chemical engineering curriculum, there seems to be no complete agreement as far as just what topics should be covered in the design course. The emphasis of the course can be significantly different at one school compared to another. This book does a very good job of covering what I, and I think probably most others, would consider the real core material, while providing a good framework for launching into most other types of material the instructor might want to cover. For example, I like to teach students a little about corporate financial analysis, culminating in them being asked to analyze a real company's financial data as reported to the SEC. This follows quite easily from the material on economic analysis in the text. I also try to provide students with some additional material on the mathematical modeling concepts and numerical methods underlying process simulation and optimization. Again, this follows very nicely from the material on simulation and optimization in the text. Overall, my feeling is that the material presented in this text provides a very sound core around which to teach a design course.

In addition to being a good text, this book also has features that should make it a particularly useful reference book for young and inexperienced engineers. These features include the compilation of cost data and correlations, and the tabulation and discussion of many rules-of-thumb for design and for process operation and improvement. Seniors who use the book in their process design class may well find continued use for it as they begin their careers in engineering.

The availability of this book represents an important new option when it comes to choosing a text for the process design course. As discussed above, I have foundthat it is a very well-written text providing excellent coverage of the core material in process design, and that it goes well beyond this to provide valuable features not found in other current texts. Many instructors may also appreciate the inclusion of some excellent design projects in the text (and the availability of additional projects from the authors). Faculty who teach process design should give this book strong consideration as a textbook for their course. ❐

ChE book review

Phase Equilibria: Measurement and Computation

by J. David Raal and Andreas L. Muhlbauer

Published by Taylor & Francis, 1900 Frost Road, Suite 101, Bristol, PA 19007-1598; 461 pages, $89.95 (1998)

Reviewed by
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I have long been looking for a book that would give equal attention to the experimental and computational aspects of phase behavior. Lately, this has become even more desirable since some of the most recent experimental methods are indirect and require substantial calculation in the reduction and analysis of data. Therefore, it was with a great deal of interest that I reviewed *Phase Equilibriq: Measurement and Computation* by Raal and Muhlbauer.

The coverage in the text is not as broad as one would expect from the title; only vapor-liquid (VLE) and binary liquid-liquid (LLE) equilibria are covered, and methods for mixtures containing polymers or electrolytes are not described. But this is more a criticism of the title than of the work since there is more than enough material in the authors' scope to fill a book.

The book is comprised of 18 chapters distributed in four parts: Low-Pressure Phase Equilibrium Measurements (Part 1, Chapters 1-4); High-Pressure Phase Equilibrium Measurements (Part 2, Chapters 5-9); Low-Pressure Phase Equilibrium Calculations (Part 3, Chapters 10-13); and Computation and Thermodynamic Interpretation of High-Pressure Vapor-Liquid Equilibrium (Part 4, Chapters 14-18).

Chapter 1 covers the thermodynamic fundamentals needed for an understanding of the experimental methods and computations. Definitions of partial molar properties, activity coefficients, fugacity coefficients and the like are given, and useful relations such as the coexistence equation and Gibbs-Duhem equation are derived. The level of detail is appropriate to the purpose of the book and only a small amount of extraneous information is given.

Chapter 2 covers the standard techniques for low-pressure VLE measurement and also includes discussions of semimicro techniques and the measurement of infinite dilution activity coefficients. Chapter 3 describes methods for measurement of LLE. These chapters, along with Chapters 6 and 7 (discussed later), are among the strongest in the book. The methods are described with ample line drawings and photographs and with textual detail that any experimenter will appreciate. The advantages and disadvantages of each technique are noted.

Gas chromatography is often used to determine compositions of coexisting phases, and the authors devote Chapter 4 to this subject. In addition to discussing response factors and composition analysis, the authors describe a technique developed by one of them to prepare standard gas mixtures for detector calibration. Enough detail is given that the reader could build the device.

After giving some background about high-pressure behavior in Chapter 5, the authors survey techniques for high-pressure phase equilibrium measurement in Chapters 6 (dynamic methods) and 7 (static methods). The coverage here is as detailed as in Chapters 2 and 3. In Chapter 8, the authors step the reader through the design, construction, and operation of an experimental facility for the measurement of high-

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point, so they avoided performing the numerical evaluation of the integral term.

FINAL REMARKS

The feedback from the students on this assignment was good. They liked working on a project that resembles a real-life problem. The time needed for writing the program and studying the results was not too long. Many of the findings outlined in the previous section were spotted by students. In any case, the alternative solution procedures and the results were finally discussed in the classroom.

The project proved to be very instructive, but it appears to be oversimplified for use at a graduate level. In this case, one may have a look at Diwekar's textbook[5] in order to get useful instructive material on advanced batch distillation design, simulation, and optimization.

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NOTATION

B	bottom product (kmol)
CAP	column capacity factor (kmol/h)
D	distillate product (kmol)
D_w	distillate product (kg)
F	feed charge (kmol)
P	column productivity (kg/h)
P_{max}	maximum column productivity (kg/h)
r	reflux ratio
t_{change}	changeover time (h)
t_{dist}	distillation time (h)
$\dot{V}$	vapor boilup rate (kmol/h)
x_B	reboiler composition (mole fraction)
$x_{B,end}$	final reboiler composition (mole fraction)
x_D	overhead vapor composition (mole fraction)
$\bar{x}_D$	average distillate product composition (mole fraction)
$\bar{x}_{D,spec}$	specification on the average distillate product composition (mole fraction)
x_F	feed composition (mole fraction)
α	relative volatility
Δ	increase
$\|k$	k-th time step

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pressure VLE and, in Chapter 9, they describe equilibrium cells for multiphase, high-pressure systems. The focus of both of these chapters is on the authors' own work, and it is written with a level of detail that one would typically find in a dissertation. Particular attention is given to experimental difficulties (usually related to sampling) and techniques to address them. For this reason, these chapters will be useful to anyone who plans to build a high-pressure apparatus—even one based on a different design.

Part 3 of the book covers low-pressure phase equilibria computations and includes chapters that cover correlative methods for activity coefficients (Chapter 10), flash calculations (Chapter 11), predictive methods for activity coefficients (Chapter 12), and liquid-liquid calculations (Chapter 13). Part 4 covers calculations at high pressure, including background information (Chapter 14), equation-of-state methods (Chapter 15), gamma-phi methods (Chapter 16), and mixing rules (Chapter 17). The book concludes with Chapter 18, which discusses thermodynamic consistency testing.

Parts 3 and 4 of the book do not have the breadth of *Phase Equilibria in Chemical Engineering* by Walas or of *Properties of Gases and Liquids* by Reid, Prausnitz, and Poling. But they are written at the depth of the former, and the breadth is consistent with the experimental techniques that are described. The discussions of mixing rules and consistency tests, and the relation between VLE and heat of mixing, are more detailed than are generally found in other books. Topics that aren't covered in extreme detail, such as methods for integrating the coexistence equation, are accompanied by enough references that the reader may find the details elsewhere.

This book will be of limited use as a textbook because it contains no exercises. But I believe that its coverage of experimental methods will be highly useful to anyone who measures phase equilibria. I know that it would have saved me months of work had it been available a number of years ago. The sections on computations will probably not (due to limited breadth) be a *primary* source of information on this topic, but they will be a useful supplement since they are current and cover several topics that are given only passing mention in other references.

I have additional criticism about the organization of the book, and I noticed a number of typographical errors and a missing figure. But the first criticism is probably a personal prejudice and the second should be fixed in the next printing. None of these minor complaints will prevent my copy of the book from receiving a lot of use. ❐