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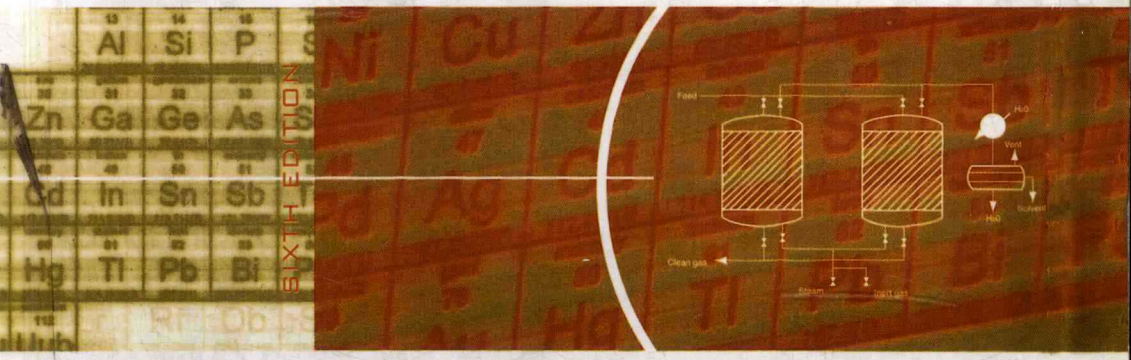
SIXTH EDITION



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UNIT OPERATIONS OF CHEMICAL ENGINEERING

SIXTH EDITION

Warren L. McCabe

Late R. J. Reynolds Professor of Chemical Engineering
North Carolina State University

Julian C. Smith

Emeritus Professor of Chemical Engineering
Cornell University

Peter Harriott

Fred H. Rhodes Professor of Chemical Engineering
Cornell University

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ABOUT THE AUTHORS

JULIAN C. SMITH (B.Chem., Chem.E., Cornell University) is Professor Emeritus of Chemical Engineering at Cornell University, where he joined the faculty in 1946. He was Director of Continuing Engineering Education at Cornell from 1965 to 1971, and Director of the School of Chemical Engineering from 1975 to 1983. He retired from active teaching in 1986. Before joining the faculty at Cornell, he was employed as a chemical engineer by E.I. duPont de Nemours and Co. He has served as a consultant on process development to Du Pont, American Cyanamid, and many other companies, as well as government agencies. He is a member of the American Chemical Society and a Fellow of the American Institute of Chemical Engineers.

PETER HARRIOTT (B. Chem.E., Cornell University, ScD., Massachusetts Institute of Technology) is the Fred H. Rhodes Professor of Chemical Engineering at Cornell University. Before joining the Cornell faculty in 1953, he worked as a chemical engineer for the E.I. duPont de Nemours and Co. and the General Electric Co. In 1966 he was awarded an NSF Senior Postdoctoral Fellowship for study at the Institute for Catalysis in Lyon, France, and in 1988 he received a DOE fellowship for work at the Pittsburgh Energy Technology Center. Professor Harriott is the author of Process Control and a member of the American Chemical Society and the American Institute of Chemical Engineers. He has been a consultant to the U.S. Department of Energy and several industrial firms on problems of mass transfer, reactor design, and air pollution control.

PREFACE

This sixth edition of the text on the unit operations of chemical engineering has been extensively revised and updated, with much new material and considerable condensation of some sections. Its basic structure and general level of treatment, however, remain unchanged. It is an introductory text, written for undergraduate students in their junior or senior years who have completed the usual courses in mathematics, physics, chemistry, and an introduction to chemical engineering. An elementary knowledge of material and energy balances and of thermodynamic principles is assumed.

Separate chapters are devoted to each of the principal unit operations, grouped into four sections: fluid mechanics, heat transfer, mass transfer and equilibrium stages, and operations involving particulate solids. One-semester or one-quarter courses may be based on any of these sections or combinations of them. The order of the first 16 chapters has not been changed; later ones, dealing with mass transfer and operations involving solids, have been rearranged in a more logical order.

Nearly all equations have been written for SI units, and the Newton's law conversion factor g_c has been eliminated except in the few instances where it must be included. Symbols for dimensionless groups have been changed to Re for N_{Re}, for example, Pr for N_{Pr}, and so forth. Many new examples and problems have been added, some reflecting the importance of biochemical engineering processes. Material on handling, mixing, and grinding particulate solids has been greatly condensed and dealt with in a single chapter. The number of appendixes is reduced from 22 to 19.

Derivations of the differential equations for continuity and momentum balances, leading to the Navier-Stokes equation, have been added, as well as the differential forms of Fourier's law and Fick's law, emphasizing the analogies among momentum, heat, and mass transfer. The chapter on adsorption has been expanded to include new material on chromatography and ion exchange, and renamed "Fixed-bed Separations." Other new material has been added on viscoelastic fluids, laminar flow in annuli, drag coefficients, affinity laws for pumps, high-efficiency agitators and motionless mixers, plate-type heat exchangers, boiling by submerged tube bundles, cooling towers, aqueous phase extraction, cross-flow filtration, and many other topics.

Many of the problems at the ends of the chapters are new or revised. Most are expressed in SI units. Nearly all the problems can be solved with the aid of a pocket calculator; for a few, a computer solution is preferable.

McGraw-Hill and the authors thank Dr. N. T. Obot for his many suggestions regarding fluid mechanics and heat transfer, and Professor Charles H. Gooding of Clemson University for his detailed and helpful review of the manuscript.

Julian C. Smith
Peter Harriott

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SECTION I

Introduction