Preface

This book provides an introduction to nuclear physics. Research in nuclear physics covers a wide variety of subjects, and one can list many key words: nuclear structure and reactions of stable and unstable nuclei, fission and decay of a nucleus, extreme states such as the limits of existence and high-spin states, properties at high temperature and high density, hypernuclei, neutron stars, and nucleosynthesis, among others. All of these are the subjects of nuclear physics. In addition to these rather static properties, nuclear reactions such as heavy-ion collisions introduce new aspects of research, i.e., dynamical properties of nuclei or reaction mechanisms, such as heavy-ion fusion reactions, dissipation phenomena and liquid–gas phase transition. Many of these phenomena can be understood from the point of view that a nucleus is a quantum many-body system of nucleons stabilized by nuclear force. On the other hand, phenomena at higher energies, driven by, e.g., high-energy heavy-ion collisions, require a different approach: the approach based on the quantum chromodynamics (QCD). The study of quark–gluon plasma and of the QCD phase diagram is representative and forms a large stream of current nuclear physics.

In this book, we largely restrict our subjects and describe basic features of nuclear structure and of nuclear decays. β-decay and most excitation motions are left to other books. Also, nuclear reactions and current subjects such as physics of unstable nuclei, hypernuclei, and nuclear physics based on QCD are untouched except for occasional very brief references. Even with these limitations, we could only briefly mention recent developments. However, we have tried to convey part of them through columns on the QCD phase diagram of nuclear matter, superheavy elements, superdeformed states, and overview of the synthesis of elements. We hope that together with the main text they help readers to grasp our current knowledge of the nucleus and some recent research trends in nuclear physics. By restricting the subjects, our aim was to contain many experimental data of basic nuclear properties or suitable illustrations and explain the main structural features of nuclei in some detail. This will be useful because most of the phenomena listed in the first paragraph, but omitted from the book, are intimately related to those basic properties. We also have attempted to explain how the nuclear model has

developed from the original phenomenological level of a shell model to the modern understanding based on a many-body theory such as the Hartree–Fock calculations. We also have described nuclear force, the basis of nuclear physics, in some detail. We sometimes introduce semi-classical approximation to the original quantum mechanical formalism. We hope that it helps the readers to intuitively grasp the underlying physics of complicated nuclear phenomena.

In writing the book our intention was to create not only a good introduction to nuclear physics, but also a good reference book for physicists to learn the application of quantum mechanics and mathematics. Toward that aim, in addition to describing the basic phenomena of a nucleus, we attempted to convey how the basic subjects of modern physics such as quantum mechanics, statistical physics, mathematics for physics, e.g., complex integrals, are used to describe or interpret various phenomena of nucleus. We also considered the standard level of knowledge of junior and senior students, and gave a detailed description to enable them to derive each equation. Finally, we added the appendix to prove a number of important formulae in the main text and to show some fundamental formulae.

The contents of the book are based on the lectures that one of the authors, N.T., has delivered at Tohoku University, Sendai, Japan, for a long time to junior and senior students in the undergraduate physics course and also to beginning graduate students. We have included as sidebars some additional material that was presented in the class in order to keep the atmosphere of the lecture. Many textbooks and original papers and figures therein have helped in preparing the lectures and this book. Several of the figures are taken from them. Using this opportunity, we wish to thank the authors. The papers cited at various places are not at all complete. Moreover, it does not mean that they are necessarily the representative papers on each citation. Nevertheless, we hope that they can help readers to do further study. This book is an English translation of the Japanese edition, which one of the authors, N.T., published in 2013. The appendix contains the errata to the original Japanese edition.

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