Contents

I. The Nature of Atomic Spectra 1

1. Basic Principles of Spectroscopy, 1
2. The Spectrum of Hydrogen, 7
3. Spectral Series, 11
4. X-Ray Spectra, 17
5. Grotrian Diagrams, 23
6. Profiles of Spectral Lines, 36

II. The Nature of Atoms 44

1. Keplerian Motion, 44
2. Central Force Motion, 50
3. Correction for Finite Mass, 55
4. Quantized Energy Levels, 56
5. Magnetic Moments, 63
6. Quantized Orientation, 67
7. Zeeman Effect, 71
8. Fine Structure, 75
9. Hyperfine Structure, 78
10. Electron Orbitals, 79
11. The Periodic System, 83
12. The Vector Model, 87
13. The Analysis of Complex Spectra, 106
14. Terminology, 110

Appendix A: Atomic Units, 113

III. Wave Mechanics 121

1. Wavelike Properties of Matter, 121
2. Equations for Waves, 123
3. The Schrödinger Equation for a Single Particle, 130
4. Boundary Conditions and Quantization, 133
5. The Schrödinger Equation in One Dimension, 134
6. The Schrödinger Equation in Three Dimensions, 140
7. The Separated ϕ-Equation, 146
8. The Separated θ-Equation: Series Solution, 148
9. The Angular Equation: Operator Approach, 154
   Proof of an Operator Inequality, 162
10. Angular Functions and Spherical Tensors, 163
11. The Radial Equation, 177
    Appendix A: The Method of Ladder Operators, 185
    Appendix B: The Spherical Bessel Functions, 189

IV. Quantum Mechanics 192

1. The Uncertainty Principle, 192
2. Macroscopic Dynamics, 195
3. States and Observables, 198
4. Abstract Vector Spaces, 199
5. Orthonormal Basis Vectors: Examples, 207
6. Transformations and Operators, 213
7. Eigenvectors and Eigenfunctions, 220
8. Quantum Mechanics as an Abstract Vector Space, 224
9. Representations, 228

V. Perturbation Theory 233

1. Time-Independent Theory, 233
2. Examples, 242
3. Time-Dependent Perturbation Theory, 245

VI. Angular-Momentum States 256

1. General Angular-Momentum Operators and Eigenstates, 256
2. Coupling and Clebsch–Gordan Coefficients, 268
3. Multiple Coupling and Racah Coefficients, 277
4. Tensor Operators and the Wigner–Eckart Theorem, 285
5. Coupling Tensor Operators, 294
   Appendix A: The Rotation Matrix, 299

VII. The Many-Electron Hamiltonian 304

1. Electrostatic Interactions, 304
2. External Electric Fields, 305
3. Relativistic Corrections, 310
4. Nuclear Effects, 313

VIII. The Hydrogen Atom 320

1. Nonrelativistic Wavefunctions, 320
2. Fine Structure, 323
3. X-Ray and Alkali Terms, 326
4. Radiative Corrections, 328
5. Parity, 331

IX. Complex Atoms 333

1. The Independent-Particle Model, 333
2. Product-Function Matrix Elements, 337
3. The Pauli Principle: Antisymmetry, 341
4. Antisymmetrized Matrix Elements, 344
5. Two Electrons: Introduction, 348
6. Russell–Saunders (*LS*) Coupling, 352
7. Other Two-Electron Coupling Schemes: *jj; jK; LK*, 364
8. Several Electrons: Parentage, 371
9. Equivalent Orbitals: Fractional Parentage, 378
10. Average Energies; Closed *l*-Shells, 391
11. Term Energies, 396

Appendix A: Properties of Coefficients of Fractional Parentage, 401

X. The Electromagnetic Field 404

1. Maxwell's Equations, 404
2. Multipole Fields, 410
3. Quantized Fields, 423
4. Matter and Radiation, 426
5. Radiative Transitions, 430
6. Magnetic-Multipole Radiation, 434
7. Electric-Multipole Radiation, 437
8. Line Strengths, 441
9. The Line Factor, 447
10. The Multiplet Factor, 465

11. The Transition Integral, 476
Appendix A: Notation Conventions, 480

XI. Static Fields 482

1. Introduction, 482
2. Uniform Magnetic Field, 487
3. Uniform Electric Field, 498

Bibliography 505

Index 515