## **Contents**

## Preface — v

1	Flow characteristics (rheology) of colloidal dispersions —— 1
1.1	Introduction —— 1
1.2	Rheological techniques —— 1
1.2.1	Steady state shear stress $\sigma$ -shear rate $\gamma$ measurements — 1
1.2.2	Rheological models for analysis of flow curves —— 3
1.2.3	Time effects during flow - thixotropy and negative (or anti-)
	thixotropy —— 5
1.2.4	Strain relaxation after sudden application of stress -
	constant stress (creep) measurements — 7
1.2.5	Stress relaxation after sudden application of strain —— 10
1.2.6	Dynamic (oscillatory) measurements —— 12
1.3	Rheology of colloidal dispersions —— 17
1.3.1	The Einstein equation —— 18
1.3.2	The Bachelor equation —— 18
1.3.3	Rheology of concentrated dispersions — 18
1.4	Examples of strongly flocculated (coagulated) suspension —— 34
1.4.1	Coagulation of electrostatically stabilized suspensions
	by addition of electrolyte —— <b>34</b>
1.4.2	Strongly flocculated sterically stabilized systems —— 36
1.4.3	Models for interpretation of rheological results —— 40
2	Wetting and spreading —— 45
2.1	Introduction —— 45
2.2	The concept of contact angle —— 47
2.3	Adhesion tension —— 49
2.4	Work of adhesion $W_a \longrightarrow 50$
2.5	Work of cohesion —— 51
2.6	Calculation of surface tension and contact angle —— 51
2.6.1	Good and Girifalco approach —— 52
2.6.2	Fowkes treatment —— 53
2.7	The spreading of liquids on surfaces —— 55
2.7.1	The spreading coefficient S —— 55
2.7.2	Contact angle hysteresis —— 56
2.7.3	Reasons for hysteresis —— 57
2.7.4	Wenzel's equation —— 57
2.7.5	Surface heterogeneity —— 58
2.8	The critical surface tension of wetting —— 59



2.9	Theoretical basis of the critical surface tension —— <b>60</b>
2.10	Effect of surfactant adsorption —— 61
2.11	Wetting of powders by liquids —— 62
2.12	Rate of penetration of liquids: The Rideal-Washburn equation —— 63
2.13	Measurement of contact angles of liquids and surfactant solutions
	on powders 64
2.14	Assessment of wettability of powders —— 65
2.14.1	Sinking time, submersion or immersion test —— 65
2.14.2	List of wetting agents for hydrophobic solids in water — 65
2.15	Measurement of contact angles on flat surfaces —— 66
2.15.1	Sessile drop or adhering gas bubble method — 66
2.15.2	Wilhelmy plate method —— 67
2.15.3	Capillary rise at a vertical plate —— 68
2.15.4	Tilting plate method —— 69
2.15.5	Capillary rise or depression method —— 69
2.16	Wetting kinetics — 70
2.17	The dynamic contact angle —— 70
2.18	Effect of viscosity and surface tension —— 73
3	Solid/liquid dispersions (suspensions) —— 75
3.1	Introduction —— 75
3.2	Preparation of suspension concentrates
	by the bottom-up process —— 83
3.2.1	Nucleation and growth —— 85
3.2.2	Precipitation kinetics —— 87
3.2.3	Seeded nucleation and growth —— 92
3.2.4	Surface modification —— 92
3.2.5	Other methods for preparation of suspensions by the bottom-up
	process — 93
3.3	Preparation of suspensions using the top-down process —— 96
3.3.1	Wetting of the bulk powder —— 97
3.3.2	Breaking of aggregates and agglomerates into individual units —— 101
3.3.3	Wet milling or comminution —— 107
3.3.4	Stabilization of the suspension during dispersion and milling
	and the resulting nanosuspension —— 111
3.4	Prevention of Ostwald ripening (crystal growth) —— 115
3.5	Sedimentation of suspensions and prevention of formation
	of hard sediments —— <b>123</b>
4	Liquid/liquid dispersions (emulsions) —— 145
4.1	Introduction —— 145
4.2	Thermodynamics of emulsion formation and breakdown —— 148

4.3	Interaction forces between emulsion droplets and factors
	affecting their stability — 153
4.4	Mechanism of emulsification and the role of the emulsifier —— 155
4.5	Methods of emulsification — 162
4.6	Selection of emulsifiers — 172
4.7	Creaming/sedimentation of emulsions and its prevention — 181
4.8	Flocculation of emulsions — 196
4.9	Ostwald ripening in emulsions and its prevention — 206
4.10	Emulsion coalescence and its prevention —— 213
4.11	Phase inversion and its prevention —— 223
5	Multiple emulsions —— 235
5.1	Introduction —— 235
5.2	Preparation of multiple emulsions —— 236
5.3	Types of multiple emulsions and their breakdown processes —— 237
5.4	Factors affecting stability of multiple emulsions and criteria
	for their stabilization —— 239
5.5	Polymeric surfactants used for preparation
	of multiple emulsions —— <b>240</b>
5.6	Interaction between oil or water droplets containing an adsorbed
	polymeric surfactant – steric stabilization — 242
5.7	Examples of multiple emulsions using polymeric surfactants —— 249
5.8	Characterization of multiple emulsions —— 250
5.8.1	Droplet size measurements —— 250
5.8.2	Rheological measurements —— 251
6	Gas (air)/liquid dispersions (foams) —— 255
6.1	Introduction —— 255
6.2	Foam preparation —— 255
6.3	Foam structure —— 256
6.4	Classification of foam stability —— 258
6.5	Drainage and thinning of foam films —— 259
6.6	Theories of foam stability —— 262
6.6.1	Surface viscosity and elasticity theory — 262
6.6.2	The Gibbs-Marangoni effect theory —— 262
6.6.3	Surface forces theory (disjoining pressure $\pi$ ) — 263
6.6.4	Stabilization by micelles (high surfactant concentrations > cmc) — 266
6.6.5	Stabilization by lamellar liquid crystalline phases — 267
6.6.6	Stabilization of foam films by mixed surfactants — 267
6.7	Foam inhibitors —— 267
6.7.1	Chemical inhibitors that lower viscosity and increase drainage —— 267
6.7.2	Solubilized chemicals which cause antifoaming — 268

6.7.3	Droplets and oil lenses which cause antifoaming and
	defoaming —— 268
6.7.4	Surface tension gradients (induced by antifoamers) —— 269
6.7.5	Hydrophobic particles as antifoamers —— 270
6.7.6	Mixtures of hydrophobic particles and oils as antifoamers —— 270
6.8	Physical properties of foams —— 271
6.8.1	Mechanical properties —— 271
6.8.2	Rheological properties —— 271
6.8.3	Electrical properties —— 272
6.8.4	Electrokinetic properties —— 273
6.8.5	Optical properties —— 273
6.9	Experimental techniques for studying foams —— 273
6.9.1	Techniques for studying foam films —— 273
6.9.2	Techniques for studying structural parameters of foams —— 274
6.9.3	Measuring foam drainage —— 275
6.9.4	Measuring foam collapse —— 275
7	Liquid/solid dispersions (gels) —— 277
7.1	Introduction —— 277
7.2	Classification of gels —— 277
7.3	Gel-forming materials —— 278
7.4	Rheological behaviour of a "gel" —— 279
7.4.1	Stress relaxation (after sudden application of strain) —— 279
7.4.2	Constant stress (creep) measurements —— 281
7.4.3	Dynamic (oscillatory) measurements —— 282
7.5	Polymer gels —— 282
7.5.1	Physical gels obtained by chain overlap —— 282
7.5.2	Gels produced by associative thickeners —— 284
7.5.3	Crosslinked gels (chemical gels) —— 287
7.6	Particulate gels —— 288
7.6.1	Aqueous clay gels —— 288
7.6.2	Organo-clays (bentones) —— 291
7.6.3	Oxide gels —— 292
7.7	Gels produced by mixtures of polymers and finely divided particulate
	solids —— <b>293</b>
7.8	Gels based on surfactant systems —— 294
8	Polymer colloids (latexes) —— 297
8.1	Introduction —— 297
8.2	Emulsion polymerization —— 297
8.3	Polymeric surfactants for stabilizing preformed
<del>-</del>	later dispersions — 307

8.4	Dispersion polymerization —— <b>311</b>
8.5	Particle formation in polar media —— 316
0.5	Farticle formation in polar media —— 316
9	Microemulsions —— 319
9.1	Introduction —— 319
9.2	Thermodynamic definition of microemulsions —— 320
9.3	Mixed film and solubilization theories of microemulsions —— 321
9.3.1	Mixed film theories —— 321
9.3.2	Solubilization theories —— 323
9.4	Thermodynamic theory of microemulsion formation —— 325
9.4.1	Reason for combining two surfactants —— 325
9.4.2	Free energy of formation of a microemulsion —— 326
9.4.3	Factors determining W/O versus O/W microemulsions —— 328
9.5	Characterization of microemulsions using scattering techniques —— 330
9.5.1	Time-average (static) light scattering —— 330
9.5.2	Calculating droplet size from interfacial area —— 333
9.5.3	Dynamic light scattering (photon correlation spectroscopy, PCS) —— 333
9.5.4	Neutron scattering —— 335
9.5.5	Contrast matching for determining the structure of
	microemulsions —— 335
9.6	Characterization of microemulsions using conductivity —— 336
9.7	NMR measurements —— 339
9.8	Formulation of microemulsions —— <b>339</b>
10	Liposomes and vesicles —— 343
10.1	Introduction —— 343
10.2	Nomenclature of liposomes and their classification —— 344
10.3	Driving force for formation of vesicles —— 345
11	Deposition of particles at interfaces and their adhesion —— 351
11.1	Introduction —— 351
11.2	Particle deposition —— 352
11.3	Effect of polymers and polyelectrolytes on particle deposition —— 357
11.4	Experimental methods for studying kinetics
- <b></b> •	of particle deposition —— 360
11.5	Linear deposition regime —— 363
11.6	Nonlinear particle deposition (high coverage) —— 370
11.7	Particle deposition on heterogeneous surfaces — 375
11.8	Particle-surface adhesion —— 378
11.8.1	Fox and Zisman critical surface tension approach —— 380
11.8.2	Neumann's equation of state approach —— 380

12	Characterization, assessment and prediction of stability
	of colloidal dispersions —— 385
12.1	Introduction —— 385
12.2	Assessment of the structure of the solid/liquid interface —— 386
12.3	Measurement of surfactant and polymer adsorption — 389
12.4	Assessment of creaming/sedimentation of dispersions —— 391
12.5	Assessment of flocculation —— 395
12.6	Measurement of Ostwald ripening —— 409
12.7	Assessment of coalescence of emulsions —— 410
12.8	Bulk properties of dispersions: Equilibrium sediment or cream volume
	(or height) and redispersion —— 410
12.9	Application of rheological techniques for the assessment and prediction
	of the physical stability of dispersions —— <b>411</b>
12.9.1	Rheological techniques for predicting sedimentation or creaming
	and syneresis —— 411
12.9.2	Prediction of emulsion creaming —— 414
12.9.3	Assessment and prediction of flocculation using rheological
	techniques —— 416
12.9.4	Assessment and prediction of emulsion coalescence
	using rheological techniques —— 422

Index —— 429