

Contents

Author's Preface	v
Editor's Preface	ix
Translator's Preface	xi
CHAPTER I. THERMODYNAMICS. GENERAL CONSIDERATIONS	1
1. Temperature as a Property of a System	1
2. Work and Heat	4
3. The Perfect Gas	8
A. Boyle's Law (The Law of Boyle and Mariotte)	8
B. Charles' Law (The Law of Gay-Lussac)	9
C. Avogadro's Law and the Universal Gas Constant	10
4. The First Law. Energy and Enthalpy as Properties	13
A. Equivalence of Heat and Work	13
B. The Enthalpy as a Property	16
C. Digression on the Ratio of Specific Heats c_p and c_v	18
5. The Reversible and the Irreversible Adiabatic Process	19
A. The Reversible Adiabatic Process	20
B. The Irreversible Adiabatic Process	22
C. The Joule-Kelvin Porous Plug Experiment	23
D. A Conclusion of Great Consequence	25
6. The Second Law	26
A. The Carnot Cycle and Its Efficiency	27
B. The First Part of the Second Law	29
C. The Second Part of the Second Law	34
D. Simplest Numerical Examples	37
E. Remarks on the Literature of the Second Law	39
F. On the Relative Rank of Energy and Entropy	40
7. The Thermodynamic Potentials and the Reciprocity Relations	42
8. Thermodynamic Equilibria	47
A. Unconstrained Thermodynamic Equilibrium and Maximum of Entropy	47
B. An Isothermal and Isobaric System in Unconstrained Thermodynamic Equilibrium	48
C. Additional Degrees of Freedom in Retarded Equilibrium	49
D. Extremum Properties of the Thermodynamic Potentials	50
E. The Theorem on Maximum Work	52
9. The van der Waals Equation	55
A. Course of Isotherms	56
B. Entropy and the Caloric Behavior of the van der Waals Gas	57

10. Remarks on the Liquefaction of Gases According to van der Waals . . .	60
A. The Integral and the Differential Joule-Thomson Effect	60
B. The Inversion Curve and Its Practical Utilization	61
C. The Boundary of the Region of Co-existing Liquid-Vapor Phases in the p, v Plane	63
11. The Kelvin Temperature Scale	68
12. Nernst's Third Law of Thermodynamics	71
CHAPTER II. THE APPLICATION OF THERMODYNAMICS TO SPECIAL SYSTEMS . . .	77
13. Gaseous Mixtures, Gibbs' Paradox. The Law Due to Guldberg and Waage	77
A. Reversible Separation of Gases	78
B. The Increase in Entropy During Diffusion and Gibbs' Paradox	80
C. The Law of Mass Action Due to Guldberg and Waage	81
14. Chemical Potentials and Chemical Constants	87
A. The Chemical Potentials μ_i	87
B. Relation Between the μ_i 's and the g_i 's for Ideal Mixtures	90
C. The Chemical Constant of a Perfect Gas	91
15. Dilute Solutions	92
A. General and Historical Remarks	92
B. Van 't Hoff's Equation of State for Dilute Solutions	93
16. The Different Phases of Water. Remarks on the Theory of the Steam Engine	96
A. The Vapor-Pressure Curve and Clapeyron's Equation	97
B. Phase Equilibrium Between Ice and Water	100
C. The Specific Heat of Saturated Steam	101
17. General Remarks on the Theory of Phase Equilibria	103
A. The Triple Point of Water	104
B. Gibbs' Phase Rule	106
C. Raoult's Laws for Dilute Solutions	108
D. Henry's Law of Absorption (1803)	111
18. The Electromotive Force of Galvanic Cells	113
A. Electrochemical Potentials	113
B. The Daniell Cell, 1836	115
C. Contraction of Individual Reactions into a Simplified Overall Reaction	116
D. The Gibbs-Helmholtz Fundamental Equation	118
E. Numerical Example	119
F. Remarks on the Integration of the Fundamental Equation	120
19. Ferro- and Paramagnetism	121
A. Work of Magnetization and Magnetic Equation of State	121
B. Langevin's Equation for Paramagnetic Substances	123
C. The Theory of Ferromagnetic Phenomena Due to Weiss	125
D. The Specific Heats c_H and c_M	129
E. The Magneto-Caloric Effect	134
20. Black Body Radiation	135
A. Kirchhoff's Law	136
B. The Stefan-Boltzmann Law	139
C. Wien's Law	140
D. Planck's Law of Radiation	145

21. Irreversible Processes. Thermodynamics of Near-Equilibrium Processes	152
A. Conduction of Heat and Local Entropy Generation	152
B. The Conduction of Heat in an Anisotropic Body and Onsager's Reciprocal Relations	155
C. Thermoelectric Phenomena	157
D. Internal Transformations	163
E. General Relations	165
F. Limitations of the Thermodynamic Theory of Irreversible Processes	168
 CHAPTER III. THE ELEMENTARY KINETIC THEORY OF GASES	 169
22. The Equation of State of a Perfect Gas	169
23. The Maxwellian Velocity Distribution	174
A. The Maxwellian Distribution for a Monatomic Gas. Proof of 1860	174
B. Numerical Values and Experimental Results	177
C. General Remarks on the Energy Distribution. The Boltzmann Factor	179
24. Brownian Motion	181
25. Statistical Considerations on Paramagnetic Substances	187
A. The Classical Langevin Function	188
B. Modification of Langevin's Function with the Aid of Quantum Mechanics	190
26. The Statistical Significance of the Constants in van der Waals' Equation	192
A. The Volume of a Molecule and the Constant b	192
B. The van der Waals Cohesion Forces and the Constant a	194
27. The Problem of the Mean Free Path	197
A. Calculation of the Mean Free Path in One Special Case	198
B. Viscosity	200
C. Thermal Conductivity	203
D. Some General Remarks on the Problems Associated with the Concept of the Mean Free Path	205
 CHAPTER IV. GENERAL STATISTICAL MECHANICS: COMBINATORIAL METHOD	 207
28. Liouville's Theorem, Γ -space and μ -space	207
A. The Multidimensional Γ -space (Phase Space)	208
B. Liouville's Theorem	209
C. Equality of Probability for the Perfect Gas	210
29. Boltzmann's Principle	213
A. Permutability as a Measure of the Probability of a State	214
B. The Maximum of Probability as a Measure of Entropy	217
C. The Combining of Elementary Cells	219
30. Comparison with Thermodynamics	221
A. Constant Volume Process	221
B. General Process Performed by a Gas in the Absence of External Forces	221
C. A Gas in a Field of Forces; the Boltzmann Factor	223
D. The Maxwell-Boltzmann Velocity Distribution Law	224
E. Gaseous Mixtures	226

31. Specific Heat and Energy of Rigid Molecules	227
A. The Monatomic Gas	227
B. Gas Composed of Diatomic Molecules	230
C. The Polyatomic Gas and Kelvin's Clouds	233
32. The Specific Heat of Vibrating Molecules and of Solid Bodies	234
A. The Diatomic Molecule	234
B. Polyatomic Gases	236
C. The Solid Body and the Dulong-Petit Rule	236
33. The Quantization of Vibrational Energy	237
A. The Linear Oscillator	237
B. The Solid Body	240
C. Generalization to Arbitrary Quantum States	240
34. The Quantization of Rotational Energy	242
35. Supplement to the Theory of Radiation and to that of Solid Bodies	245
A. Method of Natural Vibrations	246
B. Debye's Theory of the Specific Heat of a Solid	247
36. Partition Function in the Γ -space	248
A. The Gibbs Condition	248
B. Connection with Boltzmann's Method	250
C. Correction for Quantum Effects	253
D. Analysis of Gibbs' Hypothesis	256
37. Fundamentals of Quantum Statistics	257
A. Quantum Statistics of Identical Particles	257
B. The Method Due to Darwin and Fowler	259
C. Bose-Einstein and Fermi-Dirac Statistics	261
D. The Saddle-Point Method	262
38. Degenerate Gases	266
A. Bose-Einstein and Fermi-Dirac Distribution	266
B. Degree of Gas Degeneration	270
C. Highly Degenerate Bose-Einstein Gas	272
39. Electron Gas in Metals	276
A. Introductory Remark to Drude's Method	276
B. The Completely Degenerate Fermi-Dirac Gas	277
C. Almost Complete Degeneracy	280
D. Special Problems	282
40. The Mean Square of Fluctuations	286
 CHAPTER V. OUTLINE OF AN EXACT KINETIC THEORY OF GASES	 293
41. The Maxwell-Boltzmann Collision Equation	293
A. Description of a State in the Kinetic Theory of Gases	293
B. The Variation of f with Time	296
C. The Laws of Elastic Collision	297
D. Boltzmann's Collision Integral	299
E. Boltzmann's Hypothesis About Molecular Chaos	301

42. The <i>H</i> -theorem and Maxwellian Distribution	302
A. The <i>H</i> -theorem	302
B. Maxwellian Distribution	306
C. Equilibrium Distributions	309
43. Fundamental Equations of Fluid Dynamics	310
A. Series Expansion for the Distribution Function	310
B. Maxwell's Transport Equation	312
C. Conservation of Mass	315
D. Conservation of Momentum	316
E. Conservation of Energy	318
F. Entropy Theorem	320
44. On the Integration of the Collision Equation	323
A. Integration with the Aid of Moment Equations	323
B. Transformation of the Equations for Moments	325
C. Evaluation of Collision Moments	327
D. Viscosity and Thermal Conductivity	328
45. Conductivity and the Wiedemann-Franz Law	333
A. The Collision and Transfer Equations for Electrons in Metals	333
B. Approximate Solution of the Collision Equation	336
C. Flux of Current and Energy	339
D. Ohm's Law	341
E. Thermal Conductivity and Absolute Thermal Electromotive Force	342
F. The Wiedemann-Franz Law	343
Problems for Chapter I	347
Problems for Chapter II	350
Problems for Chapter III	351
Problems for Chapter IV	352
Problems for Chapter V	355
Hints for the Solution of Problems	356
Index	395