

CRYSTAL STRUCTURES

RALPH W. G. WYCKOFF

*University of Arizona, Tucson, Arizona; formerly
Laboratory of Physical Biology, National Institute of
Arthritis and Metabolic Diseases, Bethesda, Maryland*

Volume II



INTERSCIENCE PUBLISHERS, INC., NEW YORK
INTERSCIENCE PUBLISHERS LTD., LONDON

Copyright, 1948, 1951, 1953, 1957, 1958, 1959, 1960, by
INTERSCIENCE PUBLISHERS, INC.
250 Fifth Avenue, New York 1, N. Y.

ALL RIGHTS RESERVED

This book or any part thereof must not be reproduced in any form without permission of the publisher in writing. This applies specifically to photostat and microfilm reproductions.

Printed in the United States of America

WYCKOFF: CRYSTAL STRUCTURES

INORGANIC STRUCTURES

VOLUME II

V. Structures of Complex Binary Compounds R_mX_n

Text	V, text pp. 1-51
Tables	V, table pp. 1-69
Master Tables	V, table pp. 1-4, 15-17j, 29-29c, 33-35g
Illustrations	V, illus. pp. 1-23
Bibliographies	V, biblio. pp. 1-25

VI. Structures of Compounds $R(MX_2)_n$

Text	VI, text pp. 1-27
Tables	VI, table pp. 1-18
Master Tables	VI, table pp. 1-4b
Illustrations	VI, illus. pp. 1-14
Bibliographies	VI, biblio. pp. 1-9

VII. Compounds of the Type $R_n(MX_3)_p$

Text	VII, text pp. 1-32
Tables	VII, table pp. 1-34
Master Tables	VII, table pp. 1-5m, 19-20n
Illustrations	VII, illus. pp. 1-27
Bibliographies	VII, biblio. pp. 1-18

VIII. Compounds of the Type $R_n(MX_4)_p$

Text	VIII, text pp. 1-63
Tables	VIII, table pp. 1-96
Master Tables	VIII, table pp. 1-6f, 35-40j, 67-70a
Illustrations	VIII, illus. pp. 1-27
Bibliographies	VIII, biblio, pp. 1-27

(See overleaf for the contents of the other volumes)

WYCKOFF: CRYSTAL STRUCTURES

CONTENTS

VOLUME I

- I. Preface and Introduction
- II. Structures of the Elements
- III. Structures of the Compounds RX
- IV. Structures of the Compounds RX_2

VOLUME III

- IX. Compounds of the Type $R_X(MX_M)_V$
- X. The Crystal Structures of Hydrates and Ammoniates
- XI. Miscellaneous Inorganic Compounds
- XII. Structure of the Silicates
- Inorganic Formula Index
- Mineralogical Name Index

VOLUME IV

- XIII. The Structures of Aliphatic Compounds

VOLUME V

- XIV. The Structure of Benzene Derivatives
- XV. The Crystal Structures of Alicyclic and Heterocyclic Compounds, and of Carbohydrates
- Index to Organic Compounds

VOLUME II: PAGE INVENTORY

The following pages compose Volume II (Chapters V–VIII) of *Wyckoff Crystal Structures* after complete integration of all sections and supplements. The symbol (s) indicates a supplement page; (r) indicates a replacement page.

Title page for Volume II

Contents sheet for Volume II

Page Inventory sheet for Volume II

Chapter V

text pages 1–10, 10a (s), 10c–e (s), 11–25, 25a–i (s), 27–29, 29a–f (s), 31, 32, 32a (s), 32b (s), 33, 34, 34a (s), 34b (s), 35–37, 37a (s), 39, 40, 40a (s), 41, 43–45, 45a–i (s), 45k (s to p. 13), 45l–n (s to p. 15), 47 (s to p. 16), 48a (s to p. 17), 49 (s to p. 20), 50a (s to p. 21), 50c (s to p. 32), 51 (s to p. 40)
table pages 1–3, 3a–g (s), 4 (s), 5, 5a (s), 7, 7a (s), 7b (s), 9, 11, 13, 13a–d (s), 15–17, 17a–c (s), 17e–g (s), 17i (s), 17j (s), 19, 21, 21a (s to p. 21), 23, 23a (s), 25, 27, 27a (s), 27b (s), 27g (s), 27h (s), 29, 29a–c (s), 31, 31a (r), 31b (s), 32 (r), 33–35, 35a–d (s), 35f (s), 35g (s), 37 (r), 37a (r), 39, 41, 43, 43a–d (s), 45 (s), 47 (s), 49 (s), 51 (s), 52 (s), 53 (r), 54 (s), 54a (s), 54b (s), 55 (s to p. 11), 57 (s to p. 13), 57a (s to p. 13), 59 (s to p. 27), 59a (s to p. 27), 61 (s to p. 27), 63–69 (s to p. 27)
illustration pages 1, 2, 2a (s), 3, 3a (s), 3b (s), 4, 4a–k (s), 5, 6, 6a (s), 7, 7a–p (s), 8, 8a–o (s), 9, 10–23 (s)
bibliography pages 1 (r), 1a–l (s), 2 (r), 3–8, 9–25 (s)

Chapter VI

text pages 1–10, 10a (s), 11–18, 19–21 (s), 23–25 (s), 27 (s to p. 17)
table pages 1–3, 3a–c (s), 4 (s), 4a (s), 4b (s), 5, 7, 9, 11, 11a (s), 13, 13a (s), 15–18 (s)
illustration pages 1, 1a (s), 1b (s), 2–5, 5a (s), 5b (s), 6, 6a–e (s), 7, 8–14 (s)
bibliography pages 1 (r), 1a–e (s), 2 (r), 3, 5–9 (s)

Chapter VII

text pages 1–6, 6a (s), 7–23, 23a–c (s), 23e–m (s), 25 (s to p. 3), 25a (s to p. 9), 27 (s to p. 15), 28 (s to p. 15), 28a–d (s to p. 15), 29 (s to p. 20), 31 (s to p. 21), 32 (s to p. 23a)
table pages 1–5, 5a–c (s), 5e–g (s), 5i–m (s), 7, 9, 11, 12, 12a–c (s), 12e–h (s), 13, 15, 17, 17a (s), 17c–f (s), 19, 20, 20a (s), 20c–e (s), 20g (s), 20h (s), 21 (r), 23, 23a (s), 25, 27, 27a (s), 27c–e (s), 29 (s), 31–34 (s)
illustration pages 1, 2, 2a (s), 3, 3a (s), 4, 4a (s), 4b (s), 5–8, 8a–m (s), 9, 9a (s), 10, 11, 12–27 (s)
bibliography pages 1 (r), 1a–k (s), 2 (r), 3–5, 7–18 (s)

Chapter VIII

text pages 1–32, 32a–d (s), 33–35, 35a (s), 35b (s), 37–42, 42a (s), 43–46, 47–49 (s), 51 (s to p. 15), 53–58 (s to p. 15), 59 (s to p. 21), 61 (s to p. 28), 63 (s to p. 45)
table pages 1–6, 6a–f (s), 7, 9, 11, 13, 15, 17, 19, 21, 23, 24, 24a (s), 25, 27, 29, 31, 31a (s), 31b (s), 33, 34a–c (s), 35–40, 40a–c (s), 40e–j (s), 41–43, 43a (s), 43b (s), 45, 47–51, 53, 55, 57, 59, 61, 63, 63a (s), 63b (s), 65, 66, 66a–c (s), 67–69, 69a–c (s), 70 (s), 70a (s), 71, 73, 75, 77, 79, 81, 83, 85, 86, 86a (s), 87, 89, 89a–c (s), 91, 93, 95 (s), 96 (s)
illustration pages 1 (r), 1a (s), 1b (s), 2–4, 4a (s), 4b (s), 5, 5a–p (s), 6, 6a (s), 7, 7a (s), 8, 8a (s), 9–11, 11a (s), 12–14, 14a–g (s), 15–21, 21a (s), 22, 23–27 (s)
bibliography pages 1 (r), 1a–q (s), 2 (r), 3–15, 17–27 (s)

TABLE VA, 1c. EARLY BIBLIOGRAPHIC REFERENCES
TO COMPOUNDS R_2X_3

Crystal	Literature
α - Al_2O_3 (corundum)	1922, B; H; 1923, D; 1924, M; 1925, B&B; G, B&L; P&H; U; 1927, H; 1928, Z; 1930, P
γ - Al_2O_3	1932, B
As_2O_3	1923, B; 1928, P; 1932, L
Be_3N_2	1933, vS&P
Be_3P_2	1933, vS&P
Bi_2S_3 (bismuthinite)	1933, H
$Bi_2S_2Te_2$ (tetradymite)	1934, H
α - Ca_3N_2	1933, F, B&H; vS&P
Cd_3As_2	1928, P
Cd_3P_2	1928, P; 1933, vS&P
Cd_3Sb_2	1933, H, N&T
$CdTiO_3$	See Chapter VII
Ce_2O_3	1925, G, B&L; 1926, Z; 1929, P
$(Co, Fe)_2O_3$	1928, H&A
$CoTiO_3$	See Chapter VII
Cr_3C_2	1926, W&P; 1931, W
Cr_2O_3	1923, D; 1925, G, B&L; 1928, Z; 1930, P; W

TABLE VA,1c (2)

Crystal	Literature
Dy_2O_3	1925, G, B&L; 1927, Z; 1928, Z; 1930, P&S
Er_2O_3	1925, G, B&L; 1927, Z; 1930, P&S
Eu_2O_3	1925, G, B&L; 1927, Z; 1930, P&S
$\alpha\text{-Fe}_2O_3$ (hematite)	1923, D; 1924, M; 1925, B&B; G, B&L; P&H; 1928, Z; 1930, F; W; 1932, B; 1933, K&O; 1934, B
$\gamma\text{-Fe}_2O_3$ (magnetic)	1925, W&B; 1931, F&G; T
$(Fe, Mn)_2O_3$ (bixbyite)	1928, Z; 1930, P&S
$FeTiO_3$ (ilmenite)	See Chapter VII
Ga_2O_3	1925, G, B&L; 1928, Z
Gd_2O_3	1925, G, B&L; 1927, Z; 1930, P&S
Ho_2O_3	1925, G, B&L; 1927, Z; 1930, P&S
In_2O_3	1925, G, B&L; 1927, Z; 1928, Z; 1930, P&S
La_2O_3	1925, G, B&L; 1926, Z; 1929, P
$LiCbO_3$	1928, Z
Lu_2O_3	1925, G, B&L; 1927, Z; 1928, Z; 1930, P&S
Mg_3As_2	1928, N&F; 1933, vS&P; Z&H
Mg_3Bi_2	1933, Z&H
Mg_3N_2	1930, H; 1932, H; 1933vS&P

TABLE VA, 1c (3)

Crystal	Literature
Mg_3P_2	1928, P; 1933, vS&P; Z&H
Mg_3Sb_2	1933, Z&H
$MgTiO_3$	See Chapter VII
Mn_2O_3	1928, Z; 1930, W; 1930, P&S
$MnTiO_3$	See Chapter VII
Nd_2O_3	1925, G, B&L; 1926, Z; 1929, P
Ni_3S_2	1925, A
$NiTiO_3$	See Chapter VII
Pr_2O_3	1925, G, B&L; 1926, Z; 1929, P
Rh_2O_3	1927, L; 1928, Z
Sa_2O_3	1925, G, B&L; 1927, Z; 1930, P&S
$\alpha-Sb_2O_3$	1923, B; 1927, D; D&G; S; 1929, D
Sb_2S_3 (stibnite)	1926, O; 1927, G; 1929, G&L; 1933, H
Sc_2O_3	1925, G, B&L; 1927, Z; 1928, Z; 1930, P&S
Tb_2O_3	1925, G, B&L; 1927, Z; 1930, P&S
Ti_2O_3	1925, G, B&L; 1927, L; 1928, Z; 1929, H
Tl_2O_3	1925, G, B&L; 1927, Z; 1928, Z; 1930, P&S
Tm_2O_3	1925, G, B&L; 1927, Z; 1930, P&S
V_2O_3	1925, G, B&L; 1928, Z

TABLE VA,1c (4)

Crystal	Literature
Y_2O_3	1925, G, B&L; 1927, Z; 1928, Z; 1930, P&S
Yb_2O_3	1925, G, B&L; 1927, Z; 1930, P&S
Zn_3As_2	1928, N&P; 1933, vS&P
Zn_3P_2	1928, P; 1933 vS&P

TABLE VB, 1c. EARLY BIBLIOGRAPHIC REFERENCES
TO COMPOUNDS RX_3

Crystal	Literature
$AlCl_3$	1930, L
AlF_3	1929, F&S; 1931, K; 1933, K
AsH_3	1930, N&C
AsI_3	1930, B; H; 1931, H
$Al(OH)_3$ (hydrargillite)	1934, M
B_2H_6	1925, M, B&P; M&P
BiF_3	1929, H&N
BiI_3	1930, B
CeF_3	1929, O
$(Ce, La)F_3$ (tysonite)	1929, O; 1931, O
$CoAs_2$ (skutterudite)	1925, O; 1928, O
CoF_3	1931, E
$CrBr_3$	1932, B
$CrCl_3$	1927, N; 1930, W
CrO_3	1931, B; W&W
Cu_3As (domeykite)	1929, R

Chap. V, table page 17i
(Supplement)

TABLE VB,1c (2)

Crystal	Literature
Fe_3C	1922,W&P; W; 1924,W&P; 1930,H; S; 1931,O&T; 1932,W
FeCl_3	1932,W
FeF_3	1931,E; K; 1933,W
Fe_3P	1928,H; 1929,H
LaF_3	1929,O
Li_3N	1926,B; F
MoO_3	1931,B; W
NH_3	1925,M,B&P; M&P; dS
NdF_3	1929,O
PH_3	1930,N&C
PI_3	1933,B
PdF_3	1931,E
PrF_3	1929,O
ReO_3	1931,B,L&M; 1932,M; 1933,B
RhF_3	1931,E
SbF_3	1929,O
SbI_3	1930,B
WO_3	1931,B
YF_3	1923,G&T

TABLE VC, 1c. EARLY BIBLIOGRAPHIC REFERENCES
TO COMPOUNDS RX_4

Crystal	Literature
CBr_4	1924, M
CI_4	1924, M; 1931, H&K
$Fe(CO)_4$	1931, B
Fe_4N	1928, B; H; O&I; 1929, H; 1930, H
GeI_4	1925, J, T&W
HfF_4	1934, S
Mn_4N	1929, H
SiF_4	1930, N
SiI_4	1931, H&K
SnI_4	1923, D; M&W; 1926, D; O
$TiBr_4$	1932, H&K
TiI_4	1932, H&K
$ZrCl_4$	1930, H
ZrF_4	1934, S

TABLE VD, 1c. EARLY BIBLIOGRAPHIC REFERENCES
TO HIGHER COMPOUNDS R_xX_y

Crystal	Literature
COMPOUNDS OF THE TYPE RX_6	
BaB ₆	1931, vS; 1932, A; vS&N
CaB ₆	1931, vS; 1932, A; vS&N; 1934, P&W
CeB ₆	1931, vS; 1932, A; vS&N
ErB ₆	1932, A; vS&N
GdB ₆	1932, A
LaB ₆	1931, vS; 1932, A; vS&N
NdB ₆	1932, A; vS&N
PrB ₆	1932, vS&N
SrB ₆	1931, vS; 1932, A; vS&N
Te (OH) ₆	1926, K&P; 1934, G&K
ThB ₆	1929, A; 1932, A
YB ₆	1932, A
YtB ₆	1932, A
COMPOUNDS OF THE TYPE R_3X_4	
Al ₄ C ₃	1934, vS&S

TABLE VD, 1c (2)

Crystal	Literature
---------	------------

MISCELLANEOUS COMPOUNDS R_xX_y

$[\text{Fe}(\text{CN})_2]_3$	1928, B&M
Cr_7C_3	1926, W&P; 1931, W
Cr_{23}C_6	1933, W
Mn_{23}C_6	1933, W
Tb_4O_7	1925, G, U&B
Co_9S_8	1932, C&R
CsC_8	1932, S&W
KC_8	1932, S&W
RbC_8	1932, S&W
$\text{Fe}_2(\text{CO})_9$	1926, B
Pr_6O_{11}	1925, G, U&B
W_4O_{11}	1934, E&F
$\text{B}_{10}\text{H}_{14}$	1931, M
CsC_{16}	1932, S&W
KC_{16}	1932, S&W
RbC_{16}	1932, S&W

CHAPTER V

EARLY BIBLIOGRAPHY

1922

- Backhurst, I., Variation of the intensity of reflected X-radiation with the temperature of the crystal, *Proc. Roy. Soc. (London)*, 102A, 340.
- Hedvall, J.A., Changes in properties produced by different methods of preparation of some ignited oxides, as studied by X-ray interference, *Arkiv. Kemi Mineral. Geol.*, 8, No. 11; *Z. anorg. Chem.*, 120, 327.
- Westgren, A. and Phragmén, G., X-ray studies on the crystal structure of steel, *J. Iron Steel Inst.*, 105, 241; *Engineering*, 113, 630.
- Wever, F., Iron Carbide, *Mitt. Kaiser Wilhelm-Inst. Eisenforsch.*, 4, 67.

1923

- Bozorth, R.M., The crystal structures of the cubic forms of arsenious and antimonous oxides, *J. Am. Chem. Soc.*, 45, 1621.
- Davey, W.P., Precision measurements of the crystal structures of Al_2O_3 , Fe_2O_3 and Cr_2O_3 , *Phys. Rev.*, 21, 716.
- Dickinson, R.G., The crystal structure of tin tetraiodide, *J. Am. Chem. Soc.*, 45, 958.
- Goldschmidt, V.M. and Thomassen, L., The crystal structure of natural and synthetic oxides of uranium, thorium, and cerium, *Skrifter Norske Videnskaps-Akad. Oslo I. Mat.-Naturv. Klasse*, 1923, No. 2.