

Contents

Preface *XI*

Volume 1

1	Fundamental Concepts	1
1.1	The Atom	2
1.2	Atomic Processes	2
1.3	Discovery of the Atomic Nucleus	4
1.4	Nuclear Decay Types	6
1.5	Some Physical Concepts Needed in Nuclear Chemistry	11
1.5.1	Fundamental Forces	11
1.5.2	Elements from Classical Mechanics	12
1.5.3	Relativistic Mechanics	12
1.5.4	The de Broglie Wavelength	14
1.5.5	Heisenberg Uncertainty Principle	15
1.5.6	The Standard Model of Particle Physics	16
1.5.7	Force Carriers	19
	Reference	20
	Further Reading	20
2	Radioactivity in Nature	23
2.1	Discovery of Radioactivity	23
2.2	Radioactive Substances in Nature	26
	References	30
	Further Reading	30
3	Radioelements and Radioisotopes and Their Atomic Masses	33
3.1	Periodic Table of the Elements	33
3.2	Isotopes and the Chart of Nuclides	34
3.3	Nuclide Masses and Binding Energies	39
3.4	Evidence for Shell Structure in Nuclei	47
3.5	Precision Mass Spectrometry	49
	References	55
	Further Reading	55

4	Other Physical Properties of Nuclei	57
4.1	Nuclear Radii	57
4.2	Nuclear Angular Momenta	63
4.3	Magnetic Dipole Moments	65
4.4	Electric Quadrupole Moments	67
4.5	Statistics and Parity	69
4.6	Excited States	70
	References	71
	Further Reading	71
5	The Nuclear Force and Nuclear Structure	73
5.1	Nuclear Forces	73
5.2	Charge Independence and Isospin	76
5.3	Nuclear Matter	81
5.4	Fermi Gas Model	82
5.5	Shell Model	84
5.6	Collective Motion in Nuclei	94
5.7	Nilsson Model	101
5.8	The Pairing Force and Quasi-Particles	104
5.9	Macroscopic–Microscopic Model	106
5.10	Interacting Boson Approximation	108
5.11	Further Collective Excitations: Coulomb Excitation, High-Spin States, Giant Resonances	110
	References	117
	Further Reading	117
6	Decay Modes	119
6.1	Nuclear Instability and Nuclear Spectroscopy	119
6.2	Alpha Decay	119
6.2.1	Hindrance Factors	125
6.2.2	Alpha-Decay Energies	126
6.3	Cluster Radioactivity	126
6.4	Proton Radioactivity	129
6.5	Spontaneous Fission	132
6.6	Beta Decay	148
6.6.1	Fundamental Processes	148
6.6.2	Electron Capture-to-Positron Ratios	158
6.6.3	Nuclear Matrix Elements	160
6.6.4	Parity Non-conservation	162
6.6.5	Massive Vector Bosons	164
6.6.6	Cabibbo–Kobayashi–Maskawa Matrix	165
6.7	Electromagnetic Transitions	170
6.7.1	Multipole Order and Selection Rules	172
6.7.2	Transition Probabilities	174
6.7.3	Internal Conversion Coefficients	179

6.7.4	Angular Correlations	183
	References	186
	Further Reading	187
7	Radioactive Decay Kinetics	189
7.1	Law and Energy of Radioactive Decay	189
7.2	Radioactive Equilibria	191
7.3	Secular Radioactive Equilibrium	193
7.4	Transient Radioactive Equilibrium	196
7.5	Half-life of Mother Nuclide Shorter than Half-life of Daughter Nuclide	197
7.6	Similar Half-lives	198
7.7	Branching Decay	199
7.8	Successive Transformations	200
	Reference	202
	Further Reading	203
8	Nuclear Radiation	205
8.1	General Properties	205
8.2	Heavy Charged Particles ($A \geq 1$)	207
8.3	Beta Radiation	214
8.4	Gamma Radiation	220
8.5	Neutrons	227
8.6	Short-lived Elementary Particles in Atoms and Molecules	232
	References	233
	Further Reading	234
9	Measurement of Nuclear Radiation	235
9.1	Activity and Counting Rate	235
9.2	Gas-Filled Detectors	239
9.2.1	Ionization Chambers	243
9.2.2	Proportional Counters	244
9.2.3	Geiger–Müller Counters	246
9.3	Scintillation Detectors	248
9.4	Semiconductor Detectors	250
9.5	Choice of Detectors	256
9.6	Spectrometry	259
9.7	Determination of Absolute Disintegration Rates	262
9.8	Use of Coincidence and Anticoincidence Circuits	263
9.9	Low-Level Counting	263
9.10	Neutron Detection and Measurement	264
9.11	Track Detectors	266
9.11.1	Photographic Emulsions and Autoradiography	266
9.11.2	Dielectric Track Detectors	267
9.11.3	Cloud Chambers	268

9.11.4	Bubble Chambers	268
9.11.5	Spark Chambers	269
9.12	Detectors Used in Health Physics	269
9.12.1	Portable Counters and Survey Meters	269
9.12.2	Film Badges	270
9.12.3	Pocket Ion Chambers	270
9.12.4	Thermoluminescence Dosimeters	270
9.12.5	Contamination Monitors	270
9.12.6	Whole-Body Counters	271
	Reference	271
	Further Reading	271
10	Statistical Considerations in Radioactivity Measurements	273
10.1	Distribution of Random Variables	273
10.2	Probability and Probability Distributions	275
10.3	Maximum Likelihood	282
10.4	Experimental Applications	283
10.5	Statistics of Pulse-Height Distributions	285
10.6	Setting Upper Limits When No Counts Are Observed	287
	Further Reading	288
11	Techniques in Nuclear Chemistry	289
11.1	Special Aspects of the Chemistry of Radionuclides	289
11.1.1	Short-Lived Radionuclides and the Role of Carriers	289
11.1.2	Radionuclides of High Specific Activity	291
11.1.3	Microamounts of Radioactive Substances	292
11.1.4	Radiocolloids	297
11.1.5	Tracer Techniques	299
11.2	Target Preparation	300
11.3	Measuring Beam Intensity and Fluxes	306
11.4	Neutron Spectrum in Nuclear Reactors	308
11.4.1	Thermal Neutrons	308
11.4.2	Epithermal Neutrons and Resonances	310
11.4.3	Reaction Rates in Thermal Reactors	311
11.5	Production of Radionuclides	311
11.5.1	Production in Nuclear Reactors	311
11.5.2	Production by Accelerators	318
11.5.3	Separation Techniques	324
11.5.4	Radionuclide Generators	329
11.6	Use of Recoil Momenta	331
11.7	Preparation of Samples for Activity Measurements	336
11.8	Determination of Half-Lives	337
11.9	Decay-Scheme Studies	339
11.10	In-Beam Nuclear Reaction Studies	342
	References	355
	Further Reading	357

Volume 2

12	Nuclear Reactions	361
13	Chemical Effects of Nuclear Transmutations	465
14	Influence of Chemical Bonding on Nuclear Properties	487
15	Nuclear Energy, Nuclear Reactors, Nuclear Fuel, and Fuel Cycles	507
16	Sources of Nuclear Bombarding Particles	559
17	Radioelements	581
18	Radionuclides in Geo- and Cosmochemistry	677
19	Dating by Nuclear Methods	711
20	Radioanalysis	729
21	Radiotracers in Chemistry	765
22	Radionuclides in the Life Sciences	783
23	Technical and Industrial Applications of Radionuclides and Nuclear Radiation	801
24	Radionuclides in the Geosphere and the Biosphere	813
25	Dosimetry and Radiation Protection	861
	Appendix	883
	Index	891

