

Contents

Foreword	v
Preface	vii
I Thermodynamics	1
1. Equilibrium and State Quantities	3
Introduction	3
Systems, phases and state quantities	4
Equilibrium and temperature—the zeroth law of thermodynamics	6
Kinetic theory of the ideal gas	10
Pressure, work and chemical potential	13
Heat and heat capacity	15
The equation of state for a real gas	17
Specific heat	20
Changes of state—reversible and irreversible processes	23
Exact and inexact differentials, line integrals	25
2. The Laws of Thermodynamics	33
The first law	33
Carnot's process and entropy	37
Entropy and the second law	41
Insertion: Microscopic interpretation of entropy and of the second law	43
Global and local equilibrium	51
Thermodynamic engines	52
Euler's equation and the Gibbs-Duhem relation	58

3. Phase Transitions and Chemical Reactions	62
Gibbs' Phase Rule	62
Phase equilibrium and the Maxwell construction	67
The law of mass action	70
Application of the laws of thermodynamics	80
4. Thermodynamic Potentials	84
The principle of maximum entropy	84
Entropy and energy as thermodynamic potentials	85
The Legendre transformation	87
The free energy	91
The enthalpy	95
The free enthalpy	101
The grand potential	107
The transformation of all variables	108
The Maxwell relations	108
Jacobi transformations	115
Thermodynamic stability	118
 II Statistical Mechanics	 121
5. Number of Microstates Ω and Entropy S	123
Foundations	123
Phase space	124
Statistical definition of entropy	127
Gibbs' paradox	132
Quantum mechanical counting of Ω	135
6. Ensemble Theory and Microcanonical Ensemble	142
Phase-space density, ergodic hypothesis	142
Liouville's theorem	145
The microcanonical ensemble	147
Entropy as an ensemble average	149
The uncertainty function	150
7. The Canonical Ensemble	159
General foundation of the Gibbs correction factor	164
Systems of noninteracting particles	170
Calculation of observables as ensemble averages	177
Connection between microcanonical and canonical ensembles	186

Fluctuations	191
Virial theorem and equipartition theorem	194
For better understanding: canonical ensemble as the mean value of all possible distributions	200
8. Applications of Boltzmann Statistics	208
Quantum Systems in Boltzmann Statistics	208
Paramagnetism	214
Negative temperatures in two-level systems	223
Gases with internal degrees of freedom	225
Relativistic ideal gas	234
9. The Macrocanonical Ensemble	240
Fluctuations in the macrocanonical ensemble	248
III Quantum Statistics	255
10. Density Operators	257
Fundamentals	257
Pure and mixed states	261
Properties of the density matrix	266
The density operators of quantum statistics	270
11. The Symmetry Character of Many-Particle Wavefunctions	285
12. Grand Canonical Description of Ideal Quantum Systems	297
13. The Ideal Bose Gas	314
Ultrarelativistic Bose gas	325
14. Ideal Fermi Gas	341
The degenerate Fermi gas	347
Supplement: Natural units	385

15. Applications of Relativistic Bose and Fermi Gases	387
Quark–gluon plasma in the Big Bang and in heavy-ion collisions	387
 IV Real Gases and Phase Transitions	 399
16. Real Gases	401
For absorption: Mayer’s cluster expansion	404
Virial expansion	414
17. Classification of Phase Transitions	416
Theorem of corresponding states	422
Critical indices	424
Examples for phase transitions	425
18. The Models of Ising and Heisenberg	436
Index	457