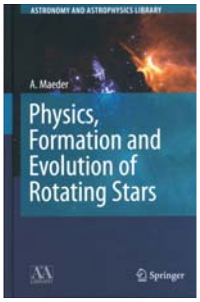

treats stellar rotation, but weaves it into the broader tapestry of stellar structure. There are already many books on the physics of stars, but as Maeder notes in his preface, they too often treat rotation as a minor side effect. He has sought to remedy that oversight with a comprehensive work for graduate students and researchers.

Maeder's book is substantial and technical, as would be expected from a prolific theorist who has devoted decades to his subject—he authored or coauthored some 70 of the 640 references cited in the back. The book covers a broad range of topics associated with rotation and contains something to pique the interest of just about any theoretically inclined reader. Magnetic dynamos, meridional circulation, rotational instabilities—all those topics and more are included. The book also contains numerous high-quality figures that illustrate physical arguments and display computational results.

Yet the work as a whole is less than the sum of its parts. Ironically, given its title and the author's explicit goal of focusing on stellar rotation, the book is too diffuse. Of the 29 chapters, 14 are designated as basic treatments, best suited for an introductory course. But 11 of those do not mention stellar rotation at all; instead, they address general aspects of structure and evolution. Only at the ends of the other three chapters is stellar rotation mentioned. Anyone using those "introductory" chapters as the basis for a course would find rotation discussed in a strictly tangential manner—exactly the problem Maeder sought to remedy.

Maeder's expertise as a theorist is evident, and many theories discussed in the book are fascinating in themselves. After all, there is a reason why Bernhard Riemann, Henri Poincaré, and numerous others have visited the realm of rotating, self-gravitating bodies. But anyone traversing the dense forest of derivations and plots in Maeder's book may easily lose sight of their purpose, which is to explain real objects in space.

That disconnect between theory and reality is evident in part 5 of the book, which discusses early stellar evolution. For example, figure 20.2 (page 517) shows theoretical evolutionary tracks for pre-main-sequence stars whose masses range from 0.8 to 60 times the solar value $M_\odot$. Although those tracks embody some interesting physics, no one has ever observed a 60-$M_\odot$ pre-main-sequence star. The most massive known ones, those of the Herbig Be class, only reach about 10 $M_\odot$. The reason is that more-massive objects contract so fast that they ignite their hydrogen and thereby join the main sequence while still accumulating material from surrounding interstellar gas.

The book is strongest when it deals exclusively with rotational issues. Maeder's inclusion of key results from helioseismology in his chapter on nonradial pulsations is especially welcome; stellar astronomers need more such exposure to important findings from the solar community. However, even the rotational sections can be tough going—the point of many of them seems to be to develop equations rather than provide physical insight. The work's awkward English is an additional impediment. Readers will have to fend for themselves when encountering such descriptors as "the momentum of force *S* by volume unity" (page 339).

With its wealth of information, Maeder's book will be useful for those seriously interested in the internal dynamics of stars. Jean-Louis Tassoul's classic *Theory of Rotating Stars* (Princeton U. Press, 1979) is less ambitious in scope and, of course, lacks recent developments. However, it presents each physical idea in a more logically transparent and methodical fashion. For those seeking a unified introductory graduate text, I recommend the second edition of *Stellar Interiors: Physical Principles, Structure, and Evolution* (Springer, 2004), by Carl Hansen, Steven Kawaler, and Virginia Trimble.

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Geochemical Kinetics

Youxue Zhang
Princeton U. Press, Princeton, NJ, 2008. $70.00 (631 pp.).
ISBN 978-0-691-12432-2

Geochemical kinetics is the study of the "when" and the "how fast" of geochemical processes. Some reactions naturally attain thermodynamic equilibrium. But for others, the minerals, glasses, and fluids involved react too slowly with each other to reach equilibrium over the broad temperature and pressure ranges found in the interiors and at the surfaces of rocky planetary bodies. Consequently, it is essential that geoscientists understand the complexities of geochemical kinetics if they are to predict how natural materials will react under a given set of conditions, and infer from preserved attributes of natural materials how long ago, how fast, and for how long past geochemical processes occurred.

Geochemical Kinetics by Youxue Zhang is intended as a graduate- and advanced-undergraduate-level textbook, but it will likely be used for other applications as well. No advanced book on geochemical kinetics yet produced, including this one, has been comprehensive. Nevertheless, the author covers an impressive range of subjects. The book's thorough coverage of rate processes in igneous and metamorphic petrology, volcanology, geochronology, and thermochronology will be especially appreciated by readers with strong backgrounds in geology, chemistry, physics, and mathematics.

A strength of the book is its thorough integration of rate equations from radioactive decay and radiogenic isotope geochemistry with those of geochemical reaction kinetics. Since both geochemical kinetics and radioisotope geochronology are about ages, durations, and rates in natural systems, such an integrated approach is highly appropriate and will hopefully be welcomed by readers. Another positive feature is the book's thorough treatment of inverse methods of applying chemical kinetic concepts to infer the ages, rates, and durations of geological phenomena.

The author is forthright and explicit on what will be covered in detail and what will not. For instance, Zhang barely mentions important concepts, such as transition state theory, and broad topics—aqueous low-temperature geochemistry, for example—that are emphasized in earlier geochemical kinetics textbooks and treatises. So that readers can pursue connections for themselves, Zhang, to his credit, directs readers to a number of major texts of similar rigor; among them are Robert Berner's *Early Diagenesis: A Theoretical Approach* (Princeton U. Press, 1980) and Bernard Boudreau's *Diagenetic Models and Their Implementation: Modelling Transport and Reactions in Aquatic Sediments* (Springer, 1997). The citations to books that address low-temperature systems are particularly helpful because, as the author points out, kinetics considerations are most important for such systems.

The book is easy to read, which is especially praiseworthy given its extensive and detailed mathematical treatments. Few typographical errors appear in the text and the equations, and only minor grammatical idiosyncrasies escaped the otherwise thorough and effective editing and proofing. For some topics, literature citations are comprehensive and self-contained; in other areas, the text relies on a few well-chosen classic treatises. However, at times, ease of reading comes at the cost of limited referencing, and some useful statements—related to cation diffusivity, the Ostwald Step Rule, and radiocarbon dating, for example—are unsupported by citations.

As a textbook, *Geochemical Kinetics* is integrative, computationally rigorous, and pedagogically masterful. It is also practical, with many detailed calculations and worked-out examples. Chapters and sections can stand alone, so readers can use them as foundations for investigating specific concepts and applications without having to jump back and forth within the book. The author warns readers that the approach can make for repetitive reading, but in my opinion, Zhang's arrangement adds to the value of the book; it is a resource that students can easily navigate even after they have left a course that used it. The standalone units also make the book useful outside the classroom as a reference manual of quantitative approaches and solutions.

Several special strengths have resulted from the text's origin as classroom lecture notes. First, the student-friendly text includes explicit reminders to keep in mind the "little things" that are second nature to experienced geochemical kineticists but common stumbling blocks to novices. Second, the text does an uncommonly good job of being realistic about what it takes to apply the more advanced, complex approaches—what can be done, what cannot be done, what is required, and what is practical. For example, there are sections that present equations for the relationship between diffusivity and viscosity and equations for dealing with diffusion in complex multicomponent systems. Those sections not only clearly characterize the equations and solution methods for which the corresponding theory is well developed but also evaluate each equation and method in terms of how conveniently and rigorously it can be applied to real situations. Finally, the book clearly identifies some large and fundamental gaps in current understanding that deserve future research effort. For example, many nucleation theories exist, but few have quantitative predictive value; what they lack is clearly highlighted in Zhang's text. All in all, *Geochemical Kinetics* is an excellent book, at home both in the classroom and on the practitioner's shelf.

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