Table of Contents

- 1 Some Basic Notions: Rates of Mass Transfer p. 1
- 1.1 Gradient-Driven and Forced Transport p. 2
- 1.1.1 The Rate Laws p. 2
- 1.1.2 The Transport Diffusivities p. 5
- 1.1.3 The Gradient p. 7
- 1.1.4 Simple Integrations of Fick's Law p. 14
- 1.2 Transport Driven by a Potential Difference (Constant Gradient): The Film Concept and the Mass Transfer Coefficient p. 21
- 1.2.1 Units of the Potential and of the Mass Transfer Coefficient p. 24
- 1.2.2 Equimolar Diffusion and Diffusion through a Stagnant Film: The Log-Mean Concentration Difference p. 26
- 1.2.2.1 Equimolar Counterdiffusion p. 27
- 1.2.2.2 Diffusion through a Stagnant Film p. 27
- 1.3 The Two-Film Theory p. 33
- 1.3.1 Overall Driving Forces and Mass Transfer Coefficients p. 36
- 1.3.1.1 Comments p. 38
- Practice Problems p. 42
- 2 Modeling Mass Transport: The Mass Balances p. 51
- 2.1 The Compartment or Stirred Tank and the One-Dimensional Pipe p. 51
- 2.2 The Classification of Mass Balances p. 62
- 2.2.1 The Role of Balance Space p. 62
- 2.2.2 The Role of Time p. 63
- 2.2.2.1 Unsteady Integral Balances p. 63
- 2.2.2.2 Cumulative (Integral) Balances p. 63
- 2.2.2.3 Unsteady Differential Balances p. 64
- 2.2.3 Dependent and Independent Variables p. 64
- 2.3 Information Obtained from Model Solutions p. 76
- 2.4 Setting Up Partial Differential Equations p. 78
- 2.5 The General Conservation Equations p. 90
- Practice Problems p. 99
- 3 Diffusion through Gases, Liquids, and Solids p. 107
- 3.1 Diffusion Coefficients p. 107
- 3.1.1 Diffusion in Gases p. 107
- 3.1.2 Diffusion in Liquids p. 111
- 3.1.3 Diffusion in Solids p. 118
- 3.1.3.1 Diffusion of Gases through Polymers and Metals p. 118
- 3.1.3.2 Diffusion of Gases through Porous Solids p. 126
- 3.1.3.3 Diffusion of Solids in Solids p. 134
- Practice Problems p. 137
- 4 More about Diffusion: Transient Diffusion and Diffusion with Reaction p. 143
- 4.1 Transient Diffusion p. 143
- 4.1.1 Source Problems p. 145
- 4.1.2 Nonsource Problems p. 157
- 4.1.2.1 Diffusion into a Semi-Infinite Medium p. 157

- 4.1.2.2 Diffusion in Finite Geometries: The Plane Sheet, the Cylinder, and the Sphere p. 161
- 4.1.2.3 Diffusion in Finite Geometries: The "Short-Time" and "Long-Time" Solutions p. 166
- 4.2 Diffusion and Reaction p. 170
- 4.2.1 Reaction and Diffusion in a Catalyst Particle p. 171
- 4.2.2 Gas-Solid Reactions Accompanied by Diffusion: Moving-Boundary Problems p. 171
- 4.2.3 Gas-Liquid Systems: Reaction and Diffusion in the Liquid Film p. 172
- Practice Problems p. 186
- 5 More about Mass Transfer Coefficients p. 195
- 5.1 Dimensionless Groups p. 196
- 5.2 Mass Transfer Coefficients in Laminar Flow: Extraction from the PDE Model p. 200
- 5.2.1 Mass Transfer Coefficients in Laminar Tubular Flow p. 201
- 5.2.2 Mass Transfer Coefficients in Laminar Flow around Simple Geometries p. 203
- 5.3 Mass Transfer in Turbulent Flow: Dimensional Analysis and the Buckingham [Pi] Theorem p. 206
- 5.3.1 Dimensional Analysis p. 206
- 5.3.2 The Buckingham [Pi] Theorem p. 207
- 5.4 Mass Transfer Coefficients for Tower Packings p. 216
- 5.5 Mass Transfer Coefficients in Agitated Vessels p. 222
- 5.6 Mass Transfer Coefficients in the Environment: Uptake and Clearance of Toxic Substances in Animals The Bioconcentration Factor p. 226
- Practice Problems p. 231
- 6 Phase Equilibria p. 239
- 6.1 Single-Component Systems: Vapor Pressure p. 240
- 6.2 Multicomponent Systems: Distribution of a Single Component p. 246
- 6.2.1 Gas-Liquid Equilibria p. 246
- 6.2.2 Liquid and Solid Solubilities p. 251
- 6.2.3 Fluid-Solid Equilibria: The Langmuir Isotherm p. 253
- 6.2.4 Liquid-Liquid Equilibria: The Triangular Phase Diagram p. 264
- 6.2.5 Equilibria Involving a Supercritical Fluid p. 270
- 6.2.6 Equilibria in Biology and the Environment: Partitioning of a Solute between Compartments p. 274
- 6.3 Multicomponent Equilibria: Distribution of Several Components p. 276
- 6.3.1 The Phase Rule p. 276
- 6.3.2 Binary Vapor-Liquid Equilibria p. 277
- 6.3.2.1 Phase Diagrams p. 277
- 6.3.2.2 Ideal Solutions and Raoult's Law: Deviation from Ideality p. 280
- 6.3.2.3 Activity Coefficients p. 282
- 6.3.3 The Separation Factor [alpha]: Azeotropes p. 284
- Practice Problems p. 293
- 7 Staged Operations: The Equilibrium Stage p. 299
- 7.1 Equilibrium Stages p. 301
- 7.1.1 Single-Stage Processes p. 301
- 7.1.2 Single-Stage Differential Operation p. 307

- 7.2 Staged Cascades p. 313
- 7.2.1 Crosscurrent Cascades p. 313
- 7.3.1 The Mixer-Settler Configuration p. 330
- 7.2.2 Countercurrent Cascades p. 320
- 7.2.3 Countercurrent Cascades: The Linear Case and the Kremser Equation p. 323
- 7.3 The Equilibrium Stage in the Real World p. 330
- 7.3.2 Gas-Liquid Systems: The Tray Tower p. 331
- 7.3.3 Staged Liquid Extraction Again: The Karr Column p. 332
- 7.3.4 Staged Leaching: Oil Extraction from Seeds p. 333
- 7.3.5 Staged Washing of Solids (CCD) p. 335
- 7.4 Multistage Distillation p. 336
- 7.4.1 Continuous Fractional Distillation p. 337
- 7.4.2 Mass and Energy Balances: Equimolar Overflow and Vaporization p. 339
- 7.4.3 The McCabe-Thiele Diagram p. 341
- 7.4.4 Minimum Reflux Ratio and Number of Plates p. 346
- 7.4.4.1 Comments p. 348
- 7.4.5 Column and Tray Parameters p. 356
- 7.4.6 Limiting Flow Rates: Column Diameter p. 358
- 7.4.6.1 Gas or Vapor Flow Rates p. 359
- 7.4.6.2 Liquid Velocities p. 360
- 7.4.6.3 Lower Limits p. 360
- 7.4.6.4 Comments p. 360
- 7.4.7 Batch Fractional Distillation: Model Equations and Some Simple Algebraic Calculations p. 360
- 7.4.7.1 Distillation at Constant x[subscript D], Variable R p. 362
- 7.4.7.2 Distillation at Constant R, Variable x[subscript D] p. 364
- 7.4.7.3 Multicomponent Batch Distillation (Forget McCabe-Thiele, Part 2) p. 366
- 7.5 Percolation Processes p. 367
- 7.6 Stage Efficiencies p. 370
- 7.6.1 Distillation and Absorption p. 370
- 7.6.2 Extraction p. 372
- 7.6.3 Adsorption and Leaching p. 372
- 7.6.4 Percolation Processes p. 373
- Practice Problems p. 376
- 8 Continuous-Contact Operations p. 385
- 8.1 Packed-Column Operation p. 386
- 8.1.1 The Countercurrent Gas Scrubber Revisited p. 387
- 8.1.1.1 Comments p. 390
- 8.1.2 The Countercurrent Gas Scrubber Again: Analysis of the Linear Case p. 391
- 8.1.2.1 Comments p. 394
- 8.1.3 Packed Column Characteristics p. 395
- 8.1.3.1 Main Features p. 395
- 8.1.3.2 Relation between HTU and HETP p. 396
- 8.1.3.3 Operational Parameters p. 396
- 8.1.3.4 Comparison of Packed and Tray Columns p. 398
- 8.1.4 Liquid-Liquid Extraction in a Packed Column p. 403

- 8.2 Membrane Processes p. 411
- 8.2.1 Membrane Structure, Configuration, and Applications p. 413
- 8.2.2 Process Considerations and Calculations p. 418
- Practice Problems p. 433
- 9 Simultaneous Heat and Mass Transfer p. 439
- 9.1 The Air-Water System: Humidification and Dehumidification, Evaporative Cooling p. 440
- 9.1.1 The Wet-Bulb Temperature p. 440
- 9.1.2 The Adiabatic Saturation Temperature and the Psychrometric Ratio p. 441
- 9.1.3 Model for Countercurrent Air-Water Contact: The Water Cooling Tower p. 448
- 9.1.3.1 Water Balance Over Gas Phase (kg H[superscript 2]O/mls) p. 448
- 9.1.3.2 Water Balance Over Water Phase p. 449
- 9.1.3.3 Gas-Phase Energy Balance (kJ/m[superscript 2]s) p. 450
- 9.1.3.4 Liquid-Phase Energy Balance (kJ/m[superscript 2]s) p. 450
- 9.2 Drying Operations p. 455
- 9.3 Heat Effects in a Catalyst Pellet: The Nonisothermal Effectiveness Factor p. 462
- 9.3.1 Comments p. 465
- Practice Problems p. 467
- Selected References p. 469
- Appendix A1 The D-Operator Method p. 475
- Appendix A2 Hyperbolic Functions and ODEs p. 477
- Index p. 479