Book Review

DIFFUSION IN MINERALS AND MELTS, Youxue Zhang and Daniele J. Cherniak, Editors. (2010) Reviews in Mineralogy and Geochemistry, vol. 72, 1038 pages. ISBN: 978-0-939950-86-7. $50.00 (U.S.) (25% discount for MSA, CMS, and GS members) (http://www.minsocam.org/MSA/Rim/).

The measurement, understanding, and application of diffusion-related processes have made great advances in recent years following a period that started in the 1950s and 1960s when systematic efforts were begun to understand the role of diffusion in geosystems evolution. Improvements in analytical and experimental tools within the past quarter century, and especially in the last decade, have made a large body of diffusion data available for minerals, glasses, and melts of varying composition under various pressure, temperature, and volatile fugacity (e.g., f_{O_2}, f_{H_2O}) conditions. Diffusion in various kinds of discontinuities (e.g., grain boundaries and other dislocations) in the crystalline state has also been increasingly studied; grain boundary diffusion can be thousands to millions of time faster than volume diffusion, typically. The ubiquitous presence of concentration gradients observed in geochemical and petrological systems may be studied to elucidate the system history, path, and evolution, a primary goal in modern geoscience research. Aside from the classical closure temperature problem, thermochronology, and the use of diffusion data to obtain time scales, diffusion coefficients are now used to understand various processes ranging from chemical weathering to silicate-oxide-metal reactions at the core-mantle boundary, a broad scope by any measure. In RIMG vol. 72, *Diffusion in Minerals and Melts*, the goals stated by the editors (Y. Zhang and D. Cherniak) are to "compile, compare, evaluate and assess diffusion data from the literature for all elements in minerals and natural melts including glasses." The volume is especially directed toward helping students and practitioners understand the basics of diffusion theory and its applications to geological (sensu lato) problems.

After a brief introductory chapter, the volume begins in earnest with a chapter that provides the essential phenomenological and theoretical background (Y. Zhang) as well as an additional two chapters offering an exposition of both non-traditional (Watson and Dohen) and analytical (D. Cherniak and four others) experimental methods useful in diffusion studies. These three chapters provide the intellectual "infrastructure" for most of the rest of the volume. The following group of six chapters provide a comprehensive review of diffusion in silicate liquids including the volatile and volumetric important components H, C, and O (Y. Zhang and H. Ni), noble gas diffusion (H. Behrens), the theory of self-diffusion (C. Lesher), and a final chapter (Y. Zhang, H. Ni, and Y. Chen) covering diffusion data of many elements in melts spanning the basalt to rhyolite compositional range, but excluding multicomponent diffusion matrix data, a topic covered in the following chapter by Y. Liang. These chapters are packed with diagrams and theoretically inspired phenomenological expressions that nicely summarize both what is known and what is unknown regarding diffusion in molten silicates. Taken as a collective whole, these chapters are the go-to place for anyone interested in diffusion in geoliquids. The following 11 chapters review diffusion in minerals focusing on elements and phases important in thermochronology, the mantle transition zone, the *P-T-t* history of metamorphic rocks, and the role of defects. Oxygen and hydrogen volume diffusion in silicates, oxides, carbonates, and phosphates is reviewed, graphically portrayed, and presented in tables (J. Farver). Chapters follow this on the diffusion of noble gases (Ar and He) in minerals, especially relevant for thermochronometry (Baxter), cation diffusion in garnet with application to *P-T-t* trajectories (Ganguly), and diffusion of Fe and Mg in olivine, wadsleyite, and ringwoodite, including the role of defects of importance in planetary mantles and shocked meteorites (Chakraborty). The six following chapters (Cherniak, Dimanov, Van Orman, Crispin) then cover diffusion of various atoms within silicate, oxide, carbonate, and sulfide phases making up the crust and mantle. Tables and analytic expressions based on rate theory summarize what is known about the temperature, pressure, and compositional effects of cation and oxygen diffusion. The volume closes out with four chapters including an overview of the diffusion experimental database (Brady and Cherniak), an exceptionally well written and comprehensive review of grain boundary diffusion in polycrystalline materials (R. Dohmen, R. Milke), the methods, theory, and examples of the computation of diffusion by molecular dynamics simulation (N. de Koker, L. Stixrude), and a final chapter that addresses the application of diffusion data to high-temperature geosystems (T. Mueller, B. Watson, M. Harrison).

In this reviewer's opinion, the aforementioned aims and goals of the volume have been admirably met; this volume should be on the shelf of any geochronologist, geochemist, petrologist, or mineralogist involved in almost any aspect of diffusive matter transport in geological systems. The critical compilation of data presented in many chapters itself is worth the price of the volume. A student or researcher who worked through this book would come away with a state-of-the-art view of diffusion in minerals and silicate liquids pertinent to many earth systems and would have a birds-eye view of available experimental data and a treasure trove of valuable references to the primary literature. Perhaps it is ironic that a book about an intrinsically entropy-producing process (diffusion) is so well organized and presented!

Frank J. Spera
Department of Earth Science
University of California, Santa Barbara
Goleta, California 93117-1815 U.S.A.

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