(*Continued from page 318*)

written for the uninitiated, but is rather flavored primarily to the selective palate of the mathematician and secondarily to that of the physical rheologist.

RICHARD W. HANKS
BRIGHAM YOUNG UNIVERSITY
PROVO, UTAH

Fuel Cells and Fuel Batteries. A Guide to Their Research and Development, H. A. Liebhafsky and E. J. Cairns, John Wiley and Sons, New York (1968). 692 pages. $27.50.

It is perhaps proper that a book summarizing the major fuel cell developments should appear at a time when fuel cells have helped make man's dream of flying to the moon a reality. Liebhafsky and Cairns give a documented historical account of the kind of fuel cells used in the Apollo project as well as of all other important types, including molten carbonate, solid oxide-ion, and ion exchange membrane fuel cells.

An effort is made to develop the pertinent theory, starting with fundamentals. The emphasis is rightly on transport phenomena. For example, an up to date treatment of mass transfer in fuel, oxidant, and free electrolyte chambers is presented. However, the authors' recommendation on page 209 to use flat plate solutions rather than the Leveque solution (linear velocity profile) for estimating Nusselt numbers in the KOH chamber seems strange. The momentum boundary layer thickness of 3.4 cm., calculated by the authors, is larger than the normal distance between the plates. Thus the momentum boundary layer should have developed well before the exit.

Again, as a part of the emphasis on transport phenomena, the authors present an integral reactor analysis of a fuel cell that had previously not made its way into the open literature. It's under the heading of "irreversibility and changing composition" in the body of the book and in the Appendix. Although the example is very good, the presentation does not make it clear that molecular diffusion of hydrogen has been neglected compared with bulk flow. Also, this type of an analysis need not be restricted to the case of constant molar flow or to control by resistive loss in the electrolyte. Usual differential reactor polarization data can be used and the conservation of mass and species equations solved numerically using Runge-Kutta subroutines. If a simple relation is desired, linearization of the Nernst equation permits one to integrate equation 4. 7-6 in closed form and thus obtain polarization curves for high conversion of fuel or oxidant from polarization data at no conversion.

In treating the problem of electrode structure the authors do a good job in discussing the requirements for no bubbling or weeping, but they do not present the important subject of porous electrode models in sufficient detail. Here and in a few other instances they appear to have dismissed or only summarized in words the more mathematical papers available to them. Partial information allows this reviewer to conclude that advanced fuel cell groups in this country and in the Soviet Union have developed reasonably sophisticated electrode models which allow a nearly complete prediction of polarization curves in some cases from basic kinetic, structural, thermodynamic and transport properties. Supporting experimental evidence remains largely confidential, but the published models show in which direction one must go to reduce polarization. The view expressed by Liebhafsky and Cairns on this subject is too pessimistic.

On the whole, this book contains such a wealth of information that it is worth, to anyone seriously interested in fuel cells, the high price charged for it by its publisher.

DIMITRI GIDASPOW
INSTITUTE OF GAS TECHNOLOGY
CHICAGO, ILLINOIS

Engineering Fluid Mechanics, John E. Plapp, Prentice-Hall, Inc., Englewood Cliffs, N. J. (1968). 654 pages. $11.95.

A book should be judged on the extent to which the author's goals are achieved. In the preface of this book Dr. Plapp states, "As a text, this treatment of fluid mechanics is designed to fit into a basically-oriented curriculum in mechanical, civil or electrical engineering, rather than into one in chemical engineering where the emphasis on transport processes is much stronger than in this volume." Whether the book might succeed as a textbook in these other branches of engineering will have to be determined by reviewers in those fields.

From the point of view of the chemical engineer in industry the book provides a more complete treatment of fluid mechanics than most chemical engineering books and one should find it useful for reviewing and expanding his knowledge of fluid behavior. The treatment is for the most part leisurely, satisfactorily rigorous, and often leads to practical results with which chemical engineers are familiar. The writing is quite good and the typeface and page layout are excellent. Both author and publisher are to be congratulated for a handsome production. About the only surprising feature noted was the short treatment given boundary layer flow. The author makes a point of acknowledging his debt to Schlicting in the preface and then deals with boundary layers rather briefly. Chemical engineers who regard boundary layer theory as the key which unlocks the door to a large part of transport behavior would find this part of the book inadequate.

PROFESSOR J. E. MYERS
UNIVERSITY OF CALIFORNIA
SANTA BARBARA, CALIFORNIA

Computer Calculations for High-Pressure Vapor-Liquid Equilibria, J. M. Prausnitz and P. L. Chueh, Prentice Hall, Inc., Englewood Cliffs, N. J. (1968). 239 pages. $12.95.

This book will be of the most interest and use to chemical engineers and thermodynamicists working in the field of liquid-vapor equilibrium. In fact, these men will very likely be already familiar with most of this work from the series of articles the authors have published in various engineering periodicals in the last two years. However, not only will the user now find everything conveniently within one binding, but the related computer programs (not previously available) form part of the Appendix. This volume is a sequel to *Computer Calculations for Multicomponent Vapor-Liquid Equilibria* published in 1967 by Professor Prausnitz and co-workers. This new work covers the much more difficult field of high pressures whereas the techniques in the previous book were only applicable to low and moderate pressures.

Turning first to the strong points of the book, the greatest contribution in this reviewer's opinion is the modification of the Redlich-Kwong equation to permit it to represent more adequately the nonideality of the vapor phase in equilibrium work. This modification appears to be far superior to ones previously proposed. It consists of two parts: 1. varying the 0.4287 and 0.0867 constants with each component and 2. providing for the inclusion of a binary interaction constant for each constituent binary in the mixture.

Another major contribution of the authors is related to the critical region of the mixtures. As the authors point out, "the thermodynamic analysis of

(*Continued on page 320*)

(*Continued from page 319*)

vapor-liquid equilibria is difficult in the critical region because thermodynamic properties are strongly sensitive to small changes in temperature, pressure, and composition." Special equations are presented for computation of the critical properties of the mixture from pure component data and from correlating parameters obtained from experimental data on the binary systems. The modified Redlich-Kwong equation of state is employed for the estimation of the critical pressures.

No procedure for carrying out phase equilibrium calculations in the high-pressure region can be successful without its being able to handle partial molar liquid volumes. Failure to do so means that the effect of pressure on activity coefficients cannot be treated properly. As part of a very extensive coverage, practical methods for obtaining this thermodynamic property are presented.

The thermodynamic procedures developed in the book are compared to data on selected systems, but no overall statistical evaluations against a mass of data was made. When a comparable correlation, the Chao-Seader Equation, was published in recent years, it was tested against 2,700 experimental points. No such thorough examination was made of the subject techniques.

Constants for the polynormal expressions for the liquid fugacity are given for twenty components; the user of these methods will encounter difficulty in applications involving other substances, for example, carbon monoxide. Furthermore, such problems are enlarged because the book contains no index to assist the reader in finding the answers to questions which arise.

Whereas the book is certainly intended to be used as a second working right-hand by the practicing engineer, and to a large extent the authors are successful, there is a serious omission. The illustrations of the methods have been restricted to cases where the equilibrium conditions have previously been provided to the authors by published data. No discussion or accompanying computer programs cover the general case faced by a process engineer, where the self-same methods on a trial and error basis must be applied to *multicomponent* systems for which the equilibrium compositions of liquid and vapor must be obtained, as by a flash calculation. More than mere programming is involved.

In spite of these limitations the book is certainly a valuable addition to the field of thermodynamics.

STANLEY B. ADLER
THE M. W. KELLOGG CO.

Kinetics of Chemical Processes, Michel Boudart, Prentice-Hall, Inc., Englewood Cliffs, N. J. (1968). 242 pages.

Not only does this book stress a realistic approach to reaction mechanisms, cautioning against too much faith in simplified concepts such as a uniform population of active centers, but it develops careful and precise statements of reaction rate, the steady state approximation, and the controlling step phenomenon in rate processes, which are helpful alike to the design engineer and the kinetics researcher.

The author first sets forth the basic concepts of kinetics, with definitions of transition state, rate and extent of reaction, and the ideal reactor types. In Chapter 2, the theoretical basis for rate expressions is presented, including a discussion of the effects of nonideality. The steady state approximation is developed, with great care, in Chapter 3. Next, kinetic models for homogeneous catalysis, chain reactions and polymerization are worked out in general terms.

Chapter 4 explains the concept of rate determining step so clearly that students should thereafter easily avoid the common sin of referring to the *slow step* of a reaction. Rate determining active centers are next defined. In logical sequence, Chapter 5 attacks the next stage of complexity: coupled sequences in reaction networks, to quote the chapter heading. Chain reactions in parallel and in sequence are analyzed.

The author is now in a position to expand his treatment of reaction models having a chain structure into acclerating, or branching chain reactions, in Chapter 6; following this with the companion topic, inhibition.

Now, in Chapter 7, the influence upon kinetics of mass and heat transfer processes is developed: including wall effects and penetration into porous catalysts or reactants.

In Chapter 8, "Correlations in Homogeneous Kinetics," the author discusses the Polanyi relation and the Brönsted relation as means of correlation, in series of reacting systems. Problems associated with extending the active center concept to heterogeneous catalysis are now treated in Chapter 9. Here the variable adsorption behavior of the surface is coupled with the concept of the compensation effect, an empirical correlation among rate constants and activation energies, to show that apparent compliance with a model which assumes uniform active centers cannot be taken as necessarily supporting so simple a model. This is a scholarly analysis, citing actual data, not presented to undermine a student's future belief in the attractive features of models built with uniform active centers, but rather to give him a little more sophistication, in the complex field of applied kinetics.

Chapter 10 introduces the student to modern methods of mechanism identification, such as Neiman's tracer technique. Wei and Prater's systematic analysis of the first order reversible network is described in detail, and illustrated.

This book is a valuable addition to the growing library of books in applied kinetics, which may be considered for texts. It would appear well suited to a course in kinetics for graduate students in chemistry and chemical engineering, and for undergraduates in a strongly science-oriented chemical engineering curriculum.

While the developments in the text are worked out in general terms, there are problems dealing with real systems interspersed in the text and coordinated with it, to aid the student in perfecting his understanding through participation. Bibliography entries at the ends of the chapters are accompanied with explanatory comments.

C. C. WATSON
UNIVERSITY OF WISCONSIN
MADISON, WISCONSIN