Process Science and Engineering for Water and Wastewater Treatment

Series Editor **Professor Tom Stephenson**

Volume Editor **Dr. Simon Judd**





Contents

Process Technologies Series		
School of Water Sciences at Cranfield University		viii x xi xii
Editors		
How to		
Introdu Water a		
Unit 1	Fundamentals of Water Chemistry	1
1.1	Introduction	5
1.2	Chemical Building Blocks	6
1.3	Measurement of Concentration	11
1.4 1.5	Electrochemistry Chemical Calculations in Water Treatment	16
1.6		21 23
1.7	Key Reactions in Water Treatment Self Assessment Questions	23 26
1.8	Glossary of Terms	20 27
1.9	Solutions to Exercises	29
Unit 2	Chemical Kinetics and Equilibria	31
2.1	Introduction	35
2.2	Kinetics	36
2.3	Equilibrium	38
2.4	Solution	40
2.5	Alkalinity and Hardness	<i>4</i> 5
2.6	Self Assessment Questions	52
2.7	Nomenclature	53
2.8	Solutions to Exercises	54
Unit 3	Colloid and Surface Chemistry	55
3.1	Introduction	59
3.2 3.3	Particles Transport	60
3.4	Transport Surface Electrical Properties	63 66
3. 4 3.5	Colloid Stability	70
3.6	Self Assessment Questions	70 74
3.7	Nomenclature	7 4 75
3.8	Solutions to Exercises	76
Unit 4	Fundamentals of Microbiology	77
4.1	Introduction	81
4.2	The Kingdom of the Protists	82
4.3	Conditions for Microbial Growth	90
4.4	Self Assessment Questions	93
4.5	Nomenclature	94
4.6	Solutions to Exercises	95

Unit 5	Fundamentals of Biochemistry	97
5.1	Introduction	101
5.2	From Microbiology to Biochemistry	102
5.2 5.3	Metabolism	105
5.4	Self Assessment Questions	108
5.5	Nomenclature	109
5.6	Solutions to Exercises	111
linit 6	Microbial Vination	113
Unit 6	Microbial Kinetics	113
6.1	Introduction	
6.2	Microbial Kinetics	118
6.3	Continuous Cultures	123
6.4	Self Assessment Questions	126
6.5	Nomenclature	127
6.6	Solutions to Exercises	128
Unit 7	Fundamentals of Process Engineering	129
7.1	Introduction	133
7.2	Dimensions and Units	134
7.2	Elements of Process Engineering	139
7.3 7.4	Elements of Process Design	142
7. 4 7.5	Self Assessment Questions	148
7.5 7.6	Nomenclature	149
	Solutions to Exercises	149 150
7.7	Solutions to Exercises	750
Unit 8	Mass and Heat Balances	151
8.1	Introduction	155
		155 156
8.1	Introduction Processes and Systems Mass Balance Calculations	
8.1 8.2	Processes and Systems	156
8.1 8.2 8.3 8.4	Processes and Systems Mass Balance Calculations Heat Balance Calculations	156 158
8.1 8.2 8.3 8.4 8.5	Processes and Systems Mass Balance Calculations Heat Balance Calculations Self Assessment Questions	156 158 163 166
8.1 8.2 8.3 8.4	Processes and Systems Mass Balance Calculations Heat Balance Calculations	156 158 163
8.1 8.2 8.3 8.4 8.5 8.6 8.7	Processes and Systems Mass Balance Calculations Heat Balance Calculations Self Assessment Questions Nomenclature Solutions to Exercises	156 158 163 166 169 170
8.1 8.2 8.3 8.4 8.5 8.6 8.7	Processes and Systems Mass Balance Calculations Heat Balance Calculations Self Assessment Questions Nomenclature Solutions to Exercises Introductory Mass and Heat Transfer	156 158 163 166 169 170
8.1 8.2 8.3 8.4 8.5 8.6 8.7 Unit 9 9.1	Processes and Systems Mass Balance Calculations Heat Balance Calculations Self Assessment Questions Nomenclature Solutions to Exercises Introductory Mass and Heat Transfer Introduction	156 158 163 166 169 170 173
8.1 8.2 8.3 8.4 8.5 8.6 8.7 Unit 9 9.1 9.2	Processes and Systems Mass Balance Calculations Heat Balance Calculations Self Assessment Questions Nomenclature Solutions to Exercises Introductory Mass and Heat Transfer Introduction Mass Transfer Mechanisms	156 158 163 166 169 170 173 177
8.1 8.2 8.3 8.4 8.5 8.6 8.7 Unit 9 9.1 9.2 9.3	Processes and Systems Mass Balance Calculations Heat Balance Calculations Self Assessment Questions Nomenclature Solutions to Exercises Introductory Mass and Heat Transfer Introduction Mass Transfer Mechanisms Heat Transfer	156 158 163 166 169 170 173 177 178
8.1 8.2 8.3 8.4 8.5 8.6 8.7 Unit 9 9.1 9.2 9.3 9.4	Processes and Systems Mass Balance Calculations Heat Balance Calculations Self Assessment Questions Nomenclature Solutions to Exercises Introductory Mass and Heat Transfer Introduction Mass Transfer Mechanisms Heat Transfer Self Assessment Questions	156 158 163 166 169 170 173 177 178 184 189
8.1 8.2 8.3 8.4 8.5 8.6 8.7 Unit 9 9.1 9.2 9.3	Processes and Systems Mass Balance Calculations Heat Balance Calculations Self Assessment Questions Nomenclature Solutions to Exercises Introductory Mass and Heat Transfer Introduction Mass Transfer Mechanisms Heat Transfer	156 158 163 166 169 170 173 177 178 184 189
8.1 8.2 8.3 8.4 8.5 8.6 8.7 Unit 9 9.1 9.2 9.3 9.4	Processes and Systems Mass Balance Calculations Heat Balance Calculations Self Assessment Questions Nomenclature Solutions to Exercises Introductory Mass and Heat Transfer Introduction Mass Transfer Mechanisms Heat Transfer Self Assessment Questions	156 158 163 166 169 170 173 177 178 184 189
8.1 8.2 8.3 8.4 8.5 8.6 8.7 Unit 9 9.1 9.2 9.3 9.4 9.5 9.6	Processes and Systems Mass Balance Calculations Heat Balance Calculations Self Assessment Questions Nomenclature Solutions to Exercises Introductory Mass and Heat Transfer Introduction Mass Transfer Mechanisms Heat Transfer Self Assessment Questions Nomenclature Solutions to Exercises	156 158 163 166 169 170 173 177 178 184 189 190
8.1 8.2 8.3 8.4 8.5 8.6 8.7 Unit 9 9.1 9.2 9.3 9.4 9.5 9.6	Processes and Systems Mass Balance Calculations Heat Balance Calculations Self Assessment Questions Nomenclature Solutions to Exercises Introductory Mass and Heat Transfer Introduction Mass Transfer Mechanisms Heat Transfer Self Assessment Questions Nomenclature Solutions to Exercises Reactor Design Theory	156 158 163 166 169 170 173 177 178 184 189 190 191
8.1 8.2 8.3 8.4 8.5 8.6 8.7 Unit 9 9.1 9.2 9.3 9.4 9.5 9.6	Processes and Systems Mass Balance Calculations Heat Balance Calculations Self Assessment Questions Nomenclature Solutions to Exercises Introductory Mass and Heat Transfer Introduction Mass Transfer Mechanisms Heat Transfer Self Assessment Questions Nomenclature Solutions to Exercises Reactor Design Theory Introduction	156 158 163 166 169 170 173 177 178 184 189 190 191
8.1 8.2 8.3 8.4 8.5 8.6 8.7 Unit 9 9.1 9.2 9.3 9.4 9.5 9.6 Unit 10 10.1 10.2	Processes and Systems Mass Balance Calculations Heat Balance Calculations Self Assessment Questions Nomenclature Solutions to Exercises Introductory Mass and Heat Transfer Introduction Mass Transfer Mechanisms Heat Transfer Self Assessment Questions Nomenclature Solutions to Exercises Reactor Design Theory Introduction Mass Balance	156 158 163 166 169 170 173 177 178 184 189 190 191
8.1 8.2 8.3 8.4 8.5 8.6 8.7 Unit 9 9.1 9.2 9.3 9.4 9.5 9.6 Unit 10 10.1 10.2 10.3	Processes and Systems Mass Balance Calculations Heat Balance Calculations Self Assessment Questions Nomenclature Solutions to Exercises Introductory Mass and Heat Transfer Introduction Mass Transfer Mechanisms Heat Transfer Self Assessment Questions Nomenclature Solutions to Exercises Reactor Design Theory Introduction Mass Balance Idealised Reactors	156 158 163 166 169 170 173 177 178 184 189 190 191
8.1 8.2 8.3 8.4 8.5 8.6 8.7 Unit 9 9.1 9.2 9.3 9.4 9.5 9.6 Unit 10 10.1 10.2 10.3 10.4	Processes and Systems Mass Balance Calculations Heat Balance Calculations Self Assessment Questions Nomenclature Solutions to Exercises Introductory Mass and Heat Transfer Introduction Mass Transfer Mechanisms Heat Transfer Self Assessment Questions Nomenclature Solutions to Exercises Reactor Design Theory Introduction Mass Balance Idealised Reactors Reactor Design Worked Example	156 158 163 166 169 170 173 177 178 184 189 190 191 191 198 199 208
8.1 8.2 8.3 8.4 8.5 8.6 8.7 Unit 9 9.1 9.2 9.3 9.4 9.5 9.6 Unit 10 10.1 10.2 10.3 10.4 10.5	Processes and Systems Mass Balance Calculations Heat Balance Calculations Self Assessment Questions Nomenclature Solutions to Exercises Introductory Mass and Heat Transfer Introduction Mass Transfer Mechanisms Heat Transfer Self Assessment Questions Nomenclature Solutions to Exercises Reactor Design Theory Introduction Mass Balance Idealised Reactors Reactor Design Worked Example Self Assessment Questions	156 158 163 166 169 170 173 177 178 184 189 190 191 193 199 208 210
8.1 8.2 8.3 8.4 8.5 8.6 8.7 Unit 9 9.1 9.2 9.3 9.4 9.5 9.6 Unit 10 10.1 10.2 10.3 10.4	Processes and Systems Mass Balance Calculations Heat Balance Calculations Self Assessment Questions Nomenclature Solutions to Exercises Introductory Mass and Heat Transfer Introduction Mass Transfer Mechanisms Heat Transfer Self Assessment Questions Nomenclature Solutions to Exercises Reactor Design Theory Introduction Mass Balance Idealised Reactors Reactor Design Worked Example	156 158 163 166 169 170 173 177 178 184 189 190 191 197 198 199 208

Unit 11	Engineering Hydraulics	213
11.1	Introduction	217
11.2	Fluid Mechanics	218
11.3	Practical Applications	221
11.4	Flow in Open Channels	226
11.5	Flow Through Porous Media	229
11.6	Pumps and Pumping	234
11.7	Hydraulic Profiling	238
11.8	Self Assessment Questions	241
11.9	Nomenclature	243
11.10	Solutions to Exercises	244
Unit 12	Particle Settlement	247
12.1	Introduction	251
12.2	Sedimentation Theory	252
12.3	Self Assessment Questions	257
12.4	Nomenclature	258
12.5	Solutions to Exercises	259
Solution	ns to Self Assessment Questions	261