

Contents

1	Microscopic Cluster Models	1
1.1	Introduction	1
1.2	Choice of the Nucleon–Nucleon Interaction	5
1.3	The Resonating Group Method	7
1.3.1	The RGM Equation	7
1.3.2	Example: Overlap Kernel of the $\alpha + n$ System	10
1.4	The Generator Coordinate Method	11
1.4.1	Introduction	11
1.4.2	Slater Determinants and GCM Basis Functions	12
1.4.3	Equivalence Between RGM and GCM	15
1.4.4	Two-Cluster Angular-Momentum Projection	16
1.5	Matrix Elements Between Slater Determinants	17
1.5.1	General Presentation	17
1.5.2	Spin and Isospin Factorization	20
1.5.3	The Spin–Orbit Interaction	22
1.5.4	Matrix Elements Between Individual Orbitals	22
1.5.5	Example: $\alpha + n$ Overlap Kernel	23
1.5.6	GCM Kernels of $\alpha + N$ Systems	25
1.6	Approximations of the RGM	28
1.6.1	Eigenvalues of the Overlap Kernel	28
1.6.2	Reformulation of the RGM Equation	30
1.6.3	The Orthogonality Condition Model	31
1.7	Recent Developments of the GCM	32
1.7.1	Introduction	32
1.7.2	Internal Wave Functions	32
1.7.3	Multicluster Angular-Momentum Projection	37
1.7.4	Multichannel Two-Cluster Systems	38
1.7.5	Multicluster Models	41

1.8	Scattering States With the GCM	47
1.8.1	Introduction	47
1.8.2	Cross Sections	48
1.8.3	The Microscopic R -matrix Method	49
1.9	Applications of the GCM	51
1.9.1	The $2\alpha + 3\alpha$ Systems	51
1.9.2	Other Applications of the Multicluster Model	55
1.9.3	Multichannel Study of the ${}^17F(p, \gamma){}^18Ne$ Reaction	57
1.9.4	${}^{12}Be$ as an Example of a Light Exotic Nucleus	60
1.10	Conclusions	61
	References	62
2	Neutron Halo and Breakup Reactions	67
2.1	Introduction	68
2.2	Coulomb Breakup at Intermediate/High Energies	71
2.3	Coulomb Breakup and Soft $E1$ Excitation of $1n$ Halo Nuclei	74
2.3.1	Coulomb Breakup of ${}^{11}Be$ and Characteristic Feature of Soft $E1$ Excitation of One-Neutron Halo Nuclei	74
2.3.2	Spectroscopy Using Coulomb Breakup of $1n$ Halo Nuclei - Application to ${}^{19}C$	82
2.3.3	Application to the Radiative Capture Reaction ${}^{14}C(n, \gamma){}^{15}C$ of Astrophysical Interest	87
2.3.4	Inclusive Coulomb Breakup of ${}^{31}Ne$	91
2.4	Coulomb Breakup and Soft $E1$ Excitation of $2n$ Halo Nuclei	96
2.4.1	Exclusive Coulomb Breakup of ${}^{11}Li$	97
2.5	Spectroscopy of Unbound States via the Nuclear Breakup	101
2.5.1	Inelastic Scattering of ${}^{14}Be$	103
2.5.2	Breakup of ${}^{14}Be$ With a Proton Target and Spectroscopy of ${}^{13}Be$	105
2.6	Concluding Remarks	114
	References	116
3	Breakup Reaction Models for Two- and Three-Cluster Projectiles	121
3.1	Introduction	122
3.2	Projectile and Reaction Models	123
3.3	Semiclassical Approximation	125
3.3.1	Time-Dependent Schrödinger Equation	125
3.3.2	Cross Sections	126
3.3.3	Resolution at the First Order of the Perturbation Theory	127

3.3.4	Numerical Resolution	129
3.4	Eikonal Approximations	131
3.4.1	Dynamical Eikonal Approximation	131
3.4.2	Cross Sections	131
3.4.3	Standard Eikonal Approximation	133
3.4.4	Coulomb-Corrected Eikonal Approximation	135
3.5	Continuum-Discretized Coupled-Channel Method	138
3.6	Breakup Reactions of Two-Body Projectiles	142
3.6.1	Two-Cluster Model	142
3.6.2	Two-Body Breakup of Exotic Nuclei	144
3.6.3	Application to Nuclear Astrophysics	146
3.7	Breakup Reactions of Three-Body Projectiles	148
3.7.1	Three-Cluster Model of Projectile	148
3.7.2	Dipole Strength Distribution	153
3.7.3	The CCE Approximation for Three-Body Projectiles	154
3.7.4	The CDCC Approximation for Three-Body Projectiles	156
3.8	Perspectives	158
	References	160
4	Clustering Effects Within the Dinuclear Model	165
4.1	Introduction	166
4.2	Adiabatic or Diabatic Potentials Between Nuclei	166
4.2.1	Two-Center Shell Model	167
4.2.2	Calculation of Adiabatic and Diabatic Potentials	168
4.2.3	The Motion of the Neck	170
4.2.4	Repulsive Potentials by the Quantization of Kinetic Energy	173
4.3	Nuclear Molecules, Hyperdeformed Nuclear Structures	175
4.3.1	Hyperdeformed States Directly Formed in the Scattering of $^{48}\text{Ca} + ^{140}\text{Ce}$ and $^{90}\text{Zr} + ^{90}\text{Zr}$	176
4.3.2	Hyperdeformed States Formed by Neutron Emission from the Dinuclear System	178
4.4	Normal Deformed and Superdeformed Nuclei	180
4.4.1	Internuclear Potential, Moments of Inertia, Quadrupole and Octupole Moments of the Dinuclear Shape	180
4.4.2	Parity Splitting in Heavy Nuclei	181
4.4.3	Cluster Effects in the Ground State and Superdeformed Bands of ^{60}Zn	185
4.4.4	Decay Out Phenomenon of Superdeformed Bands in the Mass Region $A \approx 190$	187
4.5	Complete Fusion and Quasifission in the Dinuclear Model	189

4.5.1	Reaction Models for Fusion With Adiabatic and Diabatic Potentials	189
4.5.2	Problems of Adiabatic Treatment of Fusion	190
4.5.3	Fusion to Superheavy Nuclei.	192
4.5.4	Production of Neutron-Deficient Isotopes of Pu.	204
4.5.5	Master Equations for Nucleon Transfer	205
4.5.6	Results for Quasifission	209
4.6	Multinucleon Transfer Reactions	212
4.6.1	Production of Heaviest Nuclei in Transfer Reactions	212
4.6.2	Transfer Products in Cold Fusion Reactions	214
4.6.3	Production of Neutron-Rich Isotopes in Transfer Reactions	215
4.7	Binary and Ternary Fission in the Scission-Point Model.	216
4.7.1	Fission Potential With the Dinuclear System Model.	217
4.7.2	Binary Fission	220
4.7.3	Ternary Fission	222
4.8	Selected Summarizing and Concluding Remarks	223
	References	224
5	Nuclear Alpha-Particle Condensates	229
5.1	Introduction.	230
5.2	Formulation of Alpha-Condensation: THSR Wave Function and OCM Approach	233
5.2.1	Resonating Group Method (RGM).	233
5.2.2	THSR Wave Function	234
5.2.3	$n\alpha$ Boson Wave Function and OCM.	236
5.2.4	Single α -Particle Density Matrix and Occupation Probabilities	238
5.3	THSR Wave Function versus Brink Wave Function for ${}^8\text{Be}$	239
5.4	Alpha-Gas Like States in Light Nuclei	243
5.4.1	${}^{12}\text{C}$ Case.	243
5.4.2	${}^{16}\text{O}$ Case.	255
5.4.3	Heavier $4n$ Nuclei: Gross-Pitaevskii Equation.	264
5.4.4	Hoyle-Analogue States in Non- $4n$ Nuclei: ${}^{11}\text{B}$ and ${}^{13}\text{C}$	267
5.5	Clusters in Nuclear Matter and α -Particle Condensation	271
5.5.1	Nuclear Clusters in the Medium	271
5.5.2	Four-Particle Condensates and Quartetting in Nuclear Matter	273
5.5.3	Reduction of the α -Condensate with Increasing Density	282
5.5.4	'Gap' Equation for Quartet Order Parameter.	286
5.6	Summary and Conclusions	292
	References	294

6 Cluster in Nuclei: Experimental Perspectives	299
6.1 Introduction.	300
6.2 Population of Cluster States	300
6.2.1 Radioactive Decay	300
6.2.2 In-Beam Induced Reactions	306
6.3 Targetry	312
6.3.1 Gas Targets.	313
6.3.2 Solid Hydrogen Targets	315
6.3.3 Active Targets.	318
6.4 Detection Techniques	321
6.4.1 Gamma-Ray Spectroscopy	321
6.4.2 Charged Particle Detectors	324
6.4.3 Neutron Detection	333
6.4.4 Mass Spectrometers, Mass Separators and Combined Setup	334
6.4.5 Particle Identification	337
6.4.6 Electronics and Data AcQuisition (DAQ) Systems.	342
6.5 Kinematics	344
6.5.1 Complete Kinematics	344
6.5.2 Particle Reconstruction.	345
6.5.3 Total Final State Kinetic Energy (TKE).	346
6.5.4 Dalitz Plots	347
6.6 Computer Codes	348
6.7 Concluding Remarks	350
References	350



<http://www.springer.com/978-3-642-24706-4>

Clusters in Nuclei, Vol.2

Beck, C. (Ed.)

2012, XV, 353 p. 167 illus., Softcover

ISBN: 978-3-642-24706-4