

CONTENTS

PREFACE	PAGE V
--------------------------	-------------------

CHAPTER I

ELEMENTS OF THE KINETIC THEORY OF GASES.	1
1. The Kinetic Theory of Matter.	1
2. Atoms and Molecules.	3
3. Statistical Nature of the Theory.	5
4. Gaseous Pressure	6
5. Calculation of the Pressure	7
6. Dalton's Law	9
7. Mass Motion	9
8. Reversible Expansion and Compression.	11
9. Free Expansion	14
10. Isothermal Properties of the Ideal Gas	16
11. Avogadro's Law.	18
12. The Temperature	19
13. The Thermodynamic Temperature Scale	20
14. The Perfect-gas Law.	22
15. Molecular Magnitudes	24
16. Rapidity of the Molecular Motion.	26

CHAPTER II

DISTRIBUTION LAW FOR MOLECULAR VELOCITIES	28
17. The Distribution Function for Molecular Velocity	28
18. Distribution Function in Other Variables.	30
19. Remarks on the Distribution Function.	31
20. Proofs of the Distribution Law	32
21. Molecular Chaos.	33
22. The Effect of Collisions upon f	34
23. Velocities after a Collision	36
24. The Inverse Collisions	37
25. The Rate of Change of the Distribution Function	39
26. The Equilibrium State	40
27. Rigorous Treatment of the Equilibrium State.	42
28. Maxwell's Law	45
29. Use of a Distribution-function in Calculating Averages.	48
30. Most Probable and Average Speeds	48
31. Mixed Gases. Equipartition	51
32. Uniqueness of the Maxwellian Distribution. The H -theorem.	52
33. Reversibility and the H -theorem.	55
34. Principle of Detailed Balancing	55
35. Doppler Line Breadth	58

	Page
CHAPTER III	
GENERAL MOTION AND SPATIAL DISTRIBUTION OF THE MOLECULES. . . .	60
Unilateral Flow of the Molecules:	
36. Effusive Molecular Flow	60
37. Formulas for Effusive Flow	61
38. Molecular Effusion	64
39. Thermal Transpiration	66
40. Knudsen's Absolute Manometer	67
41. Evaporation	68
42. Observations on the Rate of Evaporation	70
43. Test of the Velocity Distribution in Effusive Flow	71
The General Distribution-function:	
44. A Gas in a Force-field	74
45. Density in a Force-field	74
46. Maxwell's Law in a Force-field	76
47. The Temperature of Saturated Vapor	79
48. The Terrestrial Atmosphere	79
49. Cosmic Equilibrium of Planetary Atmospheres	81
50. The General Distribution-function	85
51. Differential Equation for the Distribution-function	85
52. Applications of the Differential Equation	89
The Boltzmann Distribution Formula:	
53. The Classical Boltzmann Distribution Formula	90
54. The Boltzmann Formula in Quantum Theory	93
55. Special Cases of the Boltzmann Formula	95
Free Paths and Collisions:	
56. Molecules of Finite Size	97
57. The Mean Free Path and Collision Rate	98
58. Dependence of L and Θ upon Density and Temperature	100
59. Distribution of Free Paths. Absorption of a Beam	101
60. The Mutual Collision Cross Section	103
61. The Mean Free Path in a Constant-speed Gas	105
62. A Molecular Beam in a Maxwellian Gas	107
63. Mean Free Path and Collision Rate at Constant Speed	109
64. Mean Free Path and Collision Rate in a Maxwellian Gas	110
65. Magnitude of the Correction for Maxwell's Law	113
66. Mode of Determining L and S or σ	113
67. Collisions in a Real Gas	113
Molecular Scattering:	
68. The Scattering Coefficient	115
69. Classical Scattering Coefficient for Symmetrical Molecules with Fixed Scatterer	116
70. Examples of the Scattering Coefficient	118
71. Relative Scattering	120
72. Classical Scattering Coefficient for Free Symmetrical Molecules	122
73. The Experimental Determination of the Collision Cross Section . . .	124
74. Knauer's Observations on Scattering	125
75. The Wave Mechanics of a Particle	127
76. The Indetermination Principle	130
77. Wave Mechanics and Molecular Collisions	131
78. Wave-mechanical Scattering Coefficients	132

CHAPTER IV

VISCOSITY, THERMAL CONDUCTION, DIFFUSION 135

A. Viscosity:

79. Viscosity	136
80. Fluid Stresses in General	137
81. Simple Theory of Viscosity	138
82. The Mean Free Path across a Fixed Plane	141
83. Correction for the Velocity Spread	142
84. Further Correction of the Viscosity Formula	145
85. New View of the Molecular Process	146
86. Final Viscosity Formula. Magnitudes of L and σ	147
87. Variation of Viscosity with Density	148
88. Variation of Viscosity with Temperature	150
89. Viscosity and Temperature with an Inverse-power Force	152
90. Viscosity and Temperature on Sutherland's Hypothesis.	154
91. Viscosity and Temperature: Other Hypotheses.	157
92. Viscosity of Mixed Gases.	160

B. Conduction of Heat:

93. The Kinetic Theory of Heat Conduction	162
94. Simple Theory of the Conductivity.	163
95. Thermal Conductivity of Symmetrical Small-field Molecules. First Step	165
96. Thermal Conductivity on Meyer's Assumption	168
97. Thermal Conductivity: Second Step	169
98. Effect of One Collision upon $\Sigma v_x v^2$	172
99. Average of the Effect on $\Sigma v_x v^2$	173
100. Total Effect of Collisions on $\Sigma v_x v^2$	175
101. Thermal Conductivity: Final Approximate Formula	177
102. Final Correction of the Conductivity Formula.	179
103. Comparison with Observed Conductivities	180
104. Conduction of Heat by Complex Molecules.	181
105. Properties of the Conductivity.	182

C. Diffusion:

106. Diffusion.	184
107. The Coefficient of Diffusion.	185
108. Simple Theory of Diffusion	188
109. Approximate Coefficient of Diffusion for Spherically Symmetrical Molecules.	190
110. Self-diffusion	194
111. The Corrected Diffusion Coefficient	195
112. Experiments on the Variation with Composition.	196
113. Diffusion at Various Pressures and Temperatures	197
114. Numerical Values of the Diffusion Coefficient	199
115. Forced Diffusion.	201
116. Thermal Diffusion.	204

CHAPTER V

THE EQUATION OF STATE.	206
117. The Equation of State	206
118. The Equation of van der Waals	206
119. The van der Waals Isothermals	208

	PAGE
120. Quantitative Tests of van der Waals' Equation	210
121. More Exact Theory of the Pressure in a Dense Gas	211
122. Hard Attracting Spheres: The Repulsive Pressure	214
123. Equation of State for Hard Attracting Spheres	217
124. The Value of b	218
125. Other Equations of State.	218
126. Series for pV ; Virial Coefficients.	221
127. The Second Virial Coefficient	222
128. The Second Virial Coefficient and van der Waals' Equation.	223
129. Theory of the Second Virial Coefficient, B	225
130. Nature of Molecular Forces.	228
131. B with an Inverse-power Force	229
132. Classical Calculations of B	230
133. Calculations of B by Wave Mechanics	232
134. B for Mixed Gases.	234
135. The Virial Theorem	235

CHAPTER VI

ENERGY, ENTROPY, AND SPECIFIC HEATS	238
Information Obtainable from Thermodynamics:	
136. Some Definitions and Basic Principles	239
137. Differential Equations for the Energy U	240
138. Experimental Measurement of Energy and Entropy; the Specific Heats	242
139. Specific-heat Relations	244
140. Variation of the Specific Heats	245
141. Thermodynamics of Perfect and van der Waals Gases	246
Specific Heat of the Perfect Gas:	
142. Molecular Energy	248
143. The Classical Theory of Specific Heat	249
144. Comparison with Actual Specific Heats.	251
145. The Specific-heat Difference.	254
146. The Problem of the Internal Energy.	254
147. Quantum Theory of the Specific Heat	255
148. Variation of Specific Heat with Temperature	257
149. The Case of Harmonic Oscillators	258
150. Hydrogen.	260
151. Para-, Ortho-, and Equilibrium Hydrogen.	262
152. Specific Heat of Hydrogen	264
153. Specific Heats of Mixed Gases.	265

CHAPTER VII

FLUCTUATIONS	267
Phenomena of Dispersion:	
154. The Simple Random Walk	268
155. The Varied Random Walk	271
156. Dispersion of a Group of Molecules	272
157. Molecular Scattering of Light.	273
Fluctuations about an Average:	
158. Theory of Fluctuations about an Average.	275
159. Examples of Molecular Fluctuations	279

Diffusion and the Brownian Motion:

160. The Brownian Motion	280
161. Theory of the Brownian Motion	281
162. Observations of Brownian Motion	284
163. Diffusion as a Random Walk	286
164. Brownian Motion under External Force	287

CHAPTER VIII

PROPERTIES OF GASES AT LOW DENSITIES	291
--	-----

Motion in Rarefied Gases:

165. Viscous Slip	292
166. Steady Flow with Slip	293
167. Maxwell's Theory of Slip	295
168. Discussion of the Slip Formula	296
169. Observations of Slip	298
170. Free-molecule Viscosity	300
171. Free-molecule Flow through Long Tubes	302
172. The Long-tube Formula	304
173. Flow through Short Tubes	306
174. Observations of Free-molecule Flow	308
175. Stokes' Law for Spheres	309

Thermal Conduction in Rarefied Gases:

176. Temperature Jump and the Accommodation Coefficient	311
177. Theory of the Temperature Jump	312
178. Free-molecule Heat Conduction between Plates	315
179. Free-molecule Conduction between Coaxial Cylinders	318
180. Observed Variation of the Accommodation Coefficient	320
181. Magnitude of the Accommodation Coefficient	322
182. Spectral Emission by an Unequally Heated Gas	324
183. Theoretical Calculations of the Accommodation Coefficient	325

Thermal Creep and the Radiometer:

184. Thermal Creep	327
185. The Creep Velocity	328
186. Thermal Pressure Gradients and Transpiration	330
187. Thermal Gradients at Moderate Pressures	331
188. The Radiometer and Photophoresis	333
189. The Quantitative Theory of Radiometer Action	335

CHAPTER IX

STATISTICAL MECHANICS	338
---------------------------------	-----

190. Nature of Statistical Mechanics	338
--	-----

A. Classical Statistical Mechanics:

191. System Phase Space	339
192. Representative Ensembles	340
193. The Ergodic Surmise	341
194. Liouville's Theorem	343
195. The Ergodic Layer and the Microcanonical Ensemble	344
196. The Point-mass Perfect Gas	346
197. The Molecular Distribution. Molecular Chaos	348
198. The Loose Many-molecule System	350

	PAGE
199. The Most Probable Distribution	352
200. The Most Probable as a Normal Distribution	354
201. Some Generalizations of the Loose Many-molecule System	355
202. Introduction of the Temperature	357
203. Entropy	360
204. Entropy of the Monatomic Gas	361
205. The General Boltzmann Distribution Law	362
206. The Equipartition of Energy	364
207. The Canonical Distribution and Ensemble	366
208. Entropy under a Canonical Distribution	367
209. The Second Law of Thermodynamics	367
210. Entropy and Probability	368
211. Relations with Boltzmann's H	371
212. Entropy as a Measure of Range in Phase	371
213. Relativity and Statistical Theory	372
B. Statistical Wave Mechanics:	
214. The Wave-mechanical Description	373
215. The Exclusion Principle	375
216. The State of Equilibrium	375
217. A Priori Probabilities	377
218. The Many-molecule System without Interaction	379
219. Fermi-Dirac and Bose-Einstein Sets of Similar Molecules	380
220. The Loosely Coupled Many-molecule System	382
221. Statistics of the Loose Many-molecule System	382
222. Introduction of the Temperature	385
223. Case of Large Energies: Classical Theory as a Limit Form	387
224. Entropy of a Loose Many-molecule System	388
225. Statistics of Mixed Systems	389
226. The Canonical Distribution in Wave Mechanics	390
227. The Entropy	391

CHAPTER X

WAVE MECHANICS OF GASES	393
228. The Perfect Gas in Wave Mechanics	393
229. The Point-mass Perfect Gas	395
230. The Two Types of Point-mass Gas	397
231. The Homogeneous Point-mass Gas in Equilibrium	397
232. The Approach to Classical Behavior	401
233. The Number of States	402
234. The Zero-point Entropy	405
235. Chemical Constant and Vapor Pressure	407
236. The Fermi-Dirac Gas of Point Masses	409
237. The Degenerate Fermi-Dirac Gas	412
238. The Bose-Einstein Gas of Point Masses	416
239. Complex Gases	417
240. Free Electrons in Metals	419
241. Degeneracy in Actual Gases	421
242. Dissociation	422
243. Dissociation in the Classical Limit	425
244. A Gas Not in Equilibrium	427

CHAPTER XI

ELECTRIC AND MAGNETIC PROPERTIES OF GASES	432
The Dielectric Constant:	
245. Polarization and the Dielectric Constant	432
246. The Local Electric Field	433
247. The Mean Molecular Moment $\bar{g}$	435
248. The Molecular Polarizability α	436
249. The Clausius-Mossotti Law	437
250. Polarization Due to a Permanent Moment	438
251. Behavior in Intense Fields	441
252. The Variation with Temperature	441
253. Quantum Theory of Polarization	442
254. Initial Polarizability by Perturbation Theory	444
255. Wave Mechanics of the Dumbbell Molecule	448
256. Polarizability of a Dumbbell Molecule with a Structural Moment	450
Magnetic Susceptibility:	
257. Magnetism and Molecular Magnetizability	454
258. Langevin's Theory of Paramagnetism	455
259. Quantum Theory and Magnetizability	456
260. Sources of Molecular Magnetism	457
261. Wave Mechanics in a Magnetic Field	458
262. Magnetizability by Perturbation Theory	460
263. Diamagnetism	462
264. Paramagnetism	463
Motion of Electricity in Gases:	
265. The Motion of Ions in Gases	464
266. The Mobility	466
267. Mobility of Heavy Ions	467
268. The Mobility of Free Electrons	469
269. Elementary Theory of Electronic Mobility	470
270. Actual Electron Mobilities	473
SOME INTEGRALS	477
IMPORTANT CONSTANTS	478
INDEX	479