
5122	Thorianite	ThO_2
521	Gummite	$UO_3 \cdot nH_2O$
522	Clarkeite	$UO_3 \cdot nH_2O$?
523	Becquerelite	$2UO_3 \cdot 3H_2O$?
524	Schoepite	$4UO_3 \cdot 9H_2O$?
531	Fourmarierite	$PbO \cdot 4UO_3 \cdot 5H_2O$?
532	Curite	$2PbO \cdot 5UO_3 \cdot 4H_2O$?
533	Uranosphaerite	$Bi_2O_3 \cdot 2UO_3 \cdot 3H_2O$?
534	Vandenbrandite	$CuO \cdot UO_3 \cdot 2H_2O$
535	Ianthinite	$2UO_2 \cdot 7H_2O$

Ref.

1. Goldschmidt and Thomassen, *Vidensk. Skr., Mat.-Nat. Kl.*, **2**, 1923.

6 HYDROXIDES AND OXIDES CONTAINING HYDROXYL

The hydroxides are, for the most part, layered-lattice structures. Brucite consists of double (OH) sheets parallel to the basal plane, with Mg between the sheets. Since only weak bonds hold the (OH) sheets together the perfect cleavage is explained by the structure.[1] The same kind of structure, with some modifications, is found in gibbsite and in lepidocrocite. Members of the hydrotalcite group and of the dimorphous sjogrenite group probably also have a brucite-like structure, as indicated by their physical and chemical similarity to the other hydroxides.

61 *AX*$_2$ TYPE

611	BRUCITE GROUP	
6111	Brucite	$Mg(OH)_2$
6112	Pyrochroite	$Mn(OH)_2$
6113	Portlandite	$Ca(OH)_2$
612	LEPIDOCROCITE GROUP	
6121	Lepidocrocite	$FeO(OH)$
6122	Boehmite	$AlO(OH)$
613	Manganite	$MnO(OH)$
614	Stainierite	$CoO(OH)$?
615	HYDROTALCITE GROUP	
6151	Hydrotalcite	$Mg_6Al_2(OH)_{16} \cdot CO_3 \cdot 4H_2O$
6152	Stichtite	$Mg_6Cr_2(OH)_{16} \cdot CO_3 \cdot 4H_2O$
6153	Pyroaurite	$Mg_6Fe_2(OH)_{16} \cdot CO_3 \cdot 4H_2O$
616	SJOGRENITE GROUP	
6161	Manasseite	$Mg_6Al_2(OH)_{16} \cdot CO_3 \cdot 4H_2O$
6162	Sjogrenite	$Mg_6Fe_2(OH)_{16} \cdot CO_3 \cdot 4H_2O$
6163	Barbertonite	$Mg_6Cr_2(OH)_{16} \cdot CO_3 \cdot 4H_2O$
617	Brugnatellite	$Mg_6Fe(OH)_{13} \cdot CO_3 \cdot 4H_2O$
618	Psilomelane	$BaMn^{2}Mn^{4}_{8}O_{16}(OH)_4$

62 *AX*$_3$ TYPE

621	Sassolite	$B(OH)_3$
622	Gibbsite	$Al(OH)_3$
623	Bauxite	
624	Hydrocalumite	$Ca_4Al_2(OH)_{14} \cdot 6H_2O$

Ref.

1. Bragg (107, 1937).

MULTIPLE OXIDES

The multiple oxides here are arranged primarily according to the $A + B : O$ ratio, and secondarily according to the $A : B$ ratio. They bear somewhat the same relation chemically to the simple oxides, that the sulfosalts bear to the sulfides. The multiple oxides have two nonequivalent metal atoms, but the strength of bonding between them and oxygen is of the same order, and therefore no discrete molecular groups are found in the structure. These minerals therefore represent the so-called isodesmic compounds,[1] as do also the simple oxides.

Many of the minerals grouped here have previously been placed in the oxides; others have been called manganates, aluminates, ferrates, columbates, tantalates, zirconates, and titanates.[2] The present classification has certain advantages in that these essentially similar minerals are placed together and near the simple oxides with which they have many properties in common.

The outstanding group in the multiple oxides is the spinel group, which shows a remarkable chemical variation. The *A* atoms are in four coordination forming a tetrahedron of oxygens, and the *B* atoms are in six coordination with octahedra of oxygen about them. The oxygens are essentially in cubic close-packing.[1]

The perovskite structure is simple with the *A* atoms in 12 coordination, and the *B* atoms in 6 coordination.[1] Other minerals of this class are more complex in structure, and many of the rarer minerals here found have not yet been studied.

The multiple oxides containing Cb, Ta, and Ti have special characteristics, and they are most conveniently separated from the other multiple oxides. They are, therefore, to be found in the section immediately after this.

7 MULTIPLE OXIDES

71 ABX_2 TYPE

711	Delafossite	$CuFeO_2$
712	GOETHITE GROUP	
7121	Diaspore	$HAlO_2$
7122	Goethite	$HFeO_2$
713	Limonite	

72 AB_2X_4 TYPE

721	SPINEL GROUP	
	Spinel series	
7211	Spinel	$MgAl_2O_4$
7212	Hercynite	$FeAl_2O_4$
7213	Gahnite	$ZnAl_2O_4$
7214	Galaxite	$MnAl_2O_4$
	Magnetite series	
7215	Magnesioferrite	$MgFe_2O_4$
7216	Magnetite	$FeFe_2O_4$
7217	Franklinite	$ZnFe_2O_4$
7218	Jacobsite	$MnFe_2O_4$
7219	Trevorite	$NiFe_2O_4$
721·10	Maghemite	Fe_2O_3
	Chromite series	
721·11	Magnesiochromite	$MgCr_2O_4$
721·12	Chromite	$FeCr_2O_4$
722	HAUSMANNITE GROUP	
7221	Hausmannite	$MnMn_2O_4$
7222	Hetaerolite	$ZnMn_2O_4$
7223	Hydrohetaerolite	$Zn_2Mn_4O_8 \cdot H_2O$
723	Chrysoberyl	$BeAl_2O_4$
724	Crednerite	$CuMn_2O_4$

73 AB_4X_7 TYPE

7311	Hoegbomite	$Mg(Al,Fe,Ti)_4O_7$
7312	Sapphirine	$(Mg,Fe)_{15}(Al,Fe)_{34}Si_7O_{80}$
732	Plumboferrite	$PbFe_4O_7$
733	Magnetoplumbite	$Pb(Fe,Mn)_6O_{10}$?
734	Hematophanite	$Pb(Cl,OH)_2 \cdot 4PbO \cdot 2Fe_2O_3$?

74 ABX_3 TYPE

741	Quenselite	$PbMnO_2(OH)$
7421	Perovskite	$CaTiO_3$
	(See also ilmenite series)	
7422	Uhligite	

75 A_2BX_5 TYPE

751	Pseudobrookite	Fe_2TiO_5

76 AB_2X_5 TYPE

761	Chalcophanite	$ZnMn_2O_5 \cdot 2H_2O$?
762	Zirkelite	$(Ca,Fe,Th,U)_2(Ti,Zr)_2O_5$

8 MULTIPLE OXIDES CONTAINING COLUMBIUM, TANTALUM, AND TITANIUM

The minerals here listed have generally been called columbates, tantalates, and titanates.[1] However, recent crystallochemical work[2] indicates that they, as well as other oxygen compounds containing more than one metallic element, are best considered as multiple oxides, of the so-called isodesmic[2] type. Early crystallographic work[3] has demonstrated the similarity of the crystals of these compounds with certain simple (isodesmic) oxides. Structural similarities have been noted[4] between the two types.

The chemical constitution of most of the minerals containing Cb, Ta, or Ti as a major constituent can be expressed[5] by the formula $A_mB_nO_{2(m+n)}$, where $m : n$ is between 1 : 1 and 1 : 2, and A = rare earths, U, Ca, Th, Fe^2, Na, Mn, Zr; B = Cb, Ta, Ti, Sn, W?, Zr?, Fe^3.

The role of Zr is uncertain, and often the role of Fe is indeterminate because the state of oxidation cannot be deduced from analysis[6] in the presence of U. The role of water in these minerals is not known, but it is generally considered the result of alteration, because the most highly altered material invariably shows the most water in analysis.

The crystallography of these multiple oxides is only imperfectly known because they are nearly all noncrystalline pseudomorphs of the original minerals, that is, they are *metamict*.[7] The crystals are usually rough and of such size that only contact measurements can be made. When they are heated they revert, presumably, to the original structure[7] (emitting a glow, due to the crystallization), but the crystalline units are tiny and not oriented with respect to the original external faces. The change in structure after the ignition can readily be detected under the microscope or by x-ray powder diffraction pictures. Most of the crystallographic measurements, except on a few species such as columbite and tapiolite (which are not metamict) are to be considered inaccurate and inconclusive. They show that the minerals are often pseudotetragonal and, by manipulating the axial ratios, can be made to agree fairly well with each other. The following table of transformations demonstrates the relationships derived.

The transformations are to tapiolite, the tetragonal member of these oxides.

	To Tapiolite	Transformed Elements
		1.000 : 1 : 1.939 (tapiolite)
Euxenite	002/200/0$\frac{3}{2}$0	0.931 : 1 : 1.980
Priorite	200/010/00$\bar{3}$	0.949 : 1 : 2.002
Eschynite	200/010/003	0.973 : 1 : 2.021
Samarskite	100/001/010	1.054 : 1 : 1.932

Also, the relation between the axial ratios of columbite and euxenite is close.

	a		b		c
Columbite	0.4023	:	1	:	0.3580
Euxenite	0.3789	:	1	:	0.3527

Certain strong similarities in the x-ray powder pictures of the ignited samples indicate that most of these multiple oxides containing the rare earths, Cb, Ta, and Ti have similar structures.[8]

The classification here is strictly on chemical grounds, that is, according to the $A + B : O$ ratio and after that according to the $A : B$ ratio, mainly because crystallographic criteria are inconclusive. For this reason many names heretofore considered as designating good species have been introduced into the synonymy of better-known minerals. An aid to classification has been x-ray powder pictures.[8] Many species of doubtful value appear among these minerals, and it is better that they be not given full status.

81 ABX_4 TYPE

			A	B
811	Pyrochlore-microlite Series $A_2B_2O_6(O,OH,F)$			
8111	Pyrochlore		Na, Ca, K, Mg, Fe, Mn, Ce,	Cb, Ta, Ti, Sn ?, Fe^3, W
8112	Microlite		La, Di, Er, Y, Th, Zr, U	Ta, Cb, Ti, Sn ?, Fe^3, W
812	Scheteligite ?			
813	Fergusonite Series ABO_4			
8131	Fergusonite		Y, Er, (Ce,La,Di),Fe^2	Cb, Ta, Ti, Sn, W
8132	Formanite		U, Zr, Th, Ca	Ta, Cb, Ti, Sn, W
814	Yttrotantalite	ABO_4 ?	Fe^2, Y, U, Ca, Mn, Ce, Th	Cb, Ta, Ti, Zr, Sn
815	Polymignite	ABO_4	Ca, Fe^2, (Y,Er,Ce), Zr, Th	Cb, Ti, Ta, Fe^3
816	Ishikawaite	ABO_4	U, Fe^2, (Y,Er,Ce)	Cb, Ta
817	Loranskite		Y, Ce, Ca, Zr (?)	Ta, Zr (?)
818	Stibiotantalite Series ABO_4			
8181	Stibiotantalite		Sb, Bi	Ta, Cb
8182	Stibiocolumbite		Sb, Bi	Cb, Ta
819	Bismutotantalite		Bi	Ta, Cb
81·10	Simpsonite	? ABO_4	Al	Ta

82 $A_mB_nX_p$ TYPE

$m : n$ from 2 : 3 to 3 : 5

821	Arizonite	Fe	Ti
822	Kalkowskite	Fe	Ti
823	Oliveiraite	Zr	Ti
824	Brannerite	U, Ca, Fe, Y, Th	Ti

83 AB_2X_6 TYPE

		A	B
831	Tapiolite Series AB_2O_6		
8311	Tapiolite	Fe, Mn	Ta, Cb
8312	Mossite	Fe, Mn	Cb, Ta
832	Columbite-tantalite Series		
8321	Columbite	Fe, Mn, Sn ?	Cb, Ta, W
8322	Tantalite	Fe, Mn	Ta, Cb
833	Euxenite-polycrase Series		
8331	Euxenite	Y, Ca, Ce, U, Th	Cb, Ta, Ti
8332	Polycrase	Y, Ca, Ce, U, Th	Ti, Cb, Ta, Fe^3
	Eschwegeite		
834	Yttrocrasite		
835	Eschynite-priorite Series		
8351	Eschynite	Ce, Ca, Fe^2, Th	Ti. Cb, Ta
8352	Priorite	Y, Er, Ca, Fe, Th	Ti, Cb, Ta
8361	Samarskite	Y, Er, Ce, La, U, Ca, Fe, Pb, Th	Cb, Ta, Ti, Sn, W, Zr (?)
8362	" Samarskite "		
837	Thoreaulite $SnTa_2O_7$	Sn	Ta

84 $A_mB_nX_p$ TYPE

where $m : n \gtreqless 1 : 3$

841	Betafite Series	U, Ca, Th, Pb, Ce, Y	Ti, Cb, Ta, Fe, Al ?
841	Betafite		
842	Djalmaite		
843	Ampangabeite	Y, Er, U, Ca, Th	Cb, Ta, Fe^3 Ti
844	Delorenzite		

Ref.

1. Dana (1892) and others.
2. For a general reference see Evans (203, 1939).
3. Brögger (1897) and Schaller, *U. S. Geol. Sur., Bull. 509*, 9, 1912, have shown the crystallographic relations of AX_2 and ABX_4 minerals (tapiolite and rutile, etc.).
4. Goldschmidt, *Vidensk. Skr., Mat.-Nat. Kl.*, no. 1, 17, 1926, has shown the structural relationship between tapiolite and rutile. Sturdivant, *Zs. Kr.*, **75**, 88 (1930), has related the structure of columbite and brookite.
5. Berman and Frondel (priv. comm., 1941). See also Machatschki, *Chem. Erde*, **7**, 56 (1932); *Zs. Kr.*, **72**, 291 (1929).
6. Wells, *J. Am. Chem. Soc.*, **50**, 1017 (1928).
7. See Brögger, *Zs. Kr.*, **25**, 427 (1896). Also Mügge, *Cbl. Min.*, 721, 753, 1922; Goldschmidt, *Vidensk. Skr., Mat.-Nat. Kl.*, 1, no. 5, 51, 1924.
8. Berman and Frondel (priv. comm., 1941).

Pyrochlore-Microlite Series

$A_2B_2O_6(O,OH,F)$

Pyrochlore is predominantly $NaCaCb_2O_6F$ and microlite is $(Na,Ca)_2Ta_2O_6(O,OH,F)$. The composition, however, varies widely, with

A = Na, Ca, K, Mg, Fe^2, Mn^2, Sb^3, Pb ?, Ce, La, Di, Er, Y, Th, Zr, U
B = Cb, Ta, Ti, Sn ?, Fe^3, W ?

HALIDES

All the minerals classed here contain a halogen as the sole or principal anionic constituent. A number of diverse types of structure are represented. They include isodesmic crystals such as halite and fluorite and a variety of more or less markedly anisodesmic structures. Among the latter are found examples of planar anionic groups, tetrahedral anions such as the $(BF_4)^-$ groups in the barite-type compound KBF_4, and octahedral anions such as the $(SiF_6)^=$ groups in K_2SiF_6 and the $(AlF_6)^{\equiv}$groups in the alumino-fluorides. The latter compounds have been tentatively arranged according to the nature of the anionic framework. The other halides are classified solely on chemical grounds.

Class 9. Normal anhydrous and hydrated halides

Type 1. AX

9.1.1	Halite group	
9.1.1.1	Halite	NaCl
9.1.1.2	Sylvite	KCl
9.1.1.3	Villiaumite	NaF
9.1.1.4	Cerargyrite	AgCl
9.1.1.5	Bromyrite	AgBr
9.1.2	Salammoniac	NH_4Cl
9.1.3	Nantokite group	
9.1.3.1	Nantokite	CuCl
9.1.3.2	Miersite	(Ag,Cu)I
9.1.3.3	Marshite	CuI
9.1.4	Iodyrite	AgI
9.1.5	Calomel	HgCl

Type 2. AX_2

9.2.1	Fluorite	CaF_2
9.2.2	Sellaite	MgF_2
9.2.3	Lawrencite group	
9.2.3.1	Lawrencite	$FeCl_2$
9.2.3.2	Scacchite	$MnCl_2$
9.2.3.3	Chloromagnesite	$MgCl_2$
9.2.4	Hydrophilite	$CaCl_2$
9.2.5	Coccinite	HgI_2
9.2.6	Cotunnite	$PbCl_2$
9.2.7	Eriochalcite	$CuCl_2 \cdot 2H_2O$
9.2.8	Bischofite	$MgCl_2 \cdot 6H_2O$

Type 3. AX_3

9.3.1	Molysite	$FeCl_3$
9.3.2	Fluocerite	$(Ce,La,Nd)F_3$
9.3.3	Chloraluminite	$AlCl_3 \cdot 6H_2O$

CLASS 10. Oxyhalides and hydroxyhalides

Type 1. $A_m(O,OH)_pX_q$

10.1.1	Eglestonite	Hg_4OCl_2
10.1.2	Terlinguaite	Hg_2OCl
10.1.3	Lorettoite	$Pb_7O_6Cl_2$
10.1.4	Mendipite	$Pb_3O_2Cl_2$
10.1.5	Daviesite	—
10.1.6	Matlockite group	
10.1.6.1	Matlockite	$PbFCl$
10.1.6.2	Bismoclite	$BiOCl$
10.1.6.3	Daubréeite	$BiO(OH,Cl)$
10.1.7	Laurionite	$Pb(OH)Cl$
10.1.8	Paralaurionite	$Pb(OH)Cl$
10.1.9	Penfieldite	$Pb_2(OH)Cl_3$
10.1.10	Fiedlerite	$Pb_3(OH)_2Cl_4$
10.1.11	Atacamite group	
10.1.11.1	Atacamite	$Cu_2(OH)_3Cl$
10.1.11.2	Kempite	$Mn_2(OH)_3Cl$
10.1.12	Paratacamite	$Cu_2(OH)_3Cl$
10.1.13	Botallackite	Basic Cu chloride
10.1.14	Cadwaladerite	$Al(OH)_2Cl\cdot 4H_2O$

Type 2. $A_mB_n(O,OH)_pX_q$

10.2.1	Boleite	$Pb_9Cu_8Ag_3Cl_{21}(OH)_{16}\cdot 2H_2O$ (?)
10.2.2	Cumengite	$Pb_4Cu_4Cl_8(OH)_8\cdot H_2O$ (?)
10.2.3	Pseudoboleite	$Pb_5Cu_4Cl_{10}(OH)_8\cdot 2H_2O$ (?)
10.2.4	Percylite	$PbCuCl_2(OH)_2$
10.2.5	Diaboleite	$Pb_2CuCl_2(OH)_4$
10.2.6	Chloroxiphite	$PbCuO_2Cl_2(OH)_2$ (?)
10.2.7	Nocerite	$Ca_3Mg_3F_8O_2$
10.2.8	Koenenite	$Mg_5Al_2(OH)_{12}Cl_4$
10.2.9	Zirklerite	Al,Fe basic chloride
10.2.10	Kleinite	Hg,NH_4,Cl,SO_4
10.2.11	Mosesite	Hg,NH_4,Cl,SO_4

CLASS 11. Halide complexes. Alumino-fluorides

Type 1. $A_mBX_3\cdot xH_2O$

11.1.1	Chlorocalcite	$KCaCl_3$
11.1.2	Carnallite	$KMgCl_3\cdot 6H_2O$
11.1.3	Tachyhydrite	$CaMg_2Cl_6\cdot 12H_2O$

Type 2. A_mBX_4

11.2.1	Pseudocotunnite	K_2PbCl_4
11.2.2	Avogadrite	$(K,Cs)BF_4$
11.2.3	Ferruccite	$NaBF_4$
11.2.4	Cryolithionite	$Na_3Li_3Al_2F_{12}$

Type 3. $A_mBX_4\cdot xH_2O$

11.3.1	Douglasite	$K_2FeCl_4\cdot 2H_2O$ (?)
11.3.2	Mitscherlichite	$K_2CuCl_4\cdot 2H_2O$
11.3.3	Erythrosiderite series	
11.3.3.1	Erythrosiderite	$K_2FeCl_5\cdot H_2O$
11.3.3.2	Kremersite	$(NH_4,K)_2FeCl_5\cdot H_2O$

Type 4. A_mBX_6

11.4.1	Hieratite group	
11.4.1.1	Hieratite	K_2SiF_6
11.4.1.2	Cryptohalite	$(NH_4)_2SiF_6$
11.4.2	Malladrite group	
11.4.2.1	Malladrite	Na_2SiF_6
11.4.2.2	Bararite	$(NH_4)_2SiF_6$
11.4.3	Rinneite	NaK_3FeCl_6
11.4.4	Chlormanganokalite	K_4MnCl_6

Type 5. Alumino-fluorides (see below)

CLASS 12. Compound halides

Type 1. Miscellaneous

12.1.1	Creedite	$Ca_3Al_2F_4(OH,F)_6(SO_4)\cdot 2H_2O$
12.1.2	Arzrunite	Pb,Cu sulfate-chloride
12.1.3	Trudellite	$Al_{10}Cl_{12}(OH)_{12}(SO_4)_3\cdot 30H_2O$
	Bandylite	[with borates]
	Teepleite	[with borates]

9 NORMAL ANHYDROUS AND HYDRATED HALIDES

TYPE 1. *AX*

9.1.1 HALITE GROUP

ISOMETRIC; HEXOCTAHEDRAL—$4/m\,\bar{3}\,2/m$

	a_0	G.	n(Na)
Halite, NaCl	5.627 *kX*	2.168	1.5443
Sylvite, KCl	6.277	1.993	1.4903
Villiaumite, NaF	4.619	2.79	1.3270
Cerargyrite series			
Cerargyrite, Ag(Cl,Br)	5.545	5.55	2.071
Bromyrite, Ag(Br,Cl)	5.755	6.47	2.253

The crystal structure of halite, NaCl, was the first structure to be analyzed by x-rays.[1] The halite structure-type is characteristic of a large number of AX compounds with a radius ratio between 0.41 and 0.73, and includes among minerals the halite group, periclase group, and galena group. The important members of the halite group are halite and sylvite. These minerals occur principally as extensive bedded deposits formed by the evaporation of oceanic waters. Villiaumite is a rare primary mineral found in the pegmatitic facies of nepheline-syenites. At ordinary temperatures the extent of substitutional solid solution between NaCl and KCl is extremely small.

The silver halides—cerargyrite, AgCl, and bromyrite, AgBr—belong to the halite structure-type but differ from the typically ionic alkali halides in that they possess an intermediate, ionic-covalent bond and show marked

CARBONATES

The carbonates comprise a family of anisodesmic oxysalts in which the fundamental anionic unit of structure is the $(CO_3)^{=}$ group. In this group a carbon atom lies at the center of an equilateral triangle of three oxygen atoms. The carbon-oxygen bonds are essentially covalent, while the bonding of these units to the cationic elements is essentially ionic. Among the natural carbonates whose structures are known may be mentioned the members of the important Calcite and Aragonite groups. The structures of most of the hydrated and basic carbonates are not known.

Class 13. Acid carbonates

Type 1. Miscellaneous

13.1.1	Nahcolite	$NaHCO_3$
13.1.2	Kalicinite	$KHCO_3$
13.1.3	Teschemacherite	$(NH_4)HCO_3$
13.1.4	Trona	$Na_3H(CO_3)_2 \cdot 2H_2O$

Class 14. Anhydrous normal carbonates

Type 1. $A(XO_3)$

14.1.1	Calcite group	
14.1.1.1	Calcite	$CaCO_3$
14.1.1.2	Magnesite	$MgCO_3$
14.1.1.3	Siderite	$FeCO_3$
14.1.1.4	Rhodochrosite	$MnCO_3$
14.1.1.5	Cobaltocalcite	$CoCO_3$
14.1.1.6	Smithsonite	$ZnCO_3$
14.1.1.7	Otavite	$CdCO_3$
14.1.2	Vaterite	$CaCO_3$
14.1.3	Aragonite group	
14.1.3.1	Aragonite	$CaCO_3$
14.1.3.2	Witherite	$BaCO_3$
14.1.3.3	Strontianite	$SrCO_3$
14.1.3.4	Cerussite	$PbCO_3$

Type 2. $AB(XO_3)_2$

14.2.1	Dolomite group	
14.2.1.1	Dolomite	$CaMg(CO_3)_2$
14.2.1.2	Ankerite	$Ca(Fe,Mg)(CO_3)_2$
14.2.1.3	Kutnahorite	$Ca(Mn,Mg)(CO_3)_2$
14.2.2	Alstonite	$CaBa(CO_3)_2$
14.2.3	Barytocalcite	$CaBa(CO_3)_2$

Type 3. Miscellaneous

14.3.1	Fairchildite	$K_2Ca(CO_3)_2$
14.3.2	Shortite	$Na_2Ca_2(CO_3)_3$

CLASS 15. Hydrated normal carbonates

Type 1. $A(XO_3) \cdot xH_2O$

15.1.1	Thermonatrite	$Na_2CO_3 \cdot H_2O$
15.1.2	Nesquehonite	$MgCO_3 \cdot 3H_2O$
15.1.3	Trihydrocalcite	$CaCO_3 \cdot 3H_2O$
15.1.4	Pentahydrocalcite	$CaCO_3 \cdot 5H_2O$
15.1.5	Lansfordite	$MgCO_3 \cdot 5H_2O$
15.1.6	Natron	$Na_2CO_3 \cdot 10H_2O$

Type 2. Miscellaneous

15.2.1	Buetschliite	$K_6Ca_2(CO_3)_5 \cdot 6H_2O$
15.2.2	Pirssonite	$Na_2Ca(CO_3)_2 \cdot 2H_2O$
15.2.3	Gaylussite	$Na_2Ca(CO_3)_2 \cdot 5H_2O$
15.2.4	Schroeckingerite	$NaCa_3(UO_2)(CO_3)_3(SO_4)F \cdot 10H_2O$
15.2.5	Voglite	U,Cu,Ca carbonate
15.2.6	Bayleyite	$Mg_2(UO_2)(CO_3)_3 \cdot 18H_2O$
15.2.7	Swartzite	$CaMg(UO_2)(CO_3)_3 \cdot 12H_2O$
15.2.8	Andersonite	$Na_2Ca(UO_2)(CO_3)_3 \cdot 6H_2O$
15.2.9	Liebigite	$Ca_2U(CO_3)_4 \cdot 10H_2O$
15.2.10	Lanthanite	$(La,Ce)_2(CO_3)_2 \cdot 8H_2O$

CLASS 16. Carbonates containing hydroxyl or halogen

Type 1. $A_m(XO_3)_pZ_q$

16.1.1	Loseyite	$(Mn,Zn)_7(CO_3)_2(OH)_{10}$
16.1.2	Zaratite	$Ni_3(CO_3)(OH)_4 \cdot 4H_2O$
16.1.3	Hydrozincite	$Zn_5(CO_3)_2(OH)_6$
16.1.4	Aurichalcite	$(Zn,Cu)_5(CO_3)_2(OH)_6$
16.1.5	Rosasite	$(Cu,Zn)_2(CO_3)(OH)_2$
16.1.6	Malachite	$Cu_2(CO_3)(OH)_2$
16.1.7	Phosgenite	$Pb_2(CO_3)Cl_2$
16.1.8	Bismutite	$(BiO)_2(CO_3)$
16.1.9	Waltherite	Bi basic carbonate
16.1.10	Artinite	$Mg_2(CO_3)(OH)_2 \cdot 3H_2O$
16.1.11	Azurite	$Cu_3(CO_3)_2(OH)_2$
16.1.12	Hydrocerussite	$Pb_3(CO_3)_2(OH)_2$
16.1.13	Hydromagnesite	$Mg_4(CO_3)_3(OH)_2 \cdot 3H_2O$
16.1.14	Rutherfordine	$(UO_2)(CO_3)$ (?)
16.1.15	Sharpite	$(UO_2)_6(CO_3)_5(OH)_2 \cdot 6H_2O$ (?)

Type 2. $A_mB_n(XO_3)_pZ_q$

16.2.1	Dawsonite	$NaAl(CO_3)(OH)_2$
16.2.2	Northupite	$Na_3Mg(CO_3)_2Cl$
16.2.3	Dundasite	$PbAl_2(CO_3)_2(OH)_4 \cdot 4H_2O$
16.2.4	Alumohydrocalcite	$CaAl_2(CO_3)_2(OH) \cdot 2H_2O$ (?)
16.2.5	Beyerite	$Ca(BiO)_2(CO_3)_2$
16.2.6	Parisite	$Ce_2Ca(CO_3)_3F_2$
16.2.7	Cordylite	$Ce_2Ba(CO_3)_3F_2$
16.2.8	Synchisite	$CeCa(CO_3)_2F$
16.2.9	Bastnäsite	$Ce(CO_3)F$
16.2.10	Ancylite	Sr,Ca,Ce carbonate

CLASS 17. Compound carbonates

Type 1. Miscellaneous

17.1.1	Tychite	$Na_6Mg_2(CO_3)_4(SO_4)$
17.1.2	Bradleyite	$Na_3Mg(CO_3)(PO_4)$
17.1.3	Leadhillite	$Pb_4(CO_3)_2(OH)_2(SO_4)$
17.1.4	Susannite	$Pb_4(CO_3)_2(OH)_2(SO_4)$
	Caledonite	[with sulfates]

NITRATES

The nitrates are anisodesmic structures and contain discrete $(NO_3)^-$ groups. These are of the same shape as the $(CO_3)^=$ group and of only slightly smaller size. The nitrates are very similar to carbonates, although in general less stable due to increased polarization of the coordinated oxygen atoms by the pentavalent N atom. The natural nitrates are few in number, relatively soluble, and with the exception of soda-niter are of rare occurrence. Soda-niter, which is isostructural with calcite, occurs abundantly in some arid regions as in South America along the Chilean coastal region.

Class 18. Normal anhydrous and hydrated nitrates

Type 1.	$A(XO_3)$	
18.1.1	Soda-niter	$Na(NO_3)$
18.1.2	Niter	$K(NO_3)$
18.1.3	Ammonia-niter	$NH_4(NO_3)$
Type 2.	$A(XO_3)_2$	
18.2.1	Nitrobarite	$Ba(NO_3)_2$
18.2.2	Nitrocalcite	$Ca(NO_3)_2 \cdot 4H_2O$
18.2.3	Nitromagnesite	$Mg(NO_3)_2 \cdot 6H_2O$

Class 19. Nitrates containing hydroxyl or halogen

Type 1.	Miscellaneous	
19.1.1	Gerhardtite	$Cu_2(NO_3)(OH)_3$
	Buttgenbachite	[with connellite]

Class 20. Compound nitrates

Type 1.	Miscellaneous	
20.1.1	Darapskite	$Na_3(NO_3)(SO_4) \cdot H_2O$

18 NORMAL ANHYDROUS AND HYDRATED NITRATES

TYPE 1. $A(XO_3)$

18.1.1 **SODA-NITER** [$NaNO_3$]. Soude nitratée native *M. de Rivero* (*Ann. mines*, **6**, 596, 1821). Salpetersaures Natron *Mohs* (**2**, 671, 1824). Zootinsalz *Breithaupt* (171, 1823). Natronsalpeter *Leonhard* (246, 1826), *Naumann* (262, 1828). Natron-Nitrat *Breithaupt* (27, 1832). Nitratin *Haidinger* (488, 1845). Natronitrite *Weisbach* (8, 1875). Nitrate of Soda. Soda Nitre. Soda Niter. Cubic Niter. Nitratite. Niter cubique. Chilisalpeter, Salpetersaures Natron *Germ.* Nitro, Salitre sodico, Caliche *Span.*

IODATES

Among the oxy-acids of the halogens only a few iodates and an iodate-chromate are known to occur in nature. The structure of none of these is known. Salesite apparently has a structure of the olivine type.[1] The compounds are classed separately rather than with the nitrates or carbonates since the structures are probably of the multiple isodesmic type, with I in six-coordination with oxygen. The natural iodates are rare and occur only along the arid western coasts of South America.

Ref.

1. Strunz, *Zs. Kr.*, **103**, 359 (1941).

CLASS 21.	Normal anhydrous and hydrated iodates	
Type 1.	$A(XO_3)_2 \cdot xH_2O$	
21.1.1	Lautarite	$Ca(IO_3)_2$
21.1.2	Bellingerite	$Cu(IO_3)_2 \cdot \frac{2}{3}H_2O$
CLASS 22.	Iodates containing hydroxyl or halogen	
Type 1.	Miscellaneous	
22.1.1	Salesite	$Cu(IO_3)(OH)$
22.1.2	Schwartzembergite	$Pb_5(IO_3)Cl_3O_3$
CLASS 23.	Compound iodates	
23.1.1	Dietzeite	$Ca_2(IO_3)_2(CrO_4)$

21 NORMAL ANHYDROUS AND HYDRATED IODATES

TYPE 1. $A(XO_3)_2 \cdot xH_2O$

21.1.1 **LAUTARITE** [$Ca(IO_3)_2$]. *Dietze* (*Zs. Kr.*, **19**, 447, 1891).

Cryst.[1] Monoclinic; prismatic—$2/m$.

$a:b:c = 0.6331:1:0.6462$; $\beta\ 106°22'$; $p_0:q_0:r_0 = 1.0207:0.6200:1$

$r_2:p_2:q_2 = 1.6129:1.6462:1$; $\mu\ 73°38'$; $p_0'\ 1.0638$, $q_0'\ 0.6462$, $x_0'\ 0.2937$

Forms:

	ϕ	ρ	ϕ_2	$\rho_2 = B$	C	A
c 001	90°00′	16°22′	73°38′	90°00′	.....	73°38′
b 010	0 00	90 00	.....	0 00	90°00′	90 00
l 120	39 27½	90 00	0 00	39 27½	79 41	50 32½
m 110	58 43½	90 00	0 00	58 43½	76 03½	31 16½
q 011	24 26½	35 22	73 38	58 12	31 48	76 08½
r 101	90 00	53 37	36 23	90 00	37 15	36 23
n $\bar{1}$01	−90 00	37 36	127 36	90 00	53 58	127 36

BORATES

In oxysalts boron occurs in triangular coordination with oxygen. The structure of borates thus is mesodesmic,[1] since the oxygen coordination is equal to the charge of the boron, and the possibility exists of forming indefinitely extending anionic groups by linkage of (BO_3) units analogous to the linkage of (SiO_4) units in the silicates. Indefinitely extending $(BO_2)^-$ chains are found in the structure of the artificial compound CaB_2O_4. In potassium metaborate, $K_3B_3O_6$, not known as a mineral, closed links of $(B_3O_6)^{\equiv}$ are found, and discrete (BO_3) triangles occur in the structure of hambergite, $Be_2(BO_3)(OH)$. Boron also occurs in fourfold coordination with oxygen in some borosilicates. Unfortunately, the crystal structures of most natural borates are still unknown, and a systematic classification[1] based on the nature of the anionic framework cannot yet be formulated. The present classification is based solely on the ratio of boron to the total number of cations.

Ref.

1. See Hendricks, *Washington Ac. Sc., J.*, **34**, 241 (1944).

Class 24. Anhydrous borates

24.1.1	Ludwigite series	
24.1.1.1	Ludwigite	$(Mg,Fe'')_2Fe'''BO_5$
24.1.1.2	Paigeite	$(Fe'',Mg)_2Fe'''BO_5$
24.1.2	Pinakiolite	$Mg_3Mn''Mn_2'''B_2O_{10}$
24.1.3	Hulsite	$(Fe'',Ca,Mg)_4(Fe''',Sn'''')_2B_2O_{10}$ (?)
24.1.4	Warwickite	$(Mg,Fe)_3TiB_2O_8$
24.1.5	Kotoite	$Mg_3(BO_3)_2$
24.1.6	Rhodizite	$NaKLi_4Al_4Be_3B_{10}O_{27}$ (?)
24.1.7	Jeremejevite	$AlBO_3$
24.1.8	Nordenskiöldine	$CaSn(BO_3)_2$

Class 25. Hydrated borates

25.1.1	Pinnoite	$Mg(BO_2)_2 \cdot 3H_2O$
25.1.2	Kernite	$Na_2B_4O_7 \cdot 4H_2O$
25.1.3	Tincalconite	$Na_2B_4O_7 \cdot 5H_2O$
25.1.4	Borax	$Na_2B_4O_7 \cdot 10H_2O$
25.1.5	Priceite	$Ca_4B_{10}O_{19} \cdot 7H_2O$ (?)
25.1.6	Probertite	$NaCaB_5O_9 \cdot 5H_2O$
25.1.7	Ulexite	$NaCaB_5O_9 \cdot 8H_2O$
25.1.8	Veatchite	$Sr_3B_{16}O_{27} \cdot 5H_2O$ (?)
25.1.9	Colemanite	$Ca_2B_6O_{11} \cdot 5H_2O$
25.1.10	Hydroboracite	$CaMgB_6O_{11} \cdot 6H_2O$
25.1.11	Inderborite	$CaMgB_6O_{11} \cdot 11H_2O$
25.1.12	Meyerhofferite	$Ca_2B_6O_{11} \cdot 7H_2O$
25.1.13	Inyoite	$Ca_2B_6O_{11} \cdot 13H_2O$
25.1.14	Kurnakovite	$Mg_2B_6O_{11} \cdot 13H_2O$
25.1.15	Inderite	$Mg_2B_6O_{11} \cdot 15H_2O$

CLASS 25. Hydrated borates—*Continued.*

25.1.16	Howlite	$Ca_2SiB_5O_9(OH)_5$
25.1.17	Bakerite	$Ca_4B_4(BO_4)(SiO_4)_3(OH)_3H_2O$
25.1.18	Paternoite	$MgB_8O_{13} \cdot 4H_2O$
25.1.19	Ginorite	$Ca_2B_{14}O_{23} \cdot 8H_2O$
25.1.20	Larderellite	$(NH_4)_2B_{10}O_{16} \cdot 5H_2O$ (?)
25.1.21	Ammonioborite	$(NH_4)_2B_{10}O_{16} \cdot 5H_2O$ (?)
25.1.22	Kaliborite	$KMg_2B_{11}O_{19} \cdot 9H_2O$

CLASS 26. Borates containing hydroxyl or halogen

26.1.1	Fluoborite	$Mg_3(BO_3)(F,OH)_3$
26.1.2	Hambergite	$Be_2(BO_3)(OH)$
26.1.3	Teepleite	$Na_2B_2O_4 \cdot 2NaCl \cdot 4H_2O$
26.1.4	Bandylite	$CuB_2O_4 \cdot CuCl_2 \cdot 4H_2O$
26.1.5	Sussexite series	
26.1.5.1	Sussexite	$(Mn,Zn)(BO_2)(OH)$
26.1.5.2	Szaibelyite	$Mg(BO_2)(OH)$
26.1.6	Roweite	$(Mn,Mg,Zn)Ca(BO_2)_2(OH)_2$
26.1.7	Boracite	$Mg_3B_7O_{13}Cl$
26.1.8	Hilgardite	$Ca_8(B_6O_{11})_3Cl_4 \cdot 4H_2O$
26.1.9	Parahilgardite	$Ca_8(B_6O_{11})_3Cl_4 \cdot 4H_2O$

CLASS 27. Compound borates

27.1.1	Luenebergite	$Mg_3B_2(OH)_6(PO_4)_2 \cdot 6H_2O$
27.1.2	Cahnite	$Ca_2B(OH)_4(AsO_4)$
27.1.3	Sulfoborite	$Mg_6H_4(BO_3)_4(SO_4)_2 \cdot 7H_2O$
27.1.4	Seamanite	$Mn_3(PO_4)(BO_3) \cdot 3H_2O$

24 ANHYDROUS BORATES

LUDWIGITE AND PINAKIOLITE

ORTHORHOMBIC

	a:b:c
Ludwigite, $(Mg,Fe'')_2Fe'''BO_5$	0.6595:1:?
Paigeite, $(Fe'',Mg)_2Fe'''BO_5$	
Pinakiolite, $Mg_3Mn''Mn_2'''B_2O_{10}$	0.8339:1:0.5881
Hulsite, $(Fe'',Ca,Mg)_4(Fe''',Sn'''')_2B_2O_{10}$ (?)	0.550 :1:?

Ludwigite and paigeite are isostructural [1] and a complete series extends between them by mutual substitution of Mg and Fe''. Pinakiolite, although similar in formula, appears to be unrelated. The ill-defined mineral hulsite seems to be distinct from both pinakiolite and ludwigite-paigeite.

Ref.

1. W. T. Schaller, priv. comm. (1949).

LUDWIGITE SERIES

24.1.1.1 **LUDWIGITE** [$(Mg,Fe)_2Fe'''BO_5$]. *Tschermak* (*Min. Mitt.*, 59, 1874). Magnesioludwigite *Butler* and *Schaller* (*Wash. Ac. Sc., J.*, 7, 29, 1917). Collbranite *Higgins* (*Econ. Geol.*, **13**, 19, 1918).

CLASS 28. Anhydrous acid and normal sulfates

Type 1. Anhydrous acid sulfates

28.1.1	Mercallite	$KHSO_4$
28.1.2	Misenite	$K_8H_6(SO_4)_7$
28.1.3	Letovicite	$(NH_4)_3H(SO_4)_2$

Type 2. A_2XO_4

28.2.1	Mascagnite group	
28.2.1.1	Mascagnite	$(NH_4)_2SO_4$
28.2.1.2	Arcanite	K_2SO_4
28.2.1.3	Taylorite	$(K,NH_4)_2SO_4$ (?)
28.2.2	Aphthitalite	$(K,Na)_3Na(SO_4)_2$
28.2.3	Palmierite	$(K,Na)_2Pb(SO_4)_2$
28.2.4	Thenardite	Na_2SO_4

Type 3. AXO_4

28.3.1	Barite group	
28.3.1.1	Barite	$BaSO_4$
28.3.1.2	Celestite	$SrSO_4$
28.3.1.3	Anglesite	$PbSO_4$
28.3.2	Anhydrite	$CaSO_4$
28.3.3	Chalcocyanite	$CuSO_4$

Type 4. $A_mB_n(XO_4)_p$

28.4.1	Vanthoffite	$Na_6Mg(SO_4)_4$
28.4.2	Glauberite	$Na_2Ca(SO_4)_2$
28.4.3	Langbeinite group	
28.4.3.1	Langbeinite	$K_2Mg_2(SO_4)_3$
28.4.3.2	Manganolangbeinite	$K_2Mn_2(SO_4)_3$

CLASS 29. Hydrated acid and normal sulfates

Type 1. Hydrated acid sulfates

29.1.1	Rhomboclase	$FeH(SO_4)_2 \cdot 4H_2O$
29.1.2	Minasragrite	$(VO)_2H_2(SO_4)_3 \cdot 15H_2O$

Type 2. $A_2(XO_4) \cdot xH_2O$

29.2.1	Lecontite	$Na(NH_4,K)(SO_4) \cdot 2H_2O$
29.2.2	Mirabilite	$Na_2SO_4 \cdot 10H_2O$

Type 3. $A_2B(XO_4)_2 \cdot xH_2O$

29.3.1	Syngenite	$K_2Ca(SO_4)_2 \cdot H_2O$
29.3.2	Koktaite	$(NH_4)_2Ca(SO_4)_2 \cdot H_2O$
29.3.3	Kroehnkite	$Na_2Cu(SO_4)_2 \cdot 2H_2O$
29.3.4	Loeweite	$Na_2Mg(SO_4)_2 \cdot 2\frac{1}{2}H_2O$
29.3.5	Bloedite group	
29.3.5.1	Bloedite	$Na_2Mg(SO_4)_2 \cdot 4H_2O$
29.3.5.2	Leonite	$K_2Mg(SO_4)_2 \cdot 4H_2C$
29.3.6	Wattevilleite	$Na_2Ca(SO_4)_2 \cdot 4H_2O$ (?)
29.3.7	Picromerite group	
29.3.7.1	Picromerite	$K_2Mg(SO_4)_2 \cdot 6H_2O$
29.3.7.2	Cyanochroite	$K_2Cu(SO_4)_2 \cdot 6H_2O$
29.3.7.3	Boussingaultite	$(NH_4)_2Mg(SO_4)_2 \cdot 6H_2O$

Type 4. $A_mB_n(XO_4)_p \cdot xH_2O$, with $(m + n):p < 3:2$ and $>1:1$

29.4.1	Ferrinatrite	$Na_3Fe(SO_4)_3 \cdot 3H_2O$
29.4.2	Polyhalite	$K_2Ca_2Mg(SO_4)_4 \cdot 2H_2O$
29.4.3	Leightonite	$K_2Ca_2Cu(SO_4)_4 \cdot 2H_2O$

Type 5. $AB(XO_4)_2 \cdot xH_2O$

29.5.1	Krausite	$KFe(SO_4)_2 \cdot H_2O$
29.5.2	Voltaite	$(K,Fe'')_3Fe'''(SO_4)_3 \cdot 4H_2O$ (?)
29.5.3	Tamarugite group	
29.5.3.1	Tamarugite	$NaAl(SO_4)_2 \cdot 6H_2O$
29.5.3.2	Amarillite	$NaFe(SO_4)_2 \cdot 6H_2O$
29.5.4	Mendozite group	
29.5.4.1	Mendozite	$NaAl(SO_4)_2 \cdot 11H_2O$
29.5.4.2	Kalinite	$KAl(SO_4)_2 \cdot 11H_2O$
29.5.5	Alum group	
29.5.5.1	Potash Alum	$KAl(SO_4)_2 \cdot 12H_2O$
29.5.5.2	Soda Alum	$NaAl(SO_4)_2 \cdot 12H_2O$
29.5.5.3	Ammonia Alum	$(NH_4)Al(SO_4)_2 \cdot 12H_2O$

Type 6. $A(XO_4) \cdot xH_2O$

29.6.1	Bassanite	$2CaSO_4 \cdot H_2O$
29.6.2	Kieserite group	
29.6.2.1	Kieserite	$MgSO_4 \cdot H_2O$
29.6.2.2	Szomolnokite	$FeSO_4 \cdot H_2O$
29.6.2.3	Szmikite	$MnSO_4 \cdot H_2O$
29.6.3	Gypsum	$CaSO_4 \cdot 2H_2O$
29.6.4	Ilesite	$MnSO_4 \cdot 4H_2O$ (?)
29.6.5	Chalcanthite group	
29.6.5.1	Chalcanthite	$CuSO_4 \cdot 5H_2O$
29.6.5.2	Siderotil	$FeSO_4 \cdot 5H_2O$
29.6.5.3	Pentahydrite	$MgSO_4 \cdot 5H_2O$
29.6.6	Hexahydrite group	
29.6.6.1	Hexahydrite	$MgSO_4 \cdot 6H_2O$
29.6.6.2	Bianchite	$ZnSO_4 \cdot 6H_2O$
29.6.7	Retgersite	$NiSO_4 \cdot 6H_2O$
29.6.8	Melanterite group	
29.6.8.1	Melanterite	$FeSO_4 \cdot 7H_2O$
29.6.8.2	Pisanite	$(Fe,Cu)SO_4 \cdot 7H_2O$
29.6.8.3	Kirovite	$(Fe,Mg)SO_4 \cdot 7H_2O$
29.6.8.4	Boothite	$CuSO_4 \cdot 7H_2O$
29.6.8.5	Bieberite	$CoSO_4 \cdot 7H_2O$
29.6.8.6	Mallardite	$MnSO_4 \cdot 7H_2O$
29.6.9	Epsomite group	
29.6.9.1	Epsomite	$MgSO_4 \cdot 7H_2O$
29.6.9.2	Goslarite	$ZnSO_4 \cdot 7H_2O$
29.6.9.3	Morenosite	$NiSO_4 \cdot 7H_2O$
29.6.9.4	Tauriscite	$FeSO_4 \cdot 7H_2O$

Type 7. $A_2B(XO_4)_4 \cdot xH_2O$

29.7.1	Ransomite	$Cu(Fe,Al)_2(SO_4)_4 \cdot 7H_2O$
29.7.2	Roemerite	$Fe''Fe_2'''(SO_4)_4 \cdot 14H_2O$
29.7.3	Halotrichite group	
29.7.3.1	Pickeringite	$MgAl_2(SO_4)_4 \cdot 22H_2O$
29.7.3.2	Halotrichite	$Fe''Al_2(SO_4)_4 \cdot 22H_2O$
29.7.3.3	Apjohnite	$Mn''Al_2(SO_4)_4 \cdot 22H_2O$
29.7.3.4	Dietrichite	$ZnAl_2(SO_4)_4 \cdot 22H_2O$
29.7.3.5	Bilinite	$Fe''Fe_2'''(SO_4)_4 \cdot 22H_2O$
29.7.3.6	Redingtonite	$(Fe'',Mn,Ni)(Cr,Al)_2(SO_4)_4 \cdot 22H_2O$ (?)

Type 8. $A_2(XO_4)_3 \cdot xH_2O$

29.8.1	Lausenite	$Fe_2(SO_4)_3 \cdot 6H_2O$
29.8.2	Kornelite	$Fe_2(SO_4)_3 \cdot 7H_2O$
29.8.3	Coquimbite	$Fe_2(SO_4)_3 \cdot 9H_2O$
29.8.4	Paracoquimbite	$Fe_2(SO_4)_3 \cdot 9H_2O$
29.8.5	Quenstedtite	$Fe_2(SO_4)_3 \cdot 10H_2O$
29.8.6	Alunogen	$Al_2(SO_4)_3 \cdot 18H_2O$

CLASS 30. Anhydrous sulfates containing hydroxyl or halogen

Type 1. $A_m(XO_4)_pZ_q$, with $m:p > 2:1$

30.1.1	Brochantite	$Cu_4(SO_4)(OH)_6$
30.1.2	Antlerite	$Cu_3(SO_4)(OH)_4$
30.1.3	Caracolite	Na,Pb chloride-sulfate
30.1.4	Chlorothionite	$K_2Cu(SO_4)Cl_2$
30.1.5	Schairerite	$Na_3(SO_4)(F,Cl)$
30.1.6	Sulfohalite	$Na_6ClF(SO_4)_2$

Type 2. $A_2(XO_4)Z_q$

30.2.1	Lanarkite	$Pb_2(SO_4)O$
30.2.2	Dolerophanite	$Cu_2(SO_4)O$
30.2.3	Linarite	$PbCu(SO_4)(OH)_2$
30.2.4	Alunite group	
30.2.4.1	Alunite	$KAl_3(SO_4)_2(OH)_6$
30.2.4.2	Natroalunite	$NaAl_3(SO_4)_2(OH)_6$
30.2.4.3	Jarosite	$KFe_3(SO_4)_2(OH)_6$
30.2.4.4	Ammoniojarosite	$(NH_4)Fe_3(SO_4)_2(OH)_6$
30.2.4.5	Natrojarosite	$NaFe_3(SO_4)_2(OH)_6$
30.2.4.6	Argentojarosite	$AgFe_3(SO_4)_2(OH)_6$
30.2.4.7	Carphosiderite	$(H_2O)Fe_3(SO_4)_2[(OH)_5 \cdot H_2O]$
30.2.4.8	Beaverite	$Pb(Cu,Fe,Al)_3(SO_4)_2(OH)_6$
30.2.4.9	Plumbojarosite	$PbFe_6(SO_4)_4(OH)_{12}$
30.2.5	Euchlorin	K,Na,Cu basic sulfate

CLASS 31. Hydrated sulfates containing hydroxyl or halogen

Type 1. $A_mB_n(XO_4)_pZ_q \cdot xH_2O$, with $(m + n):p > 4:1$

31.1.1	Connellite group	
31.1.1.1	Connellite	$Cu_{19}(SO_4)(OH)_{32}Cl_4 \cdot 3H_2O$
31.1.1.2	Buttgenbachite	$Cu_{19}(NO_3)_2(OH)_{32}Cl_4 \cdot 3H_2O$
31.1.2	Glaucocerinite	$Zn_{13}Al_8Cu_7(SO_4)_2(OH)_{60} \cdot 4H_2O$ (?)
31.1.3	Mooreite	$(Mg,Mn,Zn)_8(SO_4)(OH)_{14} \cdot 4H_2O$
31.1.4	Torreyite	$(Mg,Mn,Zn)_7(SO_4)(OH)_{12} \cdot 4H_2O$
31.1.5	Spangolite	$Cu_6Al(SO_4)(OH)_{12}Cl \cdot 3H_2O$
31.1.6	Cyanotrichite	$Cu_4Al_2(SO_4)(OH)_{12} \cdot 2H_2O$
31.1.7	Zincaluminite	$Zn_3Al_3(SO_4)(OH)_{13} \cdot 2\frac{1}{2}H_2O$
31.1.8	Woodwardite	$Cu_4Al_2(SO_4)(OH)_{12} \cdot 2\text{–}4H_2O$ (?)
31.1.9	Chalcoalumite	$CuAl_4(SO_4)(OH)_{12} \cdot 3H_2O$
31.1.10	Uranopilite	$(UO_2)_6(SO_4)(OH)_{10} \cdot 12H_2O$
31.1.11	Meta-uranopilite	$(UO_2)_6(SO_4)(OH)_{10} \cdot 5H_2O$

Type 2. $A_4(XO_4)Z_q \cdot xH_2O$

31.2.1	Klebelsbergite	Basic Sb sulfate
31.2.2	Langite	$Cu_4(SO_4)(OH)_6 \cdot H_2O$ (?)
31.2.3	Felsöbányaite	$Al_4(SO_4)(OH)_{10} \cdot 5H_2O$ (?)
31.2.4	Basaluminite	$Al_4(SO_4)(OH)_{10} \cdot 5H_2O$
31.2.5	Hydrobasaluminite	$Al_4(SO_4)(OH)_{10} \cdot 36H_2O$ (?)
31.2.6	Glockerite	$Fe_4(SO_4)(OH)_{10} \cdot nH_2O$ (?)

Type 3. $A_mB_n(XO_4)_pZ_q \cdot xH_2O$, with $(m + n):p$ from 5:2 to 3:1

31.3.1	Kamarezite	$Cu_3(SO_4)(OH)_4 \cdot 6H_2O$ (?)
31.3.2	Ettringite	$Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26H_2O$
31.3.3	Devillite	$Cu_4Ca(SO_4)_2(OH)_6 \cdot 3H_2O$
31.3.4	Arnimite	$Cu_5(SO_4)_2(OH)_6 \cdot 3H_2O$ (?)
31.3.5	Serpierite	$(Zn,Cu,Ca)_5(SO_4)_2(OH)_6 \cdot 3H_2O$ (?)

Type 4. $(AB)_z(XO_4)Z_q \cdot xH_2O$

31.4.1	Kainite	$KMg(SO_4)Cl \cdot 3H_2O$
31.4.2	Ungemachite	$Na_9K_3Fe(SO_4)_6(OH)_3 \cdot 9H_2O$
31.4.3	Clino-ungemachite	
31.4.4	Zippeite	$(UO_2)_2(SO_4)(OH)_2 \cdot 4H_2O$
31.4.5	Aluminite	$Al_2(SO_4)(OH)_4 \cdot 7H_2O$

Type 5. $A_3(XO_4)_2Z_q \cdot xH_2O$

31.5.1	Natrochalcite	$NaCu_2(SO_4)_2(OH) \cdot H_2O$
31.5.2	Metasideronatrite	$Na_4Fe_2(SO_4)_4(OH)_2 \cdot 3H_2O$
31.5.3	Sideronatrite	$Na_2Fe(SO_4)_2(OH) \cdot 3H_2O$
31.5.4	Johannite	$Cu(UO_2)_2(SO_4)_2(OH)_2 \cdot 6H_2O$
31.5.5	Vernadskite	$Cu_4(SO_4)_3(OH)_2 \cdot 4H_2O$

Type 6. $A(XO_4)Z_q \cdot xH_2O$

31.6.1	Metahohmannite	$Fe_2(SO_4)_2(OH)_2 \cdot 3H_2O$
31.6.2	Butlerite	$Fe(SO_4)(OH) \cdot 2H_2O$
31.6.3	Parabutlerite	$Fe(SO_4)(OH) \cdot 2H_2O$
31.6.4	Amarantite	$Fe(SO_4)(OH) \cdot 3H_2O$
31.6.5	Hohmannite	$Fe_2(SO_4)_2(OH)_2 \cdot 7H_2O$
31.6.6	Fibroferrite	$Fe(SO_4)(OH) \cdot 5H_2O$ (?)
31.6.7	Botryogen	$MgFe(SO_4)_2(OH) \cdot 7H_2O$
31.6.8	Guildite	$Cu_3Fe_4(SO_4)_7(OH)_4 \cdot 15H_2O$
31.6.9	Metavoltine	$(K,Na,Fe)_5Fe_3'''(SO_4)_6(OH)_2 \cdot 9H_2O$ (?)
31.6.10	Slavikite	$Na_2Fe_{10}(SO_4)_{13}(OH)_6 \cdot 63H_2O$ (?)
31.6.11	Copiapite group	
31.6.11.1	Copiapite	$Fe''Fe_4'''(SO_4)_6(OH)_2 \cdot 20H_2O$
31.6.11.2	Magnesiocopiapite	$MgFe_4'''(SO_4)_6(OH)_2 \cdot 20H_2O$
31.6.11.3	Cuprocopiapite	$CuFe_4'''(SO_4)_6(OH)_2 \cdot 20H_2O$

CLASS 32. Compound sulfates

Type 1. Miscellaneous

32.1.1	Hanksite	$Na_{22}K(SO_4)_9(CO_3)_2Cl$
32.1.2	Caledonite	$Cu_2Pb_5(SO_4)_3(CO_3)(OH)_6$
32.1.3	Wherryite	$Pb_4Cu(CO_3)(SO_4)_2(OH,Cl)O$ (?)
32.1.4	Burkeite	$Na_6(SO_4)_2(CO_3)$
	Arzrunite	[with halides]
	Trudellite	[with halides]
	Creedite	[with halides]
	Tychite	[with carbonates]
	Sulfoborite	[with borates]
	Darapskite	[with nitrates]
	Chalcophyllite	[with arsenates]
	Ardeallite	[with phosphates]
	Lindackerite	[with phosphates]
	Beudantite group	[with phosphates]

SELENATES AND TELLURATES
SELENITES AND TELLURITES

CLASS 33.	Selenates and tellurates	
Type 1.	Miscellaneous	
33.1.1	Ahlfeldite	$Ni(SeO_4)\cdot 6H_2O$ (?)
33.1.2	Teineite	$Cu(Te,SO_4)\cdot 2H_2O$
33.1.3	Montanite	$(BiO)_2(TeO_4)\cdot 2H_2O$
CLASS 34.	Selenites and tellurites	
Type 1.	$A(XO_3)\cdot xH_2O$	
34.1.1	Chalcomenite	$CuSeO_3\cdot 2H_2O$
34.1.2	Cobaltomenite	$CoSeO_3\cdot 2H_2O$ (?)
34.1.3	Kerstenite	$PbSeO_3\cdot 2H_2O$ (?)
Type 2.	$A_2(XO_3)_3\cdot xH_2O$	
34.2.1	Emmonsite	$Fe_2(TeO_3)_3\cdot 2H_2O$ (?)
34.2.2	Mackayite	$Fe_2(TeO_3)_3\cdot xH_2O$ (?)
34.2.3	Blakeite	(ferric tellurite)

33 SELENATES AND TELLURATES

TYPE 1. MISCELLANEOUS

33.1.1 **Ahlfeldite.** *Herzenberg* (*Zbl. Min.*, 189, 1935; *Inst. Boliviano de Ing. de Minas y Geol., Publ. Técu, La Paz*, no. 5, 1945; *Mineria Boliviana*, **2**, no. 25, 1945).

Greenish to yellowish crystals, with a reddish brown coating. Probably triclinic. Qualitative tests indicate the mineral to be a hydrous selenite of nickel distinct from cobaltomenite. Found as an alteration product of penroseite at the Pacajake mine, 30 km. from Colquechaca, Bolivia. Named after Friedrich Ahlfeld, German mining engineer and mineralogist.

33.1.2 **TEINEITE** [$Cu_{13}(SO_4)_3(TeO_4)_{10}\cdot 26H_2O$]. *Yosimura* (*J. Fac. Sc. Hokkaidô Univ.*, [4], **4**, 465, 1939).

Cryst. Orthorhombic; dipyramidal—$2/m\ 2/m\ 2/m$.

$$a:b:c = 0.7051:1:0.7860; \qquad p_0:q_0:r_0 = 1.1147:0.7860:1$$

$$q_1:r_1:p_1 = 0.7051:0.8971:1; \qquad r_2:p_2:q_2 = 1.2723:1.4182:1$$

Forms:

	ϕ	$\rho = C$	ϕ_1	$\rho_1 = A$	ϕ_2	$\rho_2 = B$
b 010	0°00′	90°00′	90°00′	90°00′	.....	0°00′
m 110	54 48½	90 00	90 00	35 11½	0°00′	54 48½
e 011	0 00	38 10	38 10	90 00	90 00	51 50
f 073	0 00	61 24	61 24	90 00	90 00	28 36

CHROMATES

The chromates are anisodesmic compounds containing discrete $(CrO_4)^{=}$ groups and are very similar to sulfates, with which they may form substitutional series. The natural chromates are rare and few in number. They comprise principally a group of relatively insoluble chromates and compound-chromates of lead found as secondary minerals in ore deposits. The alkali chromates and the iodate-chromate, dietzeite, are relatively soluble compounds found in the arid-region *caliche* deposits of Chile.

Class 35.	Anhydrous normal chromates	
Type 1.	$A_2(XO_4)$	
35.1.1	Tarapacaite	$K_2(CrO_4)$
Type 2.	$A_2(X_2O_7)$	
35.2.1	Lopezite	$K_2(Cr_2O_7)$
Type 3.	$A(XO_4)$	
35.3.1	Crocoite	$Pb(CrO_4)$
35.3.2	Phoenicochroite	$Pb_3(CrO_4)_2O$ (?)
Class 36.	Compound chromates	
Type 1.	Miscellaneous	
36.1.1	Vauquelinite	$Pb_5(CrO_4)_2(PO_4)_2$ (?)
36.1.2	Beresovite	$Pb_6(CrO_4)_3(CO_3)O_2$
	Dietzeite	[in iodates]

35 ANHYDROUS NORMAL CHROMATES

TYPE 1. $A_2(XO_4)$

35.1.1 **TARAPACAITE** [K_2CrO_4]. *Raimondi* (274, 1878).

Cryst.[1] Orthorhombic; dipyramidal—$2/m\ 2/m\ 2/m$.

$$a:b:c = 0.5694:1:0.7298; \qquad p_0:q_0:r_0 = 1.2817:0.7298:1$$

$$q_1:r_1:p_1 = 0.5694:0.7802:1; \qquad r_2:p_2:q_2 = 1.3702:1.7652:1$$

Forms:

	ϕ	$\rho = C$	ϕ_1	$\rho_1 = A$	ϕ_2	$\rho_2 = B$
c 001	.....	0°00′	0°00′	90°00′	90°00′	90°00′
b 010	0°00′	90 00	90 00	90 00	.....	0 00
m 110	60 20½	90 00	90 00	29 39½	0 00	60 20½
q 011	0 00	36 07½	36 07½	90 00	90 00	53 52½
Q 021	0 00	55 35	55 35	90 00	90 00	34 25
o 111	60 20½	55 51½	36 07	44 00	37 57½	65 49½

Structure cell.[2] Space group *Pncm*. a_0 5.92 kX, b_0 10.40, c_0 7.61; $a_0:b_0:c_0 = 0.571:1:0.732$. Cell contents $K_8(CrO_4)_4$. Isostructural with mascagnite.

PHOSPHATES, ARSENATES, AND VANADATES

The phosphates, arsenates, and vanadates are anisodesmic oxysalts i[n] which the anionic units of structure are tetrahedral $(XO_4)^{\equiv}$ groups, i[n] which X is P, As, or V. There is commonly a partial or complete substi[-]tutional series between P and As and between As and V, less commonl[y] between P and V. Substitutional series between these oxysalts and sul[-]fates, molybdates, tungstates, and chromates, all of which possess tetra[-]hedral $(XO_4)^{=}$ anions, generally are lacking. In only a few instance[s] have sulfates and phosphates been found to be isostructural, as in th[e] case of brushite and gypsum.

Class 37. Anhydrous acid phosphates, etc.

Type 1. Miscellaneous

37.1.1	Monetite	$CaH(PO_4)$
37.1.2	Schultenite	$PbH(AsO_4)$

Class 38. Anhydrous normal phosphates, etc.

Type 1. $AB(XO_4)$

38.1.1	Triphylite group	
38.1.1.1	Triphylite	$LiFe(PO_4)$
38.1.1.2	Lithiophilite	$LiMn(PO_4)$
38.1.1.3	Hühnerkobelite	$(Na,Ca)Fe(PO_4)$
38.1.1.4	Varulite	$(Na,Ca)Mn(PO_4)$
38.1.2	Natrophilite	$NaMn(PO_4)$
38.1.3	Sicklerite series	
38.1.3.1	Ferri-sicklerite	$(Li,Fe''',Mn'')(PO_4)$
38.1.3.2	Sicklerite	$(Li,Mn'',Fe''')(PO_4)$
38.1.4	Alluaudite series	
38.1.4.1	Alluaudite	$(Na,Fe''',Mn'')(PO_4)$
38.1.4.2	Mangan-alluaudite	$(Na,Mn'',Fe''')(PO_4)$
38.1.5	Heterosite series	
38.1.5.1	Heterosite	$(Fe''',Mn''')(PO_4)$
38.1.5.2	Purpurite	$(Mn''',Fe''')(PO_4)$
38.1.6	Beryllonite	$NaBe(PO_4)$
38.1.7	Arrojadite	$Na_2(Fe'',Mn'')_5(PO_4)_4$

Type 2. $A_3B_2(XO_4)_3$

38.2.1	Berzeliite series	
38.2.1.1	Berzeliite	$(Mg,Mn)_2(Ca,Na)_3(AsO_4)_3$
38.2.1.2	Manganberzeliite	$(Mn,Mg)_2(Ca,Na)_3(AsO_4)_3$
38.2.2	Caryinite	$(Ca,Pb,Na)_5(Mn,Mg)_4(AsO_4)_5$ (?)

Type 3. $A_3(XO_4)_2$

38.3.1	Whitlockite	$Ca_3(PO_4)_2$
38.3.2	Graftonite	$(Fe,Mn,Ca)_3(PO_4)_2$

Type 4. $A(XO_4)$

38.4.1	Xenotime	$Y(PO_4)$
38.4.2	Monazite	$(Ce,La,Di)(PO_4)$
38.4.3	Berlinite	$Al(PO_4)$
38.4.4	Rooseveltite	$Bi(AsO_4)$

CLASS 39. Hydrated acid phosphates, etc.

Type 1. $(AB)_mH_n(XO_4)_p \cdot xH_2O$, with $m + n:p > 2:1$

39.1.1	Stercorite	$Na(NH_4)H(PO_4) \cdot 4H_2O$
39.1.2	Hannayite	$Mg_3(NH_4)_2H_4(PO_4)_4 \cdot 8H_2O$
39.1.3	Hureaulite	$Mn_5H_2(PO_4)_4 \cdot 4H_2O$

Type 2. $AH(XO_4) \cdot xH_2O$

39.2.1	Brushite group	
39.2.1.1	Brushite	$CaH(PO_4) \cdot 2H_2O$
39.2.1.2	Pharmacolite	$CaH(AsO_4) \cdot 2H_2O$
39.2.2	Haidingerite	$CaH(AsO_4) \cdot H_2O$
39.2.3	Newberyite	$MgH(PO_4) \cdot 3H_2O$
39.2.4	Forbesite	$(Ni,Co)H(AsO_4) \cdot 3\frac{1}{2}H_2O$ (?)
39.2.5	Roesslerite group	
39.2.5.1	Roesslerite	$MgH(AsO_4) \cdot 7H_2O$
39.2.5.2	Phosphorroesslerite	$MgH(PO_4) \cdot 7H_2O$

CLASS 40. Hydrated normal phosphates, etc.

Type 1. $AB(XO_4) \cdot xH_2O$

40.1.1	Struvite	$(NH_4)Mg(PO_4) \cdot 6H_2O$

Type 2. $AB_2(XO_4)_2 \cdot xH_2O$

40.2.1	Dickinsonite	$Na_6(Mn,Fe,Ca)_{14}H_2(PO_4)_{12} \cdot H_2O$
40.2.2	Fillowite	$Na_6(Mn,Fe,Ca)_{14}H_2(PO_4)_{12} \cdot H_2O$ (?)
40.2.3	Fairfieldite group	
40.2.3.1	Fairfieldite	$Ca_2(Mn,Fe)(PO_4)_2 \cdot 2H_2O$
40.2.3.2	Collinsite	$Ca_2(Mg,Fe)(PO_4)_2 \cdot 2H_2O$
40.2.4	Roselite group	
40.2.4.1	Roselite	$Ca_2(Co,Mg)(AsO_4)_2 \cdot 2H_2O$
40.2.4.2	Brandtite	$Ca_2Mn(AsO_4)_2 \cdot 2H_2O$
40.2.5	Reddingite series	
40.2.5.1	Reddingite	$(Mn,Fe)_3(PO_4)_2 \cdot 3H_2O$
40.2.5.2	Phosphoferrite	$(Fe,Mn)_3(PO_4)_2 \cdot 3H_2O$
40.2.6	Landesite	$Fe_6Mn_{20}(PO_4)_{16} \cdot 27H_2O$ (?)
40.2.7	Stewartite	Mn phosphate
40.2.8	Salmonsite	Mn,Fe phosphate
40.2.9	Anapaite	$Ca_2Fe(PO_4)_2 \cdot 4H_2O$
40.2.10	Parahopeite	$Zn_3(PO_4)_2 \cdot 4H_2O$
40.2.11	Hopeite	$Zn_3(PO_4)_2 \cdot 4H_2O$
40.2.12	Phosphophyllite	$Zn_2(Fe,Mn)(PO_4)_2 \cdot 4H_2O$
40.2.13	Trichalcite	$Cu_3(AsO_4)_2 \cdot 5H_2O$ (?)
40.2.14	Picropharmacolite	$(Ca,Mg)_3(AsO_4)_2 \cdot 6H_2O$ (?)
40.2.15	Vivianite group	
40.2.15.1	Vivianite	$Fe_3(PO_4)_2 \cdot 8H_2O$
40.2.15.2	Erythrite	$Co_3(AsO_4)_2 \cdot 8H_2O$
40.2.15.4	Koettigite	$Zn_3(AsO_4)_2 \cdot 8H_2O$
40.2.15.5	Symplesite	$Fe_3(AsO_4)_2 \cdot 8H_2O$

40.2.16	Bobierrite	$Mg_3(PO_4)_2 \cdot 8H_2O$
40.2.17	Hoernesite	$Mg_3(AsO_4)_2 \cdot 8H_2O$

Type 3. $A(XO_4)\cdot xH_2O$

40.3.1	Variscite group	
40.3.1.1	Variscite	$Al(PO_4)\cdot 2H_2O$
40.3.1.2	Strengite	$Fe(PO_4)\cdot 2H_2O$
40.3.1.3	Scorodite	$Fe(AsO_4)\cdot 2H_2O$
40.3.1.4	Mansfieldite	$Al(AsO_4)\cdot 2H_2O$
40.3.2	Metavariscite group	
40.3.2.1	Metavariscite	$Al(PO_4)\cdot 2H_2O$
40.3.2.2	Metastrengite	$Fe(PO_4)\cdot 2H_2O$
40.3.3	Weinschenkite	$(Y,Er)(PO_4)\cdot 2H_2O$
40.3.4	Churchite	$(Ce,Ca)(PO_4)\cdot 2H_2O$
40.3.5	Rhabdophane	$(Ce,Y)(PO_4)\cdot H_2O$

CLASS 41. Anhydrous phosphates, etc., containing hydroxyl or halogen

Type 1. $A_m(XO_4)_pZ_q$, with $m:p > 4:1$

41.1.1	Sahlinite	$Pb_{14}(AsO_4)_2O_9Cl$
41.1.2	Holdenite	$(Mn'',Ca)_4(Zn,Mg,Fe'')_2(AsO_4)(OH)_5O_2$ (?)
41.1.3	Hematolite	$(Mn'',Mg)_4Al(AsO_4)(OH)_8$
41.1.4	Chlorophoenicite group	
41.1.4.1	Chlorophoenicite	$(Zn,Mn)_5(AsO_4)(OH)_7$
41.1.4.2	Magnesium-chlorophoenicite	$Mg_5(AsO_4)(OH)_7$
41.1.5	Synadelphite	$(Mn,Mg,Ca,Pb)_4(AsO_4)(OH)_5$

Type 2. $A_7(XO_4)_2Z_q$

41.2.1	Lacroixite	Na,Ca,Al fluo-phosphate
41.2.2	Morinite	Na,Ca,Al fluo-phosphate
41.2.3	Ježekite	$Na_4CaAl_2(PO_4)_2(OH)_2F_2O$ (?)
41.2.4	Allactite	$Mn_7(AsO_4)_2(OH)_8$

Type 3. $A_3(XO_4)Z_q$

41.3.1	Clinoclase	$Cu_3(AsO_4)(OH)_3$
41.3.2	Cornetite	$Cu_3(PO_4)(OH)_3$
41.3.3	Georgiadesite	$Pb_3(AsO_4)Cl_3$
41.3.4	Atelestite	$Bi_3(AsO_4)O_2(OH)_2$ (?)
41.3.5	Flinkite	$Mn_2''Mn'''(AsO_4)(OH)_4$
41.3.6	Retzian	

Type 4. $(AB)_5(XO_4)_2Z_q$

41.4.1	Walpurgite	$Bi_4(UO_2)(AsO_4)O_4\cdot 3H_2O$
41.4.2	Erinite	$Cu_5(AsO_4)_2(OH)_4$
41.4.3	Pseudomalachite	$Cu_5(PO_4)_2(OH)_4\cdot H_2O$ (?)
41.4.4	Arsenoclasite	$Mn_5(AsO_4)_2(OH)_4$
41.4.5	Andrewsite	$(Cu,Fe'')_3Fe_6'''(PO_4)_4(OH)_{12}$
41.4.6	Laubmannite	$Fe_3''Fe_6'''(PO_4)_4(OH)_{12}$

Type 5. $AB(XO_4)Z_q$

41.5.1	Adelite group	
41.5.1.1	Adelite	$CaMg(AsO_4)(OH,F)$
41.5.1.2	Conichalcite	$CaCu(AsO_4)(OH)$
41.5.1.3	Austinite	$CaZn(AsO_4)(OH)$
41.5.1.4	Duftite	$PbCu(AsO_4)(OH)$
41.5.2	Descloizite group	
41.5.2.1	Descloizite	$ZnPb(VO_4)(OH)$
41.5.2.2	Mottramite	$CuPb(VO_4)(OH)$
41.5.2.3	Pyrobelonite	$MnPb(VO_4)(OH)$
41.5.2.4	Calciovolborthite	$CuCa(VO_4)(OH)$

Type 5. $AB(XO_4)Z_q$—*Continued*

41.5.2.5	Turanite	$Cu_2(VO_4)(OH)$ (?)
41.5.3	Volborthite	Cu vanadate
41.5.4	Herderite series	
41.5.4.1	Herderite	$CaBe(PO_4)(F,OH)$
41.5.4.2	Hydroxyl-herderite	$CaBe(PO_4)(OH,F)$
41.5.5	Amblygonite series	
41.5.5.1	Amblygonite	$(Li,Na)Al(PO_4)(F,OH)$
41.5.5.2	Montebrasite	$(Li,Na)Al(PO_4)(OH,F)$
41.5.5.3	Natromontebrasite	$(Na,Li)Al(PO_4)(F,OH)$
41.5.6	Tilasite	$CaMg(AsO_4)F$
41.5.7	Durangite	$NaAl(AsO_4)F$
41.5.8	Plumbogummite group	
41.5.8.1	Plumbogummite	$PbAl_3(PO_4)_2(OH)_5H_2O$
41.5.8.2	Gorceixite	$BaAl_3(PO_4)_2(OH)_5H_2O$
41.5.8.3	Goyazite	$SrAl_3(PO_4)_2(OH)_5H_2O$
41.5.8.4	Crandallite	$CaAl_3(PO_4)_2(OH)_5H_2O$
41.5.8.5	Deltaite	$Ca(Al_2Ca)(PO_4)_2(OH)_4H_2O$
41.5.8.6	Florencite	$CeAl_3(PO_4)_2(OH)_6$
41.5.8.7	Dussertite	$BaFe_3(AsO_4)_2(OH)_5H_2O$
41.5.9	Chenevixite	$Cu_2Fe_2(AsO_4)_2(OH)_4 \cdot H_2O$ (?)
41.5.10	Brazilianite	$NaAl_3(PO_4)_2(OH)_4$
41.5.11	Griphite	$(Na,Ca,Fe,Al)_3Mn_2(PO_4)_{2.5}(OH,F)_2$
41.5.12	Arseniopleite	Mn basic arsenate

Type 6. $A_2(XO_4)Z_q$

41.6.1	Wagnerite	$Mg_2(PO_4)F$
41.6.2	Triplite	$(Mn'',Fe'')(PO_4)F$
41.6.3	Triploidite group	
41.6.3.1	Triploidite	$(Mn'',Fe'')_2(PO_4)(OH)$
41.6.3.2	Wolfeite	$(Fe'',Mn'')_2(PO_4)(OH)$
41.6.3.3	Sarkinite	$Mn_2(AsO_4)(OH)$
41.6.4	Sarcopside	$(Fe,Mn,Ca)_7(PO_4)_4F_2$ (?)
41.6.5	Olivenite group	
41.6.5.1	Olivenite	$Cu_2(AsO_4)(OH)$
41.6.5.2	Libethenite	$Cu_2(PO_4)(OH)$
41.6.5.3	Adamite	$Zn_2(AsO_4)(OH)$
41.6.6	Frondelite series	
41.6.6.1	Frondelite	$Mn''Fe_4'''(PO_4)_3(OH)_5$
41.6.6.2	Rockbridgeite	$Fe''Fe_4'''(PO_4)_3(OH)_5$
41.6.7	Tarbuttite	$Zn_2(PO_4)(OH)$
41.6.8	Augelite	$Al_2(PO_4)(OH)_3$
41.6.9	Dufrenite	$Fe''Fe_4'''(PO_4)_3(OH)_5 \cdot 2H_2O$ (?)
41.6.10	Dewindtite	$Pb_3(UO_2)_5(PO_4)_4(OH)_4 \cdot 10H_2O$
41.6.11	Phosphuranylite	Ca uranyl phosphate

Type 7. $A_5(XO_4)_3Z_q$

41.7.1	Apatite series	
41.7.1.1	Fluorapatite	$Ca_5(PO_4)_3F$
41.7.1.2	Chlorapatite	$Ca_5(PO_4)_3Cl$
41.7.1.3	Hydroxylapatite	$Ca_5(PO_4)_3(OH)$
41.7.1.4	Carbonate-apatite	$\sim Ca_{10}(PO_4)_6(CO_3) \cdot H_2O$
41.7.2	Pyromorphite series	
41.7.2.1	Pyromorphite	$Pb_5(PO_4)_3Cl$
41.7.2.2	Mimetite	$Pb_5(AsO_4)_3Cl$
41.7.2.3	Vanadinite	$Pb_5(VO_4)_3Cl$
41.7.3	Svabite series	

Type 7. $A_5(XO_4)_3Z_q$—*Continued*

41.7.3.1	Svabite	$Ca_5(AsO_4)_3(F,OH)$
41.7.3.2	Hedyphane	$(Ca,Pb)_5(AsO_4)_3Cl$

41.7.4	Dehrnite	$(Ca,Na,K)_5(PO_4)_3(OH)$
41.7.5	Lewistonite	$(Ca,K,Na)_5(PO_4)_3(OH)$
41.7.6	Fermorite	$(Ca,Sr)_5(P,AsO_4)_3(F,OH)$
41.7.7	Wilkeite	$Ca_5(P,S,Si,CO_4)_3(OH)$
41.7.8	Ellestadite	$Ca_5(Si,S,P)_3(Cl,F,OH)$
41.7.9	Tavistockite	$Ca_3Al_2(PO_4)_2(OH)_6$
41.7.10	Arsenobismite	Bi basic arsenate

Type 8. $(AB)_3(XO_4)_2Z_q$

41.8.1	Lazulite series	
41.8.1.1	Lazulite	$(Mg,Fe'')Al_2(PO_4)_2(OH)_2$
41.8.1.2	Scorzalite	$(Fe'',Mg)Al_2(PO_4)_2(OH)_2$
41.8.2	Souzalite	$(Mg,Fe'')_3(Al,Fe''')_4(PO_4)_4(OH)_6 \cdot 2H_2O$
41.8.3	Carminite	$PbFe_2(AsO_4)_2(OH)_2$
41.8.4	Parsonsite	$Pb_2(UO_2)(PO_4)_2 \cdot 2H_2O$

CLASS 42. Hydrated phosphates, etc., containing hydroxyl or halogen

Type 1. $(AB)_m(XO_4)_pZ_q \cdot xH_2O$, with $m:p > 3:1$

42.1.1	Borickite	$CaFe_5(PO_4)_2(OH)_{11} \cdot 3H_2O$

Type 2. $(AB)_3(XO_4)Z_q \cdot xH_2O$

42.2.1	Veszelyite	$(Cu,Zn)_3(As,PO_4)(OH)_3 \cdot 2H_2O$
42.2.2	Tsumebite	$Pb_2Cu(PO_4)(OH)_3 \cdot 3H_2O$
42.2.3	Hemafibrite	$Mn_3(AsO_4)(OH)_3 \cdot H_2O$
42.2.4	Freirinite	$Na_3Cu_3(AsO_4)_2(OH)_3 \cdot H_2O$
42.2.5	Liroconite	$Cu_2Al(AsO_4)(OH)_4 \cdot 4H_2O$
42.2.6	Evansite	$Al_3(PO_4)(OH)_6 \cdot 6H_2O$
42.2.7	Liskeardite	$(Al,Fe)_3(AsO_4)(OH)_6 \cdot 5H_2O$

Type 3. $(AB)_5(XO_4)_2Z_q \cdot xH_2O$

42.3.1	Cornwallite	$Cu_5(AsO_4)_2(OH)_4 \cdot H_2O$
42.3.2	Tyrolite	$Cu_5Ca(AsO_4)_2(CO_3)(OH)_4 \cdot 6H_2O$ (?)
42.3.3	Akrochordite	$MgMn_4(AsO_4)_2(OH)_4 \cdot 4H_2O$ (?)
42.3.4	Ceruleite	$CuAl_4(AsO_4)_2(OH)_8 \cdot 4H_2O$
42.3.5	Renardite	$Pb(UO_2)_4(PO_4)_2(OH)_4 \cdot 7H_2O$
42.3.6	Dumontite	$Pb_2(UO_2)_3(PO_4)_2(OH)_4 \cdot 3H_2O$

Type 4. $A_2(XO_4)Z_q \cdot xH_2O$

42.4.1	Bayldonite	$(Cu,Pb)_2(AsO_4)(OH)$ (?)
42.4.2	Leucochalcite	$Cu_2(AsO_4)(OH) \cdot H_2O$
42.4.3	Tagilite	$Cu_2(PO_4)(OH) \cdot H_2O$
42.4.4	Spencerite	$Zn_4(PO_4)_2(OH)_2 \cdot 3H_2O$
42.4.5	Isoclasite	$Ca_2(PO_4)(OH) \cdot 2H_2O$
42.4.6	Euchroite	$Cu_2(AsO_4)(OH) \cdot 3H_2O$
42.4.7	Delvauxite	$Fe_2(PO_4)(OH)_3 \cdot xH_2O$ (?)

Type 5. $(AB)_m(XO_4)_pZ_q \cdot xH_2O$, with $m:p = 2:1$

42.5.1	Leucophosphite	$K_2(Fe,Al)_7(PO_4)_4(OH)_{11} \cdot 6H_2O$
42.5.2	Childrenite series	
42.5.2.1	Childrenite	$(Fe'',Mn'')Al(PO_4)(OH)_2 \cdot H_2O$
42.5.2.2	Eosphorite	$(Mn'',Fe'')Al(PO_4)(OH)_2 \cdot H_2O$
42.5.3	Davisonite	$Ca_3Al(PO_4)_2(OH)_3 \cdot H_2O$ (?)

Type 5. $(AB)_m(XO_4)_pZ_q \cdot xH_2O$, with $m:p = 2:1$—*Continued*

42.5.4	Wardite	$Na_4CaAl_{12}(PO_4)_8(OH)_9 \cdot 3H_2O$
42.5.5	Millisite	$(Na,K)CaAl_6(PO_4)_4(OH)_9 \cdot 3H_2O$
42.5.6	Lehiite	$(Na,K)_2Ca_5Al_8(PO_4)_8(OH)_{12} \cdot 6H_2O$ (?)
42.5.7	Mixite	$Cu_{11}Bi(AsO_4)_5(OH)_{10} \cdot 6H_2O$ (?)

Type 6. $(AB)_m(XO_4)_pZ_q \cdot xH_2O$, with $m:p = 7:4$

42.6.1	Sampleite	$NaCaCu_5(PO_4)_4Cl \cdot 5H_2O$
42.6.2	Turquois group	
42.6.2.1	Turquois	$CuAl_6(PO_4)_4(OH)_8 \cdot 4H_2O$
42.6.2.2	Chalcosiderite	$CuFe_6(PO_4)_4(OH)_8 \cdot 4H_2O$
42.6.3	Ludlamite	$(Fe'',Mg,Mn)_3(PO_4)_2 \cdot 4H_2O$
42.6.4	Arseniosiderite	$Ca_3Fe_4(AsO_4)_4(OH)_4 \cdot 4H_2O$ (?)
42.6.5	Eguëite	$CaFe_{14}'''(PO_4)_{10}(OH)_{14} \cdot 21H_2O$ (?)
42.6.6	Mitridatite	Ca,Fe phosphate
42.6.7	Richellite	Ca,Fe phosphate
42.6.8	Englishite	$K_2Ca_4Al_8(PO_4)_8(OH)_{10} \cdot 9H_2O$

Type 7. $A_3(XO_4)_2Z_q \cdot xH_2O$

42.7.1	Legrandite	$Zn_{14}(AsO_4)_9(OH) \cdot 12H_2O$
42.7.2	Beraunite	$Fe''Fe_4'''(PO_4)_3(OH)_5 \cdot 3H_2O$ (?)
42.7.3	Coeruleolactite	$Al_3(PO_4)_2(OH)_3$
42.7.4	Wavellite	$Al_3(PO_4)_2(OH)_3 \cdot 5H_2O$
42.7.5	Sterrettite	$Al_6(PO_4)_4(OH)_6 \cdot 5H_2O$
42.7.6	Troegerite	$(UO_2)_3(AsO_4)_2 \cdot 12H_2O$

Type 8. $(AB)_m(XO_4)_pZ_q \cdot xH_2O$, with $m:p = 3:2$

42.8.1	Bermanite	$(Mn,Mg)_5(Mn,Fe)_8(PO_4)_8(OH)_{10} \cdot 15H_2O$ (?)
42.8.2	Roscherite	$(Ca,Mn,Fe)_2Al(PO_4)_2(OH) \cdot 2H_2O$
42.8.3	Minyulite	$KAl_2(PO_4)_2(OH) \cdot 3\frac{1}{2}H_2O$ (?)
42.8.4	Tinticite	$Fe_3'''(PO_4)_2(OH)_3 \cdot 3\frac{1}{2}H_2O$
42.8.5	Metavauxite	$FeAl_2(PO_4)_2(OH)_2 \cdot 8H_2O$
42.8.6	Paravauxite	$FeAl_2(PO_4)_2(OH)_2 \cdot 8H_2O$
42.8.7	Vauxite	$FeAl_2(PO_4)_2(OH)_2 \cdot 7H_2O$
42.8.8	Gordonite	$MgAl_2(PO_4)_2(OH)_2 \cdot 8H_2O$
42.8.9	Calcioferrite	$Ca_3Fe_3(PO_4)_4(OH)_3 \cdot 8H_2O$ (?)
42.8.10	Xanthoxenite	$Ca_2Fe(PO_4)_2(OH) \cdot 1\frac{1}{2}H_2O$
42.8.11	Montgomeryite	$Ca_4Al_5(PO_4)_6(OH)_5 \cdot 11H_2O$
42.8.12	Overite	$Ca_3Al_8(PO_4)_8(OH)_6 \cdot 15H_2O$
42.8.13	Torbernite group	
42.8.13.1	Torbernite	$Cu(UO_2)_2(PO_4)_2 \cdot 8\text{–}12H_2O$
42.8.13.2	Autunite	$Ca(UO_2)_2(PO_4)_2 \cdot 10\text{–}12H_2O$
42.8.13.3	Uranocircite	$Ba(UO_2)_2(PO_4)_2 \cdot 8H_2O$
42.8.13.4	Saléeite	$Mg(UO_2)_2(PO_4)_2 \cdot 10H_2O$
42.8.13.5	Zeunerite	$Cu(UO_2)_2(AsO_4)_2 \cdot 10\text{–}16H_2O$
42.8.13.6	Uranospinite	$Ca(UO_2)_2(AsO_4)_2 \cdot 8H_2O$
42.8.14	Metatorbernite group	
42.8.14.1	Metatorbernite	$Cu(UO_2)_2(PO_4)_2 \cdot 8H_2O$
	Meta-autunite	$Ca(UO_2)_2(PO_4)_2 \cdot 2\text{–}6H_2O$
42.8.14.2	Metazeunerite	$Cu(UO_2)_2(AsO_4)_2 \cdot 8H_2O$
42.8.15	Bassetite	Fe'' uranyl phosphate

Type 9. $(AB)_m(XO_4)_pZ_q \cdot xH_2O$, with $m:p < 3:2$

42.9.1	Pharmacosiderite	$Fe_3(AsO_4)_2(OH)_3 \cdot 5H_2O$
42.9.2	Cacoxenite	$Fe_4(PO_4)_3(OH)_3 \cdot 12H_2O$
42.9.3	Vashegyite	$Al_4(PO_4)_3(OH)_3 \cdot nH_2O$ (?)
42.9.4	Taranakite	$K_2Al_6(PO_4)_6(OH)_2 \cdot 18H_2O$ (?)

CLASS 43. Compound phosphates, etc.

Type 1. $AB(XO_4)Z_q$

43.1.1	Beudantite group	
43.1.1.1	Beudantite	$PbFe_3(AsO_4)(SO_4)(OH)_6$
43.1.1.2	Corkite	$PbFe_3(PO_4)(SO_4)(OH)_6$
43.1.1.3	Hinsdalite	$(Pb,Sr)Al_3(PO_4)(SO_4)(OH)_6$
43.1.1.4	Svanbergite	$SrAl_3(PO_4)(SO_4)(OH)_6$
43.1.1.5	Woodhouseite	$CaAl_3(PO_4)(SO_4)(OH)_6$
43.1.2	Lindackerite	$Cu_6Ni_3(AsO_4)_4(SO_4)(OH)_4 \cdot 5H_2O$ (?)

Type 2. Miscellaneous

43.2.1	Chalcophyllite	$Cu_{18}Al_2(AsO_4)_3(SO_4)_3(OH)_{27} \cdot 33H_2O$
43.2.2	Ardealite	$Ca_2H(PO_4)(SO_4) \cdot 4H_2O$
43.2.3	Kribergite	$Al_4(PO_4)_2(SO_4)_2(OH)_2 \cdot 8H_2O$ (?)
43.2.4	Diadochite	$Fe_2(PO_4)(SO_4)(OH) \cdot 5H_2O$
43.2.5	Sarmientite	$Fe_2(AsO_4)(SO_4)(OH) \cdot 5H_2O$
43.2.6	Pitticite	Fe sulfate-arsenate
43.2.7	Kolbeckite	Ca,Be,Al silicate-phosphate
	Vauquelinite	[with chromates]
	Lunebergite	[with borates]
	Cahnite	[with borates]
	Seamanite	[with borates]
	Bradleyite	[with carbonates]

37 ANHYDROUS ACID PHOSPHATES, ETC.

TYPE 1. MISCELLANEOUS

37.1.1 **MONETITE** [$CaH(PO_4)$]. *Shepard* (*Am. J. Sc.*, **23**, 400, 1882). Glaubapatite pt. *Shepard* (*Am. J. Sc.*, **22**, 96, 1856).

Cryst.[1] Triclinic; pinacoidal—$\bar{1}$.

$a:b:c = 0.8244:1:0.6467;$ α 89°43′, β 95°03′, γ 94°22′

$p_0:q_0:r_0 = 0.7867:0.6461:1;$ λ 89°54′, μ 84°57½′, ν 85°38½′

p_0' 0.7898, q_0' 0.6486, x_0' 0.0883, y_0' 0.0018

Forms:[2]

	ϕ	ρ	A	B	C
c 001	88°50′	5°03′	84°57½′	89°54′	.....
b 010	0 00	90 00	85 38½	.....	89°54′
m 110	47 46½	90 00	37 52	47 46½	86 12
e 101	85 34½	41 18	48 49½	87 34½	36 00
E $\bar{1}01$	−84 45½	35 04½	124 31	86 59½	39 33½
x 121	65 53	43 49	49 20	73 34	39 12½
s 321	58 45	70 46	32 38½	60 40½	66 25½
t $\bar{1}21$	−27 11	56 30	108 57	41 52	59 26½

Habit. As massive aggregates of minute crystals; also as crusts or stalactites with rough crystalline surfaces. Crystals small with rough faces,

ANTIMONATES; ANTIMONITES AND ARSENITES

CLASS 44.	Antimonates	
Type 1.	$A_2X_2O_6(O,OH,F)$	
44.1.1	Bindheimite group	
44.1.1.1	Bindheimite	$Pb_2Sb_2O_6(O,OH)$
44.1.1.2	Romeite	$Ca_2Sb_2O_6(O,OH,F)$
44.1.2	Monimolite	$(Pb,Ca)_3Sb_2O_8$ (?)
44.1.3	Tripuhyite	$Fe_2Sb_2O_7$ (?)
44.1.4	Flajolotite	$FeSbO_4 \cdot \frac{3}{4}H_2O$ (?)
Type 2.	Miscellaneous	
44.2.1	Derbylite	$Fe_6Ti_6Sb_2O_{23}$ (?)
44.2.2	Swedenborgite	$NaBe_4SbO_7$
44.2.3	Catoptrite	Mn,Al antimonate-silicate
CLASS 45.	Acid and normal antimonites and arsenites	
Type 1.	Miscellaneous	
45.1.1	Armangite	$Mn_3(AsO_3)_2$
45.1.2	Trigonite	$MnPb_3H(AsO_3)_3$
45.1.3	Trippkeite	$CuAs_2O_4$
45.1.4	Schafarzikite	$FeSb_2O_4$
CLASS 46.	Basic or halogen-containing antimonites, arsenites	
Type 1.	Miscellaneous	
46.1.1	Ecdemite	$Pb_6As_2O_7Cl_4$ (?)
46.1.2	Heliophyllite	$Pb_6As_2O_7Cl_4$ (?)
46.1.3	Finnemanite	$Pb_5(AsO_3)_3Cl$
46.1.4	Nadorite	$PbSbO_2Cl$
46.1.5	Melanostibian	$(Mn,Fe)_6(SbO_3)_2O_3$

44 ANTIMONATES

TYPE 1. $A_2X_2O_6(O,OH,F)$

44.1.1 BINDHEIMITE GROUP

ISOMETRIC; HEXOCTAHEDRAL—$4/m\,\bar{3}\,2/m$

	a_0
Bindheimite, $Pb_2Sb_2O_6(O,OH)$	10.4 kX
Romeite, $Ca_2Sb_2O_6(O,OH,F)$	10.25
Monimolite, $(Pb,Ca)_3Sb_2O_8$ (?)	

Bindheimite and romeite have crystal structures [1] of the pyrochlore type, $A_2B_2O_6(O,OH,F)$, and are probably best classed as multiple oxides rather than among anisodesmic compounds. The ill-defined hydroromeite may

VANADIUM OXYSALTS

Vanadium is very similar in the chemistry of its oxysalts to both phosphorus and arsenic. In the orthovanadates, V occurs in tetrahedral coordination with oxygen to give anisodesmic compounds with discrete $(VO_4)^{\equiv}$ groups. These compounds generally are isostructural with phosphates and arsenates of the same formula type, and V can substitute serially therein to a greater or less extent for As and P. In this work, vanadates of this nature have been described with the phosphates and arsenates. A number of other natural vanadium oxysalts are known, however, in which the nature of the anionic configuration is unknown. Some of these apparently contain polynuclear complexes, and others contain V in several different valences. These minerals are here gathered together for convenience of reference into a single class and are arranged arbitrarily in decreasing ratio of cations to V.

Class 47. Vanadium Oxysalts

Type 1. Miscellaneous

47.1.1	Carnotite	$K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$
47.1.2	Tyuyamunite	$Ca(UO_2)_2(VO_4)_2 \cdot nH_2O$
47.1.3	Sengierite	$Cu(UO_2)(VO_4)(OH) \cdot 4\text{–}5H_2O$ (?)
47.1.4	Ferghanite	$U_3(VO_4)_2 \cdot 6H_2O$
47.1.5	Kolovratite	Ni vanadate ?
47.1.6	Fervanite	$Fe_4V_4O_{16} \cdot 5H_2O$
47.1.7	Steigerite	$Al_2(VO_4)_2 \cdot 6\frac{1}{2}H_2O$
47.1.8	Pucherite	$Bi(VO_4)$
47.1.9	Brackebuschite	$Pb_4MnFe(VO_4)_4 \cdot 2H_2O$
47.1.10	Pintadoite	$Ca_2V_2O_7 \cdot 9H_2O$
47.1.11	Rossite	$CaV_2O_6 \cdot 4H_2O$
47.1.12	Metarossite	$CaV_2O_6 \cdot 2H_2O$
47.1.13	Pascoite	$Ca_2V_6O_{17} \cdot 11H_2O$
47.1.14	Uvanite	$U_2V_6O_{21} \cdot 15H_2O$
47.1.15	Sincosite	$Ca(VO)_2(PO_4)_2 \cdot 5H_2O$
47.1.16	Rauvite	$CaU_2V_{12}O_{36} \cdot 20H_2O$
47.1.17	Melanovanadite	$Ca_2V_4^4V_6^5O_{25}$
47.1.18	Hewettite	$CaV_6O_{16} \cdot 9H_2O$
47.1.19	Metahewettite	$CaV_6O_{16} \cdot 9H_2O$
47.1.20	Fernandinite	$CaO \cdot V_2O_4 \cdot 5V_2O_5 \cdot 14H_2O$

MOLYBDATES AND TUNGSTATES

The molybdates and tungstates are anisodesmic oxysalts that contain distorted $(XO_4)^=$ groups, in which X is Mo or W. The distortion is of the nature of a compression along a twofold axis of the idealized tetrahedral group, and the anion is intermediate in shape between the symmetrical coordination tetrahedra of the sulfates and phosphates and the planar, quadrilateral coordination groups such as in $K_2(PtCl_4)$. Because of the distorted shape and relatively large size of the anion in molybdates and tungstates there are no substitutional series between them and sulfates. Partial or complete anionic series are found between isostructural molybdates and tungstates, as in the Scheelite and Wulfenite Groups.

CLASS 48. Normal anhydrous molybdates and tungstates

Type 1. $A(XO_4)$

48.1.1	Wolframite group	
48.1.1.1	Huebnerite	$Mn(WO_4)$
48.1.1.2	Wolframite	$(Fe,Mn)(WO_4)$
48.1.1.3	Ferberite	$Fe(WO_4)$
48.1.2	Sanmartinite	$(Zn,Fe)(WO_4)$
48.1.3	Scheelite group	
48.1.3.1	Scheelite	$Ca(WO_4)$
48.1.3.2	Powellite	$Ca(MoO_4)$
48.1.4	Wulfenite group	
48.1.4.1	Wulfenite	$Pb(MoO_4)$
48.1.4.2	Stolzite	$Pb(WO_4)$
48.1.5	Raspite	$Pb(WO_4)$

CLASS 49. Basic and hydrated molybdates and tungstates

Type 1. Miscellaneous

49.1.1	Cuprotungstite	$Cu_2(WO_4)(OH)_2$
49.1.2	Koechlinite	$(BiO)_2(MoO_4)$
49.1.3	Ferritungstite	$Fe_2(WO_4)(OH)_4 \cdot 4H_2O$ (?)
49.1.4	Lindgrenite	$Cu_3(MoO_4)_2(OH)_2$
49.1.5	Ferrimolybdite	$Fe_2(MoO_4)_3 \cdot 8H_2O$ (?)
49.1.6	Thorotungstite	Th,Al tungstate (?)
49.1.7	Anthoinite	$Al(WO_4)(OH) \cdot H_2O$

ORGANIC COMPOUNDS

The only natural organic compounds considered in the present volume are the salts between inorganic cations (including ammonium) and organic acids. These include the oxalates together with the mellates, citrates, sulfocyanates, and acetates. The very numerous natural oxygen-free and oxygenated hydrocarbons will be treated in Volume III of this work.

Class 50. Salts of organic acids

Type 1.	Oxalates	
50.1.1	Whewellite	$CaC_2O_4 \cdot H_2O$
50.1.2	Weddellite	$CaC_2O_4 \cdot 2H_2O$
50.1.3	Humboldtine	$FeC_2O_4 \cdot 2H_2O$
50.1.4	Oxammite	$(NH_4)_2C_2O_4 \cdot H_2O$
Type 2.	Mellates, Citrates, Sulfocyanates, Acetates	
50.2.1	Mellite	$Al_2C_{12}O_{12} \cdot 18H_2O$
50.2.2	Earlandite	$Ca_3(C_6H_5O_7)_2 \cdot 4H_2O$
50.2.3	Julienite	$Na_2Co(SCN)_4 \cdot 8H_2O$
50.2.4	Calclacite	$CaCl(C_2H_3O_2) \cdot 5H_2O$

50 SALTS OF ORGANIC ACIDS

TYPE 1. OXALATES

50.1.1 **WHEWELLITE** [$Ca(C_2O_4) \cdot H_2O$]. Oxalate of Lime *Brooke* (*Phil. Mag.*, **16**, 449, 1840). Oxacalcite *Shepard* (111, 1844). Whewellite *Brooke* and *Miller* (623, 1852). Kohlenspath *Frenzel* (*Min. Mitt.*, **11**, 83, 1889). Thierschite *Liebig* (*Ann. Chemie*, **86**, 113, 1853).

Cryst.[1] Monoclinic; prismatic—$2/m$.

$a:b:c = 0.8696:1:1.3695$; $\beta\ 107°18\frac{1}{2}'$; $p_0:q_0:r_0 = 1.5749:1.3075:1$

$r_2:p_2:q_2 = 0.7648:1.2045:1$; $\mu\ 72°41\frac{1}{2}'$; $p_0'\ 1.6496$, $q_0'\ 1.3695$, $x_0'\ 0.3116$

Forms:[2]

	ϕ	ρ	ϕ_2	$\rho_2 = B$	C	A
c 001	90°00′	17°18½′	72°41½′	90°00′	.....	72°41½′
b 010	0 00	90 00	.....	0 00	90°00′	90 00
u 120	31 03½	90 00	0 00	31 03½	81 10	58 56½
m 110	50 18	90 00	0 00	50 18	76 46	39 42
z 014	42 18½	24 50½	72 41½	71 54	18 06	73 34½
y 012	24 28	36 57½	72 41½	56 49½	33 10½	75 35
x 011	12 49	54 33	72 41½	37 24½	52 35½	79 35½
k 102	90 00	48 39	41 21	90 00	31 20½	41 21
e $\bar{1}01$	−90 00	53 13½	143 13½	90 00	70 32	143 13½
f 112	58 55½	52 59½	41 21	65 39½	38 54½	46 50½
s $\bar{1}32$	−14 01½	64 43	117 10	28 41	69 58½	102 39½

MINERAL INDEX

Name, p.	Composition	Xl. Sys.	G.	H.	Remarks
Acadialite, 509					See chabazite
Acanthite, 247	Ag_2S	Mon	7.2–7.3	2–2½	Low temp. Ag_2S
Achroite, 427					Colorless tourmaline
Acmite, 439	$NaFe'''(Si_2O_6)$	Mon	3.5	6–6½	A pyroxene
Actinolite, 445	$Ca_2(Mg,Fe)_5(Si_8O_{22})(OH)_2$	Mon	3.0–3.2	5–6	An amphibole
Adularia, 491					See orthoclase
Aegirite, 439	$NaFe'''(Si_2O_6)$	Mon	3.40–3.55	6–6½	A pyroxene
Aenigmatite, 413	$(Na,Ca)_4(Fe'',Fe''',Mn,Ti,Al)_{13}(Si_2O_7)_6$	Tric	3.75	5½	Cl{110}
Agate, 482					See quartz
Alabandite, 252	MnS	Iso	4.0	3½–4	Black
Alabaster, 366					See gypsum
Albite, 495	$Na(AlSi_3O_8)$—$Ab_{90}An_{10}$	Tric	2.62	6	A feldspar
Alexandrite, 311					Gem chrysoberyl
Allanite, 419	$X_2Y_3O(SiO_4)(Si_2O_7)(OH)$	Mon	3.5–4.2	5½–6	Brown-black
Allemontite, 235	AsSb	Hex	5.8–6.2	3–4	One cleavage
Almandite, 403	$Fe_3Al_2(SiO_4)_3$	Iso	4.25	7	A garnet
Altaite, 252, 274	PbTe	Iso	8.16	3	Tin-white
Alumstone, 369					See alunite
Alunite, 369	$KAl_3(OH)_6(SO_4)_2$	Rho	2.6–2.8	4	Usually massive
Amalgam, 229					See silver
Amazonstone, 494					Green microcline
Amblygonite, 378	$LiAlFPO_4$	Tric	3.0–3.1	6	Fusible at 2
Amethyst, 481					Purple quartz
Amphibole, 443					A mineral group
Analcime, 507	$Na(AlSi_2O_6)H_2O$	Iso	2.27	5–5½	A feldspathoid
Anatase, 297	TiO_2	Tet	3.9	5½–6	Adamantine luster
Anauxite, 462		Mon	2.6	2	Si-rich kaolinite
Andalusite, 406	Al_2SiO_5	Orth	3.16–3.20	7½	Infusible
Andesine, 499	$Ab_{70}An_{30}$—$Ab_{50}An_{50}$	Tric	2.69	6	Plagioclase feldspar
Andradite, 403	$Ca_3Fe_2(SiO_4)_3$	Iso	3.75	7	A garnet
Anglesite, 362	$PbSO_4$	Orth	6.2–6.4	3	Cl {001} {110}
Anhydrite, 363	$CaSO_4$	Orth	2.89–2.98	3–3½	Cl{100} {010} {001}
Ankerite, 339	$CaCO_3 \cdot (Mg,Fe,Mn)CO_3$	Rho	2.95–3	3½	Cl {10$\bar{1}$1}
Annabergite, 383	$Ni_3(AsO_4)_2 \cdot 8H_2O$	Mon	3.0	2½–3	Nickel bloom. Green
Anorthite, 495	$Ab_{10}An_{90}$—$CaAl_2Si_2O_8$	Tric	2.76	6	Plagioclase feldspar
Anorthoclase, 494	$K(AlSi_3O_8)$—$Na(AlSi_3O_8)$	Tric	2.58	6	A feldspar
Anthophyllite, 443	$(Mg,Fe)_7(Si_8O_{22})(OH)_2$	Orth	2.85–3.2	5½–6	An amphibole
Antigorite, 463					See serpentine
Antimony, 234	Sb	Rho	6.7	3	Cl {0001}
Antlerite, 364	$Cu_3(OH)_4SO_4$	Orth	3.9 ±	3½–4	Green
Apatite, 373	$Ca_5(F,Cl,OH)(PO_4)_3$	Hex	3.15–3.20	5	Cl {0001} poor
Apophyllite, 460	$Ca_4K(Si_4O_{10})_2F \cdot 8H_2O$	Tet	2.3–2.4	4½–5	Cl {001}
Aquamarine, 425					See beryl
Aragonite, 344	$CaCO_3$	Orth	2.95	3½–4	Cl {010} {110}
Arfvedsonite, 446	$Na_3Mg_4Al(Si_8O_{22})(OH,F)_2$	Mon	3.45	6	An amphibole

MINERAL INDEX

Name, p.	Composition	Xl. Sys.	G.	H.	Remarks
Argentite, 247	Ag_2S	Iso	7.3	2–2½	Sectile
Arsenic, 235	As	Rho	5.7	3½	Cl {0001}
Arsenopyrite, 272	FeAsS	Mon	6.07±0.15	5½–6	Pseudo-orth.
Asbestos, 464					See amphibole and serpentine
Astrophyllite, 413	$(Na,Ca)_5(Fe'',Al,Ti)_{15}$-$(Si_2O_7)_6(F,OH)_8$	Orth	3.35	3	Micaceous cl.
Atacamite, 328	$Cu_2Cl(OH)_3$	Orth	3.75–3.77	3–3½	Cl {010}
Augite, 440	$(Ca,Na)(Mg,Fe'',Fe''',$-$Al)(Si,Al)_2O_6$	Mon	3.2–3.4	5–6	A pyroxene
Aurichalcite, 350	$2(Zn,Cu)CO_3 \cdot 3(Zn,Cu)$-$(OH)_2$	Mon	3.64	2	Green to blue
Autunite, 381	$Ca(UO_2)_2(PO_4)_2 \cdot$-$10\text{–}12H_2O$	Tet	3.1–3.2	2–2½	Yellow-green
Aventurine, 481					Oligoclase or qtz.
Axinite, 423	$Ca_2(Fe,Mn)Al_2(BO_3)$-$(Si_4O_{12})(OH)$	Tric	3.27–3.35	6½–7	Crystal angles acute
Azurite, 349	$Cu_3(CO_3)_2(OH)_2$	Mon	3.77	3½–4	Always blue
Balas ruby, 307					Red gem spinel
Barite, 359	$BaSO_4$	Orth	4.5	3–3½	Cl {001} {110}
Barytes, 359					See barite
Bauxite, 317	A mixture of aluminum hydroxides	Amor	2.0–2.55	1–3	An earthy rock
Beidellite, 462	$Al_8(Si_4O_{10})_3(OH)_{12} \cdot$-$12H_2O$	Orth?	2.6	1½	See kaolinite
Benitoite, 413	$BaTiSi_3O_9$	Hex	3.6	6½	Blue
Bentonite, 462					Montmorillonite
Beryl, 424	$Be_3Al_2(Si_6O_{18})$	Hex	2.75–2.8	7½–8	Usually green
Biotite, 470	$K(Mg,Fe)_3(AlSi_3O_{10})$-$(OH)_2$	Mon	2.8–3.2	2½–3	Black mica
Bismuth, 235	Bi	Rho	9.8	2–2½	Cl {0001}
Bismuthinite, 265	Bi_2S_3	Orth	6.78±0.03	2	Cl {010}
Black-band ore, 341					See siderite
Black jack, 252					See sphalerite
Black lead, 244					See graphite
Bloodstone, 482					Green and red chalcedony
Blue copper carbonate, 349					See azurite
Blue vitriol, 369					See chalcanthite
Boehmite, 317	$AlO(OH)$	Orth	3.01–3.06	.....	In bauxite
Bog-iron ore, 316					See limonite
Boracite, 353	$Mg_3B_7O_{13}Cl$	Orth	2.9–3.0	7	Pseudo-iso
Borax, 354	$Na_2B_4O_7 \cdot 10H_2O$	Mon	1.7±	2–2½	Cl {100}
Bornite, 249	Cu_5FeS_4	Iso	5.06–5.08	3	Purple-blue tarnish
Boulangerite, 283	$Pb_5Sb_4S_{11}$	Orth	6.0±	2½–3	Cl {001} {010}
Bournonite, 282	$PbCuSbS_3$	Orth	5.8–5.9	2½–3	Fusible at 1
Bravoite, 268	$(Ni,Fe)S_2$	Iso	4.66	5½–6	Steel gray
Brazilian emerald, 429					See tourmaline

MINERAL INDEX

Name, p.	Composition	Xl. Sys.	G.	H.	Remarks
Brittle mica, 472	. . . .	. . . .	. . . . . .	. . . .	See margarite
Brochantite, 365	$Cu_4(OH)_6SO_4$	Mon	3.9	$3\frac{1}{2}$–4	Cl {010}. Green
Bromyrite, 325	AgBr	Iso	5.9	1–$1\frac{1}{2}$	Sectile
Bronzite, 436	$(Mg,Fe)_2(Si_2O_6)$	Orth	3.3±	$5\frac{1}{2}$	See enstatite
Brookite, 297	TiO_2	Orth	3.9–4.1	$5\frac{1}{2}$–6	Adamantine luster
Brucite, 314	$Mg(OH)_2$	Rho	2.39	$2\frac{1}{2}$	Cl {0001}
Bytownite, 499	$Ab_{30}An_{70}$—$Ab_{10}An_{90}$	Tric	2.74	6	Plag. feldspar
Cairngorm stone, 481	. . . .	. . . .	. . . . . .	. . . .	See quartz
Calamine, 415	. . . .	. . . .	. . . . . .	. . . .	See hemimorphite
Calaverite, 274	$AuTe_2$	Mon	9.35	$2\frac{1}{2}$	Fusible at 1
Calcite, 334	$CaCO_3$	Rho	2.72	3	Cl {10$\bar{1}$1}
Californite, 420	. . . .	. . . .	. . . . . .	. . . .	See idocrase
Cancrinite, 502	$(Na,K)_{6-8}Al_6Si_6O_{24}$·$(CO_3)_{1-2}$·2–$3H_2O$	Hex	2.45	5–6	A feldspathoid
Capillary pyrites, 259	. . . .	. . . .	. . . . . .	. . . .	See millerite
Carnallite, 328	$KMgCl_3 \cdot 6H_2O$	Orth	1.6	1	Deliquescent
Carnelian, 482	. . . .	. . . .	. . . . . .	. . . .	Red chalcedony
Carnotite, 383	$K_2(UO_2)_2(VO_4)_2 \cdot nH_2O$	Orth	4.1	Soft	Yellow
Cassiterite, 299	SnO_2	Tet	6.8–7.1	6–7	Luster adamantine
Cat's-eye, 481	. . . .	. . . .	. . . . . .	. . . .	See chrysoberyl and quartz
Celestite, 361	$SrSO_4$	Orth	3.95–3.97	3–$3\frac{1}{2}$	Cl {001} {110}
Celsian, 491	$BaAl_2Si_2O_8$	Mon	3.37	6	A feldspar
Cerargyrite, 324	AgCl	Iso	5.5±	2–3	Perfectly sectile
Cerussite, 347	$PbCO_3$	Orth	6.55	3–$3\frac{1}{2}$	Effer. in HNO_3
Chabazite, 509	$(Ca,Na)_2(Al_2Si_4O_{12})$·$6H_2O$	Rho	2.05–2.15	4–5	Cubelike crystals
Chalcanthite, 369	$CuSO_4 \cdot 5H_2O$	Tric	2.12–2.30	$2\frac{1}{2}$	Soluble in water
Chalcedony, 482	. . . .	. . . .	. . . . . .	. . . .	Cryptocryst. quartz
Chalcocite, 248	Cu_2S	Orth	5.5–5.8	$2\frac{1}{2}$–3	Imperfectly sectile
Chalcopyrite, 255	$CuFeS_2$	Tet	4.1–4.3	$3\frac{1}{2}$–4	Brittle. Yellow
Chalcotrichite, 288	. . . .	. . . .	. . . . . .	. . . .	Fibrous cuprite
Chalk, 337	. . . .	. . . .	. . . . . .	. . . .	See calcite
Chalybite, 341	. . . .	. . . .	. . . . . .	. . . .	See siderite
Chert, 483	SiO_2	. . . .	2.65	7	Cryptocryst. quartz
Chessylite, 349	. . . .	. . . .	. . . . . .	. . . .	See azurite
Chiastolite, 406	. . . .	. . . .	. . . . . .	. . . .	See andalusite
Chloanthite, 275	. . . .	. . . .	. . . . . .	. . . .	Nickel skutterudite
Chlorite, 473	$Mg_3(Si_4O_{10})(OH)_2$·$Mg_3(OH)_6$	Mon	2.6–2.9	2–$2\frac{1}{2}$	Cl {001}
Chloritoid, 472	$(Fe,Mg)_2(Al_4Si_2O_{10})$-$(OH)_4$	Mon	3.5	6–7	Brittle mica
Chondrodite, 410	$Mg_5(SiO_4)_2(F,OH)_2$	Mon	3.1–3.2	6–$6\frac{1}{2}$	Yellow-red
Chromite, 310	$FeCr_2O_4$	Iso	4.6	$5\frac{1}{2}$	Luster submetallic
Chrysoberyl, 311	$BeAl_2O_4$	Orth	3.65–3.8	$8\frac{1}{2}$	Crystals tabular
Chrysocolla, 429	$CuSiO_3 \cdot 2H_2O$	?	2.0–2.4	2–4	Bluish green
Chrysolite, 400	. . . .	. . . .	. . . . . .	. . . .	See olivine
Chrysoprase, 482	. . . .	. . . .	. . . . . .	. . . .	Green chalcedony

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Name, p.	Composition	Xl. Sys.	G.	H.	Remarks
Digenite, 249	Cu_9S_5	Iso	5.6	2½–3	Like chalcocite
Diopside, 436	$CaMg(Si_2O_6)$	Mon	3.2–3.3	5–6	A pyroxene
Dioptase, 429	$Cu_6(Si_6O_{18})\cdot 6H_2O$	Rho	3.3	5	Green
Dolomite, 338	$CaMg(CO_3)_2$	Rho	2.85	3½–4	Cl {10$\bar{1}$1}
Dry-bone ore, 343	....	....	....	....	See smithsonite
Dumortierite, 413	$(Al,Fe)_7O_3(BO_3)(SiO_4)_3$	Orth	3.26–3.36	7	Radiating
Edenite, 447	$Ca_2NaMg_5(AlSi_7O_{22})$-$(OH,F)_2$	Mon	3.0	6	See hornblende
Electrum, 226	....	....	....	....	See gold
Eleolite, 502	....	....	....	....	See nepheline
Embolite, 325	Ag(Cl,Br)	Iso	5.3–5.4	1–1½	Sectile
Emerald, 425	....	....	....	....	See beryl
Emery, 291	....	....	....	....	Corundum with magnetite
Enargite, 281	Cu_3AsS_4	Orth	4.43–4.45	3	Cl {110}
Endlichite, 377	....	....	....	....	See vanadinite
Enstatite, 435	$Mg_2(Si_2O_6)$	Orth	3.2–3.5	5½	A pyroxene
Epidote, 417	$Ca_2(Al,Fe)Al_2O(SiO_4)$-$(Si_2O_7)(OH)$	Mon	3.35–3.45	6–7	Cl {001}
Epsomite, 368	$MgSO_4\cdot 7H_2O$	Orth	1.75	2–2½	Bitter taste
Epsom salt, 368	....	....	....	....	See epsomite
Erythrite, 382	$Co_3(AsO_4)_2\cdot 8H_2O$	Mon	2.95	1½–2½	Pink. Cobalt bloom
Essonite, 403	....	....	....	....	See grossularite
Euclase, 426	$Be_2Al_2(SiO_4)_2(OH)_2$	Mon	3.1	7½	Cl {010}
Eucryptite, 438	$Li(Al,Si)_2O_4$	Hex	2.67	....	Spodumene alter.
Fahlore, 280	....	....	....	....	See tetrahedrite
Fayalite, 401	Fe_2SiO_4	Orth	4.14	6½	See olivine
Feather ore, 283	....	....	....	....	See jamesonite
Feldspar, 487	....	....	....	....	A mineral group
Feldspathoid, 500	....	....	....	....	A mineral group
Ferberite, 386	$FeWO_4$	Mon	7.0–7.5	5	See wolframite
Fergusonite, 314	$R'''(Nb,Ta)O_4$	Tet	5.8	5½–6	Brown-black
Ferrosilite, 436	$Fe_2(Si_2O_6)$	Orth	3.6	6	A pyroxene
Fersmannite, 413	$Ca_4Na_2Ti_4Si_3O_{18}F_2$	Mon	3.44	5½	Brown
Fibrolite, 407	....	....	....	....	See sillimanite
Flint, 483	SiO_2	....	2.65	7	Cryptocryst. qtz.
Flos ferri, 345	....	....	....	....	See aragonite
Fluorite, 325	CaF_2	Iso	3.18	4	Cl octahedral
Forsterite, 401	Mg_2SiO_4	Orth	3.2	6½	See olivine
Fowlerite, 441	....	....	....	....	Zinc-bearing rhodonite
Franklinite, 310	(Fe,Zn,Mn)-$(Fe,Mn)_2O_4$	Iso	5.15	6	At Franklin, N. J.
Freibergite, 280	....	....	....	....	Argentiferous tetrahedrite
Gadolinite, 426	$Y_2Fe''Be_2(SiO_4)_2O_2$	Mon	4.0–4.5	6½–7	Black
Gahnite, 307	$ZnAl_2O_4$	Iso	4.55	7½–8	Green octahedrons
Galaxite, 307	$MnAl_2O_4$	Iso	4.03	7½–8	Mn spinel

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Name, p.	Composition	Xl. Sys.	G.	H.	Remarks
Galena, 250	PbS	Iso	7.4–7.6	$2\frac{1}{2}$	Cl cubic
Garnet, 401	$A_3''B_2'''(SiO_4)_3$	Iso	3.5–4.3	$6\frac{1}{2}$–$7\frac{1}{2}$	In crystals
Garnierite, 464	$(Ni,Mg)SiO_3 \cdot nH_2O$	Amor	2.2–2.8	2–3	Green
Gaylussite, 350	$Na_2Ca(CO_3)_2 \cdot 5H_2O$	Mon	1.99	2–3	Fusible at 1
Gedrite, 444	....	.....	....	.....	See anthophyllite
Geocronite, 283	$Pb_5(Sb,As)_2S_8$	Orth	6.4±	$2\frac{1}{2}$	....
Gersdorffite, 270	$NiAsS$	Iso	5.9	$5\frac{1}{2}$	See cobaltite
Geyserite, 486	....	.....	....	.....	See opal
Gibbsite, 304, 317	$Al(OH)_3$	Mon	2.3–2.4	$2\frac{1}{2}$–$3\frac{1}{2}$	Basal cl.
Glauberite, 359	$Na_2Ca(SO_4)_2$	Mon	2.70–2.85	$2\frac{1}{2}$–3	Cl {001}
Glauconite, 471	$K_2(Mg,Fe)_2Al_6(Si_4O_{10})_3$-$(OH)_{12}$	Mon	2.3±	2	In green sands
Glaucophane, 446	$Na_2Mg_3Al_2(Si_8O_{22})$-$(OH,F)_2$	Mon	3.0–3.2	6–$6\frac{1}{2}$	An amphibole
Gmelinite, 510	$(Na,Ca)_6Al_6(Al,Si)$-$Si_{12}O_{40} \cdot 20H_2O$	Rho	2.1±	$4\frac{1}{2}$	A zeolite
Goethite, 304	$HFeO_2$	Orth	4.37	5–$5\frac{1}{2}$	Cl {010}
Gold, 225	Au	Iso	15.0–19.3	$2\frac{1}{2}$–3	Yellow. Soft
Graphite, 244	C	Hex	2.3	1–2	Black. Platy
Gray copper, 280	....	.....	....	.....	See tetrahedrite
Green copper carbonate, 349	....	.....	....	.....	See malachite
Greenockite, 257	CdS	Hex	4.9	3–$3\frac{1}{2}$	Yellow-orange
Grossularite, 403	$Ca_3Al_2(SiO_4)_3$	Iso	3.53	$6\frac{1}{2}$	A garnet
Gypsum, 366	$CaSO_4 \cdot 2H_2O$	Mon	2.32	2	Cl {010} {100} {011}
Halite, 320	$NaCl$	Iso	2.16	$2\frac{1}{2}$	Cl cubic. Salty
Halloysite, 462	$Al_4(Si_4O_{10})(OH)_8$	Amor	2.0–2.2	1–2	A clay mineral
Harmotome, 511	$Ba(Al_2Si_6O_{16}) \cdot 6H_2O$	Mon	2.45	$4\frac{1}{2}$	A zeolite
Hastingsite, 447	$Ca_2NaMg_4Al_3Si_6O_{22}$-$(OH,F)_2$	Mon	3.2	6	See hornblende
Hauynite, 503	$(Na,Ca)_{6-8}Al_6Si_6O_{24}$-$(SO_4)_{1-2}$	Iso	2.4–2.5	$5\frac{1}{2}$–6	A feldspathoid
Heavy spar, 359	....	.....	....	.....	See barite
Hectorite, 462	$(Mg,Li)_6Si_8O_{20}(OH)_4$	Mon	2.5	1–$1\frac{1}{2}$	Li montmorillonite
Hedenbergite, 437	$CaFe(Si_2O_6)$	Mon	3.55	5–6	A pyroxene
Heliotrope, 482	....	.....	....	.....	Green and red chalcedony
Hematite, 292	Fe_2O_3	Rho	5.26	$5\frac{1}{2}$–$6\frac{1}{2}$	Red streak
Hemimorphite, 415	$Zn_4(Si_2O_7)(OH)_2 \cdot H_2O$	Orth	3.4–3.5	$4\frac{1}{2}$–5	Cl {110}
Hercynite, 307	$FeAl_2O_4$	Iso	4.39	$7\frac{1}{2}$–8	Iron spinel
Hessite, 274	Ag_2Te	Iso	8.4	$2\frac{1}{2}$–3	....
Heulandite, 510	$Ca(Al_2Si_7O_{18}) \cdot 6H_2O$	Mon	2.18–2.20	$3\frac{1}{2}$–4	Cl {010} perfect
Hiddenite, 437	....	.....	....	.....	Green spodumene
Holmquistite, 446	....	.....	....	.....	Lithium-bearing glaucophane
Hornblende, 446	$Ca_2Na(Mg,Fe'')_4$-$(Al,Fe''',Ti)_3Si_8O_{22}$-$(O,OH)_2$	Mon	3.2	5–6	An amphibole
Horn silver, 324	....	.....	....	.....	See cerargyrite
Huebnerite, 386	$MnWO_4$	Mon	7.0	5	See wolframite

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Name, p.	Composition	Xl. Sys.	G.	H.	Remarks
Lawsonite, 416	$CaAl_2(Si_2O_7)(OH)_2 \cdot H_2O$	Orth	3.09	8	In gneisses and schists
Lazulite, 378	$MgAl_2(OH)_2(PO_4)_2$	Mon	3.0–3.1	$5-5\frac{1}{2}$	Blue
Lazurite, 503	$(Na,Ca)_4(AlSiO_4)_3(SO_4,S,Cl)$	Iso	2.4–2.45	$5-5\frac{1}{2}$	Pyrite associated
Lechatelierite, 484	SiO_2	Amor	2.2	6–7	Fused silica
Lepidocrocite, 306	$FeO(OH)$	Orth	4.09	5	Red
Lepidolite, 471	$K_2Li_3Al_3(AlSi_3O_{10})_2(OH,F)_4$	Mon	2.8–3.0	$2\frac{1}{2}-4$	A mica
Leucite, 500	$K(AlSi_2O_6)$	......	2.45–2.50	$5\frac{1}{2}-6$	In trapezohedrons
Limonite, 316	$FeO(OH) \cdot nH_2O$	Amor	3.6–4.0	$5-5\frac{1}{2}$	Streak yellow-brown
Linnaeite, 276	Co_3S_4	Iso	4.8	$4\frac{1}{2}-5\frac{1}{2}$	....
Lithia mica, 471	....	......	......	....	See lepidolite
Lithiophilite, 373	$LiMnPO_4$	Orth	3.5	5	See triphylite
Lodestone, 309	....	......	......	....	See magnetite
Magnesiochromite, 311	$MgCr_2O_4$	Iso	4.2	$5\frac{1}{2}$	A spinel
Magnesioferrite, 309	$MgFe_2O_4$	Iso	4.5	$5\frac{1}{2}-6\frac{1}{2}$	A spinel
Magnesite, 340	$MgCO_3$	Rho	3.0–3.2	$3\frac{1}{2}-5$	Commonly massive
Magnetic pyrites, 258	....	......	......	....	See pyrrhotite
Magnetite, 308	Fe_3O_4	Iso	5.18	6	Strongly magnetic
Malachite, 349	$Cu_2CO_3(OH)_2$	Mon	3.9–4.03	$3\frac{1}{2}-4$	Green
Manganite, 315	$MnO(OH)$	Orth	4.3	4	Prismatic crystals
Mangano-tantalite, 313	$MnO(Ta,Cb)_2O_5$	Orth	6.6±	$4\frac{1}{2}$	See columbite
Marcasite, 270	FeS_2	Orth	4.89	$6-6\frac{1}{2}$	White iron pyrites
Margarite, 472	$CaAl_2(Al_2Si_2O_{10})(OH)_2$	Mon	3.0–3.1	$3\frac{1}{2}-5$	A brittle mica
Marialite, 505	$(Na,Ca)_4Al_3(Al,Si)_3Si_6O_{24}(Cl,CO_3,SO_4)$	Tet	2.60±	$5\frac{1}{2}-6$	See scapolite
Martite, 293	....	......	......	....	See hematite
Meerschaum, 473	....	......	......	....	See sepiolite
Meionite, 505	$(Ca,Na)_4Al_3(Al,Si)_3Si_6O_{24}(Cl,CO_3,SO_4)$	Tet	2.69	$5\frac{1}{2}-6$	See scapolite
Melaconite, 288	....	......	......	....	See tenorite
Melanite, 403	Black andradite	Iso	3.7	7	A garnet
Melanterite, 271	$FeSO_4 \cdot 7H_2O$	Mon	1.90	2	Green-blue
Menaccanite, 295	....	......	......	....	See ilmenite
Meneghinite, 283	$Pb_{13}Sb_7S_{23}$	Orth	6.36	$2\frac{1}{2}$	....
Mercury, 223	Hg	......	13.6	0	Fluid. Quicksilver
Mica, 467	....	......	......	....	A mineral group
Microcline, 493	$K(AlSi_3O_8)$	Tric	2.54–2.57	6	A feldspar
Microlite, 314	$Ca_2Ta_2O_7$	Iso	5.48–5.56	$5\frac{1}{2}$	Ore of tantalum
Microperthite, 490	....	......	......	....	Microcline and albite
Millerite, 259	NiS	Rho	5.5±0.2	$3-3\frac{1}{2}$	Capillary crystals
Mimetite, 376	$Pb_5Cl(AsO_4)_3$	Hex	7.0–7.2	$3\frac{1}{2}$	Like pyromorphite
Mispickel, 272	....	......	......	....	See arsenopyrite
Molybdenite, 273	MoS_2	Hex	4.62–4.73	$1-1\frac{1}{2}$	Black. Platy

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Name, p.	Composition	Xl. Sys.	G.	H.	Remarks
Peridot, 400	...	...	...	...	Gem olivine
Perovskite, 297	$CaTiO_3$	Iso	4.03	$5\frac{1}{2}$	Yellow
Perthite, 490	...	...	...	...	Microcline and albite
Petalite, 504	$Li(AlSi_4O_{10})$	Mon	2.4	$6-6\frac{1}{2}$	Good cleavage
Petzite, 274	$(Ag,Au)_2Te$	Iso?	8.7–9.0	$2\frac{1}{2}-3$	...
Phenacite, 399	$Be_2(SiO_4)$	Rho	2.97–3.00	$7\frac{1}{2}-8$	In pegmatites
Phillipsite, 511	$KCa(Al_3Si_5O_{16})\cdot 6H_2O$	Mon	2.2	$4\frac{1}{2}-5$	A zeolite
Phlogopite, 470	$KMg_3(AlSi_3O_{10})(OH)_2$	Mon	2.86	$2\frac{1}{2}-3$	Brown mica
Phosgenite, 348	$Pb_2Cl_2CO_3$	Tet	6.0–6.3	3	Fusible at 1
Phosphorite, 375	...	...	...	...	Phosphate rock
Picotite, 306	...	...	...	...	See spinel

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Name, p.	Composition	Xl. Sys.	G.	H.	Remarks
Monazite, 372	$(Ce,La,Y,Th)PO_4$	Mon	5.0–5.3	$5-5\frac{1}{2}$	Parting {001}
Monticellite, 401	$CaMgSiO_4$	Orth	3.2	5	See olivine
Montmorillonite, 462	$(Al,Mg)_8(Si_4O_{10})_3(OH)_{10}\cdot 12H_2O$	Mon	2.5	$1-1\frac{1}{2}$	A clay mineral
Moonstone, 491	...	...	...	...	See albite and orthoclase
Morganite, 425	...	...	...	...	See beryl
Mullite, 408	$Al_6Si_2O_{13}$	Orth	3.23	6–7	Cl {100}
Muscovite, 467	$KAl_2(AlSi_3O_{10})(OH)_2$	Mon	2.76–3.1	$2-2\frac{1}{2}$	Cl {001} perfect
Nacrite, 462	$Al_4(Si_4O_{10})(OH)_8$	Mon	2.6	$2-2\frac{1}{2}$	See kaolinite
Nagyagite, 274	$Pb_5Au(Te,Sb)_4S_{5-8}$	Mon?	7.4	$1-1\frac{1}{2}$	...
Natroalunite, 370	...	...	...	...	Soda alunite
Natrolite, 508	$Na_2(Al_2Si_3O_{10})\cdot 2H_2O$	Mon	2.25	$5-5\frac{1}{2}$	Cl {110} perfect
Nepheline, 501	$(Na,K)(AlSiO_4)$	Hex	2.55–2.65	$5\frac{1}{2}-6$	Greasy luster
Nephrite, 445	...	...	...	...	See tremolite
Neptunite, 413	$(Na,K)(Fe'',Mn,Ti)Si_2O_6$	Mon	3.23	5–6	Black
Niccolite, 259	$NiAs$	Hex	7.78	$5-5\frac{1}{2}$	Copper-red
Nickel bloom, 383	...	...	...	...	See annabergite
Nickel iron, 233	Ni,Fe	Iso	7.8–8.2	5	In meteorites
Nickel skutterudite, 275	$(Ni,Co,Fe)As_3$	Iso	6.5±0.4	$5\frac{1}{2}-6$	Tin white
Niter, 352	KNO_3	Orth	2.09–2.14	2	Saltpeter
Nontronite, 462	$Fe(AlSi)_8O_{20}(OH)_4$	Mon	2.5	$1-1\frac{1}{2}$	Clay mineral
Norbergite, 411	$Mg_3(SiO_4)(F,OH)_2$	Orth	3.1–3.2	6	See chondrodite
Noselite, 503	$Na_4Al_3Si_3O_{12}SO_4$	Iso	2.3±	6	A feldspathoid
Octahedrite, 297	...	...	...	...	See anatase
Oligoclase, 499	$Ab_{90}An_{10}—Ab_{70}An_{30}$	Tric	2.65	6	Plag. feldspar
Olivine, 400	$(Mg,Fe)_2SiO_4$	Orth	3.27–4.37	$6\frac{1}{2}-7$	Green rock mineral
Onyx, 483	...	...	...	...	Layered chalcedony
Opal, 485	$SiO_2\cdot nH_2O$	Amor	1.9–2.2	5–6	Conch. fracture
Orpiment, 264	As_2S_3	Mon	3.49	$1\frac{1}{2}-2$	Cl {010}. Yellow
Orthite, 419	...	...	...	...	See allanite
Orthoclase, 490	$K(AlSi_3O_8)$	Mon	2.57	6	A feldspar
Ottrelite, 472	$(Fe'',Mn)(Al,Fe''')_2Si_3O_{10}\cdot H_2O$	Mon	3.5	6–7	A brittle mica
Palladium, 233	Pd	Iso	11.9	$4\frac{1}{2}-5$	See platinum
Paragonite, 469	$NaAl_2(AlSi_3O_{10})(OH)_2$	Mon	2.85	2	Like muscovite
Pargasite, 447	$Ca_4Na_2Mg_9Al_4Si_{13}O_{44}(OH,F)_4$	Mon	3–3.5	$5\frac{1}{2}$	See hornblende
Patronite, 377	...	...	...	...	An ore of vanadium
Peacock ore, 249	...	...	...	...	See bornite
Pearceite, 277	$(Ag,Cu)_{16}As_2S_{11}$	Mon	6.15	3	Tabular crystals
Pectolite, 442	$Ca_2NaH(SiO_3)_3$	Tric	2.7–2.8	5	Crystals acicular
Penninite, 473	...	...	...	...	See chlorite
Pentlandite, 260	$(Fe,Ni)_9S_8$	Iso	4.6–5.0	$3\frac{1}{2}-4$	In pyrrhotite

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Name, p.	Composition	Xl. Sys.	G.	H.	Remarks
Ramsayite, 413	$Na_2Ti_2Si_2O_9$	Orth	3.43	6	From Kola
Rasorite, 355					See kernite
Realgar, 263	AsS	Mon	3.48	$1\frac{1}{2}$–2	Cl {010}. Red
Red copper ore, 287					See cuprite
Red ocher, 293					See hematite
Rhodochrosite, 342	$MnCO_3$	Rho	3.45–3.6	$3\frac{1}{2}$–$4\frac{1}{2}$	Cl {10$\bar{1}$1}. Pink
Rhodolite, 403	$3(Mg,Fe)O \cdot Al_2O_3 \cdot 3SiO_2$	Iso	3.84	7	See garnet
Rhodonite, 441	$Mn(SiO_3)$	Tric	3.58–3.70	$5\frac{1}{2}$–6	Pink
Riebeckite, 446	$Na_3Fe_3''Fe_2'''(Si_8O_{22})$-$(OH)_2$	Mon	3.44	4	An amphibole
Rock crystal, 481					See quartz
Rock salt, 320					See halite
Roscoelite, 378	$K_2V_4Al_2Si_6O_{20}(OH)_4$	Mon	2.97	$2\frac{1}{2}$	Vanadium mica
Rubellite, 429					See tourmaline
Ruby, 290					Red gem corundum
Ruby copper, 287					See cuprite
Ruby silver, 278					See pyrargyrite and proustite
Rutile, 296	TiO_2	Tet	4.18–4.25	6–$6\frac{1}{2}$	Adamantine luster
Saltpeter, 352					See niter
Sanidine, 491					See orthoclase
Saponite, 462	$(Mg,Al)_6(Si,Al)_8O_{20}$-$(OH)_4$	Mon	2.5	1–$1\frac{1}{2}$	Clay mineral
Sapphire, 290					Blue gem corundum
Satin spar, 367					Fibrous gypsum
Scapolite, 505	Various	Tet	2.65–2.74	5–6	Cl {010} {110}
Scheelite, 387	$CaWO_4$	Tet	5.9–6.1	$4\frac{1}{2}$–5	Cl {011}
Schorlite, 427					See tourmaline
Scolecite, 509	$Ca(Al_2Si_3O_{10}) \cdot 3H_2O$	Mon	2.2±	5–$5\frac{1}{2}$	A zeolite
Scorodite, 379	$FeAsO_4 \cdot 2H_2O$	Orth	3.1–3.3	$3\frac{1}{2}$–4	Green to brown
Scorzalite, 378	$FeAl_2(OH)_2(PO_4)_2$	Mon	3.35	$5\frac{1}{2}$–6	
Selenite, 366					See gypsum
Semseyite, 283	$Pb_9Sb_8S_{21}$	Mon	5.8	$2\frac{1}{2}$	
Sepiolite, 473	$Mg_4(Si_6O_{15})(OH)_2 \cdot 6H_2O$	Mon?	2.0	2–$2\frac{1}{2}$	Meerschaum
Sericite, 469					Fine-grained muscovite
Serpentine, 463	$Mg_6(Si_4O_{10})(OH)_8$	Mon	2.2	2–5	Green to yellow
Siderite, 341	$FeCO_3$	Rho	3.83–3.88	$3\frac{1}{2}$–4	Cl {10$\bar{1}$1}
Sillimanite, 407	Al_2SiO_5	Orth	3.23	6–7	Cl {010} perfect
Silver, 228	Ag	Iso	10.5	$2\frac{1}{2}$–3	White, malleable
Silver glance, 247					See argentite
Skutterudite, 275	$(Co,Ni,Fe)As_3$	Iso	6.5±0.4	5	Tin white
Smaltite, 276					See skutterudite
Smithsonite, 343	$ZnCO_3$	Rho	4.35–4.40	5	Reniform
Soapstone, 466					See talc
Sodalite, 502	$Na_4(AlSiO_4)_3Cl$	Iso	2.15–2.3	$5\frac{1}{2}$–6	Usually blue
Sodamicrocline, 494					See microcline
Soda niter, 351	$NaNO_3$	Rho	2.29	1–2	Cooling taste
Spathic iron, 341					See siderite
Specular iron, 293					See hematite

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Name, p.	Composition	Xl. Sys.	G.	H.	Remarks
Sperrylite, 232	$PtAs_2$	Iso	10.50	6–7	See platinum
Spessartite, 403	$Mn_3Al_2(SiO_4)_3$	Iso	4.18	7	A garnet
Sphalerite, 252	ZnS	Iso	3.9–4.1	$3\frac{1}{2}$–4	Cl {110} 6 directions
Sphene, 412	$CaTiO(SiO_4)$	Mon	3.40–3.55	5–$5\frac{1}{2}$	Wedge-shaped xls
Spinel, 306	$MgAl_2O_4$	Iso	3.6–4.0	8	In octahedrons
Spodumene, 437	$LiAl(Si_2O_6)$	Mon	3.15–3.20	$6\frac{1}{2}$–7	Cl {110}. Part {100}
Stannite, 256	Cu_2FeSnS_4	Tet	4.4	4	Easily fusible
Staurolite, 409	$Fe_2Al_9O_7(SiO_4)_4(OH)$	Orth	3.65–3.75	7–$7\frac{1}{2}$	In cruciform twins
Steatite, 466	....	....	....	....	See talc
Stephanite, 277	Ag_5SbS_4	Orth	6.2–6.3	2–$2\frac{1}{2}$	Pseudohexagonal
Stibnite, 264	Sb_2S_3	Orth	4.52–4.62	2	Cl {010} perfect
Stilbite, 510	$Ca(Al_2Si_7O_{18})\cdot 7H_2O$	Mon	2.1–2.2	$3\frac{1}{2}$–4	Sheaflike aggregates
Stolzite, 385	$PbWO_4$	Tet	7.9–8.3	$2\frac{1}{2}$–3	Cl {001} {011}
Stromeyerite, 249	$(Ag,Cu)_2S$	Orth	6.2–6.3	$2\frac{1}{2}$–3	....
Strontianite, 347	$SrCO_3$	Orth	3.7	$3\frac{1}{2}$–4	Efferv. in HCl
Sulfur, 236	S	Orth	2.05–2.09	$1\frac{1}{2}$–$2\frac{1}{2}$	Burns with blue flame
Sunstone, 499	....	....	....	....	See oligoclase
Sylvanite, 275	$(Au,Ag)Te_2$	Mon	8.0–8.2	$1\frac{1}{2}$–2	Cl {010} perfect
Sylvite, 323	KCl	Iso	1.99	2	Cl cubic perfect
Talc, 466	$Mg_3(Si_4O_{10})(OH)_2$	Mon	2.7–2.8	1	Greasy feel
Tantalite, 312	$(Fe,Mn)Ta_2O_6$	Orth	6.5±	6	See columbite
Tennantite, 280	$(Cu,Fe,Zn,Ag)_{12}As_4S_{13}$	Iso	4.6–5.1	3–$4\frac{1}{2}$	In tetrahedrons
Tenorite, 288	CuO	Tric	6.5	3–4	Black
Tephroite, 401, 442	$Mn_2(SiO_4)$	Orth	4.1	6	See olivine
Tetrahedrite, 280	$(Cu,Fe,Zn,Ag)_{12}Sb_4S_{13}$	Iso	4.6–5.1	3–$4\frac{1}{2}$	In tetrahedrons
Thenardite, 359	Na_2SO_4	Orth	2.68	$2\frac{1}{2}$	In saline lakes
Thomsonite, 508	$(Ca,Na)_6Al_8(Al,Si)_2$-$Si_{10}O_{40}\cdot 12H_2O$	Orth	2.3	5	A zeolite
Thorianite, 303	ThO_2	Iso	9.7	$6\frac{1}{2}$	Poor cleavage
Thorite, 406	$Th(SiO_4)$	Tet	5.3	5	Usually hydrated
Thulite, 417	....	....	....	....	Rose-red zoisite
Tiger's-eye, 481	....	....	....	....	See quartz
Tin, 223	Sn	Tet	7.3	2	Very rare
Tin stone, 299	....	....	....	....	See cassiterite
Titanic iron ore, 295	....	....	....	....	See ilmenite
Titanite, 412	....	....	....	....	See sphene
Topaz, 408	$Al_2(SiO_4)(F,OH)_2$	Orth	3.4–3.6	8	Cl {001} perfect
Torbernite, 382	$Cu(UO_2)_2(PO_4)_2\cdot$-8–$12H_2O$	Tet	3.22	2–$2\frac{1}{2}$	Green
Tourmaline, 426	$XY_3Al_6(BO_3)_3(Si_6O_{18})$-$(OH)_4$	Rho	3.0–3.25	7–$7\frac{1}{2}$	Trigonal section
Travertine, 337	....	....	....	....	See calcite
Tremolite, 444	$Ca_2Mg_5(Si_8O_{22})(OH)_2$	Mon	3.0–3.3	5–6	Cl {110} perfect
Tridymite, 484	SiO_2	Orth	2.26	7	In volcanic rocks
Triphylite, 373	$LiFePO_4$	Orth	3.42–3.56	$4\frac{1}{2}$–5	Cl {001} {010}
Troilite, 258	....	....	....	....	See pyrrhotite
Trona, 350	$Na_3H(CO_3)_2\cdot 2H_2O$	Mon	2.13	3	Alkaline taste

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Name, p.	Composition	Xl. Sys.	G.	H.	Remarks
Troostite, 399	....	.....	....	.....	Manganiferous willemite
Tufa, 337	....	.....	....	.....	See calcite
Turgite, 306	$2Fe_2O_3 \cdot H_2O$	.....	4.2–4.6	$6\frac{1}{2}$	Red streak
Turquoise, 380	$CuAl_6(PO_4)_4(OH)_8 \cdot 4H_2O$	Tric	2.6–2.8	6	Blue-green
Tyuyamunite, 384	$Ca(UO_2)_2(VO_4)_2 \cdot nH_2O$	Orth	3.7–4.3	2	Yellow
Ulexite, 356	$NaCaB_5O_9 \cdot 8H_2O$	Tric	1.96	1	"Cotton-balls"
Uralian emerald, 404	....	.....	....	.....	See andradite
Uralite, 447	....	.....	....	.....	See hornblende
Uraninite, 301	UO_2	Iso	9.0–9.7	$5\frac{1}{2}$	Pitchy luster
Uvarovite, 403	$Ca_3Cr_2(SiO_4)_3$	Iso	3.45	$7\frac{1}{2}$	Green garnet
Vanadinite, 377	$Pb_5Cl(VO_4)_3$	Hex	6.7–7.1	3	Luster resinous
Variscite, 382	$Al(PO_4) \cdot 2H_2O$	Orth	2.57	$3\frac{1}{2}$–$4\frac{1}{2}$	Green, massive
Verde antique, 464	....	.....	....	.....	See serpentine
Vermiculite, 471	....	Mon	2.4	$1\frac{1}{2}$	Altered biotite
Vesuvianite, 419	....	.....	....	.....	See idocrase
Vivianite, 382	$Fe_3(PO_4)_2 \cdot 8H_2O$	Mon	2.58–2.68	$1\frac{1}{2}$–2	Cl {010} perfect
Wad, 299	....	.....	....	.....	Manganese ore
Wavellite, 380	$Al_3(OH)_3(PO_4)_2 \cdot 5H_2O$	Orth	2.33	$3\frac{1}{2}$–4	Radiating aggregates
Wernerite, 505	....	.....	....	.....	See scapolite
White iron pyrites, 270	....	.....	....	.....	See marcasite
White mica, 467	....	.....	....	.....	See muscovite
Willemite, 399	Zn_2SiO_4	Rho	3.9–4.2	$5\frac{1}{2}$	From Franklin, N. J.
Witherite, 346	$BaCO_3$	Orth	4.3	$3\frac{1}{2}$	Efferv. in HCl
Wolframite, 385	$(Fe,Mn)WO_4$	Mon	7.0–7.5	5–$5\frac{1}{2}$	Cl {010} perfect
Wollastonite, 442	$Ca(SiO_3)$	Tric	2.8–2.9	5–$5\frac{1}{2}$	Cl {001} {100}
Wood tin, 299	....	.....	....	.....	See cassiterite
Wulfenite, 387	$PbMoO_4$	Tet	6.8±	3	Orange-red
Wurtzite, 253	ZnS	Hex	3.98	4	See sphalerite
Yellow copper ore, 255	....	.....	....	.....	See chalcopyrite
Zeolite, 506	....	.....	....	.....	A mineral group
Zinc blende, 252	....	.....	....	.....	See sphalerite
Zincite, 289	ZnO	Hex	5.68	4–$4\frac{1}{2}$	At Franklin, N. J.
Zinc spinel, 307	....	.....	....	.....	See gahnite
Zinkenite, 283	$Pb_6Sb_{14}S_{27}$	Hex	5.3	3–$3\frac{1}{2}$	....
Zircon, 404	$ZrSiO_4$	Tet	4.68	$7\frac{1}{2}$	In small crystals
Zoisite, 417	$Ca_2Al_3(SiO_4)_3(OH)$	Orth	3.3	6	See clinozoisite