

LANDOLT-BÖRNSTEIN

Zahlenwerte und Funktionen
aus Naturwissenschaften und Technik

Neue Serie

Editors in Chief: K.-H. Hellwege · O. Madelung

Group II: Atomic and Molecular Physics

Volume 12

Supplement 4 (1973, 1974) to Volume 2

Magnetic Properties
of Coordination and Organometallic
Transition Metal Compounds

E. König and G. König

Editors: K.-H. Hellwege and A.M. Hellwege



Springer-Verlag Berlin · Heidelberg · New York · Tokyo 1984

LANDOLT-BÖRNSTEIN

Zahlenwerte und Funktionen
aus Naturwissenschaften und Technik

Neue Serie

Gesamtherausgabe: K.-H. Hellwege · O. Madelung

Gruppe II: Atom- und Molekularphysik

Band 12

Ergänzungsband 4 (1973, 1974) zu Band 2

**Magnetische Eigenschaften der Koordinations-
und metallorganischen Verbindungen
der Übergangselemente**

Teilband a Magnetische Suszeptibilitäten

E. König und G. König

Herausgeber: K.-H. Hellwege und A.M. Hellwege



Springer-Verlag Berlin · Heidelberg · New York · Tokyo 1984

CIP-Kurztitelaufnahme der Deutschen Bibliothek

Zahlenwerte und Funktionen aus Naturwissenschaften und Technik/Landolt-Börnstein. – Berlin; Heidelberg; New York; Tokyo: Springer. Teilw. mit d. Erscheinungsorten Berlin, Heidelberg, New York. – Paralell.: Numerical data and functional relationships in science and technology

NE: Landolt, Hans [Begr.]; PT. N.S./Gesamthrg.: K.-H. Hellwege. Gruppe 2, Atom- und Molekularphysik. Bd. 12. Magnetische Eigenschaften der Koordinations- und metallorganischen Verbindungen der Übergangselemente: Erg.-Bd. 4 (1973, 1974) zu Bd. 2. Teilbd. a. Magnetische Suszeptibilitäten/E. König u. G. König. Hrsg. K.-H. Hellwege u. A.M. Hellwege. – 1984.

ISBN 3-540-12270-2 Berlin, Heidelberg, New York, Tokyo
ISBN 0-387-12270-2 New York, Heidelberg, Berlin, Tokyo

NE: Hellwege, Karl-Heinz [Hrsg.]; König, Edgar [Mitverf.]

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned specifically those of translation, reprinting, reuse of illustrations, broadcasting, reproduction by photocopying machine or similar means, and storage in data banks.

Under § 54 of the German Copyright Law where copies are made for other than private use a fee is payable to 'Verwertungsgesellschaft Wort' Munich.

© by Springer-Verlag Berlin-Heidelberg 1984

Printed in Germany

The use of registered names, trademarks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

Typesetting, printing and bookbinding: Universitätsdruckerei H. Stürtz AG Würzburg

2163/3020 – 543210

Vorwort

Band II/12 ist der vierte Ergänzungsband zu Band II/2 „Magnetische Eigenschaften der Koordinationsverbindungen und der metallorganischen Verbindungen“. Er ist nach dem gleichen Konzept aufgebaut und berücksichtigt die Veröffentlichungen über magnetische Suszeptibilitäten und Elektronenspinresonanz in den Jahren 1973 und 1974. Die Daten und die Literatur schließen unmittelbar an die der ersten beiden Ergänzungsbände, Band II/8, II/10 und II/11 an.

Wie in den Bänden II/2, II/8, II/10 und II/11 sind außer den obengenannten zusätzlich benachbarte Verbindungen mit aufgenommen worden, um dem Leser Vergleiche zu ermöglichen. Dagegen werden die speziellen Substanzengruppen der Granate, Perowskite, Spinelle und Hexagonalferrite ausführlich in eigenen Bänden, III/4a, b (Literatur bis 1969/70) und deren Ergänzungsbänden, III/12a, b, c (Literatur 1970 bis 1977, 1978 bzw. 1979) behandelt.

Die Daten sind wieder so vollständig wie möglich zusammengestellt und kritisch bearbeitet worden. Das in der Literatur vorhandene Informationsmaterial enthält sowohl funktionelle Abhängigkeiten von äußeren Parametern, die der Untersuchung physikalischer Fragen dienen, als auch Einzelwerte, die z. B. als chemisch-analytische Hilfsmittel gebraucht werden. Beide Gruppen von Daten sind hier berücksichtigt worden.

Aus technischen und zeitlichen Gründen wurde Band II/12 geteilt: der erste, hiermit vorgelegte Teilband II/12a behandelt die magnetischen Suszeptibilitäten, der bald folgende Teilband II/12b die Elektronenspinresonanz.

Das detaillierte Inhaltsverzeichnis, das beiden Teilbänden vorangestellt ist, und die ausführliche Beschreibung der Anordnung der Substanzen zu Beginn des Teilbandes a wird dem Leser das Auffinden bestimmter Daten und Substanzen erleichtern.

Dank gebührt in erster Linie den Autoren, sowie dem Verlag für die Herstellung und Veröffentlichung des Bandes. Wie alle Bände des Landolt-Börnstein ist auch dieser ohne finanzielle Unterstützung von anderen Stellen veröffentlicht worden.

Darmstadt, Herbst 1983

Die Herausgeber

Preface

Volume II/12 is the fourth supplement to vol. II/2, "Magnetic Properties of Coordination and Organometallic Transition Metal Compounds". It is based on the same principles and considers the publications on magnetic susceptibilities and electron spin resonance in 1973 and 1974 in direct subsequence to the data and literature of the first three supplements, volumes II/8, II/10, and II/11.

As in volumes II/2, II/8, II/10 and II/11, besides the compounds mentioned above, similar or related substances have been included additionally giving the reader the possibility of comparing the data, while some special groups of substances have been omitted: the information on garnets, perovskites, spinels and hexagonal ferrites is presented separately in volumes III/4a, b (literature up to 1969/70) and its supplements III/12a, b, c (literature 1970 to 1977, 1978, and 1979, respectively).

The data have been compiled again as completely as possible and are evaluated critically. The information available in the original literature contains both series of data serving the investigation of physical problems and single results used for the purpose of chemical analysis. Both kinds of data are considered here.

For technical reasons, volume II/12 has been divided: in the first subvolume, presented herewith, the magnetic susceptibilities are treated; the second subvolume, II/12b, which will soon follow, covers the electron spin resonance.

The detailed list of contents which precedes both parts and the extensive description of the arrangement of the substances on the first pages of subvolume a may help the user to locate individual substances and their data.

Thanks are primarily due to the authors, but also to the publishers for the preparation and publication of this volume. Like all volumes of Landolt-Börnstein, it is published without financial support from other sources.

Darmstadt, autumn 1983

The Editors

Supplement 4 to Volume 2
Ergänzungsband 4 zu Band 2

Magnetic Properties of Coordination and Organometallic
Transition Metal Compounds

Magnetische Eigenschaften der Koordinations- und
metallorganischen Verbindungen der Übergangselemente

Subvolume a Magnetic Susceptibilities
Teilband a Magnetische Suszeptibilitäten

E. König · G. König

Institut für Physikalische und Theoretische Chemie
Universität Erlangen-Nürnberg, D-8520 Erlangen, Germany

Survey*)

Introduction	1
Data	46
Titanium	Ti 46
Zirconium	Zr 56
Vanadium	V 56
Niobium	Nb 86
Tantalum	Ta 87
Chromium	Cr 88
Molybdenum	Mo 107
Wolfram	W (Tungsten) 120
Manganese	Mn 123
Technetium	Tc 156
Rhenium	Re 157
Iron	Fe 160
Ruthenium	Ru 223
Osmium	Os 225
Cobalt	Co 226
Rhodium	Rh 315
Iridium	Ir 318
Nickel	Ni 319
Palladium	Pd 429
Platinum	Pt 430
Copper	Cu 431
Silver	Ag 570
Diagrams	573
References	661

*) For detailed table of contents see the following pages.

Table of contents

Introduction	1
List of symbols	1
General remarks	3
Theoretical basis	3
Definitions and fundamental relations	3
Diamagnetism and diamagnetic corrections	5
Paramagnetic susceptibility of polycrystalline specimens	6
Paramagnetic anisotropy	7
Ligand field effects, high-spin and low-spin compounds and crossover situations	10
More detailed theory of magnetic susceptibilities and magnetism diagrams	11
Dimers and clusters, linear chain and planar magnetic systems	13
Long-range order: ferromagnetism, antiferromagnetism and ferrimagnetism	18
Arrangement of tables	20
Compounds listed, their designation and order	20
Presentation of experimental results	23
Selection and accuracy of data	23
Experimental methods	24
References	24
Literature coverage	24
Abbreviations	25
Selected diamagnetic ionic susceptibilities, Pascal constants, and one-electron spin-orbit coupling constants	28
Theoretical nomograms; calculated average magnetic moments as function of temperature, spin-orbit coupling, axial field splitting and orbital reduction	31
References for the introduction	41
Standard reference texts on magnetochemistry	41
General references to ligand field theory of magnetism	41
Additional references to the introduction	41
Tables of magnetic data on transition metal compounds	43
Reviews on magnetochemistry of coordination compounds published in 1973 and 1974	44
Selected references on theory and experimental methods in the magnetism of transition metal compounds (1973 and 1974)	44
Ligand field and MO theory of magnetism	44
Theory of intermolecular exchange interaction	44
Experimental methods in magnetism	45
References to crystal structure	45
 Magnetic susceptibility data	 46
Titanium Ti	46
Ti(0)	46
Ti(II)	46
Ti(III)	46
Simple compounds	46
With fluoride	46
With bromide	46
With cyanide	47
Coordination compounds with neutral and chelating ligands	47
With heterocyclic ligands	47
With amino ketones	48
With Schiff bases and related compounds	48
With acid amides and acid hydrazides	48
With urea and related compounds	48
With ligands containing sulfur	50
With ligands containing phosphorus	51
With phosphoric acids	51
With phosphonic acids	51

Ti(III) continued	
With ligands containing silicon	52
With ligands containing boron	52
Organometallic compounds	52
Ti(IV)	55
Coordination compounds with neutral and chelating ligands	55
With alcohols	55
With Schiff bases and related compounds	56
Zirkonium Zr	56
Zr(III)	56
Vanadium V	56
V(0)	56
V(II)	57
Simple compounds	57
Coordination compounds with neutral and chelating ligands	57
With amines	57
With heterocyclic ligands	58
With pyridine and derivatives	58
With pyridine	58
With alkyl pyridines	58
With quinoline and derivatives	59
With bipyridyl	59
With phenanthroline and derivatives	59
With other heterocyclic ligands	59
Organometallic compounds	59
V(III)	60
Simple compounds	60
With fluoride	60
With chloride	60
With carboxylates and dicarboxylates	60
With other simple anions	61
Coordination compounds with neutral and chelating ligands	61
With amines	61
With heterocyclic ligands	61
With bipyridyl	61
With phenanthroline	62
With Schiff bases and related compounds	62
With ligands containing sulfur	62
With ligands containing phosphorus	63
With phosphoric acids	63
With phosphonic acids	63
With ligands containing silicon	64
Organometallic compounds	64
V(IV)	64
Simple compounds	64
With oxygen	64
With fluoride, chloride, bromide	65
With carboxylates	65
With other simple anions	66
Coordination compounds with neutral and chelating ligands	66
With heterocyclic ligands	66
With pyridine	66
With bipyridyl	66
With quinoline and derivatives	66
With heterocyclic N-oxides	67
With quinoline N-oxides	67
With other heterocyclic ligands	67
With ethers	67
With ketones	67
With amino ketones	68
With Schiff bases and related compounds	68

V (IV) continued

From hydroxy arylaldehydes and aliphatic hydroxy monamines	68
From hydroxy arylaldehydes and aliphatic diamines	73
From hydroxy arylaldehydes and aromatic hydroxy monamines	73
From heteroaromatic aldehydes and monamines	77
From hydroxy aryl dialdehydes and aromatic hydroxy monamines	78
From hydroxy aryl aldehydes and amino acids	79
From aromatic aldehydes and hydrazines	80
From aromatic ketones and aliphatic diamines	81
From aliphatic diketones and hydrazines	82
With azo compounds	82
With oximes and nitroso compounds	82
With acid amides	82
With cyanides and isocyanides	82
With ligands containing sulfur	83
With sulfoxides	83
With thiols	83
With dithio carbamic acids	83
With thio carboxylic acids	83
With thiosemicarbazide and thiosemicarbazones	83
With ligands containing phosphorus	84
With phosphines	84
With phosphoric acids	84
With dithio phosphoric and dithio phosphinic acids	84
With phosphor amides	84
With ligands containing selenium	84
Organometallic compounds	85
V(V)	85
V (uncertain oxydation state)	85

Niobium Nb

Nb(II)	86
Nb(III)	86
Nb(IV)	86
Simple compounds	86
Coordination compounds with neutral and chelating ligands	87
Nb(V)	87

Tantalum Ta

Ta(V)	87
-------	----

Chromium Cr

Cr(0)	88
Cr(II)	88
Simple compounds	88
With fluoride	88
With chloride	88
With bromide	88
With sulfide	89
Coordination compounds with neutral and chelating ligands	89
Organometallic compounds	89
Cr(III)	90
Simple compounds	90
With fluoride	90
With chloride	90
With nitride and nitrate	90
With selenide and selenate	90
Coordination compounds with neutral and chelating ligands	91
With ammonia	91
With aliphatic and aromatic monamines	91
With aliphatic diamines	91
With heterocyclic ligands	95
With carboxylic acids	96

Cr(III) continued	
With aliphatic carboxylic acids	96
With ketones	98
With alicyclic ketones	98
With diketones	98
With amino ketones	98
With amino acids	98
With simple amino acids	98
With amino acids containing sulfur	99
With amine-N-polycarboxylic acids	99
With Schiff bases and related compounds	100
From hydroxy arylaldehydes and amines	100
From ketones and diamines	100
With oximes and nitroso compounds	101
With acid amides and acid hydrazides	101
With ligands containing sulfur	102
With sulfons, thiols and sulfonic acids	102
With heterocyclic thiones	102
With trithio carbonic acids	102
With dithio carbamic acids	102
With thio carboxylic acids	103
With ligands containing selenium	103
With ligands containing phosphorus	103
With phosphoric acids	103
With phosphonic acids and derivatives	104
With dithiophosphinic acids	104
With phosphor amides	105
With ligands containing silicon	105
Organometallic compounds	105
Cr(IV)	105
Cr(V)	106
Cr(VI)	106
Cr (uncertain oxydation state)	106
Molybdenum Mo	107
Mo(0)	107
Mo(II)	107
Mo(III)	107
Simple compounds	107
With chloride	107
With bromide	109
With iodide	110
With cyanide and cyanate	110
Coordination compounds with neutral and chelating ligands	110
With amines and diamines	110
With heterocyclic ligands	111
With acid amides and acid hydrazides	111
With ligands containing sulfur	112
Mo(IV)	112
Mo(V)	112
Simple compounds	112
With fluoride	112
With chloride	114
With bromide	115
With cyanide and thiocyanate	115
With other simple anions	117
Coordination compounds with neutral and chelating ligands	117
With hydrazine	117
With heterocyclic ligands	118
With amino acids	118
With ligands containing sulfur	118
With dithiocarbamates	118
With thiocarboxylic acids	119
With ligands containing phosphorus	119

Mo(VI)	119
Mo (uncertain oxydation state)	119

Wolfram W	120
W(0)	120
W(III)	120
W(IV)	120
W(V)	122
W (uncertain oxydation state)	123

Manganese Mn	123
Mn(-I)	123
Mn(0)	123
Mn(II)	124
Simple compounds	124
With oxygen	124
With fluoride	124
With chloride	124
With bromide	127
With carboxylates	127
With cyanide and cyanate	128
With other simple anions	128
Coordination compounds with neutral and chelating ligands	129
With hydrazines	129
With amines	129
With aliphatic amines	129
With aromatic amines	129
With heterocyclic ligands	130
With dipyrromethene and derivatives	130
With phthalocyanine and derivatives	130
With pyridine and derivatives	130
With 2,2-bipyridyl	131
With 4,4-bipyridyl	131
With phenanthroline and derivatives	131
With phenanthroline	131
With phenanthroline derivatives	133
With quinoline and derivatives	133
With isoquinoline	133
With heterocyclic N-oxides	133
With other N heterocyclic ligands	133
With pyrazole and derivatives	133
With imidazole and derivatives	134
With pyrazine and derivatives	135
With ketones	135
With diketones	135
With amino ketones	135
With amine-N-polycarboxylic acids	135
With Schiff bases and related compounds	136
From hydroxy arylaldehydes and aromatic monamines	136
From hydroxy arylaldehydes and aliphatic diamines	136
From heterocyclic aldehydes and aromatic diamines	136
From aromatic aldehydes and hydrazine	137
Cyclic Schiff bases from heterocyclic diketones and diamines	137
With oximes and nitroso compounds	137
With acid amides and acid hydrazides	137
With urea	137
With dimethyl urea	138
With diethyl urea	138
With other acid amides	138
With ligands containing sulfur	138
With sulfuric acids	138
With sulfinic acids	139
With thio carboxylic acids	139

Mn(II) continued	
With ligands containing phosphorus	139
With phosphine oxides	139
With phosphoric acids	139
With phosphonic acids	140
With phosphor amides	140
With ligands containing arsenic	140
Organometallic compounds	140
Mn(III)	141
Simple compounds	141
With fluoride	141
With chloride	141
With cyanide and cyanate	141
Coordination compounds with neutral and chelating ligands	142
With N heterocyclic ligands	142
With dipyrromethene and derivatives	142
With phthalocyanine	142
With porphyrins	142
With heterocyclic N-oxides	143
With ketones	143
With carboxylic acids	143
With Schiff bases and related compounds	143
From hydroxy arylaldehydes and aliphatic monamines	143
From hydroxy arylaldehydes and aromatic monamines	144
From hydroxy arylaldehydes and aliphatic diamines	145
From simple substituted hydroxy arylaldehydes and ethylenediamine	145
From sec-butyl hydroxy arylaldehydes and ethylenediamine	148
From hydroxy arylaldehydes and other aliphatic diamines	150
From hydroxy arylaldehydes and aromatic diamines	151
From hydroxy arylaldehydes and hydrazines	152
From ketones and diamines	152
With ligands containing sulfur	153
With ligands containing phosphorus	153
With ligands containing arsenic	153
Mn(IV)	153
Coordination compounds with neutral and chelating ligands	153
With heterocyclic ligands	153
With carboxylic acids	154
With Schiff bases and related compounds	154
With ligands containing sulfur	154
Mn(VI)	155
Mn(VII)	155
Mn (mixed oxydation state)	156
Technetium Tc	156
Tc(III)	156
Tc(IV)	156
Tc(V)	156
Tc(VI)	157
Tc (mixed oxydation state)	157
Rhenium Re	157
Re(I)	157
Re(II)	157
Simple compounds	157
Coordination compounds with neutral and chelating ligands	157
With heterocyclic ligands	157
With ligands containing phosphorus	158
Re(III)	158
Simple compounds	158
Coordination compounds with neutral and chelating ligands	158
Re(IV)	159
Simple compounds	159
Coordination compounds with neutral and chelating ligands	159

Re(V)	159
<i>Simple compounds</i>	159
<i>Coordination compounds with neutral and chelating ligands</i>	160
Re(VI).	160

Iron Fe

Fe(I)	160
Fe(II)	160
<i>Simple compounds</i>	160
With chloride	160
With bromide	161
With iodide	161
With sulfide and selenide	161
With other simple anions	162
With cyanide and cyanate	162
<i>Coordination compounds with neutral and chelating ligands</i>	163
With hydrazines	163
With N heterocyclic ligands	163
With dipyrromethene and derivatives	163
With porphyrins and related ligands	164
With tetraphenyl porphins	164
With other porphyrins	164
With pyridine	165
With 2,2'-bipyridyl	166
With 4,4'-bipyridyl	166
With phenanthroline and derivatives	166
With phenanthroline	166
With phenanthroline derivatives	167
With terpyridyl	169
With heterocyclic N-oxides	169
With other heterocyclic ligands	170
With pyrazoles and derivatives	170
With imidazole and derivatives	170
With benzimidazole and derivatives	171
With purine and derivatives	172
With oxadiazole and derivatives	172
With naphthyridine	172
With triazines	173
With diquinoline and derivatives	173
With aldehydes	173
With esters	174
With ketones	174
With alicyclic ketones	174
With heterocyclic ketones	175
With Schiff bases and related compounds	175
From hydroxy arylaldehydes and aromatic amines	175
From hydroxy arylaldehydes and aliphatic diamines	175
From hydroxy arylaldehydes and aromatic diamines	176
From hydroxy arylaldehydes and amino acids	176
From hydroxy arylaldehydes and carboxy arylamines	176
From heteroaromatic aldehydes and aliphatic amines	177
From heteroaromatic aldehydes and aromatic amines	179
From aromatic and heteroaromatic aldehydes and hydrazines	179
From diketones and monamines	181
With azo compounds	181
With oximes and nitroso compounds	181
With acid amides and acid hydrazides	182
With ligands containing sulfur	182
With thiols	182
With thiones	182
With aliphatic thiones	182
With heterocyclic thiones	183
With dithio carbonic acids	184
With dithiocarbamic acids	184

Fe(II) continued

With thio acid amides	185
With sulfates	186
With ligands containing phosphorus	186
With phosphines	186
With tetraphosphines	186
With phosphine oxides	187
With amino phosphines	187
With diphenylphosphino aliphatic monamines	187
With diethylphosphino heterocyclic amines	187
With phosphoric acids	187
With phosphonic acids	188
With dithiophosphinic acids	188
With ligands containing selenium	188
Organometallic compounds	188

Fe(III)

Simple compounds

With oxygen	188
With fluoride	188
With cyanide and thiocyanate	189
With sulfide and sulfate	189
With other simple anions	189

Coordination compounds with neutral and chelating ligands

With heterocyclic ligands	190
With dipyrromethene and derivatives	190
With porphyrins	190
With porphins	190
With porphyrins	191
With quinoline and derivatives	191
With 2,2'-bipyridyl	192
With 4,4'-bipyridyl	192
With terpyridyl	192
With phenanthroline and derivatives	192
With heterocyclic N-oxides	192
With other heterocyclic ligands	193
With benzimidazole and derivatives	193
With purine and derivatives	193
With carboxylic acids	193
With aliphatic carboxylic acids	193
With aromatic carboxylic acids	196
Trinuclear complexes with aliphatic carboxylic acids	199
Trinuclear complexes with aromatic carboxylic acids	200
With ketones	201
With monoketones	201
With diketones	201
With acetylacetone	201
With other diketones	202
With amino ketones	203
With amino acids	203
With amine-N-polycarboxylic acids	204
With Schiff bases and related compounds	204
From hydroxy arylaldehydes and aliphatic monamines	204
From hydroxy arylaldehydes and aromatic monamines	204
From hydroxy arylaldehydes and aliphatic diamines	204
From hydroxy arylaldehydes and aromatic diamines	205
From hydroxy arylaldehydes and aliphatic triamines	205
From monoketones and diamines	206
From diketones and diamines	206
With azo compounds	206
With oximes and nitroso compounds	207
With aldoximes	207
With ketoximes	207
With acid amides and acid hydrazides	207
With ligands containing sulfur	208

Fe(III) continued	
With thiols	208
With dithiolates	208
With maleonitrile dithiolate	208
With other dithiolates	209
With sulfides	209
With heterocyclic thiones	209
With dithiocarbamates	210
With aliphatic dithiocarbamates	210
With alicyclic and aromatic dithiocarbamates	210
With carbo thioic acids	211
With thio carboxylic acids	211
With thioethers	211
With dithiobiuret and derivatives	212
With thiosemicarbazides and thiosemicarbazones	212
With thiosemicarbazides	212
With thiosemicarbazones	212
With thio acid amides and thioacid hydrazides	216
With ligands containing selenium	217
With thio seleno carbamates	217
With selenosemicarbazides and selenosemicarbazones	217
With ligands containing phosphorus	217
With phosphoric acids	217
With phosphonic acids	217
With dithio phosphinic acids	218
With ligands containing silicon	218
Organometallic compounds	219
Fe(IV)	220
Coordination compounds with neutral and chelating ligands	220
With N heterocyclic ligands	220
With porphyrins and related ligands	220
With phthalocyanine and derivatives	220
With ligands containing sulfur	221
With thiols	221
With dithiolates	221
With dithiocarbamates	221
Fe (uncertain oxydation state)	221
Ruthenium Ru	223
Ru(III)	223
Coordination compounds with neutral and chelating ligands	223
With heterocyclic ligands	223
With carboxylic acids	223
With amino acids	224
With ligands containing sulfur	224
With sulfides	224
With dithiocarbamates	224
With ligands containing phosphorus	224
With ligands containing arsenic	225
Osmium Os	225
Os(III)	225
Os(IV)	225
Cobalt Co	226
Co(0)	226
Co(I)	226
Co(II)	226
Simple compounds	226
With oxygen	226
With chloride	227
With bromide	227

Co (II) continued

With sulfide and sulfate	227
With carboxylates	228
With cyanides	229
With cyanate and thiocyanate	229
With phosphates	230
With other simple anions	230
<i>Coordination compounds with neutral and chelating ligands</i>	231
With amines	231
With aliphatic hydroxy amines	231
With aromatic monamines	231
With aromatic diamines	232
With phenylene diamines	232
With diamino biphenyls	232
With other aromatic diamines	233
With dicyano amine	233
With hydrazine and derivatives	233
With alicyclic heteroring compounds	234
With piperidine and derivatives	234
With piperidine	234
With 1,2-dipiperidinoethane	234
With piperazine and derivatives	235
With morpholine and derivatives	235
With morpholine	235
With 1,2-dimorpholinoethane	235
With diaza cycloheptane	236
With diaza cyclooctane	236
With quinuclidinone and derivatives	236
With other alicyclic heteroring compounds	238
With spartein	238
With quinine	238
With heterocyclic ligands	238
With porphyrins	238
With phthalocyanine	239
With pyrroline and derivatives	239
With pyridine and derivatives	239
With halogeno pyridines	239
With alkyl pyridines	240
With amino pyridines and derivatives	240
With 2-(2-aminoethyl) pyridine	240
With tri(pyridyl) amines and derivatives	240
With pyridine carboxylic acids	241
With pyridine 2-carboxylic acids	241
With pyridine 3-carboxylic acids	242
With pyridine 4-carboxylic acids	242
With pyridine dicarboxylic acids	242
With quinoline and derivatives	243
With quinoline carboxylic acid and derivatives	243
With quinoxaline and derivatives	243
With 2,2'-bipyridyl	244
With 4,4'-bipyridyl	244
With phenanthroline and derivatives	244
With heterocyclic N-oxides	245
With 2,4,4,5,5-pentamethyl-1-pyrroline 1-oxide	245
With pyridine N-oxides and derivatives	245
With bipyridyl N-oxides and derivatives	245
With phenanthroline N-oxide	246
With other N-heterocyclic ligands	246
With pyrazole and derivatives	246
With imidazole and derivatives	246
With ethylimidazole	246
With propylimidazole	247
With pyridyl imidazoles	247
With other imidazole derivatives	247