CONTENTS

PART A THERMODYNAMICS AND KINETIC THEORY 1

CHAPTER 1 THE LAWS OF THERMODYNAMICS 3

1.1 Preliminaries 3
1.2 The First Law of Thermodynamics 7
1.3 The Second Law of Thermodynamics 9
1.4 Entropy 14
1.5 Some Immediate Consequences of the Second Law 19
1.6 Thermodynamic Potentials 22
1.7 The Third Law of Thermodynamics 25

CHAPTER 2 SOME APPLICATIONS OF THERMODYNAMICS 31

2.1 Thermodynamic Description of Phase Transitions 31
2.2 Surface Effects in Condensation 35
2.3 Van der Waals Equation of State 38
2.4 Osmotic Pressure 43
2.5 The Limit of Thermodynamics 48

CHAPTER 3 THE PROBLEM OF KINETIC THEORY 52

3.1 Formulation of the Problem 52
3.2 Binary Collisions 56
3.3 The Boltzmann Transport Equation 60
3.4 The Gibbsian Ensemble 62
3.5 The BBGKY Hierarchy 65

CHAPTER 4 THE EQUILIBRIUM STATE OF A DILUTE GAS 73

4.1 Boltzmann's *H* Theorem 73
4.2 The Maxwell-Boltzmann Distribution 75
4.3 The Method of the Most Probable Distribution 79
4.4 Analysis of the *H* Theorem 85
4.5 The Poincaré Cycle 90

CHAPTER 5 TRANSPORT PHENOMENA 93

5.1 The Mean Free Path 93
5.2 Effusion 95
5.3 The Conservation Laws 96
5.4 The Zero-Order Approximation 100
5.5 The First-Order Approximation 104

5.6 Viscosity **108**
5.7 Viscous Hydrodynamics **111**
5.8 The Navier-Stokes Equation **113**
5.9 Examples in Hydrodynamics **117**

PART B STATISTICAL MECHANICS **125**

CHAPTER 6 CLASSICAL STATISTICAL MECHANICS **127**

6.1 The Postulate of Classical Statistical Mechanics **127**
6.2 Microcanonical Ensemble **130**
6.3 Derivation of Thermodynamics **135**
6.4 Equipartition Theorem **136**
6.5 Classical Ideal Gas **138**
6.6 Gibbs Paradox **140**

CHAPTER 7 CANONICAL ENSEMBLE AND GRAND CANONICAL ENSEMBLE **143**

7.1 Canonical Ensemble **143**
7.2 Energy Fluctuations in the Canonical Ensemble **145**
7.3 Grand Canonical Ensemble **149**
7.4 Density Fluctuations in the Grand Canonical Ensemble **152**
7.5 The Chemical Potential **154**
7.6 Equivalence of the Canonical Ensemble and the Grand Canonical Ensemble **157**
7.7 Behavior of $W(N)$ **161**
7.8 The Meaning of the Maxwell Construction **163**

CHAPTER 8 QUANTUM STATISTICAL MECHANICS **171**

8.1 The Postulates of Quantum Statistical Mechanics **171**
8.2 Density Matrix **174**
8.3 Ensembles in Quantum Statistical Mechanics **176**
8.4 The Third Law of Thermodynamics **178**
8.5 The Ideal Gases: Microcanonical Ensemble **179**
8.6 The Ideal Gases: Grand Canonical Ensemble **185**
8.7 Foundations of Statistical Mechanics **189**

CHAPTER 9 GENERAL PROPERTIES OF THE PARTITION FUNCTION **193**

9.1 The Darwin-Fowler Method **193**
9.2 Classical Limit of the Partition Function **199**
9.3 Singularities and Phase Transitions **206**
9.4 The Lee-Yang Circle Theorem **210**

CHAPTER 10 APPROXIMATE METHODS **213**

10.1 Classical Cluster Expansion **213**
10.2 Quantum Cluster Expansion **220**
10.3 The Second Virial Coefficient **224**
10.4 Variational Principles **228**
10.5 Imperfect Gases at Low Temperatures **230**

CHAPTER 11 FERMI SYSTEMS **241**

11.1 The Equation of State of an Ideal Fermi Gas **241**
11.2 The Theory of White Dwarf Stars **247**
11.3 Landau Diamagnetism **253**
11.4 The De Haas-Van Alphen Effect **260**
11.5 The Quantized Hall Effect **261**
11.6 Pauli Paramagnetism **267**
11.7 Magnetic Properties of an Imperfect Gas **272**

CHAPTER 12 BOSE SYSTEMS **278**

12.1 Photons **278**
12.2 Phonons in Solids **283**
12.3 Bose-Einstein Condensation **286**
12.4 An Imperfect Bose Gas **294**
12.5 The Superfluid Order Parameter **298**

PART C SPECIAL TOPICS IN STATISTICAL MECHANICS **305**

CHAPTER 13 SUPERFLUIDS **307**

13.1 Liquid Helium **307**
13.2 Tisza's Two-Fluid Model **311**
13.3 The Bose-Einstein Condensate **313**
13.4 Landau's Theory **315**
13.5 Superfluid Velocity **317**
13.6 Superfluid Flow **321**
13.7 The Phonon Wave Function **325**
13.8 Dilute Bose Gas **329**

CHAPTER 14 THE ISING MODEL **341**

14.1 Definition of the Ising Model **341**
14.2 Equivalence of the Ising Model to Other Models **344**
14.3 Spontaneous Magnetization **348**
14.4 The Bragg-Williams Approximation **352**
14.5 The Bethe-Peierls Approximation **357**
14.6 The One-Dimensional Ising Model **361**

CHAPTER 15 THE ONSAGER SOLUTION **368**

15.1 Formulation of the Two-Dimensional Ising Model **368**
15.2 Mathematical Digression **374**
15.3 The Solution **378**

CHAPTER 16 CRITICAL PHENOMENA **392**

16.1 The Order Parameter **392**
16.2 The Correlation Function and the Fluctuation-Dissipation Theorem **394**
16.3 Critical Exponents **396**
16.4 The Scaling Hypothesis **399**
16.5 Scale Invariance **403**
16.6 Goldstone Excitations **406**
16.7 The Importance of Dimensionality **407**

CHAPTER 17 THE LANDAU APPROACH **416**

17.1 The Landau Free Energy **416**
17.2 Mathematical Digression **418**
17.3 Derivation in Simple Models **420**
17.4 Mean-Field Theory **422**
17.5 The Van der Waals Equation of State **426**
17.6 The Tricritical Point **428**
17.7 The Gaussian Model **434**
17.8 The Ginzburg Criterion **437**
17.9 Anomalous Dimensions **438**

CHAPTER 18 RENORMALIZATION GROUP **441**

18.1 Block Spins **441**
18.2 The One-Dimensional Ising Model **443**
18.3 Renormalization-Group Transformation **446**
18.4 Fixed Points and Scaling Fields **449**
18.5 Momentum-Space Formulation **452**
18.6 The Gaussian Model **455**
18.7 The Landau-Wilson Model **458**

APPENDIX *N*-BODY SYSTEM OF IDENTICAL PARTICLES **468**

A.1 The Two Kinds of Statistics **468**
A.2 *N*-Body Wave Functions **470**
A.3 Method of Quantized Fields **477**
A.4 Longitudinal Sum Rules **484**

INDEX **487**