

Douglas M. Ruthven  
Shamsuzzaman Farooq  
Kent S. Knaebel

# Pressure Swing Adsorption

 WILEY-VCH

# Contents

**List of Symbols**    xi

**Greek Symbols**    xv

**Subscripts**    xvii

**Figure Credits**    xix

- 1. Introduction**    1
  - 1.1 Historical Development of PSA Processes    4
  - 1.2 General Features of a PSA Process    5
  - 1.3 Major Applications of PSA    7
  - References    9
  
- 2. Fundamentals of Adsorption**    11
  - 2.1 Adsorbents    11
  - 2.2 Adsorption Equilibrium    23
  - 2.3 Adsorption Kinetics    34
  - 2.4 Adsorption Column Dynamics    52
  - References    63
  
- 3. PSA Cycles: Basic Principles**    67
  - 3.1 Elementary Steps    67
  - 3.2 Equilibrium-Controlled Separations for the Production of Pure Raffinate Product    71

3.3	Recovery of the More Strongly Adsorbed Species in Equilibrium-Controlled Separations	83
3.4	Cycles for the Recovery of Pure Raffinate Product in Kinetically Controlled Separations	85
3.5	Cycle for Recovery of the Rapidly Diffusing Species	93
	References	94
<b>4.</b>	<b>Equilibrium Theory of Pressure Swing Adsorption</b>	<b>95</b>
4.1	Background	95
4.2	Mathematical Model	97
4.3	Model Parameters	102
4.4	Cycle Analysis	105
4.5	Experimental Validation	133
4.6	Model Comparison	137
4.7	Design Example	143
4.8	Heat Effects	148
4.9	Pressurization and Blowdown Steps	151
4.10	Conclusions	161
	References	163
<b>5.</b>	<b>Dynamic Modeling of a PSA System</b>	<b>165</b>
5.1	Summary of the Dynamic Models	166
5.2	Details of Numerical Simulations	184
5.3	Continuous Countercurrent Models	201
5.4	Heat Effects in PSA Systems	207
	References	217
<b>6.</b>	<b>PSA Processes</b>	<b>221</b>
6.1	Air Drying	221
6.2	Production of Oxygen	226
6.3	Production of Nitrogen	230
6.4	PSA Process for Simultaneous Production of O <sub>2</sub> and N <sub>2</sub>	232
6.5	Hydrogen Recovery	235
6.6	Recovery of CO <sub>2</sub>	242
6.7	Recovery of Methane from Landfill Gases	244
6.8	Hydrocarbon Separations	246
6.9	Process for Simultaneous Production of H <sub>2</sub> and CO <sub>2</sub> from Reformer Off-Gas	246
6.10	PSA Process for Concentrating a Trace Component	251
6.11	Efficiency of PSA Processes	258
	References	263
<b>7.</b>	<b>Extensions of the PSA Concept</b>	<b>265</b>
7.1	The Pressure Swing Parametric Pump	265
7.2	Thermally Coupled PSA	270

7.3	Single-Column Rapid PSA System	278
7.4	Future Prospects	286
	References	287
<b>8.</b>	<b>Membrane Processes: Comparison with PSA</b>	<b>289</b>
8.1	Permeability and Separation Factor	289
8.2	Membrane Modules	295
8.3	Calculation of Recovery–Purity Profiles	299
8.4	Cascades for Membrane Processes	301
8.5	Comparison of PSA and Membrane Processes for Air Separation	303
8.6	Future Prospects	305
	References	306
<b>Appendix A.</b>	<b>The Method of Characteristics</b>	<b>307</b>
	References	311
<b>Appendix B.</b>	<b>Collocation Form of the PSA Model Equations</b>	<b>313</b>
B.1	Dimensionless Form of the LDF Model Equations	313
B.2	Collocation Form of the Dimensionless LDF Model Equations	315
B.3	Dimensionless Form of the Pore Diffusion Model Equations (Table 5.6)	318
B.4	Collocation Form of the Dimensionless Pore Diffusion Model Equations	320
<b>Appendix C.</b>	<b>Synopsis of PSA Patent Literature</b>	<b>327</b>
C.1	Introduction	327
C.2	Inventors and Patents	328
C.3	Concluding Remarks	338
<b>Index</b>	<b>345</b>	