

## Contents

PREFACE TO THE SERIES	iii
PREFACE TO VOLUME 23	v
CONTRIBUTORS	xiii
CONTENTS OF OTHER VOLUMES	xv
HANDBOOK ON TOXICITY OF INORGANIC COMPOUNDS	xxix
Chapter 1	
NICKEL IN THE NATURAL ENVIRONMENT	1
Robert W. Boyle and Heather A. Robinson	
1. General Chemistry and Geochemistry of Nickel	2
2. Nickel in the Lithosphere and in Nickel Deposits	5
3. Nickel in the Pedosphere	10
4. Nickel in the Hydrosphere	13
5. Nickel in the Atmosphere	17
6. Nickel in the Biosphere and Its Degradation Products	17
7. General Summary	25
References	25
Chapter 2	
NICKEL IN AQUATIC SYSTEMS	31
Pamela Stokes	
1. Introduction	32
2. Nickel as an Essential Element for Aquatic Biota	32
3. Nickel Toxicity	33
4. Partitioning and Chemical Forms of Nickel in Water	39
5. Bioaccumulation of Nickel by Aquatic Biota	40
6. Food Chain Transfer of Nickel	43
7. Conclusions and Recommendations	43
References	44

## Chapter 3

NICKEL AND PLANTS	47
Margaret E. Farago and Monica M. Cole	
1. Nickel—An Essential Element for Plants?	48
2. Nickel Toxicity	52
3. Nickel Uptake and Nickel Content of Plants: Background Levels	59
4. Nickel Uptake and Soil Parameters	60
5. Nickel Uptake and Pollution	63
6. Nickel Tolerance	67
7. Nickel-Accumulating Plants	70
8. Phytochemistry of Nickel-Accumulating Plants	77
9. Future Outlook	81
References	82

## Chapter 4

NICKEL METABOLISM IN MAN AND ANIMALS	91
Evert Nieboer, Rickey T. Tom, and W. (Bill) E. Sanford	
1. Introduction	92
2. Routes of Nickel Absorption	92
3. Distribution of Nickel	96
4. Nickel Transport and Cellular Uptake	99
5. Nickel Biochemistry	103
6. Routes of Elimination	107
7. Nickel as an Essential Element	109
8. Concluding Remarks and Summary	114
Abbreviations	115
References	116

## Chapter 5

NICKEL ION BINDING TO AMINO ACIDS AND PEPTIDES	123
R. Bruce Martin	
1. The Setting	124
2. Amino Acid Complexes	126
3. Citrate Complexes	142
4. Peptide Complexes	143
References	159

## Chapter 6

## NICKEL IN PROTEINS AND ENZYMES 165

Robert K. Andrews, Robert L. Blakeley, and Burt Zerner

1. Introduction	167
2. Nickel in Biology	168
3. Nickel-Binding Proteins	172
4. Enzymes and Metal Ions	179
5. Metal Ion Catalysis	186
6. Some Properties of Nickel Complexes	196
7. Nickel(II) Catalysis in Model Systems	216
8. Nickel(II)-Activated Enzymes	219
9. Binding Sites for Metal Ions	231
10. Nickel(III) Enzymes	243
11. Nickel(II) Metalloenzymes: Urease	256
12. Conclusion	263
References	263

## Chapter 7

## NICKEL-CONTAINING HYDROGENASES 285

José J. G. Moura, Isabel Moura, Miguel Teixeira,  
Antonio V. Xavier, Guy D. Fauque, and Jean LeGall

1. Introduction	286
2. Nickel Involvement in Hydrogenases	287
3. Spectroscopic Tools and Instrumental Probes: Isotopic Substitutions	287
4. Active Center Composition: Types of Hydrogenases	289
5. Cell Localization of Hydrogenases: Existence of Multiple Forms and Genetic Information	291
6. EPR and Mössbauer Studies: Nickel and [FeS] Centers	292
7. Midpoint Redox Potentials	301
8. Nickel Site Coordination	302
9. Discussion of a Mechanistic Framework for the Nickel-Containing Hydrogenases	303
10. Conclusion	309
11. Abstract	309
Note Added in Proof	310
References	311

## Chapter 8

## NICKEL ION BINDING TO NUCLEOSIDES AND NUCLEOTIDES 315

R. Bruce Martin

1. Binding to Bases and Nucleosides 316
2. Binding to Nucleotides 321
- References 328

## Chapter 9

INTERACTIONS BETWEEN NICKEL AND DNA: CONSIDERATIONS ABOUT  
THE ROLE OF NICKEL IN CARCINOGENESIS 331

E. L. Andronikashvili, V. G. Bregadze, and J. R. Monaselidze

1. Introduction 332
2. Nickel(II) Interaction with DNA 335
3. Nickel and Nucleoproteins 346
4. In Vivo Influence of Nickel(II) on the Thermal Properties  
of Chromatin Inside the Nuclei, and on Cells and Tissues  
of Normal and Tumorous Origin 348
5. Nickel(II) Incorporation in DNA and the Role of Nickel in  
Carcinogenesis 352
6. Conclusion 354
- References 356

## Chapter 10

## TOXICOLOGY OF NICKEL COMPOUNDS 359

Evert Nieboer, Franco E. Rossetto, and C. Rajeshwari Menon

1. Introduction 360
2. Human Exposures 361
3. Nickel Carbonyl Poisoning 363
4. Nickel Hypersensitivity 367
5. Nickel Carcinogenesis 373
6. Genetic Toxicology 379
7. Miscellaneous Health Effects 386
8. Concluding Remarks and Summary 390
- Abbreviations 392
- References 392

CONTENTS

xi

Chapter 11

ANALYSIS OF NICKEL IN BIOLOGICAL MATERIALS 403

Hans G. Seiler

1. General Aspects of Analyses of Nickel in Biological Materials 403
2. Choice of Implements and Chemicals 405
3. Specimen Collection; Sampling 407
4. Sample Preparation 413
5. Determination Methods 418
- Abbreviations 425
- References 426

AUTHOR INDEX 429

SUBJECT INDEX 463