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BOOK REVIEWS

THERMODYNAMICS OF NATURAL SYSTEMS. By G.M. Anderson. John Wiley & Sons, Inc., New York, 1996. 382 p. $28.95.

What is the best way to teach students the subject of thermodynamics? There must be many solutions to this question because a phenomenal number of textbooks are available on the subject. This is all the more surprising given that the fundamentals of thermodynamics are encompassed by three basic physical laws. Denbigh (1981) makes this explicit in his popular text, in which he states that the "*whole* of the fundamental theory" of thermodynamics is contained in just four simple equations. This is the great beauty of thermodynamics, but therein also lies the difficulty: The student must learn how to proceed from this simple theoretical foundation to the very practical goal of making useful calculations.

The difficulty most students have is that the application of thermodynamics requires understanding a set of rigid, but logical rules that are developed from the basic laws. Students, struggling to learn these rules, lose sight of the relationship of thermodynamic properties to real processes. In dealing with this problem, most textbooks take one of two approaches: An improved logical development from theory to practice or a practical, problem-solving approach using a minimum of theory. Greg Anderson's recent textbook *Thermodynamics of Natural Systems* takes the middle ground between these two approaches with mixed results.

Thermodynamics of Natural Systems is written primarily for undergraduates and therefore complements the more advanced textbook *Thermodynamics in Geochemistry* by Anderson and Crerar (1993; see my earlier review, Carey 1996). The outline of the new textbook is similar to the advanced text and includes a formal development of thermodynamics from the first and second laws. The approach, however, is simplified and difficult details are either omitted or given in an appendix. The idea is to give students the flavor of a rigorous development of thermodynamic principles but to proceed quickly to making practical calculations.

Anderson motivates the study of thermodynamics by raising questions about the rules that govern phase transformations in natural systems. Energy and the first law are introduced and shown to be part of the answer. Entropy is introduced not as a property illustrated by a Carnot engine, but as the missing ingredient that explains why some reactions proceed spontaneously even in the absence of changes in energy. Anderson makes these new concepts explicit by next describing how they are measured by calorimetric techniques.

The remainder of the book consists of applications of the basic equilibrium condition at constant pressure and temperature as expressed by Gibbs free energy. The applications begin simply in single component systems. Multi-component solutions and activity corrections to the Gibbs free energy are introduced without derivation, which then allows calculations of equilibrium constants and eventually activity diagrams. There is a separate chapter for redox reactions and a fairly long chapter on reading binary and ternary phase diagrams. The text concludes with a selection of advanced topics that includes kinetics, reaction progress modeling, and statistical thermodynamics. There is also an appendix that provides greater detail on the origin and derivation of some of the thermodynamic concepts.

Thermodynamics of Natural Systems is most successful as a friendly introduction that provides the basics for making simple calculations of equilibrium relations and for interpreting the most common phase diagrams. The writing style is encouraging to the student and patient with explanations. After completing a course based on this book a student should be able to interpret activity–activity and T-X phase diagrams, perform simple calculations of equilibrium relations using ideal activity models, have a beginning knowledge of redox processes and their importance, and have a reasonable idea of the role of thermodynamics in understanding chemical processes. The student should also have an understanding of the relation of thermodynamics and kinetics to actual processes. The problems at the end of each chapter help explain the concepts, but their number and range is limited.

The book's title, *Thermodynamics of Natural Systems*, is somewhat of a misnomer. The presentation, examples, and problems are almost entirely drawn from within the realm of geochemistry, particularly aqueous geochemistry. Perhaps this focus was necessary, because a text that considered a wider range of phenomena could not have been written at an elementary level.

Inevitably, any introductory work contains simplifications that some will find unsatisfactory. I think that Anderson, in trying to supply a simplified theoretical background to thermodynamics, runs the risk of confusing the more thoughtful students. For example, Anderson states that spontaneous and irreversible processes are "synonymous." Some of the phenomena he chooses to illustrate metastable equilibrium are more confusing than insightful (How is a sugar cube adjacent to a cup of coffee to be interpreted as a metastable system?). As in the more advanced textbook by Anderson and Crerar (1993), much is made of thermodynamics as a model with the implication that it is an imperfect representation of reality. I believe students will be confused by this discussion, because Anderson is not clear on the relationship between the physical laws and the models he describes. On reading this text, I would worry that a student might have the impression that thermodynamics is about 90% correct. There should be a better distinction between what is believed to be an underlying reality and the difficulties in creating an adequate model of complex systems.

Teachers looking for a basic level textbook that provides some theory but emphasizes interpretation and calculation of simple fluid-mineral equilibria should consider using *Thermo-*

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dynamics of Natural Systems. However, I find it frustrating that the scope of this book is so narrow. Students of thermodynamics should appreciate the broader applications of the subject to the analysis of heat and work. Moreover, in a book entitled "natural systems," there should be a greater discussion of the many applications of thermodynamics to understanding processes in biology, meteorology, oceanography, and astronomy.

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J. WILLIAM CAREY
Los Alamos National Laboratory

CHEMICAL FUNDAMENTALS OF GEOLOGY, second edition. By Robin Gill, Chapman & Hall, London, 1996. 296 p. 17-50 £.

With the publication of the second edition, Robin Gill's introductory geochemistry text *Chemical Fundamentals of Geology* is again available, with moderate revision and printed in a larger format. The basic organization of the text has remained unchanged, with the first three chapters devoted to introductory thermodynamics and kinetics, followed by chapters on aqueous geochemistry, atomic theory, periodic properties of the elements, and mineralogy. It concludes with two chapters describing the distribution of elements in the Earth, solar system, and universe as a whole.

The intent of the text is also unchanged. It is an introduction to the chemistry of the Earth written from a chemist's viewpoint, but with a clear understanding of how geochemists have conceptually organized the distribution of the elements in the Earth. To its credit, the text does not depict atoms as planets with orbiting dots, describe chemical bonds as sticks, or attempt to model the Earth as a slag heap. Instead there is a conscious effort to apply first principles taught in introductory college chemistry courses to the understanding of the chemical makeup of the Earth. In practice this means that while the Goldschmidt classification of the elements is duly presented, so too are element classifications based on the periodic properties of the elements and on ionic size and charge (i.e., HFSE, etc.). Mineralogy is presented with a dose of hybrid orbital and crystal field theory.

In the new version of the text, the geochemistry of some elements is described using the concepts of Lewis acids and bases. Additional improvements to the book include new figures and boxed material on such disparate topics as partial melting in the mantle, Fick's second law, and wave theory. The main text itself, however, has undergone only minor revisions. The only chapters with substantive changes are the final two, where there has been significant additions of expository material on cosmology and on the behavior of particular elements in the Earth.

The text does have its weaknesses. It is essentially a qualitative text, with few applications, and still fewer derivations, of the mathematical expressions used to describe the behavior of elements in solids and fluids. This weakness renders the book useful to introductory students as reading supplemental to other, more quantitative texts [such as G. Faure's *Inorganic Geochemistry* (Prentice-Hall, 1991)], but frustrating to both students and instructors if used as the sole basis for a serious introduction to geochemistry. In addition, the introductory thermodynamics presented here is neither as accessible, nor as rigorous, as the material presented in G.M. Anderson's recent book, *Thermodynamics of Natural Systems* (Wiley 1996). The latter book has proved popular with recent students in this reviewer's undergraduate geochemistry courses, whereas earlier students seem to find Gill's rendition of thermodynamics palatable but superficial. Finally, a minor quibble with the book is that some of the material presented is a little out of date, such as the discussion in Chapter 10 that promotes the currently out-of-favor concept that the bulk of the continental crust forms through hydrous melting of the mantle and the extraction of primary andesitic magma.

Despite these shortcomings, the new version of the text, with figures redrawn and improved and with the added text and improved glossary, is still a useful introduction to modern concepts in geochemistry. You won't be modeling multicomponent, non-ideal aqueous solutions after reading the book, but you will come away with a good overall chemical perspective of the Earth.

G. LANG FARMER
University of Colorado

GEMSTONES OF NORTH AMERICA, VOLUME III. By John Sinkankas. Geoscience Press, Tucson, Arizona, 1997. 526 pages (plus 16 pages of color plates). $65.00.

The mineral and gem communities owe a tremendous debt of gratitude to John Sinkankas for his many well-written and well-researched tomes. Few authors in any technical field can duplicate his rare combination of talents, his knowledge and grasp of the literature, his amazing ability to sense the important details and concepts and to express and explain them clearly, and his knack of humanizing the subject by including poignant anecdotes and personal observations. Each of his books convey the impression of being a true labor of love. And so it is with his newest work, Volume III of his *Gemstones of North America* series.

Sinkankas' first *Gemstones of North America* (Volume I), published in 1959, was modeled after the classic *Gems and Precious Stones of North America (1890–1892)* by George F. Kunz. Volume I became an immediate classic, the definitive, up-to-date compilation of mineralogical, gemological, geological, historical, and geographical information on North American gem materials. Volume II, published in 1976, took the tack of providing information on new developments during the intervening 17 years. Twenty-one years later, we're more than ready for another sequel, and in Volume III Sinkankas continues to use his masterful touch we have come to expect.

Data from previous volumes are not repeated here, except to introduce new data. Sinkankas also includes information from older sources that he came across while preparing Volume III. He has gone far beyond a mere literature search by presenting information drawn from years of correspondence and interviews with miners, collectors, and dealers. It is clear that the author has been careful and thorough in gathering, culling, assembling, and interpreting all of the pertinent data available.

The list of gem materials covered is surprisingly comprehensive, even more so than in previous volumes. There are many materials included that I would have never guessed had gem applications. One example is oil shale for which Sinkankas sites two references pertaining to its use as a lapidary material.

Volumes I and II were virtually identical in layout and format. Volume III departs from the earlier works in several ways. The gem materials are listed in alphabetical order, whereas material in the earlier volumes was arranged in categories such as important gemstones, rare and unusual gemstones, and massive and decorative gemstones. The individual material headings are an eclectic mix of group, species, variety, rock, organic product, and trade names. This approach, presumably chosen to facilitate use by the amateur, may somewhat confound those with more scientific mineralogical affinities. The lack of consistency is bothersome especially because cross-referencing is not sufficiently comprehensive. Peridot appears as a main heading, but there is no cross-referenced heading for forsterite. The index lists forsterite, but only with respect to the section on lapis lazuli. Amethyst cannot be found either as a cross-referenced heading or in the index, although it certainly appears many times in the 109 pages devoted to quartz. On the plus side, mineralogical terminology is generally handled conscientiously within the text of the individual entries.

Volumes I and II both listed references in appendices. Volume II was especially endowed with a very comprehensive total of 2661 numbered references. Volume III provides abundant references as well, and these are listed in much more convenient fashion immediately following the text to which they pertain. The author notes that most of the references post date those appearing in Volume II, but some are repeated. I did not see any regular pattern in the present work to suggest why certain sections include earlier references and others do not.

As in the earlier volumes the localities are described under headings corresponding to Greenland, Canadian provinces, Caribbean Islands, U. S. states, Mexican states, and finally other Central American countries. Within the larger countries the political divisions are arranged in geographical order, roughly in north-south bands proceeding from east to west. Anyone familiar with the earlier volumes will feel right at home with this arrangement.

The formatting of headings, subheadings, text, and references differs from those employed in Volumes I and II and is similar to that found in the locality section of Sinkankas' Emerald and Other Beryls. Subjectively I judge this formatting to be superior to those in the earlier Gemstones of North America volumes, but not as effective or polished in appearance as the formatting in *Emerald and Other Beryls*.

The illustrations in Volume III include 18 excellent color images of gem materials by Erica and Harold Van Pelt that precede the text, 65 black and white images mostly of gem localities scattered through the text and 33 maps also scattered through the text. The black and white images are generally well chosen, but there are significantly fewer than in the previous volumes. The presentation would have benefited from more images, particularly of gem materials; but this deficiency is alleviated if one uses the three volumes in consort. Several images depicting the title pages of old publications add little. The maps, an important asset to the book, have been drawn by Sinkankas in his usual clear readable style, and they can be found in Volume III in greater number than in Volumes I and II.

In conclusion, I strongly urge anyone interested in North American gemstones to buy this volume. It is a bargain at $65.00 and an essential reference. If you do not already own volumes I and II, by all means buy them as well.

ANTHONY R. KAMPF
Los Angeles County Museum of Natural History