Contents

Preface to the Second Edition *v*

1. Introduction **1–8**

1.1 Mass Transfer *1*
1.2 Theoretical Foundation *3*
1.3 Equipment and Methods of Operation *4*
1.4 Membrane Separations *7*

2. Molecular Diffusion **9–60**

2.1 Definitions of Diffusion Terms *10*
2.2 Fick's Law of Diffusion *12*
2.3 Steady-State Molecular Diffusion in Gases *15*
2.4 A General Equation for Steady-State Diffusion *29*
2.5 Diffusion in Multicomponent Mixtures *29*
2.6 Molecular Diffusion in Liquids *31*
2.7 Prediction of Binary Diffusivities *33*
2.8 Diffusivity in Solids *43*
2.9 Unsteady-State Diffusion *46*
Review Questions *48*
Multiple Choice Questions *49*
Exercises *53*

3. Convective Transport and Interphase Mass Transfer **61–138**

3.1 Mass Transfer Coefficients *61*
3.2 Theories of Mass Transfer *68*
3.3 Dimensional Analysis *74*
3.4 Boundary Layer Theory *79*
3.5 Analogy between Heat, Mass and Momentum Transfer *84*
3.6 Wetted-Wall Column *94*
3.7 Mass Transfer Correlations *95*
3.8 Phase Equilibrium *99*
3.9 Two-Resistance Theory *101*
3.10 Method of Contacting of the Phases *115*
Review Questions *121*
Multiple Choice Questions *122*
Exercises *127*

4. Gas Absorption **139–261**

4.1 Absorption Equipment *140*
4.2 Absorption Equilibrium: Solubility of Gases *153*

4.3 Choice of Solvent *160*
4.4 Material Balance *161*
4.5 Countercurrent Multistage Columns *176*
4.6 Plate Efficiency *190*
4.7 Absorption in Packed Columns *196*
4.8 Absorption with Chemical Reaction *240*
Review Questions *240*
Multiple Choice Questions *242*
Exercises *251*

5. Distillation **262–447**

5.1 Introduction *262*
5.2 Vapour-Liquid Equilibria *264*
5.3 Distillation Methods: Classification *286*
5.4 Flash Vaporisation *286*
5.5 Simple Distillation *294*
5.6 Steam Distillation *302*
5.7 Fractionation of Binary Mixtures *308*
5.8 McCabe-Thiele Method *320*
5.9 Enthalpy-Composition Diagrams *361*
5.10 Ponchon-Savarit Method *367*
5.11 Packed Columns for Distillation *385*
5.12 Fractionation of Partially Miscible Mixtures *390*
5.13 Azeotropic and Extractive Distillation *391*
5.14 Pressure-Swing Distillation *394*
Review Questions *395*
Multiple Choice Questions *398*
Exercises *418*

6. Humidification Operations **448–515**

6.1 Vapour-Liquid Equilibrium for Pure Substances *449*
6.2 Definitions *451*
6.3 Humidity Chart *458*
6.4 Adiabatic Saturation Temperature *462*
6.5 Wet-Bulb Temperature *465*
6.6 Cooling Towers *471*
6.7 Adiabatic Humidification *491*
6.8 Dehumidification *495*
Review Questions *499*
Multiple Choice Questions *500*
Exercises *505*

7. Liquid–Liquid Extraction **516–607**

7.1 Importance of Extraction *517*
7.2 Liquid Equilibria *519*
7.3 Choice of Solvent *534*
7.4 Extraction Equipment *536*

7.5 Immiscible Systems: Stage Contact *547*
7.6 Partially Miscible Systems: Stage Contact *557*
7.7 Extraction with Reflux *577*
7.8 Continuous Contact Extractors *583*
Review Questions *588*
Multiple Choice Questions *589*
Exercises *594*

8. Leaching **608–666**

8.1 Industrial Applications *608*
8.2 Rate of Leaching *609*
8.3 Classification of Leaching Methods *612*
8.4 Fixed Bed Percolation Equipment *613*
8.5 Moving Bed Percolation Equipment *617*
8.6 Immersion Type Batch Extractors *620*
8.7 Immersion-Type Continuous Extractors *621*
8.8 Leaching Equilibrium *625*
8.9 Calculations for Leaching Stages *630*
8.10 Super-Critical Fluid Extraction *651*
Review Questions *653*
Multiple Choice Questions *654*
Exercises *658*

9. Drying **667–766**

9.1 Drying Equilibrium *668*
9.2 Classification of Dryers *675*
9.3 Batch Dryers *678*
9.4 Continuous Dryers *683*
9.5 Dielectric and Microwave Dryers *696*
9.6 General Drying Behaviour *698*
9.7 Theoretical Estimation of Drying Rate and Time *715*
9.8 Tray-drying with Varying Air Conditions *721*
9.9 Through Circulation Drying in Packed Beds *722*
9.10 Continuous Drying *727*
9.11 Freeze Drying *737*
Review Questions *738*
Multiple Choice Questions *740*
Exercises *746*

10. Adsorption **767–840**

10.1 Industrial Applications *767*
10.2 Physical Adsorption and Chemisorption *768*
10.3 Properties of Adsorbents *769*
10.4 Industrial Adsorbents *769*
10.5 Adsorption Equilibrium *770*
10.6 Adsorbent Regeneration *785*
10.7 Adsorption Equipment *788*

10.8 Stage Contact Operations *794*
10.9 Fixed-bed Adsorption *809*
10.10 Moving Bed Adsorption *819*
Review Questions *823*
Multiple Choice Questions *824*
Exercises *828*

11. Crystallisation **841–877**

11.1 Crystals and Crystal Geometry *842*
11.2 Equilibrium Solubility *843*
11.3 Yield and Purity of Products *844*
11.4 Heat Effects in Crystallisation Process *847*
11.5 Supersaturation *850*
11.6 Nucleation *852*
11.7 Crystal Growth *854*
11.8 Crystallisation Equipment *857*
11.9 The MSMPR Crystalliser *862*
Review Questions *867*
Multiple Choice Questions *868*
Exercises *871*

12. Membrane Separations **878–934**

12.1 Definitions *879*
12.2 Membranes *881*
12.3 Membrane Modules *888*
12.4 Concentration Polarisation and Fouling *897*
12.5 Classification of Membrane Separation Processes *898*
12.6 Microfiltration *900*
12.7 Ultrafiltration *903*
12.8 Nanofiltration *906*
12.9 Reverse Osmosis *907*
12.10 Pervaporation *912*
12.11 Dialysis *917*
12.12 Electrodialysis *918*
12.13 Gas Permeation *924*
Review Questions *927*
Multiple Choice Questions *928*

Answers to Objective Questions (MCQs) **935–937**

References **939–943**

Appendices **945–959**

Appendix A: Activity Coefficient Models *945*
Appendix B: Antoine Constants *951*
Appendix C: Properties of Steam, Water and Air *952*

Index **961–974**