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THERMONUCLEAR DIVISION

ATOMIC AND MOLECULAR COLLISION CROSS SECTIONS OF INTEREST IN CONTROLLED THERMONUCLEAR RESEARCH

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ABSTRACT

A graphical compilation is presented of atomic and molecular cross sections of interest to controlled thermonuclear research. The cross sections are shown, as a function of energy, for collision processes involving molecular ion dissociation, charge exchange, excitation, ionization, photoionization, scattering, energy loss, and recombination. Pertinent nuclear cross sections are also included. A bibliography is given covering the literature since 1950.

INTRODUCTION

This report is a compilation of cross sections available in the literature since 1950. The work was undertaken some three years ago as a guide for investigators in the thermonuclear field at Oak Ridge National Laboratory. The comprehensive surveys of Massey and Burhop¹ and Allison and Warshaw² summarize the data prior to 1950. This compilation is principally limited to atomic collision processes that may be encountered in the attempts to develop a high density, high temperature plasma. In addition to presenting the cross sections in graphical form, we have compiled a bibliography in each section. References appearing during 1960 are included in Appendix A. The bibliography reference numbers follow the title and the author's name on each graph.

In the original papers, the cross sections are stated in a variety of units (πa_0^2 , collision probability, etc.). In this summary all cross sections are reduced to the common unit of $\text{cm}^2/(\text{gas atom})$ to provide a convenient means of comparing the results of various investigators. In addition, the cross sections are plotted as a function of both particle velocity and particle energy.

The notation used is that in current use. The cross section σ_{if} represents the cross section of an energetic particle of initial charge state i and final charge state f . More recently Hasted³ has used the notation ${}_{if}\sigma_{mn}$ where i, f represents the initial and final charge state of the incoming particle and m, n represents the initial and final charge state of the target atom.

In many measurements (notable in charge exchange) the data of many investigators are consistent within a few per cent; however, for convenience and to avoid duplication, only a representative sample is reproduced.

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Dissociation, Ionization, and Excitation of H_2^+ by Fast Protons.
(Theoretical: Gerjuoy G-1)

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Theoretical Dissociation of H_2^+ by Carbon Particles of Charge Z in the Vacuum Carbon Arc. (Theoretical: Alsmiller A-2)

Dissociation of H_2^+ by Electrons and Protons. (Theoretical: Ivash I-2)

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Equilibrium Fraction of H^0 in Hydrogen Gas. (Stier, Barnett, and Evans S-19)

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Fraction of Beam in +1, 0, -1 Charge State After Passage Through
"Thick" Target. H in Hydrogen Gas. (Stier, Barnett, and Evans S-19)

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Equilibrium Fraction of H^0 in Various Gases. (Stier, Barnett, and Evans S -19)

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Equilibrium Proton Charge Ratio from an Aluminum Foil Contaminated with Foreign Material on Its Surfaces as a Function of Exit Energy. (Phillips P-12)

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The Ratio of the Electron Capture Cross Section to the Electron Loss Cross Section for Protons in Various Metals. For proton energies greater than 50 kev,

$$\text{the ratio: } \frac{\sigma_{01}}{\sigma_{10}} \approx \frac{\text{Fraction of Protons}}{\text{Fraction of Neutrals}} \cdot (\text{Hall H-11})$$

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The Charge Transfer Cross Section of Hydrogen Atoms and Ions in Hydrogen Gas. (Barnett and Reynolds B-13) (Stier and Barnett S-20)

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The Charge Transfer Cross Section of Hydrogen Atoms and Ions in Argon Gas. (Barnett and Reynolds B-13) (Stier and Barnett S-20)

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The Charge Transfer Cross Section of Hydrogen Atoms and Ions in Helium Gas. (Barnett and Reynolds B-13) (Stier and Barnett S-20)

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The Electron Capture Cross Section for Protons in Atomic Hydrogen. (Fite *et al.* F-16)

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Electron Capture and Loss Cross Sections for Protons Passing Through Atomic Hydrogen. (Theoretical: Dalgarno and Griffing D-13)

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Electron Capture Cross Section of H^+ and H_2^+ in Argon Gas. (Stedeford and Hasted S-16)

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Electron Capture Cross Section of H^+ and H_2^+ in Hydrogen Gas.
(Stedeford and Hasted S-16)

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Electron Capture Cross Section of H_2^+ and H_3^+ Passing Through Hydrogen Gas. (Afrosimov, Il'in, and Fedorenko A-11)

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Electron Capture Cross Sections of H_2^+ Ions in Hydrogen Gas.
(Muschlitz and Simmons M-16)

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Electron Capture Cross Section of H_2^+ in Helium Gas. (Stedeford and Hasted S-16)

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Electron Capture Cross Section for Various Unsymmetric Reactions.
(Ghosh and Sheridan G-16)

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Charge Transfer Cross Sections for Symmetric Reactions: Ions in their Own Gas. (Ghosh and Sheridan G-15)

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Electron Capture and Loss Cross Section of Carbon Atoms in H_2 and N_2 Gas. (Fogel, Ankudinov, and Slobospitskii F-27)

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Electron Capture Cross Sections of Doubly Charged Carbon Ions in Noble Gases. (Hasted and Smith H-16)

Electron Capture and Loss of Oxygen Atoms with H_2 and N_2 Gas. (Fogel, Ankudinov, and Slobospitskii F-27)

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Electron Capture Cross Sections for Highly Ionized Krypton in Neon Gas.
(Hasted, Scott, and Chong H-17)

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Excitation Cross Section of Hydrogen Atoms by Hydrogen Atom Impact.
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Comparison of Theoretical and Experimental Cross Section for the Excitation of Lyman-Alpha Radiation by Electrons. (Fite and Brackmann F-49)

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Comparison of Cross Sections for Excitation of Lyman-Alpha Radiation from the Hydrogen Atoms and Countable Ultraviolet Radiation from the Molecule. (Fite and Brackmann F-49)

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Excitation Cross Section of Hydrogen Atoms by Proton Impact.
(Theoretical: Bates and Griffing G-44)

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Ionization Cross Section for the 2p, n = ±1 States in Hydrogen Gas by Electron Impact. (Theoretical: Mandl M-44)

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Ionization Cross Sections of Mercury Under Electron Impact. (Harrison H-43)

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Ionization Cross Section for Hydrogen, Helium, Neon, and Argon Gas
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Ionization Cross Sections for Nitrogen, Argon, and Hydrogen Gas Under Electron Impact, 1-50 kev. (Sommermeyer and Dresel S-48)

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Ionization Cross Sections of Hydrogen and Helium Gases Under Electron Impact. Formation of various product ions. (Harrison H-43)

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Ionization Cross Section for Atomic Hydrogen by Electrons. (Fite and Brackmann F-48)

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Cross Section for Production of Secondary H_2^+ Ions in Hydrogen Gas by H^+ , H_2^+ , and H_3^+ Ions. (Afrosimov, Il'in, and Fedorenko A-43)

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Cross Section for Production of Secondary Protons in Hydrogen Gas by H^+ , H_2^+ , and H_3^+ Ions. (Afrosimov, Il'in, and Fedorenko A-43)

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Total Cross Section for Production of Free Electrons in Hydrogen Gas by H^+ , H_2^+ , and H_3^+ Ions. (Afrosimov, Il'in, and Fedorenko A-43)

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Ionization Cross Section of Hydrogen Gas Under Impact of H^+ and H_2^+ Ions.
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Photoionization Cross Section of Argon, Hydrogen, and Water Vapor.
(Wainfan, Walker, and Weissler W-61)

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Photoionization Cross Sections for Oxygen and Nitrogen Gas. (Wainfan, Walker, and Weissler W-61)

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Elastic Scattering Cross Section of Electrons in Atomic Hydrogen. (Theoretical: Bransden *et al.* B-85) (Fite F-81)

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The Elastic Scattering Cross Sections of Hydrogen Ions in Hydrogen Gas.
(Muschlitz and Simmons M-91)

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The Elastic Collision of Hydrogen and Deuterium Atoms in Hydrogen, Deuterium, and Helium Gas. (Admur and Kells A-81) (Admur and Mason A-87)

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Total Elastic Collision Cross Section of H⁺ and H⁻ Ions in Atomic Hydrogen. (Theoretical: McDowell M-85)

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Elastic and Inelastic Scattering Cross Section of He^+ Ions in Helium.
(Cramer and Simmons C-86)

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Large Angle Differential Scattering Cross Section of Argon Ions in Argon Gas. (Fuls *et al.* F-82)

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Large Angle Differential Scattering Cross Section of Helium Ions in Helium Gas. (Fuls *et al.* F-82)

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APPENDIX B. LISTING OF JOURNAL AND REPORT ABBREVIATIONS

APPENDIX B. LISTING OF JOURNAL AND REPORT ABBREVIATIONS

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LIST OF JOURNALS REFERRED TO IN THE BIBLIOGRAPHY

<u>Abbreviation</u>	<u>Journal</u>
Acta Cryst.	Acta Crystallographica
Airglow and the aurorae (Belfast)	
Ann. Inst. Poincaré	Annales de l'Institut Poincaré
Ann. N. Y. Acad. Sci.	Annals of the New York Academy of Sciences
Ann. Phys. (New York)	Annals of Physics, New York
Ann. Radioelect.	Annales de Radioelectricité
Appl. sci. Res.	Applied Scientific Research
Ark. Fys.	Arkiv för Fysik
Astrophys. J.	Astrophysical Journal
Atomnaya Energiya	
Austral. J. Phys.	Australian Journal of Physics
Austral. J. Sci. Res.	Australian Journal of Scientific Research
Brit. J. Appl. Phys.	British Journal of Applied Physics
Bull. Am. Phys. Soc.	Bulletin of the American Physical Society
Bull. Chem. Soc. Japan	Bulletin of the Chemical Society of Japan
Cahier de Phys.	Cahier de Physique
Canad. J. Phys.	Canadian Journal of Physics
Compt. rend.	Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences
Dan. Mat. Fys. Medd.	Det Kongelige Danske Videnskabernes Selskab, Matematisk-fysiske Meddelelser
Disc. Faraday Soc.	Discussions of the Faraday Society
Dokl. Akad. Nauk SSSR	Doklady Akademii Nauk SSSR

<u>Abbreviation</u>	<u>Journal</u>
Exper. Tech. der Phys.	Experimentelle Technik der Physik
Fiz. Metallov i Metallovedenie	Fiziki Metallov i Metallovedenie
Health Physics	
Indian J. Phys.	Indian Journal of Physics
Izvest. Akad. Nauk SSSR Ser. Fiz.	Izvestiia Akademii Nauk SSSR, Seria Fizicheskaja
J. Am. Chem. Soc.	Journal of the American Chemical Society
J. Appl. Phys.	Journal of Applied Physics
J. Chem. Phys.	Journal of Chemical Physics
J. Chem. Soc. (London)	Journal of the Chemical Society of London
J. Opt. Soc. Am.	Journal of the Optical Society of America
J. Phys. Chem.	The Journal of Physical Chemistry
J. Phys. Radium	Journal de Physique et le Radium
J. Phys. Soc. Japan	Journal of the Physical Society of Japan
Monthly Notices, Roy. Astron. Soc.	Monthly Notices of the Royal Astronomical Society
Nature	
Nuclear Instr. and Methods	Nuclear Instruments and Methods
Nuclear Phys.	Nuclear Physics
Nuovo Cimento	

Abbreviation

Journal

Phil. Mag.

Philosophical Magazine

Phil. Trans.

Philosophical Transactions of the Royal
Society of London

Physica

Phys. in Med. Biol.

Physics in Medicine and Biology

Phys. Rev.

Physical Review

Phys. Rev. Letters

Physical Review Letters

Pribory Tekh. Eksper.

Pribory Tekhnika Eksperimenta

Proc. Phys. Soc. (London)

Proceedings of the Physical Society of
London

Proc. Roy. Soc. (London)

Proceedings of the Royal Society of London

Progr. theor. Phys.

Progress of Theoretical Physics

Rep. Progr. Phys.

Reports of the Physical Society on Progress
in Physics

Revs. Modern Phys.

Reviews of Modern Physics

Rev. Sci. Instr.

Review of Scientific Instruments

Soviet J. Atomic Energy
(English Translation)

Soviet Journal of Atomic Energy

Soviet Physics - Dokl.

Soviet Physics - Doklady

Soviet Physics - JETP

Soviet Physics - Journal of Experimental
and Theoretical Physics

Soviet Physics - Tech. Phys.

Soviet Physics - Technical Physics

Soviet Physics - Uspekhi

Uspekhi Fiz. Nauk

Uspekhi Fizicheskikh Nauk

Abbreviation

Journal

Vistas in Astronomy

Z. angew. Phys.

Zeitschrift für angewandte Physik

Z. Elektrochem.

Zeitschrift für Elektrochemie

Z. Naturforsch.

Zeitschrift für Naturforschung

Z. Naturwissenschaften

Zhurnal Naturwissenschaften

Z. Phys.

Zeitschrift für Physik

Zh. eksper. teor. Fiz.

Zhurnal eksperimentalnoi i teoreticheskoi
Fiziki

Zh. Tekh. Fiz.

Zhurnal technicheskoi Fiziki

2nd Geneva Conf.

Second International Conference on the
Peaceful Uses of Atomic Energy, Geneva,
1958

4th Int. Conf. on Ionization
Phenomena

Fourth International Conference on Ionization
Phenomena, Uppsala, 1959

<u>REPORT SYMBOL</u>	<u>ISSUING INSTALLATION</u>
AEC-TR	Atomic Energy Commission
AECU	Atomic Energy Commission
AERE T/R	Atomic Energy Research Establishment, Harwell
AFCRC-TR	Air Force Cambridge Research Center
BNL	Brookhaven National Laboratory
CEA	Commissariat a l'Energie Atomique, Paris
CX	New York University
GA	General Atomics
LA	Los Alamos Scientific Laboratory
LMSD	Lockheed Aircraft Corporation
MIT-TR	Massachusetts Institute of Technology
NBS	National Bureau of Standards
NP	Technical Information Service Extension, AEC
NYO	New York Operations Office, AEC
ORNL	Oak Ridge National Laboratory
ORO	Oak Ridge Operations Office, AEC
RISÖ	Atomenergiekommissioner, Denmark
SCTM	Sandia Corporation
TID	Technical Information Service Extension, AEC
UCRL	University of California Radiation Laboratory
Wis-AEC	University of Wisconsin, Naval Research Laboratory

APPENDIX C. ENERGY, VELOCITY, AND MOMENTUM

TABLES FOR ELECTRONS, PROTONS, H_2^+ , H_3^+ ,

AND HELIUM IONS

APPENDIX C. ENERGY, VELOCITY, AND MOMENTUM TABLES FOR ELECTRONS,

PROTONS, H_2^+ , H_3^+ , AND HELIUM IONS

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Table 1. Energy, Velocity, and Momentum for H^+ Ions

Energy (kev)	Velocity (cm/sec)	H p (Gauss-cm)	Energy (kev)	Velocity (cm/sec)	H p (Gauss-cm)
0	0	0	540	10.17×10^8	10.55×10^4
10	1.384×10^8	1.435×10^4	560	10.37	10.75
20	1.955	2.027	580	10.53	10.92
30	2.399	2.488	600	10.71	11.11
40	2.765	2.867	620	10.89	11.29
50	3.095	3.209	640	11.08	11.49
60	3.39	3.52	660	11.23	11.65
70	3.66	3.79	680	11.40	11.82
80	3.92	4.06	700	11.58	12.01
90	4.15	4.30	720	11.74	12.17
100	4.38	4.54	740	11.90	12.34
120	4.79	4.97	760	12.06	12.51
140	5.18	5.37	780	12.21	12.66
150	5.36	5.56	800	12.37	12.83
160	5.54	5.74	820	12.52	12.98
180	5.87	6.09	840	12.69	13.16
200	6.19	6.42	860	12.82	13.29
220	6.50	6.74	880	12.98	13.46
240	6.76	7.01	900	13.12	13.61
260	7.05	7.31	920	13.27	13.76
280	7.32	7.59	940	13.40	13.90
300	7.58	7.86	960	13.54	14.04
320	7.84	8.13	980	13.69	14.20
340	8.07	8.37	1000	13.84	14.35
360	8.30	8.61	2000	19.55	20.27
380	8.53	8.85	3000	23.90	24.78
400	8.75	9.07	4000	27.65	28.67
420	8.97	9.30	5000	30.9	32.04
440	9.19	9.53	6000	33.9	35.15
460	9.39	9.74	7000	36.6	37.95
480	9.59	9.94	8000	39.1	40.54
500	9.78	10.14	9000	41.5	43.04
520	9.98	10.35	10000	43.7	45.32

Table 2. Energy, Velocity, and Momentum for H_2^+ Ions

Energy (kev)	Velocity (cm/sec)	H p (Gauss-cm)	Energy (kev)	Velocity (cm/sec)	H p (Gauss-cm)
0	0	0	540	7.18×10^8	14.89×10^4
10	0.980×10^8	2.032×10^4	560	7.32	15.18
20	1.380	2.862	580	7.44	15.43
30	1.693	3.511	600	7.57	15.70
40	1.953	4.051	620	7.69	15.95
50	2.183	4.528	640	7.82	16.22
60	2.396	4.969	660	7.94	16.47
70	2.590	5.372	680	8.05	16.70
80	2.770	5.745	700	8.18	16.97
90	2.935	6.087	720	8.29	17.19
100	3.09	6.41	740	8.40	17.42
120	3.38	7.01	760	8.52	17.67
140	3.66	7.59	780	8.62	17.88
160	3.91	8.11	800	8.74	18.13
180	4.14	8.59	820	8.84	18.33
200	4.37	9.06	840	8.96	18.58
220	4.59	9.52	860	9.05	18.77
240	4.78	9.91	880	9.17	19.02
260	4.98	10.33	900	9.26	19.20
280	5.17	10.72	920	9.36	19.41
300	5.36	11.11	940	9.46	19.62
320	5.54	11.49	960	9.56	19.83
340	5.70	11.82	980	9.66	20.03
360	5.86	12.15	1000	9.78	20.28
380	6.03	12.51	2000	13.83	28.68
400	6.18	12.82	3000	16.92	35.09
420	6.34	13.15	4000	19.57	40.59
440	6.49	13.46	5000	21.85	45.32
460	6.64	13.77	6000	24.00	49.78
480	6.77	14.04	7000	25.90	53.72
500	6.92	14.35	8000	27.70	57.45
520	7.05	14.62	9000	29.35	60.87
			10000	30.90	64.09

Table 3. Energy, Velocity, and Momentum for H_3^+ Ions

Energy (kev)	Velocity (cm/sec)	H ρ (Gauss-cm)	Energy (kev)	Velocity (cm/sec)	H ρ (Gauss-cm)
0	0	0	280	4.23×10^8	13.12×10^4
10	0.79×10^8	2.45×10^4	300	4.38	13.58
20	1.13	3.50	400	5.05	15.66
40	1.6	4.96	500	5.65	17.52
60	1.96	6.08	600	6.19	19.19
80	2.26	7.01	700	6.68	20.71
100	2.52	7.81	800	7.15	22.17
110	2.65	8.22	900	7.58	23.51
120	2.77	8.59	1000	7.99	24.78
130	2.88	8.93	1200	8.75	27.13
140	2.98	9.24	1400	9.45	29.30
150	3.1	9.61	1600	10.1	31.32
160	3.2	9.92	1800	10.7	33.18
170	3.3	10.23	2000	11.3	35.04
180	3.4	10.54	2200	11.8	36.59
200	3.57	11.07	2300	12.1	37.52
240	3.91	12.12	2400	12.4	38.45

Table 4. Energy, Velocity, and Momentum for He⁺ Ions

Energy (kev)	Velocity (cm/sec)	H p (Gauss-cm)	Energy (kev)	Velocity (cm/sec)	H p (Gauss-cm)
0	0	0	460	4.69×10^8	19.45×10^4
10	0.692×10^8	2.870×10^4	480	4.80	19.91
20	0.978	4.057	500	4.89	20.28
30	1.200	4.977	520	4.99	20.70
40	1.383	5.737	540	5.09	21.11
50	1.548	6.421	560	5.18	21.49
60	1.70	7.05	580	5.27	21.86
70	1.83	7.59	600	5.36	22.23
80	1.96	8.13	620	5.45	22.60
90	2.08	8.63	640	5.54	22.98
100	2.19	9.08	660	5.62	23.31
120	2.40	9.95	680	5.70	23.64
140	2.59	10.74	700	5.79	24.02
160	2.77	11.49	720	5.87	24.35
180	2.94	12.20	740	5.95	24.68
200	3.10	12.86	760	6.03	25.01
220	3.25	13.48	780	6.11	25.34
240	3.38	14.02	800	6.19	25.68
260	3.53	14.64	820	6.26	25.97
280	3.66	15.18	840	6.35	26.34
300	3.79	15.72	860	6.41	26.59
320	3.92	16.26	880	6.49	26.92
340	4.04	16.76	900	6.56	27.21
360	4.15	17.21	920	6.64	27.54
380	4.27	17.71	940	6.70	27.79
400	4.38	18.17	960	6.77	28.08
420	4.49	18.62	980	6.85	28.41
440	4.60	19.08	1000	6.92	28.70

Table 5. Energy, Velocity, and Momentum for Electrons

Energy (ev)	Velocity (cm/sec)	H p (Gauss-cm)	Energy (ev)	Velocity (cm/sec)	H p (Gauss-cm)
0	0	0	300	10.29×10^8	57.88
10	1.879×10^8	10.51	310	10.47	58.89
20	2.655	14.93	320	10.61	59.68
30	3.255	18.31	330	10.79	60.69
40	3.760	21.15	340	10.93	61.48
50	4.19	23.57	350	11.10	62.44
60	4.61	25.93	360	11.27	63.39
70	4.97	27.96	370	11.41	64.18
80	5.32	29.93	380	11.59	65.19
90	5.63	31.67	390	11.71	65.87
100	5.94	33.41	400	11.89	66.88
110	6.23	35.04	410	12.01	67.56
120	6.50	36.56	420	12.17	68.46
130	6.77	38.08	430	12.31	69.24
140	7.02	39.49	440	12.45	70.03
150	7.27	40.89	450	12.60	70.87
160	7.53	42.36	460	12.73	71.60
170	7.74	43.54	470	12.87	72.39
180	7.97	44.83	480	13.02	73.24
190	8.17	45.96	490	13.16	74.02
200	8.39	47.19	500	13.28	74.70
210	8.60	48.37	520	13.52	76.05
220	8.80	49.50	540	13.80	77.63
230	9.00	50.63	560	14.05	79.03
240	9.19	51.69	580	14.30	80.44
250	9.39	52.82	600	14.54	81.79
260	9.56	53.77	620	14.79	83.19
270	9.75	54.84	640	15.02	84.49
280	9.92	55.80	660	15.25	85.78
290	10.10	56.81	680	15.48	87.07

Table 5. Energy, Velocity, and Momentum for Electrons

Energy (ev)	Velocity (cm/sec)	H p (Gauss-cm)	Energy (ev)	Velocity (cm/sec)	H p (Gauss-cm)
700	15.71 x 10 ⁸	88.37	1300	21.40 x 10 ⁸	120.4
720	15.94	89.66	1320	21.58	121.4
740	16.14	90.79	1340	21.77	122.5
760	16.38	92.14	1360	21.90	123.2
780	16.59	93.32	1380	22.05	124.0
800	16.80	94.50	1400	22.23	125.0
820	17.00	95.63	1420	22.39	125.9
840	17.21	96.81	1440	22.56	126.9
860	17.41	97.93	1460	22.70	127.7
880	17.62	99.11	1480	22.85	128.5
900	17.82	100.2	1500	22.99	129.3
920	18.02	101.4	1520	23.17	130.3
940	18.22	102.5	1540	23.33	131.2
960	18.40	103.5	1560	23.45	131.9
980	18.59	104.6	1580	23.60	132.7
1000	18.79	105.7	1600	23.76	133.6
1020	18.90	106.3	1620	23.90	134.4
1040	19.17	107.8	1640	24.05	135.3
1060	19.34	108.8	1660	24.20	136.1
1080	19.53	109.9	1680	24.35	137.0
1100	19.70	110.8	1700	24.50	137.8
1120	19.89	111.9	1720	24.60	138.4
1140	20.08	112.9	1740	24.75	139.2
1160	20.22	113.7	1760	24.90	140.1
1180	20.40	114.7	1780	25.05	140.9
1200	20.59	115.8	1800	25.20	141.7
1220	20.78	116.9	1820	25.35	142.6
1240	20.94	117.8	1840	25.50	143.4
1260	21.08	118.6	1860	25.60	144.0
1280	21.24	119.5	1880	25.75	144.8

Table 5. Energy, Velocity, and Momentum for Electrons

Energy (ev)	Velocity (cm/sec)	H p (Gauss-cm)	Energy (ev)	Velocity (cm/sec)	H p (Gauss-cm)
1900	25.90 x 10 ⁸	145.7	2650	30.55 x 10 ⁸	171.8
1920	26.05	146.5	2700	30.80	173.3
1940	26.20	147.4	2750	31.10	174.9
1960	26.33	148.1	2800	31.40	176.6
1980	26.40	148.5	2850	31.70	178.3
2000	26.55	149.3	2900	31.95	179.7
2020	26.70	150.2	2950	32.20	181.1
2040	26.80	150.7	3000	32.55	183.1
2060	26.95	151.6	3050	32.77	184.3
2080	27.10	152.4	3100	33.05	185.9
2100	27.25	153.3	3150	33.30	187.3
2120	27.35	153.8	3200	33.55	188.7
2140	27.50	154.7	3250	33.80	190.1
2160	27.60	155.3	3300	34.10	191.8
2180	27.75	156.1	3350	34.35	193.2
2200	27.85	156.6	3400	34.60	194.6
2220	27.95	157.2	3450	34.85	196.0
2240	28.10	158.1	3500	35.10	197.4
2260	28.25	158.9	3550	35.35	198.8
2280	28.35	159.5	3600	35.60	200.3
2300	28.50	160.3	3650	35.85	201.7
2320	28.60	160.9	3700	36.10	203.1
2340	28.70	161.4	3750	36.35	204.5
2360	28.85	162.3	3800	36.60	205.9
2380	28.95	162.8	3850	36.80	207.0
2400	29.05	163.4	3900	37.03	208.3
2450	29.37	165.2	3950	37.25	209.5
2500	29.70	167.1	4000	37.50	210.9
2550	29.95	168.5	4050	37.75	212.3
2600	30.20	169.9	4100	38.00	213.7
			4150	38.20	214.9

Table 5. Energy, Velocity, and Momentum for Electrons

Energy (ev)	Velocity (cm/sec)	H p (Gauss-cm)	Energy (ev)	Velocity (cm/sec)	H p (Gauss-cm)
4200	38.43 x 10 ⁸	216.2	5800	45.20 x 10 ⁸	254.2
4250	38.65	217.4	5850	45.40	255.4
4300	38.92	218.9	5900	45.60	256.5
4350	39.13	220.1	5950	45.78	257.5
4400	39.35	221.3	6000	45.95	258.5
4450	39.60	222.7	6050	46.18	259.8
4500	39.80	223.8	6100	46.35	260.7
4550	40.00	225.0	6150	46.50	261.6
4600	40.25	226.4	6200	46.70	262.7
4650	40.45	227.5	6250	46.90	263.8
4700	40.70	228.9	6300	47.10	264.9
4750	40.90	230.1	6350	47.30	266.1
4800	41.10	231.2	6400	47.50	267.2
4850	41.30	232.3	6450	47.65	268.0
4900	41.51	233.5	6500	47.90	269.4
4950	41.70	234.6	6550	48.00	270.0
5000	41.95	236.0	6600	48.20	271.1
5050	42.20	237.4	6650	48.40	272.2
5100	42.40	238.5	6700	48.55	273.1
5150	42.60	239.6	6750	48.75	274.2
5200	42.80	240.7	6800	48.90	275.1
5250	43.00	241.9	6850	49.10	276.2
5300	43.20	243.0	6900	49.30	277.3
5350	43.40	244.1	6950	49.45	278.2
5400	43.60	245.2	7000	49.65	279.3
5450	43.80	246.4	7050	49.80	280.1
5500	44.00	247.5	7100	50.00	281.2
5550	44.20	248.6	7150	50.20	282.4
5600	44.40	249.7	7200	50.40	283.5
5650	44.60	250.9	7250	50.50	284.1
5700	44.80	252.0	7300	50.65	284.9
5750	45.00	253.1	7350	50.85	286.0

Table 5. Energy, Velocity, and Momentum for Electrons

Energy (ev)	Velocity (cm/sec)	H p (Gauss-cm)	Energy (ev)	Velocity (cm/sec)	H p (Gauss-cm)
7400	51.05 x 10 ⁸	287.2	8700	55.40 x 10 ⁸	311.6
7450	51.20	288.0	8750	55.55	312.5
7500	51.40	289.1	8800	55.70	313.3
7550	51.55	290.0	8850	55.85	314.2
7600	51.70	290.8	8900	56.00	315.0
7650	51.90	291.9	8950	56.20	316.1
7700	52.05	292.8	9000	56.35	317.0
7750	52.25	293.9	9050	56.45	317.5
7800	52.40	294.8	9100	56.60	318.4
7850	52.60	295.9	9150	56.75	319.2
7900	52.75	296.7	9200	56.90	320.1
7950	52.90	297.6	9250	57.10	321.2
8000	53.05	298.4	9300	57.20	321.7
8050	53.25	299.5	9350	57.40	322.9
8100	53.45	300.7	9400	57.50	323.4
8150	53.55	301.2	9450	57.65	324.3
8200	53.75	302.3	9500	57.80	325.1
8250	53.90	303.2	9550	58.00	326.2
8300	54.10	304.3	9600	58.10	326.8
8350	54.20	304.9	9650	58.30	327.9
8400	54.40	306.0	9700	58.40	328.5
8450	54.55	306.8	9750	58.60	329.6
8500	54.70	307.7	9800	58.75	330.5
8550	54.90	308.8	9850	58.90	331.3
8600	55.05	309.7	9900	59.05	332.2
8650	55.20	310.5	9950	59.20	333.0
			10000	59.40	334.1

APPENDIX D. SUPPLEMENTARY BIBLIOGRAPHY, JULY 1961

APPENDIX D. SUPPLEMENTARY BIBLIOGRAPHY

Appendix D contains a bibliography of references that appeared in the latter part of 1960 and in the first half of 1961. The compilation of cross section data has been brought up to date, and a new section on energy distribution of electrons resulting from ionization has been added.

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 $H^+ + H_{(1s)} \rightarrow H^+ + H^+ + e$. (Theoretical: Bates and Griffing, 278)

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 $F(\frac{e}{\epsilon})$ = FRACTION OF ELECTRONS HAVING AN ENERGY IN EXCESS OF e EJECTED
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