

Contents

Foreword	XI
Preface	XIII
1 Introduction	1
2 Basic Equations: Determination of the Coefficients of Emission in Nucleation Theory	7
2.1 Introduction	7
2.2 Basic Kinetic Equations	9
2.3 Ratio of the Coefficients of Absorption and Emission of Particles	10
2.3.1 Traditional Approach	11
2.3.2 A New Method of Determination of the Coefficients of Emission	16
2.3.3 Applications	22
2.4 Generalization to Multicomponent Systems	22
2.4.1 Traditional Approach	23
2.4.2 New Approach	24
2.4.3 Applications	25
2.5 Generalization to Arbitrary Boundary Conditions	26
2.6 Initial Conditions for the Cluster-Size Distribution Function	28
2.7 Description of Cluster Ensemble Evolution along a Given Trajectory	30
2.7.1 Motivation	30
2.7.2 Effective Diffusion Coefficients	31
2.7.3 Evolution of the Cluster-Size Distribution Functions	36
2.8 Conclusions	37
3 Kinetics of Nucleation–Growth Processes: The First Stages	39
3.1 Introduction	39
3.2 Basic Kinetic Equations	41
3.3 Nonsteady-State Effects in the Initial Stage of Nucleation	46
3.3.1 Approximative Solution in the Range $1 \lesssim n \lesssim n_c - \delta n_c$	47
3.3.2 Time Scale of Establishment of Steady-State Cluster-Size Distributions in the Range $1 \lesssim n \lesssim n_c - \delta n_c$	50
3.3.3 Results for the Range $n_c - \delta n_c \lesssim n \lesssim n_c + \delta n_c$	51

3.3.4	Steady-State Nucleation Rate and Steady-State Cluster-Size Distribution in the Range $1 \lesssim n \lesssim n_c + \delta n_c$	51
3.4	Flux and Cluster Distributions in the Range of Supercritical Cluster Sizes	54
3.4.1	Results in the Range $n_c \lesssim n \lesssim 8n_c$	55
3.4.2	Results in the Range $n \gtrsim 8n_c$	57
3.5	Time Interval for Steady-State Nucleation	65
3.5.1	Kinetically Limited Growth	66
3.5.2	Diffusion-Limited Growth	68
3.5.3	Nonsteady-State Time Lag and the Time Scale of Steady-State Nucleation	68
3.6	Further Basic Characteristics of Nucleation–Growth Processes	69
3.6.1	Number of Clusters Formed by Nucleation	69
3.6.2	Average Size of the Clusters	70
3.6.3	Time Interval of Independent Growth	71
3.7	Time of Steady-State Nucleation and Induction Time	73
3.8	Formation of a New Phase with a Given Stoichiometric Composition	76
3.8.1	The Model	76
3.8.2	Basic Equations	76
3.8.3	Applications	81
3.9	Summary of Results	86
3.9.1	Results for the Range of Cluster Sizes $n \lesssim n_c$	86
3.9.2	Results for the Range of Cluster Sizes $n \gtrsim n_c$	87
3.9.3	Integral Characteristics of the Nucleation–Growth Process	89
3.10	Conclusions	91
4	Theory of the Late Stages of Nucleation–Growth Processes: Ostwald Ripening	93
4.1	Coarsening	93
4.1.1	Introduction: Formulation of the Problem	93
4.1.2	Asymptotic Behavior of the Critical Cluster Size	96
4.1.3	Asymptotic Behavior of the Distribution Function	100
4.1.4	Boundary Effects and Theory of Sintering	105
4.1.5	Diffusive Decomposition Involving Different Mass-transfer Mechanisms	109
4.1.6	Effects of Competition of Several Mass-Transfer Mechanisms	113
4.1.7	Asymptotic Stability of Solid Solutions	119
4.2	Rigorous Analysis of the Transformation of an Arbitrary Initial Distribution Function into a Universal One	125
4.2.1	Introduction	125
4.2.2	Canonical Form of the Basic System of Equations	125
4.2.3	Coarsening in the Case of Power-Dependent Initial Cluster Size Distributions	131
4.2.4	Coarsening in the Case of Exponentially Decaying Initial Cluster-Size Distributions	135
4.2.5	Generalizations	141
4.3	Theory of Diffusive Decomposition of Multicomponent Solutions	143
4.3.1	Introduction	143
4.3.2	Basic Equations and Their Solution	144

4.3.3	Regions of Phase Coexistence in Composition Space	152
4.3.4	Competition of Different Phases in Coarsening	156
4.3.5	Formation of Precipitates of Nonstoichiometric Composition	161
4.3.6	Comparison with Experimental Data	163
4.3.7	Conclusions	165
5	Shapes of Cluster-Size Distributions Evolving in Nucleation and Growth Processes	171
5.1	Introduction	171
5.2	Analysis of Statistical Approaches: "Equilibrium Distribution" of Classical Nucleation Theory, Fisher's Droplet, and Similar Models	172
5.3	Thermodynamic Approach: On the Possibility of Evolution of Monodisperse Cluster-Size Distributions	175
5.4	Dynamical Approach	178
5.4.1	Basic Kinetic Equations: General Expression	178
5.4.2	Determination of the Coefficients of Emission	179
5.4.3	Determination of the Coefficients of Aggregation	181
5.4.4	Description of Growth Processes of Clusters	181
5.4.5	Application to the Description of Nucleation	184
5.4.6	Basic Kinetic Equations for Different Important Growth Mechanisms	185
5.5	Numerical Solution of the Kinetic Equations	187
5.5.1	Precipitation in a Perfect Solution	187
5.5.2	Effect of Nonlinear Inhibition of Cluster Growth on the Shape of the Cluster-Size Distributions	192
5.5.3	Application of Fisher's Expression for the Work of Cluster Formation	196
5.6	Selected Applications and Conclusions	198
5.7	Discussion	201
6	Coarsening Under the Influence of Elastic Stresses and in Porous Materials	203
6.1	Introduction	203
6.2	Cluster Growth and Coarsening Under the Influence of Elastic Stresses Due to Cluster-Matrix Interactions	205
6.2.1	Models of Elastic Stress in Cluster Growth and Coarsening	205
6.2.2	Theoretical Description of Coarsening at a Nonlinear Increase of the Energy of Elastic Deformations with Cluster Volume: A First Approach	206
6.3	Ostwald Ripening in a System of Nondeformable Pores of Equal Size R_0	208
6.3.1	Mathematical Formulation of the Problem and General Solution	208
6.3.2	Approximations and Numerical Results	211
6.4	Coarsening in a System of Weak Pores	216
6.5	Coarsening in a System of Nondeformable Pores with a Given Pore-Size Distribution	219
6.5.1	A First Approximation	219
6.5.2	General Approach: Description of the Method	221
6.5.3	Results	223

6.6	Influence of Stochastic Effects on Coarsening in Porous Materials	224
6.7	Discussion	225
7	Cluster Formation and Growth in Segregation Processes at Given Input Fluxes of Monomers and Under the Influence of Radiation	227
7.1	Introduction	227
7.2	Coarsening with Input Fluxes of Raw Material	228
7.2.1	Preliminary Estimates	228
7.2.2	Basic Kinetic Equations	230
7.2.3	Results of the Numerical Solution of the Kinetic Equations	232
7.2.4	Discussion	235
7.3	Void Ripening in the Presence of Bulk Vacancy Sources	237
7.3.1	Introduction	237
7.3.2	Basic Equations	237
7.3.3	Damped Sources	239
7.3.4	Undamped Sources	243
7.3.5	Conclusions	247
7.4	Growth and Shrinkage of Precipitates under Irradiation	247
7.4.1	Introduction	247
7.4.2	Diffusion Mechanism of Radiation-Induced Shrinkage of the Precipitates	248
7.4.3	Effect of the Precipitate Incoherence and the Solute Atom Transition into the Interstitial Sites and Back in the Lattice Sites	251
7.4.4	The Case of Incoherent Precipitation	255
7.4.5	Conclusion	256
8	Formation of a Newly Evolving Phase with a Given Stoichiometric Composition	257
8.1	Introduction	257
8.2	Basic Set of Equations	259
8.3	The Stage of Nucleation of Clusters of the Newly Evolving Phase	264
8.4	The Transient Stage	272
8.5	Kinetic Equations and Thermodynamic Relationships Accounting for Solute–Solute Interactions	275
8.6	Rate of Change of the Number of Structural Elements of an Aggregate of the New Phase	280
8.7	The Coefficient of Components Mass Transfer	282
8.8	Steady-State Nucleation Rate	285
8.9	Influence of Interaction of the Solute Components on Coarsening Processes	288
8.10	Discussion and Conclusion	289
9	Nucleation and Growth of Gas-Filled Bubbles in Liquids	291
9.1	Introduction	291
9.2	Nucleation in a Low-Viscosity Liquid	292
9.2.1	Reduced Equations Describing the Process of Bubble Nucleation	292
9.2.2	Time of Establishment of Steady-State Nucleation	296
9.2.3	Quasistationary Distribution of Subcritical Bubbles	299

9.2.4	Distribution Function of Bubbles in the Range $N_c < N < \tilde{N}$	300
9.2.5	Distribution Function of Bubbles in the Range $N > \tilde{N}$	302
9.3	The Intermediate Stage	307
9.4	The Late Stage	314
9.5	Results of Numerical Computations	322
9.6	Conclusions	325
9.A	Appendices	326
9.A.1	Some Mathematical Transformations	326
9.A.2	Estimation of the Conditions when Merging of Colliding Bubbles can be Neglected	327
10	Phase Separation in Solid ^3He–^4He Mixtures	329
10.1	Introduction	329
10.2	Homogeneous Nucleation in Mixtures: Theory	331
10.3	Homogeneous Nucleation in ^3He – ^4He Solid Solutions: Experiment and Comparison with Theory	334
10.3.1	Spin Echoes in Restricted Geometry and Cluster Sizes	334
10.3.2	Experimental Details	335
10.3.3	Results and Discussion	337
10.3.4	Conclusion	339
10.4	Kinetics of Phase Transition in Solid Solutions of ^4He in ^3He at Different Degrees of Supersaturation	339
10.4.1	Experimental Results	339
10.4.2	Discussion	340
10.4.3	Conclusion	345
10.5	Influence of the Degree of Supercooling on the Kinetics of Phase Separation in Solid Mixtures of ^4He in ^3He	346
10.6	Comparison between Experiments and Conclusions	349
11	Nucleation versus Spinodal Decomposition in Confined Binary Solutions	353
11.1	Introduction	353
11.2	Spinodal Decomposition in Adiabatically Isolated Systems	355
11.2.1	The Cahn–Hilliard–Cook Equation	355
11.2.2	Thermodynamic Aspects	357
11.2.3	Results of Numerical Calculations	359
11.2.4	Theoretical Interpretation	362
11.2.5	Discussion	364
11.3	Generalized Cluster Model Approach to the Description of Phase Separation: The Model System	365
11.4	Phase Separation in Infinite Domains	368
11.4.1	Thermodynamic Analysis	368
11.4.2	Kinetics versus Thermodynamics in Phase Separation	373
11.5	Phase Separation in Finite Domains	376
11.5.1	Thermodynamic Analysis	376
11.5.2	Kinetics	384

11.5.3	Transition from Independent Cluster Growth to Coarsening	392
11.6	Results and Discussion	395
References		399
Index		413