THE CHEMISTRY OF THE ACTINIDE AND TRANSACTINIDE ELEMENTS

Joseph J. Katz

Glenn T. Seaborg

This work is dedicated to
Joseph J. Katz and Glenn T. Seaborg,
authors of the first and second editions of
The Chemistry of the Actinide Elements
and leaders in the field of actinide chemistry.

THE CHEMISTRY OF THE ACTINIDE AND TRANSACTINIDE ELEMENTS

THIRD EDITION

Volume 1

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Springer

Library of Congress Control Number: 2008922620

ISBN-10 1-4020-3555-1 (HB)
ISBN-10 1-4020-3598-5 (e-book)
ISBN-13 978-1-4020-3555-5 (HB)
ISBN-13 978-1-4020-3598-2 (e-book)

Published by Springer,
P.O. Box 17, 3300 AA Dordrecht, The Netherlands.

www.springer.com

Printed on acid-free paper

First published in 2006
Reprinted 2006
Reprinted with corrections in 2008

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PREFACE

The first edition of this work (*The Chemistry of the Actinide Elements* by J. J. Katz and G. T. Seaborg) was published in 1957, nearly a half century ago. Although the chemical properties of thorium and uranium had been studied for over a century, and those of actinium and protactinium for over fifty years, all of the chemical properties of neptunium and heavier elements as well as a great deal of uranium chemistry had been discovered since 1940. In fact, the concept that these elements were members of an "actinide" series was first enunciated in 1944. In this book of 500 pages the chemical properties of the first transuranium elements (neptunium, plutonium, and americium) were described in great detail but the last two actinide elements (nobelium and lawrencium) remained to be discovered. It is not an exaggeration to say that *The Chemistry of the Actinide Elements* expounded a relatively new branch of chemistry.

The second edition was published in 1986, by which time all of the actinide elements had been synthesized and chemically characterized, at least to some extent. At this time the chemistry of the actinide elements had reached maturity. The second edition filled two volumes, with a chapter for each of the elements (the elements beyond einsteinium were combined in one chapter) and systematic treatment of various aspects of the chemical and electronic properties of the actinide elements, ions, and compounds due to the filling of the 5f subshell. Six transactinide elements had been synthesized by 1986 but their experimentally determined chemical properties occupied only 1.5 pages of text in the second edition.

This edition was initiated by the editors of the second edition (J. J. Katz, G. T. Seaborg, and L. R. Morss) in 1997. They realized that the study of the chemical properties of the actinide elements had advanced to produce distinct subdisciplines of actinide chemistry, for example actinide coordination chemistry, actinide X-ray absorption spectroscopy, itinerancy in actinide intermetallics, organoactinide chemistry, and actinide environmental chemistry. These fields had sufficiently matured so that scientists could make more substantial contributions to predicting and controlling the fate of actinides in the laboratory, in technology, and in the environment. We now understand and are able to predict with some degree of confidence the chemical bonding and reactivity of actinides in actinide materials, in actual environmental matrices and in proposed nuclear waste repositories. Most of the unique properties of the actinides are caused by their accessible and partly filled 5f orbitals. In addition to advances with the actinides, there have been research groups at nuclear research centers in several countries that have dedicated themselves to carry out significant and systematic experimental studies on the transactinide elements for several decades. For these reasons the editors initiated the writing of a third edition, with the

enlarged title *The Chemistry of the Actinide and Transactinide Elements* that is both broader and deeper than the second edition.

The third edition follows the plan enunciated by the authors of the first edition: "This book is intended to provide a comprehensive and uniform treatment of the chemistry of the actinide [and transactinide] elements for both the nuclear technologist and the inorganic and physical chemist." To fulfill this plan consistent with the maturity of the field, the third edition is organized in three parts.

The first group of chapters follows the format of the first and second editions by beginning with chapters on individual elements or groups of elements that describe and interpret their chemical properties. A chapter on the chemical properties of the transactinide elements is included.

The second group, chapters 15-26, summarizes and correlates physical and chemical properties that are in general unique to the actinide elements, because most of these elements contain partially-filled shells of 5f electrons whether present as isolated atoms or ions, as metals, as compounds, or as ions in solution.

The third group of chapters (chapters 27-31) focuses on specialized topics that encompass contemporary fields related to actinide species in the environment, in the human body, and in storage or wastes. There are also two appendices that tabulate important nuclear properties of all actinide and transactinide isotopes.

Each chapter has been written to provide sufficient background for the substantial parts of the readership that are not specialists in actinide science, nuclear-science-related areas (nuclear physics, health physics, nuclear engineering), spectroscopy, or solid-state science (metallurgy, solid state physics). The editors hope that this work educates and informs those readers who are scientists and engineers that are unfamiliar with the field and wish to learn how to deal with actinides in their research or technology.

The editors are deeply indebted to the contributors of each chapter, all of whom agreed enthusiastically to write their chapters and all of whom did so as a labor of love as well as a long-term professional responsibility. We take special pleasure in thanking Dr. Emma Roberts, Senior Publishing Editor of Springer, who provided the resources to turn more than thirty manuscripts into this attractive and useful professional series of volumes. We also thank Roger Wayman and Aaliya Jetha of Springer and all the other professional staff at Springer and SPI Publisher Services who brought this work to completion.

The editors dedicate this work to Joseph J. Katz and Glenn T. Seaborg, the first authors of the first edition and second editions of *The Chemistry of the Actinide Elements.* They provided inspiration for the generations of scientists who followed them and they set high standards in their research. Dr. Katz guided and motivated the editors and authors of the third edition to produce a work that followed the model of the first and second editions and provided leadership as this edition was unfolding. Because of his insights and leadership as an inorganic, physical, and actinide chemist, we have asked Dr. Katz to be

listed on the title page as honorary editor, and he has agreed to accept this role. The editors also dedicate this work to the memory of Professor Seaborg, the co-discover of plutonium and many other actinide and transactinide elements, and pioneer in actinide chemistry. We note with sadness that he participated in planning this edition but passed away before any of the chapters had been written. We believe that he would have been pleased to see how productive has been the research of the authors and many other actinide and transactinide scientists who follow his leadership.

All of us who have participated in the writing, editing, and publishing *The Chemistry of the Actinide and Transactinide Elements* express our hope that this new edition will make a substantive contribution to research in actinide and transactinide science, and that it will be an appropriate source of factual information on these elements for teachers, researchers, and students and for those who have the responsibility for utilizing the actinide elements to serve humankind and to control and mitigate their environmental hazards.

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