

Contents

<i>Preface</i>	xi
Part I The Kinetic Theory of Gases	1
Introduction	3
Chapter 1 Velocity and Position Distributions of Molecules in a Gas	6
1.1 Avogadro's law, or the equation of state of an ideal gas	
1.2 Temperature and thermal equilibrium	9
1.3 Equipartition of energy per molecule and its constituent parts — a fundamental problem	13
1.4 The density in an isothermal atmosphere — the Boltzmann factor in the potential energy	20
1.5 The Maxwell–Boltzmann distribution	24
1.6 Averages and distributions	28
Chapter 2 Brownian Motion	32
2.1 Historical background	32
2.2 Characteristic scales of Brownian motion	33
2.3 Random walk	35
2.4 Brownian motion, random force and friction: the Langevin equation	37
2.5 Solving the Langevin equation: approximations and orders of magnitude	41
2.6 Applications and implications	44
Chapter 3 Transport Coefficients	49
3.1 Introduction	49
3.2 The mean free path and mean free time	50
3.3 Self-diffusion	56
3.4 The mobility coefficient	61
3.5 The connection between the diffusion coefficient and the mobility	63
3.6 Viscosity and thermal conductivity	64
3.7 Appendix: a more detailed calculation of the diffusion coefficient	68
Self-assessment exercises	71

Solutions to exercises in the text	74
Solutions to self-assessment exercises	107
Part II Statistical Physics with Paramagnets	119
Introduction	121
Chapter 0 Essential Background in Thermodynamics	124
0.1 The first law	124
0.2 The second law and the entropy	128
0.3 Thermodynamic potentials	129
0.4 The third law	133
Chapter 1 Thermodynamics with Magnetic Variables	134
1.1 Introduction	134
1.2 The first law in magnetic variables	136
Chapter 2 Microscopic States and Averages	138
2.1 Magnetic states, angular momentum and paramagnetism	138
2.2 Microscopic states, observables	141
2.3 Probabilities and averages	143
Chapter 3 Isolated Paramagnet — Microcanonical Ensemble	147
3.1 Number of states and probabilities	147
3.2 Calculating averages and correlations	149
3.3 Numerical examples and Stirling's formula	152
Chapter 4 Isolated Paramagnet — Subsystems and Temperature	156
4.1 Microscopic states and thermodynamic equilibrium	156
4.2 β and the temperature	157
4.3 Sharpness of the maximum	158
4.4 Identification of temperature and entropy	161
4.5 Negative temperature	163
4.6 Summary	164
Chapter 5 Paramagnet at a Given Temperature	165
5.1 The canonical ensemble	165
5.2 The partition function and thermodynamic quantities	167
5.3 Susceptibility and specific heat of a paramagnet	170
5.4 Paramagnet with $J > 1/2$	173

<i>Contents</i>	vii
Chapter 6 Order, Disorder and Entropy	174
Chapter 7 Comparison with Experiment	177
Summary	178
Self-assessment exercises	180
Solutions to exercises in the text	183
Solutions to self-assessment exercises	213
Part III Statistical Physics and Thermodynamics	223
Introduction	225
Chapter 1 The Canonical Ensemble and Thermodynamics	226
1.1 The partition function and the internal energy	226
1.2 Thermodynamic work	228
1.3 Entropy, free energy, the first and second laws	233
1.4 The paramagnet — revisited	236
1.5 On the statistical meaning of the free energy	237
Chapter 2 Harmonic Oscillator and Einstein Solid	243
2.1 Microscopic states	243
2.2 Partition function for oscillators	245
2.3 Einstein's solid	248
Chapter 3 Statistical Mechanics of Classical Systems	253
3.1 Statistical mechanics of a single particle	253
3.2 Statistical mechanics of a classical gas	258
Chapter 4 Statistical Mechanics of an Ideal Gas	261
4.1 The ideal gas	261
4.2 Mixtures of ideal gases — Dalton's law	263
4.3 Maxwell–Boltzmann distribution and equipartition	265
4.4 Ideal gas of quantum particles	268
Chapter 5 The Gibbs Paradox and the Third Law	275
5.1 Two difficulties	275
5.2 The Gibbs paradox and its resolution	276
5.3 Remarks on the third law of thermodynamics	281
5.4 Summary	283

Chapter 6	Fluctuations and Thermodynamic Quantities	284
6.1	Paramagnet: fluctuations in the magnetization	284
6.2	Energy fluctuations and the specific heat	286
6.3	Summary	287
	Self-assessment exercises	288
	Solutions to exercises in the text	292
	Solutions to self-assessment exercises	322
Part IV	From Ideal Gas to Photon Gas	337
	Introduction	339
Chapter 1	An Ideal Gas of Molecules with Internal Degrees of Freedom	340
1.1	Center of mass and internal motions	340
1.2	Kinematics of a diatomic molecule	342
1.3	Gas of general composite molecules	346
1.4	Diatomic gas: classical treatment	352
1.5	Diatomic molecules: vibration and rotation	356
1.6	The equipartition principle and its violation	361
1.7	Diatomic gas — quantum calculation	363
Chapter 2	Gases in Chemical Reactions	366
2.1	Conditions for chemical equilibrium	366
2.2	The law of mass action	368
2.3	Dissociation in a diatomic gas	373
Chapter 3	Phonon Gas and the Debye Model	376
3.1	Sound waves in a crystal	376
3.2	Vibrational modes, phonons and enumeration of states	379
3.3	The Debye model	382
Chapter 4	Thermodynamics of Electromagnetic Radiation	385
4.1	General considerations of radiation at thermal equilibrium	385
4.2	Radiation density	387
4.3	Black body radiation	390
4.4	Absorption and emission of radiation — Kirchhoff's law	394
4.5	Role of black body radiation in modern physics	398
Appendix	Calculation of Some Integrals	401

<i>Contents</i>	ix
Self-assessment exercises	403
Solutions to exercises in the text	406
Solutions to self-assessment exercises	434
Part V Of Fermions and Bosons	451
Introduction	453
Chapter 1 Grand Canonical Ensemble	454
1.1 Definitions and motivation	454
1.2 Connection to thermodynamics	455
Chapter 2 Statistical Mechanics of Identical Quantum Particles	458
2.1 Classification of states — occupation numbers	458
2.2 Quantum statistics — many-particle states	460
2.3 Thermodynamics of fermions and bosons	461
2.4 Average occupation numbers	463
Chapter 3 Electrical Conductivity in Metals	466
3.1 The Drude model	466
3.2 A critique of the Drude model	470
3.3 The Sommerfeld model	471
3.4 Electrons at high and low temperatures	474
3.5 Metals at room temperature	478
3.6 Thermodynamics of the Sommerfeld model	479
Chapter 4 Boson Gas	485
4.1 Bose–Einstein distribution	485
4.2 Chemical potential at low temperatures	486
4.3 Bose–Einstein condensation	488
4.4 Superfluidity	490
4.5 Bose–Einstein condensation in helium	493
4.6 Viscosity of a superfluid	497
4.7 Fermi liquid and superconductivity	503
Appendix Calculation of Some Integrals	509
Self-assessment exercises	512
Solutions to exercises in the text	514
Solutions to self-assessment exercises	536
Index	547