

Contents

1	Disperse Systems, Colloidal Systems, and their Classification	1
1.1	Common Feature of Dispersions	1
1.2	Particle Size and Chemical Bonding	2
1.3	Classification of Two-phase Disperse Systems	5
	Exercises	7
	References	7
2	Thermodynamics of Interfaces	9
2.1	Two-phase Systems	9
2.1.1	Thermodynamic Approach	9
2.1.2	Computer Simulation of Interfaces	17
2.2	Monolayers and Bilayers	20
2.2.1	Gibbs' Monolayer	20
2.2.2	Insoluble Monolayers	22
	Exercises	27
	References	29
3	Homogeneous Nucleation	32
3.1	Importance of Homogeneous Nucleation	32
3.2	Classical Nucleation Theory	32
3.3	New Approaches to Nucleation Theory	37
3.4	Atomistic Model of Nucleation Theory	40
	Exercises	41
	References	42
4	Physical Behavior of colloidal Particles	43
4.1	Brownian Motion	43
4.1.1	Translational Brownian Motion	43
4.1.2	Rotational Brownian Motion	52
4.1.3	Brownian Motion in Concentrated Suspension	60
4.2	Response to a Static Electric Field	65

VIII *Contents*

4.3	Response to a Time-dependent Electric Field	67
4.4	Response to Mechanical Stress	69
	Exercises	73
	References	74
5	Fractal and Brownian Motion	76
5.1	Fractal	76
5.2	Fractal and Dimension	78
5.3	Brownian Fractal Dimension	80
5.4	Power Law (Scaling Invariance)	81
	Exercises	83
	References	84
6	Determination of Practical Size	85
6.1	Microscopic Observation	85
6.1.1	Optical Microscopes	85
6.1.2	Transmission Electron Microscope	86
6.1.3	Scanning Microscope	86
6.2	Light Scattering for Particle Sizing	88
6.2.1	Classical Light Scattering	88
6.2.1.1	Rayleigh and Rayleigh-Gans-Debye Scattering	89
6.2.1.2	Mie Scattering	95
6.2.2	Frequency Broadening and Photon Correlation	95
6.2.2.1	Brownian Motion and Frequency Broadening	95
6.2.2.2	Autocorrelation Function and Line Shape for a Symmetric Top (Dilute Monodisperse Systems)	98
6.2.2.3	Photon Correlation in Slightly Dense Monodisperse Systems	104
6.2.2.4	Higher-order Correlation Functions	105
6.3	Small-angle X-Ray Scattering	108
6.4	Small-angle Neutron Scattering	114
6.5	Sedimentation Methods	119
6.6	The Coulter Counter	121
6.7	Hydrodynamic Chromatography (HDC)	122
	Exercises	123
	References	125
7	Particle Size Distribution and Monodisperse Sols	128
7.1	Particle Size Distribution	128
7.2	Monodisperse Systems	132
	Exercises	140
	References	141

8	Dispersion Forces	142
8.1	The Work of Adhesion and Cohesion and Dispersion Forces	142
8.1.1	The Work of Adhesion and Cohesion	142
8.1.2	van der Waals' Forces	143
8.1.3	Effects of Electrolytes on Dispersion Forces	156
8.2	Numerical Evaluations of Lifshitz' Theory and Experiments on Dispersion Forces	157
8.2.1	Numerical Evaluations of $\epsilon(iv)$	157
8.2.2	Experiments on van der Waals' Forces	159
	Exercises	160
	References	163
9	Micelles, Vesicles, and Bilayers	164
9.1	Thermodynamics of Self-Assembly	164
9.2	The Critical Micelle (or Micellization) Concentration (CMC)	169
9.3	Bilayers and Vesicles	171
9.4	Geometric Packing or Size of a Hydrocarbon Chain in a Micelle	171
9.5	Spectroscopic Technique for Investigating Micelles	172
9.5.1	Methods for determining the CMC	173
9.5.2	Methods for Determining the Aggregation Number	173
9.5.2.1	Scattering Method	173
9.5.2.2	Fluorescence Method	173
9.5.2.3	Time-resolved Fluorescence Method	174
9.5.2.4	Other Methods for Sizing	174
9.6	Micellar Dynamics	175
9.6.1	Fast Relaxation Time, τ_1	175
9.6.2	Slow Relaxation Time, τ_2	177
9.6.3	Residence Time of Micelles	178
	Exercises	179
	References	179
10	Electrostatic and Electrokinetic Phenomena	181
10.1	The Electric Stress Tensor in a Compressible Fluid	181
10.2	Ions in Liquid Dielectric and Electric Double Layer	184
10.2.1	The Poisson-Boltzmann Equation and the Debye-Hückel Approximation	184
10.2.2	The Electric Double Layer	186
10.2.3	Stern Layer or the Compact Layer	188
10.2.4	Electrocapillarometer	191
10.2.5	Test of the Poisson-Boltzmann Equation	192
10.3	Interacting Planer Double Layers	193
10.3.1	Symmetric Case	193
10.3.2	Flat Particles with Dissimilar Double Layers	196

10.4	Interaction between Charged Spheres	197
10.4.1	For Large Values of κa (~ 2.5)	197
10.4.2	For Small Values of κa	202
10.5	Electrokinetic Phenomena	203
10.5.1	ζ (zeta)-potential	204
10.5.2	Electro-osmosis and Streaming Potential	204
10.5.3	Electrophoresis	206
10.6	Measurement of ζ -potentials	210
10.7	Electrical Conductivity of Dilute Dispersions	213
	Exercises	214
	References	217
11	Stability of Dispersions	219
11.1	DLVO Theory	219
11.2	Kinetics of Coagulations	222
11.2.1	Homocoagulation	222
11.2.2	Heterocoagulation	225
11.3	Polymer or Steric Stabilization of Dispersions	226
11.4	Stability of Liquid Droplets in Liquid (Emulsion)	232
11.5	Stability of Aerosols	236
11.6	Stability of Bubbles and Foams	236
	Exercises	239
	References	241
12	Emulsions and Microemulsions	244
12.1	Inversion	244
12.2	The Hydrophile-Lipophile Balance (HLB), Factors Determining Types of Emulsions	246
12.3	Electrical Conductivity of an Emulsion	247
12.4	Droplet Size Distribution and Emulsion Preparation	248
12.4.1	Condensation under Mechanical Agitation	248
12.4.2	Emulsion Polymerization	249
12.4.3	Phase-inversion Temperature Method	249
12.5	Creaming or Sedimentation	250
12.6	Microemulsion	253
	Exercises	255
	References	256
13	Gels	257
13.1	Structure of Gels	257
13.2	Growth of Aggregates	258
13.3	Sol-Gel Transition (Gelation)	261
13.3.1	The Kinetic Theory	261

13.3.2	Percolation	264
13.4	Mechanical Properties of Gels	267
13.5	Chemical Potential of Solvent in Gels	271
13.6	Rheological Properties of Gels	274
13.7	Applications of Gels	274
	Exercises	275
	References	276
14	Aerosols	278
14.1	Formation of Aerosols	278
14.1.1	Homogeneous Nucleation of Vapor and Nucleation by Ions	279
14.1.2	Particle Growth Rate by Condensation	280
14.2	Particle Growth by Brownian Coagulation	283
14.2.1	Detailed Conditions in Coagulation Processes	283
14.2.2	Growth due to Coagulation	286
14.3	Coagulation in Shear Flows	287
14.4	Evaporation of Aerosols	289
14.5	Thermophoresis	290
14.6	Diffusiophoresis	291
14.7	Particle Capture	292
14.7.1	Capture Efficiency and the Filter Coefficient	292
14.7.2	Capture by a Sphere	293
14.7.3	Capture by a Cylinder (Fibrous Filter)	295
14.8	Effects of Inertia, Interactions, Diffusion on Capture Efficiency	297
14.8.1	Inertia and Hydrodynamics and Interparticle Interactions	297
14.8.2	Capture of Brownian Particles	300
14.9	Scavenging by Falling Water Drops	304
	Exercises	306
	References	307
Subject Index		309