# Treatise on Heavy-Ion Science

Volume 4
Extreme Nuclear States

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EDITED BY D. ALLAN BROMLEY

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Volume 1: Elastic and Quasi-Elastic Phenomena

Volume 2: Fusion and Quasi-Fusion Phenomena

Volume 3: Compound System Phenomena

Volume 4: Extreme Nuclear States

Volume 5: High-Energy Atomic Physics

Volume 6: Astrophysics, Chemistry, and Condensed Matter

Volume 7: Instrumentation and Techniques

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## Volume 4
## Extreme Nuclear States

EDITED BY

D. ALLAN BROMLEY
*Henry Ford II Professor of Physics*
*Yale University*
*New Haven, Connecticut*

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For Pat, Lynn, and David

# Preface to Treatise on Heavy-Ion Science

After a long gestation period, heavy-ion physics and chemistry is now, worldwide, the most rapidly growing area of nuclear science, and the concepts, techniques, and instrumentation of this heavy-ion work are finding ever-widening application in other areas of science and technology. Although there remain broad regions at higher energies, with heavier projectiles, and at higher excitations and angular momenta where heavy ions still provide gateways into the totally unknown, intensive studies over the past two decades have provided a sound framework of understanding of many of the salient features of interactions induced by these new heavier projectiles and a basis for coherent planning of future studies.

It thus seemed appropriate, at this point in the history of the field, to pull together in one place and in as coherent a fashion as possible, an overview of what has been accomplished and some enlightened speculation about where we go next. It is my hope that these volumes will provide a definitive reference for those working in this and neighboring fields—both students and professional scientists; beyond that I would also hope that they will make accessible to a much wider audience in other sciences and technologies some of the richness of heavy-ion research, and perhaps help to stimulate the transfer of techniques and concepts that I have already mentioned.

I have been singularly fortunate in planning these volumes in being able to persuade internationally recognized authorities to write in their areas of special expertise and interest, and also fortunate that I have not had to restrict them to any artificial or externally imposed procrustean restrictions on the scope or length of their chapters. I have asked each author to include sufficient background to make the chapter accessible to students and to the nonspecialist, to provide a broad selection of illustrations, and to feel free to extrapolate and to speculate about future directions.

In inviting contributions to these volumes I have made arbitrary decisions concerning both topics and contributors, and I make no claim to completeness. Indeed, a few chapters that I would have liked to include do not appear because of illness or other reasons which prevented their authors from completing them.

I should like to take this opportunity to thank all the authors represented for taking time in already full schedules to share with a wider audience their special experience and expertise in heavy-ion science. As was inevitable from the outset in a multiple-author venture of this scope—with over 65 different authors—my original scheduling and deadlines proved unrealistic. To all those authors who responded to them and produced manuscripts on or before the original deadline—in many cases, I am aware, at substantial personal cost—my most sincere thanks and appreciation. To them, too, however, go my apologies for the delay in bringing their work into print. I have delayed publication for over a year so that I might include a number of very important chapters without which the work would have been obviously incomplete.

Volumes 1–4 of the *Treatise on Heavy-Ion Science* are devoted to aspects of heavy-ion nuclear science, beginning with an overview of the historical development of the science and some of its simpler interactions—elastic and quasi-elastic, fusion and quasi-fusion phenomena —and moving from them to compound system phenomena and to much more complex and less well understood phenomena involving very heavy nuclear species and very high energies. Volume 5 is devoted to high-energy atomic physics, an entirely new field of science first made accessible by the availability of a broad range of heavy-ion beams, and one still very much in its infancy. Volume 6 considers the impact of heavy-ion studies on other sciences including astrophysics, chemistry, surface physics, condensed matter physics, materials science, and heavy-ion-induced fusion power. Volume 7, the concluding volume of this treatise, is devoted to some of the instrumentation peculiar to heavy-ion science and its applications.

Special thanks go to Ellis Rosenberg and Bennett K. Ragnauth of Plenum Press with whom it has been a pleasure to work on these volumes, and to Mary Anne Schulz for all her help in producing them. And I would also acknowledge my indebtedness to the Alexander von Humboldt Stiftung for a Humboldt Award that I was privileged to hold during part of the time these volumes were in preparation.

New Haven, Connecticut D. Allan Bromley

# Contributors to Volume 4

**Georgy N. Flerov,** Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, Head Post Office, P.O. Box 79, 101000 Moscow, USSR

**Erwin M. Friedlander,** Nuclear Science Division, Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720

**Walter Greiner,** Institut für Theoretische Physik der Universität Frankfurt am Main, Robert-Mayer-Strasse 8-10, D-6000 Frankfurt am Main, West Germany

**Harry H. Heckman,** Nuclear Science Division, Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720

**Yuri A. Lazarev,** Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, Head Post Office, P.O. Box 79, 101000 Moscow, USSR

**Walter D. Loveland,** Radiation Center, Oregon State University, Corvallis, Oregon 97331

**Joachim A. Maruhn,** Institut für Theoretische Physik der Universität Frankfurt am Main, Robert-Mayer-Strasse 8-10, D-6000 Frankfurt am Main, West Germany

**Yuri Ts. Oganessian,** Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, Head Post Office, P.O. Box 79, 101000 Moscow, USSR

**Glenn T. Seaborg,** Nuclear Science Division, Lawrence Berkeley Laboratory, Berkeley, California 94720

**Gurgen M. Ter-Akopian,** Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, Head Post Office, P.O. Box 79, 101000 Moscow, USSR

# Preface to Volume 4

Volume 4 completes the treatment of specifically nuclear topics in this treatise and is devoted to nuclear matter under extreme conditions. Oganessian and Lazarev review the large body of work done in recent years, much of it in the Soviet Union, on the role of heavy ions in inducing nuclear fission and in probing its detailed mechanisms. Seaborg and Loveland provide a definitive study of our search for transuranic species and their production, ranging up to $Z = 108$, in heavy-ion interactions. Since the same shell models that reproduce the structure of the transuranics and the excited quantum states of lighter nuclei in the lead region can be extrapolated to predict at least quasi-stable supertransuranic species having $Z = 114$, 126, 164, etc. extensive effort, in several countries, has been devoted to the search for such species both in nature and among heavy-ion reaction products; Flerov and Ter-Akopian review all this work, much of which has been accomplished in their own laboratories. Finally, we turn to one of the truly open frontiers—that of higher energy. As contrasted to elementary particle physics, where the goal is that of delivering ever-increasing energy to ever-decreasing volumes in the hope of materializing new entities, in heavy-ion physics at high energies, the goal is that of delivering ever-increasing energy to relatively large volumes containing many nucleons, mesons, quarks and gluons so that entirely new forms of collective behaviour and, indeed, new forms of matter become possible. Facilities are only now becoming available that have adequate energy and range of beam species to permit studies on these phenomena and on the equation of state for nuclear matter. Friedlander and Heckman review the present experimental situation while Maruhn and Greiner address current understanding of present results and make predictions for the future.

New Haven, Connecticut — D. Allan Bromley

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