American Mineralogist, Volume 81, pages 255–256, 1996

BOOK REVIEWS

THERMODYNAMICS IN GEOCHEMISTRY: THE EQUILIBRIUM MODEL. By Greg M. Anderson and David A. Crerar. Oxford University Press, New York, 1993, xx + 588 pages. $79.00.

Greg Anderson and David Crerar's *Thermodynamics in Geochemistry* is written in the personal style of a teacher who genuinely wants students to understand the subtleties of putting thermodynamic theory into geochemical practice. Accordingly, the book's approach to the conceptual development of thermodynamics is descriptive, with ample text supporting each equation. This method is helpful, and both specialist and student will benefit from the ability to compare their own thoughts with those of the authors. To aid the student, algebraic manipulations of equations are developed completely. The book is generously illustrated with figures depicting the behavior of these equations, and numerous tables contain the results of calculations. The authors also include a fairly comprehensive list of equations useful in calculating the Gibbs free energy of substances as a function of P, T, and composition using a variety of formulations for heat capacity, volume, and mixing properties. Students and professionals alike will appreciate the extensive discussion of geochemical conventions for standard states, fugacity, and activity.

In *Thermodynamics in Geochemistry* the authors emphasize that "thermodynamics is best understood as a model" and elaborate on the distinction between the physical world and the model equations that describe it. Thus, the subject of the second chapter is the mathematical basis of thermodynamics, including exact differentials, homogeneous equations, and Legendre transformations. Teachers and students interested in the mathematics will find this chapter satisfying, but it is not strictly necessary for the development of the remainder of the book and may be mysterious to students unfamiliar with thermodynamic relations. The basic subject of thermodynamics is developed in a reasonably conventional manner, though previous acquaintance with the elements of thermodynamics will help some beginning students because early chapters make use of concepts that are more fully explained later. An introduction to statistical mechanics is provided that includes the partition function and its relationship to the thermodynamic functions. There is a chapter on the calculation of the Gibbs free energy as a function of T and P using a variety of geochemical conventions. Sources of geochemical data are discussed, and methods of obtaining internally consistent data sets are explained. In a chapter on heterogeneous equilibrium, there is a useful section on the thermodynamics of open systems. The properties and representation of simple systems and of multicomponent solutions are well developed. There are separate chapters on solid, gaseous, and aqueous solutions. The discussion of nonideal solid solutions emphasizes Margules equations and the calculation of solvi, spinodal curves, and consolute points. Two thorough chapters cover aqueous electrolyte solutions and aqueous speciation calculations and another discusses redox systems. These chapters serve as excellent references because they refer to the geochemical literature and include detailed presentations of the Pitzer equations and the Helgeson, Kirkham, and Flowers model of electrolyte behavior.

The book's strengths are its attention to detail with regard to standard states, fugacity, and activity; its thorough presentation of the useful equations in geochemical calculations; and its presentation of aqueous and redox geochemistry. Many students will find the extended discussions of thermodynamic concepts helpful in understanding the meaning of some puzzling equations. On the other hand, the logical relations of some of the derived equations suffer from the intervening paragraphs of text. The book's greatest deficiency is its rather limited collection of problems and example applications of geochemical phenomena. Teachers will require their own problem sets to develop the material adequately and to show how thermodynamics is useful in fields outside geochemistry. Some geochemical topics that the book does not cover include phase transitions, critical phenomena, sorption, and the thermodynamics and modeling of magmas. There is no formal discussion of the determination of components in geochemical systems. The book does instruct the reader on the preparation of Eh-pH diagrams but does not contain a discussion of the construction of activity-activity and μ-μ diagrams, T-X diagrams, chemographic relationships, or the relationships among these and other phase diagrams. However, an extensive bibliography is provided to assist further development of the subject. The book is evidently the product of significant teaching experience, particularly with regards to concepts that many students find difficult. Other teachers will find Anderson and Crerar's emphasis on these problem areas to be especially useful.

J. William Carey
Los Alamos National Laboratory

CRYSTAL IDENTIFICATION WITH THE POLARIZING MICROSCOPE. By R.E. Stoiber and S.A. Morse. Chapman and Hall, New York, 1994. xiv + 358 pages. $39.95 (soft cover), $79.95 (hard cover).

This well-written book is a revised edition of the authors' earlier work, *Microscopic Identification of Crystals* (1972), with the addition of three new chapters, two new appendices, and one color plate. I enjoyed reading this book from cover to cover, probably because it presents optical mineralogy at a much more applied level than usual.

The authors offer this new book "in the firm belief that crystal identification with the polarizing microscope is not only still a fundamental skill in the earth sciences, but is also a tool of growing power and simplicity." This statement sounds of Don Bloss and Walter McCrone, that optical methods are still the quickest, easiest, and least expensive means of answering many materials-based questions. The cost of fully equipping a microscope laboratory is similar to that of a one-year service contract for an automated powder diffractometer or one year's fringe benefits for a microprobe technician. Unlike many new analytical methods still looking for applications, optical microscopy's application is, simply, sample identification.

The goal of the book is "to provide a working knowledge of crystal identification suitable for the advanced graduate student, but also to guide the beginning and intermediate student who may not want to specialize in petrology." Whether intended or not, this well complements another goal of the book, "to serve the needs of industrial and forensic scientists" (that is, nongeologists). I think this is still one of the most important aspects of optical mineralogy, which, unlike many other disciplines and subdisciplines in the sciences, is used across several disciplines.

The book describes optical mineralogy in a logical fashion (e.g., behavior of light, optical equipment, the immersion method, and isotropic, uniaxial, and biaxial minerals). The first chapter gives an overview of optical mineralogy and provides simple, concise definitions to much of the nomenclature. The illustrations are adequate but perhaps too few. For instance, a drawing of a microscope with all parts labeled would be helpful. Two sizes of type are employed in the book. The imbedded smaller type gives interesting anecdotes about optical mineralogy; these are not required for a working knowledge of the field but are nonetheless very informative (e.g., that gypsum plates are made of quartz and why vibration directions are always perpendicular).

The indicatrix theory is used to explain how light interacts with minerals. The authors use a unique nomenclature for interference figures, with emphasis on the symmetry of the isogyres. For instance, a centered uniaxial optic axis figure is called an "n-symmetry plane" figure. They also define 0-, 1-, and 2-symmetry plane (SP) figures. Further, a randomly oriented crystal produces a 0-SP figure, a centered biaxial optic axis produces a 1-SP figure, and a centered acute bisectrix produces a 2-SP figure. This type of classification leads to their "random search method" for refractive index determination. For biaxial minerals, one finds a liquid that matches the high index of the minerals in the grain mount and only then checks an interference figure. This method allows for rapid mineral identification in grain mounts, which is the main thrust of the book. Mineral identification in thin section is also discussed.

The book has benefited greatly from the addition of three new chapters. "Optic Orientation in Stereo" gives an introduction to stereographic projections and then uses them to incorporate all the optical and crystallographic directions onto one stereonet. Several mineralogical examples are given for triclinic, monoclinic, and orthorhombic crystals. The chapter concludes with 17 pages of determinative optical mineralogy of the feldspars, derived mainly from S.C. Su's recent works.

The next new chapter, "Use of the Dispersion Method," describes a method, recently refined by S.C. Su, that allows for rapid (a few minutes) and precise (± 0.0001 under ideal conditions) refractive index determination of minerals using the immersion method with monochromatic light. The authors provide specific examples of this method for isotropic, uniaxial, and biaxial minerals. The method requires finding a wavelength match instead of interpreting the color fringes at a near match. Techniques and examples to determine the amount of Fe (or Mg) in olivine, orthopyroxene, and augite are given. Also, an example is provided in which students determine An content (to within ± 0.2) in a labradorite.

As the name implies, the third new chapter, "Crystal Identification Recipes," provides "cookbook" methods for finding the refractive indices of isotropic and anisotropic grains using the random-search method and, for precise work, the dispersion method. The authors claim all the major minerals of a rock can be identified in 10–15 min with this method.

A list of symbols at the beginning of the book will help any reader with optical mineralogical terminology. Appendix A is a "short determinative table" of the major rock-forming minerals. It lists only 54 different minerals, 51 silicates and 3 nonsilicates, but this is enough for most work. Beginning students may find this short table listing the most common minerals to be less frustrating to use than digging through Tröger (*Optical Determination of Rock-Forming Minerals,* 1979) or Fleischer et al. (*Microscopic Determination of the Nonopaque Minerals,* 1984). The authors reference these more complete optical databases. Appendix B is a brief description of the optical methods used to identify the common asbestos minerals, with references to more complete works.

The book includes the tidbits I find of value in optical mineralogy, such as the relationship of optics to crystal structures, that uniaxial minerals are really just special cases of biaxial minerals, and that orthorhombic minerals can have inclined extinction or be uniaxial or isotropic. Also, several very useful hints for colorblind individuals are included, a feature I have never before seen in print. I found no serious omissions in the book.

The book may be used, as the authors suggest, in graduate classes to teach optical mineralogy as an analytical tool. It could also be used in undergraduate courses in which the instructor wants to emphasize hands-on data collection that students can actually perform. The students would not only identify minerals but would also indirectly determine their composition. I believe, to these ends, that the book meets its goal of providing a very applied discussion, with examples, of sample identification with the polarizing microscope. One final thought, as the Mineralogical Society of America contemplates its future, is that we should consider returning to some of the basics, such as applied optical mineralogy as presented in this book.

MICKEY E. GUNTER
University of Idaho