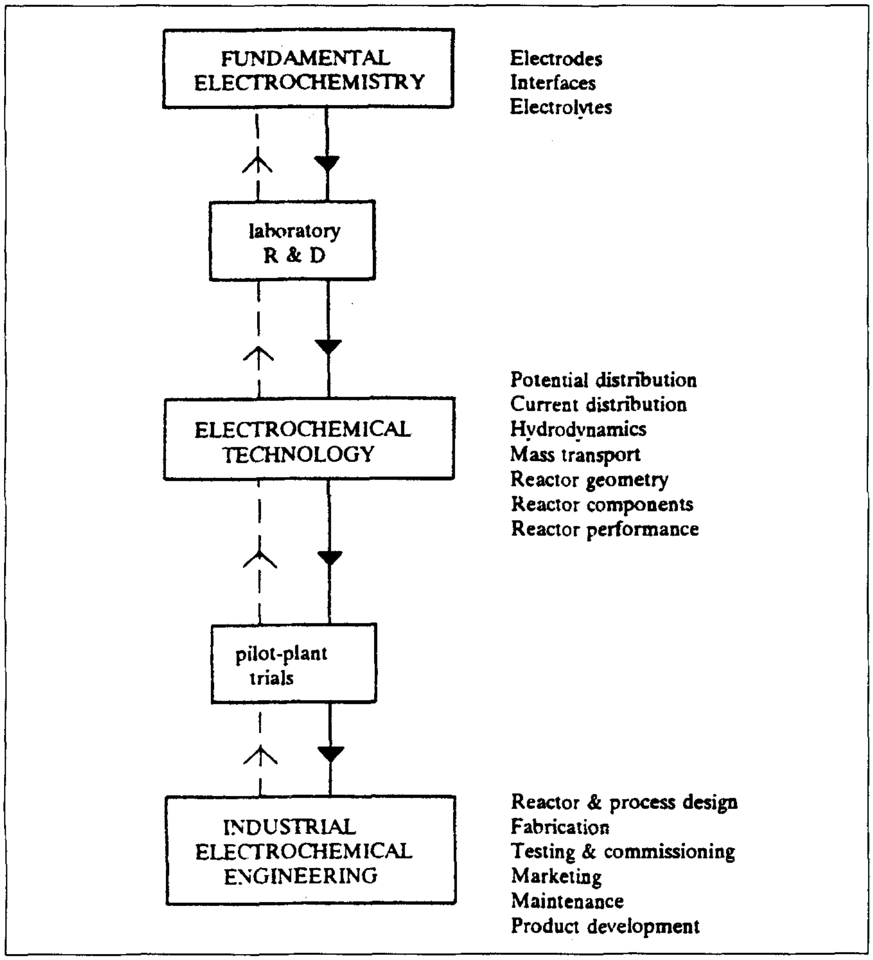

Figure 1.3. Scope of electrochemical engineering showing the bidirectional nature of scaleup and major subject areas.

tivity coefficients and transport numbers. The requisite properties of each component are described, as are their availability. Examples are used to show choice as based on individual process need. In Chapter 4, reaction stochiometry and rates of reaction are explored. First, Faraday's law is introduced, followed by a brief discussion of side reactions and current efficiency. Following an empirical display of the basic electrochemical kinetic expressions, the Butler-Volmer equation is derived from a molecular viewpoint. This order of presentation might annoy the purist, but it certainly mirrors the actual chronology; the empirical Tafel equation preceded by decades the microscopic explanation. Finally, the effect of mass transfer is introduced, with a development of the limiting current and mixed activation and concentration overpotential.

Chapter 5 is limited to transport phenomena; chemists not familiar with chemical engineering techniques for calculating mass-transfer rates will find this useful. Correlations for the Sherwood number for various cell geometries, including those with porous, 3-D electrodes, are presented. Chapter 6 will also be readily grasped by chemical engineers; basic reactor design factors are reviewed, as is calculation of yield, selectivity, and current efficiency. The important group, $k_m A/V$, for porous electrodes is illustrated.

Practical design criteria form the meat of Chapter 7. While the costing bases and optimization are not nearly as detailed as those in G-S, they will be sufficient for most readers. The three factors determining current distribution are clearly set out, followed by an excellent presentation of the design and operation of a 3-D porous electrode. These somewhat simplified equations show the ideal limitations of a finite potential window within which the desired reaction can occur, as manifested in the allowable electrode width. The criteria for separator use and the utility of the fluidized bed are set out here as well.

Chapter 8 comprises a short qualitative description and illustrations of various types of electrochemical reactors, with examples in practice. This is followed by a chapter detailing the development of several commercial processes, quantified as to reactor size, voltage, current, production rate, etc. The chronologies detail the progression of the processes from lab-size cells of a few square centimeters, through the bench-top, 100-cm^2 cell, and then to the multicell stack. The design and analysis include quantitative consideration of such practical matters as cell life, pressure drop, and cost performance prediction. The examples include interesting and important topics: recovery of metals from waste streams, synthesis of a protein, and salt splitting across ion-exchange membranes (the production of an acid and base from the neutral salt). Unfortunately, the equations used here in the design bases are not linked to those developed in the earlier chapters. Chapter 10 completes the book with completely worked practical examples.

Even considering the somewhat low production values, a step above photo-ready copy, this book makes a good text for a senior or graduate-level class. It is also extremely useful for the practicing engineer or chemist looking for a basic self-teaching manual of electrochemical engineering, one that could be readily consumed in about two weeks of concentrated effort. It is recommended over G-S for either purpose as one which is more complete, more easily assimiliated and more closely connected with actual practice.

Jack Winnick
School of Chemical Engineering
Georgia Institute of Technology
Atlanta, GA 30332

Multiphase Flow and Fluidization: Continuum and Kinetic Theory Descriptions

By Dimitri Gidaspow, Academic Press, New York, 1994, 467 pp., $69.50.

Multiphase flows are involved in numerous industrial processes such as pneumatic conveying and solid fuel combustion and occur in various natural phenomena such as sandstorms and aerodynamic ablation. Typical multiphase flow encompasses gas-solid, liquid-solid, gas-liquid and gas-liquid-solid flows. Modeling based on the continuum assumption for multiphase systems characterizes the classical approach in computational fluid dynamics for multiphase flow simulation. This book presents important fundamental and applied aspects of multiphase flow and fluidization. The uniqueness of the book, however, lies in that it is the first one including the modeling approach based on the kinetic theory of gases to describe the particulate-phase transport properties such as solid-phase viscosity and pressure, in simulating fluid-particle flows.

An analogy between particle collision in suspensions and molecules in the kinetic theory of gases was suggested as early as the 1960s. However, this approach, which rigorously follows the kinetic theories of gases for solid particles, came to a halt due to the complexity surrounding the direct application of the Boltzmann equation accounting for interparticle collisions. The physical basis of the kinetic theory of gases is elastic collisions of monodispersed spheres with Maxwellian velocity distributions in an infinite vacuum space. As a result, the fluid-solids interactions involving velocity- and pressure-dependent forces, energy dissipation due to inelasticity and friction in particle collisions and particle-wall interactions, and nonuniformity in particle size are all excluded from the direct analog between solid particle interactions and molecular interactions. These constraints physically limit the practical use of the kinetic theory to granular flows where viscous effects can be neglected. An alternative approach using simplified kinetic theories of gases based on mechanistically derived or intuitive relationships in place of the Boltzmann equation is viewed viable by various researchers. This approach in various forms has been applied to many gas-solid flow systems including fluidization and pneumatic transport and has shown very encouraging results in predicting fluid-particle flow behavior which would otherwise be unpredictable with conventional approaches. Professor Gidaspow is a major contributor in this endeavor.

The book contains 12 chapters, some basic features of each chapter are outlined below. Chapter 1 presents basic equations for single-phase laminar flows and general formulation of multiphase flow equations. Chapter 2 applies the equations in Chapter 1 to one-dimensional studies of the pneumatic conveying of solids, focusing on vertical flow and its pressure drop. Chapter 3 describes the drift flux model which estimates the volume fractions of fully developed 1-D multiphase flows. Chapter 4 on critical granular flows illustrates the governing equations for static packed powders and 1-D granular flows. Chapter 5 presents regimes and fundamental characteristics of fluidization including a kinetic energy dissipation analysis. Chapter 6 discusses modeling of bubble formations in fluidized beds and a bubbling criterion using the shock theory. Chapter 7 on the fundamental nature of bubbling fluidized beds describes classical bubbling bed models. The bulk of the chapter, however, covers the governing equations and computational results for various operating conditions and their comparisons with experimental results. Similar to Chapter 7, Chapter 8 presents fundamental characteristics of circulating fluidized beds. Chapters 9, 10 and 11 summarize the essential concepts of the kinetic theory of gases in the modeling of fluid-particle flows. Chapter 12 illustrates the phenomena of sedimentation and consolidation of solids in particulate flows, as well as an electrokinetic phenomenon (Zeta potential).

As noted, the book highlights the application of the kinetic theory of gases in fluid-particle flows, which are presented remarkably well in Chapters 9, 10 and 11. The kinetic theory of gases pertaining to the Maxwellian state, frequency of collisions, mean-free path, Boltzmann integral-differential equations, and others are comprehensibly introduced. The inherent similarity of transport properties between gaseous molecules and granular powders is thoroughly discussed. The applications of the kinetic theory to fluid-particle flow systems, such as circulating fluidized beds, are impressively demonstrated. There are places in the book, however, that could have been described somewhat differently. For example, in Chapter 2, the negative pressure drop could be explained mechanistically in terms of drag reduction phenomena contributed by various possible mechanisms including turbulence modulation of the phase rather than the "negative" friction of solids described in the chapter. In Chapter 7, Inviscid Multiphase Flows, the use of *inviscid* in the heading does not appear to be appropriate as the wake-induced vortex shedding and vortex dissipation in bubble flows introduced are all viscous-related. Some comments concerning the physical limitations of the kinetic theory application in fluid-particle flow and turbulent effects in multiphase flow would have been useful to readers. As the fundamental concepts are not very uniformly presented from first principles, instructors may need some supplementary materials when using this book as a textbook in the classroom. It is noted, however, that the homework exercise problems contain valuable information, which appreciably augments the scope of the text.

Overall, this book provides a unique and thorough review of the kinetic theory of gases in the modeling of fluid-particle flow and an impressive exposition of computational contributions by the author's research group at the Illinois Institute of Technology. The book is published at a time when predictive methodologies based on computational fluid dynamics for multiphase flow are urgently needed. Therefore, it is a welcome addition to the literature in this field. It would be an excellent addition to a collection to those who are interested in the applications of kinetic theory modeling and computation to fluidization systems. The book, however, may need to be supplemented with other materials to be effectively used as a textbook in multiphase flow.

Liang-Shih Fan
Dept. of Chemical Engineering
The Ohio State University
Columbus, OH 43210

Flow and Transport in Porous Media and Fractured Rock

By Muhammad Sahimi, VCH-Verlagsgesellschaft mbH, Weinheim, Germany, 1995, 482 pp., $65.00.

The author reviews classic methods to modern approaches for flow and transport in porous media and fractured rock. The book concentrates on modeling the morphology of porous media and of fracture systems, which eventually leads to either statistical or discrete models for calculating various properties and flow phenomena in porous systems. Since molecular or microscopic flows collectively make up the macroscopic and megascopic flows, this approach is useful for understanding the mechanisms behind various flow phenomena and provides insight into how one might model macroscopic or megascopic situations. Overall, the book is well written, reasonably descriptive and understandable. A minor irritation —it would have been useful to have a list of symbols.

There is some research on calculating flow in porous media deterministically at the macroscopic level. Also, there is literature associated with homogeniza-