Preface

Nuclear chemistry and low-energy nuclear physics have developed enormously since the time I was first introduced to the subjects formally by Charles D. Coryell. They were absolutely fascinating then and they remain so to this day. These areas have not only contributed greatly to our understanding of the nature of matter and the universe but they have had profound effects on almost all fields of science and technology and on many areas in the humanities as well.

I have taught upper division and graduate courses in low-energy nuclear physics for applications for many years. The students with whom I have had the pleasure of interacting have come from almost all areas of engineering, as well as from chemistry, physics and the geosciences. For the most part, these students have not had the extensive training in mathematics and physics found in most physics curricula and the majority of them have had but a fleeting introduction to quantum mechanics. Most have been interested in applications of nuclear physics and the interaction of radiation with matter but some have been keenly interested in nuclear physics and chemistry research.

The present text is an outgrowth of the lecture notes that I have developed over the years. It treats those aspects of low-energy nuclear physics that appear to me of greatest importance to applications and nuclear chemistry. As such, it is quite limited in its scope. It does not deal at all with many current research areas and it is almost devoid of reference to particle physics. It treats only, in some detail, the fundamentals of nuclear structure, radioactive decay and low-energy nuclear reactions, and provides an introduction to the interaction of ionizing radiation with matter.

The approach taken here is centered in the use of simple limiting models that emphasize the fundamental physics of the different topics considered. This approach is taken for a number of reasons. First and foremost, it is my belief that the simplest of models allow the student to grasp the central ideas of the physics involved in different phenomena without struggling simultaneously with the mathematical complexities needed for more sophisticated treatments. Second, it provides the student with a means of correlating information that is commonly treated either empirically or with reference to results of theoretical calculations that are too sophisticated to be presented and for which many students have no basis for interpreting physically. The use of simple models clearly has serious limita-

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tions. We are not treating the physics of a problem in its entirety and thus all of the nuances of theory will not be understood and the agreement we can expect with experimental data will be limited. Those parameters that are defined solely by conservation laws will be given "exactly" and we endeavor to provide the background for these in as simple and understandable a form as possible.

For most of the models and theory discussed here, a solid background in lower division mathematics, physics and chemistry will prove sufficient. However, it is my opinion that it is impossible to treat low-energy nuclear physics in a reasonable manner without resort to the fundamentals of quantum mechanics, and for that purpose a summary of the necessary "facts" from quantum theory is presented with a discussion that I hope provides some insight into their meaning and the physical ramifications that stem from them.

The text is written for students at the advanced undergraduate and beginning graduate level. I have attempted to provide all of the essential mathematical details in the text so that derivations can be followed with relative ease. I have tried to keep the admonition "it can be shown that" to a minimum. It appears most often in relation to the properties of some mathematical functions and differential equations. I am not a great fan of directing students to an appendix for a derivation or more detailed discussion of a topic. Almost all of what is needed is found within the text along with, I hope, sufficient discussion to make the physical relevance of the mathematics clear. Finally, while it is efficient and has much pedagogical value, I also am not a fan of collecting all of the fundamental problems in quantum mechanics in an introductory chapter to be referred to as needed later in the text. Rather, I have incorporated many of the models in those sections where it makes most sense to the topic under study. I have also included discussions of some topics in classical mechanics that are treated in detail in upper division physics courses, but which will not have been part of the curricula of many students.

The text has been written to provide a solid working foundation for those students who have had little exposure to things quantized and nuclear. I have tried to make it approachable for both beginners and more advanced students. The first five chapters are designed to provide such students with sufficient information so that they can do some useful things without the need for a detailed introduction to the more theoretical aspects considered in the remainder of the text. Most of the energetics and phenomenology of radioactive decay and nuclear reactions are covered here, as well as an introduction to statistical considerations. More advanced students might only wish to go through this material lightly to refresh some of their understanding and to become familiar with the notations and styles found in the remainder of the text. In the remaining chapters I have tried to separate general discussions and simple physical considerations from the more formal developments that might not be of interest in the first course of study.

The majority of what is presented here is "classical" and has been treated previously in many excellent texts. Unfortunately, almost all of these are no longer in print. I have learned a great deal from them over the years and I am greatly indebted to the authors who took the time to produce them. At many points, those

familiar with the wonderful texts by Evans, Marmier and Sheldon and von Buttlar may see their influence more or less strongly.

This book owes much to many people. There have been about two hundred and fifty captive students who have used various drafts of the text in their course work. Their comments and criticisms have provided the type of input needed to make the text as open and "friendly" as I can make it. I am indebted to Dr. Kexing Jing for a first and expert reading of the text. Brett Isselhardt and Bethany Lyles helped prepare the solutions to many problems and provided editorial assistance and much advice on issues with the text.

I am forever indebted to Brian Quiter who suffered through my lectures, carefully read the manuscript, provided continuous and expert comments on various topics and, of greatest importance, provided insight into what makes a text useful to students. sgp

Berkeley, July 2007 *Stanley G. Prussin*