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Atoms and Their Spectroscopic Properties

With 69 Figures and 74 Tables

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Preface

Atomic spectroscopy and the physics of atomic collisions have many applications in investigation of confined plasmas, thermonuclear fusion, laser-produced plasmas, the upper planetary atmosphere, plasma diagnostics, and many others.

The aim of this reference book is to give brief information on atomic radiative characteristics and elementary processes occurring in astrophysical and laboratory plasmas. These topics include energy levels, transition probabilities, oscillator strengths, electric multipole polarizabilities, photoionization, excitation, ionization and charge transfer cross sections.

This monograph deals mainly with the interaction of neutral atoms with photons, electrons and ions. Some elementary atomic processes involving negative and positive ions are discussed.

The book can be conditionally divided into two main parts. The first one contains information on the energy-level transition probabilities, atomic polarizabilities, fine and hyperfine structure, angular momenta coupling schemes and selection rules. The second part comprises data on collisional characteristics such as cross sections and the corresponding Maxwellian rate coefficients for different elementary processes: photoionization, excitation, single and multi-electron ionization and electron capture. In the last chapter, recent data on collisions involving H^- ions are considered.

The monograph does not contain a detailed description of complicated theoretical approaches and formulas. It presents data in a dense form using figures, tables and simple analytical formulas, which allows one to estimate the atomic characteristics without resorting to computers. This may be of a special interest to experimentalists working in some fields of atomic physics. As well as the pure atomic data, a brief physical background of specific problems is presented.

I am very grateful to Professor H.-J. Kluge (Gesellschaft für Schwerionenforschung, Darmstadt, Germany) and Professor Hiro Tawara (National Institute for Fusion Science, Nagoya, Japan) for their hospitality during my stays at GSI (October 1994 to February 1995) and NIFS (March 1995 to August 1995), where the major part of this book was written.

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Moscow-Darmstadt-Nagoya V.P. Shevelko
June 1996

Contents

Glossary of Terms

Units

The system of atomic units (a.u.) is used: $e^2 = m = \hbar = 1$.

Length (Bohr radius)	$a_0 = 0.529\,177\,249(24) \times 10^{-8}$ cm
Energy	$E_0 = e^2/a_0 = 27.211\,3961(81)$ eV $= 2$Ry
Rydberg	$1\ \text{Ry} = me^4/2\hbar^2 = 13.605\,6981(40)$ eV $= 109\,737.315\,34(13)\ \text{cm}^{-1}$
Time	$\tau_0 = \hbar^3/me^4 = a_0/v_0$ $= 2.418\,88433(11) \times 10^{-17}$ s
Velocity	$v_0 = e^2\hbar = 2.187\,691\,417(98) \times 10^8$ cm/s
Cross section	$\pi a_0^2 = 0.879\,735\,6696(80) \times 10^{-16}\ \text{cm}^2$
Fine-structure constant	$\alpha = e^2/\hbar c = 1/137.035\,9895(61)$
Velocity of light	$c = 1/\alpha = 137.035\,9895(61)$ a.u. $= 2.997\,92458 \times 10^{10}$ cm/s

The values of the fundamental physical constants are given in a report of the CODATA Task Group on Fundamental Constants, CODATA Bulletin No. 63, E.R. Cohen, B.N. Taylor: Rev. Mod. Phys. **59**, 1121 (1987).

List of Symbols

A	Autoionization transition probability
[A]	Ions of the isoelectronic sequence of an atom A or A-like ions
E	Incident particle energy
E_{cm}	Center-of-mass energy
$E\varkappa$	Electric $2^\varkappa$-pole transition
f	Oscillator strength
I	Binding energy; ionization potential
l	Orbital quantum number
M	Nuclear mass
$M\varkappa$	Magnetic $2^\varkappa$-pole transition
m	Electron mass
N	Total number of atomic electrons
n	Principal quantum number
q	Number of equivalent electrons

T	Electron or ion temperature
v	Relative velocity
$\langle v\sigma \rangle$	Maxwellian rate coefficient
X_z	Ion with a charge $z-1$: $X_z = X^{(z-1)+}$
W	Radiative transition probability
Z	Nuclear charge
z	Spectroscopic symbol: $z = Z - N + 1$
$\beta_\varkappa$	Electric $2^\varkappa$-pole polarizability
ΔE	Transition energy, energy shift
γ	Hyperpolarizability
$\varkappa$	Multiplicity
$\varkappa_r$	Radiative recombination rate coefficient
λ	Wavelength
μ	Reduced mass
σ	Cross section
σ_+	Net (gross) ionization cross section

Special mathematical functions used in the book can be found in *Handbook of Mathematical Functions*, ed. by N. Abramowitz, I.A. Stegun (Constable, London 1970).