

## Contents of further subvolumes of III/27

### Magnetic properties of non-metallic inorganic compounds based on transition elements

#### Subvolume A: Pnictides and chalcogenides I

1	Magnetic properties of pnictides and chalcogenides . . . . .	1
1.1	Pnictides and chalcogenides based on 3d transition elements (K. ADACHI, S. OGAWA) . . . .	1
1.1.1	Introduction . . . . .	1
1.1.1.1	General remarks . . . . .	1
1.1.1.2	List of frequently used symbols and abbreviations . . . . .	1
1.1.2	Compounds with pyrite, marcasite and arsenopyrite structures . . . . .	7
1.1.2.1	$\text{MX}_2$ compounds with pyrite ( $\text{FeS}_2$ ) type structure . . . . .	8
1.1.2.1.1	$\text{MnX}_2$ ( $\text{X}=\text{S}, \text{Se}, \text{Te}$ ) . . . . .	15
1.1.2.1.2	$\text{FeX}_2$ ( $\text{X}=\text{S}, \text{Se}, \text{Te}$ ) . . . . .	18
1.1.2.1.3	$\text{CoX}_2$ ( $\text{X}=\text{S}, \text{Se}, \text{Te}$ ) . . . . .	20
1.1.2.1.4	$\text{NiX}_2$ ( $\text{X}=\text{S}, \text{Se}, \text{Te}$ ) . . . . .	28
1.1.2.1.5	$\text{CuX}_2$ ( $\text{X}=\text{S}, \text{Se}, \text{Te}$ ) . . . . .	33
1.1.2.1.6	$\text{ZnX}_2$ ( $\text{X}=\text{S}, \text{Se}$ ) . . . . .	36
1.1.2.2	$\text{M}_x\text{M}'_{1-x}\text{X}_2$ mixed systems with pyrite (C2) type structure . . . . .	37
1.1.2.2.1	$\text{Cr}_x\text{Co}_{1-x}\text{S}_2$ . . . . .	37
1.1.2.2.2	$\text{Mn}_x\text{M}'_{1-x}\text{X}_2$ ( $\text{M}'=\text{Fe}, \text{Mg}, \text{Cu}, \text{Zn}; \text{X}=\text{S}, \text{Se}, \text{Te}$ ) . . . . .	37
1.1.2.2.3	$\text{Fe}_{1-x}\text{M}'_x\text{S}_2$ ( $\text{M}'=\text{Co}, \text{Ni}$ ) . . . . .	41
1.1.2.2.4	$\text{Co}_{1-x}\text{Ni}_x\text{S}_2$ . . . . .	45
1.1.2.2.5	$\text{Ni}_{1-x}\text{Cu}_x\text{S}_2$ . . . . .	46
1.1.2.3	$\text{MS}_{2-x}\text{Se}_x$ mixed systems with pyrite (C2) type structure . . . . .	47
1.1.2.3.1	$\text{CoS}_{2-x}\text{Se}_x$ . . . . .	47
1.1.2.3.2	$\text{NiS}_{2-x}\text{Se}_x$ . . . . .	52
1.1.2.4	$\text{MY}_x\text{X}_{2-x}$ and $\text{M}_{1-x}\text{M}'_x\text{YX}$ mixed systems with cobaltite or pyrite (C2) type structure . . . . .	54
1.1.2.4.1	$\text{CoP}_x\text{S}_{2-x}$ . . . . .	55
1.1.2.4.2	$\text{CoAs}_x\text{S}_{2-x}$ . . . . .	56
1.1.2.4.3	$\text{NiPS}$ . . . . .	57
1.1.2.4.4	$\text{NiAs}_x\text{S}_{2-x}$ . . . . .	58
1.1.2.4.5	$\text{Co}_{1-x}\text{Ni}_x\text{AsS}$ . . . . .	58
1.1.2.5	$\text{MX}_2, \text{MY}_2, \text{M}_x\text{M}'_{1-x}\text{Y}_2$ and $\text{MY}_{2-x}\text{X}_x$ compounds with marcasite (C18) type structure . . . . .	59
1.1.2.5.1	$\text{CrSb}_2$ . . . . .	60
1.1.2.5.2	$\text{FeP}_2$ . . . . .	61
1.1.2.5.3	$\text{FeAs}_2$ . . . . .	61
1.1.2.5.4	$\text{FeSb}_2$ . . . . .	61
1.1.2.5.5	$\text{CoSb}_2$ . . . . .	62
1.1.2.5.6	$\text{CoTe}_2$ . . . . .	63
1.1.2.5.7	$\text{NiAs}_2$ ( $\beta\text{-NiAs}_2$ ) . . . . .	63
1.1.2.5.8	$\text{NiSb}_2$ . . . . .	63

1.1.2.5.9	$M_{1-x}M'_xY_2$ (M, M'=Cr, Fe, Ni; Y=As, Sb) . . . . .	64
1.1.2.5.10	$FeAs_{2-x}Se_x$ . . . . .	64
1.1.2.6	$MY_xX_{2-x}$ and $MY_2$ compounds with arsenopyrite (E07) type structure . . . . .	64
1.1.2.6.1	$FeSb_xTe_{2-x}$ . . . . .	64
1.1.2.6.2	$CoP_2$ . . . . .	64
1.1.2.6.3	$CoAs_2$ . . . . .	65
1.1.2.6.4	$CoSb_2$ . . . . .	65
1.1.2.7	References for 1.1.2 . . . . .	65
1.1.3	Compounds with NiAs and MnP structures . . . . .	70
1.1.3.1	$M_{1-x}X$ chalcogenides with NiAs type structure and their mixed systems . . . . .	70
1.1.3.1.1	$Ti_{1-x}X$ (X=S, Se, Te) . . . . .	81
1.1.3.1.2	$V_{1-x}X$ (X=S, Se, Te) . . . . .	81
1.1.3.1.3	$Cr_{1-x}X$ (X=S, Se, Te) . . . . .	83
1.1.3.1.4	$MnX$ (X=S, Se, Te) . . . . .	88
1.1.3.1.5	$Fe_{1-x}X$ (X=S, Se, Te) . . . . .	89
1.1.3.1.6	$Co_{1-x}X$ (X=S, Se, Te) . . . . .	92
1.1.3.1.7	$Ni_{1-x}X$ (X=S, Se, Te) . . . . .	93
1.1.3.1.8	References for 1.1.3.1 . . . . .	140
1.1.3.2	$MY$ pnictides with MnP and NiAs type structures and their mixed systems . . . . .	148
1.1.3.2.1	$MP$ (M=V, Cr, Mn, Fe) . . . . .	159
1.1.3.2.2	$MAs$ (M=Ti, V, Cr, Mn, Fe, Co, Ni) . . . . .	163
1.1.3.2.3	$MSb$ (M=Ti, V, Cr, Mn, Fe, Co, Ni) . . . . .	170
1.1.3.2.4	$MBi$ (M=Mn, Ni) . . . . .	180
1.1.3.2.5	$Mn_{1-x}M_xP$ (M=V, Cr, Fe, Co) . . . . .	182
1.1.3.2.6	$MnP_{1-x}As_x$ . . . . .	190
1.1.3.2.7	$Mn_{1-x}M_xAs$ (M=Ti, V, Cr, Fe, Co, Ni) . . . . .	197
1.1.3.2.8	$MnAs_{1-x}Sb_x$ . . . . .	206
1.1.3.2.9	$Mn_{1-x}M_xSb$ (M=Ti, V, Cr, Fe, Co, Ni) . . . . .	208
1.1.3.2.10	$MnSb_{1-x}Sn_x$ . . . . .	213
1.1.3.2.11	Arsenides containing Cr . . . . .	214
1.1.3.2.12	Antimonides containing Cr . . . . .	221
1.1.3.2.13	Other mixed pnictides containing Fe . . . . .	224
1.1.3.2.14	References for 1.1.3.2 . . . . .	227
1.1.4	Compounds and mixed systems with $Fe_2P$ and $Cu_2Sb$ structures . . . . .	232
1.1.4.1	$M_2P$ compounds with $Fe_2P$ type structure and their mixed systems . . . . .	232
1.1.4.1.1	$M_2P$ (M=Mn, Fe, Co, Ni) . . . . .	236
1.1.4.1.2	Mixed system $(M, M')_2P$ (M, M'=Co, Mn, Fe, Ni) . . . . .	248
1.1.4.1.3	$Fe_2As_xP_{1-x}$ and related systems containing As . . . . .	261
1.1.4.1.4	Other mixed systems containing P . . . . .	263
1.1.4.1.5	References for 1.1.4.1 . . . . .	264
1.1.4.2	$M_2Y$ compounds with $Cu_2Sb$ type structure and their mixed systems . . . . .	265
1.1.4.2.1	$M_2As$ (M=Cr, Mn, Fe) . . . . .	269
1.1.4.2.2	$M_2Sb$ (M=Mn, Cu) . . . . .	270
1.1.4.2.3	$MnMGe$ (M=Al, Ga) . . . . .	273
1.1.4.2.4	$(M, M')_2Y$ and $M_2(Y, Y')$ compounds (M, M'=3d metals; Y, Y'=Sb, As) . . . . .	275
1.1.4.2.5	$Mn_{1-x}M_x(Al, Ga)Ge$ (M=3d metals) . . . . .	284
1.1.4.2.6	References for 1.1.4.2 . . . . .	286

1.1.5	Chalcogenide spinels and their mixed systems . . . . .	288
	References for 1.1.5 . . . . .	373
1.1.6	Other pnictides and chalcogenide . . . . .	383
1.1.6.1	Chalcopyrite, $\text{CuFeS}_2$ , and its Fe-substituted systems . . . . .	383
1.1.6.2	Anti- $\text{CaF}_2$ type antimonides, $\text{M}'\text{MSb}$ , and their mixed systems . . . . .	385
1.1.6.3	Heusler type antimonides, $\text{M}'_2\text{MSb}$ , and their mixed systems . . . . .	400
1.1.6.4	References for 1.1.6 . . . . .	423

### Subvolume B1: Pnictides and chalcogenides II (Lanthanide monopnictides)

1	Magnetic and related properties of pnictides and chalcogenides . . . . .	1
1.2	Pnictides and chalcogenides based on lanthanides (W. SUSKI, T. PALEWSKI) . . . . .	1
1.2.1	Lanthanide monopnictides . . . . .	1
1.2.1.1	Introduction . . . . .	1
1.2.1.2	List of frequently used symbols and abbreviations . . . . .	5
1.2.1.3	Survey of lanthanide monopnictides . . . . .	11
	La monopnictides . . . . .	11
	Ce monopnictides . . . . .	15
	Pr monopnictides . . . . .	46
	Nd monopnictides . . . . .	50
	Sm monopnictides . . . . .	51
	Eu monopnictides . . . . .	54
	Gd monopnictides . . . . .	55
	Tb monopnictides . . . . .	57
	Dy monopnictides . . . . .	61
	Ho monopnictides . . . . .	64
	Er monopnictides . . . . .	67
	Tm monopnictides . . . . .	70
	Yb monopnictides . . . . .	73
	Lu monopnictides . . . . .	81
1.2.1.4	Figures and tables . . . . .	83
1.2.1.5	References for 1.2.1 . . . . .	418
1.2.2	Lanthanide monochalcogenides . . . . .	see subvolume B2
1.2.3	Binary lanthanide polypnictides and polychalcogenides . . . . .	see subvolume B3
1.2.4	Ternary lanthanide pnictides and chalcogenides . . . . .	see subvolumes B4, B5
	Contents of further subvolumes of III/27 . . . . .	429
	List of editor and authors of Vol. III/27 . . . . .	452

**Subvolume B2: Pnictides and chalcogenides II (Lanthanide monochalcogenides)**

1	Magnetic and related properties of pnictides and chalcogenides . . . . .	1
1.2	Pnictides and chalcogenides based on lanthanides . . . . .	1
1.2.1	Lanthanide monopnictides . . . . .	see subvolume B1
1.2.2	Lanthanide monochalcogenides (W. SUSKI, T. PALEWSKI) . . . . .	1
1.2.2.1	Introduction . . . . .	1
1.2.2.2	List of frequently used symbols and abbreviations . . . . .	2
1.2.2.3	Survey of lanthanide monochalcogenides . . . . .	9
	La monochalcogenides . . . . .	9
	Ce monochalcogenides . . . . .	11
	Pr monochalcogenides . . . . .	17
	Nd monochalcogenides . . . . .	18
	Sm monochalcogenides . . . . .	19
	Eu monochalcogenides . . . . .	34
	Gd monochalcogenides . . . . .	56
	Tb monochalcogenides . . . . .	59
	Dy monochalcogenides . . . . .	60
	Ho monochalcogenides . . . . .	61
	Er monochalcogenides . . . . .	61
	Tm monochalcogenides . . . . .	62
	Yb monochalcogenides . . . . .	77
1.2.2.4	Figures and tables . . . . .	83
1.2.2.5	References for 1.2.2 . . . . .	421

**Subvolume B3: Pnictides and chalcogenides II (Binary lanthanide polypnictides and polychalcogenides)**

1	Magnetic and related properties of pnictides and chalcogenides . . . . .	1
1.2	Pnictides and chalcogenides based on lanthanides . . . . .	1
1.2.1	Lanthanide monopnictides . . . . .	see subvolume B1
1.2.2	Lanthanide monochalcogenides . . . . .	see subvolume B2
1.2.3	Binary lanthanide polypnictides and polychalcogenides (W. SUSKI, T. PALEWSKI) . . . . .	1
1.2.3.0	Introduction . . . . .	1
	References for 1.2.3.0 . . . . .	11
1.2.3.1	List of frequently used symbols and abbreviations . . . . .	13

1.2.3.2	Survey of binary lanthanide pnictides . . . . .	19
1.2.3.2.1	Ln <sub>4</sub> X <sub>3</sub> pnictides with anti-Th <sub>3</sub> P <sub>4</sub> structure . . . . .	19
	Figures and tables for 1.2.3.2.1 . . . . .	28
	References for 1.2.3.2.1 . . . . .	84
1.2.3.2.2	LnX <sub>3</sub> tripnictides EuP <sub>3</sub> , EuAs <sub>3</sub> , and their mutually mixed compounds. . . . .	87
	Figures and tables for 1.2.3.2.2 . . . . .	93
	References for 1.2.3.2.2 . . . . .	129
1.2.3.2.3	Ln <sub>2</sub> X, Ln <sub>5</sub> X <sub>3</sub> , Ln <sub>3</sub> X <sub>2</sub> and LnX <sub>2</sub> lanthanide pnictides. . . . .	130
	Figures and tables for 1.2.3.2.3 . . . . .	141
	References for 1.2.3.2.3 . . . . .	176
1.2.3.3	Survey of binary lanthanide chalcogenides . . . . .	178
1.2.3.3.1	Ln <sub>3</sub> X <sub>4</sub> chalcogenides with Th <sub>3</sub> P <sub>4</sub> -type structure . . . . .	178
	Figures and tables for 1.2.3.3.1 . . . . .	199
	References for 1.2.3.3.1 . . . . .	274
1.2.3.3.2	Ln <sub>2</sub> X <sub>3</sub> chalcogenides . . . . .	279
	Figures for 1.2.3.3.2 . . . . .	290
	References for 1.2.3.3.2 . . . . .	316
1.2.3.3.3	LnX <sub>2</sub> , Ln <sub>2</sub> X <sub>5</sub> and LnX <sub>3</sub> lanthanide and other polychalcogenides . . . . .	318
	Figures and tables for 1.2.3.3.3 . . . . .	328
	References for 1.2.3.3.3 . . . . .	360
1.2.4	Ternary lanthanide pnictides and chalcogenides . . . . . see subvolumes B4, B5	
	Contents of further subvolumes of III/27 . . . . .	362
	List of editor and authors of Vol. III/27 . . . . .	387

## Subvolume B4: Pnictides and Chalcogenides II (Ternary lanthanide pnictides)

### Part α: 1:1:1 and 1:1:2 type compounds

1	Magnetic and related properties of pnictides and chalcogenides . . . . .	1
1.2	Pnictides and chalcogenides based on lanthanides . . . . .	1
1.2.1	Lanthanide monopnictides . . . . . see subvolume B1	
1.2.2	Lanthanide monochalcogenides . . . . . see subvolume B2	
1.2.3	Binary lanthanide polypnictides and polychalcogenides . . . . . see subvolume B3	
1.2.4	Ternary lanthanide pnictides and chalcogenides . . . . .	1
1.2.4.1	Ternary lanthanide pnictides (Ln-T-X) (T. PALEWSKI, W. SUSKI) . . . . .	1
1.2.4.1.0	Introduction . . . . .	1
	Figures for the Introduction . . . . .	12
1.2.4.1.1	List of frequently used symbols and abbreviations . . . . .	61
1.2.4.1.2	Survey of ternary lanthanide pnictides . . . . .	67
1.2.4.1.2.1	Ternary 1:1:1 compounds . . . . .	67
	Figures and Tables for 1.2.4.1.2.1 . . . . .	106

1.2.4.1.2.2	Ternary 1:1:2 compounds . . . . .	367
	Figures and Tables for 1.2.4.1.2.2 . . . . .	379
1.2.4.1.2.3	Ternary 1:2:2 compounds . . . . .	see subvolume B4 $\beta$
1.2.4.1.2.4	Ternary 1:4:12 compounds . . . . .	see subvolume B4 $\beta$
1.2.4.1.2.5	Ternary 3:3:4 compounds . . . . .	see subvolume B4 $\beta$
1.2.4.1.2.6	Ternary compounds of various types . . . . .	see subvolume B4 $\beta$
	References for 1.2.4.1 . . . . .	429
	Contents of further subvolumes of III/27 . . . . .	444
	List of editor and authors of Vol. III/27 . . . . .	475

### Subvolume B4: Pnictides and Chalcogenides II (Ternary lanthanide pnictides)

#### Part $\beta$ : 1:2:2, 1:4:12, 3:3:4 and other type compounds

1	Magnetic and related properties of pnictides and chalcogenides . . . . .	1
1.2	Pnictides and chalcogenides based on lanthanides . . . . .	1
1.2.1	Lanthanide monopnictides . . . . .	see subvolume B1
1.2.2	Lanthanide monochalcogenides . . . . .	see subvolume B2
1.2.3	Binary lanthanide polypnictides and polychalcogenides . . . . .	see subvolume B3
1.2.4	Ternary lanthanide pnictides and chalcogenides . . . . .	1
1.2.4.1	Ternary lanthanide pnictides (Ln-T-X) (T. PALEWSKI, W. SUSKI) . . . . .	1
1.2.4.1.0	Introduction . . . . .	1
	Figures for the Introduction . . . . .	12
1.2.4.1.1	List of frequently used symbols and abbreviations . . . . .	61
1.2.4.1.2	Survey of ternary lanthanide pnictides . . . . .	67
1.2.4.1.2.1	Ternary 1:1:1 compounds . . . . .	see subvolume B4 $\alpha$
1.2.4.1.2.2	Ternary 1:1:2 compounds . . . . .	see subvolume B4 $\alpha$
1.2.4.1.2.3	Ternary 1:2:2 compounds . . . . .	67
	Figures and Tables for 1.2.4.1.2.3 . . . . .	82
1.2.4.1.2.4	Ternary 1:4:12 compounds . . . . .	146
	Figures and Tables for 1.2.4.1.2.4 . . . . .	161
1.2.4.1.2.5	Ternary 3:3:4 compounds . . . . .	247
	Figures and Tables for 1.2.4.1.2.5 . . . . .	257
1.2.4.1.2.6	Ternary compounds of various type . . . . .	316
	Figures and Tables for 1.2.4.1.2.6 . . . . .	334
	References for 1.2.4.1 . . . . .	404
	Contents of further subvolumes of III/27 . . . . .	419
	List of editor and authors of Vol. III/27 . . . . .	450

**Subvolume B5: Pnictides and Chalcogenides II (Ternary lanthanide chalcogenides, misfit compounds, and ternary lanthanide pnictides s containing s-or p- electron elements)**

1	Magnetic and related properties of pnictides and chalcogenides . . . . .	1
1.2	Pnictides and chalcogenides based on lanthanides . . . . .	1
1.2.1	Lanthanide monopnictides . . . . .	see subvolume B1
1.2.2	Lanthanide monochalcogenides . . . . .	see subvolume B2
1.2.3	Binary lanthanide polypnictides and polychalcogenides . . . . .	see subvolume B3
1.2.4	Ternary lanthanide pnictides and chalcogenides	
1.2.4.1	Ternary lanthanide pnictides (Ln-T-X) . . . . .	see subvolumes B4 $\alpha$ , $\beta$
1.2.4.2	Ternary lanthanide chalcogenides, misfit compounds, and ternary lanthanide pnictides containing s- or p-electron elements (T. PALEWSKI, W. SUSKI) . . . . .	1
1.2.4.2.1	Introduction . . . . .	1
	Figures for 1.2.4.2.1 . . . . .	10
	References for 1.2.4.2.1 . . . . .	33
1.2.4.2.2	List of frequently used symbols and abbreviations . . . . .	35
1.2.4.2.3	Survey of ternary chalcogenides containing d-electron elements . . . . .	43
	Figures and tables for 1.2.4.2.3 . . . . .	64
	References for 1.2.4.2.3 . . . . .	148
1.2.4.2.4	Survey of misfit compounds . . . . .	151
	Figures and tables for 1.2.4.2.4 . . . . .	176
	References for 1.2.4.2.4 . . . . .	295
1.2.4.2.5	Survey of ternary pnictides and chalcogenides containing s-, p- or f-electron elements . . . . .	298
	Figures and tables for 1.2.4.2.5 . . . . .	328
	References for 1.2.4.2.5 . . . . .	425
	Contents of further subvolumes of III/27 . . . . .	433
	List of editor and authors of Vol. III/27 . . . . .	465

**Subvolume B 6 $\alpha$ : Pnictides and chalcogenides III (Actinide monopnictides)**

1	Magnetic and related properties of pnictides and chalcogenides . . . . .	1
1.3	Pnictides and chalcogenides based on actinides . . . . .	1
1.3.1	Actinide monopnictides and monochalcogenides . . . . .	1
1.3.1.1	Actinide monopnictides (R. TROĆ) . . . . .	1
1.3.1.1.1	Introduction . . . . .	1
1.3.1.1.1.1	General considerations . . . . .	1
1.3.1.1.1.2	Historical view . . . . .	2
1.3.1.1.1.3	Preparation and crystal structure . . . . .	2
1.3.1.1.1.4	Physical properties . . . . .	4
1.3.1.1.1.5	Magnetic properties . . . . .	7
1.3.1.1.1.6	Transport properties . . . . .	10

1.3.1.1.1.7	Arrangement of tables and figures . . . . .	10
1.3.1.1.2	List of frequently used symbols and abbreviations . . . . .	12
1.3.1.1.2.1	Symbols . . . . .	12
1.3.1.1.2.2	Abbreviations . . . . .	16
1.3.1.1.3	Survey . . . . .	20
1.3.1.1.4	Figures and tables . . . . .	65
	Figures . . . . .	65
	R. AnX. General properties of actinide mononpnictides . . . . .	65
	I. AnC. Actinide monocarbides . . . . .	102
	II. AnN. Actinide mononitrides . . . . .	136
	III. AnP. Actinide monophosphides . . . . .	187
	IV. AnAs. Actinide monoarsenides . . . . .	239
	V. AnSb. Actinide monoantimonides . . . . .	306
	VI. AnBi. Actinide monobismuthides . . . . .	406
	Tables . . . . .	417
1.3.1.1.5	References for 1.3.1.1 . . . . .	424
	Index of substances for Volume III/27B6 $\alpha$ . . . . .	445
	Contents of further subvolumes of III/27 . . . . .	453
	List of editor and authors of Vol. III/27 . . . . .	491

**Subvolume B7: Pnictides and Chalcogenides III (Binary non-equiatomic actinide pnictides and chalcogenides)**

1	Magnetic and related properties of pnictides and chalcogenides . . . . .	1
1.3	Pnictides and chalcogenides based on actinides . . . . .	1
1.3.1	Actinide mononpnictides and monochalcogenides . . . . .	see subvolume B6
1.3.2	Binary non-equiatomic actinide pnictides and chalcogenides (D. KACZOROWSKI; R. TROĆ) . . . . .	1
1.3.2.1	Introduction . . . . .	1
1.3.2.1.1	General remarks . . . . .	1
1.3.2.1.2	Synthesis of binary phases and their crystallochemistry . . . . .	1
1.3.2.1.3	Crystal structures and valence states . . . . .	4
1.3.2.1.4	Physical properties . . . . .	8
1.3.2.1.5	Arrangement of figures and tables . . . . .	13
1.3.2.2	List of frequently used symbols and abbreviations . . . . .	14
1.3.2.2.1	Symbols . . . . .	14
1.3.2.2.2	Abbreviations . . . . .	17
1.3.2.3	Survey . . . . .	19
1.3.2.4	Figures and tables . . . . .	49
1.3.2.5	References for 1.3.2 . . . . .	290
	Index of substances for Volume III/27B7 . . . . .	301
	Contents of further subvolumes of III/27 . . . . .	310
	List of editor and authors of Vol. III/27 . . . . .	348



**Subvolume B8: Pnictides and Chalcogenides III (Ternary actinide pnictides and chalcogenides)**

1	Magnetic and related properties of pnictides and chalcogenides . . . . .	1
1.3	Pnictides and chalcogenides based on actinides . . . . .	1
1.3.1	Actinide monopnictides and monochalcogenides . . . . .	see subvolume B6
1.3.2	Binary non-equiatomic actinide pnictides and chalcogenides . . . . .	see subvolume B7
1.3.3	Ternary actinide pnictides and chalcogenides (D. KACZOROWSKI) . . . . .	1
1.3.3.1	Introduction . . . . .	1
1.3.3.1.1	General . . . . .	1
1.3.3.1.2	Magnetic and related properties . . . . .	2
1.3.3.1.2.1	Ternary actinide pnictides and chalcogenides containing s- and p-electron elements . . . . .	2
1.3.3.1.2.2	Ternary actinide pnictides and chalcogenides containing d-electron elements . . . . .	5
1.3.3.1.2.3	Ternary actinide pnictides and chalcogenides containing 4f-electron elements . . . . .	10
1.3.3.1.3	Arrangement of figures and tables . . . . .	10
1.3.3.1.4	References for 1.3.3.1 . . . . .	11
1.3.3.2	List of frequently used symbols and abbreviations . . . . .	15
1.3.3.2.1	Symbols . . . . .	15
1.3.3.2.2	Abbreviations . . . . .	18
1.3.3.3	Ternary actinide pnictides and chalcogenides containing s- and p-electron elements (A = Li, Na, K, Rb, Cs; B = Mg, Ca, Sr, Ba; M = Si, Ge, Sn, Pb; Z = Cl, Br, I) . . . . .	20
1.3.3.3.1	Survey . . . . .	20
1.3.3.3.2	Figures and tables . . . . .	35
1.3.3.4	Ternary actinide pnictides and chalcogenides containing d-electron transition elements (T) . . . . .	171
1.3.3.4.1	Survey . . . . .	171
1.3.3.4.2	Figures and tables . . . . .	184
1.3.3.5	Ternary actinide pnictides and chalcogenides containing lanthanide atoms (Ln) . . . . .	331
1.3.3.5.1	Survey . . . . .	331
1.3.3.5.2	Figures and tables . . . . .	335
1.3.3.6	References for 1.3.3.2...1.3.3.5 . . . . .	349
	Contents of further subvolumes of III/27 . . . . .	358
	List of editor and authors of Vol. III/27 . . . . .	391

**Subvolume C1: Binary lanthanide oxides**

2	Magnetic properties of binary lanthanide and actinide oxides . . . . .	1
2.1	Binary lanthanide oxides (W. SUSKI, T. PALEWSKI) . . . . .	1
2.1.1	Introduction . . . . .	1

2.1.2	List of frequently used symbols and abbreviations . . . . .	6
2.1.3	Survey of lanthanide oxides . . . . .	10
	La oxides . . . . .	10
	Ce oxides . . . . .	10
	Pr oxides . . . . .	13
	Nd oxides . . . . .	16
	Pm oxides . . . . .	16
	Sm oxides . . . . .	16
	Eu oxides . . . . .	18
	Gd oxides . . . . .	25
	Tb oxides . . . . .	25
	Dy oxides . . . . .	27
	Ho oxides . . . . .	27
	Er oxides . . . . .	28
	Tm oxides . . . . .	29
	Yb oxides . . . . .	29
	Lu oxides . . . . .	30
2.1.4	Figures and tables . . . . .	31
2.1.5	References for 2.1 . . . . .	121

### Subvolume C2: Binary actinide oxides

2	Magnetic and related properties of binary lanthanide and actinide oxides . . . . .	1
2.1	Binary lanthanide oxides . . . . .	see subvolume C1
2.2	Binary actinide oxides (R. TROĆ, D. KACZOROWSKI) . . . . .	1
2.2.1	Introduction . . . . .	1
2.2.1.1	General . . . . .	1
2.2.1.2	Chemical stability of binary actinide oxides . . . . .	2
2.2.1.3	Preparation technique and phase relations of binary actinide oxides . . . . .	3
2.2.1.4	Electronic structure of binary actinide oxides . . . . .	5
2.2.1.5	Magnetic and related properties of binary actinide oxides . . . . .	7
2.2.1.6	Arrangement of figures and tables . . . . .	10
2.2.1.7	References for 2.2.1 . . . . .	11
2.2.2	List of frequently used symbols and abbreviations . . . . .	13
2.2.3	Survey of binary actinide oxides with the $\text{CaF}_2$ -type crystal structure (actinide dioxides) . . . . .	17
	$\text{AnO}_2$ , comparison of properties . . . . .	17
	$\text{ThO}_2$ . . . . .	18
	$\text{UO}_2$ . . . . .	19
	$\text{UO}_{2+x}$ . . . . .	28
	$(\text{U}, \text{M})\text{O}_{2+x}$ . . . . .	29
	$\text{NpO}_2$ . . . . .	35
	$\text{NpO}_{2+x}$ . . . . .	37
	$\text{U}_{1-y}\text{Np}_y\text{O}_2$ . . . . .	38
	$\text{PuO}_2$ . . . . .	38
	$\text{U}_{1-y}\text{Pu}_y\text{O}_{2.00}$ . . . . .	39

	Pu <sub>1-y</sub> Np <sub>y</sub> O <sub>2</sub> . . . . .	40
	AmO <sub>2</sub> . . . . .	40
	U <sub>1-y</sub> Am <sub>y</sub> O <sub>2-x</sub> . . . . .	40
	CmO <sub>2</sub> . . . . .	40
	BkO <sub>2</sub> . . . . .	41
	CfO <sub>2</sub> . . . . .	41
2.2.4	Survey of binary actinide oxides with miscellaneous crystal structures . . . . .	42
	An <sub>2</sub> O <sub>3</sub> , comparison of properties . . . . .	42
	Np <sub>2</sub> O <sub>3</sub> . . . . .	42
	Pu <sub>2</sub> O <sub>3</sub> . . . . .	42
	Am <sub>2</sub> O <sub>3</sub> . . . . .	42
	Cm <sub>2</sub> O <sub>3</sub> . . . . .	42
	Bk <sub>2</sub> O <sub>3</sub> . . . . .	43
	Cf <sub>2</sub> O <sub>3</sub> . . . . .	43
	Cf <sub>7</sub> O <sub>12</sub> . . . . .	43
	Es <sub>2</sub> O <sub>3</sub> . . . . .	43
	Survey of binary uranium oxides UO <sub>x</sub> (x ≥ 2.25) . . . . .	43
	U <sub>4</sub> O <sub>9</sub> (UO <sub>2.25</sub> ) . . . . .	43
	U <sub>3</sub> O <sub>7</sub> (UO <sub>2.33</sub> ) . . . . .	44
	U <sub>3</sub> O <sub>8</sub> (UO <sub>2.67</sub> ) . . . . .	45
	U <sub>2</sub> O <sub>5</sub> (UO <sub>2.5</sub> ) . . . . .	45
	UO <sub>3</sub> . . . . .	45
2.2.5	Figures and tables . . . . .	47
2.2.6	References for 2.2.2 - 2.2.5 . . . . .	213
	Contents of further subvolumes of III/27 . . . . .	224
	List of editor and authors of Vol. III/27 . . . . .	248

## Subvolume D: Oxy-spinels

3	Magnetic properties of oxy-spinels . . . . .	1
3.1	Binary oxy-spinels (Co <sub>3</sub> O <sub>4</sub> , Fe <sub>3</sub> O <sub>4</sub> , γ-Fe <sub>2</sub> O <sub>3</sub> , Mn <sub>3</sub> O <sub>4</sub> ) (V. A. M. BRABERS, T. E. WHALL) . . . . .	1
3.1.1	Introduction . . . . .	1
	a) List of frequently used symbols . . . . .	1
	b) List of abbreviations . . . . .	3
3.1.2	Cobalt oxide, Co <sub>3</sub> O <sub>4</sub> . . . . .	4
	References for 3.1.2 . . . . .	16
3.1.3	Magnetite, Fe <sub>3</sub> O <sub>4</sub> . . . . .	72
	References for 3.1.3 . . . . .	72
3.1.4	Maghemite, γ-Fe <sub>2</sub> O <sub>3</sub> . . . . .	77
	References for 3.1.4 . . . . .	85
3.1.5	Hausmannite, Mn <sub>3</sub> O <sub>4</sub> . . . . .	86
	References for 3.1.5 . . . . .	99
3.2	Iron oxy-spinels (V. A. M. BRABERS) . . . . .	100

3.2.1	Introduction . . . . .	100
	a) General remarks . . . . .	100
	b) List of frequently used symbols . . . . .	100
	c) List of abbreviations . . . . .	103
	d) Survey on tables and figures for 3.2 . . . . .	105
3.2.2	Fe-oxide spinels containing Al, Ca or Cd . . . . .	106
	References for 3.2.2 . . . . .	141
3.2.3	Fe-oxide spinels containing Co . . . . .	143
	References for 3.2.3 . . . . .	173
3.2.4	Fe-oxide spinels containing Cr . . . . .	175
	References for 3.2.4 . . . . .	189
3.2.5	Fe-oxide spinels containing Cu . . . . .	190
	References for 3.2.5 . . . . .	216
3.2.6	Fe-oxide spinels containing Ga, Ge, In, Li or Mg . . . . .	218
	References for 3.2.6 . . . . .	267
3.2.7	Fe-oxide spinels containing Mn, Mo . . . . .	270
	References for 3.2.7 . . . . .	301
3.2.8	Fe-oxide spinels containing Ni . . . . .	303
	References for 3.2.8 . . . . .	331
3.2.9	Fe-oxide spinels containing Sb, Sn, Ti, V or Zn . . . . .	333
	References for 3.2.9 . . . . .	365
3.3	Non-iron oxy-spinels (E. AGOSTINELLI, D. FIORANI, A. M. TESTA) . . . . .	367
3.3.1	Introduction . . . . .	367
	a) General remarks . . . . .	367
	b) List of frequently used symbol . . . . .	367
	c) List of abbreviations . . . . .	369
3.3.2	General properties of oxide spinels . . . . .	370
	References for 3.3.2 . . . . .	374
3.3.3	Al-oxide spinels and Al-oxide spinels with substitutions . . . . .	375
	References for 3.3.3 . . . . .	386
3.3.4	Co-oxide spinels and Co-oxide spinels with substitutions . . . . .	387
	References for 3.3.4 . . . . .	400
3.3.5	Cr-oxide spinels and Cr-oxide spinels with substitutions . . . . .	401
	References for 3.3.5 . . . . .	420
3.3.6	Ga-oxide spinels and Ga-oxide spinels with substitutions . . . . .	421
	References for 3.3.6 . . . . .	426
3.3.7	Ge-oxide spinels and Ge-oxide spinels with substitutions . . . . .	427
	References for 3.3.7 . . . . .	434
3.3.8	In-oxide spinels and In-oxide spinels with substitutions . . . . .	434
	References for 3.3.8 . . . . .	436
3.3.9	Mn-oxide spinels and Mn-oxide spinels with substitutions . . . . .	437
	References for 3.3.9 . . . . .	463
3.3.10	Rh-oxide spinels and Rh-oxide spinels with substitutions . . . . .	465
	References for 3.3.10 . . . . .	469
3.3.11	Sb-oxide spinels and Sb-oxide spinels with substitutions . . . . .	469
	References for 3.3.11 . . . . .	475
3.3.12	Sn-oxide spinels and Sn-oxide spinels with substitutions . . . . .	475
	References for 3.3.12 . . . . .	478
3.3.13	Te-oxide spinels and Te-oxide spinels with substitutions . . . . .	479
	Reference for 3.3.13 . . . . .	479
3.3.14	Ti-oxide spinels and Ti-oxide spinels with substitutions . . . . .	480

	References for 3.3.14 . . . . .	495
3.3.15	V-oxide spinels and V-oxide spinels with substitutions . . . . .	496
	References for 3.3.15 . . . . .	501

## Subvolume E: Garnets

4	Magnetic properties of garnets . . . . .	1
4.1	Iron garnets (P. NOVAK) . . . . .	1
4.1.1	Introduction . . . . .	1
4.1.1.1	General remarks . . . . .	1
4.1.1.2	List of frequently used symbols and abbreviations . . . . .	1
4.1.2	Magnetic properties . . . . .	4
4.1.2.1	Magnetic moments and molecular field data . . . . .	4
4.1.2.1.1	Saturation magnetization and Curie temperature . . . . .	4
4.1.2.1.2	Molecular-field- and exchange constants . . . . .	18
4.1.2.1.3	Magnetic moments of the rare earth ions . . . . .	20
4.1.2.2	Magnetic phase transitions . . . . .	21
4.1.2.2.1	Spontaneous spin-reorientational transitions . . . . .	22
4.1.2.2.2	Field induced transitions . . . . .	23
4.1.2.3	Magnetocrystalline anisotropy . . . . .	25
4.1.2.3.1	Cubic anisotropy . . . . .	25
4.1.2.3.2	Non-cubic anisotropy . . . . .	31
4.1.2.4	Ferromagnetic resonance (FMR) . . . . .	39
4.1.2.4.1	Resonance field . . . . .	39
4.1.2.4.2	FMR line width . . . . .	40
4.1.2.4.3	g-factor . . . . .	43
4.1.2.5	Spin waves, magnetostatic modes and relaxation . . . . .	45
4.1.2.5.1	Spin waves and magnetostatic modes . . . . .	45
4.1.2.5.2	Non-linear effects and relaxation . . . . .	46
4.1.2.6	Nuclear magnetic resonance (NMR) . . . . .	49
4.1.2.7	Mössbauer spectroscopy . . . . .	51
4.1.2.8	Magnetic domains (stripe and bubble domains) . . . . .	53
4.1.2.8.1	Static properties . . . . .	53
4.1.2.8.2	Dynamic properties . . . . .	58
4.1.3	Magnetoelastic properties . . . . .	60
4.1.3.1	Magnetostriction . . . . .	60
4.1.3.2	Magnetoelastic waves . . . . .	63
4.1.4	Elastic properties . . . . .	63
4.1.5	Optical and magneto-optical properties . . . . .	64
4.1.5.1	Optical properties . . . . .	65
4.1.5.1.1	Absorption of light . . . . .	65
4.1.5.1.2	Reflection of light . . . . .	73
4.1.5.1.3	Refractive index . . . . .	75
4.1.5.2	Magneto-optical properties . . . . .	77
4.1.5.2.1	Faraday rotation . . . . .	77
4.1.5.2.2	Magnetic circular dichroism (MCD) . . . . .	93
4.1.5.2.3	Kerr effects . . . . .	100
4.1.5.2.4	Magnetic linear birefringence (MLB) and nonmagnetic linear birefringence . . . . .	102

4.1.5.2.5	Magnetic linear dichroism (MLD) . . . . .	103
4.1.5.3	Photoinduced effects . . . . .	104
4.1.6	Thermal properties . . . . .	106
4.1.7	Electrical properties . . . . .	107
4.1.7.1	Electrical conductivity . . . . .	107
4.1.7.2	Magnetoresistance and magnetoelectric effect . . . . .	110
4.1.8	Crystal structure . . . . .	111
4.1.9	References for 4.1 . . . . .	113
4.1.10	List of iron garnets in III/4a, b, 12a and 27e . . . . .	125
4.2	Non-iron garnets (Z. A. KAZEI, N. P. KOLMAKOVA, V. I. SOKOLOV) . . . . .	136
4.2.1	Introduction . . . . .	136
4.2.1.1	General remarks . . . . .	136
4.2.1.2	List of frequently used symbols and abbreviation . . . . .	136
4.2.2	Magnetic susceptibility . . . . .	140
4.2.2.1	Rare earth garnets . . . . .	140
4.2.2.2	3d-ion garnets . . . . .	143
4.2.3	Magnetization and magnetic structure . . . . .	148
4.2.3.1	Magnetic moments and magnetic anisotropies of terbium, dysprosium and holmium aluminum garnets . . . . .	149
4.2.3.2	Magnetic moments of rare earth gallium garnets . . . . .	151
4.2.3.3	Magnetic neutron scattering in dysprosium aluminum garnets . . . . .	151
4.2.3.4	Magnetic neutron scattering in terbium, holmium and dysprosium gallium garnets . . . . .	156
4.2.3.5	Magnetization and magnetic phase transitions in manganese germanium garnets . . . . .	157
4.2.3.6	Garnets with several 3d-ions . . . . .	160
4.2.4	Results of magnetic resonance experiments . . . . .	162
4.2.4.1	Electron paramagnetic resonance of paramagnetic metal ions in diamagnetic garnets . . . . .	162
4.2.4.2	Electron paramagnetic resonance of rare earth ions in diamagnetic garnets . . . . .	164
4.2.4.3	Electron paramagnetic resonance of impurities in paramagnetic garnets . . . . .	166
4.2.4.4	Nuclear magnetic resonance . . . . .	167
4.2.4.5	Antiferromagnetic resonance . . . . .	167
4.2.5	Optical and magneto-optical properties . . . . .	169
4.2.5.1	Crystal-field parameters . . . . .	169
4.2.5.2	Optical spectra and index of refraction . . . . .	171
4.2.5.3	Information on colour centres . . . . .	186
4.2.5.4	Further references for results from optical measurements . . . . .	190
4.2.5.5	Magneto-optical properties . . . . .	197
4.2.6	Mössbauer spectroscopy . . . . .	202
4.2.7	Electron spin-lattice relaxation of paramagnetic ions in garnets . . . . .	205
4.2.8	Thermal properties . . . . .	207
4.2.8.1	Heat capacity . . . . .	207
4.2.8.2	Derived thermodynamic functions . . . . .	215
4.2.8.3	Debye temperature . . . . .	218
4.2.8.4	Thermal expansion . . . . .	219
4.2.8.5	Kapitza conductance . . . . .	222
4.2.8.6	Thermal conductivity . . . . .	223
4.2.8.7	Ultrasound attenuation . . . . .	227
4.2.9	Elastic and photoelastic properties . . . . .	230
4.2.9.1	Elastic and photoelastic constants at room temperature . . . . .	230
4.2.9.2	Temperature dependences . . . . .	231
4.2.10	Magnetostriction . . . . .	232
4.2.10.1	Magnetostriction of rare earth garnets . . . . .	232

4.2.10.2	Magnetostriction of antiferromagnetic garnets with 3d-ions . . . . .	235
4.2.11	Electrical properties . . . . .	237
4.2.11.1	Electrical conductivity and thermoelectric power . . . . .	238
4.2.11.2	Photoconductivity . . . . .	242
4.2.12	References for 4.2 . . . . .	243
4.2.13	List of non-iron garnets in III/4b, 12a and 27e . . . . .	253

### Subvolume F1α: Perovskites I (Part α)

5	Magnetic properties of oxides with perovskite, corundum, ilmenite and amorphous structures . . . . .	1
5.1	Perovskite-type oxides based on 3d elements (E. BURZO) . . . . .	1
5.1.1	Introduction for Chap. 5.1 - 5.3 . . . . .	1
5.1.1.1	General remarks . . . . .	1
5.1.1.2	List of frequently used symbols and abbreviations . . . . .	2
5.1.2	Scandium-based perovskites . . . . .	6
	References for 5.1.2 . . . . .	8
5.1.3	Titanium-based perovskites . . . . .	9
5.1.3.1	Crystal structure. Lattice parameters . . . . .	9
5.1.3.2	Magnetization and magnetic susceptibilities . . . . .	20
5.1.3.3	Electron paramagnetic resonance (EPR) data . . . . .	27
5.1.3.4	Nuclear gamma resonance (NGR) data . . . . .	30
5.1.3.5	Perturbed angular correlations (PAC) . . . . .	33
5.1.3.6	Electrical resistivities . . . . .	33
5.1.3.7	Heat capacity . . . . .	42
5.1.3.8	Dielectric properties . . . . .	44
5.1.3.9	Electron spectroscopy data . . . . .	46
5.1.3.10	Infrared spectra . . . . .	48
5.1.3.11	Optical spectra . . . . .	49
5.1.3.12	References for 5.1.3 . . . . .	53
5.1.4	Vanadium-based perovskites . . . . .	62
5.1.4.1	Crystal structure. Lattice parameters . . . . .	62
5.1.4.2	Magnetization and magnetic susceptibilities . . . . .	71
5.1.4.3	<sup>51</sup> V nuclear magnetic resonance (NMR) data . . . . .	84
5.1.4.4	Electron paramagnetic resonance (EPR) data . . . . .	86
5.1.4.5	Electrical resistivities . . . . .	87
5.1.4.6	Heat capacity . . . . .	94
5.1.4.7	Infrared spectra . . . . .	94
5.1.4.8	Electron spectroscopy data . . . . .	95
5.1.4.9	Optical spectra . . . . .	98
5.1.4.10	References for 5.1.4 . . . . .	99
5.1.5	Chromium-based perovskites . . . . .	102
5.1.5.1	Crystal structure. Lattice parameters . . . . .	102
5.1.5.2	Magnetization and magnetic susceptibilities . . . . .	109
5.1.5.3	Neutron diffraction data . . . . .	112
5.1.5.4	Electrical resistivities . . . . .	113
5.1.5.5	Dielectric properties . . . . .	118
5.1.5.6	Thermal properties . . . . .	118

5.1.5.7	Infrared spectra . . . . .	119
5.1.5.8	Electron spectroscopy data . . . . .	119
5.1.5.9	References for 5.1.5 . . . . .	120
5.1.6	Manganese-based perovskites . . . . .	123
5.1.6.1	Introduction . . . . .	123
5.1.6.2	Crystal structure. Lattice parameters. Preparation methods . . . . .	123
5.1.6.3	Magnetization and magnetic susceptibilities . . . . .	147
5.1.6.4	Neutron diffraction data . . . . .	166
5.1.6.5	Nuclear magnetic resonance (NMR) data . . . . .	169
5.1.6.6	Nuclear gamma resonance (NGR) data . . . . .	170
5.1.6.7	Positron annihilation . . . . .	171
5.1.6.8	Heat capacity . . . . .	171
5.1.6.9	Electrical resistivities . . . . .	173
5.1.6.10	Mechanical properties . . . . .	186
5.1.6.11	Infrared data . . . . .	186
5.1.6.12	Magneto-optical properties . . . . .	188
5.1.6.13	X-ray photoelectron spectroscopy . . . . .	189
5.1.6.14	References for 5.1.6 . . . . .	194
5.1.7	Iron-based perovskites . . . . .	200
5.1.7.1	Crystal structure. Lattice parameters . . . . .	200
5.1.7.2	Magnetization and magnetic susceptibilities . . . . .	220
5.1.7.3	Neutron diffraction data . . . . .	227
5.1.7.4	Nuclear gamma resonance (NGR) data . . . . .	229
5.1.7.5	Electron paramagnetic resonance (EPR) data . . . . .	249
5.1.7.6	Electrical resistivities . . . . .	251
5.1.7.7	Magnetoelectric effect . . . . .	260
5.1.7.8	Dielectric properties . . . . .	262
5.1.7.9	X-ray photoemission (XPS) and ultraviolet photoemission (UPS) spectroscopy data . . . . .	264
5.1.7.10	References for 5.1.7 . . . . .	267
5.1.8	Cobalt-based perovskites . . . . .	274
5.1.8.1	Crystal structure. Lattice parameters. Preparation . . . . .	274
5.1.8.2	Magnetic properties . . . . .	288
5.1.8.3	Neutron diffraction data . . . . .	298
5.1.8.4	Nuclear gamma resonance (NGR) data . . . . .	299
5.1.8.5	Ferromagnetic resonance data . . . . .	304
5.1.8.6	Electrical resistivities . . . . .	305
5.1.8.7	Electron spectroscopy data . . . . .	311
5.1.8.8	References for 5.1.8 . . . . .	312
5.1.9	Nickel-based perovskites . . . . .	316
5.1.9.1	Crystal structure. Lattice parameters . . . . .	316
5.1.9.2	Magnetization and magnetic susceptibilities . . . . .	326
5.1.9.3	Neutron diffraction data . . . . .	332
5.1.9.4	Electron paramagnetic resonance (EPR) data . . . . .	338
5.1.9.5	Electrical resistivities . . . . .	338
5.1.9.6	Heat capacity . . . . .	342
5.1.9.7	Optical studies . . . . .	342
5.1.9.8	X-ray absorption spectroscopy . . . . .	342
5.1.9.9	References for 5.1.9 . . . . .	343



**Subvolume F1  $\beta$ : Perovskites I (Part  $\beta$ )**

5	Magnetic properties of oxides with perovskite, corundum, ilmenite and amorphous structures . . . . .	1
5.1	Perovskite-type oxides based on 3d elements (E. BURZO) . . . . .	1
5.1.1	Introduction for Chap. 5.1 - 5.3 . . . . .	1
5.1.1.1	General remarks . . . . .	1
5.1.1.2	List of frequently used symbols and abbreviations . . . . .	2
5.1.2 - 5.1.9	. . . . .	see subvolume F1 $\alpha$
5.1.10	Copper-based perovskites . . . . .	6
5.1.10.1	Crystal structure. Lattice parameters . . . . .	6
5.1.10.2	Magnetization and magnetic susceptibilities . . . . .	19
5.1.10.3	Neutron diffraction data . . . . .	28
5.1.10.4	Nuclear gamma resonance (NGR) data . . . . .	30
5.1.10.5	Nuclear quadrupol resonance (NQR) data . . . . .	31
5.1.10.6	Electron paramagnetic resonance (EPR) data . . . . .	32
5.1.10.7	Heat capacity . . . . .	32
5.1.10.8	Electrical resistivities . . . . .	33
5.1.10.9	X-ray photoelectron spectroscopy . . . . .	38
5.1.10.10	Optical studies . . . . .	39
5.1.10.11	Muon spin rotation . . . . .	39
5.1.10.12	References for 5.1.10 . . . . .	40
5.1.11	Mixed transition metal perovskites . . . . .	45
5.1.11.1	Crystal structure. Lattice parameters . . . . .	45
5.1.11.2	Magnetization and magnetic susceptibilities . . . . .	65
5.1.11.3	Neutron diffraction data . . . . .	87
5.1.11.4	Nuclear magnetic resonance (NMR) data . . . . .	88
5.1.11.5	Electron paramagnetic resonance (EPR) data . . . . .	91
5.1.11.6	Nuclear gamma resonance (NGR) data . . . . .	93
5.1.11.7	Electrical resistivities . . . . .	107
5.1.11.8	Magnetoelectric effect . . . . .	121
5.1.11.9	Dielectric properties . . . . .	121
5.1.11.10	X-ray electron spectroscopy . . . . .	125
5.1.11.11	Infrared and optical spectroscopy . . . . .	126
5.1.11.12	References for 5.1.11 . . . . .	128
5.2	Perovskite-type oxides based on 4d or 5d elements (E. BURZO) . . . . .	135
5.2.1	Rhutenium-based perovskites . . . . .	135
5.2.1.1	Crystal structure. Lattice parameters . . . . .	135
5.2.1.2	Magnetic properties . . . . .	150
5.2.1.3	Neutron diffraction data . . . . .	164
5.2.1.4	Nuclear gamma resonance (NGR) data . . . . .	165
5.2.1.5	Magnetic anisotropy . . . . .	171
5.2.1.6	Electrical resistivities . . . . .	172
5.2.1.7	Infrared spectra . . . . .	175
5.2.1.8	References for 5.2.1 . . . . .	176
5.2.2	Other 4d element perovskites . . . . .	179
5.2.2.1	Crystal structure. Lattice parameters . . . . .	179

5.2.2.2	Magnetization and magnetic susceptibilities . . . . .	196
5.2.2.3	Neutron diffraction data . . . . .	202
5.2.2.4	Electron paramagnetic resonance (EPR) data . . . . .	204
5.2.2.5	Nuclear gamma resonance (NGR) data . . . . .	204
5.2.2.6	Heat capacity . . . . .	205
5.2.2.7	Electrical resistivities . . . . .	205
5.2.2.8	Dielectric properties . . . . .	213
5.2.2.9	Optical data . . . . .	217
5.2.2.10	Infrared spectra . . . . .	218
5.2.2.11	Photoelectron spectroscopy . . . . .	218
5.2.2.12	References for 5.2.2 . . . . .	220
5.2.3	Iridium-based perovskites . . . . .	226
5.2.3.1	Crystal structure. Lattice parameters . . . . .	226
5.2.3.2	Magnetic properties . . . . .	232
5.2.3.3	Neutron diffraction data . . . . .	241
5.2.3.4	Nuclear gamma resonance (NGR) data . . . . .	241
5.2.3.5	Electrical resistivities . . . . .	243
5.2.3.6	Infrared spectra . . . . .	244
5.2.3.7	References for 5.2.3 . . . . .	244
5.2.4	Other 5d element perovskites . . . . .	246
5.2.4.1	Crystal structure. Lattice parameters . . . . .	246
5.2.4.2	Magnetization and magnetic susceptibilities . . . . .	262
5.2.4.3	Neutron diffraction data . . . . .	269
5.2.4.4	Nuclear gamma resonance (NGR) data . . . . .	270
5.2.4.5	Electron paramagnetic resonance (EPR) data . . . . .	271
5.2.4.6	Electrical resistivities . . . . .	271
5.2.4.7	Dielectric properties . . . . .	272
5.2.4.8	Birefringence . . . . .	273
5.2.4.9	Raman spectroscopy. IR spectroscopy . . . . .	274
5.2.4.10	References for 5.2.4 . . . . .	275
5.3	Miscellaneous perovskite-type oxides ( $[\text{AC}_3](\text{B}_4)\text{O}_{12}$ -type perovskites) (E. BURZO) . . . . .	280
5.3.1	Crystal structure. Lattice parameters. Preparation . . . . .	280
5.3.2	Magnetization and magnetic susceptibilities . . . . .	290
5.3.3	Neutron diffraction data . . . . .	297
5.3.4	Nuclear magnetic resonance (NMR) data . . . . .	301
5.3.5	Nuclear gamma resonance (NGR) data . . . . .	301
5.3.6	Electrical resistivities . . . . .	303
5.3.7	Elastic properties . . . . .	304
5.3.8	Kerr effect. . . . .	304
5.3.9	Infrared spectra . . . . .	305
5.3.10	References for 5.3 . . . . .	307

**Subvolume F2: Perovskite-type layered cuprates (high- $T_c$  superconductors and related compounds)**

5.4	Perovskite-type layered cuprates (high- $T_c$ superconductors and related compounds) (Z.A. KAZEI, I.B. KRYNETSKII) . . . . .	1
5.4.1	Introduction . . . . .	1
5.4.1.1	General remarks . . . . .	1
5.4.1.2	List of frequently used symbols and abbreviations . . . . .	3
5.4.2	Magnetic susceptibility and concentration phase diagrams . . . . .	8
5.4.2.1	Rare earth cuprates $\text{Ln}_2\text{CuO}_{4-y}$ (2-1-4) . . . . .	8
5.4.2.1.1	Pure $\text{La}_2\text{CuO}_4$ , $\text{Y}_2\text{CuO}_4$ and model compounds $\text{Sr}_2\text{CuO}_2\text{Cl}_2$ , $\text{CuO}$ . . . . .	9
5.4.2.1.2	Doped $\text{La}_{2-x}\text{M}'_x\text{Cu}_{1-y}\text{M}''_y\text{O}_{4-\delta}$ ( $\text{M}' = \text{Ba, Bi, Ca, Sr}$ ; $\text{M}'' = \text{Li, Ni, Zn}$ ) . . . . .	16
5.4.2.1.3	$\text{Ln}_2\text{CuO}_{4-y}$ with magnetic rare earth ions ( $\text{Ln} = \text{Pr-Gd, Dy-Tm}$ ) . . . . .	23
5.4.2.2	Rare earth cuprates $\text{LnBa}_2\text{Cu}_3\text{O}_{7-y}$ (1-2-3), $\text{YBa}_2\text{Cu}_4\text{O}_8$ (1-2-4) . . . . .	32
5.4.2.2.1	Pure compounds $\text{YBa}_2\text{Cu}_3\text{O}_x$ and $\text{YBa}_2\text{Cu}_4\text{O}_8$ . . . . .	32
5.4.2.2.2	Doped $\text{Y}(\text{Ba}_{0.55}\text{La}_{0.45})_2\text{Cu}_3\text{O}_{7+y}$ , $\text{YBa}_2(\text{Cu}_{1-y}\text{M}_y)_3\text{O}_x$ ( $\text{M} = \text{Co, Fe, Ni, Sc, Zn}$ ), and $\text{Y}_{1-x}\text{Na}_x\text{Ba}_2\text{Cu}_3\text{O}_{7-d}$ . . . . .	39
5.4.2.2.3	$\text{LnBa}_2\text{Cu}_3\text{O}_{7-y}$ with magnetic rare earth ions ( $\text{Ln} = \text{Pr-Gd, Dy-Yb}$ ) . . . . .	45
5.4.2.2.4	Summary of susceptibility parameters and transition temperatures for $\text{LnBa}_2\text{Cu}_3\text{O}_{7-y}$ series . . . . .	57
5.4.2.3	Bi- and Tl- based layered cuprates . . . . .	64
5.4.2.4	Related compounds $\text{Ln}_2\text{Cu}_2\text{O}_5$ ( $\text{Ln} = \text{Tb-Lu, Y, Sc, In}$ ) (2-2-5) . . . . .	69
5.4.2.5	Related compounds $\text{Ln}_2\text{BaCuO}_5$ ( $\text{Ln} = \text{Dy, Ho, Er, Y}$ ) (2-1-1-5) . . . . .	73
5.4.3	Magnetization and magnetic phase transitions . . . . .	75
5.4.3.1	Pure $\text{La}_2\text{CuO}_4$ and doped $\text{La}_{2-x}\text{M}'_x\text{Cu}_{1-y}\text{M}''_y\text{O}_4$ ( $\text{M}' = \text{Y, Ba, Sr}$ ; $\text{M}'' = \text{Fe, Ni, Zn}$ ). Model compounds $\text{Sr}_2\text{CuO}_2\text{Cl}_2$ , $\text{CuO}$ , Bi-based cuprates . . . . .	75
5.4.3.2	$\text{Ln}_2\text{CuO}_{4-y}$ with magnetic rare earth ions ( $\text{Ln} = \text{Pr-Gd}$ ) . . . . .	80
5.4.3.3	Rare earth cuprates $\text{LnBa}_2\text{Cu}_3\text{O}_{7-y}$ ( $\text{Ln} = \text{Y, Pr-Gd, Dy-Yb}$ ) . . . . .	86
5.4.3.4	Rare earth cuprates $\text{Ln}_2\text{Cu}_2\text{O}_5$ ( $\text{Ln} = \text{Y, Dy-Yb}$ ) and $\text{Ln}_2\text{BaCuO}_5$ ( $\text{Ln} = \text{Gd, Dy-Er}$ ) . . . . .	96
5.4.4	Magnetic neutron scattering and diffraction . . . . .	102
5.4.4.1	Magnetic structures and spin correlations . . . . .	102
5.4.4.1.1	$\text{La}_2\text{CuO}_4$ , $\text{La}_{2-x}\text{Sr}_x\text{CuO}_4$ , $\text{Bi}_2\text{CuO}_4$ and model compounds $\text{Sr}_2\text{CuO}_2\text{Cl}_2$ , $\text{CuO}$ . . . . .	102
5.4.4.1.2	$\text{Ln}_2\text{CuO}_{4-y}$ with magnetic rare earth ions ( $\text{Pr, Nd, Gd}$ ) . . . . .	110
5.4.4.1.3	Pure and doped $\text{LnBa}_2\text{Cu}_3\text{O}_x$ ( $\text{Ln} = \text{Y, Pr, Nd}$ ), $\text{TlBa}_2\text{YCu}_2\text{O}_7$ . . . . .	117
5.4.4.1.4	$\text{LnBa}_2\text{Cu}_3\text{O}_{7-y}$ with magnetic rare earth ions ( $\text{Ln} = \text{Gd, Dy-Tm}$ ) . . . . .	128
5.4.4.1.5	Rare earth cuprates $\text{DyBa}_2\text{Cu}_4\text{O}_8$ and $\text{ErBa}_2\text{Cu}_4\text{O}_8$ (1-2-4) . . . . .	136
5.4.4.1.6	Related compounds $\text{Ln}_2\text{Cu}_2\text{O}_5$ . . . . .	139
5.4.4.2	Inelastic neutron scattering and crystal field parameters . . . . .	141
5.4.4.2.1	Pure and doped $\text{Nd}_2\text{CuO}_4$ . . . . .	141
5.4.4.2.2	Rare earth cuprates $\text{LnBa}_2\text{Cu}_3\text{O}_{7-y}$ . . . . .	144
5.4.5	Magnetic resonance experiments . . . . .	157
5.4.5.1	Nuclear resonance measurements . . . . .	157
5.4.5.1.1	Pure and doped $\text{La}_2\text{CuO}_4$ , model compound $\text{CuO}$ , pure and doped $\text{Nd}_2\text{CuO}_4$ . . . . .	158

5.4.5.1.2	Pure and doped $\text{LnBa}_2\text{Cu}_3\text{O}_x$ ( $\text{Ln} = \text{Y}, \text{Pr-Gd}, \text{Dy-Er}, \text{Yb}$ ), $\text{Bi}_2\text{Sr}_2(\text{Ca}_{1-x}\text{Y}_x)\text{Cu}_2\text{O}_{8+y}$ , $\text{Pb}_2\text{Sr}_2\text{YCu}_3\text{O}_{8+\delta}$ . . . . .	162
5.4.5.2	Electron paramagnetic and antiferromagnetic resonance measurements . . . . .	170
5.4.5.2.1	Pure and doped $\text{Ln}_2\text{CuO}_{4-y}$ ( $\text{Ln} = \text{La}, \text{Gd}$ ) . . . . .	170
5.4.5.2.2	$\text{YBa}_2\text{Cu}_3\text{O}_7$ and related compounds, Bi-based cuprates . . . . .	172
5.4.5.2.3	$\text{Y}_{1-x}\text{Gd}_x\text{Ba}_2\text{Cu}_3\text{O}_{7-y}$ and $\text{Y}_{2-x}\text{Gd}_x\text{BaCuO}_5$ . . . . .	176
5.4.5.3	$\mu^+$ SR measurements . . . . .	186
5.4.5.3.1	Pure and doped $\text{Ln}_2\text{CuO}_4$ ( $\text{Ln} = \text{La}, \text{Pr}, \text{Nd}, \text{Sm}$ ), model compounds $\text{Sr}_2\text{CuO}_2\text{Cl}_2$ , $\text{CuO}$ . . . . .	186
5.4.5.3.2	Pure and doped compounds $\text{LnBa}_2\text{Cu}_3\text{O}_x$ ( $\text{Ln} = \text{Y}, \text{Pr}, \text{Gd}, \text{Dy-Er}$ ), related compounds $\text{Y}_2\text{BaCuO}_5$ and $\text{BaCuO}_2$ . . . . .	191
5.4.5.3.3	Bi-based cuprates . . . . .	198
5.4.6	Mössbauer spectroscopy . . . . .	200
5.4.6.1	Pure and doped $\text{Ln}_2\text{CuO}_4$ ( $\text{Ln} = \text{La}, \text{Eu}, \text{Gd}$ ), $\text{La}_2\text{CoO}_4$ , $\text{SrLaFeO}_4$ . . . . .	200
5.4.6.2	Pure and doped $\text{LnBa}_2(\text{Cu}_{1-x}\text{Fe}_x)_3\text{O}_z$ ( $\text{Ln} = \text{Dy}, \text{Pr}, \text{Gd}, \text{Er}, \text{Yb}$ ) . . . . .	203
5.4.6.2.1	Mössbauer spectra for rare earth elements . . . . .	203
5.4.6.2.2	Mössbauer spectra of $^{57}\text{Fe}$ doped $\text{LnBa}_2\text{Cu}_3\text{O}_z$ ( $\text{Ln} = \text{Y}, \text{Pr}, \text{Gd}$ ), $\text{YBa}_2\text{Cu}_4\text{O}_8$ and related compounds . . . . .	204
5.4.6.3	Compounds related to Bi-based high- $T_c$ cuprates . . . . .	214
5.4.7	Heat capacity and derived thermodynamic properties . . . . .	215
5.4.7.1	$\text{La}_{2-x}\text{M}_x\text{CuO}_{4-y}$ ( $\text{M} = \text{Sr}, \text{Ba}$ ), $\text{YBa}_2\text{Cu}_3\text{O}_{7-y}$ and $\text{Bi}_2\text{Sr}_2(\text{Ca}, \text{Y})\text{Cu}_2\text{O}_{8-y}$ . . . . .	215
5.4.7.2	$\text{Ln}_2\text{CuO}_{4-y}$ with magnetic rare earth ions ( $\text{Ln} = \text{Pr-Gd}$ ) . . . . .	224
5.4.7.3	$\text{LnBa}_2\text{Cu}_3\text{O}_{7-y}$ with magnetic rare earth ions ( $\text{Ln} = \text{Pr-Gd}, \text{Dy-Yb}$ ) . . . . .	227
5.4.7.4	Related compounds $\text{Ln}_2\text{Cu}_2\text{O}_5$ ( $\text{Ln} = \text{Tb-Yb}, \text{Y}, \text{Lu}$ ), $\text{Ln}_2\text{BaCuO}_5$ ( $\text{Ln} = \text{Sm-Gd}, \text{Dy-Yb}, \text{Y}$ ), and $\text{Y}_2\text{BaZnO}_5$ . . . . .	241
5.4.8	Thermal expansion and magnetostriction . . . . .	244
5.4.8.1	Thermal expansion of $\text{LnBa}_2\text{Cu}_3\text{O}_{7-x}$ ( $\text{Ln} = \text{Y}, \text{Sm-Gd}, \text{Dy-Tm}$ ) . . . . .	244
5.4.8.2	Magnetostriction . . . . .	246
5.4.8.2.1	$\text{La}_2\text{CuO}_4$ . . . . .	247
5.4.8.2.2	$\text{LnBa}_2\text{Cu}_3\text{O}_{7-x}$ ( $\text{Ln} = \text{Y}, \text{Pr}, \text{Nd}, \text{Sm-Gd}, \text{Dy-Tm}$ ) and related compounds $\text{Ln}_2\text{Cu}_2\text{O}_5$ ( $\text{Ln} = \text{Y}, \text{Dy-Lu}$ ) . . . . .	248
5.4.9	Transport properties . . . . .	255
5.4.10	References for 5.4 . . . . .	259

## Subvolume F2S: Perovskite-type layered cuprates (high- $T_c$ superconductors and related compounds)

Supplement and extension to Vol. III/27F2.

5	Magnetic properties of oxides with perovskite, corundum and ilmenite type structures and amorphous oxides . . . . .	1
5.4	Perovskite-type layered cuprates (high- $T_c$ superconductors and related compounds) (Z.A. KAZEI, I.B. KRYNETSKII) . . . . .	1

Numbering of chapters in this supplement is the same as in III/27F2. For reasons of simplicity the prefix 5.4 is dropped, i.e. section 5.4.1 is given as 1 only, 5.4.1.1 as 1.1, etc..

1	Introduction . . . . .	1
1.1	General remarks . . . . .	1
1.2	List of frequently used symbols and abbreviations . . . . .	3
2	Magnetic susceptibilities and concentration phase diagrams . . . . .	10
2.1	Rare earth cuprates $\text{Ln}_2\text{CuO}_4$ (2-1-4) . . . . .	10
2.1.1	Pure $\text{La}_2\text{CuO}_{4\pm\delta}$ , $\text{La}_2\text{NiO}_{4\pm\delta}$ , $\text{Y}_2\text{CuO}_4$ , $\text{Bi}_2\text{CuO}_4$ and model compounds $\text{CuO}$ , $\text{BaCuO}_{2+x}$ . . . . .	10
2.1.2	Doped $\text{La}_{2-x}\text{M}'_x\text{Cu}_{1-y}\text{M}''_y\text{O}_{4-\delta}$ ( $\text{M}' = \text{Bi, Sr}$ ; $\text{M}'' = \text{Co, Fe, Ga, Ni, Zn}$ ) . . . . .	16
2.1.3	Pure and doped $\text{Ln}_{2-x}\text{M}_x\text{CuO}_{4-\delta}$ , $\text{Ln}_2\text{NiO}_{4-\delta}$ with magnetic rare earth or transuranium ions ( $\text{Ln} = \text{Pr} - \text{Tm, Cm}$ ; $\text{M} = \text{Ce, Ln, Sr, Y}$ ) . . . . .	25
2.2	Rare earth cuprates $\text{LnBa}_2\text{Cu}_3\text{O}_{7-\delta}$ (1-2-3), $\text{LnBa}_2\text{Cu}_4\text{O}_{8-\delta}$ (1-2-4), $\text{Ln}_2\text{Ba}_4\text{Cu}_7\text{O}_{15-\delta}$ (2-4-7) . . . . .	37
2.2.1	Pure $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ and $\text{YBa}_2\text{Cu}_4\text{O}_{8-\delta}$ . . . . .	37
2.2.2	Doped $\text{YBa}_2\text{Cu}_{3-y}\text{M}_y\text{O}_{7-\delta}$ and $\text{YBa}_2\text{Cu}_{4-y}\text{M}_y\text{O}_{8-\delta}$ ( $\text{M} = \text{Co, Fe, Zn}$ ) . . . . .	40
2.2.3	Pure and substituted $\text{LnM}_2\text{Cu}_3\text{O}_{7-\delta}$ , $\text{LnM}_2\text{Cu}_4\text{O}_{8-\delta}$ , $\text{Ln}_2\text{M}_4\text{Cu}_7\text{O}_{15-\delta}$ , $\text{LnM}_2\text{Cu}_2\text{NbO}_{8-\delta}$ with magnetic rare earth ions ( $\text{Ln} = \text{Pr} - \text{Yb}$ ; $\text{M} = \text{Ba, Sr}$ ) . . . . .	44
2.3	Bi-, Hg-, Pb-, Tl- based layered cuprates and spin ladder systems ( $\text{Sr,A})_{14}\text{Cu}_{24}\text{O}_{41}$ , $\text{Sr}_2\text{CuO}_3$ , $(\text{La,Sr})\text{CuO}_{2.5}$ ( $\text{A} = \text{Ca, Ba, La}$ ) . . . . .	61
2.4	Related compounds $\text{Ln}_2\text{Cu}_2\text{O}_5$ (2-2-5), $\text{Ln}_2\text{BaMO}_5$ (2-1-1-5) ( $\text{Ln} = \text{Pr} - \text{Yb, Y}$ ; $\text{M} = \text{Co, Cu, Ni, Fe, Zn}$ ) . . . . .	69
3	Magnetization and magnetic phase transitions . . . . .	76
3.1	Pure and doped $\text{La}_2\text{CuO}_4$ , model compounds $\text{CuO}$ , $\text{Ca}_2\text{CuO}_2\text{Cl}_2$ , $\text{Sr}_2\text{CuO}_2\text{Cl}_2$ , $\text{Ba}_2\text{Cu}_3\text{O}_4\text{Cl}_2$ , and $\text{Bi}_2\text{CuO}_4$ . . . . .	76
3.2	Pure and doped $\text{Ln}_2\text{CuO}_4$ ( $\text{Ln} = \text{Y, Pr, Nd, Sm-Tb, Ho}$ ) . . . . .	81
3.3	Pure and doped $\text{LnBa}_2\text{Cu}_3\text{O}_x$ ( $\text{Ln} = \text{Y; Pr, Nd, Gd, Dy}$ ) . . . . .	91
3.3.1	Pure and doped $\text{YBa}_2\text{Cu}_3\text{O}_x$ . . . . .	91
3.3.2	Pure and doped $\text{LnBa}_2\text{Cu}_3\text{O}_x$ with magnetic rare earth ions ( $\text{Ln} = \text{Pr, Nd, Gd, Dy}$ ) . . . . .	96
3.4	Related compounds $\text{Ln}_2\text{Cu}_2\text{O}_5$ ( $\text{Ln} = \text{Y, Sc, In, Tm, Yb, Lu}$ ) . . . . .	100
3.5	Layered cuprates of quaternary family (M-2122) . . . . .	104
3A	Electric polarization and magnetoelectric effect . . . . .	110
3A.1	Pure cuprates $\text{Ln}_2\text{CuO}_{4-y}$ with magnetic rare earth ions ( $\text{Ln} = \text{La, Nd, Sm, Gd}$ ) . . . . .	110
4	Magnetic neutron scattering and diffraction . . . . .	114
4.1	Magnetic structures and spin correlations . . . . .	114
4.1.1	Pure $\text{La}_2\text{CuO}_{4\pm\delta}$ , $\text{La}_2\text{NiO}_{4\pm\delta}$ , $\text{Bi}_2\text{CuO}_4$ and model compounds $\text{M}_2\text{CuO}_2\text{Cl}_2$ ( $\text{M} = \text{Ca, Sr}$ ) . . . . .	114
4.1.2	Doped $\text{La}_{2-x}\text{M}'_x\text{Cu}_{1-y}\text{M}''_y\text{O}_{4-\delta}$ ( $\text{M}' = \text{Ba, Sr, Nd}$ ; $\text{M}'' = \text{Zn}$ ) . . . . .	122
4.1.3	Pure and doped $\text{Ln}_{2-x}\text{M}_x\text{CuO}_{4-\delta}$ , $\text{Ln}_2\text{NiO}_{4-\delta}$ with magnetic rare earth ions ( $\text{Ln} = \text{La, Pr} - \text{Gd}$ ; $\text{M} = \text{Ce, Ln, Sr}$ ) . . . . .	130
4.1.4	Pure and doped $\text{YBa}_2(\text{Cu}_{1-x}\text{M}_x)_3\text{O}_{7-\delta}$ , $\text{YBa}_2(\text{Cu}_{1-x}\text{M}_x)_4\text{O}_{8-\delta}$ ( $\text{M} = \text{Al, Co, Fe, Ni, Zn}$ ) . . . . .	139
4.1.5	Pure and substituted $\text{LnM}_2\text{Cu}_3\text{O}_{7-\delta}$ , $\text{LnM}_2\text{Cu}_4\text{O}_{8-\delta}$ , $\text{Ln}_2\text{M}_4\text{Cu}_7\text{O}_{15-\delta}$ , $\text{LnM}_2\text{Cu}_2\text{NbO}_{8-\delta}$ with magnetic rare earth ions ( $\text{Ln} = \text{Pr} - \text{Er}$ ; $\text{M} = \text{Ba, Sr}$ ) . . . . .	151
4.1.6	Bi-, Tl- and Hg- based layered cuprates and spin ladder systems . . . . .	165
4.1.7	Related compounds $\text{Ln}_2\text{Cu}_2\text{O}_5$ (2-2-5), $\text{Ln}_2\text{BaMO}_5$ (2-1-1-5) ( $\text{Ln} = \text{Pr} - \text{Yb, Y}$ ; $\text{M} = \text{Co, Cu, Ni, Fe, Zn}$ ) . . . . .	166
4.2	Inelastic neutron scattering and crystal field parameters . . . . .	171

4.2.1	Pure and doped $\text{Ln}_2\text{Cu}_{1-x}\text{M}_x\text{O}_{4-\delta}$ with magnetic rare earth ions (Ln = La, Pr, Nd; M = Ce) . . . . .	171
4.2.2	$\text{LnBa}_2\text{Cu}_3\text{O}_{7-\delta}$ , $\text{LnBa}_2\text{Cu}_4\text{O}_{8-\delta}$ with magnetic rare earth ions (Ln = Pr – Er) . . . . .	181
4.2.3	Related compounds $\text{Ln}_2\text{Cu}_2\text{O}_5$ (2-2-5) (Ln = Er) . . . . .	200
5	Magnetic resonance experiments . . . . .	201
5.1	Nuclear resonance measurements . . . . .	201
5.1.1	Pure and doped $\text{Ln}_2\text{CuO}_4$ (Ln = La, Pr, Nd) . . . . .	201
5.1.1.1	Pure and doped $\text{La}_{2-x}\text{M}'_x\text{Cu}_{1-y}\text{M}''_y\text{O}_4$ (M' = Sr, Ba, Eu; M'' = Li, Zn) . . . . .	202
5.1.1.2	Doped $\text{Ln}_2\text{CuO}_4$ with rare earth ions (Ln = Pr, Nd), model compounds $\text{CuO}$ , $\text{Sr}_2\text{CuO}_2\text{Cl}_2$ , and $\text{La}_4\text{Ba}_2\text{Cu}_2\text{O}_{10}$ . . . . .	209
5.1.2	$\text{LnBa}_2\text{Cu}_3\text{O}_x$ and $\text{LnBa}_3\text{Cu}_4\text{O}_8$ . . . . .	211
5.1.2.1	Pure and doped $\text{LnBa}_2\text{Cu}_3\text{O}_x$ (Ln = Y, Pr, Gd, Tm) . . . . .	211
5.1.2.2	Pure and doped $\text{LnBa}_2\text{Cu}_4\text{O}_8$ (Ln = Y, Gd), $\text{Y}_2\text{Ba}_4\text{Cu}_7\text{O}_{15}$ and $\text{La}_{1.89}\text{Ca}_{1.11}\text{Cu}_2\text{O}_6$ . . . . .	220
5.1.2.3	$\text{LnSr}_2\text{Cu}_2\text{GaO}_7$ (Ln = Y, Nd, Pr, Gd) and $\text{LnBa}_2\text{Cu}_2\text{NbO}_8$ (Ln = Y, Nd, Pr, La) . . . . .	225
5.1.3	Hg- and Bi- based cuprates . . . . .	227
5.2	Electron paramagnetic and antiferromagnetic resonance measurements . . . . .	230
5.2.1	Pure and doped $\text{Ln}_2\text{CuO}_4$ (Ln = La, Pr, Nd, Gd), model compounds $\text{Sr}_2\text{CuO}_2\text{F}_{2.4}$ , $\text{Ba}_2\text{Cu}_3\text{O}_4\text{Cl}_2$ , and $\text{Bi}_2\text{CuO}_4$ . . . . .	230
5.2.2	Pure and doped $\text{LnBa}_2\text{Cu}_3\text{O}_6$ (Ln = Y, Pr, Sm, Gd, Er) . . . . .	236
5.2.2.1	Related compounds $\text{Ln}_2\text{Cu}_2\text{O}_5$ (Ln = Y, In, Lu) and $\text{Ln}_2\text{BaCuO}_5$ (Ln = Y, Gd, Yb) . . . . .	240
5.2.3	Tl- and Bi- based cuprates . . . . .	243
5.3	$\mu^+\text{SR}$ measurements . . . . .	245
5.3.1	Pure and doped $\text{La}_{2-x}\text{M}'_x\text{Cu}_{1-y}\text{M}''_y\text{O}_4$ (M' = Sr, Ba, Nd; M'' = Li, Zn) . . . . .	245
5.3.2	Pure and doped $\text{LnBa}_2\text{Cu}_3\text{O}_x$ (Ln = Y, Gd), $\text{La}_2\text{SrCu}_2\text{O}_{6+\delta}$ . . . . .	249
6	Mössbauer spectroscopy . . . . .	251
6.1	Pure and doped $\text{Ln}_2\text{CuO}_4$ (Ln = La, Gd), model compounds $(\text{Sr,Ca})_2\text{CuO}_2\text{Cl}_2$ , $\text{Sr}_2\text{CuO}_3$ and $\text{CuO}$ . . . . .	251
6.1.1	Transmission Mössbauer spectroscopy . . . . .	251
6.1.2	Emission Mössbauer spectroscopy . . . . .	258
6.2	Pure and doped $\text{LnBa}_2\text{Cu}_3\text{O}_x$ (Ln = Y, Pr, Nd, Gd, Er, Tm, Yb) . . . . .	259
6.2.1	Transmission Mössbauer spectroscopy . . . . .	259
6.2.1.1	Pure and doped $\text{YBa}_2\text{Cu}_3\text{O}_x$ , $\text{YBa}_2\text{Cu}_4\text{O}_{8+\delta}$ . . . . .	259
6.2.1.2	Pure and doped $\text{LnBa}_2\text{Cu}_3\text{O}_x$ with magnetic rare earth ions (Ln = Pr, Gd, Dy, Er, Yb) . . . . .	265
6.2.2	Emission Mössbauer spectroscopy . . . . .	271
6.3	Compounds related to $\text{LnBa}_2\text{Cu}_3\text{O}_x$ . . . . .	272
6.4	Bi- and Pb- based cuprates . . . . .	279
7	Heat capacity and derived thermodynamic properties . . . . .	284
7.1	Pure and substituted $\text{La}_{2-x}\text{M}'_x\text{Cu}_{1-y}\text{M}''_y\text{O}_{4\pm\delta}$ (M' = Ba, Sr; M'' = Zn) . . . . .	284
7.2	Pure and substituted $\text{Ln}_{2-x}\text{M}_x\text{CuO}_{4-\delta}$ with magnetic rare earth ions (Ln = Pr – Yb; M = Ce, Ln) . . . . .	286
7.3	Pure and substituted $\text{LnM}'_2\text{Cu}_{3-y}\text{M}''_y\text{O}_{7-\delta}$ , $\text{LnM}'_2\text{Cu}_4\text{O}_{8-\delta}$ , $\text{Ln}_2\text{M}'_4\text{Cu}_7\text{O}_{15-\delta}$ , $\text{LnM}'_2\text{Cu}_2\text{NbO}_{8-\delta}$ with magnetic rare earth ions (Ln = Pr – Yb, Y; M' = Ba, Sr; M'' = Al, Ga, Mo) . . . . .	291
7.4	Bi-, Hg-, Pb-, Tl- based layered cuprates . . . . .	307
7.5	Related compounds $\text{Ln}_2\text{Cu}_2\text{O}_5$ (2-2-5), $\text{Ln}_2\text{BaMO}_5$ (2-1-1-5) (Ln = Pr – Yb, Y; M = Cu, Zn) . . . . .	310
8	Elastic and magnetoelastic properties . . . . .	312

8.1	Elastic moduli and sound velocity . . . . .	312
8.1.1	$\text{La}_{2-x}\text{Sr}_x\text{CuO}_4$ . . . . .	312
8.1.2	Pure and doped $\text{Ln}_2\text{CuO}_4$ with magnetic rare earth ions ( $\text{Ln} = \text{Nd}, \text{Gd}$ ) . . . . .	313
8.1.3	$\text{LnBa}_2\text{Cu}_3\text{O}_x$ ( $\text{Ln} = \text{Gd}, \text{Dy}$ ) . . . . .	315
8.2	Thermal expansion . . . . .	316
8.2.1	Pure $\text{Ln}_2\text{CuO}_4$ with magnetic rare earth ions ( $\text{Ln} = \text{Pr}, \text{Nd}, \text{Sm} - \text{Gd}$ ) and $\text{LnBa}_2\text{Cu}_3\text{O}_{7-\delta}$ ( $\text{Ln} = \text{Pr}, \text{Dy}$ ) . . . . .	316
8.3	Magnetostriction . . . . .	317
8.3.1	$\text{DyBa}_2\text{Cu}_3\text{O}_{6.8}$ , model compound $\text{CuO}$ , and rare earth cuprates $\text{Ln}_2\text{Cu}_2\text{O}_5$ ( $\text{Ln} = \text{Dy}, \text{Ho}$ ) . . . . .	317
9	References for 1 - 8 . . . . .	320
	Contents of further subvolumes of III/27 . . . . .	354
	List of editor and authors of Vol. III/27 . . . . .	382

### Subvolume F3: Perovskites II, oxides with corundum, ilmenite and amorphous structures

5.5	Perovskite-type oxides $\text{RMO}_3$ ( $\text{R} = \text{rare earth element}, \text{M} = 3\text{d element or Al}$ ) (H.P.J. WIJN) . . . . .	1
5.5.1	Introduction . . . . .	1
5.5.1.1	General remarks . . . . .	1
5.5.1.2	Magnetic configurations . . . . .	2
5.5.1.3	List of frequently used symbols and abbreviations . . . . .	5
5.5.2	$\text{RAIO}_3$ compounds . . . . .	8
5.5.3	$\text{RScO}_3$ compounds . . . . .	22
5.5.4	$\text{RTiO}_3$ compounds . . . . .	25
5.5.5	$\text{RVO}_3$ compounds . . . . .	46
5.5.6	$\text{RCrO}_3$ compounds . . . . .	56
5.5.7	$\text{RMnO}_3$ compounds . . . . .	91
5.5.8	$\text{RFeO}_3$ compounds . . . . .	101
5.5.8.1	$\text{LaFeO}_3$ compounds . . . . .	104
5.5.8.2	$\text{CeFeO}_3$ . . . . .	107
5.5.8.3	$\text{PrFeO}_3$ . . . . .	107
5.5.8.4	$\text{NdFeO}_3$ compounds . . . . .	108
5.5.8.5	$\text{SmFeO}_3$ compounds . . . . .	110
5.5.8.6	$\text{EuFeO}_3$ compounds . . . . .	116
5.5.8.7	$\text{GdFeO}_3$ compounds . . . . .	118
5.5.8.8	$\text{TbFeO}_3$ compounds . . . . .	120
5.5.8.9	$\text{DyFeO}_3$ compounds . . . . .	125
5.5.8.10	$\text{HoFeO}_3$ compounds . . . . .	134
5.5.8.11	$\text{ErFeO}_3$ compounds . . . . .	138
5.5.8.12	$\text{TmFeO}_3$ compounds . . . . .	143
5.5.8.13	$\text{YbFeO}_3$ . . . . .	146
5.5.8.14	$\text{LuFeO}_3$ compounds . . . . .	146
5.5.8.15	$\text{YFeO}_3$ compounds . . . . .	147

5.5.9	RCoO <sub>3</sub> compounds . . . . .	152
5.5.10	RNiO <sub>3</sub> compounds . . . . .	158
5.5.11	References for 5.5 . . . . .	159
5.6	Oxides with corundum and ilmenite structures (Y. ENDOH, K. KAKURAI, A.K. KATORI) . . . . .	173
5.6.1	Introduction . . . . .	173
5.6.2	List of frequently used symbols and abbreviations . . . . .	173
5.6.3	Oxides with corundum structure . . . . .	176
5.6.3.1	Binary oxides M <sub>2</sub> O <sub>3</sub> ; M = 3d transition element . . . . .	177
5.6.3.2	Pseudo-binary and ternary oxides (M <sub>1-x</sub> M' <sub>x</sub> ) <sub>2</sub> O <sub>3</sub> ; M, M' = 3d transition elements . . . . .	190
5.6.4	Oxides with ilmenite structure . . . . .	205
5.6.4.1	Single ternary oxides MM'O <sub>3</sub> ; M, M' = 3d transition elements . . . . .	205
5.6.4.2	Mixed pseudo-ternary Ti oxides (M <sub>x</sub> M' <sub>1-x</sub> )TiO <sub>3</sub> ; M, M' = Mn, Fe, Co or Ni . . . . .	221
5.6.5	Solid solutions between oxides with corundum and ilmenite structure . . . . .	233
5.6.6	References for 5.6 . . . . .	235
5.7	Amorphous oxides (M.S. SEEHRA, G. SRINIVASAN) . . . . .	239
5.7.1	Introduction . . . . .	239
5.7.1.0	Scope of the review . . . . .	239
5.7.1.1	Symbols and abbreviations . . . . .	240
5.7.2	Oxide glasses . . . . .	242
5.7.2.0	General remarks . . . . .	242
5.7.2.1	Phosphate glasses . . . . .	242
5.7.2.1.0	General remarks . . . . .	242
5.7.2.1.1	Ti - based phosphates . . . . .	243
5.7.2.1.2	V - based phosphates . . . . .	244
5.7.2.1.3	Cr - based phosphates . . . . .	244
5.7.2.1.4	Mn - based phosphates . . . . .	246
5.7.2.1.5	Fe - based phosphates . . . . .	246
5.7.2.1.6	Co - based phosphates . . . . .	247
5.7.2.1.7	Spinel ferrite based phosphates . . . . .	248
5.7.2.2	Borate glasses . . . . .	249
5.7.2.2.0	General remarks . . . . .	249
5.7.2.2.1	Mn - borate glasses . . . . .	250
5.7.2.2.2	Fe - alkali - borate glasses . . . . .	252
5.7.2.2.3	Fe - BaO - borate glasses . . . . .	253
5.7.2.2.4	Fe - CaO - borate glasses . . . . .	256
5.7.2.3	Silicate glasses . . . . .	259
5.7.2.3.0	General remarks . . . . .	259
5.7.2.3.1	Mn - aluminosilicate glasses . . . . .	259
5.7.2.3.2	Mixed-valence Fe - silicate glasses . . . . .	261
5.7.2.3.3	Ferrous - silicate glasses . . . . .	263
5.7.2.3.4	Co - aluminosilicate glasses . . . . .	264
5.7.3	Amorphous oxides prepared by various techniques . . . . .	267
5.7.3.1	Amorphous 3d oxides . . . . .	267
5.7.3.1.0	General remarks . . . . .	267
5.7.3.1.1	Cr - oxides . . . . .	267
5.7.3.1.2	Fe (ferric) - oxides . . . . .	267
5.7.3.2	Mixed binary oxides . . . . .	269
5.7.3.2.0	General remarks . . . . .	269



5.7.3.2.1	Amorphous garnets . . . . .	270
5.7.3.2.2	Other mixed oxides . . . . .	275
5.7.3.2.2.1	$\text{ZnFe}_2\text{O}_4$ . . . . .	275
5.7.3.2.2.2	$\text{Fe}_{0.69}\text{Ga}_{1.37}\text{O}_3$ . . . . .	276
5.7.3.2.2.3	$(\text{Fe}_2\text{O}_3)_x(\text{SrO})_{1-x}$ . . . . .	278
5.7.3.2.2.4	$(\text{Fe}_2\text{O}_3)_x(\text{Bi}_2\text{O}_3)_{1-x}$ . . . . .	279
5.7.3.2.2.5	$\text{CoFe}_2\text{O}_4$ . . . . .	281
5.7.3.2.2.6	$\text{CuFe}_2\text{O}_4$ . . . . .	282
5.7.3.2.2.7	$\text{Bi}_2\text{CuO}_4$ . . . . .	284
5.7.3.3	$\text{Fe}_2\text{O}_3$ - $\text{Bi}_2\text{O}_3$ - based ternary oxides . . . . .	285
5.7.3.3.0	General remarks . . . . .	285
5.7.3.3.1	$\text{Fe}_2\text{O}_3 \cdot \text{Li}_2\text{O} \cdot \text{Bi}_2\text{O}_3$ oxides . . . . .	286
5.7.3.3.2	$\text{Fe}_2\text{O}_3 \cdot \text{K}_2\text{O} \cdot \text{Bi}_2\text{O}_3$ oxides . . . . .	289
5.7.3.3.3	$\text{Fe}_2\text{O}_3 \cdot \text{CaO} \cdot \text{Bi}_2\text{O}_3$ oxides . . . . .	290
5.7.3.3.4	$\text{Fe}_2\text{O}_3 \cdot \text{ZnO} \cdot \text{Bi}_2\text{O}_3$ oxides . . . . .	295
5.7.3.3.5	$\text{Fe}_2\text{O}_3 \cdot \text{CuO} \cdot \text{Bi}_2\text{O}_3$ oxides . . . . .	301
5.7.3.3.6	$\text{Fe}_2\text{O}_3 \cdot \text{Bi}_2\text{O}_3 \cdot \text{ABO}_3$ oxides . . . . .	307
5.7.4	Theoretical status . . . . .	315
5.7.5	References for 5.7 . . . . .	317

## Subvolume G: Various other oxides

6	Magnetic properties of oxides with various other structures . . . . .	1
6.1	Binary oxides of d transition elements (M. S. SEEHRA, H. P. J. WIJN) . . . . .	1
6.1.1	Introduction . . . . .	1
6.1.1.1	Scope of the review . . . . .	1
6.1.1.2	Earlier reviews . . . . .	1
6.1.1.3	Symbols and abbreviations . . . . .	2
6.1.2	Monoxides of 3d transition elements . . . . .	4
6.1.2.1	Simple monoxides $\text{MO}$ . . . . .	4
	References for 6.1.2.1 . . . . .	26
6.1.2.2	Mixed monoxides $\text{M}_{1-p}^{\text{I}}\text{M}_p^{\text{II}}\text{O}$ . . . . .	30
	References for 6.1.2.2 . . . . .	31
6.1.2.3	Diluted monoxides $\text{M}_p\text{N}_{1-p}\text{O}$ . . . . .	31
	References for 6.1.2.3 . . . . .	37
6.1.2.4	Electronic structures . . . . .	37
6.1.3	Dioxides of 3d transition elements . . . . .	38
6.1.3.1	Simple dioxides $\text{MO}_2$ . . . . .	38
6.1.3.2	Pseudo binary vanadium dioxides $\text{V}_{1-x}\text{M}_x\text{O}_2$ . . . . .	44
	References for 6.1.3 . . . . .	60
6.1.4	Intermediate phase binary oxides . . . . .	62
6.1.4.1	Magnéli phases $\text{M}_n\text{O}_{2n-1}$ . . . . .	62
6.1.4.2	The vanadium compounds $\text{V}_n\text{O}_{2n+1}$ . . . . .	65
	References for 6.1.4 . . . . .	69

6.1.5	Oxides of 4d and 5d transition elements . . . . .	71
	References of 6.1.5 . . . . .	84
6.2	Oxides with trirutile and pyrochlore structure (J. E. GREEDAN) . . . . .	87
6.2.0	Introduction . . . . .	87
6.2.1	Trirutile structure oxides . . . . .	88
6.2.1.1	Crystal structure and crystallographic data . . . . .	88
6.2.1.2	Magnetic properties . . . . .	89
6.2.1.2.1	$A^{6+}B_2^{3+}O_6$ . . . . .	90
6.2.1.2.2	$A^{2+}B_2^{5+}O_6$ . . . . .	94
6.2.1.3	References for 6.2.1 . . . . .	99
6.2.2	Pyrochlore structure oxides . . . . .	100
6.2.2.1	Crystal structure . . . . .	100
6.2.2.1.1	Space group and atomic positions . . . . .	100
6.2.2.1.2	$B_2O_6$ network . . . . .	100
6.2.2.1.3	$A_2O'$ network . . . . .	101
6.2.2.1.4	Magnetic sublattices . . . . .	102
6.2.2.2	Magnetic properties . . . . .	103
6.2.2.2.1	$A_2^{3+}B_2^{4+}O_6O'$ pyrochlores . . . . .	103
6.2.2.2.2	$A_2^{3+}BB'O_7$ pyrochlores . . . . .	118
6.2.2.2.3	$(AA')(BB')O_7$ . . . . .	121
6.2.2.2.4	$A_2^{2+}B_2^{5+}O_7$ pyrochlores . . . . .	121
6.2.2.2.5	$(AA')^{2+}(BB')^{5+}O_7$ . . . . .	121
6.2.2.3	References for 6.2.2 . . . . .	122
6.3	Hexagonal ferrites (G. ALBANESE, A. DERIU) . . . . .	124
6.3.1	Introduction . . . . .	124
6.3.1.1	General remarks . . . . .	124
6.3.1.2	Quantities and units . . . . .	124
6.3.1.3	List of symbols and abbreviations . . . . .	128
6.3.2	Chemical compositions and phase diagrams of hexagonal ferrites . . . . .	130
6.3.3	Crystal structures of hexagonal ferrites . . . . .	130
6.3.4	M(magnetoplumbite)-type ferrites . . . . .	131
6.3.4.1	Reviewed compositions . . . . .	131
6.3.4.2	Intrinsic magnetic properties and crystalline structure . . . . .	136
6.3.4.3	Extrinsic magnetic properties and microstructure . . . . .	147
6.3.4.4	Phase formation and morphology studies . . . . .	156
6.3.4.5	Electric and dielectric properties . . . . .	162
6.3.4.6	High frequency magnetic properties . . . . .	165
6.3.4.7	Optical properties . . . . .	168
6.3.5	W-type ferrites . . . . .	172
6.3.5.1	Reviewed compositions . . . . .	172
6.3.5.2	Intrinsic magnetic properties and crystalline structure . . . . .	173
6.3.5.3	Extrinsic magnetic properties and microstructure . . . . .	182
6.3.5.4	Phase formation and morphology studies . . . . .	183
6.3.5.5	Electric and dielectric properties . . . . .	185
6.3.5.6	High frequency magnetic properties . . . . .	185
6.3.5.7	Optical properties . . . . .	186
6.3.6	Y-type ferrites . . . . .	187
6.3.6.1	Reviewed compositions . . . . .	187

6.3.6.2	Intrinsic magnetic properties and crystalline structure . . . . .	188
6.3.6.3	Extrinsic magnetic properties and microstructure . . . . .	191
6.3.6.4	Phase formation and morphology studies . . . . .	191
6.3.6.5	Electric and dielectric properties . . . . .	192
6.3.6.6	High frequency magnetic properties . . . . .	192
6.3.6.7	Optical properties . . . . .	194
6.3.7	Z-type ferrites . . . . .	194
6.3.7.1	Reviewed compositions . . . . .	194
6.3.7.2	Intrinsic magnetic properties and crystalline structure . . . . .	194
6.3.7.3	Phase formation and morphology studies . . . . .	195
6.3.7.4	High frequency magnetic properties . . . . .	195
6.3.7.5	Optical properties . . . . .	196
6.3.8	X-type ferrites . . . . .	197
6.3.8.1	Reviewed compositions . . . . .	197
6.3.8.2	Intrinsic magnetic properties and crystalline structure . . . . .	197
6.3.8.3	Phase formation and morphology studies . . . . .	198
6.3.9	Further compositions . . . . .	199
6.3.10	Microwave device applications of hexagonal ferrites . . . . .	207
6.3.11	Magnetic recording applications of hexagonal ferrites . . . . .	209
6.3.12	References for 6.3 . . . . .	216
6.4	RFe <sub>2</sub> O <sub>4</sub> compounds (K. SIRATORI) . . . . .	225
6.4.1	Introduction . . . . .	225
6.4.2	General background and scope . . . . .	226
6.4.3	Exchange coupling constants estimated from the data in the paramagnetic region . . . . .	227
6.4.4	The Verwey transition . . . . .	229
6.4.5	Magnetization in the state of 2-dimensional spin order . . . . .	231
6.4.6	Relaxation . . . . .	237
6.4.7	References for 6.4 . . . . .	238

## Subvolume H: Boron containing oxides

7	Magnetic properties of crystalline and vitreous boron containing oxide systems . . . . .	1
7.0	Introduction (E. BURZO) . . . . .	1
7.0.1	General remarks . . . . .	1
7.0.2	List of frequently used symbols and abbreviations . . . . .	1
7.1	Crystalline boron containing oxide compounds (E. BURZO) . . . . .	6
7.1.1	FeBO <sub>3</sub> and other MBO <sub>3</sub> -based compounds (M = 3d or 4f element) . . . . .	6
7.1.1.0	Introduction . . . . .	6
7.1.1.1	Preparation. Crystal structures . . . . .	7
7.1.1.2	Magnetization and magnetic susceptibility . . . . .	13
7.1.1.3	Magnetic structure . . . . .	18
7.1.1.4	Hyperfine parameters determined by nuclear gamma resonance method . . . . .	18
7.1.1.5	Antiferromagnetic resonance (AFMR). Magnetostatic modes. Spin waves . . . . .	25
7.1.1.6	Electron paramagnetic resonance data . . . . .	34

7.1.1.7	Magnetic properties as determined by nuclear magnetic resonance method . . . . .	34
7.1.1.8	Anisotropy . . . . .	40
7.1.1.9	Magnetoelastic properties. Magnetostriction . . . . .	41
7.1.1.10	Magneto-optical and optical properties . . . . .	43
7.1.1.11	Photomagnetic effects . . . . .	50
7.1.1.12	Surface magnetism (with an introduction on domain structure) . . . . .	53
7.1.1.13	References for 7.1.1 . . . . .	58
7.1.2	Fe <sub>3</sub> BO <sub>6</sub> -based compounds . . . . .	65
7.1.2.0	Introduction . . . . .	65
7.1.2.1	Crystal structure and lattice parameters . . . . .	67
7.1.2.2	Magnetization and magnetic susceptibility . . . . .	68
7.1.2.3	Magnetic structure . . . . .	71
7.1.2.4	Hyperfine parameters . . . . .	73
7.1.2.5	Data obtained by antiferromagnetic resonance . . . . .	77
7.1.2.6	Magneto-optical and optical properties . . . . .	78
7.1.2.7	References for 7.1.2 . . . . .	80
7.1.3	Boron ferrites and related compounds . . . . .	82
7.1.3.0	Introduction . . . . .	82
7.1.3.1	Crystal structures. Lattice parameters . . . . .	84
7.1.3.2	Magnetization and magnetic susceptibility . . . . .	88
7.1.3.3	Neutron data . . . . .	90
7.1.3.4	Nuclear gamma resonance data . . . . .	91
7.1.3.5	Heat capacity . . . . .	94
7.1.3.6	Infrared properties . . . . .	94
7.1.3.7	References for 7.1.3 . . . . .	95
7.1.4	Miscellaneous boron containing oxide compounds . . . . .	96
7.1.4.0	Introduction . . . . .	96
7.1.4.1	Crystal structures. Lattice parameters . . . . .	98
7.1.4.2	Magnetic properties . . . . .	114
7.1.4.3	Magnetic structure . . . . .	116
7.1.4.4	Local structure as determined by NMR method . . . . .	117
7.1.4.5	Electron paramagnetic resonance data . . . . .	118
7.1.4.6	Resistive properties . . . . .	119
7.1.4.7	Optical properties . . . . .	119
7.1.4.8	References for 7.1.4 . . . . .	123
7.2	Boracites M <sub>3</sub> B <sub>7</sub> O <sub>13</sub> X and related compounds (E. BURZO) . . . . .	128
7.2.1	Preparation. Crystal structures . . . . .	128
7.2.2	Magnetization and magnetic susceptibility . . . . .	148
7.2.3	Magnetic structure . . . . .	152
7.2.4	Hyperfine parameters as determined from nuclear gamma resonance studies . . . . .	156
7.2.5	Nuclear magnetic resonance (NMR) data . . . . .	160
7.2.6	Electron paramagnetic resonance data . . . . .	161
7.2.7	Heat capacity . . . . .	165
7.2.8	Resistivity data . . . . .	168
7.2.9	Dielectric and related properties . . . . .	169
7.2.10	Magnetoelectric properties . . . . .	174
7.2.11	Elastic and magnetoelastic properties . . . . .	181
7.2.12	Optical properties . . . . .	181
7.2.13	References for 7.2 . . . . .	198
7.3	Boron glasses (E. BURZO) . . . . .	205

7.3.0	Introduction . . . . .	205
7.3.1	Structure of glasses (X-ray and neutron diffraction) . . . . .	206
7.3.2	Local structure of glasses as determined by nuclear magnetic resonance . . . . .	213
7.3.3	Thermal expansion . . . . .	219
7.3.4	Magnetization. Magnetic susceptibility . . . . .	222
7.3.5	Hyperfine parameters as determined by nuclear gamma resonance . . . . .	229
7.3.6	Glass properties determined from electron paramagnetic resonance studies . . . . .	240
7.3.7	Resistive and dielectric properties . . . . .	245
7.3.8	Heat capacity . . . . .	256
7.3.9	Optical properties . . . . .	258
7.3.10	Electron spectroscopy . . . . .	266
7.3.11	References for 7.3 . . . . .	267

### Subvolume I 1: Orthosilicates

List of frequently used symbols and abbreviations. . . . .	XI
Symbols. . . . .	XI
Abbreviations. . . . .	XIV

8	Magnetic and related properties of silicates and phosphates . . . . .	1
8.1	Silicates . . . . .	1
8.1.1	Orthosilicates (E. BURZO) . . . . .	1
8.1.1.1	$M_2SiO_4$ ( $M_2 = Be_2, Zn_2, LiAl, Li_2Be, Li_4$ ) orthosilicates and related compounds . . . . .	1
8.1.1.1.1	Crystal structure. Lattice parameters . . . . .	1
8.1.1.1.2	Electron paramagnetic resonance (EPR) data . . . . .	8
8.1.1.1.3	Nuclear magnetic resonance (NMR) data . . . . .	8
8.1.1.1.4	Electrical conductivity . . . . .	10
8.1.1.1.5	Heat capacity . . . . .	11
8.1.1.1.6	Dielectric properties . . . . .	12
8.1.1.1.7	X-ray emission spectra . . . . .	12
8.1.1.1.8	Optical properties . . . . .	12
	Tables and figures . . . . .	13
	References for 8.1.1.1 . . . . .	29
8.1.1.2	Chiavennite, esperite, larsenite and related silicates . . . . .	31
8.1.1.2.1	Crystal structure. Lattice parameters . . . . .	31
8.1.1.2.2	Magnetic properties . . . . .	33
8.1.1.2.3	Optical properties . . . . .	33
	Tables and figures . . . . .	34
	References for 8.1.1.2 . . . . .	41
8.1.1.3	Olivines, their polymorphs and related silicates . . . . .	42
8.1.1.3.1	Crystal structure. Lattice parameters . . . . .	42
8.1.1.3.2	Neutron diffraction data . . . . .	54
8.1.1.3.3	Magnetizations, magnetic susceptibilities, magnetic ordering temperatures . . . . .	57
8.1.1.3.4	Nuclear gamma resonance (NGR) data . . . . .	60
8.1.1.3.5	Nuclear magnetic resonance (NMR) data . . . . .	63
8.1.1.3.6	Electron paramagnetic resonance (EPR) data . . . . .	64

8.1.1.3.7	Thermal properties . . . . .	65
8.1.1.3.8	Electrical resistivity . . . . .	66
8.1.1.3.9	Dielectric properties . . . . .	69
8.1.1.3.10	Optical properties . . . . .	70
	Tables and figures . . . . .	77
	References for 8.1.1.3 . . . . .	130
8.1.1.4	Calcium and europium containing olivines and related silicates . . . . .	141
8.1.1.4.1	Crystal structure. Lattice parameters . . . . .	141
8.1.1.4.2	Neutron diffraction data . . . . .	149
8.1.1.4.3	Magnetic susceptibility . . . . .	149
8.1.1.4.4	Nuclear gamma resonance (NGR) data . . . . .	150
8.1.1.4.5	Nuclear magnetic resonance (NMR) data . . . . .	150
8.1.1.4.6	Ferroelastic properties . . . . .	152
8.1.1.4.7	Optical properties . . . . .	152
	Tables and figures . . . . .	154
	References for 8.1.1.4 . . . . .	174
8.1.1.5	Silicate garnets . . . . .	179
8.1.1.5.1	Crystal structure. Lattice parameters . . . . .	179
8.1.1.5.2	Magnetic properties . . . . .	188
8.1.1.5.3	Neutron diffraction data . . . . .	193
8.1.1.5.4	Nuclear gamma resonance (NGR) data . . . . .	194
8.1.1.5.5	Nuclear magnetic resonance (NMR) and EPR data . . . . .	197
8.1.1.5.6	Heat capacity . . . . .	199
8.1.1.5.7	Electrical resistivity . . . . .	199
8.1.1.5.8	Raman and infrared data . . . . .	200
8.1.1.5.9	Optical data. Faraday rotation . . . . .	202
	Tables and figures . . . . .	206
	References for 8.1.1.5 . . . . .	246
8.1.1.6	ASiO <sub>4</sub> (A = Zr, Hf, U, Th) and related compounds . . . . .	254
8.1.1.6.1	Crystal structure. Lattice parameters . . . . .	254
8.1.1.6.2	Magnetic properties . . . . .	257
8.1.1.6.3	Nuclear magnetic resonance (NMR) data . . . . .	257
8.1.1.6.4	Electron paramagnetic resonance (EPR) data . . . . .	257
8.1.1.6.5	Optical properties . . . . .	259
	Tables and figures . . . . .	260
	References for 8.1.1.6 . . . . .	269
8.1.1.7	Afwillite, vyuntspakhite, kinoite, euclase and related silicates . . . . .	272
8.1.1.7.1	Crystal structure. Lattice parameters . . . . .	272
8.1.1.7.2	Heat capacity . . . . .	275
8.1.1.7.3	Optical properties . . . . .	275
	Tables and figures . . . . .	276
	References for 8.1.1.7 . . . . .	283
8.1.1.8	Al <sub>2</sub> SiO <sub>5</sub> and related structures . . . . .	284
8.1.1.8.1	Crystal structure. Lattice parameters . . . . .	284
8.1.1.8.2	Magnetic data . . . . .	292
8.1.1.8.3	Nuclear gamma resonance (NGR) data . . . . .	292
8.1.1.8.4	Nuclear magnetic resonance (NMR) data . . . . .	295
8.1.1.8.5	Electron spin resonance (ESR) data . . . . .	295
8.1.1.8.6	Thermal properties . . . . .	297
8.1.1.8.7	X-ray absorption spectroscopy . . . . .	298

8.1.1.8.8	Optical properties . . . . .	298
8.1.1.8.9	Dielectric properties . . . . .	301
	Tables and figures . . . . .	302
	References for 8.1.1.8 . . . . .	334
8.1.1.9	Sapphirine and related silicates . . . . .	339
8.1.1.9.1	Crystal structure. Lattice parameters . . . . .	339
8.1.1.9.2	Nuclear gamma resonance (NGR) data . . . . .	343
8.1.1.9.3	Optical properties . . . . .	343
	Tables and figures . . . . .	345
	References for 8.1.1.9 . . . . .	354
8.1.1.10	Humite and leucophoenicite groups . . . . .	355
8.1.1.10.1	Crystal structure. Lattice parameters . . . . .	355
8.1.1.10.2	Nuclear gamma resonance (NGR) data . . . . .	359
8.1.1.10.3	Nuclear magnetic resonance (NMR) data . . . . .	359
8.1.1.10.4	Optical properties . . . . .	359
	Tables and figures . . . . .	362
	References for 8.1.1.10 . . . . .	375
8.1.1.11	Welinite, katoptrite, tritomite and related silicates . . . . .	377
8.1.1.11.1	Crystal structure. Lattice parameters . . . . .	377
8.1.1.11.2	Optical properties . . . . .	379
	Tables and figures . . . . .	380
	References for 8.1.1.11 . . . . .	385
8.1.1.12	CaTiSiO <sub>5</sub> , CaSnSiO <sub>5</sub> and related silicates . . . . .	386
8.1.1.12.1	Crystal structure. Lattice parameters . . . . .	386
8.1.1.12.2	Nuclear gamma resonance (NGR) data . . . . .	391
8.1.1.12.3	Nuclear magnetic resonance (NMR) data . . . . .	391
8.1.1.12.4	Electron paramagnetic resonance (EPR) data . . . . .	392
8.1.1.12.5	Heat capacity . . . . .	392
8.1.1.12.6	Dielectric properties . . . . .	393
8.1.1.12.7	EXAFS and XANES data . . . . .	393
8.1.1.12.8	Optical properties . . . . .	394
	Tables and figures . . . . .	396
	References for 8.1.1.12 . . . . .	416
8.1.1.13	Cerites and chloritoids . . . . .	418
8.1.1.13.1	Crystal structure. Lattice parameters . . . . .	418
8.1.1.13.2	Nuclear gamma resonance (NGR) data . . . . .	420
8.1.1.13.3	Heat capacity . . . . .	420
8.1.1.13.4	Optical properties . . . . .	421
	Tables and figures . . . . .	423
	References for 8.1.1.13 . . . . .	435
8.1.1.14	Borosilicates and related compounds . . . . .	436
8.1.1.14.1	Crystal structures. Lattice parameters . . . . .	436
8.1.1.14.2	Nuclear gamma resonance (NGR) data . . . . .	442
8.1.1.14.3	Nuclear magnetic resonance (NMR) data . . . . .	443
8.1.1.14.4	Optical properties . . . . .	444
8.1.1.14.5	XAFS spectroscopy . . . . .	444
	Tables and figures . . . . .	445
	References for 8.1.1.14 . . . . .	472
8.1.1.15	Uranyl silicates . . . . .	475

8.1.1.15.1	Crystal structure. Lattice parameters . . . . .	475
8.1.1.15.2	Nuclear magnetic resonance (NMR) data . . . . .	477
8.1.1.15.3	Optical properties . . . . .	477
	Tables and figures . . . . .	479
	References for 8.1.1.15 . . . . .	487
8.1.1.16	Thörnebohmites, britholites and related silicates . . . . .	488
8.1.1.16.1	Crystal structures. Lattice parameters . . . . .	488
8.1.1.16.2	Magnetic properties . . . . .	491
8.1.1.16.3	Nuclear gamma resonance (NGR) data . . . . .	491
8.1.1.16.4	Thermal properties . . . . .	491
8.1.1.16.5	Optical properties . . . . .	491
	Tables and figures . . . . .	492
	References for 8.1.1.16 . . . . .	504
	Contents of further subvolumes of III/27 . . . . .	506
	List of editor and authors of III/27 . . . . .	539

## Subvolume I 2: Sorosilicates

	List of frequently used symbols and abbreviations . . . . .	IX
	Symbols . . . . .	IX
	Abbreviations . . . . .	XI
8	Magnetic and related properties of silicates and phosphates . . . . .	1
8.1	Silicates (E. BURZO) . . . . .	1
8.1.1	Orthosilicates . . . . . see subvolume III/2711	
8.1.2	Sorosilicates . . . . .	1
8.1.2.1	Diorthopyrosilicates . . . . .	1
8.1.2.1.1	Crystal structures. Lattice parameters . . . . .	1
8.1.2.1.2	Magnetic properties . . . . .	6
8.1.2.1.3	Nuclear magnetic resonance (NMR) data . . . . .	7
8.1.2.1.4	Optical properties . . . . .	7
	Tables and figures . . . . .	8
	References for 8.1.2.1 . . . . .	27
8.1.2.2	Melilites and related silicates . . . . .	29
8.1.2.2.1	Crystal structure. Lattice parameters . . . . .	29
8.1.2.2.2	Magnetic properties. Neutron diffraction data . . . . .	43
8.1.2.2.3	<sup>57</sup> Fe nuclear gamma resonance (NGR) data . . . . .	46
8.1.2.2.4	Perturbed angular correlation (PAC) . . . . .	47
8.1.2.2.5	Nuclear magnetic resonance (NMR) data . . . . .	47
8.1.2.2.6	EXAFS data . . . . .	48
8.1.2.2.7	Heat capacity . . . . .	48
8.1.2.2.8	Piezoelectric properties . . . . .	49
8.1.2.2.9	Optical properties . . . . .	50
	Tables and figures . . . . .	52



	References for 8.1.2.2 . . . . .	85
8.1.2.3	Ilvaite, lawsonite and related silicates . . . . .	90
8.1.2.3.1	Crystal structure. Lattice parameters . . . . .	90
8.1.2.3.2	Neutron diffraction data . . . . .	97
8.1.2.3.3	Magnetization and magnetic susceptibilities . . . . .	97
8.1.2.3.4	Nuclear gamma resonance (NGR) data . . . . .	98
8.1.2.3.5	Nuclear magnetic resonance (NMR) data . . . . .	100
8.1.2.3.6	Dielectric properties . . . . .	101
8.1.2.3.7	Electrical resistivity . . . . .	101
8.1.2.3.8	Heat capacity . . . . .	102
8.1.2.3.9	Optical properties . . . . .	103
	Tables and figures . . . . .	106
	References for 8.1.2.3 . . . . .	139
8.1.2.4	Tilleyite, hemimorphite, wöhlerite and related silicates . . . . .	142
8.1.2.4.1	Crystal structures. Lattice parameters . . . . .	142
8.1.2.4.2	Nuclear magnetic resonance (NMR) data . . . . .	145
8.1.2.4.3	Optical properties . . . . .	145
	Tables and figures . . . . .	147
	References for 8.1.2.4 . . . . .	158
8.1.2.5	Götzenite, labuntsovitte, andremeyerite and related silicates . . . . .	160
8.1.2.5.1	Crystal structure. Lattice parameters . . . . .	160
8.1.2.5.2	Nuclear gamma resonance (NGR) data . . . . .	164
8.1.2.5.3	Nuclear magnetic resonance (NMR) data . . . . .	164
8.1.2.5.4	Optical properties . . . . .	165
	Tables and figures . . . . .	166
	References for 8.1.2.5 . . . . .	184
8.1.2.6	Lomonosovite, innelite, kentrolite and related silicates . . . . .	187
8.1.2.6.1	Crystal structure. Lattice parameters . . . . .	187
8.1.2.6.2	Optical properties . . . . .	191
	Tables and figures . . . . .	192
	References for 8.1.2.6 . . . . .	206
8.1.2.7	Epidotes, chevkinites, vesuvianite, orientite and related silicates . . . . .	207
8.1.2.7.1	Crystal structure. Lattice parameters . . . . .	207
8.1.2.7.2	Magnetic properties . . . . .	215
8.1.2.7.3	Nuclear gamma resonance (NGR) data . . . . .	215
8.1.2.7.4	Nuclear magnetic resonance (NMR) data . . . . .	216
8.1.2.7.5	Electron paramagnetic resonance (EPR) data . . . . .	217
8.1.2.7.6	Dielectric properties . . . . .	218
8.1.2.7.7	Heat capacity . . . . .	218
8.1.2.7.8	EXAFS and XANES data . . . . .	218
8.1.2.7.9	Optical properties . . . . .	218
	Tables and figures . . . . .	221
	References for 8.1.2.7 . . . . .	255
8.1.2.8	Zunyite, davreuxite, keldyshite, gageite, pumpellyite, jennite and related silicates . . . . .	259
8.1.2.8.1	Crystal structures. Lattice parameters . . . . .	259
8.1.2.8.2	Nuclear gamma resonance (NGR) data . . . . .	264
8.1.2.8.3	Nuclear magnetic resonance (NMR) data . . . . .	264
8.1.2.8.4	Optical properties . . . . .	265
	Tables and figures . . . . .	266
	References for 8.1.2.8 . . . . .	283

Index of substances for Volume III/27I2 . . . . .	285
A) Alphabetical index of element systems . . . . .	286
B) Alphabetical index of mineral names . . . . .	306
Contents of further subvolumes of III/27 . . . . .	311
List of editor and authors of III/27 . . . . .	347

## Subvolume J1: Halides I

9	Magnetic properties of halides . . . . .	1
9.1	$\text{MX}_2$ and $\text{MX}_2 \cdot n\text{H}_2\text{O}$ compounds ( $M = 3d$ element, $X =$ halogen element) (K. KATSUMATA) . . . . .	1
9.1.1	Introduction . . . . .	1
9.1.1.1	General remarks . . . . .	1
9.1.1.2	List of frequently used symbols and abbreviations . . . . .	2
9.1.2	Macroscopic magnetic and related properties of $\text{MX}_2$ compounds . . . . .	4
9.1.2.1	$\text{MF}_2$ compounds . . . . .	4
9.1.2.2	$\text{MCl}_2$ compounds . . . . .	13
9.1.2.3	$\text{MBr}_2$ compounds . . . . .	20
9.1.2.4	$\text{MI}_2$ compounds . . . . .	25
9.1.3	Macroscopic magnetic and related properties of $\text{MX}_2 \cdot n\text{H}_2\text{O}$ compounds . . . . .	28
9.1.4	Microscopic magnetic and related properties of $\text{MX}_2$ and $\text{MX}_2 \cdot n\text{H}_2\text{O}$ compounds . . . . .	47
9.1.4.1	$\text{MX}_2$ compounds . . . . .	47
9.1.4.2	$\text{MX}_2 \cdot n\text{H}_2\text{O}$ compounds . . . . .	54
9.1.5	References for 9.1 . . . . .	56
9.2	$\text{M}_{1-x}\text{M}'_x\text{X}_2$ and $\text{M}_{1-x}\text{M}'_x\text{X}_2 \cdot n\text{H}_2\text{O}$ compounds ( $M, M' = 3d$ element, $X =$ halogen element) (K. KATSUMATA) . . . . .	59
9.2.1	Introduction . . . . .	59
9.2.1.1	General remarks . . . . .	59
9.2.1.2	List of frequently used symbols and abbreviations . . . . .	60
9.2.2	Static magnetic and related properties of $\text{M}_{1-x}\text{M}'_x\text{X}_2$ and $\text{M}_{1-x}\text{M}'_x\text{X}_2 \cdot n\text{H}_2\text{O}$ compounds . . . . .	61
9.2.2.1	Static magnetic and related properties of $\text{M}_{1-x}\text{M}'_x\text{F}_2$ compounds . . . . .	61
9.2.2.2	Static magnetic and related properties of $\text{M}_{1-x}\text{M}'_x\text{Cl}_2$ compounds . . . . .	72
9.2.2.3	Static magnetic and related properties of $\text{Fe}_{1-x}\text{Co}_x\text{Br}_2$ compound . . . . .	88
9.2.2.4	Static magnetic and related properties of $\text{M}_{1-x}\text{M}'_x\text{X}_2 \cdot n\text{H}_2\text{O}$ compounds . . . . .	92
9.2.3	Dynamical magnetic and related properties of $\text{M}_{1-x}\text{M}'_x\text{X}_2$ and $\text{M}_{1-x}\text{M}'_x\text{X}_2 \cdot n\text{H}_2\text{O}$ compounds . . . . .	103
9.2.3.1	Dynamical magnetic and related properties of $\text{M}_{1-x}\text{M}'_x\text{F}_2$ compounds . . . . .	103
9.2.3.2	Dynamical magnetic and related properties of $\text{M}_{1-x}\text{M}'_x\text{Cl}_2$ compounds . . . . .	104

9.2.3.3	Dynamical magnetic and related properties of $\text{Fe}_{1-x}\text{Co}_x\text{Br}_2$ compound . . . . .	110
9.2.3.4	Dynamical magnetic and related properties of $\text{Fe}_{1-x}\text{Co}_x\text{Cl}_2 \cdot 2\text{H}_2\text{O}$ compound . . . . .	111
9.2.4	References for 9.2 . . . . .	112
9.3	$\text{MX}_3$ compounds ( $\text{M} = 3\text{d element}$ , $\text{X} = \text{halogen element}$ ) (K. KATSUMATA) . . . . .	114
9.3.1	Introduction . . . . .	114
9.3.1.1	General remarks . . . . .	114
9.3.1.2	List of frequently used symbols and abbreviations . . . . .	114
9.3.2	Macroscopic magnetic and related properties of $\text{MX}_3$ compounds . . . . .	116
9.3.2.1	$\text{MF}_3$ compounds . . . . .	117
9.3.2.2	$\text{MCl}_3$ compounds . . . . .	121
9.3.2.3	$\text{MBr}_3$ compounds . . . . .	128
9.3.2.4	$\text{MI}_3$ compounds . . . . .	130
9.3.3	Microscopic magnetic and related properties of $\text{CrX}_3$ compounds . . . . .	132
9.3.4	References for 9.3 . . . . .	134
9.4	$\text{MCl}_2$ -GIC; $\text{MCl}_3$ -GIC ( $\text{M} = 3\text{d element}$ ) (M. MATSUURA, M. HAGIWARA) . . . . .	136
9.4.1	Introduction . . . . .	136
9.4.1.1	General remarks . . . . .	136
9.4.1.2	List of frequently used symbols . . . . .	140
9.4.1.3	List of abbreviations . . . . .	142
9.4.2	Singly intercalated compounds . . . . .	144
9.4.2.1	General survey . . . . .	144
9.4.2.2	$\text{CoCl}_2$ -GIC . . . . .	148
9.4.2.2.1	Stage 2 $\text{CoCl}_2$ -GIC . . . . .	148
9.4.2.2.2	Stage $n$ $\text{CoCl}_2$ -GIC ( $n \geq 3$ ) . . . . .	159
9.4.2.2.3	Stage 1 $\text{CoCl}_2$ -GIC . . . . .	160
9.4.2.3	$\text{NiCl}_2$ -GIC . . . . .	163
9.4.2.3.1	Stage 2 $\text{NiCl}_2$ -GIC . . . . .	163
9.4.2.3.2	Stage $n$ $\text{NiCl}_2$ -GIC ( $n \geq 3$ ) . . . . .	168
9.4.2.3.3	Stage 1 $\text{NiCl}_2$ -GIC . . . . .	168
9.4.2.4	$\text{MCl}_2$ -GIC ( $\text{M} = \text{Mn, Cu}$ ) . . . . .	170
9.4.2.4.1	Stage $n$ $\text{MnCl}_2$ -GIC . . . . .	170
9.4.2.4.2	Stage $n$ $\text{CuCl}_2$ -GIC . . . . .	175
9.4.2.5	$\text{MCl}_3$ -GIC ( $\text{M} = \text{Cr, Fe}$ ) . . . . .	176
9.4.2.5.1	Stage $n$ $\text{CrCl}_3$ -GIC . . . . .	176
9.4.2.5.2	Stage 1 $\text{FeCl}_3$ -GIC . . . . .	179
9.4.2.5.3	Stage $n$ $\text{FeCl}_3$ -GIC ( $n \geq 2$ ) . . . . .	182
9.4.3	Bi-intercalation compounds . . . . .	184
9.4.3.1	General survey . . . . .	184
9.4.3.2	$\text{M}'(\text{magnetic})\text{Cl}_n\text{-M}''(\text{nonmagnetic})\text{Cl}_m\text{-GBIC}$ ( $\text{M}' = \text{Co, Cr}$ , $\text{M}'' = \text{Al, Ga, Cd}$ ) . . . . .	186
9.4.3.2.1	$\text{CoCl}_2\text{-GaCl}_3\text{-GBIC}$ . . . . .	186
9.4.3.2.2	$\text{CoCl}_2\text{-AlCl}_3\text{-GBIC}$ . . . . .	186
9.4.3.2.3	$\text{CrCl}_3\text{-AlCl}_3\text{-GBIC}$ . . . . .	186

9.4.3.2.4	CrCl <sub>3</sub> -CdCl <sub>2</sub> -GBIC . . . . .	186
9.4.3.3	M'(magnetic)Cl <sub>n</sub> -M''(magnetic)Cl <sub>m</sub> -GBIC (M', M'' = Cr, Mn, Fe, Co, Ni) . . . . .	188
9.4.3.3.1	CoCl <sub>2</sub> -FeCl <sub>3</sub> -GBIC . . . . .	188
9.4.3.3.2	NiCl <sub>2</sub> -FeCl <sub>3</sub> -GBIC . . . . .	189
9.4.3.3.3	NiCl <sub>2</sub> -CrCl <sub>3</sub> -GBIC . . . . .	191
9.4.3.3.4	MnCl <sub>2</sub> -CrCl <sub>3</sub> -GBIC . . . . .	193
9.4.4	Mixed intercalation compounds . . . . .	193
9.4.4.1	General survey . . . . .	193
9.4.4.2	Mixed compounds . . . . .	194
9.4.4.2.1	Co <sub>1-x</sub> Ni <sub>x</sub> Cl <sub>2</sub> -GIC . . . . .	194
9.4.4.2.2	Co <sub>1-x</sub> Mn <sub>x</sub> Cl <sub>2</sub> -GIC . . . . .	196
9.4.4.2.3	Co <sub>1-x</sub> Fe <sub>x</sub> Cl <sub>2</sub> -GIC . . . . .	198
9.4.4.3	Diluted compounds . . . . .	198
9.4.4.3.1	Co <sub>1-x</sub> Al <sub>x</sub> Cl <sub>2</sub> -GIC . . . . .	198
9.4.4.3.2	Co <sub>1-x</sub> Mg <sub>x</sub> Cl <sub>2</sub> -GIC . . . . .	199
9.4.5	References for 9.4 . . . . .	201
9.5	MM'F <sub>5</sub> and MM'F <sub>5</sub> · nH <sub>2</sub> O compounds (M, M' = 3d element or Al; n = 2 or 7) (H.P.J. WIJN) . . . . .	206
9.5.1	List of symbols and abbreviations . . . . .	206
9.5.2	MM'F <sub>5</sub> compounds . . . . .	206
9.5.3	MM'F <sub>5</sub> · 2H <sub>2</sub> O compounds . . . . .	213
9.5.3.1	Crystal structure . . . . .	213
9.5.3.2	Magnetic structures . . . . .	214
9.5.3.3	Mössbauer data . . . . .	217
9.5.3.4	Magnetization curves . . . . .	222
9.5.3.5	Paramagnetic properties . . . . .	224
9.5.4	MM'F <sub>5</sub> · 7H <sub>2</sub> O compounds . . . . .	226
9.5.5	References for 9.5 . . . . .	232

## Subvolume J2: Halides II

9.6	AMX <sub>3</sub> and AMX <sub>3</sub> · 2H <sub>2</sub> O compounds (A, M = metal, X = halogen element) (A. CHELKOWSKI) . . . . .	1
9.6.0	Introduction . . . . .	1
9.6.0.1	General remarks . . . . .	1
9.6.0.2	List of frequently used symbols and abbreviations . . . . .	2
9.6.1	Table . . . . .	7
9.6.2	Figures . . . . .	56
9.6.3	References for 9.6 and 9.9 . . . . .	247
9.7	AMF <sub>4</sub> and AMF <sub>4</sub> · H <sub>2</sub> O compounds (A = alkali element, Tl or NH <sub>4</sub> , M = 3d element) (H.P.J. WIJN) . . . . .	259

9.7.1	AMF <sub>4</sub> compounds . . . . .	259
9.7.2	AMF <sub>4</sub> · H <sub>2</sub> O compounds . . . . .	275
9.7.3	References for 9.7 . . . . .	280
9.8	A <sub>2</sub> MX <sub>5</sub> and A <sub>2</sub> MX <sub>5</sub> · H <sub>2</sub> O compounds (A = Li, Na, K, Rb, Cs, Tl, NH <sub>4</sub> ; M = 3d element; X = F, Cl, Br) (A. CHELKOWSKI, H.P.J. WIJN) . . . . .	282
9.8.1	Introduction . . . . .	282
9.8.2	A <sub>2</sub> MX <sub>5</sub> compounds . . . . .	282
9.8.2.1	Crystallographic properties of A <sub>2</sub> MX <sub>5</sub> compounds . . . . .	282
9.8.2.2	Magnetic properties of A <sub>2</sub> MX <sub>5</sub> compounds . . . . .	284
9.8.3	A <sub>2</sub> MX <sub>5</sub> · H <sub>2</sub> O compounds . . . . .	296
9.8.3.1	Crystallographic properties of A <sub>2</sub> MX <sub>5</sub> · H <sub>2</sub> O compounds . . . . .	296
9.8.3.2	Magnetic properties of A <sub>2</sub> MX <sub>5</sub> · H <sub>2</sub> O compounds . . . . .	296
9.8.4	References for 9.8 . . . . .	318
9.9	A <sub>2</sub> MM'X <sub>6</sub> compounds (A, M, M' = metal, X = halogen element) (A. CHELKOWSKI) . . . . .	321
9.9.0	Introduction . . . . .	321
9.9.1	Table . . . . .	322
9.9.2	Figures . . . . .	326
9.10	A <sub>2</sub> M <sup>2+</sup> M <sup>3+</sup> F <sub>7</sub> compounds (A = Na, Ag; M = 3d element, Mg, Al or In) (H.P.J. WIJN) . . . . .	337
9.10.1	Introduction . . . . .	337
9.10.2	Crystallographic properties of A <sub>2</sub> M <sup>2+</sup> M <sup>3+</sup> F <sub>7</sub> compounds . . . . .	337
9.10.3	Magnetic properties of A <sub>2</sub> M <sup>2+</sup> M <sup>3+</sup> F <sub>7</sub> compounds . . . . .	340
9.10.4	References for 9.10 . . . . .	350
9.11	A <sub>5</sub> M <sub>3</sub> F <sub>14</sub> compounds (A = Na, K or Ag; M = 3d element or Al) (H.P.J. WIJN) . . . . .	351
9.11.1	Crystallographic properties of A <sub>5</sub> M <sub>3</sub> F <sub>14</sub> compounds . . . . .	351
9.11.2	Magnetic properties of A <sub>5</sub> M <sub>3</sub> F <sub>14</sub> compounds . . . . .	352
9.11.3	References for 9.11 . . . . .	359

### Subvolume J3: Halide perovskite-type layer structures

9.12	Halide perovskite-type layer structures (R. GEICK) . . . . .	1
9.12.1	Introduction . . . . .	1
9.12.1.1	Characterization of perovskite-type Layer structures . . . . .	1
9.12.1.2	Lattice dynamics: intralayer and interlayer forces . . . . .	4
9.12.1.3	Comments on notation and units and Table 1 . . . . .	9
9.12.1.4	References for 9.12.1 . . . . .	40
9.12.2	Structural properties . . . . .	43

9.12.2.1	Structures . . . . .	43
9.12.2.1.1	General aspects . . . . .	43
9.12.2.1.2	Easy-axis antiferromagnets . . . . .	45
9.12.2.1.3	Easy-plane ferromagnets and antiferromagnets . . . . .	47
9.12.2.1.4	Structures resulting from structural phase transitions . . . . .	49
9.12.2.1.5	Mixed crystals . . . . .	52
9.12.2.2	Structural phase transitions . . . . .	54
9.12.2.2.1	Experimental investigations . . . . .	54
9.12.2.2.2	Group-theoretical considerations . . . . .	61
9.12.2.2.3	Structural phase transitions in monoammonium compounds . . . . .	65
9.12.2.2.4	Model for the phase transitions in monoammonium compounds . . . . .	68
9.12.2.2.5	Long-chain compounds . . . . .	73
9.12.2.2.6	Diammonium compounds . . . . .	74
9.12.2.3	Figures for 9.12.2 and Tables 2, 3 and 4 . . . . .	78
9.12.2.4	References for 9.12.2 . . . . .	148
9.12.3	Magnetic properties . . . . .	159
9.12.3.1	Antiferromagnets . . . . .	159
9.12.3.1.1	Exchange interaction . . . . .	159
9.12.3.1.2	Mn-compounds, spin-wave theory . . . . .	160
9.12.3.1.3	Temperature-dependent properties, high temperature series . . . . .	167
9.12.3.1.4	Double-layer compounds . . . . .	171
9.12.3.1.5	Ni- and Fe-compounds . . . . .	172
9.12.3.1.6	Spin-flop transition – AFMR under various conditions . . . . .	175
9.12.3.1.7	Canted antiferromagnets, weak ferromagnetism . . . . .	181
9.12.3.1.8	Antiferromagnetic Cu-compounds . . . . .	184
9.12.3.1.9	Co-compounds (2D Ising Model) . . . . .	186
9.12.3.2	Ferromagnets . . . . .	188
9.12.3.2.1	Cu-compounds . . . . .	188
9.12.3.2.2	Cr-compounds . . . . .	195
9.12.3.2.3	Spin-reorientation transitions – FMR under various conditions . . . . .	201
9.12.3.2.4	Magnetic polaritons . . . . .	208
9.12.3.2.5	Parallel pumping experiments . . . . .	210
9.12.3.3	Doped and mixed systems . . . . .	213
9.12.3.3.1	Paramagnetic centres in diamagnetic host crystals . . . . .	213
9.12.3.3.2	Magnetic ordering in diluted systems . . . . .	216
9.12.3.3.3	Spin waves in diluted magnets . . . . .	222
9.12.3.3.4	Excitations in mixed antiferromagnets . . . . .	227
9.12.3.3.5	Mixed antiferromagnets with competing anisotropies . . . . .	233
9.12.3.3.6	Mixed magnets with competing exchange interactions . . . . .	236
9.12.3.4	Figures for 9.12.3 and Table 5 . . . . .	243
9.12.3.5	References for 9.12.3 . . . . .	328
9.12.4	Critical phenomena . . . . .	349
9.12.4.1	Static critical behaviour . . . . .	349
9.12.4.1.1	General . . . . .	349
9.12.4.1.2	2D Ising Model . . . . .	351

9.12.4.1.3	Experimental determination of $\alpha$ . . . . .	354
9.12.4.1.4	Experimental determination of $\beta$ . . . . .	356
9.12.4.1.5	Experimental determination of $\gamma$ , $\nu$ and $\eta$ . . . . .	357
9.12.4.1.6	Experimental test of the two-scale-factor universality . . . . .	360
9.12.4.1.7	2D Heisenberg model . . . . .	361
9.12.4.1.8	2D XY-model . . . . .	364
9.12.4.1.9	Crossover phenomena . . . . .	376
9.12.4.1.10	3D XY-model – structural phase transitions . . . . .	379
9.12.4.1.11	Critical behaviour near the percolation threshold . . . . .	382
9.12.4.1.12	Random field effects – random field Ising model . . . . .	391
9.12.4.1.13	Critical properties of spin glasses – 2D Ising spin glass . . . . .	398
9.12.4.2	Dynamic critical properties and relaxation . . . . .	402
9.12.4.2.1	Characteristic frequency from neutron inelastic scattering . . . . .	402
9.12.4.2.2	Relaxation time – activated dynamics – aging . . . . .	403
9.12.4.2.3	Spin-wave lineshape of a 2D Heisenberg ferromagnet . . . . .	409
9.12.4.2.4	2D XY-model: influence of vortices on $S(\mathbf{q}, \omega)$ . . . . .	411
9.12.4.2.5	Critical broadening of the NMR linewidth . . . . .	413
9.12.4.2.6	Critical broadening of the EPR linewidth . . . . .	414
9.12.4.2.7	Critical EPR linewidth due to solitons or due to magnons? . . . . .	417
9.12.4.2.8	EPR linewidth at high temperatures – spin diffusion . . . . .	420
9.12.4.2.9	EPR linewidth in mixed crystals . . . . .	423
9.12.4.3	Figures for 9.12.4 and Table 6 . . . . .	427
9.12.4.4	References for 9.12.4 . . . . .	485
	Contents of further subvolumes of III/27 . . . . .	504
	List of editor and authors of Vol. III/27 . . . . .	530

## List of editor and authors of III/27

### Editor

**H. P. J. Wijn**, Institut für Werkstoffe der Elektrotechnik der Rheinisch-Westfälischen Technischen Hochschule Aachen, Templergraben, 52062 Aachen, FRG

### Authors

**K. Adachi**, Department of Physics, Nagoya University, Nagoya 464, Japan (27 A)

**E. Agostinelli**, Istituto di Teoria e Struttura Elettronica - CNR, Via Salaria, 00016 Monterotondo Stazione (Roma), Italy (27 D)

**G. Albanese**, Dipartimento di Fisica, Università degli Studi di Parma, Viale delle Scienze, I-43100 Parma, Italy (27 G)

**V. A. M. Brabers**, Technische Universiteit Eindhoven, Den Dolech, 5600 MB Eindhoven, The Netherlands (27 D)

**E. Burzo**, Universitatea Babes Bolyai, Facultatea de Fizica, 3400 Cluj-Napoca, Romania (27 H, 27 F1 $\alpha$ , 27 F1 $\beta$ , 27 I 1, 27 I 2)

**A. Chelkowski**, Institute of Physics, Silesian University, 40-007 Katowice, Poland (27 J2)

**A. Deriu**, Dipartimento di Fisica, Università degli Studi di Parma, Viale delle Scienze, I-43100 Parma, Italy (27 G)

**Y. Endoh**, Neutron Scattering Laboratory, Department of Physics, Tohoku University, Aramaki, Aoba-ku, Sendai 980, Japan (27 F3)

**D. Fiorani**, Istituto di Teoria e Struttura Elettronica - CNR, Via Salaria, 00016 Monterotondo Stazione (Roma), Italy (27 D)

**R. Geick**, Physikalisches Institut der Universität Würzburg, Am Hubland, 97074 Würzburg, FRG (27 J3)

**J. E. Greedan**, Institute for Material Research, McMaster University, Main Street West, Hamilton, Ontario L8S, 4M1, Canada (27 G)

**M. Hagiwara**, Department of Electronics and Information Science, Kyoto Institute of Technology, Matsugasaki, Kyoto 606, Japan (27 J1)

**D. Kaczorowski**, Polish Academy of Sciences, W. Trzebiatowski Institute of Low Temperature and Structure Research, 50-950 Wrocław 2, Poland (27 B7, 27 B8, 27 C2)

**K. Kakurai**, Neutron Scattering Facility, Institute for Solid State Physics, University of Tokyo, Tokai mura, Ibaraki 319-11, Japan (27 F3)

**A. K. Katori**, Institute for Solid State Physics, University of Tokyo, Roppongi, Minato-ku, Tokyo 107, Japan (27 F3)

**K. Katsumata**, Institute of Physical and Chemical Research (RIKEN), Wako, Saitama, 351-01, Japan (27 J1)



**Z.A. Kazei**, Department of Physics (DFEF), Problem Laboratory for Magnetism, Moscow State University, Leninskiye Gory, 119899 Moscow, Russia **(27 E, 27 F2, 27 F2S)**

**N. P. Kolmakova**, Department of Physics (DFEF), Problem Laboratory for Magnetism, Moscow State University, Leninskiye Gory, 119899 Moscow, Russia **(27 E)**

**I. B. Krynetskii**, Department of Physics (DFEF), Laboratory for Problems of Magnetism, Moscow State University, Leninskiye Gory, 119899 Moscow, Russia **(27 F2, 27 F2S)**

**M. Matsuura**, Department of Electronics and Information Science, Kyoto Institute of Technology, Matsugasaki Sakyo, Kyoto 606, Japan **(27 J1)**

**P. Novák**, Institute of Physics, Czechoslovak Academy of Sciences, Na Slovance, 18040 Prague 8, Czechoslovakia **(27 E)**

**S. Ogawa**, Institute of Solid State Physics, Tokyo University, Roppongi, Minatu-ku, Tokyo, Japan **(27 A)**

**T. Palewski**, International Laboratory of High Magnetic Fields and Low Temperatures, 53-421 Wrocław, Poland **(27 B1, 27 B2, 27 B3, 27 B4 $\alpha$ , 27 B4 $\beta$ , 27 B5, 27 C1)**

**M. S. Seehra**, Phys. Dept., West Virginia University, Morgantown WV 26506, USA **(27 G, 27 F3)**

**K. Siratori**, Dept. of Physics, Faculty of Science, Osaka University, Toyonaka, Osaka 560, Japan **(27 G)**

**G. Srinivasan**, Department of Physics, Oakland University, Rochester, Michigan 48309 - 4401, USA **(27 F3)**

**V. I. Sokolov**, Department of Physics (DFEF), Problem Laboratory for Magnetism, Moscow State University, Leninskiye Gory, 119899 Moscow, Russia **(27 E)**

**W. Suski**, Polish Academy of Sciences, W. Trzebiatowski Institute of Low Temperature and Structure Research, 50-950 Wrocław 2, and International Laboratory of High Magnetic Fields and Low Temperatures, 53-421 Wrocław, Poland **(27 B1, 27 B2, 27 B3, 27 B4 $\alpha$ , 27 B4 $\beta$ , 27 B5, 27 C1)**

**A.M. Testa**, Istituto di Teoria e Struttura Elettronica - CNR, Via Salaria, 00016 Monterotondo Stazione (Roma), Italy **(27 D)**

**R. Troć**, Polish Academy of Sciences, W. Trzebiatowski Institute of Low Temperature and Structure Research, 50-950 Wrocław 2, Poland **(27 B6 $\alpha$ , 27 B7, 27 C2)**

**T. E. Whall**, Department of Physics, University of Warwick, Coventry CV4-7AL, United Kingdom **(27 D)**

**H. P. J. Wijn**, Institut für Werkstoffe der Elektrotechnik der Rheinisch-Westfälischen Technischen Hochschule Aachen, Templergraben, 52062 Aachen, FRG **(27 G, 27 J1, 27 J2)**