INTRODUCTION TO NANOSCIENCE

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Preface

Nanoscience is not physics, chemistry, engineering, or biology. It is all of them, and the first motivation for this text is to present an integrated description. A second motivation for this book lies with the *complexity* of nanostructures, an issue that is not widely addressed. Richard Feynman described the remarkable consequences of scale and quantum effects in his visionary essay "There's Plenty of Room at the Bottom" and I think enough of it to have purchased the rights to reproduce it here (as Appendix B). But nanoscale objects, where hundreds, thousands, or hundreds of thousands of atoms make up systems, are complex enough to show what is called "emergent behavior": Quite new phenomena arise from rare configurations of the system. We will encounter this in the Kramers theory of reactions in Chapter 3, the Marcus theory of electron transfer in Chapter 8, and several times again in the final chapter on Nanobiology.

I teach the class on which this book is based to upper division undergraduates and beginning graduate students, and do not impose prerequisites for enrollment. I do this precisely because of the integrative nature of the material. I would like biologists to be able to get the gist of quantum mechanics and statistical mechanics. To this end, much of the material is conceptual, and conceptual questions have been included at the end of Chapter 2 (quantum mechanics) and Chapter 3 (statistical mechanics). It is possible to teach to a broad audience: a social sciences undergraduate (from the Center for Nanotechnology in Society at Arizona State University) has scored better on the conceptual quantum test than some physics graduate students!

The class does not have to be taught this way and much of the introductory material may be skipped in the appropriate settings. But physics majors will want to review the material on reaction kinetics and chemical equilibria. Some of the material on Brownian motion may not have been covered in the undergraduate curriculum. The chemical aspects of molecular electronics (Chapter 8) will probably be completely new too. Chemistry majors may want to review aspects of quantum mechanics, and the basics of statistical mechanics and fluctuations. The use of a partition function to justify what is normally done on the basis of mass action will be new to most chemistry students. The properties of electrons in periodic solids (Chapter 7) are not part of the regular chemistry curriculum either.

The mathematics has been kept to a minimum. Introductory calculus and some knowledge of linear algebra is a sufficient background for the student who wants to follow all of the mathematical detail presented in the text and its appendices. Bibliographies and references to the primary research literature at the end of every chapter also make this a suitable starting point for research in nanoscience. One last goal was to make this the "handbook" containing the stuff that I want the students in my lab to know, and I hope I have succeeded.

Solutions to most of the problems are given in Appendix M. They include detailed derivations where needed for support of the main text. A CD contains Powerpoint presentations for the lectures, as well as color figures and movies.

A book produced to a deadline, its production taking second place to all the other demands of an academic job, is bound to contain mistakes. They are far fewer in number because of the critical input of many of my colleagues and students. Mark Ratner read most of the first draft, providing valuable comments. I received valuable feedback from Nongjian Tao, Timothy Newman, Otto Sankey, John Spence, Larry Nagahara, Peiming Zhang, and Ralph Chamberlin. Students in my class helped me refine the problems at the end of each chapter and caught many errors in this version. They include Ashley Kibel, Eric Alonas, Shreya Bhattacharya, Kevin Brown, Jared Burdick, Di Cao, Shuai Chang, Eric Dailey, Shaoyin Guo, Kaushik Gurunathan, Billie Harvey, Shuao Huang, Deepthi Jampala, Parminder Kaur, Steven Klein, Lisha Lin, Hao Liu, Dan and Alise Martin, Chelsea Mcintosh, Douglas Moorhead, Jeff Moran, Pei Pang, Peter Pelletier, Suman Ranjit, Kamil Salloum, Dan Shea, Nathaniel Sylvain, Matthijs Smith, Jill Stock, Tim Lomb and Nick Teodori. Hao Liu also created the cover art. Hosam Yousif checked the problems and produced clean solutions for Chapters 1 through 5. I am grateful to Maggie Black for tracking down permissions and taking care of copyright issues. Health issues did not get in the way of this project thanks to the diligent care of Dr. Alan Wachter M.D. Finally, the debt I owe to my remarkable wife, Christine, is enormous. She is constantly supportive, loving, and kind.

Tempe, AZ, 2008

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