Contents

Preface xiii

Chapter 1. Filtration of Liquids and Gases Screening of Divided Solids 1

1.1. General considerations 1
1.1.1. Fundamental parameters 1
1.1.2. Pressure drop across a bed of spherical particles 4
1.1.3. General laws of filtration 7
1.1.4. Purging the cake 8
1.1.5. Equivalent pore: a useful concept 10
1.2. Liquid filters 10
1.2.1. Partially immersed filter cloth 10
1.2.2. Projecting the pre-filter solution on to a belt filter cloth 13
1.2.3. Choice of liquid filter 15
1.3. Centrifugal spin-drying (liquid–solid suspensions) 16
1.3.1. Theoretical background 16
1.4. Deep-bed filtration of liquids 24
1.5. Filtration of gases 25
1.5.1. Aerosols heavily laden with dust (bag filters) 25
1.5.2. High-efficiency filters (HEFs) 26
1.6. Evacuation of the liquid by compression 27

1.7. Screening 27
1.7.1. General considerations 27
1.7.2. Screens 28
1.7.3. Vibrating screens 29
1.7.4. Screening surface 30
1.7.5. Characteristics of the feed to a vibrating screen 31
1.7.6. Working parameters and manufacture parameters 34
1.7.7. Screen-performance criteria 34
1.7.8. Aforementioned considerations in quantitative terms 35

Chapter 2. Theory of Membrane Filtration 41

2.1. Introduction 41
2.1.1. Convective filtration: definition 41
2.2. Single solute and electrically inert membrane 43
2.2.1. Definitions 43
2.2.2. Polarization layer, and observable- and intrinsic transmissions 44
2.2.3. Thickness of the polarization layer 46
2.2.4. Case of large molecules, macromolecules, microparticles 48
2.2.5. Intrinsic transmission (in the membrane) 48
2.2.6. Variations in the observable transmission 51
2.2.7. Apparition of a gel 53
2.2.8. The Maxwell–Stefan equation and dialysis (see discussion in section 4.2, Vol. 1) 54
2.2.9. Practical equations 59
2.2.10. Expression of the rejection using the practical equations 60
2.2.11. Pervaporation 62
2.2.12. Industrial applications of filtration on an electrically inert membrane 62
2.3. The membrane and the solutes are electrically charged 63
2.3.1. Prior conventions: notations 63
2.3.2. Dielectrical exclusion 65
2.3.3. The fixed charge of the membranes: influence of pH 67

2.3.4. Effectiveness coefficient of the fixed charge . . . 69
2.3.5. Mobility of ions in the membrane . . . 70
2.3.6. The supplemented Nernst–Plank equation (SNP) . . . 71
2.3.7. Numerical resolution of the DMC system of equations . . . 73
2.3.8. The approximate calculations presented by Dresner . . . 75
2.3.9. Influence of pore radius . . . 76
2.3.10. Transport of electrolytes across a charged membrane . . . 77
2.3.11. Structure of pores and rejection . . . 77
2.3.12. At least three different g-ions . . . 79
2.3.13. Additional information . . . 80
2.4. Electrohydraulic values . . . 81
2.4.1. Electro-osmotic parameters: specific cases . . . 81
2.4.2. Mobility, diffusivity, conductivity, transport number . . . 83
2.4.3. Measuring the potential ζ (see section 5.1.2) . . . 84
2.4.4. The flow potential . . . 85
2.5. Fouling of membranes . . . 86
2.5.1. Introduction . . . 86
2.5.2. Adsorption of organics and colloids . . . 87
2.5.3. Partial blocking (braking) of the filtrate in the pores by adsorption . . . 89
2.5.4. Scale formation by inorganic substances . . . 92
2.5.5. Total blocking of the pores by the particles . . . 93
2.5.6. Partial blocking by the particles (hindrance by arching): formation of filtration cake . . . 95
2.5.7. Cleansing of fouled surfaces . . . 96
2.5.8. Depending on the type of industry . . . 96
2.5.9. Empirical laws governing fouling . . . 97
2.5.10. Prediction and prevention of fouling . . . 98
2.5.11. Biofilms . . . 98

Chapter 3. Theory of Dialysis-Biological Membranes – Electrodialysis . . . 101

3.1. Introduction . . . 101
3.1.1. Means of crossing a membrane separating two solutions at the same pressure . . . 101
3.1.2. Liquid membranes . . . 102

3.2. Electrically neutral solutes 102
3.2.1. The Maxwell–Stefan equation in a membrane 102
3.2.2. Influence of the molecular diameter 104
3.2.3. Crossing of the membrane. 105
3.3. Electrically charged membrane: conventions 105
3.3.1. Preliminary hypotheses 105
3.3.2. Definitions 106
3.4. Ionic concentrations inside and outside the membrane 107
3.4.1. Donnan equilibrium (ions of whatever valence) 107
3.4.2. Donnan exclusion. 108
3.4.3. Total potential different and Donnan potentials 109
3.4.4. Case study (monovalent ions) 109
3.5. Internal potential and concentrations 111
3.5.1. Calculation of the internal potential: ions all monovalent 111
3.5.2. Flux density of each ion 114
3.5.3. Electrical neutrality of the total ionic flux 114
3.5.4. Isotonic solutions 115
3.5.5. Practical calculation of the internal potential and of the ionic fluxes 116
3.5.6. Profiles of the internal potential and concentrations 117
3.5.7. Transport of a single compound 118
3.5.8. Numerical integration of the diffusion/migration equations 119
3.6. Assisted permeation 121
3.6.1. Definition 121
3.6.2. General 121
3.6.3. Case study I: the supporting reaction is at equilibrium at all points 124
3.6.4. Case study II: the diffusions of B and AB are quasi-instantaneous in comparison to the reaction rate. 125
3.7. Permeation by the tunnel effect 126
3.7.1. Principle 126
3.8. Hemodialysis 127
3.8.1. Definition 127
3.8.2. Material transfer 128

3.9. Electrodialysis 128
3.9.1. Principle 128
3.9.2. Transport number 130
3.9.3. Electrical resistance of the membrane 131
3.9.4. Electrical resistance of a cell 133
3.9.5. Ion-transfer equation 136
3.9.6. Limiting current density 139
3.9.7. Transference and permselectivity of a membrane 141
3.9.8. Transport number of water 142
3.9.9. Current yield 143
3.9.10. Bipolar membranes 146

Chapter 4. Fractionation of Dispersions by Natural Decantation (by Gravity) 147

4.1. Decantation rate 147
4.1.1. General 147
4.1.2. Limiting velocity of a lone particle 148
4.1.3. Division of the height between the clear liquid and the sediment 149
4.1.4. Friction velocity of liquid-on-solid 151
4.1.5. Decantation velocity of a particle cloud 152
4.2. Decanters in the chemical industry 153
4.2.1. Types of decanters 153
4.2.2. Test in a test chamber 154
4.2.3. Characteristic curves of decantation (extrapolation) 154
4.2.4. Horizontal surface of a decanter 157
4.2.5. Recap 158
4.2.6. Height of a decanter 160
4.2.7. Flux density of the solid 160
4.2.8. Torque of the scraper (circular decanters) 162
4.3. Decanters in ore extraction 164
4.3.1. Grooved tables 164
4.3.2. Multi-component hydraulic sorter 165
4.3.3. Jigs 166
4.3.4. Classification by dense liquor (gravimetric sorting) 166
4.3.5. Helical differential decantation (Humphrey system) 167

Chapter 5. Destabilization of Sols (Colloidal Dispersions), Coagulation and Flocculation 169

5.1. Colloidal dispersions: the double layer. 169
5.1.1. Introduction 169
5.1.2. Charge, surface potential and ζ potential 170
5.1.3. The Stern–Hamburg rigid layer 172
5.1.4. Diffuse layer: potential profile 173
5.1.5. Electrophoresis of colloids 179
5.1.6. Osmotic pressure of dispersions of colloids 181
5.2. Adsorption in the double layer 181
5.2.1. Definitions 181
5.2.2. Variations of the IEP and PZC with adsorption 183
5.2.3. Recap on the influence of pH 183
5.2.4. Specific adsorption of ions at the surface of the particles. 186
5.2.5. Adsorption of polymers: flocculation 187
5.3. Interaction between two particles 190
5.3.1. Hamaker's law 190
5.3.2. Attraction and repulsion between two particles supposed to be spherical and identical 192
5.3.3. Coagulation of sols according to Ostwald 194
5.4. Practice of destabilization 196
5.4.1. Destabilization methods 196
5.4.2. Gibbs energy of interaction of two particles; critical temperature. 196
5.4.3. Frequency of clumping and energy barrier 198
5.4.4. Collision mechanisms 200
5.4.5. Predominant collision mechanism 204
5.4.6. Destabilization by trapping 206
5.4.7. Recap of the distinction between coagulation and flocculation 206
5.4.8. Smoluchowski kinetics 207
5.5. Destabilizing adjuvants 209
5.5.1. Ions as adjuvants 209
5.5.2. Polymer adjuvants 210

Chapter 6. Flotation: Froth Columns 213

6.1. Flotation. 213
6.1.1. Principle of flotation 213
6.1.2. Fixation between bubbles and ore particles 214

6.1.3. Criteria for the occurrence of flotation 215
6.1.4. Dispersion of air in the cell 217
6.1.5. Collectors 218
6.1.6. Other adjuvants 219
6.1.7. Flowrate of solid brought to the froth from the pulp 220
6.1.8. Flowrate in terms of number of particles in the froth 221
6.1.9. Diameter of bubbles in the froth 222
6.1.10. Concentration of the pulp: material balance 223
6.1.11. Flotation parameters 223
6.1.12. Battery of cells. 223
6.1.13. Uses of flotation 224
6.1.14. Additional indications 225
6.1.15. Particle diameter. 225
6.2. Froth columns 226
6.2.1. Operation. 226

Chapter 7. Expulsion of a Liquid by Pressing 229

7.1. Mechanism for pressing inorganic DSs 229
7.1.1. An ideal representation: unidirectional pressing. 229
7.1.2. Law for pressing solids 230
7.1.3. Pressure of fluids 231
7.1.4. Theoretical process of pressing. 232
7.1.5. Equipment used for pressing inorganic dispersions 233
7.2. Pressing of plant matter. 234
7.2.1. Advantage of pressing 234
7.2.2. Terminology 234
7.2.3. Mechanism of pressing 235
7.3. Equipment used for pressing plants. 237
7.3.1. Hydraulic press 237
7.3.2. Continuous screw press 237
7.3.3. Other continuous presses 240
7.3.4. Characteristics of oilseeds. 241
7.3.5. Maximum pressure depending on product 241
7.3.6. Pressing adjuvants 242
7.3.7. Factors influencing the yield when pressing oils 243

Appendices 245

Appendix 1. Numerical Integration 4th-order Runge–Kutta Method 247

Appendix 2. The CGS Electromagnetic System 249

Appendix 3. Characteristics of Screening Surfaces 253

Appendix 4. Definition and Aperture of Sieve Cloths 255

Bibliography 257

Index 269