Preface

Introduction to Chemical Processes: Principles, Analysis, Synthesis is intended for use in an introductory, one-semester course for students in chemical engineering and related disciplines. The text assumes that the students have had one semester of college-level general chemistry and one or two semesters of college-level calculus. Although student understanding of the material would be deeper with greater background in linear algebra or organic chemistry, the text is organized so that this background is not required for successful completion.

Course Trends

Introductory chemical engineering courses traditionally focus on chemical process calculations. Material and energy balances are taught, a few concepts in thermodynamics are introduced and miscellaneous information on units, dimensions, and curve fitting are included. By the end of the semester most students, given a well-defined problem, can set up and solve material and energy balance equations, but they do not have a good understanding of how these calculations are related to actually designing chemical processes to make products.

Several years ago the chemical engineering faculty at UW—Madison decided to redesign our introductory course. Our goals were twofold: (1) to give the students a better flavor of how chemical processes convert raw materials to useful products and (2) to provide the students with an appreciation for the ways in which chemical engineers make decisions and balance constraints to come up with new processes and products. At the end of the semester, we wanted students to be able, with a minimum amount of information, to synthesize a chemical process flowsheet that would approximate real industrial processes. This includes selection of appropriate separation technology, determination of reasonable operating conditions, optimization of key process variables, integration of energy needs, and calculation of material and energy flows. This becomes possible at the introductory level through use of limiting cases, idealizations, approximations, and heuristics.

The modern approach equips students with the tools necessary for thinking about the creative strategies of chemical process synthesis and greatly enhances students' understanding of the connection between the *chemistry* and the *process*. It provides the students a framework for much of the rest of the curriculum: Students are more motivated to struggle through the rigor and abstraction of engineering science courses in thermodynamics, transport, and kinetics, because the connection between fundamental concepts and practical engineering problem solving has been made. Senior process design courses revisit the same terrain but at a more sophisticated level. Students learn that the principles of chemical processes, and the strategies of process synthesis and analysis, can be advantageously applied to an enormous diversity of problems, from intracellular trafficking of a drug to accumulation of pollutants in the ecosystem. The ready availability of easy-to-use computational tools means that students in an introductory course can tackle challenging and complex problems.

Organization

Many times, students decide to major in chemical engineering because they like chemistry and math, and are interested in practical applications. In designing this text, we have tried to keep this motivation in mind. We start right off the bat, in Chap. 1, providing a link to freshman chemistry courses. We show how simple stoichiometric concepts are used to make informed choices about raw materials and reaction pathways. Students should understand that engineering is not simply about doing calculations, but about using calculations wisely to make good choices. The idea of combining calculations, data and heuristics to make choices is a central theme throughout the text.

Chapter 2 introduces the simple but powerful idea of process flow sheeting as the chemical engineer's means to communicate ideas about raw materials, reaction chemistry, processing steps, and products. Here students learn the 10 Easy Steps for process flow calculations, and are introduced, in a very conceptual manner, to system variables, system and stream specifications, and material balances. Many example problems, drawn from a wide diversity of applications, are worked out in detail.

In Chap. 3 we revisit material balance equations, reaction stoichiometry, and process flow sheeting, but with a more rigorous and mathematical approach. Throughout, the text retains this spiral organization, in which we first reinforce concepts introduced in earlier chapters, and then expand and deepen student understanding of these concepts. In this chapter, material balance equations are derived from conservation-of-mass principles, using a format students will see in more advanced classes, and we do not shy away from transient processes. In optional sections, we demonstrate the power of linear algebra to find independent systems of chemical reactions, to determine the existence and uniqueness of solutions to systems of linear equations, and to develop flexible linear models of chemical processes.

Chapters 4 and 5 delve in greater depth into reactors and separators. Heuristics for synthesizing reactor and separation-train flow sheets are discussed. Quantitative measures of reactor and separator performance are introduced, and students learn how performance specifications influence process flow calculations and process design. Within this context, chemical reaction equilibrium and phase equilibrium are discussed in some detail. Students learn that equilibrium places constraints on the performance of reactors and separators, but also learn how to select process operating conditions and how to design around these constraints. Additionally, students gain considerable experience with using physical property data, graphs, and model equations.

Finally, Chap. 6 covers energy balance equations and process energy calculations. A 12 Easy Step strategy for attacking these problems is developed; the strategy is illustrated in many example problems. Students learn techniques for conserving energy resources wisely and safely.

!

?