

Contents

Preface to the First Edition ix

Preface to the Third Edition xi

To the Instructor xiii

Interactive Chemical Process Principles xv

Nomenclature xvii

Glossary xx

PART 1 **ENGINEERING PROBLEM ANALYSIS** 1

Chapter 1 **What Some Chemical Engineers Do for a Living** 3

Chapter 2 **Introduction to Engineering Calculations** 7

- 2.0 Instructional Objectives 7
- 2.1 Units and Dimensions 8
- 2.2 Conversion of Units 9
- 2.3 Systems of Units 10
- 2.4 Force and Weight 12
- 2.5 Numerical Calculation and Estimation 13
- 2.6 Dimensional Homogeneity and Dimensionless Quantities 20
- 2.7 Process Data Representation and Analysis 22
- 2.8 Summary 30
- Problems 31

Chapter 3 **Processes and Process Variables** 42

- 3.0 Instructional Objectives 43
- 3.1 Mass and Volume 43
- 3.2 Flow Rate 45
- 3.3 Chemical Composition 47
- 3.4 Pressure 54
- 3.5 Temperature 60
- 3.6 Summary 63
- Problems 65

PART 2**Chapter 4****MATERIAL BALANCES 81**

Fundamentals of Material Balances	83
4.0 Instructional Objectives	83
4.1 Process Classification	84
4.2 Balances	85
4.3 Material Balance Calculations	89
4.4 Balances on Multiple-Unit Processes	104
4.5 Recycle and Bypass	110
4.6 Chemical Reaction Stoichiometry	116
4.7 Balances on Reactive Processes	125
4.8 Combustion Reactions	142
4.9 Some Additional Considerations about Chemical Processes	151
4.10 Summary	153
Problems	155

Chapter 5**Single-Phase Systems 187**

5.0 Instructional Objectives	188
5.1 Liquid and Solid Densities	189
5.2 Ideal Gases	191
5.3 Equations of State for Nonideal Gases	199
5.4 The Compressibility Factor Equation of State	206
5.5 Summary	213
Problems	214

Chapter 6**Multiphase Systems 237**

6.0 Instructional Objectives	239
6.1 Single-Component Phase Equilibrium	240
6.2 The Gibbs Phase Rule	247
6.3 Gas–Liquid Systems: One Condensable Component	249
6.4 Multicomponent Gas–Liquid Systems	255
6.5 Solutions of Solids in Liquids	264
6.6 Equilibrium Between Two Liquid Phases	271
6.7 Adsorption on Solid Surfaces	275
6.8 Summary	278
Problems	280

PART 3**Chapter 7****ENERGY BALANCES 311****Energy and Energy Balances 313**

7.0 Instructional Objectives	314
7.1 Forms of Energy: The First Law of Thermodynamics	315
7.2 Kinetic and Potential Energy	317
7.3 Energy Balances on Closed Systems	318

7.4	Energy Balances on Open Systems at Steady State	320
7.5	Tables of Thermodynamic Data	325
7.6	Energy Balance Procedures	329
7.7	Mechanical Energy Balances	333
7.8	Summary	337
	Problems	340

Chapter 8

Balances on Nonreactive Processes 357

8.0	Instructional Objectives	357
8.1	Elements of Energy Balance Calculations	358
8.2	Changes in Pressure at Constant Temperature	365
8.3	Changes in Temperature	366
8.4	Phase Change Operations	377
8.5	Mixing and Solution	395
8.6	Summary	406
	Problems	409

Chapter 9

Balances on Reactive Processes 440

9.0	Instructional Objectives	441
9.1	Heats of Reaction	442
9.2	Measurement and Calculation of Heats of Reaction: Hess's Law	445
9.3	Formation Reactions and Heats of Formation	447
9.4	Heats of Combustion	448
9.5	Energy Balances on Reactive Processes	450
9.6	Fuels and Combustion	464
9.7	Summary	473
	Problems	475

Chapter 10

Computer-Aided Balance Calculations 504

10.0	Instructional Objectives	504
10.1	Degree-of-Freedom Analysis Revisited	504
10.2	Sequential Modular Simulation	511
10.3	Equation-Based Simulation	522
10.4	Commercial Process Simulation Packages	533
10.5	Final Considerations	533
	Problems	534

Chapter 11

Balances on Transient Processes 543

11.0	Instructional Objectives	543
11.1	The General Balance Equation...Again	544
11.2	Material Balances	548
11.3	Energy Balances on Single-Phase Nonreactive Processes	554
11.4	Simultaneous Transient Balances	560
11.5	Summary	563
	Problems	564

PART 4**Chapter 12****CASE STUDIES 577****Production of Chlorinated Polyvinyl Chloride 579**

PVC Chlorination Reaction Chemistry 580

Process Description 581

Problems 584

Chapter 13**Steam Reforming of Natural Gas
and Subsequent Synthesis of Methanol 591**

Process Description 592

Problems 595

Chapter 14**Scrubbing of Sulfur Dioxide from Power Plant Stack Gases 607**

Process Description 603

Problems 605

Appendix A**Computational Techniques 607**

A.1 The Method of Least Squares 607

A.2 Iterative Solution of Nonlinear Algebraic Equations 610

A.3 Numerical Integration 622

Appendix B**Physical Property Tables 627**

B.1 Selected Physical Property Data 628

B.2 Heat Capacities 635

B.3 Vapor Pressure of Water 638

B.4 Antoine Equation Constants 640

B.5 Properties of Saturated Steam: Temperature Table 642

B.6 Properties of Saturated Steam: Pressure Table 644

B.7 Properties of Superheated Steam 650

B.8 Specific Enthalpies of Selected Gases: SI Units 652

B.9 Specific Enthalpies of Selected Gases: American Engineering Units 652

B.10 Atomic Heat Capacities for Kopp's Rule 653

B.11 Integral Heats of Solution and Mixing at 25°C 653

Answers to Test Yourselfs 655**Answers to Selected Problems 665****Index 669**