Contents

vii

Preface

Intr	oduction to statistical methods	
RANI	OOM WALK AND BINOMIAL DISTRIBUTION	
1.1	Elementary statistical concepts and examples 4	
1.2	The simple random walk problem in one dimension 7	
1.3	General discussion of mean values 11	
1.4	Calculation of mean values for the random walk problem	1
1.4	Probability distribution for large N 17	
1.6	Gaussian probability distributions 21	
GEN	ERAL DISCUSSION OF THE RANDOM WALK	
1.7	Probability distributions involving several variables 25	
	Comments on continuous probability distributions 27	
1.8	General calculation of mean values for the random walk	32
1.9	Calculation of the probability distribution 35	
*1 · 10	Calculation of the producting distribution	
*1 · 11	Probability distribution for large N 37	
2 Sta	itistical description of systems of particles	
STA	TISTICAL FORMULATION OF THE MECHANICAL PROBLEM	1
2.1		, f.,
2.1	77 50	
2.3		
2·3 2·4		
2.5	and the state of t	

INTE	RACTION BETWEEN MACROSCOPIC SYSTEMS	
$2 \cdot 6$	Thermal interaction 66	
$2 \cdot 7$	Mechanical interaction 68	
2.8	General interaction 73	
	Quasi-static processes 74	
2.10	· ·	
	Exact and "inexact" differentials 78	
Stat	tistical thermodynamics	87
IRRE	VERSIBILITY AND THE ATTAINMENT OF EQUILIBRIUM	
$3 \cdot 1$	Equilibrium conditions and constraints 87	
3.2	Reversible and irreversible processes 91	
-	Therefore with with and proceeded by	
THE	RMAL INTERACTION BETWEEN MACROSCOPIC SYSTEMS	
$3 \cdot 3$	Distribution of energy between systems in equilibrium 94	
$3 \cdot 4$	The approach to thermal equilibrium 100	
$3 \cdot 5$	Temperature 102	
$3 \cdot 6$	Heat reservoirs 106	
$3 \cdot 7$	Sharpness of the probability distribution 108	* ;
	ERAL INTERACTION BETWEEN MACROSCOPIC SYSTEMS	
3.8	Dependence of the density of states on the external parameters 112	
$3 \cdot 9$	Equilibrium between interacting systems 114	
$3 \cdot 10$	Properties of the entropy 117	
SUM	MARY OF FUNDAMENTAL RESULTS	
3.11	Thermodynamic laws and basic statistical relations 122	
3.12		
0.12	Statistical calculation of thermodynamic quantities 124	
Mac	croscopic parameters and their measurement	128
$4 \cdot 1$	Work and internal energy 128	
$4 \cdot 2$	Heat 131	
$4 \cdot 3$	Absolute temperature 133	
4-4	Heat capacity and specific heat 189	
$4 \cdot 5$	Entropy 142	
$4 \cdot 6$	Consequences of the absolute definition of entropy 145	
4.7	Extensive and intensive parameters 148	
Ç:	inle applications of macroscopie thermodynamics	152
Sun	ple applications of macroscopic thermodynamics	104
_	PERTIES OF IDEAL GASES	
$5 \cdot 1$	Equation of state and internal energy 153	
$5 \cdot 2$	Specific heats 156	

$5 \cdot 4$	Entropy 160	· ·	
GÉN	ERAL RELATIONS FOR A HOMOGENEOUS SUBSTANCE		
5.5	Derivation of general relations 161		
5.6	Summary of Maxwell relations and thermodynamic function	rs 164	
5.7	Specific heats 166	104	
5.8	Entropy and internal energy 171		
0.0	Thurspy with their field energy 111	100	
FREI	E EXPANSION AND THROTTLING PROCESSES	** ,	
$5 \cdot 9$	Free expansion of a gas 175	• •	
5.10	Throttling (or Joule-Thomson) process 178	* *	
HEAT	F ENGINES AND REFRIGERATORS		
5.11	Heat engines 184		
$5 \cdot 12$	Refrigerators 190		
_			_
Bas	ic methods and results of statistical mechanics	20	L
ENSI	EMBLES REPRESENTATIVE OF SITUATIONS OF PHYSICAL	INTEREST	
$6 \cdot 1$	Isolated system 201		
$6 \cdot 2$	System in contact with a heat reservoir 202	•	
6.3	Simple applications of the canonical distribution 206		
6.4	System with specified mean energy 211		
6.5	Calculation of mean values in a canonical ensemble 212	i i i i i i i i i i i i i i i i i i i	
6.6			
0 0	Connection with the mongrations 214		
APPI	ROXIMATION METHODS		
6.7	Ensembles used as approximations 219	10 m	
*6.8	Mathematical approximation methods 221	~	
GEN	ERALIZATIONS AND ALTERNATIVE APPROACHES	•	
*6.9	Grand canonical and other ensembles 225		
*6.10	Alternative derivation of the canonical distribution 229		
0.10	Atternative derivation of the canonical distribution 229		
Sim	ple applications of statistical mechanics	23	7
~~~	pro approaction of statistical intentation	7 N	•
		•	
	ERAL METHOD OF APPROACH		
$7 \cdot 1$	Partition functions and their properties 237		
IDEA	AL MONATOMIC GAS		
7.2	Calculation of thermodynamic quantities 239		
7.3	Gibbs paradox 243		
7.4	Validity of the classical approximation 246		
	and and an annual articles and an analysis and		

Adiabatic expansion or compression

IHE.	EQUIPARTITION THEOREM	
7.5	Proof of the theorem 248 Simple applications 250	
7.6	Simple applications 250 Specific heats of solids 253	•
••		
	MAGNETISM	
<b>7</b> ·8	General calculation of magnetization 257	
KINE	TIC THEORY OF DILUTE GASES IN EQUILIBRIUM	
$7 \cdot 9$	Maxwell velocity distribution 262	
$7 \cdot 10$	Related velocity distributions and mean values 265	
$7 \cdot 11$	Number of molecules striking a surface 269	
$7 \cdot 12$	Effusion 273	
$7 \cdot 13$	Pressure and momentum transfer 278	
F	ilibrium between phases or chemical species	288
Equ	mortum between phases or chemical species	200
	ERAL EQUILIBRIUM CONDITIONS	
8.1	Isolated system 289	
8.2	System in contact with a reservoir at constant temperature 291	
$8 \cdot 3$	System in contact with a reservoir at constant temperature and	
	pressure 294 Stability conditions for a homogeneous substance 296	
8.4	Stability conditions for a homogeneous substance 296	
EQUI	ILIBRIUM BETWEEN PHASES	
8.5	Equilibrium conditions and the Clausius-Clapeyron equation 301	
8.6	Phase transformations and the equation of state 306	
SYST	TEMS WITH SEVERAL COMPONENTS; CHEMICAL EQUILIBRIUM	
8.7	General relations for a system with several components 312	
8.8	Alternative discussion of equilibrium between phases 315	
8.9	General conditions for chemical equilibrium 317	
8.10	Chemical equilibrium between ideal gases 319	
		331
Que	antum statistics of ideal gases	991
MAX	WELL-BOLTZMANN, BOSE-EINSTEIN, AND FERMI-DIRAC STATISTICS	•
$9 \cdot 1$	Identical particles and symmetry requirements 331	
$9 \cdot 2$		
9.3		
9.4		
9.5	•	
9.6		
9.7		
9.8	Quantum statistics in the classical limit 351	

	IDE	AL GAS IN THE CLASSICAL LIMIT		
	9.9	Quantum states of a single particle 353		
	9.10	Evaluation of the partition function 360		
	9-11	Physical implications of the quantum-mechanical enum states 363	eration of	
. •	*9.12	Partition functions of polyatomic molecules 367		
	BLA	CK-BODY RADIATION		
	9.13	Electromagnetic radiation in thermal equilibrium inside enclosure 373	e an	
	$9 \cdot 14$	Nature of the radiation inside an arbitrary enclosure	<i>378</i>	•
	9.15	Radiation emitted by a body at temperature T 381		
	CON	DUCTION ELECTRONS IN METALS		
	$9 \cdot 16$	Consequences of the Fermi-Dirac distribution 388		
	*9.17	Quantitative calculation of the electronic specific heat	393	
10	G			
10	Sys	tems of interacting particles	•	40
	SOLI	DS		
	10.1	Lattice vibrations and normal modes 407		
	10.2	Debye approximation 411		
	NON	IDEAL CLASSICAL GAS		
	$10 \cdot 3$	Calculation of the partition function for low densities	418	
	$10 \cdot 4$	Equation of state and virial coefficients 422		
	10.5	Alternative derivation of the van der Waals equation	426	-
	FERI	ROMAGNETISM		
	10.6	Interaction between spins 428		
		Weiss molecular-field approximation 430	•	
11	Mai	gnetism and low temperatures		43
	11200	section and tow temperatures		40
	11.1	Magnetic work 439		
	$11 \cdot 2$	Magnetic cooling 445		
	$11 \cdot 3$	Measurement of very low absolute temperatures 452		
	11.4	Superconductivity 455		
12	Elei	nentary kinetic theory of transport processe	es	46
	19.1	Collision time 100		
	12.1	Collision time 463		
	12.2	Collision time and scattering cross section 467		

	14.4	Thermal conductivity 478	
	$12 \cdot 5$	Self-diffusion 483	
	$12 \cdot 6$	Electrical Conductivity 488	
3	Tra	nsport theory using the relaxation time approximation	49
	13.1	Transport processes and distribution functions 494	
	$13 \cdot 1$		
		Boltzmann equation in the absence of collisions 498	
	13.3		
	13.4		
	13.5	1	
	$13 \cdot 6$		
	$13 \cdot 7$		
	13.8	Examples of the Boltzmann equation method 511	
**			•
1			
4	Nea	r-exact formulation of transport theory	<i>51</i> (
	14.1	Description of two-particle collisions 516	
	14.2	Scattering cross sections and symmetry properties 520	
	14.3	Derivation of the Boltzmann equation 523	
	14.5		
		Conservation equations and hydrodynamics 529	
	14.6	Example: simple discussion of electrical conductivity 531	
	14.7	Approximation methods for solving the Boltzmann equation 534	
	14.8	Example: calculation of the coefficient of viscosity 539	
5	7	27.7	
J	irre	versible processes and fluctuations	548
	TRAN	NSITION PROBABILITIES AND MASTER EQUATION	
	$15 \cdot 1$	Isolated system 548	
	$15 \cdot 2$	System in contact with a heat reservoir 551	
:	15.3	Magnetic resonance 553	
	$15 \cdot 4$	Dynamic nuclear polarization; Overhauser effect 556	
		~granite indicat polarization, ordinatal officer	
	SIMP	LE DISCUSSION OF BROWNIAN MOTION	
	15.5	Langevin equation 560	
	15.6	Calculation of the mean-square displacement 565	
	- <del>-</del>	and the state of any are broken to the	
	DETA	AILED ANALYSIS OF BROWNIAN MOTION	
	15.7	Relation between dissingtion and the fluctuating force 567	

Viscosity

15.8	Correlation functions and the friction constant 570	
*15.9	Calculation of the mean-square velocity increment 574	
*15 · 10	Velocity correlation function and mean-square displacement 575	
CALC	CULATION OF PROBABILITY DISTRIBUTIONS	
*15.11	The Fokker-Planck equation 577	
*15.12	Solution of the Fokker-Planck equation 580	
	RIER ANALYSIS OF RANDOM FUNCTIONS	
15.13	Fourier analysis 582	
15.14		
	Wiener-Khintchine relations 585	
15.16		
15.17	Nyquist's theorem and equilibrium conditions 589	
GEN	ERAL DISCUSSION OF IRREVERSIBLE PROCESSES	
$15 \cdot 18$	Fluctuations and Onsager relations 594	
4	pendices	605
App	ienuices	000
A.1	Review of elementary sums 605	
A.2	Evaluation of the integral $\int_{-\infty}^{\infty} e^{-x^2} dx$ 606	
A.3	Evaluation of the integral $\int_0^\infty e^{-x} x^n dx$ 607	
A.4	Evaluation of integrals of the form $\int_0^\infty e^{-\alpha x^2} x^n dx$ 608	
A.5		
A.6	Stirling's formula 610	
A.7	The Dirac delta function 614	
A.8	The inequality $\ln x \le x - 1$ 618	
A.9	Relations between partial derivatives of several variables 619	
A.10	The method of Lagrange multipliers 620	
A.11	Evaluation of the integral $\int_0^\infty (e^z - 1)^{-1} x^3 dx$ 622	
A.12	The H theorem and the approach to equilibrium 624	
A.13	Liouville's theorem in classical mechanics 626	
. N	merical constants	629
110	nei veuv constantis	0-2
		٠
Bib	liography	631
Ans	swers to selected problems	637
Ind	lex	645