

# Contents

<b>Preface</b>	<b>xi</b>
<b>Glossary</b>	<b>xvii</b>
Miscellanea . . . . .	xvii
Latin alphabet . . . . .	xviii
Greek alphabet and Greek-Latin combinations . . . . .	xxii
A note on units . . . . .	xxiii
<b>1. Review of Selected Topics in Thermodynamics</b>	<b>1</b>
1.1 Four laws of thermodynamics . . . . .	2
1.1.1 The Minus-First Law . . . . .	2
1.1.2 The Zeroth Law . . . . .	3
1.1.3 The First Law . . . . .	4
1.1.4 The Second Law . . . . .	5
1.1.5 Temperature . . . . .	7
1.2 Ideal gas . . . . .	8
1.3 Maximum property of the entropy . . . . .	12
1.4 Minimum property of the energy . . . . .	13
1.5 The Second Law and thermal equilibrium . . . . .	14
1.6 Thermodynamical potentials: Free energy, enthalpy, free enthalpy . . . . .	16
1.7 Heat capacities of the ideal gas . . . . .	20
1.8 Minimum property of the free energy . . . . .	22
1.9 Maxwell relations . . . . .	24
1.10 Heat capacities . . . . .	26
1.11 Gibbs–Duhem relation . . . . .	30
1.12 Stability criteria; coexisting phases . . . . .	33
1.13 Gibbs phase rule . . . . .	39

1.14	Clausius–Clapeyron equation . . . . .	43
1.15	Phase transition; Maxwell construction . . . . .	46
1.16	Van der Waals gas . . . . .	50
1.17	Coexisting phases: Entropy, heat capacity . . . . .	57
1.18	Interfaces . . . . .	64
<b>2.</b>	<b>Statistical ensembles</b>	<b>69</b>
2.1	The benefit of large numbers . . . . .	70
2.2	Ergodic principle . . . . .	72
2.3	Microcanonical ensemble . . . . .	73
2.4	Correct Boltzmann counting . . . . .	77
2.5	Canonical ensemble . . . . .	79
2.6	Other ensembles . . . . .	85
2.7	Gibbs’s entropy formula . . . . .	87
2.8	Grand canonical ensemble . . . . .	88
2.9	Fluctuating particle numbers . . . . .	89
2.10	Gibbs’s entropy formula as a basic statement . . . . .	93
<b>3.</b>	<b>Ideal gases</b>	<b>97</b>
3.1	Getting started . . . . .	97
3.2	Occupation numbers; bosons; fermions . . . . .	98
3.3	Average occupation numbers . . . . .	100
3.3.1	Bosons . . . . .	100
3.3.2	Fermions . . . . .	102
3.3.3	Dilute-gas limit . . . . .	103
3.4	Photon gas . . . . .	105
3.5	Phonon gas . . . . .	108
3.6	Bose–Einstein condensation . . . . .	112
3.7	Fermion gas . . . . .	120
3.8	Electron gas in a metal . . . . .	126
3.9	Pressure and energy density . . . . .	130
3.10	The Third Law . . . . .	131
<b>4.</b>	<b>Systems with interaction</b>	<b>133</b>
4.1	Thomas–Fermi model . . . . .	133
4.2	One-dimensional Ising model . . . . .	140
4.3	Renormalization group method (Ising chain) . . . . .	149
4.4	Renormalization group method (Ising square lattice) . . . . .	153
4.5	Order-disorder phase transition . . . . .	159

4.6	Onsager's solution . . . . .	162
4.7	Three-dimensional Ising model. Spontaneous magnetization . . . . .	164
4.8	Mean-field approximation . . . . .	166
<b>5.</b>	<b>Perturbation theory</b>	<b>171</b>
5.1	Large and small contributions . . . . .	171
5.2	Gibbs–Bogolyubov inequality . . . . .	172
5.2.1	Example: Ising model (mean-field approximation) . . . . .	173
5.2.2	Quantum aspects . . . . .	174
5.3	Peierls inequality . . . . .	178
5.4	Minimum principle for the free energy . . . . .	180
5.5	Ising chain with next-next-neighbors interaction . . . . .	183
5.6	Ising model and two-state quantum system . . . . .	187
<b>6.</b>	<b>Real gases</b>	<b>191</b>
6.1	Interacting atoms . . . . .	191
6.2	Clusters . . . . .	193
6.3	Cluster expansion; virial expansion . . . . .	198
6.4	Finite volume, finite number of particles . . . . .	200
6.5	Second virial coefficient: van der Waals gas . . . . .	202
<b>7.</b>	<b>Stochastic processes</b>	<b>205</b>
7.1	Random jumps . . . . .	205
7.1.1	Recurrence relation; generating function . . . . .	206
7.1.2	Example: Symmetric one-unit jumps . . . . .	208
7.2	Asymptotic gaussian distribution . . . . .	210
7.3	Poisson processes . . . . .	212
7.4	Brownian motion: Langevin's random force . . . . .	215
7.5	Autocorrelation function . . . . .	217
7.6	Fluctuations and dissipation . . . . .	222
7.7	Dynamics in phase space . . . . .	222
7.8	Brownian motion: Fokker–Planck equation . . . . .	226
7.8.1	Expected values . . . . .	226
7.8.2	Generating function . . . . .	228
7.8.3	Green's function . . . . .	233
	<b>Exercises with Hints</b>	<b>237</b>
	Exercises for Chapters 1–7 . . . . .	237
	Hints . . . . .	263
	<b>Index</b>	<b>275</b>