

CONTENTS

ACKNOWLEDGMENTS

I.	EARLY DEVELOPMENT OF THE KINETIC THEORY OF GASES	3
1.1	Introduction	3
1.2	Mechanical Foundations	4
1.3	Gas Pressure	11
1.4	Newton and the Theory of Gases	20
1.5	Daniel Bernoulli and the First Kinetic Theory of Gases	26
1.6	Chemical Atomic Theory	31
1.7	John Herapath and the Second Kinetic Theory of Gases	35
1.8	The Nature of Heat	39
1.9	Clausius: "The Kind of Motion we call Heat"	46
1.10	Transport Theory and the Size of Atoms	54
1.11	The Maxwell-Boltzmann Statistical Approach	59
1.12	The Van der Waals Equation and the Critical Point	68
1.13	The "Statistical Mechanics" of J. Willard Gibbs	72
II.	IRREVERSIBILITY AND INDETERMINISM	79
2.1	Introduction	79
2.2	The Cooling of the Earth	81
2.3	The Second Law of Thermodynamics	84
2.4	Maxwell and his Demon	86
2.5	Boltzmann and the Statistical Interpretation of Thermodynamics	90
2.6	Max Planck on Indeterminism	93
2.7	The New Century: Brownian Movement	96
2.8	Einstein's Theories and Randomness	98
2.9	What's going on inside the atom?	99
2.10	Heisenberg's Principle	102
III.	THE QUANTUM THEORY	105
3.1	The Planck and Einstein Hypotheses	105
3.2	Line Spectra	114
3.3	The Bohr Model of the Atom	118

3.4	Wave Mechanics	126
3.5	The Philosophy of Quantum Mechanics	139
IV.	QUANTUM MECHANICAL PROPERTIES OF MATTER	145
4.1	Specific Heats of Solids and Gases	145
4.2	Absolute Entropy and Chemical Reactions: Ionization and Stellar Atmospheres	149
4.3	Zero-point Energy	156
4.4	Bose-Einstein Statistics	157
4.5	Fermi-Dirac Statistics	159
4.6	Quantum Degeneracy in the Stars	162
4.7	Magnetic Properties of the Electron Gas	167
4.8	Superconductivity	168
4.9	Superfluidity of Liquid Helium	172
V.	INTERATOMIC FORCES AND THE CHEMICAL BOND	204
5.1	Early Ideas about Interatomic Forces	204
5.2	Force Laws in 19th-century Kinetic Theory	206
5.3	Electrostatic Forces and Another Try with Kinetic Theory	208
5.4	The Quantum Theory of Dispersion Forces	210
5.5	What is the true interatomic force law?	212
5.6	The Exclusion Principle and the Electronic Structure of Atoms	217
5.7	The Lewis-Langmuir Theory	220
5.8	Resonance and the Heitler-London Theory	222
5.9	Valence Bond versus Molecular Orbital	227
5.10	The Reduction of Chemistry	230
VI.	PHASE TRANSITIONS AND THE CRITICAL POINT	233
6.1	The van der Waals Theory of the Gas-Liquid Critical Point	233
6.2	The Solid-Liquid Transition	234
6.3	Magnetism and the Curie Temperature	236
6.4	The Lenz-Ising Model	239
6.5	Theory of Gas Condensation	246
6.6	The Hard-sphere Phase Transition	250
6.7	Toward a Universal Theory of Critical Phenomena	251
VII.	STATISTICAL MECHANICS AND THE PHILOSOPHY OF SCIENCE	259
7.1	Reduction, Statistics, and Irreversibility	259
7.2	Beginnings of Statistical Mechanics	263

CONTENTS

ix

7.3	Victory	267
7.4	Entropy and Probability	268
7.5	Phase Transitions	270
7.6	What is reduction?	274
VIII. OUTSTANDING PROBLEMS IN STATISTICAL PHYSICS		276
BIBLIOGRAPHY		287
INDEX		337