

CONTENTS

1. Beam Measurements of Atomic Polarizabilities	
By Benjamin Bederson and Edward J. Robinson	1
2. Elastic Scattering of High-Energy Beams: Repulsive Forces	
By I. Amdur and J. E. Jordan	29
3. Quantum Effects in Elastic Molecular Scattering	
By Richard B. Bernstein	75
4. Elastic Scattering in Chemically Reactive Systems	
By E. F. Greene, A. L. Moursund, and J. Ross	135
5. Collisions of Electronically Excited Atoms and Molecules	
By E. E. Muschlitz, Jr.	171
6. Charge Transfer	
By R. F. Stebbings	195
7. Ion-Neutral Reactions	
By C. F. Giese	247
8. Supersonic Nozzle Beams	
By J. B. Anderson, R. P. Andres, and J. B. Fenn	275
9. Reactive Scattering in Molecular Beams	
By D. R. Herschbach	319
Appendix. Selected References on Molecular Beam Research	395
Author Index	397
Subject Index	411

1. BEAM MEASUREMENTS OF ATOMIC POLARIZABILITIES*

BENJAMIN BEDERSON and EDWARD J. ROBINSON

Physics Department, New York University, New York

CONTENTS

I. Introduction	1
II. Theory	2
III. Methods of Calculating Polarizabilities	6
IV. Atomic Beam Experiments	9
A. Alkali Measurements	9
B. Measurements of Metastable 3P_2 Argon	20
V. Conclusion	25
References	26

2. ELASTIC SCATTERING OF HIGH-ENERGY BEAMS: REPULSIVE FORCES

I. AMDUR and J. E. JORDAN

*Department of Chemistry, Massachusetts Institute of Technology,
Cambridge, Massachusetts*

CONTENTS

I. Introduction	29
II. Fundamental Concepts	31
III. Analysis	33
A. General Features of Elastic Scattering	33
B. Detailed Analysis of Scattering Experiments	35
1. Classical Analysis for Central Forces	35
2. Scattering by a Non-Central Force	47
3. Background Scattering	50
4. Quantum Scattering	53
5. Inelastic Scattering	54
IV. Experimental	57
A. Typical Apparatus	57
B. Modifications	59
V. Results	62
VI. Applications	68
VII. Summary	70
References	71

3. QUANTUM EFFECTS IN ELASTIC MOLECULAR SCATTERING†

RICHARD B. BERNSTEIN

*Theoretical Chemistry Institute and Chemistry Department,
University of Wisconsin, Madison, Wisconsin*

CONTENTS

I. Introduction	75
II. Résumé of Classical Treatment of Potential Scattering	76
III. Résumé of Quantum Scattering Treatment.....	83
IV. Approximation Methods	88
A. The Radial Wave Function	89
B. The Phase Shifts	91
V. The Scattering Amplitude	94
VI. The Interference Pattern	99
VII. Rainbow Scattering	103
VIII. Low-Angle Scattering	105
IX. Glory Interference Effect at Low Angles	114
X. Total Elastic Cross Section	117
XI. Extrema in Total Cross Sections	120
XII. Maxima in Impact Spectra and the Bound States	124
XIII. Influence of Concurrent Inelastic Processes.....	126
References	131

4. ELASTIC SCATTERING IN CHEMICALLY REACTIVE SYSTEMS*

E. F. GREENE, A. L. MOURSUND,[†] and J. ROSS

*Metcalf Chemical Laboratories, Brown University,
Providence, Rhode Island*

CONTENTS

I. Introduction	135
II. Experiments	139
III. The Elastic Scattering of K + Kr, K + HCl, K + HBr, and K + HI ...	142
A. Threshold Energies	153
B. Threshold Distances	153
C. Probability of Reaction and Populations of Product States	154
D. Independent Estimates of the Size Parameter r_m	154
E. Total Reaction Cross Section	157
IV. The Elastic Scattering of K + CH ₃ Br	157
V. The Elastic Scattering of K + C(CH ₃) ₄ and K + CBr ₄	160
VI. Conclusion	165
Appendix	166
References	168

5. COLLISIONS OF ELECTRONICALLY EXCITED ATOMS AND MOLECULES

E. E. MUSCHLITZ, Jr.

*Department of Chemistry, University of Florida,
Gainesville, Florida*

CONTENTS

I. Introduction	171
II. Production and Detection of Molecular Beams of Excited Species	172
A. Production	172
B. Detection	174
III. Lifetimes of Excited Species	176
IV. Elastic Collisions	179
A. Total Elastic Cross Sections	179
B. Differential Elastic Cross Sections	184
V. Inelastic Collisions	187
References	191

6. CHARGE TRANSFER

R. F. STEBBINGS

*General Atomic Division of General Dynamics Corporation,
San Diego, California*

CONTENTS

I.	Introduction	195
II.	Charge Transfer	197
	A. The Near-Adiabatic Hypothesis	197
	B. The Collision Cross Section	198
	C. Classification of Collisions	199
III.	Experimental Methods for Measurement of Charge Transfer Cross Sections	200
	A. Slow Particle Detection	200
	1. The Condenser Method	200
	2. Mass Analysis of the Target Ions	202
	B. Fast Particle Detection	206
	1. Analysis of Particles After Gas Traversal	207
	2. Beam Attenuation in a Transverse Field	209
	C. Measurement of Angular and Energy Distribution	212
	1. Observations of Incident or Recoil Particles	212
	2. Coincidence Detection of Scattered Particles	215
IV.	Study of Chemically Unstable Gases	218
	A. Crossed Beam Techniques	218
	B. Collision Chamber Techniques	222
V.	The Influence of Excited Particles upon Charge Transfer	225
	A. Metastable Ions in the Primary Beam	225
	B. Excited Products of Charge Transfer	228
VI.	Theoretical Considerations	234
	A. High Velocity Region	234
	B. Low Velocity Region	239
	C. Energy Resonance	240
	References	243

89. W. L. Fite, R. F. Stebbings, D. G. Hummer, and R. T. Brackmann, *Phys. Rev.*, **119**, 663 (1960).
90. A. Dalgarno and H. N. Yadav, *Proc. Phys. Soc.*, **A66**, 173 (1953).
91. T. J. M. Boyd and A. Dalgarno, *Proc. Phys. Soc.*, **72**, 694 (1958).
92. A. Dalgarno and M. R. C. McDowell, *Proc. Phys. Soc.*, **A69**, 615 (1956).
93. A. F. Ferguson and B. L. Moiseiwitsch, *Proc. Phys. Soc.*, **A74**, 457 (1959).
94. E. F. Gurnee and J. L. Magee, *J. Chem. Phys.*, **26**, 1237 (1957).
95. S. B. Karmohapatro and T. P. Das, *J. Chem. Phys.*, **29**, 240 (1958).
96. S. B. Karmohapatro, *J. Chem. Phys.*, **30**, 538 (1959).
97. I. P. Iovitsu and N. Ionescu-Pallas, *Soviet Phys. Tech. Phys.*, **4**, 791 (1960).
98. D. R. Bates and N. Lynn, *Proc. Roy. Soc. (London)*, **A253**, 141 (1959).
99. A. Dalgarno, *Ann. Geophys.*, **17**, 16 (1961).

7. ION-NEUTRAL REACTIONS

C. F. GIESE

*Department of Physics, University of Chicago,
Chicago, Illinois*

CONTENTS

I.	Introduction.....	247
II.	General Comments	248
III.	Recent Refinements in Technique	250
IV.	Low-Energy Charge Transfer	252
	A. Energetics of Reactions	252
	B. Low-Energy Asymmetric Near-Resonance Charge Transfer	254
	C. Threshold Behavior of Endothermic Charge Transfer	256
V.	Ion-Molecule Reactions	258
	A. Information Obtained from Variation of Electron Energy	258
	B. Temperature Effects.....	259
	C. Repeller Effects	260
	D. Isotopic Effects	262
	E. Persistent Complexes.....	264
	F. Theory of Ion-Neutral Reactions.....	265
VI.	Miscellaneous Aspects of Ion-Neutral Reactions	268
VII.	Future Prospects	269
	References	271

8. SUPERSONIC NOZZLE BEAMS*

J. B. ANDERSON, R. P. ANDRES, and J. B. FENN

Beam Kinetics Laboratory, School of Engineering and Applied Sciences, Princeton University, Princeton, New Jersey

CONTENTS

I.	Introduction	275
II.	Basic Principles of Nozzle Beam Operation	277
	A. General Considerations	277
	B. Theoretical Nozzle Beam Performance	279
	C. Comparison of Nozzle and Oven Beams	282
III.	Some Design Considerations and Experimental Results	282
	A. Pumping Speed Requirements	283
	B. The Nozzle-Jet System	284
	C. The Skimmer	292
IV.	Applications of Nozzle Beams	304
	A. Sampling Experiments and Their Interpretation	304
	B. Direct Studies with Beam Molecules	306
V.	Energy Limitations and the Use of Mixed Gases	308
	A. The General Problem of Energy	308
	B. Nozzle Beams and Mixed Gases	311
	C. Related Experiments with Gas Mixtures	313
	References	315

9. REACTIVE SCATTERING IN MOLECULAR BEAMS

D. R. HERSCHBACH

*Department of Chemistry, Harvard University,
Cambridge, Massachusetts*

CONTENTS

I. Experimental Methods and Results.....	322
A. Apparatus and Experimental Conditions.....	322
B. Angular Distribution Measurements.....	328
C. Magnetic Deflection Analysis.....	341
D. Velocity Analysis of Products.....	344
E. Electric Deflection Analysis.....	347
F. Summary and Discussion.....	356
II. Chemical Forces in Charge-Transfer Reactions.....	367
A. The Harpooning Mechanism.....	368
B. Correlation with Electronic Structure.....	379
References	388

The atoms move in the void and catching each other up jostle together, and some recoil in any direction that may chance, and others become entangled with one another in various degrees according to the symmetry of their shapes and sizes and positions and order, and they remain together and thus the coming into being of composite things is effected.

SIMPLICIUS (6th Century A.D.)