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Physics Division

ATOMIC DATA FOR FUSION

VOLUME 1

COLLISIONS OF H, H_2, He and Li ATOMS and IONS with ATOMS and MOLECULES

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ATOMIC DATA FOR FUSION

VOL. 1

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FOREWORD

The Controlled Fusion Atomic Data Center (CFADC) was founded informally at Oak Ridge National Laboratory by Clarence F. Barnett in 1959, and was officially established six years later. The continuing mission of the CFADC is to identify, compile, evaluate and recommend data on atomic and molecular collision processes which are important in fusion energy research. "Barney" dedicated much of his professional career to the promotion of effective scientific communication between the atomic and fusion research communities, and was still actively engaged in this mission at the time of his death in 1989. This "Redbook" volume represents a major part of his continuing professional efforts during the years following his formal retirement from ORNL in 1985. Barnett's insights, guidance and dedication to this mission will be sorely missed by the CFADC and by the fusion research community.

Ronald A. Phaneuf
Hamilton T. Hunter
M. Imogene Kirkpatrick
David H. Crandall (DOE)

This photo is from his "official" retirement in 1985. His spirit will continue to encourage us in the future.

Series Preface

The primary objective of the Controlled Fusion Atomic Data Center at Oak Ridge National Laboratory is to publish and distribute handbooks containing numerical and graphical cross-section and other physical data relevent to fusion energy research. In 1977, a two-volume compilation was published as ORNL reports ORNL-5206 and ORNL-5207. Since that time, a large volume of pertinent data has become available, necessitating an update and expansion of the previous compilation. The specific volumes in this series, entitled "Atomic Data for Fusion," are listed below.

Vol. 1, "Collisions of H, H_2, He, and Li Atoms and Ions with Atoms and Molecules," C. F. Barnett, ORNL, ORNL-6086 (June 1990).

Vol. 2, "Collisions of Electrons with Atoms and Molecules," J. W. Gallagher, National Institute of Standards and Technology; and D. C. Gregory, ORNL (in preparation).

Vol. 3, "Particle Interactions with Surfaces," E. W. Thomas, Georgia Institute of Technology, ORNL-6088 (January 1985).

Vol. 4, "Spectroscopic Data for Iron," W. L. Wiese, National Bureau of Standards, ORNL-6089 (March 1985).

Vol. 5, "Collisions of Carbon and Oxygen Ions with Electrons, H, H_2, and He," R. A. Phaneuf, ORNL; R. K. Janev, Institute of Physics, Yugoslavia; and M. S. Pindzola, Auburn University, ORNL-6090 (January 1987).

Vol. 6, "Spectroscopic Data for Titanium, Chromium, and Nickel," W. L. Wiese and A. Musgrove, National Institute for Standards and Technology, ORNL-6551 (September 1989).

C. F. Barnett
H. T. Hunter
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June 1990

ABSTRACT

This report provides a handbook of recommended cross-section and rate-coefficient data for inelastic collisions between hydrogen, helium and lithium atoms, molecules and ions, and encompasses more than 400 different reactions of primary interest in fusion research. Published experimental and theoretical data have been collected and evaluated, and the recommended data are presented in tabular, graphical and parametrized form. Processes include excitation and spectral line emission, charge exchange, ionization, stripping, dissociation and particle interchange reactions. The range of collision energies is appropriate to applications in fusion-energy research.

INTRODUCTION

This volume contains recommended cross-section and rate-coefficient data for inelastic collisions between hydrogen, helium and lithium atoms, molecules and ions, and encompasses 383 different reactions of primary interest in fusion research. Published experimental and theoretical data have been collected and evaluated, and the recommended data are presented in tabular, graphical and parametrized form. Inelastic processes include excitation and spectral-line emission, charge exchange, ionization, stripping, dissociation and particle interchange reactions. Emphasis has been given to the range of collision energies appropriate to diagnostic and modelling applications in fusion-energy research.

The data which form the basis for this volume of recommended data are those which were available as of September 1988. The bibliographic files of the ORNL Controlled Fusion Atomic Data Center provided the lists of references for this volume. In the vast majority of cases, the numerical data were obtained from the original publications, either from tables where available, or from figures using a precision graphical digitizer system. The rms uncertainty associated with the digitization system was determined to be less than 2%.

The recommended data in this compilation are based almost exclusively on experimental data. Theoretical data have been considered when it was desirable to extend the measurements to higher or lower collision energies, and also for a few important reactions where experimental data were unavailable. Specific references to the literature and notes are presented for each reaction, along with an estimated uncertainty in the recommended cross section. The latter was determined from uncertainties quoted in the original data sources, and also from the consistency of the data when more than one source was available. To determine the recommended cross sections in the latter case, relative weightings were made on the basis of the reliability of the different experimental methods used. In some cases, possible effects on the measurements due to other competing processes were also considered in determining the recommended cross section and its estimated uncertainty. For some reactions, it was not possible to estimate an uncertainty. In all cases, the estimated accuracies of the recommended data are believed to have been conservatively estimated, and are intended to represent upper limits.

Reaction rate coefficients have been calculated from the recommended cross-section data where appropriate for fusion applications, and where the energy range of the available data permits. These are based on Maxwellian velocity distributions for each reactant, where each may be characterized by a different temperature, and also for the case of a monoenergetic (neutral) beam interacting with a Maxwellian distribution. The temperature ranges for the calculated rate coefficients are constrained by the energy range over which cross-section data are available. The tabulated values for the rate coefficients have been flagged in those temperature ranges where the limited energy range of the data appreciably influences their accuracy.

For convenience, least-squares Chebyshev polynomial fits to the recommended cross-sections and rate coefficients are presented for each reaction. These polynomial fits are indicated graphically, and a statement is made concerning the accuracy of each fit to the recommended data. Practical details on the least-squares fits and sample computer programs for rapidly generating the recommended cross sections and rate coefficients from the fitting coefficients are presented in Appendix 1.

For further ease of retrieval and application of the recommended cross-section data, a PC-DOS formatted diskette has been prepared and is available for distribution. Included on this diskette are data files with the Chebyshev fitting coefficients for each reaction encoded in *ALADDIN* format,[1,2] along with a copy of the *ALADDIN* program (written in FORTRAN-77). The *ALADDIN* program and data files may also be conveniently transmitted by electronic mail. Further details about *ALADDIN* are presented in Appendix 2, along with samples of the data entries from each chapter. Information about how to obtain the program and data files for this and other compilations may also be found in Appendix 2.

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1. R. A. Hulse, "The ALADDIN Atomic Physics Database System," pp. 63-72 in Atomic Processes in Plasmas, AIP Conference Proceedings 206, ed. Y. K. Kim and R. C. Elton, AIP, New York, 1990.

2. ALADDIN Manual, A System for Storage, Exchange and Management of Atomic and Molecular Data for Fusion, IAEA-NDS-AM-17, Atomic and Molecular Data Unit, Nuclear Data Section, International Atomic Energy Agency, Vienna, June 1989.

A. Total Electron Capture Cross Sections

(* denotes rate coefficient data also)

Electron Capture Cross Sections for
$H + H \rightarrow H^- + H^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.0E+03	6.21E+07	1.56E-18
4.0E+03	8.79E+07	3.64E-18
7.0E+03	1.16E+08	7.63E-18
1.0E+04	1.39E+08	1.18E-17
1.6E+04	1.76E+08	1.63E-17
2.0E+04	1.96E+08	1.55E-17
3.1E+04	2.45E+08	9.98E-18
4.0E+04	2.78E+08	5.58E-18
7.0E+04	3.68E+08	1.48E-18
7.3E+04	3.75E+08	1.37E-18

References: 33, 34, 396

Accuracy: $E < 8\times10^3$ eV/amu - 50%; $E > 8\times10^3$ eV/amu - 20%

Note: For energies less than 8×10^3 eV/amu large discrepancies exist between the data.

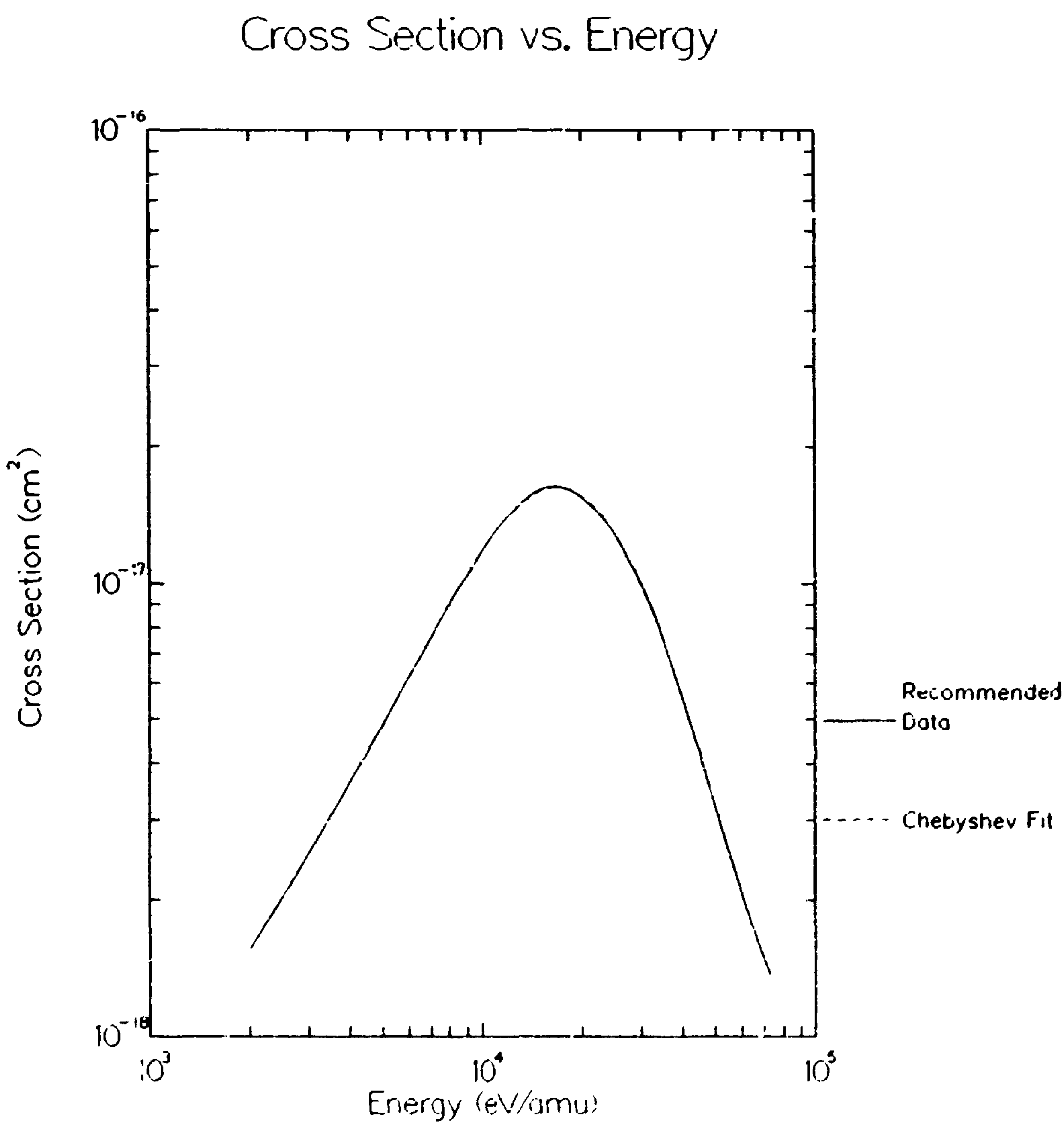
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.0E+03 eV/amu, E_{max} = 7.3E+04 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-79.9637	.00368622	-1.08628	-.302134	.0745111	.148356	-.0426883	.0535533	-.0289283

The fit represents the above cross sections with an rms deviation of 1.0%.
The maximum deviation is 2.0% at 2.0E+04 eV/amu.
See appendix for Chebyshev fit details.

$H + H \rightarrow H^- + H^+$



Electron Capture Rate Coefficients for
$H + H \rightarrow H^- + H^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

H Temp. (eV)	Equal Temp.	H Temp. (eV) 1000.	2000.	5000.	10000.	12000.	15000.	20000.
1.0E+02	1.96E-14	7.56E-11	2.82E-10	1.01E-09	1.62E-09	1.70E-09	1.72E-09	1.65E-09
2.0E+02	2.57E-12	9.22E-11	3.06E-10	1.03E-09	1.63E-09	1.70E-09	1.72E-09	1.65E-09
4.0E+02	3.36E-11	1.29E-10	3.56E-10	1.07E-09	1.64E-09	1.71E-09	1.72E-09	1.64E-09
7.0E+02	1.29E-10	1.90E-10	4.32E-10	1.13E-09	1.65E-09	1.71E-09	1.72E-09	1.63E-09
1.0E+03	2.58E-10	2.58E-10	5.10E-10	1.18E-09	1.66E-09	1.72E-09	1.72E-09	1.63E-09
2.0E+03	7.64E-10	5.10E-10	7.64E-10	1.34E-09	1.70E-09	1.72E-09	1.71E-09	1.60E-09
4.0E+03	1.46E-09	9.91E-10	1.18E-09	1.55E-09	1.72E-09	1.72E-09	1.67E-09	1.55E-09
7.0E+03	1.72E-09	1.46E-09	1.55E-09	1.70E-09	1.71E-09	1.67E-09	1.60E-09	1.47E-09
1.0E+04	1.65E-09	1.66E-09	1.70E-09	1.72E-09	1.65E-09	1.60E-09	1.52E-09	1.38E-09
2.0E+04	1.14E-09*	1.63E-09	1.60E-09	1.52E-09	1.38E-09	1.33E-09	1.26E-09*	1.14E-09*

Accuracy: * - Possible Error Greater Than 10%

** - Possible Error Greater Than 100%

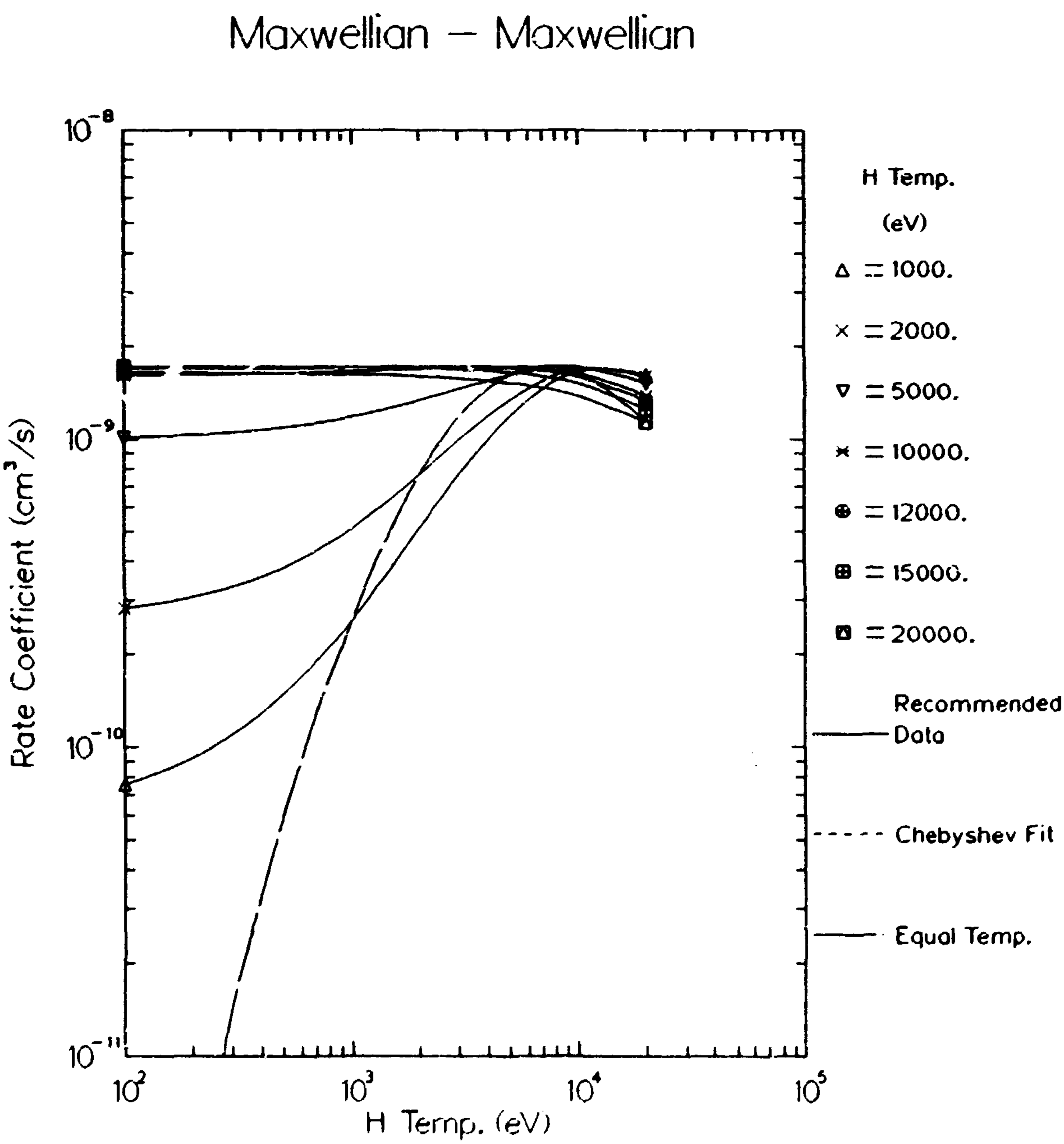
Note: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+02 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

H Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
1000.	-4.34136E+01	1.77058E+00	-2.19086E-02	-1.54539E-01	-5.12704E-02	1.82644E-02	9.12815E-03
2000.	-4.22141E+01	1.02952E+00	3.42057E-02	-1.66830E-01	-5.60021E-02	5.86271E-03	8.15346E-03
5000.	-4.09368E+01	2.82198E-01	-5.96305E-03	-7.32604E-02	-3.54191E-02	-5.05727E-03	2.39134E-03
10000.	-4.04860E+01	-3.08846E-02	-5.68396E-02	-4.34280E-02	-1.90470E-02	-4.61028E-03	-1.80695E-05
12000.	-4.04639E+01	-7.77066E-02	-6.68905E-02	-3.99404E-02	-1.61322E-02	-3.99466E-03	-2.04042E-04
15000.	-4.04949E+01	-1.18325E-01	-7.60484E-02	-3.69771E-02	-1.33535E-02	-3.24671E-03	-2.69603E-04
20000.	-4.06294E+01	-1.47825E-01	-8.23614E-02	-3.42640E-02	-1.08621E-02	-2.44826E-03	-2.60694E-04
Equal Temp.	-4.70326E+01	4.89621E+00	-2.27782E+00	4.67042E-01	-2.66936E-01	1.22082E-01	-1.65425E-02

See appendix for Chebyshev fit details.

$H + H \rightarrow H^- + H^+$



Electron Capture Rate Coefficients for
$H + H \rightarrow H^- + H^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	45000.	50000.	60000.	70000.
1.0E+00	1.63E-09**	3.03E-09**	1.55E-09**	1.24E-09**	1.02E-09**	7.26E-10**	5.45E-10**
2.0E+00	1.63E-09*	3.03E-09*	1.55E-09**	1.24E-09**	1.02E-09**	7.26E-10**	5.45E-10**
4.0E+00	1.63E-09*	3.02E-09*	1.55E-09**	1.24E-09**	1.02E-09**	7.26E-10**	5.45E-10**
7.0E+00	1.63E-09*	3.02E-09*	1.55E-09**	1.24E-09**	1.02E-09**	7.26E-10**	5.45E-10**
1.0E+01	1.63E-09*	3.01E-09*	1.55E-09**	1.24E-09**	1.02E-09**	7.26E-10**	5.43E-10**
2.0E+01	1.63E-09*	3.00E-09*	1.54E-09**	1.24E-09**	1.02E-09**	7.26E-10**	5.27E-10**
4.0E+01	1.63E-09*	2.98E-09*	1.54E-09**	1.25E-09**	1.02E-09**	7.27E-10**	4.94E-10**
7.0E+01	1.63E-09*	2.96E-09*	1.54E-09**	1.25E-09**	1.02E-09**	7.28E-10**	4.62E-10**
1.0E+02	1.64E-09*	2.94E-09*	1.54E-09**	1.25E-09**	1.03E-09**	7.29E-10**	4.42E-10**
2.0E+02	1.66E-09*	2.89E-09*	1.54E-09**	1.25E-09**	1.03E-09**	7.29E-10**	4.10E-10**
4.0E+02	1.71E-09*	2.81E-09*	1.55E-09*	1.26E-09**	1.04E-09**	7.19E-10**	3.91E-10**
7.0E+02	1.76E-09*	2.71E-09*	1.55E-09*	1.27E-09**	1.05E-09**	7.03E-10**	3.66E-10**
1.0E+03	1.80E-09*	2.62E-09*	1.54E-09*	1.28E-09*	1.05E-09**	6.93E-10**	3.88E-10**
2.0E+03	1.88E-09*	2.40E-09*	1.52E-09*	1.27E-09*	1.05E-09**	6.86E-10**	4.08E-10**
4.0E+03	1.90E-09	2.12E-09*	1.42E-09*	1.21E-09*	1.02E-09**	6.97E-10**	4.51E-10**
7.0E+03	1.86E-09*	1.85E-09*	1.28E-09*	1.12E-09*	9.66E-10*	7.01E-10**	4.92E-10**
1.0E+04	1.78E-09*	1.67E-09*	1.16E-09*	1.03E-09*	9.10E-10*	6.90E-10**	5.11E-10**
2.0E+04	1.48E-09*	1.29E-09*	9.21E-10*	8.39E-10*	7.61E-10**	6.22E-10**	5.03E-10**

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Note: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

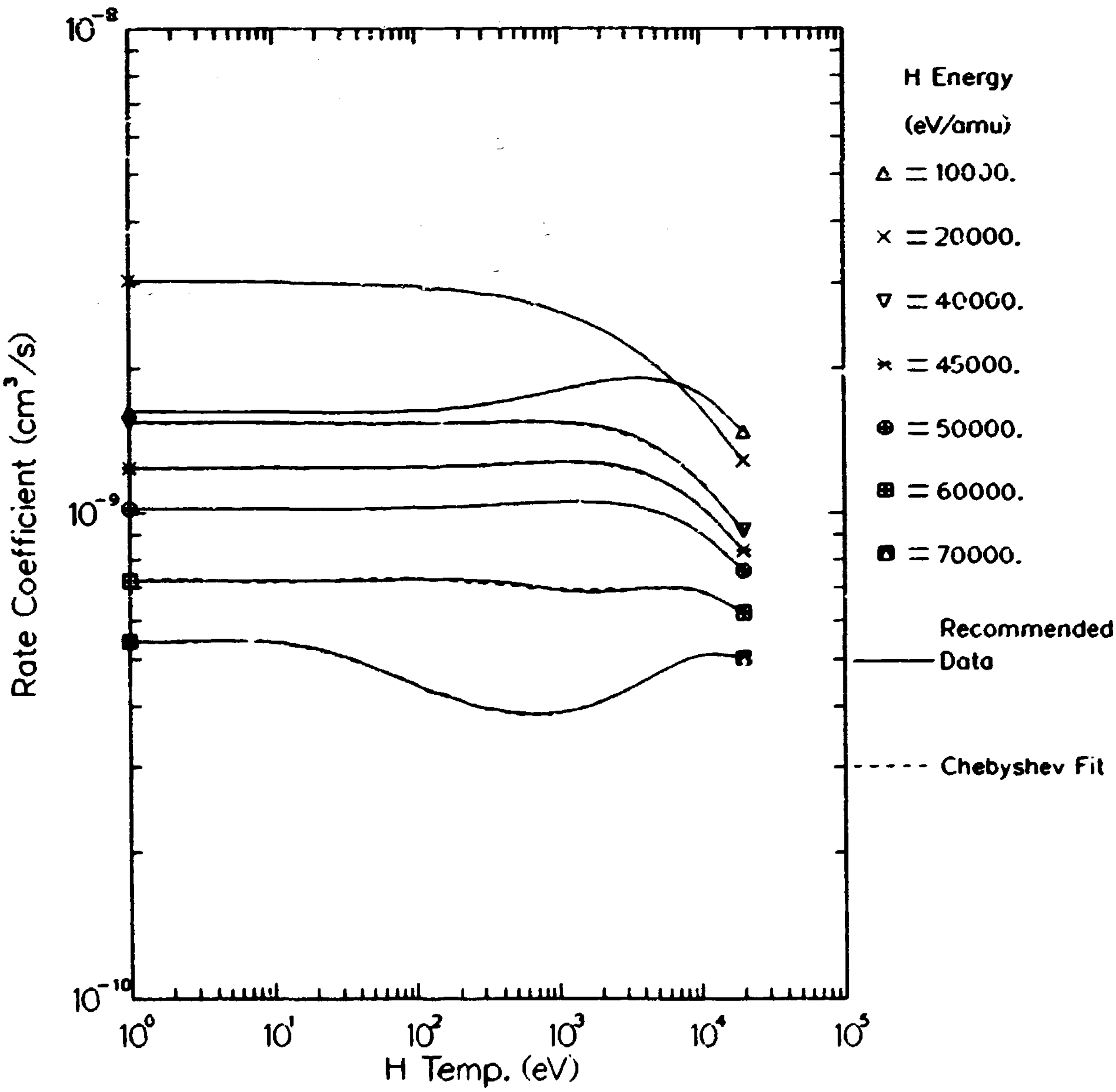
Chebyshev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-4.04105E+01	2.91340E-02	-2.63688E-02	-6.02938E-02	-4.80367E-02	-1.89721E-02	-1.81756E-03
20000.	-3.96573E+01	-3.51288E-01	-1.95694E-01	-7.65178E-02	-1.76176E-02	6.76024E-05	8.20202E-04
40000.	-4.07630E+01	-1.72032E-01	-1.30927E-01	-8.12602E-02	-3.70555E-02	-8.68416E-03	3.26863E-03
45000.	-4.11299E+01	-1.16178E-01	-1.03253E-01	-7.22628E-02	-3.62733E-02	-1.02839E-02	1.83555E-03
50000.	-4.14810E+01	-7.82977E-02	-7.66264E-02	-5.87240E-02	-3.17702E-02	-1.03177E-02	-4.83902E-04
60000.	-4.21440E+01	-5.01687E-02	-2.65441E-02	-1.11314E-02	-8.49686E-03	-1.30422E-02	-1.43356E-02
70000.	-4.28827E+01	-7.90160E-02	1.09848E-01	8.45395E-02	-3.13642E-02	-4.50109E-02	-6.86268E-03

See appendix for Chebyshev fit details.

$H + H \rightarrow H^- + H^+$

Beam — Maxwellian



Electron Capture Cross Sections for
$H + H_2 \rightarrow H^-$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
4.0E+01	8.79E+06	1.05E-18
7.0E+01	1.16E+07	1.78E-18
1.0E+02	1.39E+07	2.52E-18
1.4E+02	1.64E+07	3.08E-18
2.0E+02	1.96E+07	2.74E-18
4.0E+02	2.78E+07	1.70E-18
7.0E+02	3.68E+07	1.24E-18
1.0E+03	4.39E+07	1.31E-18
2.0E+03	6.21E+07	5.28E-18
4.0E+03	8.79E+07	1.46E-17
7.0E+03	1.16E+08	2.18E-17
1.0E+04	1.39E+08	2.32E-17
2.0E+04	1.96E+08	1.91E-17
4.0E+04	2.78E+08	9.93E-18
7.0E+04	3.68E+08	4.07E-18
1.0E+05	4.39E+08	1.68E-18
2.0E+05	6.21E+06	1.72E-19
4.0E+05	8.78E+08	6.12E-21
4.6E+05	9.42E+08	2.97E-21

References: 26, 27, 28, 29, 30, 31, 32, 33, 35, 396

Accuracy: 25%

Note: The quoted results are believed to be accurate to within 25%, although the data presented in some of the references may deviate by 50-60%.

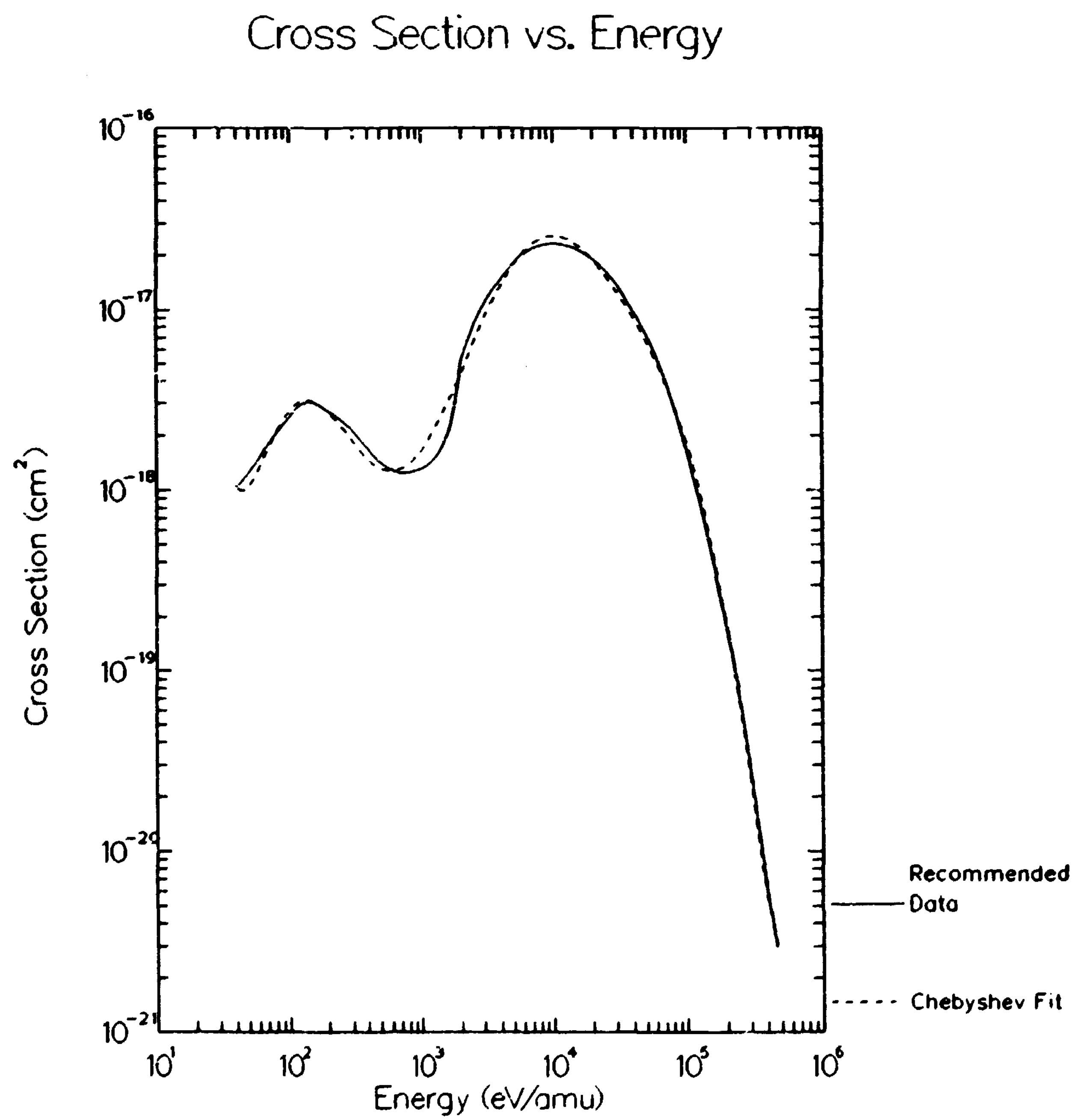
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 4.0E+01 eV/amu, E_{max} = 4.6E+05 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-82.8333	-1.65457	-2.60408	-1.53870	-.368649	.413620	-.165702	-.127116	.256041

The fit represents the above cross sections with an rms deviation of 9.5%.
The maximum deviation is 26.2% at 1.0E+03 eV/amu.
See appendix for Chebyshev fit details.

$H + H_2 \rightarrow H^-$



Electron Capture Cross Sections for
$H + He \rightarrow H^- + He^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
7.7E+02	3.85E+07	1.47E-19
1.0E+03	4.39E+07	2.15E-19
2.0E+03	6.21E+07	5.80E-19
3.0E+03	7.61E+07	1.04E-18
4.0E+03	8.79E+07	1.61E-18
5.0E+03	9.82E+07	2.23E-18
6.0E+03	1.08E+08	2.88E-18
7.0E+03	1.16E+08	3.46E-18
9.0E+03	1.32E+08	4.34E-18
1.0E+04	1.39E+08	4.83E-18
2.0E+04	1.96E+08	6.51E-18
3.0E+04	2.41E+08	6.06E-18
4.0E+04	2.78E+08	5.28E-18
7.0E+04	3.68E+08	2.92E-18
1.0E+05	4.39E+08	1.46E-18
2.0E+05	6.21E+08	2.33E-19
4.0E+05	8.78E+08	2.47E-20
7.0E+05	1.16E+09	1.87E-21
7.6E+05	1.21E+09	1.16E-21

<u>References:</u> 26, 27, 29, 35, 268, 269, 270

<u>Accuracy:</u> 30%

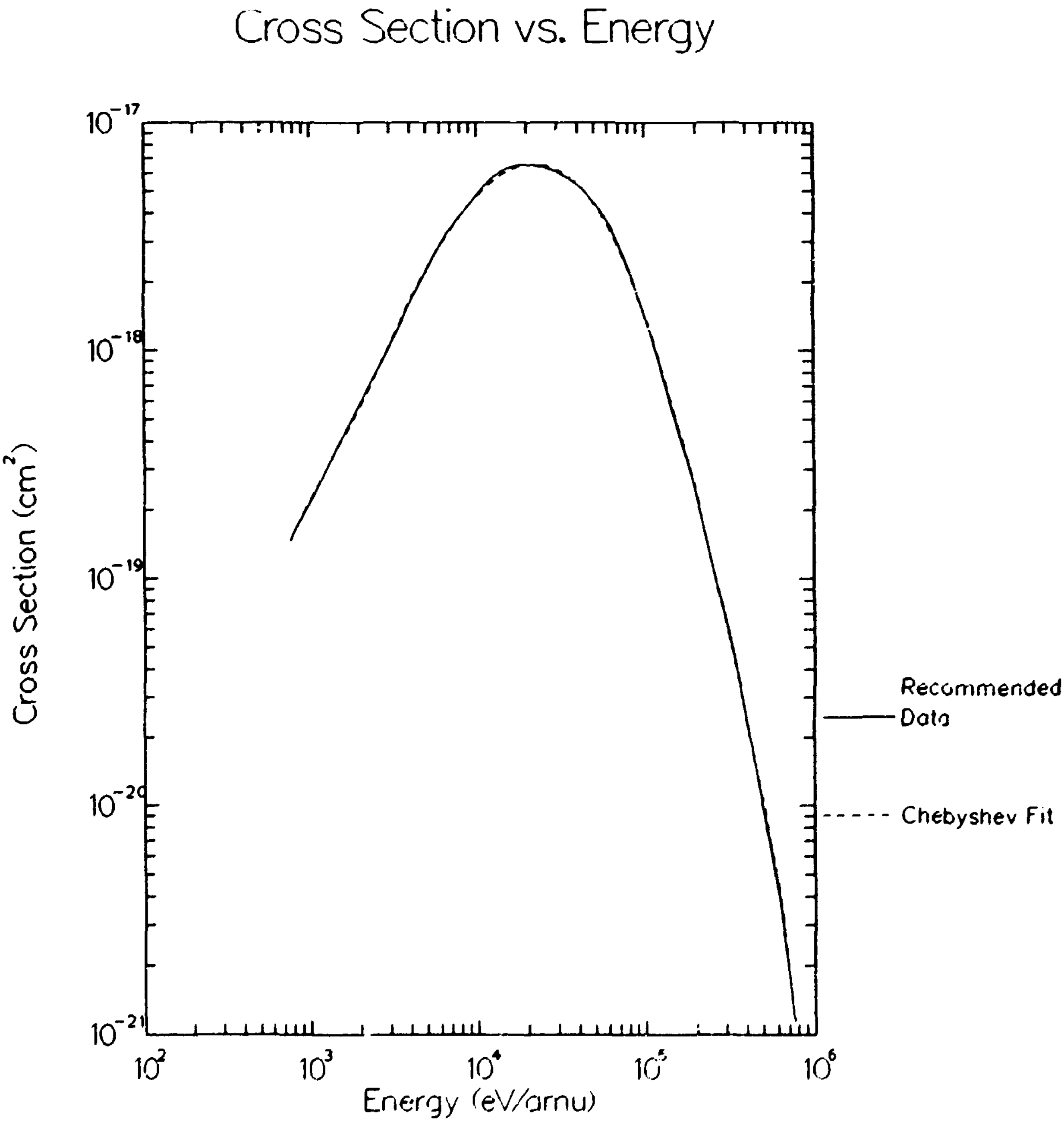
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 7.7E+02 eV/amu, E_{max} = 7.6E+05 eV/amu

<u>Chebyshev Fitting Parameters for Cross Sections</u>

A0	A1	A2	A3	A4	A5	A6	A7	A8
-85.5215	-1.87685	-3.06302	-.492323	.117220	-.0269941	-.0479364	-.0315786	-.0439288

The fit represents the above cross sections with an rms deviation of 1.8%.
The maximum deviation is 2.9% at 7.0E+05 eV/amu.
See appendix for Chebyshev fit details.

$H + He \rightarrow H^- + He^+$



Electron Capture Rate Coefficients for
$H + He \rightarrow H^- + He^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

H Temp. (eV)	Equal Temp.	He Temp. (eV) 1.	100.	500.	1000.	5000.	10000.	20000.
7.0E+01	3.79E-15	4.61E-16	7.47E-15	4.58E-13	2.43E-12	5.54E-11	1.74E-10	4.26E-10
1.0E+02	5.02E-14	1.13E-14	5.02E-14	7.92E-13	3.11E-12	5.78E-11	1.77E-10	4.28E-10
2.0E+02	1.14E-12	5.09E-13	7.92E-13	2.54E-12	5.86E-12	6.60E-11	1.87E-10	4.37E-10
4.0E+02	7.50E-12	4.40E-12	5.11E-12	8.38E-12	1.34E-11	8.33E-11	2.08E-10	4.55E-10
7.0E+02	2.48E-11	1.57E-11	1.69E-11	2.20E-11	2.93E-11	[illegible].11E-10	2.40E-10	4.82E-10
1.0E+03	5.00E-11	3.24E-11	3.40E-11	4.08E-11	5.00E-11	1.41E-10	2.71E-10	5.08E-10
2.0E+03	1.67E-10	1.16E-10	1.19E-10	1.29E-10	1.41E-10	2.45E-10	3.72E-10	5.86E-10
4.0E+03	4.19E-10	3.22E-10	3.25E-10	3.35E-10	3.47E-10	4.42E-10	5.48E-10	7.17E-10
7.0E+03	7.02E-10	5.86E-10	5.88E-10	5.96E-10	6.05E-10	6.72E-10	7.44E-10	8.55E-10
1.0E+04	8.73E-10	7.70E-10	7.71E-10	7.76E-10	7.82E-10	8.26E-10	8.73E-10	9.43E-10
2.0E+04	1.04E-09	1.02E-09	1.02E-09	1.02E-09	1.02E-09	1.02E-09	1.03E-09	1.04E-09

Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 7.0E+01 eV, E_{max} = 2.0E+04 eV

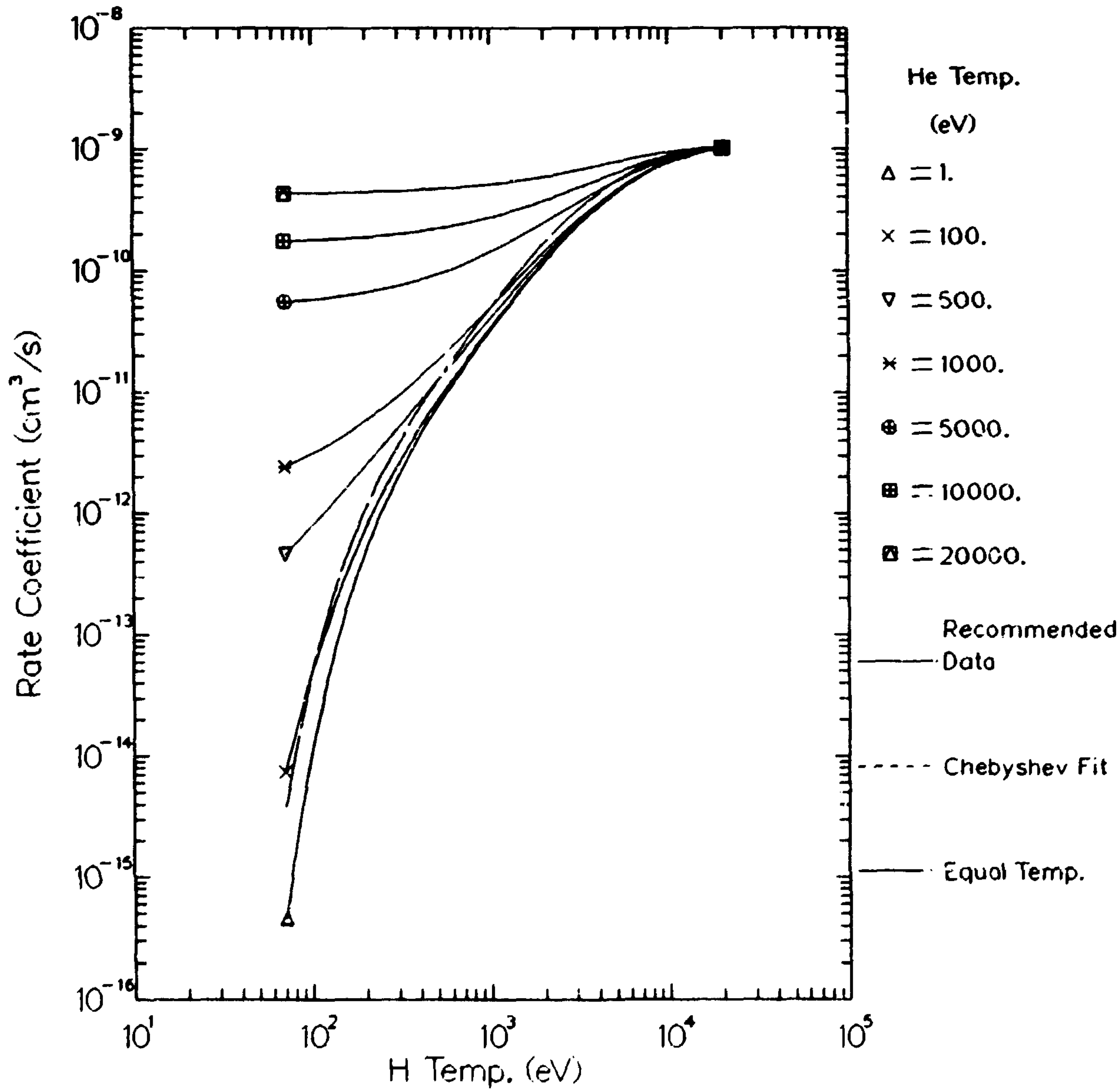
Chebyshev Fitting Parameters for Rate Coefficients

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
1.	-5.10941E+01	6.54972E+00	-2.07764E+00	6.21336E-01	-3.71355E-01	1.34135E-01	-1.51404E-02
100.	-5.00589E+01	5.62889E+00	-1.42974E+00	2.34011E-01	-1.74762E-01	5.17776E-02	1.40144E-02
500.	-4.81708E+01	4.05303E+00	-4.72178E-01	-2.11436E-01	-1.16459E-02	1.30366E-02	9.51225E-03
1000.	-4.71671E+01	3.28859E+00	-1.32390E-01	-2.90109E-01	-1.07340E-02	2.14696E-02	2.38292E-03
5000.	-4.45966E+01	1.61569E+00	1.93393E-01	-1.64393E-01	-5.91438E-02	7.61287E-03	6.54831E-03
10000.	-4.34391E+01	9.76929E-01	1.85422E-01	-8.18919E-02	-5.25533E-02	-5.26730E-03	3.99780E-03
20000.	-4.2439[illegible]E+01	4.84530E-01	1.19557E-01	-3.07242E-02	-3.26702E-02	-9.20869E-03	1.64244E-04
Equal Temp.	-4.97998E+01	5.73848E+00	-1.74839E+00	4.04712E-01	-2.79431E-01	1.17900E-01	-2.07435E-02

See appendix for Chebyshev fit details.

$H + He \rightarrow H^- + He^+$

Maxwellian – Maxwellian



Electron Capture Rate Coefficients for
$He + H \rightarrow H^- + He^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	6.69E-10	1.28E-09	1.46E-09	1.07E-09	6.41E-10	1.45E-10	8.66E-12**
2.0E+00	6.69E-10	1.27E-09	1.46E-09	1.07E-09	6.40E-10	1.45E-10	8.67E-12**
4.0E+00	6.67E-10	1.27E-09	1.46E-09	1.07E-09	6.40E-10	1.45E-10	8.67E-12**
7.0E+00	6.66E-10	1.27E-09	1.46E-09	1.07E-09	6.39E-10	1.44E-10	8.67E-12**
1.0E+01	6.65E-10	1.27E-09	1.46E-09	1.07E-09	6.39E-10	1.44E-10	8.67E-12**
2.0E+01	6.64E-10	1.27E-09	1.46E-09	1.06E-09	6.38E-10	1.44E-10	8.67E-12**
4.0E+01	6.63E-10	1.26E-09	1.45E-09	1.06E-09	6.37E-10	1.44E-10	8.68E-12**
7.0E+01	6.63E-10	1.26E-09	1.45E-09	1.06E-09	6.36E-10	1.44E-10	8.68E-12**
1.0E+02	6.64E-10	1.25E-09	1.44E-09	1.05E-09	6.35E-10	1.44E-10	8.69E-12**
2.0E+02	6.69E-10	1.24E-09	1.43E-09	1.05E-09	6.33E-10	1.44E-10	8.72E-12**
4.0E+02	6.82E-10	1.24E-09	1.42E-09	1.04E-09	6.31E-10	1.44E-10	8.77E-12*
7.0E+02	7.04E-10	1.23E-09	1.40E-09	1.03E-09	6.30E-10	1.44E-10	8.85E-12*
1.0E+03	7.2[illegible]E-10	1.22E-09	1.39E-09	1.02E-09	6.30E-10	1.45E-10	8.93E-12*
2.0E+03	7.87E-10	1.21E-09	1.34E-09	9.96E-10	6.29E-10	1.47E-10	9.20E-12*
4.0E+03	8.79E-10	1.18E-09	1.27E-09	9.60E-10	6.26E-10	1.52E-10	9.70E-12*
7.0E+03	9.65E-10	1.15E-09	1.18E-09	9.11E-10	6.18E-10	1.60E-10	1.04E-11*
1.0E+04	1.01E-09	1.12E-09	1.11E-09	8.67E-10	6.07E-10	1.68E-10	1.10E-11*
2.0E+04	1.05E-09	1.04E-09	9.50E-10	7.54E-10	5.63E-10	1.90E-10	1.34E-11*

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

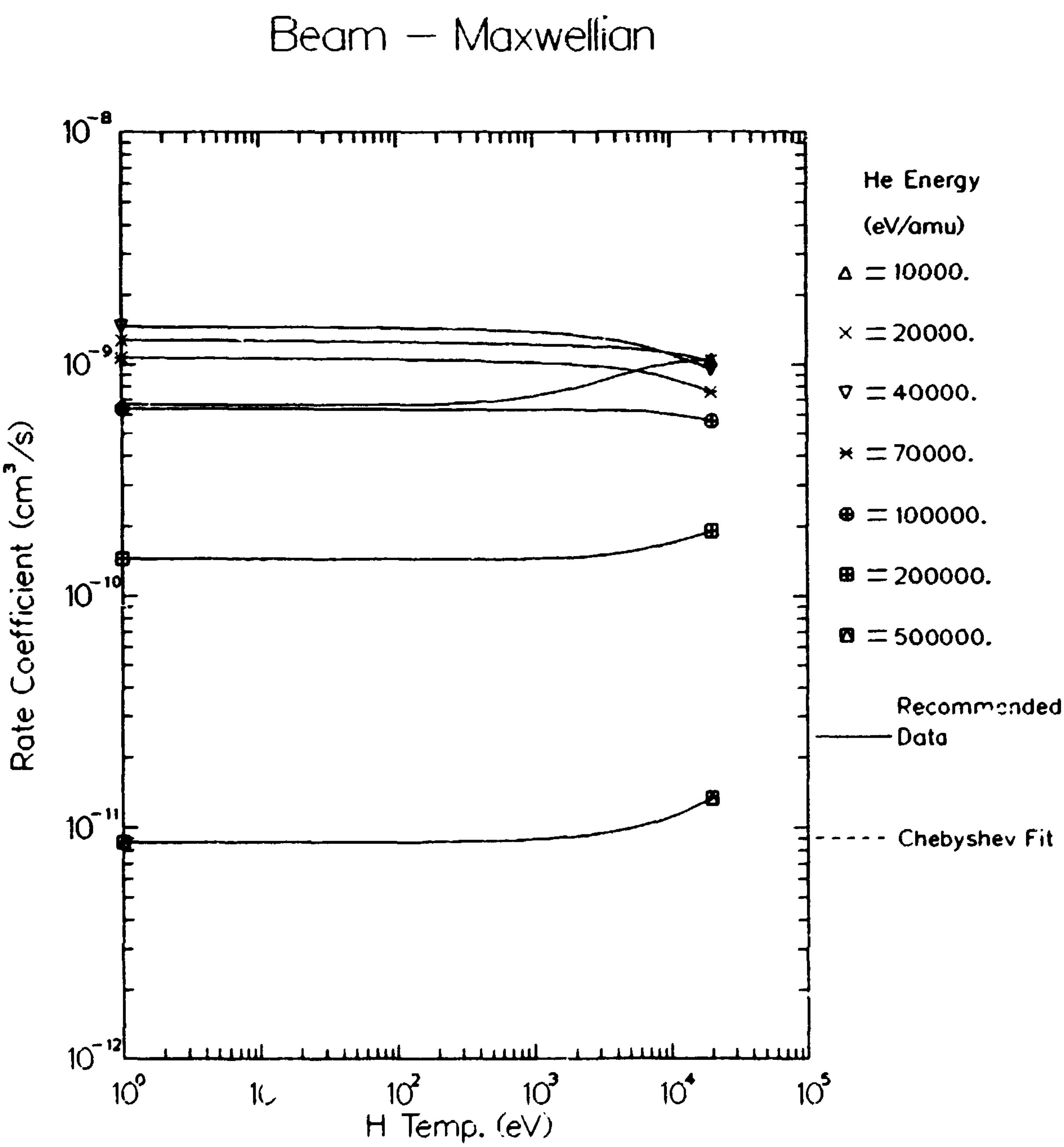
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-4.19935E+01	2.19891E-01	1.24242E-01	2.58739E-02	-1.96928E-02	-2.10662E-02	-9.41303E-03
20000.	-4.10635E+01	-7.94718E-02	-3.94031E-02	-1.87660E-02	-9.93076E-03	-4.65478E-03	-1.66689E-03
40000.	-4.08823E+01	-1.64742E-01	-9.93840E-02	-4.75948E-02	-1.79398E-02	-4.36181E-03	4.08769E-04
70000.	-4.14695E+01	-1.30558E-01	-7.61140E-02	-3.80809E-02	-1.75717E-02	-6.97521E-03	-1.71873E-03
100000.	-4.23878E+01	-4.00395E-02	-2.39094E-02	-1.67316E-02	-1.22134E-02	-7.11472E-03	-2.89733E-03
200000.	-4.52157E+01	9.17644E-02	7.16076E-02	4.20628E-02	1.78905E-02	4.62301E-03	-6.38872E-04
500000.	-5.07701E+01	1.52640E-01	1.03844E-01	5.55224E-02	2.32810E-02	7.67676E-03	2.39728E-03

See appendix for Chebyshev fit details.

He + H -> H^- + He^+


Beam – Maxwellian
Rate Coefficient (cm³/s)
H Temp. (eV)
He Energy
(eV/amu)
△ = 10000.
× = 20000.
▽ = 40000.
✱ = 70000.
⊕ = 100000.
⊞ = 200000.
⊠ = 500000.
Recommended Data
Chebyshev Fit

Electron Capture Cross Sections for
$H + Li \rightarrow H^- + Li^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
3.0E+05	7.61E+08	1.71E-18
4.0E+05	8.78E+08	8.97E-19
5.0E+05	9.82E+08	6.99E-19
6.0E+05	1.08E+09	6.13E-19
7.0E+05	1.16E+09	5.48E-19
8.0E+05	1.24E+09	4.93E-19
9.0E+05	1.32E+09	4.49E-19
1.0E+06	1.39E+09	4.15E-19

References: 268

Accuracy: 30%

For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 3.0E+05 eV/amu, E_{max} = 1.0E+06 eV/amu

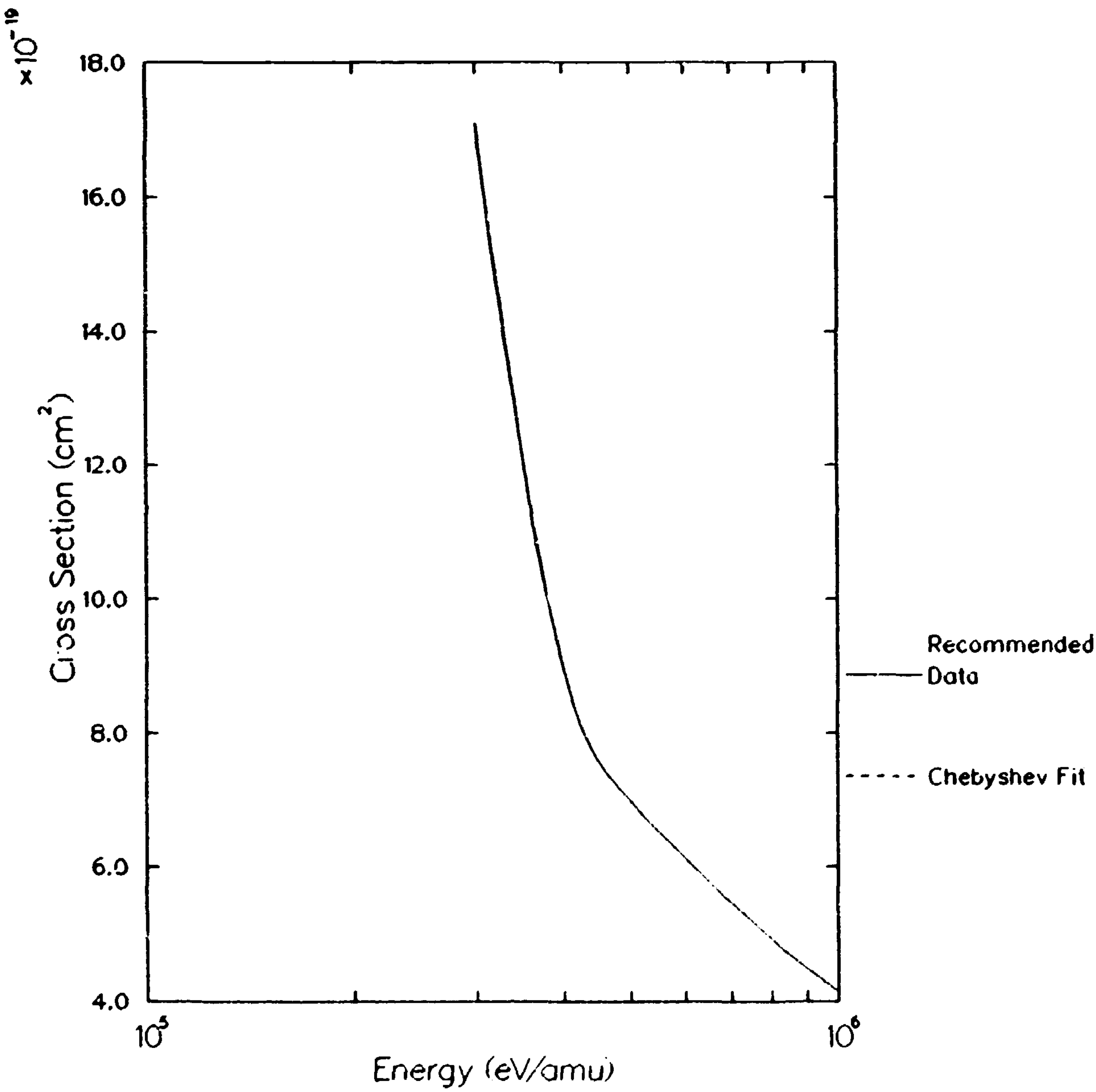
Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-83.5167	-.651028	.130590	-.0639887	.0130205	6.98064E-03	-3.26857E-03	5.16789E-05	

The fit represents the above cross sections with an rms deviation of 0.0%.
The maximum deviation is 0.0%.
See appendix for Chebyshev fit details.

$H + Li \rightarrow H^- + Li^+$

Cross Section vs. Energy



Electron Capture Rate Coefficients for
$Li + H \rightarrow H^- + Li^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H Temp. (eV)	Li Energy (eV/amu) 300000.	350000.	400000.	450000.	500000.	550000.	600000.
1.0E+00	6.49E-10**	9.94E-10**	7.89E-10**	7.33E-10**	6.87E-10**	6.72E-10**	6.59E-10**
2.0E+00	6.48E-10**	9.94E-10**	7.89E-10**	7.33E-10**	6.87E-10**	6.72E-10**	6.59E-10**
4.0E+00	6.47E-10**	9.94E-10**	7.89E-10**	7.33E-10**	6.87E-10**	6.72E-10**	6.59E-10**
7.0E+00	6.46E-10**	9.94E-10**	7.90E-10**	7.33E-10**	6.87E-10**	6.72E-10**	6.59E-10**
1.0E+01	6.45E-10**	9.94E-10**	7.90E-10**	7.33E-10**	6.87E-10**	6.72E-10**	6.59E-10**
2.0E+01	6.43E-10**	9.94E-10**	7.91E-10**	7.33E-10**	6.87E-10**	6.72E-10**	6.59E-10**
4.0E+01	6.40E-10**	9.95E-10**	7.93E-10**	7.33E-10**	6.88E-10**	6.72E-10**	6.59E-10**
7.0E+01	6.37E-10**	9.95E-10**	7.95E-10**	7.33E-10**	6.88E-10**	6.72E-10**	6.59E-10**
1.0E+02	6.34E-10**	9.95E-10**	7.96E-10**	7.33E-10**	6.89E-10**	6.72E-10**	6.59E-10**
2.0E+02	6.28E-10**	9.95E-10**	7.99E-10**	7.33E-10**	6.89E-10**	6.72E-10**	6.59E-10**
4.0E+02	6.19E-10**	9.96E-10**	8.05E-10**	7.33E-10**	6.91E-10**	6.72E-10**	6.59E-10**
7.0E+02	6.09E-10**	9.87E-10**	8.10E-10**	7.33E-10**	6.92E-10**	6.72E-10**	6.59E-10**
1.0E+03	6.02E-10**	9.70E-10**	8.15E-10**	7.34E-10**	6.93E-10**	6.72E-10**	6.59E-10**
2.0E+03	5.84E-10**	9.04E-10**	8.24E-10**	7.39E-10**	6.96E-10**	6.74E-10**	6.59E-10**
4.0E+03	5.62E-10**	8.10E-10**	8.13E-10**	7.49E-10**	7.02E-10**	6.76E-10**	6.60E-10**
7.0E+03	5.43E-10**	7.33E-10**	7.78E-10**	7.49E-10**	7.09E-10**	6.81E-10**	6.61E-10**
1.0E+04	5.31E-10**	6.89E-10**	7.46E-10**	7.39E-10**	7.11E-10**	6.84E-10**	6.63E-10**
2.0E+04	5.11E-10**	6.17E-10**	6.75E-10**	6.96E-10**	6.92E-10**	6.77E-10**	6.55E-10**

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

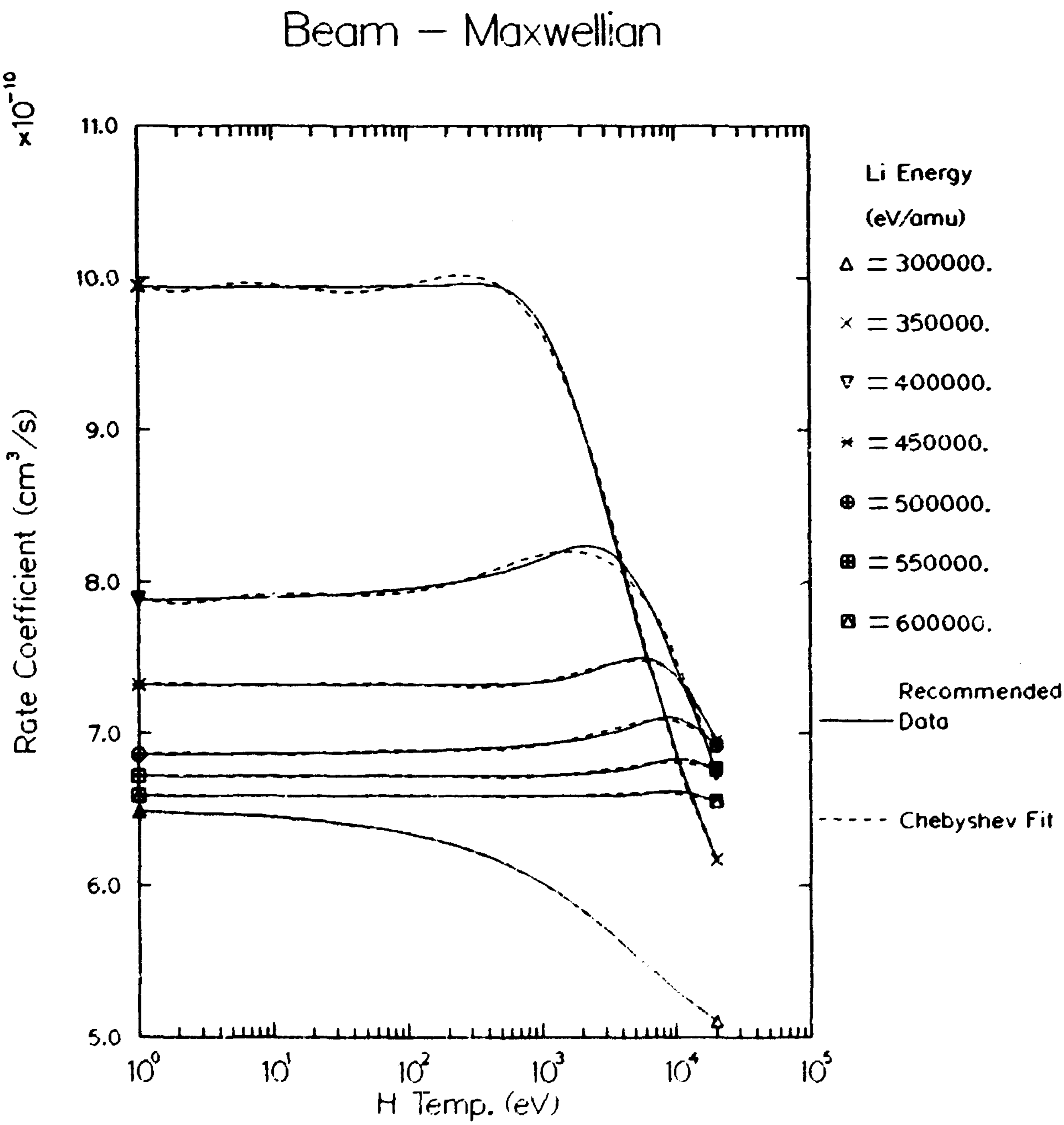
Note: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

Li Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
300000.	-4.24630E+01	-1.12797E-01	-4.73823E-02	-9.52319E-03	2.18237E-03	2.88098E-03	1.39108E-03
350000.	-4.16874E+01	-2.00135E-01	-1.31634E-01	-5.41437E-02	-1.93565E-03	1.56830E-02	1.05923E-02
400000.	-4.19480E+01	-3.48038E-02	-4.56039E-02	-3.81117E-02	-2.13775E-02	-6.73960E-03	1.93438E-03
450000.	-4.20718E+01	-4.96888E-03	-8.42094E-03	-1.19219E-02	-1.19411E-02	-8.70975E-03	-4.48543E-03
500000.	-4.21803E+01	1.24481E-02	3.32025E-03	-3.09575E-03	-5.02533E-03	-4.35643E-03	-3.20289E-03
550000.	-4.22344E+01	5.60707E-03	3.46072E-03	4.86332E-04	-1.43623E-03	-1.96514E-03	-1.82432E-03
600000.	-4.22797E+01	-3.01170E-04	-3.84669E-04	-9.55080E-04	-1.27882E-03	-1.24680E-03	-1.16149E-03

See appendix for Chebyshev fit details.

Li + H -> H^- + Li^+



Beam – Maxwellian
$\times 10^{-10}$
Rate Coefficient (cm^3/s)
11.0
10.0
9.0
8.0
7.0
6.0
5.0
10^0
10^1
10^2
10^3
10^4
10^5
H Temp. (eV)
Li Energy
(eV/amu)
Δ = 300000.
× = 350000.
∇ = 400000.
* = 450000.
⊕ = 500000.
⊞ = 550000.
⊠ = 600000.
Recommended Data
Chebyshev Fit

Electron Capture Cross Sections for

$H + H^- \rightarrow H^- + H$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.0E+00	1.96E+06	1.33E-14
4.0E+00	2.78E+06	1.24E-14
7.0E+00	3.68E+06	1.15E-14
1.0E+01	4.39E+06	1.07E-14
2.0E+01	6.21E+06	8.97E-15
4.0E+01	8.79E+06	7.24E-15
7.0E+01	1.16E+07	5.99E-15
9.9E+01	1.38E+07	5.27E-15
2.0E+02	1.96E+07	4.20E-15
4.0E+02	2.78E+07	3.19E-15
7.0E+02	3.68E+07	2.43E-15
1.0E+03	4.39E+07	1.90E-15
2.0E+03	6.21E+07	9.49E-16
4.0E+03	8.79E+07	3.29E-16
7.1E+03	1.17E+08	1.03E-16

References: 162, 271, 272, 281

Accuracy: 30%

Note: For energies less than 40 eV the data were taken from the theoretical papers of Ref. 271 and 272.

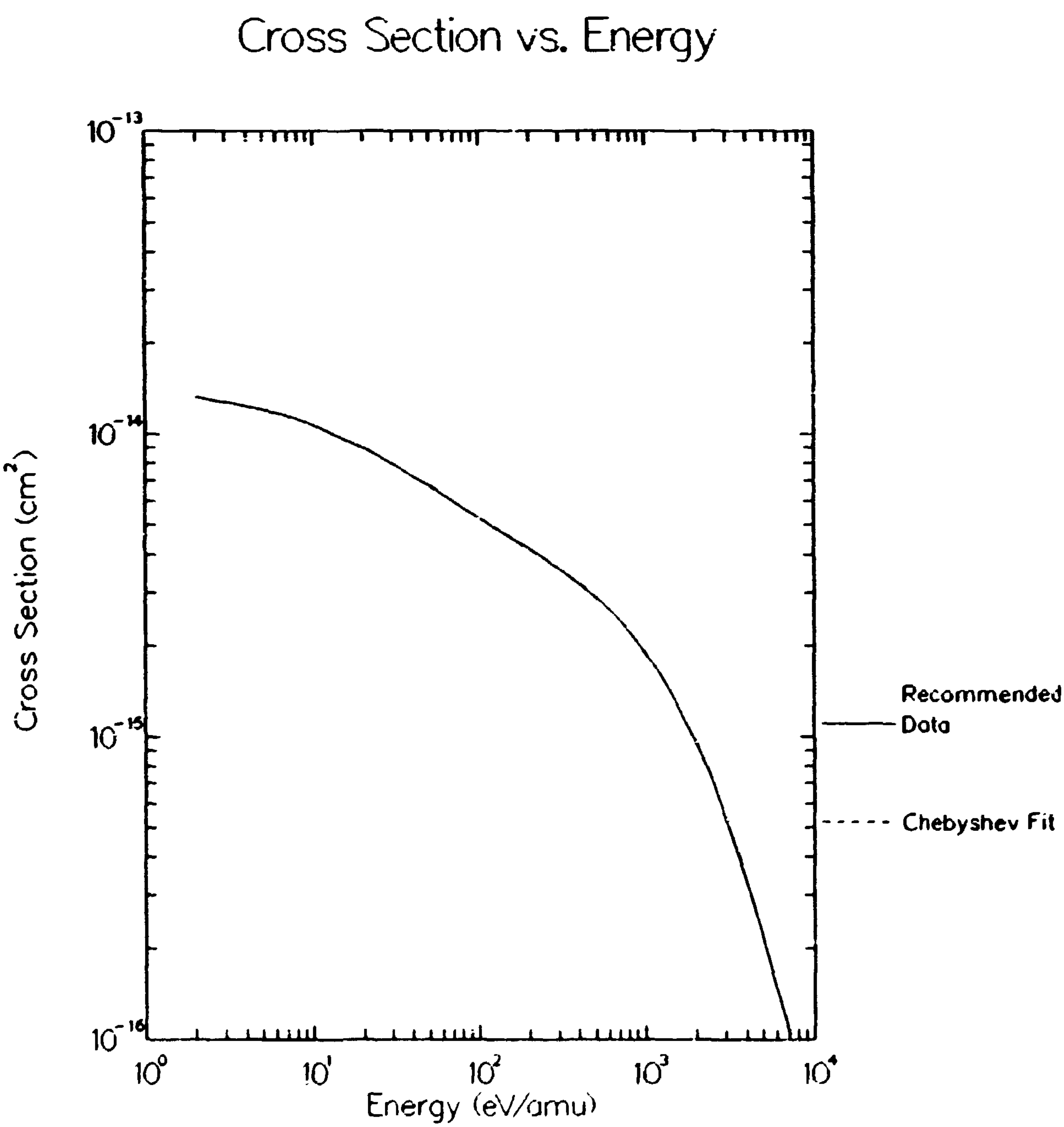
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.0E+00 eV/amu, E_{max} = 7.1E+03 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-67.0414	-2.13773	-.748888	-.288550	-.136764	-.0116298	.0247820	.00770226	2.25210E-04

The fit represents the above cross sections with an rms deviation of 0.3%.
The maximum deviation is 0.7% at 4.0E+02 eV/amu.
See appendix for Chebyshev fit details.

$H + H^- \rightarrow H^- + H$



Electron Capture Cross Sections for
$H^+ + H \rightarrow H + H^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.2E-01	4.79E+05	4.96E-15
2.0E-01	6.21E+05	4.70E-15
4.0E-01	8.79E+05	4.45E-15
7.0E-01	1.16E+06	4.24E-15
1.0E+00	1.39E+06	4.10E-15
2.0E+00	1.96E+06	3.83E-15
4.0E+00	2.78E+06	3.58E-15
7.0E+00	3.68E+06	3.33E-15
1.0E+01	4.39E+06	3.17E-15
2.0E+01	6.21E+06	2.93E-15
4.0E+01	8.79E+06	2.70E-15
7.0E+01	1.16E+07	2.54E-15
1.0E+02	1.39E+07	2.44E-15
2.0E+02	1.96E+07	2.22E-15
4.0E+02	2.78E+07	2.03E-15
7.0E+02	3.68E+07	1.88E-15
1.0E+03	4.39E+07	1.71E-15
2.0E+03	6.21E+07	1.44E-15
4.0E+03	8.79E+07	1.20E-15
7.0E+03	1.16E+08	9.42E-16
1.0E+04	1.39E+08	7.75E-16
2.0E+04	1.96E+08	4.45E-16
4.0E+04	2.78E+08	1.67E-16
7.0E+04	3.68E+08	3.77E-17
1.0E+05	4.39E+08	1.01E-17
2.0E+05	6.21E+08	6.09E-19
4.0E+05	8.78E+08	1.76E-20
6.3E+05	1.10E+09	1.35E-21

<u>References:</u> 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 273, 395

<u>Accuracy:</u> H^+ Energy: < 10 eV/amu, 10%; 10 eV/amu - 1×10^3 eV/amu, 15%; 1×10^3 eV/amu - 1×10^5 eV/amu, 5%; 1×10^5 eV/amu - 6.25×10^5 eV/amu, 20%

<u>Notes:</u> (1) This reaction has been measured by three different techniques: 1. Static Gas Target, 2. Cross Beams, 3. Merged Beams.

(2) The maximum deviation of the recommended data from the data points in the references cited is less than 45%.

(3) Newman in reference 9 found that when D atoms were the target the cross section decreased 16% from that using H atoms at an energy of .12 eV. At high energies the cross sections were the same.

(4) The recent ref. 273 extends the measurements up to an energy of 7.5×10^6 eV/amu. The cross sections are (a) 2.0×10^6 eV/amu - 5.25×10^{-24} cm^2; (b) 3.5×10^6 eV/amu - 2.14×10^{-25} cm^2; (c) 5.0×10^6 eV/amu - 3.1×10^{-26} cm^2; (d) 7.5×10^6 eV/amu - 4.10×10^{-27} cm^2. Quoted errors are as great as 43%.

For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.2E-01 eV/amu, E_{max} = 6.3E+05 eV/amu

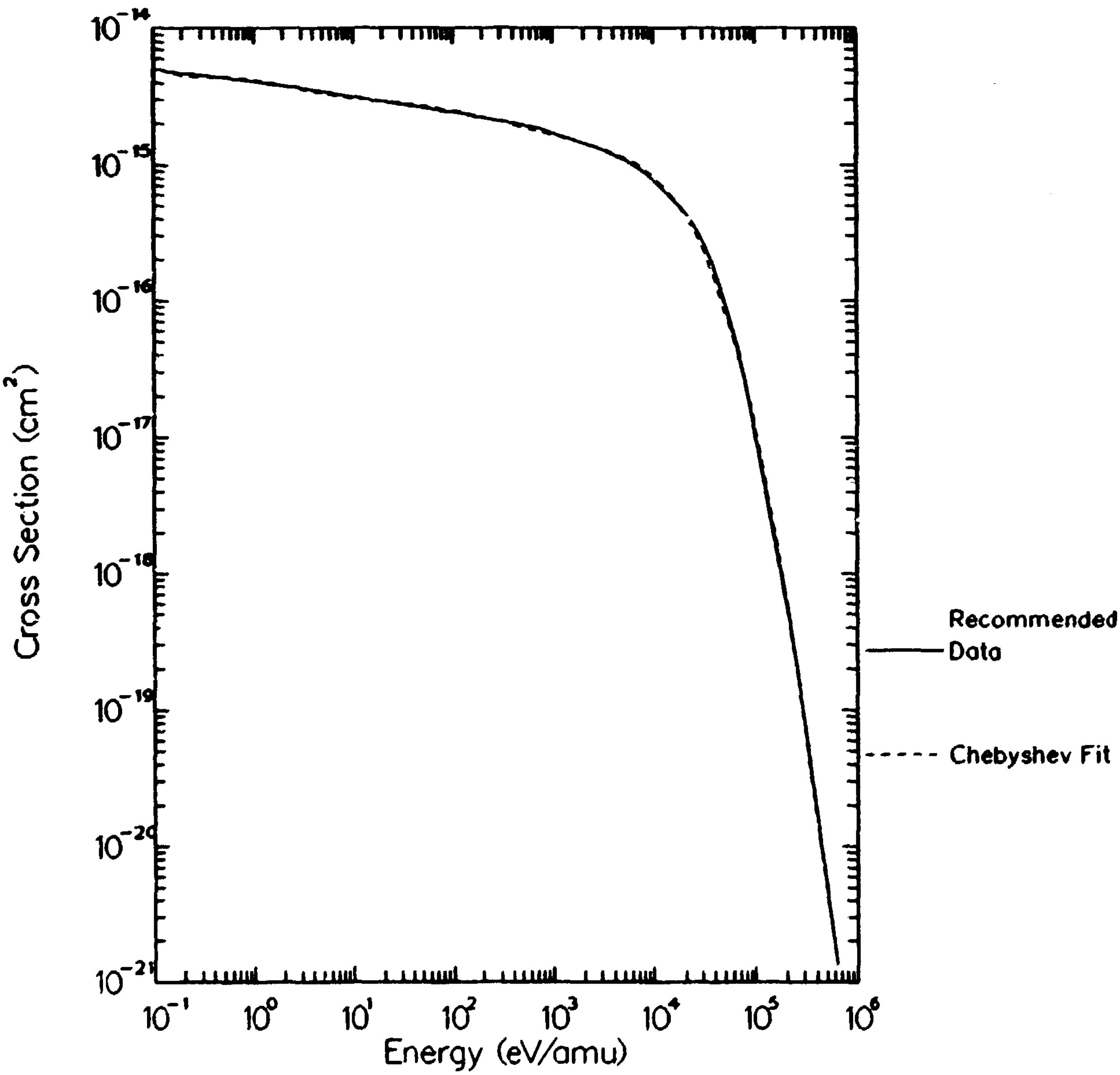
<u>Chebyshev Fitting Parameters for Cross Sections</u>

A0	A1	A2	A3	A4	A5	A6	A7	A8
-72.6656	-5.49142	-3.42948	-1.98377	-.878009	-.198932	.0837431	.121252	.0827182

The fit represents the above cross sections with an rms deviation of 4.5%.
The maximum deviation is 13.5% at 1.0E+05 eV/amu.
See appendix for Chebyshev fit details.

$H^+ + H \rightarrow H + H^+$

Cross Section vs. Energy



Electron Capture Rate Coefficients for
$H^+ + H \rightarrow H + H^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	Equal Temp.	H Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.0E+00	8.10E-09	8.10E-09	1.56E-08	3.63E-08	7.65E-08	9.74E-08	8.95E-08	6.34E-08
2.0E+00	1.06E-08	9.50E-09	1.61E-08	3.64E-08	7.65E-08	9.74E-08	8.95E-08	6.84E-08
4.0E+00	1.38E-08	1.16E-08	1.71E-08	3.67E-08	7.66E-08	9.74E-08	8.95E-08	6.84E-08
7.0E+00	1.71E-08	1.38E-08	1.85E-08	3.71E-08	7.66E-08	9.74E-08	8.95E-08	6.84E-08
1.0E+01	1.96E-08	1.56E-08	1.96E-08	3.75E-08	7.67E-08	9.74E-08	8.95E-08	6.84E-08
2.0E+01	2.56E-08	2.00E-08	2.30E-08	3.87E-08	7.69E-08	9.74E-08	8.95E-08	6.84E-08
4.0E+01	3.33E-08	2.59E-08	2.79E-08	4.10E-08	7.73E-08	9.74E-08	8.94E-08	6.84E-08
7.0E+01	4.10E-08	3.18E-08	3.33E-08	4.40E-08	7.78E-08	9.74E-08	8.94E-08	6.83E-08
1.0E+02	4.66E-08	3.63E-08	3.75E-08	4.66E-08	7.84E-08	9.74E-08	8.93E-08	6.83E-08
2.0E+02	5.88E-08	4.67E-08	4.74E-08	5.36E-08	8.00E-08	9.73E-08	8.91E-08	6.81E-08
4.0E+02	7.21E-08	5.89E-08	5.93E-08	6.30E-08	8.30E-08	9.72E-08	8.87E-08	6.77E-08
7.0E+02	8.30E-08	6.95E-08	6.98E-08	7.21E-08	8.65E-08	9.70E-08	8.80E-08	6.72E-08
1.0E+03	8.92E-08	7.65E-08	7.67E-08	7.84E-08	8.92E-08	9.67E-08	8.73E-08	6.66E-08
2.0E+03	9.70E-08	8.92E-08	8.93E-08	9.00E-08	9.48E-08	9.54E-08	8.51E-08	6.49E-08
4.0E+03	9.36E-08	9.70E-08	9.70E-08	9.71E-08	9.74E-08	9.17E-08	8.06E-08	6.16E-08
7.0E+03	8.06E-08	9.54E-08	9.54E-08	9.52E-08	9.36E-08	8.51E-08	7.43E-08	5.70E-08
1.0E+04	6.84E-08	8.95E-08	8.95E-08	8.93E-08	8.73E-08	7.84E-08	6.84E-08	5.30E-08
2.0E+04	4.23E-08	6.84E-08	6.84E-08	6.83E-08	6.66E-08	6.00E-08	5.30E-08	4.23E-08

Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

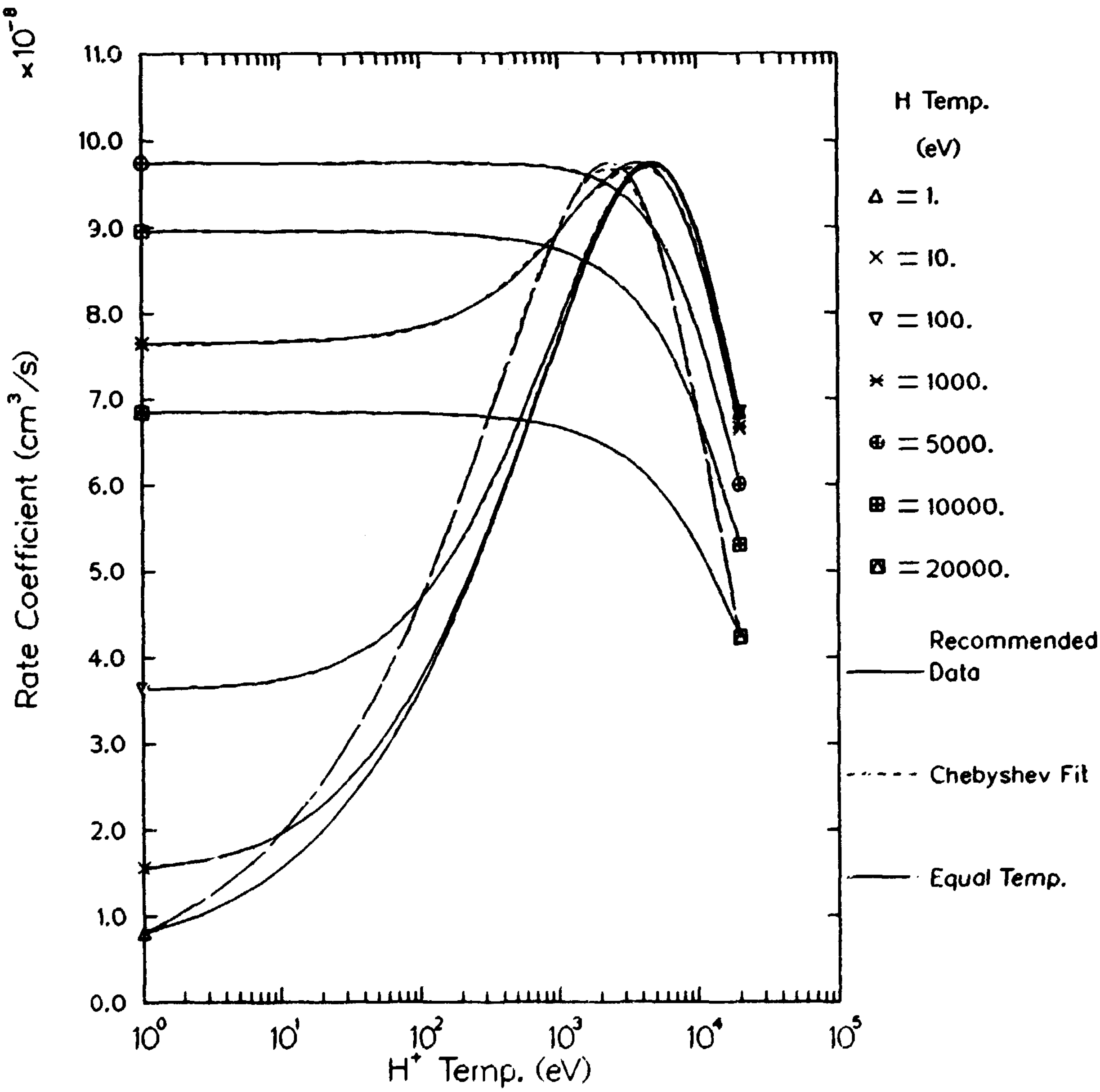
Chebyshev Fitting Parameters for Rate Coefficients

H Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
1.	-3.44869E+01	1.27901E+00	-2.75515E-01	-1.94518E-01	-4.14913E-02	-1.79417E-02	-4.17985E-03
10.	-3.41227E+01	9.80499E-01	-1.17702E-01	-2.36330E-01	-4.90489E-02	-5.73981E-03	-8.76848E-03
100.	-3.34478E+01	5.02257E-01	-2.99001E-03	-1.75672E-01	-9.20126E-02	-1.06753E-02	3.21804E-03
1000.	-3.26740E+01	4.69533E-02	-4.61309E-02	-8.81367E-02	-6.79803E-02	-2.93738E-02	-4.42210E-03
5000.	-3.24495E+01	-1.48073E-01	-1.15160E-01	-7.59145E-02	-4.13891E-02	-1.79143E-02	-5.55664E-03
10000.	-3.26521E+01	-1.74458E-01	-1.25225E-01	-7.36305E-02	-3.55149E-02	-1.38261E-02	-4.10388E-03
20000.	-3.31787E+01	-1.63538E-01	-1.15089E-01	-6.54004E-02	-3.01053E-02	-1.10769E-02	-3.10752E-03
Equal Temp.	-3.44313E+01	1.06711E+00	-5.19907E-01	-2.29247E-01	-6.98896E-02	-1.36578E-02	4.42580E-04

See appendix for Chebyshev fit details.

$H^+ + H \rightarrow H + H^+$

Maxwellian – Maxweilian



Electron Capture Rate Coefficients for
$H + H^+ \rightarrow H + H^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	1.08E-07	8.72E-08	4.62E-08	1.38E-08	4.43E-09	3.78E-10	4.79E-12**
2.0E+00	1.07E-07	8.71E-08	4.62E-08	1.38E-08	4.43E-09	3.78E-10	4.79E-12**
4.0E+00	1.07E-07	8.70E-08	4.61E-08	1.38E-08	4.43E-09	3.77E-10	4.79E-12**
7.0E+00	1.07E-07	8.69E-08	4.60E-08	1.38E-08	4.43E-09	3.77E-10	4.79E-12**
1.0E+01	1.07E-07	8.68E-08	4.59E-08	1.38E-08	4.43E-09	3.77E-10	4.79E-12**
2.0E+01	1.07E-07	8.65E-08	4.57E-08	1.37E-08	4.43E-09	3.77E-10	4.79E-12**
4.0E+01	1.07E-07	8.61E-08	4.55E-08	1.37E-08	4.44E-09	3.76E-10	4.80E-12**
7.0E+01	1.06E-07	8.57E-08	4.52E-08	1.37E-08	4.44E-09	3.76E-10	4.80E-12**
1.0E+02	1.06E-07	8.53E-08	4.50E-08	1.37E-08	4.45E-09	3.76E-10	4.81E-12**
2.0E+02	1.05E-07	8.45E-08	4.45E-08	1.37E-08	4.48E-09	3.77E-10	4.83E-12**
4.0E+02	1.04E-07	8.34E-08	4.39E-08	1.37E-08	4.55E-09	3.79E-10	4.88E-12**
7.0E+02	1.03E-07	8.21E-08	4.34E-08	1.38E-08	4.67E-09	3.84E-10	4.96E-12**
1.0E+03	1.01E-07	8.10E-08	4.31E-08	1.40E-08	4.79E-09	3.89E-10	5.03E-12**
2.0E+03	9.70E-08	7.79E-08	4.23E-08	1.46E-08	5.17E-09	4.11E-10	5.29E-12**
4.0E+03	9.00E-08	7.24E-08	4.11E-08	1.56E-08	5.91E-09	4.64E-10	5.82E-12*
7.0E+03	8.16E-08	6.57E-08	3.92E-08	1.66E-08	6.90E-09	5.69E-10	6.71E-12*
1.0E+04	7.46E-08	6.03E-08	3.74E-08	1.72E-08	7.74E-09	7.01E-10	7.80E-12*
2.0E+04	5.70E-08	4.72E-08	3.20E-08	1.75E-08	9.46E-09	1.28E-09	1.36E-11*

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

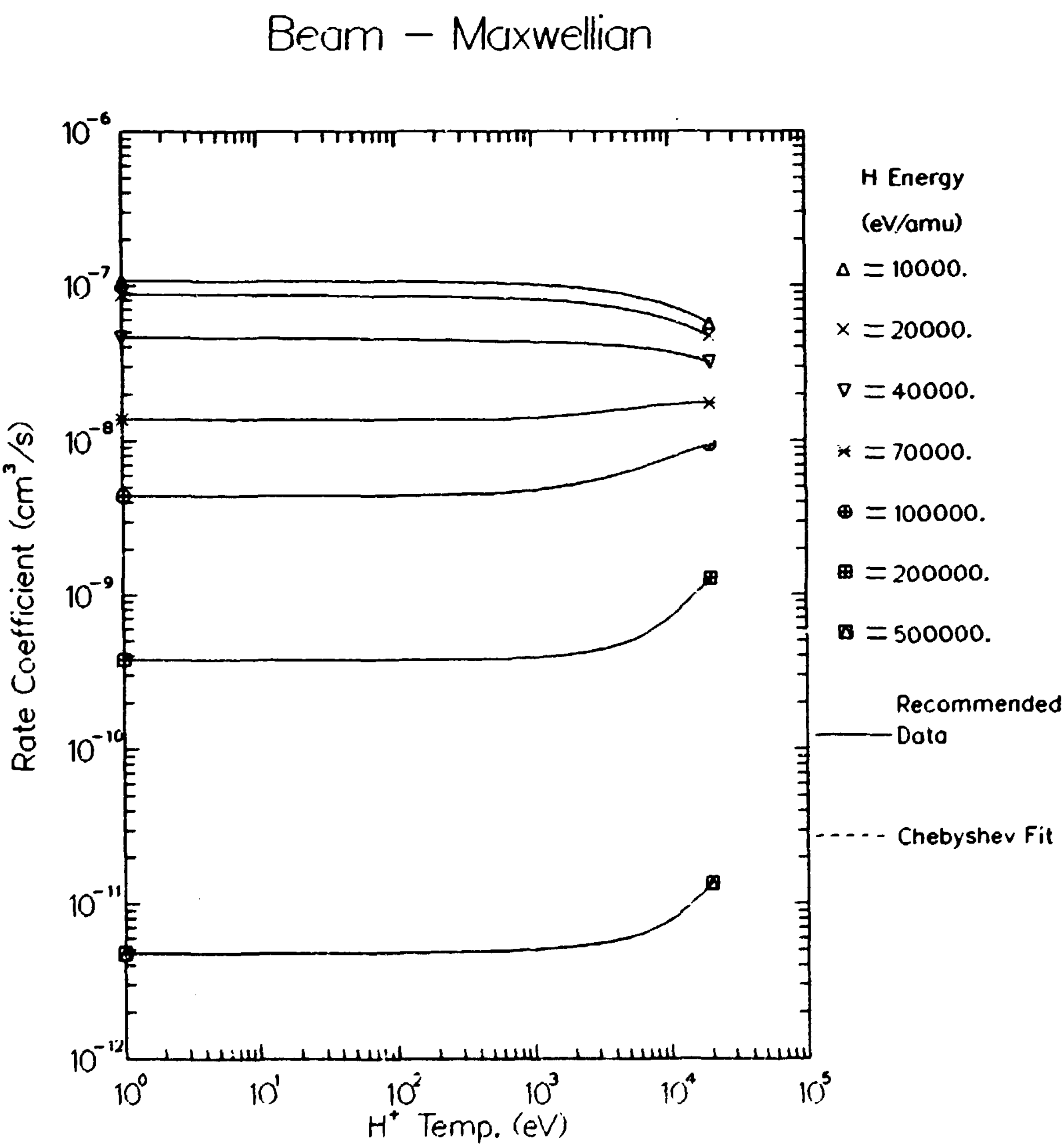
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-3.23588E+01	-2.28428E-01	-1.47539E-01	-7.73418E-02	-3.29002E-02	-1.09141E-02	-2.93158E-03
20000.	-3.27829E+01	-2.26775E-01	-1.38750E-01	-7.04432E-02	-3.03096E-02	-1.00013E-02	-1.47228E-03
40000.	-3.39547E+01	-1.36550E-01	-7.15786E-02	-3.65682E-02	-2.10115E-02	-1.11355E-02	-4.14062E-03
70000.	-3.60736E+01	1.09084E-01	7.35296E-02	2.31264E-02	-7.74992E-03	-1.38165E-02	-8.49906E-03
100000.	-3.81082E+01	3.09107E-01	1.95996E-01	8.14408E-02	1.35787E-02	-9.21346E-03	-1.02081E-02
200000.	-4.29608E+01	3.96726E-01	2.99000E-01	1.81207E-01	8.74182E-02	3.26701E-02	7.33350E-03
500000.	-5.17564E+01	3.37283E-01	2.43298E-01	1.48098E-01	7.72749E-02	3.54105E-02	1.56884E-02

See appendix for Chebyshev fit details.

$H + H^+ \to H + H^+$



Beam — Maxwellian
Rate Coefficient (cm³/s)
H⁺ Temp. (eV)
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁰
10¹
10²
10³
10⁴
10⁵
H Energy
(eV/amu)
= 10000.
= 20000.
= 40000.
= 70000.
= 100000.
= 200000.
= 500000.
Recommended Data
Chebyshev Fit

Electron Capture Cross Sections for
$H^+ + H_2 \rightarrow H$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.6E+00	2.24E+06	1.81E-17
4.0E+00	2.78E+06	4.96E-17
4.7E+00	3.01E+06	5.68E-17
7.0E+00	3.68E+06	2.76E-17
1.0E+01	4.39E+06	1.30E-17
1.4E+01	5.20E+06	1.01E-17
2.0E+01	6.21E+06	1.11E-17
4.0E+01	8.79E+06	1.68E-17
7.0E+01	1.16E+07	2.61E-17
1.0E+02	1.39E+07	3.65E-17
2.0E+02	1.96E+07	6.96E-17
4.0E+02	2.78E+07	1.56E-16
7.0E+02	3.68E+07	2.93E-16
1.0E+03	4.39E+07	4.26E-16
2.0E+03	6.21E+07	6.88E-16
4.0E+03	8.79E+07	9.33E-16
7.0E+03	1.16E+08	9.57E-16
1.0E+04	1.39E+08	8.66E-16
2.0E+04	1.96E+08	5.79E-16
4.0E+04	2.78E+08	2.50E-16
7.0E+04	3.68E+08	7.78E-17
1.0E+05	4.39E+08	2.91E-17
2.0E+05	6.21E+08	1.76E-18
4.0E+05	8.78E+08	6.09E-20
7.0E+05	1.16E+09	3.64E-21
1.0E+06	1.39E+09	4.14E-22
2.0E+06	1.96E+09	1.68E-23
4.0E+06	2.77E+09	1.03E-24

<u>References:</u> 7, 27, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 47, 48, 62, 273, 395

<u>Accuracy:</u> E < 100 eV/amu - Unknown; E > 100 eV/amu - 10%

<u>Notes:</u> (1) The peak in the cross section at 4 eV comes from the data of reference 41. The origin of this maximum is unknown.
(2) Recent data of reference 273 extend the energy range to $7.5x10^5$ eV/amu. The cross sections reported are: (a) $2.0x10^6$ eV/amu - $7.00x10^{-24}$ cm^2; (b) $3.5x10^6$ eV/amu - $4.85x10^{-25}$ cm^2; (c) $5.0x10^6$ eV/amu - $6.47 \; x10^{-26}$ cm^2; (d) $7.5x10^6$ eV/amu - [illegible].$30x10^{-27}$ cm^2. Errors of 10-15% are reported.

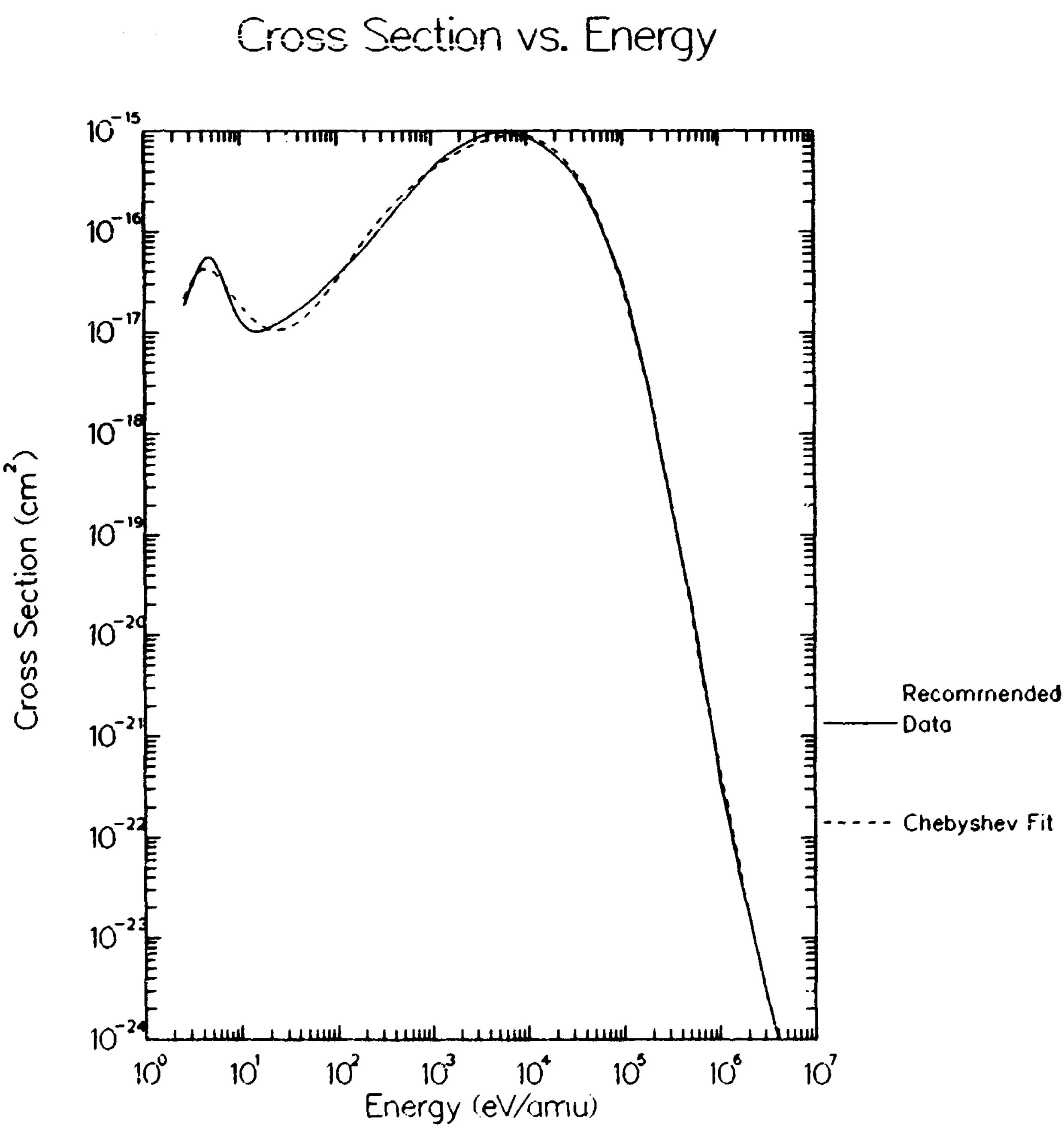
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.6E+00 eV/amu, E_{max} = 4.0E+06 eV/amu

<u>Chebyshev Fitting Parameters for Cross Sections</u>

A0	A1	A2	A3	A4	A5	A6	A7	A8
-82.5164	-6.70755	-6.10977	-2.62810	.709759	.639033	.102980	.261240	-.263817

The fit represents the above cross sections with an rms deviation of 15.5%.
The maximum deviation is 41.3% at 1.0E+01 eV/amu.
See appendix for Chebyshev fit details.

$H^+ + H_2 \rightarrow H$



Double Electron Capture Cross Sections for
$H^+ + H_2 \rightarrow H^- + 2H^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.0E+02	1.96E+07	1.17E-20
4.0E+02	2.78E+07	2.22E-20
7.0E+02	3.68E+07	4.82E-20
1.0E+03	4.39E+07	8.94E-20
2.0E+03	6.21E+07	2.80E-19
4.0E+03	8.79E+07	8.64E-19
7.0E+03	1.16E+08	2.09E-18
1.0E+04	1.39E+08	3.63E-18
2.0E+04	1.96E+08	8.89E-18
4.0E+04	2.78E+08	2.21E-18
7.0E+04	3.68E+08	2.42E-19
1.0E+05	4.39E+08	3.15E-20
2.0E+05	6.21E+08	1.84E-22
4.0E+05	8.78E+08	7.22E-25
7.0E+05	1.16E+09	6.64E-27
1.0E+06	1.39E+09	2.70E-28

References: 35, 44, 50, 51, 52, 53, 54

Accuracy: $E < 1\times10^4$ eV/amu - 25%; 1×10^4 eV/amu $< E < 1\times10^5$ eV/amu - 15%; $E > 1\times10^5$ eV/amu - 40%

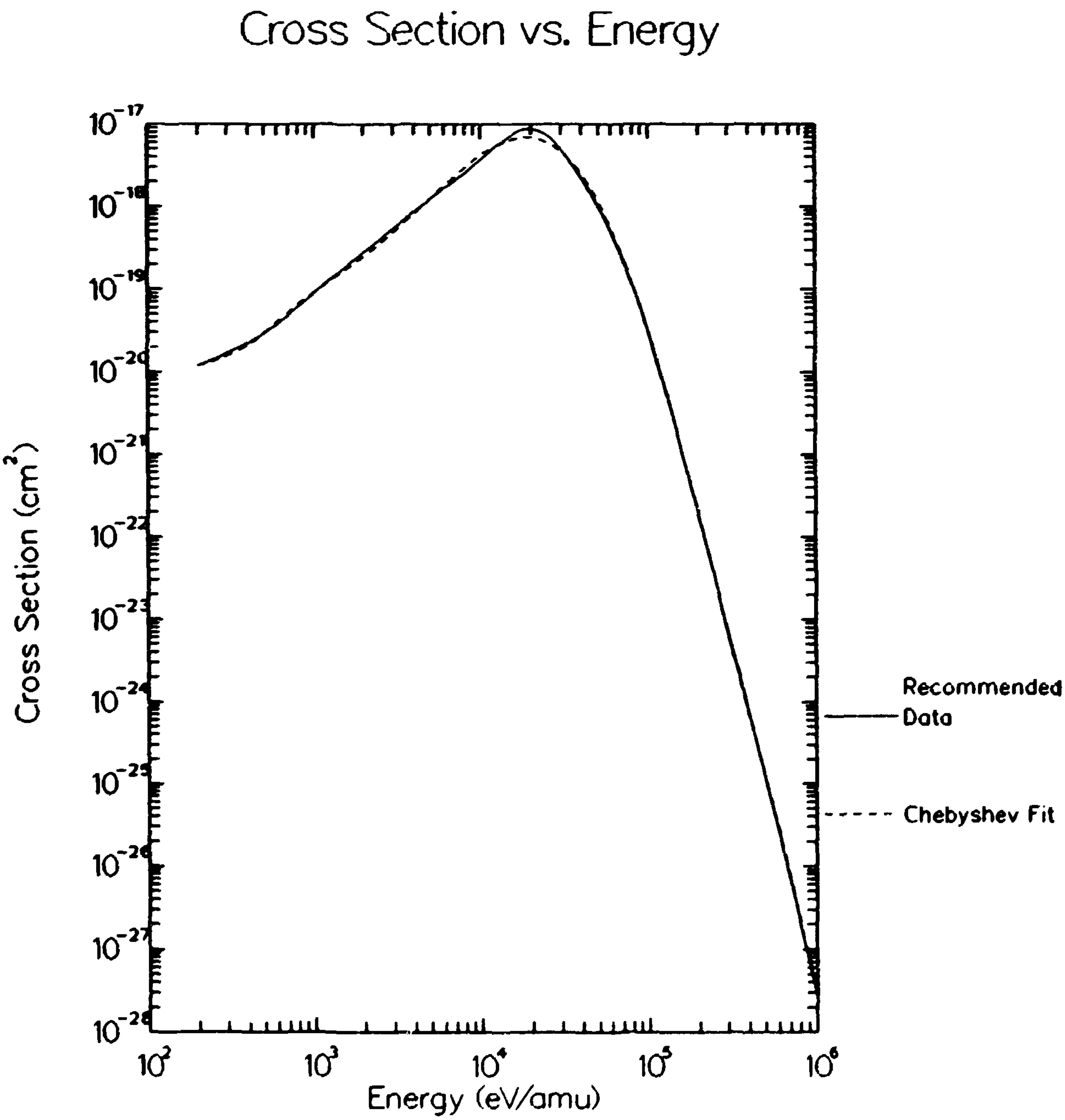
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.0E+02 eV/amu, E_{max} = 1.0E+06 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-95.8165	-7.17049	-7.48288	-1.93034	.761153	.556689	-.0542859	-.270184	-.0147551

The fit represents the above cross sections with an rms deviation of 9.4%.
The maximum deviation is 15.0% at 1.0E+04 eV/amu.
See appendix for Chebyshev fit details.

$H^+ + H_2 \rightarrow H^- + 2H^+$



Electron Capture Cross Sections for $H^+ + He \rightarrow H + He^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
9.9E+01	1.38E+07	4.28E-22
2.0E+02	1.96E+07	2.46E-21
4.0E+02	2.78E+07	1.77E-20
7.0E+02	3.68E+07	1.12E-19
1.0E+03	4.39E+07	4.73E-19
2.0E+03	6.21E+07	4.25E-18
4.0E+03	8.79E+07	1.98E-17
7.0E+03	1.16E+08	5.18E-17
1.0E+04	1.39E+08	8.52E-17
2.0E+04	1.96E+08	1.75E-16
2.4E+04	2.15E+08	1.83E-16
4.0E+04	2.78E+08	1.41E-16
7.0E+04	3.68E+08	6.98E-17
1.0E+05	4.39E+08	3.38E-17
2.0E+05	6.21E+08	3.95E-18
4.0E+05	8.78E+08	3.22E-19
7.0E+05	1.16E+09	3.07E-20
1.0E+06	1.39E+09	5.42E-21
2.0E+06	1.96E+09	1.42E-22
4.0E+06	2.77E+09	3.29E-24
7.0E+06	3.65E+09	1.62E-25
1.0E+07	4.36E+09	2.09E-26
1.1E+07	4.57E+09	1.02E-26

References: 27, 35, 37, 40, 47, 49, 51, 82, 83, 84, 85, 86, 87, 88, 89, 272

Accuracy: $E < 5 \times 10^3$ eV/amu - 40%; $E > 5 \times 10^3$ eV/amu - 20%

For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 9.9E+01 eV/amu, E_{max} = 1.1E+07 eV/amu

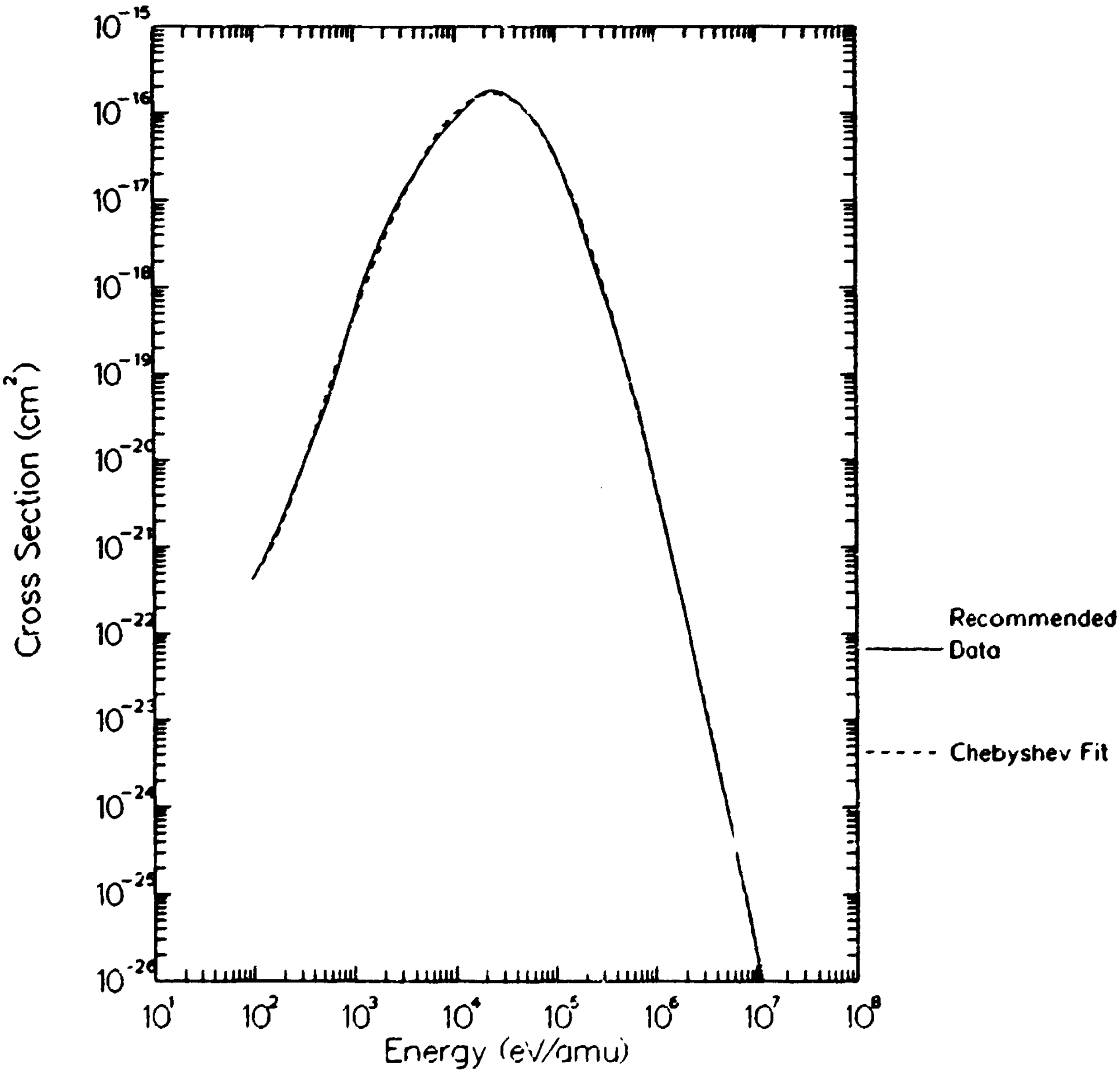
Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-92.7819	-4.69073	-8.99666	-.490484	.935276	-.0504853	-.0430750	-.0730136	.0189320

The fit represents the above cross sections with an rms deviation of 10.0%.
The maximum deviation is 18.7% at 7.0E+02 eV/amu.
See appendix for Chebyshev fit details.

$H^+ + He \rightarrow H + He^+$

Cross Section vs. Energy



Electron Capture Rate Coefficients for
$H^+ + He \rightarrow H + He^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	Equal Temp.	He Temp. (eV) 50.	100.	500.	1000.	5000.	10000.	20000.
7.0E+01	7.21E-14	5.81E-14	9.77E-14	1.60E-12	1.02E-11	6.38E-10	2.68E-09	8.50E-09
1.0E+02	2.79E-13	1.85E-13	2.79E-13	2.78E-12	1.39E-11	6.73E-10	2.74E-09	8.57E-09
2.0E+02	4.14E-12	2.23E-12	2.78E-12	1.08E-11	3.22E-11	7.95E-10	2.95E-09	8.81E-09
4.0E+02	4.51E-11	2.43E-11	2.68E-11	5.24E-11	9.92E-11	1.07E-09	3.37E-09	9.28E-09
7.0E+02	2.27E-10	1.29E-10	1.36E-10	1.94E-10	2.82E-10	1.53E-09	4.03E-09	5.99E-09
1.0E+03	5.60E-10	3.32E-10	3.42E-10	4.33E-10	5.60E-10	2.06E-09	4.73E-09	1.07E-08
2.0E+03	2.54E-09	1.64E-09	1.66E-09	1.83E-09	2.06E-09	4.15E-09	7.12E-09	1.29E-08
4.0E+03	8.33E-09	5.94E-09	5.97E-09	6.21E-09	6.52E-09	8.93E-09	1.18E-08	1.66E-08
7.0E+03	1.62E-08	1.29E-08	1.29E-08	1.31E-08	1.34E-08	1.53E-08	1.74E-08	2.07E-08
1.0E+04	2.12E-08	1.82E-08	1.82E-08	1.83E-08	1.85E-08	1.98E-08	2.12E-08	2.33E-08
2.0E+04	2.60E-08	2.55E-08	2.55E-08	2.55E-08	2.55E-08	2.57E-08	2.59E-08	2.60E-08

Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 7.0E+01 eV, E_{max} = 2.0E+04 eV

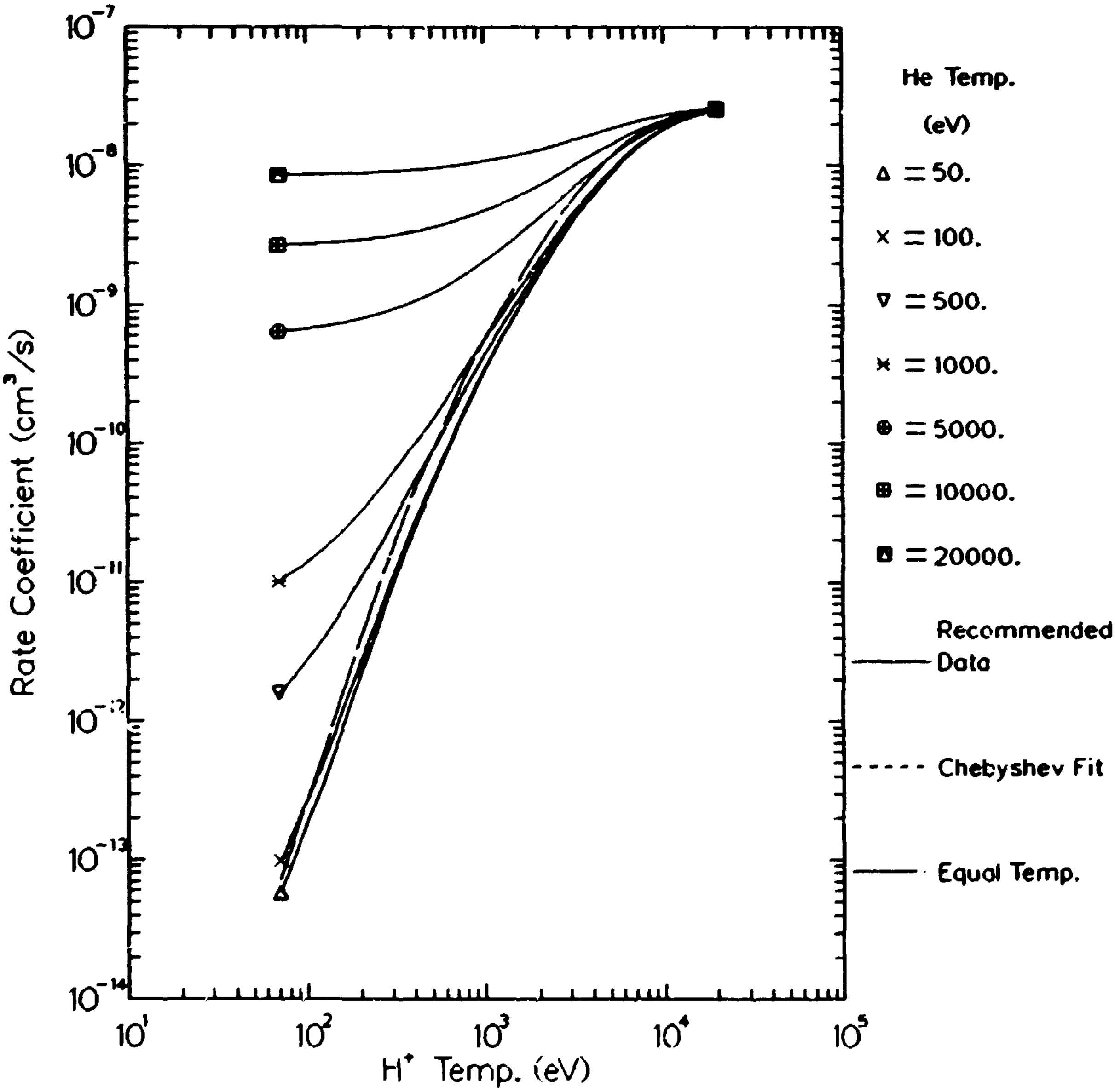
Chebyshev Fitting Parameters for Rate Coefficients

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
50.	-4.54767E+01	6.67186E+00	-1.30388E+00	-1.33476E-01	4.39632E-02	-4.52889E-02	1.85831E-02
100.	-4.51974E+01	6.44612E+00	-1.18362E+00	-1.72127E-01	4.66619E-02	-4.04263E-02	1.55388E-02
500.	-4.35812E+01	5.17359E+00	-5.65656E-01	-3.28985E-01	3.26661E-02	-7.75934E-03	1.09010E-03
1000.	-4.23753E+01	4.27018E+00	-2.07470E-01	-3.69408E-01	-9.50854E-04	1.17863E-02	-8.41076E-04
5000.	-3.90038E+01	2.05191E+00	2.49124E-01	-2.12101E-01	-8.19217E-02	7.92950E-03	1.06018E-02
10000.	-3.75454E+01	1.24999E+00	2.32693E-01	-1.10685E-01	-6.99375E-02	-5.62572E-03	6.74424E-03
20000.	-3.62570E+01	6.12670E-01	1.45612E-01	-4.25717E-02	-4.13562E-02	-1.03361E-02	9.23441E-04
Equal Temp.	-4.47894E+01	6.48647E+00	-1.50363E+00	-5.56465E-02	1.00897E-02	-3.20031E-02	2.61002E-02

See appendix for Chebyshev fit details.

$H^+ + He \rightarrow H + He^+$

Maxwellian — Maxwellian



Electron Capture Rate Coefficients for
$He + H^{+} \rightarrow H + He^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H^{+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	1.18E-08	3.43E-08	3.91E-08	2.56E-08	1.48E-08	2.45E-09	1.24E-10
2.0E+00	1.18E-08	3.42E-08	3.91E-08	2.56E-08	1.48E-08	2.45E-09	1.24E-10
4.0E+00	1.18E-08	3.42E-08	3.90E-08	2.56E-08	1.48E-08	2.45E-09	1.24E-10
7.0E+00	1.18E-08	3.41E-08	3.90E-08	2.55E-08	1.48E-08	2.45E-09	1.24E-10
1.0E+01	1.18E-08	3.41E-08	3.89E-08	2.55E-08	1.48E-08	2.45E-09	1.24E-10
2.0E+01	1.18E-08	3.40E-08	3.88E-08	2.55E-08	1.47E-08	2.45E-09	1.24E-10
4.0E+01	1.19E-08	3.38E-08	3.87E-08	2.54E-08	1.47E-08	2.45E-09	1.24E-10
7.0E+01	1.19E-08	3.37E-08	3.85E-08	2.53E-08	1.46E-08	2.45E-09	1.24E-10
1.0E+02	1.20E-08	3.36E-08	3.84E-08	2.53E-08	1.46E-08	2.45E-09	1.24E-10
2.0E+02	1.24E-08	3.33E-08	3.80E-08	2.51E-08	1.45E-08	2.45E-09	1.24E-10
4.0E+02	1.31E-08	3.29E-08	3.76E-08	2.49E-08	1.45E-08	2.45E-09	1.25E-10
7.0E+02	1.41E-08	3.25E-08	3.70E-08	2.47E-08	1.44E-08	2.47E-09	1.26E-10
1.0E+03	1.51E-08	3.21E-08	3.66E-08	2.46E-08	1.44E-08	2.48E-09	1.27E-10
2.0E+03	1.77E-08	3.14E-08	3.53E-08	2.42E-08	1.44E-08	2.55E-09	1.30E-10
4.0E+03	2.11E-08	3.05E-08	3.30E-08	2.34E-08	1.44E-08	2.70E-09	1.36E-10
7.0E+03	2.39E-08	2.95E-08	3.03E-08	2.23E-08	1.43E-08	2.94E-09	1.45E-10
1.0E+04	2.54E-08	2.87E-08	2.82E-08	2.12E-08	1.41E-08	3.18E-09	1.55E-10
2.0E+04	2.64E-08	2.61E-08	2.37E-08	1.83E-08	1.32E-08	3.84E-09	1.94E-10

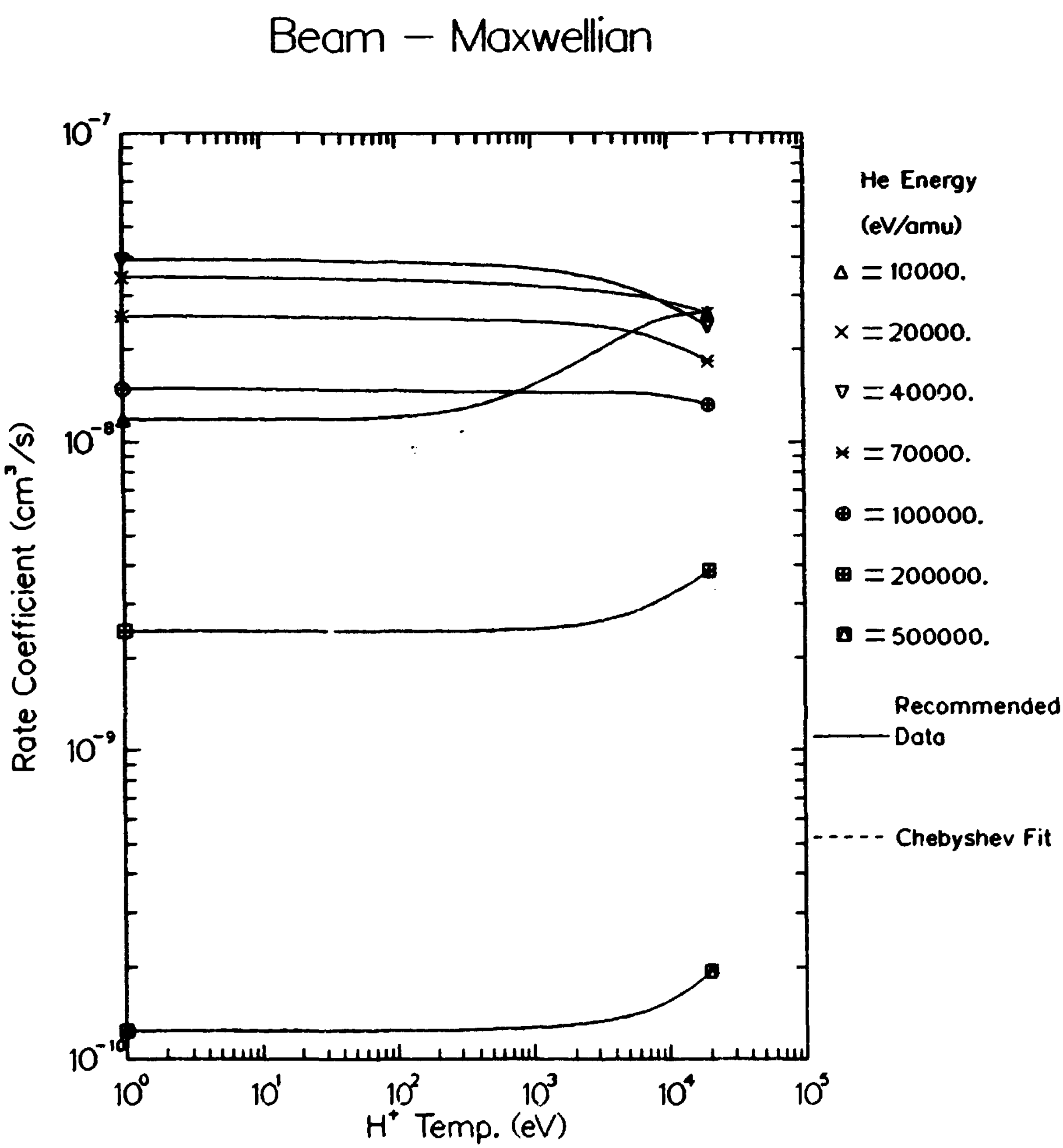
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-3.59874E+01	4.17430E-01	1.93060E-01	1.41316E-02	-4.62466E-02	-3.20698E-02	-6.14466E-03
20000.	-3.45210E+01	-1.10051E-01	-5.31364E-02	-2.09508E-02	-8.28916E-03	-4.29131E-03	-2.80760E-03
40000.	-3.43497E+01	-1.93363E-01	-1.15051E-01	-5.41354E-02	-1.98052E-02	-4.14043E-03	1.32023E-03
70000.	-3.51059E+01	-1.20106E-01	-7.36757E-02	-4.02144E-02	-2.03546E-02	-8.65732E-03	-2.24607E-03
100000.	-3.61082E+01	-3.88036E-02	-1.73976E-02	-1.16387E-02	-1.05935E-02	-7.51826E-03	-3.79933E-03
200000.	-3.94814E+01	1.55478E-01	1.14512E-01	6.41579E-02	2.61502E-02	6.20889E-03	-1.41106E-03
500000.	-4.54567E+01	1.49642E-01	1.06212E-01	6.21478E-02	3.03614E-02	1.26308E-02	4.94057E-03

See appendix for Chebyshev fit details.

$He + H^+ \rightarrow H + He^+$



Double Electron Capture Cross Sections for
$H^+ + He \rightarrow H^- + He^{2+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
4.7E+02	3.01E+07	2.70E-22
7.0E+02	3.68E+07	5.75E-22
1.0E+03	4.37E+07	1.12E-21
2.0E+03	6.21E+07	4.20E-21
4.0E+03	8.89E+07	1.78E-20
7.0E+03	1.16E+08	5.08E-20
1.0E+04	1.38E+08	1.06E-19
2.0E+04	1.96E+08	3.75E-19
3.2E+04	2.48E+08	7.08E-19
4.0E+04	2.78E+08	6.42E-19
7.0E+04	3.65E+08	1.73E-19
1.0E+05	4.37E+08	3.76E-20
2.0E+05	6.21E+08	9.67E-22
4.0E+05	8.78E+08	7.64E-24
7.0E+05	1.15E+09	9.68E-26
1.0E+06	1.38E+09	3.76E-27

References: 35, 50, 52, 53, 54

Accuracy: $E < 1 \times 10^4$ eV/amu - factor 2 or more; $E > 1 \times 10^4$ eV/amu - 40%

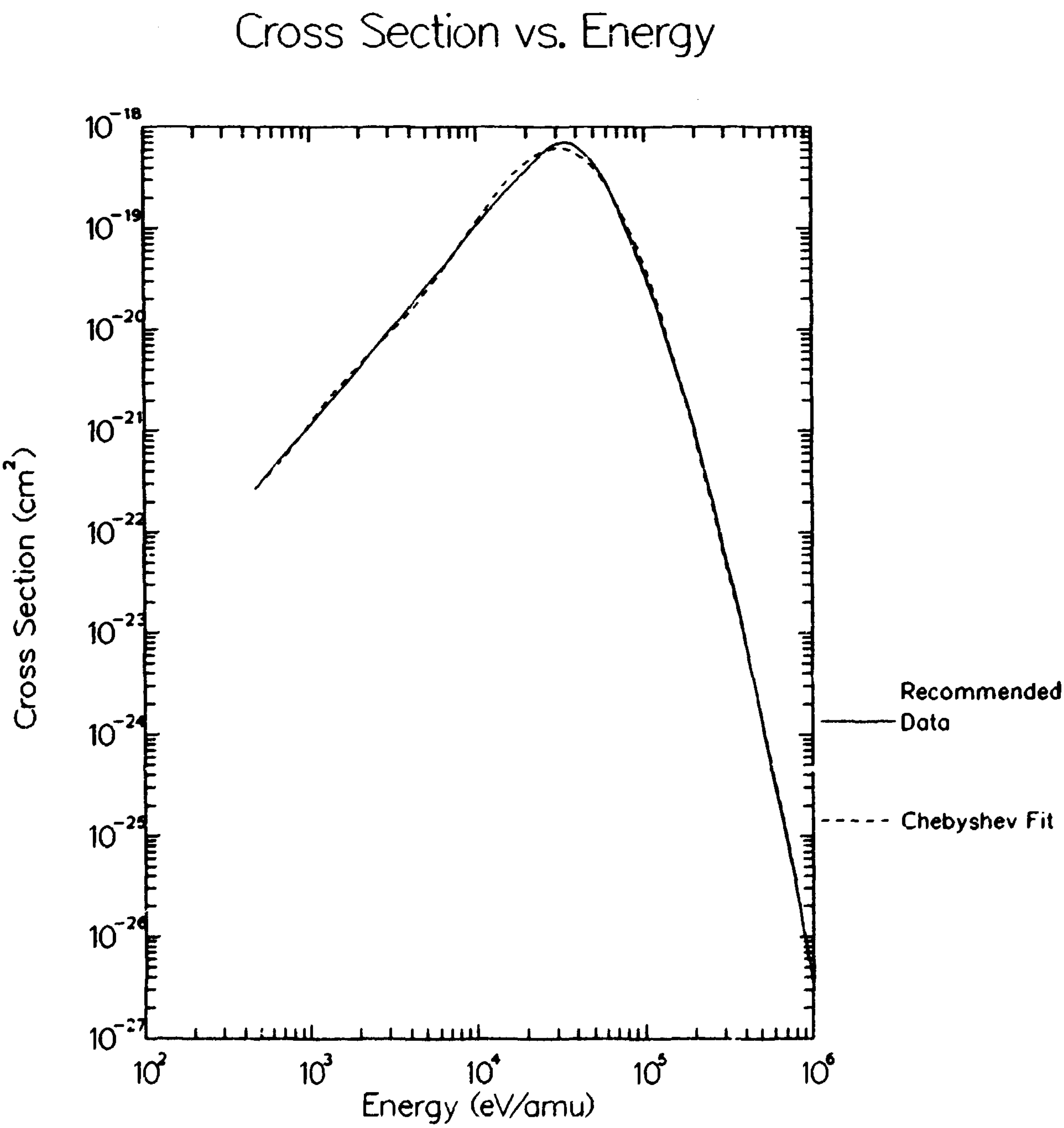
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 4.7E+02 eV/amu, E_{max} = 9.9E+05 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-98.3453	-4.13574	-6.43185	-1.70697	.435158	.417370	-.125015	-.191020	.0356727

The fit represents the above cross sections with an rms deviation of 10.0%.
The maximum deviation is 20.7% at 2.0E+04 eV/amu.
See appendix for Chebyshev fit details.

$H^+ + He \rightarrow H^- + He^{2+}$



Electron Capture Cross Sections for
$H^+ + Li \rightarrow H + Li^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.5E+02	2.20E+07	1.75E-16
3.0E+02	2.41E+07	2.38E-16
4.0E+02	2.78E+07	3.79E-16
5.0E+02	3.11E+07	5.40E-16
7.0E+02	3.68E+07	8.95E-16
1.0E+03	4.39E+07	1.40E-15
2.0E+03	6.21E+07	3.28E-15
3.0E+03	7.61E+07	4.26E-15
3.6E+03	8.33E+07	4.35E-15
5.0E+03	9.82E+07	4.07E-15
8.0E+03	1.24E+08	2.68E-15
1.0E+04	1.39E+08	1.80E-15
1.5E+04	1.70E+08	7.52E-16
3.0E+04	2.41E+08	7.98E-17
5.0E+04	3.11E+08	2.84E-17
8.0E+04	3.93E+08	1.77E-17
1.5E+05	5.38E+08	8.73E-18
2.0E+05	6.21E+08	5.21E-18
3.0E+05	7.61E+08	1.88E-18
4.0E+05	8.78E+08	7.17E-19
5.0E+05	9.82E+08	2.93E-19
5.6E+05	1.04E+09	2.02E-19

References: 230, 231, 232, 233, 234, 235, 236, 237, 238, 239

Accuracy: 30%

Notes: (1) Gruebler et al. (Ref. 235) found up to a factor of 2 greater cross section when H^+ was the projectile compared to D^+ incident at equivalent velocities.
(2) For data on electron capture cross sections of $Li^+ + H$ see references 247, 248, 252, 253.

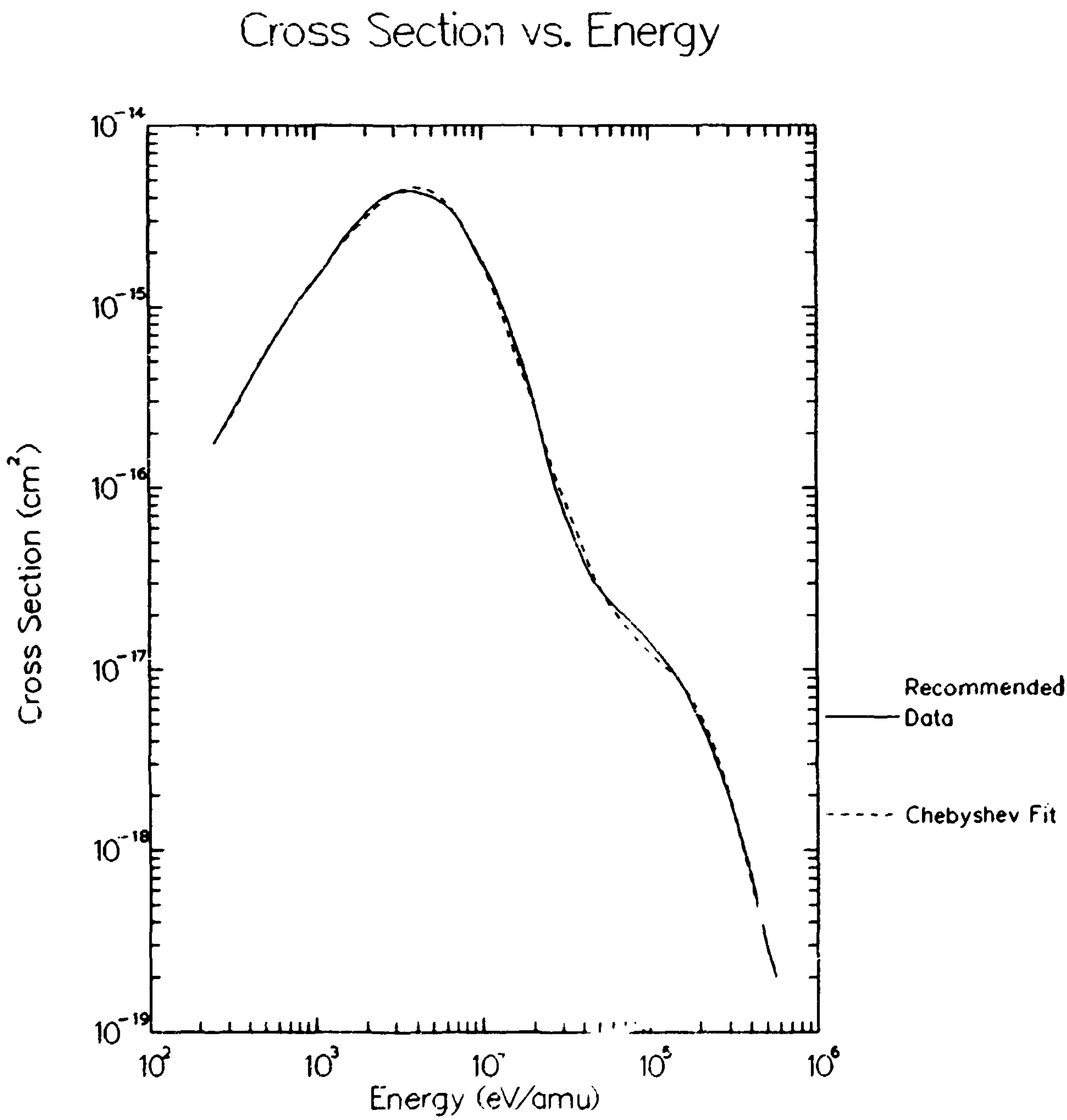
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.5E+02 eV/amu, E_{max} = 5.6E+05 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-74.2905	-3.64125	-2.48131	.598612	.0178325	-.507845	-.166745	.177271	.132733

The fit represents the above cross sections with an rms deviation of 6.4%.
The maximum deviation is 17.7% at 3.0E+04 eV/amu.
See appendix for Chebyshev fit details.

$H^+ + Li \rightarrow H + Li^+$



Electron Capture Rate Coefficients for
$Li + H^{+} \rightarrow H + Li^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H^{+} Temp. (eV)	Li Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	2.50E-07	5.82E-08	1.24E-08	7.44E-09	6.05E-09*	3.23E-09*	2.88E-10**
2.0E+00	2.49E-07	5.83E-08	1.24E-08	7.44E-09	6.05E-09*	3.23E-09*	2.88E-10**
4.0E+00	2.49E-07	5.83E-08	1.24E-08	7.44E-09	6.05E-09*	3.23E-09*	2.88E-10**
7.0E+00	2.49E-07	5.84E-08	1.24E-08	7.44E-09	6.05E-09*	3.23E-09*	2.88E-10**
1.0E+01	2.49E-07	5.84E-08	1.24E-08	7.44E-09	6.05E-09*	3.23E-09*	2.88E-10**
2.0E+01	2.48E-07	5.86E-08	1.24E-08	7.44E-09	6.05E-09*	3.22E-09*	2.89E-10**
4.0E+01	2.48E-07	5.89E-08	1.24E-08	7.44E-09	6.05E-09	3.22E-09*	2.89E-10**
7.0E+01	2.48E-07	5.95E-08	1.24E-08	7.44E-09	6.05E-09	3.21E-09*	2.89E-10**
1.0E+02	2.47E-07	6.00E-08	1.24E-08	7.44E-09	6.05E-09	3.21E-09*	2.90E-10**
2.0E+02	2.44E-07	6.17E-08	1.25E-08	7.44E-09	6.05E-09	3.20E-09*	2.91E-10**
4.0E+02	2.39E-07	6.46E-08	1.27E-08	7.44E-09	6.05E-09	3.19E-09*	2.93E-10**
7.0E+02	2.30E-07	6.81E-08	1.30E-08	7.44E-09	6.05E-09	3.18E-09*	2.93E-10**
1.0E+03	2.21E-07	7.10E-08	1.35E-08	7.45E-09	6.05E-09	3.17E-09*	2.91E-10**
2.0E+03	1.96E-07	7.73E-08	1.56E-08	7.53E-09	6.04E-09	3.16E-09*	2.86E-10**
4.0E+03	1.64E-07	8.02E-08	2.04E-08	7.94E-09	6.04E-09	3.14E-09*	2.85E-10**
7.0E+03	1.34E-07	7.67E-08	2.59E-08	9.12E-09	6.14E-09	3.11E-09	2.94E-10**
1.0E+04	1.14E-07	7.14E-08	2.90E-08	1.06E-08	6.44E-09	3.08E-09	3.08E-10**
2.0E+04	7.50E-08	5.52E-08	3.08E-08	1.44E-08	8.16E-09	3.06E-09	3.61E-10**

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

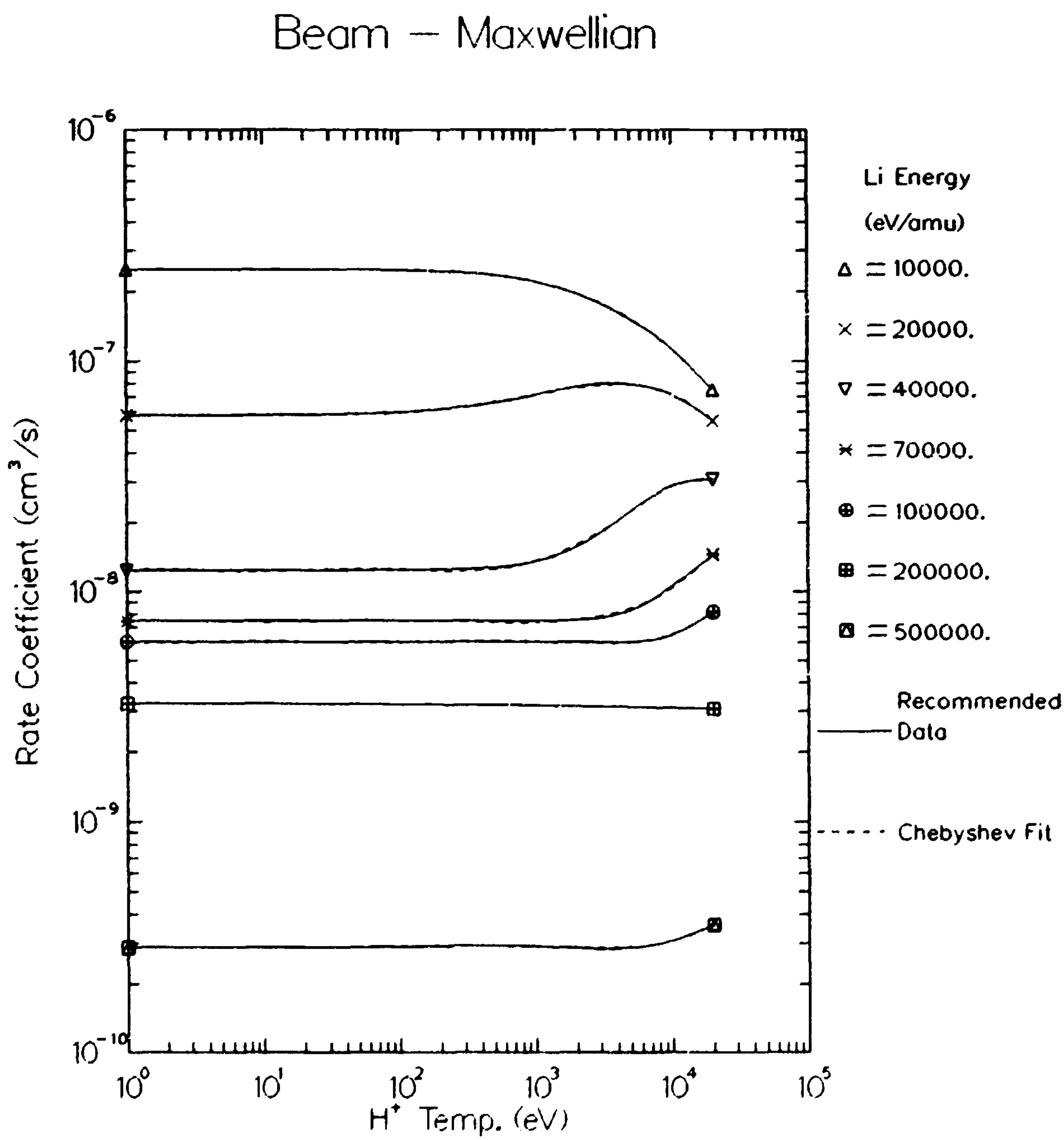
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

Li Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-3.09481E+01	-4.64901E-01	-2.95108E-01	-1.33838E-01	-3.59323E-02	-1.29218E-03	8.76916E-04
20000.	-3.31581E+01	9.29024E-02	-3.27874E-02	-9.34862E-02	-7.42714E-02	-2.98862E-02	-6.36610E-04
40000.	-3.59040E+01	4.30313E-01	2.62445E-01	8.26693E-02	-2.56118E-02	-5.35625E-02	-3.78019E-02
70000.	-3.72045E+01	2.09566E-01	1.66816E-01	1.08374E-01	5.50349E-02	1.81051E-02	-2.94289E-03
100000.	-3.77748E+01	7.11403E-02	6.19800E-02	5.19417E-02	3.83027E-02	2.39693E-02	1.32084E-02
200000.	-3.91351E+01	-2.54412E-02	-9.95070E-03	-2.34861E-03	-2.74660E-04	3.66029E-04	9.29558E-04
500000.	-4.38736E+01	5.64031E-02	4.45512E-02	3.82771E-02	3.08448E-02	1.91863E-02	5.93228E-03

See appendix for Chebyshev fit details.

$Li + H^{+} \rightarrow H + Li^{+}$



Double Electron Capture Cross Sections for
$H^+ + H^- \rightarrow H^- + H^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
5.9E+01	1.07E+07	9.98E-17
6.4E+01	1.11E+07	1.02E-16
6.9E+01	1.15E+07	8.45E-17
7.4E+01	1.19E+07	5.63E-17
8.0E+01	1.24E+07	3.96E-17
8.1E+01	1.25E+07	3.95E-17
8.4E+01	1.27E+07	4.63E-17
8.9E+01	1.31E+07	6.11E-17
9.4E+01	1.35E+07	7.54E-17
9.9E+01	1.38E+07	8.72E-17
1.0E+02	1.39E+07	8.82E-17
1.1E+02	1.46E+07	6.84E-17
1.2E+02	1.52E+07	4.70E-17
1.3E+02	1.58E+07	4.23E-17
1.4E+02	1.64E+07	4.84E-17
1.5E+02	1.70E+07	6.33E-17
1.6E+02	1.76E+07	7.20E-17
1.7E+02	1.81E+07	6.12E-17
1.8E+02	1.86E+07	4.27E-17
1.9E+02	1.91E+07	4.10E-17
2.0E+02	1.96E+07	4.62E-17
2.5E+02	2.20E+07	8.33E-17
3.0E+02	2.41E+07	1.08E-16
3.5E+02	2.60E+07	1.27E-16
4.0E+02	2.78E+07	1.44E-16
4.5E+02	2.95E+07	1.50E-16
4.7E+02	3.01E+07	1.51E-16
5.0E+02	3.11E+07	1.50E-16
6.0E+02	3.40E+07	1.40E-16
8.0E+02	3.93E+07	1.14E-16
8.4E+02	4.03E+07	1.07E-16
1.0E+03	4.39E+07	8.79E-17
1.1E+03	4.61E+07	7.48E-17

__References:__ 69, 274, 275, 276

__Accuracy:__ 30%

__Notes:__ (1) The oscillatory behaviour results from the formation of a quasi-H_2 molecule.
(2) The cross section as plotted is an average of that measured by Peart (Ref. 274) and that of Brouillard et al. (Ref. 275).
(3) Plotted are the H^+ energies with the H^- at rest.
(4) The interaction energy is given by $E_{int} = \frac{E_{H^+}}{2}$ for equal masses.

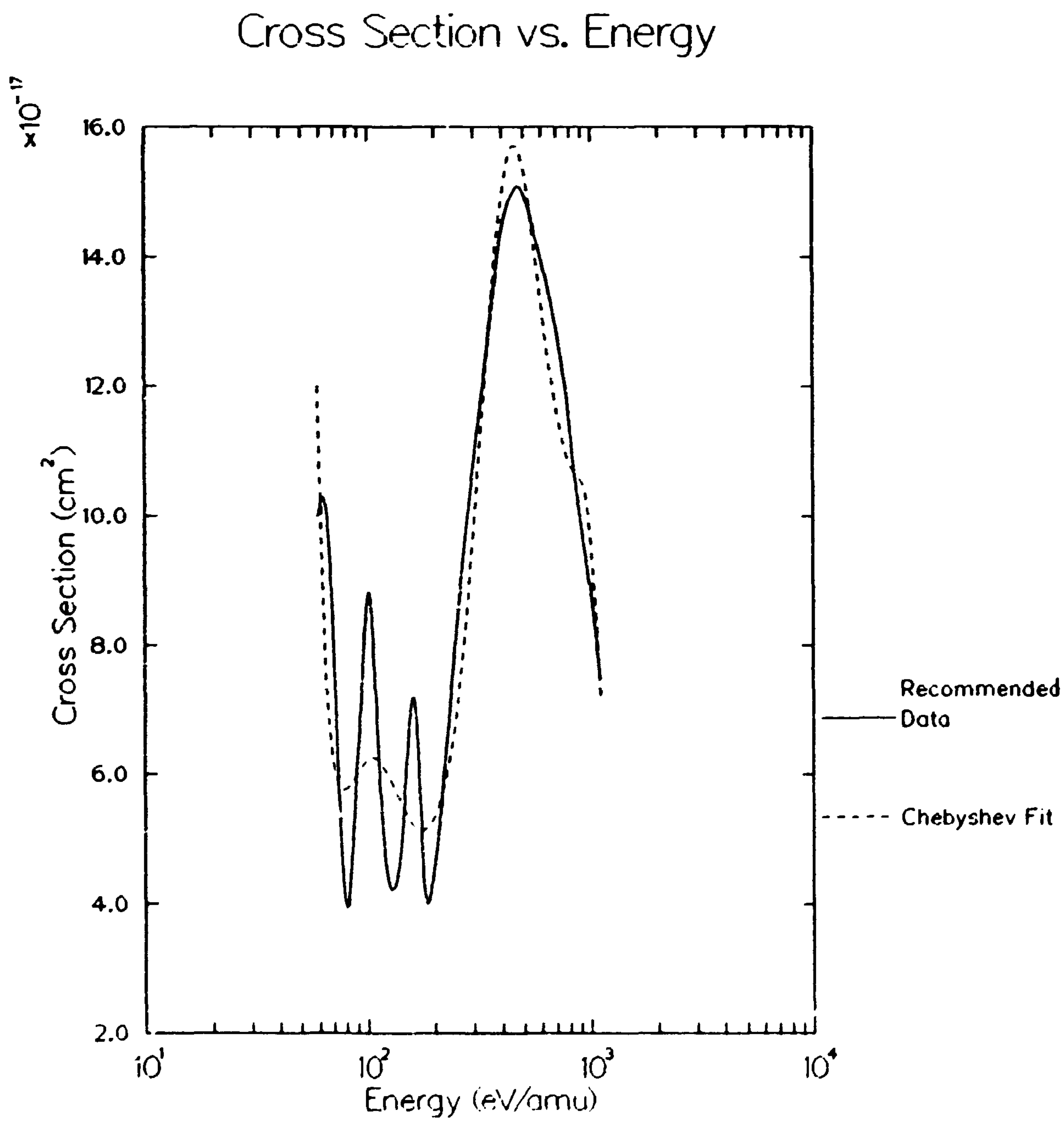
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 5.9E+01 eV/amu, E_{max} = 1.1E+03 eV/amu

__Chebyshev Fitting Parameters for Cross Sections__

A0	A1	A2	A3	A4	A5	A6	A7	A8
-74.0098	.227379	.0232305	-.388332	-.00604588	.0351509	.101175	-.132093	-.0302977

The fit represents the above cross sections with an rms deviation of [illegible]%.
The maximum deviation is 46.4% at 8.1E+01 eV/amu.
See appendix for Chebyshev fit details.

$H^+ + H^- \rightarrow H^- + H^+$



Mutual Neutralization Cross Sections for
$H^+ + H^- \rightarrow H + H$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.0E-01	6.21E+05	1.69E-13
4.0E-01	8.79E+05	9.09E-14
7.0E-01	1.16E+06	5.74E-14
1.0E+00	1.39E+06	4.27E-14
2.0E+00	1.96E+06	2.40E-14
4.0E+00	2.78E+06	1.40E-14
7.0E+00	3.68E+06	9.21E-15
1.0E+01	4.39E+06	7.36E-15
2.0E+01	6.21E+06	6.53E-15
4.0E+01	8.79E+06	7.11E-15
7.0E+01	1.16E+07	8.20E-15
1.0E+02	1.39E+07	8.80E-15
2.0E+02	1.96E+07	1.06E-14
4.0E+02	2.78E+07	1.30E-14
7.0E+02	3.68E+07	1.39E-14
1.0E+03	4.39E+07	1.38E-14
2.0E+03	6.21E+07	1.17E-14
4.0E+03	8.79E+07	7.54E-15
4.8E+03	9.62E+07	6.36E-15

References: 63, 64, 65, 66, 67, 68, 69, 280

Accuracy: E > 20 eV/amu - 20%; E < 20 eV/amu - factor 2 (see notes)

Notes: (1) Measurements made in the 1970's showed structure in the cross section curve in the energy range of 40 - 700 eV/amu. More recent measurements (Ref. 67 and 68) show no evidence of structure and the cross sections are approximately a factor of 2 less than those reported in Refs. 63-66 for energies less than 400 eV.

(2) Mosley (Ref. 63) found a sharp rise in the cross section for energies less than 30 eV/amu. In the region of overlap, with the most recent papers, Mosely was a factor of two greater. Thus, the data of Mosely have been reduced by approximately a factor of two which more nearly coincides with the theoretical data of Ref. 280.

(3) The data below 10 eV/amu should be used with caution.

(4) Plotted is the H^+ energy with H^- at rest.

(5) The interaction energy is given by $E_{int} = E_{H^+}/2$.

(6) See Dolder's review (Ref. 69) for a discussion of this reaction.

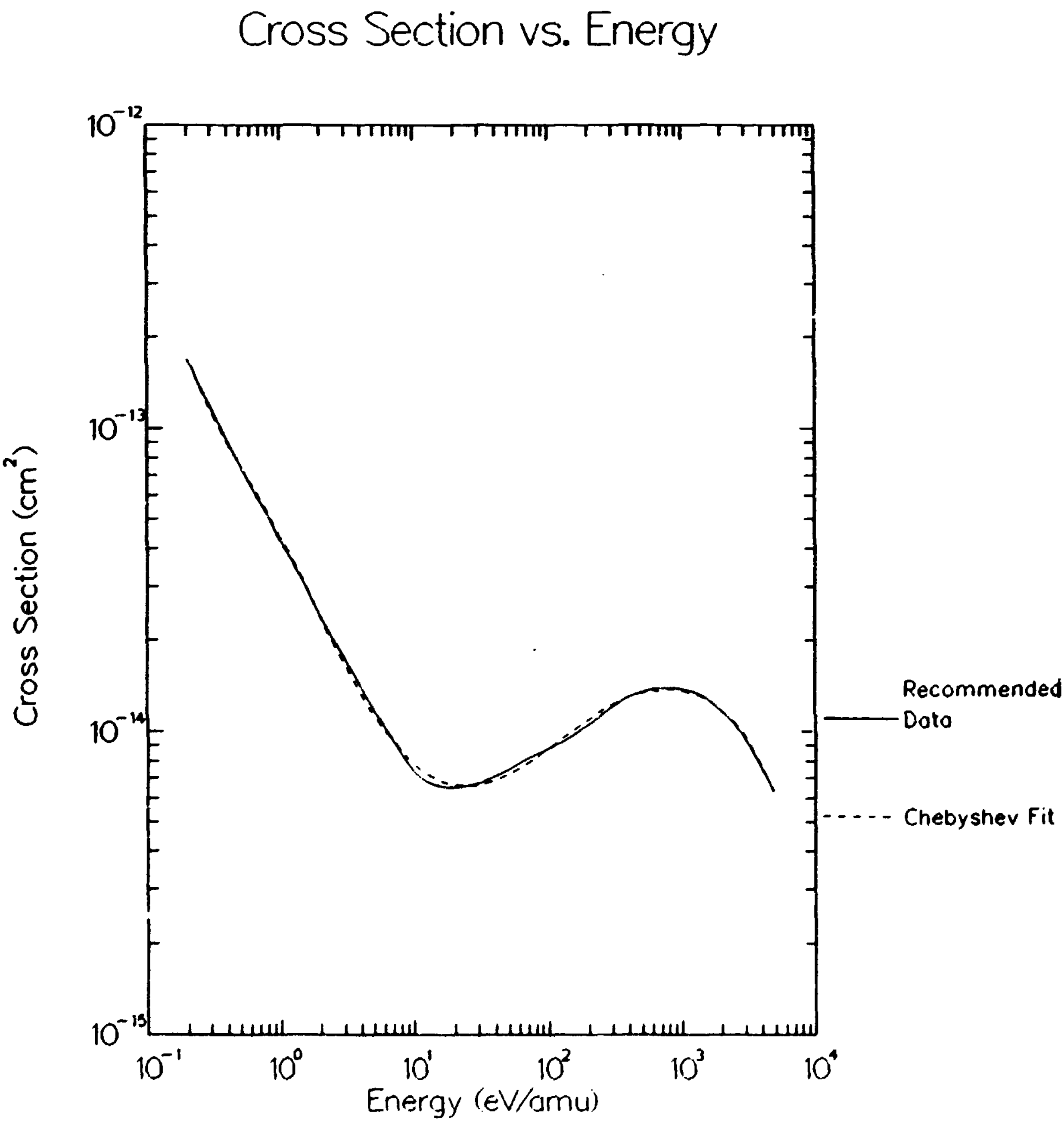
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.0E-01 eV/amu, E_{max} = 4.8E+03 eV/amu

Chebyshev Fitting Paramete.s for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-63.1439	-1.23277	.753504	-.408901	-.276190	.0381613	.0408940	-.0423914	.00269073

The fit represents the above cross sections with an rms deviation of 2.4%.
The maximum deviation is 5.8% at 1.0E+01 eV/amu.
See appendix for Chebyshev fit details.

$H^{+} + H^{-} \rightarrow H + H$



Sum of the Electron Capture and Ionization Cross Sections for
$H^+ + He^+ \rightarrow [(H + He^{2+}) + (H^+ + He^{2+} + e^-)]$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
3.3E+03	7.98E+07	7.43E-20
4.0E+03	8.79E+07	1.04E-19
7.0E+03	1.16E+08	3.62E-19
1.0E+04	1.39E+08	9.89E-19
2.0E+04	1.96E+08	1.00E-17
4.0E+04	2.78E+08	2.31E-17
7.0E+04	3.68E+08	2.55E-17
1.0E+05	4.39E+08	2.19E-17
2.0E+05	6.21E+08	1.38E-17
4.0E+05	8.78E+08	6.84E-18
5.2E+05	1.00E+09	4.82E-18

References: 69, 73, 75, 76, 77, 81, 277, 278, 279

Accuracy: 20%

Notes: (1) Plotted are H^+ energies with the He^+ particles at rest.
(2) The interaction energy is given by $E_{int} = \frac{E_{H^+}}{1.25}$.

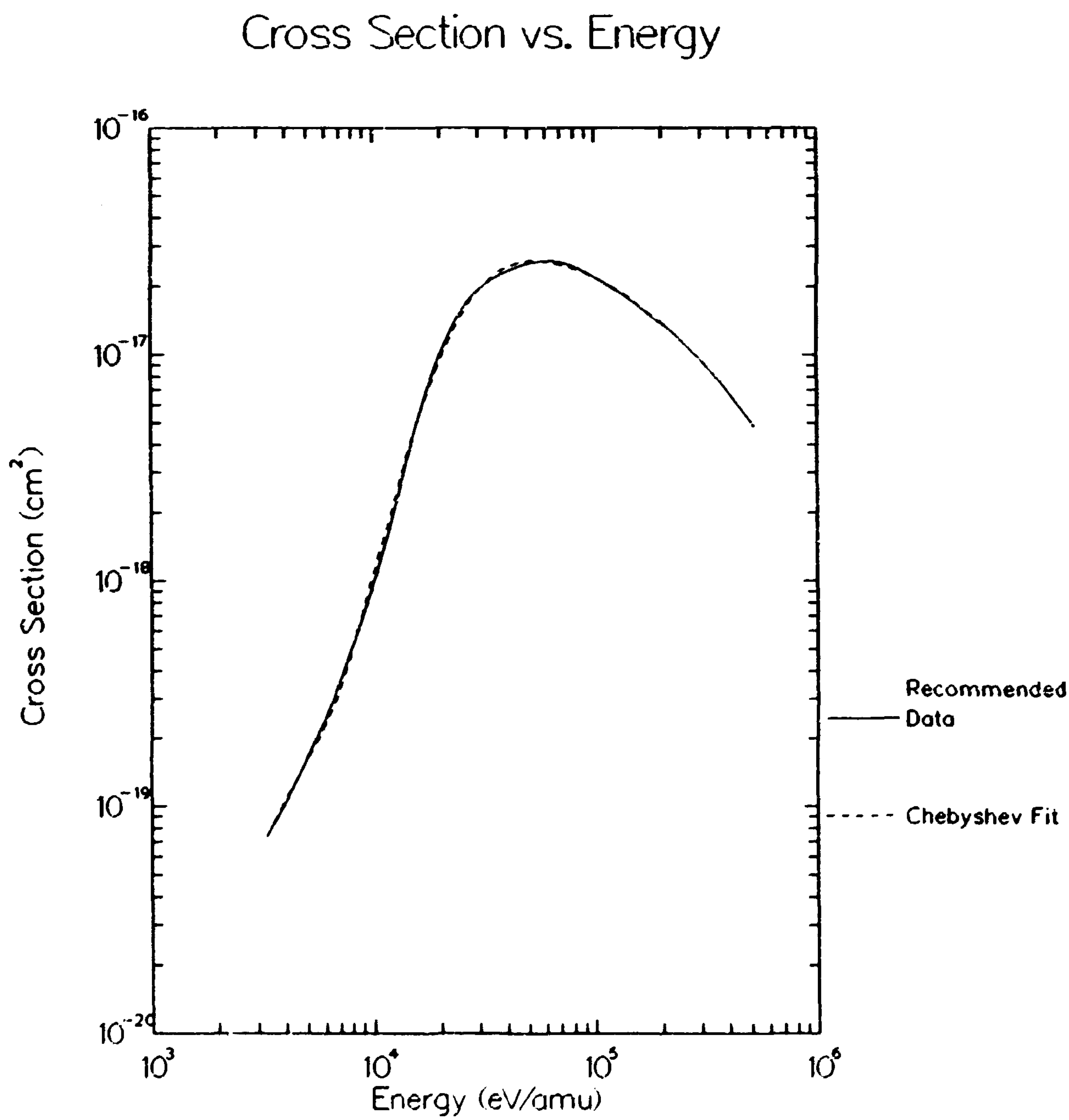
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 3.3E+03 eV/amu, E_{max} = 5.2E+05 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-80.8329	2.22908	-1.82091	-.0490894	.341964	-.150988	-.0383566	.0746090	-.0322523

The fit represents the above cross sections with an rms deviation of 4.3%.
The maximum deviation is 9.2% at 1.0E+04 eV/amu.
See appendix for Chebyshev fit details.

$H^+ + He^+ \rightarrow ((H + He^{2+}) + (H^+ + He^{2+} + e^-))$



Sum of the Electron Capture and Ionization Rate Coefficients for
$H^+ + He^+ \rightarrow [(H + He^{2+}) + (H^+ + He^{2+} + e^-)]$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	Equal Temp.	He+ Temp. (eV) 500.	750.	1000.	2500.	5000.	10000.	20000.
2.0E+02	5.59E-17	1.11E-15	5.53E-15	1.78E-14	5.49E-13	4.80E-12	4.15E-11	3.10E-10
4.0E+02	3.71E-14	5.08E-14	1.00E-13	1.74E-13	1.35E-12	7.55E-12	5.28E-11	3.42E-10
7.0E+02	7.08E-13	5.49E-13	7.52E-13	9.96E-13	3.49E-12	1.35E-11	7.31E-11	3.93E-10
1.0E+03	2.83E-12	1.92E-12	2.35E-12	2.83E-12	7.15E-12	2.22E-11	9.75E-11	4.46E-10
2.0E+03	3.19E-11	1.82E-11	2.01E-11	2.22E-11	3.77E-11	7.69E-11	2.08E-10	6.41E-10
4.0E+03	2.79E-10	1.62E-10	1.69E-10	1.76E-10	2.25E-10	3.18E-10	5.41E-10	1.08E-09
7.0E+03	1.02E-09	6.66E-10	6.79E-10	6.92E-10	7.72E-10	9.10E-10	1.20E-09	1.78E-09
1.0E+04	1.90E-09	1.34E-09	1.36E-09	1.37E-09	1.46E-09	1.61E-09	1.90E-09	2.47E-09
2.0E+04	4.31E-09	3.51E-09	3.52E-09	3.53E-09	3.60E-09	3.71E-09	3.92E-09	4.31E-09

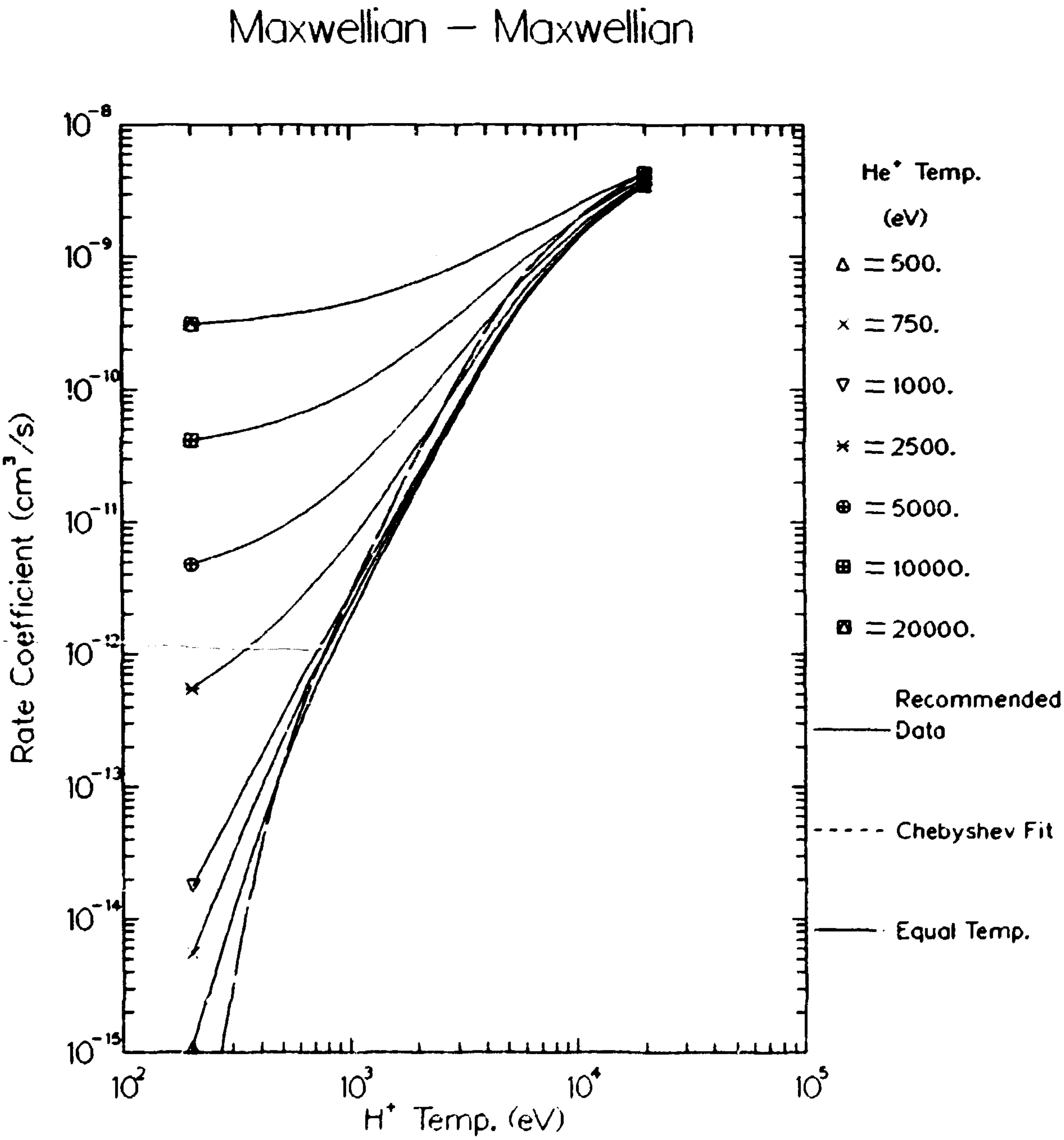
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 2.0E+02 eV, E_{max} = 2.0E+04 eV

<u>Chebyshev Fitting Parameters for Rate Coefficients</u>

He^+ Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
500.	-5.13885E+01	7.38050E+00	-1.17079E+00	6.70967E-02	-1.42287E-01	3.79377E-02	5.35545E-02
750.	-5.05826E+01	6.73738E+00	-8.10583E-01	-8.73094E-02	-9.21944E-02	3.17877E-02	4.71527E-02
1000.	-4.99515E+01	6.24899E+00	-5.58489E-01	-1.82760E-01	-6.61605E-02	3.20490E-02	4.02355E-02
2500.	-4.77567E+01	4.68556E+00	6.56666E-02	-3.34420E-01	-3.90804E-02	4.27066E-02	1.48636E-02
5000.	-4.59364E+01	3.57181E+00	2.68644E-01	-2.79208E-01	-4.43108E-02	3.19665E-02	6.39440E-03
10000.	-4.38282E+01	2.41498E+00	3.24673E-01	-1.50289E-01	-4.79414E-02	9.61266E-03	5.76632E-03
20000.	-4.16749E+01	1.36451E+00	2.92509E-01	-4.41725E-02	-3.60762E-02	-3.52436E-03	2.65593E-03
Equal Temp.	-5.18052E+01	8.42203E+00	-2.10191E+00	5.09552E-01	-3.49726E-01	1.50596E-01	1.11481E-02

See appendix for Chebyshev fit details.

$H^{+} + He^{+} \rightarrow ((H + He^{2+}) + (H^{+} + He^{2+} + e^{-}))$



Total Electron Capture Rate Coefficients for
$He^{+} + H^{+} \rightarrow ((H + He^{2+}) + (H^{+} + He^{2+} + e^{-}))$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H^{+} Temp. (eV)	He⁺ Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	1.42E-10	1.95E-09	6.39E-09	9.31E-09	9.56E-09	8.57E-09	4.98E-09
2.0E+00	1.43E-10	1.94E-09	6.39E-09	9.31E-09	9.56E-09	8.57E-09	4.98E-09
4.0E+00	1.43E-10	1.94E-09	6.38E-09	9.31E-09	9.55E-09	8.56E-09	4.98E-09
7.0E+00	1.44E-10	1.93E-09	6.37E-09	9.31E-09	9.55E-09	8.56E-09	4.98E-09
1.0E+01	1.45E-10	1.92E-09	6.36E-09	9.30E-09	9.55E-09	8.56E-09	4.98E-09
2.0E+01	1.47E-10	1.91E-09	6.34E-09	9.29E-09	9.55E-09	8.55E-09	4.98E-09
4.0E+01	1.53E-10	1.90E-09	6.31E-09	9.27E-09	9.54E-09	8.55E-09	4.98E-09
7.0E+01	1.60E-10	1.89E-09	6.29E-09	9.25E-09	9.53E-09	8.54E-09	4.94E-09
1.0E+02	1.68E-10	1.89E-09	6.27E-09	9.23E-09	9.53E-09	8.53E-09	4.87E-09
2.0E+02	1.94E-10	1.90E-09	6.22E-09	9.19E-09	9.51E-09	8.52E-09	4.59E-09
4.0E+02	2.53E-10	1.95E-09	6.18E-09	9.13E-09	9.49E-09	8.49E-09	4.20E-09*
7.0E+02	3.50E-10	2.06E-09	6.15E-09	9.07E-09	9.46E-09	8.47E-09	3.88E-09*
1.0E+03	4.49E-10	2.17E-09	6.16E-09	9.02E-09	9.44E-09	8.45E-09	3.69E-09*
2.0E+03	7.69E-10	2.52E-09	6.19E-09	8.90E-09	9.36E-09	8.39E-09	3.40E-09*
4.0E+03	1.37E-09	3.11E-09	6.29E-09	8.70E-09	9.23E-09	8.32E-09	3.18E-09*
7.0E+03	2.18E-09	3.79E-09	6.44E-09	8.49E-09	9.05E-09	8.23E-09	3.05E-09*
1.0E+04	2.88E-09	4.33E-09	6.57E-09	8.34E-09	8.89E-09	8.16E-09	2.99E-09*
2.0E+04	4.61E-09	5.54E-09	6.93E-09	8.06E-09	8.48E-09	7.90E-09	2.90E-09*

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

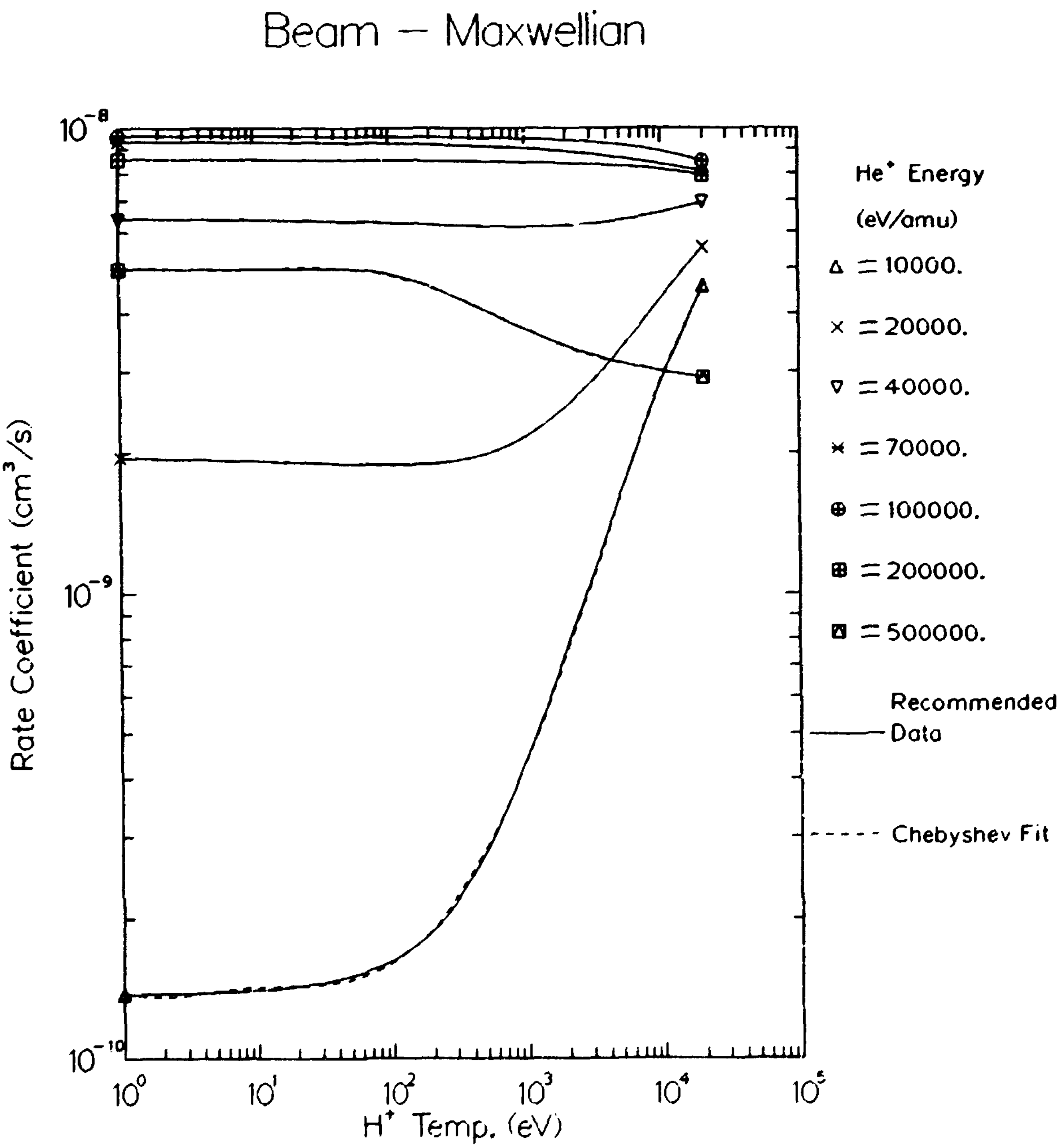
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

He^{+} Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-43.1609	1.70961	.748336	.0779426	-.109478	-.0550219	.00900977
20000.	-39.6126	.447496	.287036	.0983789	-.00499034	-.0233174	-.00975898
40000.	-37.7344	.0172991	.0327260	.0232302	.00718786	6.985132E-05	-.00119392
70000.	-37.0628	-.0628379	-.0317506	-.0103654	-.00206175	4.854519E-04	.00112569
100000.	-36.9842	-.0440273	-.0277168	-.0140155	-.00593012	-.00184524	-1.575483E-04
200000.	-37.1894	-.0312141	-.0170352	-.00770730	-.00339568	-.00158336	-7.883493E-04
500000.	-38.6322	-.298865	-.0952539	.0317736	.0355560	-.00369627	-.0132072

See appendix for Chebyshev fit details

$$He^{+} + H^{+} \rightarrow ((H + He^{2+}) + (H^{+} + He^{2+} + e^{-}))$$



Electron Capture Cross Sections for
$H^+ + He^+ \rightarrow H + He^{2+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.8E+03	5.89E+07	5.84E-22
2.0E+03	6.21E+07	1.55E-21
4.0E+03	8.79E+07	8.84E-20
7.0E+03	1.16E+08	4.91E-19
1.0E+04	1.39E+08	1.40E-18
2.0E+04	1.96E+08	1.17E-17
4.0E+04	2.78E+08	2.46E-17
4.4E+04	2.91E+08	2.48E-17
5.6E+04	3.29E+08	2.35E-17
7.0E+04	3.68E+08	1.92E-17
1.0E+05	4.39E+08	1.20E-17
2.0E+05	6.21E+08	4.06E-18
2.4E+05	6.80E+08	3.0CE-18

References: 69, 71, 73, 74, 75, 76, 77, 78, 79, 80

Accuracy: $E < 1\times10^4$ eV/amu - factor 2; 1×10^4 eV/amu $< E < 2.2\times10^5$ eV/amu - 25%

Notes: (1) At energies less than 1×10^4 eV/amu the assumption was made that the electron capture cross section (σ_C) is equal to the total cross section (σ_T). σ_C: $H^+ + He^+ \rightarrow H + He^{2+}$; σ_T: $H^+ + He^+ \rightarrow [(H + He^+) + (H^+ + He^{2+} + e^-)]$.

(2) Data below 3×10^3 eV/amu rely on theory of references 71, 79, and 80.

(3) Plotted is the H^+ energy with He^+ at rest.

(4) The interaction energy is given by $E_{int} = \frac{E_{H^+}}{1.25}$.

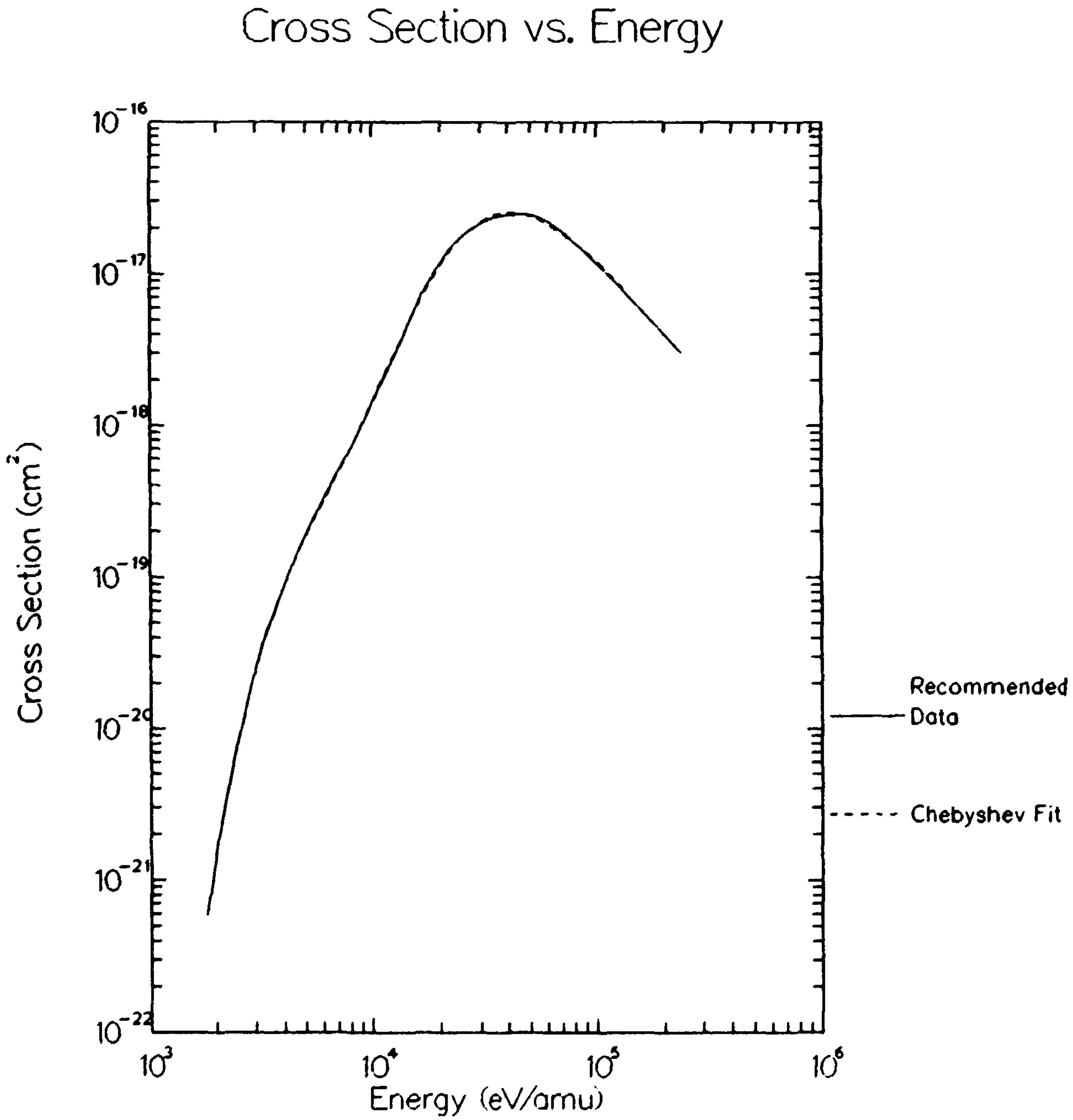
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.8E+03 eV/amu, E_{max} = 2.4E+05 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-83.5391	3.94447	-2.70255	.0791317	-.0544615	.290337	-.133801	-.0294272	.0518279

The fit represents the above cross sections with an rms deviation of 2.4%.
The maximum deviation is 3.8% at 4.0E+04 eV/amu.
See appendix for Chebyshev fit details.

$H^+ + He^+ \rightarrow H + He^{2+}$



Electron Capture Rate Coefficients for
$H^+ + He^+ \rightarrow H + He^{2+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	Equal Temp.	He+ Temp. (eV) 200.	750.	1000.	2500.	5000.	10000.	20000.
1.0E+02	1.84E-19	2.17E-18	1.20E-15	4.99E-15	3.22E-13	4.38E-12	4.62E-11	3.50E-10
2.0E+02	3.92E-16	3.92E-16	5.86E-15	2.52E-14	5.84E-13	5.73E-12	5.24E-11	3.68E-10
4.0E+02	4.67E-14	2.52E-14	1.13E-13	1.89E-13	1.48E-12	9.25E-12	6.64E-11	4.05E-10
7.0E+02	7.57E-13	3.78E-13	8.95E-13	1.08E-12	4.07E-12	1.69E-11	9.13E-11	4.62E-10
1.0E+03	3.26E-12	1.63E-12	2.67E-12	3.26E-12	8.74E-12	2.81E-11	1.21E-10	5.22E-10
2.0E+03	4.04E-11	2.02E-11	2.54E-11	2.81E-11	4.77E-11	9.59E-11	2.51E-10	7.37E-10
4.0E+03	3.33E-10	1.87E-10	2.06E-10	2.14E-10	2.71E-10	3.77E-10	6.27E-10	1.20E-09
7.0E+03	1.14E-09	7.48E-10	7.79E-10	7.93E-10	8.80E-10	1.03E-09	1.32E-09	1.91E-09
1.0E+04	2.02E-09	1.46E-09	1.49E-09	1.50E-09	1.59E-09	1.74E-09	2.02E-09	2.53E-09
2.0E+04	3.87E-09	3.34E-09	3.35E-09	3.36E-09	3.41E-09	3.49E-09	3.63E-09	3.87E-09

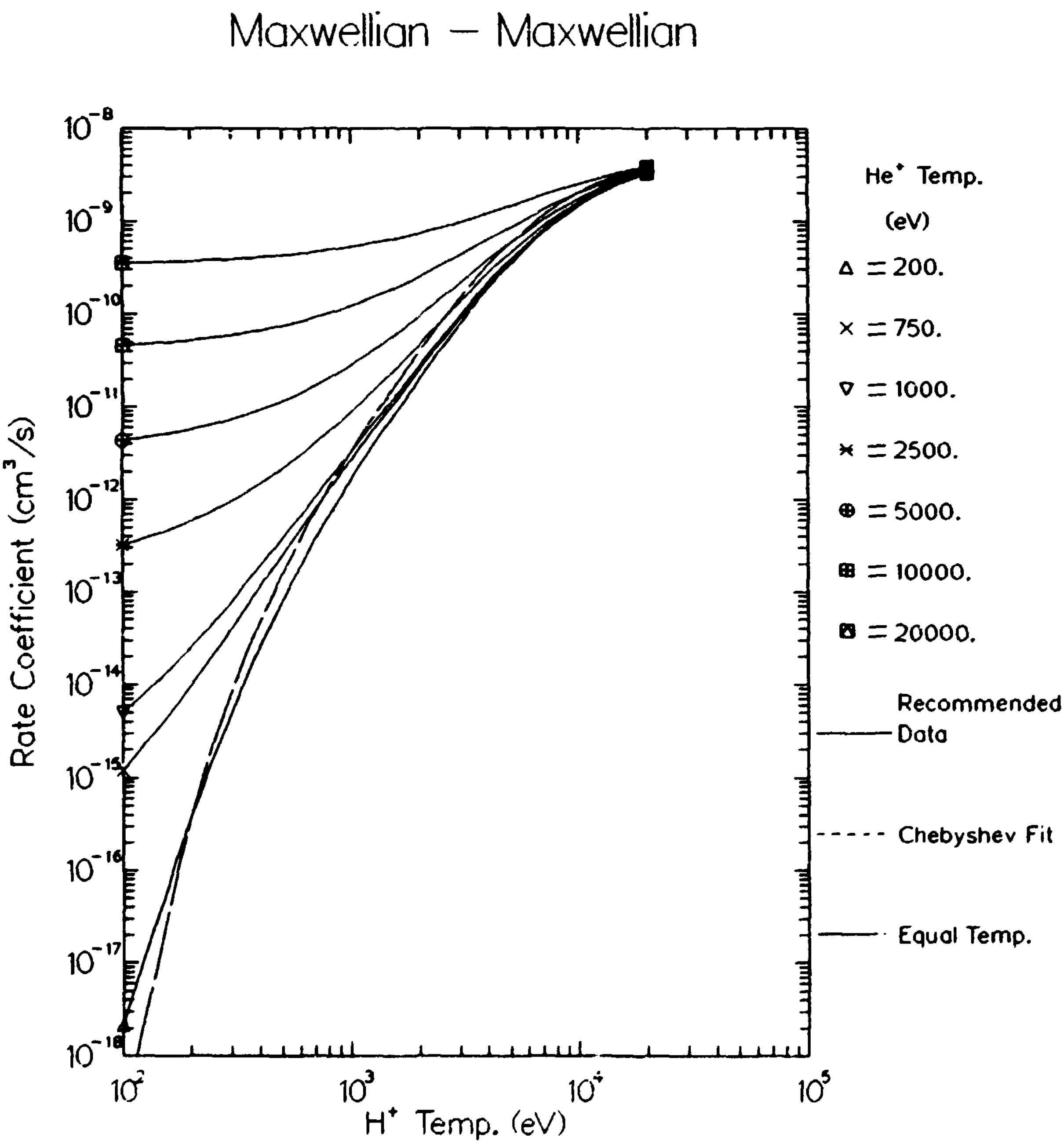
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+02 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

He^+ Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
200.	-5.56691E+01	1.03931E+01	-2.17666E+00	2.00410E-01	-1.29725E-01	-1.82527E-02	4.71659E-02
750.	-5.24322E+01	7.77856E+00	-7.52983E-01	-3.38100E-01	-3.27433E-03	-1.92121E-02	3.80958E-02
1000.	-5.15600E+01	7.11555E+00	-4.59118E-01	-4.02692E-01	-1.26409E-02	-3.27140E-03	3.15657E-02
2500.	-4.86136E+01	5.03638E+00	2.33460E-01	-4.36889E-01	-7.67903E-02	3.44015E-02	1.99228E-02
5000.	-4.63267E+01	3.63467E+00	4.33629E-01	-3.18641E-01	-1.01089E-01	2.48311E-02	1.64483E-02
10000.	-4.39403E+01	2.34146E+00	4.31460E-01	-1.58490E-01	-8.81424E-02	-4.91624E-04	1.03754E-02
20000.	-4.16815E+01	1.25619E+00	3.21917E-01	-4.30200E-02	-5.44652E-02	-1.22828E-02	2.56368E-03
Equal Temp.	-5.56573E+01	1.11221E+01	-3.07961E+00	6.63079E-01	-3.65584E-01	9.91144E-02	1.99414E-02

See appendix for Chebyshev fit details.

$H^+ + He^+ \rightarrow H + He^{2+}$



Electron Capture Cross Sections for:

$H_2^+ + H_2 \rightarrow H_2 + H_2^+$

Energy eV/amu	Cross Section cm^2
2.0E+00	1.22E-15
4.0E+00	1.12E-15
7.0E+00	1.06E-15
1.0E+01	1.01E-15
2.0E+01	9.21E-16
4.0E+01	7.83E-16
8.0E+01	6.06E-16
1.0E+02	5.64E-16
2.0E+02	4.95E-16
3.0E+02	4.89E-16
6.0E+02	4.96E-16
8.0E+02	5.28E-16
1.0E+03	5.39E-16
2.0E+03	5.49E-16
3.0E+03	5.26E-16
5.0E+03	4.81E-16
8.0E+03	3.86E-16
1.0E+04	3.39E-16
2.0E+04	2.04E-16
3.0E+04	1.26E-16
5.0E+04	4.58E-17
6.0E+04	2.72E-17
8.0E+04	1.15E-17
1.0E+05	6.43E-18

$H_2^+ + H \rightarrow H_2 + H^+$

Energy eV/amu	Cross Section cm^2
5.0E+01	8.00E-16
7.0E+01	8.36E-16
1.0E+02	8.75E-16
2.0E+02	9.54E-16
4.0E+02	1.02E-15
7.0E+02	1.07E-15
1.0E+03	1.09E-15
2.0E+03	1.02E-15
3.5E+03	8.96E-16
5.0E+03	7.23E-16

$H_2^+ + He \rightarrow H_2 + He^+$

Energy eV/amu	Cross Section cm^2
1.2E+03	1.39E-18
2.0E+03	1.50E-18
4.0E+03	1.64E-18
7.0E+03	1.73E-18
8.0E+03	1.82E-18
9.0E+03	2.18E-18
1.0E+04	2.68E-18
1.5E+04	5.45E-18
2.0E+04	7.26E-18
2.4E+04	7.49E-18

References: $H_2^+ + H_2$ - 39, 43, 82, 208, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220
$H_2^+ + H$ - 3, 228
$H_2^+ + He$ - 82

Accuracy: $H_2^+ + H_2$ - 30% $E < 1x10^3$ eV/amu; 20% $E > 1x10^3$ eV/amu
$H_2^+ + H$ - 30%
$H_2^+ + He$ - unknown

Notes: (1) At energies less than $1.5x10^3$ eV/amu the cross sections were determined by measuring the slow ion current produced in the collisions. The cross section was calculated assuming that H_2^+ ions formed in ionizing collisions were negligible. Latimer et al. (Ref. 213) found the ratio of H^+/H_2^+ produced to be .024 at $7.5x10^2$ eV/amu and increased monotonically to .2 at $25x10^3$ eV/amu.

(2) A proportional counter was used in many experiments at energies greater than $1x10^3$ eV/amu to measure H_2 formed in the collision.

(3) It is well known that the H_2^+ electron capture cross sections are dependent on the vibrational levels of the incident H_2^+ ion. See the following set of data for the magnitude of this effect which increases as the energy decreases.

(4) Karpas et al. (Ref. 228) found the rate constants at thermal energies to be $6.4x10^{-10}$ cm^3/s for $H_2^+ + H$ and $5x10^{-10}$ cm^3/s for $D_2^+ + D$.

(5) Electron capture data for H_2^+ in He are very scarce. The data presented here should be used with caution.

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

$H_2^+ + H_2$: E_{min} = 2.0E+00 eV/amu, E_{max} = 1.0E+05 eV/amu
$H_2^+ + H$: E_{min} = 5.0E+01 eV/amu, E_{max} = 5.0E+03 eV/amu
$H_2^+ + He$: E_{min} = 1.2E+03 eV/amu, E_{max} = 2.4E+04 eV/amu

Chebyshev Fitting Parameters for Cross Sections

	A0	A1	A2	A3	A4	A5	A6	A7	A8
$H_2^+ + H_2$:	-71.4572	-1.88878	-.906965	-.676593	-.388666	-.0528444	.0283239	-.0386419	.00767518
$H_2^+ + H$:	-69.2642	.0203046	-.153359	-.0596508	-.0175975	-.00448389	-.00355258	-.00672273	-.00592839
$H_2^+ + He$:	-81.0697	.916248	.310573	.0729101	-.120222	-.148642	.0679087		

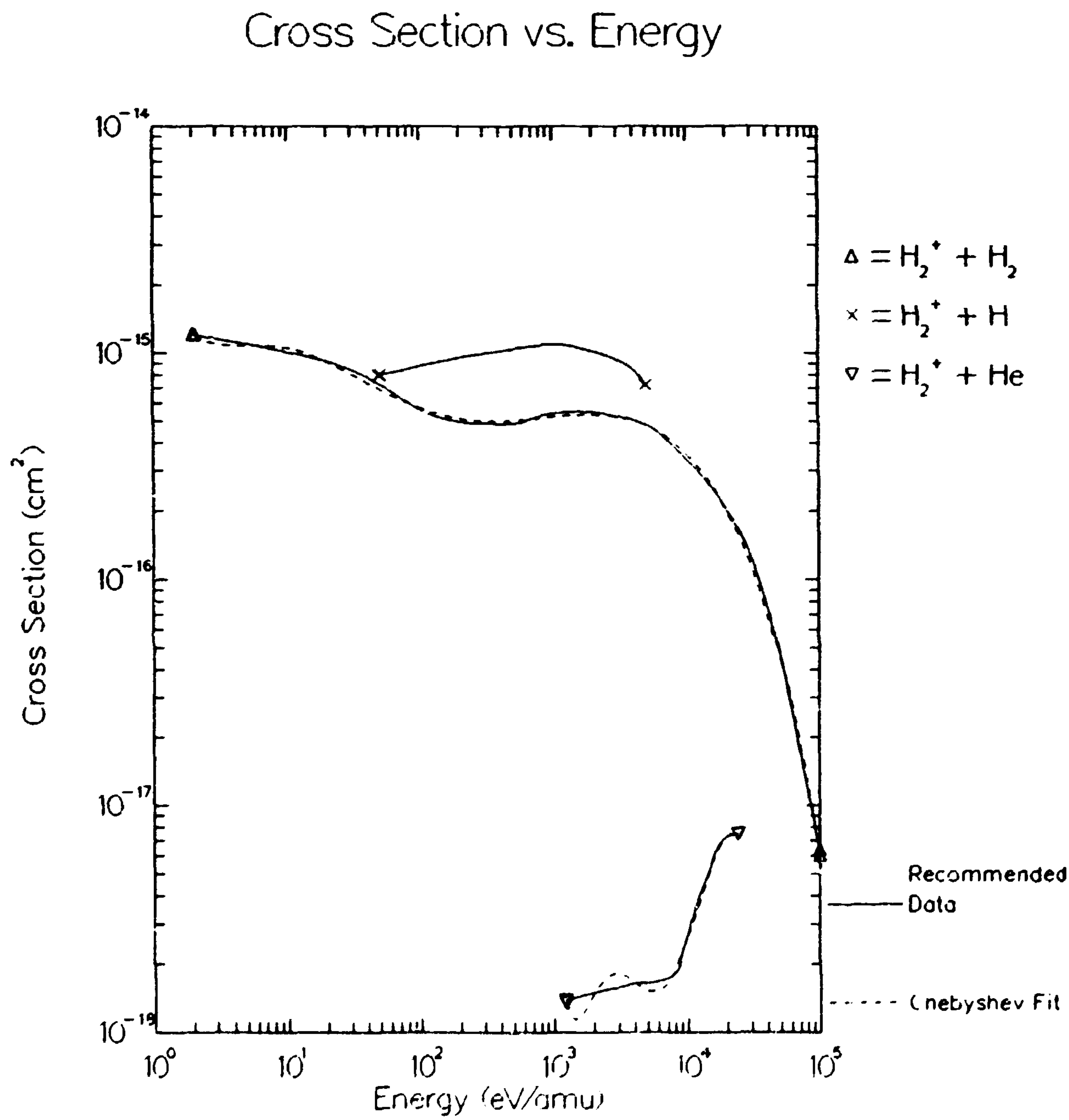
The fit represents the $H_2^+ + H_2$ cross section with an rms deviation of 3.8%.
The maximum deviation is 7.1% at 8.1E+04 eV/amu.

The fit represents the $H_2^+ + H$ cross section with an rms deviation of 0.1%.
The maximum deviation is 0.2% at 7.0E+02 eV/amu.

The fit represents the $H_2^+ + He$ cross section with an rms deviation of 2.0%.
The maximum deviation is 4.0% at 8.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$H_2^+ + H, H_2, He \rightarrow H_2$



Electron Capture Cross Sections for

$H_2^+(\nu = 0,1,2,3) + H_2 \rightarrow H_2$

(ν = 0) Energy eV/amu	(ν = 0) Cross Section cm^2	(ν = 1) Energy eV/amu	(ν = 1) Cross Section cm^2	(ν = 2) Energy eV/amu	(ν = 2) Cross Section cm^2	(ν = 3) Energy eV/amu	(ν = 3) Cross Section cm^2
4.0E+00	7.65E-16	4.0E+00	1.20E-15	4.0E+00	1.22E-15	4.0E+00	1.10E-15
5.0E+00	7.78E-16	6.0E+00	1.15E-15	6.0E+00	1.14E-15	7.5E+00	1.09E-15
6.0E+00	7.90E-16	8.0E+00	1.11E-15	7.5E+00	1.10E-15	1.0E+01	1.05E-15
7.7E+00	8.05E-16	1.5E+01	1.05E-15	1.5E+01	1.04E-15	1.5E+01	9.92E-16
1.0E+01	8.03E-16	2.5E+01	9.97E-16	2.5E+01	9.98E-16	3.0E+01	8.95E-16
1.5E+01	8.04E-16	4.0E+01	9.54E-16	4.0E+01	9.56E-16	6.0E+01	7.98E-16
2.0E+01	8.03E-16	6.0E+01	9.16E-16	7.0E+01	9.11E-16	7.5E+01	7.65E-16
4.0E+01	8.09E-16	9.0E+01	8.72E-16	7.5E+01	9.03E-16	1.5E+02	7.36E-16
6.0E+01	8.07E-16	1.5E+02	8.09E-16	1.0E+02	8.55E-16	2.0E+02	7.20E-16
7.5E+01	8.09E-16	2.0E+02	7.74E-16	2.0E+02	7.45E-16	4.0E+02	6.75E-16
9.0E+01	7.86E-16	3.0E+02	7.62E-16	5.0E+02	5.97E-16	5.0E+02	6.59E-16
1.5E+02	7.19E-16	5.0E+02	7.43E-16				
2.0E+02	6.83E-16						
3.0E+02	6.98E-16						
4.0E+02	7.11E-16						
5.0E+02	7.20E-16						

References: 221, 222, 223, 224, 225, 226, 227, 295

Accuracy: unknown

Note: (1) These experimental data are taken from Campbell et al. (Ref. 221). For further information see theoretical references 222 - 227 and experimental measurements of Liao et al. (Ref. 295).

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

(ν = 0) E_{min} = 4.0E+00 eV/amu, E_{max} = 5.0E+02 eV/amu
(ν = 1) E_{min} = 4.0E+00 eV/amu, E_{max} = 5.0E+02 eV/amu
(ν = 2) E_{min} = 4.0E+00 eV/amu, E_{max} = 5.0E+02 eV/amu
(ν = 3) E_{min} = 4.0E+00 eV/amu, E_{max} = 5.0E+02 eV/amu

Chebyshev Fitting Parameters for Cross Sections

	A0	A1	A2	A3	A4	A5	A6	A7	A8
(ν = 0)	-69.6245	-.0593713	-.0380137	.0269366	.0238283	.0156238	-.00842422	-.0146446	-.00321688
(ν = 1)	-69.2068	-.245756	.00730004	.0108746	.0127040	.00132443	-.00641668	-.00611834	-.00633415
(ν = 2)	-69.2536	-.288634	-.0220048	-.0199150	2.45200E-04	-.0241700	-.0316741	-.0245964	-.0170459
(ν = 3)	-69.3794	-.283633	.0144526	.0213835	-.0200482	-.00269142	-.00368054	.00893694	-5.08689E-04

The fit represents the ν=0 cross section with an rms deviation of 0.6%.
The maximum deviation is 0.9% at 2.0E+02 eV/amu.

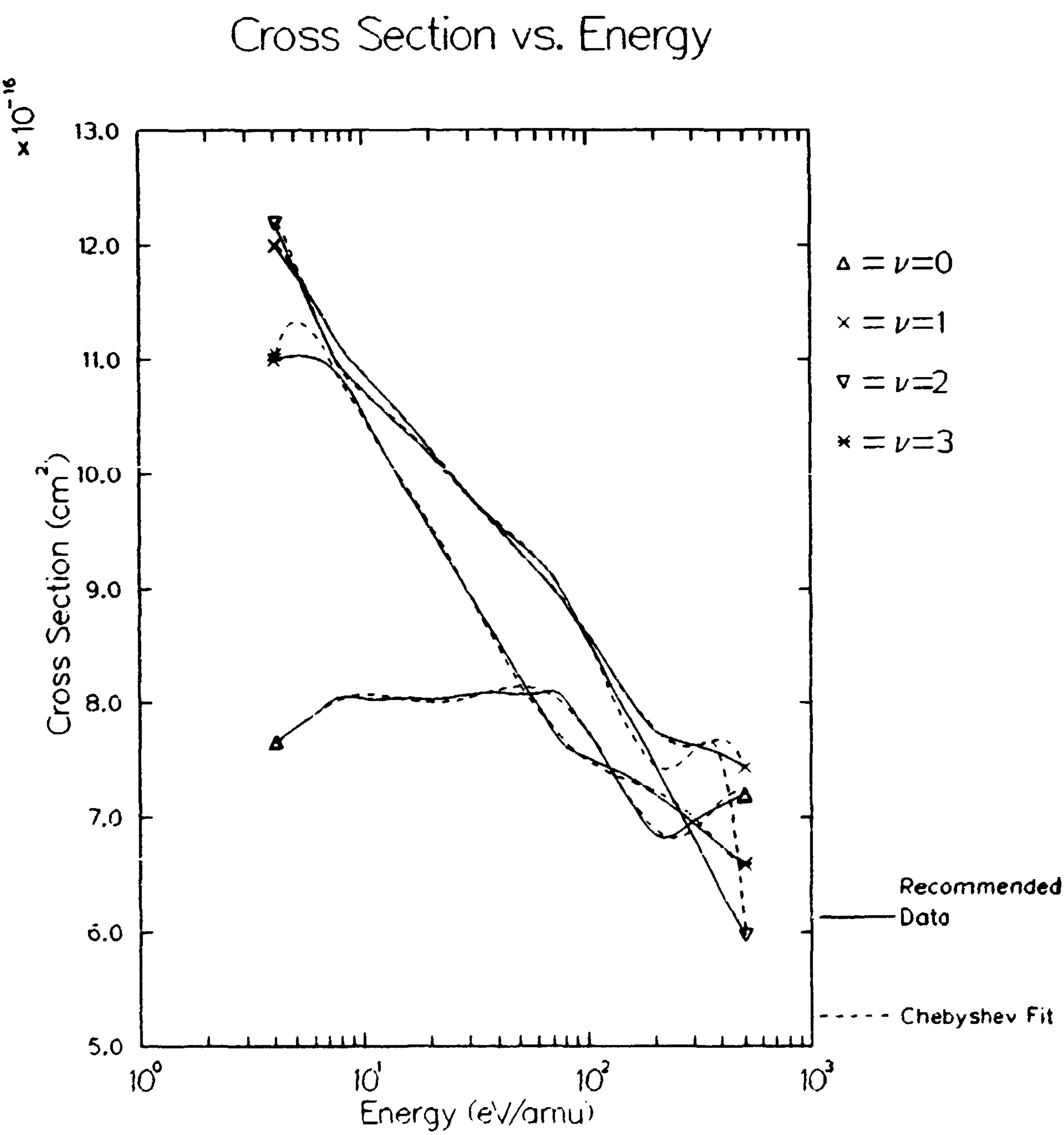
The fit represents the ν=1 cross section with an rms deviation of 0.3%.
The maximum deviation is 0.2% at 2.0E+02 eV/amu.

The fit represents the ν=2 cross section with an rms deviation of 0.1%.
The maximum deviation is 0.2% at 4.0E+01 eV/amu.

The fit represents the ν=3 cross section with an rms deviation of 0.3%.
The maximum deviation is 0.7% at 7.5E+01 eV/amu.

See appendix for Chebyshev fit details.

$H_2^+(\nu=0,1,2,3) + H_2 \rightarrow H_2$



Electron Capture Cross Sections for
$He^+ + H \rightarrow He + H^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.5E+02	2.20E+07	1.54E-17
4.0E+02	2.78E+07	2.39E-17
7.0E+02	3.68E+07	3.99E-17
1.0E+03	4.39E+07	4.74E-17
2.0E+03	6.21E+07	5.57E-17
4.0E+03	8.79E+07	9.08E-17
7.0E+03	1.16E+08	1.71E-16
1.0E+04	1.39E+08	2.33E-16
2.0E+04	1.96E+08	2.42E-16
4.0E+04	2.78E+08	1.00E-16
7.0E+04	3.68E+08	2.97E-17
1.0E+05	4.39E+08	1.29E-17
2.0E+05	6.21E+08	1.01E-18
4.0E+05	8.78E+08	7.94E-20
7.0E+05	1.16E+09	2.46E-21

References: 7, 22, 59, 60, 61

Accuracy: E < 600 eV/amu - unknown; E > 600 eV - 30%

Note: The lowest experimental measurement was at an energy of 500 eV/amu. Data was extrapolated to 250 eV/amu by using the theoretical results of Ref. 61.

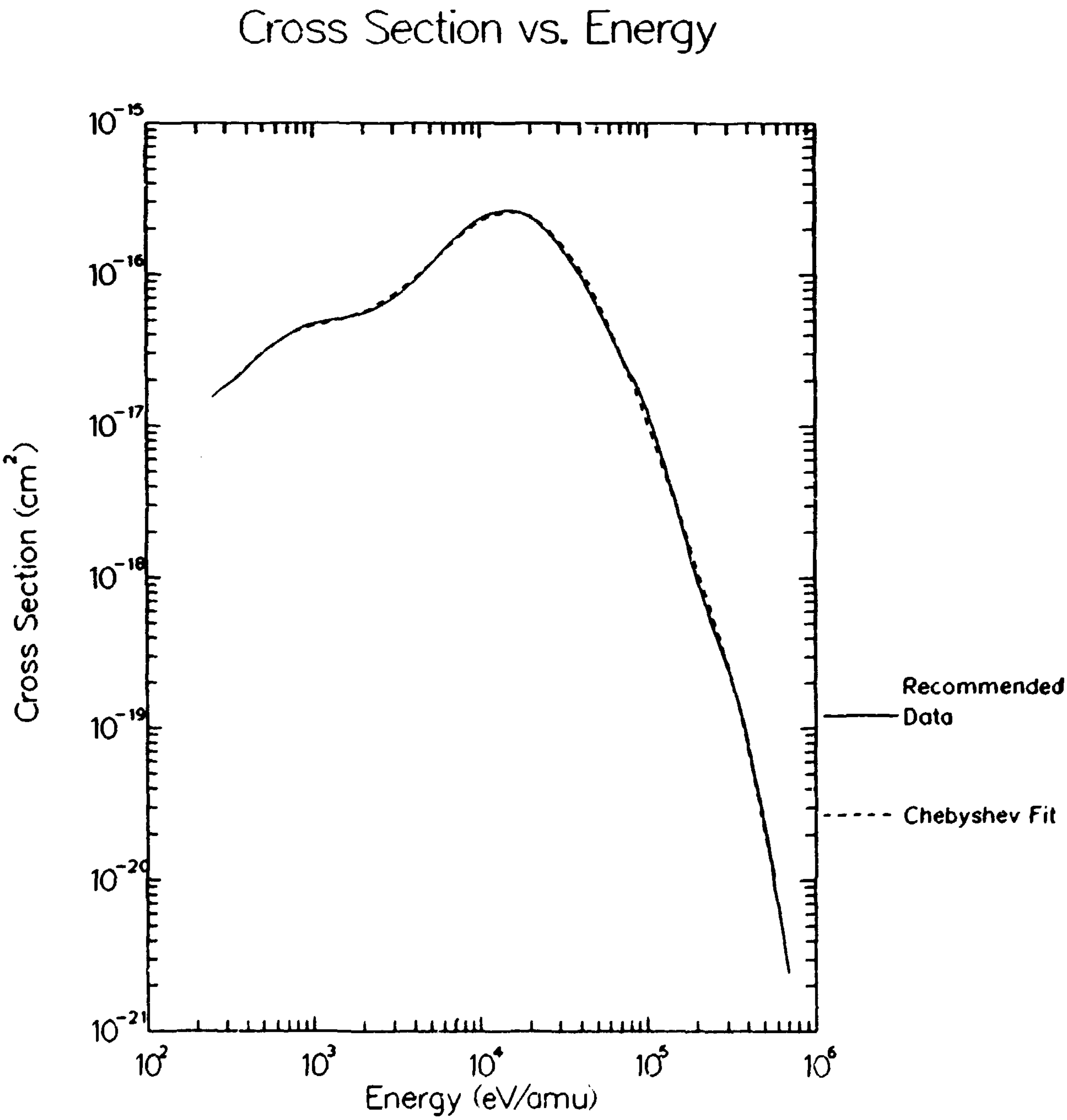
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.5E+02 eV/amu, E_{max} = 7.0E+05 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-79.2449	-3.43445	-3.38701	-.953151	.0800233	.153935	-.198503	-.126958	.0492936

The fit represents the above cross sections with an rms deviation of 6.7%.
The maximum deviation is 15.8% at 2.0E+05 eV/amu.
See appendix for Chebyshev fit details.

$He^{+} + H \rightarrow He + H^{+}$



Electron Capture Rate Coefficients for
$He^{+} + H \rightarrow He + H^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

He^{+} Temp. (eV)	Equal Temp.	H Temp. (eV) 10.	100.	1000.	2500.	5000.	10000.	20000.
7.0E+01	7.06E-11	1.60E-13	1.51E-10	2.97E-09	9.16E-09	1.88E-08	2.75E-08	2.77E-08
1.0E+02	1.74E-10	1.05E-12	1.74E-10	3.00E-09	9.20E-09	1.88E-08	2.75E-08	2.77E-08
2.0E+02	5.93E-10	1.89E-11	2.54E-10	3.08E-09	9.31E-09	1.89E-08	2.75E-08	2.77E-08
4.0E+02	1.37E-09	1.29E-10	4.23E-10	3.25E-09	9.53E-09	1.91E-08	2.75E-08	2.77E-08
7.0E+02	2.50E-09	3.71E-10	6.76E-10	3.52E-09	9.86E-09	1.93E-08	2.76E-08	2.77E-08
1.0E+03	3.79E-09	6.26E-10	9.18E-10	3.79E-09	1.02E-08	1.95E-08	2.77E-08	2.77E-08
2.0E+03	9.08E-09	1.40E-09	1.67E-09	4.76E-09	1.13E-08	2.02E-08	2.78E-08	2.76E-08
4.0E+03	1.88E-08	2.95E-09	3.25E-09	6.87E-09	1.34E-08	2.15E-08	2.81E-08	2.74E-08
7.0E+03	2.63E-08	5.83E-09	6.21E-09	1.02E-08	1.63E-08	2.32E-08	2.84E-08	2.72E-08
1.0E+04	2.86E-08	9.13E-09	9.53E-09	1.34E-08	1.68E-08	2.46E-08	2.86E-08	2.69E-08
2.0E+04	2.59E-08	1.88E-08	1.91E-08	2.15E-08	2.46E-08	2.75E-08	2.88E-08	2.59E-08

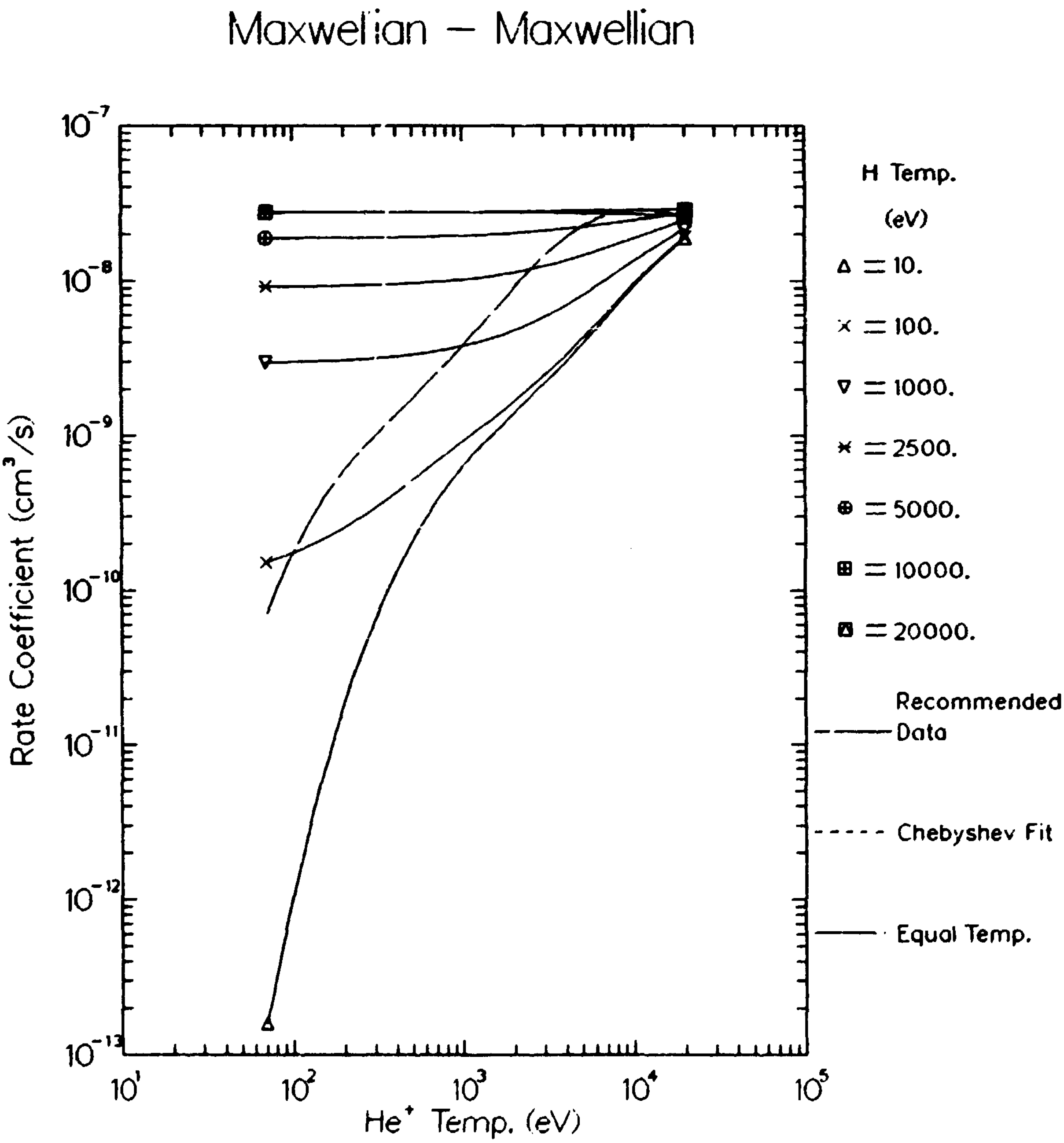
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 7.0E+01 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

H Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
10.	-4.44012E+01	5.33316E+00	-1.31634E+00	5.53831E-01	-1.05230E-01	-4.75481E-02	-6.48771E-03
100.	-4.08648E+01	2.48428E+00	2.58050E-01	-3.12250E-02	9.54007E-04	-3.30158E-02	-2.12794E-02
1000.	-3.79160E+01	9.81592E-01	3.54607E-01	2.81517E-02	-3.71282E-02	-1.95845E-02	-3.45087E-03
2500.	-3.63706E+01	4.76956E-01	1.86293E-01	2.58640E-0[illegible]	-1.33869E-02	-9.40073E-03	-2.40891E-03
5000.	-3.53362E+01	1.79870E-01	7.40800E-02	1.32222E-02	-3.81465E-03	-3.86405E-03	-1.31950E-03
10000.	-3.47840E+01	2.52895E-02	8.72489E-03	-3.06100E-04	-2.09262E-03	-1.25992E-03	-3.74090E-04
20000.	-3.48330E+01	-2.63999E-02	-1.50886E-02	-6.64467E-03	-2.39705E-03	-7.47129E-04	-1.92495E-04
Equal Temp.	-3.92825E+01	2.95989E+00	-6.50284E-01	-6.36867E-02	-1.59695E-01	6.25401E-02	2.55537E-02

See appendix for Chebyshev fit details.

$He^{+} + H \rightarrow He + H^{+}$



Electron Capture Rate Coefficients for
$H + He^{+} \rightarrow He + H^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{+} Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	3.19E-08	4.74E-08	2.77E-08	1.09E-08	5.66E-09	6.28E-10	1.95E-11**
2.0E+00	3.23E-08	4.74E-08	2.77E-08	1.09E-08	5.66E-09	6.27E-10	1.95E-11**
4.0E+00	3.22E-08	4.73E-08	2.77E-08	1.09E-08	5.65E-09	6.27E-10	1.95E-11**
7.0E+00	3.22E-08	4.72E-08	2.77E-08	1.09E-08	5.65E-09	6.27E-10	1.95E-11**
1.0E+01	3.21E-08	4.71E-08	2.77E-08	1.09E-08	5.65E-09	6.27E-10	1.95E-11**
2.0E+01	3.21E-08	4.70E-08	2.76E-08	1.09E-08	5.64E-09	6.27E-10	1.95E-11**
4.0E+01	3.19E-08	4.68E-08	2.76E-08	1.09E-08	5.63E-09	6.28E-10	1.95E-11**
7.0E+01	3.18E-08	4.65E-08	2.75E-08	1.09E-08	5.62E-09	6.28E-10	1.95E-11**
1.0E+02	3.17E-08	4.63E-08	2.74E-08	1.09E-08	5.61E-09	6.28E-10	1.95E-11**
2.0E+02	3.16E-08	4.58E-08	2.73E-08	1.09E-08	5.59E-09	6.29E-10	1.96E-11**
4.0E+02	3.14E-08	4.51E-08	2.72E-08	1.09E-08	5.56E-09	6.30E-10	1.96E-11**
7.0E+02	3.12E-08	4.44E-08	2.70E-08	1.09E-08	5.54E-09	6.32E-10	1.97E-11**
1.0E+03	3.12E-08	4.38E-08	2.68E-08	1.09E-08	5.52E-09	6.34E-10	1.98E-11*
2.0E+03	3.12E-08	4.24E-08	2.65E-08	1.10E-08	5.50E-09	6.41E-10	2.01E-11*
4.0E+03	3.15E-08	4.04E-08	2.62E-08	1.11E-08	5.51E-09	6.55E-10	2.07E-11*
7.0E+03	3.17E-08	3.82E-08	2.57E-08	1.13E-08	5.56E-09	6.77E-10	2.17E-11*
1.0E+04	3.18E-08	3.65E-08	2.53E-08	1.15E-08	5.63E-09	7.01E-10	2.26E-11*
2.0E+04	3.13E-08	3.26E-08	2.37E-08	1.18E-08	5.92E-09	7.89E-10	2.54E-11*

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

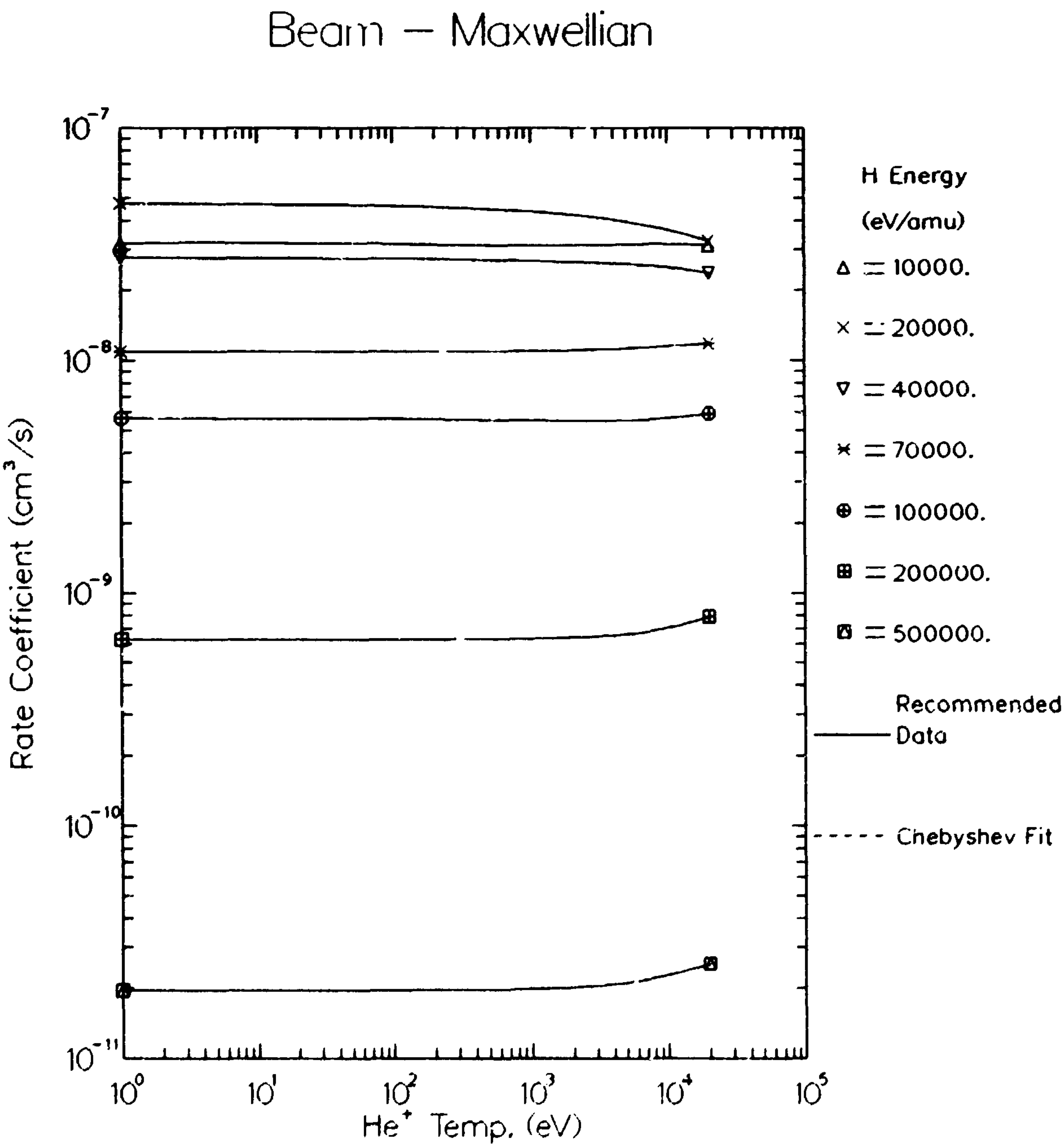
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-3.45301E+01	-1.16460E-02	2.95116E-03	6.60447E-03	-4.30159E-03	-3.33439E-03	-4.15571E-03
20000.	-3.39259E+01	-1.54811E-01	-7.89802E-02	-3.03904E-02	-9.78923E-03	-2.83585E-03	-6.35026E-04
40000.	-3.48770E+01	-5.98881E-02	-3.03031E-02	-1.35966E-02	-7.00807E-03	-4.08339E-03	-2.34824E-03
70000.	-3.66351E+01	2.84585E-02	2.06398E-02	1.05841E-02	3.32277E-03	-4.79714E-05	-9.38437E-04
100000.	-3.79874E+01	2.72710E-03	1.55802E-02	1.57294E-02	9.39045E-03	3.99108E-03	1.23431E-03
200000.	-4.22957E+01	7.45856E-02	5.41115E-02	3.23181E-02	1.66050E-02	6.94819E-03	2.78456E-03
500000.	-4.92176E+01	9.14498E-02	6.40861E-02	3.57259E-02	1.57066E-02	5.13868E-03	8.46885E-04

See appendix for Chebyshev fit details.

H + He^+ -> He + H^+


Beam – Maxwellian
Rate Coefficient (cm^3/s)
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^0
10^1
10^2
10^3
10^4
10^5
He^+ Temp. (eV)
H Energy
(eV/amu)
= 10000.
= 20000.
= 40000.
= 70000.
= 100000.
= 200000.
= 500000.
Recommended Data
Chebyshev Fit

Electron Capture Cross Sections for
$He^+ + H_2 \rightarrow He$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.4E-03	6.81E+04	1.65E-18
7.0E-03	1.16E+05	1.20E-18
1.0E-02	1.39E+05	1.07E-18
4.0E-02	2.78E+05	6.66E-19
1.0E-01	4.39E+05	4.35E-19
4.0E-01	8.79E+05	1.89E-19
7.0E-01	1.16E+06	9.93E-20
1.0E+00	1.39E+06	5.21E-20
1.3E+00	1.58E+06	4.40E-20
1.5E+00	1.70E+06	5.70E-20
3.0E+00	2.41E+06	2.15E-19
4.0E+00	2.78E+06	2.41E-19
7.0E+00	3.68E+06	2.65E-19
1.0E+01	4.39E+06	2.77E-19
4.0E+01	8.79E+06	5.03E-19
7.0E+01	1.16E+07	1.13E-18
1.0E+02	1.39E+07	1.88E-18
4.0E+02	2.78E+07	1.18E-17
7.0E+02	3.68E+07	2.46E-17
1.0E+03	4.39E+07	3.77E-17
4.0E+03	8.79E+07	1.42E-16
7.0E+03	1.16E+08	2.09E-16
1.0E+04	1.39E+08	2.42E-16
1.6E+04	1.76E+08	2.69E-16
4.0E+04	2.78E+08	1.54E-16
7.0E+04	3.70E+08	6.41E-17
1.0E+05	4.39E+08	2.84E-17
4.0E+05	8.78E+08	2.15E-19
7.0E+05	1.16E+09	1.35E-20

__References:__ 7, 22, 82, 91, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107

__Accuracy:__ $E < 2x10^3$ eV/amu - unknown; $E > 2x10^3$ eV/amu - 20%

__Notes:__ (1) The data between 40 - 2000 eV/amu have been interpolated
(2) The data of Moran and Conrads (Ref. 107) are essentially independent of energy in the 250 - 800 eV/amu region and are approximately a factor of 10 above the values shown.
(3) The low energy data ($E < 2x10^3$ eV/amu) of Stedeford and Hasted (Ref. 82) are 1 to 2 orders of magnitude greater than the extrapolated data.
(4) The data below $2x10^3$ eV/amu have large uncertainties
(5) In the experiments cited the He^+ metastable state population is dependent on the ion source used and the operating parameters of the source. As the metastable population increases the total cross section increases.

For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.4E-03 eV/amu, E_{max} = 7.0E+05 eV/amu

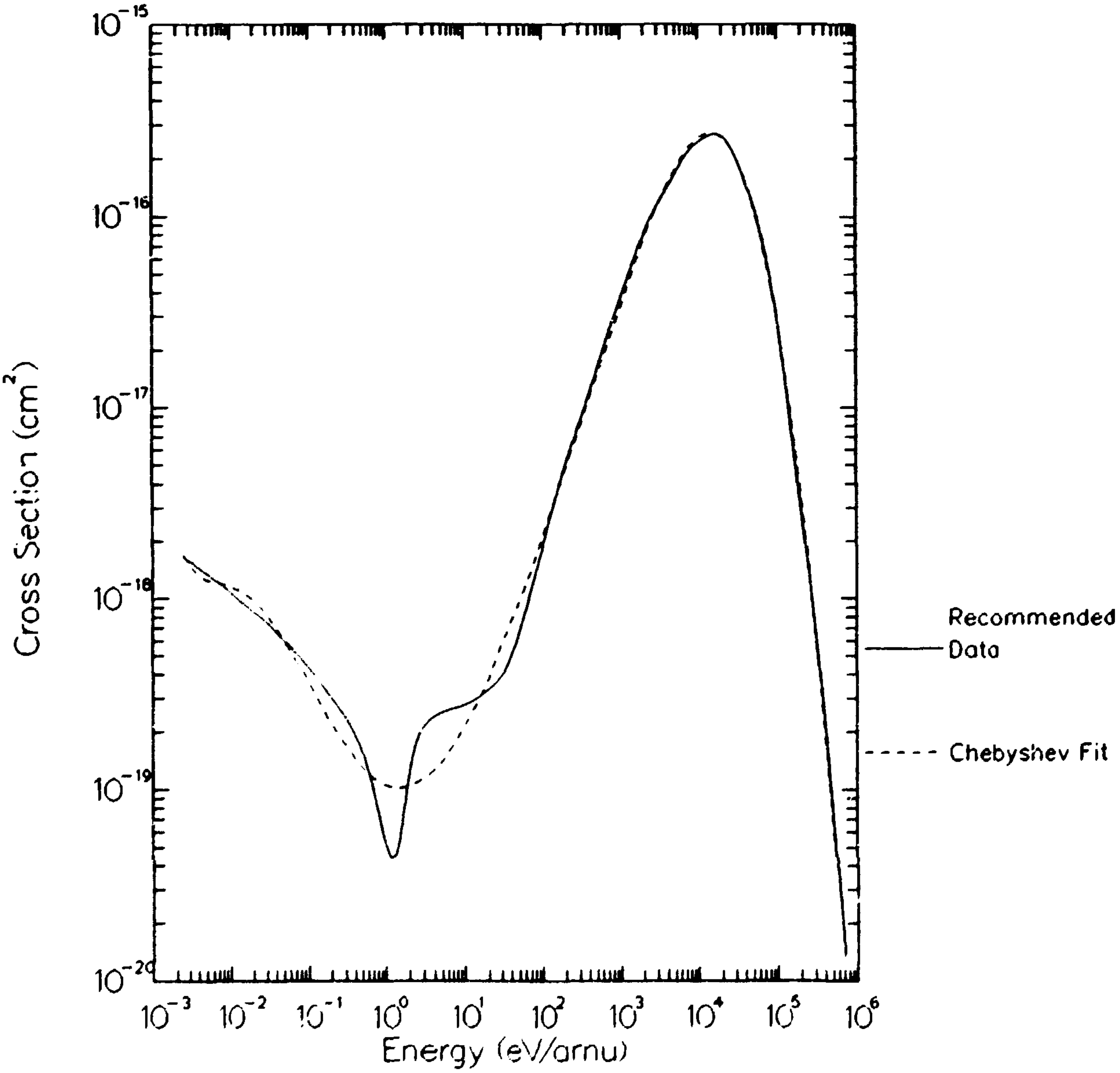
__Chebyshev Fitting Parameters for Cross Sections__

A0	A1	A2	A3	A4	A5	A6	A7	A8
-61.9486	.720256	-.856412	-3.13728	-1.68226	.0267213	.0474764	3.15823E-03	.164787

The fit represents the above cross sections with an rms deviation of 34.8%.
The maximum deviation is 132.4% at 1.3E+00 eV/amu.
See appendix for Chebyshev fit details.

$He^{+} + H_2 \rightarrow He$

Cross Section vs. Energy



Electron Capture Cross Sections for
$He^{+} + He \rightarrow He + He^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
4.0E-02	2.78E+05	3.32E-15
7.0E-02	3.68E+05	3.12E-15
1.0E-01	4.39E+05	2.97E-15
2.0E-01	6.21E+05	2.85E-15
4.0E-01	8.79E+05	2.64E-15
7.0E-01	1.16E+06	2.43E-15
1.0E+00	1.39E+06	2.31E-15
2.0E+00	1.96E+06	2.10E-15
4.0E+00	2.78E+06	1.96E-15
7.0E+00	3.68E+06	1.83E-15
1.0E+01	4.39E+06	1.75E-15
2.0E+01	6.21E+06	1.54E-15
4.0E+01	8.79E+06	1.39E-15
7.0E+01	1.16E+07	1.31E-15
1.0E+02	1.39E+07	1.26E-15
2.0E+02	1.96E+07	1.11E-15
4.0E+02	2.78E+07	9.87E-16
7.0E+02	3.6[illegible]E+07	8.56E-16
1.0E+03	4.39E+07	7.92E-16
2.0E+03	6.21E+07	6.48E-16
4.0E+03	8.79E+07	5.26E-16
7.0E+03	1.16E+08	4.22E-16
1.0E+04	1.39E+08	3.60E-16
2.0E+04	1.96E+08	2.36E-16
4.0E+04	2.78E+08	1.28E-16
7.0E+04	3.68E+08	5.58E-17
1.0E+05	4.39E+08	2.68E-17
2.0E+05	6.21E+08	5.49E-18
4.0E+05	8.78E+08	4.12E-19
5.3E+05	1.01E+09	1.08E-19

References: 91, 96, 97, 98, 99, 103, 104, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 390, 397

Accuracy: 20% throughout the energy range

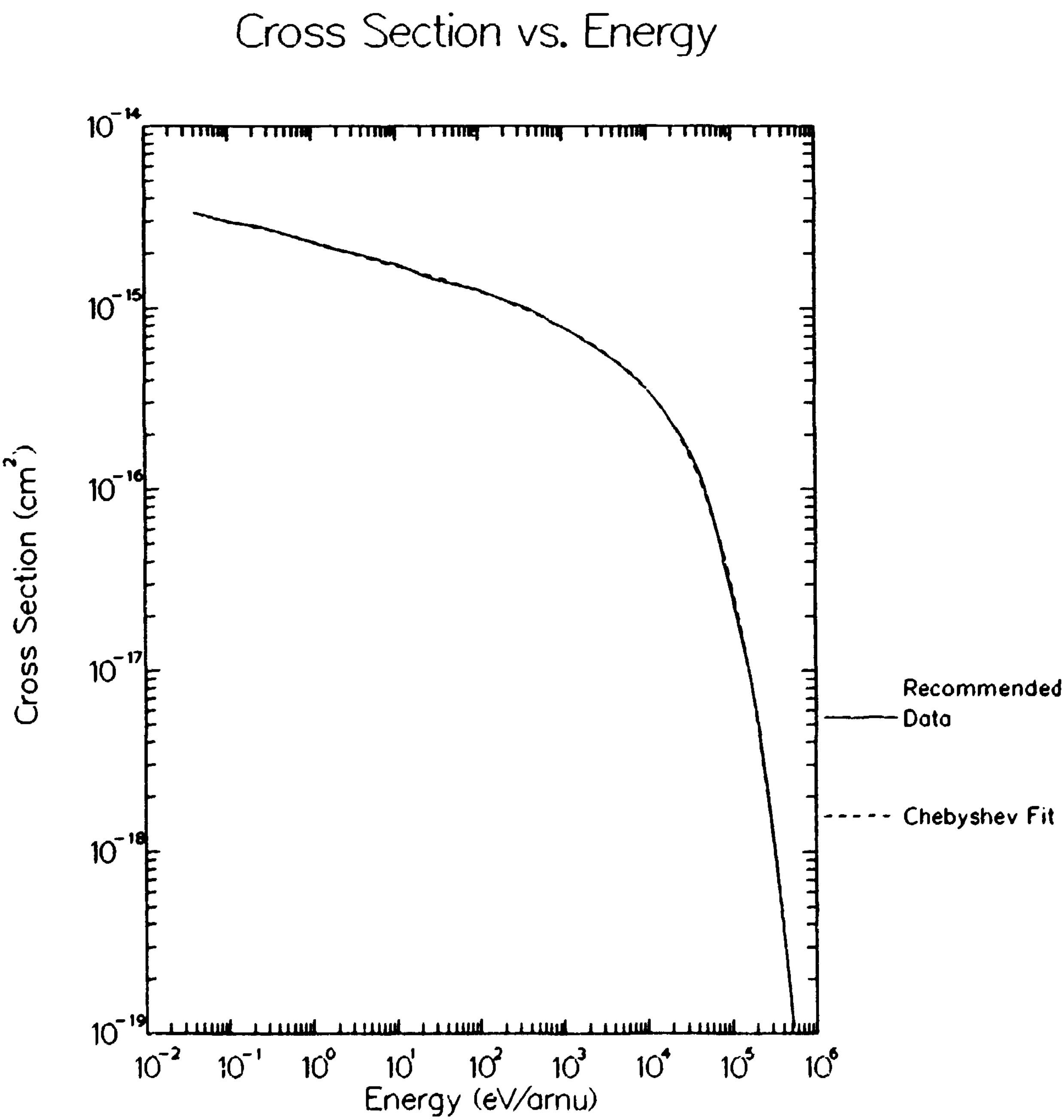
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 4.0E-02 eV/amu, E_{max} = 5.3E+05 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-71.6915	-3.72702	-1.97026	-1.16040	-.605858	-.259050	-.0892322	-.0165873	9.75783E-03

The fit represents the above cross sections with an rms deviation of 2.4%.
The maximum deviation is 9.2% at 1.0E+05 eV/amu.
See appendix for Chebyshev fit details.

$He^+ + He \rightarrow He + He^+$



Electron Capture Rate Coefficients for
$He^{+} + He \rightarrow He + He^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

He^{+} Temp. (eV)	Equal Temp.	He Temp. (eV) 1.	100.	500.	1000.	5000.	10000.	20000.
1.0E+00	2.66E-09	2.66E-09	1.12E-08	1.97E-08	2.44E-08	3.68E-08	4.18E-08	4.51E-08
2.0E+00	3.45E-09	3.10E-09	1.13E-08	1.97E-08	2.44E-08	3.68E-08	4.18E-08	4.51E-08
4.0E+00	4.49E-09	3.75E-09	1.13E-08	1.97E-08	2.44E-08	3.68E-08	4.18E-08	4.51E-08
7.0E+00	5.54E-09	4.49E-09	1.15E-08	1.97E-08	2.44E-08	3.68E-08	4.18E-08	4.51E-08
1.0E+01	6.30E-09	5.06E-09	1.16E-08	1.98E-08	2.44E-08	3.68E-08	4.18E-08	4.51E-08
2.0E+01	8.06E-09	6.42E-09	1.19E-08	1.99E-08	2.45E-08	3.68E-08	4.18E-08	4.51E-08
4.0E+01	1.03E-08	8.13E-09	1.26E-08	2.01E-08	2.47E-08	3.68E-08	4.18E-08	4.51E-08
7.0E+01	1.26E-08	9.87E-09	1.35E-08	2.05E-08	2.49E-08	3.69E-08	4.18E-08	4.51E-08
1.0E+02	1.43E-08	1.12E-08	1.43E-08	2.08E-08	2.51E-08	3.69E-08	4.18E-08	4.51E-08
2.0E+02	1.82E-08	1.44E-08	1.65E-08	2.19E-08	2.57E-08	3.71E-08	4.19E-08	4.51E-08
4.0E+02	2.28E-08	1.83E-08	1.96E-08	2.36E-08	2.69E-08	3.74E-08	4.20E-08	4.51E-08
7.0E+02	2.69E-08	2.19E-08	2.28E-08	2.57E-08	2.83E-08	3.78E-08	4.22E-08	4.52E-08
1.0E+03	2.96E-08	2.44E-08	2.51E-08	2.74E-08	2.96E-08	3.82E-08	4.24E-08	4.52E-08
2.0E+03	3.50E-08	2.96E-08	2.99E-08	3.13E-08	3.27E-08	3.93E-08	4.29E-08	4.53E-08
4.0E+03	4.03E-08	3.50E-08	3.52E-08	3.59E-08	3.68E-08	4.11E-08	4.37E-08	4.54E-08
7.0E+03	4.37E-08	3.93E-08	3.94E-08	3.98E-08	4.03E-08	4.29E-08	4.46E-08	4.55E-08
1.0E+04	4.51E-08	4.18E-08	4.18E-08	4.21E-08	4.24E-08	4.40E-08	4.51E-08	4.54E-08
2.0E+04	4.47E-08	4.51E-08	4.51E-08	4.51E-08	4.52E-08	4.55E-08	4.54E-08	4.47E-08

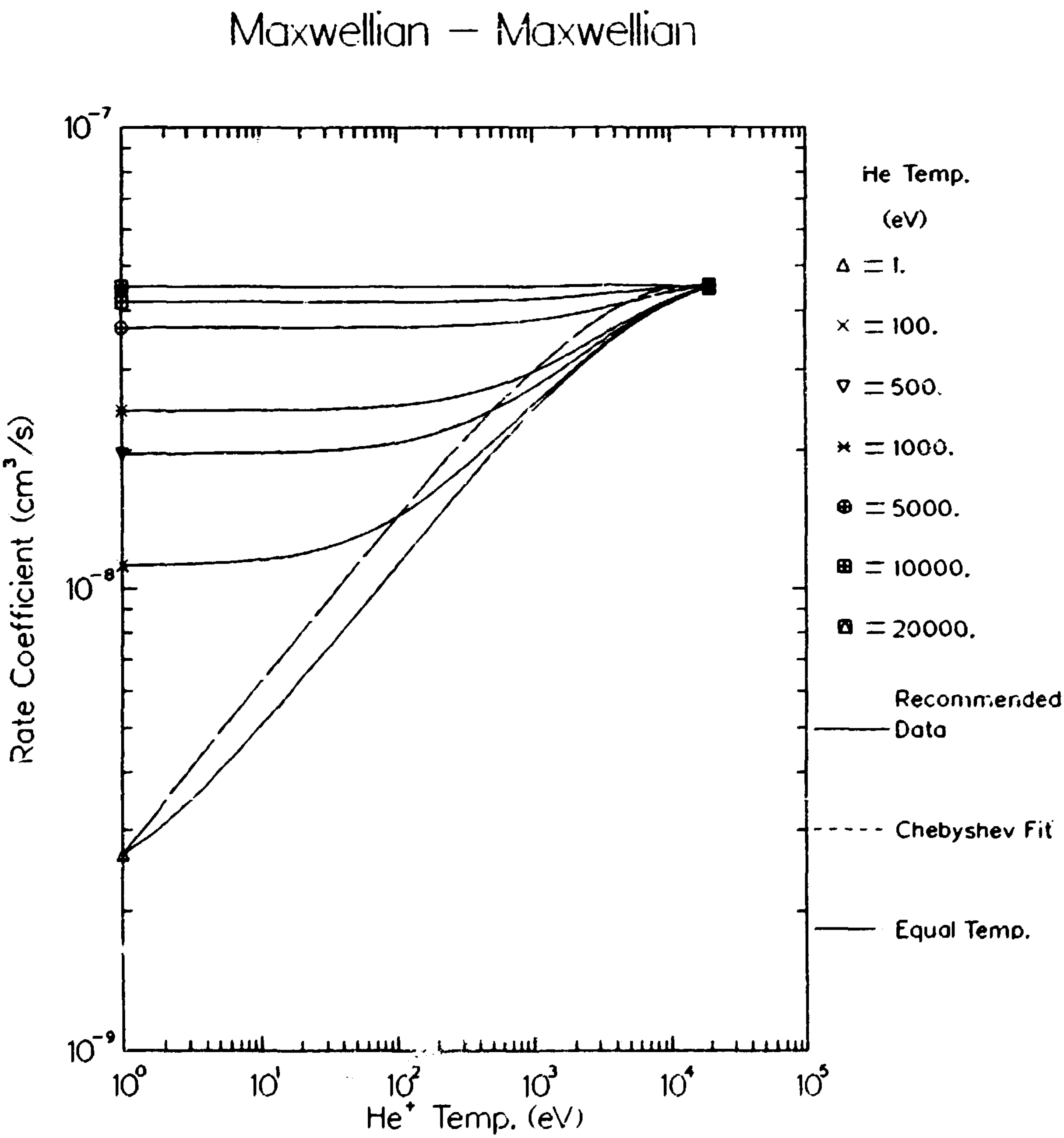
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
1.	-3.65091E+01	1.50347E+00	-7.73477E-02	-8.34424E-02	-7.59297E-04	-3.1777[illegible]E-03	2.46929E-03
100.	-3.55092E+01	7.61944E-01	1.84506E-01	-6.99606E-02	-4.58282E-02	5.01278E-03	6.02365E-03
500.	-3.49239E+01	4.30514E-01	1.66682E-01	-1.76952E-03	-3.51444E-02	-1.39113E-02	1.27578E-03
1000.	-3.46672E+01	3.07854E-01	1.38199E-01	1.53048E-02	-2.27026E-02	-1.52299E-02	-2.87864E-03
5000.	-3.41193E+01	9.72499E-02	5.39119E-02	1.55767E-02	-2.97046E-03	-6.16891E-03	-3.80972E-03
10000.	-3.39337E+01	3.94479E-02	2.21217E-02	6.22476E-03	-1.76048E-03	-3.26193E-03	-2.26998E-03
20000.	-3.38270E+01	1.35988E-03	-9.13724E-04	-2.77809E-03	-3.01978E-03	-2.17733E-03	-1.25142E-03
Equal Temp.	-3.62362E+01	1.48422E+00	-1.94700E-01	-6.90443E-02	-1.94257E-02	-1.35547E-03	-2.79202E-03

See appendix for Chebyshev fit details.

$He^{+} + He \rightarrow He + He^{+}$



Electron Capture Rate Coefficients for
$He + He^{+} \rightarrow He + He^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	400000.
1.0E+00	5.00E-08	4.63E-08	3.55E-08	2.05E-08	1.18E-08	3.41E-09*	3.61E-10**
2.0E+00	5.00E-08	4.63E-08	3.55E-08	2.05E-08	1.18E-08	3.40E-09*	3.62E-10**
4.0E+00	5.00E-08	4.63E-08	3.55E-08	2.05E-08	1.18E-08	3.40E-09*	3.61E-10**
7.0E+00	4.99E-08	4.63E-08	3.55E-08	2.05E-08	1.18E-08	3.40E-09*	3.61E-10**
1.0E+01	4.99E-08	4.63E-08	3.55E-08	2.05E-08	1.18E-08	3.40E-09*	3.61E-10**
2.0E+01	4.99E-08	4.62E-08	3.54E-08	2.05E-08	1.18E-08	3.40E-09*	3.61E-10**
4.0E+01	4.99E-08	4.62E-08	3.54E-08	2.04E-08	1.18E-08	3.39E-09*	3.61E-10**
7.0E+01	4.98E-08	4.61E-08	3.53E-08	2.04E-08	1.18E-08	3.39E-09*	3.61E-10**
1.0E+02	4.98E-08	4.61E-08	3.53E-08	2.04E-08	1.18E-08	3.38E-09*	3.60E-10**
2.0E+02	4.97E-08	4.60E-08	3.51E-08	2.03E-08	1.17E-08	3.37E-09*	3.60E-10**
4.0E+02	4.95E-08	4.58E-08	3.50E-08	2.03E-08	1.17E-08	3.36E-09*	3.60E-10**
7.0E+02	4.94E-08	4.57E-08	3.48E-08	2.02E-08	1.17E-08	3.34E-09*	3.59E-10**
1.0E+03	4.93E-08	4.55E-08	3.47E-08	2.02E-08	1.18E-08	3.33E-09	3.59E-10**
2.0E+03	4.89E-08	4.52E-08	3.43E-08	2.01E-08	1.18E-08	3.31E-09	3.60E-10**
4.0E+03	4.83E-08	4.46E-08	3.38E-08	2.00E-08	1.18E-08	3.30E-09	3.62E-10**
7.0E+03	4.75E-08	4.39E-08	3.32E-08	1.99E-08	1.19E-08	3.29E-09	3.67E-10**
1.0E+04	4.68E-08	4.31E-08	3.28E-08	1.98E-08	1.20E-08	3.30E-09	3.72E-10**
2.0E+04	4.48E-08	4.09E-08	3.13E-08	1.96E-08	1.22E-08	3.37E-09	3.91E-10*

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

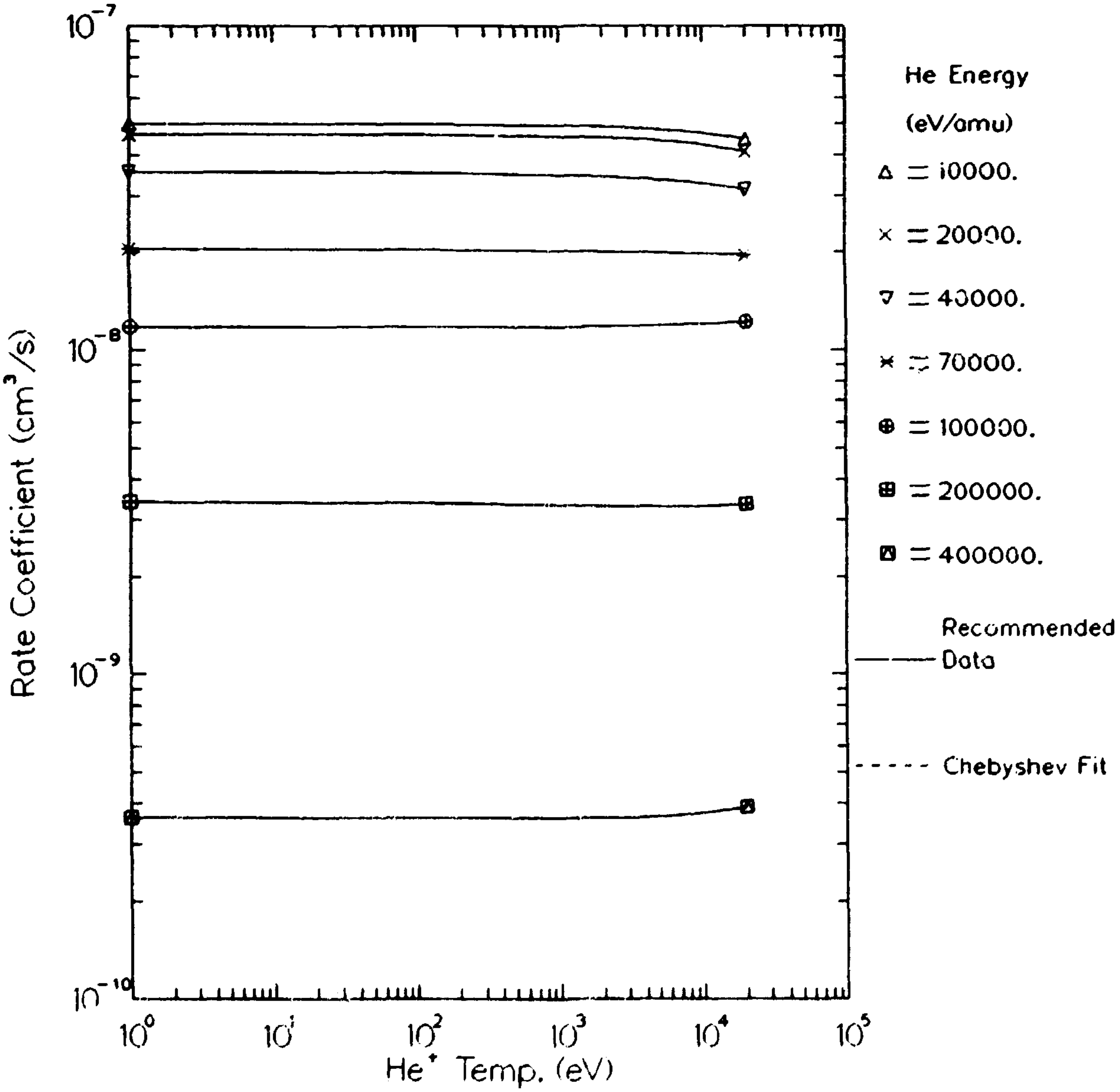
Chebyshev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-3.36725E+01	-4.07805E-02	-2.43723E-02	-1.21532E-02	-5.34881E-03	-2.01573E-03	-5.49929E-04
20000.	-3.38300E+01	-4.55632E-02	-2.69923E-02	-1.37596E-02	-6.60783E-03	-3.00454E-03	-1.25225E-03
40000.	-3.43690E+01	-5.00191E-02	-2.61460E-02	-1.10247E-02	-4.45099E-03	-1.92372E-03	-9.15345E-04
70000.	-3.54336E+01	-2.00865E-02	-7.82001E-03	-2.03461E-03	-7.58265E-04	-7.02792E-04	-6.07996E-04
100000.	-3.65032E+01	1.22086E-02	1.00798E-02	5.91914E-03	2.15183E-03	3.37849E-04	-2.72081E-04
200000.	-3.90194E+01	-1.48944E-02	8.12695E-04	5.76317E-03	5.00317E-03	2.19384E-03	1.07961E-03
400000.	-4.34614E+01	2.08264E-02	2.00251E-02	1.46660E-02	7.48524E-03	3.55071E-03	7.16357E-04

See appendix for Chebyshev fit details.

He + He$^+$ -> He + He$^+$

Beam - Maxwellian



Electron Capture Cross Sections for
$He^+ + Li \rightarrow He + Li^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
6.4E+01	1.11E+07	7.80E-16
1.0E+02	1.39E+07	1.53E-15
2.0E+02	1.96E+07	3.27E-15
5.0E+02	3.11E+07	5.25E-15
8.0E+02	3.93E+07	5.61E-15
1.0E+03	4.39E+07	5.60E-15
2.0E+03	6.21E+07	5.12E-15
4.0E+03	8.79E+07	4.17E-15
7.0E+03	1.16E+08	2.93E-15
1.0E+04	1.39E+08	1.76E-15
2.0E+04	1.96E+08	3.26E-16
2.5E+04	2.20E+08	1.33E-16
3.0E+04	2.41E+08	6.37E-17
4.0E+04	2.78E+08	4.17E-17
5.0E+04	3.11E+08	3.42E-17
7.0E+04	3.68E+08	2.60E-17
1.0E+05	4.39E+08	2.00E-17

References: 230, 231, 232, 233, 234, 242

Accuracy: 30%

Note: For electron capture cross sections of Li^+ and Li^{2+} in He see references 249, 250, 251, 254.

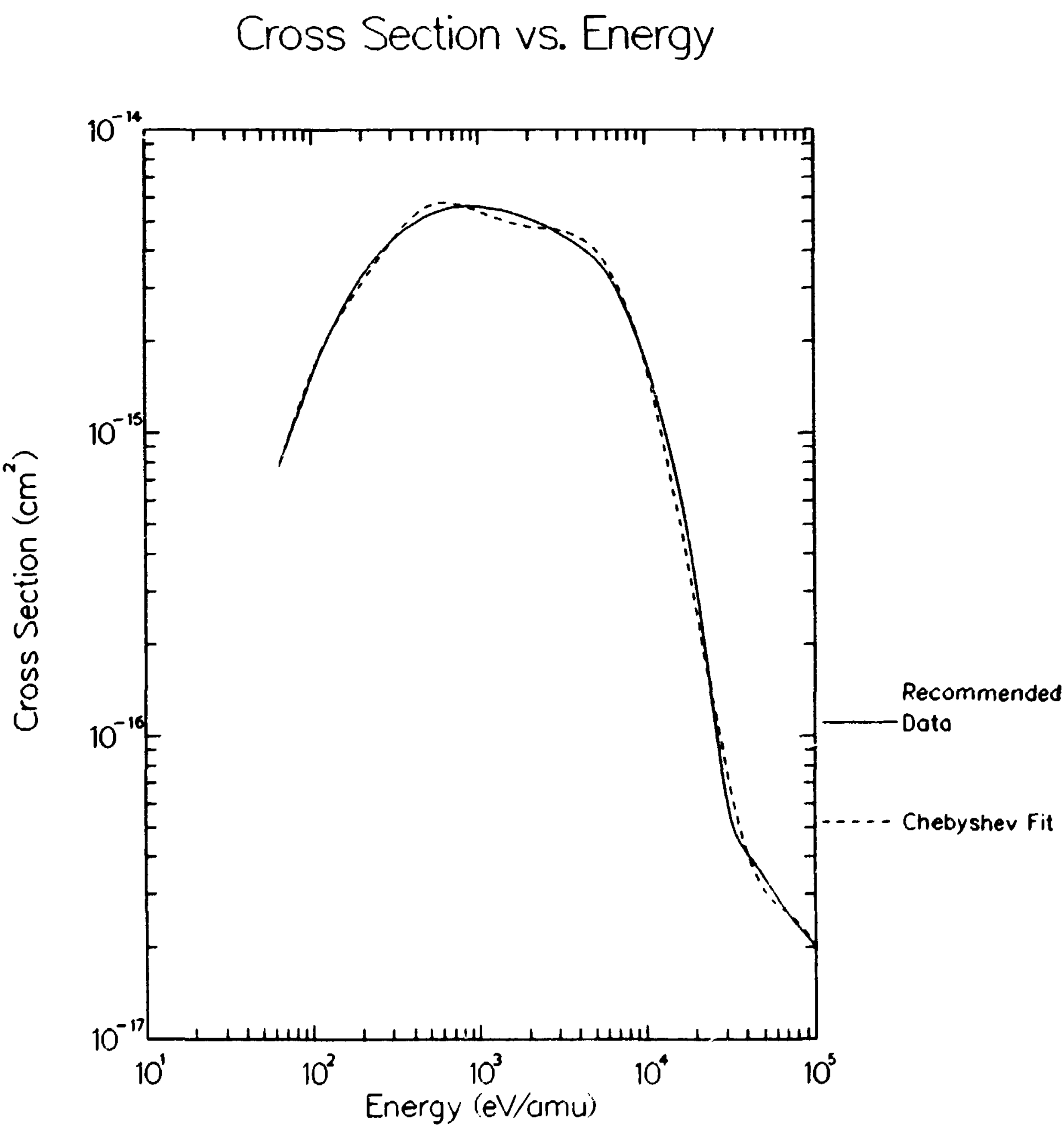
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 6.4E+01 eV/amu, E_{max} = 1.0E+05 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-69.9420	-2.17479	-1.90237	.153408	.309985	.316010	.0848497	-.118385	-.140948

The fit represents the above cross sections with an rms deviation of 8.8%.
The maximum deviation is 26.5% at 3.0E+04 eV/amu.
See appendix for Chebyshev fit details.

$He^{+} + Li \rightarrow He + Li^{+}$



Electron Capture Rate Coefficients for
$Li + He^{+} \rightarrow He + Li^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{+} Temp. (eV)	Li Energy (eV/amu) 10000.	20000.	30000.	40000.	60000.	80000.	100000.
1.0E+00	2.44E-07	6.38E-08*	1.54E-08**	1.16E-08**	1.00E-08**	9.26E-09**	4.39E-09**
2.0E+00	2.44E-07	6.38E-08*	1.54E-08**	1.16E-08**	1.00E-08**	9.26E-09**	4.39E-09**
4.0E+00	2.43E-07	6.37E-08*	1.55E-08**	1.16E-08**	1.00E-08**	9.26E-09**	4.39E-09**
7.0E+00	2.43E-07	6.35E-08*	1.55E-08**	1.16E-08**	1.00E-08**	9.26E-09**	4.39E-09**
1.0E+01	2.42E-07	6.35E-08*	1.55E-08**	1.16E-08**	1.00E-08**	9.26E-09**	4.39E-09**
2.0E+01	2.42E-07	6.32E-08*	1.56E-08**	1.16E-08**	1.00E-08**	9.26E-09**	4.38E-09**
4.0E+01	2.40E-07	6.30E-08*	1.58E-08**	1.16E-08**	1.00E-08**	9.26E-09**	4.38E-09**
7.0E+01	2.39E-07	6.27E-08*	1.59E-08**	1.17E-08**	1.00E-08**	9.26E-09**	4.38E-09**
1.0E+02	2.38E-07	6.25E-08*	1.60E-08**	1.17E-08**	1.00E-08**	9.26E-09**	4.37E-09**
2.0E+02	2.36E-07	6.22E-08*	1.64E-08**	1.17E-08**	1.00E-08**	9.26E-09**	4.36E-09**
4.0E+02	2.34E-07	6.19E-08*	1.70E-08**	1.18E-08**	1.00E-08**	9.26E-09**	4.35E-09**
7.0E+02	2.31E-07	6.19E-08*	1.77E-08*	1.19E-08**	1.00E-08**	9.26E-09**	4.34E-09**
1.0E+03	2.29E-07	6.22E-08*	1.83E-08*	1.19E-08**	1.00E-08**	9.24E-09**	4.33E-09**
2.0E+03	2.21E-07	6.38E-08*	2.03E-08*	1.22E-08**	1.00E-08**	9.09E-09**	4.30E-09**
4.0E+03	2.09E-07	6.77E-08*	2.36E-08*	1.31E-08**	1.01E-08**	8.59E-09**	4.26E-09**
7.0E+03	1.93E-07	7.22E-08	2.78E-08*	1.48E-08*	1.01E-08**	7.97E-09**	4.22E-09**
1.0E+04	1.80E-07	7.49E-08	3.14E-08*	1.66E-08*	1.01E-08**	7.54E-09**	4.18E-09**
2.0E+04	1.50E-07	7.63E-08	3.93E-08*	2.22E-08*	1.08E-08**	6.91E-09**	4.13E-09**

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

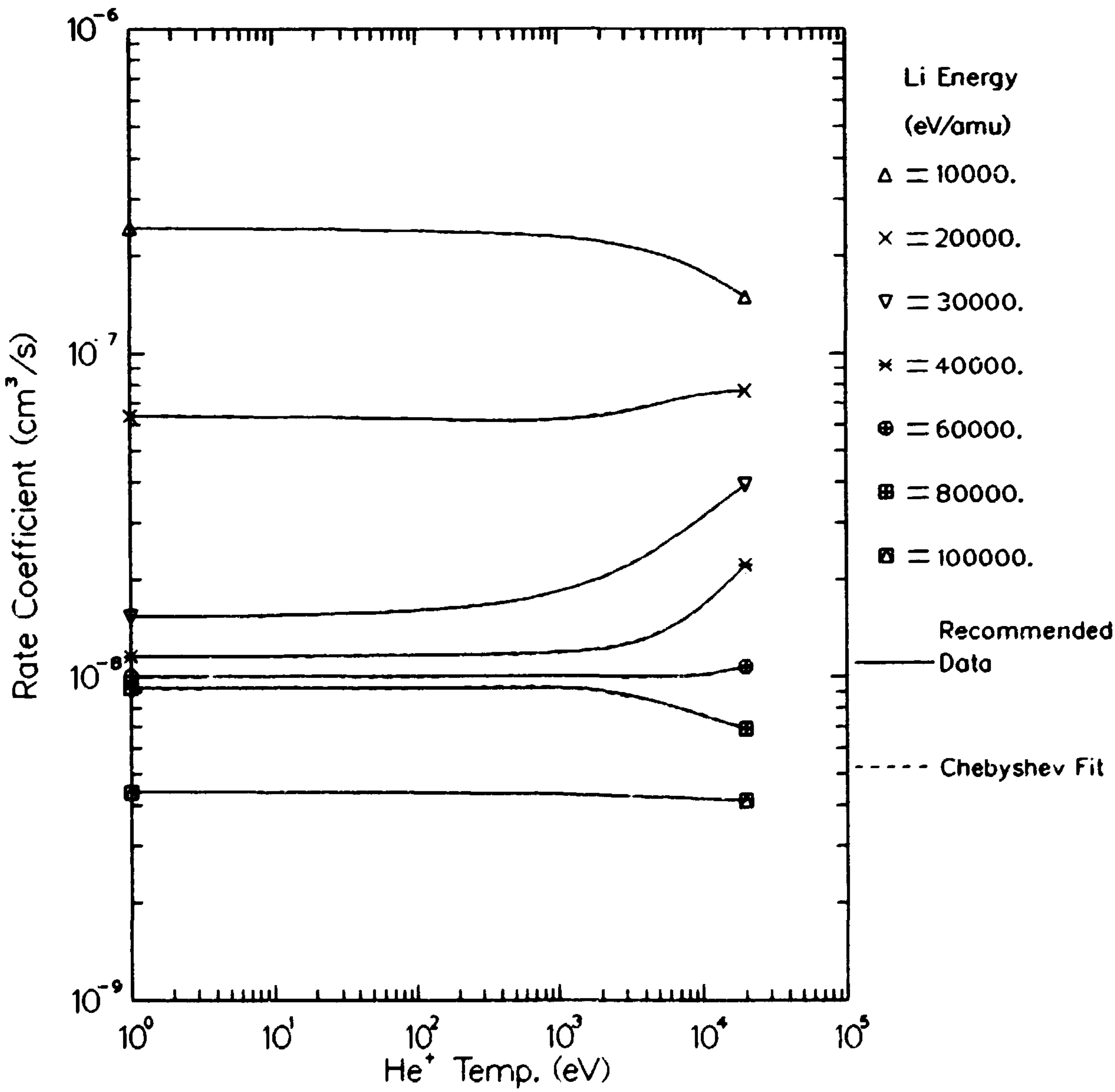
Chebyshev Fitting Parameters for Rate Coefficients

Li Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-3.06784E+01	-1.83367E-01	-1.08562E-01	-5.42037E-02	-2.28601E-02	-6.74194E-03	-2.90887E-04
20000.	-3.30630E+01	7.50860E-02	6.65545E-02	2.87114E-02	-2.24836E-03	-1.23958E-02	-1.01177E-02
30000.	-3.54800E+01	4.01173E-01	2.16479E-01	7.71491E-02	1.07563E-02	-8.06147E-03	-8.04622E-03
40000.	-3.62976E+01	2.18893E-01	1.57718E-01	9.39441E-02	4.47005E-02	1.42990E-02	-8.03805E-04
60000.	-3.68192E+01	1.63206E-02	1.40921E-02	1.21589E-02	9.29880E-03	6.22735E-03	4.24079E-03
80000.	-3.71186E+01	-1.09657E-01	-8.05414E-02	-4.26549E-02	-1.26465E-02	3.18261E-03	7.94923E-03
100000.	-3.85227E+01	-2.71037E-02	-1.31775E-02	-4.13455E-03	-5.05274E-04	3.90860E-04	4.43525E-04

See appendix for Chebyshev fit details.

Li + He^+ -> He + Li^+

Beam – Maxwellian



Electron Capture Cross Sections for
$He^{+} + He^{+} \rightarrow He + He^{2+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.5E+04	1.70E+08	1.95E-18
2.0E+04	1.96E+08	3.25E-18
3.0E+04	2.41E+08	6.28E-18
4.0E+04	2.78E+08	9.44E-18
5.0E+04	3.11E+08	1.22E-17
6.0E+04	3.40E+08	1.45E-17
7.0E+04	3.68E+08	1.64E-17
9.0E+04	4.17E+08	1.88E-17
1.0E+05	4.39E+08	1.90E-17
1.5E+05	5.38E+08	1.73E-17
2.0E+05	6.21E+08	1.42E-17
2.3E+05	6.66E+08	1.24E-17

References: 69, 277, 278, 283, 284

Accuracy: 20%

Note: (1) Good agreement of the experimental data exists with the theoretical data of Ref. 284.

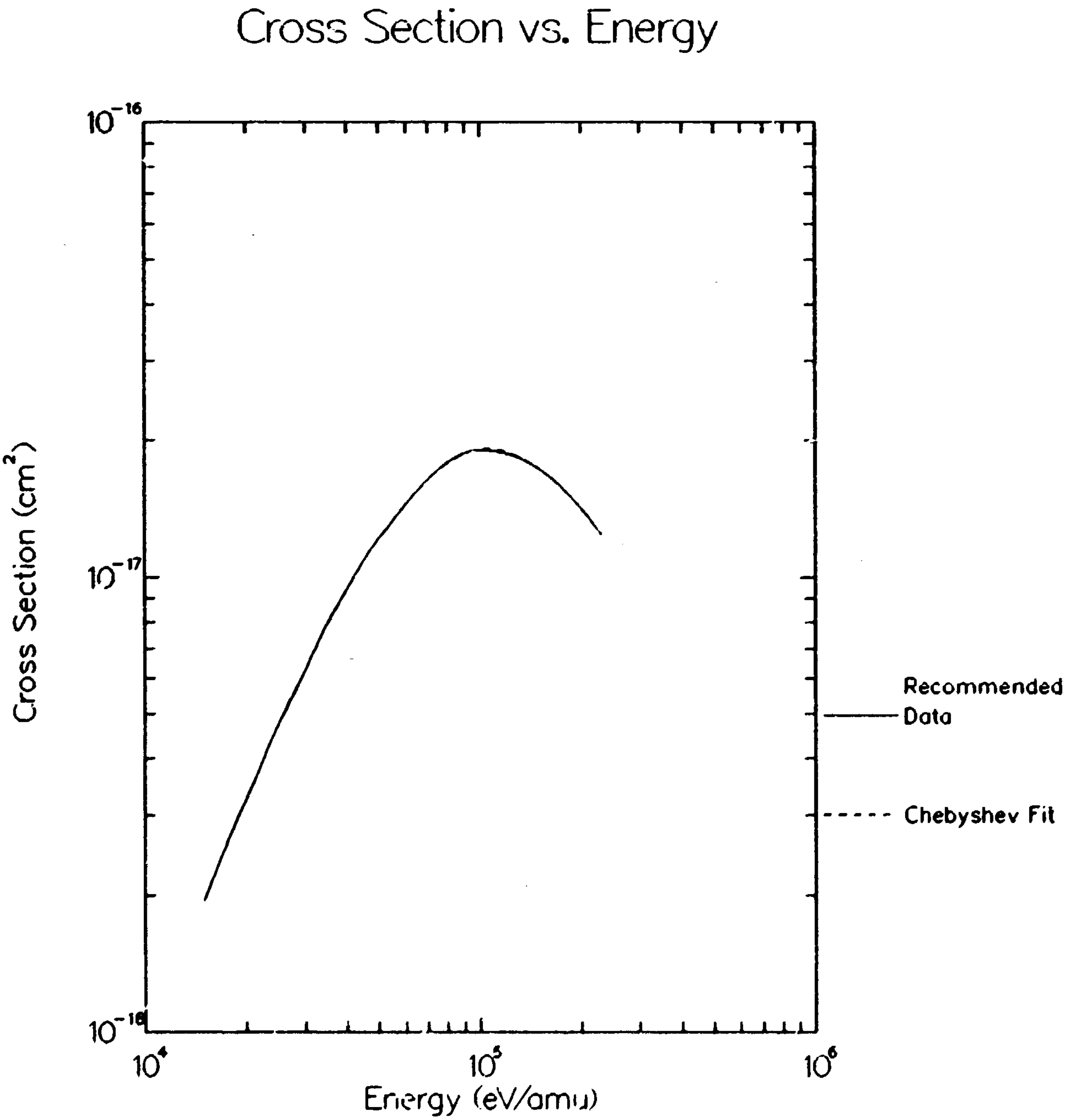
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.5E+04 eV/amu, E_{max} = 2.3E+05 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-78.6559	.981266	-.533866	-.0667013	.0133417	.00898626	.00154609	.00128923	-.00693562

The fit represents the above cross sections with an rms deviation of 0.3%.
The maximum deviation is 0.6% at 1.0E+05 eV/amu.
See appendix for Chebyshev fit details.

$He^{+} + He^{+} \rightarrow He + He^{2+}$



Electron Capture Rate Coefficients for
$He^{+} + He^{+} \rightarrow He + He^{2+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

He^+ Temp. (eV)	Equal Temp.	He^+ Temp. (eV) 10000.	12000.	14000.	16000.	18000.	20000.	25000.
4.0E+03	8.29E-13	2.06E-11	3.60E-11	5.61E-11	8.08E-11	1.10E-10	1.43E-10	2.40E-10
6.0E+03	9.94E-12	3.60E-11	5.61E-11	8.08E-11	1.10E-10	1.43E-10	1.79E-10	2.85E-10
8.0E+03	3.60E-11	5.61E-11	8.08E-11	1.10E-10	1.43E-10	1.79E-10	2.19E-10	3.32E-10
1.0E+04	8.08E-11	8.08E-11	1.10E-10	1.43E-10	1.79E-10	2.19E-10	2.62E-10	3.81E-10
1.2E+04	1.43E-10	1.10E-10	1.43E-10	1.79E-10	2.19E-10	2.62E-10	3.08E-10	4.33E-10
1.4E+04	2.19E-10	1.43E-10	1.79E-10	2.19E-10	2.62E-10	3.08E-10	3.56E-10	4.87E-10
1.6E+04	3.08E-10	1.79E-10	2.19E-10	2.62E-10	3.08E-10	3.56E-10	4.07E-10	5.42E-10
1.8E+04	4.07E-10	2.19E-10	2.62E-10	3.08E-10	3.56E-10	4.07E-10	4.60E-10	5.99E-10
2.0E+04	5.14E-10	2.62E-10	3.08E-10	3.56E-10	4.07E-10	4.60E-10	5.14E-10	6.58E-10
2.2E+04	6.28E-10	3.08E-10	3.56E-10	4.07E-10	4.60E-10	5.14E-10	5.71E-10	7.18E-10
2.4E+04	7.49E-10	3.56E-10	4.07E-10	4.60E-10	5.14E-10	5.71E-10	6.28E-10	7.80E-10

Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 4.0E+03 eV, E_{max} = 2.4E+04 eV

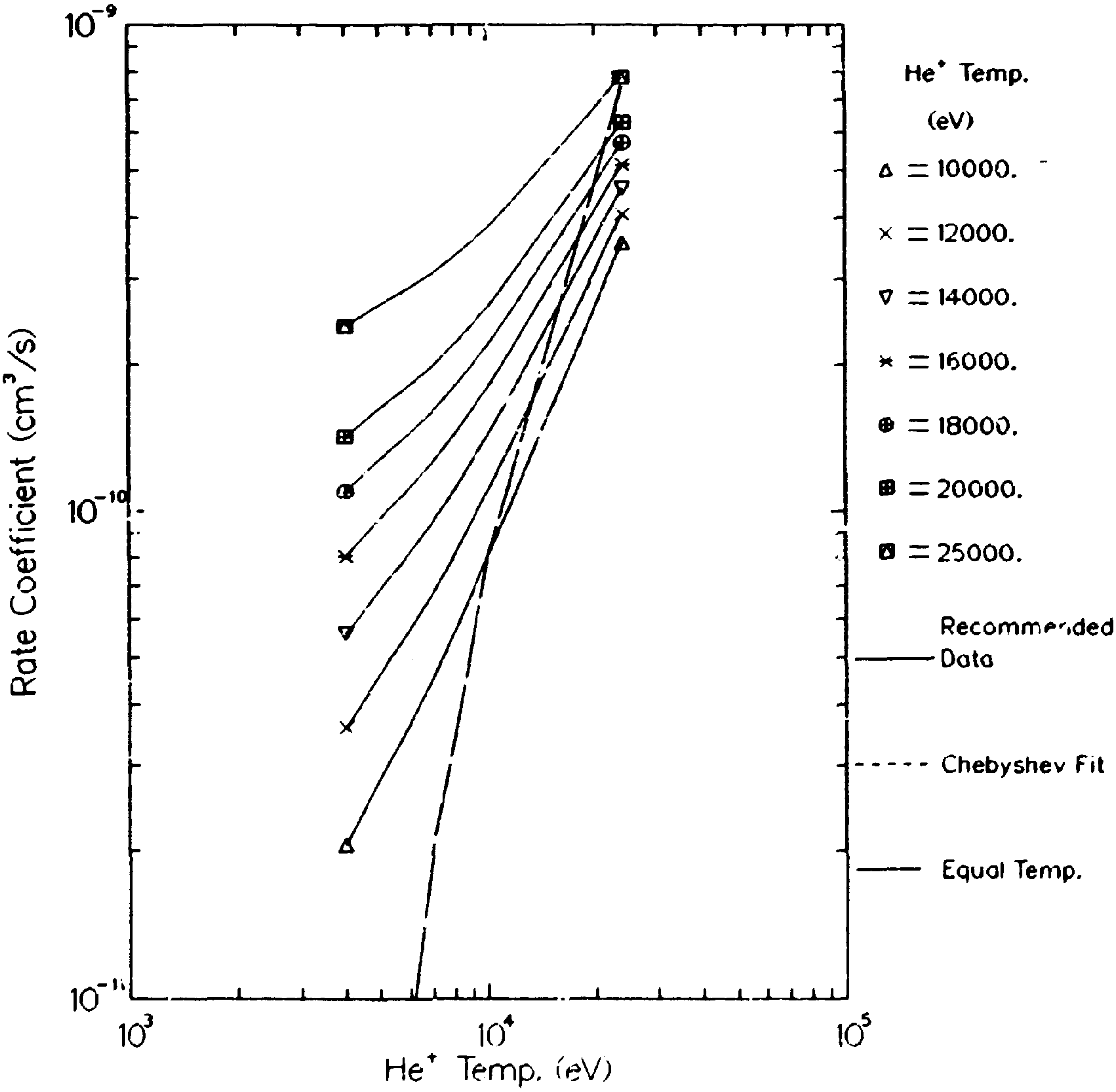
Chebyshev Fitting Parameters for Rate Coefficients

He^+ Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
10000.	-4.64541E+01	1.43962E+00	4.63030E-02	-1.49060E-02	-2.30149E-04	2.44855E-04	-4.28539E-05
12000.	-4.57963E+01	1.22412E+00	6.31757E-02	-1.13559E-02	-6.21329E-04	1.52187E-04	1.97060E-04
14000.	-4.52461E+01	1.05998E+00	7.17125E-02	-8.34828E-03	-9.77820E-04	2.30920E-04	-9.51457E-06
16000.	-4.47759E+01	9.31470E-01	7.53759E-02	-5.93773E-03	-1.18832E-03	1.95011E-04	-1.89337E-04
18000.	-4.43672E+01	8.28548E-01	7.61027E-02	-4.06263E-03	-1.22968E-03	-1.52699E-05	-1.37761E-04
20000.	-4.40069E+01	7.44390E-01	7.51176E-02	-2.63629E-03	-1.17745E-03	-2.47636E-04	7.54863E-05
25000.	-4.32601E+01	5.88552E-01	7.03946E-02	-1.20370E-04	-1.13108E-03	1.84062E-04	-1.45794E-04
Equal Temp.	-4.76973E+01	3.30679E+00	-5.53811E-01	9.53225E-02	-1.30960E-02	6.76109E-04	1.60674E-04

See appendix for Chebyshev fit details.

$He^{+} + He^{+} \rightarrow He + He^{2+}$

Maxwellian – Maxwellian



Partial and Total Electron Capture Cross Sections for

$He^{2+} + He^{+} \rightarrow He^{+} + He^{2+}$

(Partial)

He^{+} Energy eV/amu	Cross Section cm^2
7.0E+00	3.04E-17
1.0E+01	4.02E-17
1.5E+01	7.57E-17
2.0E+01	2.00E-16
2.5E+01	2.98E-16
3.0E+01	3.48E-16
4.0E+01	4.04E-16
6.0E+01	4.45E-16
7.0E+01	4.55E-16
1.0E+02	4.79E-16
2.0E+02	4.84E-16
4.0E+02	4.64E-16
7.0E+02	4.38E-16
1.0E+03	4.19E-16
2.0E+03	3.76E-16
4.0E+03	3.28E-16
7.0E+03	2.83E-16
1.0E+04	2.52E-16
1.6E+04	2.07E-16

(Total)

He^{+} Energy eV/amu	Cross Section cm^2
8.5E+00	3.39E-16
1.0E+01	4.09E-16
1.5E+01	6.01E-16
2.0E+01	6.99E-16
4.0E+01	7.77E-16
7.0E+01	7.80E-16
1.0E+02	7.66E-16
2.0E+02	7.16E-16
4.0E+02	6.64E-16
7.0E+02	6.13E-16
1.0E+03	5.75E-16
2.0E+03	5.01E-16
4.0E+03	4.30E-16
7.0E+03	3.76E-16
1.0E+04	3.23E-16
2.0E+04	2.03E-16
4.0E+04	1.01E-16
7.0E+04	4.50E-17
1.0E+05	2.65E-17
1.5E+05	1.33E-17
2.0E+05	6.34E-18
2.5E+05	2.83E-18
3.0E+05	1.27E-18

<u>References:</u> 69, 288, 391, 392, 393

<u>Accuracy:</u> unknown

<u>Notes:</u> (1) In the measurements a problem arises from the mutual repulsion between the He^{+} and He^{2+}. The repulsion results in scattering with some of the ions not reaching the detector which has a finite acceptance angle. These measurements are termed partial cross sections.
(2) The total cross section data are from theoretical values in Ref. 288 and 391. The theoretical data has been joined with a smooth curve between $6x10^{3}$ and 10^{5} eV/amu.
(3) For this simple one electron, resonant system, the theoretical data should be accurate to within 20%.

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

(Partial) E_{min} = 7.1E+00 eV/amu, E_{max} = 1.6E+04 eV/amu
(Total) E_{min} = 8.5E+00 eV/amu, E_{max} = 3.0E+05 eV/amu

<u>Chebyshev Fitting Parameters for Cross Sections</u>

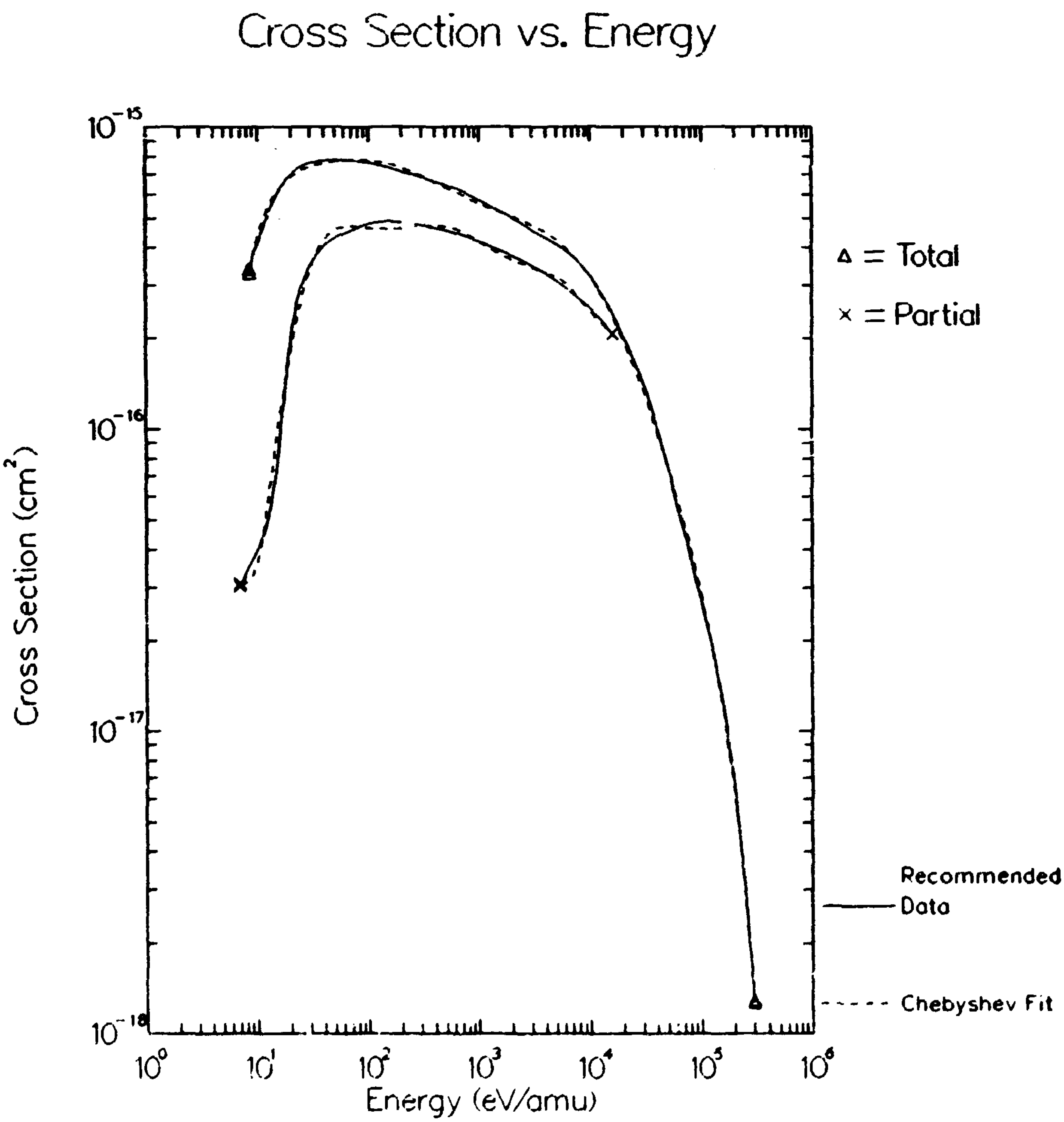
	A0	A1	A2	A3	A4	A5	A6	A7	A8
(Partial)	-72.2134	.725003	-1.00558	.400148	-.150634	-.0556029	.119500	-.118086	.0830868
(Total)	-72.8308	-2.29484	-1.54555	-.441776	-.328931	-.00327441	-.0709033	-.0333345	-.0595299

The fit represents the partial cross section with an rms deviation of 7.4%.
The maximum deviation is 25.2% at 1.5E+01 eV/amu.

The fit represents the total cross section with an rms deviation of 2.8%.
The maximum deviation is 5.6% at 7.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^{2+} + He^{+} \rightarrow He^{+} + He^{2+}$



Single Electron Capture Cross Sections for

$He^{2+} + H^- \rightarrow He^+ + H$

$He^+ + H^- \rightarrow He + H$

$He^{2+} + H^-$

Energy eV/amu	Cross Section cm^2
4.7E-01	1.82E-13
5.0E-01	1.72E-13
6.0E-01	1.52E-13
8.0E-01	1.30E-13
1.0E+00	1.17E-13
2.0E+00	8.90E-14
3.0E+00	7.78E-14
4.0E+00	7.13E-14
6.0E+00	6.44E-14
8.0E+00	6.01E-14
1.0E+01	5.79E-14
2.0E+01	5.31E-14
3.0E+01	5.08E-14
5.0E+01	4.77E-14
8.0E+01	4.55E-14
1.0E+02	4.43E-14
2.0E+02	4.12E-14
4.0E+02	3.73E-14
7.0E+02	3.46E-14
1.0E+03	3.22E-14
2.0E+03	2.79E-14
3.0E+03	2.50E-14

$He^+ + H^-$

Energy eV/amu	Cross Section cm^2
4.2E+01	3.03E-14
5.0E+01	2.18E-14
6.0E+01	1.83E-14
7.0E+01	1.66E-14
8.0E+01	1.56E-14
1.0E+02	1.46E-14
1.5E+02	1.40E-14
2.0E+02	1.37E-14
3.0E+02	1.32E-14
4.0E+02	1.30E-14
5.0E+02	1.28E-14
7.0E+02	1.24E-14
1.0E+03	1.19E-14
2.0E+03	9.78E-15
3.0E+03	7.89E-15
4.0E+03	6.06E-15
5.0E+03	4.40E-15
7.0E+03	2.43E-15
7.7E+03	2.01E-15

<u>References:</u> ($He^+ + H^-$) 68, 292, 293, 394 ; ($He^{2+} + H^-$) 69, 290, 291, 294

<u>Accuracy:</u> ($He^+ + H^-$) - 20%; ($He^{2+} + H^-$) - 40%

<u>Notes:</u> (1) In the energy region of overlap, the $He^{2+} + H^-$ cross sections of Terao et al (ref. 290, 291) are consistently greater than those of the Dolder and Peart group (ref. 69, 294).

(2) The measurements indicate some structure in the cross sections for both the He^+ and He^{2+} reactions. This oscillation has been smoothed out in the data presented here.

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

($He^{2+} + H^-$) E_{min} = 4.7E-01 eV/amu, E_{max} = 3.0E+03 eV/amu

($He^+ + H^-$) E_{min} = 4.2E+01 eV/amu, E_{max} = 7.7E+03 eV/amu

<u>Chebyshev Fitting Parameters for Cross Sections</u>

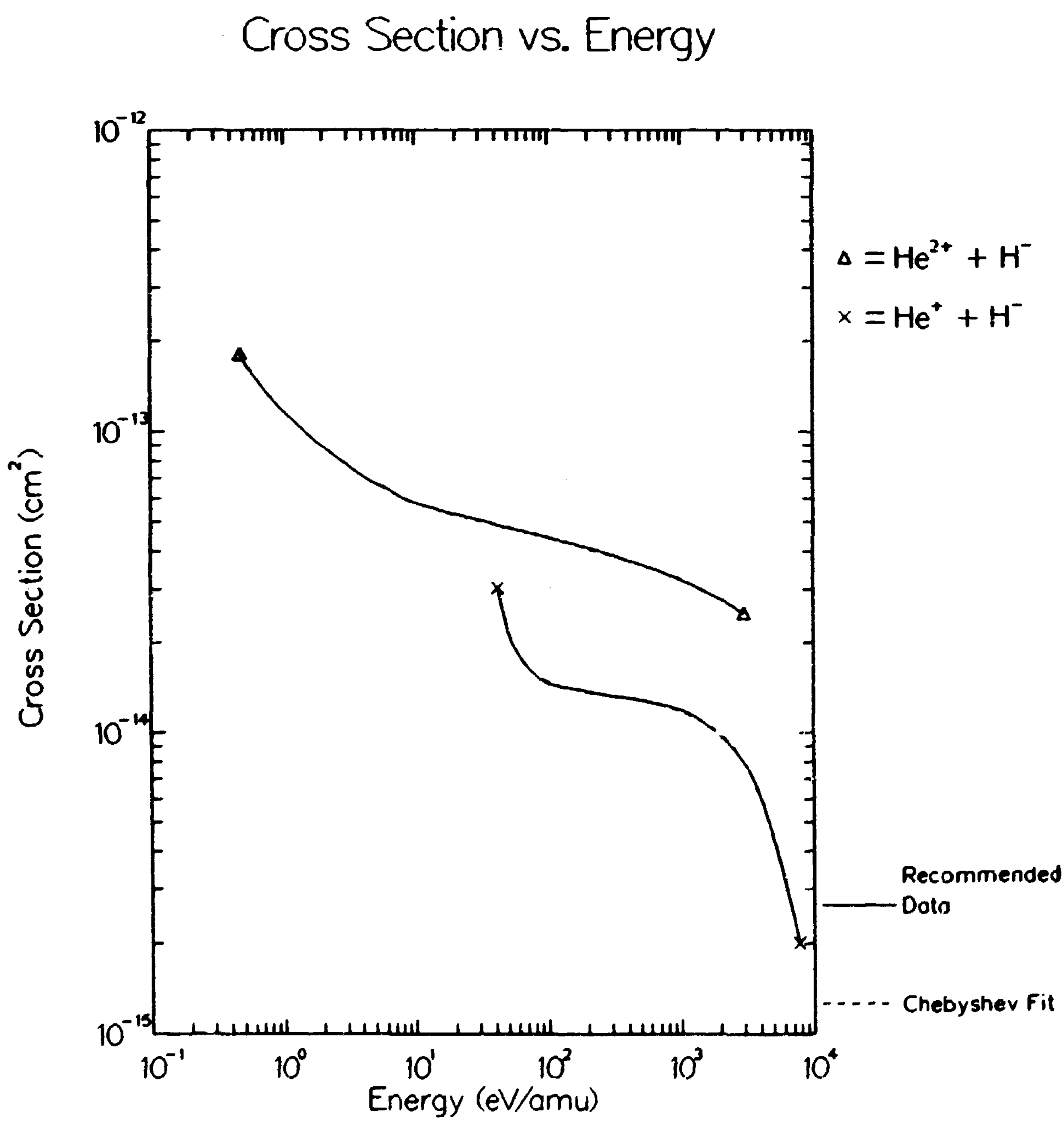
	A0	A1	A2	A3	A4	A5	A6	A7	A8
($He^{2+} + H^-$)	-61.0067	-.855510	.155087	-.126012	.0124474	-6.60133E-04	-7.30771E-04	-.00636246	.00615254
($He^+ + H^-$)	-64.4915	-.959186	-.269411	-.331423	-.00745857	-.0611579	.0257220	-.00396428	.0113568

The fit represents the $He^{2+} + H^-$ cross section with an rms deviation of 0.4%.
The maximum deviation is 0.8% at 5.0E-01 eV/amu.

The fit represents the $He^+ + H^-$ cross section with an rms deviation of 0.6%.
The maximum deviation is 1.2% at 1.0E+02 eV/amu.

See appendix for Chebyshev fit details.

$He^{q+} + H^{-} \rightarrow He^{(q-1)+} + H \; (q=1,2)$



Electron Capture Cross Sections for
$He^{2+} + H \rightarrow He^{+} + H^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
7.0E+01	1.16E+07	1.25E-20
1.0E+02	1.39E+07	2.20E-19
2.0E+02	1.96E+07	3.10E-18
4.0E+02	2.78E+07	1.90E-17
5.0E+02	3.11E+07	3.24E-17
7.0E+02	3.68E+07	8.67E-17
1.0E+03	4.39E+07	1.87E-16
2.0E+03	6.21E+07	5.96E-16
4.0E+03	8.79E+07	9.74E-16
7.0E+03	1.16E+08	1.18E-15
1.0E+04	1.39E+08	1.22E-15
2.0E+04	1.96E+08	1.09E-15
4.0E+04	2.78E+08	5.28E-16
7.0E+04	3.68E+08	1.59E-16
1.0E+05	4.39E+08	5.23E-17
2.0E+05	6.21E+08	4.63E-18
4.0E+05	8.78E+08	2.64E-19
5.0E+05	9.82E+08	1.15E-19

References: 5, 7, 21, 22, 23, 24, 25, 57, 58

Accuracy: He^{2+} E < 600 eV/amu - unknown; He^{2+} E > 600 eV/amu - 20%

Notes: (1) At energies less than 2 keV/amu the results of Fite et al. (Ref. 5) and Nutt et al. (Ref. 23) diverge by as much as a factor of 10. This is believed to be due to the fact that the results reported by Fite et al. were obtained by measuring the slow ions produced in the collision, and are less reliable than those of Nutt et al at low energies.
(2) No experimental data exist below 500 eV/amu. Cross sections below 500 eV/amu were taken from calculations of Ref. 57 and 58 using multi-state close coupling methods.

For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 7.0E+01 eV/amu, E_{max} = 5.0E+05 eV/amu

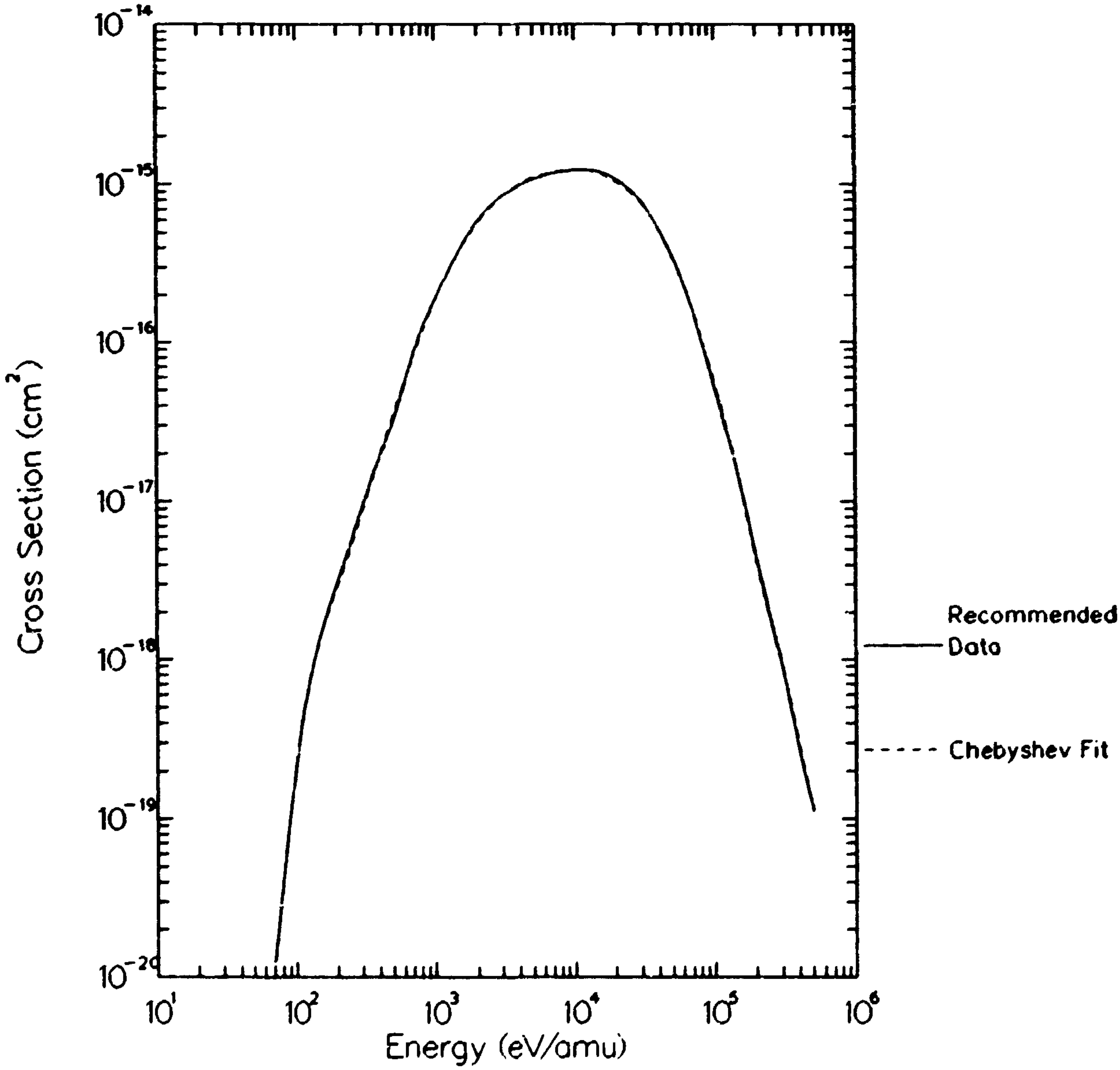
Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-78.3976	.773499	-5.12346	-.125575	-.232331	.261317	-.0479652	.189434	-.138708

The fit represents the above cross sections with an rms deviation of 3.9%.
The maximum deviation is 7.6% at 5.0E+02 eV/amu.
See appendix for Chebyshev fit details.

$He^{2+} + H \rightarrow He^{+} + H^{+}$

Cross Section vs. Energy



Electron Capture Rate Coefficients for $He^{2+} + H \rightarrow He^{+} + H^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

He^{2+} Temp. (eV)	Equal Temp.	H Temp. (eV) 10.	100.	500.	1000.	5000.	10000.	20000.
2.0E+01	6.28E-13	4.12E-14	1.22E-10	7.36E-09	2.36E-08	1.14E-07	1.47E-07	1.42E-07
4.0E+01	1.04E-11	2.09E-13	1.42E-10	7.50E-09	2.38E-08	1.14E-07	1.47E-07	1.42E-07
7.0E+01	6.86E-11	9.71E-13	1.74E-10	7.72E-09	2.40E-08	1.14E-07	1.47E-07	1.42E-07
1.0E+02	2.10E-10	2.70E-12	2.10E-10	7.94E-09	2.43E-08	1.14E-07	1.47E-07	1.42E-07
2.0E+02	1.49E-09	1.97E-11	3.63E-10	8.68E-09	2.51E-08	1.14E-07	1.47E-07	1.42E-07
4.0E+02	7.21E-09	1.42E-10	8.23E-10	1.02E-08	2.68E-08	1.15E-07	1.47E-07	1.42E-07
7.0E+02	1.92E-08	6.63E-10	1.89E-09	1.26E-08	2.93E-08	1.16E-07	1.47E-07	1.42E-07
1.0E+03	3.18E-08	1.65E-09	3.37E-09	1.50E-08	3.18E-08	1.17E-07	1.47E-07	1.42E-07
2.0E+03	6.80E-08	7.50E-09	1.02E-08	2.34E-08	3.99E-08	1.19E-07	1.48E-07	1.41E-07
4.0E+03	1.13E-07	2.38E-08	2.68E-08	3.99E-08	5.48E-08	1.25E-07	1.49E-07	1.40E-07
7.0E+03	1.43E-07	4.78E-08	5.05E-08	6.16E-08	7.40E-08	1.31E-07	1.49E-07	1.39E-07
1.0E+04	1.50E-07	6.83E-08	7.05E-08	7.97E-08	8.98E-08	1.36E-07	1.50E-07	1.37E-07
2.0E+04	1.32E-07	1.14E-07	1.15E-07	1.19E-07	1.25E-07	1.47E-07	1.49E-07	1.32E-07

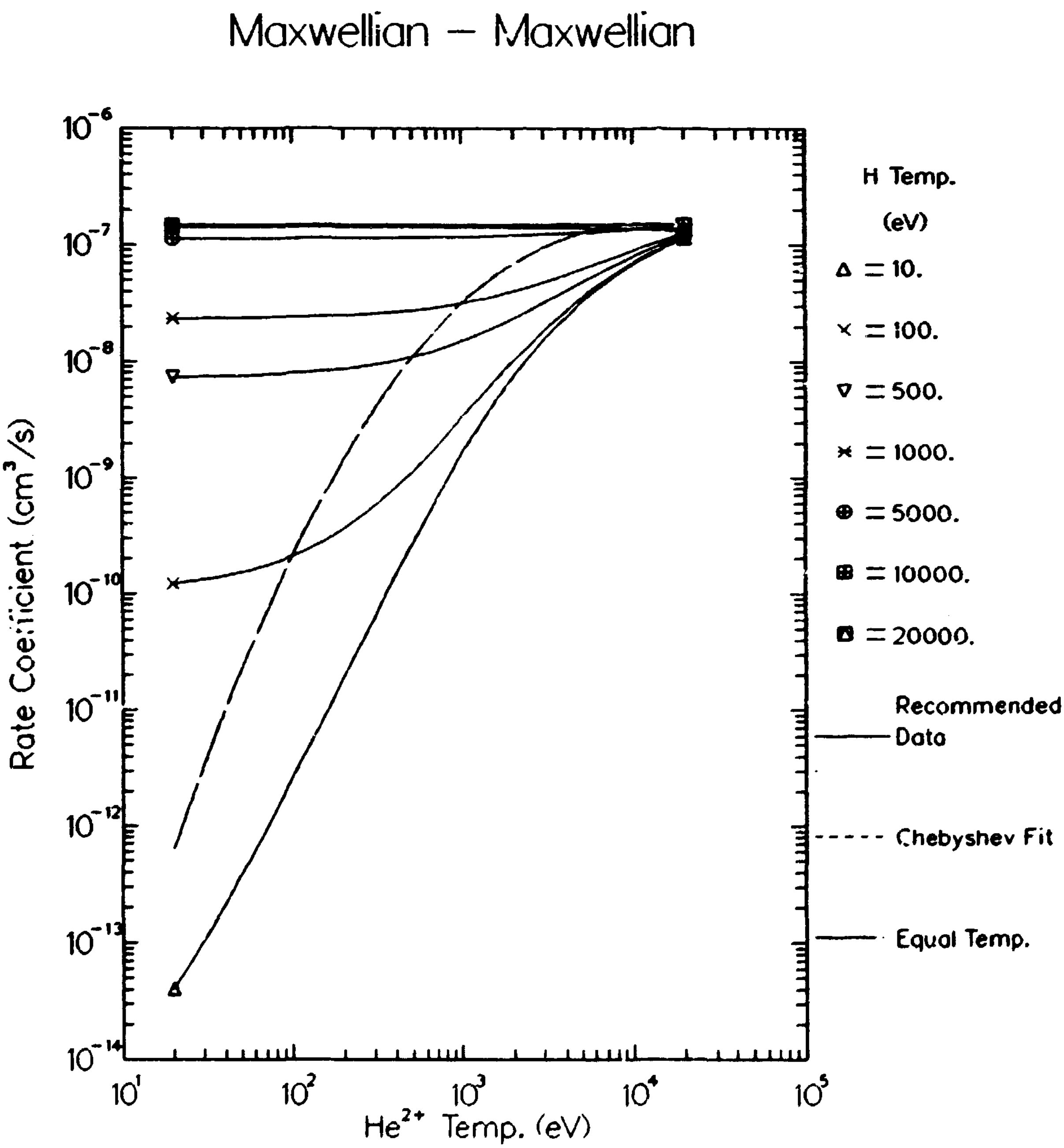
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 2.0E+01 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

H Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
10.	-4.49742E+01	7.78326E+00	-1.00928E+00	-3.95746E-01	8.29111E-02	3.18952E-02	5.49793E-03
100.	-3.94867E+01	3.76780E+00	4.07631E-01	-4.05432E-01	-7.75944E-02	6.09541E-02	1.07817E-02
500.	-3.54181E+01	1.44543E+00	4.43041E-01	-3.74033E-02	-7.53578E-02	-1.52405E-02	7.25877E-03
1000.	-3.40218E+01	8.22262E-01	3.19564E-01	2.78648E-02	-3.66721E-02	-1.86208E-02	-1.77688E-03
5000.	-3.18356E+01	1.16105E-01	5.74535E-02	1.52669E-02	-1.09084E-03	-3.28066E-03	-1.76834E-03
10000.	-3.14549E+01	1.12080E-02	3.75806E-03	-1.00216E-03	-2.02657E-03	-1.36406E-03	-6.16274E-04
20000.	-3.15643E+01	-2.69513E-02	-1.69052E-02	-8.31717E-03	-3.31404E-03	-1.08242E-03	-2.94451E-04
Equal Temp.	-3.99202E+01	6.04131E+00	-1.99447E+00	9.39512E-02	1.34081E-02	-1.22695E-02	-2.34071E-02

See appendix for Chebyshev fit details.

$He^{2+} + H \rightarrow He^{+} + H^{+}$



Electron Capture Rate Coefficients for
$H + He^{2+} \rightarrow He^{+} + H^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{2+} Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	400000.
1.0E+00	1.69E-07	2.14E-07	1.46E-07	5.84E-08	2.30E-08	2.88E-09*	2.32E-10**
2.0E+00	1.69E-07	2.14E-07	1.46E-07	5.83E-08	2.30E-08	2.87E-09*	2.32E-10**
4.0E+00	1.69E-07	2.13E-07	1.46E-07	5.83E-08	2.30E-08	2.87E-09*	2.32E-10**
7.0E+00	1.69E-07	2.13E-07	1.46E-07	5.83E-08	2.30E-08	2.87E-09*	2.32E-10**
1.0E+01	1.69E-07	2.13E-07	1.46E-07	5.82E-08	2.30E-08	2.87E-09*	2.32E-10**
2.0E+01	1.69E-07	2.12E-07	1.46E-07	5.82E-08	2.29E-08	2.87E-09*	2.32E-10**
4.0E+01	1.69E-07	2.12E-07	1.45E-07	5.81E-08	2.29E-08	2.87E-09*	2.32E-10**
7.0E+01	1.69E-07	2.11E-07	1.45E-07	5.80E-08	2.29E-08	2.87E-09*	2.32E-10**
1.0E+02	1.68E-07	2.10E-07	1.44E-07	5.79E-08	2.29E-08	2.87E-09*	2.32E-10**
2.0E+02	1.68E-07	2.09E-07	1.44E-07	5.77E-08	2.29E-08	2.87E-09*	2.33E-10**
4.0E+02	1.68E-07	2.07E-07	1.42E-07	5.75E-08	2.30E-08	2.87E-09*	2.33E-10**
7.0E+02	1.68E-07	2.04E-07	1.41E-07	5.73E-08	2.30E-08	2.87E-09*	2.34E-10**
1.0E+03	1.67E-07	2.03E-07	1.40E-07	5.72E-08	2.31E-08	2.87E-09*	2.35E-10**
2.0E+03	1.67E-07	1.98E-07	1.38E-07	5.71E-08	2.34E-08	2.89E-09*	2.37E-10**
4.0E+03	1.67E-07	1.92E-07	1.35E-07	5.74E-08	2.43E-08	2.94E-09	2.41E-10**
7.0E+03	1.66E-07	1.84E-07	1.32E-07	5.79E-08	2.48E-08	3.02E-09	2.46E-10**
1.0E+04	1.65E-07	1.78E-07	1.29E-07	5.85E-08	2.56E-08	3.10E-09	2.50E-10**
2.0E+04	1.61E-07	1.62E-07	1.20E-07	5.95E-08	2.79E-08	3.45E-09	2.65E-10**

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

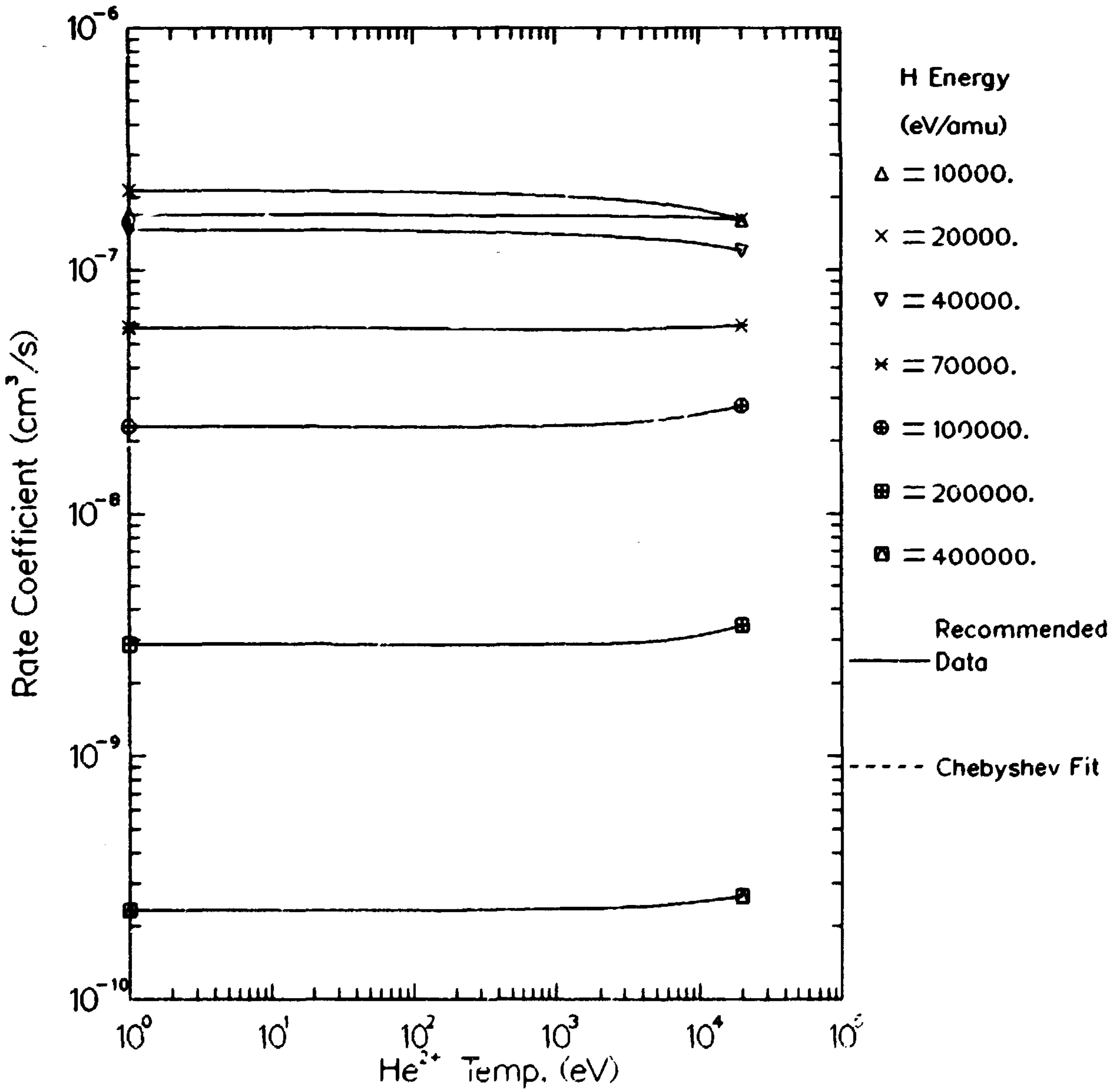
Chebyshev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-3.12062E+01	-1.74693E-02	-8.09939E-03	-4.73707E-03	-3.77313E-03	-2.52573E-03	-1.15127E-03
20000.	-3.08555E+01	-1.09982E-01	-5.81296E-02	-2.43325E-02	-9.22165E-03	-3.45740E-03	-1.26420E-03
40000.	-3.15751E+01	-7.97039E-02	-4.01409E-02	-1.65010E-02	-6.97466E-03	-3.39246E-03	-1.78170E-03
70000.	-3.33202E+01	3.45964E-04	1.03619E-02	9.16031E-03	3.80511E-03	1.91641E-04	-1.02574E-03
100000.	-3.51051E+01	6.70775E-02	4.92944E-02	2.76338E-02	1.12857E-02	2.98288E-03	1.23487E-05
200000.	-3.92776E+01	5.41764E-02	4.43066E-02	2.88380E-02	1.56821E-02	6.68430E-03	2.77948E-03
400000.	-4.43133E+01	4.82448E-02	3.15762E-02	1.67996E-02	7.00532E-03	2.75553E-03	5.24833E-04

See appendix for Chebyshev fit details.

$H + He^{2+} \rightarrow He^{+} + H^{+}$

Beam – Maxwellian



Electron Capture Cross Sections for
$He^{2+} + H_2 \rightarrow He^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.4E+02	1.64E+07	3.70E-17
1.7E+02	1.81E+07	5.83E-17
2.0E+02	1.96E+07	7.31E-17
2.6E+02	2.24E+07	8.77E-17
4.0E+02	2.78E+07	1.07E-16
7.0E+02	3.68E+07	1.32E-16
1.0E+03	4.39E+07	1.52E-16
2.0E+03	6.21E+07	2.20E-16
4.0E+03	8.79E+07	4.12E-16
7.0E+03	1.16E+08	6.41E-16
1.0E+04	1.39E+08	8.01E-16
2.0E+04	1.96E+08	1.07E-15
4.0E+04	2.78E+08	7.23E-16
7.0E+04	3.68E+08	3.13E-16
1.0E+05	4.39E+08	1.39E-16
2.0E+05	6.21E+08	1.46E-17
4.0E+05	8.78E+08	1.02E-18
7.0E+05	1.16E+09	9.04E-20
1.0E+06	1.39E+09	1.63E-20

References: 7, 22, 23, 24, 90, 91, 92, 93, 94, 95, 101, 142

Accuracy: 20%

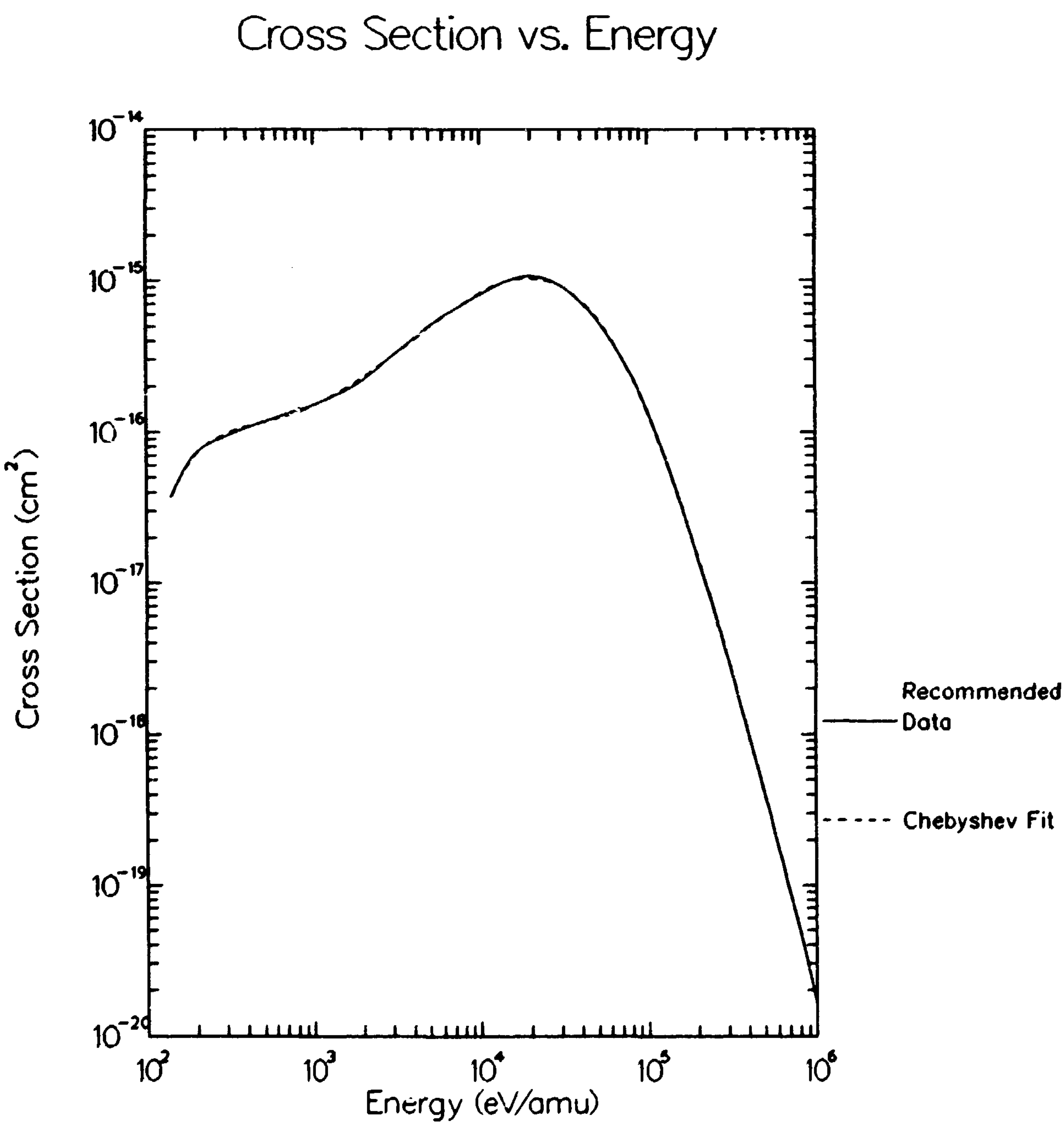
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.4E+02 eV/amu, E_{max} = 1.0E+06 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-76.3856	-3.05275	-3.46462	-1.13751	.0656712	.340604	-.0614851	-.0248706	-.0398477

The fit represents the above cross sections with an rms deviation of 2.2%.
The maximum deviation is 4.1% at 2.0E+03 eV/amu.
See appendix for Chebyshev fit details.

$He^{2+} + H_2 \rightarrow He^{+}$



Double Electron Capture Cross Sections for
$He^{2+} + H_2 \rightarrow He + 2H^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
3.0E+02	2.41E+07	3.68E-17
4.0E+02	2.78E+07	6.05E-17
5.6E+02	3.29E+07	7.02E-17
7.0E+02	3.68E+07	6.63E-17
1.0E+03	4.39E+07	4.70E-17
2.0E+03	6.21E+07	1.34E-17
2.7E+03	7.22E+07	1.20E-17
4.0E+03	8.79E+07	1.56E-17
7.0E+03	1.16E+08	2.75E-17
1.0E+04	1.39E+08	3.74E-17
2.0E+04	1.96E+08	5.51E-17
2.3E+04	2.11E+08	5.71E-17
4.0E+04	2.78E+08	3.84E-17
7.0E+04	3.68E+08	9.91E-18
1.0E+05	4.39E+08	3.33E-18
2.0E+05	6.21E+08	1.62E-19
3.7E+05	8.45E+08	3.88E-21

References: 7, 22, 27, 90, 91, 92, 93, 94, 95

Accuracy: $E < 2.5\times10^3$ eV/amu - unknown; 2.5×10^3 eV/amu $< E < 1\times10^5$ eV/amu - 40%; $E > 1\times10^5$ eV/amu - 50%

For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 3.0E+02 eV/amu, E_{max} = 3.7E+05 eV/amu

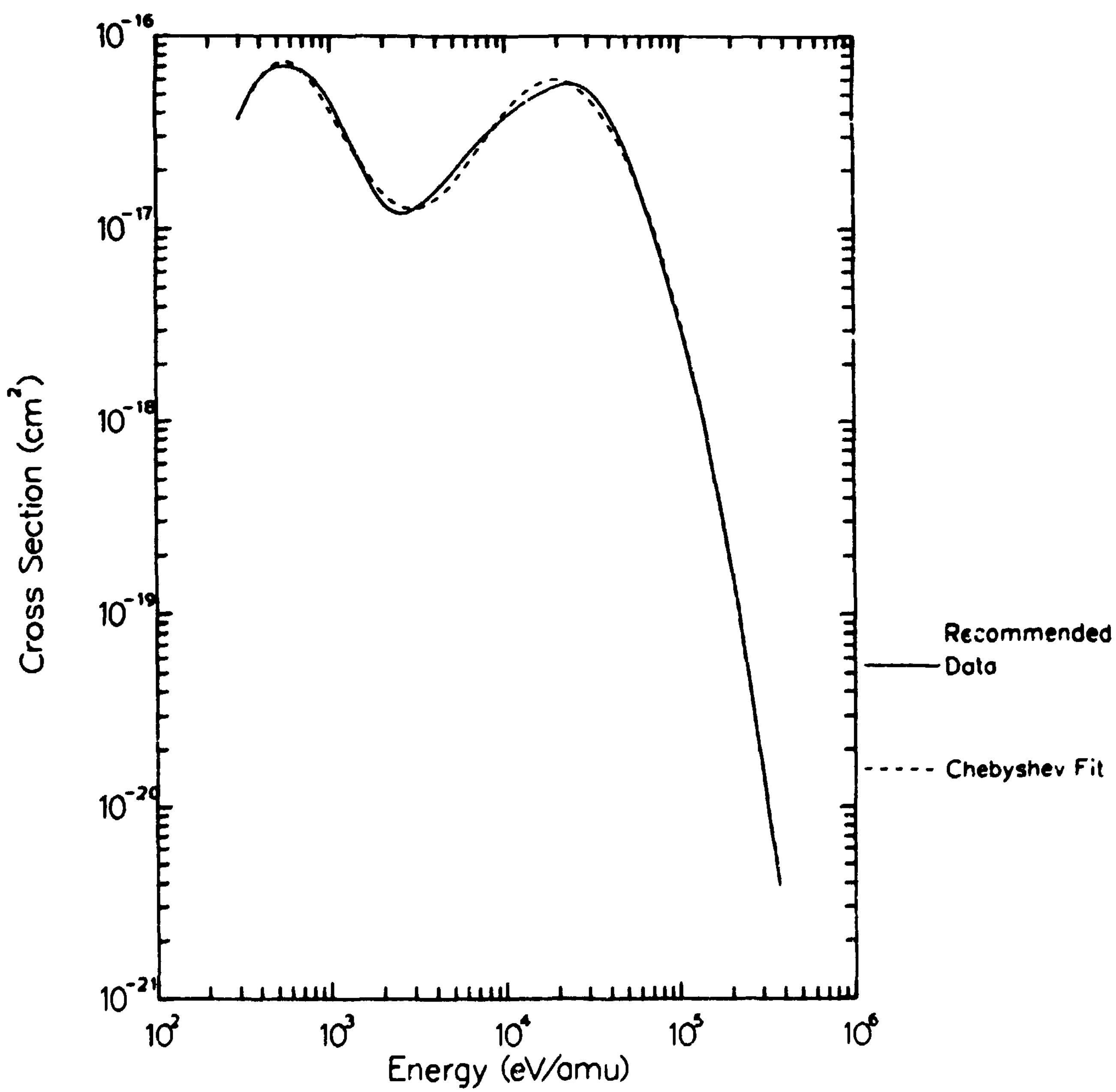
Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-79.5999	-3.55036	-2.20554	-1.45406	-.357248	.498461	-.146918	-.0680202	.0918861

The fit represents the above cross sections with an rms deviation of 6.8%.
The maximum deviation is 12.8% at 2.0E+03 eV/amu.
See appendix for Chebyshev fit details.

$He^{2+} + H_2 \rightarrow He + 2H^+$

Cross Section vs. Energy



Electron Capture Cross Sections for:
$He^{2+} + He \rightarrow He^{+} + He^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.4E-04	2.15E+04	1.39E-18
4.0E-04	2.78E+04	9.33E-19
1.0E-03	4.39E+04	5.95E-19
4.0E-03	8.79E+04	3.01E-19
1.0E-02	1.39E+05	1.90E-19
4.0E-02	2.78E+05	8.18E-20
1.0E-01	4.39E+05	5.26E-20
4.0E-01	8.79E+05	3.05E-20
7.0E-01	1.16E+06	2.54E-20
1.0E+00	1.39E+06	2.29E-20
1.6E+00	1.76E+06	2.21E-20
4.0E+00	2.78E+06	3.66E-20
1.0E+01	4.39E+06	1.07E-19
4.0E+01	8.79E+06	5.15E-19
1.0E+02	1.39E+07	1.44E-18
4.0E+02	2.78E+07	6.58E-18
1.0E+03	4.39E+07	1.75E-17
4.0E+03	8.79E+07	6.42E-17
1.0E+04	1.39E+08	1.52E-16
2.0E+04	1.96E+08	2.72E-16
4.0E+04	2.78E+08	3.03E-16
7.0E+04	3.68E+08	1.89E-16
1.0E+05	4.39E+08	1.11E-16
4.0E+05	8.78E+08	3.94E-18
7.0E+05	1.16E+09	3.61E-19
1.0E+06	1.39E+09	6.99E-20
2.0E+06	1.96E+09	3.33E-21

References: 90, 91, 92, 94, 97, 117, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 265, 266, 282

Accuracy: E < 250 eV/amu - see notes; E > 250 eV/amu - 20%

Notes: (1) The data for energies less than 250 eV/amu have been obtained using the theoretical results of Cohen and Bardsley (Ref. 149). From 250 eV/amu the data have been extrapolated down to 2.5 eV/amu to join smoothly with the theoretical results.
(2) Johnson et al. (Ref. 265) have measured the rate coefficient to be 4.8×10^{-14} cm^3/s at a temperature of 300 K.
(3) Theoretical values of the rate coefficient of Bardsley et al. (Ref. 266) are: T=100 K, k=4.43×10^{-14} cm^3/s; 300 K, 4.24×10^{-14} cm^3/s; 600 K, 4.02×10^{-14} cm^3/s; 1000 K, 3.79×10^{-14} cm^3/s; 3000 K, 3.25×10^{-14} cm^3/s.

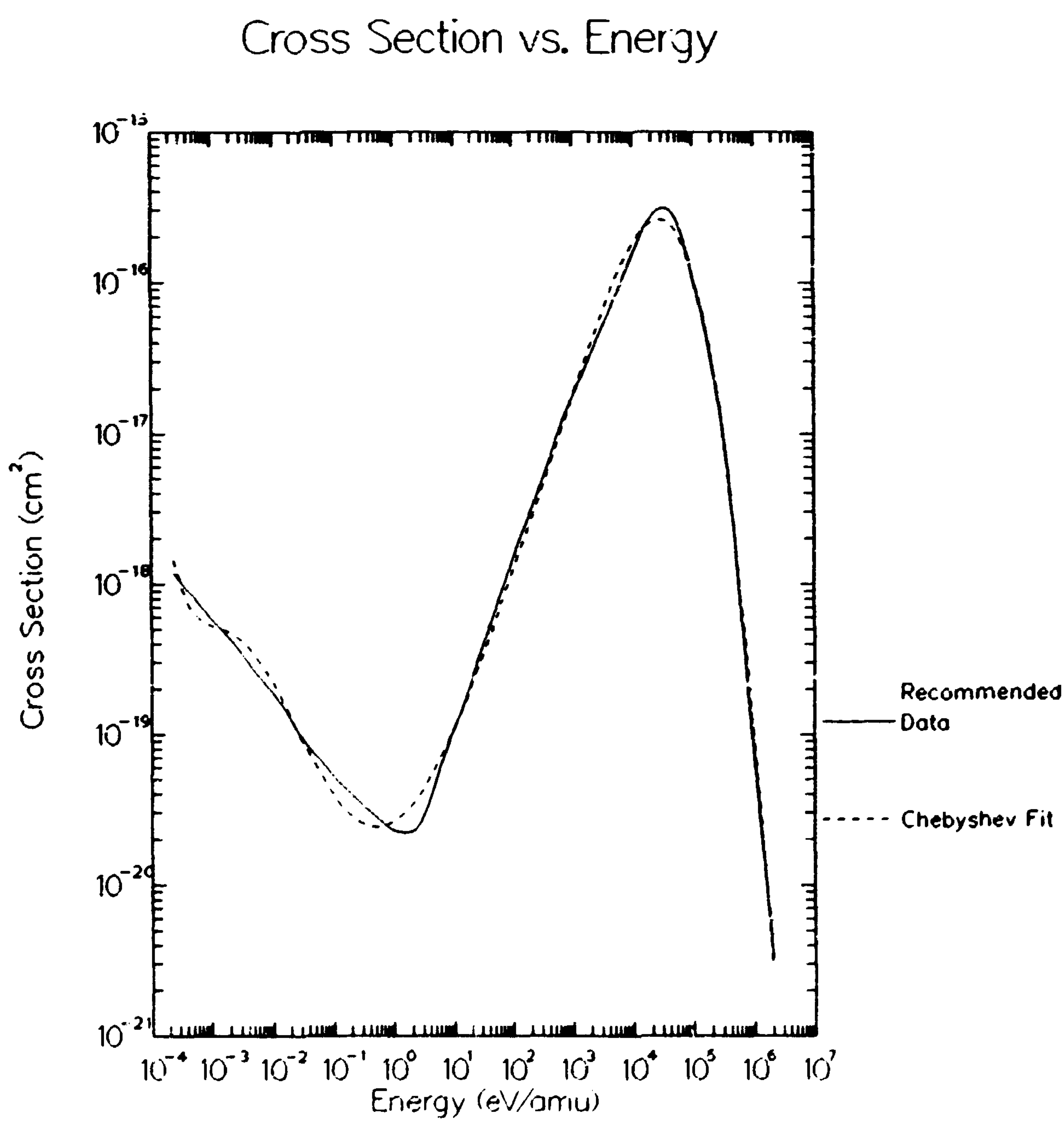
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.4E-04 eV/amu, E_{max} = 2.0E+06 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-83.5447	.758421	-.673803	-3.68088	-2.02719	-.148166	.0237951	-.0738396	.243993

The fit represents the above cross sections with an rms deviation of 19.9%.
The maximum deviation is 52.7% at 2.0E+00 eV/amu.
See appendix for Chebyshev fit details.

$He^{2+} + He \rightarrow He^{+} + He^{+}$



Electron Capture Rate Coefficients for
$He^{2+} + He \rightarrow He^{+} + He^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

He^{2+} Temp. (eV)	Equal Temp.	He Temp. (eV) 1.	100.	500.	1000.	5000.	10000.	20000.
1.0E+00	3.05E-14	3.05E-14	5.38E-12	7.10E-11	2.12E-10	2.25E-09	6.04E-09	1.55E-08
2.0E+00	4.41E-14	3.61E-14	5.46E-12	7.13E-11	2.12E-10	2.25E-09	6.04E-09	1.55E-08
4.0E+00	9.66E-14	5.44E-14	5.64E-12	7.17E-11	2.13E-10	2.25E-09	6.04E-09	1.55E-08
7.0E+00	2.21E-13	9.66E-14	5.90E-12	7.24E-11	2.14E-10	2.25E-09	6.05E-09	1.55E-08
1.0E+01	3.88E-13	1.53E-13	6.17E-12	7.31E-11	2.15E-10	2.26E-09	6.05E-09	1.55E-08
2.0E+01	1.19E-12	4.20E-13	7.11E-12	7.54E-11	2.18E-10	2.26E-09	6.06E-09	1.55E-08
4.0E+01	3.68E-12	1.24E-12	9.12E-12	8.01E-11	2.25E-10	2.27E-09	6.07E-09	1.55E-08
7.0E+01	9.12E-12	3.03E-12	1.25E-11	8.74E-11	2.35E-10	2.29E-09	6.10E-09	1.55E-08
1.0E+02	1.62E-11	5.38E-12	1.62E-11	9.48E-11	2.45E-10	2.31E-09	6.13E-09	1.56E-08
2.0E+02	4.94E-11	1.63E-11	3.11E-11	1.21E-10	2.79E-10	2.38E-09	6.21E-09	1.57E-08
4.0E+02	1.50E-10	4.96E-11	7.08E-11	1.80E-10	3.52E-10	2.51E-09	6.38E-09	1.59E-08
7.0E+02	3.52E-10	1.21E-10	1.50E-10	2.79E-10	4.71E-10	2.71E-09	6.64E-09	1.61E-08
1.0E+03	5.98E-10	2.12E-10	2.45E-10	3.91E-10	5.98E-10	2.92E-09	6.91E-09	1.64E-08
2.0E+03	1.63E-09	5.98E-10	6.42E-10	8.28E-10	1.08E-09	3.64E-09	7.80E-09	1.74E-08
4.0E+03	4.40E-09	1.63E-09	1.69E-09	1.93E-09	2.25E-09	5.20E-09	9.66E-09	1.93E-08
7.0E+03	9.66E-09	3.64E-09	3.71E-09	4.01E-09	4.40E-09	7.80E-09	1.25E-08	2.21E-08
1.0E+04	1.55E-08	6.04E-09	6.13E-09	6.47E-09	6.91E-09	1.06E-08	1.55E-08	2.48E-08
2.0E+04	3.28E-08	1.55E-08	1.56E-08	1.59E-08	1.64E-08	2.03E-08	2.48E-08	3.28E-08

Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

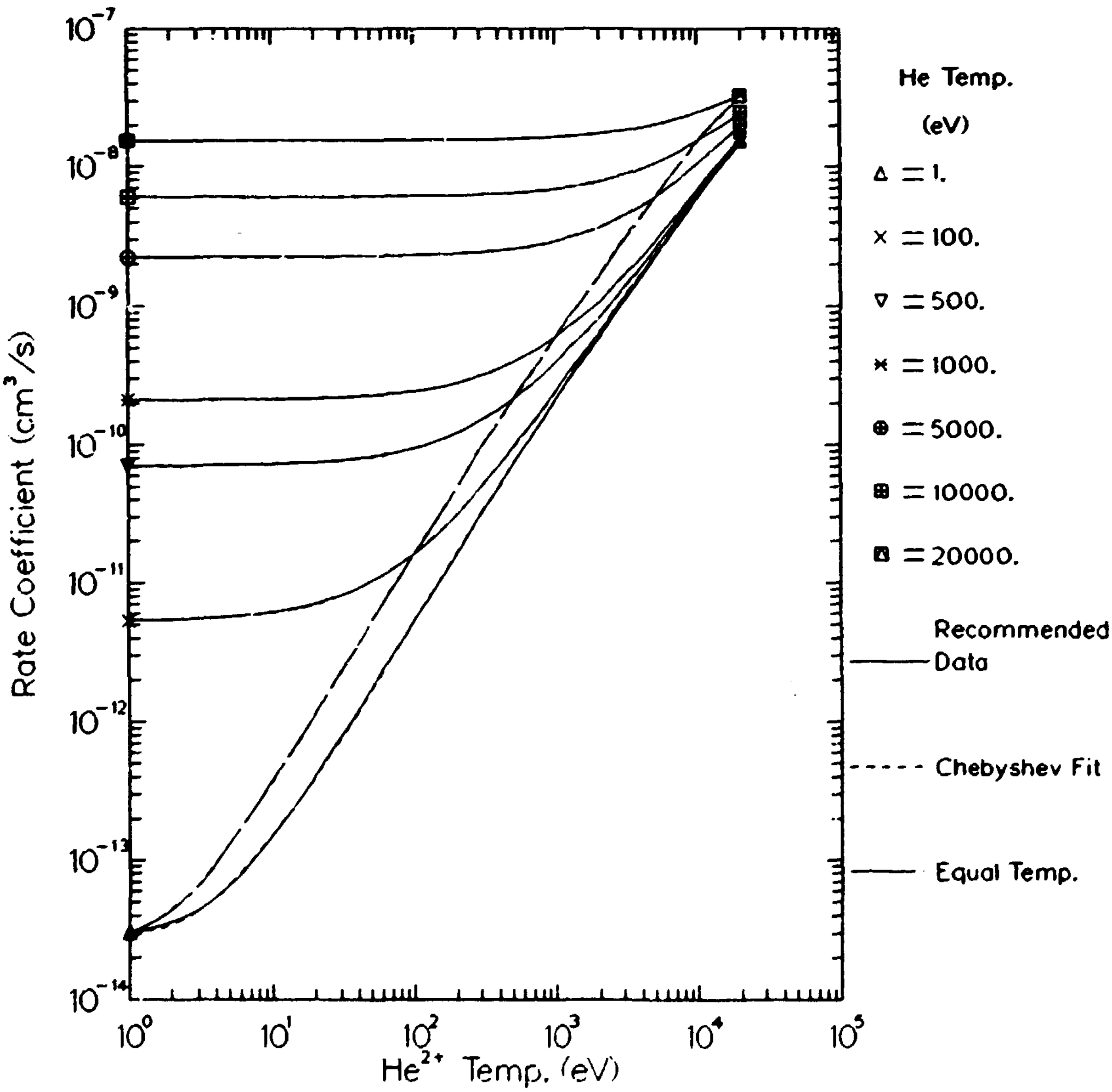
Chebyshev Fitting Parameters for Rate Coefficients

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A5
1.	-5.01963E+01	6.98068E+00	4.23808E-01	-3.99615E-01	1.34075E-01	-2.04534E-02	-6.31634E-03
100.	-4.61698E+01	4.09338E+00	1.25172E+00	-1.33442E-01	-1.61511E-01	2.93643E-02	3.24079E-02
500.	-4.34226E+01	2.58703E+00	1.14624E+00	1.66058E-01	-1.03603E-01	-4.97857E-02	9.07394E-03
1000.	-4.20905E+01	1.98401E+00	1.00005E+00	2.44794E-01	-4.33832E-02	-5.53954E-02	-1.11309E-02
5000.	-3.87801E+01	8.37534E-01	5.45829E-01	2.27039E-01	4.75018E-02	-1.20021E-02	-1.64614E-02
10000.	-3.72149E+01	5.46062E-01	3.51272E-01	1.61982E-01	4.68205E-02	1.29171E-03	-8.13292E-03
20000.	-3.56466E+01	2.80620E-01	1.85602E-01	9.16706E-02	3.15681E-02	5.20354E-03	-2.25604E-03
Equal Temp.	-4.86572E+01	7.31907E+00	4.09101E-02	-2.98991E-01	1.03426E-01	-6.77656E-02	6.42732E-03

See appendix for Chebyshev fit details.

$He^{2+} + He \rightarrow He^{+} + He^{+}$

Maxwellian – Maxwellian



Electron Capture Rate Coefficients for
$He + He^{2+} \rightarrow He^{+} + He^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{2+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	2.50E-08	5.92E-08	8.41E-08	6.94E-08	4.87E-08	1.84E-08	1.49E-09
2.0E+00	2.15E-08	5.40E-08	8.40E-08	6.94E-08	4.87E-08	1.84E-08	1.49E-09
4.0E+00	2.11E-08	5.33E-08	8.40E-08	6.94E-08	4.87E-08	1.84E-08	1.49E-09
7.0E+00	2.11E-08	5.33E-08	8.39E-08	6.93E-08	4.87E-08	1.84E-08	1.49E-09
1.0E+01	2.11E-08	5.33E-08	8.39E-08	6.93E-08	4.87E-08	1.83E-08	1.49E-09
2.0E+01	2.11E-08	5.32E-08	8.38E-08	6.92E-08	4.87E-08	1.83E-08	1.49E-09
4.0E+01	2.11E-08	5.31E-08	8.36E-08	6.92E-08	4.86E-08	1.83E-08	1.49E-09
7.0E+01	2.11E-08	5.30E-08	8.34E-08	6.91E-08	4.86E-08	1.83E-08	1.49E-09
1.0E+02	2.12E-08	5.30E-08	8.33E-08	6.90E-08	4.86E-08	1.83E-08	1.49E-09
2.0E+02	2.13E-08	5.29E-08	8.29E-08	6.88E-08	4.85E-08	1.82E-08	1.49E-09
4.0E+02	2.15E-08	5.28E-08	8.23E-08	6.85E-08	4.84E-08	1.82E-08	1.50E-09
7.0E+02	2.19E-08	5.27E-08	8.18E-08	6.82E-08	4.84E-08	1.81E-08	1.50E-09
1.0E+03	2.22E-08	5.28E-08	8.13E-08	6.80E-08	4.83E-08	1.81E-08	1.50E-09
2.0E+03	2.35E-08	5.31E-08	8.01E-08	6.74E-08	4.82E-08	1.80E-08	1.51E-09
4.0E+03	2.60E-08	5.38E-08	7.84E-08	6.66E-08	4.80E-08	1.79E-08	1.53E-09
7.0E+03	2.93E-08	5.47E-08	7.63E-08	6.56E-08	4.78E-08	1.78E-08	1.56E-09
1.0E+04	3.22E-08	5.55E-08	7.47E-08	6.47E-08	4.76E-08	1.78E-08	1.58E-09
2.0E+04	3.96E-08	5.70E-08	7.03E-08	6.19E-08	4.68E-08	1.79E-08	1.67E-09

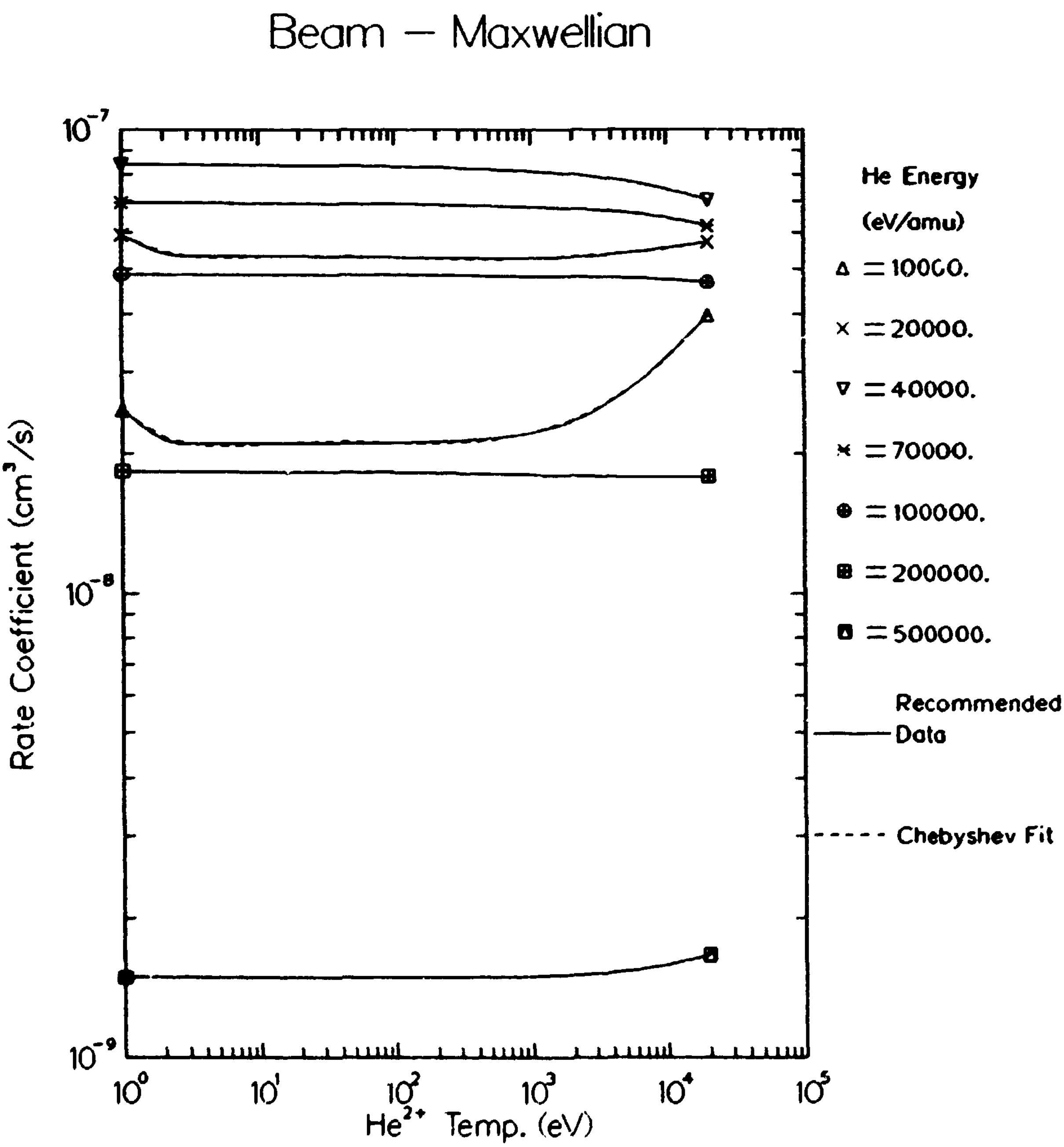
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-3.50304E+01	2.06181E-01	1.92296E-01	4.56411E-02	4.15838E-02	-1.64172E-02	5.89475E-03
20000.	-3.34502E+01	-1.69065E-03	4.25743E-02	-4.85577E-03	1.65855E-02	-1.02931E-02	4.96346E-03
40000.	-3.26729E+01	-7.16579E-02	-3.83983E-02	-1.62201E-02	-5.97032E-03	-1.96773E-03	-5.29171E-04
70000.	-3.30216E+01	-4.42089E-02	-2.40130E-02	-1.09682E-02	-4.88645E-03	-2.28859E-03	-1.09577E-03
100000.	-3.36938E+01	-1.54667E-02	-7.60687E-03	-3.31747E-03	-1.90471E-03	-1.15086E-02	-7.19346E-04
200000.	-3.56481E+01	-1.62738E-02	-3.50236E-03	1.52811E-03	2.39339E-03	1.00308E-03	6.34282E-04
500000.	-4.06040E+01	3.82554E-02	2.68882E-02	1.51307E-02	6.78931E-03	2.33434E-03	4.95076E-04

See appendix for Chebyshev fit details.

$He + He^{2+} \rightarrow He^{+} + He^{+}$



Double Electron Capture Cross Sections for
He^{2+} + He -> He + He^{2+}

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
7.0E+00	3.68E+06	4.62E-16
1.0E+01	4.39E+06	4.48E-16
2.0E+01	6.21E+06	4.10E-16
4.0E+01	8.79E+06	3.83E-16
7.0E+01	1.16E+07	3.58E-16
1.0E+02	1.39E+07	3.44E-16
2.0E+02	1.96E+07	3.19E-16
4.0E+02	2.78E+07	2.88E-16
7.0E+02	3.68E+07	2.62E-16
1.0E+03	4.39E+07	2.44E-16
2.0E+03	6.21E+07	2.10E-16
4.0E+03	8.79E+07	1.73E-16
7.0E+03	1.16E+08	1.46E-16
1.0E+04	1.39E+08	1.29E-16
2.0E+04	1.96E+08	9.68E-17
4.0E+04	2.78E+08	6.08E-17
7.0E+04	3.68E+08	2.73E-17
1.0E+05	4.39E+08	9.83E-18
2.0E+05	6.21E+08	6.36E-19
4.0E+05	8.78E+08	2.09E-20

References: 90, 91, 92, 94, 140, 144, 145, 148, 150, 151, 152, 153, 282

Accuracy: 20% throughout the energy range

Note: (1) The data below 100 eV/amu are theoretical data of reference 153 (Ferguson and Moiseiwitsch).

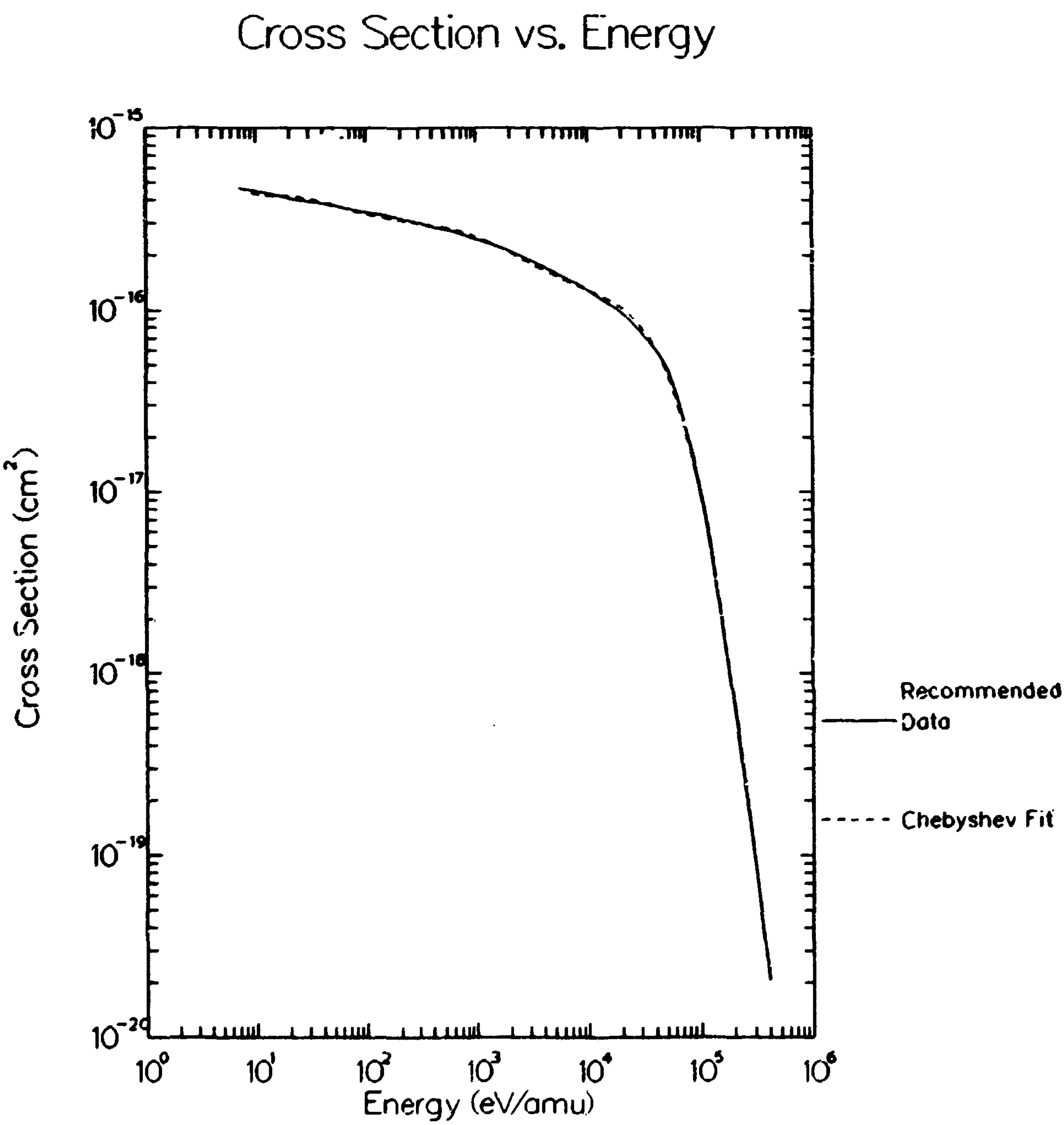
For a Chebyshev fit of the above cross section it is necessary to use the following parameters.
E_{min} = 7.0E+00 eV/amu, E_{max} = 4.0E+05 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-75.3410	-3.70255	-2.16467	-1.23660	-.590825	-.179613	.0396927	.102768	.0774058

The fit represents the above cross sections with an rms deviation of 3.2%.
The maximum deviation is 6.8% at 2.0E+04 eV/amu.
See appendix for Chebyshev fit details.

$He^{2+} + He \rightarrow He + He^{2+}$



Double Electron Capture Rate Coefficients for He^{2+} + He -> He + He^{2+}

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

He^{2+} Temp. (eV)	Equal Temp.	He Temp. (eV) 1.	100.	500.	1000.	5000.	10000.	20000.
2.0E+00	5.21E-12	5.68E-13	2.92E-09	5.58E-09	7.14E-09	1.17E-08	1.38E-08	1.57E-08
4.0E+00	1.36E-10	1.94E-11	2.94E-09	5.58E-09	7.15E-09	1.17E-08	1.38E-08	1.57E-08
7.0E+00	5.25E-10	1.36E-10	2.98E-09	5.60E-09	7.16E-09	1.17E-08	1.38E-08	1.57E-08
1.0E+01	8.99E-10	3.22E-10	3.02E-09	5.61E-09	7.16E-09	1.17E-08	1.38E-08	1.57E-08
2.0E+01	1.73E-09	9.54E-10	3.14E-09	5.65E-09	7.19E-09	1.17E-08	1.38E-08	1.57E-08
4.0E+01	2.60E-09	1.76E-09	3.36E-09	5.73E-09	7.24E-09	1.17E-08	1.38E-08	1.57E-08
7.0E+01	3.36E-09	2.45E-09	3.65E-09	5.84E-09	7.31E-09	1.17E-08	1.38E-08	1.57E-08
1.0E+02	3.90E-09	2.90E-09	3.90E-09	5.95E-09	7.38E-09	1.17E-08	1.38E-08	1.57E-08
2.0E+02	5.12E-09	3.91E-09	4.58E-09	6.30E-09	7.60E-09	1.18E-08	1.39E-08	1.57E-08
4.0E+02	6.60E-09	5.12E-09	5.57E-09	6.88E-09	8.00E-09	1.19E-08	1.39E-08	1.58E-08
7.0E+02	8.00E-09	6.30E-09	6.60E-09	7.60E-09	8.52E-09	1.21E-08	1.40E-08	1.58E-08
1.0E+03	8.97E-09	7.14E-09	7.38E-09	8.18E-09	8.97E-09	1.22E-08	1.41E-08	1.58E-08
2.0E+03	1.10E-08	8.97E-09	9.10E-09	9.60E-09	1.01E-08	1.27E-08	1.43E-08	1.60E-08
4.0E+03	1.31E-08	1.10E-08	1.11E-08	1.14E-08	1.17E-08	1.35E-08	1.48E-08	1.51E-08
7.0E+03	1.48E-08	1.27E-08	1.28E-08	1.29E-08	1.31E-08	1.43E-08	1.53E-08	1.64E-08
1.0E+04	1.57E-08	1.38E-08	1.38E-08	1.39E-08	1.41E-08	1.50E-08	1.57E-08	1.66E-08
2.0E+04	1.69E-08	1.57E-08	1.57E-08	1.58E-08	1.58E-08	1.62E-08	1.66E-08	1.69E-08

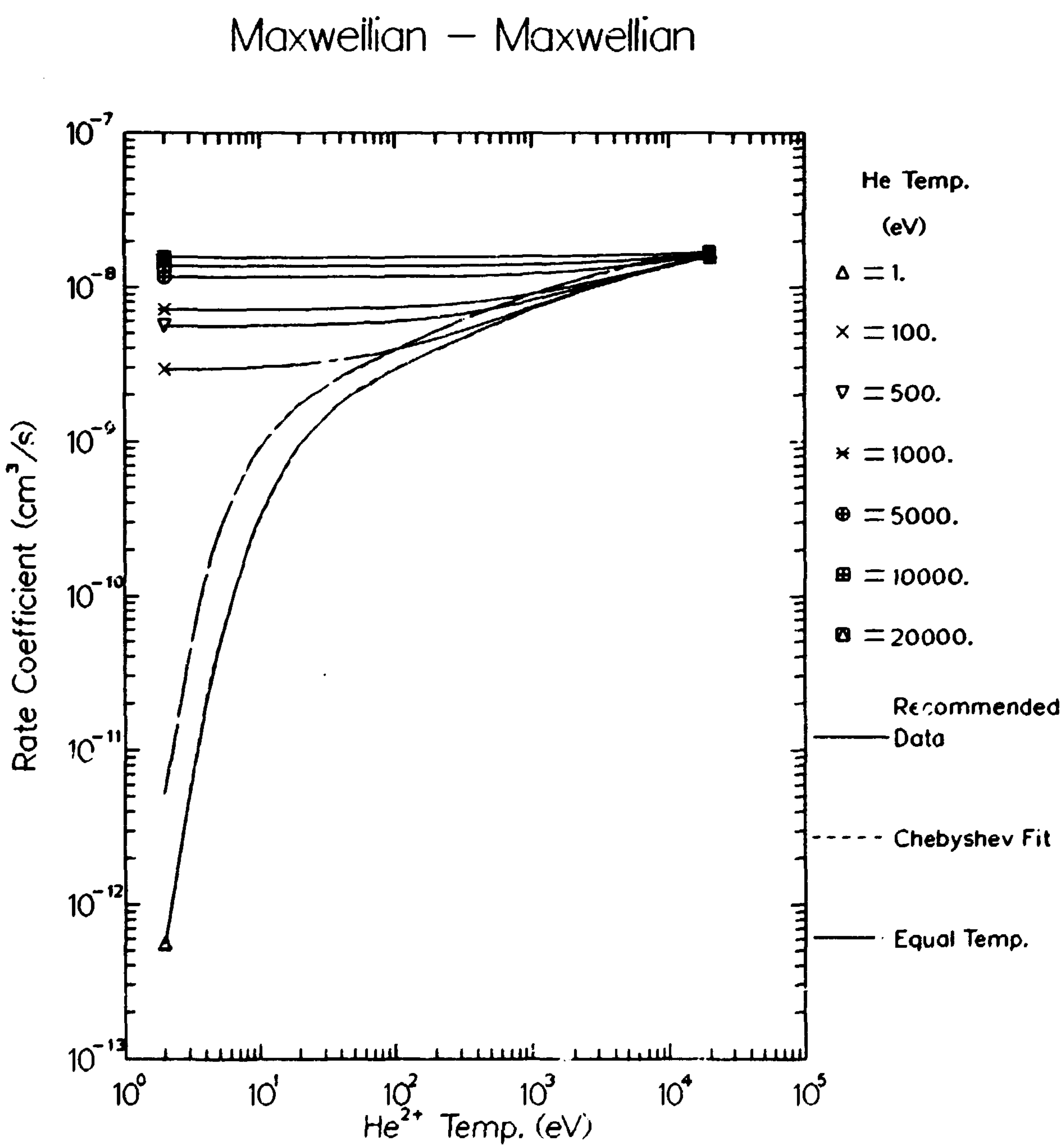
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 2.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
1.	-4.15949E+01	4.05943E+00	-1.86222E+00	9.53695E-01	-4.31628E-01	1.13605E-01	1.67894E-03
100.	-3.79435E+01	9.09167E-01	1.91522E-01	-7.51345E-02	-3.33315E-02	9.43860E-03	3.83286E-03
500.	-3.72996E+01	5.30896E-01	1.95295E-01	-2.21372E-03	-3.37015E-02	-9.19923E-03	3.89947E-03
1000.	-3.70111E+01	3.90475E-01	1.68883E-01	1.91542E-02	-2.19861E-02	-1.21205E-02	-1.71700E-04
5000.	-3.63583E+01	1.43130E-01	8.03033E-02	2.65227E-02	7.89255E-04	-4.74954E-03	-3.10575E-03
10000.	-3.61072E+01	7.57604E-02	4.50781E-02	1.73388E-02	2.65954E-03	-1.73029E-03	-1.75170E-03
20000.	-3.59012E+01	2.91780E-02	1.75429E-02	6.74273E-03	9.12966E-04	-9.12778E-04	-9.71523E-04
Equal Temp.	-4.01576E+01	3.11099E+00	-1.35722E+00	7.35133E-01	-4.32956E-01	1.86361E-01	-6.65206E-02

See appendix for Chebyshev fit details.

$He^{2+} + He \rightarrow He + He^{2+}$



Double Electron Capture Rate Coefficients for
$He + He^{2+} \rightarrow He + He^{2+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{2+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	400000.
1.0E+00	1.79E-08	1.90E-08	1.69E-08	1.00E-08	4.31E-09	3.95E-10*	9.21E-12**
2.0E+00	1.79E-08	1.90E-08	1.69E-08	1.00E-08	4.31E-09	3.95E-10*	9.22E-12**
4.0E+00	1.79E-08	1.90E-08	1.69E-08	1.00E-08	4.31E-09	3.95E-10*	9.24E-12**
7.0E+00	1.79E-08	1.90E-08	1.68E-08	9.99E-09	4.31E-09	3.94E-10*	9.26E-12**
1.0E+01	1.79E-08	1.90E-08	1.68E-08	9.99E-09	4.31E-09	3.94E-10*	9.28E-12**
2.0E+01	1.79E-08	1.90E-08	1.68E-08	9.97E-09	4.30E-09	3.94E-10*	9.32E-12**
4.0E+01	1.79E-08	1.90E-08	1.68E-08	9.94E-09	4.29E-09	3.94E-10*	9.39E-12**
7.0E+01	1.79E-08	1.89E-08	1.67E-08	9.91E-09	4.29E-09	3.93E-10*	9.45E-12**
1.0E+02	1.79E-08	1.89E-08	1.67E-08	9.89E-09	4.28E-09	3.93E-10*	9.51E-12**
2.0E+02	1.79E-08	1.89E-08	1.66E-08	9.83E-09	4.27E-09	3.93E-10*	9.65E-12**
4.0E+02	1.79E-08	1.88E-08	1.65E-08	9.76E-09	4.26E-09	3.93E-10*	9.86E-12**
7.0E+02	1.79E-08	1.88E-08	1.64E-08	9.68E-09	4.26E-09	3.93E-10*	1.01E-11**
1.0E+03	1.78E-08	1.87E-08	1.63E-08	9.63E-09	4.26E-09	3.94E-10*	1.03E-11**
2.0E+03	1.78E-08	1.86E-08	1.61E-08	9.50E-09	4.28E-09	3.97E-10*	1.08E-11**
4.0E+03	1.78E-08	1.84E-08	1.58E-06	9.34E-09	4.34E-09	4.06E-10*	1.17E-11**
7.0E+03	1.77E-08	1.81E-08	1.54E-08	9.20E-09	4.42E-09	4.21E-10*	1.28E-11**
1.0E+04	1.76E-08	1.79E-08	1.51E-08	9.08E-09	4.49E-09	4.39E-10	1.38E-11**
2.0E+04	1.74E-08	1.71E-08	1.42E-08	8.74E-09	4.65E-09	5.07E-10	1.71E-11**

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

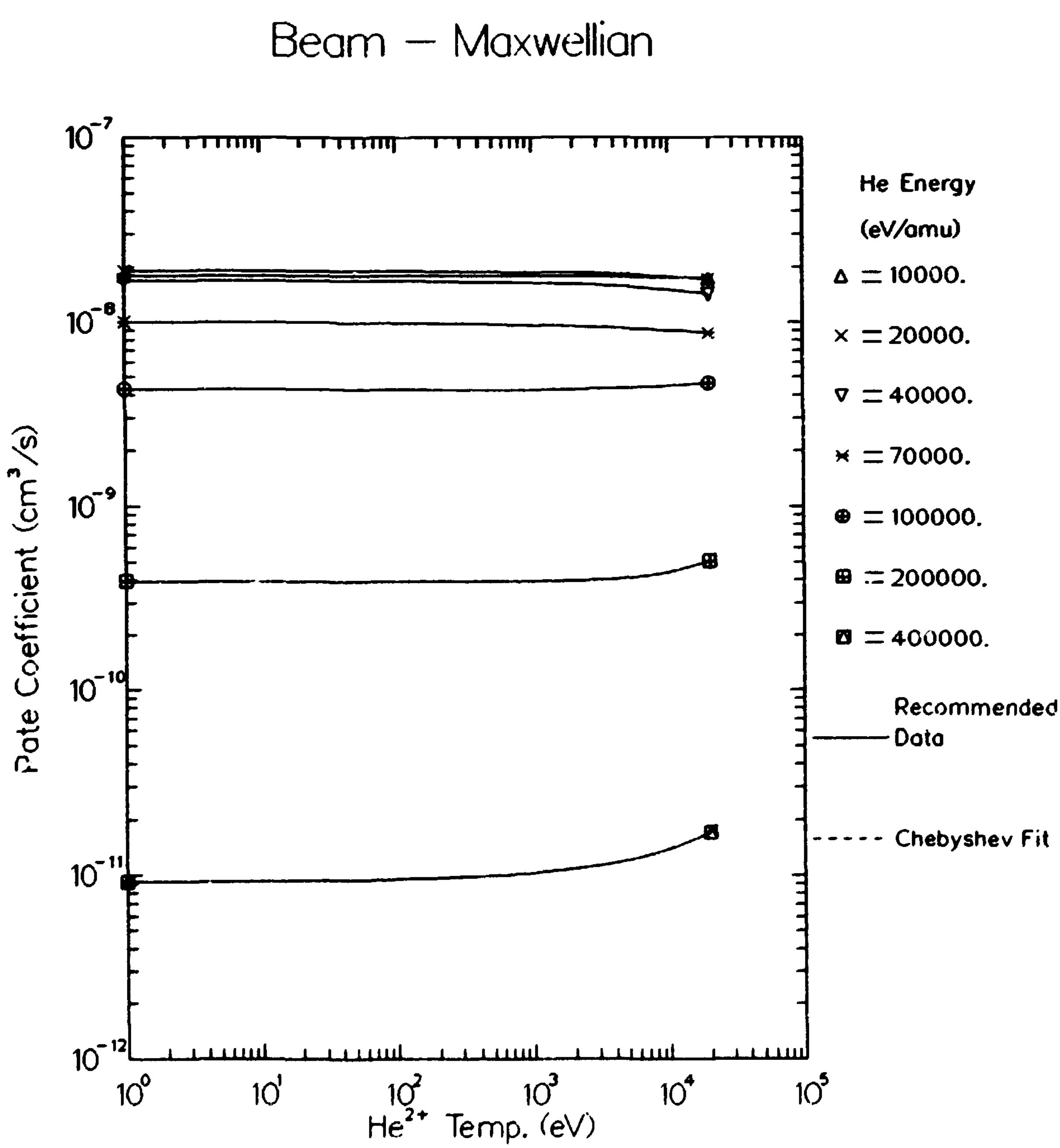
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-3.56880E+01	-1.04856E-02	-6.22291E-03	-3.54221E-03	-2.04547E-03	-1.06539E-03	-4.43802E-04
20000.	-3.56043E+01	-3.86901E-02	-2.24247E-02	-1.12950E-02	-5.53082E-03	-2.66314E-03	-1.23198E-03
40000.	-3.58798E+01	-6.74672E-02	-3.60384E-02	-1.56499E-02	-6.43318E-03	-2.74207E-03	-1.24709E-03
70000.	-3.69171E+01	-5.93014E-02	-2.54553E-02	-7.53787E-03	-2.21925E-03	-1.22692E-03	-8.87276E-04
100000.	-3.85034E+01	2.31019E-02	2.39390E-02	1.48606E-02	4.98011E-03	-1.80325E-05	-1.31207E-03
200000.	-4.32277E+01	7.43187E-02	6.13383E-02	4.01508E-02	2.17045E-02	9.21568E-03	3.71392E-03
400000.	-5.05148E+01	2.45518E-01	1.32039E-01	5.66724E-02	2.09008E-02	7.13076E-03	2.41652E-03

See appendix for Chebyshev fit details.

He + He^{2+} -> He + He^{2+}



Beam – Maxwellian
Rate Coefficient (cm³/s)
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{0} 10^{1} 10^{2} 10^{3} 10^{4} 10^{5}
He^{2+} Temp. (eV)
He Energy
(eV/amu)
△ = 10000.
× = 20000.
▽ = 40000.
✳ = 70000.
⊕ = 100000.
⊞ = 200000.
⊠ = 400000.
Recommended Data
Chebyshev Fit

Electron Capture Cross Sections for
$He^{2+} + Li \rightarrow He^{+} + Li^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+02	1.39E+07	4.22E-15
2.0E+02	1.96E+07	6.95E-15
4.0E+02	2.78E+07	9.64E-15
7.0E+02	3.68E+07	1.11E-14
1.0E+03	4.39E+07	1.15E-14
2.0E+03	6.21E+07	1.14E-14
4.0E+03	8.79E+07	1.06E-14
7.0E+03	1.16E+08	9.25E-15
1.0E+04	1.39E+08	7.39E-15
1.5E+04	1.70E+08	4.51E-15
2.0E+04	1.96E+08	2.24E-15
3.0E+04	2.41E+08	6.70E-16
5.0E+04	3.11E+08	2.11E-16
7.0E+04	3.68E+08	1.43E-16
1.0E+05	4.39E+08	9.57E-17
1.5E+05	5.38E+08	5.79E-17
2.0E+C5	6.21E+08	3.82E-17
2.5E+05	6.94E+08	2.32E-17
3.0E+05	7.61E+08	1.38E-17
4.0E+05	8.78E+08	5.17E-18
5.0E+05	9.82E+08	2.26E-18
5.9E+05	1.07E+09	1.21E-18

References: 230, 231, 232, 234, 241, 242, 244, 246

Accuracy: $E < 2 \times 10^5$ eV/amu - 30%; $E > 2 \times 10^5$ eV/amu - 40%

Notes: (1) For data of the sum of the single and double (total) cross sections see Kadota et al references 243 and 245.
(2) For the electron capture cross sections for Li^{+}, Li^{2+} + He see references 249, 250, 251, and 254.

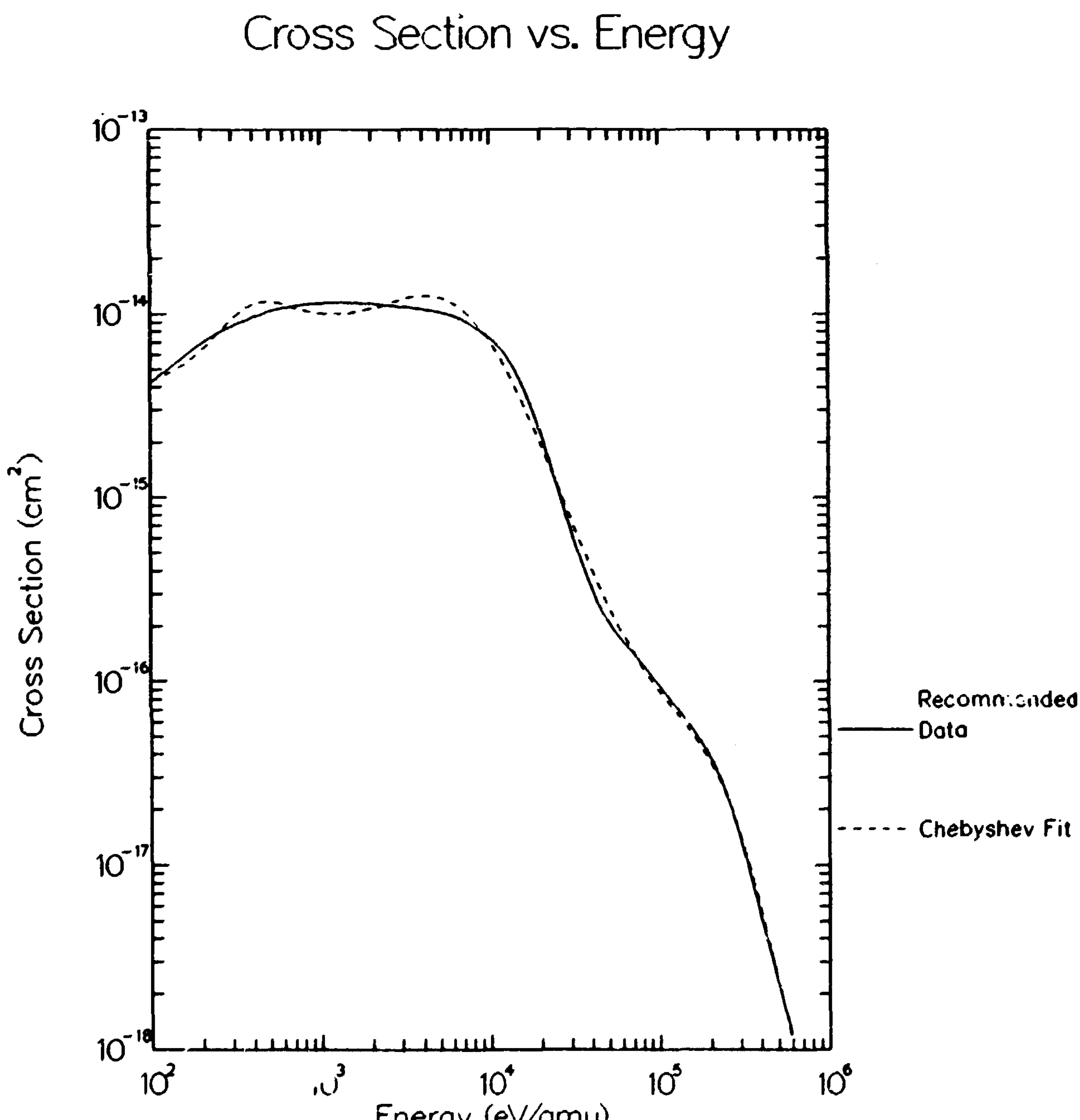
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+02 eV/amu, E_{max} = 5.9E+05 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-69.9969	-3.86583	-2.18937	.0319758	.0613398	-.163069	-.271234	-.111623	.204819

The fit represents the above cross sections with an rms deviation of 11.0%.
The maximum deviation is 22.5% at 5.0E+04 eV/amu.
See appendix for Chebyshev fit details.

$He^{2+} + Li \rightarrow He^{+} + Li^{+}$



Electron Capture Rate Coefficients for
$Li + He^{2+} \rightarrow He^{+} + Li^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{2+} Temp. (eV)	Li Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	1.02E-06	4.40E-07	9.71E-08	5.26E-08	4.20E-08*	2.37E-08*	2.20E-09**
2.0E+00	1.02E-06	4.39E-07	9.71E-08	5.26E-08	4.20E-08*	2.37E-08*	2.23E-09**
4.0E+00	1.02E-06	4.39E-07	9.71E-08	5.26E-08	4.20E-08*	2.37E-08*	2.22E-09**
7.0E+00	1.02E-06	4.39E-07	9.71E-08	5.26E-08	4.20E-08*	2.37E-08*	2.22E-09**
1.0E+01	1.02E-06	4.39E-07	9.71E-08	5.26E-08	4.20E-08*	2.37E-08*	2.22E-09**
2.0E+01	1.02E-06	4.38E-07	9.71E-08	5.26E-08	4.20E-08*	2.37E-08*	2.22E-09**
4.0E+01	1.02E-06	4.38E-07	9.72E-08	5.26E-08	4.20E-08*	2.37E-08*	2.22E-09**
7.0E+01	1.01E-06	4.37E-07	9.72E-08	5.26E-08	4.20E-08*	2.36E-08*	2.22E-09**
1.0E+02	1.01E-06	4.37E-07	9.72E-08	5.26E-08	4.20E-08	2.36E-08*	2.22E-09**
2.0E+02	1.00E-06	4.37E-07	9.74E-08	5.26E-08	4.20E-08	2.36E-08*	2.22E-09**
4.0E+02	9.93E-07	4.39E-07	9.76E-08	5.26E-08	4.20E-08	2.35E-08*	2.22E-09**
7.0E+02	9.81E-07	4.41E-07	9.81E-08	5.26E-08	4.19E-08	2.34E-08*	2.22E-09**
1.0E+03	9.69E-07	4.42E-07	9.86E-08	5.26E-08	4.19E-08	2.34E-08*	2.23E-09**
2.0E+03	9.35E-07	4.45E-07	1.01E-07	5.27E-08	4.19E-08	2.33E-08*	2.24E-09**
4.0E+03	8.74E-07	4.45E-07	1.06E-07	5.29E-08	4.18E-08	2.31E-08*	2.25E-09**
7.0E+03	8.03E-07	4.38E-07	1.16E-07	5.36E-08	4.18E-08	2.30E-08*	2.26E-09**
1.0E+04	7.48E-07	4.29E-07	1.25E-07	5.46E-08	4.18E-08	2.28E-08	2.26E-09**
2.0E+04	6.25E-07	3.94E-07	1.48E-07	5.95E-08	4.21E-08	2.25E-08	2.28E-09**

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

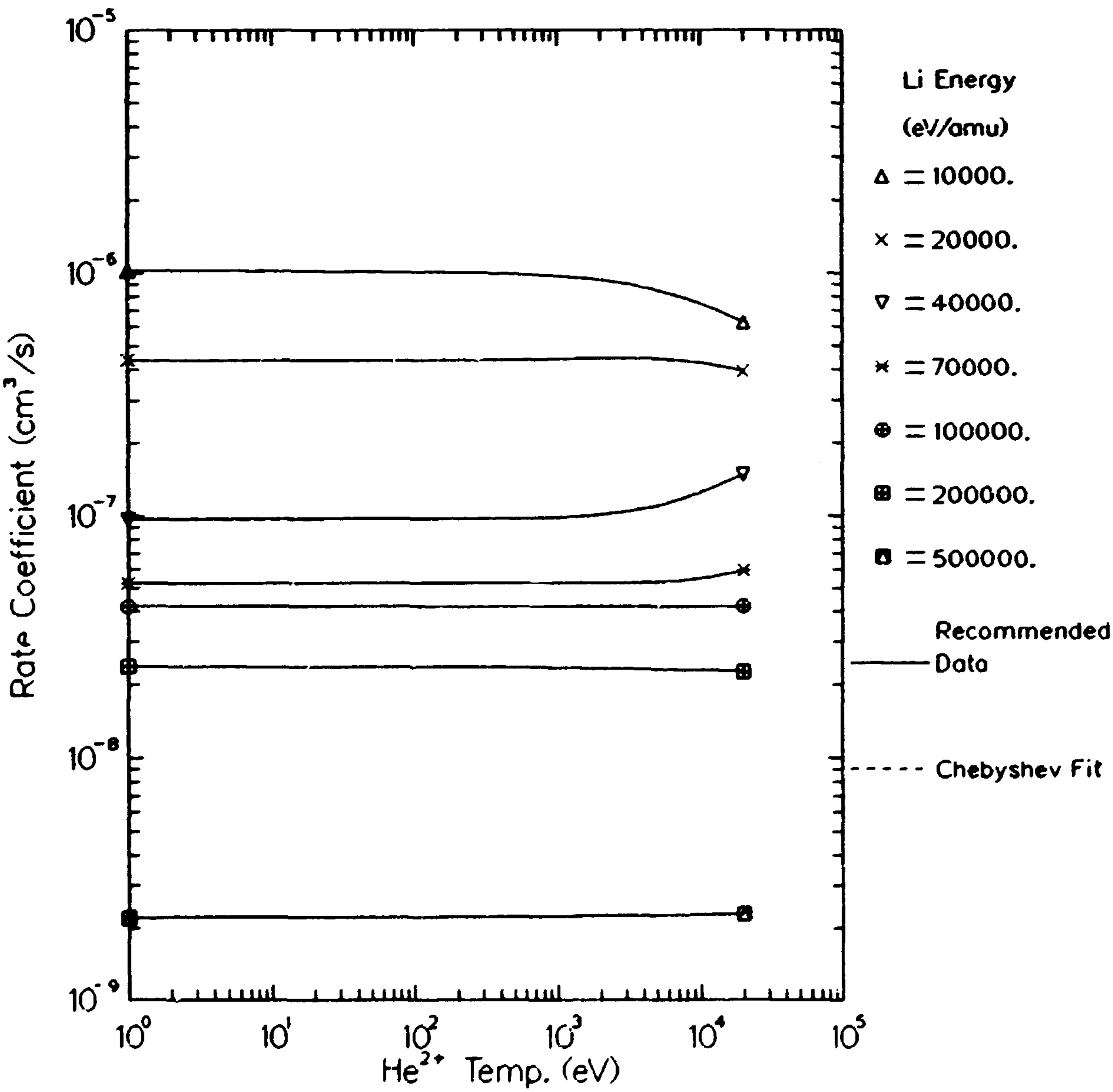
Chebyshev Fitting Parameters for Rate Coefficients

Li Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-2.78062E+01	-1.87483E-01	-1.15766E-01	-5.63757E-02	-2.07864E-02	-4.18092E-03	1.20353E-03
20000.	-2.93011E+01	-2.38001E-02	-2.23600E-02	-2.23853E-02	-1.68257E-02	-8.26641E-03	-2.16146E-03
40000.	-3.21294E+01	1.47297E-01	1.06505E-01	5.96604E-02	2.42461E-02	4.76111E-03	-3.24711E-03
70000.	-3.34880E+01	3.30410E-02	2.70085E-02	2.03864E-02	1.35662E-02	7.66428E-03	3.81877E-03
100000.	-3.39729E+01	-1.63250E-03	3.97915E-04	1.54890E-03	1.48096E-03	1.08056E-03	6.82015E-04
200000.	-3.51439E+01	-2.29742E-02	-1.03372E-02	-3.67071E-03	-8.35726E-04	-5.21814E-04	-6.93460E-05
500000.	-3.98397E+01	1.28943E-02	5.77153E-03	3.54906E-03	-1.13575E-03	6.68011E-04	-9.25001E-0[illegible]

See appendix for Chebyshev fit details.

$Li + He^{2+} \rightarrow He^{+} + Li^{+}$

Beam – Maxwellian



Double Electron Capture Cross Sections for
$He^{2+} + Li \rightarrow He + Li^{2+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
6.1E+03	1.08E+08	9.12E-18
7.0E+03	1.16E+08	1.30E-17
9.0E+03	1.32E+08	2.39E-17
1.0E+04	1.39E+08	2.99E-17
1.5E+04	1.70E+08	4.44E-17
2.0E+04	1.96E+08	4.03E-17
3.0E+04	2.41E+08	2.66E-17
5.0E+04	3.11E+08	1.42E-17
7.0E+04	3.68E+08	9.17E-18
1.0E+05	4.39E+08	5.86E-18
1.5E+05	5.38E+08	3.12E-18
2.0E+05	6.21E+08	1.17E-18
2.5E+05	6.94E+08	3.16E-19
3.0E+05	7.61E+08	1.05E-19
4.0E+05	8.78E+08	1.62E-20
5.0E+05	9.82E+08	1.03E-20

References: 231, 232, 241, 242, 244, 246

Accuracy: 30%

Notes: (1) In the region ($1-3\times10^4$ eV/amu) where the cross section is a maximum the experimental data fluctuates by a factor of ± 2. We believe that the value quoted can be relied on to 30%.
(2) For data of the sum of the single and double electron capture see Kadota et al references 243 and 245.
(3) For electron capture cross sections of Li^+, Li^{2+} + He see references 249, 250, 251, and 254.

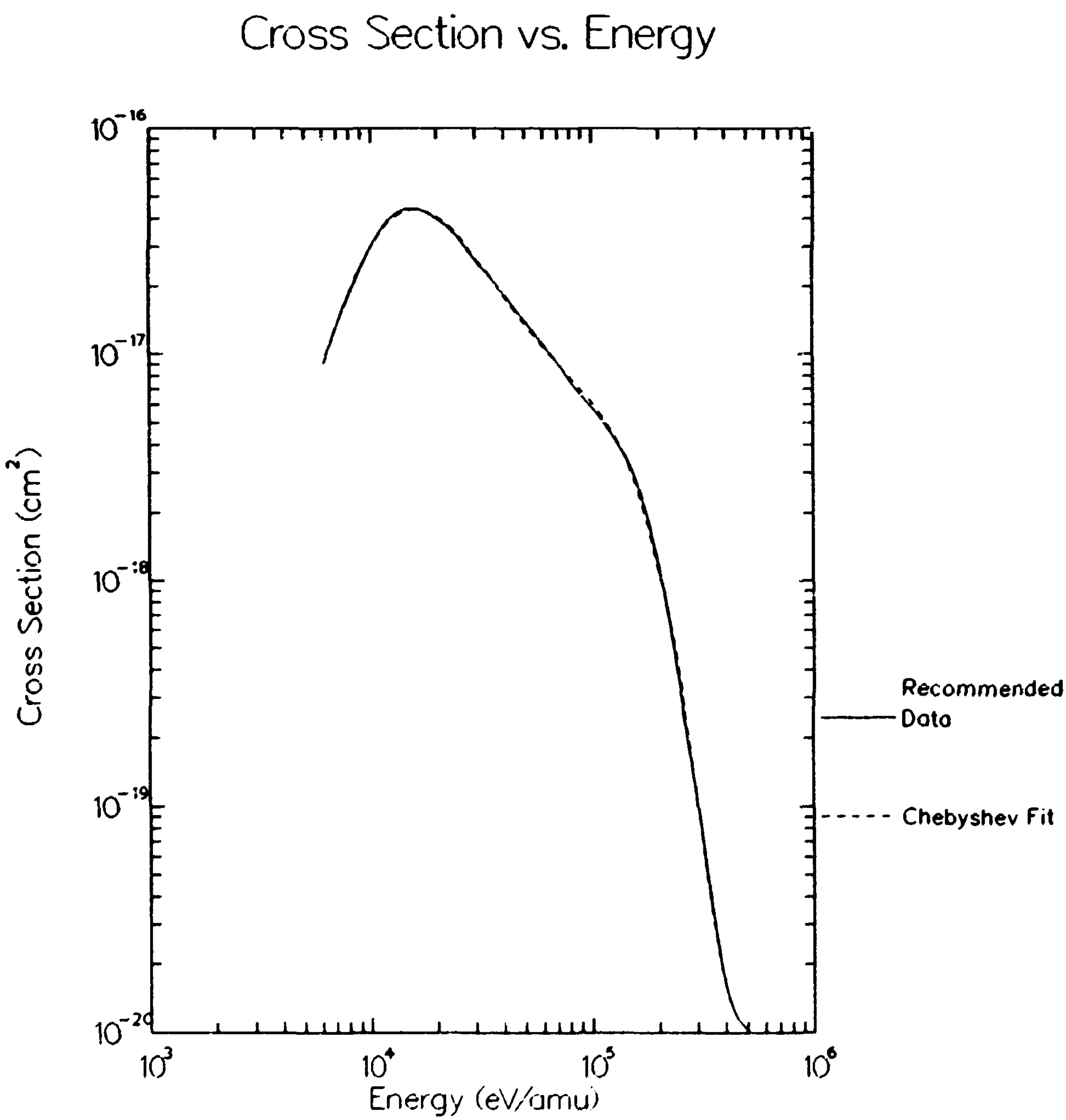
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 6.1E+03 eV/amu, E_{max} = 5.0E+05 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-81.1888	-3.55493	-2.11208	-.149724	-.232101	.216608	.275776	.0980514	.0367760

The fit represents the above cross sections with an rms deviation of 3.1%.
The maximum deviation is 8.4% at 2.5E+05 eV/amu.
See appendix for Chebyshev fit details.

$He^{2+} + Li \rightarrow He + Li^{2+}$



Double Electron Capture Rate Coefficients for
$Li + He^{2+} \rightarrow He + Li^{2+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{2+} Temp. (eV)	Li Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	400000.
1.0E+00	4.14E-09	7.91E-09	5.19E-09	3.37E-09	2.57E-09	7.25E-10*	1.43E-11**
2.0E+00	4.14E-09	7.90E-09	5.19E-09	3.37E-09	2.57E-09	7.25E-10*	1.43E-11**
4.0E+00	4.13E-09	7.90E-09	5.19E-09	3.37E-09	2.57E-09	7.25E-10*	1.43E-11**
7.0E+00	4.12E-09	7.89E-09	5.19E-09	3.37E-09	2.57E-09	7.24E-10*	1.43E-11**
1.0E+01	4.12E-09	7.88E-09	5.19E-09	3.37E-09	2.57E-09	7.23E-10*	1.43E-11**
2.0E+01	4.10E-09	7.87E-09	5.19E-09	3.37E-09	2.57E-09	7.22E-10*	1.44E-11**
4.0E+01	4.09E-09	7.85E-09	5.19E-09	3.37E-09	2.57E-09	7.20E-10*	1.44E-11**
7.0E+01	4.08E-09	7.83E-09	5.19E-09	3.37E-09	2.57E-09	7.18E-10*	1.45E-11**
1.0E+02	4.07E-09	7.81E-09	5.19E-09	3.37E-09	2.57E-09	7.17E-10	1.45E-11**
2.0E+02	4.07E-09	7.76E-09	5.19E-09	3.37E-09	2.56E-09	7.14E-10	1.47E-11**
4.0E+02	4.08E-09	7.70E-09	5.19E-09	3.37E-09	2.56E-09	7.10E-10	1.49E-11**
7.0E+02	4.13E-09	7.62E-09	5.19E-09	3.38E-09	2.56E-09	7.07E-10	1.51E-11**
1.0E+03	4.18E-09	7.55E-09	5.19E-09	3.38E-09	2.55E-09	7.05E-10	1.53E-11**
2.0E+03	4.31E-09	7.34E-09	5.19E-09	3.38E-09	2.55E-09	7.03E-10	1.59E-11**
4.0E+03	4.51E-09	6.99E-09	5.19E-09	3.39E-09	2.54E-09	7.07E-10	1.68E-11**
7.0E+03	4.68E-09	6.60E-09	5.16E-09	3.40E-09	2.53E-09	7.16E-10	1.81E-11**
1.0E+04	4.79E-09	6.31E-09	5.11E-09	3.40E-09	2.52E-09	7.26E-10	1.93E-11**
2.0E+04	4.95E-09	5.71E-09	4.90E-09	3.40E-09	2.50E-09	7.51E-10	2.35E-11**

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

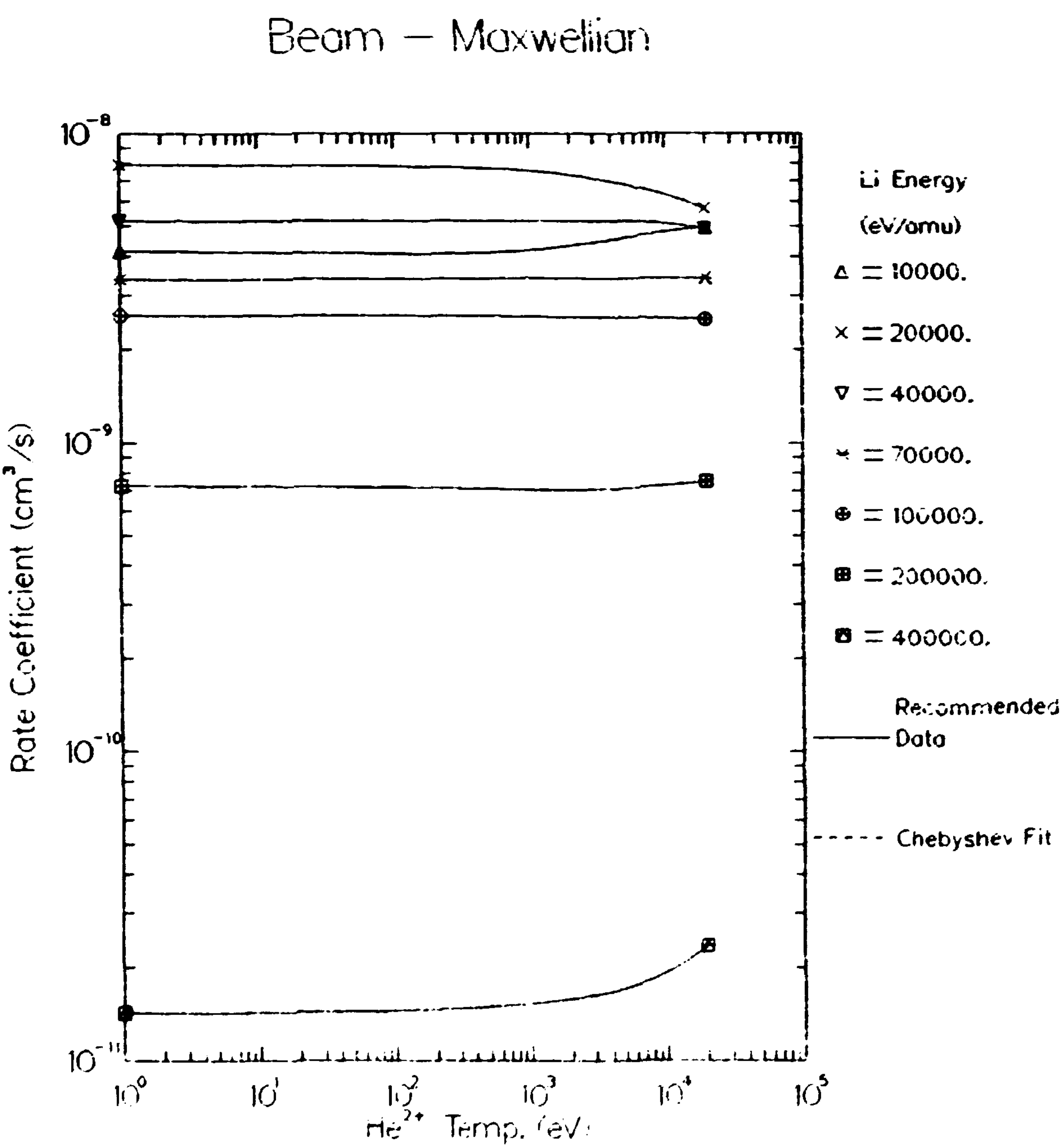
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

Li Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-3.85237E+01	7.92423E-02	5.63215E-02	1.72118E-02	-5.29456E-03	-7.47819E-03	-2.52581E-03
20000.	-3.74702E+01	-1.30340E-01	-7.61020E-02	-3.32737E-02	-9.67526E-03	-1.15041E-04	2.05695E-03
40000.	-3.81678E+01	-1.43365E-02	-1.25875E-02	-1.01317E-02	-6.93426E-03	-3.91276E-03	-1.88591E-03
70000.	-3.90109E+01	4.43065E-03	2.10527E-03	3.09061E-04	-4.54509E-04	-5.21843E-04	-3.71172E-04
100000.	-3.95717E+01	-1.18800E-02	-5.53013E-03	-2.04086E-03	-8.30113E-04	-4.87010E-04	-3.29738E-04
200000.	-4.20984E+01	1.49204E-03	1.62234E-02	1.48608E-02	6.78142E-03	1.37283E-03	-7.46341E-04
400000.	-4.97186E+01	1.87794E-01	1.11341E-01	5.29149E-02	2.28786E-02	8.25402E-03	3.38953E-03

See appendix for Chebyshev fit details.

$Li + He^{2+} \rightarrow He + Li^{2+}$



B. Electron Capture into Excited States
(* denotes rate coefficient data also)

B. (Cont'd)

Electron Capture Cross Sections for
$H^+ + H \rightarrow H(2s) + H^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.0E+03	6.21E+07	1.41E-18
3.0E+03	7.61E+07	2.77E-18
4.0E+03	8.79E+07	4.59E-18
5.0E+03	9.82E+07	6.78E-18
6.0E+03	1.08E+08	8.91E-18
7.0E+03	1.16E+08	1.19E-17
1.0E+04	1.39E+08	1.98E-17
2.0E+04	1.96E+08	3.65E-17
4.0E+04	2.78E+08	2.17E-17
5.0E+04	3.11E+08	1.39E-17
6.0E+04	3.40E+08	9.05E-18
7.0E+04	3.68E+08	5.56E-18
1.0E+05	4.39E+08	1.93E-18
2.0E+05	6.21E+08	2.59E-19

<u>References:</u> 1, 11, 12, 13, 14, 15, 16, 70, 71, 72

<u>Accuracy:</u> Energy < $3x10^3$ eV/amu - factor 2; $3x10^3$ eV/amu < E < $1x10^5$ eV/amu - 30%; E > $1x10^5$ eV/amu - 50%

<u>Notes:</u> (1) For energies greater than $5x10^3$ eV/amu, the crossed beam results of references 12 and 14 are in good agreement with the data obtained using the tungsten oven H cell employed in the other experimental references.

(2) No corrections were applied for cascading but the effect is believed to be no more than 5%.

(3) Data for energies greater than $1.2x10^5$ eV/amu were taken from the theoretical paper by Shakeshaft (ref. 70) who computed the cross sections using time-dependent impact parameter coupled-state equations.

(4) Cross sections in the energy range $1x10^3$ - $5x10^3$ eV/amu rely on the experimental results of Morgan et al (ref. 15) and theoretical results of ref. 71 and 72.

(5) Cross sections for the 2s state were found by mixing the 2s and 2p states with an electric field.

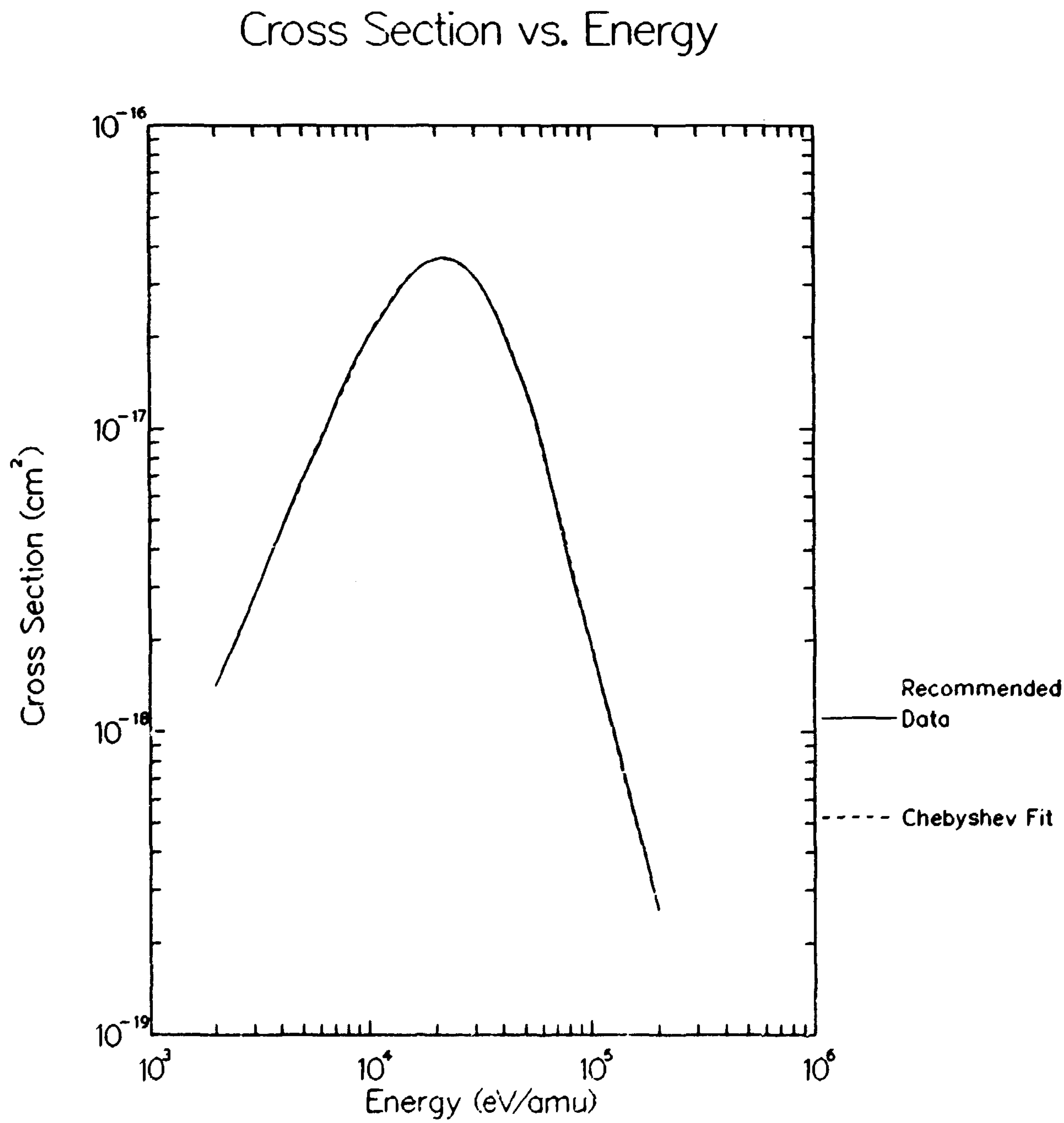
For a Chebyshev fit of the above cross section it is necessary to use the following parameters.
E_{min} = 2.0E+03 eV/amu, E_{max} = 2.0E+05 eV/amu

<u>Chebyshev Fitting Parameters for Cross Sections</u>

A0	A1	A2	A3	A4	A5	A6	A7	A8
-80.2974	-.711716	-2.02522	-.193493	.250985	.0856986	-.0237110	-.0276091	-.00357455

The fit represents the above cross sections with an rms deviation of 1.3%.
The maximum deviation is 2.4% at 7.0E+04 eV/amu.
See appendix for Chebyshev fit details.

$H^+ + H \rightarrow H(2s) + H^+$



Electron Capture Rate Coefficients for
$H^+ + H \rightarrow H(2s) + H^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	Equal Temp.	H Temp. (eV) 500.	1000.	2000.	4000.	7000.	10000.	20000.
1.0E+02	1.86E-14	1.48E-11	9.32E-11	4.11E-10	1.35E-09	2.66E-09	3.50E-09	4.23E-09
2.0E+02	2.59E-12	2.51E-11	1.16E-10	4.52E-10	1.40E-09	2.70E-09	3.52E-09	4.23E-09
4.0E+02	3.83E-11	5.41E-11	1.69E-10	5.36E-10	1.50E-09	2.77E-09	3.57E-09	4.23E-09
7.0E+02	1.69E-10	1.16E-10	2.63E-10	6.70E-10	1.65E-09	2.87E-09	3.62E-09	4.22E-09
1.0E+03	3.72E-10	1.98E-10	3.72E-10	8.12E-10	1.79E-09	2.96E-09	3.68E-09	4.22E-09
2.0E+03	1.30E-09	5.80E-10	8.12E-10	1.30E-09	2.23E-09	3.25E-09	3.83E-09	4.20E-09
4.0E+03	2.96E-09	1.55E-09	1.79E-09	2.23E-09	2.96E-09	3.68E-09	4.05E-09	4.14E-09
7.0E+03	4.05E-09	2.80E-09	2.96E-09	3.25E-09	3.68E-09	4.05E-09	4.20E-09	4.03E-09
1.0E+04	4.23E-09	3.59E-09	3.68E-09	3.83E-09	4.05E-09	4.20E-09	4.23E-09	3.90E-09
2.0E+04	3.42E-09	4.22E-09	4.22E-09	4.20E-09	4.14E-09	4.03E-09	3.90E-09	3.42E-09

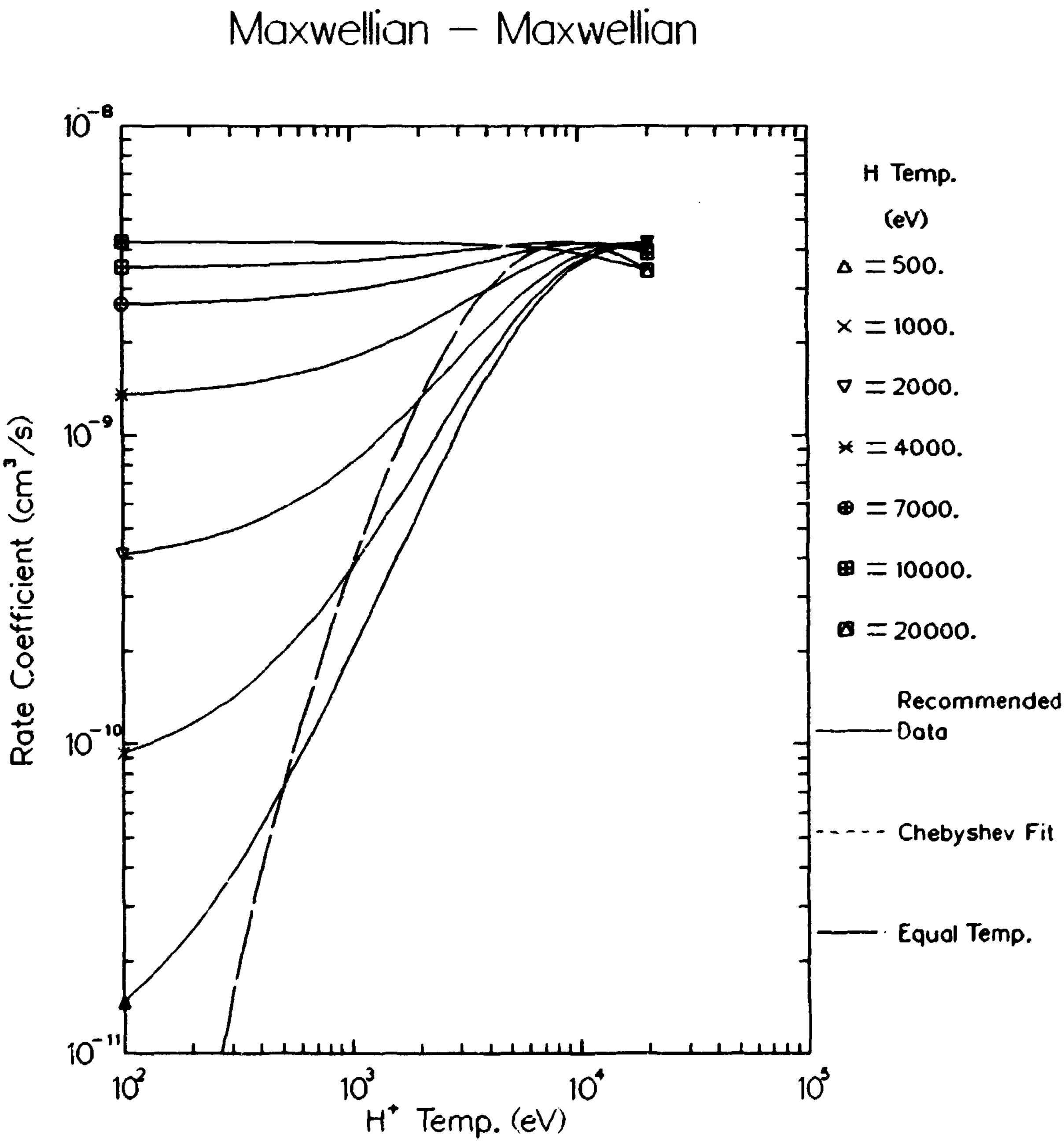
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+02 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

H Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
500.	-4.38672E+01	3.12293E+00	-1.60004E-01	-3.10412E-01	-2.36074E-02	1.60083E-02	6.19524E-03
1000.	-4.24130E+01	2.14668E+00	6.37440E-02	-2.57968E-01	-5.56388E-02	1.72468E-02	8.38626E-03
2000.	-4.10369E+01	1.31982E+00	1.21498E-01	-1.62370E-01	-6.16572E-02	4.43261E-03	8.17248E-03
4000.	-3.98120E+01	6.46066E-01	8.59976E-02	-8.09184E-02	-4.48832E-02	-5.52064E-03	3.62665E-03
7000.	-3.90771E+01	2.57541E-01	2.91176E-02	-4.35279E-02	-2.76600E-02	-6.63736E-03	5.07727E-04
10000.	-3.87811E+01	9.11341E-02	-6.21649E-03	-3.19458E-02	-1.89226E-02	-5.58779E-03	-2.28503E-04
20000.	-3.86539E+01	-7.79801E-02	-5.02818E-02	-2.49832E-02	-9.47407E-03	-2.56718E-03	-3.98810E-04
Equal Temp.	-4.60750E+01	5.50322E+00	-2.23799E+00	4.38735E-01	-2.58100E-01	1.18690E-01	-1.94375E-02

See appendix for Chebyshev fit details.

$H^+ + H \to H(2s) + H^+$



Maxwellian — Maxwellian
Rate Coefficient (cm³/s)
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
10²
10³
10⁴
10⁵
H⁺ Temp. (eV)
H Temp.
(eV)
= 500.
= 1000.
= 2000.
= 4000.
= 7000.
= 10000.
= 20000.
Recommended Data
Chebyshev Fit
Equal Temp.

Electron Capture Rate Coefficients for
$H + H^{+} \rightarrow H(2s) + H^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	60000.	80000.	100000.	150000.
1.0E+00	2.74E-09	7.12E-09	6.01E-09*	3.07E-09*	1.47E-09**	8.48E-10**	3.21E-10**
2.0E+00	2.74E-09	7.11E-09	6.00E-09*	3.07E-09*	1.47E-09**	8.48E-10**	3.21E-10**
4.0E+00	2.74E-09	7.08E-09	5.99E-09*	3.07E-09*	1.47E-09*	8.48E-10**	3.21E-10**
7.0E+00	2.74E-09	7.05E-09	5.97E-09*	3.07E-09*	1.47E-09*	8.48E-10**	3.21E-10**
1.0E+01	2.73E-09	7.03E-09	5.96E-09	3.06E-09*	1.47E-09*	8.48E-10**	3.21E-10**
2.0E+01	2.73E-09	6.97E-09	5.94E-09	3.06E-09*	1.47E-09*	8.49E-10**	3.21E-10**
4.0E+01	2.74E-09	6.89E-09	5.90E-09	3.05E-09*	1.47E-09*	8.50E-10*	3.21E-10**
7.0E+01	2.75E-09	6.81E-09	5.86E-09	3.05E-09*	1.48E-09*	8.51E-10*	3.21E-10**
1.0E+02	2.76E-09	6.75E-09	5.83E-09	3.04E-09*	1.48E-09*	8.53E-10*	3.22E-10**
2.0E+02	2.82E-09	6.60E-09	5.75E-09	3.04E-09*	1.49E-09*	8.57E-10*	3.23E-10**
4.0E+02	2.95E-09	6.40E-09	5.64E-09	3.04E-09	1.51E-09*	8.66E-10*	3.25E-10**
7.0E+02	3.14E-09	6.21E-09	5.52E-09	3.05E-09	1.54E-09*	8.80E-10*	3.28E-10**
1.0E+03	3.30E-09	6.08E-09	5.42E-09	3.05E-09	1.57E-09*	8.94E-10*	3.30E-10**
2.0E+03	3.69E-09	5.77E-09	5.14E-09	3.05E-09	1.65E-09*	9.42E-10*	3.37E-10**
4.0E+03	4.10E-09	5.35E-09	4.69E-09	3.00E-09	1.75E-09*	1.03E-09*	3.52E-10**
7.0E+03	4.35E-09	4.90E-09	4.19E-09	2.88E-09	1.82E-09*	1.14E-09*	3.87E-10**
1.0E+04	4.40E-09	4.57E-09	3.82E-09	2.74E-09	1.84E-09	1.20E-09*	4.28E-10*
2.0E+04	4.08E-09	3.80E-09	3.07E-09	2.35E-09	1.74E-09	1.26E-09*	5.48E-10*

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

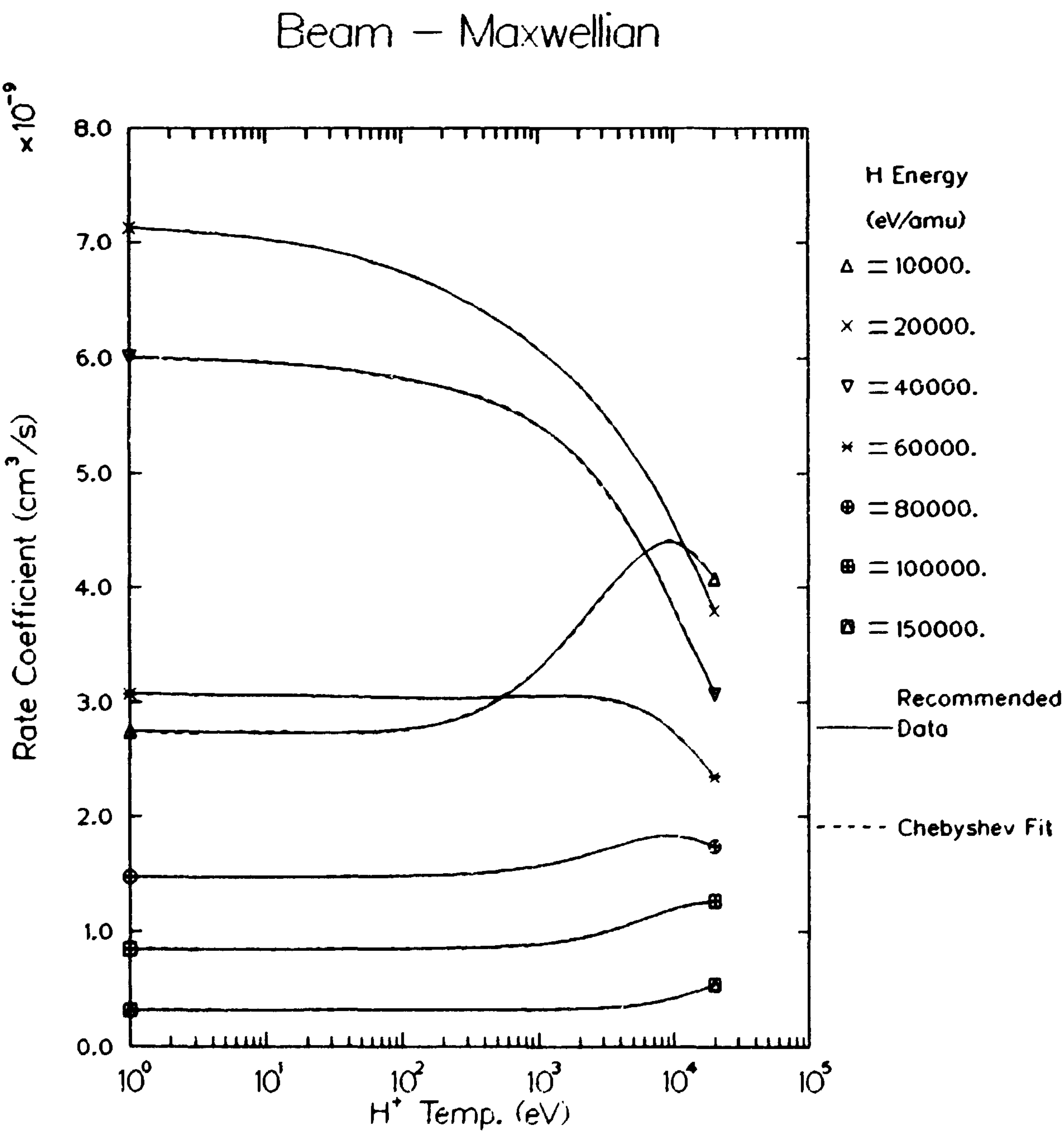
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-3.91129E+01	2.48347E-01	9.68613E-02	-2.22662E-02	-5.16334E-02	-2.86624E-02	-4.22512E-03
20000.	-3.78678E+01	-2.64262E-01	-1.22968E-01	-4.41549E-02	-1.57924E-02	-6.00867E-03	-1.43873E-03
40000.	-3.81878E+01	-2.65205E-01	-1.50964E-01	-6.70004E-02	-2.27907E-02	-3.96914E-03	2.12259E-03
60000.	-3.92919E+01	-7.86994E-02	-5.90240E-02	-4.39866E-02	-2.75365E-02	-1.19525E-02	-2.20171E-03
80000.	-4.05364E+01	1.08994E-01	4.62123E-02	-5.38404E-03	-2.37480E-02	-1.87047E-02	-8.06980E-03
100000.	-4.15580E+01	1.82433E-01	1.07666E-01	3.51890E-02	-4.95054E-03	-1.53694E-02	-1.20555E-02
150000.	-4.35210E+01	1.78485E-01	1.28691E-01	7.63149E-02	2.78040E-02	1.49449E-02	2.43305E-03

See appendix for Chebyshev fit details.

$H + H^+ \rightarrow H(2s) + H^+$



Electron Capture Cross Sections for
$H^+ + H \rightarrow H(2p) + H^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
6.0E+02	3.40E+07	6.05E-18
7.0E+02	3.68E+07	8.69E-18
1.0E+03	4.39E+07	1.85E-17
1.5E+03	5.38E+07	3.10E-17
2.0E+03	6.21E+07	3.05E-17
3.0E+03	7.61E+07	2.87E-17
4.0E+03	8.79E+07	2.89E-17
7.0E+03	1.16E+08	3.06E-17
1.0E+04	1.39E+08	2.99E-17
2.0E+04	1.96E+08	1.79E-17
3.0E+04	2.41E+08	1.01E-17
4.0E+04	2.78E+08	5.83E-18
7.0E+04	3.68E+08	1.46E-18
1.0E+05	4.39E+08	6.18E-19
2.0E+05	6.21E+08	1.41E-19
2.4E+05	6.80E+08	1.00E-19

References: 17, 18, 19, 20, 70

Accuracy: $E < 2x10^3$ eV/amu - 40%; $2x10^3$ eV/amu $< E < 3x10^4$ eV/amu - 25%; $E > 3x10^4$ eV/amu - unknown

Notes: (1) Thomas in ref. 20 has applied a correction to ref. 19.

(2) All cross sections have been normalized to either the $H^+ + H_2 \rightarrow H(2p) + H_2^+$ or $e^- + H(1s) \rightarrow e^- + H(2p)$ cross sections.

(3) Cross sections for H impact energies greater than $3x10^4$ eV/amu rely on computations of Shakeshaft (ref. 70). Data were obtained using time-dependent impact parameter coupled-state equations.

(4) The cross section (σ_i) for capture into state i is determined by measuring the emission cross section (σ_{ij}) for a transition from state i to j, correcting for any branching from state i, and correcting for cascading from upper states.

(5) Cascading from upper states to the 2p state is less than 5%. Thus $\sigma(2p) \approx \sigma(\text{Lyman-}\alpha)$ emission cross section.

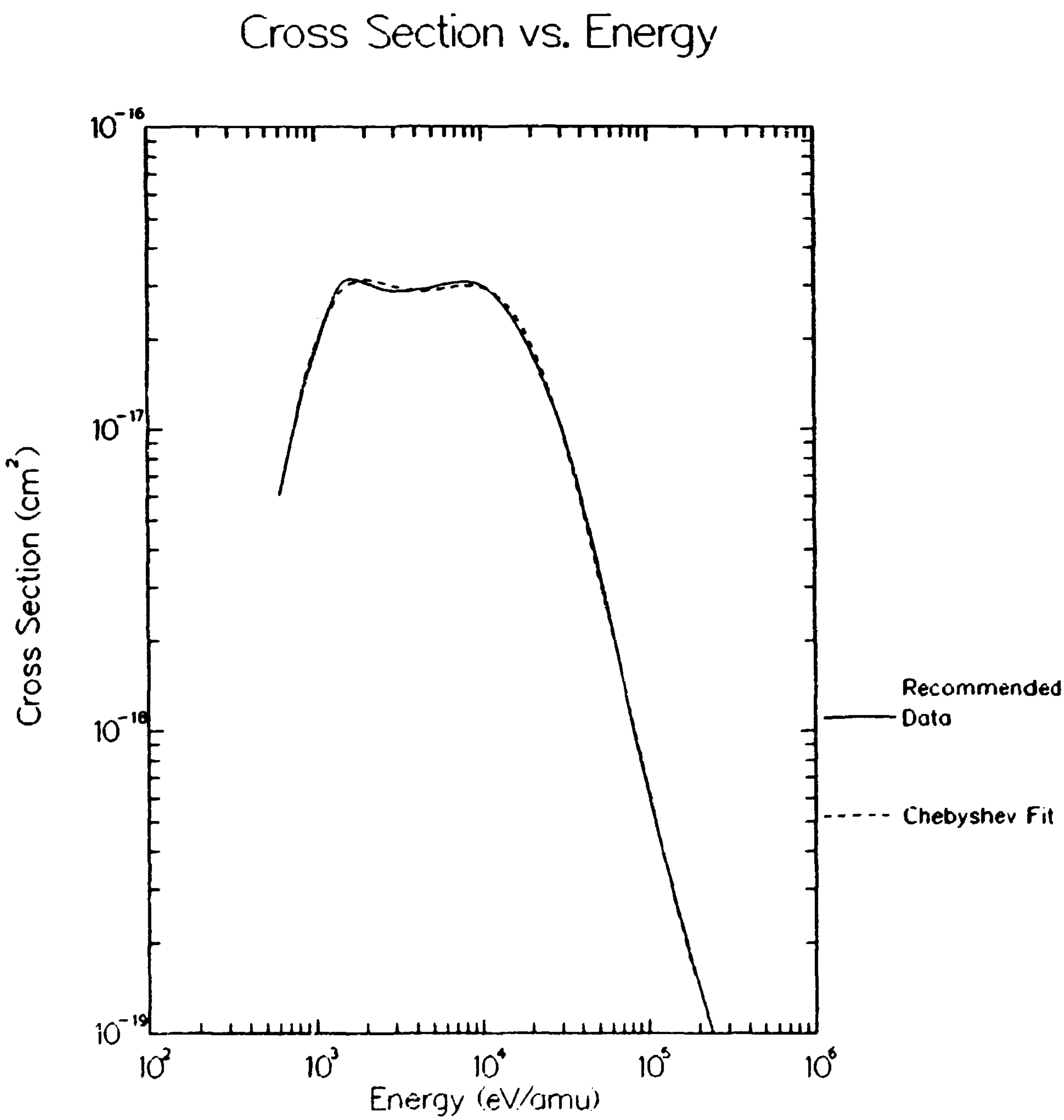
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 6.0E+02 eV/amu, E_{max} = 2.4E+05 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-79.9812	-2.30968	-1.73621	.110265	.0489823	.217654	-.0576541	-.0617916	.0399669

The fit represents the above cross sections with an rms deviation of 2.8%.
The maximum deviation is 5.8% at 2.0E+04 eV/amu.
See appendix for Chebyshev fit details.

$H^+ + H \rightarrow H(2p) + H^+$



Electron Capture Rate Coefficients for
$H^+ + H \rightarrow H(2p) + H^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	Equal Temp.	H Temp. (eV) 50.	100.	500.	1000.	5000.	10000.	20000.
4.0E+01	5.58E-13	1.28E-12	1.45E-11	5.48E-10	1.16E-09	2.88E-09	3.03E-09	2.47E-09
7.0E+01	1.45E-11	6.91E-12	3.22E-11	5.92E-10	1.19E-09	2.89E-09	3.03E-09	2.47E-09
1.0E+02	5.74E-11	1.95E-11	5.74E-11	6.36E-10	1.22E-09	2.89E-09	3.03E-09	2.46E-09
2.0E+02	3.33E-10	1.13E-10	1.81E-10	7.73E-10	1.32E-09	2.91E-09	3.03E-09	2.46E-09
4.0E+02	8.99E-10	4.11E-10	4.98E-10	1.02E-09	1.49E-09	2.93E-09	3.02E-09	2.45E-09
7.0E+02	1.49E-09	8.38E-10	8.99E-10	1.32E-09	1.71E-09	2.96E-09	3.01E-09	2.43E-09
1.0E+03	1.90E-09	1.17E-09	1.22E-09	1.56E-09	1.90E-09	2.99E-09	3.00E-09	2.41E-09
2.0E+03	2.68E-09	1.93E-09	1.96E-09	2.17E-09	2.38E-09	3.05E-09	2.95E-09	2.36E-09
4.0E+03	3.07E-09	2.70E-09	2.71E-09	2.79E-09	2.88E-09	3.06E-09	2.84E-09	2.25E-09
7.0E+03	2.84E-09	3.05E-09	3.05E-09	3.06E-09	3.07E-09	2.95E-09	2.65E-09	2.09E-09
1.0E+04	2.47E-09	3.03E-09	3.03E-09	3.02E-09	3.00E-09	2.78E-09	2.47E-09	1.96E-09
2.0E+04	1.59E-09	2.47E-09	2.46E-09	2.44E-09	2.41E-09	2.19E-09	1.96E-09	1.59E-09

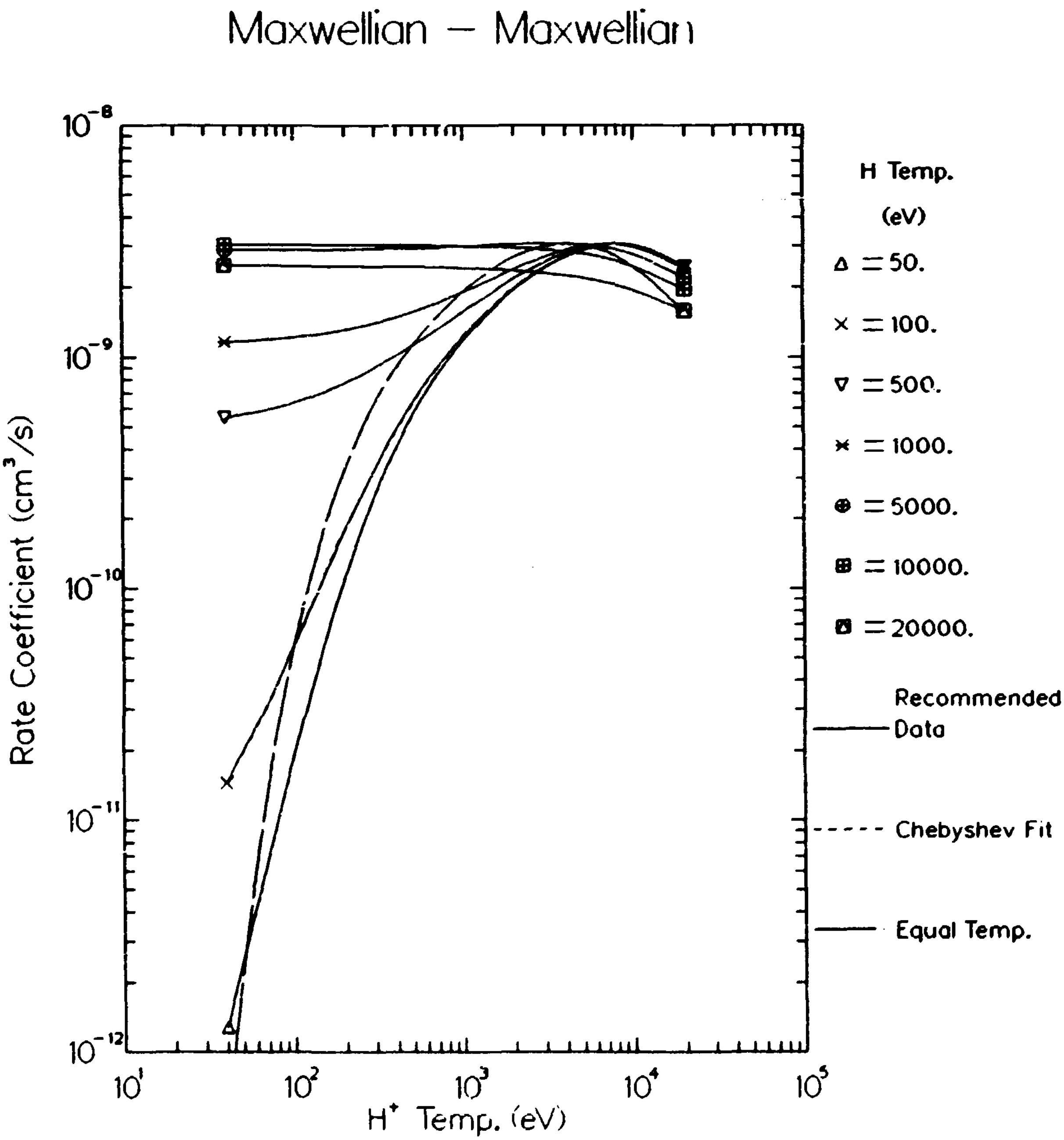
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 4.0E+01 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

H Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
50.	-4.42667E+01	3.68258E+00	-1.49113E+00	1.59924E-01	3.18208E-03	-6.21884E-02	2.01934E-02
100.	-4.30926E+01	2.69099E+00	-8.96227E-01	-7.60448E-02	4.64849E-02	-4.73878E-02	6.77301E-03
500.	-4.08437E+01	9.29788E-01	-1.25719E-01	-1.89331E-01	-3.21599E-02	5.88363E-03	2.45244E-03
1000.	-4.02252E+01	5.06698E-01	-5.16460E-02	-1.44926E-01	-4.91357E-02	2.77891E-03	6.06624E-03
5000.	-3.93773E+01	-6.84093E-02	-8.56458E-02	-6.23155E-02	-2.73651E-02	-6.00122E-03	5.77484E-04
10000.	-3.94214E+01	-1.65763E-01	-1.04137E-01	-4.96524E-02	-1.77141E-02	-4.10624E-03	-1.51335E-04
20000.	-3.98550E+01	-1.76608E-01	-9.99144E-02	-4.14670E-02	-1.28283E-02	-2.76171E-03	-2.52981E-04
Equal Temp.	-4.38515E+01	3.35460E+00	-2.04640E+00	5.49669E-01	-2.67503E-01	7.12101E-02	2.83428E-03

See appendix for Chebyshev fit details.

$H^+ + H \rightarrow H(2p) + H^+$



Electron Capture Rate Coefficients for
$H + H^{+} \rightarrow H(2p) + H^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	60000.	80000.	100000.	200000.
1.0E+00	4.14E-09	3.51E-09	1.62E-09*	7.27E-10*	4.16E-10**	2.72E-10**	8.76E-11**
2.0E+00	4.13E-09	3.50E-09	1.62E-09*	7.27E-10*	4.16E-10**	2.72E-10**	8.76E-11**
4.0E+00	4.12E-09	3.50E-09	1.61E-09*	7.28E-10*	4.16E-10**	2.72E-10**	8.76E-11**
7.0E+00	4.11E-09	3.49E-09	1.61E-09*	7.28E-10*	4.16E-10**	2.72E-10**	8.77E-11**
1.0E+01	4.10E-09	3.49E-09	1.61E-09*	7.28E-10*	4.16E-10*	2.72E-10**	8.77E-11**
2.0E+01	4.08E-09	3.47E-09	1.61E-09	7.28E-10*	4.16E-10*	2.72E-10**	8.77E-11**
4.0E+01	4.06E-09	3.46E-09	1.61E-09	7.29E-10*	4.16E-10*	2.73E-10**	8.78E-11**
7.0E+01	4.03E-09	3.44E-09	1.60E-09	7.30E-10*	4.17E-10*	2.73E-10*	8.79E-11**
1.0E+02	4.00E-09	3.42E-09	1.60E-09	7.31E-10*	4.17E-10*	2.73E-10*	8.79E-11**
2.0E+02	3.94E-09	3.39E-09	1.60E-09	7.35E-10*	4.19E-10*	2.75E-10*	8.81E-11**
4.0E+02	3.86E-09	3.34E-09	1.60E-09	7.42E-10*	4.22E-10*	2.77E-10*	8.83E-11**
7.0E+02	3.77E-09	3.27E-09	1.60E-09	7.53E-10*	4.27E-10*	2.80E-10*	8.80E-11**
1.0E+03	3.69E-09	3.22E-09	1.60E-09	7.64E-10*	4.32E-10*	2.82E-10*	8.71E-11**
2.0E+03	3.50E-09	3.05E-09	1.59E-09	7.95E-10	4.49E-10*	2.92E-10*	8.40E-11**
4.0E+03	3.23E-09	2.77E-09	1.57E-09	8.40E-10	4.85E-10*	3.12E-10*	8.06E-11**
7.0E+03	2.93E-09	2.46E-09	1.50E-09	8.76E-10	5.29E-10*	3.42E-10*	8.00E-11**
1.0E+04	2.69E-09	2.25E-09	1.43E-09	8.88E-10	5.60E-10*	3.69E-10*	8.18E-11**
2.0E+04	2.10E-09	1.76E-09	1.23E-09	8.56E-10	5.99E-10	4.24E-10*	9.59E-11**

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

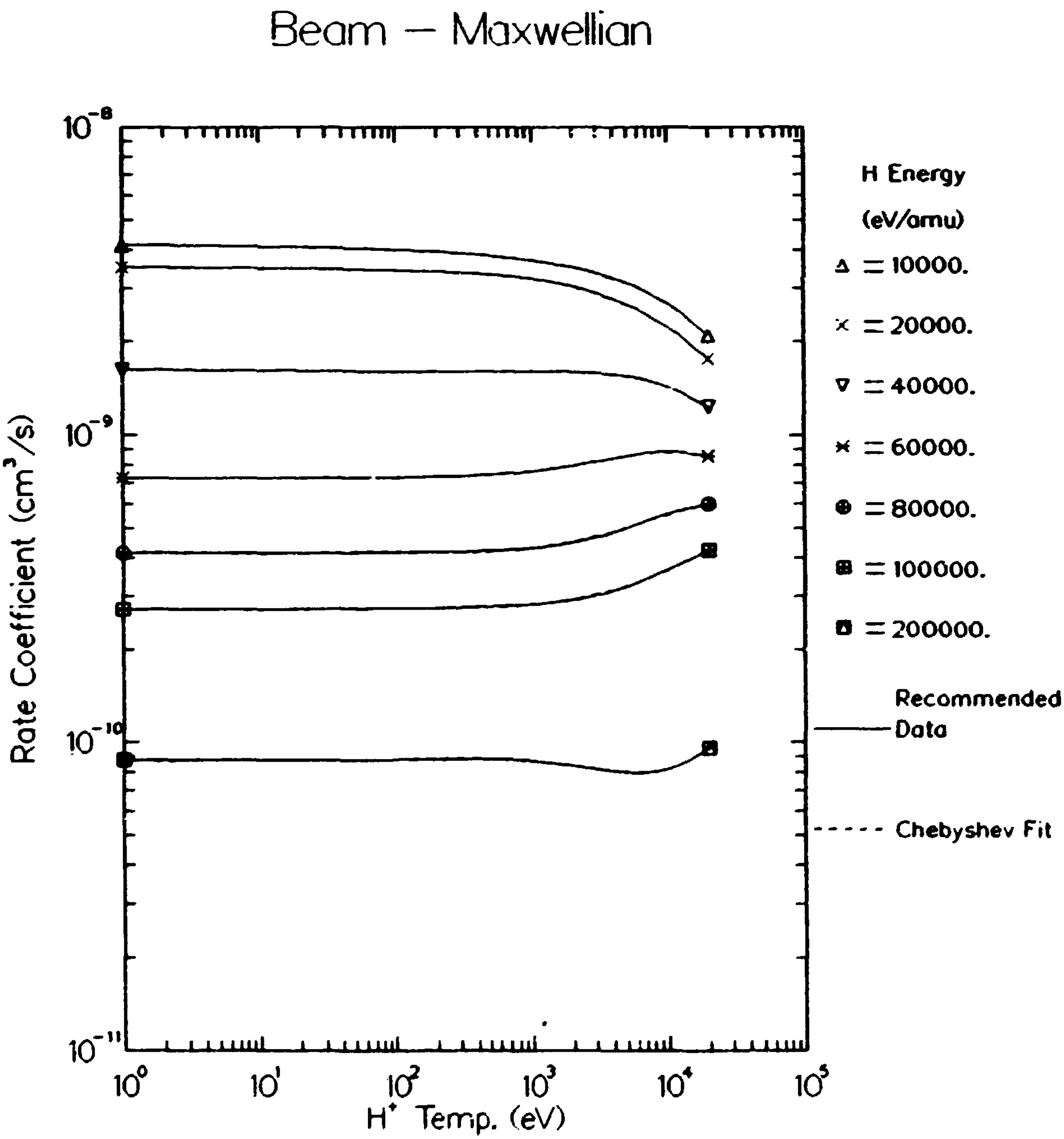
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-3.89330E+01	-2.63479E-01	-1.46563E-01	-6.61908E-02	-2.64497E-02	-9.58772E-03	-3.32633E-03
20000.	-3.92573E+01	-2.65213E-01	-1.59204E-01	-7.45512E-02	-2.59202E-02	-4.40931E-03	1.71443E-03
40000.	-4.05806E+01	-8.23737E-02	-5.96947E-02	-4.22268E-02	-2.58735E-02	-1.17419E-02	-3.02153E-03
60000.	-4.19604E+01	9.70829E-02	4.52599E-02	7.29529E-04	-1.72682E-02	-1.54561E-02	-7.90347E-03
80000.	-4.30171E+01	1.56735E-01	9.77827E-02	3.77245E-02	1.87118E-03	-9.85709E-03	-9.46753E-03
100000.	-4.38524E+01	1.71818E-01	1.11913E-01	5.35817E-02	1.64028E-02	-2.85661E-04	-5.46080E-03
200000.	-4.63327E+01	-9.29799E-03	6.37363E-03	2.65872E-02	3.44937E-02	2.70598E-02	1.28430E-02

See appendix for Chebyshev fit details.

H + H^+ -> H(2p) + H^+



Beam — Maxwellian
10^{-8}
10^{-9}
10^{-10}
10^{-11}
Rate Coefficient (cm^3/s)
10^0
10^1
10^2
10^3
10^4
10^5
H^+ Temp. (eV)
H Energy
(eV/amu)
= 10000.
= 20000.
= 40000.
= 60000.
= 80000.
= 100000.
= 200000.
Recommended Data
Chebyshev Fit

Electron Capture Cross Sections for

$H^{+} + H_2 \rightarrow H(2s,2p)$

H(2s)

Energy eV/amu	Cross Section cm^2
2.0E+03	2.64E-18
4.0E+03	5.08E-18
7.0E+03	9.24E-18
1.0E+04	1.37E-17
2.0E+04	2.69E-17
2.5E+04	2.79E-17
4.0E+04	2.21E-17
7.0E+04	9.53E-18
1.0E+05	4.28E-18
2.0E+05	4.24E-19

H(2p)

Energy eV/amu	Cross Section cm^2
4.0E+03	1.99E-17
7.0E+03	2.37E-17
1.0E+04	2.64E-17
1.4E+04	2.72E-17
2.0E+04	2.35E-17
4.0E+04	8.74E-18
7.0E+04	3.39E-18
1.0E+05	1.75E-18
1.5E+05	1.00E-18

__References:__ H(2s) - 13, 16, 18, 121, 122, 123, 124, 125, 126; H(2p) - 18, 122, 124, 128

__Accuracy:__ See notes

__Notes:__ (1) Large errors are usually associated with measuring emission from excited states to obtain either electron capture, dissociative or excitation emission cross sections. The cross sections reported here are emission cross sections from electron capture collisions. The H(2s) cross sections are determined by observing the excited H atom in an electric field which mixes the 2s state with the 2p state. The scatter of the data in the references is a factor of 2 for H(2s) capture and 20% for H(2p). We estimate that the data presented here have a confidence level to within 50%.

(2) For the collisions in an electromagnetic field sufficient to mix the 2s and 2p, the Lyman-α emission cross section is obtained from $\sigma(2s)+\sigma(2p)$.

(3) The cross section (σ_i) for capture into state i is determined by measuring the emission cross section for a transition from state i to j, correcting for any branching from state i and correcting for cascading from upper states.

(4) Since cascading to the 2p state is less than 5% $\sigma(2p) \approx \sigma$(Lyman-$\alpha$) emission.

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

H(2s) E_{min} = 2.0E+03 eV/amu, E_{max} = 2.0E+05 eV/amu
H(2p) E_{min} = 4.0E+03 eV/amu, E_{max} = 1.5E+05 eV/amu

__Chebyshev Fitting Parameters for Cross Sections__

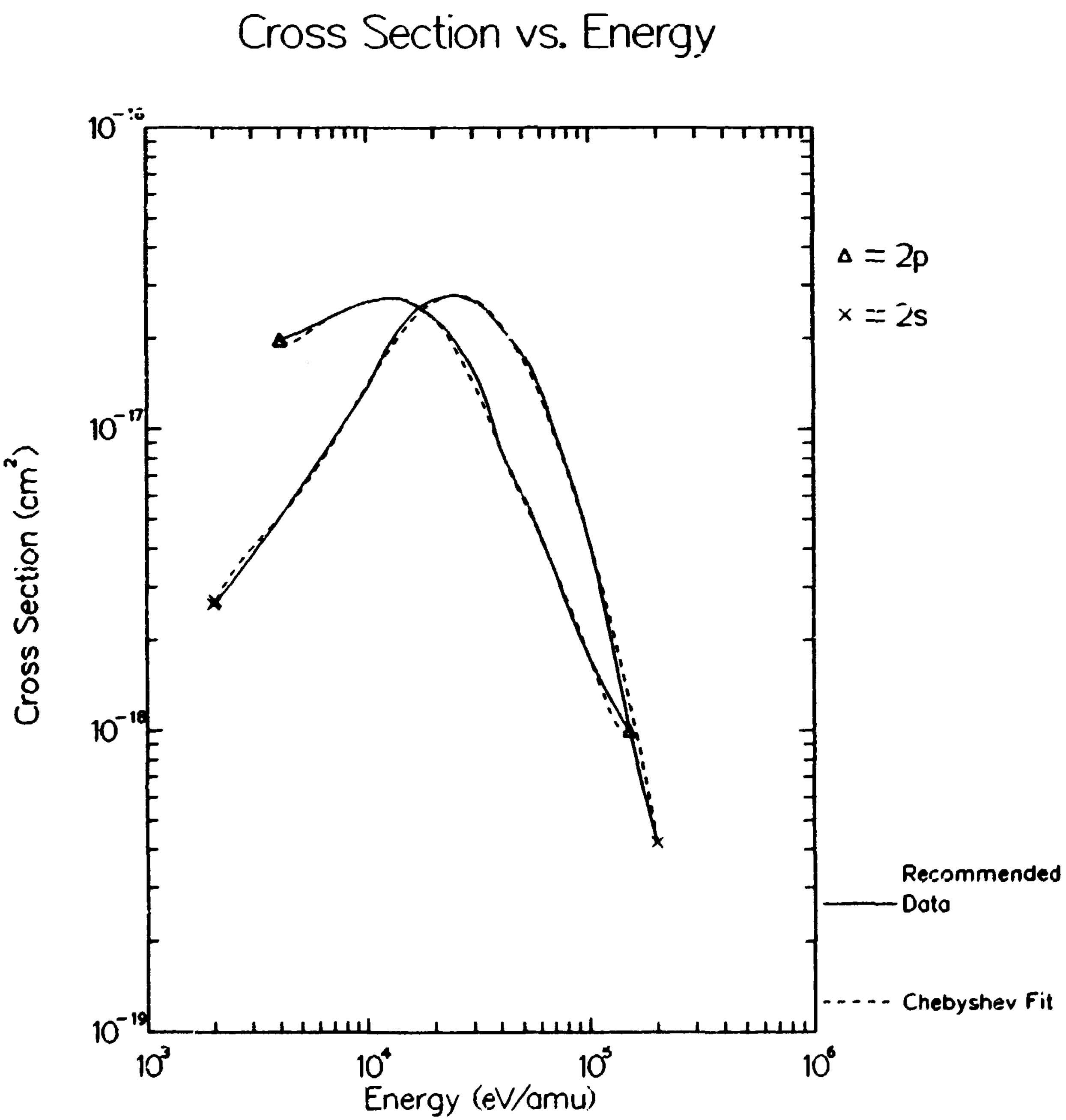
	A0	A1	A2	A3	A4	A5	A6	A7	A8
H(2s)	-79.7252	-.533265	-1.56108	-.431130	.0810709	.0519074	-.0478876	-.00197365	
H(2p)	-78.7561	-1.60375	-.734004	.106262	.120750	-.0254921	.00605546	.0276214	.0341018

The fit represents the H(2s) cross section with an rms deviation of 1.3%.
The maximum deviation is 2.5% at 1.0E+04 eV/amu.

The fit represents the H(2p) cross section with an rms deviation of 1.5%.
The maximum deviation is 8.5% at 1.3E+05 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + H_2 \rightarrow H(2s, 2p)$



Line Emission Cross Sections of Electron Capture Collisions for
$H^+ + H_2 \rightarrow H(Ly_\alpha)$ Total

Energy (eV/amu)	Velocity (cm/s).	Cross Section (cm^2)
8.2E+01	1.26E+07	7.15E-20
1.0E+02	1.39E+07	1.37E-19
2.0E+02	1.96E+07	9.34E-19
4.0E+02	2.78E+07	4.56E-18
7.0E+02	3.68E+07	1.20E-17
1.0E+03	4.39E+07	1.69E-17
1.5E+03	5.38E+07	1.97E-17
2.0E+03	6.21E+07	2.11E-17
3.0E+03	7.61E+07	2.39E-17
4.0E+03	8.79E+07	2.94E-17
7.0E+03	1.16E+08	4.30E-17
1.0E+04	1.39E+08	5.22E-17
1.4E+04	1.64E+08	5.61E-17
2.0E+04	1.96E+08	4.87E-17
4.0E+04	2.78E+08	2.97E-17
7.0E+04	3.68E+08	1.94E-17
1.0E+05	4.39E+08	1.46E-17
1.4E+05	5.20E+08	1.19E-17

References: 124, 128, 187, 188, 193, 195, 197

Accuracy: 40%

Notes: (1) The cross section σ_i for capture into state i is determined by measuring the emission cross section (σ_{ij}) for a transition from state i to j, correcting for any branching from state i and correcting for cascading from upper states.
(2) The capture cross section into excited states is measured by making use of the Doppler shift. The total $\sigma(Ly_\alpha)$ was determined from the total of the shifted and unshifted radiation.

For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 8.2E+01 eV/amu, E_{max} = 1.4E+05 eV/amu

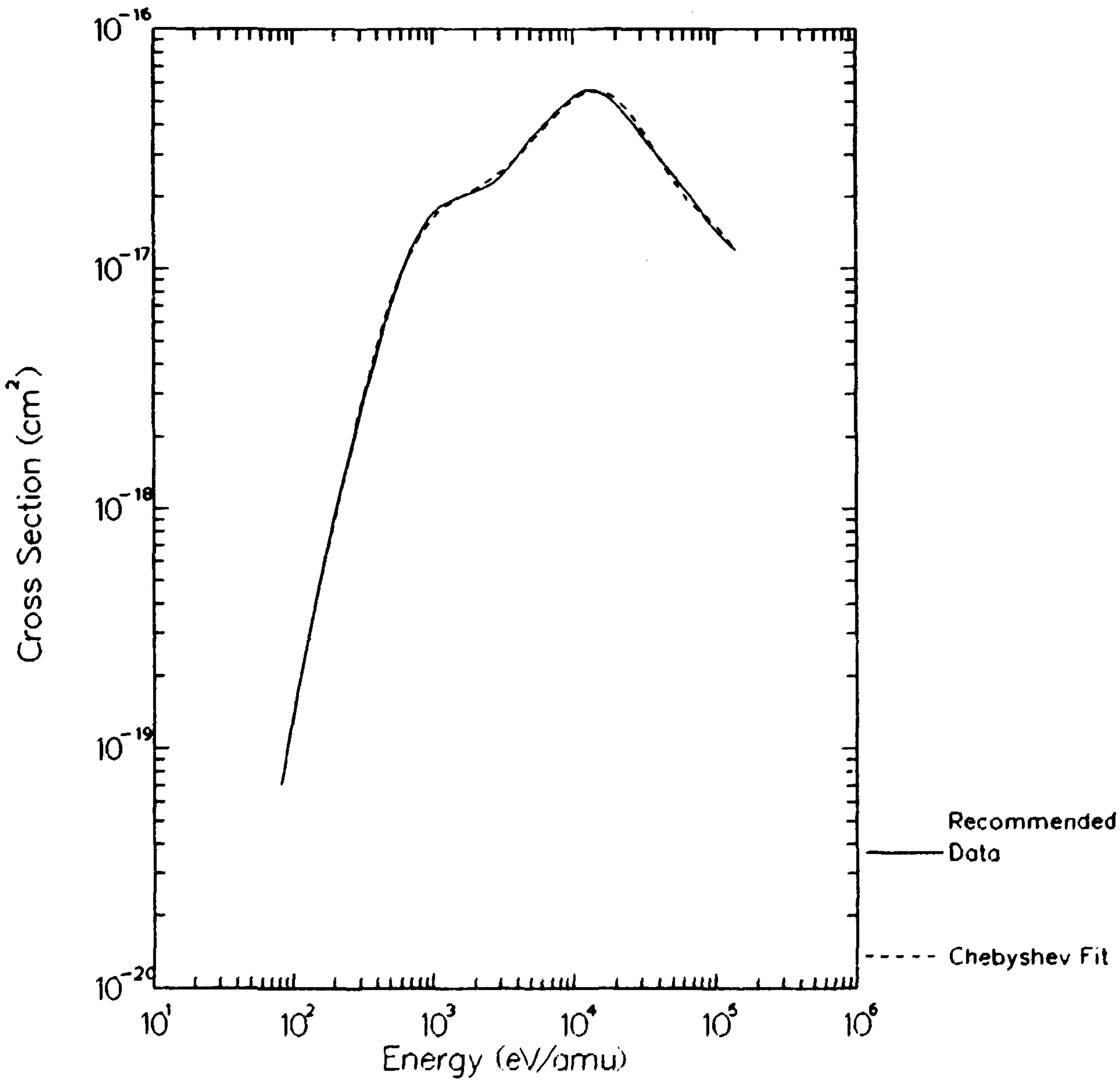
Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-79.2785	2.29244	-1.84261	.243522	-.113691	.0377226	.155522	-.0201741	-.0977164

The fit represents the above cross sections with an rms deviation of 3.4%.
The maximum deviation is 6.0% at 2.0E+04 eV/amu.
See appendix for Chebyshev fit details.

$H^+ + H_2 \rightarrow H(\text{Lyman}-\alpha)\text{Total}$

Cross Section vs. Energy



Line Emission Cross Sections of Electron Capture Collisions for

$H^{+} + H_2 \rightarrow H(H_\alpha, H_\beta)$

(H_α) Energy eV/amu	(H_α) Cross Section cm^2
5.0E+02	2.44E-19
7.0E+02	6.10E-19
1.0E+03	1.13E-18
2.0E+03	2.13E-18
4.0E+03	3.11E-18
7.0E+03	4.17E-18
1.0E+04	4.95E-18
2.0E+04	7.18E-18
3.0E+04	8.52E-18
4.0E+04	7.68E-18
7.0E+04	3.34E-18
1.0E+05	1.25E-18
2.0E+05	1.06E-19
4.0E+05	4.17E-21

(H_β) Energy eV/amu	(H_β) Cross Section cm^2
5.0E+02	4.24E-20
7.0E+02	9.36E-20
1.0E+03	1.61E-19
2.0E+03	3.12E-19
4.0E+03	4.27E-19
7.0E+03	4.96E-19
1.0E+04	5.17E-19
2.0E+04	4.82E-19
4.0E+04	2.94E-19
7.0E+04	1.11E-19
1.0E+05	4.45E-20
1.5E+05	1.74E-20

<u>References:</u> (H_α) - 131, 133, 134, 135, 136, 137, 138, 139; (H_β) - 137, 138, 139

<u>Accuracy:</u> See notes

<u>Notes:</u> (1) Large errors are usually associated with measuring optical emission from excited states which arise from electron capture, dissociative or excitation collisions. The cross sections reported here are for electron capture collisions resulting in Balmer-α emission (n=3->2), λ=6562.79 Å) and Balmer-β emission (n=4->2, λ=4861.33 Å). Errors arise mainly from the detecter calibration which for the visible spectrum varies over many orders of magnitude. We can only estimate the error to be more than a factor of 2 for H_α.

(2) The H_α emission cross section is found from the following relation - $\sigma(H_\alpha) = \sigma(3s) + .118\sigma(3p) + \sigma(3d)$.

(3) Cascading from upper levels contribute no more than 5% to the measured cross sections.

(4) H_α cross sections below 3×10^3 eV/amu were found by normalizing Hess's results (ref. 137 and 138) to other results at 3×10^3 eV/amu.

(5) Very little data are available for Balmer-β (H_β) emission cross sections.

(6) H_β cross sections below 3×10^3 eV/amu were found by normalizing Hess's data (refs. 137 and 138) at 3×10^3 eV/amu to Hughes et al data (ref. 139).

(7) No estimate is given for errors in the H_β data.

(8) Data are available for capture in the 4s state (see refs. 130 and 132).

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

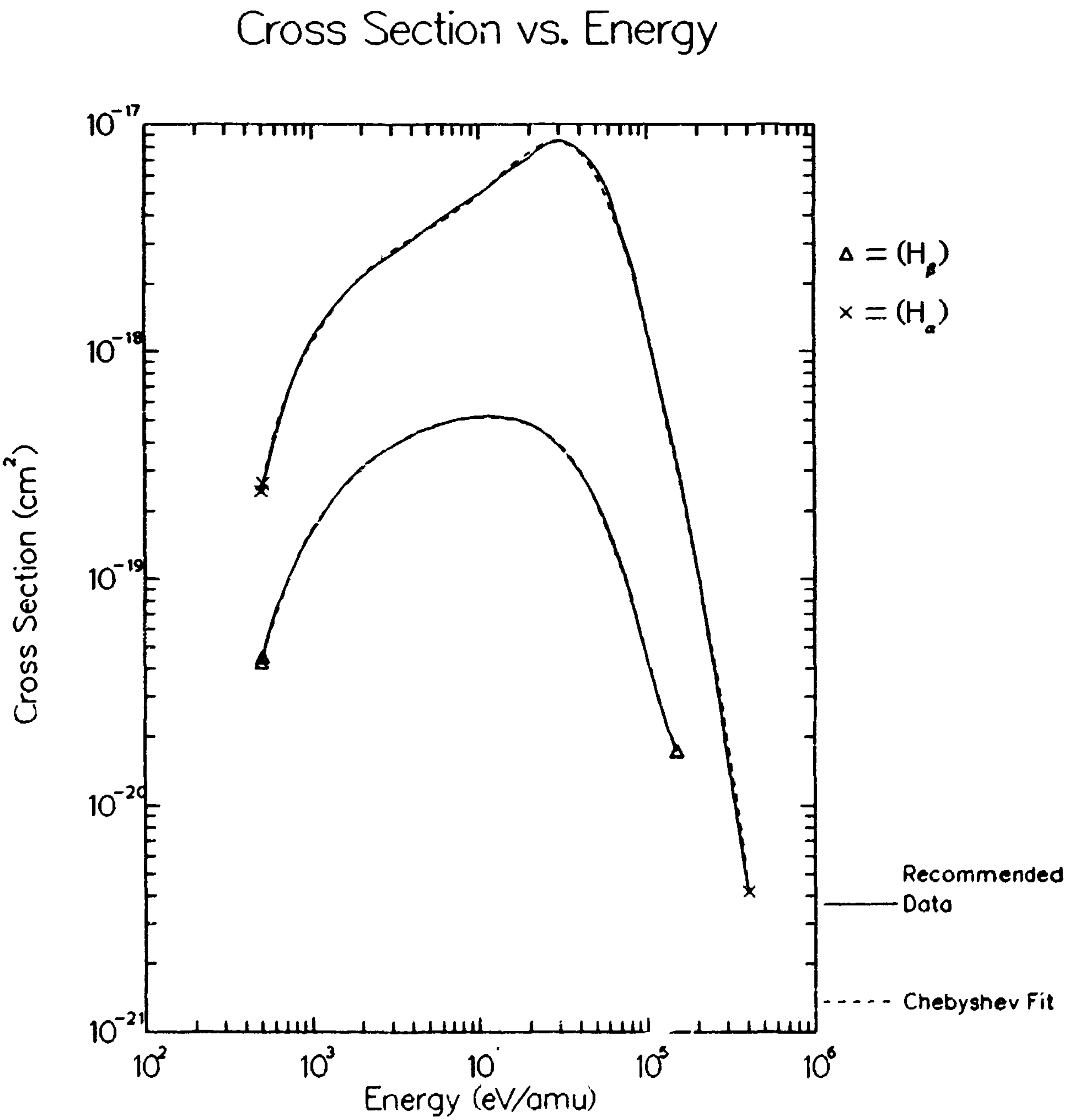
(H_α) E_{min} = 5.0E+02 eV/amu, E_{max} = 4.0E+05 eV/amu
(H_β) E_{min} = 5.0E+02 eV/amu, E_{max} = 1.5E+05 eV/amu

<u>Chebyshev Fitting Parameters for Cross Sections</u>

	A0	A1	A2	A3	A4	A5	A6	A7	A8
(H_α)	-83.9403	-1.52055	-2.66829	-.703430	-.220654	.245822	.0371514	-.0525595	-.0727916
(H_β)	-86.8907	-.394318	-1.51191	-.164906	-.148036	.0816213	.0463644	.0309715	.00687359

The fit represents the (H_α) cross section with an rms deviation of 2.2%.
The maximum deviation is 5.1% at 2.0E+04 eV/amu.
The fit represents the (H_β) cross section with an rms deviation of 0.6%.
The maximum deviation is 1.1% at 1.0E+03 eV/amu.
See appendix for Chebyshev fit details.

$H^+ + H_2 \rightarrow H(H_\alpha, H_\beta)$



Electron Capture Cross Sections for

$H^+ + H_2 \rightarrow H(3s,3p,3d) + H_2^+$

H(3s)		H(3p)		H(3d)	
Energy eV/amu	Cross Section cm^2	Energy eV/amu	Cross Section cm^2	Energy eV/amu	Cross Section cm^2
1.0E+03	3.33E-19	2.2E+03	1.18E-18	1.4E+03	4.27E-19
2.0E+03	5.25E-19	4.0E+03	3.49E-18	2.0E+03	5.56E-19
4.0E+03	8.67E-19	5.9E+03	4.19E-18	4.0E+03	8.89E-19
7.0E+03	1.45E-18	7.0E+03	4.17E-18	7.0E+03	1.27E-18
1.0E+04	2.10E-18	1.0E+04	3.86E-18	1.0E+04	1.57E-18
2.0E+04	4.90E-18	2.0E+04	2.83E-18	1.1E+04	1.60E-18
3.2E+04	7.21E-18	3.2E+04	1.63E-18	2.0E+04	1.04E-18
4.0E+04	6.54E-18	4.0E+04	1.07E-18	4.0E+04	3.94E-19
7.0E+04	2.88E-18	7.0E+04	2.96E-19	7.0E+04	1.03E-19
1.0E+05	1.16E-18	1.0E+05	1.35E-19	1.0E+05	3.09E-20
2.0E+05	9.99E-20	1.6E+05	4.76E-20	1.4E+05	8.93E-21
3.0E+05	1.83E-20	2.0E+05	3.13E-20	2.0E+05	4.39E-21
		3.4E+05	1.01E-20	3.0E+05	2.47E-21

References: H(3s) 129, 130, 131, 132, 133, 134, 135; H(3p) 122, 131, 133, 134, 136; H(3d) 131, 134, 136

Accuracy: See notes

Notes: (1) Large errors are usually associated with measuring optical emission from excited states which arise either from electron capture, dissociative, or excitation collisions. The cross sections reported here are for electron capture of the fast proton into a fast H atom. Errors arise mainly from absolute calibration of the detector which for the visible spectrum varies over orders of magnitude from blue to red. We estimate the data presented to be accurate to a factor of 2.

(2) The cross section (σ_i) for capture into state i is determined by measuring the emission cross section (σ_{ij}) for a transition from state i to j, correcting for any branching from state i and correcting for cascading from upper states.

(3) For the n=3 levels cascading is less than 5%.

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

H(3s) E_{min} = 1.0E+03 eV/amu, E_{max} = 3.0E+05 eV/amu
H(3p) E_{min} = 2.2E+03 eV/amu, E_{max} = 3.4E+05 eV/amu
H(3d) E_{min} = 1.4E+03 eV/amu, E_{max} = 3.0E+05 eV/amu

Chebyshev Fitting Parameters for Cross Sections

	A0	A1	A2	A3	A4	A5	A6	A7	A8
H(3s)	-84.0392	-.728083	-2.03457	-.860699	.0489259	.212089	.0319211	-.0748778	-.0241098
H(3p)	-84.5768	-2.73107	-1.38696	.326474	.0471408	.0427739	-.0758510	-.0181499	.0430074
H(3d)	-86.9132	-2.76179	-1.74766	.0813682	.392354	.101286	.0203703	.00824074	-.0805033

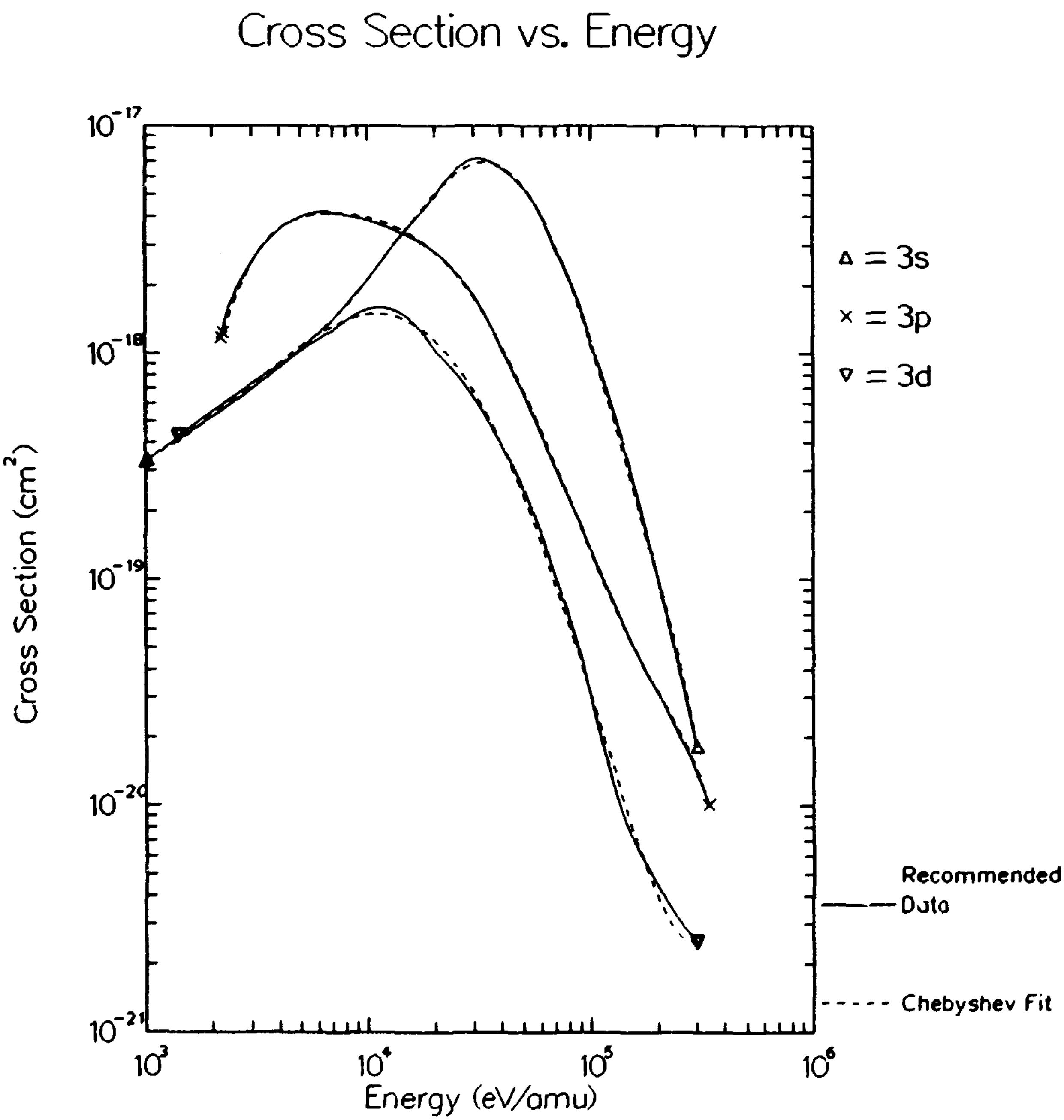
The fit represents the H(3s) cross section with an rms deviation of 2.3%.
The maximum deviation is 4.0% at 7.0E+04 eV/amu.

The fit represents the H(3p) cross section with an rms deviation of 1.3%.
The maximum deviation is 2.6% at 1.6E+05 eV/amu.

The fit represents the H(3d) cross section with an rms deviation of 5.0%.
The maximum deviation is 10.4% at 7.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$H^{+} + H_2 -> H(3s, 3p, 3d)$


Cross Section vs. Energy
Cross Section (cm²)
Energy (eV/amu)
10⁻¹⁷
10⁻¹⁸
10⁻¹⁹
10⁻²⁰
10⁻²¹
10³
10⁴
10⁵
10⁶
Δ = 3s
× = 3p
∇ = 3d
Recommended Data
Chebyshev Fit

Electron Capture Cross Sections for
H^+ + He -> H(2s) + He^+

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.8E+03	7.35E+07	5.16E-20
4.0E+03	8.79E+07	1.45E-19
7.0E+03	1.16E+08	5.91E-19
1.0E+04	1.39E+08	1.03E-18
1.4E+04	1.64E+08	1.47E-18
2.0E+04	1.96E+08	2.44E-18
3.0E+04	2.41E+08	5.61E-18
4.0E+04	2.78E+08	7.74E-18
5.0E+04	3.11E+08	8.08E-18
7.0E+04	3.68E+08	6.60E-18
1.0E+05	4.39E+08	3.75E-18
2.0E+05	6.21E+08	4.23E-19

References: 16, 121, 125, 126, 183, 184, 189, 190, 191

Accuracy: 50%

Note: (1) The σ(2s) cross section is found by mixing the 2s state with the 2p state by an electric field.

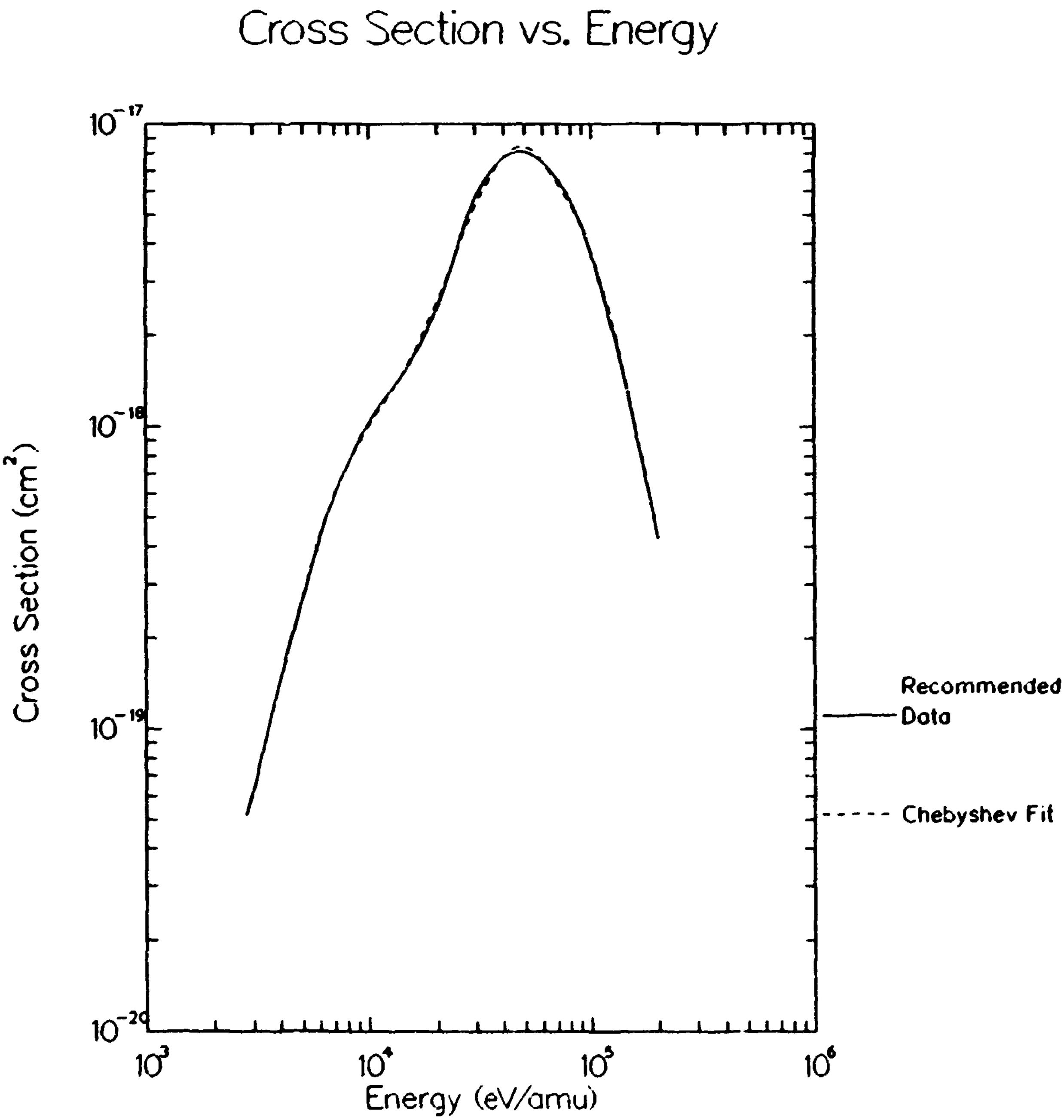
For Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.8E+03 eV/amu, E_{max} = 2.0E+05 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-83.0478	1.54023	-1.55597	-.364564	-.186200	.0423931	-.0198717	-.166625	-.0726702

The fit represents the above cross sections with an rms deviation of 2.5%.
The maximum deviation is 4.2% at 5.0E+04 eV/amu.
See appendix for Chebyshev fit details.

$H^+ + He \rightarrow H(2s) + He^+$



Electron Capture Rate Coefficients for
$H^+ + He \rightarrow H(2s) + He^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	Equal Temp.	He Temp. (eV) 500.	1000.	2000.	4000.	7000.	10000.	20000.
2.0E+02	2.85E-16	3.73E-15	4.23E-14	4.60E-13	3.64E-12	1.48E-11	3.22E-11	1.30E-10
4.0E+02	8.08E-14	1.07E-13	3.25E-13	1.32E-12	5.90E-12	1.89E-11	3.78E-11	1.40E-10
7.0E+02	1.18E-12	9.32E-13	1.61E-12	3.64E-12	1.03E-11	2.58E-11	4.68E-11	1.57E-10
1.0E+03	4.16E-12	2.94E-12	4.16E-12	7.24E-12	1.58E-11	3.35E-11	5.68E-11	1.74E-10
2.0E+03	2.70E-11	1.83E-11	2.11E-11	2.70E-11	4.07E-11	6.58E-11	9.64E-11	2.35E-10
4.0E+03	1.20E-10	8.03E-11	8.55E-11	9.64E-11	1.20E-10	1.59E-10	2.03E-10	3.72E-10
7.0E+03	3.54E-10	2.43E-10	2.51E-10	2.68E-10	3.02E-10	3.54E-10	4.08E-10	5.86E-10
1.0E+04	6.20E-10	4.53E-10	4.62E-10	4.80E-10	5.15E-10	5.68E-10	6.20E-10	7.81E-10
2.0E+04	1.21E-09	1.04E-09	1.05E-09	1.06E-09	1.08E-09	1.11E-09	1.13E-09	1.21E-09

Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 2.0E+02 eV, E_{max} = 2.0E+04 eV

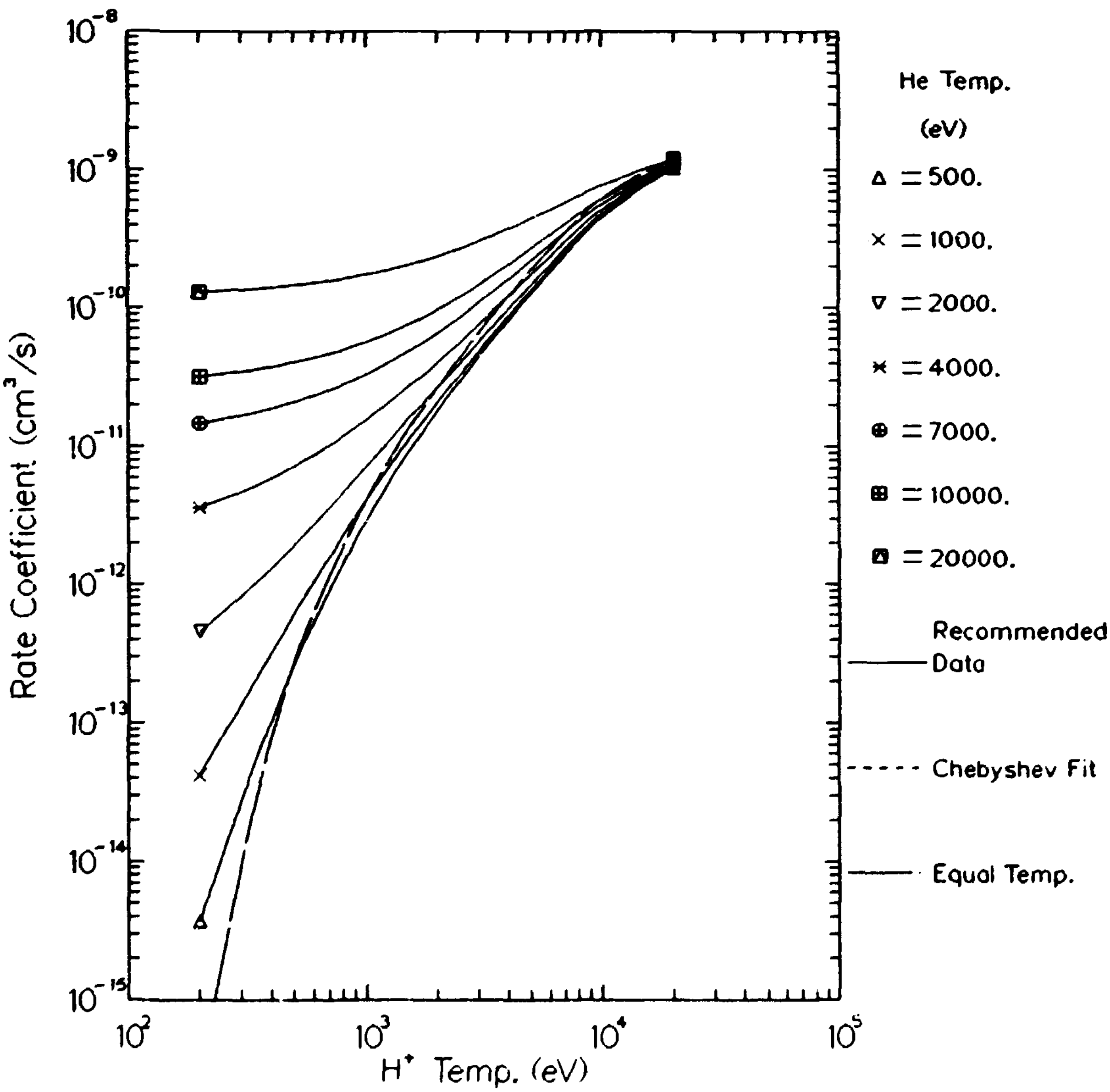
Chebyshev Fitting Parameters for Rate Coefficients

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
500.	-5.15547E+01	6.12867E+00	-1.10703E+00	1.83503E-01	-6.31506E-02	-4.18133E-02	-5.16887E-03
1000.	-5.02988E+01	5.12782E+00	-5.67743E-01	-2.34476E-02	-1.29792E-02	-4.58512E-02	-5.85869E-03
2000.	-4.88467E+01	4.04429E+00	-9.26042E-02	-1.42687E-01	-1.51195E-02	-3.17168E-02	-6.62145E-03
4000.	-4.73254E+01	3.01860E+00	2.18123E-01	-1.57967E-01	-4.76884E-02	-1.64944E-02	-1.20711E-03
7000.	-4.60971E+01	2.29486E+00	3.28511E-01	-1.26781E-01	-6.47340E-02	-1.05302E-02	4.12821E-03
10000.	-4.53140E+01	1.88943E+00	3.36913E-01	-1.00227E-01	-6.44137E-02	-9.37217E-03	4.93922E-03
20000.	-4.37344E+01	1.17101E+00	2.58458E-01	-4.78379E-02	-4.40287E-02	-8.69295E-03	2.45757E-03
Equal Temp.	-5.19683E+01	7.03024E+00	-1.90084E+00	5.72322E-01	-2.68910E-01	2.66381E-02	-1.15409E-02

See appendix for Chebyshev fit details.

$H^+ + He \rightarrow H(2s) + He^+$

Maxwellian – Maxwellian



Electron Capture Rate Coefficients for
$He + H^+ \rightarrow H(2s) + He^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	60000.	80000.	100000.	120000.
1.0E+00	1.43E-10**	4.81E-10**	2.14E-09*	2.46E-09*	2.10E-09**	1.64E-09**	1.02E-09**
2.0E+00	1.43E-10**	4.81E-10**	2.14E-09*	2.46E-09*	2.10E-09**	1.64E-09**	1.02E-09**
4.0E+00	1.43E-10**	4.82E-10**	2.14E-09*	2.46E-09*	2.10E-09**	1.64E-09**	1.02E-09**
7.0E+00	1.42E-10**	4.84E-10*	2.14E-09*	2.46E-09*	2.10E-09*	1.64E-09**	1.02E-09**
1.0E+01	1.42E-10**	4.85E-10*	2.13E-09*	2.46E-09*	2.10E-09*	1.63E-09**	1.02E-09**
2.0E+01	1.42E-10**	4.88E-10*	2.13E-09*	2.46E-09*	2.10E-09*	1.63E-09*	1.02E-09**
4.0E+01	1.43E-10*	4.93E-10*	2.12E-09*	2.46E-09*	2.10E-09*	1.62E-09*	1.02E-09**
7.0E+01	1.44E-10*	5.00E-10*	2.11E-09*	2.46E-09*	2.10E-09*	1.61E-09*	1.02E-09**
1.0E+02	1.45E-10*	5.07E-10*	2.11E-09*	2.46E-09*	2.10E-09*	1.61E-09*	1.02E-09**
2.0E+02	1.49E-10*	5.28E-10*	2.09E-09*	2.46E-09*	2.10E-09*	1.59E-09*	1.03E-09**
4.0E+02	1.59E-10*	5.68E-10*	2.07E-09*	2.45E-09*	2.09E-09*	1.57E-09*	1.03E-09*
7.0E+02	1.77E-10*	6.23E-10*	2.05E-09*	2.42E-09*	2.08E-09*	1.56E-09*	1.04E-09*
1.0E+03	1.97E-10*	6.73E-10*	2.03E-09*	2.39E-09*	2.06E-09*	1.54E-09*	1.05E-09*
2.0E+03	2.79E-10*	8.12E-10*	1.98E-09*	2.29E-09*	1.99E-09*	1.51E-09*	1.06E-09*
4.0E+03	4.63E-10*	1.01E-09*	1.90E-09	2.12E-09*	1.87E-09*	1.46E-09*	1.07E-09*
7.0E+03	7.11E-10	1.19E-09	1.81E-09	1.92E-09*	1.72E-09*	1.38E-09*	1.05E-09*
1.0E+04	9.07E-10	1.29E-09	1.73E-09	1.78E-09*	1.59E-09*	1.31E-09*	1.02E-09*
2.0E+04	1.27E-09	1.42E-09	1.54E-09	1.47E-09*	1.31E-09*	1.12E-09*	9.16E-10*

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

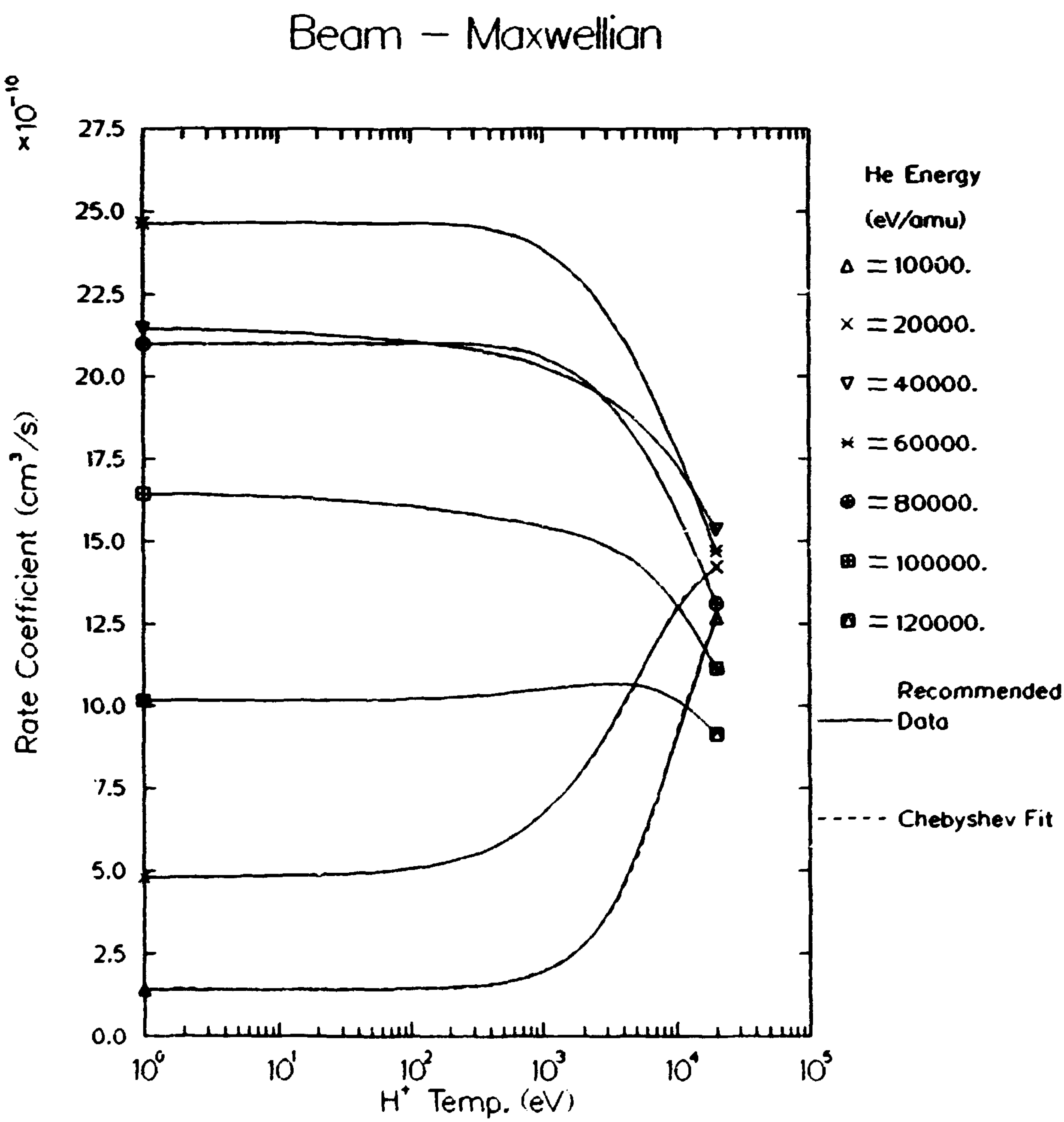
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-4.41473E+01	1.00293E+00	5.77264E-01	1.69345E-01	-4.20278E-02	-7.82819E-02	-4.04936E-02
20000.	-4.22126E+01	5.46817E-01	2.44571E-01	2.72848E-02	-4.37757E-02	-3.23001E-02	-7.56613E-03
40000.	-4.00821E+01	-1.29340E-01	-7.16121E-02	-3.33138E-02	-1.32072E-02	-4.05181E-03	-1.23221E-03
60000.	-3.98602E+01	-1.91480E-01	-1.30757E-01	-6.51877E-02	-2.04843E-02	-1.38003E-03	2.12462E-03
80000.	-4.01499E+01	-1.66211E-01	-1.18429E-01	-6.40569E-02	-2.40368E-02	-4.53618E-03	8.86157E-04
100000.	-4.05316E+01	-1.42002E-01	-8.01346E-02	-4.14812E-02	-2.15460E-02	-9.87334E-03	-2.92063E-03
120000.	-4.14146E+01	-1.03802E-02	-2.66264E-02	-3.13729E-02	-2.24983E-02	-1.04122E-02	-2.88295E-03

See appendix for Chebyshev fit details.

He + H^+ -> H(2s) + He^+


Beam – Maxwellian
×10^{-10}
Rate Coefficient (cm^3/s)
27.5
25.0
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
10^0
10^1
10^2
10^3
10^4
10^5
H$^+$ Temp. (eV)
He Energy
(eV/amu)
= 10000.
= 20000.
= 40000.
= 60000.
= 80000.
= 100000.
= 120000.
Recommended Data
Chebyshev Fit

Electron Capture Cross Sections for
$H^+ + He \rightarrow H(2p) + He^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
7.0E+02	3.68E+07	2.02E-20
1.0E+03	4.39E+07	4.48E-20
2.0E+03	6.21E+07	2.10E-19
4.0E+03	8.79E+07	6.83E-19
7.0E+03	1.16E+08	1.57E-18
1.0E+04	1.39E+08	2.32E-18
2.0E+04	1.96E+08	3.14E-18
3.0E+04	2.41E+08	2.88E-18
4.0E+04	2.78E+08	2.17E-18
7.0E+04	3.68E+08	8.52E-19
1.0E+05	4.39E+08	3.93E-19
2.0E+05	6.21E+08	3.86E-20
3.0E+05	7.61E+08	9.74E-21

<u>References:</u> 24, 46, 125, 163, 164, 165, 166, 183, 184, 185, 186, 187, 188, 245

<u>Accuracy:</u> 30%

<u>Notes:</u> (1) If cascade is neglected $\sigma(H\ Ly_\alpha) = \sigma(H\ 2p)$. Cascade contributions are less than 5%.
(2) The cross sections for capture into the 2p state or Ly_α emission have large discrepancies at energies less than $1x10^4$ eV/amu. These discrepancies are thought to be due to a small amount of H^0 present in the H^+ beam during measurements. The cross section for excitation of $H + He \rightarrow H(2p)$ is approximatly 2 orders of magnitude greater than $H^+ + He \rightarrow H(2p) + He^+$.

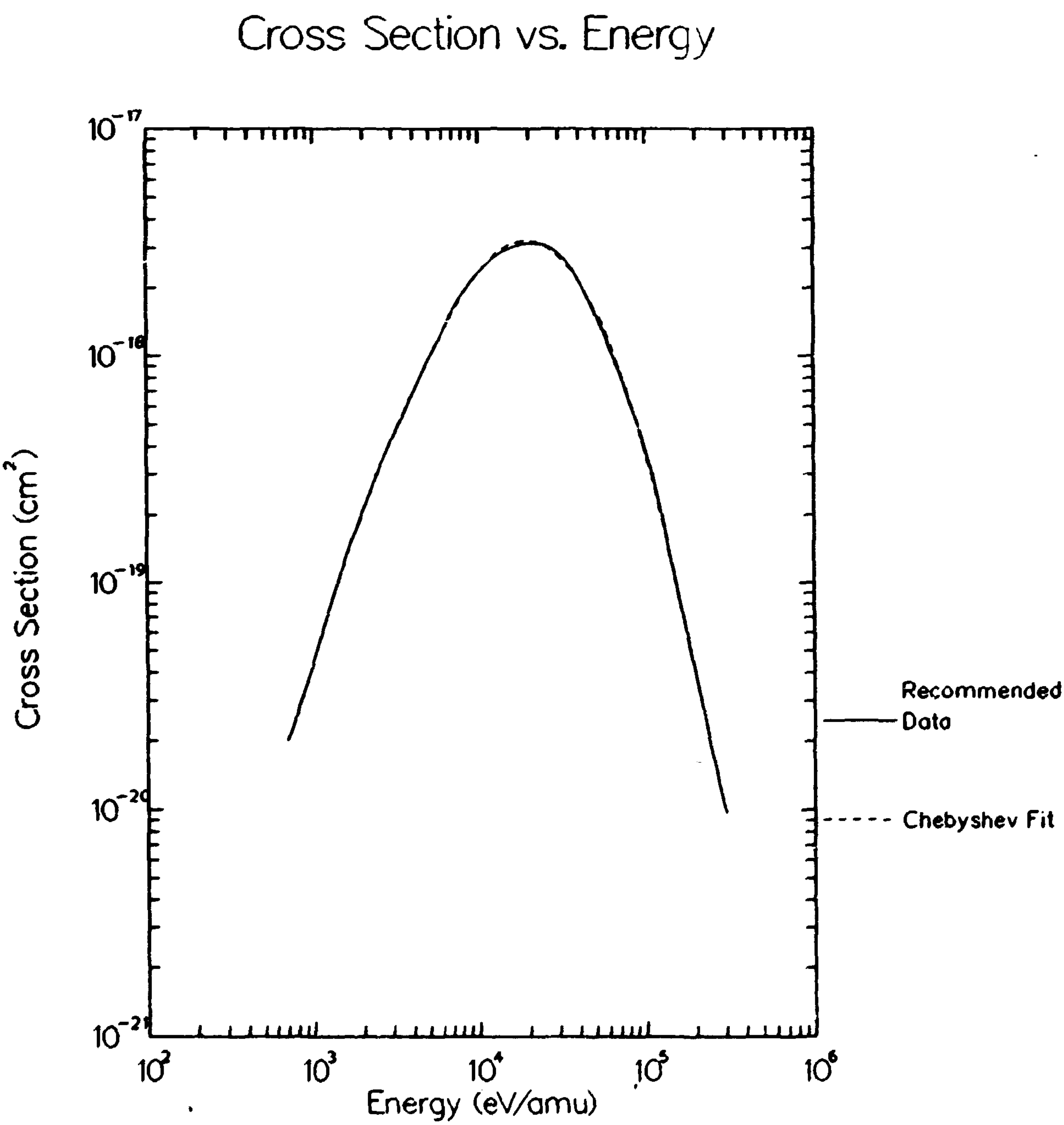
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 7.0E+02 eV/amu, E_{max} = 3.0E+05 eV/amu

<u>Chebyshev Fitting Parameters for Cross Sections</u>

A0	A1	A2	A3	A4	A5	A6	A7	A8
-86.2710	-.0743636	-2.70622	-.368010	.0743916	.0747662	.0195366	.00225497	.0337284

The fit represents the above cross sections with an rms deviation of 1.9%.
The maximum deviation is 4.1% at 7.0E+04 eV/amu.
See appendix for Chebyshev fit details.

$H^+ + He \rightarrow H(2p) + He^+$



Electron Capture Rate Coefficients for
$H^+ + He \rightarrow H(2p) + He^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	Equal Temp.	He Temp. (eV) 100.	1000.	2000.	4000.	7000.	10000.	20000.
4.0E+01	3.31E-18	7.92E-17	4.90E-13	2.90E-12	1.36E-11	4.11E-11	7.62E-11	1.98E-10
7.0E+01	1.22E-15	2.29E-15	6.69E-13	3.33E-12	1.45E-11	4.25E-11	7.77E-11	1.99E-10
1.0E+02	1.36E-14	1.36E-14	8.78E-13	3.79E-12	1.54E-11	4.38E-11	7.92E-11	2.00E-10
2.0E+02	2.97E-13	2.03E-13	1.79E-12	5.52E-12	1.85E-11	4.82E-11	8.41E-11	2.05E-10
4.0E+02	2.38E-12	1.53E-12	4.61E-12	9.89E-12	2.55E-11	5.74E-11	9.42E-11	2.13E-10
7.0E+02	9.28E-12	6.00E-12	1.12E-11	1.85E-11	3.73E-11	7.18E-11	1.09E-10	2.26E-10
1.0E+03	2.02E-11	1.32E-11	2.02E-11	2.93E-11	5.05E-11	8.66E-11	1.24E-10	2.38E-10
2.0E+03	7.43E-11	5.16E-11	6.21E-11	7.43E-11	9.92E-11	1.37E-10	1.73E-10	2.75E-10
4.0E+03	1.96E-10	1.50E-10	1.61E-10	1.73E-10	1.96E-10	2.28E-10	2.57E-10	3.34E-10
7.0E+03	3.27E-10	2.76E-10	2.83E-10	2.92E-10	3.07E-10	3.27E-10	3.45E-10	3.91E-10
1.0E+04	3.98E-10	3.57E-10	3.62E-10	3.66E-10	3.75E-10	3.87E-10	3.98E-10	4.22E-10
2.0E+04	4.33E-10	4.38E-10	4.39E-10	4.39E-10	4.39E-10	4.38E-10	4.38E-10	4.33E-10

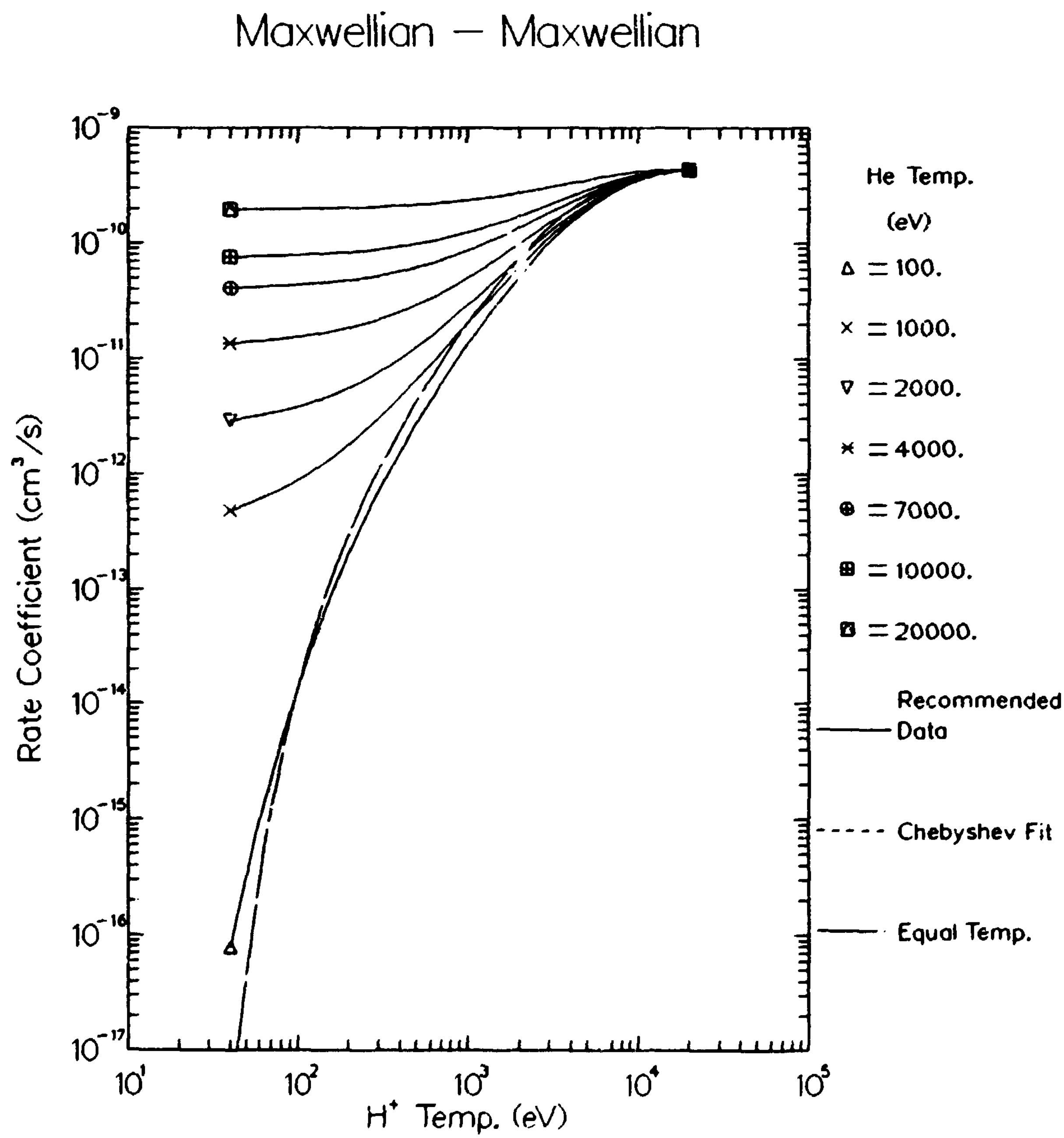
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 4.0E+01 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
100.	-5.42320E+01	7.44291E+00	-2.03521E+00	2.94202E-01	-1.85784E-01	2.90590E-02	2.43336E-02
1000.	-4.97005E+01	3.78186E+00	-7.01113E-02	-4.11509E-01	-2.83920E-02	2.87633E-02	2.44756E-03
2000.	-4.83079E+01	2.82754E+00	1.63410E-01	-3.46227E-01	-7.46954E-02	2.85450E-02	8.40255E-03
4000.	-4.69020E+01	1.95707E+00	2.50111E-01	-2.30851E-01	-9.41042E-02	9.45349E-03	1.19992E-02
7000.	-4.57899E+01	1.32780E+00	2.41351E-01	-1.38821E-01	-8.61534E-02	-6.49649E-03	8.83775E-03
10000.	-4.51295E+01	9.78457E-01	2.08879E-01	-9.24217E-02	-7.29486E-02	-1.27985E-02	5.37477E-03
20000.	-4.40453E+01	4.43773E-01	1.12537E-01	-3.78696E-02	-4.20886E-02	-1.39142E-02	-2.74451E-04
Equal Temp.	-5.47397E+01	8.28139E+00	-2.97971E+00	8.65229E-01	-5.12815E-01	1.97141E-01	-4.18893E-02

See appendix for Chebyshev fit details.

$H^+ + He \rightarrow H(2p) + He^+$



Electron Capture Rate Coefficients for
$He + H^+ \rightarrow H(2p) + He^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	60000.	80000.	100000.	200000.
1.0E+00	3.21E-10	6.15E-10	6.02E-10	3.75E-10	2.51E-10*	1.72E-10*	2.40E-11**
2.0E+00	3.21E-10	6.15E-10	6.01E-10	3.75E-10*	2.51E-10*	1.72E-10*	2.40E-11**
4.0E+00	3.20E-10	6.14E-10	6.01E-10	3.75E-10*	2.51E-10*	1.72E-10*	2.40E-11**
7.0E+00	3.20E-10	6.13E-10	6.00E-10	3.75E-10	2.51E-10*	1.72E-10*	2.40E-11**
1.0E+01	3.19E-10	6.12E-10	5.99E-10	3.75E-10	2.51E-10*	1.72E-10*	2.40E-11**
2.0E+01	3.18E-10	6.10E-10	5.98E-10	3.75E-10	2.51E-10*	1.71E-10*	2.40E-11**
4.0E+01	3.18E-10	6.08E-10	5.96E-10	3.75E-10	2.51E-10	1.71E-10*	2.40E-11**
7.0E+01	3.17E-10	6.05E-10	5.93E-10	3.75E-10	2.51E-10	1.70E-10*	2.40E-11**
1.0E+02	3.17E-10	6.03E-10	5.92E-10	3.76E-10	2.51E-10	1.70E-10*	2.40E-11**
2.0E+02	3.19E-10	5.99E-10	5.87E-10	3.76E-10	2.52E-10	1.69E-10*	2.41E-11**
4.0E+02	3.25E-10	5.94E-10	5.81E-10	3.76E-10	2.52E-10	1.68E-10	2.43E-11**
7.0E+02	3.35E-10	5.88E-10	5.72E-10	3.77E-10	2.52E-10	1.68E-10	2.45E-11**
1.0E+03	3.46E-10	5.82E-10	5.64E-10	3.77E-10	2.53E-10	1.68E-10	2.48E-11**
2.0E+03	3.75E-10	5.64E-10	5.41E-10	3.75E-10	2.53E-10	1.68E-10	2.56E-11*
4.0E+03	4.13E-10	5.34E-10	5.02E-10	3.66E-10	2.52E-10	1.71E-10	2.75E-11*
7.0E+03	4.40E-10	5.01E-10	4.58E-10	3.49E-10	2.49E-10	1.74E-10	3.04E-11*
1.0E+04	4.50E-10	4.75E-10	4.24E-10	3.31E-10	2.44E-10	1.75E-10	3.34E-11*
2.0E+04	4.33E-10	4.12E-10	3.51E-10	2.83E-10	2.22E-10	1.71E-10	4.25E-11*

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

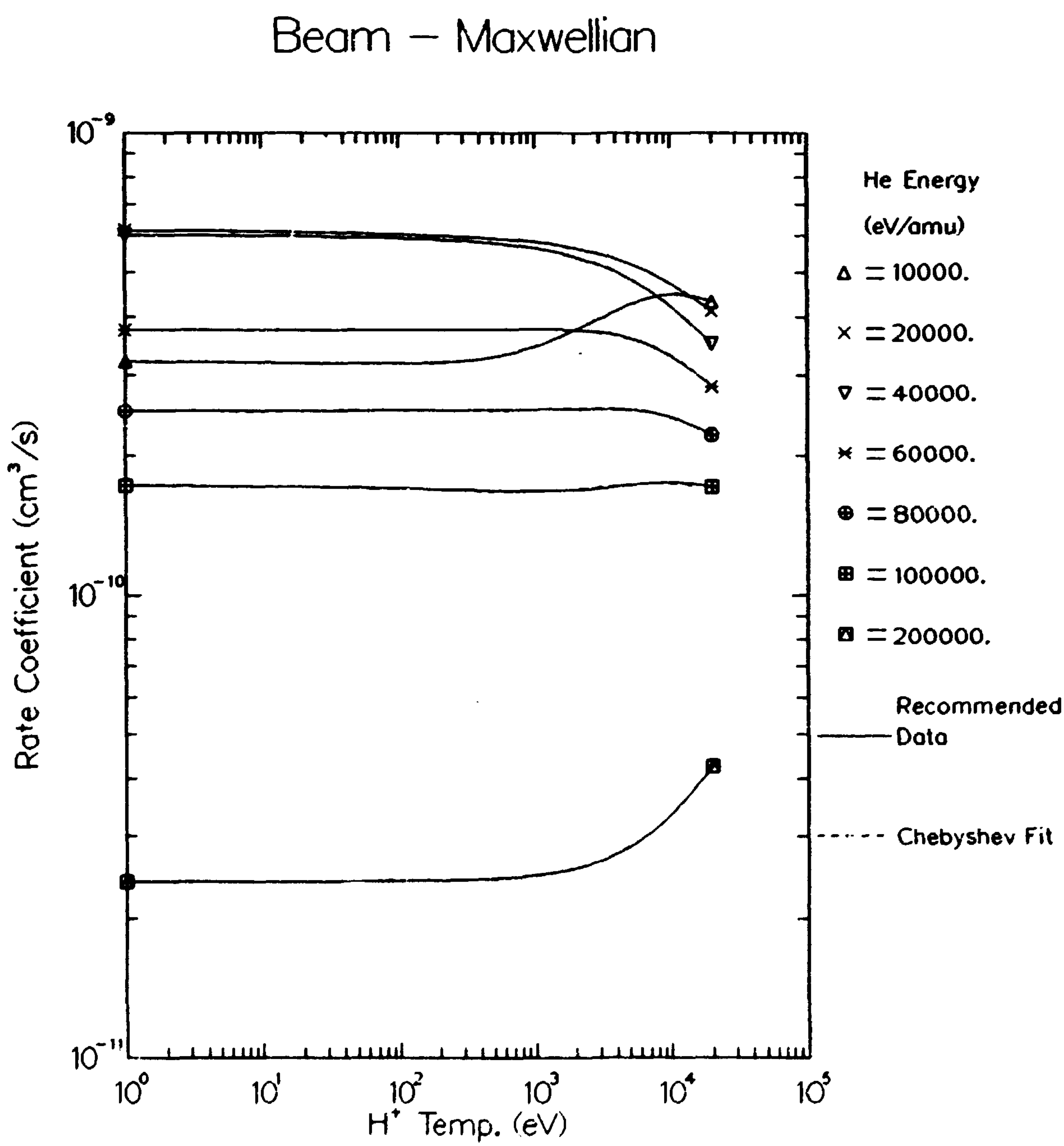
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-4.35175E+01	1.70837E-01	8.90710E-02	3.52059E-03	-[illegible].19243E-02	2.56283E-02	-9.06765E-03
20000.	-4.26087E+01	-1.54555E-01	-8.94632E-02	-4.26611E-02	-1.61171E-02	-3.24065E-03	7.74472E-04
40000.	-4.27112E+01	-2.07196E-01	-1.26305E-01	-5.98268E-02	-2.07064E-02	-3.39655E-03	1.43741E-03
60000.	-4.34961E+01	-8.32780E-02	-6.90413E-02	-4.75586E-02	-2.57998E-02	-1.00636E-02	-1.67943E-03
80000.	-4.42403E+01	-2.77368E-02	-2.78472E-02	-2.36213E-02	-1.56284E-02	-8.38900E-03	-4.20444E-03
100000.	-4.4[illegible]754E+01	-4.83485E-04	1.15859E-02	4.48823E-03	-4.64650E-03	-6.95457E-03	-5.16220E-03
200000.	-4.86[illegible]02E+01	2.01513E-01	1.40611E-01	7.66020E-02	3.17782E-02	8.85564E-03	7.47137E-05

See appendix for Chebyshev fit details.

$He + H^{+} \rightarrow H(2p) + He^{+}$



Line Emission Cross Sections of Electron Capture Collisions for
$H^+ + He \rightarrow H(H_\alpha) + He^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.3E+03	5.01E+07	5.94E-21
2.0E+03	6.21E+07	1.62E-20
4.0E+03	8.79E+07	6.73E-20
7.0E+03	1.16E+08	2.14E-19
1.0E+04	1.39E+08	4.29E-19
2.0E+04	1.96E+08	1.45E-18
4.0E+04	2.78E+08	2.92E-18
7.1E+04	3.70E+08	1.90E-18
1.0E+05	4.39E+08	1.13E-18
2.0E+05	6.21E+08	1.74E-19
3.0E+05	7.61E+08	4.13E-20

References: 122, 134, 136, 136, 156, 160, 192

Accuracy: 40%

Notes: (1) H Balmer-α emission is H_α with λ=656.3 nm.

(2) Balmer-α emission is the n=3->2 transition and is equal to σ(3s) + .118 σ(3p) + σ(3d) where σ(3l) is the cross section for capture into each n=3 angular momentum state. The factor .118 is for the branching ratio of the 3p state.

(3) If the cross sections from pages B-40, B-46 and B-52 are summed using this formula then the H_α cross sections are within 10-20% of the evaluated sums.

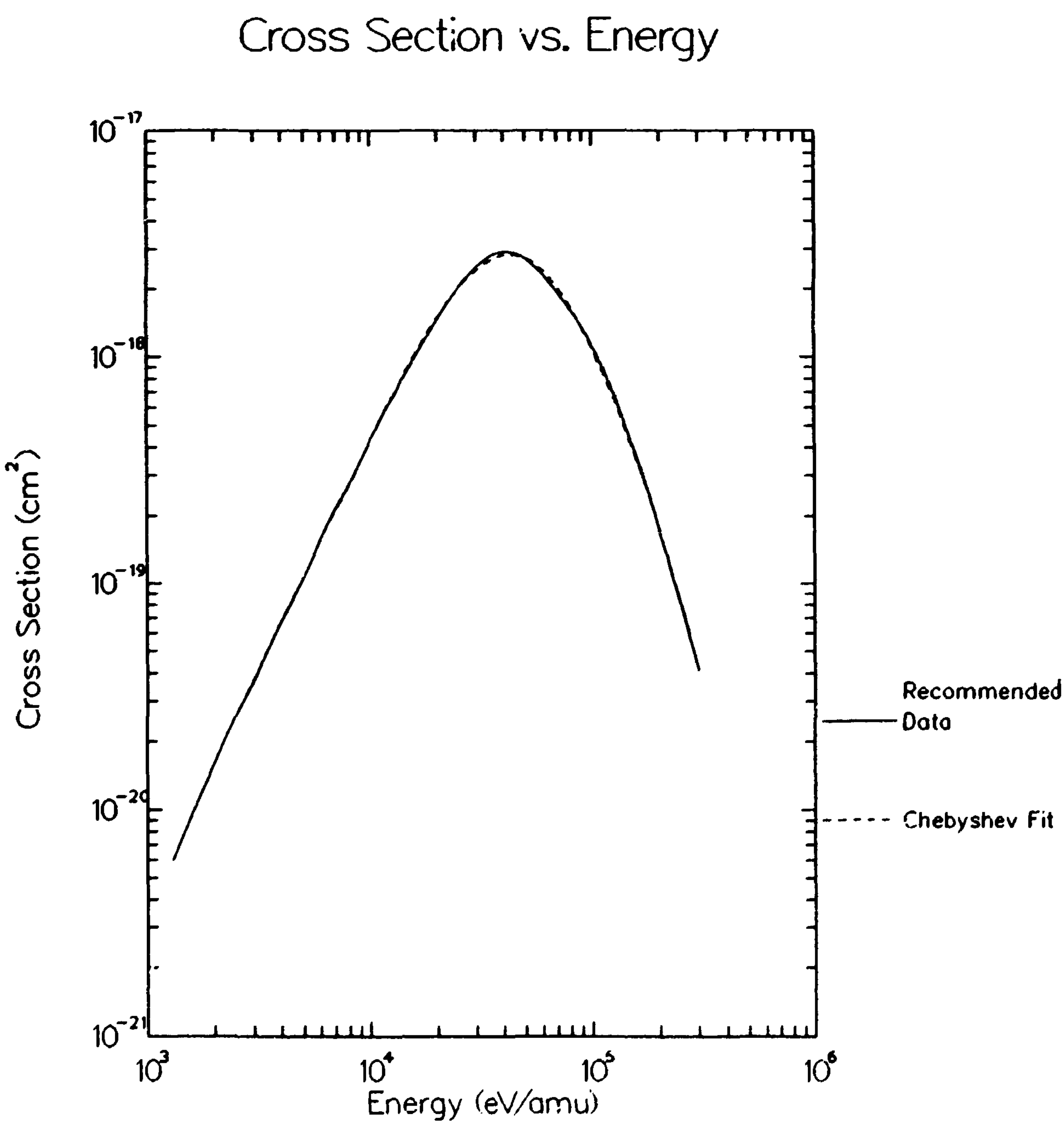
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.3E+03 eV/amu, E_{max} = 3.0E+05 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-86.7431	1.47945	-2.26092	-.605332	.0536620	.125835	-.00401562	-.0314533	-.0205645

The fit represents the above cross sections with an rms deviation of 2.4%.
The maximum deviation is 5.5% at 7.1E+04 eV/amu.
See appendix for Chebyshev fit details.

$H^+ + He \rightarrow H(H_\alpha) + He^+$



Line Emission Rate Coefficients of Electron Capture Collisions for
$H^+ + He \rightarrow H(H_\alpha) + He^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	Equal Temp.	He Temp. (eV) 100.	500.	1000.	5000.	10000.	15000.	20000.
1.0E+02	4.62E-17	4.62E-17	4.63E-15	4.11E-14	2.61E-12	1.33E-11	3.27E-11	5.90E-11
2.0E+02	8.39E-15	4.63E-15	3.00E-14	1.07E-13	3.14E-12	1.45E-11	3.45E-11	6.13E-11
4.0E+02	1.54E-13	8.75E-14	1.81E-13	3.53E-13	4.36E-12	1.72E-11	3.84E-11	6.61E-11
7.0E+02	8.25E-13	4.86E-13	7.01E-13	1.03E-12	6.62E-12	2.16E-11	4.46E-11	7.34E-11
1.0E+03	2.14E-12	1.27E-12	1.62E-12	2.14E-12	9.40E-12	2.64E-11	5.11E-11	8.10E-11
2.0E+03	1.21E-11	7.26E-12	8.18E-12	9.40E-12	2.24E-11	4.56E-11	7.47E-11	1.07E-10
4.0E+03	5.67E-11	3.60E-11	3.79E-11	4.04E-11	6.25E-11	9.38E-11	1.27E-10	1.61E-10
7.0E+03	1.54E-10	1.08E-10	1.10E-10	1.14E-10	1.41E-10	1.75E-10	2.07E-10	2.38E-10
1.0E+04	2.49E-10	1.88E-10	1.91E-10	1.94E-10	2.20E-10	2.49E-10	2.77E-10	3.02E-10
2.0E+04	4.27E-10	3.80E-10	3.81E-10	3.83E-10	3.94E-10	4.07E-10	4.18E-10	4.27E-10

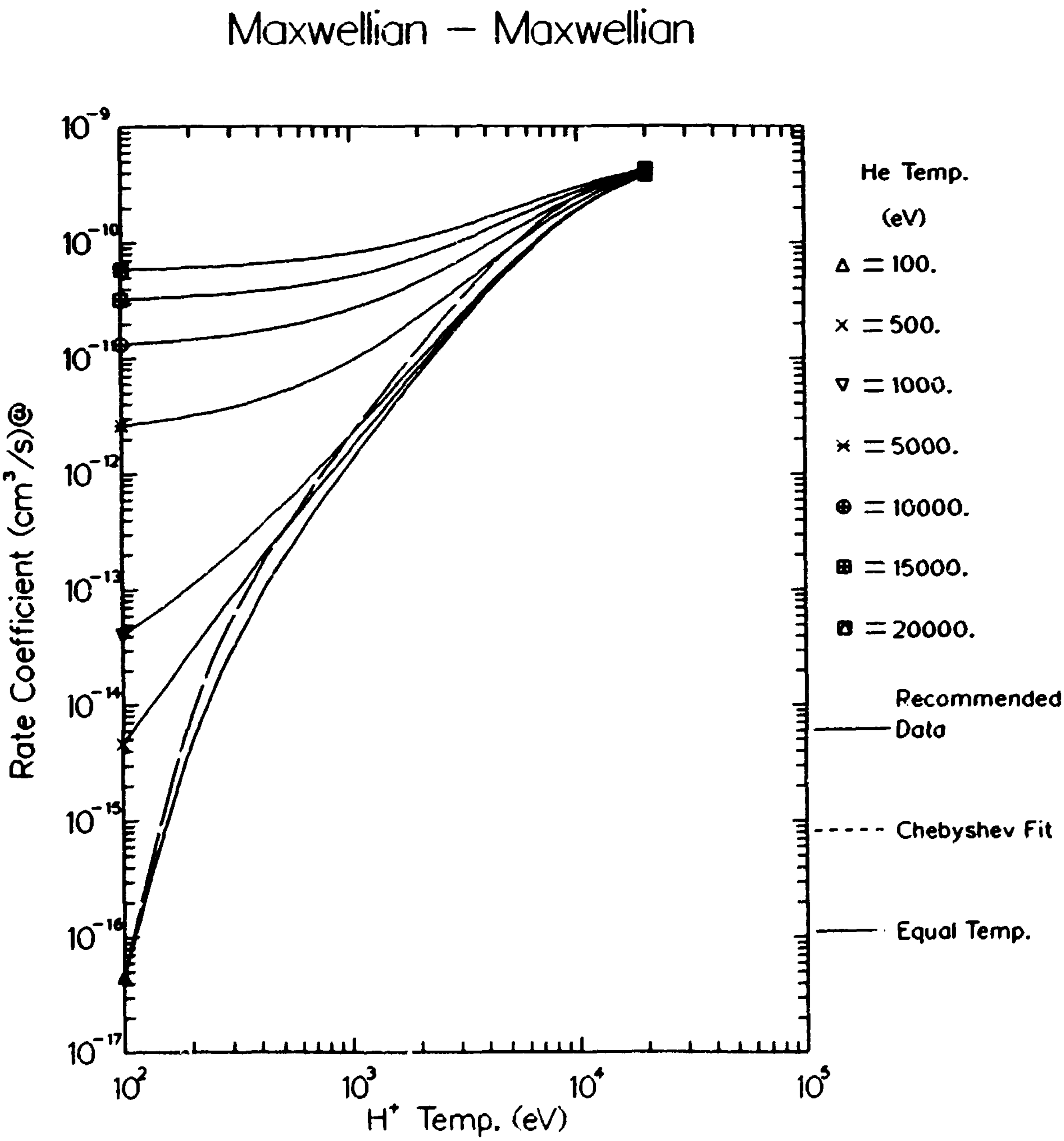
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+02 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
100.	-5.56271E+01	7.54225E+00	-1.58664E+00	3.76818E-01	-2.66300E-01	4.31633E-02	1.35706E-02
500.	-5.35452E+01	5.80636E+00	-5.23960E-01	-1.37429E-01	-6.79972E-02	-9.79835E-03	1.77516E-02
1000.	-5.22967E+01	4.84928E+00	-6.69532E-02	-2.78274E-01	-4.61871E-02	-1.88369E-03	9.07721E-03
5000.	-4.89693E+01	2.71099E+00	4.02894E-01	-2.04786E-01	-8.92702E-02	1.65791E-03	8.93841E-03
10000.	-4.72849E+01	1.82717E+00	3.81313E-01	-1.07442E-01	-7.83908E-02	-9.54437E-03	6.43829E-03
15000.	-4.62748E+01	1.34714E+00	3.25406E-01	-6.01114E-02	-6.20496E-02	-1.28087E-02	3.45512E-03
20000.	-4.55796E+01	1.03752E+00	2.73271E-01	-3.47245E-02	-4.87660E-02	-1.29560E-02	1.49966E-03
Equal Temp.	-5.48859E+01	7.46410E+00	-1.79561E+00	4.52870E-01	-3.47418E-01	1.03439E-01	-8.24563E-03

See appendix for Chebyshev fit details.

$H^+ + He \rightarrow H(H_a) + He^+$



Line Emission Rate Coefficients of Electron Capture Collisions for
$He + H^+ \rightarrow H(H\alpha) + He^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	60000.	80000.	100000.	200000.
1.0E+00	5.96E-11*	2.84E-10*	8.07E-10*	7.33E-10*	6.23E-10*	4.95E-10*	1.08E-10**
2.0E+00	5.96E-11*	2.84E-10*	8.06E-10*	7.33E-10*	6.23E-10*	4.95E-10*	1.08E-10**
4.0E+00	5.96E-11*	2.83E-10*	8.03E-10*	7.33E-10*	6.23E-10*	4.94E-10*	1.08E-10**
7.0E+00	5.97E-11*	2.83E-10*	8.01E-10*	7.33E-10*	6.23E-10*	4.94E-10*	1.08E-10**
1.0E+01	5.98E-11*	2.83E-10*	7.99E-10	7.33E-10*	6.23E-10*	4.93E-10*	1.08E-10**
2.0E+01	6.01E-11*	2.82E-10	7.94E-10	7.33E-10*	6.23E-10*	4.92E-10*	1.08E-10**
4.0E+01	6.08E-11*	2.82E-10	7.67E-10	7.33E-10	6.23E-10*	4.90E-10*	1.07E-10**
7.0E+01	6.18E-11*	2.82E-10	7.80E-10	7.33E-10	6.23E-10*	4.88E-10*	1.07E-10**
1.0E+02	6.29E-11*	2.83E-10	7.74E-10	7.33E-10	6.23E-10*	4.87E-10*	1.07E-10**
2.0E+02	6.67E-11	2.85E-10	7.60E-10	7.33E-10	6.23E-10	4.84E-10*	1.07E-10**
4.0E+02	7.45E-11	2.92E-10	7.42E-10	7.31E-10	6.21E-10	4.79E-10*	1.07E-10**
7.0E+02	8.65E-11	3.04E-10	7.24E-10	7.27E-10	6.17E-10	4.75E-10*	1.07E-10**
1.0E+03	9.83E-11	3.16E-10	7.11E-10	7.22E-10	6.12E-10	4.72E-10*	1.07E-10**
2.0E+03	1.36E-10	3.52E-10	6.80E-10	7.02E-10	5.97E-10	4.64E-10*	1.09E-10*
4.0E+03	2.05E-10	4.00E-10	6.43E-10	6.60E-10	5.69E-10	4.51E-10	1.12E-10*
7.0E+03	2.87E-10	4.40E-10	6.04E-10	6.08E-10	5.33E-10	4.33E-10	1.17E-10*
1.0E+04	3.46E-10	4.63E-10	5.75E-10	5.68E-10	5.02E-10	4.16E-10	1.22E-10*
2.0E+04	4.46E-10	4.86E-10	5.07E-10	4.79E-10	4.27E-10	3.67E-10	1.33E-10*

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

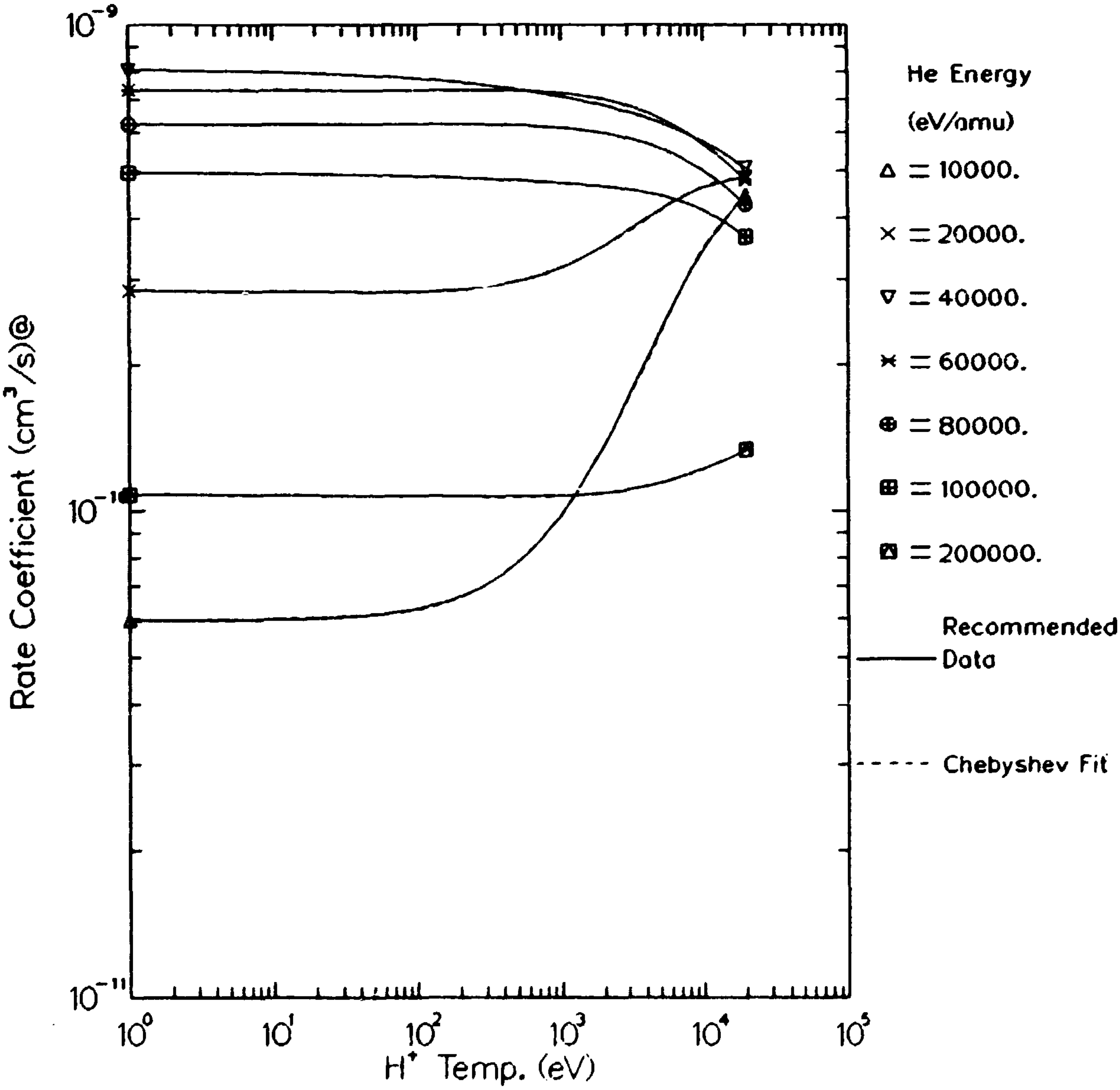
Chebyshev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-4.58848E+01	9.71807E-01	4.83279E-01	9.11138E-02	-6.12690E-02	-5.76723E-02	-1.79106E-02
20000.	-4.36507E+01	2.64211E-01	1.43555E-01	2.70221E-02	-2.48764E-02	-2.40082E-02	-7.54802E-03
40000.	-4.21414E+01	-2.00867E-01	-8.98633E-02	-2.87027E-02	-8.54506E-03	-3.26747E-03	-1.21561E-03
60000.	-4.22369E+01	-1.51900E-01	-1.08731E-01	-5.90440E-02	-2.19357E-02	-7.21591E-03	2.30144E-03
80000.	-4.25414E+01	-1.32445E-01	-9.43661E-02	-5.17183E-02	-2.05460E-02	-5.15132E-03	-3.15003E-04
100000.	-4.29896E+01	-1.10475E-01	-6.22264E-02	-3.20171E-02	-1.65763E-02	-7.76766E-03	-2.70010E-03
200000.	-4.58241E+01	7.16963E-02	5.83098E-02	3.32118E-02	1.21459E-02	1.47440E-03	-1.87694E-03

See appendix for Chebyshev fit details.

$$He + H^{+} \rightarrow H(H_{\alpha}) + He^{+}$$

Beam – Maxwellian



Electron Capture Cross Sections for
$H^+ + He \rightarrow H(3s) + He^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.2E+03	4.81E+07	7.9[illegible]E-20
2.0E+03	6.21E+07	9.72E-20
4.0E+03	8.79E+07	1.39E-19
7.0E+03	1.16E+08	1.94E-19
1.0E+04	1.39E+08	2.59E-19
2.0E+04	1.96E+08	6.57E-19
4.0E+04	2.78E+08	1.65E-18
4.4E+04	2.91E+08	1.67E-18
7.0E+04	3.68E+08	1.20E-18
1.0E+05	4.39E+08	7.58E-19
2.0E+05	6.21E+08	1.65E-19
4.0E+05	8.78E+08	1.10E-20
7.0E+05	1.16E+09	1.16E-21
1.0E+[illegible]	1.39E+09	2.40E-22
1.3E+06	1.58E+09	6.65E-23

References: 20, 129, 130, 134, 154, 155, 156, 157, 158, 159, 160, 161

Accuracy: unknown

Notes: (1) Very few papers report absolute cross sections. The overall assessment of the data is in doubt due to the validity of the different normalization schemes.

(2) Cascade from higher states is usually neglected and can contribute up to a 5% error in the reported cross sections.

(3) The cross section (σ_i) for capture into state i is determined by measuring the emission cross section (σ_{ij}) for a transition from state i to j, correcting for any branching and correcting for cascading from upper states. For Balmer-α emission from the n=3 state, the cross section $\sigma(H_\alpha)=\sigma(3s) + .188\ \sigma(3p) + \sigma(3d)$.

For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.2E+03 eV/amu, E_{max} = 1.3E+06 eV/amu

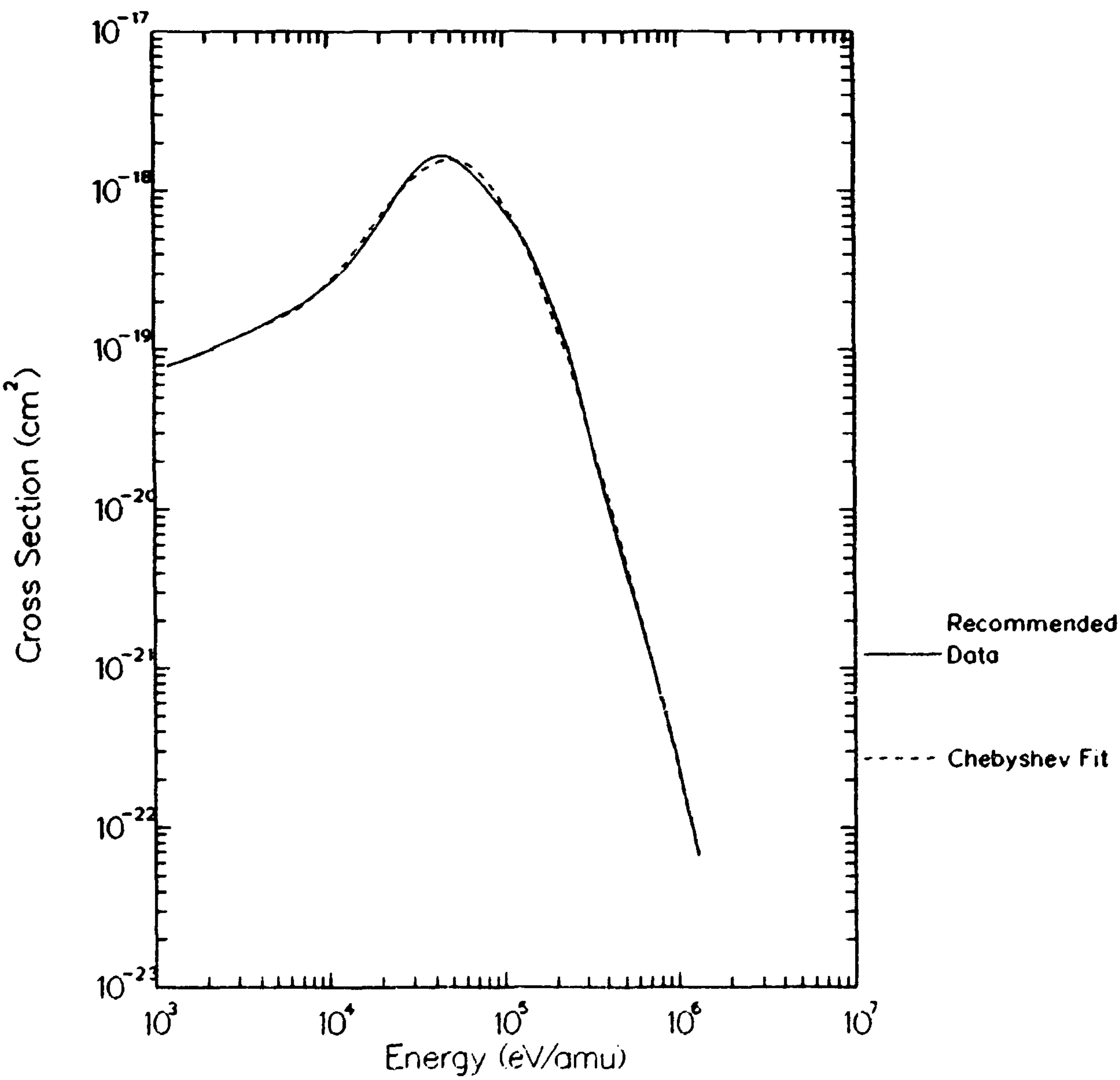
Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-89.3963	-2.75333	-3.10976	-.952686	.352124	.248416	-.119805	-.0706000	.0607563

The fit represents the above cross sections with an rms deviation of 7.1%.
The maximum deviation is 12.3% at 7.0E+04 eV/amu.
See appendix for Chebyshev fit details.

$H^+ + He \rightarrow H(3s) + He^+$

Cross Section vs. Energy



Electron Capture Rate Coefficients for
$H^+ + He \rightarrow H(3s) + He^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	Equal Temp.	He Temp. (eV) 100.	500.	1000.	5000.	10000.	15000.	20000.
1.0E+02	1.04E-15	1.04E-15	6.14E-14	3.76E-13	5.53E-12	1.30E-11	2.28E-11	3.55E-11
2.0E+02	1.02E-13	6.14E-14	2.92E-13	7.83E-13	6.07E-12	1.36E-11	2.37E-11	3.67E-11
4.0E+02	1.02E-12	6.72E-13	1.14E-12	1.78E-12	7.17E-12	1.51E-11	2.56E-11	3.90E-11
7.0E+02	2.98E-12	2.17E-12	2.71E-12	3.38E-12	8.87E-12	1.73E-11	2.86E-11	4.26E-11
1.0E+03	4.99E-12	3.78E-12	4.32E-12	4.99E-12	1.07E-11	1.97E-11	3.17E-11	4.63E-11
2.0E+03	1.23E-11	9.31E-12	9.91E-12	1.07E-11	1.77E-11	2.91E-11	4.32E-11	5.94E-11
4.0E+03	3.44E-11	2.44E-11	2.54E-11	2.66E-11	3.72E-11	5.27E-11	6.98E-11	8.78E-11
7.0E+03	8.42E-11	5.98E-11	6.12E-11	6.29E-11	7.70E-11	9.50E-11	1.13E-10	1.30E-10
1.0E+04	1.37E-10	1.03E-10	1.04E-10	1.06E-10	1.20E-10	1.37E-10	1.53E-10	1.68E-10
2.0E+04	2.48E-10	2.17E-10	2.17E-10	2.18E-10	2.26E-10	2.34E-10	2.42E-10	2.48E-10

Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+02 eV, E_{max} = 2.0E+04 eV

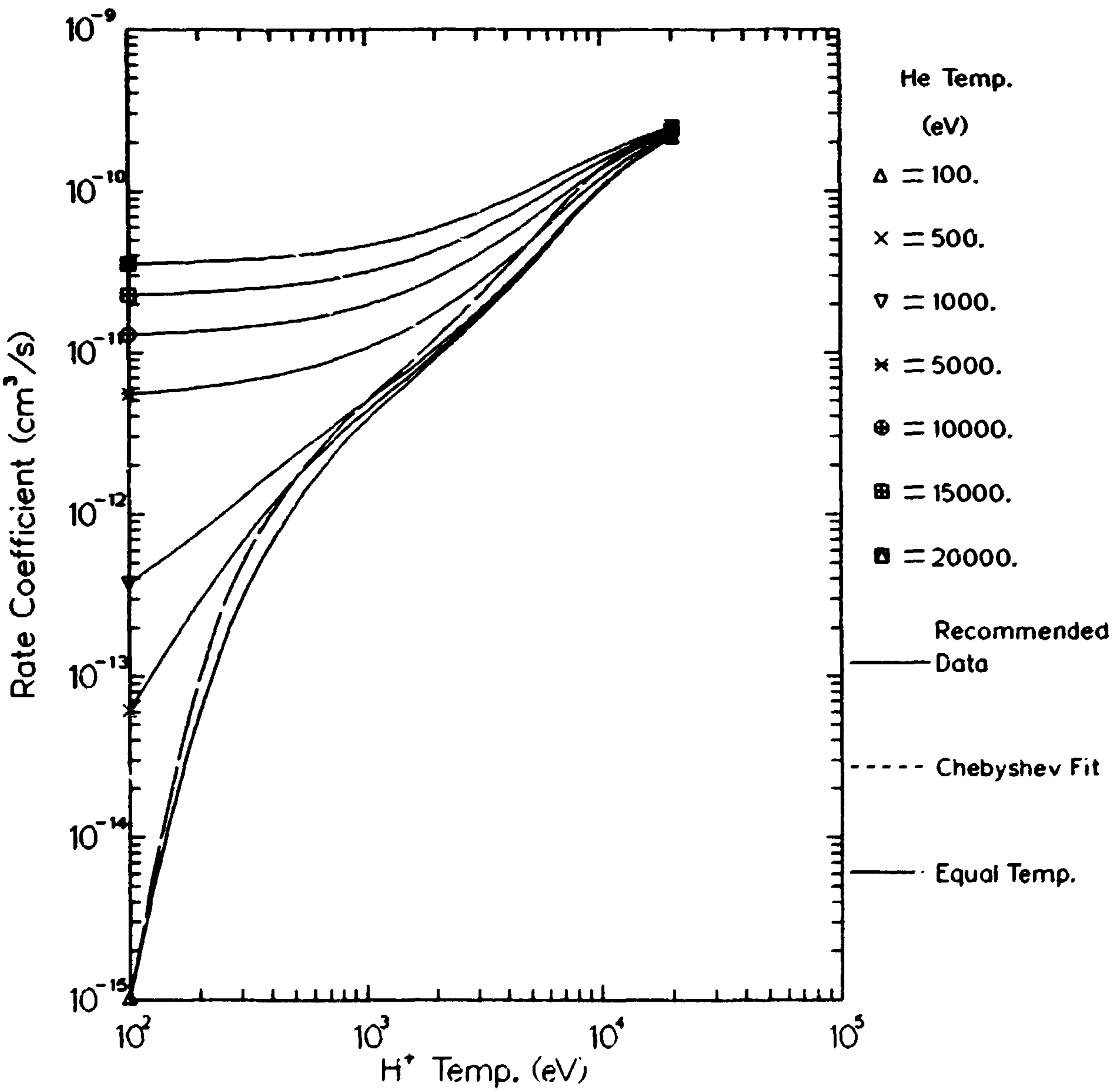
Chebyshev Fitting Parameters for Rate Coefficients

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
100.	-5.37012E+01	5.51736E+00	-1.26631E+00	6.41819E-01	-2.59717E-01	-3.50690E-02	-8.79675E-04
500.	-5.19390E+01	4.01666E+00	-2.93656E-01	1.47807E-01	-7.57652E-02	-7.86568E-02	3.19866E-03
1000.	-5.09725E+01	3.25191E+00	1.17635E-01	-4.41960E-03	-5.45641E-02	-6.54437E-02	-4.41120E-03
5000.	-4.89296E+01	1.94263E+00	4.86039E-01	-5.6[illegible]01E-02	-8.77510E-02	-3.17734E-02	-1.68441E-04
10000.	-4.79520E+01	1.50755E+00	4.27186E-01	-3.56552E-02	-7.51944E-02	-2.47079E-02	1.68707E-03
15000.	-4.72456E+01	1.22338E+00	3.57663E-01	-2.27359E-02	-5.99425E-02	-2.00776E-02	7.63417E-04
20000.	-4.66818E+01	1.00201E+00	2.99649E-01	-1.36330E-02	-4.72262E-02	-1.65699E-02	-1.65257E-05
Equal Temp.	-5.31267E+01	5.47937E+00	-1.36275E+00	6.93916E-01	-3.79924E-01	1.82789E-02	-3.07574E-03

See appendix for Chebyshev fit details.

$H^+ + He \rightarrow H(3s) + He^+$

Maxwellian – Maxwellian



Electron Capture Rate Coefficients for
$He + H^+ \rightarrow H(3s) + He^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	3.61E-11	1.29E-10	4.57E-10	4.40E-10	3.32E-10	1.02E-10	4.40E-12*
2.0E+00	3.62E-11	1.29E-10	4.56E-10	4.40E-10	3.32E-10	1.02E-10	4.40E-12*
4.0E+00	3.62E-11	1.29E-10	4.55E-10	4.40E-10	3.32E-10	1.02E-10	4.40E-12*
7.0E+00	3.63E-11	1.29E-10	4.54E-10	4.40E-10	3.32E-10	1.02E-10	4.40E-12*
1.0E+01	3.64E-11	1.29E-10	4.54E-10	4.39E-10	3.31E-10	1.02E-10	4.40E-12*
2.0E+01	3.67E-11	1.30E-10	4.52E-10	4.39E-10	3.31E-10	1.02E-10	4.41E-12*
4.0E+01	3.72E-11	1.30E-10	4.50E-10	4.38E-10	3.30E-10	1.01E-10	4.41E-12*
7.0E+01	3.78E-11	1.31E-10	4.47E-10	4.37E-10	3.29E-10	1.01E-10	4.41E-12*
1.0E+02	3.83E-11	1.32E-10	4.44E-10	4.36E-10	3.28E-10	1.01E-10	4.41E-12*
2.0E+02	4.01E-11	1.35E-10	4.38E-10	4.33E-10	3.26E-10	9.99E-11	4.42E-12
4.0E+02	4.35E-11	1.40E-10	4.29E-10	4.30E-10	3.24E-10	9.92E-11	4.44E-12
7.0E+02	4.86E-11	1.49E-10	4.19E-10	4.27E-10	3.21E-10	9.86E-11	4.47E-12
1.0E+03	5.37E-11	1.57E-10	4.12E-10	4.24E-10	3.19E-10	9.82E-11	4.50E-12
2.0E+03	7.17E-11	1.82E-10	3.96E-10	4.14E-10	3.14E-10	9.78E-11	4.60E-12
4.0E+03	1.08E-10	2.16E-10	3.78E-10	3.93E-10	3.06E-10	9.84E-11	4.81E-12
7.0E+03	1.56E-10	2.47E-10	3.59E-10	3.66E-10	2.93E-10	1.00E-10	5.14E-12
1.0E+04	1.93E-10	2.66E-10	3.46E-10	3.44E-10	2.82E-10	1.02E-10	5.51E-12
2.0E+04	2.61E-10	2.90E-10	3.13E-10	2.94E-10	2.48E-10	1.06E-10	7.04E-12

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

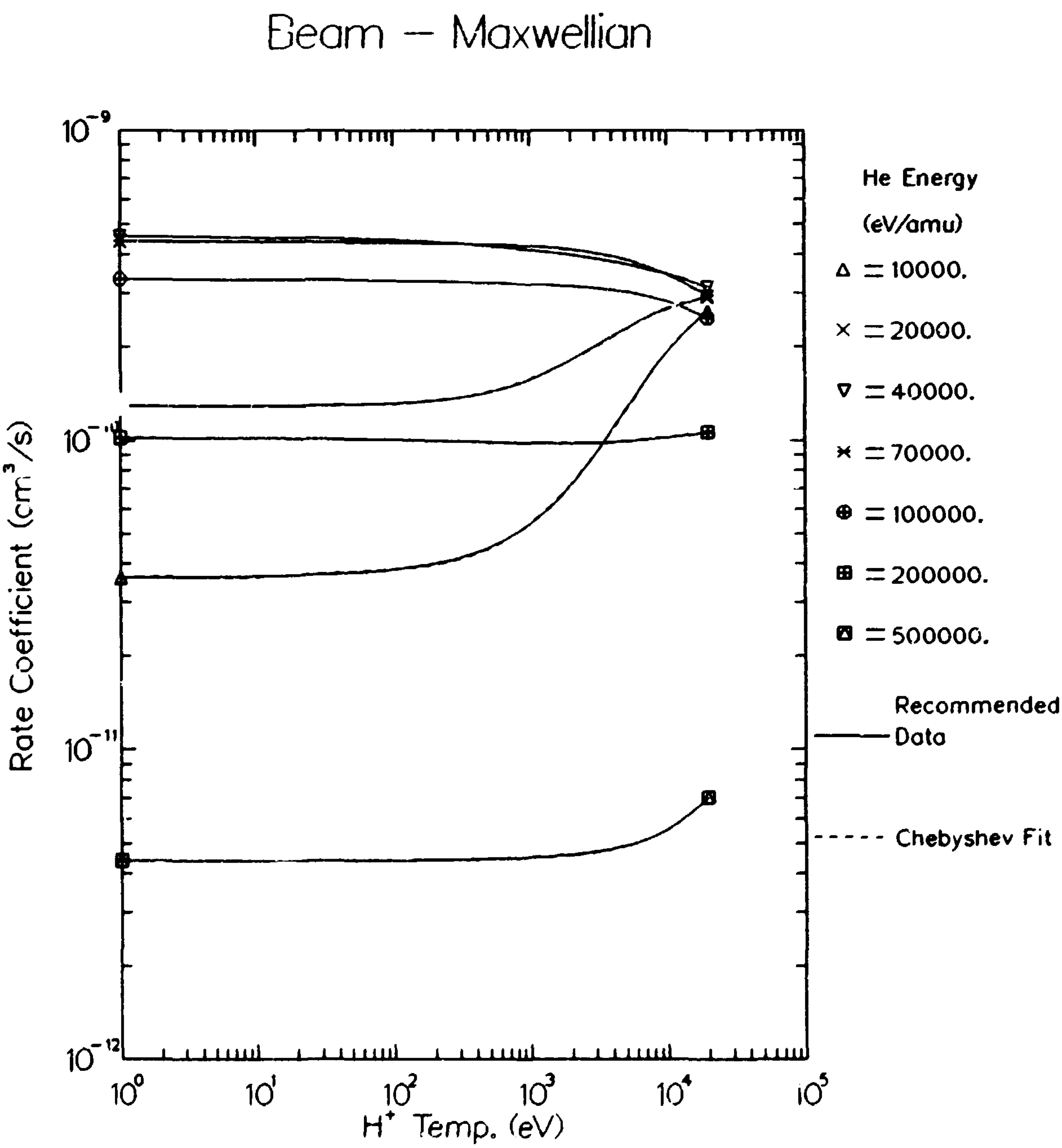
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-4.69590E+01	9.17776E-01	4.84822E-01	1.28148E-01	-3.38227E-02	-5.58964E-02	-2.93167E-02
20000.	-4.50524E+01	3.95677E-01	1.97669E-01	3.56569E-02	-3.01554E-02	-2.88658E-02	-8.74226E-03
40000.	-4.32289E+01	-1.65074E-01	-7.60355E-02	-2.21081E-02	-4.24972E-03	-1.82033E-03	-1.77544E-03
70000.	-4.32620E+01	-1.48289E-01	-9.51993E-02	-4.97051E-02	-2.06125E-02	-5.32942E-03	1.01964E-03
100000.	-4.37786E+01	-1.05527E-01	-6.21604E-02	-3.28418E-02	-1.67932E-02	-7.71384E-03	-2.68575E-03
200000.	-4.60232E+01	3.14283E-05	2.12471E-02	1.95060E-02	8.72740E-03	1.21515E-03	-1.62989E-03
500000.	-5.21281E+01	1.52077E-01	1.10093E-01	6.67186E-02	3.41707E-02	1.49151E-02	5.83661E-03

See appendix for Chebyshev fit details.

He + H^+ -> H(3s) + He^+


Beam — Maxwellian
Rate Coefficient (cm³/s)
H⁺ Temp. (eV)
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁰
10¹
10²
10³
10⁴
10⁵
He Energy
(eV/amu)
= 10000.
= 20000.
= 40000.
= 70000.
= 100000.
= 200000.
= 500000.
Recommended Data
Chebyshev Fit

Electron Capture Cross Sections for
$H^{+} + He \rightarrow H(3p) + He^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.7E+03	5.73E+07	1.35E-19
2.0E+03	6.21E+07	1.48E-19
4.0E+03	8.79E+07	2.45E-19
7.0E+03	1.16E+08	3.84E-19
1.0E+04	1.39E+08	5.13E-19
2.0E+04	1.96E+08	8.57E-19
3.6E+04	2.64E+08	1.14E-18
4.0E+04	2.78E+08	1.14E-18
7.0E+04	3.69E+08	7.28E-19
1.0E+05	4.39E+08	3.49E-19
2.0E+05	6.21E+08	3.95E-20
4.0E+05	8.78E+08	1.75E-21
7.0E+05	1.16E+09	1.02E-22
1.0E+06	1.39E+09	1.44E-23
1.2E+06	1.52E+09	4.95E-24

References: 134, 136, 156, 157, 159, 160, 163, 164, 165, 166, 167

Accuracy: Unknown

Notes: (1) Very few papers report absolute cross sections. The overall assessment of the data is in doubt due to the validity of the different normalization schemes.
(2) Cascade from higher states is usually neglected but can contribute up to 5% error in the reported cross section measurements.
(3) The cross section (σ_i) for capture into state i is determined by measuring the emission cross section (σ_{ij}) for a transition from state i to j, correcting for cascading from upper states and correcting for any branching. For Balmer-α emission from the n=3 state the cross section $\sigma(H_\alpha)=\sigma(3s) + .118\sigma(3p) + \sigma(3d)$.

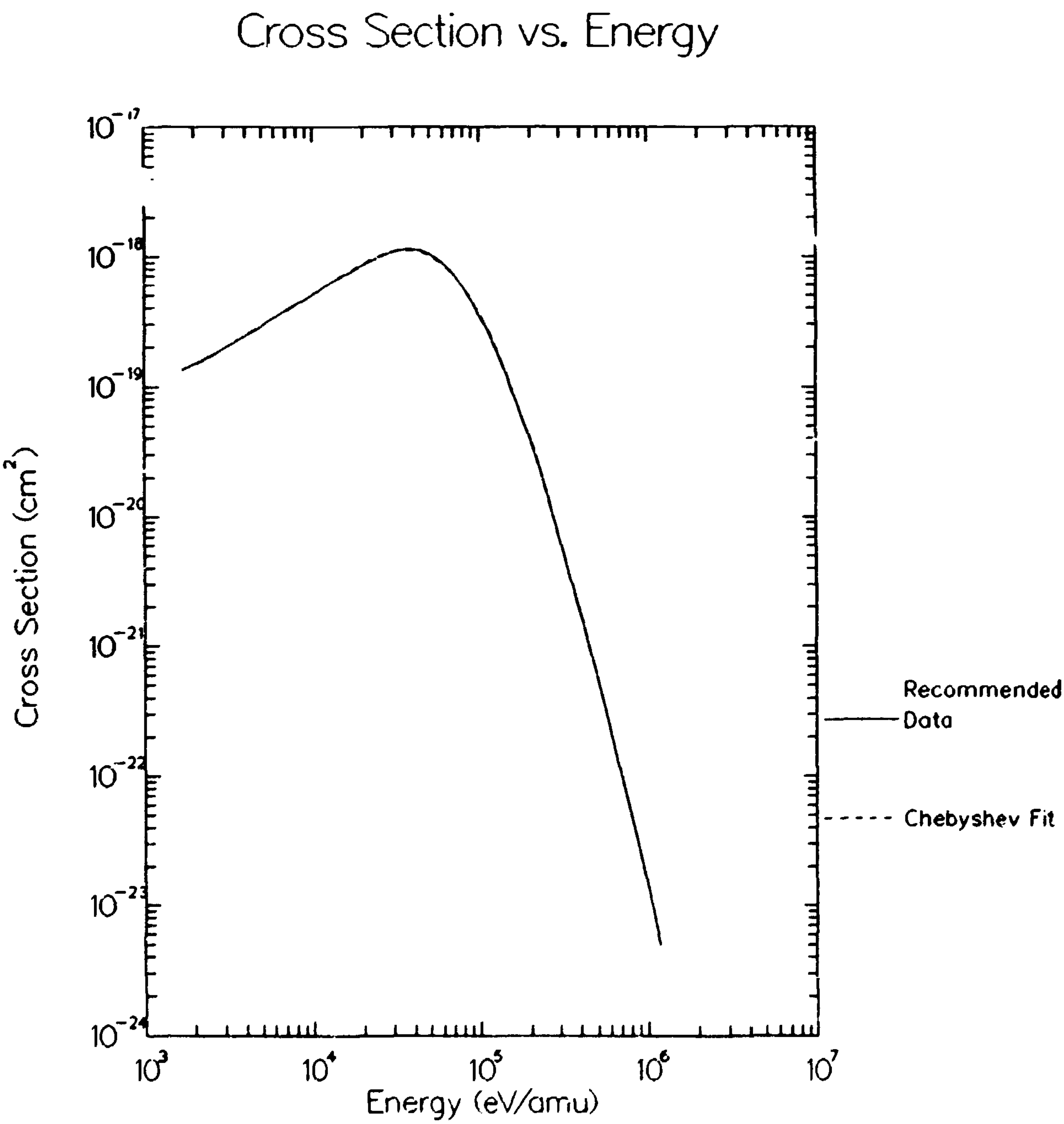
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.7E+03 eV/amu, E_{max} = 1.2E+06 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-90.6049	-4.52585	-3.52507	-.678448	.325826	.143519	-.0657813	-.0500666	.0154546

The fit represents the above cross sections with an rms deviation of 1.7%.
The maximum deviation is 3.6% at 2.0E+04 eV/amu.
See appendix for Chebyshev fit details.

$H^+ + He \rightarrow H(3p) + He^+$



Electron Capture Rate Coefficients for
$H^+ + He \rightarrow H(3p) + He^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	Equal Temp.	He Temp. (eV) 100.	500.	1000.	5000.	10000.	15000.	20000.
1.0E+02	4.48E-17	4.48E-17	1.54E-14	2.06E-13	8.41E-12	2.24E-11	3.77E-11	5.37E-11
2.0E+02	3.19E-14	1.54E-14	1.44E-13	5.85E-13	9.46E-12	2.36E-11	3.90E-11	5.49E-11
4.0E+02	8.46E-13	4.71E-13	9.92E-13	1.85E-12	1.16E-11	2.60E-11	4.15E-11	5.75E-11
7.0E+02	3.74E-12	2.44E-12	3.29E-12	4.43E-12	1.49E-11	2.96E-11	4.54E-11	6.14E-11
1.0E+03	7.38E-12	5.15E-12	6.13E-12	7.38E-12	1.83E-11	3.34E-11	4.92E-11	6.52E-11
2.0E+03	2.12E-11	1.57E-11	1.69E-11	1.83E-11	3.02E-11	4.60E-11	6.20E-11	7.77E-11
4.0E+03	5.24E-11	3.99E-11	4.12E-11	4.28E-11	5.56E-11	7.15E-11	8.68E-11	1.01E-10
7.0E+03	9.84E-11	7.80E-11	7.93E-11	8.08E-11	9.26E-11	1.07E-10	1.19E-10	1.31E-10
1.0E+04	1.35E-10	1.12E-10	1.13E-10	1.14E-10	1.24E-10	1.35E-10	1.45E-10	1.53E-10
2.0E+04	1.90E-10	1.78E-10	1.78E-10	1.79E-10	1.82E-10	1.85E-10	1.88E-10	1.90E-10

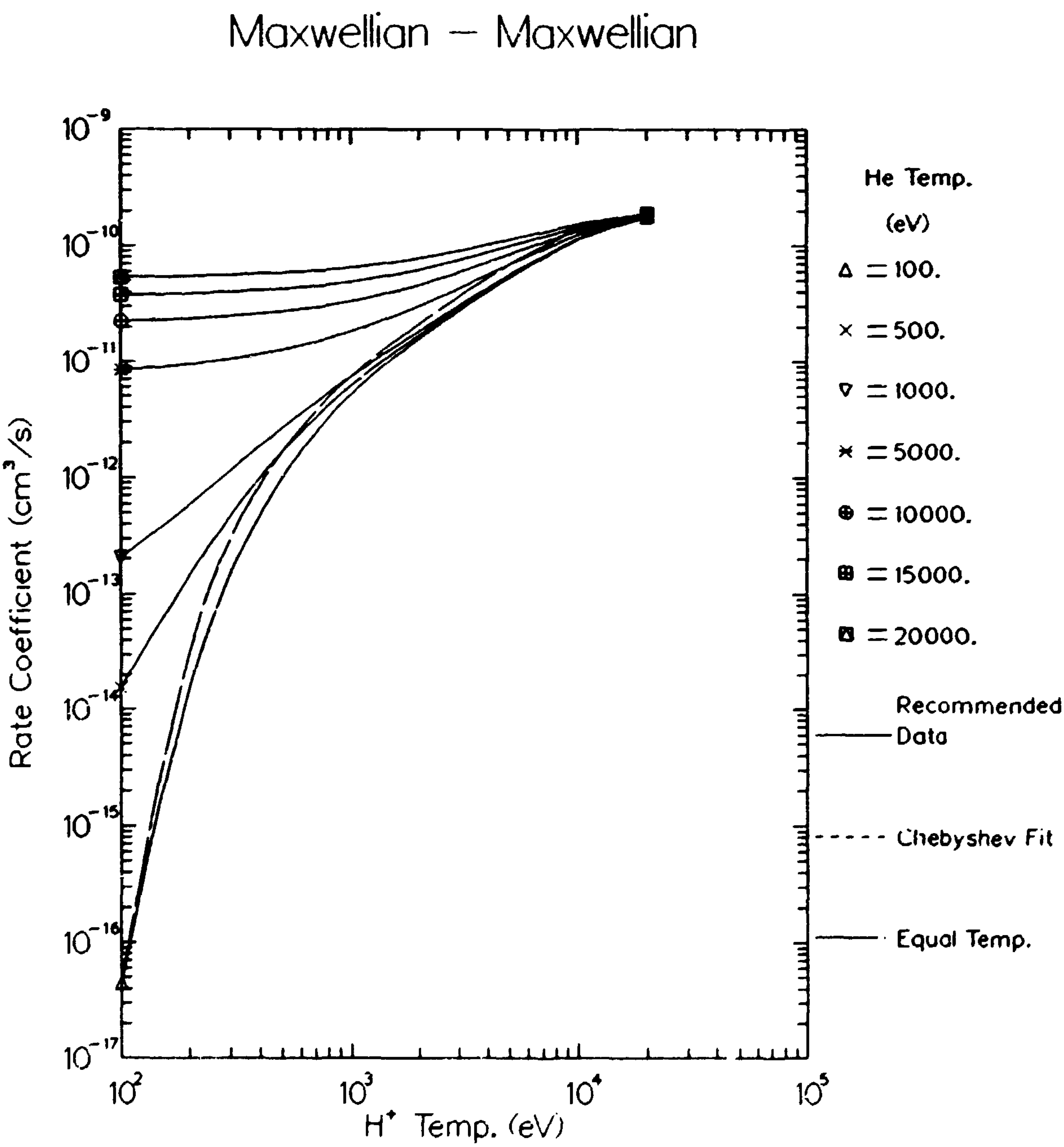
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+02 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
100.	-5.48603E+01	6.73175E+00	-2.33750E+00	8.57032E-01	-2.92258E-01	8.89193E-03	1.19267E-02
500.	-5.23540E+01	4.57847E+00	-9.34127E-01	1.52574E-01	-2.98508E-02	-5.41726E-02	1.56047E-02
1000.	-5.09960E+01	3.48139E+00	-3.33404E-01	-6.24733E-02	4.55378E-04	-3.70467E-02	2.75925E-03
5000.	-4.83469E+01	1.64909E+00	2.61394E-01	-1.05216E-01	-5.38273E-02	-7.49908E-03	7.09196E-04
10000.	-4.73425E+01	1.12338E+00	2.55051E-01	-5.63104E-02	-5.16563E-02	-1.13825E-02	1.38299E-03
15000.	-4.67459E+01	8.47733E-01	2.16661E-01	-3.36664E-02	-4.24929E-02	-1.19700E-02	4.13866E-04
20000.	-4.63234E+01	6.64850E-01	1.80257E-01	-2.17729E-02	-3.47781E-02	-1.13742E-02	-1.56934E-04
Equal Temp.	-5.42194E+01	6.56075E+00	-2.45975E+00	9.87265E-01	-4.35539E-01	8.21003E-02	-9.92180E-03

See appendix for Chebyshev fit details.

$H^+ + He \rightarrow H(3p) + He^+$



Electron Capture Rate Coefficients for
He + H^+ -> H(3p) + He^+

Beam - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	7.13E-11	1.68E-10	3.16E-10	2.67E-10	1.53E-10	2.45E-11	5.53E-13*
2.0E+00	7.13E-11	1.68E-10	3.16E-10	2.67E-10	1.53E-10	2.45E-11	5.53E-13*
4.0E+00	7.13E-11	1.68E-10	3.15E-10	2.66E-10	1.53E-10	2.45E-11	5.53E-13*
7.0E+00	7.13E-11	1.68E-10	3.15E-10	2.66E-10	1.53E-10	2.44E-11	5.53E-13*
1.0E+01	7.13E-11	1.68E-10	3.14E-10	2.65E-10	1.52E-10	2.44E-11	5.53E-13*
2.0E+01	7.15E-11	1.68E-10	3.14E-10	2.64E-10	1.52E-10	2.44E-11	5.54E-13*
4.0E+01	7.17E-11	1.68E-10	3.12E-10	2.63E-10	1.52E-10	2.43E-11	5.54E-13*
7.0E+01	7.21E-11	1.68E-10	3.11E-10	2.62E-10	1.51E-10	2.43E-11	5.55E-13
1.0E+02	7.26E-11	1.68E-10	3.09E-10	2.61E-10	1.51E-10	2.42E-11	5.55E-13
2.0E+02	7.41E-11	1.69E-10	3.06E-10	2.58E-10	1.50E-10	2.42E-11	5.57E-13
4.0E+02	7.71E-11	1.71E-10	3.01E-10	2.54E-10	1.49E-10	2.42E-11	5.61E-13
7.0E+02	8.16E-11	1.74E-10	2.95E-10	2.50E-10	1.49E-10	2.42E-11	5.68E-13
1.0E+03	8.61E-11	1.77E-10	2.90E-10	2.47E-10	1.49E-10	2.43E-11	5.74E-13
2.0E+03	1.00E-10	1.86E-10	2.79E-10	2.39E-10	1.48E-10	2.49E-11	5.97E-13
4.0E+03	1.24E-10	1.96E-10	2.63E-10	2.25E-10	1.46E-10	2.63E-11	6.43E-13
7.0E+03	1.51E-10	2.04E-10	2.45E-10	2.08E-10	1.42E-10	2.88E-11	7.17E-13
1.0E+04	1.70E-10	2.07E-10	2.30E-10	1.95E-10	1.38E-10	3.12E-11	8.02E-13
2.0E+04	1.95E-10	2.03E-10	1.97E-10	1.64E-10	1.24E-10	3.75E-11	1.18E-12

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

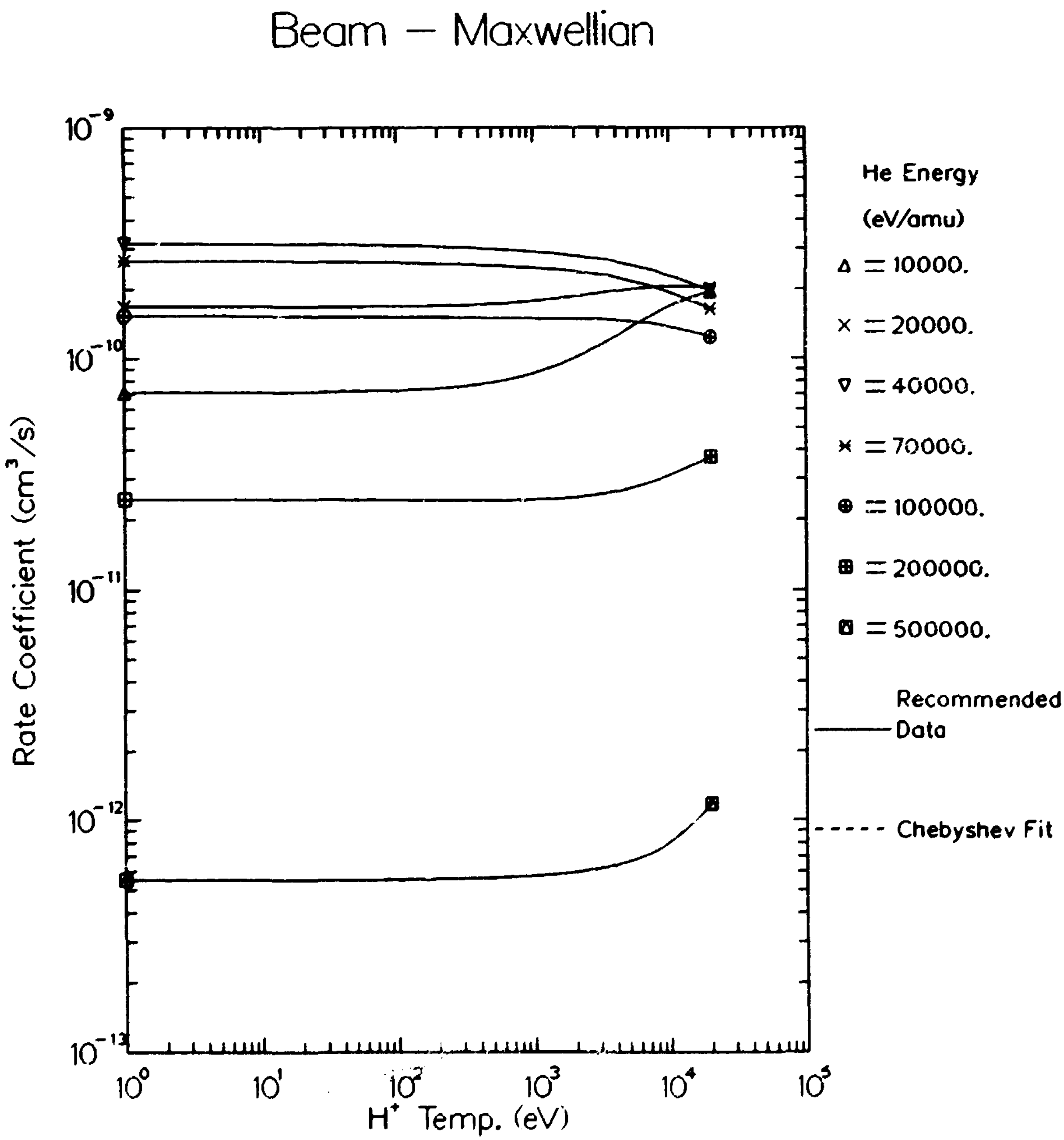
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-4.61593E+01	4.69768E-01	2.55845E-01	6.75806E-02	-2.06018E-02	-3.21005E-02	-1.71678E-02
20000.	-4.48832E+01	1.05388E-01	5.13750E-02	1.87880E-03	-1.77315E-02	-1.43595E-02	-5.26979E-03
40000.	-4.39844E+01	-1.88716E-01	-1.03793E-01	-4.31001E-02	-1.44695E-02	-4.32136E-03	-8.32803E-04
70000.	-4.43219E+01	-1.88451E-01	-1.07258E-01	-4.99127E-02	-2.00817E-02	-6.25364E-03	-3.66359E-04
100000.	-4.52889E+01	-7.00699E-02	-4.15959E-02	-2.66009E-02	-1.74699E-02	-9.19908E-03	-3.00670E-03
200000.	-4.87156E+01	1.42634E-01	1.14850E-01	6.70006E-02	2.67000E-02	5.12084E-03	-2.83726E-03
500000.	-5.61687E+01	2.49112E-01	1.78331E-01	1.05979E-01	5.28963E-02	2.25156E-02	8.83834E-03

See appendix for Chebyshev fit details.

$He + H^{+} \rightarrow H(3p) + He^{+}$



Electron Capture Cross Sections for
$H^+ + He \rightarrow H(3d) + He^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
3.0E+03	7.61E+07	1.16E-19
4.0E+03	8.79E+07	1.36E-19
7.0E+03	1.16E+08	1.65E-19
1.0E+04	1.39E+08	1.71E-19
2.0E+04	1.96E+08	1.43E-19
4.0E+04	2.78E+08	8.33E-20
7.0E+04	3.68E+08	3.95E-20
1.0E+05	4.39E+08	1.53E-20
2.0E+05	6.21E+08	1.44E-21
2.7E+05	7.22E+08	4.00E-22
3.2E+05	7.86E+08	1.67E-22

References: 134, 136, 156, 157, 158, 159, 160

Accuracy: Unknown

Notes: (1) Very few papers report the absolute cross sections. The overall assessment of the data is in doubt due to the validity of the different normalization schemes.
(2) Cascade from higher states is usually neglected, but can contribute up to a 5% error in the reported cross section.

For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 3.0E+03 eV/amu, E_{max} = 3.2E+05 eV/amu

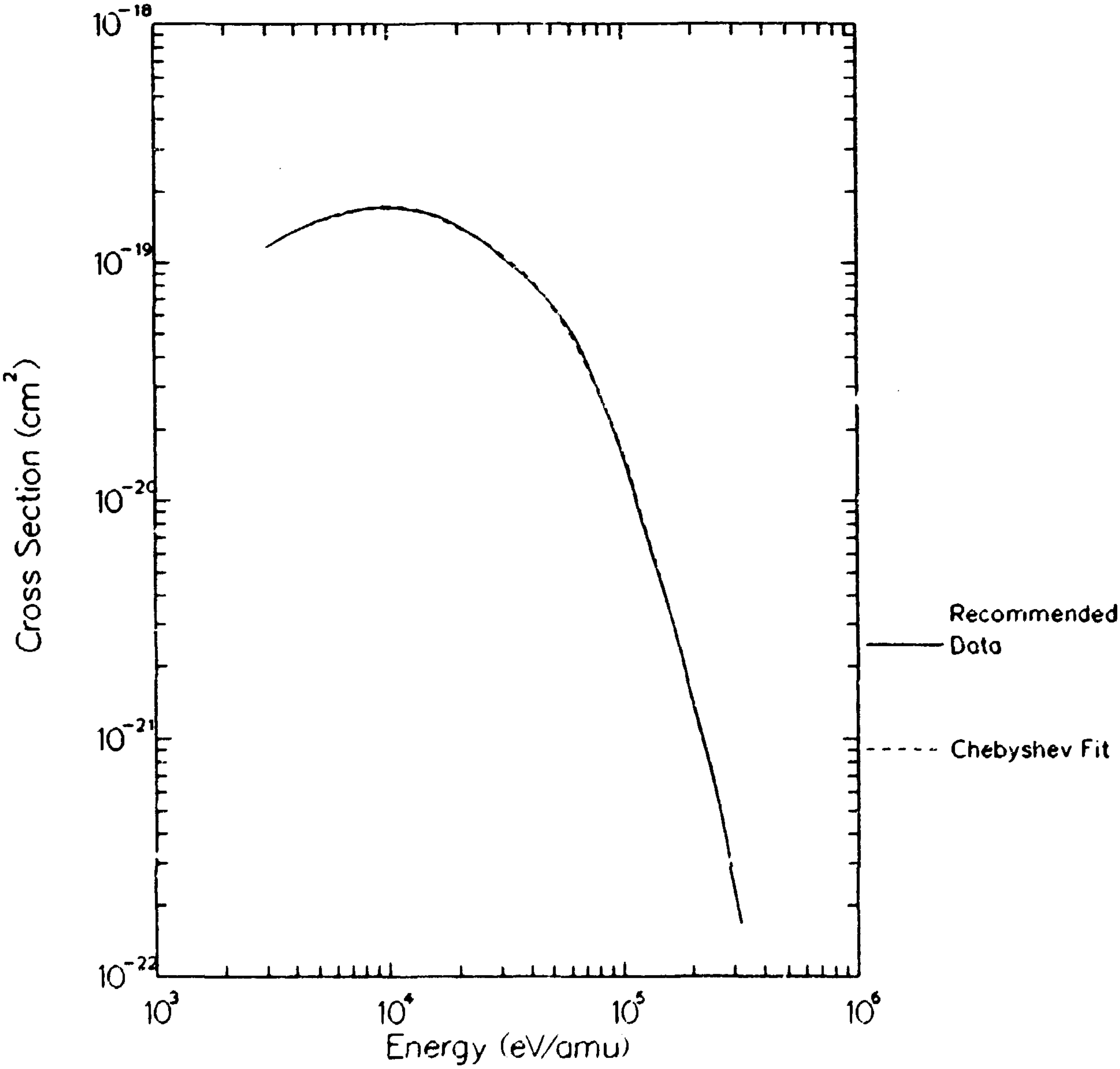
Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-90.4702	-2.39013	-1.60913	-.296858	-.0140200	.0353005	.0153108	-.0221875	-.0321765

The fit represents the above cross sections with an rms deviation of 1.9%.
The maximum deviation is 3.1% at 1.0E+05 eV/amu.
See appendix for Chebyshev fit details.

$H^{+} + He \rightarrow H(3d) + He^{+}$

Cross Section vs. Energy



Electron Capture Rate Coefficients for
$B^+ + He \rightarrow B(3d) + He^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

B^+ Temp. (eV)	Equal Temp.	He Temp. (eV) 100.	500.	1000.	5000.	10000.	15000.	20000.
2.0E+02	2.41E-16	6.60E-17	3.49E-15	4.08E-14	3.27E-12	8.54E-12	1.24E-11	1.52E-11
4.0E+02	7.71E-14	2.80E-14	1.01E-13	2.88E-13	4.19E-12	9.26E-12	1.29E-11	1.55E-11
7.0E+02	8.89E-13	4.53E-13	7.29E-13	1.15E-12	5.53E-12	1.03E-11	1.36E-11	1.60E-11
1.0E+03	2.38E-12	1.43E-12	1.84E-12	2.38E-12	6.80E-12	1.12E-11	1.43E-11	1.65E-11
2.0E+03	7.79E-12	5.85E-12	6.28E-12	6.80E-12	1.04E-11	1.37E-11	1.61E-11	1.78E-11
4.0E+03	1.48E-11	1.26E-11	1.29E-11	1.32E-11	1.52E-11	1.72E-11	1.85E-11	1.95E-11
7.0E+03	1.94E-11	1.78E-11	1.79E-11	1.80E-11	1.90E-11	1.98E-11	2.04E-11	2.08E-11
1.0E+04	2.10E-11	2.01E-11	2.02E-11	2.02E-11	2.06E-11	2.10E-11	2.12E-11	2.12E-11
2.0E+04	2.01E-11	2.09E-11	2.09E-11	2.09E-11	2.08E-11	2.05E-11	2.03E-11	2.01E-11

Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 2.0E+02 eV, E_{max} = 2.0E+04 eV

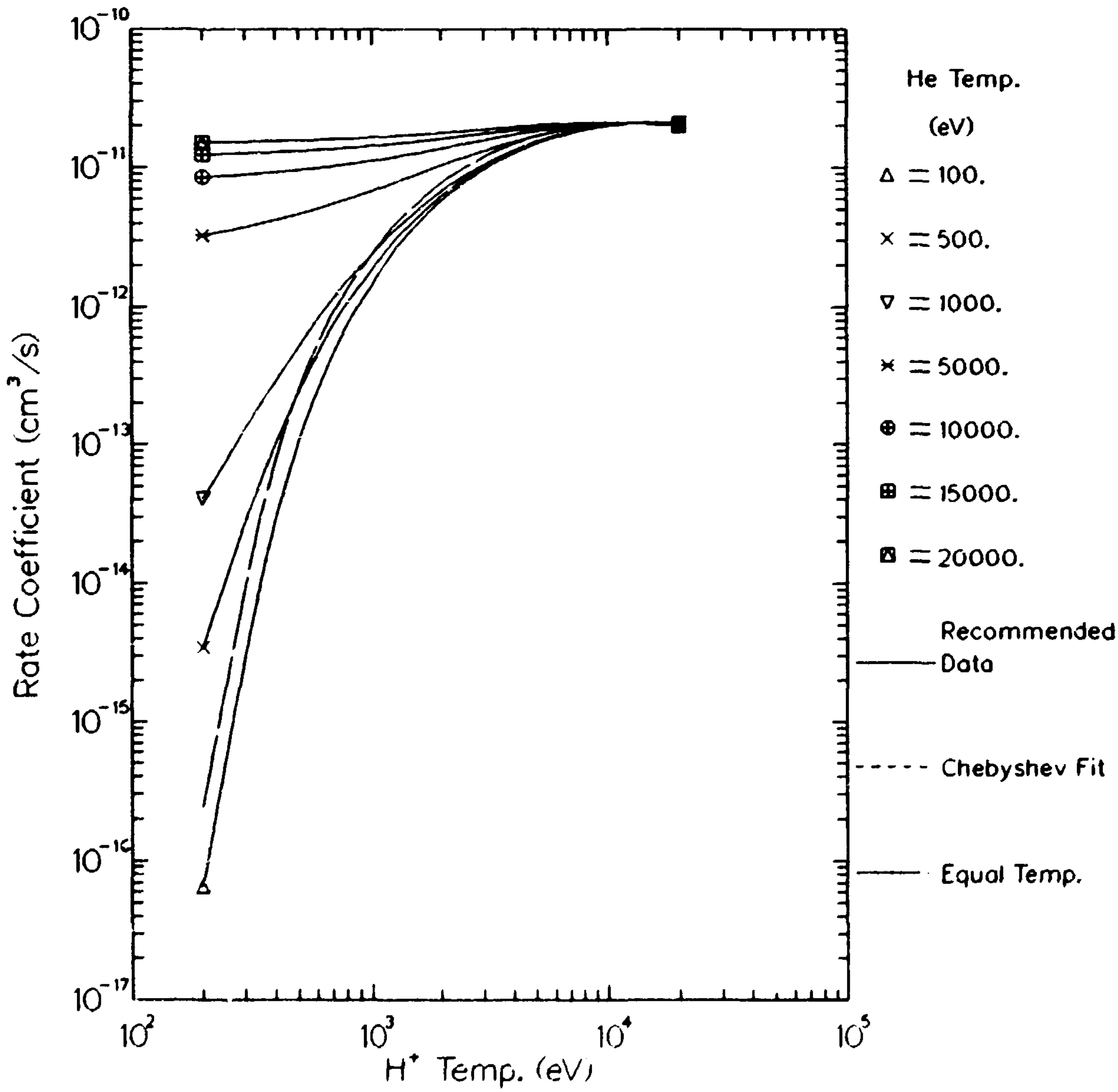
Chebyshev Fitting Parameters for Rate Coefficients

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
100.	-5.63688E+01	5.53526E+00	-2.53031E+00	7.68047E-01	-2.09210E-01	3.02777E-02	8.99288E-04
500.	-5.46783E+01	4.07558E+00	-1.58318E+00	2.94914E-01	-2.76037E-02	-2.07878E-02	1.01392E-02
1000.	-5.34861E+01	3.08285E+00	-1.00328E+00	6.05624E-02	3.07528E-02	-2.37156E-02	4.91264E-03
5000.	-5.08092E+01	1.02925E+00	-1.15489E-01	-1.11263E-01	1.29497E-04	5.31512E-03	-1.44689E-03
10000.	-5.00260E+01	5.09612E-01	-1.91665E-02	-7.34488E-02	-1.56542E-02	2.56893E-03	7.98864E-04
15000.	-4.96848E+01	2.98178E-01	-7.68530E-03	-5.18119E-02	-1.65953E-02	-3.35169E-04	1.07168E-03
20000.	-4.94956E+01	1.81879E-01	-1.04948E-02	-3.99118E-02	-1.50920E-02	-1.49095E-03	1.11348E-03
Equal Temp.	-5.53820E+01	4.85397E+00	-2.35173E+00	7.57520E-01	-2.46645E-01	5.44226E-02	-8.31810E-03

See appendix for Chebyshev fit details.

$H^+ + He \rightarrow H(3d) + He^+$

Maxwellian – Maxwellian



Electron Capture Rate Coefficients for
He + H^+ -> H(3d) + He^+

Beam - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	60000.	80000.	100000.	200000.
1.0E+00	2.37E-11	2.80E-11	2.31E-11	1.65E-11	1.09E-11	6.71E-12*	8.94E-13**
2.0E+00	2.37E-11	2.80E-11	2.31E-11	1.65E-11	1.09E-11	6.71E-12*	8.93E-13**
4.0E+00	2.37E-11	2.80E-11	2.31E-11	1.65E-11	1.09E-11	6.70E-12*	8.93E-13**
7.0E+00	2.36E-11	2.79E-11	2.30E-11	1.65E-11	1.09E-11	6.70E-12*	8.92E-13**
1.0E+01	2.36E-11	2.79E-11	2.30E-11	1.65E-11	1.09E-11	6.70E-12*	8.92E-13**
2.0E+01	2.36E-11	2.78E-11	2.30E-11	1.65E-11	1.09E-11	6.69E-12	8.91E-13**
4.0E+01	2.35E-11	2.77E-11	2.29E-11	1.65E-11	1.09E-11	6.68E-12	8.90E-13**
7.0E+01	2.34E-11	2.76E-11	2.28E-11	1.65E-11	1.09E-11	6.67E-12	8.89E-13*
1.0E+02	2.34E-11	2.75E-11	2.28E-11	1.65E-11	1.09E-11	6.67E-12	8.89E-13*
2.0E+02	2.33E-11	2.73E-11	2.26E-11	1.65E-11	1.10E-11	6.66E-12	8.89E-13*
4.0E+02	2.31E-11	2.70E-11	2.24E-11	1.65E-11	1.10E-11	6.68E-12	8.92E-13*
7.0E+02	2.30E-11	2.66E-11	2.22E-11	1.64E-11	1.10E-11	6.72E-12	8.98E-13*
1.0E+03	2.29E-11	2.63E-11	2.20E-11	1.63E-11	1.09E-11	6.76E-12	9.05E-13*
2.0E+03	2.26E-11	2.55E-11	2.15E-11	1.59E-11	1.08E-11	6.90E-12	9.35E-13*
4.0E+03	2.24E-11	2.41E-11	2.05E-11	1.53E-11	1.06E-11	7.06E-12	1.01E-12*
7.0E+03	2.22E-11	2.26E-11	1.92E-11	1.45E-11	1.04E-11	7.19E-12	1.13E-12*
1.0E+04	2.18E-11	2.14E-11	1.80E-11	1.38E-11	1.01E-11	7.22E-12	1.26E-12*
2.0E+04	1.98E-11	1.83E-11	1.51E-11	1.20E-11	9.26E-12	7.06E-12	1.66E-12*

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

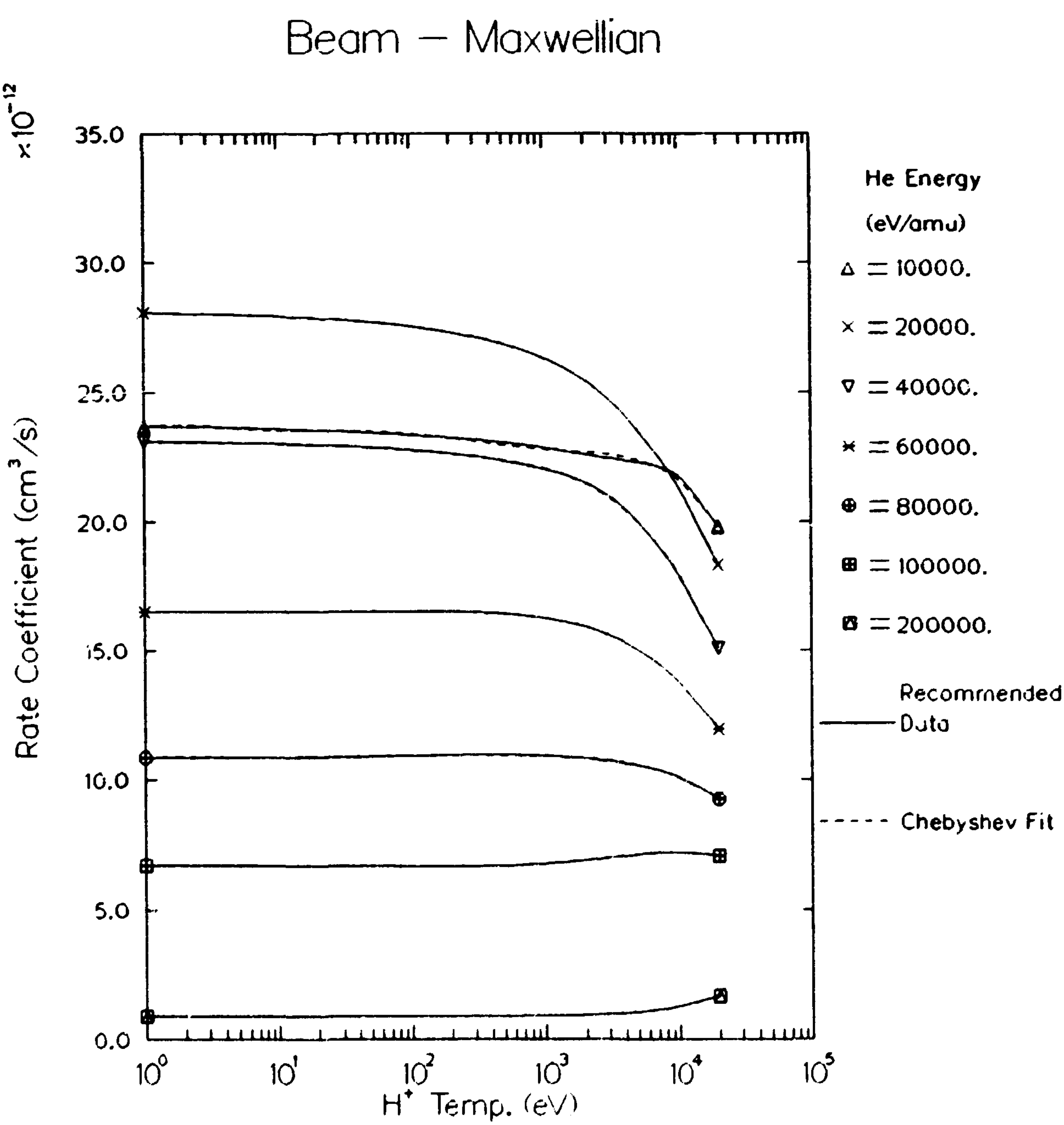
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-4.90115E+01	-6.26583E-02	-3.14715E-02	-1.74368E-02	-1.18746E-02	-8.00345E-03	-5.51328E-03
20000.	-4.87965E+01	-1.63847E-01	-9.40039E-02	4.32626E-02	-1.65508E-02	-4.78447E-03	-6.28354E-04
40000.	-4.91665E+01	-1.54448E-01	-9.66541E-02	-5.08695E-02	-2.30319E-02	-8.09916E-03	-1.06973E-03
60000.	-4.97788E+01	-1.11497E-01	-7.93398E-02	-4.38613E-02	-1.80124E-02	-5.25241E-03	-1.28373E-03
80000.	-5.05382E+01	-4.92366E-02	-4.11913E-02	-2.64723E-02	-1.18809E-02	-3.95220E-03	-2.08141E-03
100000.	-5.14178E+01	3.35427E-02	2.01516E-02	3.56710E-04	-9.44387E-03	-8.21678E-03	-3.58171E-03
200000.	-5.52583E+01	2.09996E-01	1.57946E-01	9.13682E-02	3.94669E-02	1.12103E-02	-2.26555E-04

See appendix for Chebyshev fit details.

$He + H^+ \rightarrow H(3d) + He^+$



Electron Capture Cross Sections for

$H^+ + Li \rightarrow H(2s,2p) + Li^+$

H(2s)

Energy eV/amu	Cross Section cm^2
9.6E+02	1.09E-15
1.9E+03	2.22E-15
2.4E+03	2.52E-15
2.9E+03	2.56E-15
4.8E+03	2.06E-15
6.7E+03	1.39E-15
8.6E+03	9.00E-16
9.5E+03	7.26E-16
1.4E+04	2.73E-16
1.9E+04	1.23E-16
2.4E+04	6.20E-17
3.8E+04	1.40E-17
4.9E+04	6.29E-18
5.9E+04	3.55E-18
6.8E+04	2.22E-18
8.8E+04	9.76E-19
9.8E+04	6.77E-19
1.3E+05	2.72E-19

H(2p)

Energy eV/amu	Cross Section cm^2
9.8E+02	1.44E-15
2.0E+03	2.37E-15
2.9E+03	2.95E-15
3.4E+03	3.05E-15
4.9E+03	2.75E-15
6.8E+03	2.02E-15
9.7E+03	1.13E-15
1.4E+04	3.01E-16
1.9E+04	9.71E-17
2.4E+04	3.76E-17
2.9E+04	1.76E-17
3.9E+04	3.98E-18
4.9E+04	1.21E-18
5.9E+04	4.47E-19
6.9E+04	1.94E-19
8.9E+04	4.96E-20
1.1E+05	1.69E-20

References: 255, 256, 257

Accuracy: $E < 2\times10^4$ eV/amu - 60%; $E > 2\times10^4$ eV/amu - unknown

Notes: (1) The cross section data for energies greater than 2×10^4 eV/amu are theoretical results of Ermolaev (ref. 257); for excitation of the Li(2p) level by protons see ref. 258.

(2) Cascading from higher states is less than 5%, thus $\sigma(2p) \cong \sigma(Ly_\alpha)$.

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

H(2s) E_{min} = 9.55E+02 eV/amu, E_{max} = 1.3E+05 eV/amu
H(2p) E_{min} = 9.8E+02 eV/amu, E_{max} = 1.1E+05 eV/amu

Chebyshev Fitting Parameters for Cross Sections

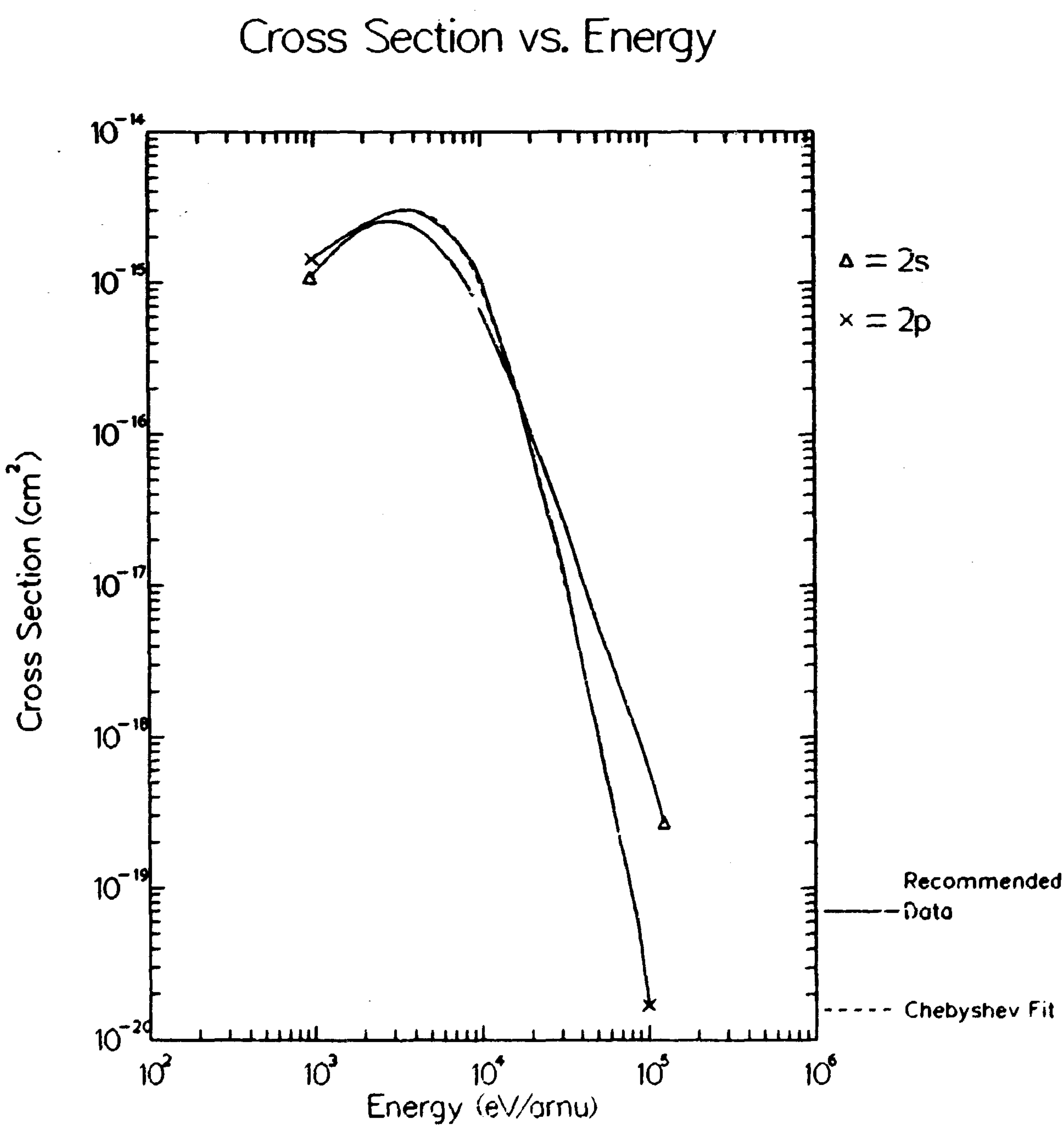
	A0	A1	A2	A3	A4	A5	A6	A7	A8
H(2s)	-73.9306	-4.42348	-1.68271	.337287	.0753407	-.0624317	-.0223686	6.11347E-04	-.00573178
H(2p)	-75.0922	-5.75721	-2.57021	.0939967	.255624	-.0329880	-.0184241	.0249338	.0333479

The fit represents the H(2s) cross section with an rms deviation of 0.9%.
The maximum deviation is 1.7% at 4.8E+04 eV/amu.

The fit represents the H(2p) cross section with an rms deviation of 3.2%.
The maximum deviation is 5.5% at 1.9E+04 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + Li \rightarrow H(2s,2p) + Li^+$



Electron Capture Cross Sections for

$H^+ + Li \rightarrow H(3s,3p,3d) + Li^+$

(3s) Energy eV/amu	(3s) Cross Section cm^2	(3p) Energy eV/amu	(3p) Cross Section cm^2	(3d) Energy eV/amu	(3d) Cross Section cm^2
1.3E+03	7.96E-17	9.8E+02	1.28E-16	3.1E+03	7.47E-17
2.8E+03	9.60E-17	1.5E+03	1.51E-16	3.9E+03	8.78E-17
2.9E+03	1.23E-16	2.0E+03	1.76E-16	4.8E+03	9.79E-17
3.9E+03	1.35E-16	2.9E+03	2.33E-16	6.8E+03	1.06E-16
4.9E+03	2.07E-16	3.9E+03	3.17E-16	9.7E+03	8.39E-17
6.8E+03	3.46E-16	4.9E+03	3.65E-16	1.3E+04	4.31E-17
6.9E+03	4.43E-16	6.9E+03	3.45E-16	1.5E+04	2.78E-17
7.9E+03	4.55E-16	8.9E+03	2.81E-16	2.0E+04	1.16E-17
8.9E+03	4.29E-16	9.9E+03	2.47E-16	2.9E+04	2.97E-18
1.0E+04	3.83E-16	1.5E+04	1.23E-16	3.9E+04	1.11E-18
1.5E+04	1.64E-16	2.0E+04	5.12E-17	4.9E+04	4.65E-19
2.0E+04	6.88E-17	2.5E+04	2.18E-17	7.0E+04	1.44E-19
2.5E+04	3.15E-17	3.0E+04	1.05E-17	9.9E+04	3.63E-20
3.5E+04	7.97E-18	3.5E+04	6.04E-18	1.3E+05	1.20E-20
4.9E+04	1.96E-18	4.5E+04	2.25E-18	1.5E+05	7.57E-21
6.0E+04	1.03E-18	5.0E+04	1.63E-18		
8.0E+04	3.69E-19	6.0E+04	6.60E-19		
1.0E+05	1.81E-19	7.0E+04	3.86E-19		
1.3E+05	8.92E-20	9.0E+04	1.48E-19		
		1.0E+05	9.25E-20		
		1.3E+05	3.87E-20		

References: 256, 257

Accuracy: $E < 2 \times 10^4$ eV/amu - 60%; $E > 2 \times 10^4$ eV/amu - unknown

Notes: (1) The cross section data for energies greater than 2×10^4 eV/amu are the theoretical results of Ermolaev (ref. 257).

(2) The cross section (σ_i) for capture into state i is determined by measuring the emission cross section (σ_{ij}) for a transition from state i to j, correcting for any branching from state i and correcting for cascading from upper states.

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

(3s) E_{min} = 1.3E+03 eV/amu, E_{max} = 1.2E+05 eV/amu
(3p) E_{min} = 9.8E+02 eV/amu, E_{max} = 1.2E+05 eV/amu
(3d) E_{min} = 3.1E+03 eV/amu, E_{max} = 1.5E+05 eV/amu

Chebyshev Fitting Parameters for Cross Sections

	A0	A1	A2	A3	A4	A5	A6	A7	A8
(3s)	-77.4321	-3.51092	-2.10742	.102860	.543366	-.0941225	-.179427	.114301	-.00463843
(3p)	-77.4555	-4.03388	-2.19950	.00628310	.364180	-.0330367	-.0799875	.00340643	-.00766823
(3d)	-80.9668	-4.92271	-1.27692	.391264	-.0254482	-.0874189	.0722031	.0109053	-.0235328

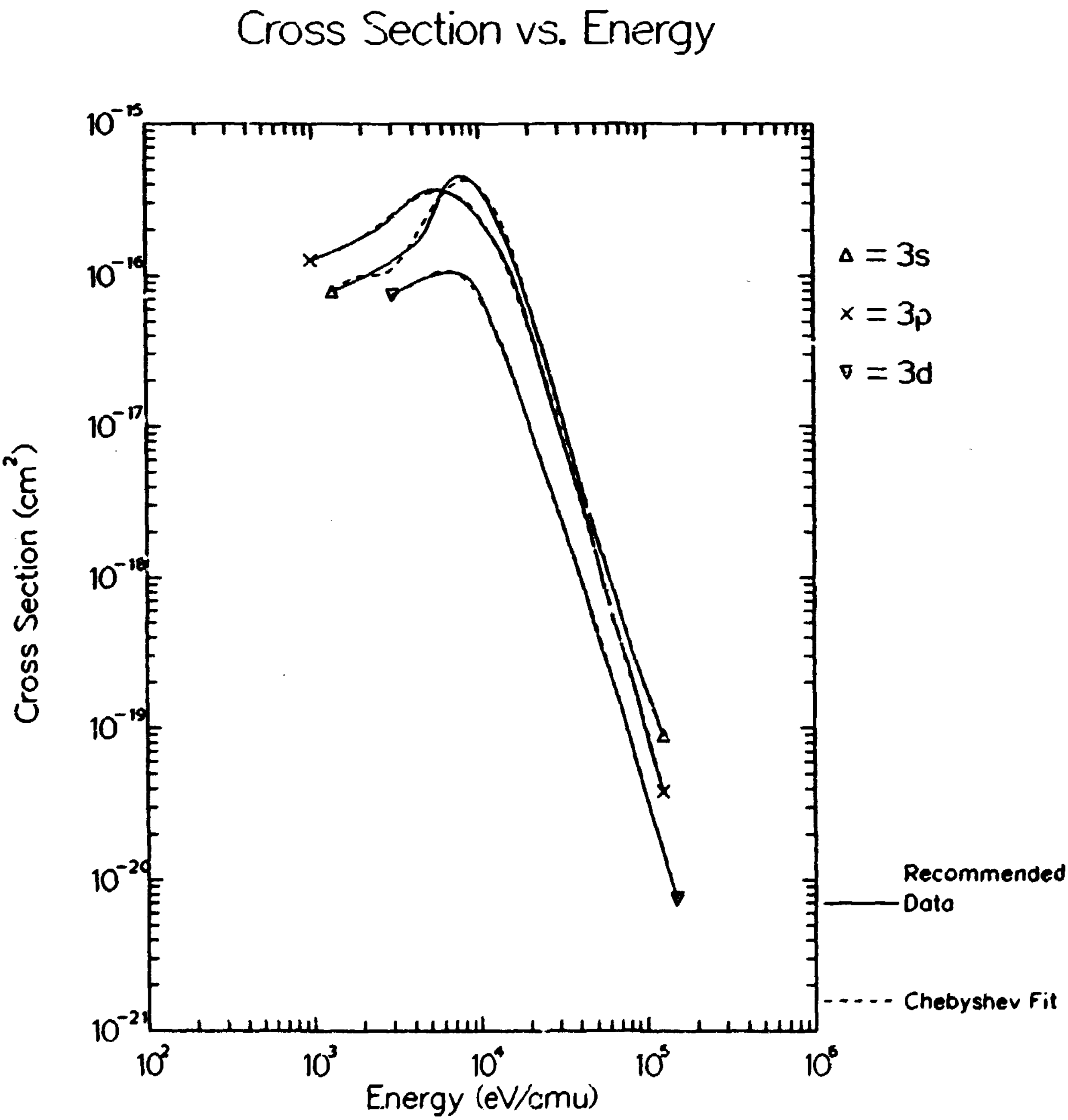
The fit represents the (3s) cross section with an rms deviation of 6.8%.
The maximum deviation is 19.4% at 4.9E+03 eV/amu.

The fit represents the (3p) cross section with an rms deviation of 3.7%.
The maximum deviation is 6.6% at 3.0E+04 eV/amu.

The fit represents the (3d) cross section with an rms deviation of 3.2%.
The maximum deviation is 6.5% at 4.9E+04 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + Li \rightarrow H(3s,3p,3d) + Li^+$



Electron Capture Cross Sections for
$He^{+} + H_2 \rightarrow He(2^1S + 2^3S)$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.5E+03	6.95E+07	6.75E-18
3.0E+03	7.61E+07	9.57E-18
4.0E+03	8.79E+07	1.58E-17
5.0E+03	9.82E+07	2.18E-17
7.0E+03	1.16E+08	3.14E-17
9.0E+03	1.32E+08	4.14E-17
1.0E+04	1.39E+08	4.63E-17
1.5E+04	1.70E+08	6.54E-17
2.0E+04	1.96E+08	7.00E-17
2.5E+04	2.20E+08	6.69E-17
3.5E+04	2.60E+08	5.28E-17
4.5E+04	2.95E+08	4.03E-17
5.0E+04	3.11E+08	3.52E-17
6.0E+04	3.40E+08	2.75E-17
6.4E+04	3.51E+08	2.46E-17

References: 98, 102, 196, 197, 198

Accuracy: 40%

Note: The cross sections are for capture into the metastable states 2^1S and 2^3S.

For Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.5E+03 eV/amu, E_{max} = 6.4E+04 eV/amu

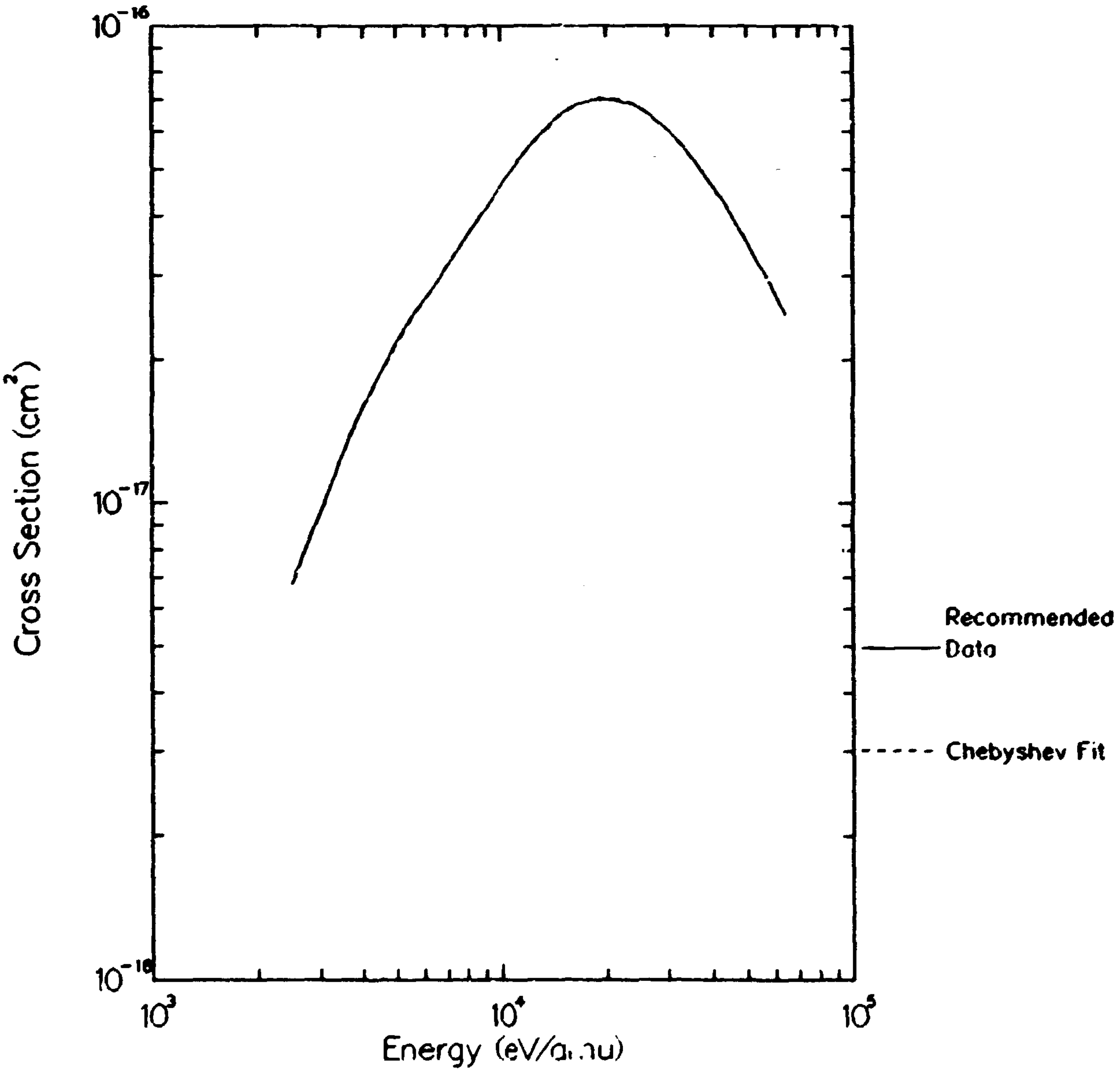
Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-76.2905	.717609	-.746846	-.0903391	1.71246E-03	.0416862	-7.59576E-04	-.0179523	6.07163E-03

The fit represents the above cross sections with an rms deviation of 0.5%.
The maximum deviation is 0.9% at 4.0E+03 eV/amu.
See appendix for Chebyshev fit details.

$He^{+} + H_{2} \rightarrow He(2^{1}S + 2^{3}S)$

Cross Section vs. Energy



Electron Capture Cross Sections for

$He^{+} + H_2 \rightarrow He(2^1P, 3^1P)$

(2^1P)

Energy eV/amu	Cross Section cm^2
1.3E+03	2.95E-17
1.5E+03	3.02E-17
2.0E+03	3.37E-17
3.0E+03	3.67E-17
3.5E+03	3.90E-17
4.3E+03	4.12E-17
5.0E+03	4.22E-17
5.8E+03	4.19E-17
6.5E+03	4.13E-17
7.0E+03	4.11E-17
8.0E+03	4.05E-17
8.5E+03	3.96E-17
8.8E+03	3.92E-17

(3^1P)

Energy eV/amu	Cross Section cm^2
2.5E+03	2.05E-18
3.0E+03	1.89E-18
3.5E+03	1.61E-18
4.3E+03	1.45E-18
5.0E+03	1.33E-18
5.8E+03	1.28E-18
6.5E+03	1.33E-18
7.9E+03	1.47E-18
8.0E+03	1.64E-18
8.5E+03	1.83E-18
9.0E+03	1.91E-18

<u>References:</u> 20, 163

<u>Accuracy:</u> 60%

<u>Notes:</u> (1) The cross section (σ_i) for capture into state i is determined by measuring the emission cross section (σ_{ij}) for a transition from state i to j, correcting for any branching from state i and correcting for cascading from upper states.
(2) In these measurements cascade was neglected in the analysis of the cross section.

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

(2^1P) E_{min} = 1.3E+03 eV/amu, E_{max} = 8.8E+03 eV/amu

(3^1P) E_{min} = 2.5E+03 eV/amu, E_{max} = 9.0E+03 eV/amu

<u>Chebyshev Fitting Parameters for Cross Sections</u>

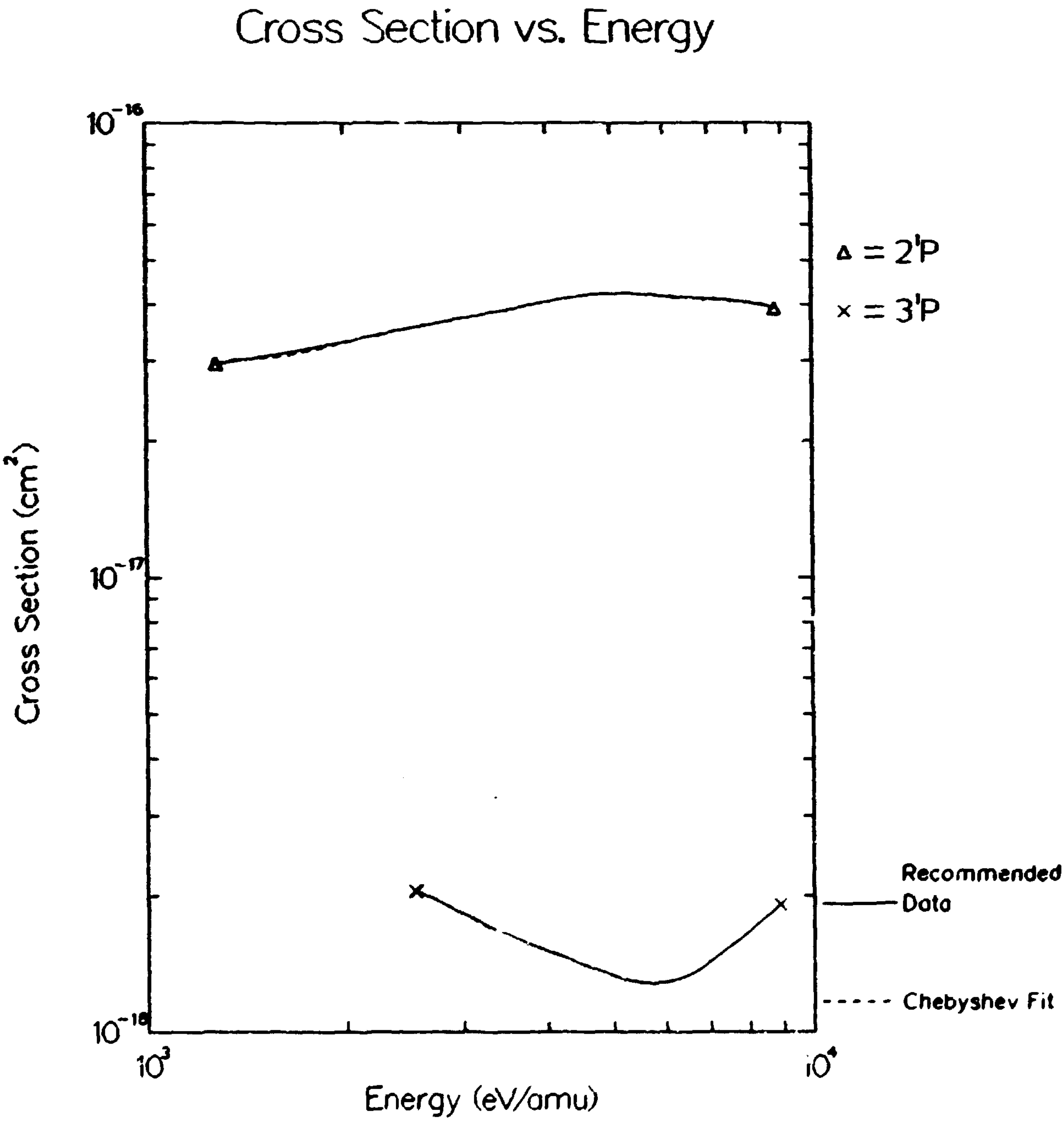
	A0	A1	A2	A3	A4	A5	A6	A7	A8
(2^1P)	-75.7187	.173380	-.0602524	-.0334767	.00459756	.00195946	.00158847	-4.27148E-04	-.00726785
(3^1P)	-81.8842	-.0794869	.196956	.0554748	-.00702131	-.0164034	-.0116162	.00548035	1.56409E-04

The fit represents the (2^1P) cross sections with an rms deviation of 0.2%.
The maximum deviation is 0.2% at 6.4E+03 eV/amu.

The fit represents the (3^1P) cross sections with an rms deviation of 0.2%.
The maximum deviation is 0.4% at 7.9E+03 eV/amu.

See appendix for Chebyshev fit details.

$He^+ + H_2 \rightarrow He(2^1P, 3^1P)$



Line Emission Cross Sections of Electron Capture Collisions for

$He^{+} + H_2 \rightarrow He(587.6, 447.1, 667.8\ nm)$

(587.6 nm) Energy eV/amu	(587.6 nm) Cross Section cm^2	(667.8 nm) Energy eV/amu	(667.8 nm) Cross Section cm^2	(447.1 nm) Energy eV/amu	(447.1 nm) Cross Section cm^2
1.7E+01	1.12E-21	3.7E+01	9.97E-22	2.0E+01	9.98E-22
2.0E+01	3.58E-21	5.0E+01	7.92E-21	2.5E+01	2.67E-21
2.5E+01	7.90E-21	6.0E+01	1.47E-20	3.0E+01	3.75E-21
3.0E+01	8.74E-21	8.0E+01	4.70E-20	4.0E+01	5.02E-21
4.0E+01	1.26E-20	1.0E+02	1.34E-19	5.0E+01	6.21E-21
5.0E+01	1.81E-20	1.5E+02	2.70E-19	6.0E+01	7.65E-21
6.0E+01	2.83E-20	1.8E+02	3.35E-19	7.0E+01	1.00E-20
8.2E+01	7.80E-20	2.0E+02	3.95E-19	8.0E+01	1.77E-20
1.0E+02	1.72E-19			1.0E+02	6.11E-20
1.5E+02	6.40E-19			1.2E+02	9.53E-20
2.0E+02	1.12E-18			1.5E+02	1.30E-19
2.4E+02	1.17E-18			2.0E+02	1.60E-19
3.0E+02	1.16E-18			2.5E+02	1.75E-19
5.2E+02	1.02E-18			3.0E+02	1.82E-19
8.3E+02	8.33E-19			4.0E+02	1.81E-19
1.0E+03	7.69E-19			6.0E+02	1.63E-19
1.6E+03	7.00E-19			8.0E+02	1.45E-19
2.0E+03	6.93E-19			1.0E+03	1.31E-19
3.0E+03	7.25E-19			1.5E+03	1.07E-19
4.0E+03	7.68E-19			2.0E+03	9.32E-20
5.2E+03	8.05E-19			3.0E+03	8.58E-20
7.8E+03	8.90E-19			4.0E+03	8.98E-20
				5.0E+03	9.72E-20
				6.0E+03	1.06E-19
				7.2E+03	1.16E-19
				8.2E+03	1.27E-19
				1.0E+04	1.48E-19

References: 199, 200

Accuracy: 40%

Notes: (1) Relative data of Polyakova et al (ref. 200) have been normalized to data of Isler et al (ref. 199) at 125 eV/amu.

(2) The 587.6 nm transition is the strongest He emission from He^{+} capture collisions in H_2.

(3) The $4^3D \rightarrow 2^3P$ transition is 447.1 nm, the $3^3D \rightarrow 2^3P$ transition is 587.6 nm, and the $3^1D \rightarrow 2^1P$ transition is 667.8 nm.

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

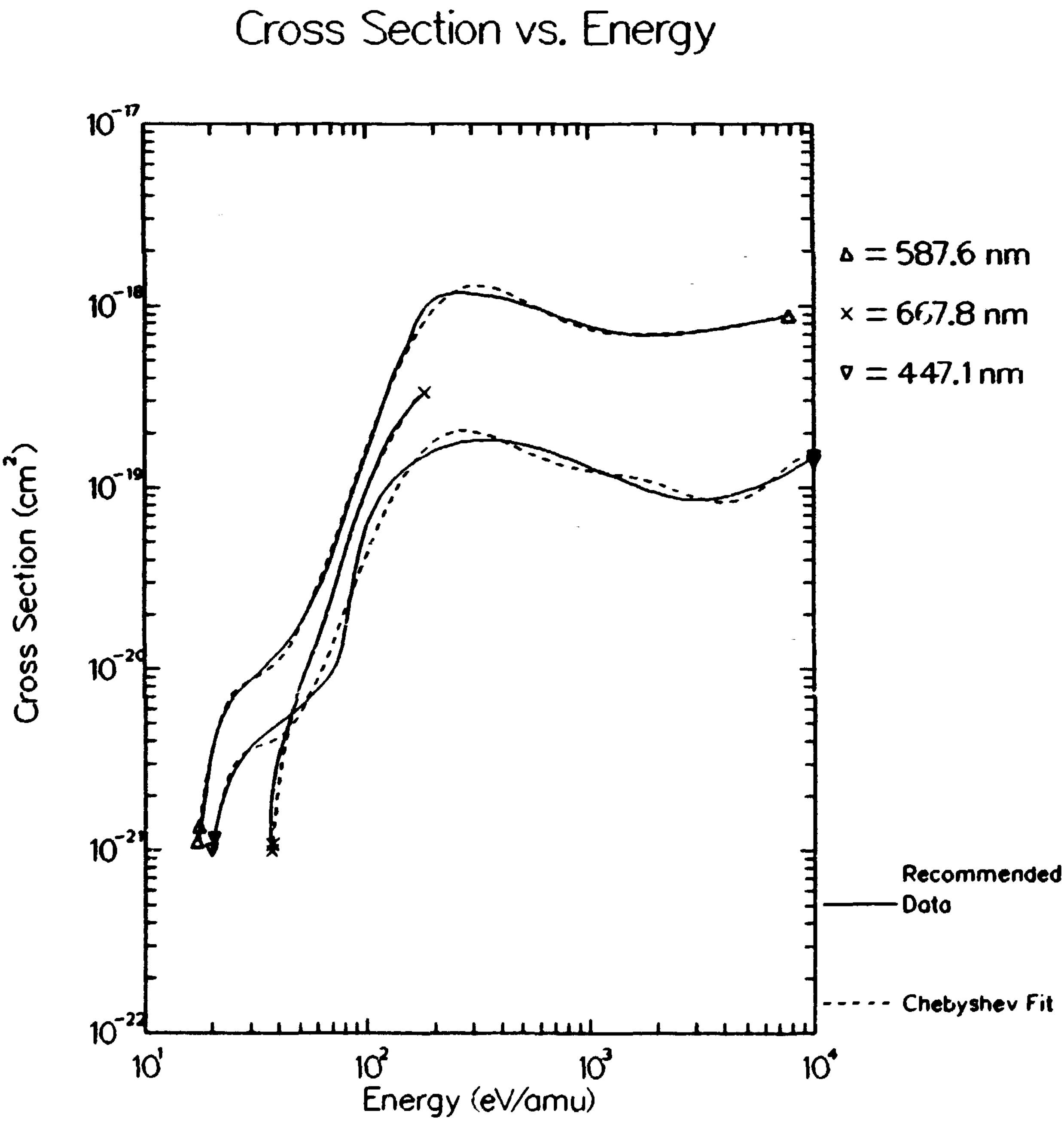
(587.6 nm) E_{min} = 1.7E+01 eV/amu, E_{max} = 7.8E+03 eV/amu
(667.8 nm) E_{min} = 3.7E+01 eV/amu, E_{max} = 2.0E+02 eV/amu
(447.1 nm) E_{min} = 2.0E+01 eV/amu, E_{max} = 1.0E+04 eV/amu

Chebyshev Fitting Parameters for Cross Sections

	A0	A1	A2	A3	A4	A5	A6	A7	A8
(587.6 nm)	-86.6646	2.83888	-1.58217	.357959	.371758	-.133932	-.263367	.286400	-.104165
(667.8 nm)	-89.3928	2.77428	-.477423	.0466864	-.123082	.139543	-.0694321	.0304386	
(447.1 nm)	-89.4303	1.99037	-1.26304	.473572	.362531	-.183668	-.0812802	.198425	-.197268

The fit represents the 587.6 nm cross section with an rms deviation of 4.7%.
The maximum deviation is 10.8% at 3.1E+02 eV/amu.
The fit represents the 667.8 nm cross section with an rms deviation of 0.0%.
The maximum deviation is 0.0%.
The fit represents the 447.1 nm cross section with an rms deviation of 14.7%.
The maximum deviation is 42.6% at 7.1E+01 eV/amu.
See appendix for Chebyshev fit details.

$He^+ + H_2 \rightarrow He(587.6, 667.8, 447.1\ nm)$



Electron Capture Cross Sections for $He^{+} + He \rightarrow He(2^{1}S + 2^{3}S)$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+01	4.39E+06	1.00E-19
1.5E+01	5.38E+06	1.94E-19
3.0E+01	7.61E+06	7.49E-19
5.0E+01	9.82E+06	1.69E-18
8.0E+01	1.24E+07	2.33E-18
1.5E+02	1.70E+07	2.81E-18
3.0E+02	2.41E+07	2.99E-18
6.0E+02	3.40E+07	3.35E-18
1.5E+03	5.38E+07	4.54E-18
2.5E+03	6.95E+07	6.54E-18
4.0E+03	8.79E+07	9.49E-18
6.0E+03	1.08E+08	1.46E-17
9.0E+03	1.32E+08	2.40E-17
1.0E+04	1.39E+08	2.61E-17
1.5E+04	1.70E+08	2.41E-17
3.3E+04	2.50E+08	1.85E-17
5.0E+04	3.11E+08	1.52E-17

References: 98, 196, 197, 201, 202

Accuracy: 40%

Note: (1) Theoretical values of Sural et al (ref. 202) are used to extrapolate the data of Gilbody et al (ref. 98) at $5x10^{3}$ eV/amu to those of MacVicar and Barat (ref. 201) at 55 eV/amu.

For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+01 eV/amu, E_{max} = 5.0E+04 eV/amu

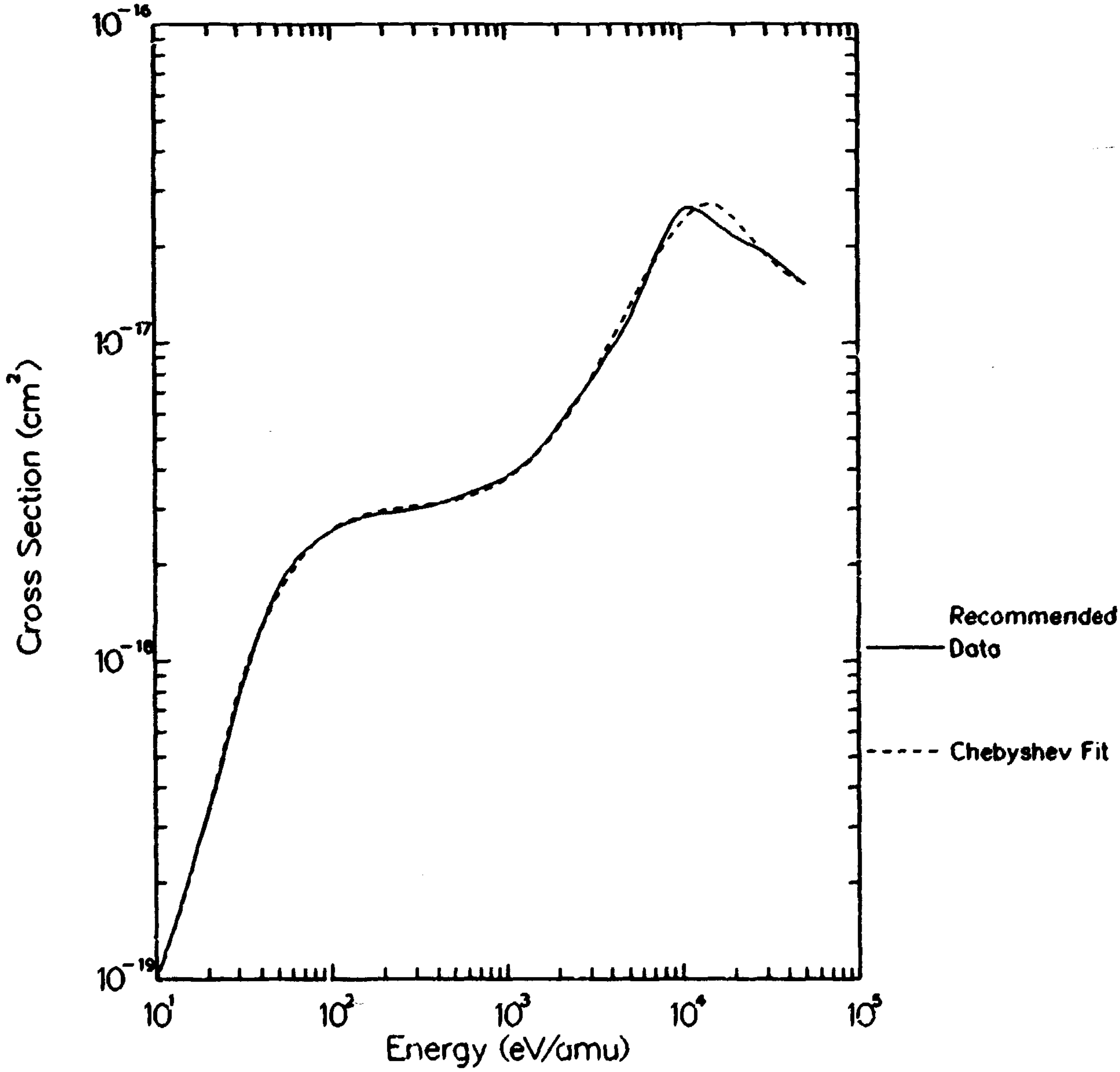
Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-80.6529	2.39212	-.649912	.218666	-.468812	-.126058	.149096	.0275996	.0661909

The fit represents the above cross sections with an rms deviation of 5.2%.
The maximum deviation is 12.8% at 1.5E+04 eV/amu.
See appendix for Chebyshev fit details.

$He^{+} + He \rightarrow He(2^1S + 2^3S)$

Cross Section vs. Energy



Electron Capture Rate Coefficients for $He^+ + He \rightarrow He(2^1S + 2^3S)$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

He^+ Temp. (eV)	Equal Temp.	He Temp. (eV) 10.	100.	500.	1000.	5000.	10000.	20000.
2.0E+00	9.32E-17	7.50E-14	1.05E-11	4.83E-11	7.97E-11	3.80E-10	9.44E-10	1.97E-09
4.0E+00	1.30E-14	1.29E-13	1.08E-11	4.84E-11	7.98E-11	3.80E-10	9.44E-10	1.97E-09
7.0E+00	1.29E-13	2.39E-13	1.12E-11	4.86E-11	8.00E-11	3.81E-10	9.45E-10	1.97E-09
1.0E+01	3.83E-13	3.83E-13	1.16E-11	4.88E-11	8.02E-11	3.81E-10	9.45E-10	1.97E-09
2.0E+01	2.09E-12	1.09E-12	1.30E-11	4.95E-11	8.08E-11	3.82E-10	9.46E-10	1.97E-09
4.0E+01	7.41E-12	3.29E-12	1.56E-11	5.09E-11	8.19E-11	3.84E-10	9.48E-10	1.97E-09
7.0E+01	1.56E-11	7.41E-12	1.93E-11	5.29E-11	8.37E-11	3.87E-10	9.52E-10	1.97E-09
1.0E+02	2.27E-11	1.16E-11	2.27E-11	5.49E-11	8.55E-11	3.90E-10	9.56E-10	1.98E-09
2.0E+02	4.08E-11	2.38E-11	3.25E-11	6.13E-11	9.14E-11	3.99E-10	9.67E-10	1.98E-09
4.0E+02	6.75E-11	4.15E-11	4.81E-11	7.36E-11	1.03E-10	4.19E-10	9.91E-10	2.00E-09
7.0E+02	1.03E-10	6.20E-11	6.75E-11	9.14E-11	1.21E-10	4.50E-10	1.03E-09	2.03E-09
1.0E+03	1.40E-10	8.02E-11	8.55E-11	1.09E-10	1.40E-10	4.82E-10	1.06E-09	2.05E-09
2.0E+03	2.88E-10	1.41E-10	1.46E-10	1.73E-10	2.09E-10	5.92E-10	1.18E-09	2.13E-09
4.0E+03	7.07E-10	2.89E-10	2.97E-10	3.33E-10	3.80E-10	8.25E-10	1.40E-09	2.27E-09
7.0E+03	1.40E-09	5.93E-10	6.03E-10	6.49E-10	7.07E-10	1.18E-09	1.70E-09	2.46E-09
1.0E+04	1.97E-09	9.45E-10	9.56E-10	1.00E-09	1.06E-09	1.50E-09	1.97E-09	2.62E-09
2.0E+04	2.98E-09	1.97E-09	1.98E-09	2.01E-09	2.05E-09	2.33E-09	2.62E-09	2.98E-09

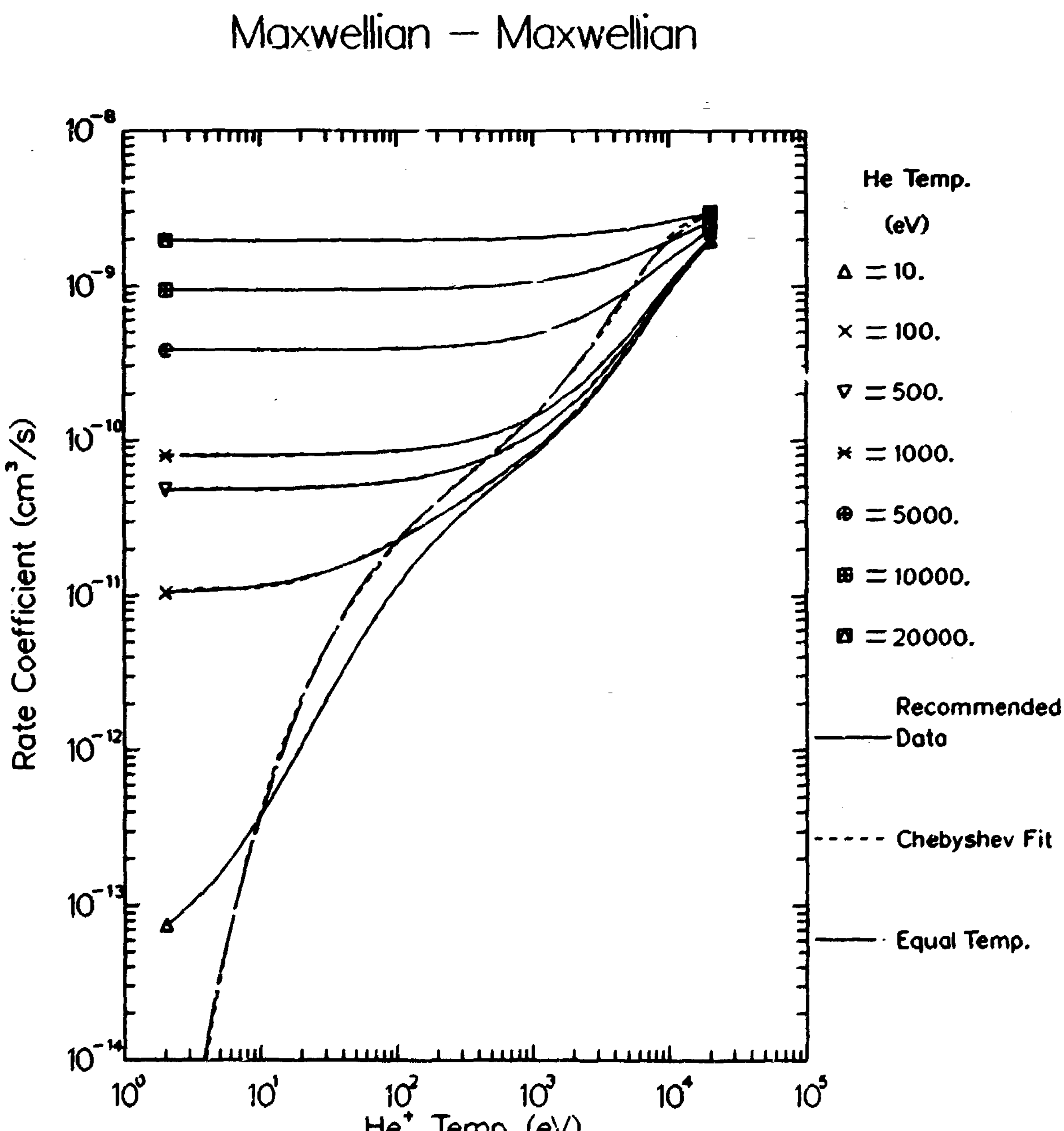
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 2.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
10.	-5.00830E+01	5.12336E+00	-2.62808E-01	8.40742E-02	2.48250E-01	-1.23169E-01	-7.59116E-02
100.	-4.68137E+01	2.59124E+00	7.95345E-01	5.35033E-02	1.89675E-03	-1.71822E-02	-5.25035E-02
500.	-4.53295E+01	1.72678E+00	8.43475E-01	1.98073E-01	-3.44676E-02	3.47555E-02	-3.44800E-03
1000.	-4.46993E+01	1.46770E+00	7.78110E-01	2.19162E-01	-2.15385E-02	-5.87801E-02	-3.66707E-02
5000.	-4.24353E+01	7.86347E-01	4.49607E-01	1.53041E-01	5.53429E-03	-2.94156E-02	-2.10243E-02
10000.	-4.10534E+01	4.26270E-01	2.51921E-01	9.52564E-02	1.32834E-02	-1.03321E-02	-9.66498E-03
20000.	-3.98951E+01	1.67503E-01	1.03069E-01	4.32423E-02	9.86815E-03	-1.82969E-03	-3.51334E-03
Equal Temp.	-5.11417E+01	7.32023E+00	-2.04605E+00	1.24837E+00	-5.12909E-01	3.38169E-02	-1.21200E-01

See appendix for Chebyshev fit details.

$He^{+} + He \rightarrow He(2^1S + 2^3S)$



Electron Capture Rate Coefficients for
$He + He^{+} \rightarrow He(2^{1}S + 2^{3}S)$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^+ Temp. (eV)	He Energy (eV/amu) 10000.	15000.	20000.	25000.	30000.	35000.	40000.
1.0E+00	3.62E-09**	4.10E-09**	4.29E-09**	4.44E-09**	4.57E-09**	4.65E-09**	4.68E-09**
2.0E+00	3.61E-09**	4.10E-09**	4.29E-09**	4.44E-09**	4.57E-09**	4.65E-09**	4.68E-09**
4.0E+00	3.61E-09**	4.10E-09**	4.29E-09**	4.44E-09**	4.57E-09**	4.65E-09**	4.68E-09**
7.0E+00	3.60E-09**	4.10E-09**	4.29E-09**	4.44E-09**	4.57E-09**	4.65E-09**	4.68E-09**
1.0E+01	3.59E-09**	4.10E-09**	4.29E-09**	4.44E-09**	4.57E-09**	4.65E-09**	4.68E-09**
2.0E+01	3.58E-09**	4.09E-09**	4.29E-09**	4.44E-09**	4.57E-09**	4.65E-09**	4.68E-09**
4.0E+01	3.57E-09**	4.09E-09**	4.29E-09**	4.44E-09**	4.57E-09**	4.65E-09**	4.68E-09**
7.0E+01	3.55E-09**	4.09E-09**	4.29E-09**	4.45E-09**	4.57E-09**	4.65E-09**	4.68E-09**
1.0E+02	3.53E-09**	4.09E-09**	4.29E-09**	4.45E-09**	4.57E-09**	4.65E-09**	4.68E-09**
2.0E+02	3.50E-09**	4.08E-09**	4.29E-09**	4.45E-09**	4.57E-09**	4.65E-09**	4.68E-09**
4.0E+02	3.45E-09**	4.08E-09**	4.29E-09**	4.45E-09**	4.57E-09**	4.64E-09**	4.67E-09**
7.0E+02	3.40E-09**	4.07E-09**	4.29E-09**	4.45E-09**	4.57E-09**	4.64E-09**	4.64E-09**
1.0E+03	3.37E-09**	4.06E-09**	4.29E-09**	4.45E-09**	4.57E-09**	4.64E-09**	4.58E-09**
2.0E+03	3.31E-09**	4.03E-09**	4.29E-09**	4.45E-09**	4.56E-09**	4.57E-09**	4.30E-09**
4.0E+03	3.28E-09*	3.99E-09**	4.28E-09**	4.43E-09**	4.4[illegible]E-09**	4.32E-09**	3.86E-09**
7.0E+03	3.30E-09*	3.93E-09**	4.23E-09**	4.34E-09**	4.25E-09**	3.96E-09**	3.45E-09**
1.0E+04	3.34E-09*	3.89E-09**	4.14E-09**	4.18E-09**	4.02E-09**	3.67E-09**	3.18E-09**
2.0E+04	3.43E-09*	3.71E-09*	3.77E-09**	3.65E-09**	3.40E-09**	3.07E-09**	2.68E-09**

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

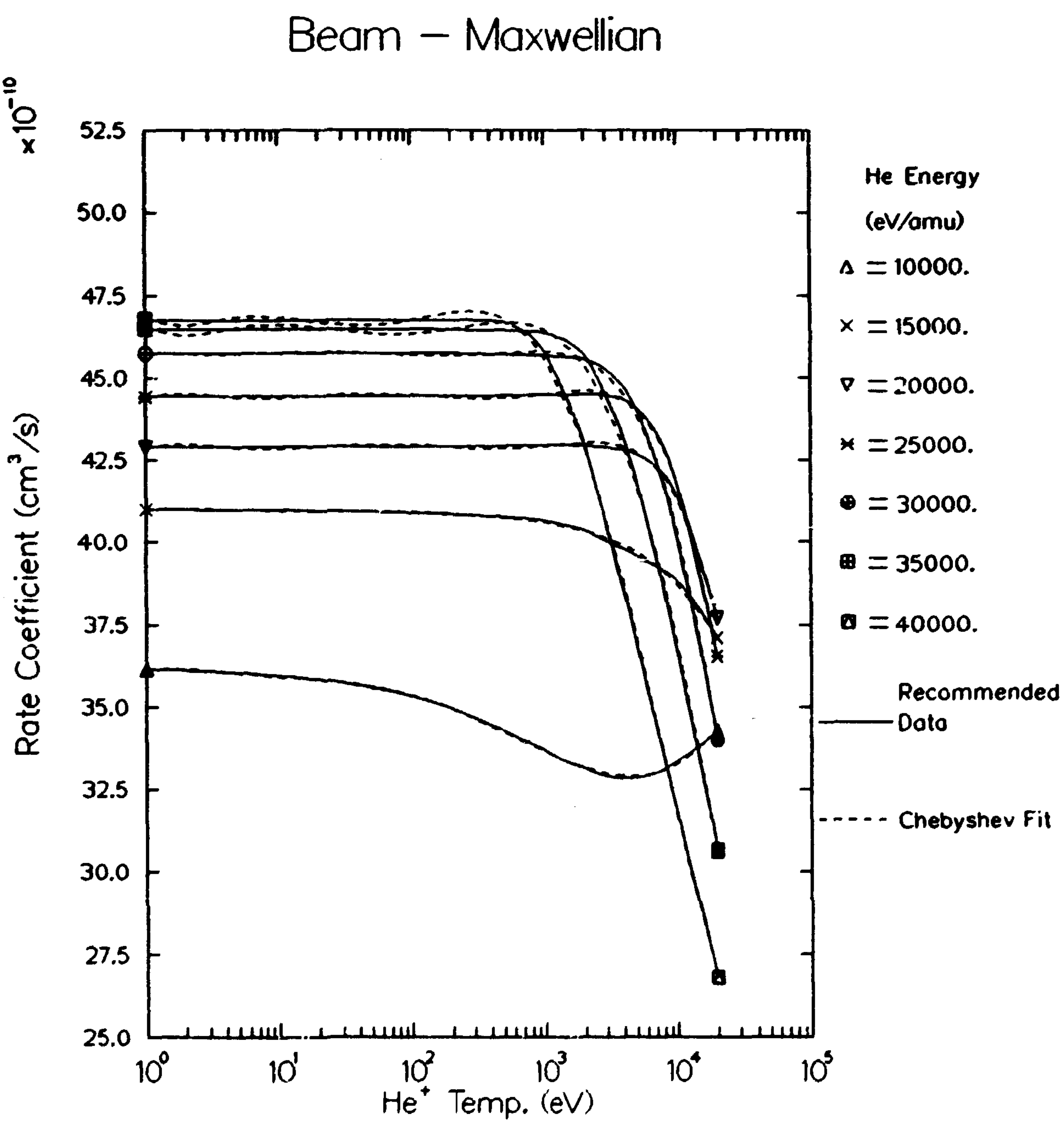
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-3.89516E+01	-4.51244E-02	1.69953E-03	1.65062E-02	1.06870E-02	2.64417E-03	-1.07811E-03
15000.	-3.86669E+01	-3.54627E-02	-2.26753E-02	-1.21671E-02	-5.34610E-03	-1.80140E-03	-7.78336E-04
20000.	-3.85671E+01	-3.27909E-02	-2.82327E-02	-2.24375E-02	-1.53665E-02	-8.81047E-03	-4.39280E-03
25000.	-3.85158E+01	-5.09890E-02	-4.36393E-02	-3.40163E-02	-2.27913E-02	-1.25967E-02	-5.50588E-03
30000.	-3.84991E+01	-8.72591E-02	-7.04596E-02	-4.87052E-02	-2.79930E-02	-1.24934E-02	-2.97299E-03
35000.	-3.85280E+01	-1.39891E-01	-1.06634E-01	-6.39054E-02	-2.79358E-02	-6.05892E-03	3.51648E-03
40000.	-3.86081E+01	-2.17036E-01	-1.48805E-01	-7.02850E-02	-1.44258E-02	8.74155E-03	8.88909E-03

See appendix for Chebyshev fit details.

He + He^{+} -> He(2^{1}S + 2^{3}S)



Electron Capture Cross Sections for
He^{+} + He -> He(2^1P) + He^{+}

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.3E+03	4.91E+07	1.25E-18
2.0E+03	6.21E+07	1.18E-18
3.0E+03	7.61E+07	1.07E-18
5.0E+03	9.82E+07	9.00E-19
8.0E+03	1.24E+08	7.67E-19
1.0E+04	1.39E+08	7.03E-19
2.0E+04	1.96E+08	5.17E-19
4.0E+04	2.78E+08	3.52E-19
7.0E+04	3.68E+08	2.29E-19
1.0E+05	4.39E+08	1.46E-19
1.5E+05	5.38E+08	4.86E-20
2.0E+05	6.21E+08	1.60E-20
2.5E+05	6.94E+08	6.01E-21

References: 163, 203

Accuracy: Unknown

Notes: (1) Data between 1.2 - $9x10^3$ eV/amu were never published in a referred journal.
(2) Cross sections between $9x10^3$ and $1x10^5$ eV/amu were obtained by interpolation between the low and high energy data.
(3) For energies less than $1x10^5$ eV/amu the cross sections measured by Hippler et al (ref. 203) diverge from the data presented here.

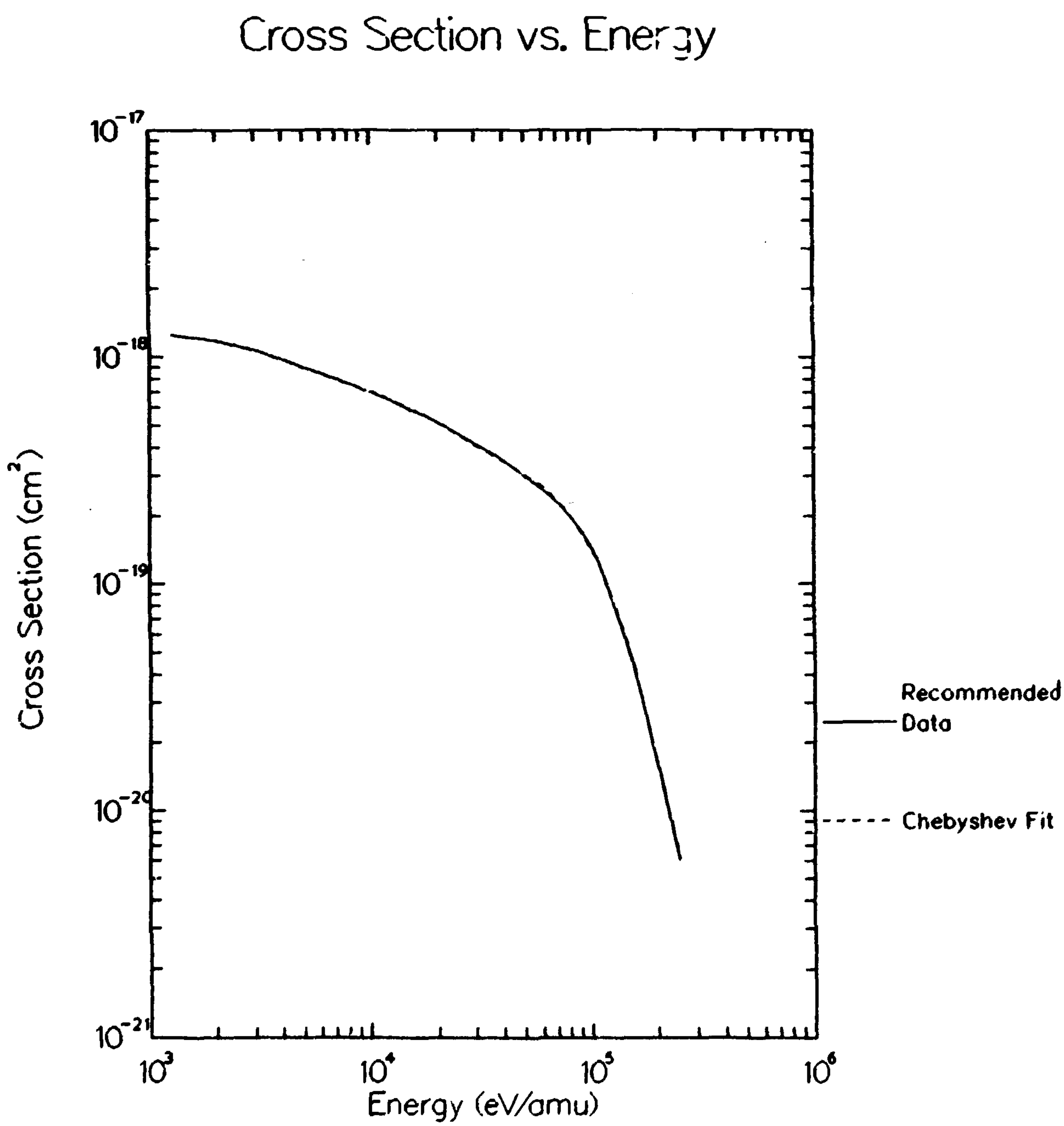
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.3E+03 eV/amu, E_{max} = 2.5E+05 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-85.5425	-2.19593	-.936988	-.450041	-.224752	-.0551700	.0123849	.0330118	.0293219

The fit represents the above cross sections with an rms deviation of 1.0%.
The maximum deviation is 2.0% at 7.0E+04 eV/amu.
See appendix for Chebyshev fit details.

$He^{+} + He \rightarrow He(2^{1}P) + He^{+}$



Electron Capture Rate Coefficients for
$He^{+} + He \rightarrow He(2^{1}P) + He^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

He^{+} Temp. (eV)	Equal Temp.	He Temp. (eV) 500.	1000.	2000.	4000.	7000.	10000.	20000.
4.0E+02	3.80E-13	7.28E-13	4.54E-12	1.72E-11	3.90E-11	5.75E-11	6.77E-11	8.29E-11
7.0E+02	4.54E-12	2.64E-12	8.03E-12	2.11E-11	4.15E-11	5.87E-11	6.85E-11	8.32E-11
1.0E+03	1.19E-11	5.64E-12	1.19E-11	2.48E-11	4.38E-11	5.99E-11	6.92E-11	8.34E-11
2.0E+03	3.54E-11	1.85E-11	2.48E-11	3.54E-11	5.03E-11	6.36E-11	7.15E-11	8.42E-11
4.0E+03	5.99E-11	3.98E-11	4.38E-11	5.03E-11	5.99E-11	6.92E-11	7.52E-11	8.56E-11
7.0E+03	7.52E-11	5.79E-11	5.99E-11	6.36E-11	6.92E-11	7.52E-11	7.95E-11	8.73E-11
1.0E+04	8.26E-11	6.80E-11	6.92E-11	7.15E-11	7.52E-11	7.95E-11	8.26E-11	8.87E-11
2.0E+04	9.16E-11	8.30E-11	8.34E-11	8.42E-11	8.56E-11	8.73E-11	8.87E-11	9.16E-11

Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 4.0E+02 eV, E_{max} = 2.0E+04 eV

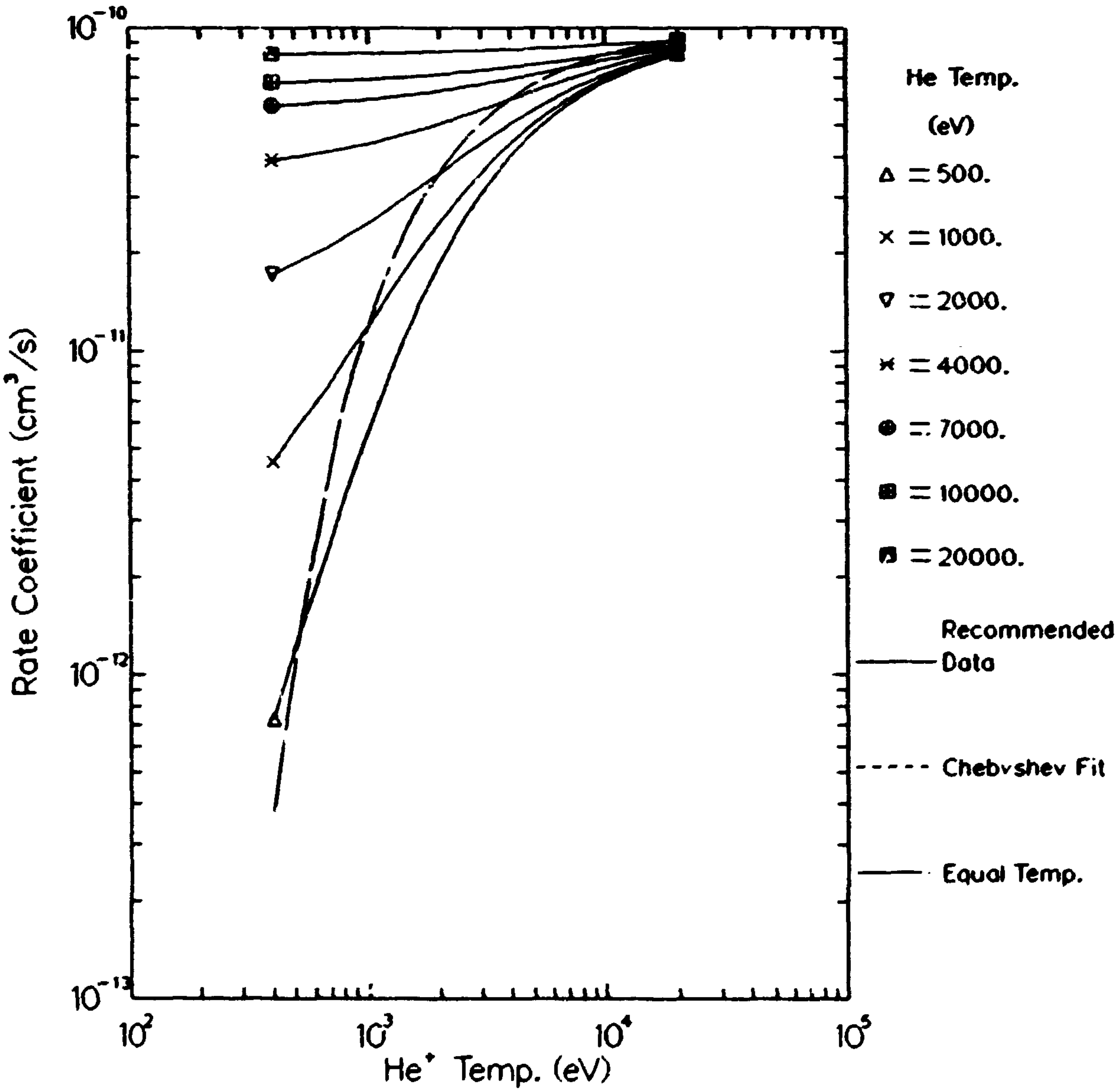
Chebyshev Fitting Parameters for Rate Coefficients

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
500.	-4.99295E+01	2.33819E+00	-6.50090E-01	4.21924E-02	3.49426E-02	-1.24395E-02	-1.11293E-04
1000.	-4.88301E+01	1.49821E+00	-2.72937E-01	-6.12913E-02	2.79783E-02	-2.24988E-03	-2.38793E-03
2000.	-4.78893E+01	8.38347E-01	-5.35952E-02	-4.83802E-02	7.58342E-03	3.24901E-03	-2.41972E-04
4000.	-4.71958E+01	4.15561E-01	2.60934E-02	-2.42784E-02	-3.22992E-03	1.67069E-03	3.02996E-04
7000.	-4.68029E+01	2.17494E-01	3.41131E-02	-8.30328E-03	-3.82190E-03	-5.16068E-05	2.23742E-04
10000.	-4.66140E+01	1.38147E-01	2.86268E-02	-2.78051E-03	-2.76127E-03	-4.58542E-04	5.63634E-05
20000.	-4.63524E+01	4.94719E-02	1.41098E-02	5.11657E-04	-9.99744E-04	-2.34546E-04	-2.76502E-04
Equal Temp.	-4.94385E+01	2.39001E+00	-1.04807E+00	3.37080E-01	-8.59497E-02	1.50447E-02	-2.44681E-03

See appendix for Chebyshev fit details.

$He^{+} + He \rightarrow He(2^1P) + He^{+}$

Maxwellian – Maxwellian



Electron Capture Rate Coefficients for
$He + He^+ \rightarrow He(2^1P) + He^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^+ Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	60000.	80000.	100000.	120000.
1.0E+00	9.76E-11	1.02E-10*	9.78E-11*	8.77E-11*	7.60E-11*	6.40E-11*	4.28E-11**
2.0E+00	9.76E-11	1.02E-10	9.78E-11*	8.77E-11*	7.60E-11*	6.40E-11*	4.28E-11**
4.0E+00	9.76E-11	1.02E-10	9.77E-11*	8.77E-11*	7.60E-11*	6.40E-11*	4.28E-11**
7.0E+00	9.76E-11	1.02E-10	9.77E-11*	8.77E-11*	7.60E-11*	6.39E-11*	4.28E-11**
1.0E+01	9.76E-11	1.01E-10	9.77E-11*	8.77E-11*	7.60E-11*	6.39E-11*	4.28E-11**
2.0E+01	9.76E-11	1.01E-10	9.77E-11*	8.77E-11*	7.60E-11*	6.38E-11*	4.28E-11**
4.0E+01	9.76E-11	1.01E-10	9.76E-11*	8.77E-11*	7.60E-11*	6.36E-11*	4.29E-11*
7.0E+01	9.75E-11	1.01E-10	9.75E-11	8.77E-11*	7.60E-11*	6.35E-11*	4.29E-11*
1.0E+02	9.75E-11	1.01E-10	9.75E-11	8.77E-11*	7.60E-11*	6.33E-11*	4.29E-11*
2.0E+02	9.75E-11	1.01E-10	9.74E-11	8.77E-11	7.60E-11*	6.30E-11*	4.29E-11*
4.0E+02	9.74E-11	1.01E-10	9.72E-11	8.77E-11	7.60E-11*	6.26E-11*	4.30E-11*
7.0E+02	9.73E-11	1.01E-10	9.70E-11	8.77E-11	7.60E-11*	6.21E-11*	4.31E-11*
1.0E+03	9.72E-11	1.01E-10	9.68E-11	8.76E-11	7.60E-11*	6.18E-11*	4.32E-11*
2.0E+03	9.70E-11	1.01E-10	9.64E-11	8.74E-11	7.58E-11*	6.10E-11*	4.34E-11*
4.0E+03	9.68E-11	1.00E-10	9.58E-11	8.68E-11	7.50E-11	5.99E-11*	4.36E-11*
7.0E+03	9.63E-11	9.96E-11	9.51E-11	8.59E-11	7.38E-11	5.88E-11*	4.36E-11*
1.0E+04	9.59E-11	9.90E-11	9.43E-11	8.50E-11	7.26E-11	5.80E-11*	4.35E-11*
2.0E+04	9.52E-11	9.71E-11	9.18E-11	8.18E-11	6.92E-11	5.56E-11*	4.27E-11*

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

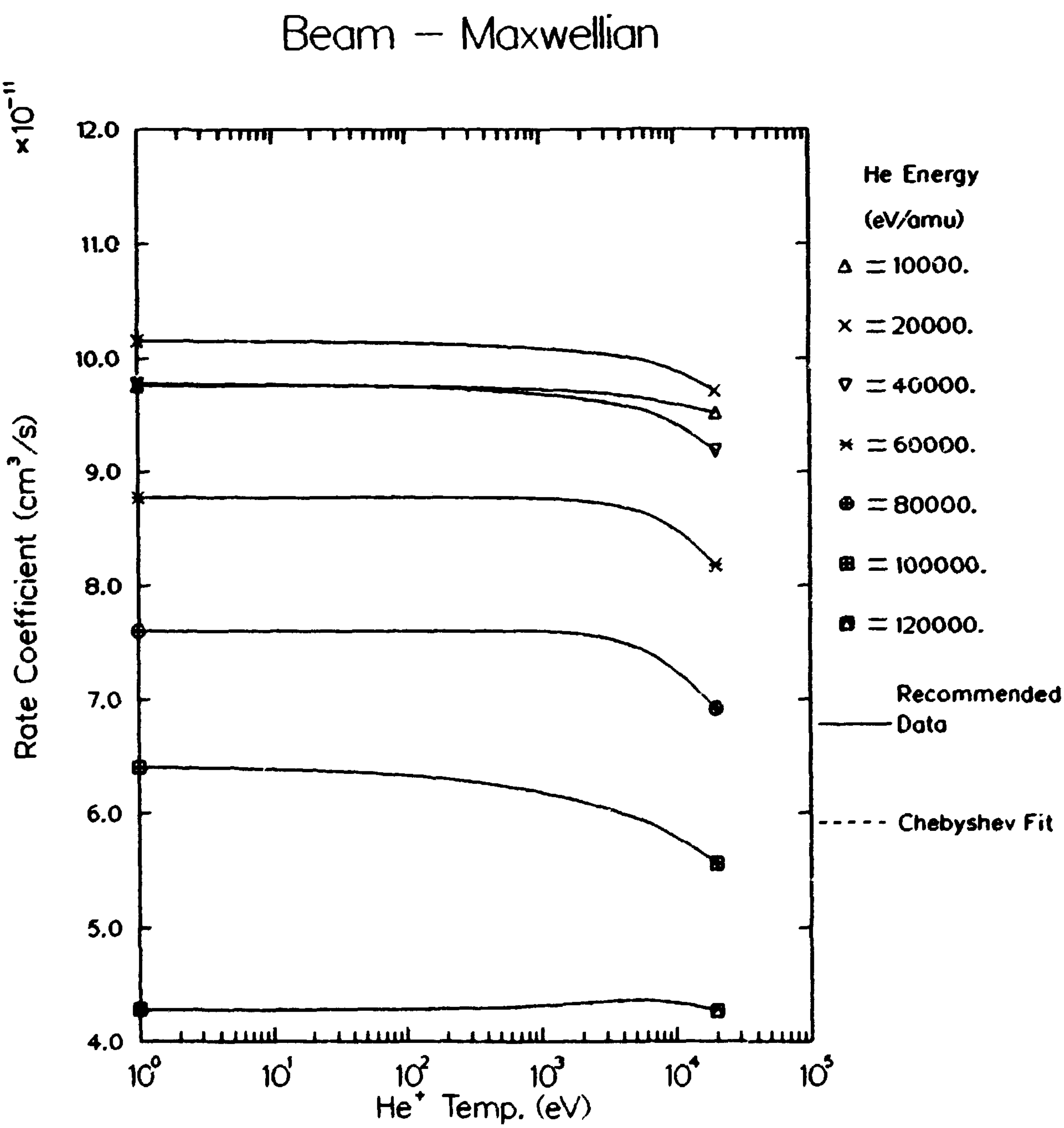
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-4.61121E+01	-1.01540E-02	-5.73295E-03	-2.50999E-03	-8.40721E-04	-1.26867E-04	1.76279E-04
20000.	-4.60412E+01	-1.63968E-02	-9.47895E-03	-4.78055E-03	-2.35744E-03	-1.14505E-03	-5.31594E-04
40000.	-4.61253E+01	-2.31383E-02	-1.33331E-02	-6.62458E-03	-3.18902E-03	-1.53689E-03	-7.59534E-04
60000.	-4.63375E+01	-2.16963E-02	-1.67017E-02	-1.07850E-02	-5.66807E-03	-2.33604E-03	-7.64767E-04
80000.	-4.66323E+01	-2.96500E-02	-2.31326E-02	-1.47960E-02	-7.40205E-03	-2.57953E-03	-2.97132E-04
100000.	-4.70209E+01	-5.97314E-02	-2.79167E-02	-9.52672E-03	-2.96002E-03	-1.17463E-03	-6.06512E-04
120000.	-4.77385E+01	5.70178E-03	-3.34664E-04	-4.37679E-03	-4.62136E-03	-2.70887E-03	-7.41640E-04

See appendix for Chebyshev fit details.

He + He$^+$ -> He(2^1P) + He$^+$



Electron Capture Cross Sections for

$He^{+} + He \rightarrow He(3^1S, 3^1P, 3^1D) + He^{+}$

(3^1S) Energy eV/amu	(3^1S) Cross Section cm^2	(3^1P) Energy eV/amu	(3^1P) Cross Section cm^2	(3^1D) Energy eV/amu	(3^1D) Cross Section cm^2
2.5E+03	2.17E-19	7.5E+02	2.34E-19	2.0E+03	5.30E-19
3.0E+03	2.02E-19	1.0E+03	2.53E-19	2.5E+03	4.91E-19
3.8E+03	1.94E-19	1.5E+03	3.57E-19	3.0E+03	[illegible].42E-19
5.0E+03	2.13E-19	2.0E+03	6.16E-19	3.5E+03	6.64E-19
7.0E+03	2.79E-19	2.5E+03	7.91E-19	4.0E+03	7.76E-19
8.0E+03	3.30E-19	2.6E+03	7.96E-19	5.0E+03	8.93E-19
1.0E+04	4.93E-19	3.0E+03	7.34E-19	6.0E+03	9.23E-19
1.5E+04	8.44E-19	3.5E+03	6.28E-19	7.0E+03	9.13E-19
2.0E+04	1.13E-18	5.0E+03	5.00E-19	1.0E+04	8.17E-19
2.5E+04	1.27E-18	6.5E+03	4.72E-19	1.5E+04	6.28E-19
3.5E+04	1.38E-18	8.0E+03	5.03E-19	2.0E+04	4.69E-19
4.0E+04	1.40E-18	1.0E+04	5.97E-19	2.5E+04	3.48E-19
		1.3E+04	8.63E-19	3.0E+04	2.50E-19
		1.5E+04	1.32E-18	3.7E+04	1.41E-19
		2.0E+04	1.44E-18		
		2.2E+04	1.45E-18		
		2.5E+04	1.40E-18		
		3.0E+04	1.24E-18		
		3.5E+04	1.02E-18		
		3.8E+04	8.69E-19		

<u>References:</u> 3^1S - 204; 3^1P - 20, 204, 205, 206; 3^1D - 20, 204, 206

<u>Accuracy:</u> 40%

<u>Notes:</u> (1) The quoted accuracy is only an estimate. The disagreement between the data sets is as large as a factor of 2 or more.
(2) The cross section (σ_i) for capture into state i is determined by measuring the emission cross section (σ_{ij}) for a transition from state i to j, correcting for any branching from state i and correcting for cascading from upper states.

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

(3^1S) E_{min} = 2.5E+03 eV/amu, E_{max} = 4.0E+04 eV/amu
(3^1P) E_{min} = 7.5E+02 eV/amu, E_{max} = 3.8E+04 eV/amu
(3^1D) E_{min} = 2.0E+03 eV/amu, E_{max} = 3.7E+04 eV/amu

<u>Chebyshev Fitting Parameters for Cross Sections</u>

	A0	A1	A2	A3	A4	A5	A6	A7	A8
(3^1S)	-84.2567	1.14450	.0774864	-.248351	.00546389	.0475617	-6.68831E-04	-.0125101	.00445413
(3^1P)	-83.9443	.784951	-.124752	.0431388	-.173909	-.262303	.0929503	.0081808	-.0630714
(3^1D)	-84.3847	-.485772	-.595547	-.0904580	.0360540	-.0805642	.0223178	-.00673603	-.0137040

The fit represents the (3^1S) cross section with an rms deviation of 1.2%.
The maximum deviation is 1.9% at 8.0E+03 eV/amu.

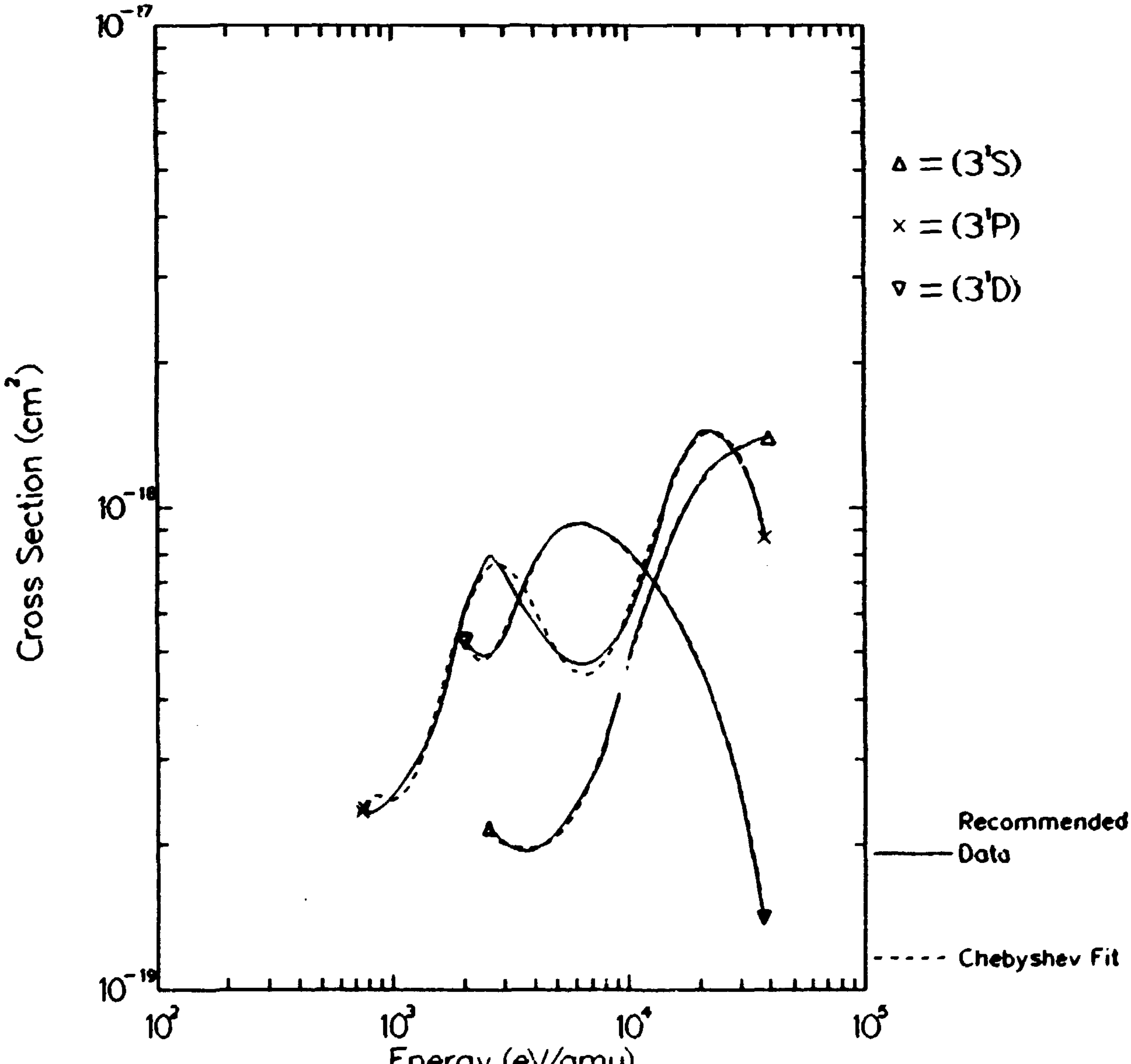
The fit represents the (3^1P) cross section with an rms deviation of 3.7%.
The maximum deviation is 9.7% at 3.5E+03 eV/amu.

The fit represents the (3^1D) cross section with an rms deviation of 1.0%.
The maximum deviation is 2.5% at 3.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$He^+ + He \rightarrow He(3^1S, 3^1P, 3^1D) + He^+$

Cross Section vs. Energy



Electron Capture Cross Sections for

$He^+ + He \rightarrow He(3^3S, 3^3P, 3^3D) + He^+$

(3^3S)

Energy eV/amu	Cross Section cm^2
5.0E+03	4.52E-19
6.0E+03	4.65E-19
7.0E+03	4.89E-19
9.0E+03	5.87E-19
1.0E+04	6.64E-19
1.5E+04	1.26E-18
2.0E+04	1.93E-18
2.5E+04	2.68E-18
3.0E+04	3.06E-18

(3^3P)

Energy eV/amu	Cross Section cm^2
2.5E+02	2.05E-19
3.6E+02	2.02E-19
4.0E+02	2.01E-19
6.0E+02	2.33E-19
8.0E+02	3.03E-19
1.0E+03	3.79E-19
1.5E+03	6.16E-19
2.0E+03	8.05E-19
2.5E+03	6.58E-19
3.0E+03	6.31E-19
4.0E+03	6.60E-19
6.0E+03	7.15E-19
8.0E+03	7.71E-19
9.9E+03	8.35E-19
1.5E+04	9.99E-19
2.0E+04	1.11E-18
3.0E+04	1.25E-18
3.7E+04	1.31E-18

(3^3D)

Energy eV/amu	Cross Section cm^2
2.5E+02	1.34E-18
3.5E+02	1.21E-18
5.0E+02	1.07E-18
7.0E+02	8.97E-19
8.0E+02	8.81E-19
9.0E+02	8.94E-19
1.0E+03	9.43E-19
1.4E+03	1.35E-18
1.7E+03	1.08E-18
2.0E+03	7.98E-19
2.5E+03	6.61E-19
2.8E+03	7.27E-19
3.4E+03	8.22E-19
3.8E+03	8.50E-19
4.5E+03	8.12E-19
5.4E+03	6.94E-19
5.9E+03	6.69E-19
6.5E+03	7.03E-19
7.1E+03	8.22E-19
7.7E+03	9.52E-19
8.5E+03	9.90E-19
1.0E+04	9.53E-19
1.2E+04	8.48E-19
1.5E+04	6.73E-19
1.7E+04	5.33E-19
2.2E+04	3.49E-19
2.9E+04	2.34E-19
3.8E+04	1.63E-19

__References:__ (3^3S) - 20, 206; (3^3P) - 20, 204, 205, 206; (3^3D) - 20, 204, 205, 206

__Accuracy:__ 40%

__Notes:__ (1) The quoted accuracy is only an estimate. The disagreement between the data sets is as large as a factor of 2 or more.

(2) The cross section (σ_i) for capture into state i is determined by measuring the emission cross section (σ_{ij}) for a transition from state i to j, correcting for any branching from state i and correcting for cascading from upper states.

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

(3^3S) E_{min} = 5.0E+03 eV/amu, E_{max} = 3.0E+04 eV/amu
(3^3P) E_{min} = 2.5E+02 eV/amu, E_{max} = 3.7E+04 eV/amu
(3^3D) E_{min} = 2.5E+02 eV/amu, E_{max} = 3.8E+04 eV/amu

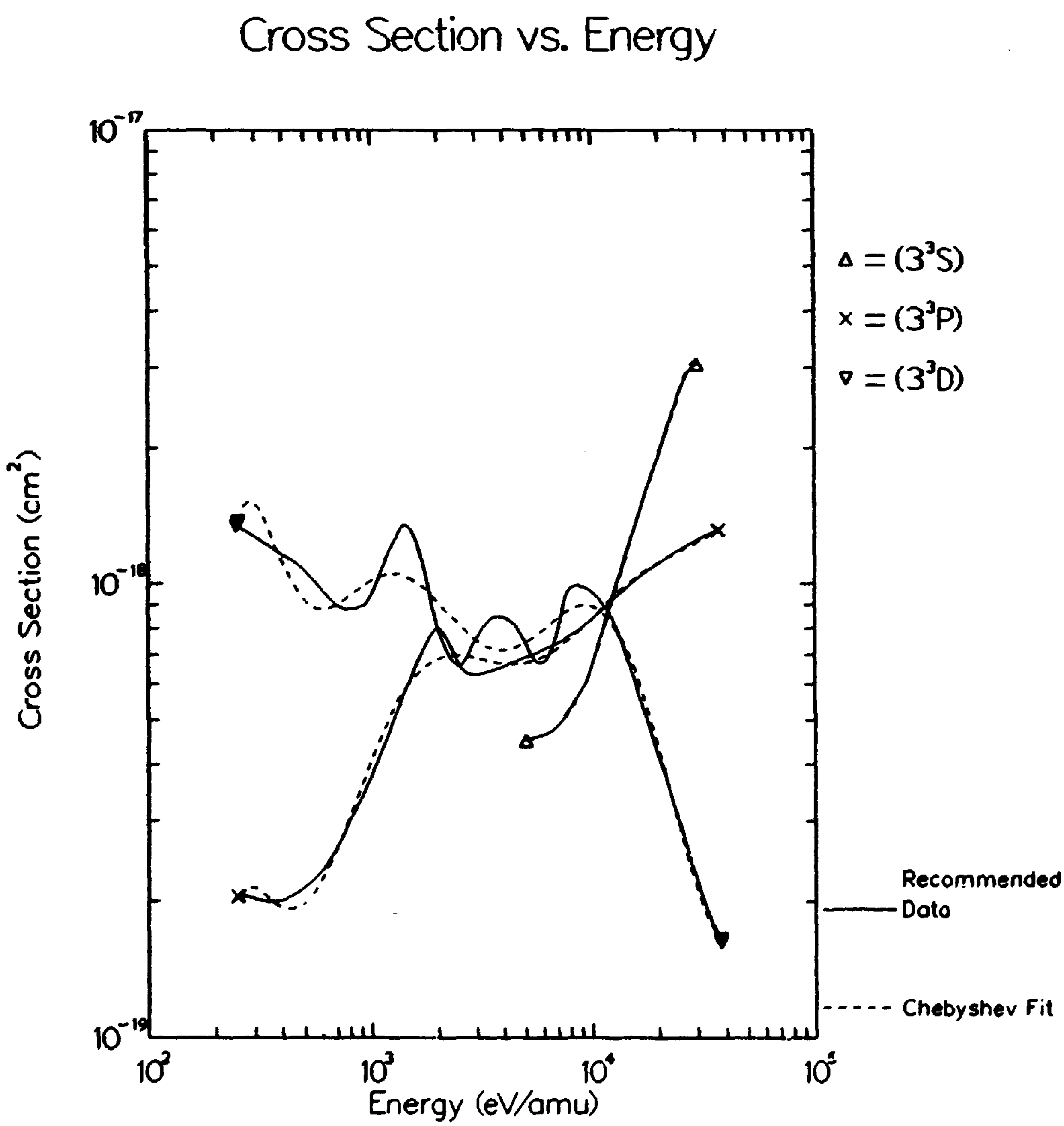
__Chebyshev Fitting Parameters for Cross Sections__

	A0	A1	A2	A3	A4	A5	A6	A7	A8
(3^3S)	-82.7952	1.05996	.146880	-.0978993	-.0162972	.00664821	-.0131980	-.0124651	-.00414755
(3^3P)	-84.1155	.979750	-.132417	.00802795	.121042	-.129354	-.0123880	.0827080	-.0303641
(3^3D)	-83.6477	-.841000	-.315720	-.312650	-.0741395	-.00902084	.0814994	.122383	-.0655599

The fit represents the (3^3S) cross section with an rms deviation of 0.0%.
The maximum deviation is 0.0% at 6.0E+03 eV/amu.
The fit represents the (3^3P) cross section with an rms deviation of 5.3%.
The maximum deviation is 9.0% at 3.0E+03 eV/amu.
The fit represents the (3^3D) cross section with an rms deviation of 11.0%.
The maximum deviation is 23.9% at 2.5E+03 eV/amu.

See appendix for Chebyshev fit details.

$He^+ + He \rightarrow He(3^3S, 3^3P, 3^3D) + He^+$



Electron Capture Cross Sections for
$He^+ + He \rightarrow He(4^1S, 4^1P, 4^1D) + He^+$

(4^1S) Energy eV/amu	(4^1S) Cross Section cm^2	(4^1P) Energy eV/amu	(4^1P) Cross Section cm^2	(4^1D) Energy eV/amu	(4^1D) Cross Section cm^2
6.2E+02	8.66E-21	1.0E+03	8.65E-20	2.5E+02	7.24E-20
7.3E+02	1.11E-20	1.1E+03	6.69E-20	3.0E+02	9.38E-20
9.4E+02	1.29E-20	1.2E+03	5.33E-20	3.5E+02	1.03E-19
1.0E+03	1.30E-20	1.3E+03	4.82E-20	4.1E+02	8.76E-20
1.2E+03	1.23E-20	1.3E+03	4.83E-20	5.0E+02	5.10E-20
1.3E+03	1.36E-20	1.4E+03	5.17E-20	6.2E+02	3.55E-20
1.4E+03	1.18E-20	1.6E+03	6.04E-20	7.2E+02	3.9[illegible]E-20
1.5E+03	1.33E-20	1.8E+03	7.45E-20	8.1E+02	[illegible].6E-20
1.6E+03	1.65E-20	2.2E+03	9.50E-20	9.1E+02	[illegible].14E-20
1.8E+03	2.32E-20	2.6E+03	1.16E-19	1.0E+03	7.60E-20
2.0E+03	2.87E-20	3.2E+03	1.41E-19	1.1E+03	7.06E-20
2.3E+03	3.62E-20	3.6E+03	1.61E-19	1.3E+03	7.94E-20
2.6E+03	3.87E-20	3.9E+03	1.63E-19	1.6E+03	8.07E-20
2.7E+03	3.93E-20	4.3E+03	1.61E-19	1.9E+03	8.23E-20
3.0E+03	3.83E-20	4.9E+03	1.52E-19	2.1E+03	8.65E-20
3.2E+03	3.72E-20	5.4E+03	1.52E-19	2.2E+03	1.04E-19
3.7E+03	3.62E-20	6.4E+03	1.64E-19	2.4E+03	1.16E-19
4.1E+03	3.69E-20	7.5E+03	1.86E-19	2.5E+03	1.18E-19
4.9E+03	4.02E-20	8.6E+03	2.32E-19	2.7E+03	1.10E-19
6.5E+03	5.10E-20	1.0E+04	2.90E-19	2.9E+03	8.95E-20
7.9E+03	6.19E-20	1.1E+04	3.50E-19	3.0E+03	7.13E-20
9.6E+03	7.73E-20	1.3E+04	4.29E-19	3.1E+03	6.36E-20
1.2E+04	1.00E-19	1.6E+04	5.01E-19	3.3E+03	6.24E-20
1.4E+04	1.39E-19	1.8E+04	5.80E-19	3.5E+03	6.40E-20
1.6E+04	1.74E-19	2.0E+04	6.08E-19	3.7E+03	7.01E-20
1.9E+04	2.02E-19	2.4E+04	5.83E-19	3.9E+03	8.14E-20
2.2E+04	2.20E-19	2.8E+04	5.20E-19	4.1E+03	9.54E-20
2.8E+04	2.29E-19	3.2E+04	4.40E-19	4.4E+03	1.10E-19
3.3E+04	2.25E-19	3.7E+04	3.78E-19	4.8E+03	1.42E-19
3.8E+04	2.14E-19	3.9E+04	3.53E-19	5.6E+03	1.71E-19
				7.0E+03	2.11E-19
				8.3E+03	2.42E-19
				9.7E+03	2.75E-19
				1.2E+04	3.12E-19
				2.0E+04	2.73E-19
				3.0E+04	8.42E-20
				3.8E+04	4.33E-20

__References:__ (4^1S) - 20, 204, 205, 206, 207; (4^1P) - 20, 166, 204, 205; (4^1D) - 28, 166, 204, 205, 206

__Accuracy:__ 40%

__Notes:__ (1) The quoted accuracy is only an estimate. The disagreement between the data sets is as large as a factor of 2 or more.

(2) The cross section (σ_i) for capture into state i is determined by measuring the emission cross section (σ_{ij}) for a transition from state i to j, correcting for any branching from state i and correcting for cascading from upper states.

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

(4^1S) E_{min} = 6.2E+02 eV/amu, E_{max} = 3.8E+04 eV/amu
(4^1P) E_{min} = 1.0E+03 eV/amu, E_{max} = 3.9E+04 eV/amu
(4^1D) E_{min} = 2.5E+02 eV/amu, E_{max} = 3.8E+04 eV/amu

__Chebyshev Fitting Parameters for Cross Sections__

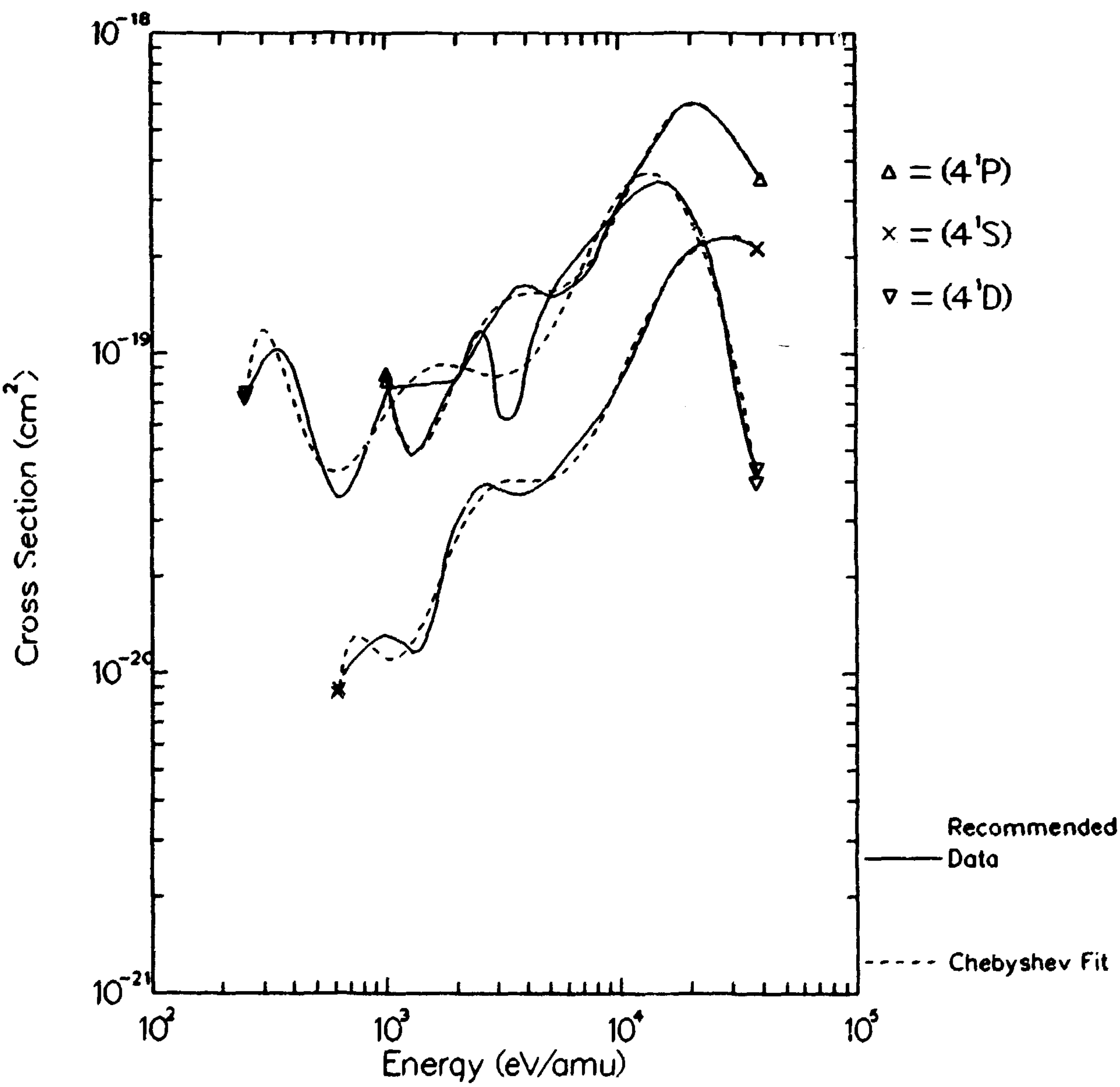
	A0	A1	A2	A3	A4	A5	A6	A7	A8
(4^1S)	-88.9247	1.69591	.0188804	-.0955575	-.0823400	-.127347	-.00167808	.149767	-.0939805
(4^1P)	-86.2453	1.12538	-.147764	-.263207	-.0637178	-.168724	.168441	.00791441	-.0240953
(4^1D)	-87.4670	.304065	-.224271	-.683543	-.287424	-.118320	-.0304248	.229919	-.141272

The fit represents the (4^1S) cross section with an rms deviation of 8.5%.
The maximum deviation is 17.4% at 7.3E+02 eV/amu.
The fit represents the (4^1P) cross section with an rms deviation of 3.5%.
The maximum deviation is 7.1% at 2.6E+03 eV/amu.
The fit represents the (4^1D) cross section with an rms deviation of 16.5%.
The maximum deviation is 37.8% at 3.3E+03 eV/amu.

See appendix for Chebyshev fit details.

$He^+ + He \rightarrow He(4^1S, 4^1P, 4^1D) + He^+$

Cross Section vs. Energy



Electron Capture Cross Sections for
$He^+ + He \rightarrow He(4^3S, 4^3P, 4^3D) + He^+$

(4^3S) Energy eV/amu	(4^3S) Cross Section cm^2	(4^3P) Energy eV/amu	(4^3P) Cross Section cm^2	(4^3D) Energy eV/amu	(4^3D) Cross Section cm^2
3.7E+02	3.99E-20	2.5E+02	3.05E-20	2.5E+02	2.84E-19
4.0E+02	3.25E-20	3.0E+02	2.38E-20	3.0E+02	3.39E-19
5.0E+02	2.09E-20	4.0E+02	1.78E-20	3.5E+02	3.62E-19
6.0E+02	2.12E-20	5.0E+02	1.62E-20	3.8E+02	3.56E-19
7.0E+02	3.06E-20	5.3E+02	1.64E-20	4.2E+02	3.26E-19
7.7E+02	3.58E-20	5.6E+02	1.95E-20	4.9E+02	2.51E-19
8.6E+02	3.44E-20	5.7E+02	3.00E-20	5.7E+02	2.06E-19
9.7E+02	3.17E-20	6.3E+02	4.53E-20	6.8E+02	1.76E-19
1.1E+03	3.88E-20	6.7E+02	3.97E-20	7.7E+02	1.[illegible]6E-19
1.3E+03	3.30E-20	7.5E+02	3.37E-20	8.1E+02	1.71E-19
1.5E+03	4.12E-20	8.3E+02	2.95E-20	8.9E+02	1.97E-19
1.7E+03	4.94E-20	9.2E+02	2.72E-20	9.9E+02	2.33E-19
2.0E+03	6.01E-20	1.0E+03	2.64E-20	1.1E+03	2.68E-19
2.4E+03	6.91E-20	1.1E+03	2.85E-20	1.2E+03	2.89E-19
2.6E+03	7.00E-20	1.4E+03	3.84E-20	1.3E+03	2.89E-19
3.0E+03	6.90E-20	1.7E+03	4.83E-20	1.5E+03	2.64E-19
3.6E+03	6.54E-20	2.0E+03	6.20E-20	1.7E+03	2.26E-19
4.1E+03	6.71E-20	2.3E+03	8.50E-20	2.0E+03	1.85E-19
5.5E+03	7.97E-20	2.6E+03	9.79E-20	2.4E+03	1.50E-19
7.6E+03	1.09E-19	3.0E+03	1.02E-19	2.6E+03	1.35E-19
9.7E+03	1.48E-19	3.5E+03	9.51E-20	2.9E+03	1.21E-19
1.2E+04	1.96E-19	4.0E+03	8.49E-20	3.2E+03	1.20E-19
1.5E+04	2.73E-19	4.7E+03	7.84E-20	3.4E+03	1.23E-19
1.7E+04	3.88E-19	4.8E+03	7.76E-20	3.8E+03	1.37E-19
2.1E+04	5.52E-19	5.2E+03	8.09E-20	4.4E+03	1.60E-19
2.6E+04	7.13E-19	6.3E+03	9.53E-20	5.1E+03	1.91E-19
3.0E+04	8.28E-19	8.0E+03	1.28E-19	6.1E+03	2.30E-19
3.4E+04	8.61E-19	1.4E+04	1.88E-19	7.3E+03	2.77E-19
3.7E+04	8.65E-19	2.0E+04	2.47E-19	8.4E+03	3.08E-19
		2.7E+04	3.26E-19	9.8E+03	3.20E-19
		3.3E+04	3.87E-19	1.1E+04	3.24E-19
		3.8E+04	4.07E-19	1.3E+04	2.96E-19
				1.4E+04	2.63E-19
				1.6E+04	2.29E-19
				2.0E+04	1.70E-19
				2.5E+04	1.31E-19
				3.0E+04	1.07E-19
				3.4E+04	8.10E-20
				3.8E+04	6.62E-20

<u>References:</u> (4^3S) - 20, 166, 204, 205, 206, 207; (4^3P) - 20, 166, 204, 205, 207; (4^3D) - 20, 166, 204, 205, 206, 207

<u>Accuracy:</u> 40%

<u>Notes:</u> (1) The quoted accuracy is only an estimate. The disagreement between the data sets is as large as a factor of 2 or more.

(2) The cross section (σ_i) for capture into state i is determined by measuring the emission cross section (σ_{ij}) for a transition from state i to j, correcting for any branching from state i and correcting for cascading from upper states.

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

(4^3S) E_{min} = 3.7E+02 eV/amu, E_{max} = 3.7E+04 eV/amu
(4^3P) E_{min} = 2.5E+02 eV/amu, E_{max} = 3.7E+04 eV/amu
(4^3D) E_{min} = 2.5E+02 eV/amu, E_{max} = 3.8E+04 eV/amu

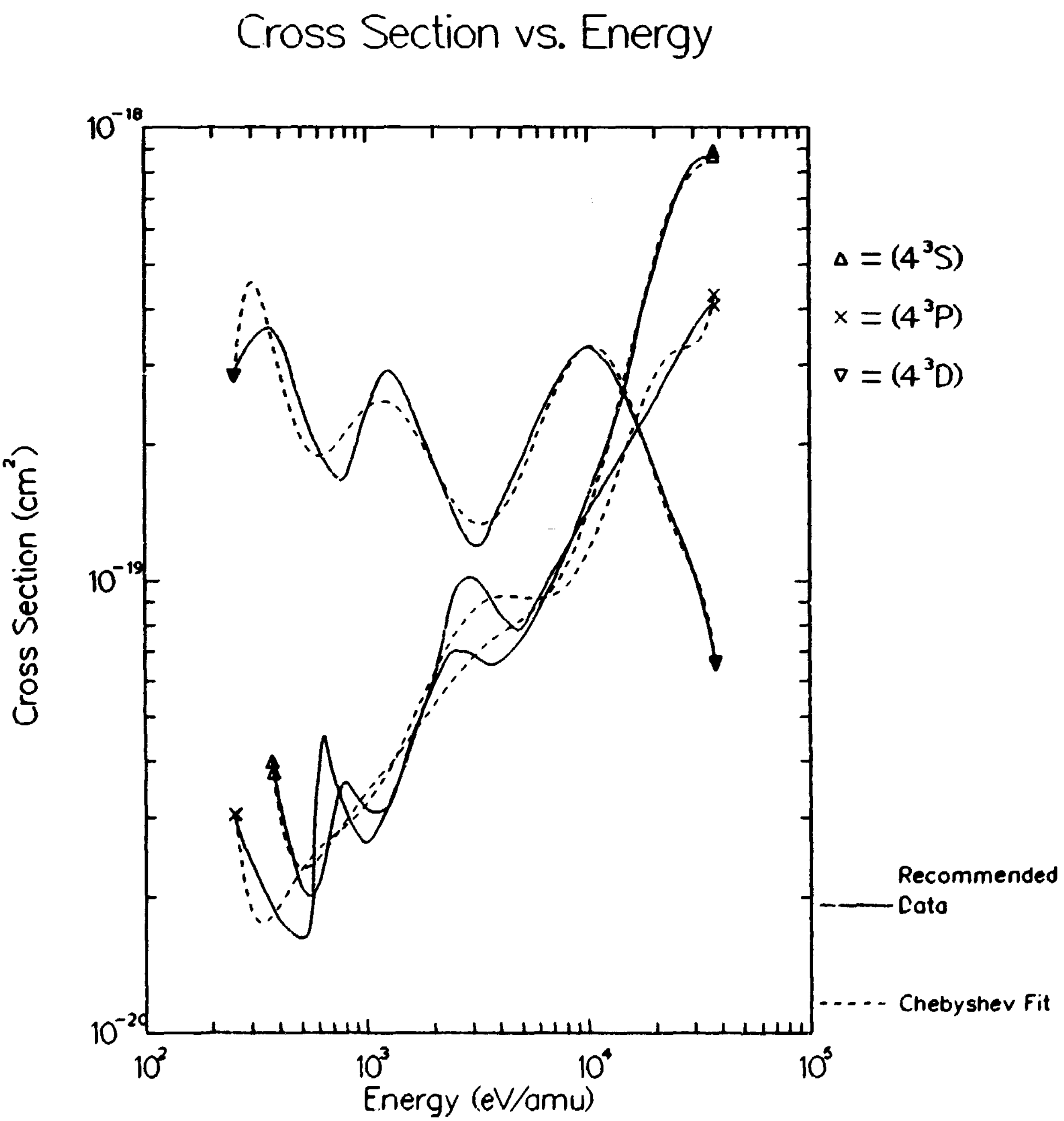
<u>Chebyshev Fitting Parameters for Cross Sections</u>

	A0	A1	A2	A3	A4	A5	A6	A7	A8
(4^3S)	-87.3205	1.78746	.468525	-.0126958	.0197677	-.212447	6.16402E-04	-.0153550	.0609384
(4^3P)	-87.9948	1.50655	.179990	-.0510960	.136680	-.148566	-.0170060	-.0293030	.130037
(4^3D)	-86.1432	-.506204	-.0953983	-.353322	-.207541	.0157713	.0723366	.167609	-.197508

The fit represents the (4^3S) cross section with an rms deviation of 9.9%.
The maximum deviation is 20.9% at 1.3E+03 eV/amu.
The fit represents the (4^3P) cross section with an rms deviation of 19.8%.
The maximum deviation is 45.5% at 5.3E+02 eV/amu.
The fit represents the (4^3D) cross section with an rms deviation of 11.3%.
The maximum deviation is 34.8% at 3.0E+02 eV/amu.

See appendix for Chebyshev fit details.

$He^{+} + He \rightarrow He(4\,^3S, 4\,^3P, 4\,^3D) + He^{+}$



Line Emission Cross Sections of Electron Capture Collisions for

$Be^{+} + Li \rightarrow Be(58.4,53.7) + Li^{+}$

(58.4 nm)

Energy eV/amu	Cross Section cm^2
5.0E+02	1.54E-16
1.0E+03	2.45E-16
1.3E+03	2.63E-16
1.5E+03	2.68E-16
2.0E+03	2.87E-16
2.5E+03	3.31E-16
3.0E+03	4.38E-16
3.5E+03	5.02E-16
4.0E+03	5.21E-16
4.5E+03	5.38E-16
5.0E+03	5.53E-16

(53.7 nm)

Energy eV/amu	Cross Section cm^2
5.0E+02	1.29E-18
8.4E+02	4.50E-18
1.0E+03	6.81E-18
1.5E+03	1.05E-17
2.0E+03	1.47E-17
2.5E+03	2.06E-17
3.0E+03	2.93E-17
3.5E+03	3.98E-17
4.0E+03	4.53E-17
4.5E+03	4.77E-17
5.0E+03	4.80E-17

References: 267

Accuracy: Unknown

Note: (1) The 3p $^1P^0$ - $1s^2$ ^1S transition gives rise to the 53.7 nm line with the 58.4 line radiation coming from the 2p $^1P^0$ - $1s^2$ ^1S transition.

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

(58.4 nm) E_{min} = 5.0E+02 eV/amu, E_{max} = 5.0E+03 eV/amu
(53.7 nm) E_{min} = 5.0E+02 eV/amu, E_{max} = 5.0E+03 eV/amu

Chebyshev Fitting Parameters for Cross Sections

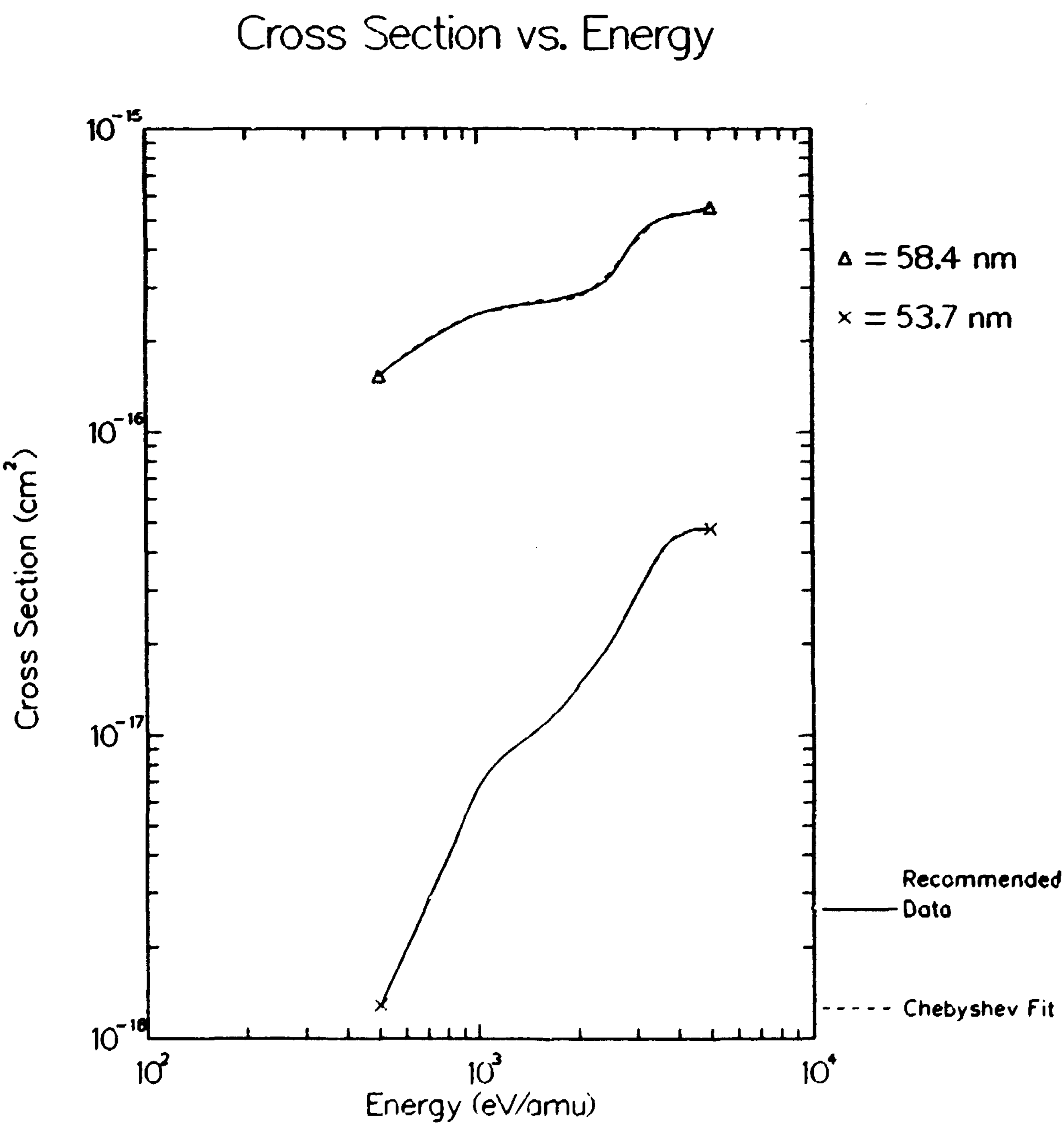
	A0	A1	A2	A3	A4	A5	A6	A7	A8
(58.4 nm)	-70.6362	-.107414	.390900	.106996	-.435807	.414268	-.355868	.226467	-.0503910
(53.7 nm)	-78.5786	2.06788	-.344623	.0776140	.0263737	-.246781	.172594	-.0896915	.0520900

The fit represents the 58.4 nm cross section with an rms deviation of 1.3%.
The maximum deviation is 2.6% at 2.5E+03 eV/amu.

The fit represents the 53.7 nm cross section with an rms deviation of 0.6%.
The maximum deviation is 1.4% at 4.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$He^{+} + Li \rightarrow He(58.4, 53.7) + Li^{+}$



Electron Capture Cross Sections for
$He^{2+} + H \rightarrow He^{+}(2s) + H^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.3E+01	6.66E+06	1.01E-23
4.0E+01	8.79E+06	1.93E-22
7.0E+01	1.16E+07	2.96E-21
1.0E+02	1.39E+07	1.64E-20
2.0E+02	1.96E+07	5.15E-19
4.0E+02	2.78E+07	5.71E-18
7.0E+02	3.68E+07	2.19E-17
1.0E+03	4.39E+07	3.92E-17
2.0E+03	6.21E+07	9.06E-17
4.0E+03	8.79E+07	1.35E-16
7.0E+03	1.16E+08	1.57E-16
1.0E+04	1.39E+08	1.63E-16
2.0E+04	1.96E+08	1.40E-16
4.0E+04	2.78E+08	6.73E-17
7.0E+04	3.68E+08	1.95E-17
1.0E+05	4.39E+08	7.15E-18
2.0E+05	6.21E+08	6.07E-19
4.0E+05	8.78E+08	3.70E-20
7.0E+05	1.16E+09	3.23E-21
1.0E+06	1.39E+09	6.01E-22
2.0E+06	1.96E+09	1.56E-23
2.5E+06	2.19E+09	4.77E-24

References: 21, 24, 25, 56, 57, 168, 169, 170, 171, 172, 173

Accuracy: $E < 1.5\times10^3$ eV/amu - unknown; 1.5×10^3 eV/amu $< E < 1.2\times10^5$ eV/amu - 40%; $E > 1.2\times10^5$ eV/amu - unknown

Notes: (1) Data for energies less than 1.5×10^3 eV/amu and greater than 1.2×10^5 eV/amu are theoretical data.
(2) The $He^{+}(2s)$ population is obtained by quenching in an electric field and measuring the additional 30.4 nm photons observed.

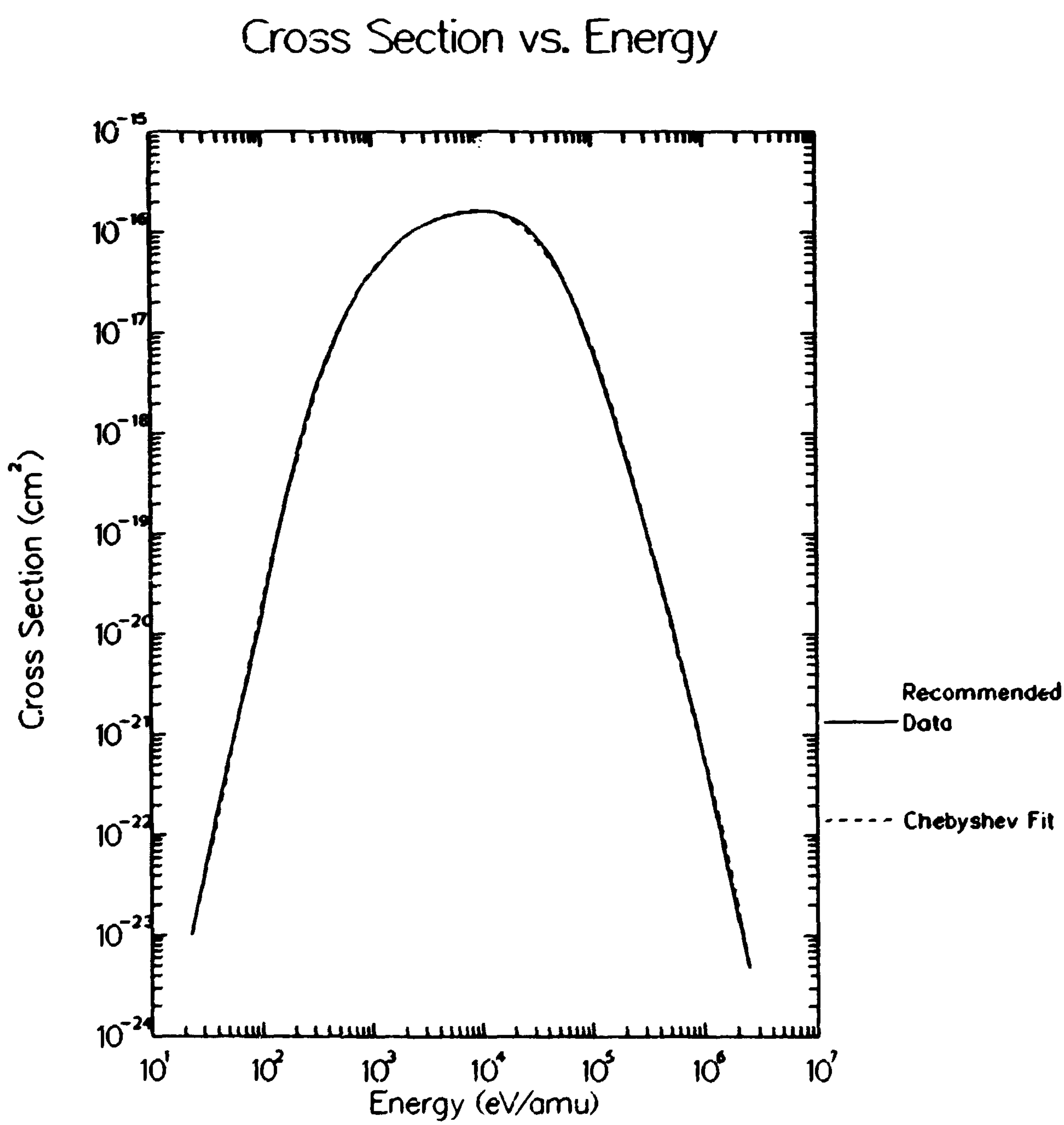
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.3E+01 eV/amu, E_{max} = 2.5E+06 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-89.4268	-.438776	-8.73454	.130314	-.0101210	.0343355	.227699	-.188121	-.130396

The fit represents the above cross sections with an rms deviation of 8.2%.
The maximum deviation is 19.6% at 2.0E+06 eV/amu.
See appendix for Chebyshev fit details.

$He^{2+} + H \rightarrow He^{+}(2s) + H^{+}$



Electron Capture Rate Coefficients for
$He^{2+} + H \rightarrow He^{+}(2s) + H^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

He^{2+} Temp. (eV)	Equal Temp.	H Temp. (eV) 10.	100.	500.	1000.	5000.	10000.	20000.
7.0E+00	2.97E-16	1.49E-15	2.81E-11	1.30E-09	3.62E-09	1.53E-08	1.93E-08	1.84E-08
1.0E+01	2.08E-15	2.08E-15	2.88E-11	1.30E-09	3.63E-09	1.53E-08	1.93E-08	1.84E-08
2.0E+01	8.24E-14	5.56E-15	3.11E-11	1.31E-09	3.64E-09	1.53E-08	1.93E-08	1.84E-08
4.0E+01	2.04E-12	2.59E-14	3.60E-11	1.33E-09	3.66E-09	1.53E-08	1.93E-08	1.84E-08
7.0E+01	1.70E-11	1.33E-13	4.42E-11	1.37E-09	3.69E-09	1.53E-08	1.93E-08	1.84E-08
1.0E+02	5.34E-11	4.24E-13	5.34E-11	1.40E-09	3.73E-09	1.53E-08	1.93E-08	1.84E-08
2.0E+02	3.27E-10	4.25E-12	9.04E-11	1.51E-09	3.84E-09	1.53E-08	1.93E-08	1.84E-08
4.0E+02	1.29E-09	3.60E-11	1.93E-10	1.74E-09	4.07E-09	1.54E-08	1.93E-08	1.84E-08
7.0E+02	3.03E-09	1.58E-10	4.04E-10	2.09E-09	4.41E-09	1.55E-08	1.93E-08	1.84E-08
1.0E+03	4.75E-09	3.57E-10	6.67E-10	2.44E-09	4.75E-09	1.56E-08	1.94E-08	1.84E-08
2.0E+03	9.49E-09	1.33E-09	1.74E-09	3.61E-09	5.81E-09	1.60E-08	1.94E-08	1.83E-08
4.0E+03	1.53E-08	3.66E-09	4.07E-09	5.81E-09	7.77E-09	1.66E-08	1.95E-08	1.82E-08
7.0E+03	1.88E-08	6.87E-09	7.21E-09	8.66E-09	1.03E-08	1.74E-08	1.96E-08	1.80E-08
1.0E+04	1.96E-08	9.52E-09	9.80E-09	1.10E-08	1.23E-08	1.81E-08	1.96E-08	1.78E-08
2.0E+04	1.71E-08	1.53E-08	1.54E-08	1.60E-08	1.66E-08	1.93E-08	1.95E-08	1.71E-08

Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 7.0E+00 eV, E_{max} = 2.0E+04 eV

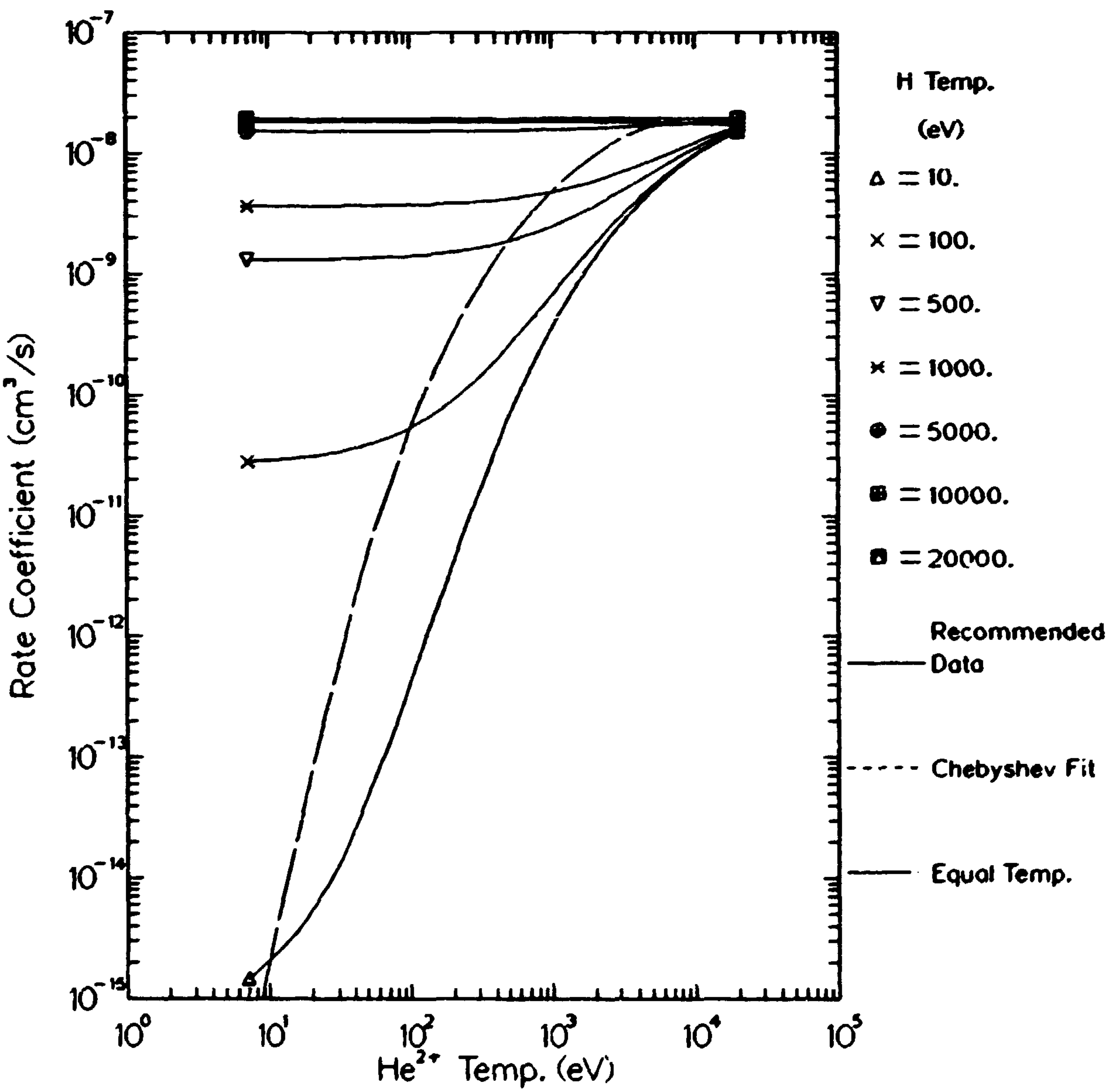
Chebyshev Fitting Parameters for Rate Coefficients

H Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
10.	-5.09308E+01	8.87617E+00	-8.39518E-01	-8.53899E-01	3.05164E-01	4.68396E-02	-6.90001E-02
100.	-4.33040E+01	3.45156E+00	6.25707E-01	-3.52271E-01	-1.41060E-01	4.76365E-02	2.50861E-02
500.	-3.92464E+01	1.26410E+00	4.89137E-01	2.19874E-02	-7.43310E-02	-3.13817E-02	1.62905E-03
1000.	-3.79446E+01	7.26279E-01	3.33593E-01	6.06574E-02	-2.84279E-02	-2.45434E-02	-6.72865E-03
5000.	-3.58707E+01	1.02283E-01	5.59105E-02	1.82827E-02	7.91325E-04	-3.18886E-03	-2.27033E-03
10000.	-3.55175E+01	7.32263E-03	2.24624E-03	-1.32249E-03	-2.19045E-03	-1.61111E-03	-8.21561E-04
20000.	-3.56488E+01	-2.68120E-02	-1.78967E-02	-9.56011E-03	-4.19249E-03	-1.52887E-03	-4.56494E-04
Equal Temp.	-4.73886E+01	8.61752E+00	-3.14861E+00	4.07425E-01	9.02464E-03	-8.82451E-02	3.10401E-02

See appendix for Chebyshev fit details.

$He^{2+} + H \rightarrow He^{+}(2s) + H^{+}$

Maxwellian – Maxwellian



Electron Capture Rate Coefficients for
$H + Be^{2+} \rightarrow Be^{+}(2s) + H^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

Be^{2+} Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	2.26E-08	2.75E-08	1.87E-08	7.16E-09	3.14E-09	3.77E-10	1.37E-11
2.0E+00	2.26E-08	2.74E-08	1.87E-08	7.16E-09	3.14E-09	3.77E-10	1.37E-11
4.0E+00	2.26E-08	2.74E-08	1.86E-08	7.16E-09	3.14E-09	3.77E-10	1.37E-11
7.0E+00	2.26E-08	2.74E-08	1.86E-08	7.15E-09	3.14E-09	3.77E-10	1.37E-11
1.0E+01	2.26E-08	2.74E-08	1.86E-08	7.15E-09	3.13E-09	3.77E-10	1.37E-11
2.0E+01	2.26E-08	2.73E-08	1.86E-08	7.15E-09	3.13E-09	3.77E-10	1.37E-11
4.0E+01	2.25E-08	2.72E-08	1.85E-08	7.14E-09	3.13E-09	3.76E-10	1.37E-11
7.0E+01	2.25E-08	2.71E-08	1.85E-08	7.13E-09	3.13E-09	3.76E-10	1.37E-11
1.0E+02	2.25E-08	2.70E-08	1.84E-08	7.13E-09	3.12E-09	3.76E-10	1.37E-11
2.0E+02	2.24E-08	2.69E-08	1.83E-08	7.12E-09	3.12E-09	3.76E-10	1.38E-11
4.0E+02	2.23E-08	2.66E-08	1.81E-08	7.11E-09	3.12E-09	3.76E-10	1.38E-11
7.0E+02	2.23E-08	2.63E-08	1.80E-08	7.10E-09	3.12E-09	3.77E-10	1.38E-11
1.0E+03	2.22E-08	2.61E-08	1.78E-08	7.10E-09	3.12E-09	3.78E-10	1.38E-11
2.0E+03	2.21E-08	2.55E-08	1.75E-08	7.11E-09	3.14E-09	3.81E-10	1.39E-11
4.0E+03	2.20E-08	2.47E-08	1.72E-08	7.18E-09	3.19E-09	3.87E-10	1.41E-11
7.0E+03	2.19E-08	2.38E-08	1.67E-08	7.28E-09	3.27E-09	3.99E-10	1.44E-11
1.0E+04	2.17E-08	2.30E-08	1.64E-08	7.37E-09	3.35E-09	4.11E-10	1.47E-11
2.0E+04	2.11E-08	2.09E-08	1.53E-08	7.54E-09	3.61E-09	4.58E-10	1.57E-11

Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

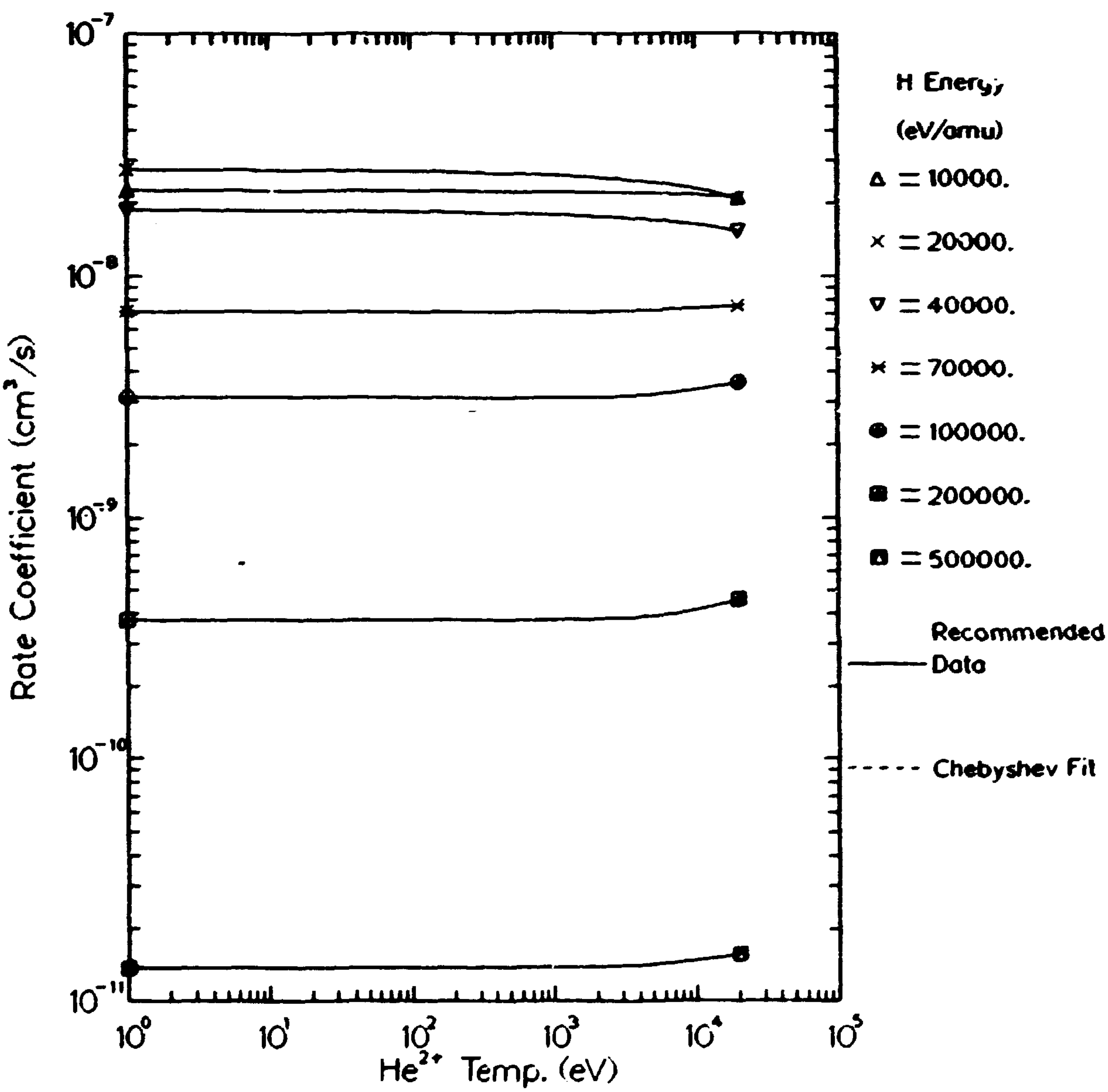
Chebyshev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-3.52453E+01	-2.72966E-02	-1.25046E-02	-5.94386E-03	-3.93360E-03	-2.52788E-03	-1.15226E-03
20000.	-3.49559E+01	-1.07234E-01	-5.74126E-02	-2.46077E-02	-9.61541E-03	-3.68199E-03	-1.33552E-03
40000.	-3.56977E+01	-8.13307E-02	-4.02505E-02	-1.59626E-02	-6.46672E-03	-3.09676E-03	-1.64827E-03
70000.	-3.74954E+01	1.58892E-02	1.66995E-02	1.04165E-02	3.58841E-03	-1.14383E-04	-1.18569E-03
100000.	-3.91164E+01	4.26359E-02	3.67186E-02	2.35687E-02	1.10156E-02	3.70448E-03	6.54932E-04
200000.	-4.33336E+01	5.99177E-02	4.72882E-02	2.99739E-02	1.60765E-02	6.77381E-03	2.80729E-03
500000.	-4.99733E+01	4.33562E-02	3.10236E-02	1.83053E-02	8.97845E-03	3.66858E-03	1.27965E-03

See appendix for Chebyshev fit details.

$H + He^{2+} \rightarrow He^{+}(2s) + H^{+}$

Beam – Maxwellian



Electron Capture Cross Sections for
$He^{2+} + H \rightarrow He^{+}(2p) + H^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
3.0E+02	2.41E+07	2.55E-17
4.0E+02	2.78E+07	4.12E-17
5.0E+02	3.11E+07	5.94E-17
7.0E+02	3.68E+07	1.04E-16
9.0E+02	4.17E+07	1.61E-16
1.0E+03	4.39E+07	1.91E-16
1.5E+03	5.38E+07	3.44E-16
2.0E+03	6.21E+07	4.71E-16
2.5E+03	6.95E+07	5.68E-16
3.0E+03	7.61E+07	6.57E-16
4.0E+03	8.79E+07	7.80E-16
5.0E+03	9.82E+07	8.63E-16
7.0E+03	1.16E+08	9.31E-16
9.0E+03	1.32E+08	9.39E-16
1.5E+04	1.70E+08	8.73E-16
2.0E+04	1.96E+08	7.12E-16
2.5E+04	2.20E+08	5.35E-16
3.0E+04	2.41E+08	3.89E-16
4.0E+04	2.78E+08	2.13E-16
5.0E+04	3.11E+08	1.19E-16
6.0E+04	3.40E+08	7.18E-17
8.0E+04	3.93E+08	3.12E-17
1.0E+05	4.39E+08	1.36E-17
1.5E+05	5.38E+08	3.32E-18
2.0E+05	6.21E+08	1.24E-18
2.5E+05	6.94E+08	6.06E-19
3.0E+05	7.61E+08	3.48E-19
4.0E+05	8.78E+08	1.81E-19
5.7E+05	1.05E+09	1.01E-19

<u>References:</u> 169, 170, 172, 173, 174, 175, 176

<u>Accuracy:</u> $1 < E < 1X10^4$ eV/amu - 20%

<u>Note:</u> (1) References 172 and 173 (Ciric et al.) are the only experimental results. Other data are theoretical data which in the energy region of overlap agree well with experiment.

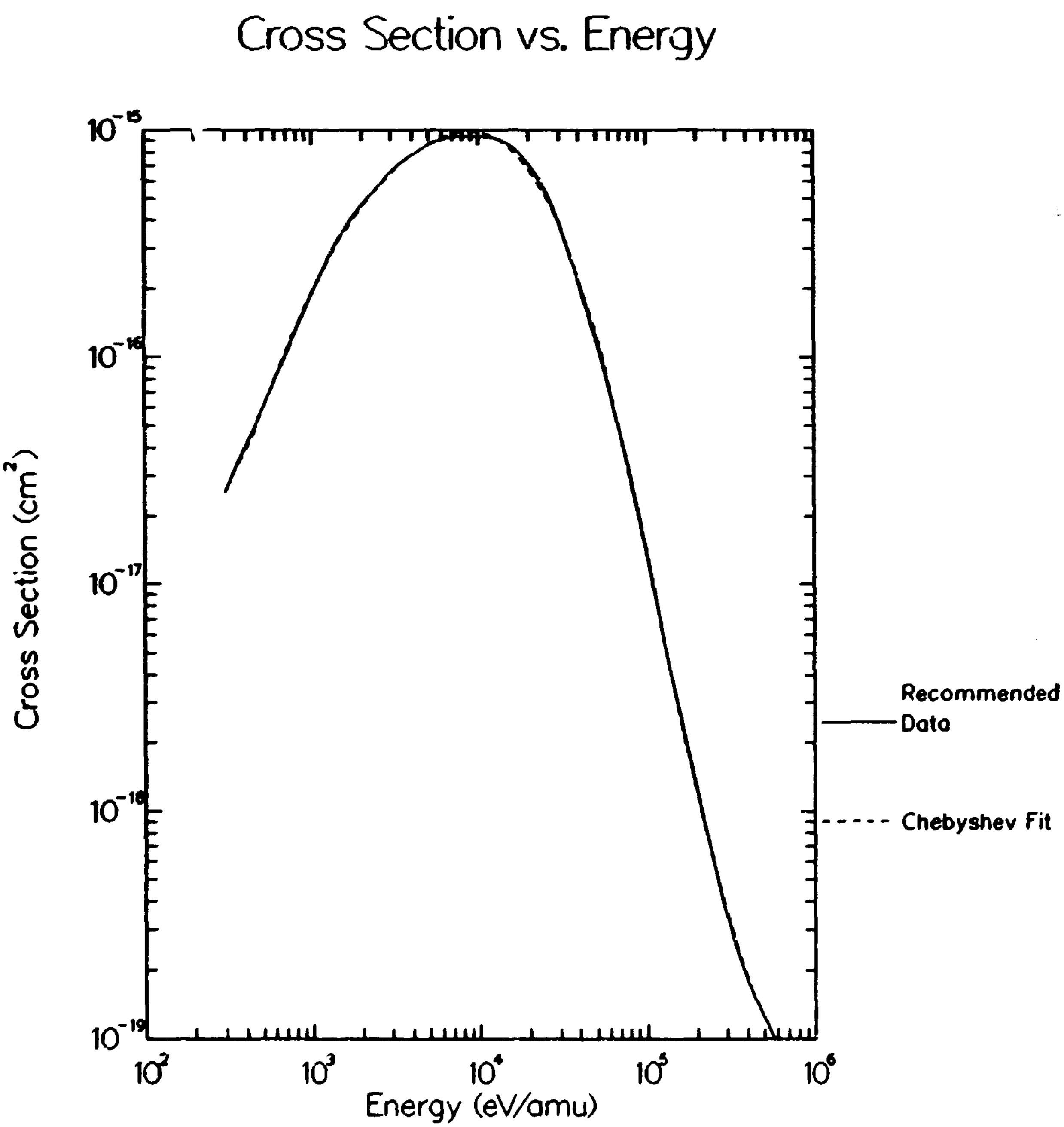
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 3.0E+02 eV/amu, E_{max} = 5.7E+05 eV/amu

<u>Chebyshev Fitting Parameters for Cross Sections</u>

A0	A1	A2	A3	A4	A5	A6	A7	A8
-76.4723	-2.98918	-3.20835	.0657861	.450590	.217258	.0371010	-.0738139	-.0123768

The fit represents the above cross sections with an rms deviation of 2.8%.
The maximum deviation is 5.3% at 9.0E+03 eV/amu.
See appendix for Chebyshev fit details.

$He^{2+} + H \rightarrow He^{+}(2p) + H^{+}$



Electron Capture Rate Coefficients for
$He^{2+} + H \rightarrow He^{+}(2p) + H^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

He^{2+} Temp. (eV)	Equal Temp.	H Temp. (eV) 100.	500.	1000.	5000.	10000.	15000.	20000.
1.0E+02	2.98E-10	2.98E-10	7.39E-09	2.06E-08	8.70E-08	1.03E-07	9.73E-08	8.77E-08
2.0E+02	1.72E-09	4.98E-10	8.00E-09	2.12E-08	8.72E-08	1.03E-07	9.72E-08	8.77E-08
4.0E+02	6.76E-09	1.03E-09	9.26E-09	2.26E-08	8.76E-08	1.03E-07	9.71E-08	8.76E-08
7.0E+02	1.65E-08	2.11E-09	1.12E-08	2.46E-08	8.82E-08	1.03E-07	9.70E-08	8.74E-08
1.0E+03	2.65E-08	3.48E-09	1.32E-08	2.65E-08	8.87E-08	1.03E-07	9.69E-08	8.73E-08
2.0E+03	5.46E-08	9.26E-09	1.99E-08	3.29E-08	9.06E-08	1.03E-07	9.64E-08	8.68E-08
4.0E+03	8.68E-08	2.26E-08	3.29E-08	4.45E-08	9.36E-08	1.02E-07	9.55E-08	8.58E-08
7.0E+03	1.02E-07	4.12E-08	4.98E-08	5.92E-08	9.71E-08	1.02E-07	9.41E-08	8.44E-08
1.0E+04	1.01E-07	5.65E-08	6.33E-08	7.08E-08	9.96E-08	1.01E-07	9.27E-08	8.30E-08
2.0E+04	7.83E-08	8.76E-08	9.06E-08	9.36E-08	1.03E-07	9.73E-08	8.78E-08	7.83E-08

Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+02 eV, E_{max} = 2.0E+04 eV

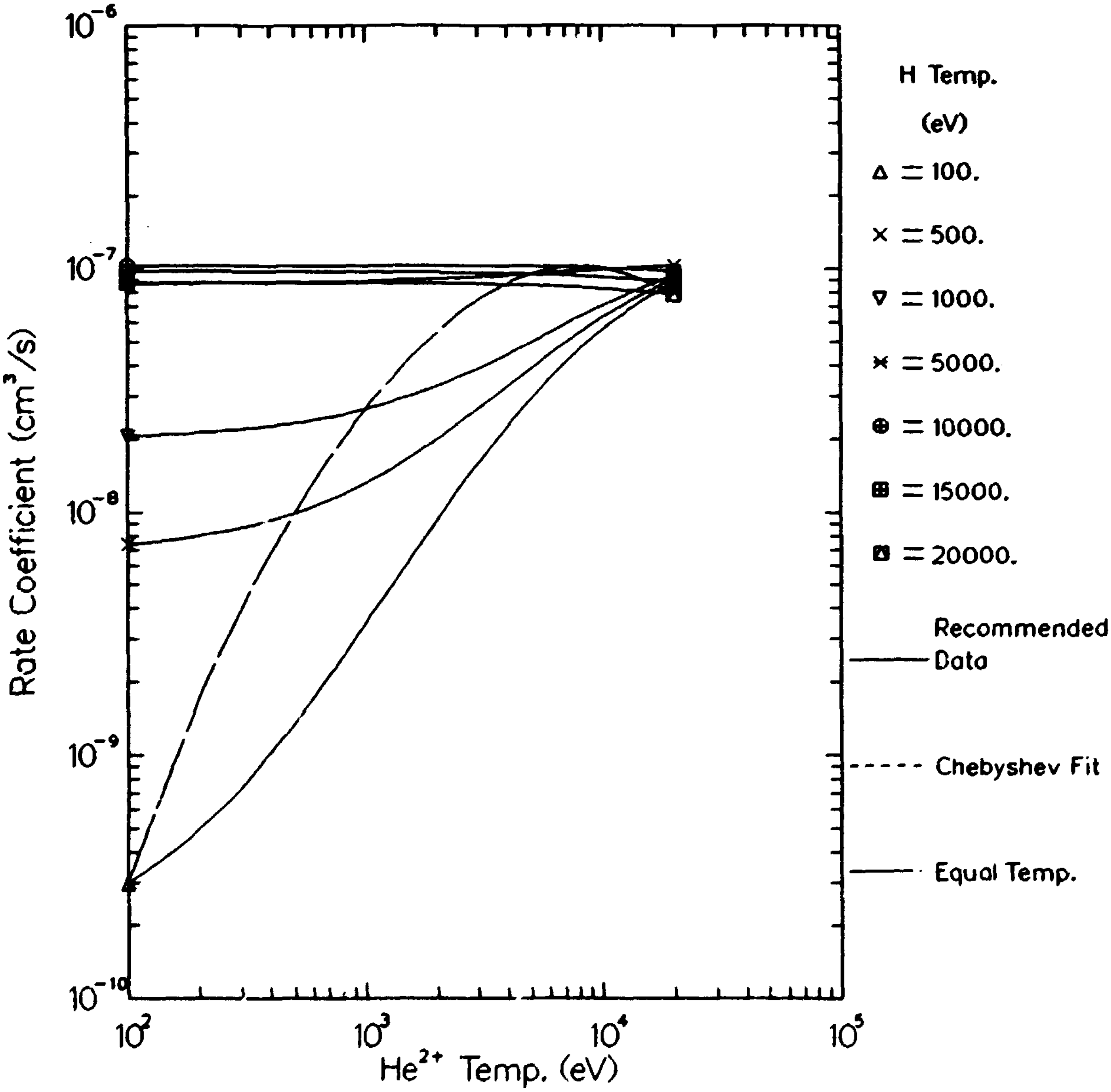
Chebyshev Fitting Parameters for Rate Coefficients

H Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
100.	-3.80891E+01	3.04269E+00	-5.03692E-02	-2.14921E-01	7.02489E-03	1.33936E-02	-3.51323E-03
500.	-3.53407E+01	1.33422E+00	2.37587E-01	-8.16883E-02	-4.11875E-02	4.97820E-04	3.60655E-03
1000.	-3.42278E+01	7.87638E-01	2.02270E-01	-2.32859E-02	-3.10588E-02	-7.16158E-03	1.05223E-03
5000.	-3.23931E+01	8.58442E-02	2.79249E-02	-7.64042E-04	-5.28180E-03	-2.73625E-03	-8.72863E-04
10000.	-3.22047E+01	-1.79017E-02	-1.27932E-02	-7.35687E-03	-3.35962E-03	-1.20009E-03	-3.44007E-04
15000.	-3.23427E+01	-4.11290E-02	-2.23406E-02	-9.19084E-03	-3.13037E-03	-9.49262E-04	-2.08801E-04
20000.	-3.25558E+01	-4.63175E-02	-2.453[illegible]8E-02	-9.65926E-03	-2.98432E-03	-7.43123E-04	-1.57791E-04
Equal Temp.	-3.61487E+01	2.77246E+00	-1.05020E+00	7.78393E-03	-2.49781E-02	4.65115E-03	2.17778E-03

See appendix for Chebyshev fit details.

$He^{2+} + H \rightarrow He^{+}(2p) + H^{+}$

Maxwellian – Maxwellian



Electron Capture Rate Coefficients for
$H + He^{2+} \rightarrow He^{+}(2p) + H^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{2+} Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	1.28E-07	1.40E-07	5.91E-08	1.69E-08	5.97E-09	7.71E-10**	1.23E-10**
2.0E+00	1.28E-07	1.40E-07	5.91E-08	1.69E-08	5.98E-09	7.70E-10**	1.23E-10**
4.0E+00	1.28E-07	1.40E-07	5.91E-08	1.69E-08	5.98E-09	7.70E-10**	1.23E-10**
7.0E+00	1.28E-07	1.39E-07	5.91E-08	1.69E-08	5.98E-09	7.71E-10**	1.23E-10**
1.0E+01	1.29E-07	1.39E-07	5.90E-08	1.69E-08	5.98E-09	7.71E-10**	1.23E-10**
2.0E+01	1.29E-07	1.39E-07	5.90E-08	1.69E-08	5.98E-09	7.71E-10**	1.23E-10**
4.0E+01	1.29E-07	1.39E-07	5.89E-08	1.69E-08	5.99E-09	7.71E-10**	1.23E-10**
7.0E+01	1.29E-07	1.39E-07	5.89E-08	1.69E-08	5.99E-09	7.72E-10*	1.23E-10**
1.0E+02	1.29E-07	1.38E-07	5.88E-08	1.69E-08	6.00E-09	7.72E-10*	1.23E-10**
2.0E+02	1.29E-07	1.38E-07	5.88E-08	1.69E-08	6.02E-09	7.73E-10*	1.23E-10**
4.0E+02	1.28E-07	1.37E-07	5.87E-08	1.70E-08	6.05E-09	7.75E-10*	1.23E-10**
7.0E+02	1.28E-07	1.36E-07	5.87E-08	1.71E-08	6.09E-09	7.77E-10*	1.23E-10**
1.0E+03	1.28E-07	1.34E-07	5.87E-08	1.71E-08	6.14E-09	7.80E-10*	1.23E-10**
2.0E+03	1.28E-07	1.31E-07	5.89E-08	1.74E-08	6.28E-09	7.88E-10*	1.23E-10**
4.0E+03	1.26E-07	1.25E-07	5.93E-08	1.78E-08	6.53E-09	8.03E-10*	1.21E-10**
7.0E+03	1.22E-07	1.18E-07	5.95E-08	1.85E-08	6.88E-09	8.27E-10*	1.18E-10**
1.0E+04	1.19E-07	1.13E-07	5.93E-08	1.92E-08	7.22E-09	8.52E-10*	1.14E-10**
2.0E+04	1.10E-07	9.85E-08	5.73E-08	2.12E-08	8.38E-09	9.47E-10*	1.06E-10**

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

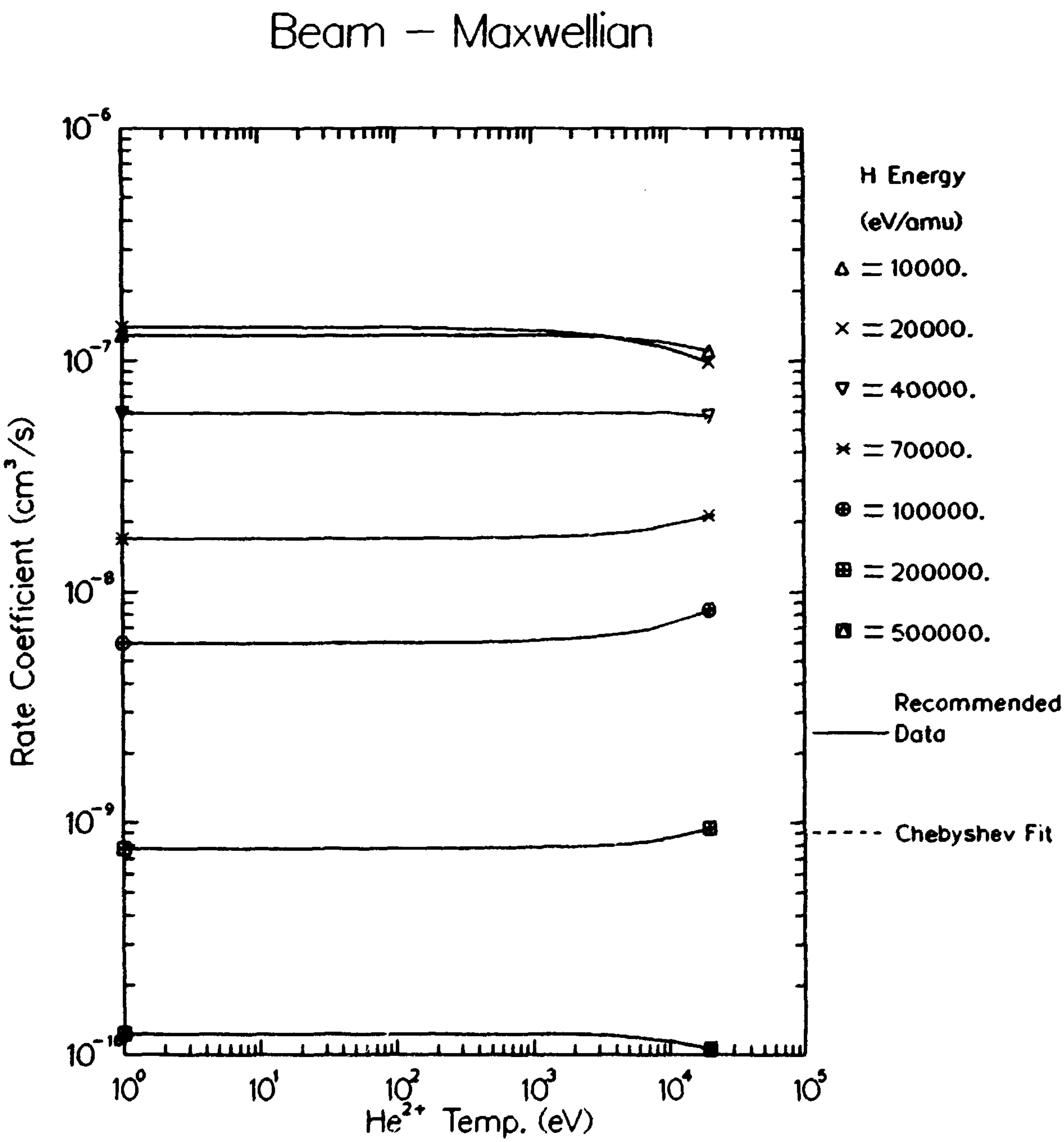
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-3.17882E+01	-4.92276E-02	-3.82539E-02	-2.43393E-02	-1.22728E-02	-4.54785E-03	-7.79239E-04
20000.	-3.17232E+01	-1.30716E-01	-8.13104E-02	-4.04778E-02	-1.57809E-02	-3.98767E-03	3.36890E-05
40000.	-3.32955E+01	-5.40047E-03	-1.99166E-03	-4.45358E-03	-6.27891E-03	-5.14199E-03	-2.92410E-03
70000.	-3.57028E+01	8.02848E-02	5.54250E-02	3.03851E-02	1.33090E-02	4.49405E-03	7.72971E-04
100000.	-3.77338E+01	1.19799E-01	7.98553E-02	4.24318E-02	1.81018E-02	6.30836E-03	2.00635E-03
200000.	-4.18916E+01	6.78830E-02	4.78977E-02	2.81571E-02	1.45668E-02	6.26534E-03	2.69138E-03
500000.	-4.56871E+01	-4.63255E-02	-3.72726E-02	-2.45372E-02	-1.26363E-02	-4.18959E-03	7.18096E-04

See appendix for Chebyshev fit details.

$H + He^{2+} \rightarrow He^{+}(2p) + H^{+}$



Line Emission Cross Sections of Electron Capture Collisions for

$He^{2+} + H \rightarrow He^{+}(Ly_{\alpha}, Ly_{\beta}, Ly_{\gamma}, H_{\alpha}) + H^{+}$

(Ly_{α})		(Ly_{β})		(Ly_{γ})		(H_{α})	
Energy eV/amu	Cross Section cm^2	Energy eV/amu	Cross Section cm^2	Energy eV/amu	Cross Section cm^2	Energy eV/amu	Cross Section cm^2
1.2E+03	2.68E-16	1.6E+03	6.37E-18	4.8E+03	2.39E-18	2.8E+03	1.99E-17
1.5E+03	3.21E-16	2.2E+03	1.30E-17	5.0E+03	2.45E-18	2.9E+03	2.03E-17
2.2E+03	4.90E-16	2.9E+03	1.93E-17	5.7E+03	2.75E-18	3.6E+03	2.36E-17
2.9E+03	6.35E-16	3.6E+03	2.18E-17	6.4E+03	3.08E-18	4.3E+03	2.73E-17
3.6E+03	7.49E-16	4.3E+03	2.32E-17	7.2E+03	3.48E-18	5.0E+03	3.17E-17
4.3E+03	8.30E-16	5.0E+03	2.39E-17	7.9E+03	3.96E-18	5.7E+03	3.70E-17
5.0E+03	8.82E-16	5.7E+03	2.47E-17	8.6E+03	4.47E-18	6.5E+03	4.22E-17
5.7E+03	9.11E-16	6.5E+03	2.54E-17	9.1E+03	4.89E-18	7.2E+03	4.70E-17
6.5E+03	9.31E-16	7.2E+03	2.64E-17	9.3E+03	5.08E-18	7.9E+03	5.03E-17
7.2E+03	9.50E-16	7.9E+03	2.75E-17	1.0E+04	5.84E-18	8.6E+03	5.24E-17
7.9E+03	9.59E-16	8.6E+03	2.87E-17			9.3E+03	5.35E-17
8.6E+03	9.73E-16	9.3E+03	3.04E-17			1.0E+04	5.40E-17
9.3E+03	9.87E-16	1.0E+04	3.24E-17				
1.0E+04	9.91E-16						

__References:__ 173

__Accuracy:__ 30%

__Notes:__ (1) Transition wavelengths are: Lyman-α - (2p->1s) 30.4 nm; Lyman-β - (3p->1s) 25.6 nm; Lyman-γ - (4p->1s) 24.3 nm; Balmer-α - (n=3->2) 164 nm.
(2) The Balmer-β emission cannot be measured since the transition has the same wave length as the Lyman-α radiation.

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

(Ly_{α}) E_{min} = 1.2E+03 eV/amu, E_{max} = 1.0E+04 eV/amu
(Ly_{β}) E_{min} = 1.6E+03 eV/amu, E_{max} = 1.0E+04 eV/amu
(Ly_{γ}) E_{min} = 4.8E+03 eV/amu, E_{max} = 1.0E+04 eV/amu
(H_{α}) E_{min} = 2.8E+03 eV/amu, E_{max} = 1.0E+04 eV/amu

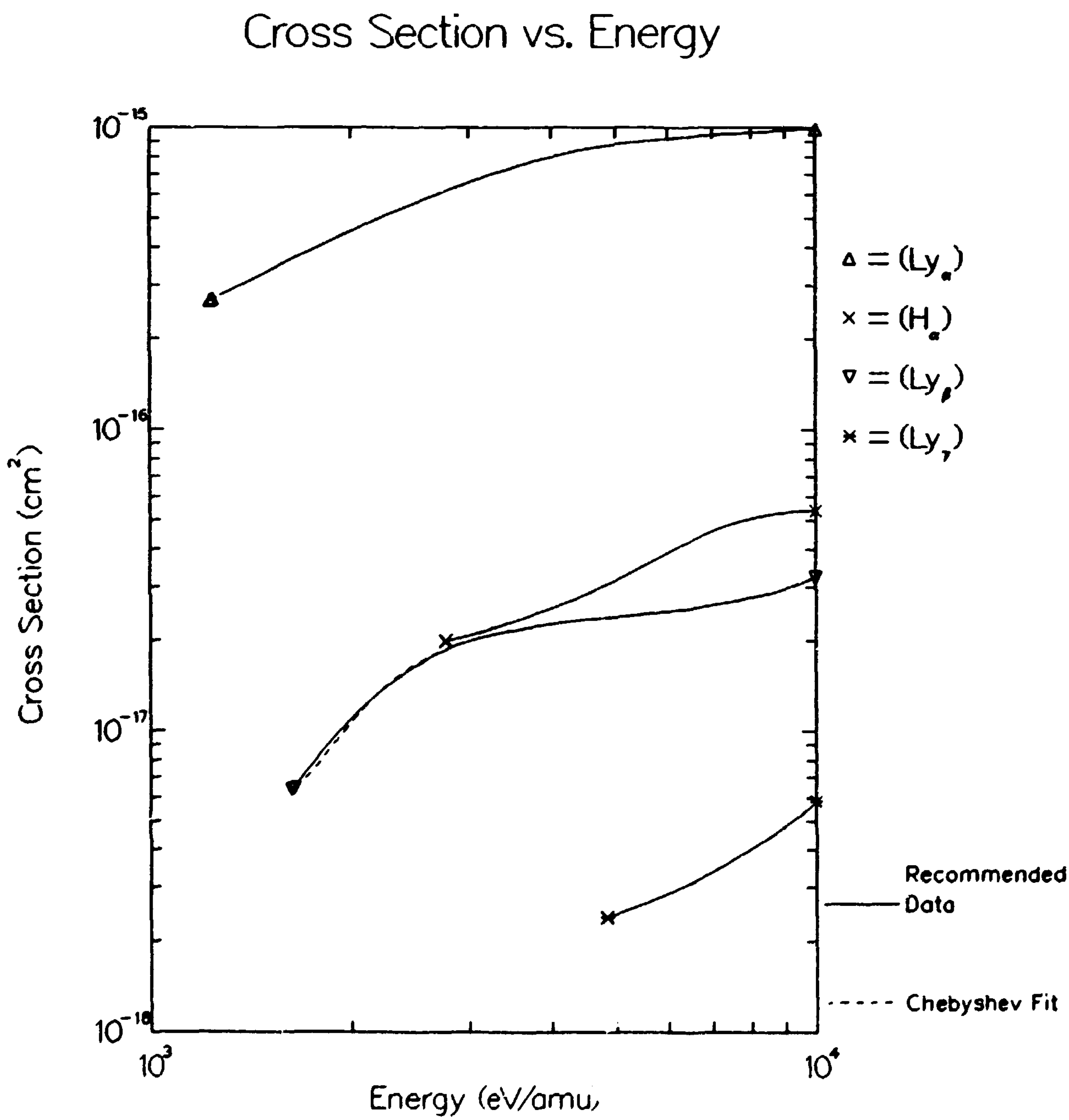
__Chebyshev Fitting Parameters for Cross Sections__

	A0	A1	A2	A3	A4	A5	A6	A7	A8
(Ly_{α})	-70.0765	.658545	-.176878	-.00575199	.0163374	.00346973	-.00221833	-.00217295	-4.61984E-04
(Ly_{β})	-77.0977	.692364	-.245444	.142376	-.00794442	-.0119412	.0163687	-.00929968	.00446139
(Ly_{γ})	-80.3639	.441485	.0512890	.00405517	9.45294E-04	.00161819	.00182462	-4.78184E-04	-6.34056E-04
(H_{α})	-75.8681	.546644	-.0142448	-.0516937	-.0137147	.00553121	.00525928	-.00130955	9.09970E-05

The fit represents the (Ly_{α}) cross section with an rms deviation of 0.1%.
The maximum deviation is 0.2% at 7.9E+03 eV/amu.
The fit represents the (Ly_{β}) cross section with an rms deviation of 0.2%.
The maximum deviation is 0.3% at 8.6E+03 eV/amu.
The fit represents the (Ly_{γ}) cross section with an rms deviation of 0.1%.
The maximum deviation is 0.2% at 8.6E+03 eV/amu.
The fit represents the (H_{α}) cross section with an rms deviation of 0.1%.
The maximum deviation is 0.2% at 6.4E+03 eV/amu.

See appendix for Chebyshev fit details.

$He^{2+} + H \rightarrow He^{+}(Ly_{\alpha}, Ly_{\beta}, Ly_{\gamma}, H_{\alpha}) + H^{+}$



Electron Capture Cross Sections for

$He^{2+} + H \rightarrow He^{+}(3p,3s+3d,4p) + H^{+}$

(3p) Energy eV/amu	(3p) Cross Section cm^2	(3s+3d) Energy eV/amu	(3s+3d) Cross Section cm^2	(4p) Energy eV/amu	(4p) Cross Section cm^2
1.6E+03	7.71E-18	2.5E+03	1.78E-17	5.0E+03	2.49E-18
2.0E+03	1.46E-17	3.0E+03	1.87E-17	5.5E+03	2.73E-18
2.5E+03	2.09E-17	3.5E+03	2.01E-17	6.0E+03	2.99E-18
3.0E+03	2.40E-17	4.0E+03	2.23E-17	7.0E+03	3.56E-18
3.5E+03	2.63E-17	4.5E+03	2.51E-17	8.0E+03	4.22E-18
4.0E+03	2.83E-17	5.0E+03	2.81E-17	9.0E+03	4.96E-18
4.5E+03	2.97E-17	6.0E+03	3.49E-17	1.0E+04	6.03E-18
5.5E+03	3.20E-17	7.0E+03	4.15E-17		
6.0E+03	3.29E-17	8.0E+03	4.63E-17		
7.0E+03	3.43E-17	9.0E+03	4.89E-17		
8.0E+03	3.57E-17	1.0E+04	4.97E-17		
9.0E+03	3.67E-17				
1.0E+04	3.74E-17				

<u>References</u>: 172, 173

<u>Accuracy</u>: 30%

<u>Notes</u>: (1) The 3s and 3d states could not be determined separately due to the degeneracy of states in He^{+}.

(2) Capture into the ground state is negligible at low energies for a H target.

(3) The cross section (σ_i) for capture into state i is determined by measuring the emission cross section (σ_{ij}) for a transition from state i to j, correcting for any branching from state i and correcting for cascading from upper states.

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

(3p)	E_{min} = 1.6E+03 eV/amu,	E_{max} = 1.0E+04 eV/amu
(3s+3d)	E_{min} = 2.5E+03 eV/amu,	E_{max} = 1.0E+04 eV/amu
(4p)	E_{min} = 5.0E+03 eV/amu,	E_{max} = 1.0E+04 eV/amu

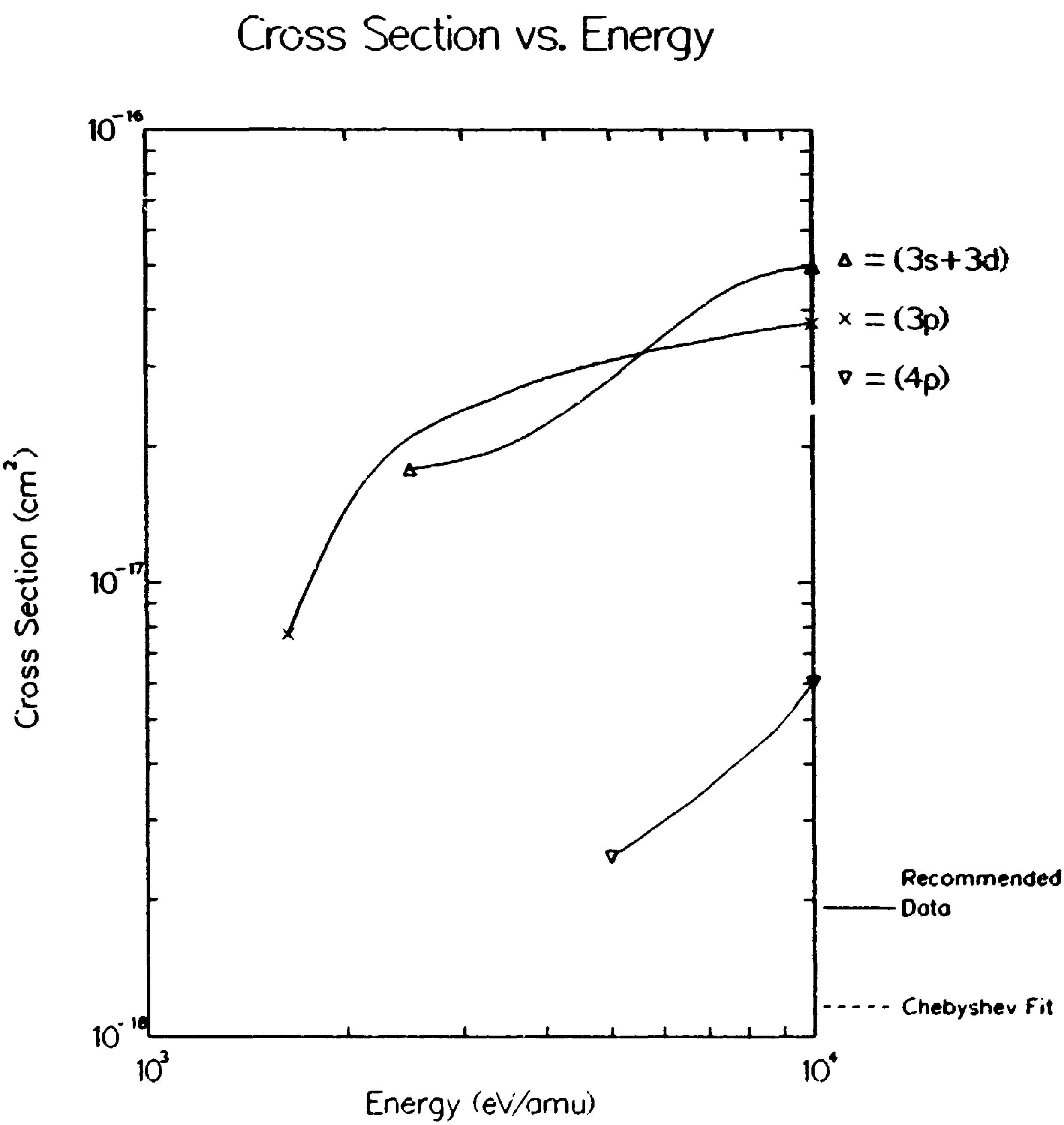
<u>Chebyshev Fitting Parameters for Cross Sections</u>

	A0	A1	A2	A3	A4	A5	A6	A7	A8
(3p)	-76.6256	.667773	-.257128	.115045	-.0496129	.0142615	9.03999E-04	-.00746439	.00421196
(3s+3d)	-76.1346	.575824	.0291040	-.0715718	-.0133196	.00539953	-.00104695	.00377347	-.00137059
(4p)	-80.2658	.432003	.0343796	.00725815	.00469173	.00296970	.00183023		

The fit represents the (3p) cross section with an rms deviation of 0.1%.
The maximum deviation is 0.3% at 4.5E+03 eV/amu.
The fit represents the (3s+3d) cross section with an rms deviation of 0.1%.
The maximum deviation is 0.1% at 4.0E+03 eV/amu.
The fit represents the (4p) cross section with an rms deviation of 0.0%.
The maximum deviation is 0.0%

See appendix for Chebyshev fit details.

$He^{2+} + H \rightarrow He^{+}(3p,3s+3d,4p) + H^{+}$



Electron Capture Cross Sections for

$He^{2+} + H_2 \rightarrow He^{+}(2s,2p)$

$He^{+}(2p)$

Energy eV/amu	Cross Section cm^2
1.2E+03	4.90E-17
1.5E+03	5.94E-17
2.0E+03	8.22E-17
3.0E+03	1.35E-16
4.0E+03	2.15E-16
5.0E+03	3.16E-16
7.0E+03	4.79E-16
9.0E+03	6.18E-16
1.0E+04	7.08E-16

$He^{+}(2s)$

Energy eV/amu	Cross Section cm^2
2.0E+03	7.99E-18
3.0E+03	1.97E-17
4.0E+03	3.33E-17
5.0E+03	4.56E-17
5.5E+03	5.12E-17
6.0E+03	5.76E-17
7.0E+03	7.46E-17
7.5E+03	8.86E-17
8.0E+03	9.88E-17
9.0E+03	1.17E-16
1.0E+04	1.28E-16
1.5E+04	1.37E-16

References: $He^{+}(2s)$ - 56, 165, 177; $He^{+}(2p)$ - 172, 173

Accuracy: $He^{+}(2s)$ - 60%; $He^{+}(2p)$ - 30%

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

$He^{+}(2p)$ E_{min} = 1.2E+03 eV/amu, E_{max} = 1.0E+04 eV/amu
$He^{+}(2s)$ E_{min} = 2.0E+03 eV/amu, E_{max} = 2.0E+04 eV/amu

Chebyshev Fitting Parameters for Cross Sections

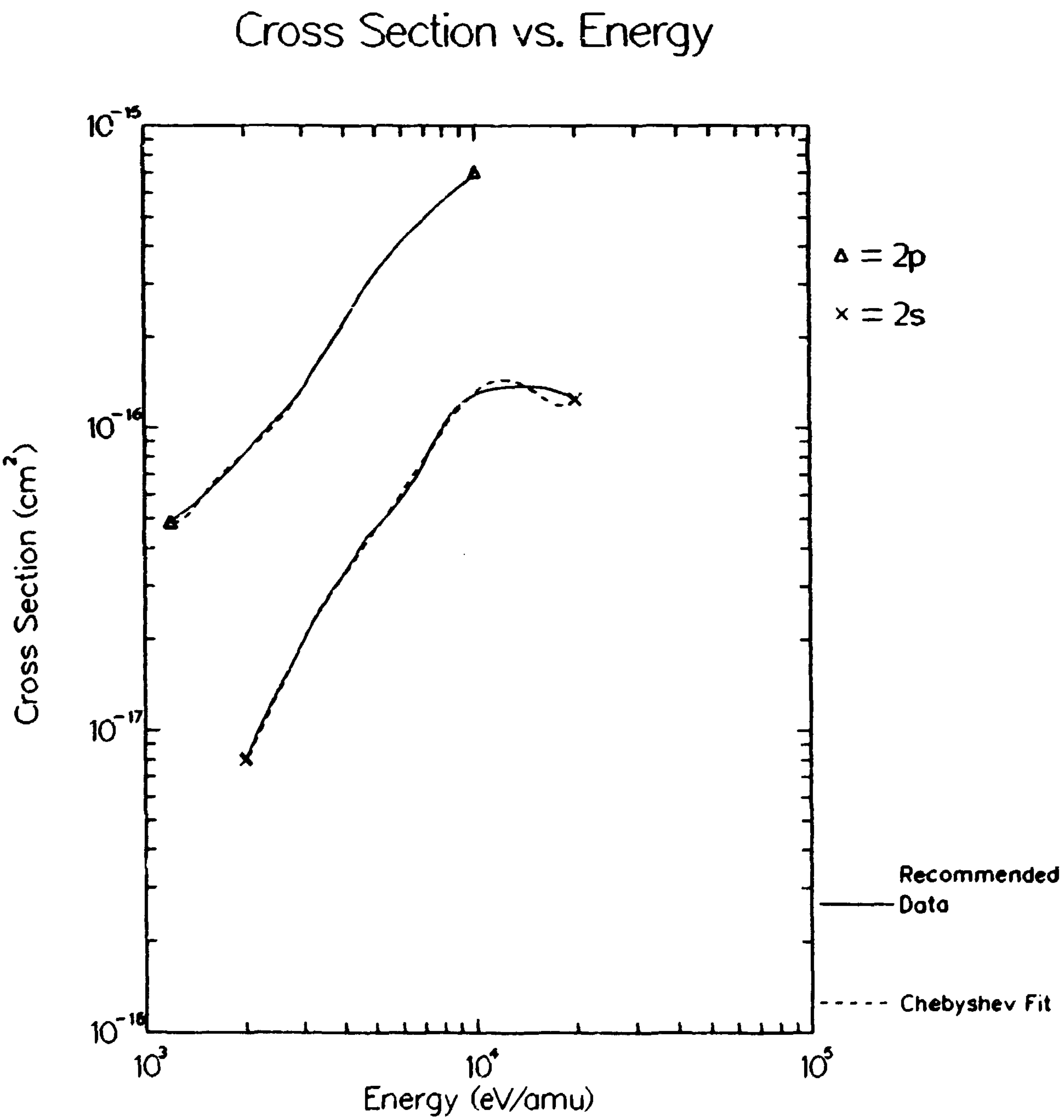
	A0	A1	A2	A3	A4	A5	A6	A7	A8
$He^{+}(2p)$	-72.5057	1.39004	.0296375	-.0736032	-.0100517	.0209333	.0217835	-.00206200	-.00793171
$He^{+}(2s)$	-75.1849	1.42417	-.425662	-.0917408	-.0265286	.0447348	.0526597		

The fit represents the $He^{+}(2p)$ cross section with an rms deviation of 0.0%.
The maximum deviation is 0.0%

The fit represents the $He^{+}(2s)$ cross section with an rms deviation of 2.4%.
The maximum deviation is 4.6% at 1.3E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^{2+} + H_2 \rightarrow He^{+}(2s, 2p)$



Line Emission Cross Sections of Electron Capture Collisions for

$He^{2+} + H_2 \rightarrow He^+(Ly_\alpha, Ly_\beta, Ly_\gamma, H_\alpha)$

Ly_α Energy eV/amu	Ly_α Cross Section cm^2	H_α Energy eV/amu	H_α Cross Section cm^2	Ly_β Energy eV/amu	Ly_β Cross Section cm^2	Ly_γ Energy eV/amu	Ly_γ Cross Section cm^2
1.3E+03	4.02E-17	2.5E+03	6.44E-18	1.7E+03	1.77E-18	5.0E+03	4.93E-19
1.5E+03	5.62E-17	2.9E+03	7.44E-18	2.2E+03	2.52E-18	5.7E+03	7.56E-19
2.2E+03	9.21E-17	3.6E+03	9.63E-18	2.9E+03	3.75E-18	6.5E+03	1.15E-18
2.9E+03	1.37E-16	4.3E+03	1.18E-17	3.6E+03	5.18E-18	7.2E+03	1.77E-18
3.6E+03	1.96E-16	5.0E+03	1.44E-17	4.3E+03	6.94E-18	7.9E+03	2.32E-18
4.3E+03	2.58E-16	5.7E+03	1.75E-17	5.0E+03	8.79E-18	8.6E+03	2.68E-18
5.0E+03	3.25E-16	6.4E+03	2.10E-17	5.7E+03	1.06E-17	9.3E+03	2.94E-18
5.7E+03	3.94E-16	7.2E+03	2.48E-17	6.4E+03	1.24E-17	1.0E+04	3.15E-18
6.5E+03	4.59E-16	7.9E+03	2.89E-17	7.2E+03	1.42E-17		
7.2E+03	5.24E-16	8.6E+03	3.23E-17	7.9E+03	1.51E-17		
7.9E+03	5.88E-16	9.3E+03	3.49E-17	8.6E+03	1.55E-17		
8.6E+03	6.56E-16	1.0E+04	3.65E-17	9.3E+03	1.56E-17		
9.3E+03	7.36E-16			1.0E+04	1.52E-17		
1.0E+04	8.06E-16						

__References:__ 173

__Accuracy:__ 30%

__Notes:__ 1) Transition wavelengths are: Lyman-α (2p->1s) 30.4 nm; Lyman-β (3p->1s) 25.6 nm; Lyman-γ (4p->1s) 24.3 nm; Balmer-α (H_α, n=3->2) 164 nm.
(2) The Balmer-β radiation cannot be measured since the transition has the same wave length as the Lyman-α radiation.

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

(Ly_α) E_{min} = 1.3E+03 eV/amu, E_{max} = 1.0E+04 eV/amu
(H_α) E_{min} = 2.5E+03 eV/amu, E_{max} = 1.0E+04 eV/amu
(Ly_β) E_{min} = 1.7E+03 eV/amu, E_{max} = 1.0E+04 eV/amu
(Ly_γ) E_{min} = 5.0E+03 eV/amu, E_{max} = 1.0E+04 eV/amu

__Chebyshev Fitting Parameters for Cross Sections__

	A0	A1	A2	A3	A4	A5	A6	A7	A8
(Ly_α)	-72.3692	1.45574	.0140540	-.0435817	.00709587	.00345598	.0136342	-.00698786	-.00272240
(H_α)	-77.4506	.904442	.0279735	-.0253175	-.0268277	-.00920018	.00430881	-.00254282	.00325844
(Ly_β)	-79.3508	1.17675	-.116050	-.0780599	-.0348000	-.0102977	.0150173	-.0123859	.0116818
(Ly_γ)	-82.1736	.953689	-.126724	-.0689492	.0127445	.0372528	-.0256612	.00533416	

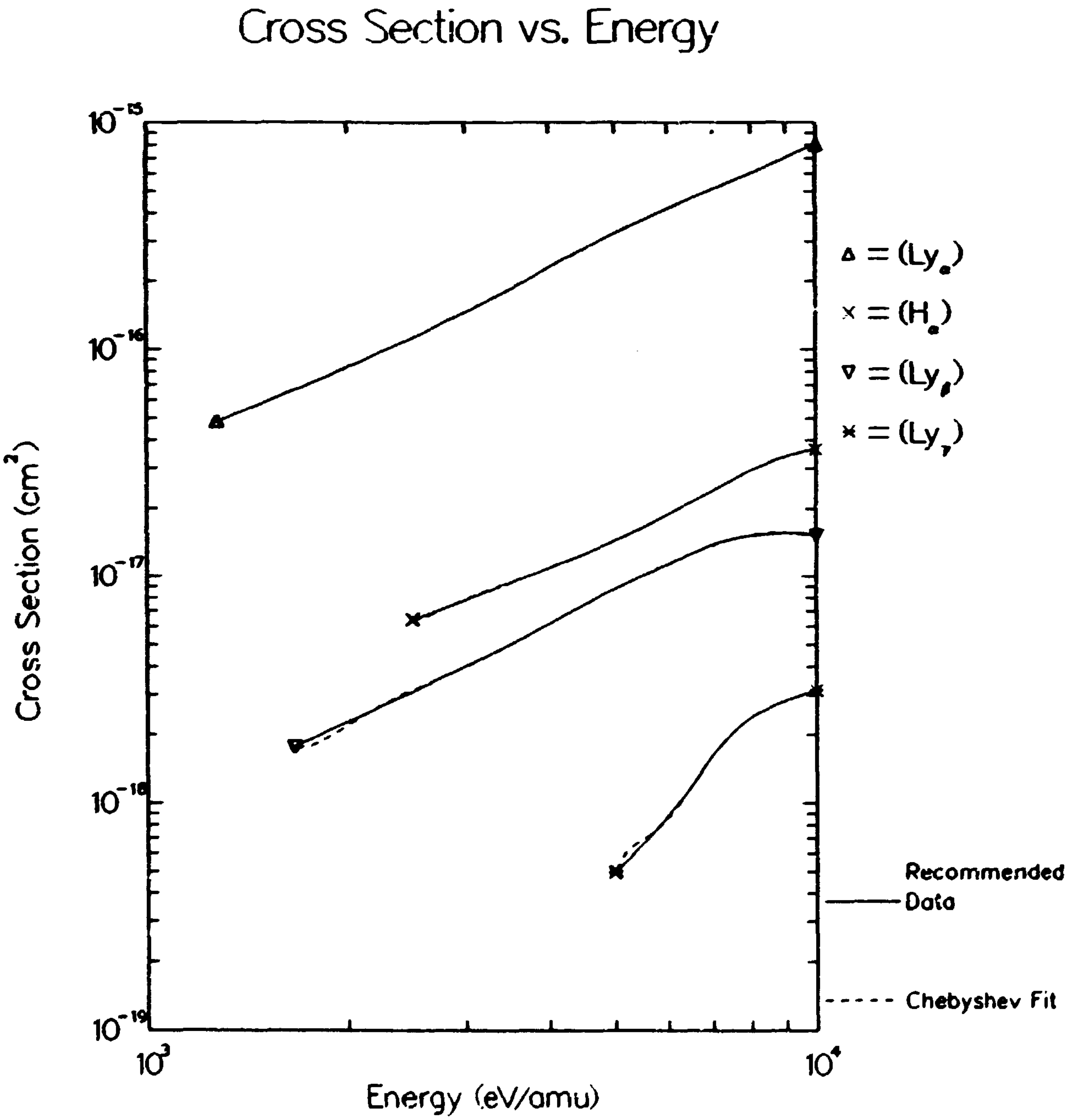
The fit represents the Ly_α cross section with an rms deviation of 0.3%.
The maximum deviation is 0.6% at 3.6E+03 eV/amu.

The fit represents the H_α cross section with an rms deviation of 0.1%.
The maximum deviation is 0.2% at 7.1E+03 eV/amu.

The fit represents the Ly_β cross section with an rms deviation of 0.4%.
The maximum deviation is 0.7% at 8.6E+03 eV/amu.

The fit represents the Ly_γ cross section with an rms deviation of 0.0%.
The maximum deviation is 0.0%.
See appendix for Chebyshev fit details.

$He^{2+} + H_2 \rightarrow He^{+}(Ly_{\alpha}, Ly_{\beta}, Ly_{\gamma}, H_{\alpha})$



Electron Capture Cross Sections for

$He^{2+} + H_2 \rightarrow He^{+}(3p, 3s+3d, 4p)$

(3p)		(3s+3d)		(4p)	
Energy eV/amu	Cross Section cm^2	Energy eV/amu	Cross Section cm^2	Energy eV/amu	Cross Section cm^2
2.5E+03	6.70E-18	1.9E+03	1.96E-18	5.0E+03	5.78E-19
3.0E+03	7.05E-18	2.3E+03	2.64E-18	5.8E+03	9.10E-19
3.5E+03	9.24E-18	3.0E+03	4.59E-18	6.5E+03	1.39E-18
4.3E+03	1.17E-17	3.5E+03	6.18E-18	7.3E+03	2.10E-18
5.0E+03	1.45E-17	4.3E+03	7.72E-18	8.0E+03	2.82E-18
5.8E+03	1.75E-17	5.0E+03	9.58E-18	8.5E+03	3.38E-18
6.5E+03	2.05E-17	5.8E+03	1.17E-17	9.3E+03	3.64E-18
7.3E+03	2.35E-17	6.5E+03	1.3[illegible]E-17	1.0E+04	3.84E-18
8.0E+03	2.65E-17	7.3E+03	1.56E-17		
8.5E+03	2.96E-17	8.0E+03	1.68E-17		
9.3E+03	3.25E-17	8.5E+03	1.75E-17		
1.0E+04	3.54E-17	9.3E+03	1.78E-17		
		1.0E+04	1.71E-17		

<u>**References:**</u> 173

<u>**Accuracy:**</u> 30%

<u>**Notes:**</u> (1) The 3s and 3d states could not be determined separately due to the degeneracy of states in He^{+}.
(2) The cross section for capture into state i is determined by measuring the emission cross section (σ_{ij}) for a transition from state i to j, correcting for any branching from state i and correcting for cascading from upper states.

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

(3p) E_{min} = 2.5E+03 eV/amu, E_{max} = 1.0E+04 eV/amu
(3s+3d) E_{min} = 1.9E+03 eV/amu, E_{max} = 1.0E+04 eV/amu
(4p) E_{min} = 5.0E+03 eV/amu, E_{max} = 1.0E+04 eV/amu

<u>Chebyshev Fitting Parameters for Cross Sections</u>

	A0	A1	A2	A3	A4	A5	A6	A7	A8
(3p)	-77.5134	.877384	.0236181	-.0330936	.0119138	-.00648625	.00667714	-.00553227	.00234918
(3s+3d)	-78.9402	1.10256	-.166612	-.0123653	-.0567272	-.00713119	.00939783	4.30617E-04	-.00609836
(4p)	-81.8167	.998271	-.145943	-.0608582	.0111762	.0174494	-.00474599	-.00803524	

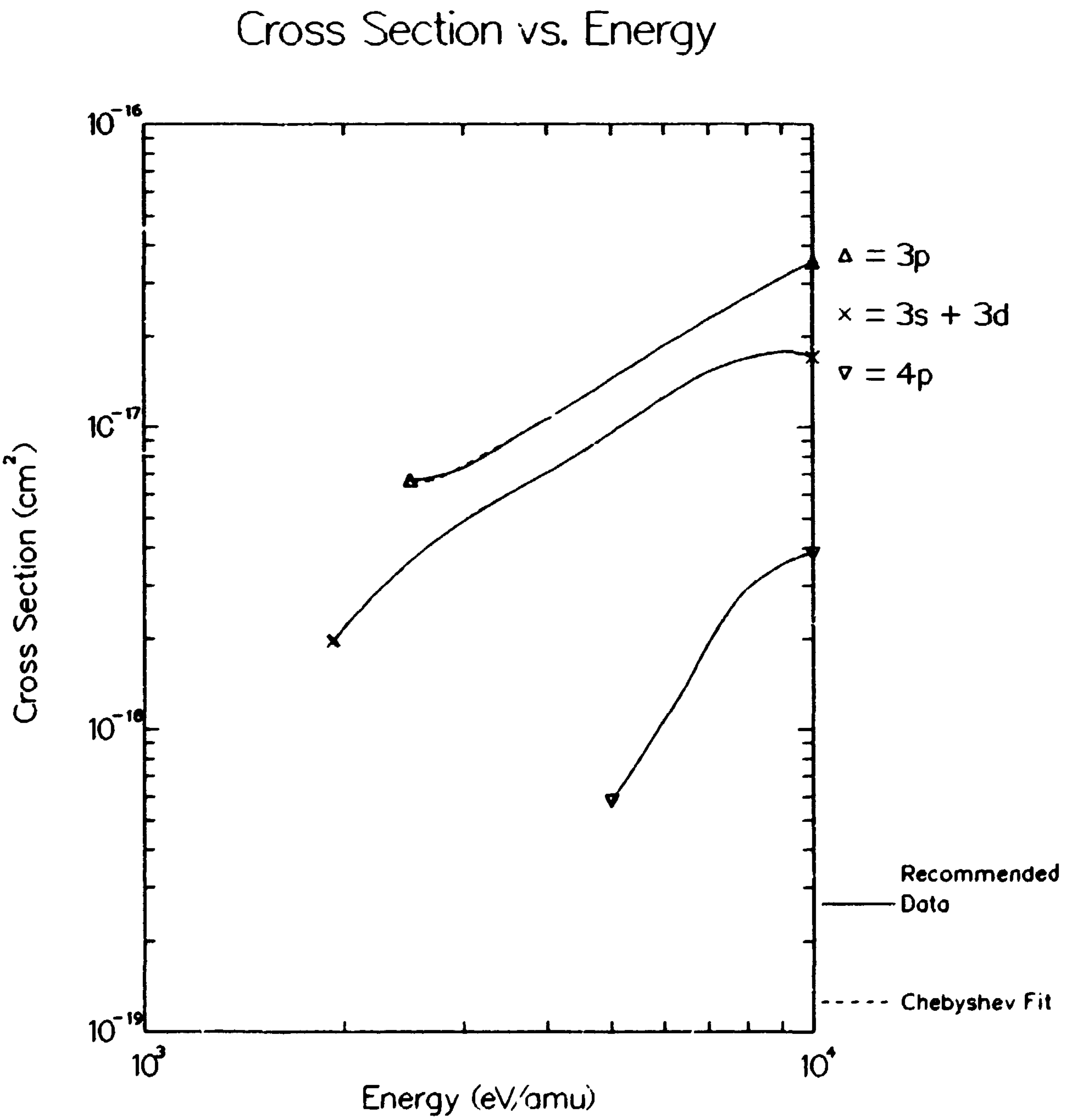
The fit represents the 3p cross section with an rms deviation of 0.1%.
The maximum deviation is 0.1% at 7.9E+03 eV/amu.

The fit represents the 3s+3d cross section with an rms deviation of 0.2%.
The maximum deviation is 0.4% at 8.6E+03 eV/amu.

The fit represents the 4p cross section with an rms deviation of 0.0%.
The maximum deviation is 0.0%.

See appendix for Chebyshev fit details.

$He^{2+} + H_2 \rightarrow He^{+}(3p, 3s+3d, 4p)$



Electron Capture Cross Sections for
$He^{2+} + He \rightarrow He^{+}(2s) + He^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.0E+03	6.21E+07	2.79E-18
3.0E+03	7.61E+07	3.30E-18
4.0E+03	8.73E+07	4.04E-18
5.0E+03	9.82E+07	5.32E-18
7.0E+03	1.16E+08	9.18E-18
9.0E+03	1.32E+08	1.37E-17
1.0E+04	1.39E+08	1.62E-17
1.5E+04	1.70E+08	3.04E-17
2.0E+04	1.96E+08	3.75E-17
2.5E+04	2.20E+08	3.90E-17
3.0E+04	2.41E+08	3.84E-17
4.0E+04	2.78E+08	3.36E-17
6.0E+04	3.40E+08	2.21E-17
8.0E+04	3.93E+08	1.40E-17
1.0E+05	4.39E+08	8.65E-18
1.5E+05	5.38E+08	2.83E-18
2.0E+05	6.21E+08	1.26E-18
2.5E+05	6.94E+08	6.87E-19
3.0E+05	7.61E+08	4.10E-19
4.0E+05	8.78E+08	1.75E-19
4.7E+05	9.52E+08	1.27E-19

References: 56, 145, 177, 178, 179, 180, 181, 182

Accuracy: $E < 2x10^4$ eV/amu - 50%; $E > 2x10^4$ eV/amu - unknown

Notes: (1) Experimental data (ref. 56, 145, 177) extends only to $2x10^4$ eV/amu. In the energy region of overlap ($7x10^3$ eV/amu-$2x10^4$ eV/amu) between experimental data and theoretical data (ref. 178, 180, 181) the theoretical data is greater than experimental by 1.5-2.5 orders of magnitude. Data above $2x10^4$ eV/amu should be used with caution.
(2) No experimental data exists for $He^{2+} + He \rightarrow He^{+}(2p)$.

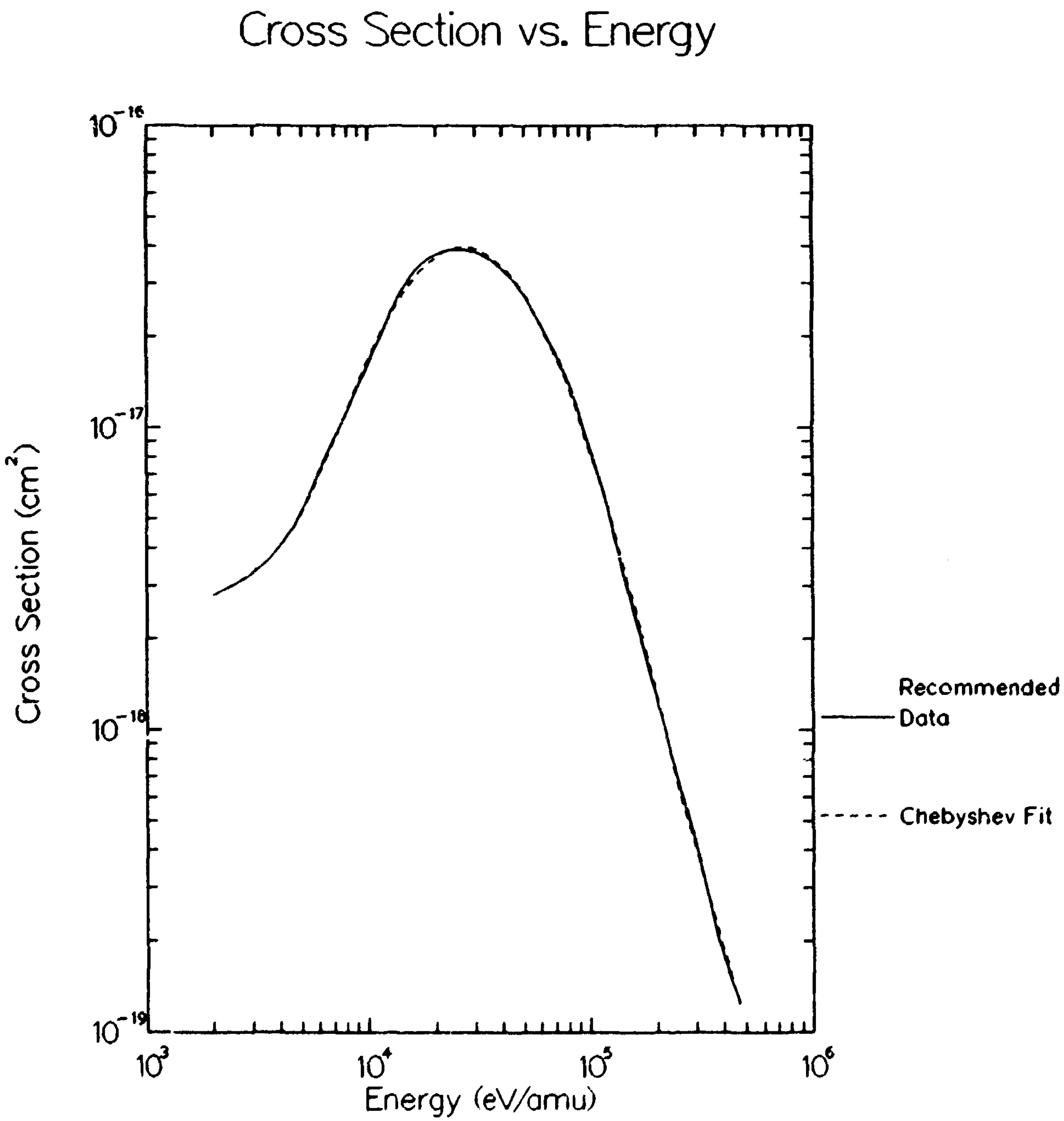
For a Chebyshev fit of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.0E+03 eV/amu, E_{max} = 4.7E+05 eV/amu

Chebyshev Fitting Parameters for Cross Sections

A0	A1	A2	A3	A4	A5	A6	A7	A8
-80.4752	-1.31324	-2.07504	-.281865	.383911	5.87536E-03	-.0220039	.0340012	-.0262370

The fit represents the above cross sections with an rms deviation of 2.7%.
The maximum deviation is 5.6% at 4.0E+05 eV/amu.
See appendix for Chebyshev fit details.

$He^{2+} + He \rightarrow He^{+}(2s) + He^{+}$



Electron Capture Rate Coefficients for
He^{2+} + He -> He^{+}(2s) . $\_^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

He^{2+} Temp. (eV)	Equal Temp.	He Temp. (eV) 500.	1000.	2000.	4000.	7000.	10000.	20000.
7.0E+02	1.96E-12	7.88E-13	5.12E-12	2.78E-11	1.11E-10	3.08E-10	5.88E-10	1.84E-09
1.0E+03	1.01E-11	2.81E-12	1.01E-11	3.76E-11	1.27E-10	3.32E-10	6.20E-10	1.88E-09
2.0E+03	7.73E-11	2.20E-11	3.76E-11	7.73E-11	1.86E-10	4.20E-10	7.31E-10	2.02E-09
4.0E+03	3.32E-10	1.01E-10	1.27E-10	1.86E-10	3.32E-10	6.20E-10	9.70E-10	2.28E-09
7.0E+03	9.70E-10	2.92E-10	3.32E-10	4.20E-10	6.20E-10	9.70E-10	1.35E-09	2.65E-09
1.0E+04	1.75E-09	5.67E-10	6.20E-10	7.31E-10	9.70E-10	1.35E-09	1.75E-09	3.01E-09
2.0E+04	4.01E-09	1.82E-09	1.88E-09	2.02E-09	2.28E-09	2.65E-09	3.01E-09	4.01E-09

Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 7.0E+02 eV, E_{max} = 2.0E+04 eV

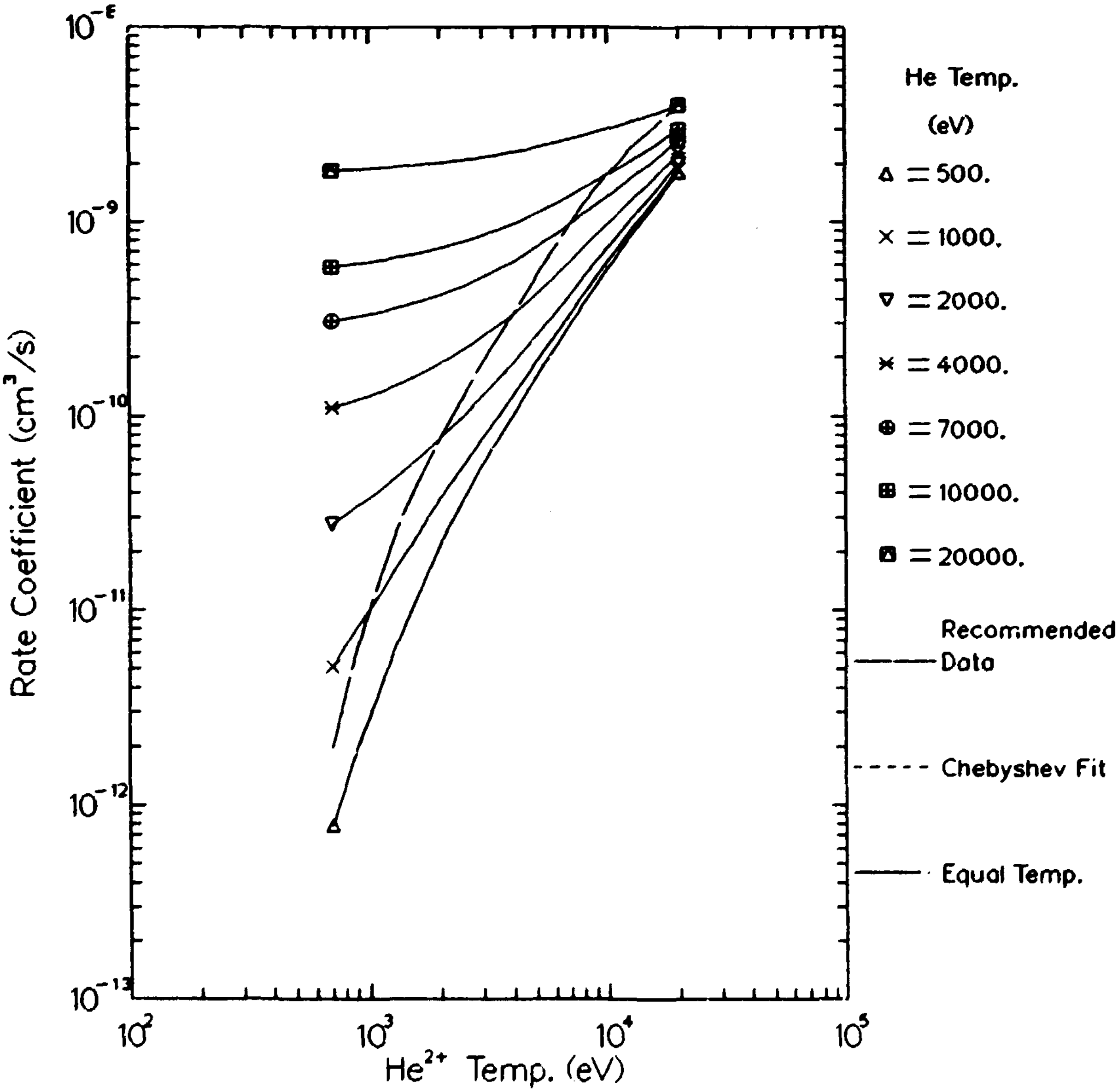
Chebyshev Fitting Parameters for Rate Coefficients

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
500.	-4.71093E+01	3.78408E+00	-4.25226E-01	1.09485E-01	-1.88308E-02	-2.18471E-02	1.64914E-03
1000.	-4.59288E+01	2.96506E+00	-6.94375E-02	4.01519E-03	-9.10887E-03	-1.53339E-02	-4.97257E-04
2000.	-4.46311E+01	2.18675E+00	1.67647E-01	-3.86105E-02	-1.57224E-02	-6.51960E-03	-3.71278E-04
4000.	-4.32631E+01	1.54495E+00	2.39004E-01	-3.13418E-02	-1.96927E-02	-2.77831E-03	6.46638E-04
7000.	-4.20414E+01	1.09232E+00	2.10178E-01	-1.36333E-02	-1.49539E-02	-2.16792E-03	5.39745E-04
10000.	-4.12037E+01	8.21778E-01	1.74596E-01	-3.48824E-03	-1.10046E-02	-2.36544E-03	-2.58516E-04
20000.	-3.96301E+01	3.84302E-01	9.69796E-02	5.67825E-03	-3.92022E-03	-1.53584E-03	-5.16122E-04
Equal Temp.	-4.49085E+01	3.65780E+00	-6.02220E-01	1.33794E-01	-9.85265E-02	2.12708E-02	8.09123E-03

See appendix for Chebyshev fit details.

$He^{2+} + He \rightarrow He^{+}(2s) + He^{+}$

Maxwellian – Maxwellian



Electron Capture Rate Coefficients for
$He + He^{2+} \rightarrow He^{+}(2s) + He^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{2+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	60000.	80000.	100000.	200000.
1.0E+00	2.25E-09	7.35E-09	9.33E-09	7.51E-09	5.50E-09*	3.80E-09*	7.83E-10**
2.0E+00	2.25E-09	7.36E-09	9.32E-09	7.51E-09	5.50E-09*	3.80E-09*	7.83E-10**
4.0E+00	2.25E-09	7.35E-09	9.32E-09	7.51E-09	5.49E-09*	3.80E-09*	7.83E-10**
7.0E+00	2.25E-09	7.35E-09	9.31E-09	7.51E-09	5.49E-09	3.79E-09*	7.83E-10**
1.0E+01	2.25E-09	7.34E-09	9.31E-09	7.50E-09	5.49E-09	3.79E-09*	7.83E-10**
2.0E+01	2.26E-09	7.33E-09	9.30E-09	7.50E-09	5.49E-09	3.79E-09*	7.83E-10**
4.0E+01	2.26E-09	7.32E-09	9.29E-09	7.49E-09	5.48E-09	3.79E-09*	7.83E-10**
7.0E+01	2.27E-09	7.31E-09	9.27E-09	7.48E-09	5.48E-09	3.78E-09*	7.83E-10**
1.0E+02	2.28E-09	7.30E-09	9.26E-09	7.47E-09	5.47E-09	3.78E-09	7.83E-10*
2.0E+02	2.31E-09	7.28E-09	9.23E-09	7.45E-09	5.46E-09	3.78E-09	7.84E-10*
4.0E+02	2.37E-09	7.26E-09	9.19E-09	7.43E-09	5.45E-09	3.77E-09	7.85E-10*
7.0E+02	2.45E-09	7.23E-09	9.14E-09	7.40E-09	5.43E-09	3.76E-09	7.87E-10*
1.0E+03	2.54E-09	7.22E-09	9.10E-09	7.38E-09	5.42E-09	3.76E-09	7.88E-10*
2.0E+03	2.79E-09	7.17E-09	8.99E-09	7.32E-09	5.40E-09	3.76E-09	7.93E-10*
4.0E+03	3.20E-09	7.11E-09	8.81E-09	7.23E-09	5.36E-09	3.76E-09	8.02E-10*
7.0E+03	3.68E-09	7.05E-09	8.57E-09	7.11E-09	5.31E-09	3.77E-09	8.15E-10*
1.0E+04	4.06E-09	7.01E-09	8.35E-09	6.98E-09	5.25E-09	3.77E-09	8.29E-10*
2.0E+04	4.94E-09	6.91E-09	7.72E-09	6.58E-09	5.08E-09	3.75E-09	8.76E-10*

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

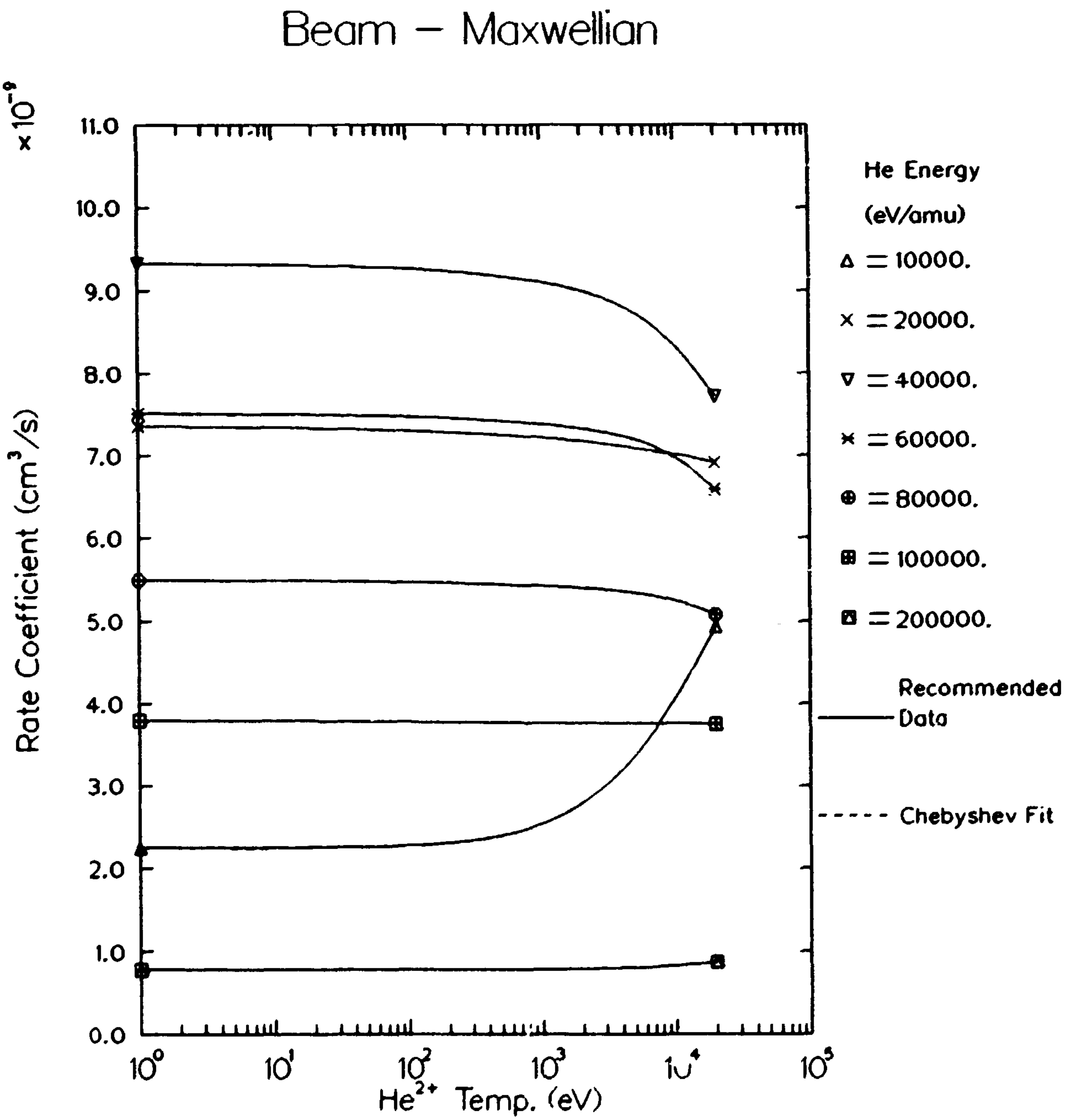
Notes: For Chebyshev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebyshev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-3.94248E+01	3.34599E-01	1.94015E-01	6.86806E-02	4.95694E-03	-9.99564E-03	-6.10649E-03
20000.	-3.74937E+01	-2.78645E-02	-1.11501E-02	-3.09862E-03	-9.33585E-04	8.71220E-06	1.09550E-04
40000.	-3.70648E+01	-6.95474E-02	-4.17914E-02	-2.13044E-02	-9.81107E-03	-3.95679E-03	-1.20270E-03
60000.	-3.74705E+01	-4.74430E-02	-2.81261E-02	-1.48208E-02	-7.60963E-03	-3.68669E-03	-1.56303E-03
80000.	-3.80745E+01	-2.90089E-02	-1.58763E-02	-8.00256E-03	-4.24777E-03	-2.17637E-03	-8.77601E-04
100000.	-3.87379E+01	-5.76796E-03	1.27600E-04	8.95128E-04	-2.39349E-04	-7.73294E-04	-5.69452E-04
200000.	-4.18939E+01	3.77781E-02	2.64380E-02	1.53165E-02	7.52659E-03	3.09706E-03	1.14409E-03

See appendix for Chebyshev fit details.

$He + He^{2+} \rightarrow He^{+}(2s) + He^{+}$



Electron Capture Cross Sections for

$He^{2+} + Li \rightarrow He^{+}(2p, 3p, 4p, 3s+3d, 4s+4d) + Li^{+}$

(2p) Energy eV/amu	(2p) Cross Section cm^2	(3p) Energy eV/amu	(3p) Cross Section cm^2	(4p) Energy eV/amu	(4p) Cross Section cm^2	(3s+3d) Energy eV/amu	(3s+3d) Cross Section cm^2	(4s+4d) Energy eV/amu	(4s+4d) Cross Section cm^2
1.1E+04	3.70E-16	5.6E+02	4.96E-15	1.3E+03	2.99E-16	3.8E+03	6.02E-15	3.8E+03	9.77E-16
1.5E+04	2.71E-16	7.1E+02	4.56E-15	1.5E+03	3.54E-16	5.0E+03	5.31E-15	5.0E+03	1.39E-15
2.0E+04	1.97E-16	9.1E+02	4.20E-15	2.0E+03	4.29E-16	7.0E+03	4.17E-15	6.0E+03	1.51E-15
3.0E+04	1.15E-16	1.5E+03	3.55E-15	3.0E+03	5.30E-16	1.0E+04	2.64E-15	7.0E+03	1.50E-15
3.8E+04	5.90E-17	2.0E+03	3.23E-15	4.0E+03	6.08E-16	1.5E+04	9.31E-16	1.0E+04	1.28E-15
		3.0E+03	2.82E-15	6.0E+03	7.51E-16	2.0E+04	3.60E-16	1.5E+04	6.27E-16
		5.0E+03	2.24E-15	7.0E+03	8.00E-16	2.5E+04	1.50E-16	2.0E+04	3.38E-16
		7.0E+03	1.68E-15	8.6E+03	8.36E-16	3.0E+04	7.39E-17	2.5E+04	1.89E-16
		1.0E+04	9.50E-16	1.0E+04	7.94E-16	3.8E+04	2.19E-17	3.0E+04	1.18E-16
		1.5E+04	3.53E-16	1.5E+04	4.72E-16			3.7E+04	6.50E-17
		2.0E+04	1.45E-16	2.0E+04	2.34E-16				
		2.5E+04	5.49E-17	2.5E+04	9.89E-17				
		3.0E+04	1.77E-17	3.0E+04	4.39E-17				
		3.2E+04	1.00E-17	3.8E+04	1.44E-17				

<u>References:</u> 240, 243, 245, 259, 262, 263, 264

<u>Accuracy:</u> unknown

<u>Notes:</u> (1) Cross sections into excited states are determined by measuring the emission from the state and subtracting cascade transitions from higher states and making corrections for the branching ratios.

(2) It is believed that the data are accurate to within 60%.

(3) References 263 and 264 contain theoretical data that were not included in compiling the present data.

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

(2p) E_{min} = 1.1E+04 eV/amu, E_{max} = 3.8E+04 eV/amu
(3p) E_{min} = 5.6E+02 eV/amu, E_{max} = 3.2E+04 eV/amu
(4p) E_{min} = 1.3E+03 eV/amu, E_{max} = 3.8E+04 eV/amu
(3s+3d) E_{min} = 3.8E+03 eV/amu, E_{max} = 3.8E+04 eV/amu
(4s+4d) E_{min} = 3.8E+03 eV/amu, E_{max} = 3.7E+04 eV/amu

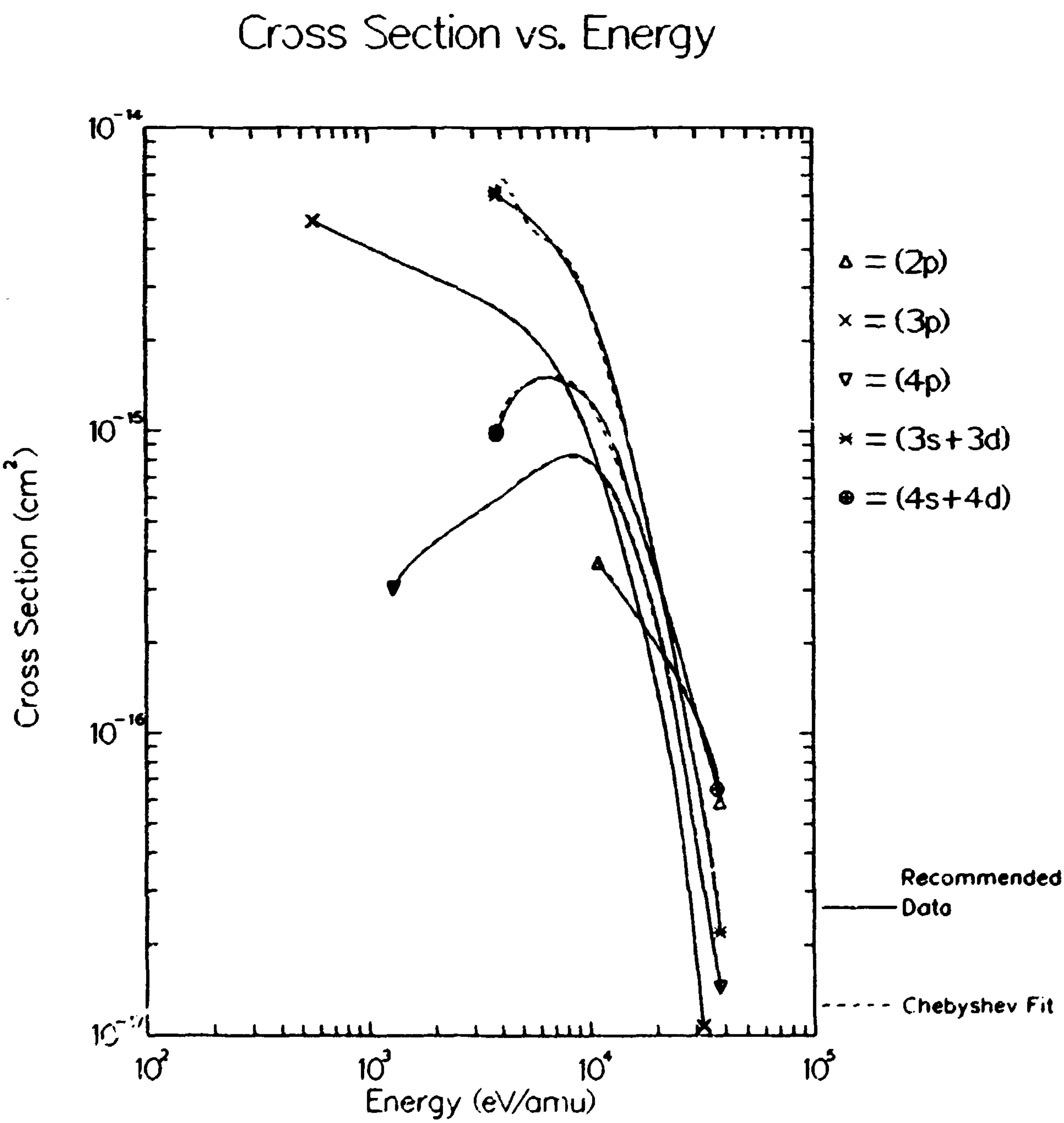
<u>Chebyshev Fitting Parameters for Cross Sections</u>

	A0	A1	A2	A3	A4	A5	A6	A7	A8
(2p)	-72.5775	-.854328	-.132073	-.0636576	-.0301663				
(3p)	-69.3960	-2.53366	-1.15152	-.477709	-.109491	-.0224733	-.0359280	-.0364469	-.0124596
(4p)	-71.9553	-1.18550	-1.26810	-.417040	-.0333091	.0822485	.0142456	.00155260	.00317940
(3s+3d)	-69.5364	-2.77071	-.724373	-.0299068	.0383153	-.0274998	-.0511074	.0199350	-.0465182
(4s+4d)	-70.4843	-1.46194	-.666629	.0919477	.0166653	-.00399733	-.0199710	.0194456	-.00484478

The fit represents the above cross sections with an rms deviation of 0.0%.
The maximum deviation is 0.0%.
The fit represents the above cross sections with an rms deviation of 0.8%.
The maximum deviation is 1.5% at 3.0E+04 eV/amu.
The fit represents the above cross sections with an rms deviation of 1.2%.
The maximum deviation is 2.7% at 1.5E+04 eV/amu.
The fit represents the above cross sections with an rms deviation of 0.0%.
The maximum deviation is 0.0%.
The fit represents the above cross sections with an rms deviation of 1.1%.
The maximum deviation is 1.7% at 7.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$He^{2+} + Li \rightarrow He^{+}(2p, 3p, 4p, 3s+3d, 4s+4d) + Li^{+}$



Line Emission Cross Sections of Electron Capture Collisions for

$He^{2+} + Li \rightarrow He^{+}(Ly_{\alpha}, Ly_{\beta}, Ly_{\gamma}) + Li^{+}$

(Ly_{α}) Energy eV/amu	(Ly_{α}) Cross Section cm^2	(Ly_{β}) Energy eV/amu	(Ly_{β}) Cross Section cm^2	(Ly_{γ}) Energy eV/amu	(Ly_{γ}) Cross Section cm^2
8.1E-01	4.72E-16	8.3E-01	3.71E-16	1.3E+03	2.55E-16
1.0E+00	4.83E-16	1.0E+00	4.42E-16	1.5E+03	3.01E-16
1.5E+00	5.53E-16	1.5E+00	6.23E-16	2.0E+03	3.77E-16
2.0E+00	7.30E-16	2.0E+00	7.70E-16	3.0E+03	4.69E-16
2.5E+00	9.40E-16	3.0E+00	8.83E-16	4.0E+03	5.31E-16
3.0E+00	1.12E-15	4.0E+00	8.42E-16	6.6E+03	6.25E-16
4.0E+00	1.26E-15	5.0E+00	7.65E-16	8.0E+03	6.89E-16
6.0E+00	1.28E-15	6.0E+00	7.02E-16	9.1E+03	6.94E-16
8.0E+00	1.21E-15	8.0E+00	5.99E-16	1.0E+04	6.74E-16
1.0E+01	1.13E-15	1.0E+01	5.32E-16	1.5E+04	4.06E-16
1.3E+01	1.04E-15	1.4E+01	4.43E-16	2.0E+04	2.02E-16
5.4E+02	7.23E-15	5.4E+02	4.60E-15	2.5E+04	8.81E-17
8.0E+02	7.35E-15	7.8E+02	4.04E-15	3.0E+04	4.00E-17
1.0E+03	7.30E-15	9.0E+02	3.59E-15	3.5E+04	1.98E-17
1.5E+03	7.31E-15	9.9E+02	3.42E-15		
2.0E+03	7.27E-15	1.5E+03	2.93E-15		
3.0E+03	7.07E-15	2.0E+C3	2.75E-15		
5.0E+03	6.77E-15	3.0E+03	2.67E-15		
6.9E+03	5.67E-15	4.0E+03	2.63E-15		
1.0E+04	4.10E-15	5.0E+03	2.51E-15		
1.5E+04	2.04E-15	7.0E+03	2.03E-15		
2.0E+04	1.00E-15	9.0E+03	1.49E-15		
3.0E+04	3.39E-16	1.0E+04	1.29E-15		
3.8E+04	1.79E-16	1.5E+04	5.97E-16		
		2.0E+04	3.02E-16		
		3.0E+04	6.52E-17		
		3.8E+C4	2.20E-17		

References: 240, 243, 245, 259, 262

Accuracy: unknown

Notes: (1) On purpose, no attempt has been made to extrapolate the data between the low and high energy regions.

(2) The emission cross section is defined as the photon emission from state nl with no correction for cascading from higher states.

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

(Ly_{α}) E_{min} = 8.1E-01 eV/amu, E_{max} = 3.8E+04 eV/amu

(Ly_{β}) E_{min} = 8.3E-01 eV/amu, E_{max} = 3.8E+04 eV/amu

(Ly_{γ}) E_{min} = 1.3E+03 eV/amu, E_{max} = 3.8E+04 eV/amu

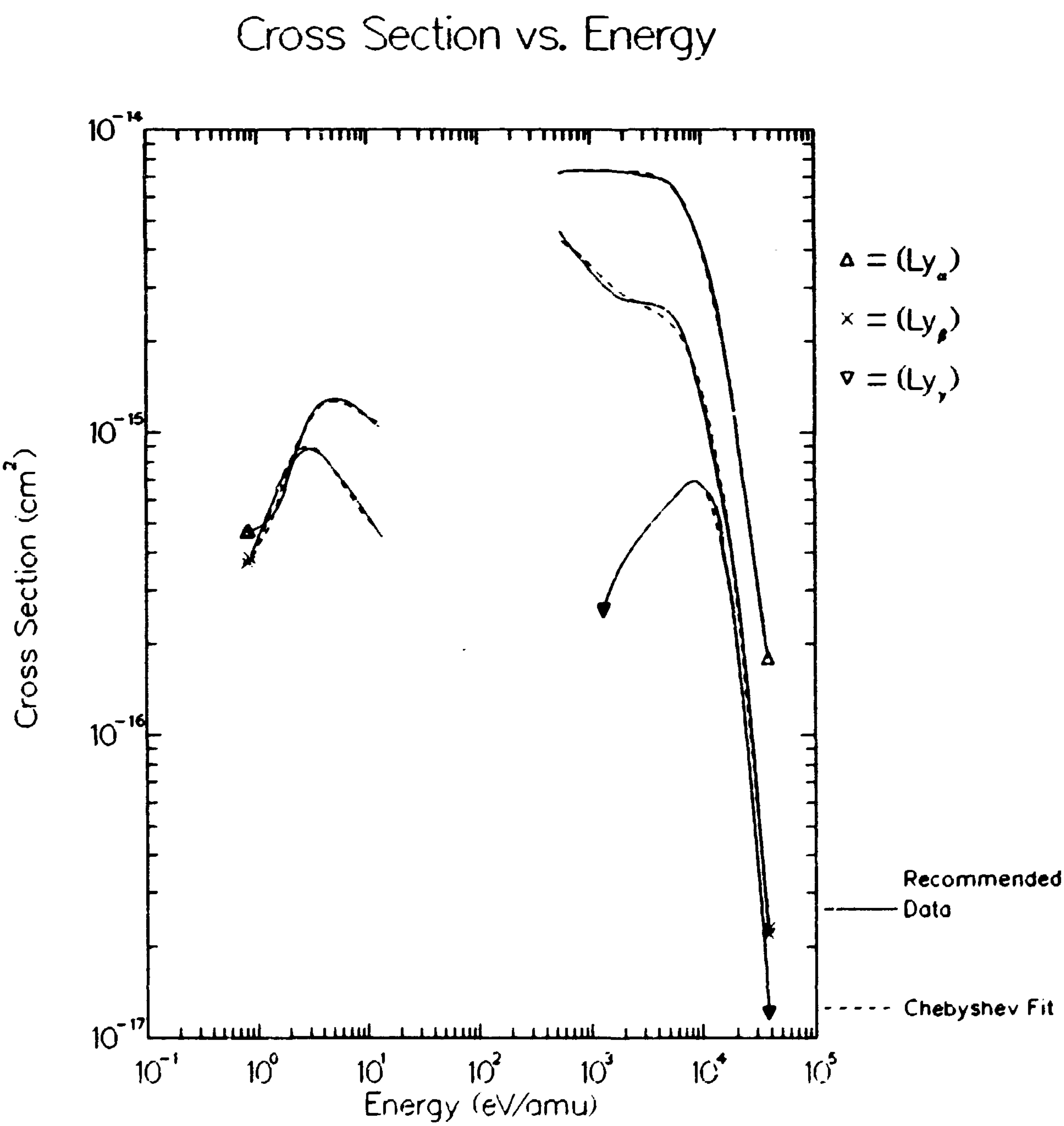
Chebyshev Fitting Parameters for Cross Sections

	A0	A1	A2	A3	A4	A5	A6	A7	A8
(Ly_{α})	-68.3492	.342390	-1.29878	-.802770	-.377264	.0373709	-.0758138	-.0906659	.182862
(Ly_{β})	-69.8158	-.370103	-1.48217	-1.03893	-.380773	.0694862	-.330382	-.0604033	.195831
(Ly_{γ})	-72.2366	-1.16996	-1.25436	-.404927	-.0551144	.0691596	.0107803	-.0171457	-.0103497

The fit represents the (Ly_{α}) cross section with an rms deviation of 3.3%.
The maximum deviation is 6.3% at 2.0E+00 eV/amu.
The fit represents the (Ly_{β}) cross section with an rms deviation of 4.6%.
The maximum deviation is 7.3% at 1.4E+01 eV/amu.
The fit represents the (Ly_{γ}) cross section with an rms deviation of 1.4%.
The maximum deviation is 2.7% at 1.5E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^{2+} + Li \rightarrow He^{+}(Ly_{\alpha}, Ly_{\beta}, Ly_{\gamma}) + Li^{+}$



Line Emission Cross Sections of Electron Capture Collisions for

$He^{2+} + Li \rightarrow He^{+}(H_{\alpha},H_{\beta},H_{\gamma},H_{\delta}) + Li^{+}$

(H_{α}) Energy eV/amu	(H_{α}) Cross Section cm^2	(H_{β}) Energy eV/amu	(H_{β}) Cross Section cm^2	(H_{γ}) Energy eV/amu	(H_{γ}) Cross Section cm^2	(H_{δ}) Energy eV/amu	(H_{δ}) Cross Section cm^2
3.9E+03	9.19E-15	3.8E+03	7.87E-16	5.0E+03	2.26E-16	5.0E+03	1.19E-16
5.1E+03	8.03E-15	5.1E+03	1.05E-15	6.0E+03	3.19E-16	6.0E+03	1.24E-16
6.1E+03	7.23E-15	6.0E+03	1.10E-15	7.1E+03	3.60E-16	8.1E+03	1.32E-16
7.1E+03	6.55E-15	7.1E+03	1.11E-15	8.0E+03	3.66E-16	1.0E+04	1.30E-16
8.1E+03	5.73E-15	1.0E+04	9.79E-16	1.0E+04	3.41E-16	1.5E+04	1.29E-16
1.0E+04	4.07E-15	1.5E+04	5.20E-16	1.5E+04	2.33E-16	2.0E+04	8.23E-17
1.5E+04	1.49E-15	2.0E+04	2.71E-16	2.0E+04	1.46E-16	2.5E+04	3.58E-17
2.0E+04	6.02E-16	3.0E+04	9.35E-17	2.5E+04	7.35E-17	3.0E+04	2.30E-17
2.5E+04	2.60E-16	3.8E+04	5.04E-17	3.0E+04	4.61E-17	3.8E+04	1.59E-17
3.0E+04	1.03E-16			3.8E+04	2.99E-17		
3.7E+04	4.36E-17						

<u>References:</u> 240, 243, 245, 262

<u>Accuracy:</u> 60%

<u>Notes:</u> (1) The emission cross section is defined as the photon emission from state nl with no corrections for cascading i.e. Balmer-α emission cross section is the emission of photons in the 3 ->2 transition at λ =164 nm which does not include any other transitions.

(2) The probable accuracy of the data is estimated at 60%.

For Chebyshev fits of the above cross sections it is necessary to use the following parameters.

(H_{α}) E_{min} = 3.9E+03 eV/amu, E_{max} = 3.7E+04 eV/amu
(H_{β}) E_{min} = 3.8E+03 eV/amu, E_{max} = 3.8E+04 eV/amu
(H_{γ}) E_{min} = 5.0E+03 eV/amu, E_{max} = 3.8E+04 eV/amu
(H_{δ}) E_{min} = 5.0E+03 eV/amu, E_{max} = 3.8E+04 eV/amu

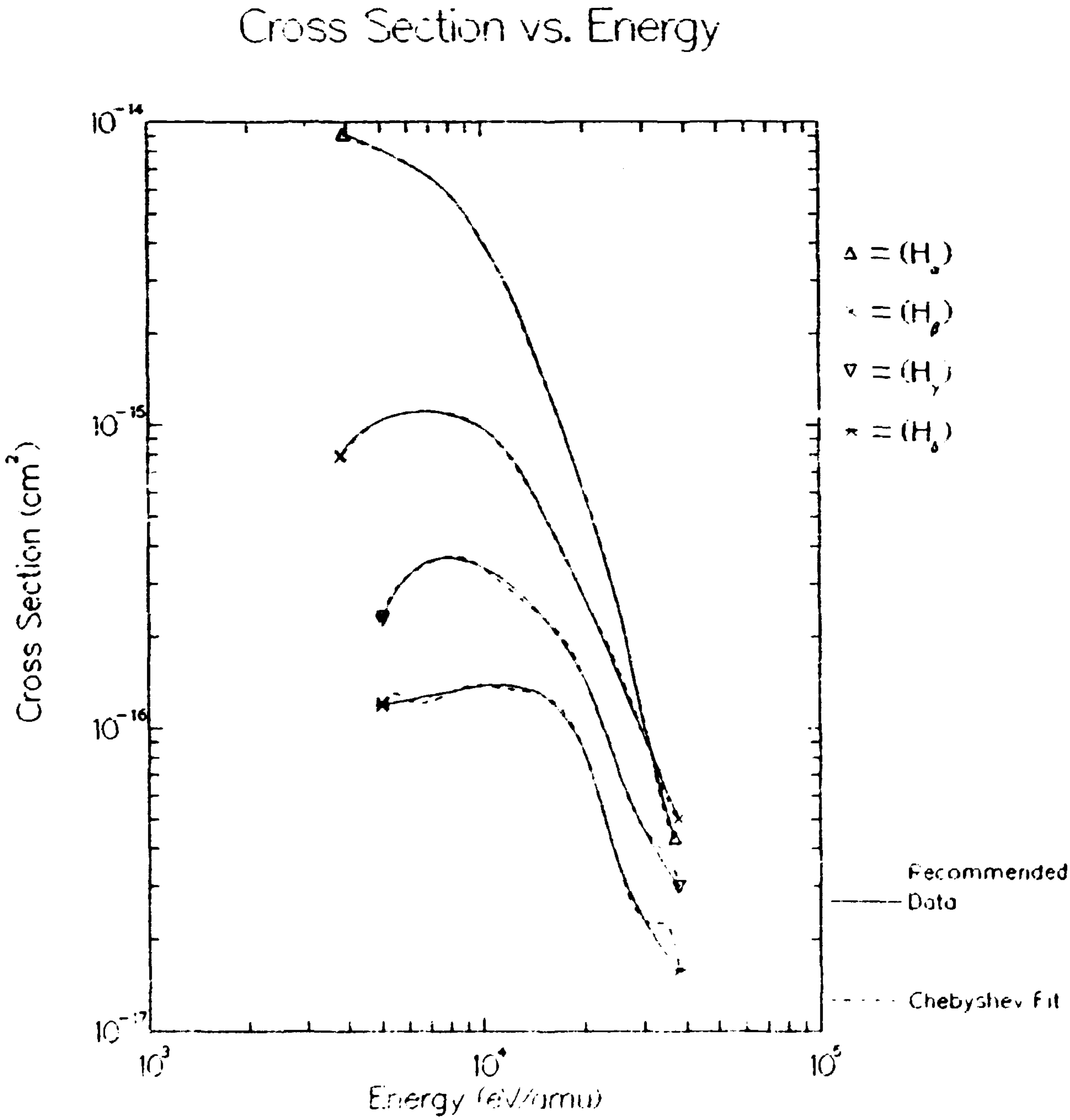
<u>Chebyshev Fitting Parameters for Cross Sections</u>

	A0	A1	A2	A3	A4	A5	A6	A7	A8
(H_{α})	-68.6366	-2.68265	-.765389	-.0308549	.0354272	.00127287	.0359553	.0365120	.0161142
(H_{β})	-71.6392	-1.46157	-.677621	.0638841	.0375648	.00465953	-.00918230	.0189071	.0164169
(H_{γ})	-72.9366	-1.14183	-.554068	.105201	.0358399	.0591287	-.00855619	-.0336544	-.0423521
(H_{δ})	-74.4125	-.995923	-.511481	-.0119520	.159667	.0670561	-.0432569	-.0655825	-.0724875

The fit represents the (H_{α}) cross section with an rms deviation of 0.6%.
The maximum deviation is 1.0% at 2.0E+04 eV/amu.
The fit represents the (H_{β}) cross section with an rms deviation of 0.0%.
The maximum deviation is 0.0%.
The fit represents the (H_{γ}) cross section with an rms deviation of 0.5%.
The maximum deviation is 1.1% at 8.0E+03 eV/amu.
The fit represents the (H_{δ}) cross section with an rms deviation of 0.0%.
The maximum deviation is 0.0%.

See appendix for Chebyshev fit details.

$He^{2+} + Li \rightarrow He^{+}(H_{\alpha}, H_{\beta}, H_{\gamma}, H_{\delta}) + Li^{+}$



C. Cross Sections for Excitation and Spectral Line Emission

(* denotes rate coefficient data also)

C. (Cont'd)

C. (Cont'd)

Excitation Cross Sections for

H + H -> H(2s,2p) + H(Σ)

H(2s)

Energy (eV/amu)	Cross Section (cm^2)
2.0E+03	8.03E-18
3.0E+03	9.80E-18
4.0E+03	1.15E-17
5.0E+03	1.29E-17
6.0E+03	1.43E-17
7.0E+03	1.51E-17
8.0E+03	1.56E-17
9.0E+03	1.59E-17
1.0E+04	1.60E-17
1.5E+04	1.37E-17
2.0E+04	1.04E-17
3.0E+04	6.64E-18
4.0E+04	4.65E-18
5.0E+04	3.48E-18
6.0E+04	2.74E-18
7.0E+04	2.28E-18
8.0E+04	2.02E-18
9.0E+04	1.84E-18

H(2p)

Energy (eV/amu)	Cross Section (cm^2)
4.0E+03	1.62E-17
5.0E+03	2.29E-17
6.0E+03	2.44E-17
7.0E+03	2.47E-17
8.0E+03	2.41E-17
9.0E+03	2.35E-17
1.0E+04	2.28E-17
1.5E+04	1.92E-17
2.0E+04	1.58E-17
3.0E+04	1.17E-17

<u>References:</u> 15, 592, 593, 594, 595, 596, 597, 598

<u>Accuracy:</u> Unknown

<u>Notes:</u> (1) The symbol H(Σ) denotes that the target atom may be left in any [excited] state after the collision. (2) All theoretical treatments of the H + H excitation cross sections are in serious disagreement with experiment and with each other, both in absolute magnitude and energy dependence. For various theoretical treatments see Flannery (Ref. 594 - four state impact parameter method), McLaughlin and Bell (Ref. 595 - close coupling exchange), Shingal et al. (Ref. 596 - four state semiclassical impact parameter), and Khurana et al. (Ref. 597 - 2nd Born approximation and also distorted wave Born).

<u>Chebyshev Fitting Parameters for Cross Sections</u>

H(2s) E_{min} = 2.0E+03, E_{max} = 9.0E+04
H(2p) E_{min} = 4.0E+03, E_{max} = 3.0E+04

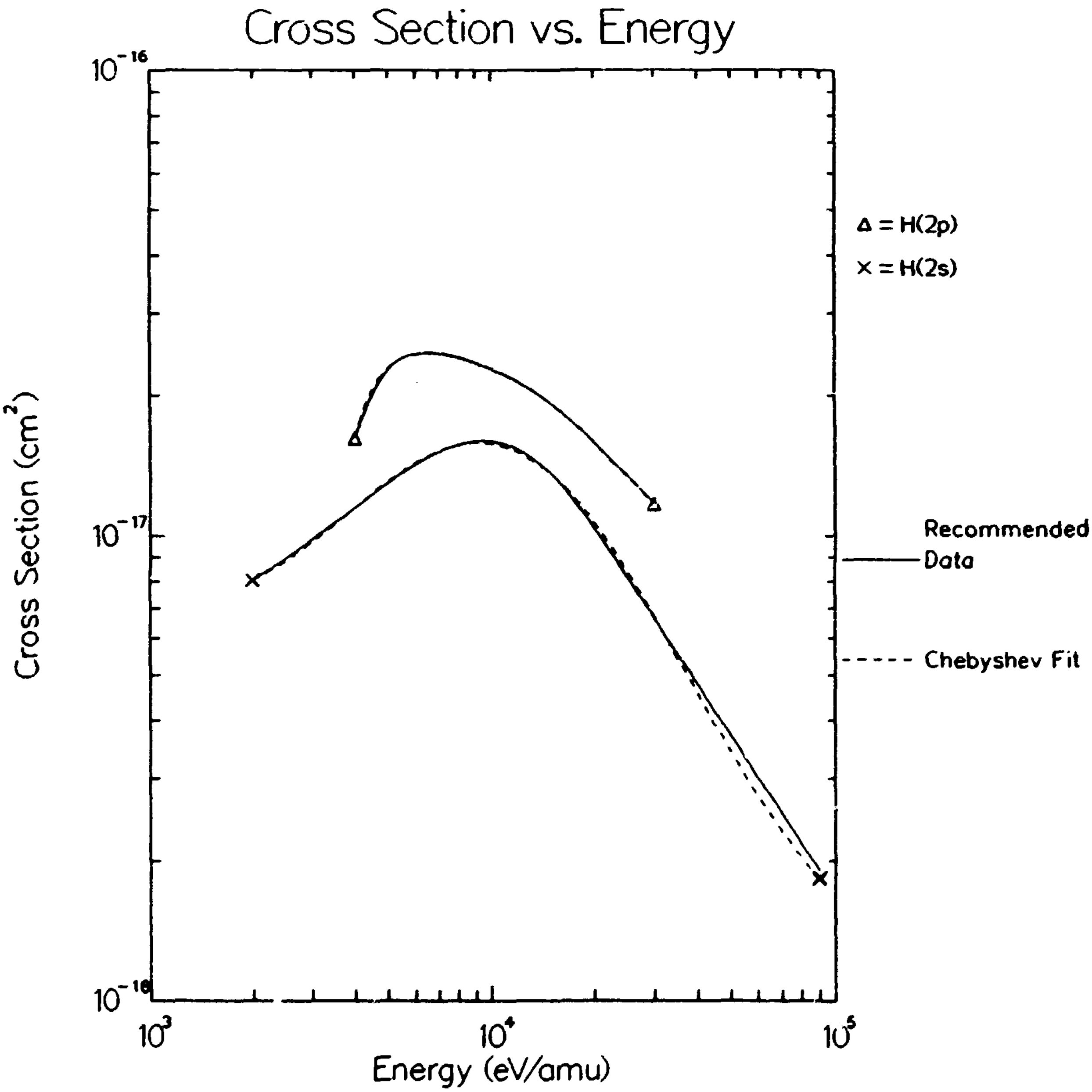
	A0	A1	A2	A3	A4	A5	A06
H(2s)	-79.[illegible]098	-.784062	-.651723	.0462865	.114234	-.00[illegible]87654	-.0114391
H(2p)	-77.1082	-.256046	-.232311	.0701782	-.0315673	.0229762	.00612383

The fit represents the H(2s) cross section with an rms deviation of 1.2%. The maximum deviation is 2.8% at 2.0E+04 eV/amu.

The fit represents the H(2p) cross section with an rms deviation of 0.3%. The maximum deviation is 0.6% at 6.0E+03 eV/amu.

See appendix for Chebyshev fit details.

H + H -> H(2s,2p)


Cross Section vs. Energy
10^{-16}
10^{-17}
10^{-18}
Cross Section (cm^2)
10^3
10^4
10^5
Energy (eV/amu)
Δ = H(2p)
× = H(2s)
Recommended Data
Chebyshev Fit

Excitation and Spectral Line Emission Cross Sections for

$$H + H \rightarrow H(3s,3p,3d) + H(\Sigma)$$
$$\rightarrow \text{Balmer-}\alpha \text{ emission}$$

H(3s)		H(3p)		H(3d)		Hα	
Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)
1.0E+03	1.68E-18	1.0E+03	7.24E-19	1.0E+03	2.53E-20	1.0E+03	1.87E-18
2.0E+03	6.73E-18	2.0E+03	5.76E-18	2.0E+03	3.22E-19	2.0E+03	8.27E-18
4.0E+03	1.22E-17	4.0E+03	1.45E-17	4.0E+03	1.14E-18	4.0E+03	1.45E-17
7.0E+03	8.59E-18	6.0E+03	1.63E-17	6.0E+03	1.39E-18	7.0E+03	1.20E-17
1.0E+04	6.47E-18	7.0E+03	1.59E-17	7.0E+03	1.38E-18	1.0E+04	9.34E-18
2.0E+04	3.48E-18	1.0E+04	1.34E-17	1.0E+04	1.18E-18	2.0E+04	5.05E-18
4.0E+04	1.76E-18	2.0E+04	7.42E-18	2.0E+04	6.78E-19	4.0E+04	2.68E-18
7.0E+04	1.07E-18	4.0E+04	4.27E-18	4.0E+04	4.11E-19	7.0E+04	1.71E-18
1.0E+05	7.69E-19	7.0E+04	3.11E-18	7.0E+04	2.99E-19	1.0E+05	1.32E-18
2.0E+05	4.08E-19	1.0E+05	2.55E-18	1.0E+05	2.44E-19	2.0E+05	7.60E-19
4.0E+05	2.11E-19	2.0E+05	1.61E-18	2.0E+05	1.50E-19	4.0E+05	3.97E-19
7.0E+05	1.20E-19	4.0E+05	9.29E-19	4.0E+05	8.23E-20	7.0E+05	2.32E-19
1.0E+06	8.72E-20	7.0E+05	5.57E-19	7.0E+05	4.91E-20	1.0E+06	1.65E-19
		1.0E+06	4.00E-19	1.0E+06	3.56E-20		

<u>Reference:</u> 598

<u>Accuracy:</u> Unknown

<u>Notes:</u> (1) We are not aware of any experimental data for the excitation of the n = 3 levels of H by H impact. (2) The data shown are obtained from McLaughlin and Bell (Ref. 598) using first order exchange theory. They also calculated these excitation cross sections using the first Born approximation. Below 10^5 eV/amu the Born calculations are as much as a factor of 5 below the data obtained from the exchange theory. These data are placed here to provide an insight as to the magnitude and energy dependence of the n = 3 excitation cross sections. (3) The Hα emission cross section is given by Hα = σ(3s) + 0.118 σ(3p) + σ(3d). (4) The symbol Σ denotes that the target atom may be left in any state.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

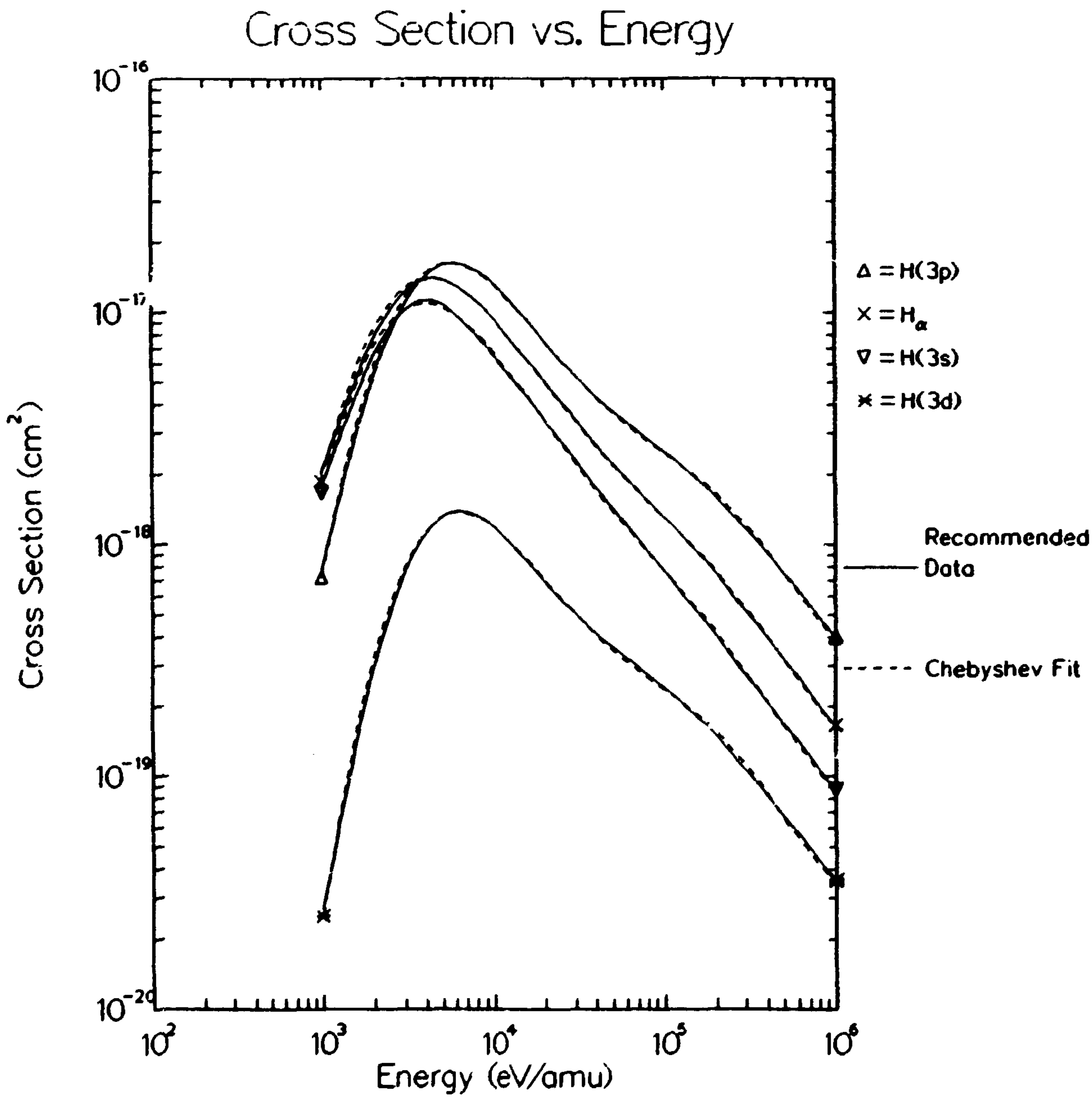
H(3s)	E_{min} = 1.0E+03 eV/amu,	E_{max} = 1.0E+06 eV/amu
H(3p)	E_{min} = 1.0E+03 eV/amu,	E_{max} = 1.0E+06 eV/amu
H(3d)	E_{min} = 1.0E+03 eV/amu,	E_{max} = 1.0E+06 eV/amu
Hα	E_{min} = 1.0E+03 eV/amu,	E_{max} = 1.0E+06 eV/amu

	A0	A1	A2	A3	A4	A5	A6
H(3s)	-82.5799	-2.05302	-.908967	.534101	-.249917	.0520636	.0418468
H(3p)	-81.2005	-.954175	-1.20328	.638574	-.328341	.0263311	.0719202
H(3d)	-86.3820	-.612848	-1.47849	.754596	-.362929	.0428931	.0876543
Hα	-81.7586	-1.76650	-.933877	.519497	.264797	.0406777	.0464266

The fit represents the H(3s) cross section with an rms deviation of 4.2%.
The maximum deviation is 6.2% at 2.0E+03 eV/amu.
The fit represents the H(3p) cross section with an rms deviation of 2.0%.
The maximum deviation is 2.9% at 2.0E+05 eV/amu.
The fit represents the H(3d) cross section with an rms deviation of 2.6%.
The maximum deviation is 4.6% at 2.0E+04 eV/amu.
The fit represents the Hα cross section with an rms deviation of 1.6%.
The maximum deviation is 2.2% at 2.0E+03 eV/amu.

See appendix for Chebyshev fit details.

H + H -> H(3s,3p,3d,H_α)



Projectile Excitation and Target Dissociative Excitation Cross Sections for

$$H + H_2 \rightarrow H(2s,2p) + \Sigma H_2$$
$$\rightarrow \Sigma H + H(2s,2p) + H$$

H(2s)[proj.]		H(2p)[proj.]		H(2s)[targ.]		H(2p)[targ.]	
Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)
2.0E+03	5.56E-18	5.0E+03	4.13E-17	5.0E+03	2.78E-18	5.0E+03	6.90E-18
3.0E+03	6.69E-18	6.0E+03	3.53E-17	6.0E+03	3.26E-18	6.0E+03	8.60E-18
4.0E+03	7.62E-18	7.0E+03	3.11E-17	7.0E+03	3.57E-18	7.0E+03	9.97E-18
5.0E+03	8.47E-18	8.0E+03	2.79E-17	8.0E+03	3.75E-18	8.0E+03	1.12E-17
6.0E+03	9.19E-18	9.0E+03	2.61E-17	9.0E+03	3.81E-18	9.0E+03	1.22E-17
7.0E+03	9.90E-18	1.0E+04	2.49E-17	1.0E+04	3.86E-18	1.0E+04	1.32E-17
8.0E+03	1.05E-17	1.5E+04	2.40E-17	1.3E+04	3.88E-18	1.3E+04	1.39E-17
9.0E+03	1.11E-17	2.0E+04	2.08E-17	1.5E+04	3.83E-18	1.5E+04	1.37E-17
1.0E+04	1.16E-17	2.5E+04	1.78E-17	2.0E+04	3.68E-18	2.0E+04	1.16E-17
1.5E+04	1.32E-17			2.5E+04	3.53E-18	2.5E+04	9.03E-18
2.0E+04	1.20E-17						
2.5E+04	9.84E-18						

References: 124, 592

Accuracy: Unknown

Notes: (1) H is considered the projectile and H_2 the target. (2) The symbol Σ denotes all states in which the products are left. (3) The n=2->1 transition is at wavelength 121.57nm.

Chebyshev Fitting Parameters for Cross Sections

H(2s) proj. E_{min} = 2.0E+03 eV/amu, E_{max} = 2.5E+04 eV/amu
H(2p) proj. E_{min} = 5.0E+03 eV/amu, E_{max} = 2.5E+04 eV/amu
H(2s) targ. E_{min} = 5.0E+03 eV/amu, E_{max} = 2.5E+04 eV/amu
H(2p) targ. E_{min} = 5.0E+03 eV/amu, E_{max} = 2.5E+04 eV/amu

	A0	A1	A2	A3	A4	A5	A6
H(2s) proj.	-78.5298	.381193	-.153241	-.0981960	-.0354361	-.00839689	.00756242
H(2p) proj.	-76.3640	-.378165	.0409330	-.0624299	-.0180012	.0197844	.0125324
H(2s) targ.	-80.3831	.0903819	-.109415	.0282363	-.00676568	.000903034	.00303522
H(2p) targ.	-78.2178	.158165	-.269341	-.0251991	.00457227	.00145158	-.00685275

The fit represents the H(2s) proj. cross section with an rms deviation of 0.5%. The maximum deviation is 0.8% at 1.0E+04 eV/amu.

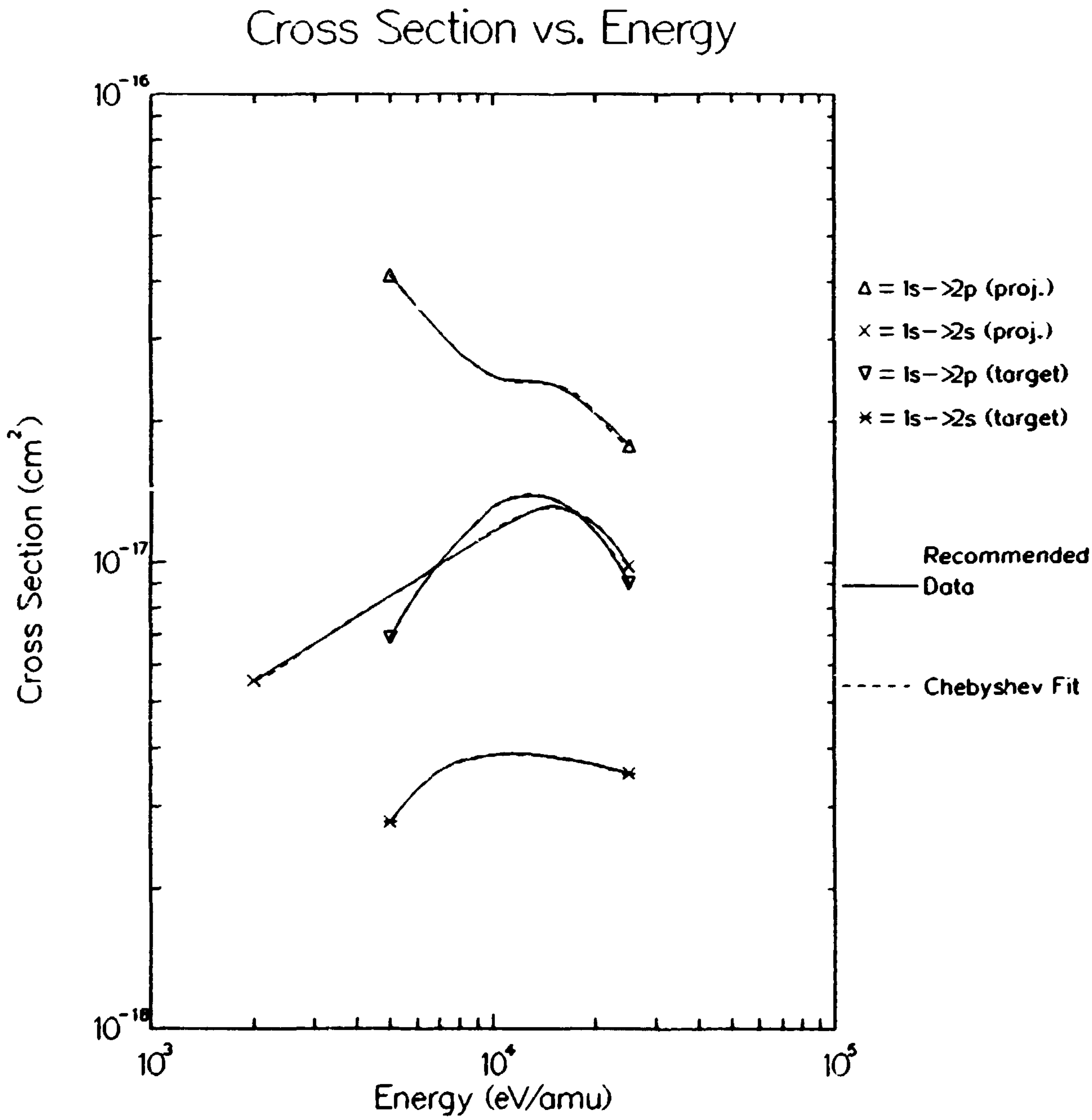
The fit represents the H(2p) proj. cross section with an rms deviation of 0.2%. The maximum deviation is 0.3% at 8.0E+03 eV/amu.

The fit represents the H(2s) targ. cross section with an rms deviation of 0.2%. The maximum deviation is 0.3% at 9.0E+03 eV/amu.

The fit represents the H(2p) targ. cross section with an rms deviation of 0.4%. The maximum deviation is 0.7% at 1.3E+04 eV/amu.

See appendix for Chebyshev fit details.

$H + H_2 \rightarrow H(2s,2p) + \Sigma H_2$
$H + H_2 \rightarrow \Sigma H + H(2s,2p) + H$



Total Spectral Line Emission Cross Sections for

$H + H_2 \rightarrow H(\text{Lyman-}\alpha)$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.5E+03	5.38E+07	7.17E-17
2.0E+03	6.21E+07	6.67E-17
3.0E+03	7.61E+07	5.98E-17
4.0E+03	8.79E+07	5.38E-17
5.0E+03	9.82E+07	4.91E-17
6.0E+03	1.08E+08	4.50E-17
7.0E+03	1.16E+08	4.22E-17
8.0E+03	1.24E+08	4.04E-17
9.0E+03	1.32E+08	3.92E-17
1.0E+04	1.39E+08	3.80E-17
1.5E+04	1.70E+08	3.48E-17
2.0E+04	1.96E+08	3.20E-17
2.5E+04	2.20E+08	2.97E-17
3.0E+04	2.41E+08	2.81E-17
4.0E+04	2.78E+08	2.52E-17
5.0E+04	3.11E+08	2.28E-17
6.0E+04	3.40E+08	2.15E-17
7.0E+04	3.68E+08	2.06E-17
8.0E+04	3.93E+08	1.98E-17
9.0E+04	4.17E+08	1.92E-17
1.0E+05	4.39E+08	1.88E-17
1.3E+05	5.01E+08	1.77E-17

<u>References:</u> 124, 194, 333

<u>Accuracy:</u> Unknown

<u>Note:</u> The total spectral line emission includes radiation from excitation of the H projectile and the dissociative excitation of the H_2 target.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

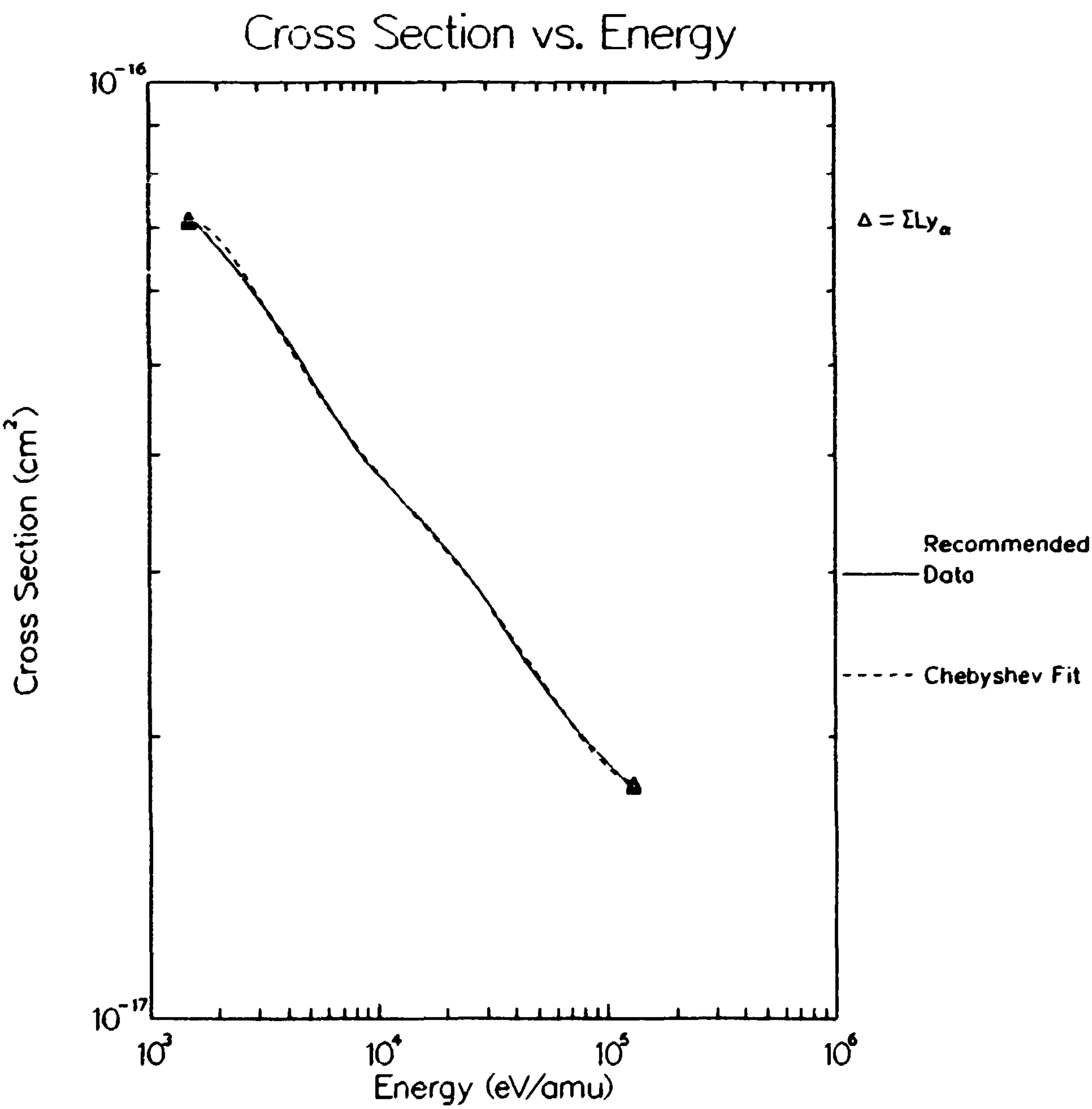
E_{min} = 1.5E+03 eV/amu, E_{max} = 1.3E+05 eV/amu

A0	A1	A2	A3	A4	A5	A6
-75.7615	-.720784	.0118[illegible]	.00540110	-.00257496	.0252003	-.00232715

The fit represents the above cross section with an rms deviation of 1.2%
The maximum deviation is 2.4% at 2.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$H + H_2 \rightarrow \Sigma Ly_\alpha$



Excitation Cross Sections for

$$H + H_2 \rightarrow H(3s) + H_2$$
$$\rightarrow H(3p+3d) + H_2$$

H(3s) Energy (eV/amu)	H(3s) Cross Section (cm^2)	H(3p+3d) Energy (eV/amu)	H(3p+3d) Cross Section* (cm^2)
2.0E+02	1.84E-18	2.0E+02	5.72E-18
4.0E+02	4.61E-18	4.0E+02	1.01E-17
6.4E+02	5.66E-18	7.0E+02	1.25E-17
7.0E+02	5.61E-18	1.0E+03	1.35E-17
1.0E+03	4.95E-18	1.5E+03	1.28E-17
1.5E+03	3.53E-18	2.0E+03	1.17E-17
2.0E+03	2.96E-18	3.0E+03	8.66E-18
4.0E+03	2.43E-18	4.0E+03	6.34E-18
5.0E+03	2.36E-18	7.0E+03	3.91E-18
7.0E+03	2.46E-18	1.0E+04	3.64E-18
1.0E+04	3.21E-18	1.5E+04	3.13E-18
1.5E+04	4.07E-18	2.0E+04	2.13E-18
2.0E+04	4.41E-18	4.0E+04	1.29E-18
2.3E+04	4.50E-18	7.0E+04	1.17E-18
2.5E+04	4.46E-18	1.0E+05	1.16E-18
4.0E+04	3.59E-18		
7.0E+04	2.86E-18		
1.0E+05	2.73E-18		

* see notes (3) and (4)

References: 133, 500, 601

Accuracy: Unknown

Notes: (1) Because of its much longer lifetime, the 3s excitation is resolvable in the Balmer-α emission. (2) The 3s cross section represents that for excitation of the H projectile only. (3) The cross section labelled H(3p + 3d) is determined by subtracting $\sigma(3s)$ from the total Balmer-α emission cross section, and therefore represents $\sigma(3d) + 0.12\ \sigma(3p)$ because of branching ratios. (4) For energies above 2 keV/amu, the H(3p + 3d) cross section represents excitation of the projectile only. At lower energies, contributions from dissociative excitation of H_2 target molecules are included. Comparison of the data suggests that these contributions are small.

Chebyshev Fitting Parameters for Cross Sections

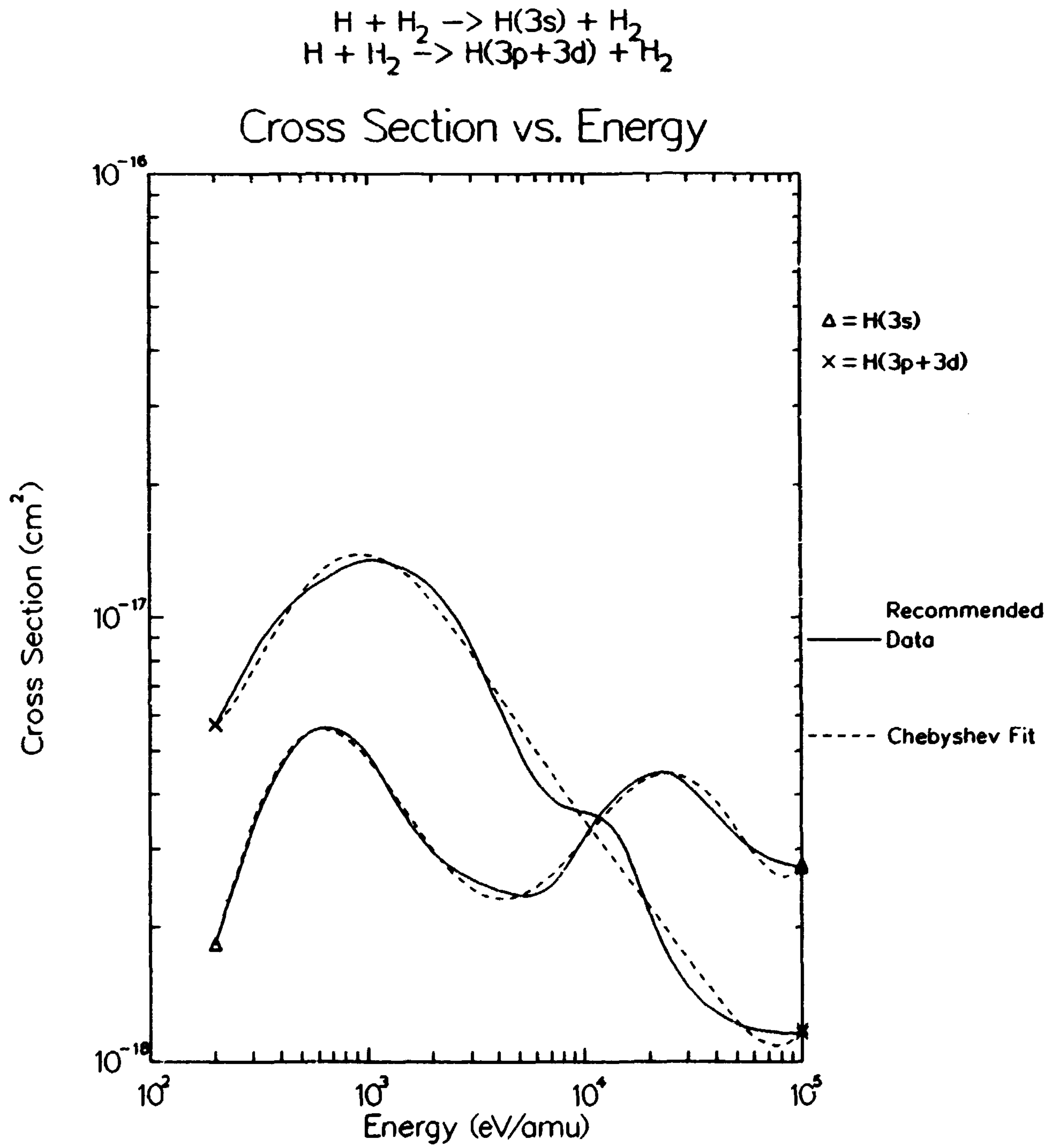
H(3s) E_{min} = 2.0E+02 eV/amu, E_{max} = 1.0E+05 eV/amu
H(3p+3d) E_{min} = 2.0E+02 eV/amu, E_{max} = 1.0E+05 eV/amu

	A0	A1	A2	A3	A4	A5	A6
H(3s)	-80.5534	-.0150679	-.145036	.109627	-.341180	.113781	.131159
H(3p+3d)	-80.1203	-1.13376	-.496856	.359704	.00520846	-.0168457	.0653151

The fit represents the H(3s) cross section with an rms deviation of 3.2%. The maximum deviation is 7.0% at 4.0E+04 eV/amu.

The fit represents the H(3p+3d) cross section with an rms deviation of 7.1%. The maximum deviation is 14.5% at 7.0E+03 eV/amu.

See appendix for Chebyshev fit details.


H + H2 -> H(3s) + H2
H + H2 -> H(3p+3d) + H2
Cross Section vs. Energy
10^-16
10^-17
10^-18
Cross Section (cm^2)
10^2
10^3
10^4
10^5
Energy (eV/amu)
Δ = H(3s)
× = H(3p+3d)
Recommended Data
Chebyshev Fit

Total Spectral Line Emission Cross Sections for

$H + H_2 \rightarrow$ (Balmer-α)

Total ($H + H_2$)		H_2 (targ.)		H (proj.)	
Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)
5.0E+01	1.98E-19	2.0E+03	1.90E-18	2.0E+03	1.58E-17
7.0E+01	6.35E-19	3.0E+03	1.87E-18	3.0E+03	1.14E-17
1.0E+02	1.67E-18	4.0E+03	1.90E-18	4.0E+03	9.06E-18
1.5E+02	4.93E-18	5.0E+03	1.95E-18	5.0E+03	7.61E-18
2.0E+02	7.69E-18	6.0E+03	2.02E-18	6.0E+03	6.83E-18
4.0E+02	1.47E-17	7.0E+03	2.11E-18	7.0E+03	6.54E-18
7.0E+02	1.80E-17	8.0E+03	2.24E-18	7.5E+03	6.52E-18
9.0E+02	1.84E-17	9.0E+03	2.37E-18	8.0E+03	6.62E-18
1.0E+03	1.82E-17	1.0E+04	2.54E-18	9.0E+03	6.88E-18
1.5E+03	1.75E-17	1.5E+04	2.94E-18	1.0E+04	7.04E-18
2.0E+03	1.56E-17	2.0E+04	3.15E-18	1.5E+04	7.11E-18
4.0E+03	1.10E-17	2.3E+04	3.18E-18	2.0E+04	6.69E-18
7.0E+03	8.76E-18	3.0E+04	2.89E-18	3.0E+04	5.39E-18
8.0E+03	8.69E-18	4.0E+04	2.30E-18	4.0E+04	4.73E-18
1.0E+04	9.54E-18	5.0E+04	1.93E-18	5.0E+04	4.43E-18
1.4E+04	1.01E-17	6.0E+04	1.63E-18	6.0E+04	4.25E-18
2.0E+04	9.84E-18	7.0E+04	1.41E-18	7.0E+04	4.20E-18
4.0E+04	7.14E-18	8.0E+04	1.24E-18	8.0E+04	4.18E-18
7.0E+04	5.26E-18	9.0E+04	1.11E-18	9.0E+04	4.17E-18
1.0E+05	4.61E-18	1.0E+05	1.01E-18	1.0E+05	4.17E-18

References: 133, 500, 601

Accuracy: Unknown

Notes: (1) The total Balmer-α emission cross section Hα is equal to the sum of the emission from the projectile ($H_{P\alpha}$) and the target ($H_{T\alpha}$). (2) Balmer-α radiation is from the n=3->n=2 transition in H with λ = 656.28nm.

Chebyshev Fitting Parameters for Cross Sections

Total	E_{min} = 5.0E+01 eV/amu,	E_{max} = 1.0E+05 eV/amu
H_2	E_{min} = 2.0E+03 eV/amu,	E_{max} = 1.0E+05 eV/amu
H	E_{min} = 2.0E+03 eV/amu,	E_{max} = 1.0E+05 eV/amu

	A0	A1	A2	A3	A4	A5	A6
Total	-79.7992	.953923	-1.39409	.663856	-.262806	-.0749405	.0516520
H_2	-81.5995	-.183064	-.361113	-.185120	.0559114	.0591802	-.0130234
H	-79.0077	-.627859	.128139	-.0950362	.0772477	.0565053	-.0596124

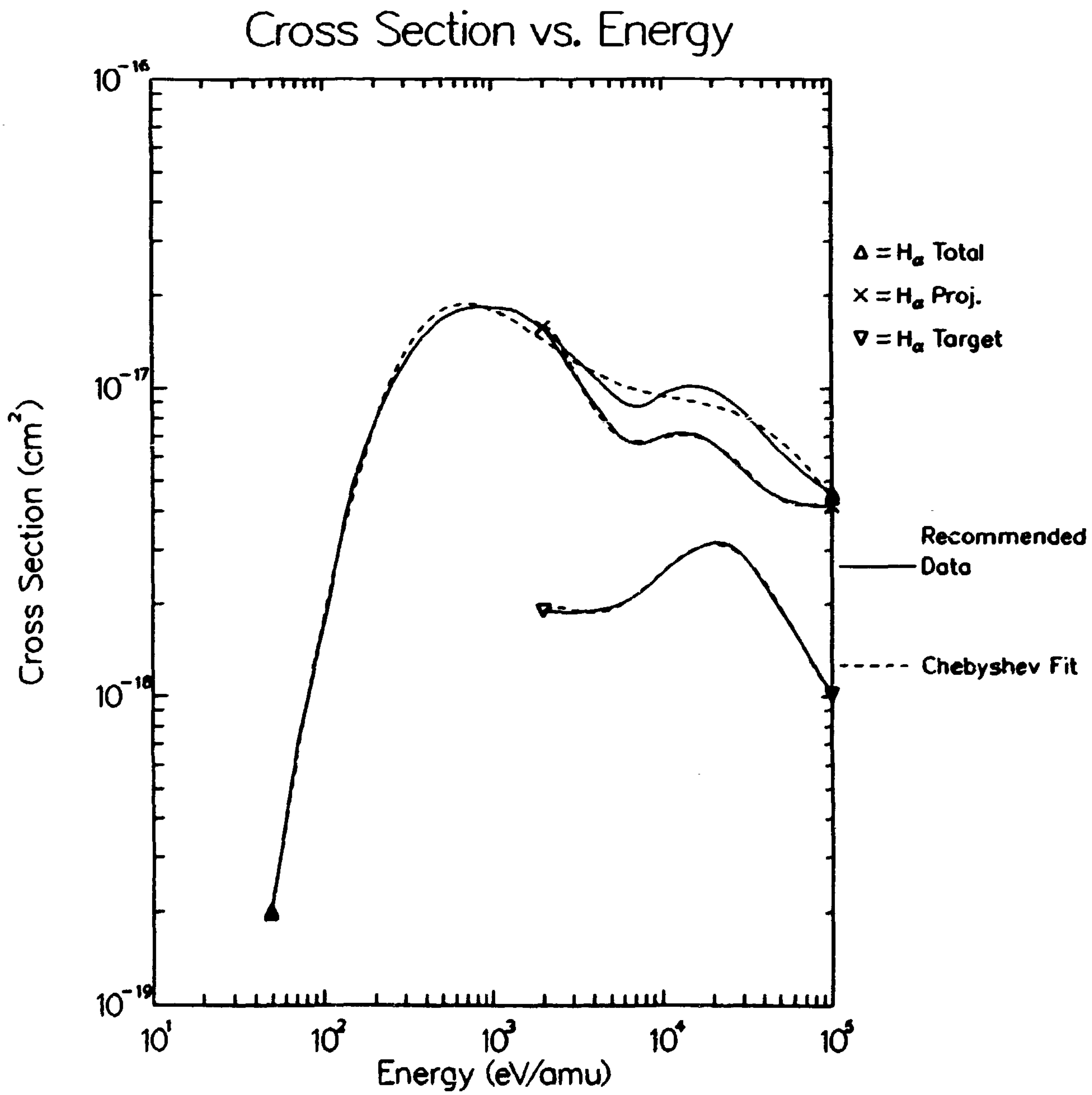
The fit represents the Total cross section with an rms deviation of 7.0%. The maximum deviation is 13.6% at 7.0E+03 eV/amu.

The fit represents the H_2 cross section with an rms deviation of 1.4%. The maximum deviation is 3.0% at 4.0E+04 eV/amu.

The fit represents the H cross section with an rms deviation of 1.9%. The maximum deviation is 3.4% at 3.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$H + H_2 \rightarrow H_\alpha$



Total Excitation and Spectral Line Emission Cross Sections for

$H + H_2 \rightarrow H(4s,4p+4d)$
$\rightarrow H(\text{Balmer-}\beta)$

H(4s)		H(4p+4d)		H(Balmer-β)	
Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)
2.0E+02	2.69E-19	2.0E+02	9.25E-19	6.0E+01	3.13E-20
3.0E+02	5.20E-19	3.0E+02	1.50E-18	7.0E+01	5.98E-20
4.0E+02	8.30E-19	4.0E+02	1.91E-18	1.0E+02	2.19E-19
5.0E+02	1.01E-18	5.0E+02	2.20E-18	1.5E+02	7.38E-19
6.0E+02	1.11E-18	6.0E+02	2.40E-18	2.0E+02	1.24E-18
7.0E+02	1.12E-18	7.0E+02	2.54E-18	4.0E+02	2.67E-18
8.0E+02	1.10E-18	8.0E+02	2.66E-18	7.0E+02	3.66E-18
9.0E+02	1.06E-18	9.0E+02	2.76E-18	1.0E+03	3.90E-18
1.0E+03	1.02E-18	1.0E+03	2.86E-18	1.5E+03	3.95E-18
1.5E+03	8.58E-19	1.3E+03	2.99E-18	2.0E+03	3.69E-18
2.0E+03	7.48E-19	1.5E+03	2.98E-18	2.5E+03	3.37E-18
2.5E+03	6.67E-19	2.0E+03	2.84E-18		
		2.5E+03	2.64E-18		

<u>References:</u> 600, 601

<u>Accuracy:</u> Unknown

<u>Notes:</u> (1) The cross sections include excitation of the projectile H, dissociative excitation of the target H_2, and H Balmer-β line emission from both projectile and target. (2) The Balmer-β radiation has a wavelength of 486.13nm, and corresponds to the n=4->n=2 transition in H.

<u>Chebyshev Fitting Parameters for cross Sections</u>

H(4s)	E_{min} = 2.0E+02 eV/amu,	E_{max} = 2.5E+03 eV/amu
H(4p+4d)	E_{min} = 2.0E+02 eV/amu,	E_{max} = 2.5E+03 eV/amu
H(Balmer-β)	E_{min} = 6.0E+01 eV/amu,	E_{max} = 2.5E+03 eV/amu

	A0	A1	A2	A3	A4	A5	A6
H(4s)	-83.7360	.403599	-.495244	.0926298	.0476553	-.0421657	.00996875
H(4p+4d)	-81.4782	.513746	-.253426	.0120434	-.0154708	-.00146007	.00795248
H(Balmer-β)	-82.9678	2.14325	-1.06498	.222304	-.0396703	-.0277369	.0217573

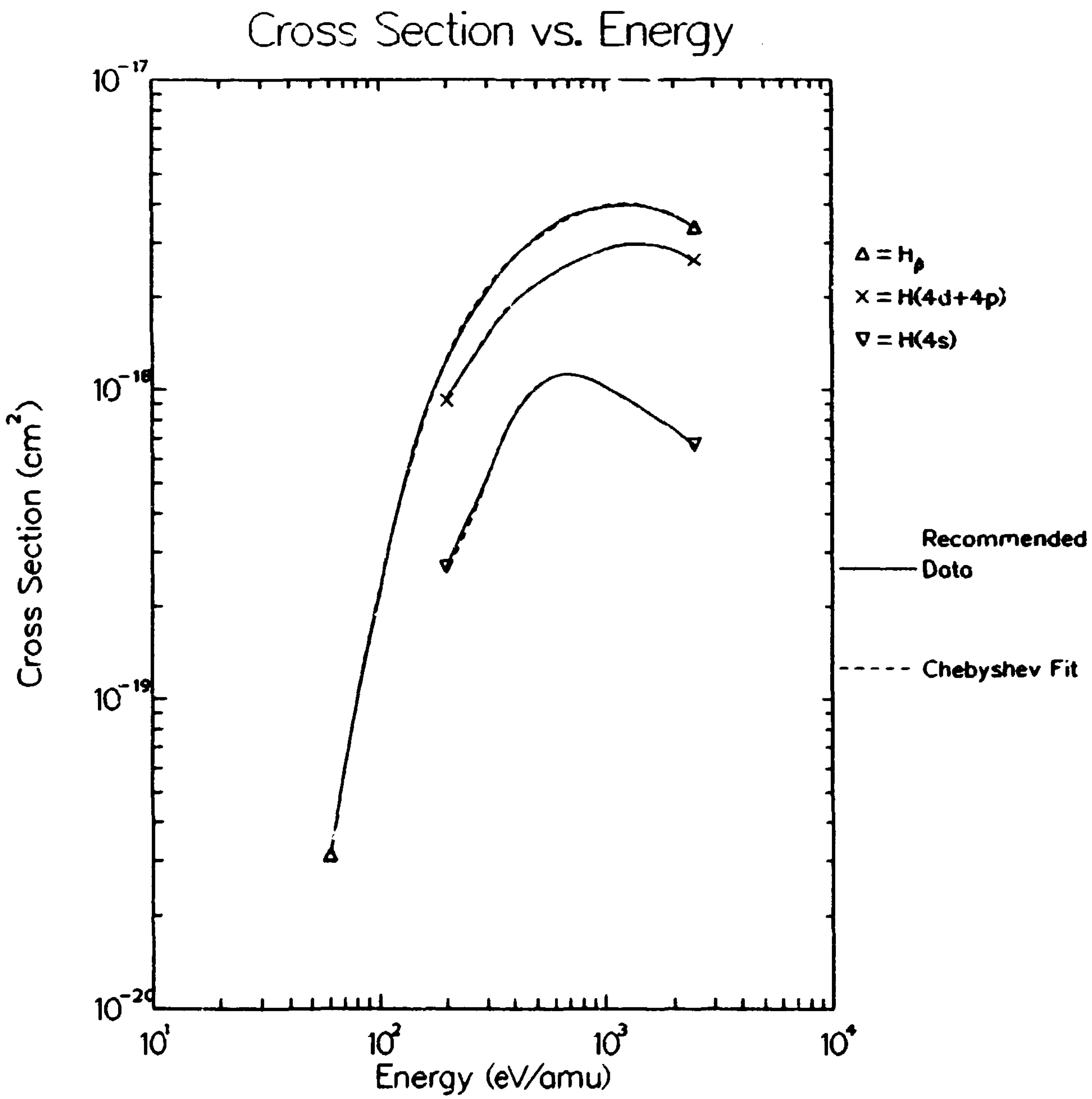
The fit represents the H(4s) cross section with an rms deviation of 0.4%. The maximum deviation is 1.1% at 5.0E+02 eV/amu.

The fit represents the H(4p+4d) cross section with an rms deviation of 0.3%. The maximum deviation is 0.4% at 4.0E+02 eV/amu.

The fit represents the H(Balmer-β) cross section with an rms deviation of 1.6%. The maximum deviation is 2.5% at 1.0E+02 eV/amu.

See appendix for Chebyshev fit details.

$H + H_2 \rightarrow H(4s, 4p+4d)$
$H + H_2 \rightarrow H_\beta$



Total Spectral Line Emission Cross Sections for

$H(2s) + H_2 \rightarrow H(\text{Lyman-}\alpha)$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
7.0E+03	1.16E+08	1.46E-16
8.0E+03	1.24E+08	1.49E-16
9.0E+03	1.32E+08	1.50E-16
1.0E+04	1.39E+08	1.49E-16
1.1E+04	1.46E+08	1.48E-16
1.2E+04	1.52E+08	1.46E-16
1.3E+04	1.58E+08	1.43E-16
1.4E+04	1.64E+08	1.41E-16
1.5E+04	1.70E+08	1.38E-16
1.6E+04	1.76E+08	1.34E-16
1.7E+04	1.81E+08	1.31E-16
1.8E+04	1.86E+08	1.27E-16
1.9E+04	1.91E+08	1.23E-16
2.0E+04	1.96E+08	1.20E-16
2.1E+04	2.01E+08	1.16E-16
2.2E+04	2.06E+08	1.13E-16
2.3E+04	2.11E+08	1.10E-16
2.4E+04	2.15E+08	1.07E-16
2.5E+04	2.20E+08	1.04E-16
2.6E+04	2.24E+08	1.02E-16

References: 333, 692

Accuracy: 60%

Notes: (1) These data include emission from excitation of the projectile H and from the dissociative excitation of H_2. (2) Lyman-α emission occurs at a wavelength of 121.57nm.

Chebyshev Fitting Parameters for Cross Sections

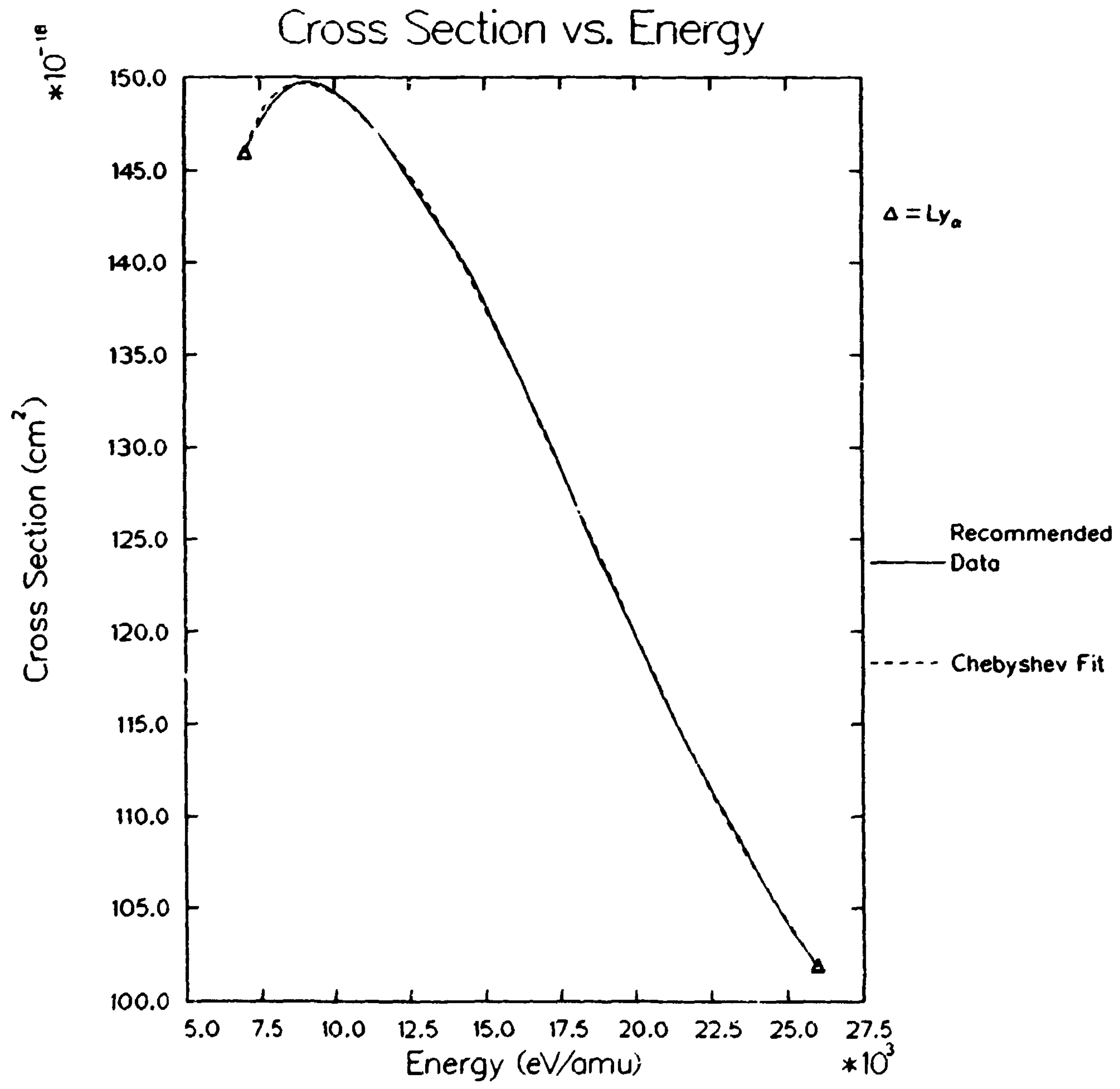
E_{min} = 7.0E+03 eV/amu, E_{max} = 2.6E+04 eV/amu

A0	A1	A2	A3	A4	A5	A6
-73.1370	-.183791	-.0767839	.00130611	.00262379	.00284123	-8.70436E-05

The fit represents the above cross section with an rms deviation of 0.2%. The maximum deviation is 0.4% at 1.3E+04 eV/amu.

See appendix for Chebyshev fit details.

$H(2s) + H_2 \rightarrow Ly_\alpha$



Excitation and Spectral Line Emission Cross Sections for

$H(2s) + H_2 \rightarrow H(3s)$
$\rightarrow H(\text{Balmer-}\alpha)$

H(Balmer-α) Energy (eV/amu)	H(Balmer-α) Cross Section (cm^2)	H(3s) Energy (eV/amu)	H(3s) Cross Section (cm^2)
5.0E+03	2.27E-17	5.0E+03	1.58E-17
6.0E+03	2.29E-17	6.0E+03	1.60E-17
8.0E+03	2.31E-17	8.0E+03	1.64E-17
1.0E+04	2.32E-17	9.0E+03	1.65E-17
1.2E+04	2.33E-17	1.0E+04	1.64E-17
1.4E+04	2.31E-17	1.2E+04	1.60E-17
1.6E+04	2.22E-17	1.4E+04	1.53E-17
1.8E+04	2.06E-17	1.6E+04	1.45E-17
2.0E+04	1.88E-17	1.8E+04	1.36E-17
2.2E+04	1.75E-17	2.0E+04	1.28E-17
2.4E+04	1.66E-17	2.2E+04	1.21E-17
2.6E+04	1.58E-17	2.4E+04	1.15E-17
		2.6E+04	1.10E-17

Reference: 691

Accuracy: 50%

Notes: (1) The Balmer-α cross sections are determined by measuring the emission at λ = 656.28nm from the n = 3 states of H and are related to the level excitation cross sections as follows: $\sigma(H_\alpha) = \sigma(3s) + 0.118\ \sigma(3p) + \sigma(3d)$. The factor 0.118 arises from the branching ratio for decay of the 3p state. (2) The $\sigma(3s)$ have been corrected for cascading.

Chebyshev Fitting Parameters for Cross Sections

H(Balmer-α) E_{min} = 5.0E+03 eV/amu, E_{max} = 2.6E+04 eV/amu
H(3s) E_{min} = 5.0E+03 eV/amu, E_{max} = 2.6E+04 eV/amu

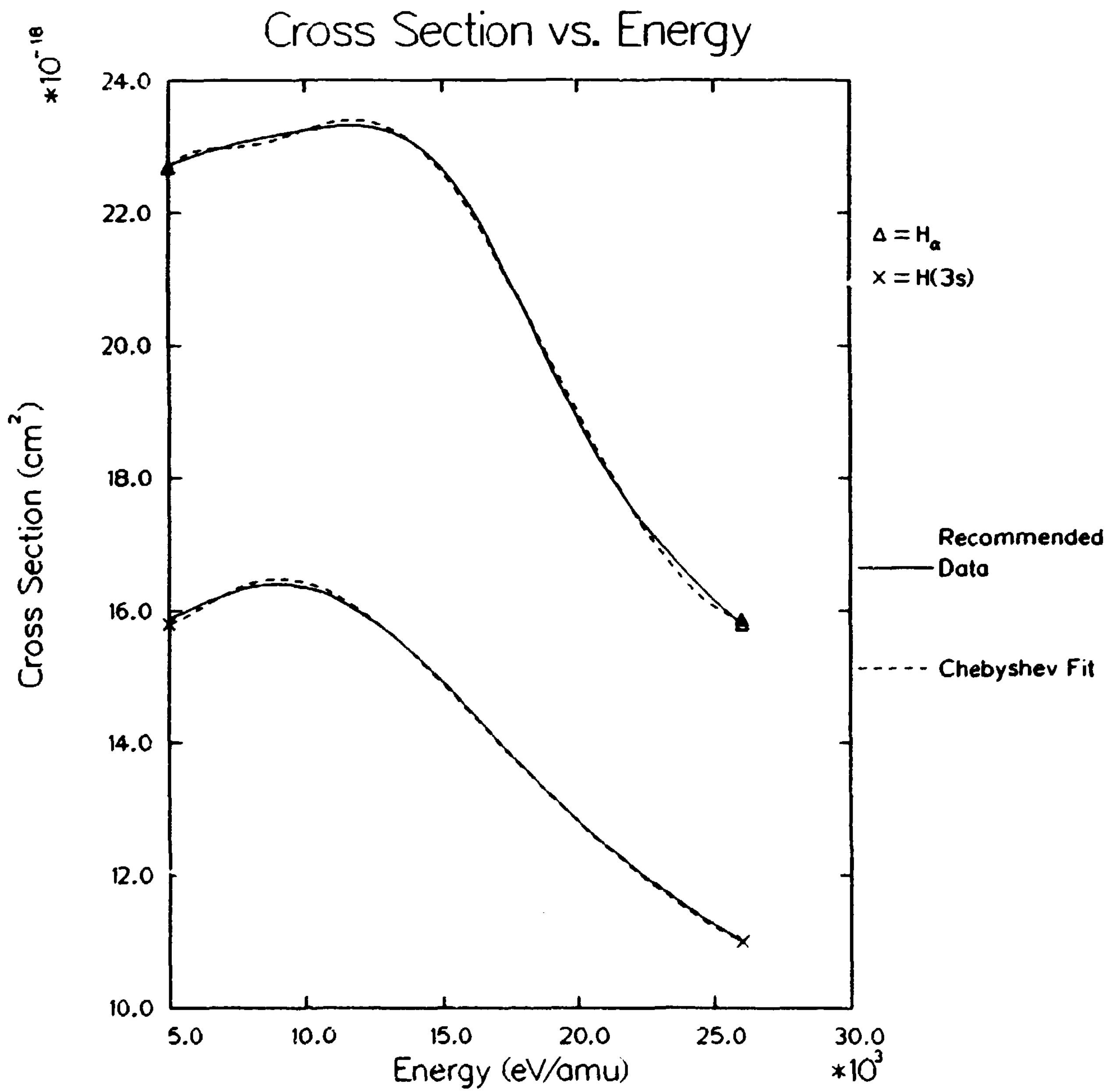
	A0	A1	A2	A3	A4	A5	A6
H(Balmer-α)	-76.8150	-.162721	-.109854	-.0325036	.0085463	.0165529	.00525437
H(3s)	-77.5541	-.175436	-.101810	-.00744771	.0115273	.00202386	-7.45889E-05

The fit represents the H(Balmer-α) cross section with an rms deviation of 0.5%. The maximum deviation is 1.0% at 2.0E+04 eV/amu.

The fit represents the H(3s) cross section with an rms deviation of 0.1%. The maximum deviation is 0.1% at 1.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$H(2s) + H_2 \rightarrow H(3s)$
$H(2s) + H_2 \rightarrow H_\alpha$



Spectral Line Emission Cross Sections for

$H(2s) + He \rightarrow H(\text{Lyman-}\alpha)$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+04	1.39E+08	1.86E-17
1.1E+04	1.46E+08	1.75E-17
1.2E+04	1.52E+08	1.65E-17
1.3E+04	1.58E+08	1.56E-17
1.4E+04	1.64E+08	1.48E-17
1.5E+04	1.70E+08	1.46E-17
1.6E+04	1.76E+08	1.43E-17
1.7E+04	1.81E+08	1.41E-17
1.8E+04	1.86E+08	1.37E-17
1.9E+04	1.91E+08	1.32E-17
2.0E+04	1.96E+08	1.28E-17
2.1E+04	2.01E+08	1.24E-17
2.2E+04	2.06E+08	1.22E-17
2.3E+04	2.11E+08	1.20E-17
2.4E+04	2.15E+08	1.19E-17
2.5E+04	2.20E+08	1.19E-17
2.6E+04	2.24E+08	1.18E-17

Reference: 333

Accuracy: 80%

Note: The H Lyman-α radiation is at a wavelength of 121.57nm.

Chebyshev Fitting Parameters for Cross Sections

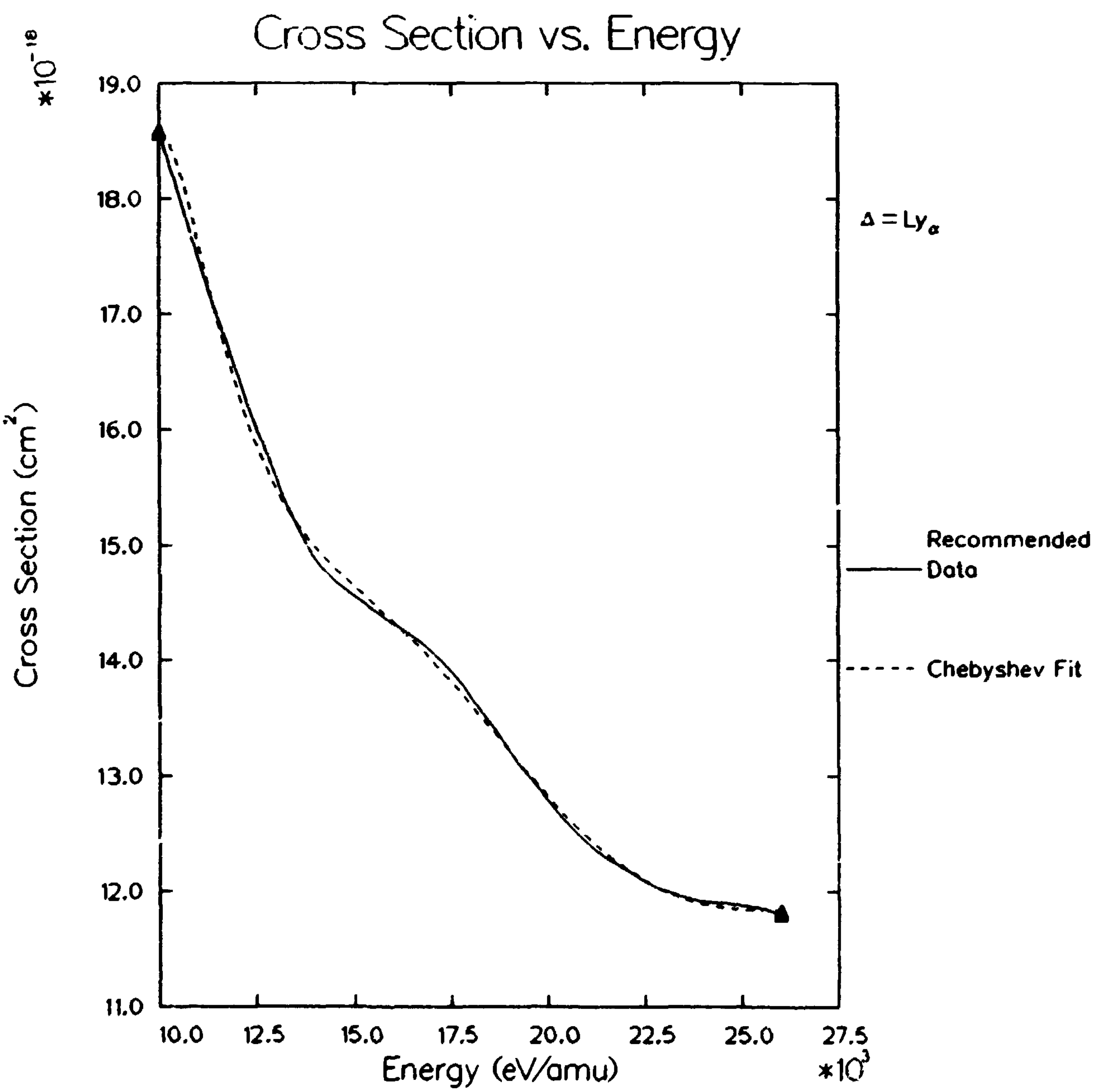
E_{min} = 1.0E+04 eV/amu, E_{max} = 2.6E+04 eV/amu

A0	A1	A2	A3	A4	A5	A6
-77.5542	-.232829	.0249886	-.00284785	.0873114	.0106037	-.00679600

The fit represents the above cross section with an rms deviation of 0.5%.
The maximum deviation is 1.2% at 1.4E+04 eV/amu.

See appendix for Chebyshev fit details.

H(2s) + He –> H(Ly_α)



Excitation and Spectral Line Emission Cross Sections For

H(2s) + He -> H(3s)
-> H(Balmer-α)

H(3s)		H(Balmer-α)	
Energy (eV/amu)	Cross Section (cm^2)	Energy (eV/amu)	Cross Section (cm^2)
5.0E+03	7.05E-18	5.0E+03	1.15E-17
6.0E+03	6.62E-18	6.0E+03	1.11E-17
8.0E+03	5.95E-18	8.0E+03	1.04E-17
1.0E+04	5.53E-18	1.0E+04	9.86E-18
1.2E+04	5.21E-18	1.2E+04	9.35E-18
1.4E+04	5.05E-18	1.4E+04	8.97E-18
1.6E+04	4.95E-18	1.6E+04	8.66E-18
1.8E+04	4.83E-18	1.8E+04	8.37E-18
2.0E+04	4.67E-18	2.0E+04	8.13E-18
2.2E+04	4.44E-18	2.2E+04	7.87E-18
2.4E+04	4.23E-18	2.4E+04	7.64E-18
2.6E+04	4.07E-18	2.6E+04	7.42E-18

<u>Reference:</u> 691

<u>Accuracy:</u> 50%

<u>Notes:</u> (1) The Balmer-α emission cross section is given by σ(3s) + 0.118 σ(3p) + σ(3d). The factor 0.118 is to correct for the branching ratio of the 3p state. (2) The σ(3s) has been corrected for cascading. (3) The Balmer-α radiation is at a wavelength of 656.28nm.

<u>Chebyshev fitting Parameters for Cross Sections</u>

H(3s) E_{min} = 5.0E+03 eV/amu, E_{max} = 2.6E+04 eV/amu
H(Balmer-α) E_{min} = 5.0E+03 eV/amu, E_{max} = 2.6E+04 eV/amu

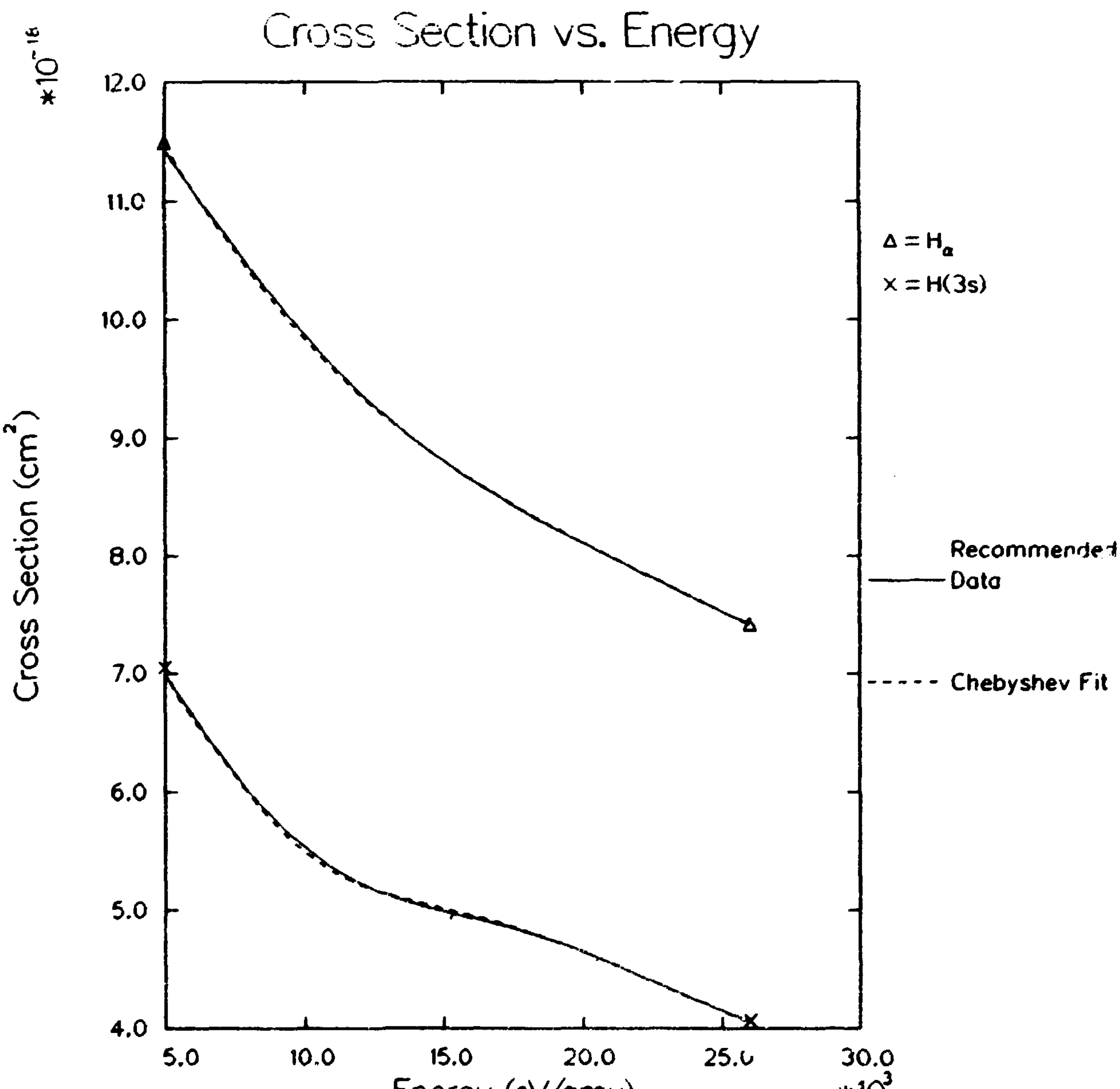
	A0	A1	A2	A3	A4	A5	A6
H(3s)	-79.5230	-.258972	7.15363E-04	-.0165922	-.0141266	-2.93267E-04	.00596856
H(Balmer-α)	-78.4151	-.218179	-.0140659	2.10927E-05	-.00210701	-.00118313	3.35892E-04

The fit represents the H(3s) cross section with an rms deviation of 0.3%. The maximum deviation is 0.5% at 8.0E+03 eV/amu.

The fit represents the H(Balmer-α) cross section with an rms deviation of 0.1%. The maximum deviation is 0.1% at 8.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$H(2s) + He \rightarrow H_\alpha$
$H(2s) + He \rightarrow H(3s)$



Spectral Line Emission Cross Sections for

H + He -> H(Lyman-α)

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
3.0E+01	7.61E+06	1.01E-17
4.0E+01	8.79E+06	2.41E-17
7.0E+01	1.16E+07	4.35E-17
1.0E+02	1.39E+07	5.23E-17
2.0E+02	1.96E+07	6.65E-17
4.0E+02	2.78E+07	6.96E-17
7.0E+02	[illegible].68E+07	6.90E-17
1.0E+03	4.39E+07	6.58E-17
2.0E+03	6.21E+07	5.61E-17
7.0E+03	1.16E+08	2.63E-17
1.0E+04	1.39E+08	1.95E-17
2.0E+04	1.96E+08	1.00E-17
4.0E+04	2.78E+08	4.40E-18
7.0E+04	3.68E+08	1.90E-18
9.0E+04	4.17E+08	1.26E-18

References: 46, 639, 643, 644, 645, 651

Accuracy: 80%

Note: The Lyman-α emission at 121.6nm includes small contributions due to cascade from the n = 3 and higher levels.

Chebyshev Fitting Parameters for Cross Sections

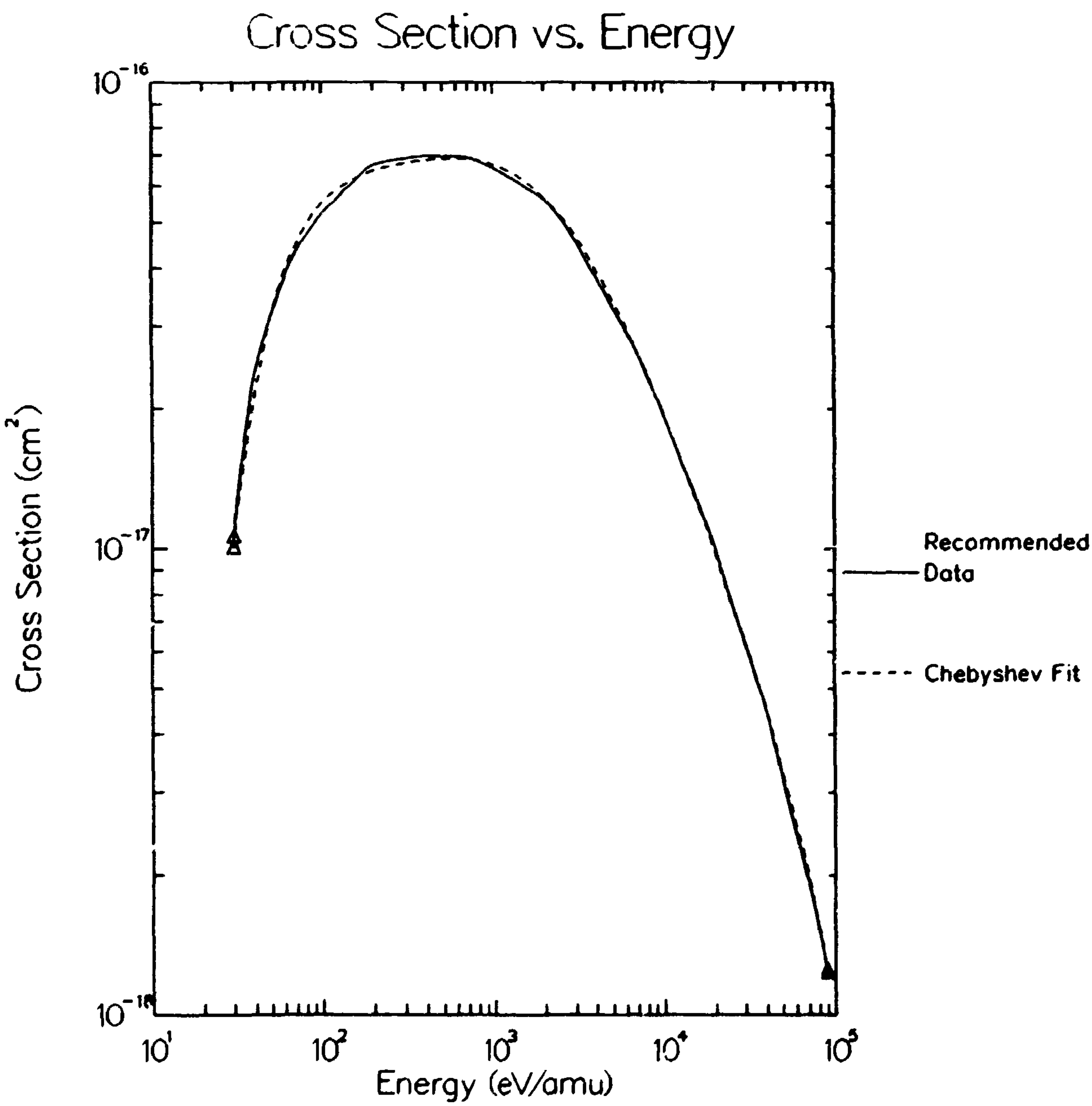
E_{min} = 3.0E+01 eV/amu, E_{max} = 9.0E+04 eV/amu

A0	A1	A2	A3	A4	A5	A6
-77.2423	-1.27626	-1.33104	.105602	-.131109	.0901017	-.0744630

The fit represents the above cross sections with an rms deviation of 3.8%. The maximum deviation is 5.8% at 3.0E+01 eV/amu.

See appendix for Chebyshev fit details.

H + He -> H(Lyman$_\alpha$)



Spectral Line Emission Rate Coefficients for

H + He -> H(Lyman-α)

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

H Temp. (eV)	Equal Temp.	He Temp. (eV) 10.	100.	500.	1000.	5000.	10000.	20000.
1.0E+01	4.37E-11*	4.37E-11*	3.03E-10	1.10E-09	1.64E-09	2.86E-09	3.02E-09	2.85E-09
2.0E+01	1.86E-10*	1.56E-10*	4.13E-10	1.15E-09	1.67E-09	2.87E-09	3.02E-09	2.85E-09
4.0E+01	4.64E-10	3.86E-10	6.06E-10	1.26E-09	1.74E-09	2.87E-09	3.02E-09	2.85E-09
6.0E+01	6.92E-10	5.84E-10	7.71E-10	1.3[illegible]E-09	1.80E-09	2.88E-09	3.02E-09	2.85E-09
8.0E+01	8.80E-10	7.52E-10	9.14E-10	1.44E-09	1.85E-09	2.89E-09	3.02E-09	2.84E-09
1.0E+02	1.04E-09	8.97E-10	1.04E-09	1.51E-09	1.91E-09	2.89E-09	3.02E-09	2.84E-09
2.0E+02	1.61E-09	1.43E-09	1.51E-09	1.84E-09	2.13E-09	2.92E-09	3.01E-09	2.83E-09
4.0E+02	2.22E-09	2.03E-09	2.08E-09	2.26E-09	2.44E-09	2.96E-09	3.01E-09	2.81E-09
6.0E+02	2.55E-09	2.38E-09	2.41E-09	2.53E-09	2.64E-09	2.99E-09	3.00E-09	2.80E-09
8.0E+02	2.74E-09	2.60E-09	2.62E-09	2.69E-09	2.77E-09	3.00E-09	2.99E-09	2.78E-09
1.0E+03	2.86E-09	2.74E-09	2.75E-09	2.81E-09	2.86E-09	3.01E-09	2.98E-09	2.76E-09
2.0E+03	3.02E-09	3.00E-09	3.00E-09	3.01E-09	3.01E-09	2.99E-09	2.90E-09	2.67E-09
4.0E+03	2.85E-09	2.94E-09	2.94E-09	2.93E-09	2.92E-09	2.83E-09	2.71E-09	2.50E-09
6.0E+03	2.62E-09	2.76E-09	2.76E-09	2.75E-09	2.74E-09	2.64E-09	2.54E-09	2.34E-09
8.0E+03	2.42E-09	2.58E-09	2.58E-09	2.57E-09	2.56E-09	2.47E-09	2.38E-09	2.20E-09
1.0E+04	2.24E-09	2.42E-09	2.41E-09	2.41E-09	2.40E-09	2.32E-09	2.24E-09	2.08E-09
1.5E+04	1.88E-09	2.08E-09	2.08E-09	2.07E-09	2.07E-09	2.01E-09	1.94E-09	1.82E-09
2.0E+04	1.61E-09	1.82E-09	1.82E-09	1.81E-09	1.81E-09	1.76E-09	1.71E-09	1.61E-09

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

Chebyshev Fitting Parameters for Rate Coefficients

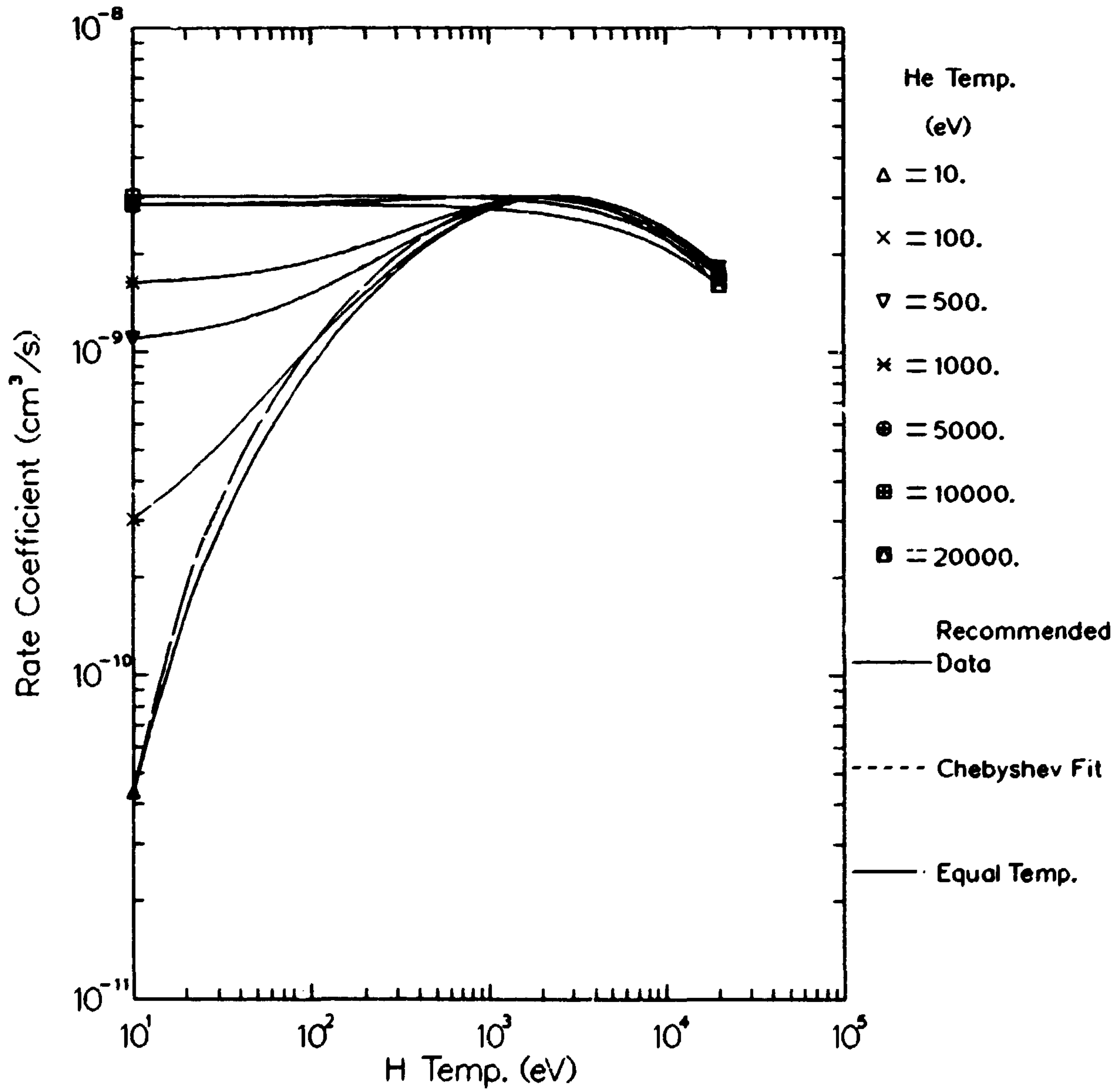
E_{min} = 1.0E+01 eV, E_{max} = 2.0E+04 eV

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
10.	-41.8408	1.73612	-1.00696	.107279	-.0576945	.0226348	-.00478217
100.	-41.0379	1.03224	-.535100	-.134058	.0352264	-.00215004	-.00222457
500.	-40.2599	.410395	-.247167	-.176225	.00337909	.0177532	-.00518248
1000.	-39.9551	.185465	-.185562	-.151177	-.0159001	.0155346	-1.77904E-04
5000.	-39.4938	-.156752	-.142409	-.0847522	-.0277793	-.00101284	.00283315
10000.	-39.4782	-.210389	-.141402	-.0704827	-.0240167	-.00386296	8.94493E-04
20000.	-39.6096	-.218997	-.135741	-.0627840	-.0213979	-.00486653	-4.40643E-04
Equal Temp.	-41.7630	1.61688	-1.06969	.147665	-.0861736	.0380393	-.0145355

See appendix for Chebyshev fit details.

H + He -> H(Lyman$_{\alpha}$)

Maxwellian – Maxwellian



Spectral Line Emission Rate Coefficients for

He + H -> He + H(Lyman-α)

Beam - Maxwellian Rate Coefficients (cm^3/s)

H Temp. (eV)	He Energy (eV/amu) 10000.	20000.	30000.	40000.	50000.	60000.	70000.
1.0E+00	2.68E-09	1.96E-09	1.49E-09	1.22E-09	9.78E-10	8.15E-10	6.98E-10
2.0E+00	2.68E-09	1.96E-09	1.49E-09	1.22E-09	9.78E-10	8.15E-10	6.98E-10
4.0E+00	2.68E-09	1.96E-09	1.49E-09	1.22E-09	9.78E-10	8.15E-10	6.98E-10
7.0E+00	2.68E-09	1.96E-09	1.49E-09	1.22E-09	9.78E-10	8.15E-10	6.97E-10
1.0E+01	2.68E-09	1.96E-09	1.49E-09	1.22E-09	9.78E-10	8.15E-10	6.97E-10
2.0E+01	2.68E-09	1.96E-09	1.49E-09	1.22E-09	9.78E-10	8.15E-10	6.97E-10
4.0E+01	2.68E-09	1.95E-09	1.49E-09	1.22E-09	9.78E-10	8.15E-10	6.97E-10
7.0E+01	2.67E-09	1.95E-09	1.49E-09	1.21E-09	9.78E-10	8.15E-10	6.96E-10
1.0E+02	2.67E-09	1.95E-09	1.49E-09	1.21E-09	9.79E-10	8.15E-10	6.96E-10
2.0E+02	2.66E-09	1.94E-09	1.49E-09	1.21E-09	9.80E-10	8.16E-10	6.95E-10
4.0E+02	2.64E-09	1.93E-09	1.49E-09	1.20E-09	9.81E-10	8.17E-10	6.90E-10
7.0E+02	2.61E-09	1.92E-09	1.49E-09	1.20E-09	9.81E-10	8.17E-10	6.74E-10
1.0E+03	2.58E-09	1.91E-09	1.48E-09	1.20E-09	9.80E-10	8.13E-10	6.58E-10
2.0E+03	2.49E-09	1.88E-09	1.47E-09	1.19E-09	9.73E-10	7.92E-10	6.18E-10*
4.0E+03	2.32E-09	1.81E-09	1.44E-09	1.16E-09	9.43E-10	7.53E-10*	5.81E-10*
7.0E+03	2.12E-09	1.70E-09	1.37E-09	1.11E-09	8.98E-10	7.15E-10*	5.59E-10*
1.0E+04	1.96E-09	1.59E-09	1.30E-09	1.06E-09	8.60E-10*	6.90E-10*	5.47E-10*
2.0E+04	1.53E-09	1.29E-09	1.08E-09*	9.04E-10*	7.54E-10*	6.26E-10*	5.18E-10*

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

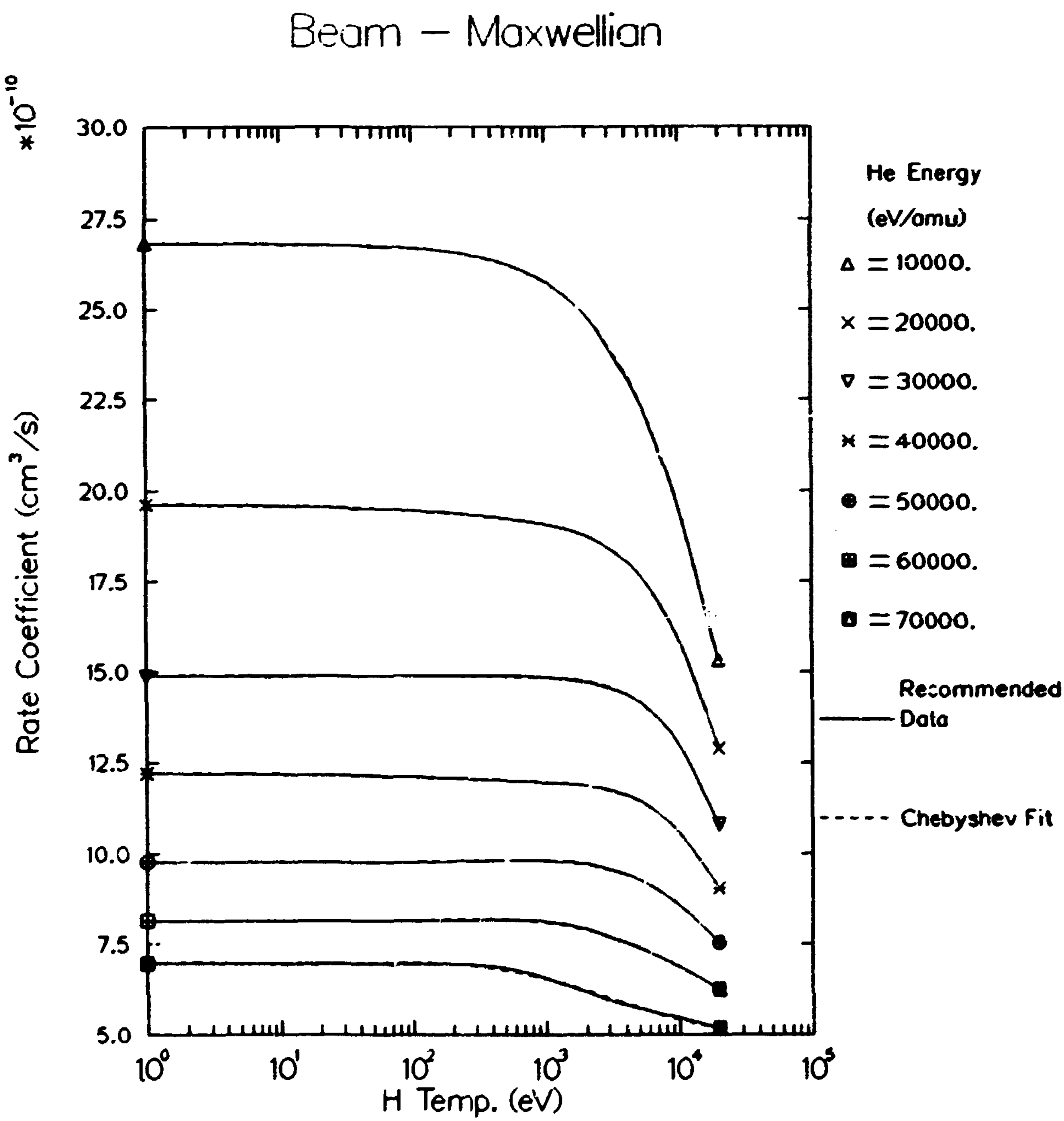
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-39.6987	-.197802	-.134319	-.0723203	-.0304433	-.00974030	-.00251684
20000.	-40.2569	-.138429	-.0956246	-.0581643	-.0310565	-.0136698	-.00449523
30000.	-40.7530	-.0951522	-.0755129	-.0512811	-.0288118	-.0130297	-.00477600
40000.	-41.1570	-.0957055	-.0666225	-.0426726	-.0248045	-.0119141	-.00390059
50000.	-41.5800	-.0821883	-.0654040	-.0420679	-.0203976	-.00620683	2.45851E-06
60000.	-41.9647	-.0972904	-.0701222	-.0364437	-.0102495	.00215119	.00335803
70000.	-42.3333	-.139674	-.0746309	-.0176390	.00996598	.0106575	-8.59901E-05

See appendix for Chebyshev fit details.

H + He -> H(Lyman$_\alpha$)



Excitation Cross Sections for

H + He -> H(2s,2p)

H(2s) Energy (eV/amu)	H(2s) Cross Section (cm^2)	H(2p) Energy (eV/amu)	H(2p) Cross Section (cm^2)
6.0E+01	1.43E-18	2.0E+01	1.87E-18
7.0E+01	1.81E-18	4.0E+01	2.36E-17
1.0E+02	3.04E-18	7.0E+01	4.33E-17
2.0E+02	6.70E-18	1.0E+02	5.22E-17
4.0E+02	1.10E-17	2.0E+02	6.08E-17
7.0E+02	1.29E-17	4.0E+02	6.30E-17
8.6E+02	1.31E-17	7.0E+02	6.11E-17
1.0E+03	1.30E-17	1.0E+03	5.81E-17
2.0E+03	1.10E-17	2.0E+03	5.16E-17
4.0E+03	8.41E-18	4.0E+03	3.73E-17
7.0E+03	6.54E-18	7.0E+03	2.58E-17
1.0E+04	5.51E-18	1.0E+04	1.95E-17
2.0E+04	4.15E-18	2.0E+04	1.01E-17
4.0E+04	3.64E-18	4.0E+04	5.16E-18
7.0E+04	2.67E-18	7.0E+04	4.52E-18
1.0E+05	2.04E-18	1.0E+05	4.41E-18
1.4E+05	1.59E-18		

<u>References:</u> 46, 639, 640, 641, 642, 643, 644, 645, 646, 648, 650

<u>Accuracy:</u> 50%

<u>Notes:</u> (1) Excitation of an excited state is found by measuring the emission from that state and correcting for cascades into that state. (2) The 2s state cross sections are found from the electric-field-induced transition (2s -> 2p -> 1s). (3) If cascading is neglected the Lyman-α emission cross sections are equal to the 2p excitation cross sections.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

H(2s) E_{min} = 6.0E+01 eV/amu, E_{max} = 1.4E+05 eV/amu
H(2p) E_{min} = 2.0E+01 eV/amu, E_{max} = 1.0E+05 eV/amu

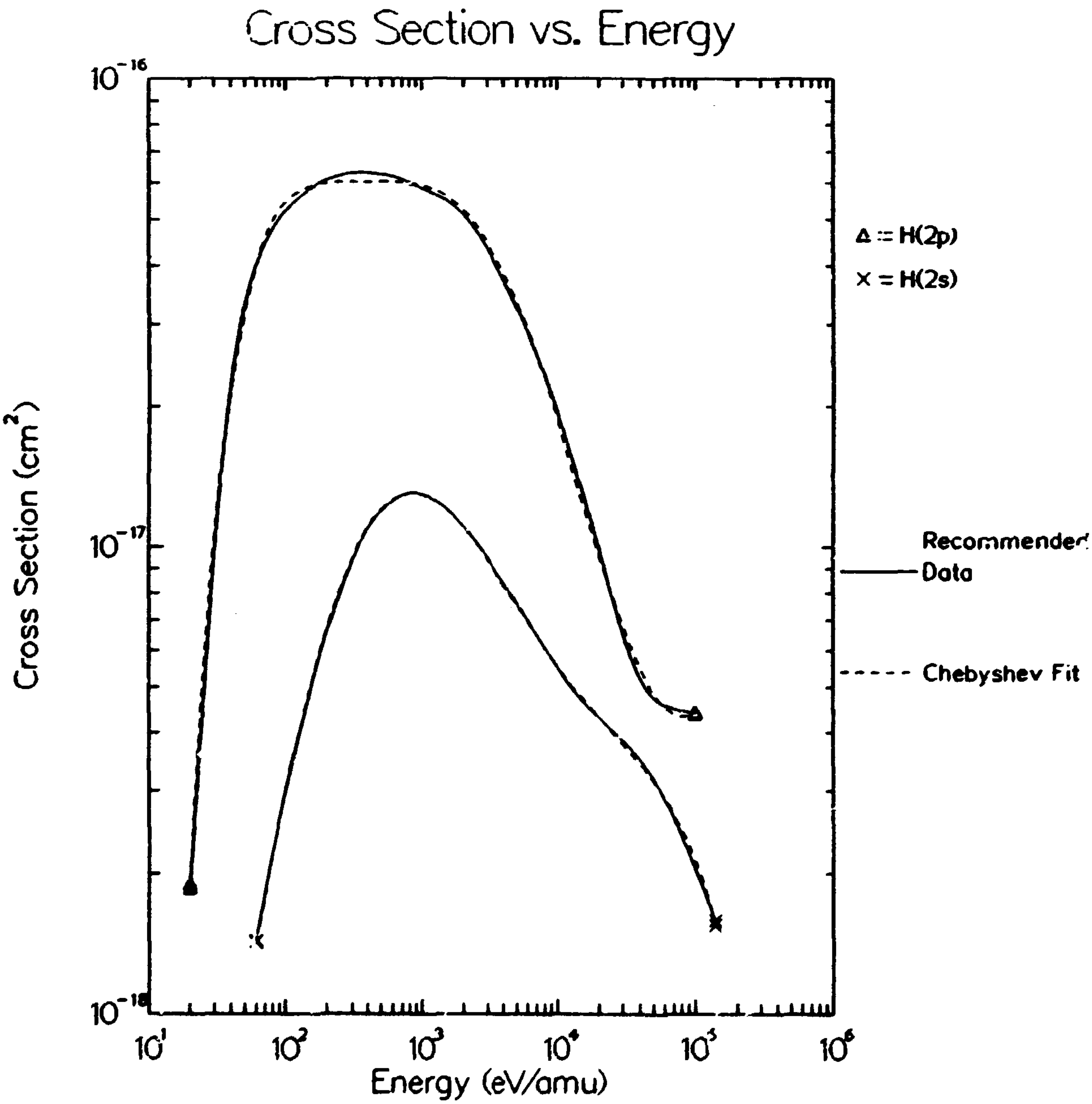
	A0	A1	A2	A3	A4	A5	A6
H(2s)	-80.0462	-.212389	-.933176	.333291	-.0922211	-.0813910	.00473762
H(2p)	-77.4567	-.447338	-1.40980	.577607	-.164863	.291318	-.0758830

The fit represents the H(2s) cross section with an rms deviation of 2.2%. The maximum deviation is 4.3% at 1.0E+05 eV/amu.

The fit represents the H(2p) cross section with an rms deviation of 3.8%. The maximum deviation is 6.9% at 4.0E+04 eV/amu.

See appendix for Chebyshev fit details.

H + He -> H(2s,2p)


Cross Section vs. Energy
Cross Section (cm^2)
10^{-16}
10^{-17}
10^{-18}
10^1
10^2
10^3
10^4
10^5
10^6
Energy (eV/amu)
Δ = H(2p)
× = H(2s)
Recommended Data
Chebyshev Fit

Excitation Cross Sections for

H + He -> H(3s,3p,3d)
-> H(3p+3d)

H(3s)		H(3p)		H(3d)		H(3p+3d)	
Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)
1.5E+02	1.00E-18	5.0E+03	2.41E-18	1.0E+04	1.20E-18	1.5E+02	2.54E-18
2.0E+02	1.84E-18	5.5E+03	2.33E-18	1.3E+04	1.05E-18	2.0E+02	3.28E-18
4.0E+02	4.18E-18	6.0E+03	2.25E-18	1.5E+04	8.64E-19	3.0E+02	4.24E-18
6.0E+02	4.64E-18	7.0E+03	2.08E-18	2.0E+04	5.96E-19	4.0E+02	4.41E-18
7.0E+02	4.57E-18	8.0E+03	1.94E-18	2.5E+04	4.88E-19	5.0E+02	4.33E-18
1.0E+03	3.99E-18	9.0E+03	1.82E-18	3.0E+04	4.48E-19	6.0E+02	4.26E-18
2.0E+03	2.74E-18	1.5E+04	1.38E-18	3.5E+04	4.41E-19	7.0E+02	4.17E-18
4.0E+03	1.90E-18	2.0E+04	1.15E-18			8.0E+02	4.08E-18
7.0E+03	1.46E-18	2.5E+04	1.02E-18			9.0E+02	4.02E-18
1.0E+04	1.26E-18	3.0E+04	9.31E-19			1.0E+03	3.95E-18
2.0E+04	9.39E-19	3.5E+04	8.75E-19			1.5E+03	3.70E-18
3.5E+04	7.98E-19	4.0E+04	8.40E-19			2.0E+03	3.50E-18
						2.5E+03	3.36E-18

References: 500, 601, 645

Accuracy: See notes

Notes: (1) The excitation cross section is found by measuring the emission cross section from that state and correcting for cascade from measurements or using known transition probabilities. (2) Excitation cross sections are often inaccurate due to problems with the absolute calibration of the photon detector.

Chebyshev Fitting Parameters for Cross Sections

H(3s)	E_{min} = 1.5E+02 eV/amu,	E_{max} = 3.5E+04 eV/amu
H(3p)	E_{min} = 5.0E+03 eV/amu,	E_{max} = 4.0E+04 eV/amu
H(3d)	E_{min} = 1.0E+04 eV/amu,	E_{max} = 3.5E+04 eV/amu
H(3p+3d)	E_{min} = 1.5E+02 eV/amu,	E_{max} = 2.5E+03 eV/amu

	A0	A1	A2	A3	A4	A5	A6
H(3s)	-81.8143	-.503310	-.548175	.379377	-.131005	.0123345	.0265299
H(3p)	-82.1981	-.551194	.00275721	.0217903	.00543228	.00224727	-.00356334
H(3d)	-83.6281	-.558730	.0544644	.0648205	-.0102011	-.00660745	.00511818
H(3p+3d)	-80.3437	.0712330	-.198300	.0790347	-.0161614	-.00946588	.0121131

The fit represents the H(3s) cross section with an rms deviation of 0.5%. The maximum deviation is 1.1% at 1.0E+03 eV/amu.

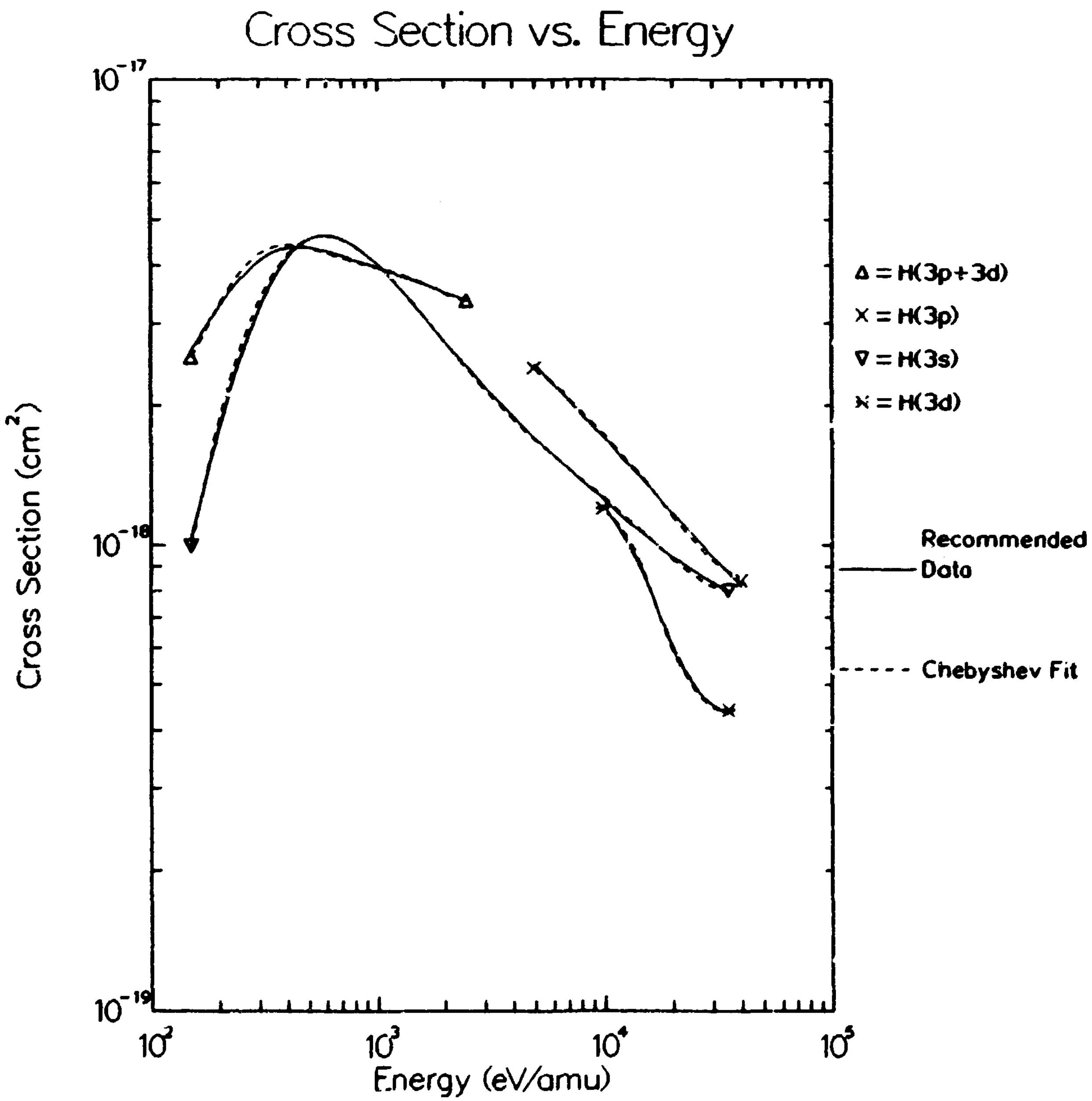
The fit represents the H(3p) cross section with an rms deviation of 0.2%. The maximum deviation is 0.5% at 2.0E+04 eV/amu.

The fit represents the H(3d) cross section with an rms deviation of 0.0%. The maximum deviation is 0.[illegible]% at 2.0E+04 eV/amu.

The fit represents the H(3p+3d) cross section with an rms deviation of 0.3%. The maximum deviation is 0.7% at 5.0E+02 eV/amu.

See appendix for Chebyshev fit details.

H + He -> H(3s,3d,3p)
H + He -> H(3p+3d)



Spectral Line Emission Cross Sections for

H + He -> H(Balmer-α,Balmer-β)

H(Balmer-α)

Energy (eV/amu)	Cross Section (cm^2)
3.0E+01	5.35E-20
4.0E+01	2.73E-19
7.0E+01	9.03E-19
1.0E+02	1.36E-18
1.5E+02	3.47E-18
2.0E+02	5.11E-18
4.0E+02	8.99E-18
5.0E+02	9.14E-18
7.0E+02	8.77E-18
1.0E+03	7.86E-18
2.0E+03	6.22E-18
4.0E+03	4.55E-18
7.0E+03	3.35E-18
1.0E+04	2.72E-18
2.0E+04	1.64E-18
3.0E+04	1.39E-18
3.5E+04	1.35E-18

H(Balmer-β)

Energy (eV/amu)	Cross Section (cm^2)
4.0E+01	2.19E-20
7.0E+01	8.68E-20
1.0E+02	1.51E-19
1.5E+02	4.00E-19
2.0E+02	7.19E-19
4.0E+02	1.88E-18
7.0E+02	2.28E-18
1.0E+03	2.17E-18
2.0E+03	1.73E-18
2.5E+03	1.60E-18

References: 500, 601

Accuracy: 50%

Notes: (1) The Balmer-α wavelength is 656.3nm and the Balmer-β wavelength is 486.1nm. (2) These cross sections are for the total line emission including cascade contributions and branching corrections. Balmer-α cross sections are the sum of $\sigma(3s)$ + 0.118 $\sigma(3p)$ + $\sigma(4D)$ where the factor 0.118 is the fraction of the 3p state decaying by Balmer-α radiation. Balmer-β emission cross sections are for the n=4->2 transitions with the branching ratio of the 4s to 3p transition being 0.584.

Chebyshev Fitting Parameters for Cross Sections

H(Balmer-α) E_{min} = 3.0E+01 eV/amu, E_{max} = 3.5E+04 eV/amu
H(Balmer-β) E_{min} = 4.0E+01 eV/amu, E_{max} = 2.5E+03 eV/amu

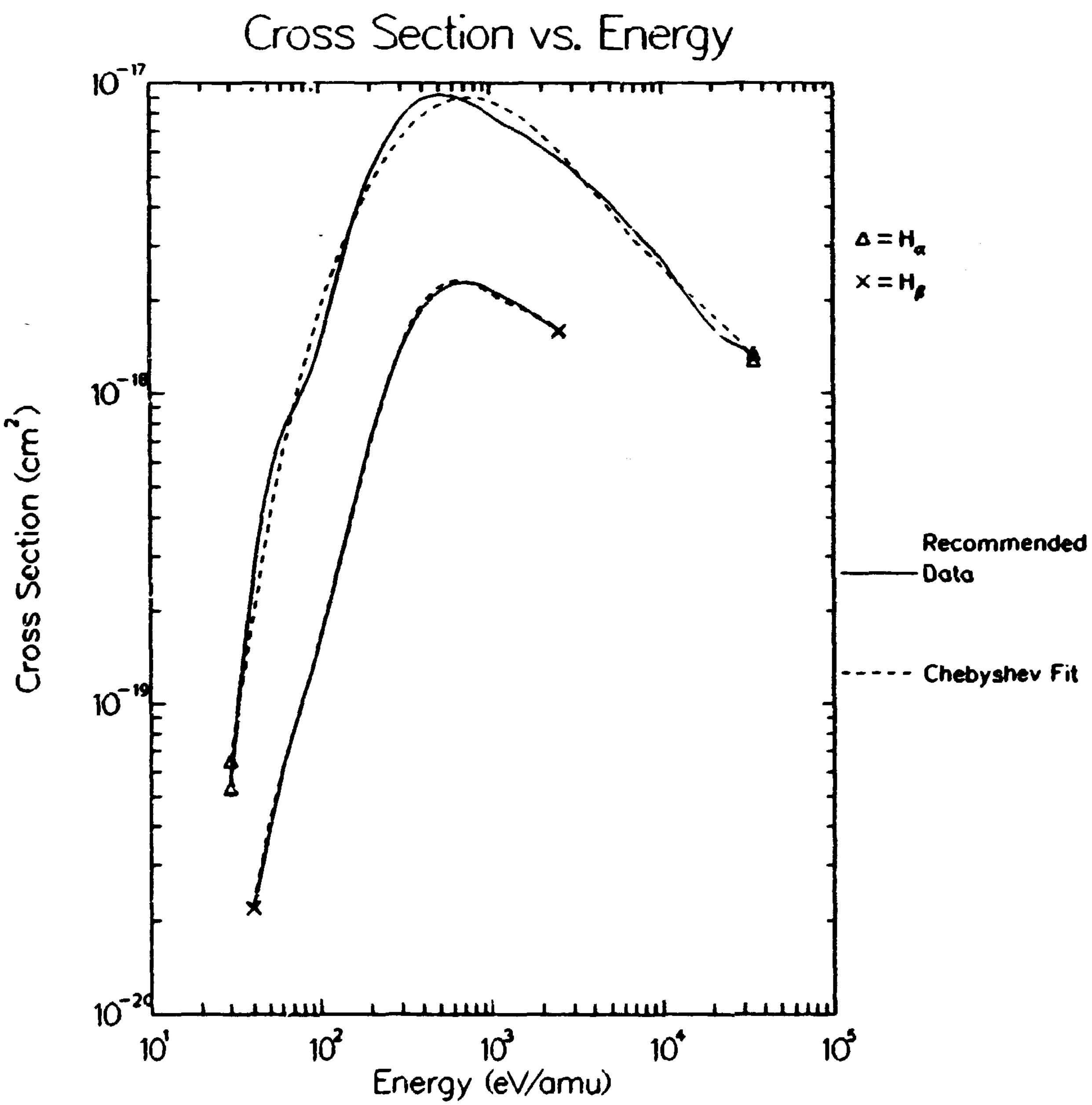
	A0	A1	A2	A3	A4	A5	A6
H(Balmer-α)	-81.8706	.929497	-1.66225	.554407	-.0518605	.00374127	-.0418064
H(Balmer-β)	-84.3982	2.15229	-.976804	-.0709114	.119448	.0571307	-.0675516

The fit represents the H(Balmer-α) cross section with an rms deviation of 13.9%. The maximum deviation is 35.9% at 1.0E+02 eV/amu.

The fit represents the H(Balmer-β) cross section with an rms deviation of 3.6%. The maximum deviation is 8.7% at 1.0E+02 eV/amu.

See appendix for Chebyshev fit details.

$H + He \rightarrow H_\alpha, H_\beta$



Excitation Cross Sections for

H + He -> H(4s,4p+4d)

H(4s) Energy (eV/amu)	H(4s) Cross Section (cm^2)	H(4p+4d) Energy (eV/amu)	H(4p+4d) Cross Section (cm^2)
1.5E+02	1.30E-19	1.5E+02	3.07E-19
2.0E+02	2.60E-19	2.0E+02	5.35E-19
3.0E+02	4.77E-19	3.0E+02	1.06E-18
4.0E+02	6.75E-19	4.0E+02	1.30E-18
5.0E+02	8.10E-19	5.0E+02	1.37E-18
6.0E+02	8.78E-19	6.0E+02	1.38E-18
6.4E+02	8.79E-19	7.0E+02	1.37E-18
7.0E+02	8.72E-19	8.0E+02	1.35E-18
8.0E+02	8.40E-19	9.0E+02	1.33E-18
9.0E+02	7.99E-19	1.0E+03	1.31E-18
1.0E+03	7.56E-19	1.5E+03	1.23E-18
1.5E+03	6.06E-19	2.0E+03	1.19E-18
2.0E+03	5.21E-19	2.5E+03	1.16E-18
2.5E+03	4.62E-19		

Reference: 601

Accuracy: 50%

Notes: (1) As far as we are aware only one measurement has been made of the n = 4 excited state formation. Thus, the stated accuracy only includes accountable errors. (2) These data have ignored any cascade contributions.

Chebyshev Fitting Parameters for Cross Sections

H(4s) E_{min} = 1.5E+02 eV/amu, E_{max} = 2.5E+03 eV/amu
H(4p+4d) E_{min} = 1.5E+02 eV/amu, E_{max} = 2.5E+03 eV/amu

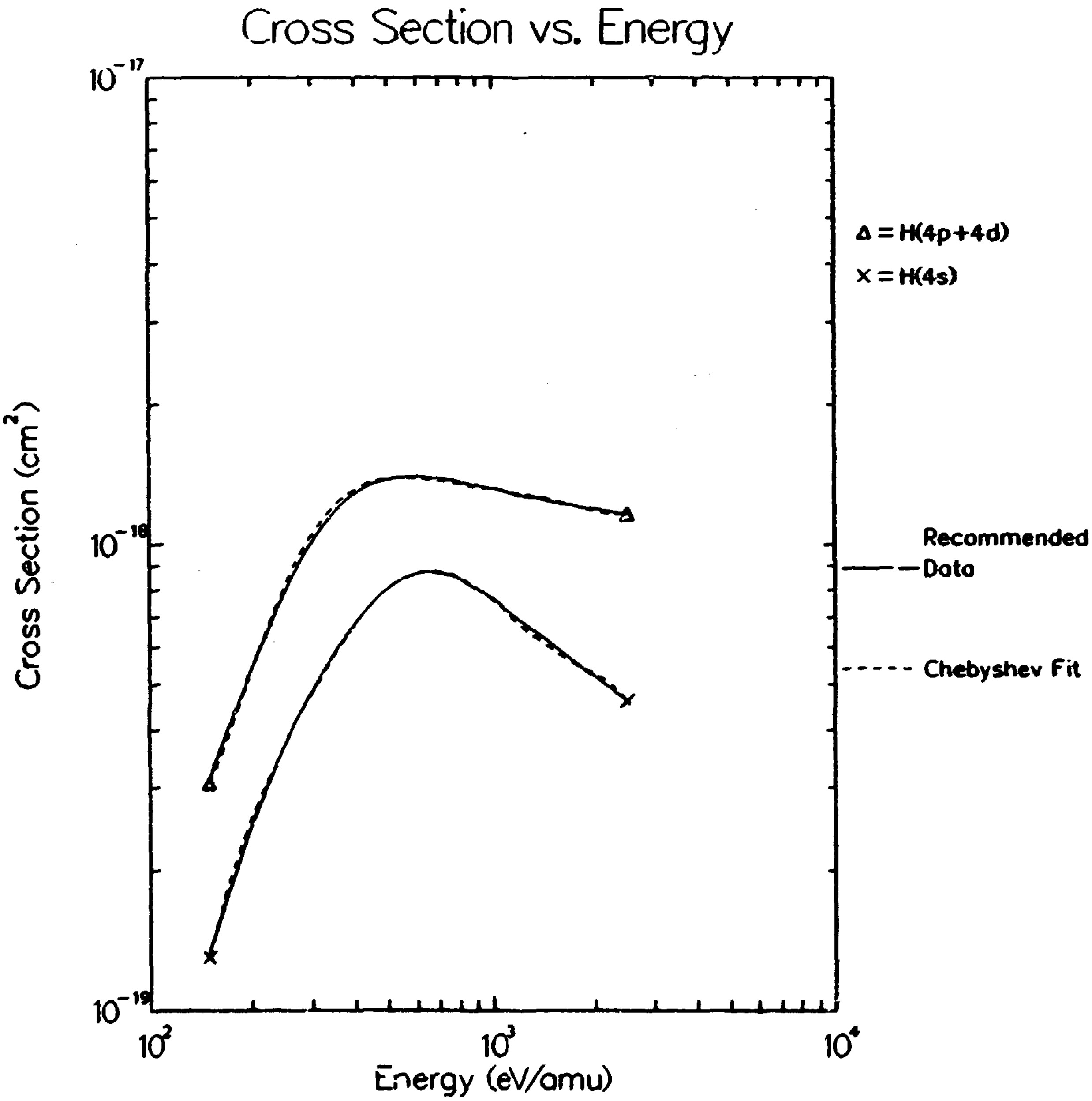
	A0	A1	A2	A3	A4	A5	A6
H(4s)	-84.5175	.519837	-.602123	.107056	.0399676	.00471154	-.0330016
H(4p+4d)	-83.0777	.537485	-.440970	.159743	-.00409905	-.0305454	.0217549

The fit represents the H(4s) cross section with an rms deviation of 0.7%. The maximum deviation is 1.3% at 2.0E+03 eV/amu.

The fit represents the H(4p+4d) cross section with an rms deviation of 0.6%. The maximum deviation is 1.1% at 1.5E+03 eV/amu.

See appendix for Chebyshev fit details.

H + He -> H(4s,4p+4d)



Cross Section vs. Energy
10^{-17}
10^{-18}
10^{-19}
Cross Section (cm^2)
10^2
10^3
10^4
Energy (eV/amu)
Δ = H(4p+4d)
× = H(4s)
Recommended Data
Chebyshev Fit

Excitation Cross Sections for

H + He -> He($3^1P,3^3P,3^3D$)

He(3^1P) Energy (eV/amu)	σ (cm^2)	He(3^3P) Energy (eV/amu)	σ (cm^2)	He(3^3D) Energy (eV/amu)	σ (cm^2)
1.0E+04	5.60E-20	1.0E+04	9.67E-19	1.0E+04	1.60E-19
1.3E+04	1.16E-19	1.3E+04	1.16E-18	1.3E+04	2.19E-19
1.5E+04	1.79E-19	1.5E+04	1.18E-18	1.4E+04	2.37E-19
1.8E+04	2.19E-19	1.8E+04	1.04E-18	1.5E+04	2.32E-19
2.0E+04	2.53E-19	2.0E+04	8.64E-19	1.8E+04	1.95E-19
2.3E+04	2.83E-19	2.3E+04	7.19E-19	2.0E+04	1.62E-19
2.5E+04	3.14E-19	2.5E+04	5.93E-19	2.3E+04	1.37E-19
2.8E+04	3.46E-19	2.8E+04	4.92E-19	2.5E+04	1.17E-19
3.0E+04	3.75E-19	3.0E+04	4.07E-19	2.8E+04	1.00E-19
3.3E+04	4.01E-19	3.3E+04	3.33E-19	3.0E+04	8.62E-20
3.5E+04	4.29E-19	3.5E+04	2.72E-19	3.3E+04	7.57E-20
				3.5E+04	6.86E-20

References: 166, 678, 683, 684

Accuracy: Unknown

Notes: (1) Only one absolute measurement of cross sections for excitation of these states has been made. See: Van Eck et al. (Ref. 678). These data have been corrected in the review papers of de Heer (Ref. 166) and Thomas (Ref. 684). The corrected values are probably too low by a factor of 2-3.

Chebyshev Fitting Parameters for Cross Sections

He(3^1P) E_{min} = 1.0E+04 eV/amu, E_{max} = 3.5E+04 eV/amu
He(3^3P) E_{min} = 1.0E+04 eV/amu, E_{max} = 3.5E+04 eV/amu
He(3^3D) E_{min} = 1.0E+04 eV/amu, E_{max} = 3.5E+04 eV/amu

	A0	A1	A2	A3	A4	A5	A6
He(3^1P)	-86.1894	.957985	-.222479	.0796768	-.00575983	-.0194864	.0121076
He(3^3P)	-83.6070	-.654163	-.317139	.0375222	-3.81314E-04	-.0176396	.00667369
He(3^3D)	-66.8654	-.503446	-.290764	.103755	-.00276954	-.0224516	.0247251

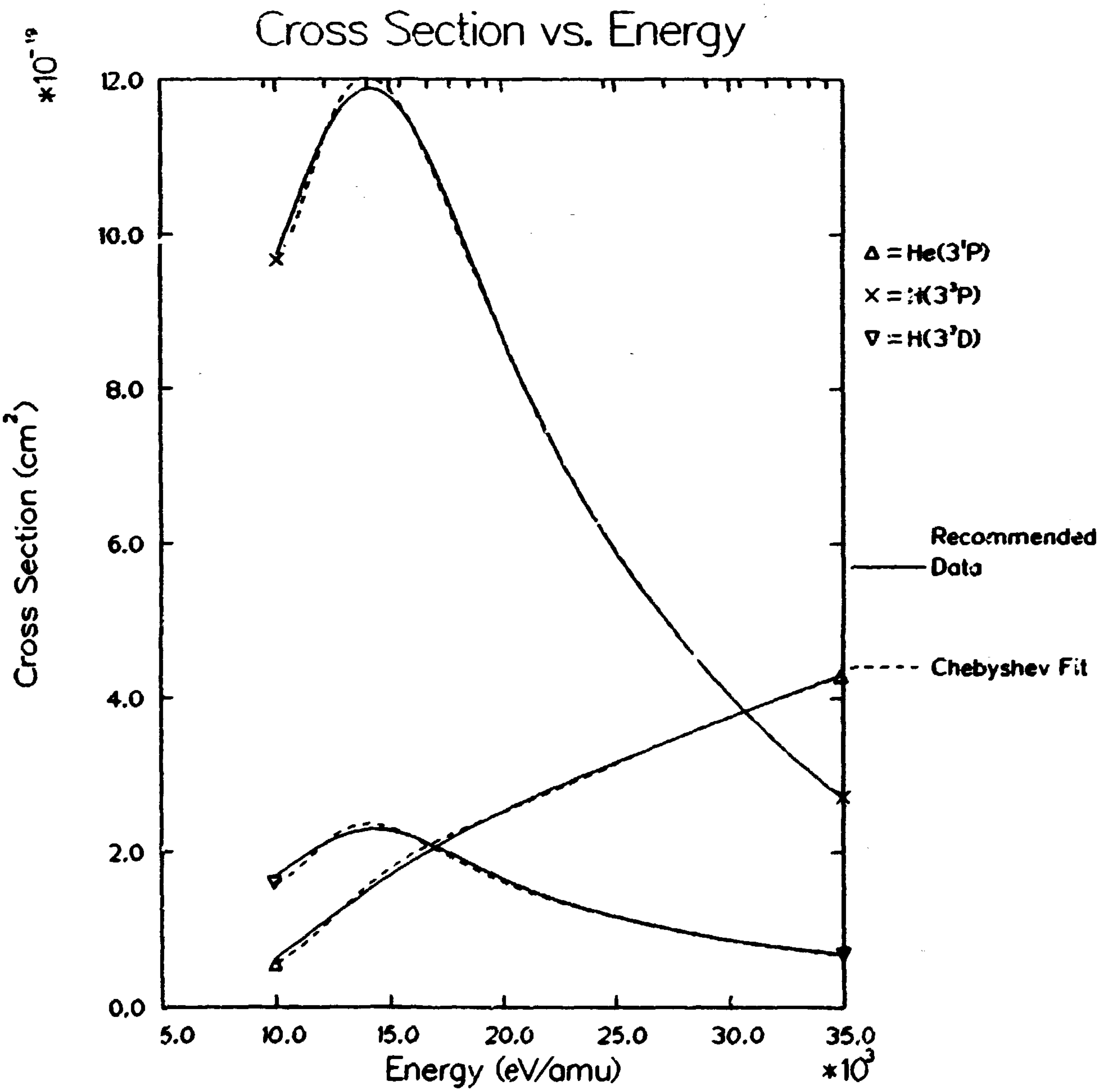
The fit represents the He(3^1P) cross section with an rms deviation of 0.3%. The maximum deviation is 0.6% at 1.8E+04 eV/amu.

The fit represents the He(3^3P) cross section with an rms deviation of 0.2%. The maximum deviation is 0.3% at 2.0E+04 eV/amu.

The fit represents the He(3^3D) cross section with an rms deviation of 0.4%. The maximum deviation is 0.8% at 1.8E+04 eV/amu.

See appendix for Chebyshev fit details.

H + He -> He(3¹P,3³P,3³D)



Excitation Cross Sections for

H + He -> He(4^1S,4^1P,4^1D)

He(4^1S) Energy (eV/amu)	He(4^1S) σ (cm^2)	He(1^1P) Energy (eV/amu)	He(1^1P) σ (cm^2)	He(4^1D) Energy (eV/amu)	He(4^1D) σ (cm^2)
1.0E+04	2.87E-19	1.0E+04	6.19E-20	1.0E+04	5.34E-20
1.5E+04	3.64E-19	1.3E+04	1.30E-19	1.5E+04	8.41E-20
2.0E+04	4.09E-19	1.5E+04	1.92E-19	2.0E+04	9.12E-20
2.5E+04	4.34E-19	2.0E+04	3.03E-19	2.5E+04	8.01E-20
3.0E+04	4.34E-19	2.5E+04	3.80E-19	3.0E+04	7.68E-20
3.5E+04	4.27E-19	3.0E+04	4.48E-19	3.0E+04	7.72E-20
4.0E+04	4.08E-19	3.5E+04	5.13E-19	3.7E+04	8.87E-20
4.5E+04	3.88E-19			4.0E+04	8.79E-20
5.0E+04	3.68E-19			4.5E+04	8.51E-20
5.5E+04	3.51E-19			5.0E+04	8.48E-20
6.0E+04	3.33E-19			5.5E+04	8.24E-20
6.5E+04	3.10E-19			6.0E+04	7.83E-20
7.0E+04	2.81E-19			6.5E+04	7.27E-20
7.5E+04	2.48E-19			7.0E+04	6.66E-20
8.0E+04	2.20E-19			7.5E+04	6.28E-20
8.5E+04	1.97E-19			8.0E+04	6.00E-20
9.0E+04	1.80E-19			8.5E+04	5.81E-20
9.5E+04	1.69E-19			9.0E+04	5.62E-20
1.0E+05	1.61E-19			9.5E+04	5.47E-20
				1.0E+05	5.34E-20

<u>References:</u> 166, 677, 678, 679, 684

<u>Accuracy:</u> E > $2x10^3$ eV/amu - 40%
E < $2x10^3$ eV/amu - Unknown

<u>Notes:</u> (1) The data have been obtained by measuring the line emissions for the following transitions: (a) 4^1S -> 2^2P, 504.7nm, (b) 4^2D -> 2^2P, 492.2nm, (c) 4^2P -> 2^2S, 396.5nm. (2) The cross section data have been corrected for cascades using known transition probabilities. (3) The corrected data of Van Eck et al. (Ref. 678) - (see corrections of de Heer Ref. 166 and Thomas Ref. 684) have been normalized to the data of Blair et al. (Ref. 677) at $2x10^3$ eV/amu for the 4^2S and 4^2D states.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

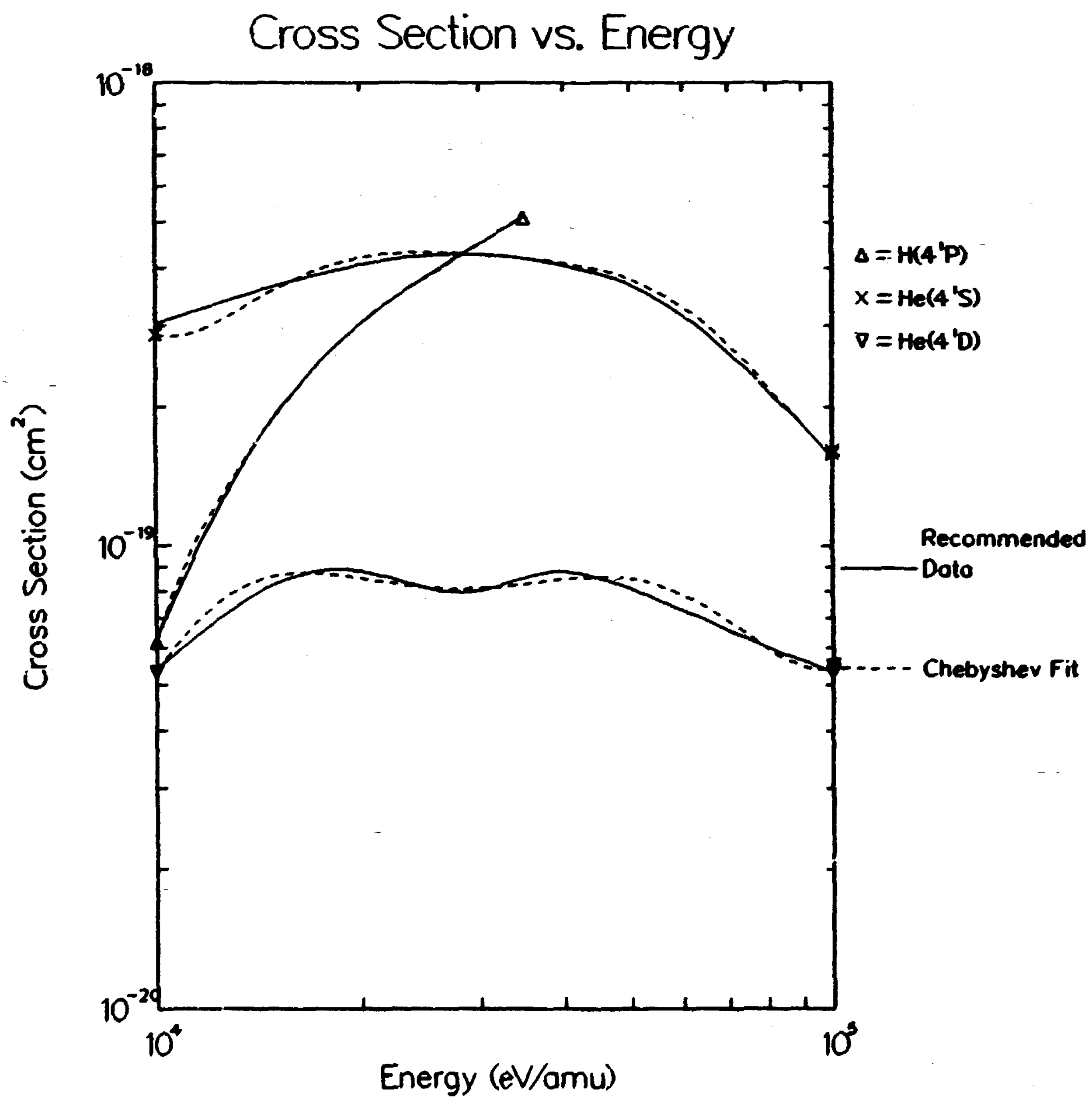
He(4^1S) E_{min} = 1.0E+04 eV/amu, E_{max} = 1.0E+05 eV/amu
He(4^1P) E_{min} = 1.0E+04 eV/amu, E_{max} = 3.5E+04 eV/amu
He(4^1D) E_{min} = 1.0E+04 eV/amu, E_{max} = 1.0E+05 eV/amu

	A0	A1	A2	A3	A4	A5	A6
He(4^1S)	-85.2953	-.236370	-.375570	-.0526312	1.43777E-04	-.00898368	.0314058
He(4^1P)	-85.8813	.991657	-.212955	.0558510	-.00900116	.00987058	-.00878102
He(4^1D)	-88.1942	-.0703862	-.233023	.0274405	-.0616908	.0587687	.0287005

The fit represents the He(4^1S) cross section with an rms deviation of 1.7%. The maximum deviation is 2.7% at 5.0E+04 eV/amu.
The fit represents the He(4^1P) cross section with an rms deviation of 0.1%. The maximum deviation is 5.0% at 1.2E+04 eV/amu.
The fit represents the He(4^2D) cross section with an rms deviation of 3.1%. The maximum deviation is 5.3% at 2.9E+04 eV/amu.

See appendix for Chebyshev fit details.

H + He -> He(4^1S,4^1P,4^1D)



Excitation Cross Sections for

H + He -> He(4^3S,4^3P,4^3D)

He(4^3S) Energy (eV/amu)	σ (cm²)	He(4^3P) Energy (eV/amu)	σ (cm²)	He(4^3D) Energy (eV/amu)	σ (cm²)
1.0E+04	3.69E-19	1.0E+04	8.78E-19	1.0E+04	1.59E-19
1.5E+04	8.38E-19	1.2E+04	1.08E-18	1.5E+04	2.06E-19
2.0E+04	1.00E-18	1.4E+04	1.15E-18	2.0E+04	1.71E-19
3.0E+04	8.70E-19	1.5E+04	1.15E-18	2.5E+04	1.33E-19
4.0E+04	5.43E-19	2.0E+04	8.82E-19	3.0E+04	9.92E-20
5.0E+04	3.56E-19	2.5E+04	6.05E-19	3.5E+04	8.03E-20
6.0E+04	2.48E-19	3.0E+04	4.11E-19	4.0E+04	6.71E-20
7.0E+04	1.79E-19	3.5E+04	3.00E-19	5.0E+04	5.21E-20
8.0E+04	1.25E-19			6.0E+04	4.36E-20
9.0E+04	9.92E-20			7.0E+04	3.80E-20
1.0E+05	8.50E-20			8.0E+04	3.38E-20
				9.0E+04	3.05E-20
				1.0E+05	2.80E-20

References: 166, 677, 678, 684

Accuracy: $E > 2\times10^3$ eV/amu - 40%
$E < 2\times10^3$ eV/amu - Unknown

Notes: (1) The data have been obtained by measuring the line emissions for the following transitions: (a) $4^3S \rightarrow 2^3P$, 471.3nm, (b) $4^3P \rightarrow 2^3S$, 318.8nm, (c) $4^3D \rightarrow 2^3P$, 447.1nm. (2) The cross section data have been corrected for cascading using known transition probabilities. (3) The corrected data of Van Eck et al. (Ref. 678) - (see corrections of de Heer Ref. 166 and Thomas, Ref. 684) have been normalized to the data of Blair et al. (Ref. 677) at 2×10^3 eV/amu for the 4^1S and 4^1D states.

Chebyshev Fitting Parameters for Cross Sections

He(4^3S) E_{min} = 1.0E+04 eV/amu, E_{max} = 1.0E+05 eV/amu
He(4^3P) E_{min} = 1.0E+04 eV/amu, E_{max} = 3.5E+04 eV/amu
He(4^3D) E_{min} = 1.0E+04 eV/amu, E_{max} = 1.0E+05 eV/amu

	A0	A1	A2	A3	A4	A5	A6
He(4^3S)	-84.9236	-.910048	-.757778	.164455	.0260068	-7.50878E-04	.00468518
He(4^3P)	-83.6191	-.587215	-.319615	.0516334	.0108396	-.00145124	.00476885
He(4^3D)	-87.8723	-1.03617	-.177049	.184100	-.0530501	-.0167810	.0122418

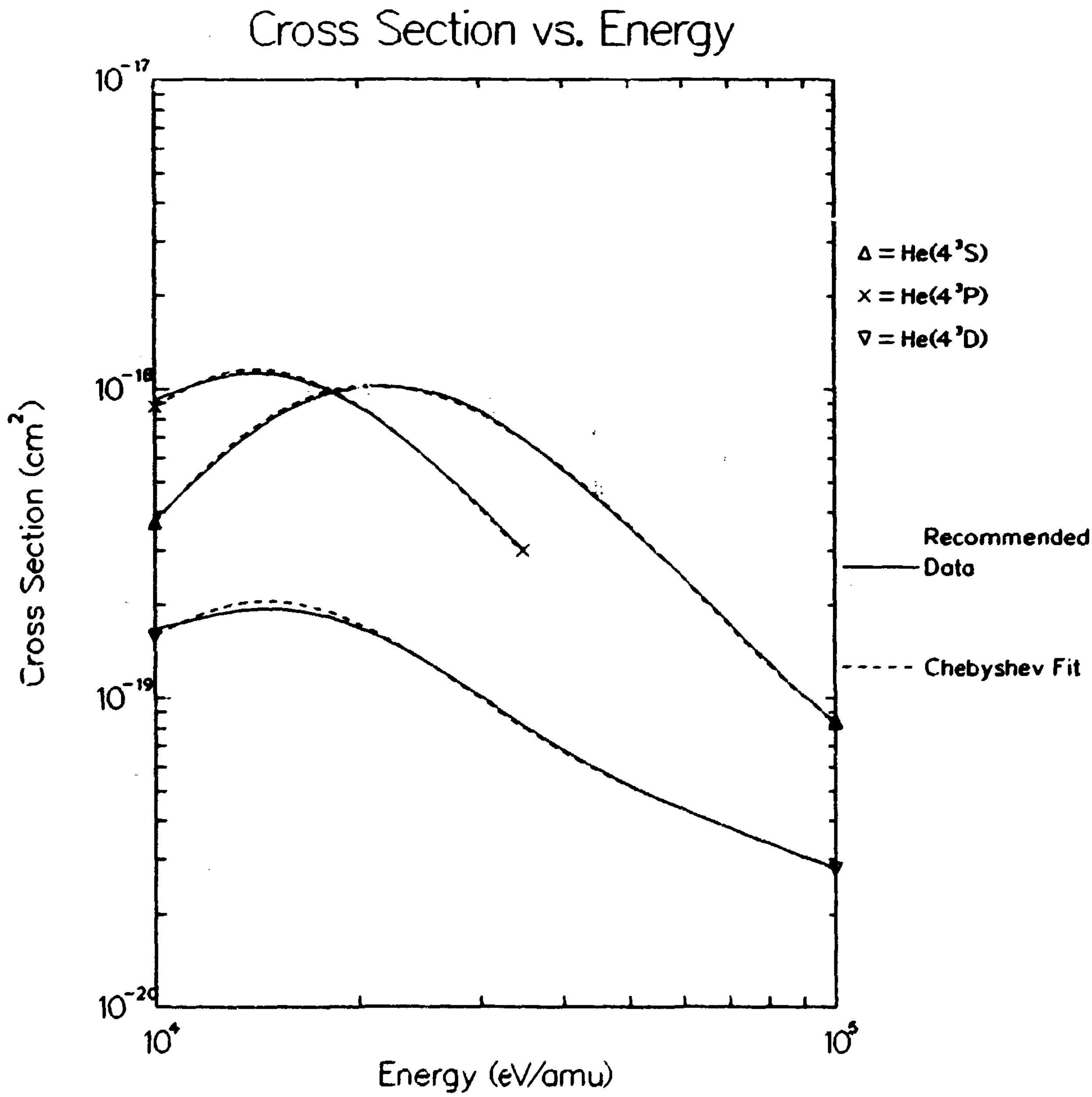
The fit represents the He(4^3S) cross section with an rms deviation of 2.2%. The maximum deviation is 2.6% at 8.0E+04 eV/amu.

The fit represents the He(4^3P) cross section with an rms deviation of 0.2%. The maximum deviation is 0.5% at 1.4E+04 eV/amu.

The fit represents the He(4^3D) cross section with an rms deviation of 0.6%. The maximum deviation is 1.1% at 2.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$H + He \rightarrow He(4\,^3S, 4\,^3P, 4\,^3D)$



Excitation Cross Sections for

$H^+ + H \rightarrow H^+ + H(2s,2p)$

H(2s) Energy (eV/amu)	H(2s) Cross Section (cm^2)	H(2p) Energy (eV/amu)	H(2p) Cross Section (cm^2)
5.0E+03	5.42E-18	5.0E+02	2.43E-18
6.0E+03	5.38E-18	6.0E+02	8.90E-18
7.0E+03	5.36E-18	7.0E+02	1.64E-17
8.0E+03	5.40E-18	8.0E+02	2.03E-17
9.0E+03	5.43E-18	9.0E+02	2.25E-17
1.0E+04	5.54E-18	1.0E+03	2.41E-17
1.2E+04	5.87E-18	1.5E+03	2.73E-17
1.5E+04	8.62E-18	2.0E+03	2.80E-17
2.0E+04	1.04E-17	3.0E+03	2.91E-17
2.5E+04	1.06E-17	4.0E+03	2.97E-17
		5.0E+03	3.02E-17
		6.0E+03	3.06E-17
		7.0E+03	2.98E-17
		8.0E+03	2.78E-17
		9.0E+03	2.56E-17
		1.0E+04	2.40E-17
		1.1E+04	2.35E-17
		1.5E+04	2.81E-17
		2.0E+04	3.65E-17
		3.0E+04	5.50E-17

References: H(2s) - 12, 14
H(2p) - 14, 17, 712

Accuracy: H(2s) - Unknown
H(2p) - 40%

Notes: (1) Since the cascading into the 2p state is less than 5%, the cross section for excitation of the 2p state is essentially the same as Lyman-α emission cross section. The 2p data has not been corrected for cascading. (2) The two sets of data for the 2s state differ by a factor of 2 to 3.

Chebyshev Fitting Parameters for Cross Sections

H(2s) E_{min} = 5.0E+03 eV/amu, E_{max} = 2.5E+04 eV/amu
H(2p) E_{min} = 5.0E+02 eV/amu, E_{max} = 3.0E+04 eV/amu

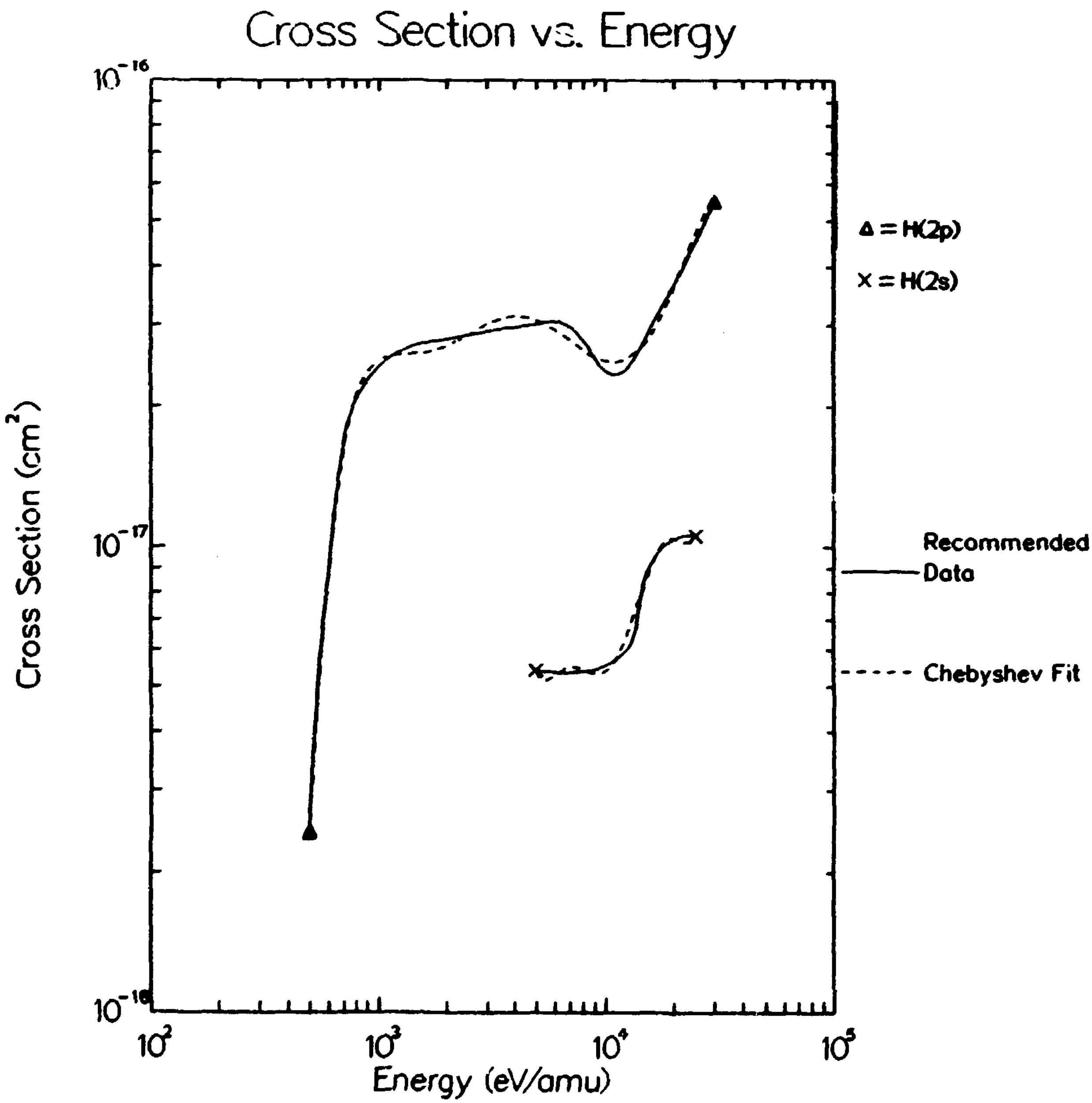
	A0	A1	A2	A3	A4	A5	A6
H(2s)	-78.9900	.401365	.0930849	-.0759638	-.0649979	.00791412	.0468211
H(2p)	-76.6674	.854989	-.357230	.529756	-.161903	.168930	-.136550

The fit represents the H(2s) cross section with an rms deviation of 2.3%. The maximum deviation is 4.8% at 1.2E+04 eV/amu.

The fit represents the H(2p) cross section with an rms deviation of 3.7%. The maximum deviation is 6.3% at 1.1E+04 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + H \rightarrow H^+ + H(2s,2p)$



Excitation Rate Coefficients for

$H^{+} + H \rightarrow H^{+} + H(2p)$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

H Temp. (eV)	Equal Temp.	H Temp. (eV) 500.	750.	1000.	1250.	5000.	10000.	20000.
5.0E+02	1.16E-09	1.16E-09	1.39E-09	1.58E-09	1.75E-09	3.33E-09	4.11E-09*	3.43E-09#
7.5E+02	1.58E-09	1.39E-09	1.58E-09	1.75E-09	1.90E-09	3.41E-09	4.11E-09*	3.41E-09#
1.0E+03	1.90E-09	1.58E-09	1.75E-09	1.90E-09	2.03E-09	3.48E-09	4.11E-09*	3.39E-09#
1.3E+03	2.16E-09	1.75E-09	1.90E-09	2.03E-09	2.16E-09	3.55E-09	4.11E-09*	3.36E-09#
1.5E+03	2.38E-09	1.90E-09	2.03E-09	2.16E-09	2.27E-09	3.61E-09*	4.11E-09*	3.34E-09#
1.8E+03	2.59E-09	2.03E-09	2.16E-09	2.27E-09	2.38E-09	3.67E-09*	4.10E-09*	3.31E-09#
2.0E+03	2.80E-09	2.16E-09	2.27E-09	2.38E-09	2.49E-09	3.73E-09*	4.10E-09*	3.29E-09#
3.0E+03	3.48E-09	2.59E-09	2.70E-09	2.80E-09	2.89E-09	3.91E-09*	4.06E-09*	3.20E-09#
4.0E+03	3.91E-09*	2.99E-09	3.08E-09	3.17E-09	3.25E-09	4.03E-09*	4.00E-09*	3.11E-09#
5.0E+03	4.09E-09*	3.33E-09	3.41E-09	3.48E-09	3.55E-09	4.09E-09*	3.93E-09#	3.02E-09#
6.0E+03	4.10E-09*	3.61E-09*	3.67E-09*	3.73E-09*	3.78E-09*	4.11E-09*	3.85E-09#	2.94E-09#
7.0E+03	4.00E-09*	3.83E-09*	3.87E-09*	3.91E-09*	3.94E-09*	4.10E-09*	3.76E-09#	2.85E-09#
8.0E+03	3.85E-09#	3.98E-09*	4.00E-09*	4.03E-09*	4.05E-09*	4.06E-09*	3.67E-09#	2.77E-09#
9.0E+03	3.67E-09#	4.07E-09*	4.08E-09*	4.09E-09*	4.10E-09*	4.00E-09*	3.58E-09#	2.70E-09#
1.0E+04	3.48E-09#	4.11E-09*	4.11E-09*	4.11E-09*	4.11E-09*	3.93E-09#	3.48E-09#	2.62E-09#
1.2E+04	3.11E-09#	4.08E-09*	4.07E-09*	4.06E-09*	4.05E-09*	3.76E-09#	3.29E-09#	2.48E-09#
1.5E+04	2.62E-09#	3.89E-09#	3.87E-09#	3.85E-09#	3.83E-09#	3.48E-09#	3.02E-09#	2.29E-09#
2.0E+04	2.02E-09#	3.43E-09#	3.41E-09#	3.39E-09#	3.36E-09#	3.02E-09#	2.62E-09#	2.02E-09#

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

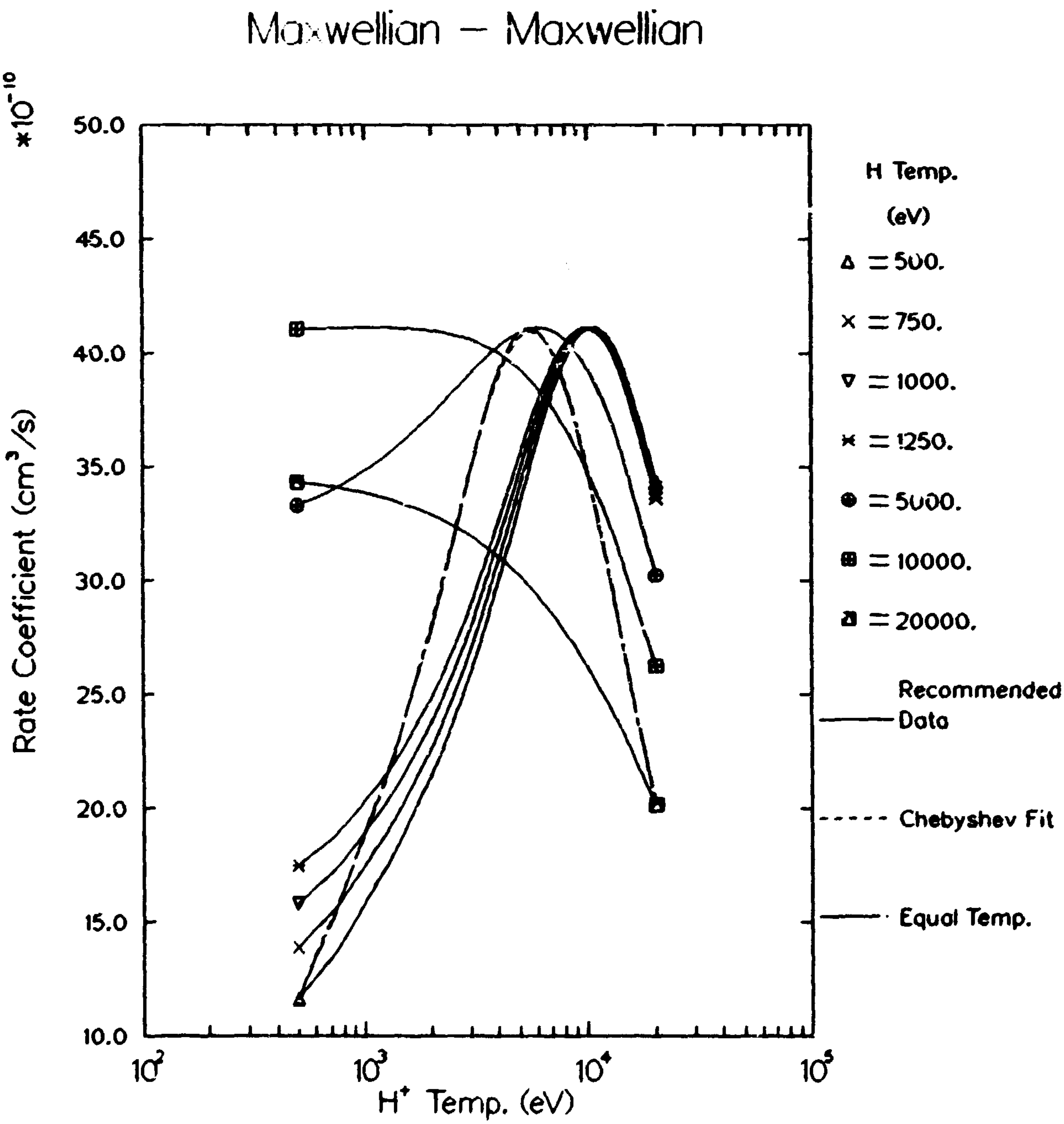
Chebyshev Fitting Parameters for Cross Sections

E_{min} = 5.0E+02 eV, E_{max} = 2.0E+04 eV

H Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
500.	-39.7100	.631450	-.153568	-.0909606	-.0319929	2.01118E-04	.00981582
750.	-39.5923	.543848	-.128283	-.0971754	-.0299354	.00227565	.00859152
1000.	-39.4997	.476362	-.113723	-.0995434	-.0281721	.00377301	.00746751
1250.	-39.4237	.421755	-.105533	-.0997854	-.0264000	.00472594	.00647274
5000.	-38.9001	.0101105	-.108849	-.0609619	-.0111639	.00213821	.00143014
10000.	-38.8452	-.187122	-.105864	-.0371107	-.00678512	2.66271E-04	5.36963E-04
20000.	-39.3124	-.240533	-.0956162	-.0251663	-.00414891	-1.62169E-04	1.56753E-04
Equal Temp.	-39.7457	.353158	-.421145	-.103566	-3.86751E-04	.272186	-.00215387

See appendix for Chebyshev fit details.

$H^+ + H \rightarrow H^+ + H(2p)$



Excitation Cross Sections for

$H^+ + H \rightarrow H^+ + H(n=2,3,4)$

H(n=2)		H(n=3)		H(n=4)	
Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)
1.5E+04	3.43E-17	1.5E+04	1.09E-17	2.5E+04	7.69E-18
2.0E+04	5.22E-17	2.0E+04	1.29E-17	3.0E+04	8.68E-18
2.5E+04	6.64E-17	2.5E+04	1.53E-17	4.0E+04	1.02E-17
3.0E+04	7.89E-17	3.0E+04	1.80E-17	5.0E+04	1.12E-17
4.0E+04	9.59E-17	4.0E+04	2.33E-17	6.0E+04	1.18E-17
5.0E+04	1.05E-16	5.0E+04	2.54E-17	7.0E+04	1.19E-17
5.5E+04	1.07E-16	6.0E+04	2.51E-17	8.0E+04	1.18E-17
6.0E+04	1.07E-16	7.0E+04	2.42E-17	9.0E+04	1.14E-17
7.0E+04	1.03E-16	8.0E+04	2.32E-17	1.0E+05	1.10E-17
8.0E+04	9.72E-17	9.0E+04	2.21E-17	1.5E+05	9.06E-18
9.0E+04	9.28E-17	1.0E+05	2.14E-17	2.0E+05	7.69E-18
1.0E+05	8.90E-17	1.5E+05	1.70E-17		
1.5E+05	7.48E-17	2.0E+05	1.36E-17		
2.0E+05	6.53E-17				

<u>**References:**</u> 709, 710, 711

<u>**Accuracy:**</u> 40%

<u>**Notes:**</u> (1) These cross sections were determined by measuring the energy loss of the incident proton beam after passing through an H target. The energy resolution was not sufficient to separate the nl levels. (2) To obtain absolute cross sections the results were normalized to the Born approximation of Bates and Griffing (Ref. 711) at 200 keV.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

H(n=2) E_{min} = 1.5E+04 eV/amu, E_{max} = 2.0E+05 eV/amu
H(n=3) E_{min} = 1.5E+04 eV/amu, E_{max} = 2.0E+05 eV/amu
H(n=4) E_{min} = 2.5E+04 eV/amu, E_{max} = 2.0E+05 eV/amu

	A0	A1	A2	A3	A4	A5	A6
H(n=2)	-74.4276	.262934	-.326115	.0616937	.0293129	-.00255599	-.0190829
H(n=3)	-77.2728	.149236	-.351549	-.0157777	.0571627	-.0247442	-.0161701
H(n=4)	-78.4118	-.00702352	-.213691	.00801652	.0182541	-8.70179E-04	-.00538651

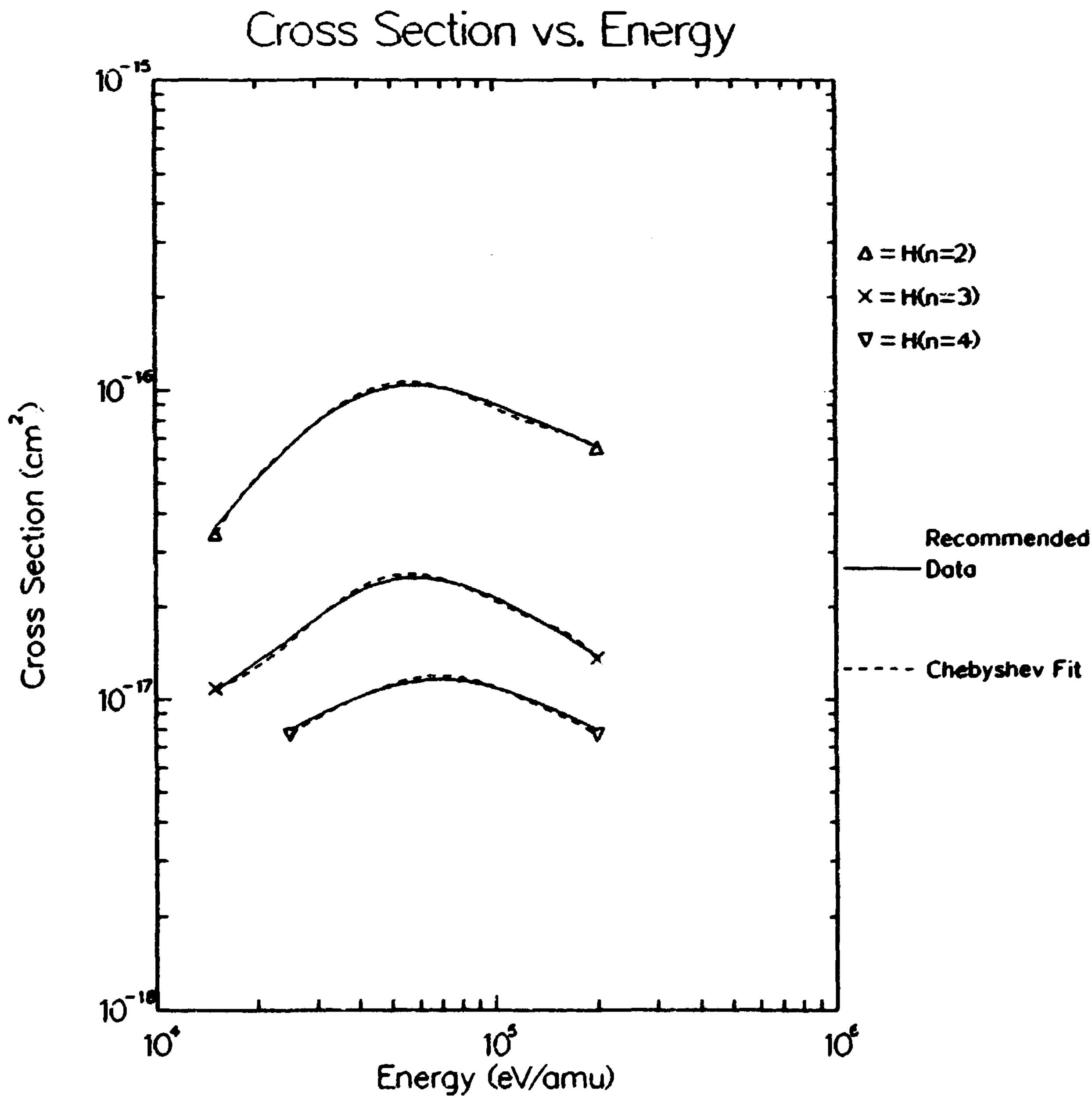
The fit represents the H(n=2) cross section with an rms deviation of 0.5%. The maximum deviation is 0.9% at 8.0E+04 eV/amu.

The fit represents the H(n=3) cross section with an rms deviation of 1.2%. The maximum deviation is 1.5% at 7.0E+04 eV/amu.

The fit represents the H(n=4) cross section with an rms deviation of 0.2%. The maximum deviation is 0.2% at 5.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + H \rightarrow H(n=2,3,4)$ Target



Dissociative Excitation Cross Sections for

$H^+ + H_2 \rightarrow H^+ + H(2s,2p) + H$

H(2s) Energy (eV/amu)	H(2s) Cross Section (cm^2)	H(2p) Energy (eV/amu)	H(2p) Cross Section (cm^2)
5.0E+03	1.32E-18	4.0E+03	6.36E-18
7.0E+03	3.59E-18	7.0E+03	1.84E-17
1.0E+04	4.70E-18	1.0E+04	2.76E-17
1.5E+04	5.73E-18	1.5E+04	3.12E-17
2.0E+04	6.38E-18	2.0E+04	2.96E-17
4.0E+04	7.69E-18	4.0E+04	2.14E-17
7.0E+04	8.00E-18	7.0E+04	1.48E-17
1.0E+05	7.88E-18	1.0E+05	1.21E-17
1.5E+05	7.04E-18	1.5E+05	9.23E-18
2.0E+05	6.23E-18	2.0E+05	7.42E-18
4.0E+05	4.18E-18	4.0E+05	4.34E-18
7.0E+05	2.75E-18	7.0E+05	2.81E-18
1.0E+06	2.00E-18	1.0E+06	2.14E-18

References: 122, 124, 128, 649

Accuracy: 50%

Notes: (1) The 2s cross section has been measured by field-induced emission of Lyman-α radiation (2s -> 2p -> 1s). If cascade is neglected, this is equal to the cross section for H(2s) formation. (2) The 2p cross section was determined by measuring the Lyman-α emission. If cascade is neglected, this is equal to the cross section for H(2p) formation.

Chebyshev Fitting Parameters for Cross Sections

H(2s) E_{min} = 5.0E+03 eV/amu, E_{max} = 1.0E+06 eV/amu
H(2p) E_{min} = 4.0E+03 eV/amu, E_{max} = 1.0E+06 eV/amu

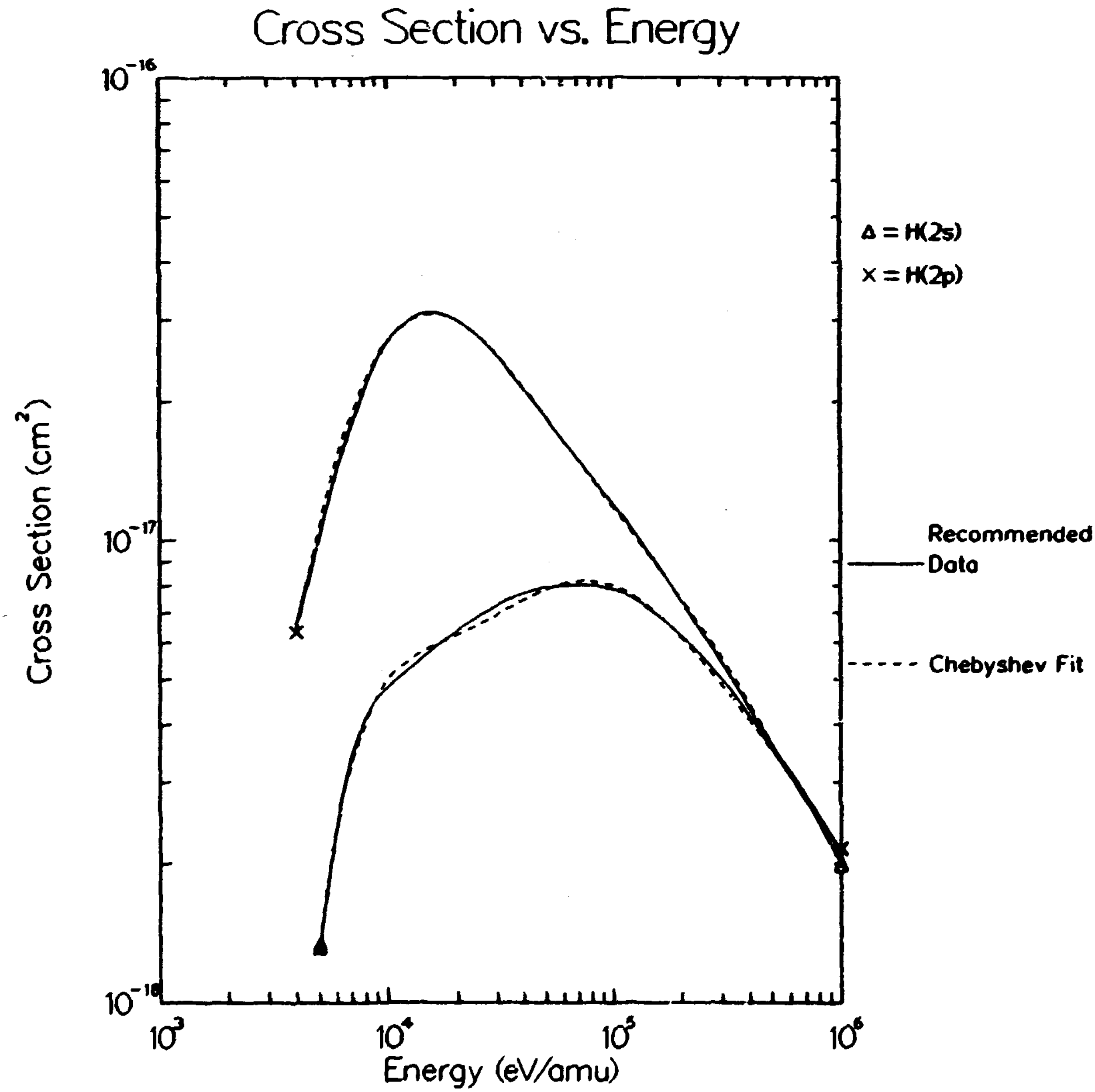
	A0	A1	A2	A3	A4	A5	A6
H(2s)	-80.1116	-.0216909	-.735933	.117161	-.0952706	.0960395	-.0678792
H(2p)	-78.5492	-.910686	-.758592	.347330	-.131263	.0249389	.0249642

The fit represents the H(2s) cross section with an rms deviation of 3.1%. The maximum deviation is 5.9% at 1.0E+04 eV/amu.

The fit represents the H(2p) cross section with an rms deviation of 1.6%. The maximum deviation is 2.5% at 7.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + H_2 \rightarrow H^+ + H(2s,2p)$



Dissociative Excitation Cross Sections for

$H^+ + H_2 \rightarrow H^+ + H(3p) + H$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.5E+04	1.70E+08	1.99E-18
1.6E+04	1.76E+08	2.14E-18
1.7E+04	1.81E+08	2.25E-18
1.8E+04	1.86E+08	2.34E-18
1.9E+04	1.91E+08	2.38E-18
2.0E+04	1.96E+08	2.39E-18
2.1E+04	2.01E+08	2.36E-18
2.2E+04	2.06E+08	2.31E-18
2.3E+04	2.11E+08	2.24E-18
2.4E+04	2.15E+08	2.16E-18
2.5E+04	2.20E+08	2.07E-18
2.6E+04	2.24E+08	1.95E-18
2.7E+04	2.28E+08	1.81E-18
2.8E+04	2.32E+08	1.65E-18
2.9E+04	2.37E+08	1.45E-18
3.0E+04	2.41E+08	1.20E-18

Reference: 122

Accuracy: 30%

Note: The cross sections for H(3p) formation deduced from emission measurements on the (unsubstantiated) assumption that cascade may be neglected.

Chebyshev Fitting Parameters for Cross Sections

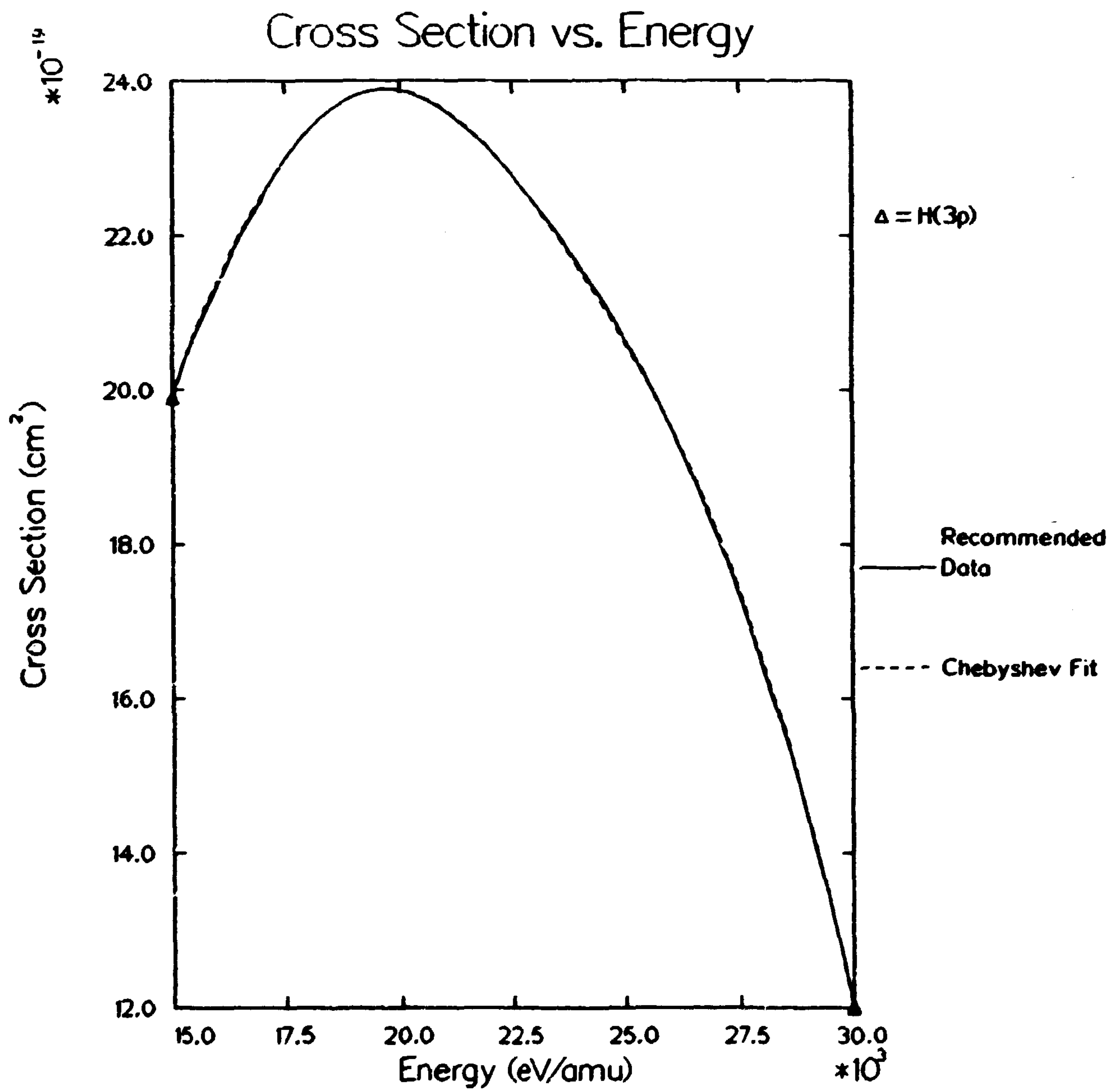
E_{min} = 1.5E+04 eV/amu, E_{max} = 3.0E+04 eV/amu

A0	A1	A2	A3	A4	A5	A6
-81.5559	-.198605	-.205491	-.0404366	-.0225806	-.0130785	-.00450361

The fit represents the above cross section with an rms deviation of 0.2%. The maximum deviation is 0.4% at 2.7E+04 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + H_2 \rightarrow H(3p)$ Target



Spectral Line Emission Cross Sections for

$H^+ + H_2 \rightarrow H(\text{Lyman-}\alpha)$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
5.0E+02	3.11E+07	6.56E-18
7.0E+02	3.68E+07	9.30E-18
1.0E+03	4.39E+07	1.31E-17
1.5E+03	5.38E+07	1.86E-17
2.0E+03	6.21E+07	2.35E-17
4.0E+03	8.79E+07	3.74E-17
7.0E+03	1.16E+08	4.98E-17
1.0E+04	1.39E+08	5.68E-17
1.5E+04	1.70E+08	6.17E-17
2.0E+04	1.96E+08	5.50E-17
4.0E+04	2.78E+08	2.78E-17
7.0E+04	3.68E+08	1.77E-17
1.0E+05	4.39E+08	1.40E-17
1.4E+05	5.20E+08	1.20E-17

<u>References:</u> 188, 194, 195, 676

<u>Accuracy:</u> 50%

<u>Note:</u> Cross sections correspond to 121.57nm emission resulting from dissociative excitation of H_2 by proton impact.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

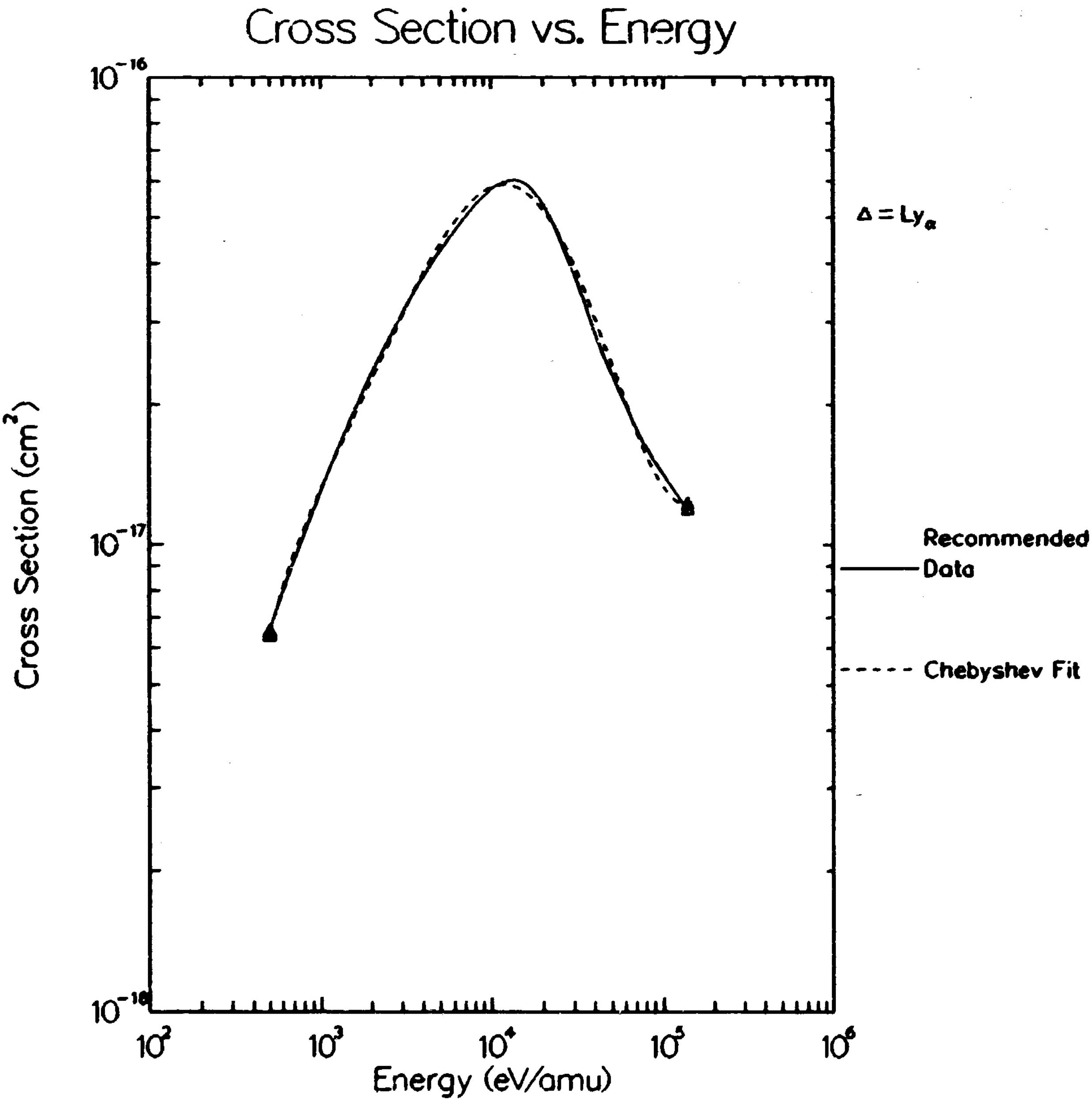
E_{min} = 5.0E+02 eV/amu, E_{max} = 1.4E+05 eV/amu

A0	A1	A2	A3	A4	A5	A6
-76.9474	.268573	-.911806	-.0361054	.132508	.0899171	-.00698679

The fit represents the above cross section with an rms deviation of 4.5%. The maximum deviation is 10.4% at 4.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + H_2 \rightarrow Ly_\alpha$ Target



Spectral Line Emission Cross Sections for

$H^+ + H_2 \rightarrow H(\text{Balmer-}\alpha, \text{Balmer-}\beta, \text{Balmer-}\gamma)$

H_α		H_β		H_γ	
Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)
1.5E+03	2.09E-19	5.0E+03	1.75E-19	1.0E+04	1.00E-19
2.0E+03	2.70E-19	6.0E+03	2.37E-19	1.4E+04	1.09E-19
4.0E+03	5.80E-19	7.0E+03	2.98E-19	1.5E+04	1.08E-19
7.0E+03	1.51E-18	8.0E+03	3.53E-19	2.0E+04	9.91E-20
1.0E+04	2.24E-18	9.0E+03	3.95E-19	3.0E+04	7.64E-20
1.5E+04	2.62E-18	1.0E+04	4.28E-19	4.0E+04	6.00E-20
2.0E+04	2.44E-18	1.5E+04	4.70E-19	5.0E+04	4.93E-20
4.0E+04	1.55E-18	2.0E+04	4.22E-19	6.0E+04	4.21E-20
7.0E+04	9.06E-19	3.0E+04	3.00E-19	7.0E+04	3.59E-20
1.0E+05	6.50E-19	4.0E+04	2.29E-19	8.0E+04	3.29E-20
1.5E+05	4.57E-19	5.0E+04	1.88E-19	9.0E+04	2.96E-20
2.0E+05	3.57E-19	6.0E+04	1.59E-19	1.0E+05	2.70E-20
4.0E+05	1.96E-19	7.0E+04	1.37E-19	1.5E+05	1.87E-20
7.0E+05	1.20E-19	8.0E+04	1.21E-19	2.0E+05	1.46E-20
1.0E+06	8.90E-20	9.0E+04	1.08E-19	3.0E+05	1.02E-20
		1.0E+05	9.78E-20	4.0E+05	7.97E-21
		1.5E+05	6.72E-20	5.0E+05	6.52E-21
		2.0E+05	5.18E-20	6.0E+05	5.57E-21
		3.0E+05	3.60E-20	7.0E+05	4.88E-21
		4.0E+05	2.75E-20	8.0E+05	4.38E-21
		5.0E+05	2.25E-20	9.0E+05	3.98E-21
		6.0E+05	1.90E-20	1.0E+06	3.65E-21
		7.0E+05	1.66E-20		
		8.0E+05	1.46E-20		
		9.0E+05	1.32E-20		
		1.0E+06	1.19E-20		

References: 133, 139, 655

Accuracy: 50%

Notes: (1) The data correspond to Balmer-series emission resulting from dissociative excitation of H_2, and have been normalized in the high energy region to data of Edwards and Thomas (Ref. 655). (2) Differences in magnitudes of the reported cross sections for each transition are due to differences in calibration between the experimental systems. (3) The wavelengths are as follows: H_α= 656.28nm; H_β=486.13nm; H_γ=434.05nm.

Chebyshev Fitting Parameters for Cross Sections

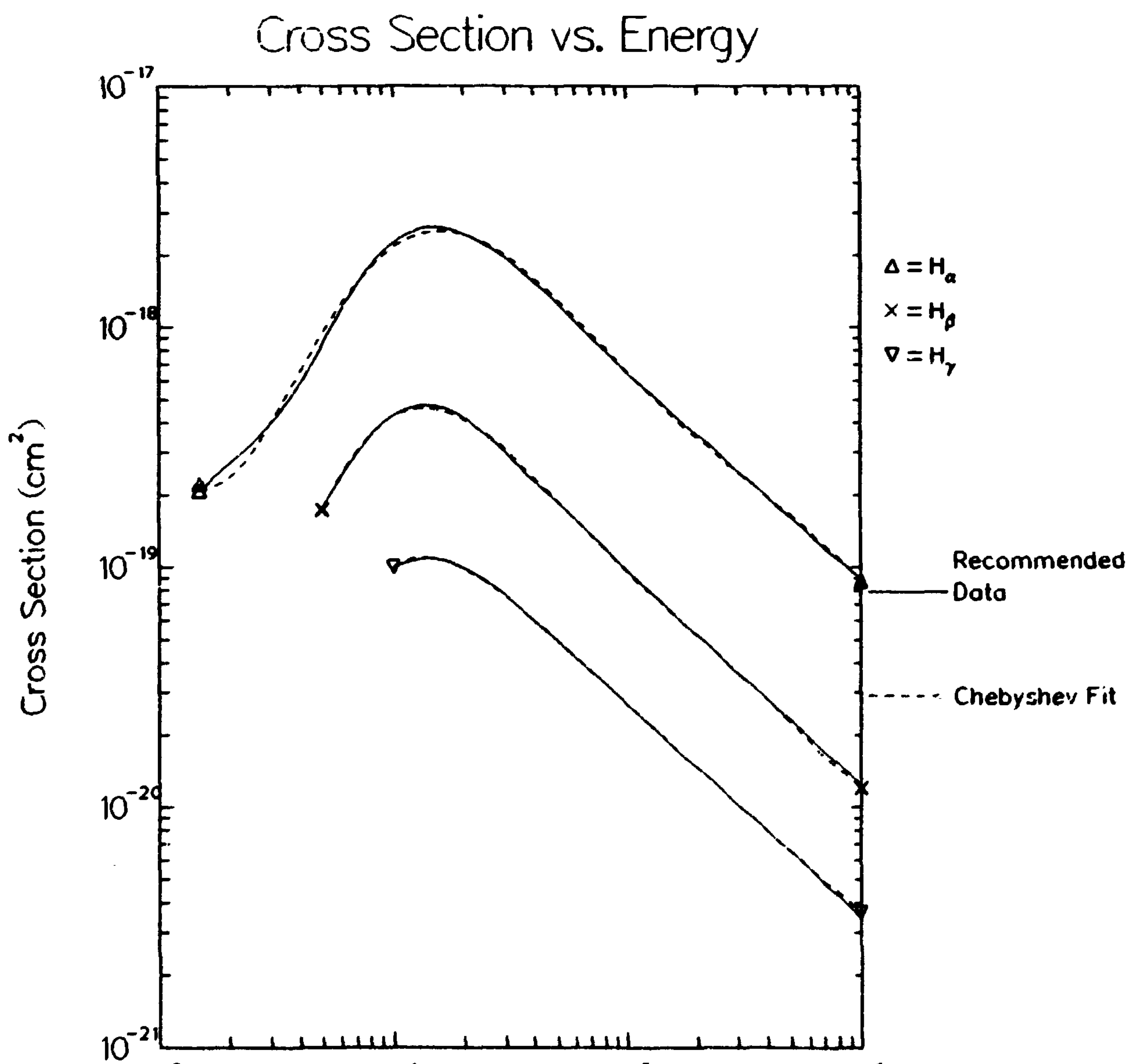
H_α E_{min} = 1.5E+03 eV/amu, E_{max} = 1.0E+06 eV/amu
H_β E_{min} = 6.0E+03 eV/amu, E_{max} = 1.0E+06 eV/amu
H_γ E_{min} = 1.0E+04 eV/amu, E_{max} = 1.0E+06 eV/amu

	A0	A1	A2	A3	A4	A5	A6
H_α	-84.6647	-.627902	-1.28581	.366073	.150564	-.204615	.0536705
H_β	-87.6626	-1.78903	-.434179	.278457	-.129747	.0301375	.0113784
H_γ	-90.3588	-1.79519	.168084	.119053	-.0545231	.0225899	-.00228634

The fit represents the H_α cross section with an rms deviation of 5.4%. The maximum deviation is 12.3% at 4.0E+03 eV/amu.
The fit represents the H_β cross section with an rms deviation of 1.4%. The maximum deviation is 3.1% at 4.0E+04 eV/amu.
The fit represents the H_γ cross section with an rms deviation of 0.4%. The maximum deviation is 0.8% at 5.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + H_2 \rightarrow H_\alpha, H_\beta, H_\gamma$



Spectral Band Emission Cross Sections for

$H^+ + H_2 \rightarrow H^+ + H_2^*$

160.6nm Band

Energy (eV/amu)	Cross Section (cm^2)
7.0E+03	2.17E-18
8.0E+03	2.31E-18
9.0E+03	2.44E-18
1.0E+04	2.56E-18
1.5E+04	3.00E-18
2.0E+04	3.30E-18
3.0E+04	3.69E-18
4.0E+04	3.84E-18
5.0E+04	3.87E-18
6.0E+04	3.83E-18
7.0E+04	3.76E-18
8.0E+04	3.67E-18
9.0E+04	3.55E-18
1.0E+05	3.42E-18
1.3E+05	3.01E-18

418.0nm Band

Energy (eV/amu)	Cross Section (cm^2)
1.5E+05	8.06E-21
2.0E+05	6.25E-21
2.5E+05	5.06E-21
3.0E+05	4.21E-21
3.5E+05	3.62E-21
4.0E+05	3.17E-21
5.0E+05	2.54E-21
6.0E+05	2.11E-21
7.0E+05	1.81E-21
8.0E+05	1.59E-21
9.0E+05	1.39E-21

<u>References:</u> 194, 654

<u>Accuracy:</u> 50%

<u>Note:</u> The 160.6nm Band is the Lyman band of H_2 [B $^1\Sigma_u^+ \rightarrow$ X $^1\Sigma_g^+$, (4,11), (5,12) and (6,13)]. The 418.0nm Band of H_2 is for the transitions [3d $^1\pi_g \rightarrow$ 2p $^1\Sigma_u^+$ (1,0)].

<u>Chebyshev Fitting Parameters for Cross Sections</u>

160.6 nm E_{min} = 7.0E+03 eV/amu, E_{max} = 1.3E+05 eV/amu
418.0 nm E_{min} = 1.5E+05 eV/amu, E_{max} = 9.0E+05 eV/amu

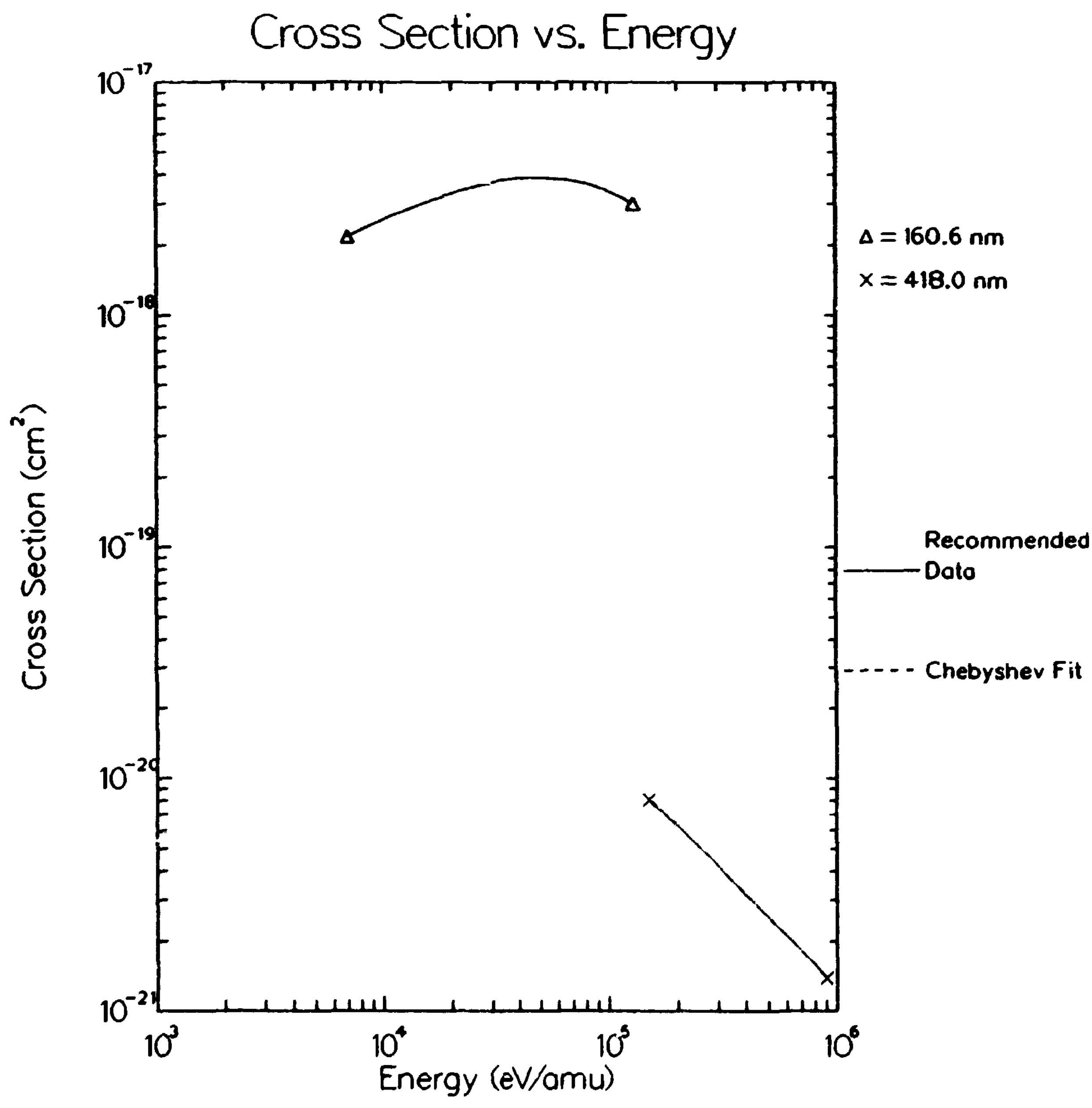
	A0	A1	A2	A3	A4	A5	A6
160.6 nm	-80.6464	.194014	-.181339	-.0301739	-.00212964	3.13808E-04	-.00210888
418.0 nm	-94.2526	-.881302	-.0131335	.00371515	-.00433338	-6.45602E-04	-.00195489

The fit represents the 160.6nm emission cross section with an rms deviation of 0.2%.
The maximum deviation is 0.3% at 2.0E+04 eV/amu.

The fit represents the 418.0nm emission cross section with an rms deviation of 0.2%.
The maximum deviation is 0.3% at 7.0E+05 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + H_2 \rightarrow$ 160.6, 418.0 nm



Excitation Cross Sections for

$H^+ + He \rightarrow H^+ + He^*(2^1S, 2^1P)$
$H^+ + He^*(2^1S + 2^1P)$

He(2^1S) Energy (eV/amu)	He(2^1S) σ (cm^2)	He(2^1P) Energy (eV/amu)	He(2^1P) σ (cm^2)	He($2^1S + 2^1P$) Energy (eV/amu)	He($2^1S + 2^1P$) σ (cm^2)
2.5E+04	3.79E-18	2.3E+04	2.00E-18	2.3E+04	5.38E-18
3.0E+04	4.52E-18	2.5E+04	2.44E-18	3.0E+04	7.52E-18
3.5E+04	5.28E-18	3.0E+04	3.44E-18	4.0E+04	1.12E-17
4.0E+04	6.05E-18	3.5E+04	4.61E-18	5.0E+04	1.47E-17
4.5E+04	6.68E-18	4.0E+04	5.76E-18	6.0E+04	1.50E-17
5.0E+04	6.87E-18	4.5E+04	6.91E-18	7.0E+04	1.48E-17
5.5E+04	6.59E-18	5.0E+04	7.65E-18	8.0E+04	1.55E-17
6.0E+04	6.22E-18	5.5E+04	7.96E-18	9.0E+04	1.71E-17
7.0E+04	5.33E-18	6.0E+04	8.39E-18	1.0E+05	1.79E-17
8.0E+04	4.94E-18	7.0E+04	9.39E-18	1.3E+05	1.62E-17
9.0E+04	5.16E-18	8.0E+04	1.08E-17		
1.0E+05	5.43E-18	9.0E+04	1.23E-17		
		1.0E+05	1.36E-17		
		1.2E+05	1.43E-17		
		1.5E+05	1.35E-17		
		2.0E+05	1.21E-17		
		2.5E+05	1.10E-17		
		3.0E+05	1.01E-17		
		3.5E+05	9.32E-18		
		4.0E+05	8.71E-18		
		5.0E+05	7.80E-18		
		6.0E+05	6.91E-18		
		7.0E+05	6.31E-18		
		8.0E+05	5.88E-18		
		9.0E+05	5.52E-18		
		1.0E+06	5.23E-18		

References: 665, 680, 681, 682

Accuracy: $E < 1.5\times10^5$ eV/amu - 50%
$E > 1.5\times10^5$ eV/amu - 30%

Note: For angular distributions see Park et al. (Ref. 681), and Kvale et al. (Ref. 665).

Chebyshev Fitting Parameters for Cross Sections

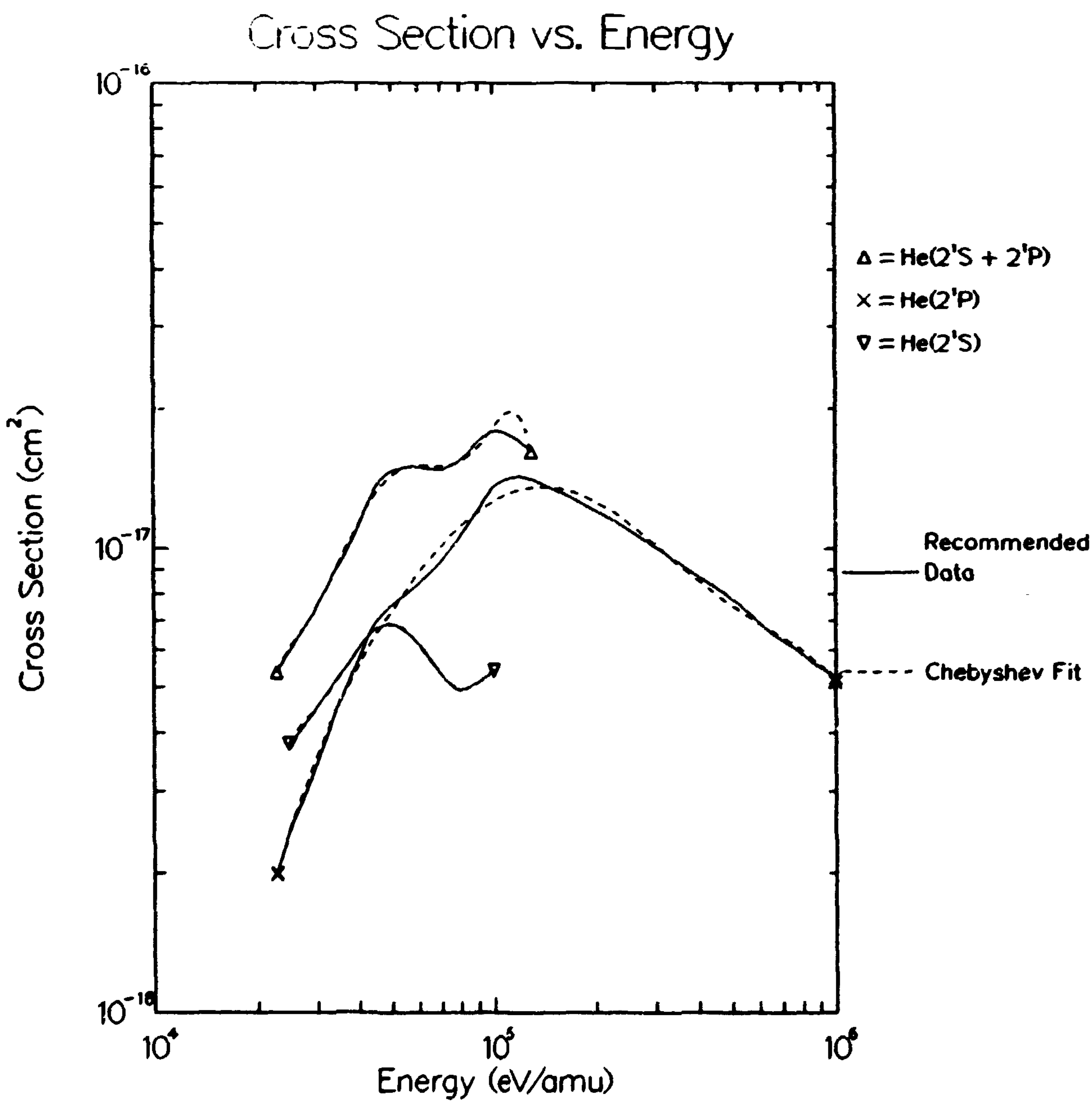
He*(2^1S) E_{min} = 2.5E+04 eV/amu, E_{max} = 1.0E+05 eV/amu
He*(2^1P) E_{min} = 2.3E+04 eV/amu, E_{max} = 1.0E+06 eV/amu
He*($2^1S + 2^1P$) E_{min} = 2.3E+04 eV/amu, E_{max} = 1.3E+05 eV/amu

	A0	A1	A2	A3	A4	A5	A6
He*(2^1S)	-79.6082	.117213	-.178720	.0616470	.0764221	.00195815	-.0273944
He*(2^1P)	-79.1761	.318296	-.694295	.161212	.0240083	-.00395403	-.0285411
He*($2^1S + 2^1P$)	-77.9705	.598490	-.190056	.0136746	.00624072	-.0619807	-.0460015

The fit represents the He*(2^1S) cross section with an rms deviation of 0.5%. The maximum deviation is 0.7% at 8.0E+04 eV/amu.
The fit represents the He*(2^1P) cross section with an rms deviation of 3.7%. The maximum deviation is 8.4% at 7.0E+04 eV/amu.
The fit represents the He*($2^1S + 2^1P$) cross section with an rms deviation of 1.6%. The maximum deviation is 2.0% at 7.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + He \rightarrow He(2^1S, 2^1P, 2^1S + 2^1P)$



Excitation Rate Coefficients for

$He + H^+ \rightarrow H^+ + He^*(2^1S)$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H Temp. (eV)	He Energy (eV/amu) 30000.	40000.	50000.	60000.	70000.	80000.	100000.
1.0E+00	1.09E-09	1.68E-09	2.13E-09	2.11E-09	1.96E-09	1.94E-09	1.19E-09#
2.0E+00	1.09E-09	1.68E-09	2.13E-09	2.11E-09	1.96E-09	1.95E-09	1.18E-09#
4.0E+00	1.09E-09	1.68E-09	2.13E-09	2.11E-09	1.96E-09	1.95E-09	1.18E-09#
7.0E+00	1.09E-09	1.68E-09	2.12E-09	2.11E-09	1.96E-09	1.95E-09	1.18E-09#
1.0E+01	1.09E-09	1.68E-09	2.12E-09	2.11E-09	1.96E-09	1.95E-09	1.17E-09#
2.0E+01	1.09E-09	1.68E-09	2.12E-09	2.11E-09	1.97E-09	1.96E-09	1.16E-09#
4.0E+01	1.09E-09	1.68E-09	2.11E-09	2.11E-09	1.97E-09	1.96E-09	1.15E-09#
7.0E+01	1.09E-09	1.68E-09	2.10E-09	2.10E-09	1.97E-09	1.97E-09	1.14E-09#
1.0E+02	1.09E-09	1.68E-09	2.09E-09	2.10E-09	1.98E-09	1.98E-09	1.13E-09#
2.0E+02	1.07E-09	1.68E-09	2.08E-09	2.09E-09	1.99E-09	2.00E-09	1.11E-09#
4.0E+02	1.04E-09	1.68E-09	2.04E-09	2.07E-09	2.00E-09	2.00E-09	1.07E-09#
7.0E+02	1.04E-09*	1.67E-09	2.00E-09	2.06E-09	2.01E-09	1.95E-09	1.04E-09#
1.0E+03	1.05E-09*	1.66E-09	1.97E-09	2.04E-09	2.00E-09	1.89E-09*	1.02E-09#
2.0E+03	1.10E-09*	1.61E-09	1.89E-09	1.97E-09	1.91E-09	1.71E-09*	9.77E-10#
4.0E+03	1.17E-09*	1.55E-09	1.75E-09	1.79E-09*	1.69E-09*	1.48E-09*	9.29E-10#
7.0E+03	1.23E-09*	1.47E-09	1.57E-09*	1.56E-09*	1.45E-09*	1.28E-09*	8.75E-10#
1.0E+04	1.23E-09*	1.38E-09*	1.43E-09*	1.39E-09*	1.29E-09*	1.15E-09*	8.27E-10#
2.0E+04	1.15E-09*	1.15E-09*	1.12E-09*	1.06E-09*	9.83E-10#	8.92E-10#	7.02E-10#

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

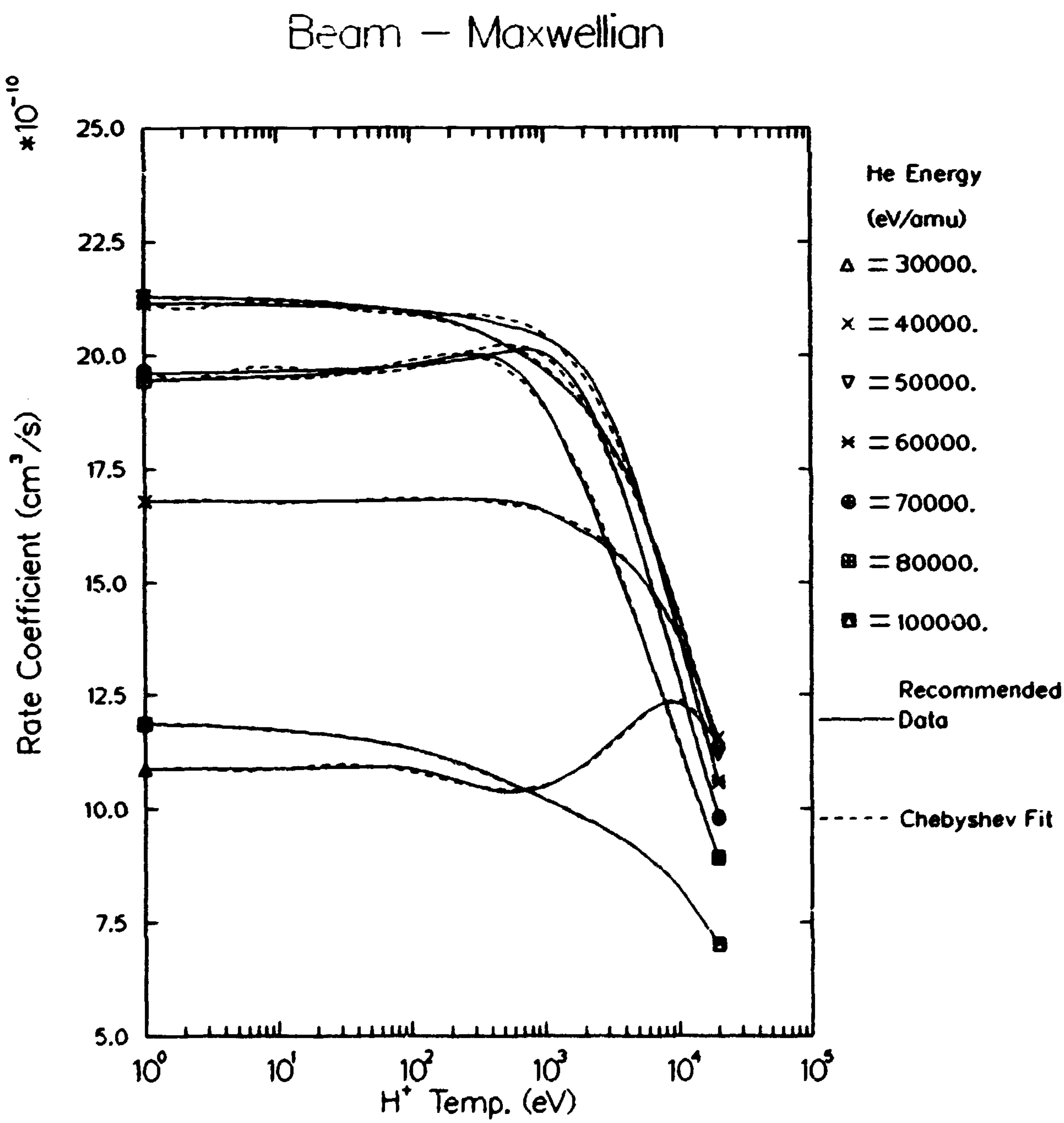
Chebyshev Fitting Parameters for Rate Coefficients

$$E_{min} = 1.0E+00 \text{ eV}, \quad E_{max} = 2.0E+04 \text{ eV}$$

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
30000.	-41.2314	.0438795	.0359901	.0113183	-.01831772	-.0298761	-.0164179
40000.	-40.5478	-.126080	-.0918486	-.0530702	-.0226281	-.00730499	-.00342970
50000.	-40.2209	-.240437	-.148187	-.0719185	-.0283797	-.00898769	-8.65703E-04
60000.	-40.231[illegible]	-.246864	-.171734	-.0935161	-.0372433	-.00687580	.00536462
70000.	-40.3601	-.241292	-.189416	-.108326	-.0372244	.00170975	.0115451
80000.	-40.4485	-.303064	-.213746	-.0974470	-.0150843	.0124774	.00596267
100000.	-41.3985	-.220781	-.0969877	-.0320398	-.0136188	-.00923349	-.00545964

See appendix for Chebyshev fit details.

$He + H^+ \rightarrow H^+ + He(2^1S)$



Excitation Rate Coefficients for

$He + H^+ \rightarrow H^+ + He^*(2^1P)$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H Temp. (eV)	He Energy (eV/amu) 30000.	40000.	60000.	80000.	100000.	200000.	400000.
1.0E+00	8.28E-10	1.60E-09	2.86E-09	4.24E-09	5.97E-09	7.52E-09	7.65E-09
2.0E+00	8.28E-10	1.60E-09	2.86E-09	4.24E-09	5.96E-09	7.52E-09	7.65E-09
4.0E+00	8.29E-10	1.60E-09	2.86E-09	4.24E-09	5.96E-09	7.51E-09	7.65E-09
7.0E+00	8.29E-10	1.60E-09	2.86E-09	4.25E-09	5.96E-09	7.51E-09	7.65E-09
1.0E+01	8.30E-10	1.60E-09	2.86E-09	4.25E-09	5.95E-09	7.51E-09	7.65E-09
2.0E+01	8.32E-10	1.60E-09	2.86E-09	4.25E-09	5.94E-09	7.51E-09	7.65E-09
4.0E+01	8.36E-10	1.61E-09	2.86E-09	4.25E-09	5.93E-09	7.51E-09	7.65E-09
7.0E+01	8.41E-10	1.61E-09	2.87E-09	4.26E-09	5.92E-09	7.51E-09	7.65E-09
1.0E+02	8.47E-10	1.61E-09	2.87E-09	4.27E-09	5.91E-09	7.51E-09	7.65E-09
2.0E+02	8.60E-10	1.63E-09	2.89E-09	4.28E-09	5.89E-09	7.51E-09	7.65E-09
4.0E+02	8.80E-10	1.65E-09	2.92E-09	4.32E-09	5.87E-09	7.50E-09	7.65E-09
7.0E+02	9.14E-10	1.67E-09	2.96E-09	4.36E-09	5.84E-09	7.51E-09	7.65E-09
1.0E+03	9.52E-10	1.69E-09	2.99E-09	4.41E-09	5.82E-09	7.50E-09	7.65E-09
2.0E+03	1.07E-09	1.78E-09	3.12E-09	4.51E-09	5.77E-09	7.50E-09	7.65E-09
4.0E+03	1.30E-09	1.97E-09	3.33E-09	4.63E-09	5.73E-09	7.48E-09	7.65E-09
7.0E+03	1.63E-09	2.28E-09	3.58E-09	4.75E-09	5.70E-09	7.45E-09	7.64E-09
1.0E+04	1.93E-09	2.57E-09	3.78E-09	4.85E-09	5.69E-09	7.41E-09	7.63E-09
2.0E+04	2.79E-09	3.32E-09	4.29E-09	5.09E-09	5.74E-09	7.27E-09	7.60E-09

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

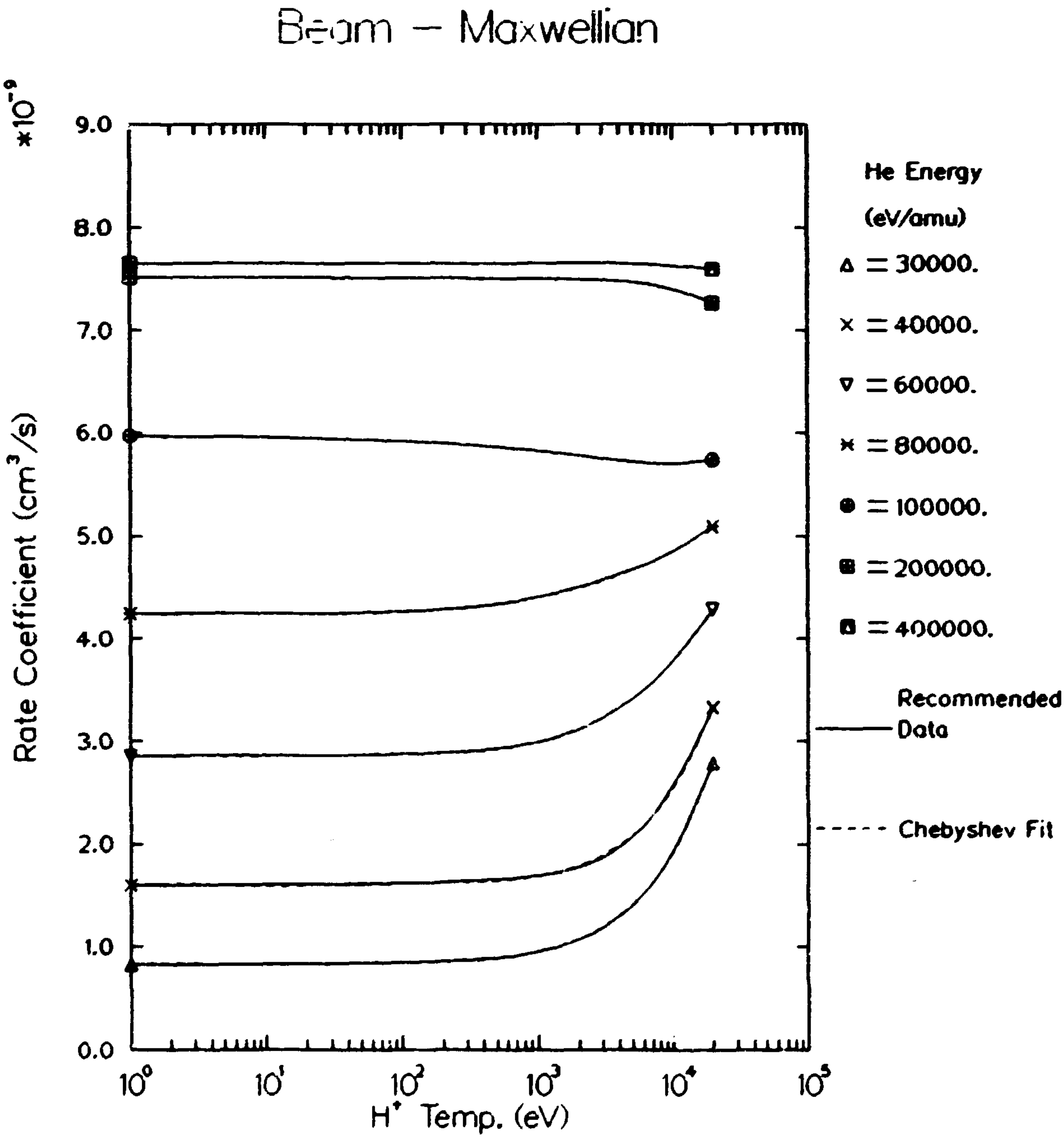
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
30000.	-41.2504	.486127	.299576	.128300	.0302620	-.00574350	-.00993827
40000.	-40.1898	.273759	.181714	.0905572	.0322161	.00429196	-.00603203
60000.	-39.1561	.162678	.0999502	.0424831	.00981070	-.00141938	-.00247916
80000.	-38.4598	.0783748	.0416546	.0129989	.00102165	-5.19012E-04	6.56879E-04
100000.	-37.9111	-.0245928	-.00529346	.00275039	.00343274	.00202306	8.64146E-04
200000.	-37.4242	-.0102727	-.00738113	-.00482593	-.00285436	-.00141545	-4.70357E-04
400000.	-37.3788	-.00169868	-.00156122	-.00125546	-8.10521E-04	-4.46724E-04	-1.48377E-04

See appendix for Chebyshev fit details.

$He + H^{+} \rightarrow H^{+} + He(2^{1}P)$



Excitation Cross Sections for

$H^+ + He \rightarrow H^+ + He^*(3^1S, 3^1P, 3^1D)$

$He^*(3^1S)$ Energy (eV/amu)	$He^*(3^1S)$ σ (cm^2)	$He^*(3^1P)$ Energy (eV/amu)	$He^*(3^1P)$ σ (cm^2)	$He^*(3^1D)$ Energy (eV/amu)	$He^*(3^1D)$ σ (cm^2)
5.0E+03	6.81E-20	2.0E+03	7.41E-21	3.5E+03	4.51E-20
6.0E+03	1.08E-19	4.0E+03	4.38E-20	4.0E+03	6.18E-20
7.0E+03	1.65E-19	7.0E+03	1.90E-19	7.0E+03	3.11E-19
8.0E+03	2.26E-19	1.0E+04	5.04E-19	1.0E+04	3.90E-19
9.0E+03	2.96E-19	1.5E+04	1.04E-18	1.5E+04	4.30E-19
1.0E+04	3.65E-19	2.0E+04	1.25E-18	2.0E+04	3.74E-19
1.5E+04	6.83E-19	2.7E+04	1.21E-18	2.8E+04	2.83E-19
2.0E+04	9.53E-19	4.0E+04	1.56E-18	4.0E+04	3.57E-19
3.0E+04	1.30E-18	7.0E+04	2.50E-18	5.5E+04	3.82E-19
4.0E+04	1.43E-18	1.0E+05	3.05E-18	7.0E+04	3.47E-19
5.0E+04	1.39E-18	1.3E+05	3.27E-18	1.0E+05	2.68E-19
6.0E+04	1.29E-18	2.0E+05	3.13E-18	1.5E+05	2.02E-19
7.0E+04	1.21E-18	4.0E+05	2.35E-18		
8.0E+04	1.12E-18	7.0E+05	1.67E-18		
9.0E+04	1.03E-18	1.0E+06	1.30E-18		
1.0E+05	9.63E-19				
1.5E+05	6.92E-19				
2.0E+05	5.07E-19				
2.5E+05	3.91E-19				

References: 680, 685, 686, 687, 688, 689, 690

Accuracy: 40%

Notes: None

Chebyshev Fitting Parameters for Cross Sections

$He^*(3^1S)$ E_{min} = 5.0E+03 eV/amu, E_{max} = 2.5E+05 eV/amu
$He^*(3^1P)$ E_{min} = 2.0E+03 eV/amu, E_{max} = 1.0E+06 eV/amu
$He^*(3^1D)$ E_{min} = 3.5E+03 eV/amu, E_{max} = 1.5E+05 eV/amu

	A0	A1	A2	A3	A4	A5	A6
$He^*(3^1S)$	-84.4433	.775561	-1.05948	.110960	.0219972	-.00305073	-.00996704
$He^*(3^1P)$	-84.5124	2.50529	-1.63211	.133239	-.0277337	-.0862483	.168352
$He^*(3^1D)$	-85.9726	.503209	-.748814	.283442	-.187874	-.0352298	.123942

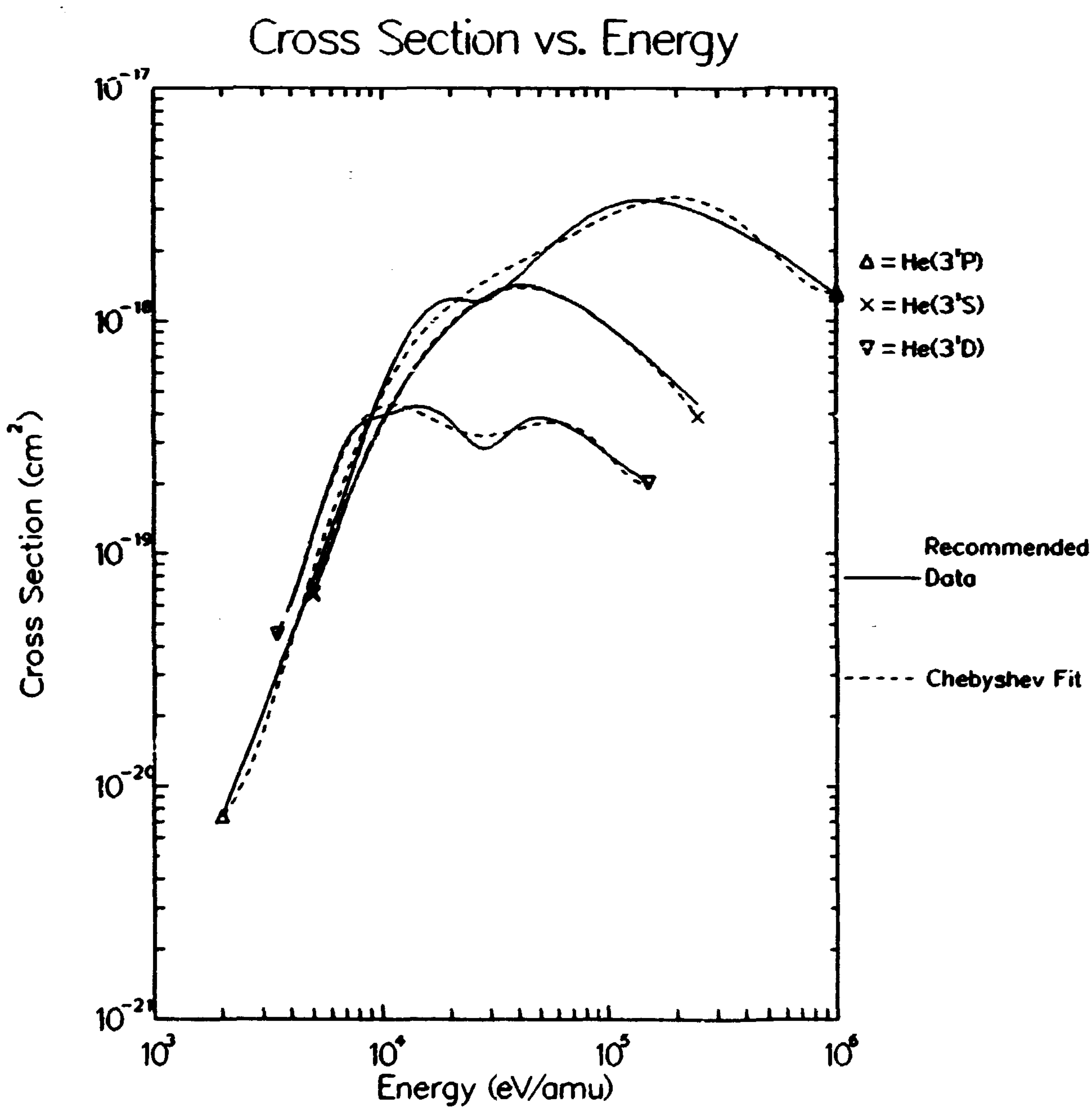
The fit represents the $He^*(3^1S)$ cross section with an rms deviation of 1.6%. The maximum deviation is 3.9% at 6.0E+03 eV/amu.

The fit represents the $He^*(3^1P)$ cross section with an rms deviation of 9.8%. The maximum deviation is 18.7% at 2.7E+04 eV/amu.

The fit represents the $He^*(3^1D)$ cross section with an rms deviation of 6.2%. The maximum deviation is 13.9% at 2.8E+04 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + He \rightarrow He(3^1S, 3^1P, 3^1D)$



Excitation Cross Sections for

$H^+ + He \rightarrow H^+ + He^*(4^1S, 4^1P, 4^1D)$

$He^*(4^1S)$ Energy (eV/amu)	$He^*(4^1S)$ σ (cm^2)	$He^*(4^1P)$ Energy (eV/amu)	$He^*(4^1P)$ σ (cm^2)	$He^*(4^1D)$ Energy (eV/amu)	$He^*(4^1D)$ σ (cm^2)
1.0E+03	2.09E-22	1.0E+04	1.19E-19	2.0E+03	2.21E-21
2.0E+03	1.64E-21	1.5E+04	2.63E-19	4.0E+03	7.14E-21
3.0E+03	2.98E-21	2.0E+04	3.19E-19	7.0C+03	7.63E-20
4.0E+03	2.02E-21	3.0E+04	3.61E-19	1.0E+04	1.52E-19
4.5E+03	1.70E-21	4.0E+04	4.49E-19	1.3E+04	1.79E-19
7.0E+03	3.94E-20	5.0E+04	5.72E-19	2.0E+04	1.18E-19
1.0E+04	8.88E-20	6.0E+04	6.92E-19	2.6E+04	1.05E-19
1.5E+04	1.34E-19	7.0E+04	7.73E-19	4.0E+04	1.30E-19
2.0E+04	2.15E-19	8.0E+04	8.43E-19	5.0E+04	1.38E-19
4.0E+04	4.94E-19	9.0E+04	9.14E-19	7.0E+04	1.31E-19
4.4E+04	5.15E-19	1.0E+05	9.72E-19	1.0E+05	1.07E-19
7.0E+04	4.01E-19	1.3E+05	1.06E-18	1.5E+05	7.17E-20
1.0E+05	2.87E-19	1.5E+05	1.05E-18	2.0E+05	5.12E-20
1.5E+05	1.93E-19	2.0E+05	1.00E-18	4.0E+05	2.42E-20
2.0E+05	1.41E-19	3.0E+05	8.79E-19	4.0E+05	2.42E-20
4.0E+05	6.74E-20	4.0E+05	7.84E-19	7.0E+05	1.34E-20
7.0E+05	3.94E-20	5.0E+05	6.81E-19	1.0E+06	9.00E-21
1.0E+06	2.69E-20	6.0E+05	6.07E-19		
		7.0E+05	5.46E-19		
		8.0E+05	5.00E-19		
		9.0E+05	4.50E-19		
		1.0E+06	4.00E-19		

References: 680, 685, 686, 687, 688, 689, 690

Accuracy: 40%

Notes: None

Chebyshev Fitting Parameters for Cross Sections

$He^*(4^1S)$ E_{min} = 1.0E+03 eV/amu, E_{max} = 1.0E+06 eV/amu
$He^*(4^1P)$ E_{min} = 1.0E+04 eV/amu, E_{max} = 1.0E+06 eV/amu
$He^*(4^1D)$ E_{min} = 2.0E+03 eV/amu, E_{max} = 1.0E+06 eV/amu

	A0	A1	A2	A3	A4	A5	A6
$He^*(4^1S)$	-90.7744	2.47036	-2.37315	-.112038	.549272	-.0385738	-.264616
$He^*(4^1P)$	-84.4673	.568166	-.658688	-.0606377	.0615161	.0857392	-.0897306
$He^*(4^1D)$	-90.3972	.468672	-1.92730	.452357	7.32888E-04	-.125659	.290353

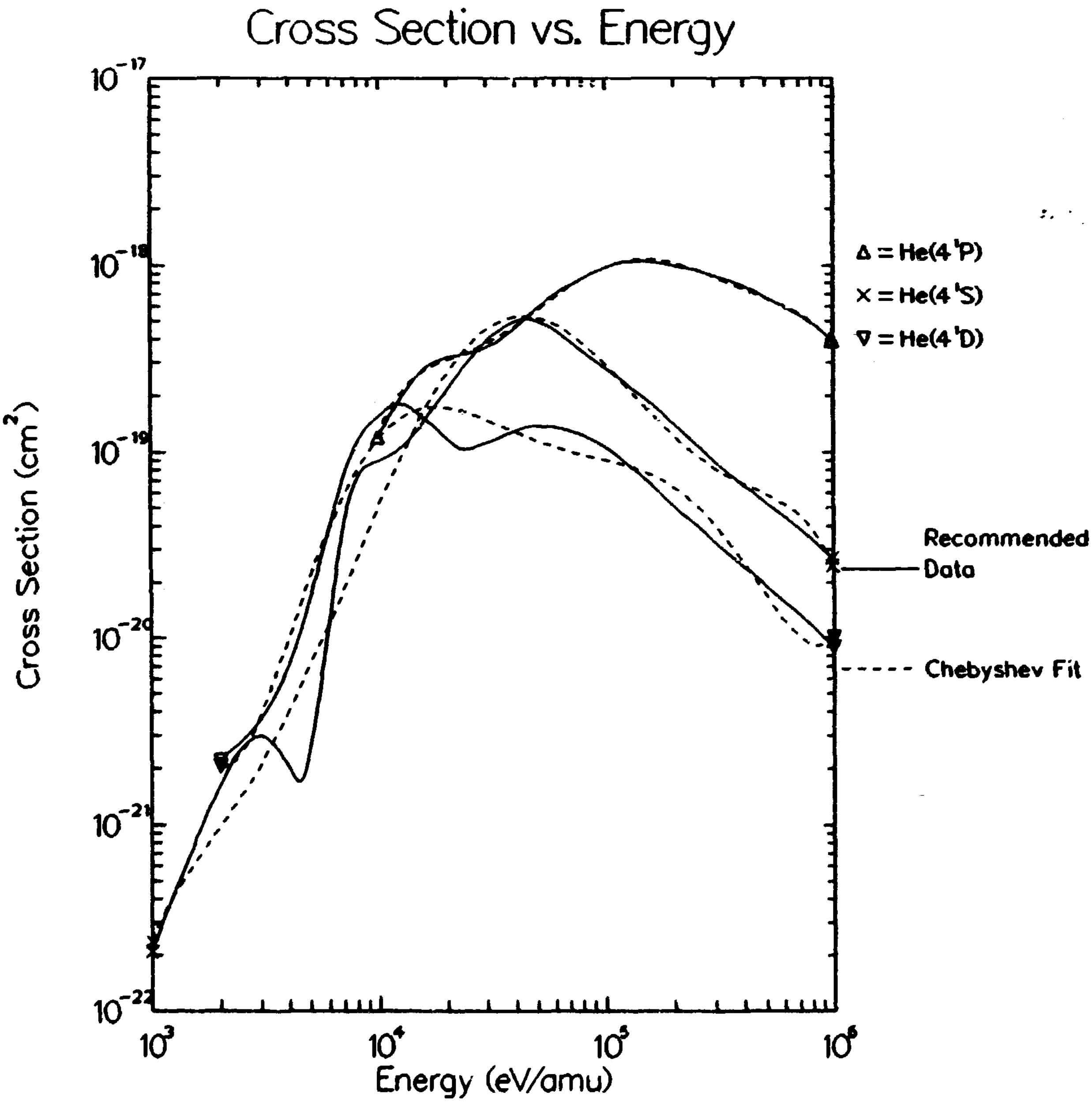
The fit represents the $He^*(4^1S)$ cross section with an rms deviation of 60.6%. The maximum deviation is 217.9% at 4.5E+03 eV/amu.

The fit represents the $He^*(4^1P)$ cross section with an rms deviation of 2.4%. The maximum deviation is 4.9% at 3.0E+04 eV/amu.

The fit represents the $He^*(4^1D)$ cross section with an rms deviation of 25.2%. The maximum deviation is 50.7% at 2.6E+04 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + He \rightarrow H^+ + He(4^1S, 4^1P, 4^1D)$



Total Vacuum Ultraviolet Emission Cross Sections for

$H^+ + He \rightarrow$ v.u.v. (λ = 20-140nm)

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
4.2E+03	9.00E+07	1.05E-18
5.0E+03	9.82E+07	1.25E-18
6.0E+03	1.08E+08	1.49E-18
7.0E+03	1.16E+08	1.70E-18
8.0E+03	1.24E+08	1.89E-18
9.0E+03	1.32E+08	2.05E-18
1.0E+04	1.39E+08	2.20E-18
1.5E+04	1.70E+08	2.73E-18
2.0E+04	1.96E+08	3.00E-18
3.0E+04	2.41E+08	3.21E-18
4.0E+04	2.78E+08	3.30E-18
5.0E+04	3.11E+08	3.33E-18
6.0E+04	3.40E+08	3.34E-18
7.0E+04	3.68E+08	3.32E-18
8.0E+04	3.93E+08	3.31E-18
9.0E+04	4.17E+08	3.28E-18
1.0E+05	4.39E+08	3.25E-18
1.5E+05	5.38E+08	3.14E-18

Reference: 654

Accuracy: 40%

Note: Values shown in the graph correspond to values of measured cross sections for v.u.v. emission which have been corrected for the photoelectric yield integrated over the wavelength range of sensitivity of the detector (approx. 20-140nm).

Chebyshev Fitting Parameters for Cross Sections

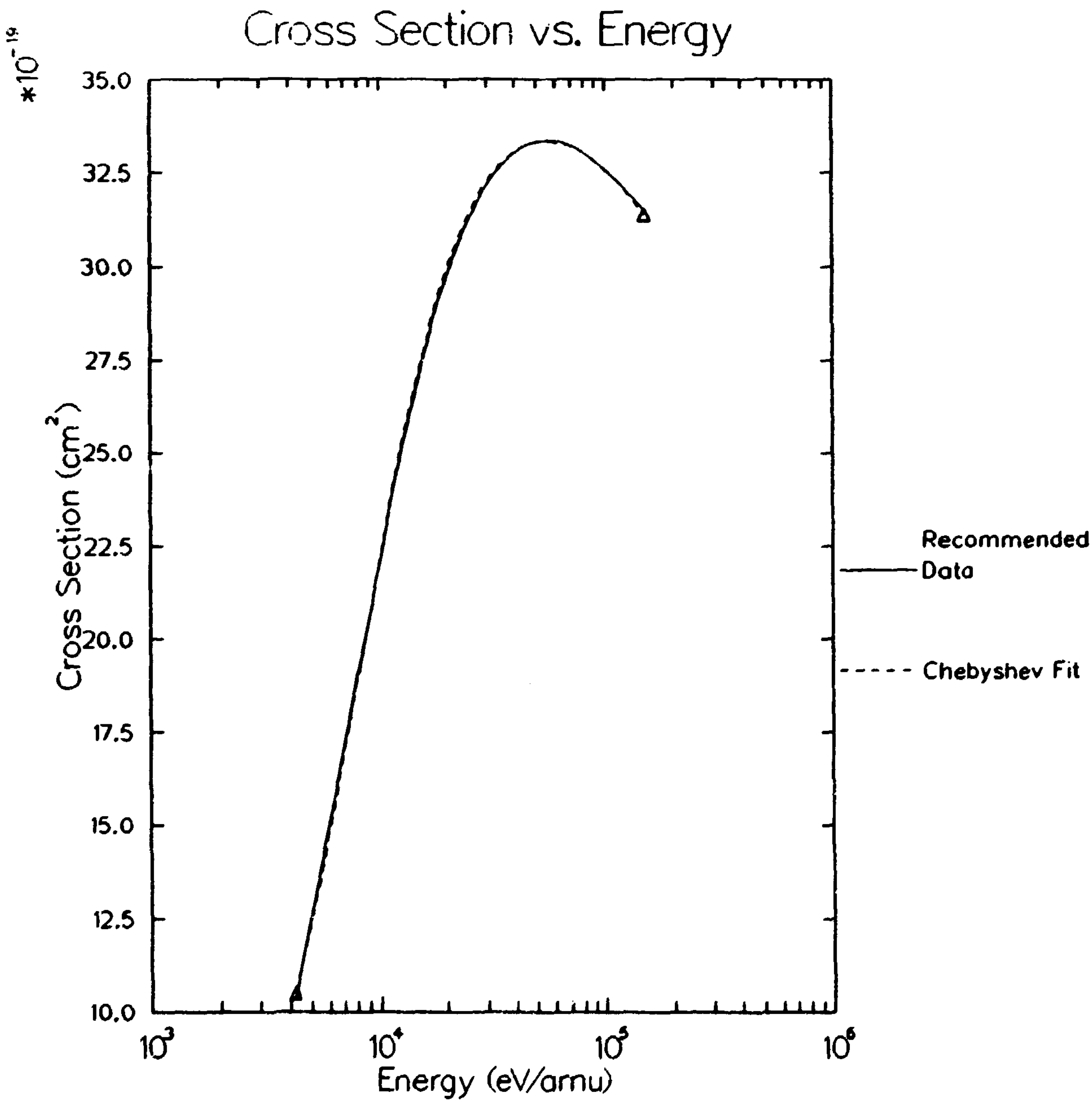
E_{min} = 4.2E+03 eV/amu, E_{max} = 1.5E+05 eV/amu

A0	A1	A2	A3	A4	A5	A6
-81.1574	.502834	-.275390	.0508166	.00293296	-.00661360	.00122541

The fit represents the above cross section with an rms deviation of 0.3%. The maximum deviation is 0.5% at 3.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + He \rightarrow$ v.u.v. (20–140 nm)



Excitation Cross Sections for

$He^+ + H \rightarrow H(n=2)$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
3.8E+03	8.56E+07	5.98E-17
4.0E+03	8.79E+07	6.01E-17
5.0E+03	9.82E+07	6.07E-17
6.0E+03	1.08E+08	6.13E-17
7.0E+03	1.16E+08	6.16E-17
8.0E+03	1.24E+08	6.19E-17
9.0E+03	1.32E+08	6.18E-17
1.0E+04	1.39E+08	6.17E-17
1.5E+04	1.70E+08	6.17E-17
2.0E+04	1.96E+08	6.27E-17
3.0E+04	2.41E+08	6.59E-17
4.0E+04	2.78E+08	7.52E-17
5.0E+04	3.11E+08	8.96E-17
5.2E+04	3.17E+08	9.30E-17

Reference: 716

Accuracy: 50%

Note: These data were obtained by measuring the energy loss of the He^+ ion after collision. The resolution of the energy-loss spectrometer was not sufficient to resolve the 2s and 2p states.

Chebyshev Fitting Parameters for Cross Sections

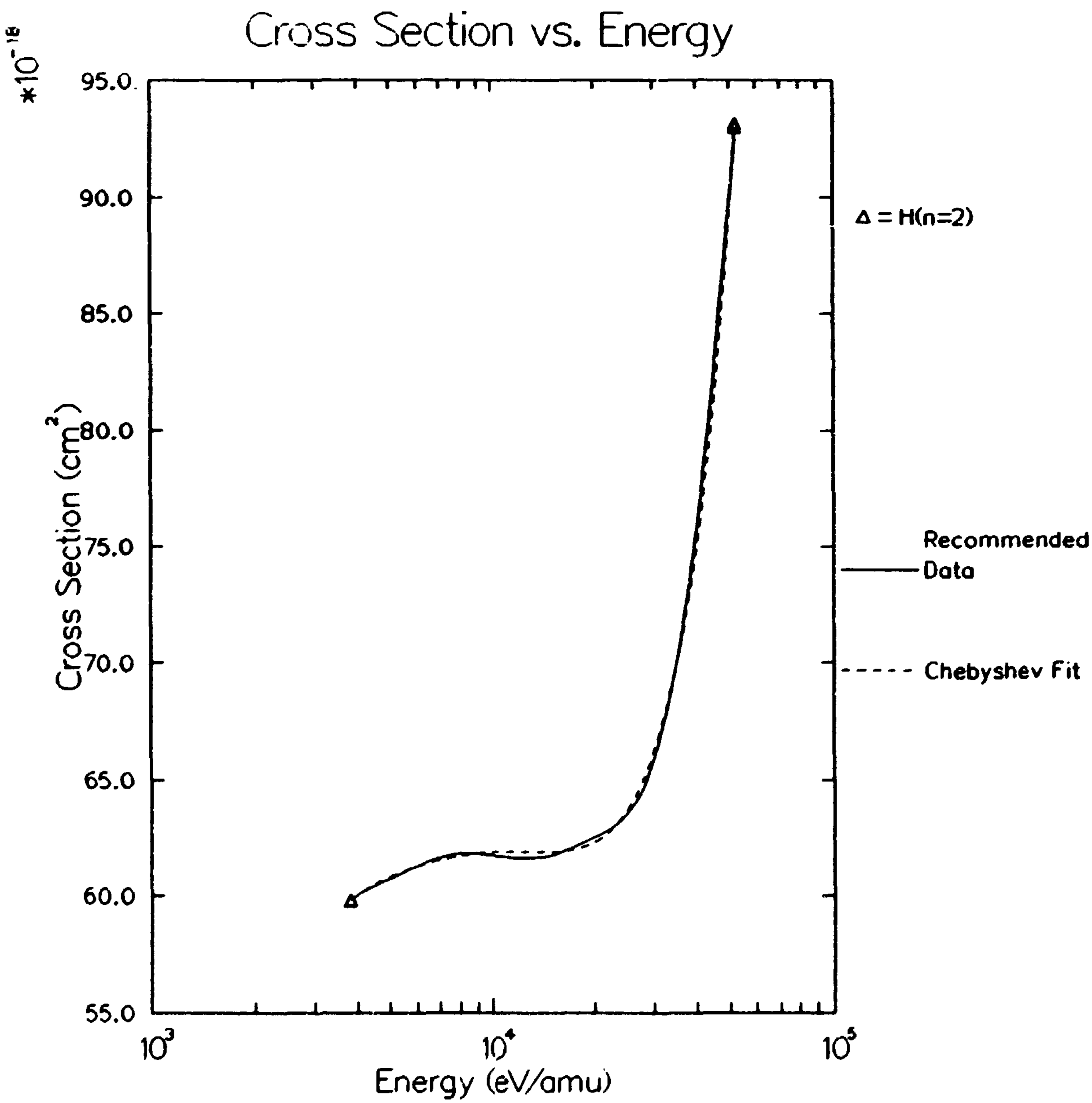
E_{min} = 3.8E+03 eV/amu, E_{max} = 5.2E+04 eV/amu

A0	A1	A2	A3	A4	A5	A6
-74.4909	.160714	.0943278	.0580551	.0178172	.00276895	-4.72682E-04

The fit represents the above cross section with an rms deviation of 0.3%. The maximum deviation is 0.5% at 3.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^{+} + H \rightarrow He^{+} + H(n=2)$



Excitation Cross Sections for

$He^{+} + H \rightarrow He^{+} + H(2s,2p)$

H(2s) Energy (eV/amu)	H(2s) Cross Section (cm^2)	H(2p) Energy (eV/amu)	H(2p) Cross Section (cm^2)
1.5E+03	1.04E-17	1.3E+02	9.03E-18
2.0E+03	6.59E-18	1.5E+02	1.36E-17
2.8E+03	4.60E-18	2.0E+02	2.18E-17
3.0E+03	4.61E-18	3.0E+02	2.95E-17
4.0E+03	7.95E-18	4.0E+02	3.22E-17
4.7E+03	1.12E-17	5.0E+02	3.39E-17
5.0E+03	1.11E-17	6.0E+02	3.51E-17
6.0E+03	5.82E-18	7.0E+02	3.60E-17
6.6E+03	4.51E-18	8.0E+02	3.66E-17
		9.0E+02	3.72E-17
		1.0E+03	3.75E-17
		1.5E+03	3.85E-17
		2.0E+03	3.90E-17
		3.0E+03	3.96E-17
		4.0E+03	3.98E-17
		5.0E+03	4.02E-17
		6.0E+03	4.04E-17
		7.0E+03	4.07E-17
		8.0E+03	4.07E-17
		9.0E+03	4.08E-17
		9.6E+03	4.08E-17

<u>References:</u> 701, 712, 715

<u>Accuracy:</u> 30%

<u>Note:</u> The data for the excitation of the 2p state are (within the experimental error) the same as the Lyman-α emission cross section.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

H(2s) E_{min} = 1.5E+03 eV/amu, E_{max} = 6.6E+03 eV/amu
H(2p) E_{min} = 1.3E+02 eV/amu, E_{max} = 9.6E+03 eV/amu

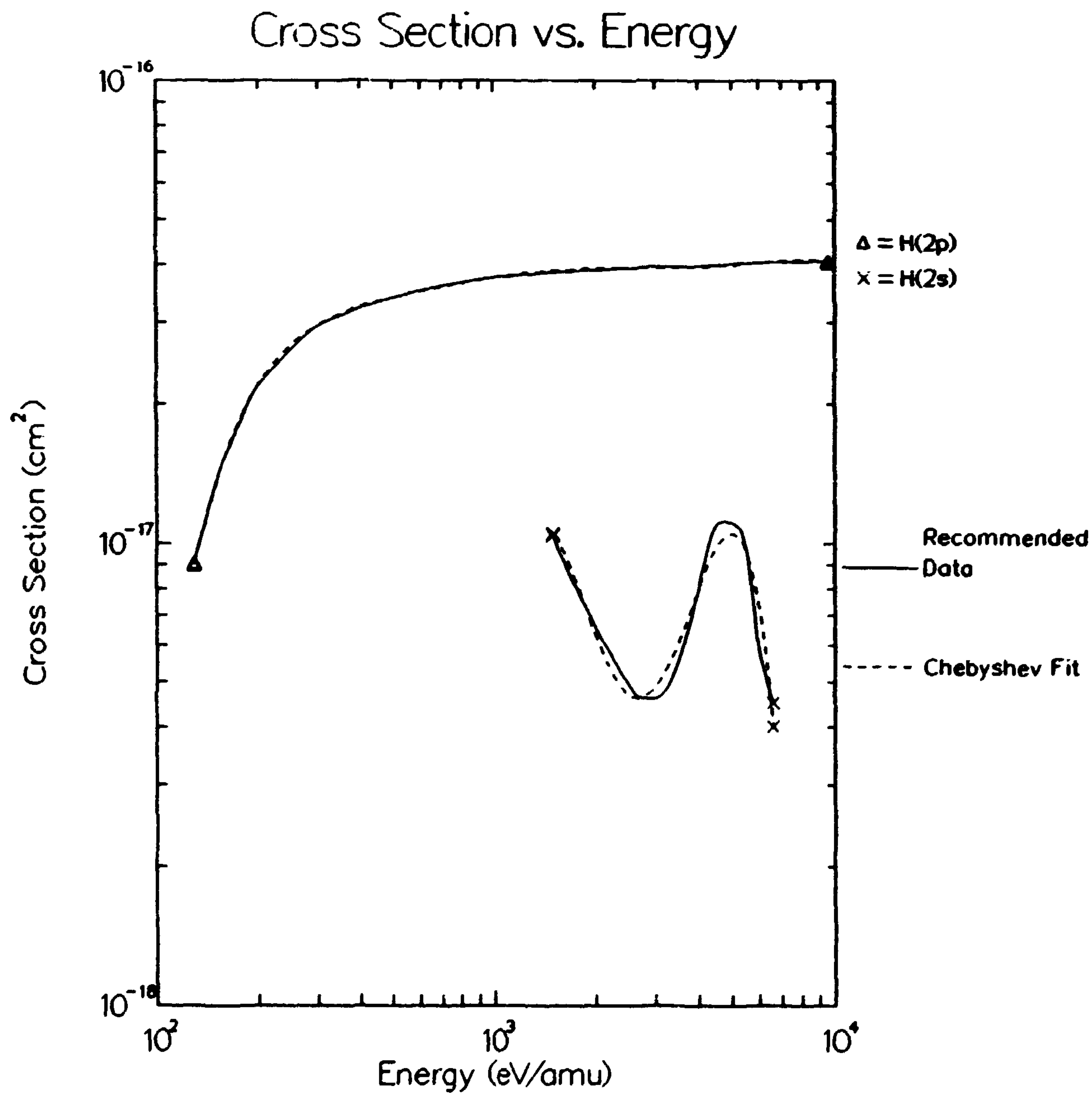
	A0	A1	A2	A3	A4	A5	A6
H(2s)	-78.9847	-.124567	.114965	-.358545	-.199857		
H(2p)	-76.1170	.522520	-.318078	.179576	-.0921414	.0455819	-.0220305

The fit represents the H(2s) cross section with an rms deviation of 10.1%. The maximum deviation is 25.2% at 6.0E+03 eV/amu.

The fit represents the H(2p) cross section with an rms deviation of 0.5%. The maximum deviation is 0.8% at 1.5E+03 eV/amu.

See appendix for Chebyshev fit details.

$He^{+} + H \rightarrow He^{+} + H(2s,2p)$



Excitation Rate Coefficients for

He^{+} + H -> He^{+} + H(2p)

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

He Temp. (eV)	Equal Temp.	H Temp. (eV) 100.	200.	500.	1000.	5000.	10000.	20000.
1.0E+02	3.27E-10*	3.27E-10*	6.34E-10	1.24E-09	1.88E-09	2.52E-09*	1.57E-09#	7.49E-10#
2.0E+02	6.98E-10	4.12E-10	6.98E-10	1.28E-09	1.90E-09	2.52E-09*	1.56E-09#	7.48E-10#
3.0E+02	9.76E-10	4.91E-10	7.59E-10	1.31E-09	1.93E-09	2.51E-09*	1.56E-09#	7.47E-10#
4.0E+02	1.20E-09	5.65E-10	8.17E-10	1.35E-09	1.96E-09	2.51E-09*	1.56E-09#	7.46E-10#
5.0E+02	1.39E-09	6.34E-10	8.72E-10	1.39E-09	1.98E-09	2.50E-09*	1.55E-09#	7.45E-10#
6.0E+02	1.56E-09	6.98E-10	9.24E-10	1.42E-09	2.01E-09	2.50E-09*	1.55E-09#	7.4[illegible]-10#
7.0E+02	1.71E-09	7.59E-10	9.74E-10	1.46E-09	2.03E-09	2.49E-09*	1.54E-09#	7.43E-10#
8.0E+02	1.85E-09	8.17E-10	1.02E-09	1.49E-09	2.05E-09	2.49E-09*	1.54E-09#	7.42E-10#
9.0E+02	1.98E-09	8.72E-10	1.07E-09	1.53E-09	2.08E-09	2.48E-09*	1.54E-09#	7.41E-10#
1.0E+03	2.10E-09	9.24E-10	1.11E-09	1.56E-09	2.10E-09	2.47E-09*	1.53E-09#	7.40E-10#
2.0E+03	2.76E-09*	1.35E-09	1.49E-09	1.85E-09	2.31E-09	2.42E-09*	1.50E-09#	7.29E-10#
4.0E+03	2.53E-09*	1.96E-09	2.05E-09	2.31E-09	2.61E-09	2.31E-09#	1.44E-09#	7.08E-10#
6.0E+03	1.99E-09#	2.38E-09	2.45E-09	2.61E-09	2.76E-09*	2.20E-09#	1.38E-09#	6.88E-10#
8.0E+03	1.57E-09#	2.65E-09	2.68E-09	2.76E-09*	2.81E-09*	2.09E-09#	1.3E-09#	6.69E-10#
1.0E+04	1.27E-09#	2.78E-09*	2.79E-09*	2.81E-09*	2.79E-09*	1.99E-09#	1.27E-09#	6.51E-10#
1.2E+04	1.04E-09#	2.82E-09*	2.81E-09*	2.79E-09*	2.73E-09*	1.90E-09#	1.22E-09#	6.34E-10#
1.5E+04	8.10E-10#	2.75E-09*	2.74E-09*	2.68E-09*	2.58E-09*	1.76E-09#	1.15E-09#	6.09E-10#
2.0E+04	5.71E-10#	2.51E-09*	2.49E-09*	2.42E-09*	2.31E-09#	1.57E-09#	1.04E-09#	5.71E-10#

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

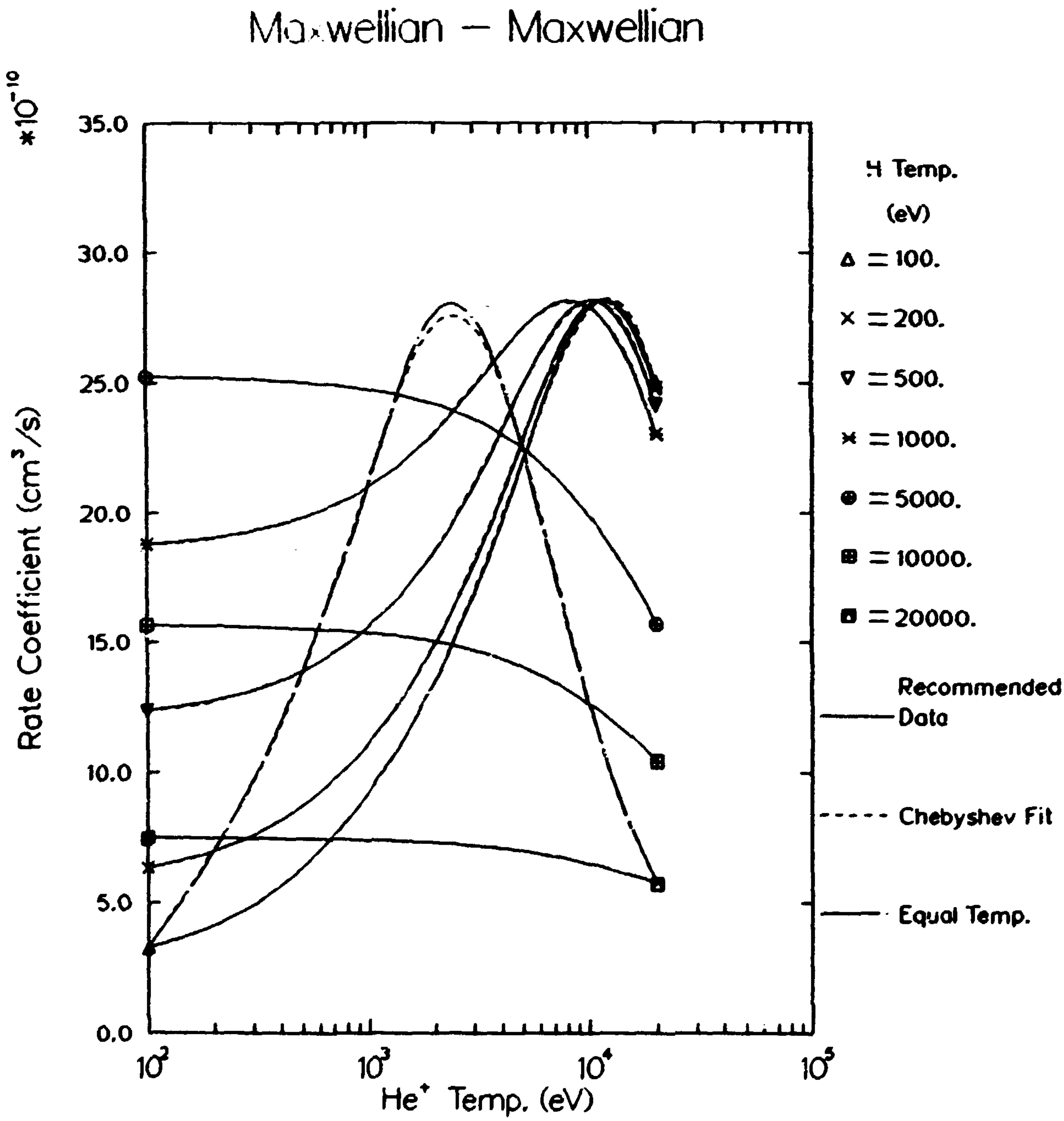
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+02 eV, E_{max} = 2.0E+04 eV

H Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
100.	-41.3676	1.16527	-.103922	-.132163	-.0348422	-.0167981	-.00106673
200.	-40.8770	.821004	-.0109340	-.127376	-.0485804	-.0120056	7.63058E-04
500.	-40.2738	.442909	.00923768	-.0979147	-.0519441	-.0112276	.00362652
1000.	-39.8495	.187131	-.0287907	-.0768304	-.0399746	-.00851390	.00286700
5000.	-39.8387	-.195041	-.104148	-.0404533	-.0115750	-.00220721	-2.40196E-06
10000.	-40.7661	-.170203	-.0865943	-.0313220	-.00824330	-.00148203	-7.88573E-05
20000.	-42.1667	-.113121	-.0579411	-.0213073	-.00583215	-.00116246	-1.36085E-04
Equal Temp.	-41.3902	.353784	-.066154	-.123235	.00687538	.0519228	-.00558678

See appendix for Chebyshev fit details

$He^{+} + H \rightarrow He^{+} + H(2p)$



Spectral Line Emission Cross Sections for

$He^+ + H_2 \rightarrow H(\text{Lyman-}\alpha, \text{Lyman-}\beta)$

H(Lyman-α)

Energy (eV/amu)	Cross Section (cm^2)
7.7E+00	4.33E-18
8.0E+00	5.16E-18
1.0E+01	1.05E-17
2.0E+01	3.39E-17
4.0E+01	5.51E-17
7.0E+01	6.19E-17
1.0E+02	6.01E-17
2.0E+02	4.57E-17
4.0E+02	3.56E-17
7.0E+02	3.20E-17
1.0E+03	3.13E-17
2.0E+03	3.35E-17
4.0E+03	4.45E-17
5.0E+03	4.61E-17
7.0E+03	4.53E-17
7.4E+03	4.48E-17

H(Lyman-β)

Energy (eV/amu)	Cross Section (cm^2)
1.2E+01	1.06E-18
1.5E+01	2.15E-18
2.0E+01	3.68E-18
3.0E+01	5.82E-18
4.0E+01	7.07E-18
5.0E+01	7.81E-18
6.0E+01	8.21E-18
7.0E+01	8.57E-18
8.0E+01	8.64E-18
9.0E+01	8.56E-18
1.0E+02	8.46E-18
1.5E+02	7.67E-18
2.0E+02	6.78E-18

References: 188, 195, 199, 700

Accuracy: 40%

Notes: (1) The Lyman-α transition is at 121.57nm and the Lyman-β transition is at 102.57nm. (2) Data on polarization of emissions may be found in Isler and Nathan (Ref. 199) and Young et al. (Ref. 700).

Chebyshev Fitting Parameters for Cross Sections

H(Lyman-α) E_{min} = 7.7E+00 eV/amu, E_{max} = 7.4E+03 eV/amu
H(Lyman-β) E_{min} = 1.2E+01 eV/amu, E_{max} = 2.0E+02 eV/amu

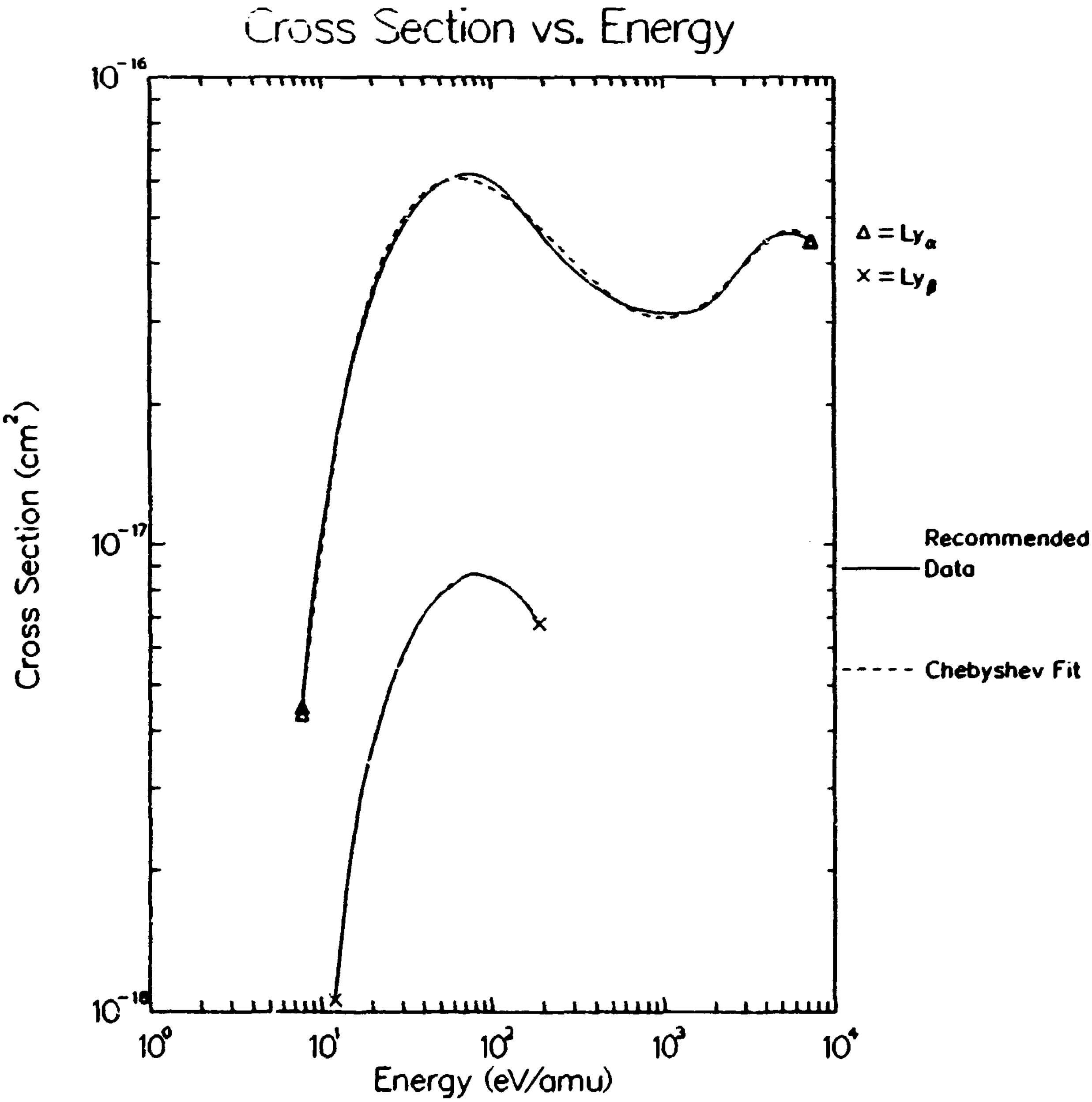
	A0	A1	A2	A3	A4	A5	A6
H(Lyman-α)	-76.0522	.584543	-.527735	.587085	-.202654	-.0240480	-.0420581
H(Lyman-β)	-79.7592	.790251	-.524833	.114100	-.0482761	.0226572	-.00698738

The fit represents the H(Lyman-α) cross section with an rms deviation of 2.5%. The maximum deviation is 3.5% at 7.7E+00 eV/amu.

The fit represents the H(Lyman-β) cross section with an rms deviation of 0.5%. The maximum deviation is 1.0% at 6.0E+01 eV/amu.

See appendix for Chebyshev fit details.

$He^+ + H_2 \rightarrow H$(Lyman-α, Lyman-β)



Spectral Line Emission Cross Sections for

$He^{+} + H_2 \rightarrow H(\text{Balmer-}\alpha, \text{Balmer-}\beta)$

H(Balmer-α)

Energy (eV/amu)	Cross Section (cm^2)
1.0E+01	8.81E-19
2.0E+01	4.79E-18
4.0E+01	7.18E-18
7.0E+01	6.36E-18
1.0E+02	5.16E-18
2.0E+02	3.09E-18
4.0E+02	2.26E-18
7.0E+02	1.99E-18
1.0E+03	1.93E-18
2.0E+03	2.12E-18
4.0E+03	3.00E-18
7.0E+03	3.39E-18
1.0E+04	3.29E-18

H(Balmer-β)

Energy (eV/amu)	Cross Section (cm^2)
1.5E+01	2.00E-19
2.0E+01	5.60E-19
4.0E+01	1.33E-18
5.0E+01	1.41E-18
7.0E+01	1.34E-18
1.0E+02	1.10E-18
2.0E+02	5.50E-19
4.0E+02	3.47E-19
7.0E+02	2.98E-19
1.0E+03	3.12E-19
2.0E+03	3.91E-19
4.0E+03	5.56E-19
5.0E+03	5.78E-19
7.0E+03	5.28E-19
8.0E+03	4.83E-19

References: 166, 199, 461, 464, 693, 694, 695

Accuracy: Unknown

Notes: (1) The Balmer-α emission is from the n=3->2 transition (656.28nm). (2) The Balmer-β emission is from the n=4->2 transition (486.13nm). (3) Data on polarization of emissions may be found in Isler and Nathan (Refs. 199 and 694).

Chebyshev Fitting Parameters for Cross Sections

H(Balmer-α)	E_{min} = 1.0E+01 eV/amu,	E_{max} = 1.0E+04 eV/amu
H(Balmer-β)	E_{min} = 1.5E+01 eV/amu,	E_{max} = 8.0E+03 eV/amu

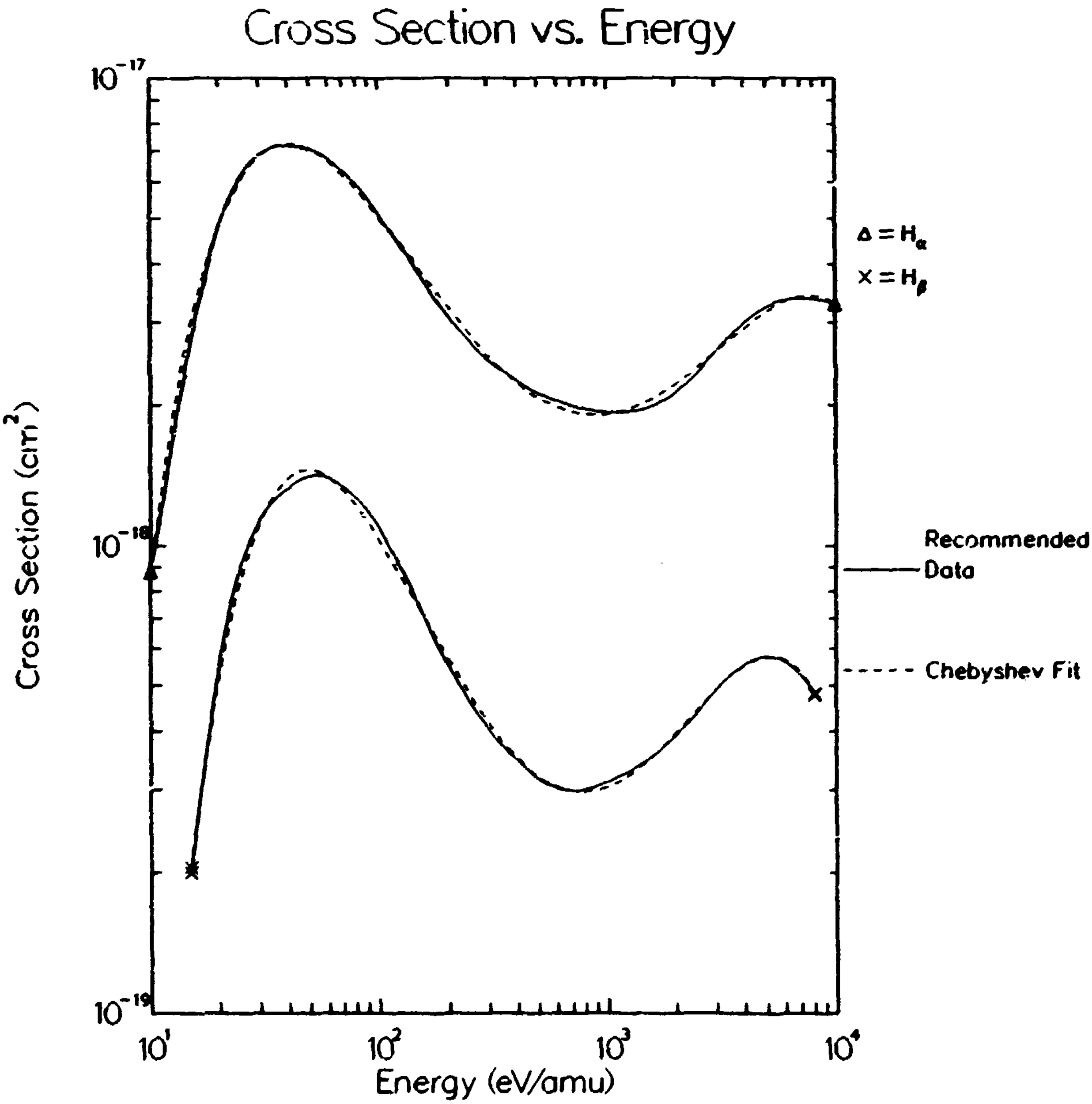
	A0	A1	A2	A3	A4	A5	A6
H(Balmer-α)	-80.7189	.0329782	-.173449	.608331	-.365301	.0179138	-.0168644
H(Balmer-β)	-84.1448	-.135846	-.0820835	.566238	-.436982	-.00523445	-.0131479

The fit represents the H(Balmer-α) cross section with an rms deviation of 2.2%. The maximum deviation is 4.5% at 2.0E+02 eV/amu.

The fit represents the H(Balmer-β) cross section with an rms deviation of 2.9%. The maximum deviation is 4.9% at 4.0E+01 eV/amu.

See appendix for Chebyshev fit details.

$He^+ + H_2 \rightarrow H(\text{Balmer}-\alpha, \text{Balmer}-\beta)$



Dissociative Excitation Cross Sections for

$He^{+} + H_2 \rightarrow He^{+} + H(2s,2p) + H(\Sigma)$

H(2s) Energy (eV/amu)	H(2s) Cross Section (cm^2)	H(2p) Energy (eV/amu)	H(2p) Cross Section (cm^2)
1.4E+03	4.92E-18	1.3E+01	2.11E-17
1.5E+03	4.93E-18	2.0E+01	3.62E-17
1.7E+03	4.93E-18	4.0E+01	5.59E-17
2.0E+03	4.92E-18	6.0E+01	5.81E-17
2.5E+03	4.93E-18	7.0E+01	5.80E-17
3.0E+03	4.91E-18	1.0E+02	5.61E-17
3.5E+03	4.93E-18	2.0E+02	4.75E-17
4.0E+03	4.91E-18	4.0E+02	3.75E-17
4.5E+03	4.91E-18	7.0E+02	3.31E-17
5.0E+03	4.91E-18	1.0E+03	3.24E-17
5.5E+03	4.91E-18	2.0E+03	3.32E-17
6.0E+03	4.91E-18	4.0E+03	3.73E-17
6.4E+03	4.92E-18	5.0E+03	3.81E-17
		7.0E+03	3.75E-17
		7.4E+03	3.72E-17

References: 183, 195, 700, 701

Accuracy: Within a factor of 2

Notes: (1) The excitation cross sections for H(2s) and H(2p) are determined by the field-induced emission of Lyman-α (2s -> 2p -> 1s), and by Lyman-α emission (2p -> 1s), respectively. If cascade can be neglected, these are equal to the cross sections for the formation of the H(2s) and H(2p) states. (2) The notation H(Σ) designates all possible states for the other fragment (unspecified).

Chebyshev Fitting Parameters for Cross Sections

H(2s) E_{min} = 1.4E+03 eV/amu, E_{max} = 6.4E+03 eV/amu
H(2p) E_{min} = 1.3E+01 eV/amu, E_{max} = 7.4E+03 eV/amu

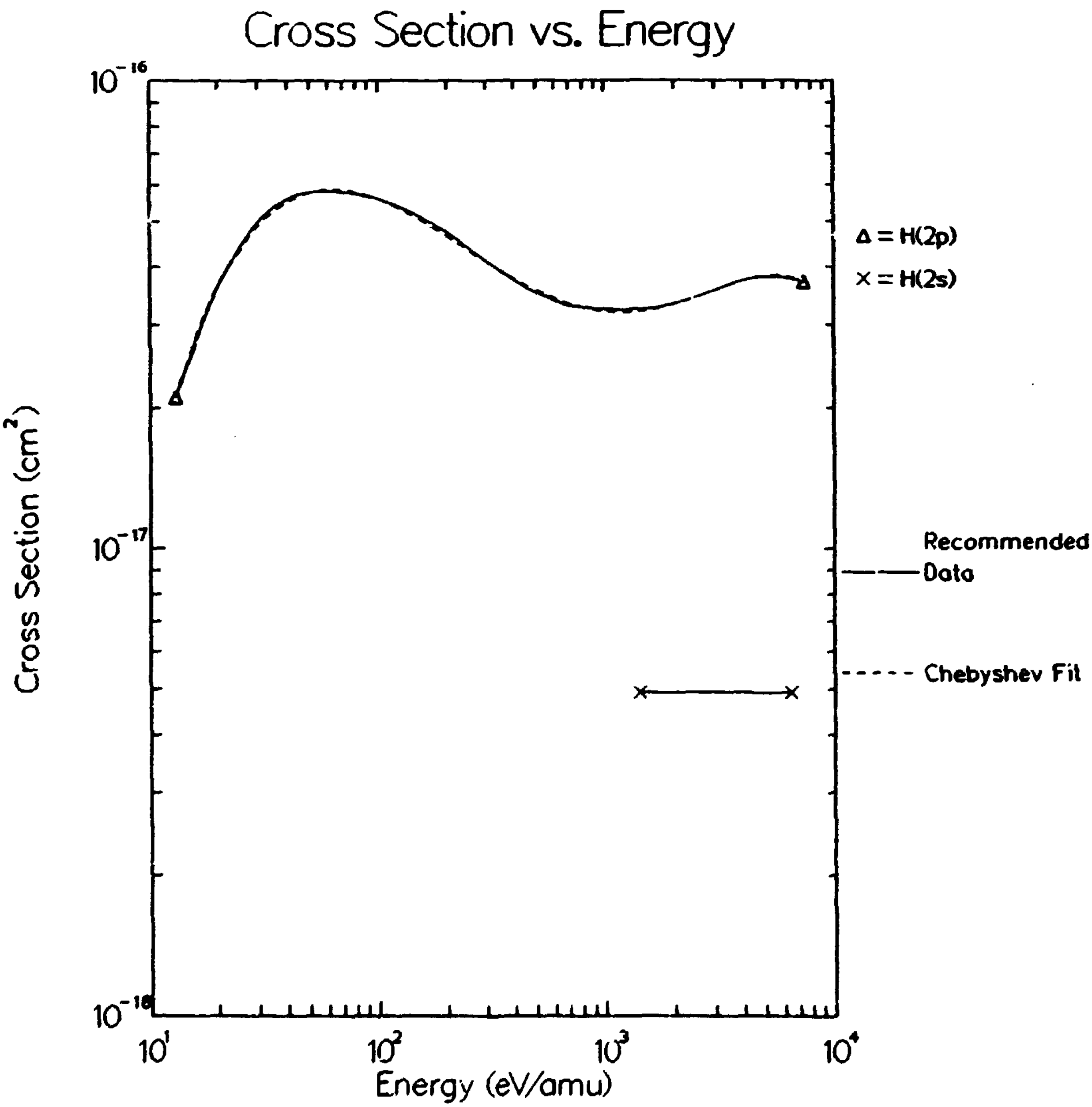
	A0	A1	A2	A3	A4	A5	A6
H(2s)	-79.7066	-.00160282	1.58249E-05	7.60977E-04	2.44965E-04	6.18338E-04	
H(2p)	-75.6225	.00962025	-.178354	.293814	-.115895	-.0206130	-.00983973

The fit represents the H(2s) cross section with an rms deviation of 0.1%. The maximum deviation is 0.2% at 3.0E+03 eV/amu.

The fit represents the H(2p) cross section with an rms deviation of 0.8%. The maximum deviation is 0.9% at 7.0E+01 eV/amu.

See appendix for Chebyshev fit details.

$He^+ + H_2 \rightarrow He^+ + H(2s,2p) + H(\Sigma)$



Dissociative Excitation Cross Sections for

$He^{+} + H_2 \rightarrow He^{+} + H(3s,3p) + H(\Sigma)$

H(3s) Energy (eV/amu)	H(3s) Cross Section (cm^2)	H(3p) Energy (eV/amu)	H(3p) Cross Section (cm^2)
2.5E+03	2.16E-19	2.5E+03	2.36E-18
3.0E+03	2.28E-19	3.0E+03	2.29E-18
3.5E+03	2.34E-19	3.5E+03	2.32E-18
4.0E+03	2.37E-19	4.0E+03	2.41E-18
4.5E+03	2.37E-19	4.5E+03	2.55E-18
5.0E+03	2.35E-19	5.0E+03	2.70E-18
5.5E+03	2.33E-19	5.5E+03	2.77E-18
6.0E+03	2.28E-19	6.0E+03	2.76E-18
7.0E+03	2.19E-19	7.0E+03	2.56E-18
		7.6E+03	2.29E-18

References: 183, 702

Accuracy: 50%

Notes: (1) The H(3s) and H(3p) cross sections are deduced from spectral-line emission measurements on the (unsubstantiated) assumption that cascade can be neglected. (2) The notation $H(\Sigma)$ designates all possible states for the other fragment (unspecified).

Chebyshev Fitting Parameters for Cross Sections

H(3s) E_{min} = 2.5E+03 eV/amu, E_{max} = 7.0E+03 eV/amu
H(3p) E_{min} = 2.5E+03 eV/amu, E_{max} = 7.6E+03 eV/amu

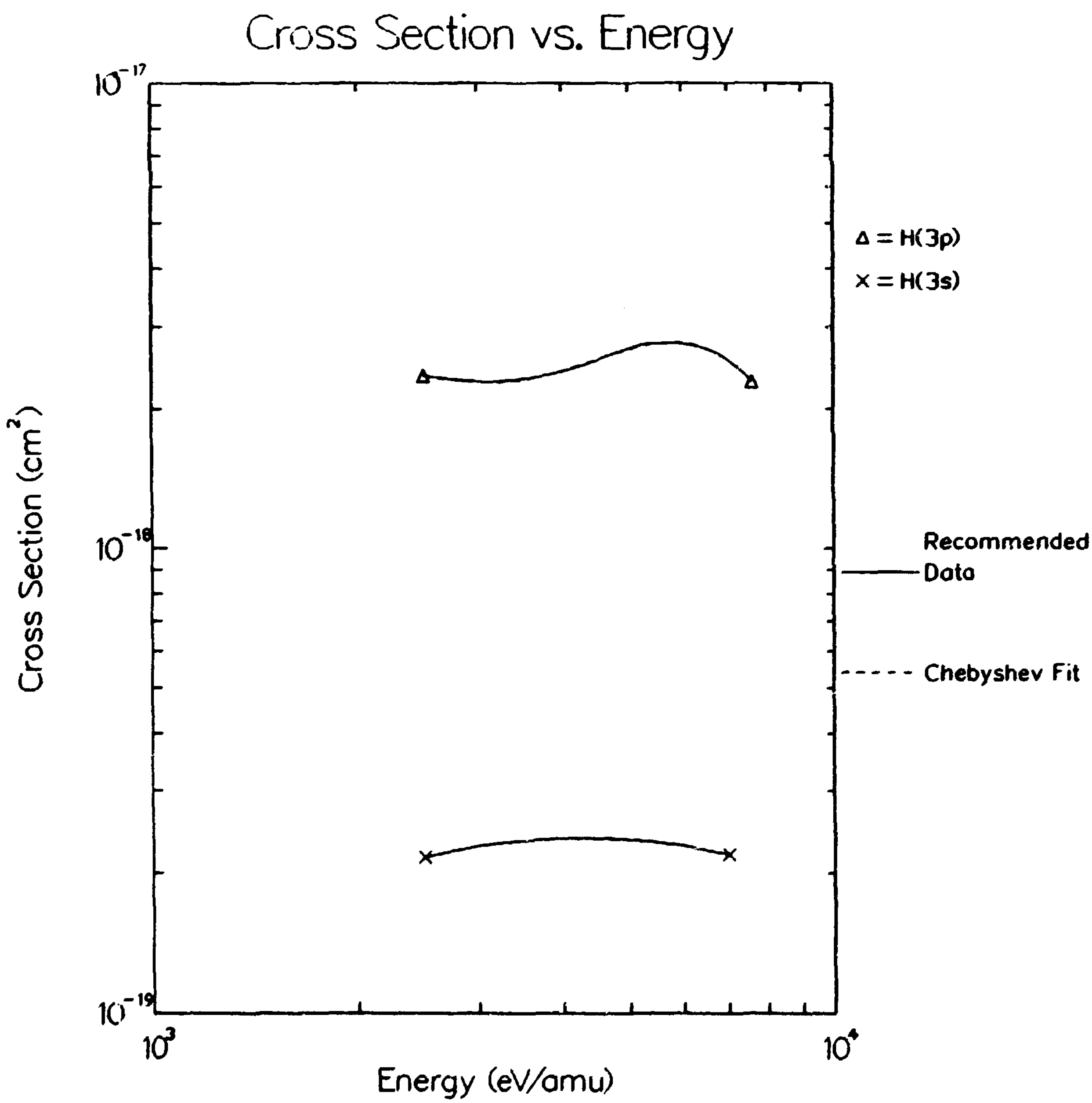
	A0	A1	A2	A3	A4	A5	A6
H(3s)	-85.8579	.00631068	-.0437007	-2.23538E-05	-1.27246E-04	5.58521E-04	6.28175E-04
H(3p)	-81.0948	.0512586	-.0390305	-.0692130	-.0155312	.00341300	-5.63877E-04

The fit represents the H(3s) cross section with an rms deviation of 0.1%. The maximum deviation is 0.2% at 5.0E+03 eV/amu.

The fit represents the H(3p) cross section with an rms deviation of 0.3%. The maximum deviation is 0.5% at 6.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$He^{+} + H_2 \rightarrow He^{+} + H(3s,3p) + H(\Sigma)$



Projectile Excitation Cross Sections for

$He^+ + H_2 \rightarrow He^+(2s) + H_2$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.5E+03	6.95E+07	1.38E-20
3.0E+03	7.61E+07	2.18E-20
3.5E+03	8.22E+07	3.25E-20
4.0E+03	8.79E+07	4.58E-20
4.5E+03	9.32E+07	6.18E-20
5.0E+03	9.82E+07	8.10E-20
5.5E+03	1.03E+08	1.04E-19
6.0E+03	1.08E+08	1.30E-19
7.0E+03	1.16E+08	1.92E-19
7.6E+03	1.21E+08	2.31E-19

Reference: 706

Accuracy: Factor of 2

Notes: None

Chebyshev Fitting Parameters for Cross Sections

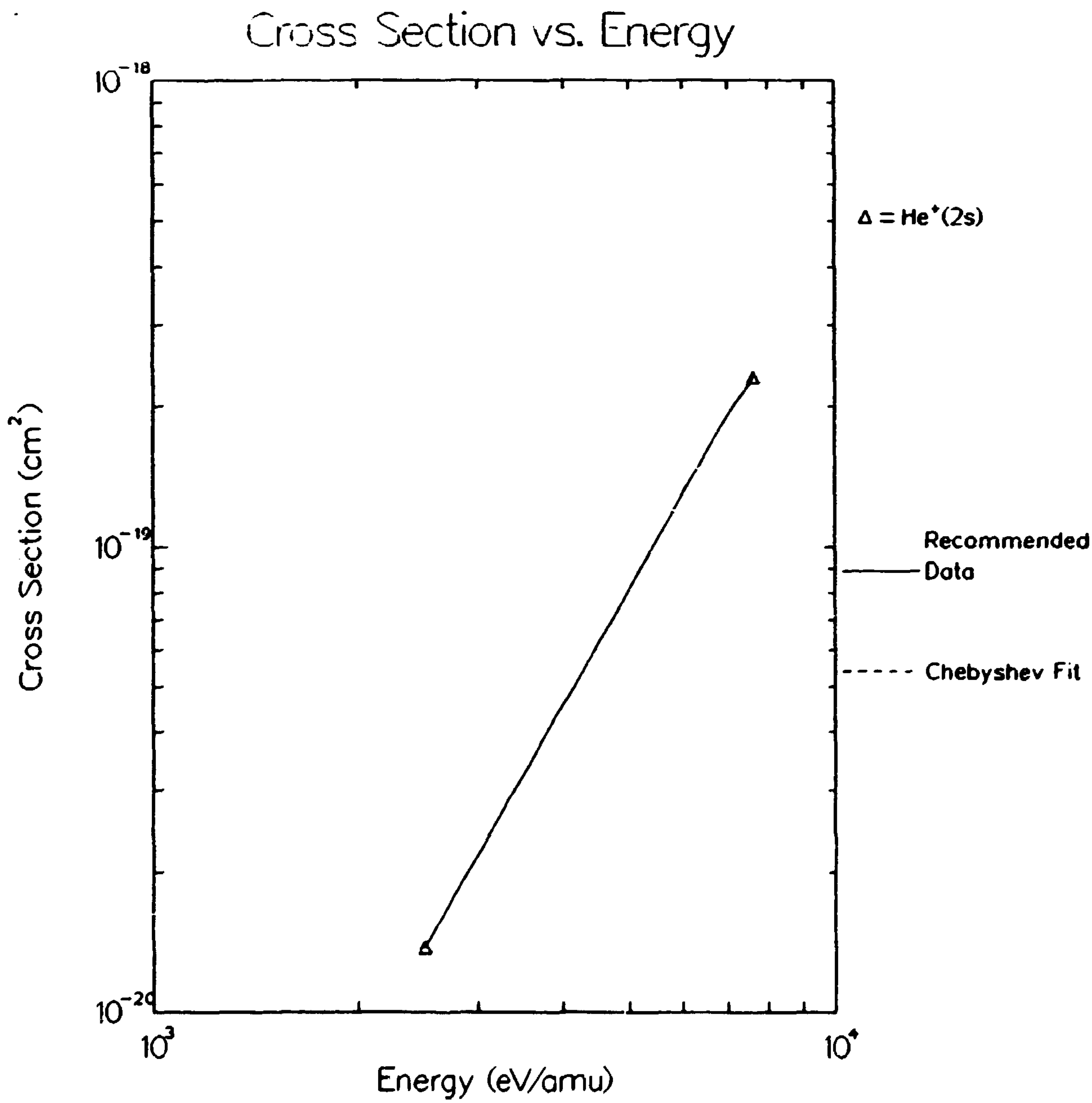
E_{min} = 2.5E+03 eV/amu, E_{max} = 7.6E+03 eV/amu

A0	A1	A2	A3	A4	A5	A6
-88.6255	1.42095	-.00467445	-.00728965	-.00322271	-.00472755	-3.43794E-05

The fit represents the above cross section with an rms deviation of 0.1%. The maximum deviation is 0.1% at 6.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$He^{+} + H_2 \rightarrow He^{+}(2s) + H_2$



Excitation Cross Sections for

$He^+ + He \rightarrow He^+ + He^*(2^1S, 2^1P)$

$He^*(2^1S)$ Energy (eV/amu)	Cross Section (cm^2)	$He^*(2^1P)$ Energy (eV/amu)	Cross Section (cm^2)
7.0E+03	2.98E-18	6.0E+03	9.41E-18
8.0E+03	2.41E-18	7.0E+03	7.31E-18
9.0E+03	2.03E-18	1.0E+04	4.60E-18
1.0E+04	1.76E-18	1.5E+04	2.90E-18
1.5E+04	1.09E-18	2.0E+04	2.52E-18
2.0E+04	9.39E-19	4.0E+04	4.97E-18
2.5E+04	1.09E-18	7.0E+04	9.22E-18
3.0E+04	1.41E-18	1.0E+05	1.08E-17
		1.5E+05	1.13E-17
		2.5E+05	1.07E-17

References: 203, 684, 697, 699, 704, 705, 707, 717

Accuracy: 40%

Notes: (1) For relative cross sections see Refs. 697, 705, and 707. (2) For cross sections $He^+(1s) + He(1s^2)^1S \rightarrow He^+(1s) + He(1s2p)^{1,3}P$ see Bordenave-Montesquieu et al. (Ref. 704). (3) See Thomas (Ref. 684) for more details.

Chebyshev Fitting Parameters for Cross Sections

$He^*(2^1S)$ E_{min} = 7.0E+03 eV/amu, E_{max} = 3.0E+04 eV/amu
$He^*(2^1P)$ E_{min} = 6.0E+03 eV/amu, E_{max} = 2.5E+05 eV/amu

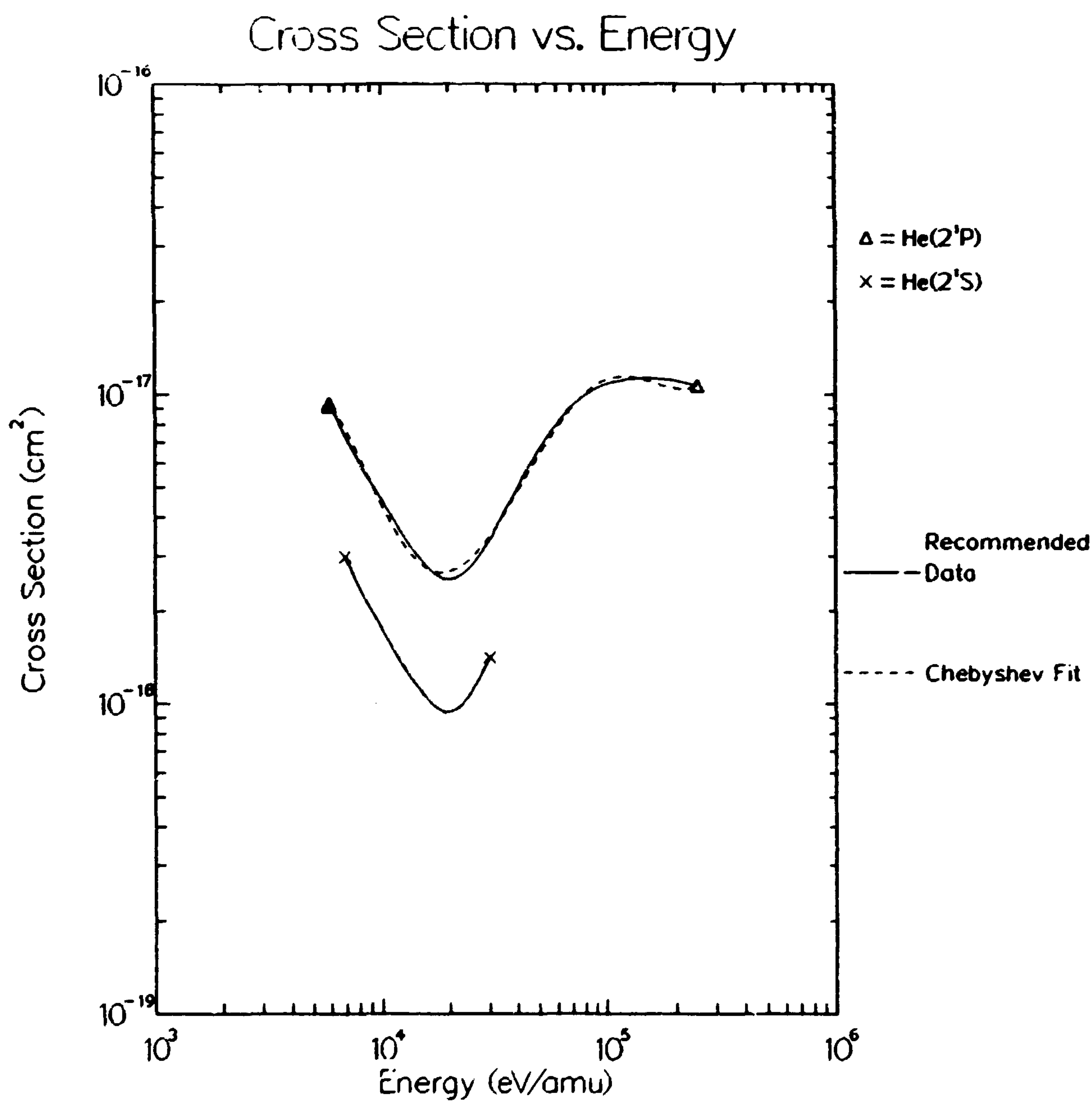
	A0	A1	A2	A3	A4	A5	A6
$He^*(2^1S)$	-82.0676	-.438515	.304992	.0789808	.0643720	-.0146204	-.00639777
$He^*(2^1P)$	-79.0520	.385720	.388654	-.432765	-.00474225	.126047	-.0106668

The fit represents the $He^*(2^1S)$ cross section with an rms deviation of 0.0%. The maximum deviation is 0.0% at 1.0E+04 eV/amu.

The fit represents the $He^*(2^1P)$ cross section with an rms deviation of 3.4%. The maximum deviation is 5.8% at 2.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^{+} + He \rightarrow He^{+} + He(2^1S, 2^1P)$



Excitation Cross Sections for

$He^{+} + He \rightarrow He^{+} + He^{*}(2^{3}S, 2^{3}P)$

$He^{*}(2^{3}S)$ Energy (eV/amu)	$He^{*}(2^{3}S)$ Cross Section (cm^2)	$He^{*}(2^{3}P)$ Energy (eV/amu)	$He^{*}(2^{3}P)$ Cross Section (cm^2)
6.4E+03	2.82E-18	6.5E+03	4.49E-18
7.0E+03	3.22E-18	7.0E+03	5.91E-18
8.0E+03	3.92E-18	8.0E+03	8.72E-18
9.0E+03	4.57E-18	8.4E+03	9.11E-18
1.0E+04	5.07E-18	9.0E+03	8.19E-18
1.5E+04	5.81E-18	1.0E+04	5.45E-18
2.0E+04	4.77E-18	1.5E+04	3.23E-18
2.5E+04	3.38E-18	2.0E+04	2.53E-18
3.0E+04	2.20E-18	2.5E+04	2.01E-18
		3.0E+04	1.18E-18
		3.2E+04	1.00E-18

References: 617, 684, 697, 699, 704, 708, 717

Accuracy: $E < 7.5\times10^{3}$ eV/amu - 75%
$E > 7.5\times10^{3}$ eV/amu - 40%

Notes: (1) For relative cross sections at lower energies see Bordenave-Montesquieu et al. (Ref. 704) and Dworetsky et al. (708). (2) For cross sections: $He^{+}(1s) + He^{+}(1s) \rightarrow He^{+}(1s) + He(1s2p)^{1,3}P$ see Ref. 704. (3) For more details see Thomas (Ref. 684).

Chebyshev Fitting Parameters for Cross Sections

$He^{*}(2^{3}S)$ E_{min} = 6.4E+03 eV/amu, E_{max} = 3.0E+04 eV/amu
$He^{*}(2^{3}P)$ E_{min} = 6.5E+03 eV/amu, E_{max} = 3.2E+04 eV/amu

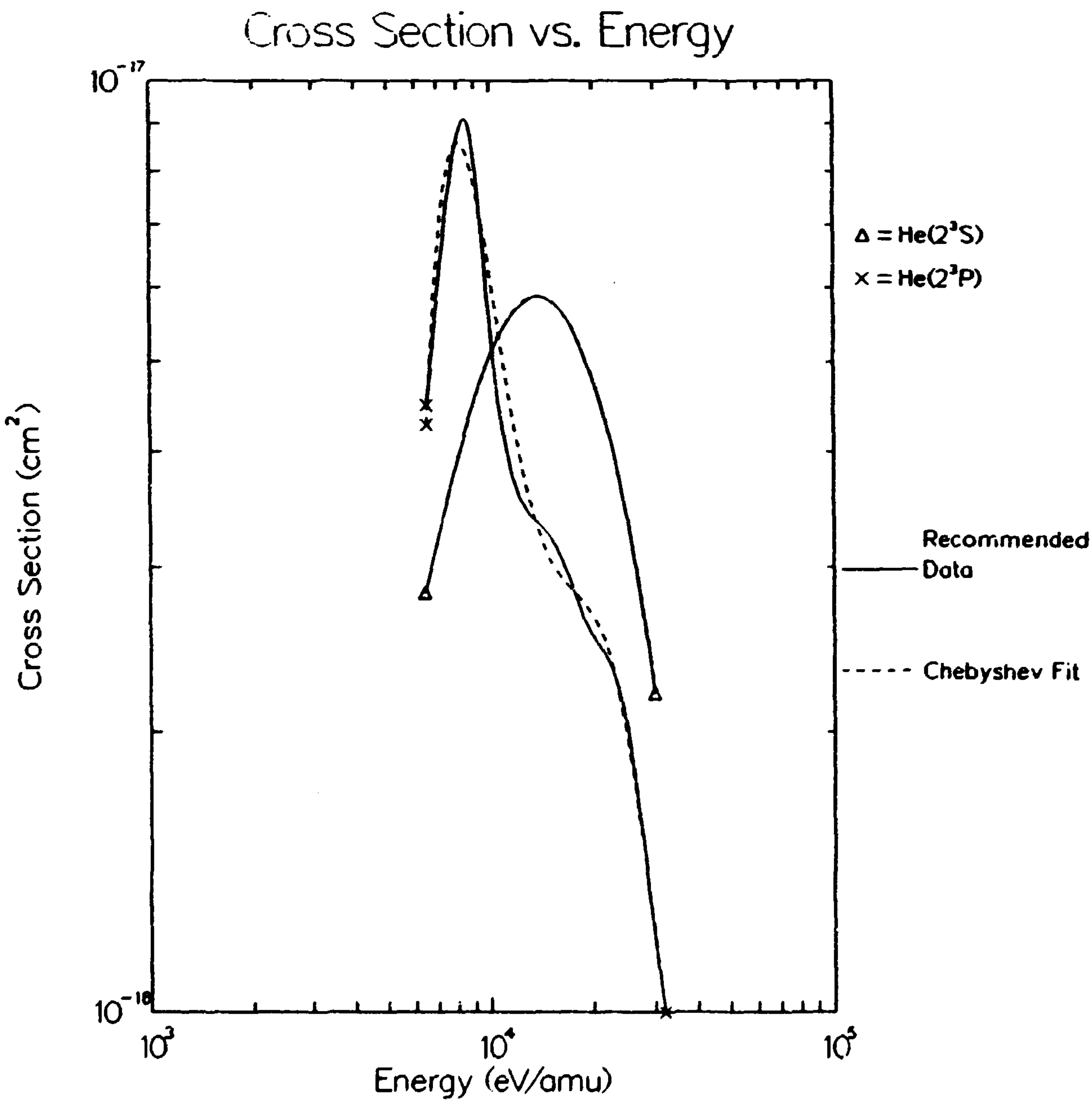
	A0	A1	A2	A3	A4	A5	A6
$He^{*}(2^{3}S)$	-80.2166	-.0867600	-.430158	-.0323601	.00266805	-.00483153	.00172788
$He^{*}(2^{3}P)$	-80.5638	-.897275	-.226853	.0854789	-.228846	.0840160	.0168192

The fit represents the $He^{*}(2^{3}S)$ cross section with an rms deviation of 0.1%. The maximum deviation is 0.2% at 1.0E+04 eV/amu.

The fit represents the $He^{*}(2^{3}P)$ cross section with an rms deviation of 6.8%. The maximum deviation is 14.1% at 1.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^{+} + He \rightarrow He^{+} + He(2^3S, 2^3P)$



Excitation Cross Sections for

$He^{+} + He \rightarrow He^{+} + He^{*}(3^1S, 3^1P, 3^1D)$

$He^{*}(3^1S)$ Energy (eV/amu)	σ (cm^2)	$He^{*}(3^1P)$ Energy (eV/amu)	σ (cm^2)	$He^{*}(3^1D)$ Energy (eV/amu)	σ (cm^2)
3.0E+03	2.96E-19	1.8E+03	4.84E-19	2.5E+03	3.98E-19
3.5E+03	2.78E-19	2.0E+03	5.24E-19	3.0E+03	5.16E-19
3.7E+03	2.75E-19	3.5E+03	6.61E-19	4.0E+03	8.25E-19
4.0E+03	2.93E-19	4.0E+03	6.50E-19	5.0E+03	1.02E-18
4.5E+03	3.33E-19	5.0E+03	6.28E-19	6.0E+03	1.04E-18
5.0E+03	3.64E-19	7.0E+03	8.19E-19	7.0E+03	1.03E-18
5.5E+03	3.83E-19	9.0E+03	9.18E-19	7.6E+03	1.02E-18
6.0E+03	3.98E-19	1.0E+04	9.04E-19		
7.0E+03	4.03E-19	1.5E+04	6.73E-19		
8.0E+03	4.02E-19	2.0E+04	5.62E-19		
		4.0E+04	1.49E-18		
		7.0E+04	2.34E-18		
		1.0E+05	2.81E-18		
		1.5E+05	3.07E-18		
		2.0E+05	3.14E-18		
		3.0E+05	2.90E-18		

References: 204, 696, 697, 698, 705, 708

Accuracy: 30%

Notes: (1) For relative cross sections at lower energies see Refs. 697, 705, and 708. (2) For more details see Ref. 684. (3) Acceptable polynomial fits were not possible for the $He^{*}(3^1P)$ data.

Chebyshev Fitting Parameters for Cross Sections

$He^{*}(3^1S)$ E_{min} = 3.0E+03 eV/amu, E_{max} = 8.0E+03 eV/amu
$He^{*}(3^1D)$ E_{min} = 2.5E+03 eV/amu, E_{max} = 7.6E+03 eV/amu

	A0	A1	A2	A3	A4	A5	A6
$He^{*}(3^1S)$	-85.0346	.210040	-.00809700	-.0618979	.0267187	.00449587	-.0121214
$He^{*}(3^1D)$	-83.4873	.491131	-.174973	-.0770949	.0308684	.00651934	-.00951236

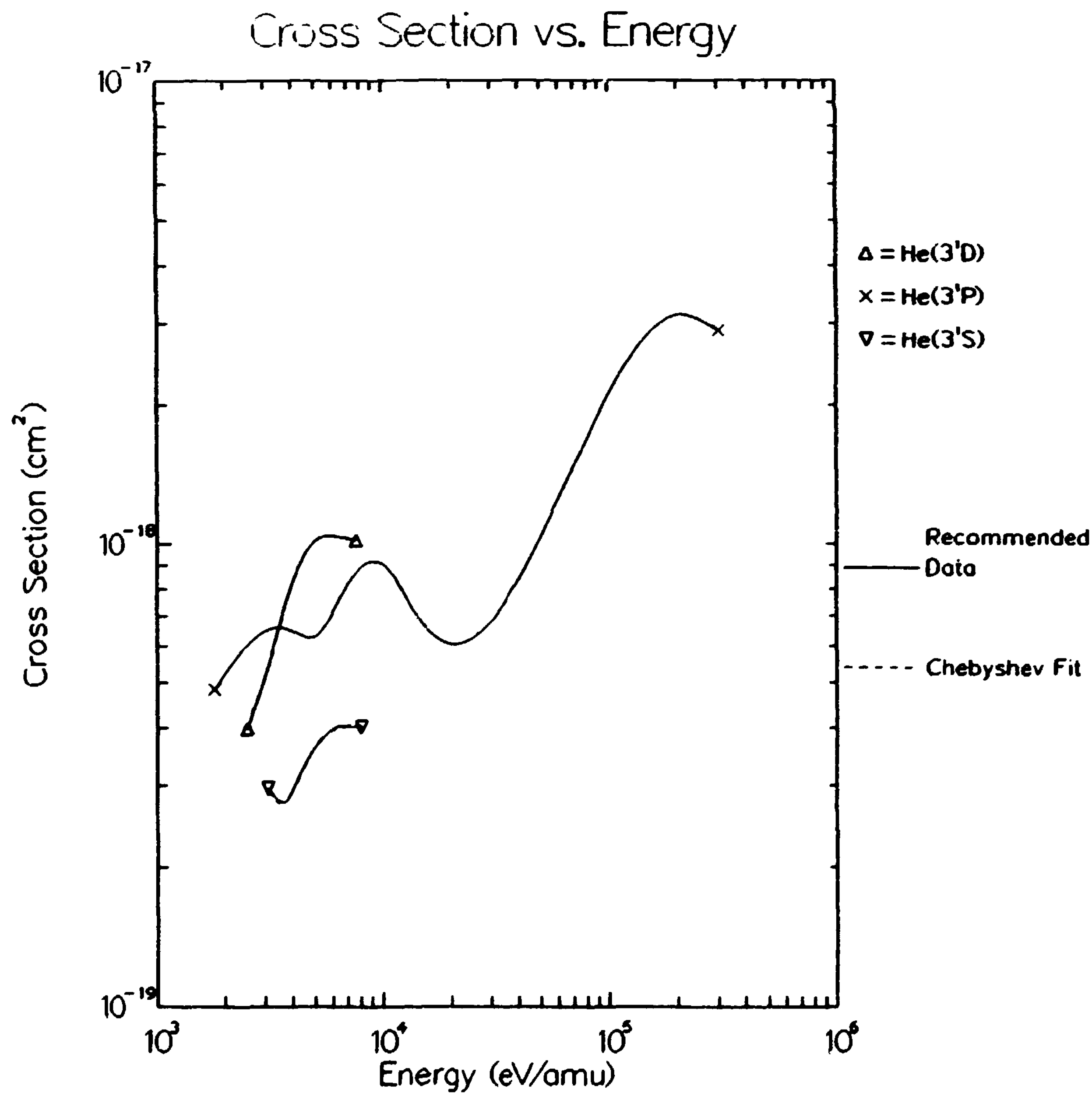
The fit represents the $He^{*}(3^1S)$ cross section with an rms deviation of 0.6%. The maximum deviation is 1.2% at 3.7E+03 eV/amu.

No fit to $He^{*}(3^1P)$ data.

The fit represents the $He^{*}(3^1D)$ cross section with an rms deviation of 0.0%. The maximum deviation is 0.0% at 0.0E+00 eV/amu.

See appendix for Chebyshev fit details.

$He^+ + He \to He^+ + He(3^1S, 3^1P, 3^1D)$



Excitation Cross Sections for

$He^+ + He \rightarrow He^+ + He^*(3^3S, 3^3P, 3^3D)$

He*(3³S)		He*(3³P)		He*(3³D)	
Energy (eV/amu)	σ (cm²)	Energy (eV/amu)	σ (cm²)	Energy (eV/amu)	σ (cm²)
2.5E+03	6.21E-19	2.5E+02	2.05E-19	2.5E+02	1.49E-18
3.0E+03	5.84E-19	3.2E+02	1.89E-19	3.7E+02	1.23E-18
3.5E+03	5.93E-19	4.0E+02	2.19E-19	4.0E+02	1.24E-18
4.0E+03	6.58E-19	7.0E+02	3.28E-19	6.0E+02	1.44E-18
4.5E+03	7.44E-19	7.4E+02	3.30E-19	7.0E+02	1.35E-18
5.0E+03	8.49E-19	1.0E+03	1.93E-19	1.0E+03	9.74E-19
5.5E+03	9.21E-19	1.1E+03	1.78E-19	1.5E+03	7.92E-19
6.0E+03	9.87E-19	1.5E+03	3.17E-19	2.0E+03	9.07E-19
7.0E+03	1.05E-18	2.0E+03	4.30E-19	3.0E+03	7.59E-19
7.7E+03	1.08E-18	3.7E+03	5.78E-19	4.0E+03	9.50E-19
		4.0E+03	5.65E-19	6.0E+03	1.47E-18
		5.0E+03	5.12E-19	7.0E+03	1.30E-18
		7.0E+03	6.98E-19	1.0E+04	3.73E-19
		1.0E+04	9.85E-19	2.0E+04	3.36E-19
		1.2E+04	1.07E-18	4.0E+04	1.35E-19
		2.0E+04	8.19E-19		
		4.0E+04	4.05E-19		

References: 204, 696, 697, 705, 707, 708

Accuracy: Unknown

Notes: (1) Relative cross sections may be found in Refs. 697, 705, 707, and 708. (2) Accuracies reported in Refs. 204 and 696 are: systematic error < 10%; random error < 5% on each; however, results differ by a factor of 2 at some energies common to both experiments. (3) Acceptable polynomial fits to the $He^*(3^3P)$ and $He^*(3^3D)$ data were not possible.

Chebyshev Fitting Parameters for Cross Sections

$He^*(3^3S)$ E_{min} = 2.5E+03 eV/amu, E_{max} = 7.7E+03 eV/amu

	A0	A1	A2	A3	A4	A5	A6
He*(3³S)	-83.4063	.336147	.0620301	-.0763959	-.00323136	.0169475	-.00192645

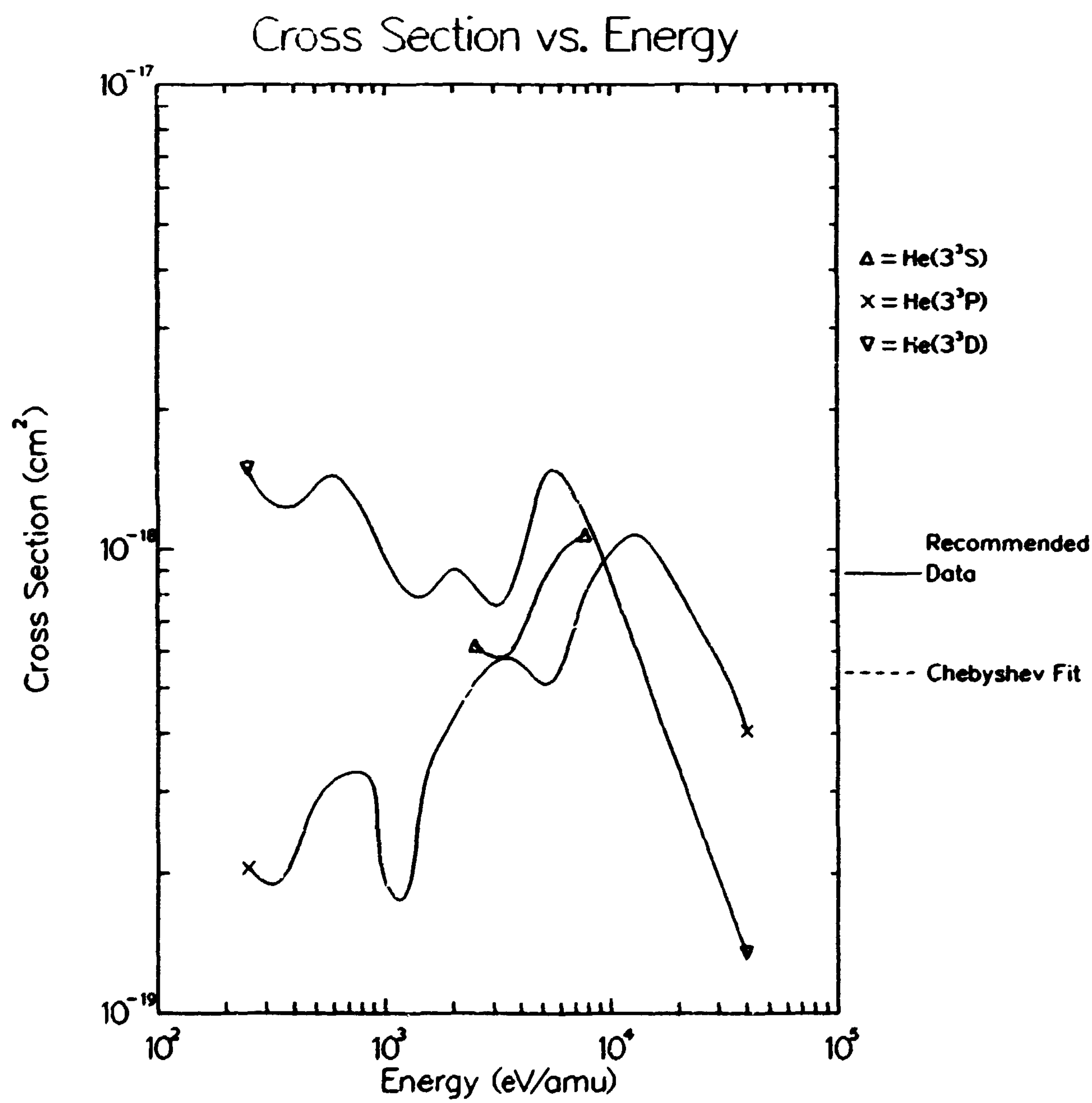
The fit represents the $He^*(3^3S)$ cross section with an rms deviation of 0.3%. The maximum deviation is 0.5% at 4.5E+03 eV/amu.

No fit to $He^*(3^3P)$ data.

No fit to $He^*(3^3D)$ data.

See appendix for Chebyshev fit details.

$He^{+} + He \rightarrow He^{+} + He(3^3S, 3^3P, 3^3D)$



Excitation Cross Sections for

$He^{+} + He \rightarrow He^{+} + He^{*}(4^{1}S, 4^{1}P, 4^{1}D)$

$He^{*}(4^{1}S)$		$He^{*}(4^{1}P)$		$He^{*}(4^{1}D)$	
Energy (eV/amu)	σ (cm^{2})	Energy (eV/amu)	σ (cm^{2})	Energy (eV/amu)	σ (cm^{2})
5.0E+02	7.34E-21	3.0E+03	2.03E-19	2.5E+02	8.39E-20
5.8E+02	6.87E-21	3.5E+03	2.63E-19	3.0E+02	9.35E-20
7.0E+02	8.28E-21	4.0E+03	2.93E-19	3.5E+02	9.18E-20
1.0E+03	1.49E-20	4.5E+03	3.07E-19	4.0E+02	8.22E-20
1.2E+03	1.81E-20	5.0E+03	2.95E-19	5.0E+02	6.48E-20
1.5E+03	1.72E-20	5.5E+03	2.70E-19	6.0E+02	5.93E-20
2.0E+03	3.22E-20	6.0E+03	2.44E-19	7.0E+02	5.92E-20
2.7E+03	4.40E-20	6.6E+03	2.35E-19	1.0E+03	6.79E-20
3.5E+03	4.21E-20	7.0E+03	2.43E-19	1.5E+03	6.27E-20
4.0E+03	4.27E-20	8.0E+03	2.82E-19	2.0E+03	7.15E-20
5.0E+03	4.92E-20	9.0E+03	3.12E-19	3.0E+03	1.03E-19
6.0E+03	6.04E-20	1.0E+04	3.19E-19	4.0E+03	1.55E-19
7.0E+03	6.58E-20	1.5E+04	2.60E-19	7.0E+03	4.10E-19
1.0E+04	9.65E-20	2.0E+04	2.11E-19	8.5E+03	4.92E-19
1.3E+04	1.17E-19			1.0E+04	4.31E-19
2.0E+04	9.49E-20			1.5E+04	2.02E-19
4.0E+04	2.37E-19			2.0E+04	1.21E-19
7.0E+04	2.99E-19			2.3E+04	1.16E-19
1.0E+05	2.82E-19			3.0E+04	1.36E-19
2.0E+05	1.95E-19			4.0E+04	1.74E-19
3.0E+05	1.41E-19			5.5E+04	1.90E-19
				7.0E+04	1.82E-19
				1.0E+05	1.51E-19
				1.5E+05	1.10E-19
				2.0E+05	8.42E-20
				3.0E+05	5.94E-20

References: 204, 696, 698, 703, 705

Accuracy: Unknown

Notes: (1) Relative cross sections may be found in Ref. 705. (2) Accuracies reported in Refs. 204 and 696 are: systematic error < 10%; random error < 5% on each; however, results differ by a factor of 2 at some energies common to both experiments. (3) Acceptable polynomial fits to the $He^{*}(4^{1}D)$ data were not possible.

Chebyshev Fitting Parameters for Cross Sections

$He^{*}(4^{1}S)$ E_{min} = 5.0E+02 eV/amu, E_{max} = 3.0E+05 eV/amu
$He^{*}(4^{1}P)$ E_{min} = 3.0E+03 eV/amu, E_{max} = 2.0E+04 eV/amu

	A0	A1	A2	A3	A4	A5	A6
$He^{*}(4^{1}S)$	-88.4744	1.72074	-.628284	-.185014	-.137545	-.0287794	.0855418
$He^{*}(4^{1}P)$	-85.6466	-.0488093	-.204458	-.0516457	-.0853529	.120960	.0910818

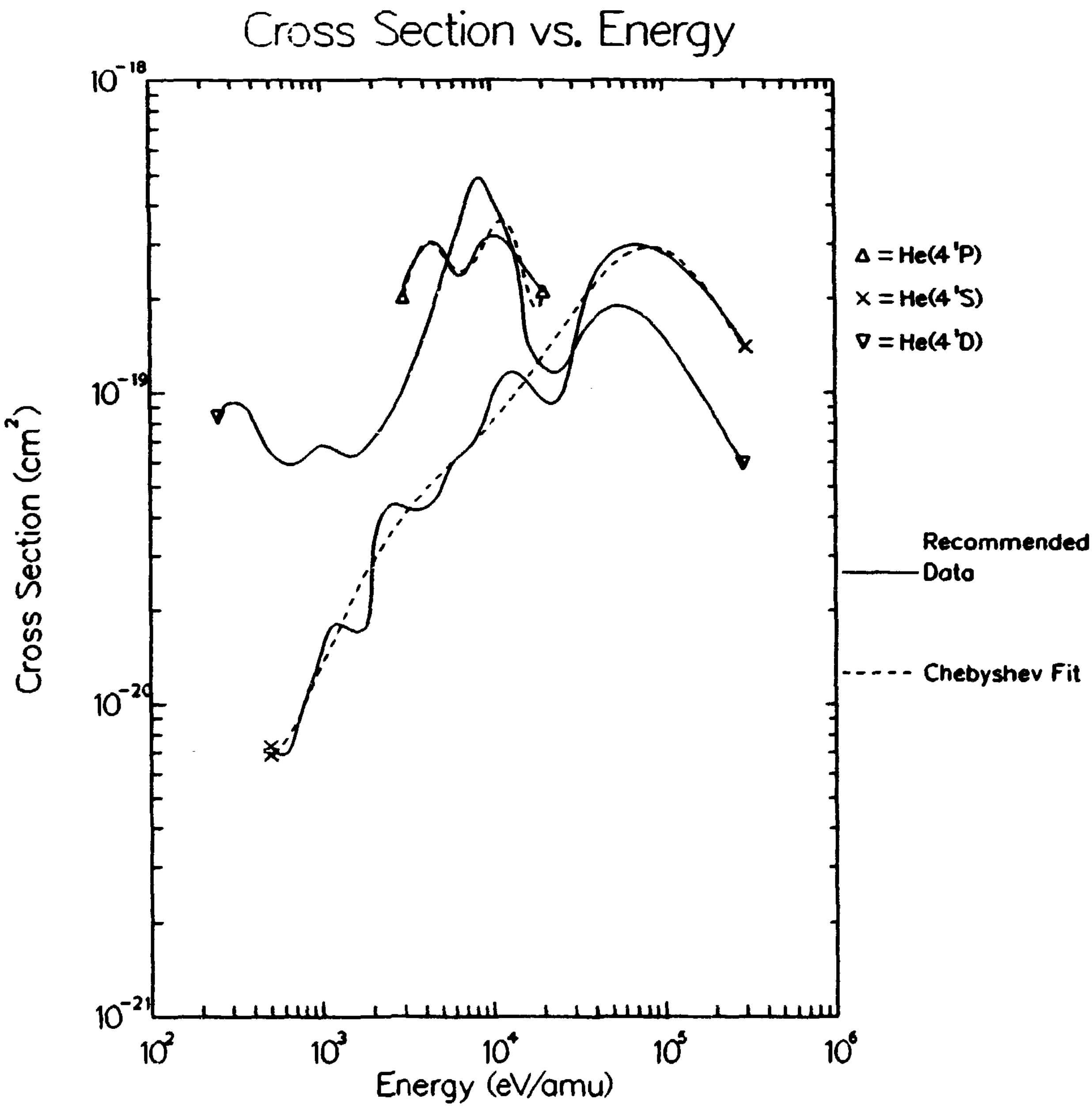
The fit represents the $He^{*}(4^{1}S)$ cross section with an rms deviation of 13.5%. The maximum deviation is 38.5% at 2.0E+04 eV/amu.

The fit represents the $He^{*}(4^{1}P)$ cross section with an rms deviation of 3.0%. The maximum deviation is 5.1% at 1.0E+04 eV/amu.

No fit to $He^{*}(4^{1}D)$ data.

See appendix for Chebyshev fit details.

$He^+ + He \rightarrow He^+ + He(4\,^1S, 4\,^1P, 4\,^1D)$



Excitation Cross Sections for

$He^{+} + He \rightarrow He^{+} + He^{*}(4^3S, 4^3P, 4^3D)$

$He^{*}(4^3S)$ Energy (eV/amu)	σ (cm^2)	$He^{*}(4^3P)$ Energy (eV/amu)	σ (cm^2)	$He^{*}(4^3D)$ Energy (eV/amu)	σ (cm^2)
1.2E+03	2.24E-20	2.5E+02	2.15E-20	2.5E+02	2.91E-19
1.8E+03	4.12E-20	3.3E+02	2.30E-20	3.6E+02	3.48E-19
2.0E+03	3.93E-20	4.0E+02	2.13E-20	4.0E+02	3.37E-19
2.4E+03	3.38E-20	4.7E+02	1.96E-20	6.0E+02	1.96E-19
3.6E+03	7.03E-20	7.0E+02	2.97E-20	7.0E+02	1.82E-19
4.0E+03	6.50E-20	1.0E+03	2.06E-20	9.5E+02	2.06E-19
5.2E+03	4.84E-20	1.5E+03	2.63E-20	1.0E+03	2.05E-19
7.0E+03	6.87E-20	2.0E+03	3.87E-20	1.5E+03	1.59E-19
1.0E+04	1.28E-19	4.0E+03	1.15E-19	2.0E+03	1.36E-19
1.5E+04	1.96E-19	4.5E+03	1.17E-19	2.2E+03	1.33E-19
2.0E+04	2.54E-19	5.5E+03	1.13E-19	3.0E+03	1.53E-19
2.6E+04	2.25E-19	7.0E+03	1.24E-19	3.7E+03	1.50E-19
		1.0E+04	1.84E-19	4.0E+03	1.54E-19
		1.5E+04	2.60E-19	7.0E+03	3.55E-19
		2.0E+04	2.06E-19	8.0E+03	3.73E-19
		2.7E+04	1.41E-19	1.0E+04	3.40E-19
		3.2E+04	1.70E-19	2.0E+04	1.57E-19
		3.7E+04	1.41E-19	3.5E+04	6.48E-20

<u>References:</u> 204, 696, 703, 705, 708

<u>Accuracy:</u> Unknown

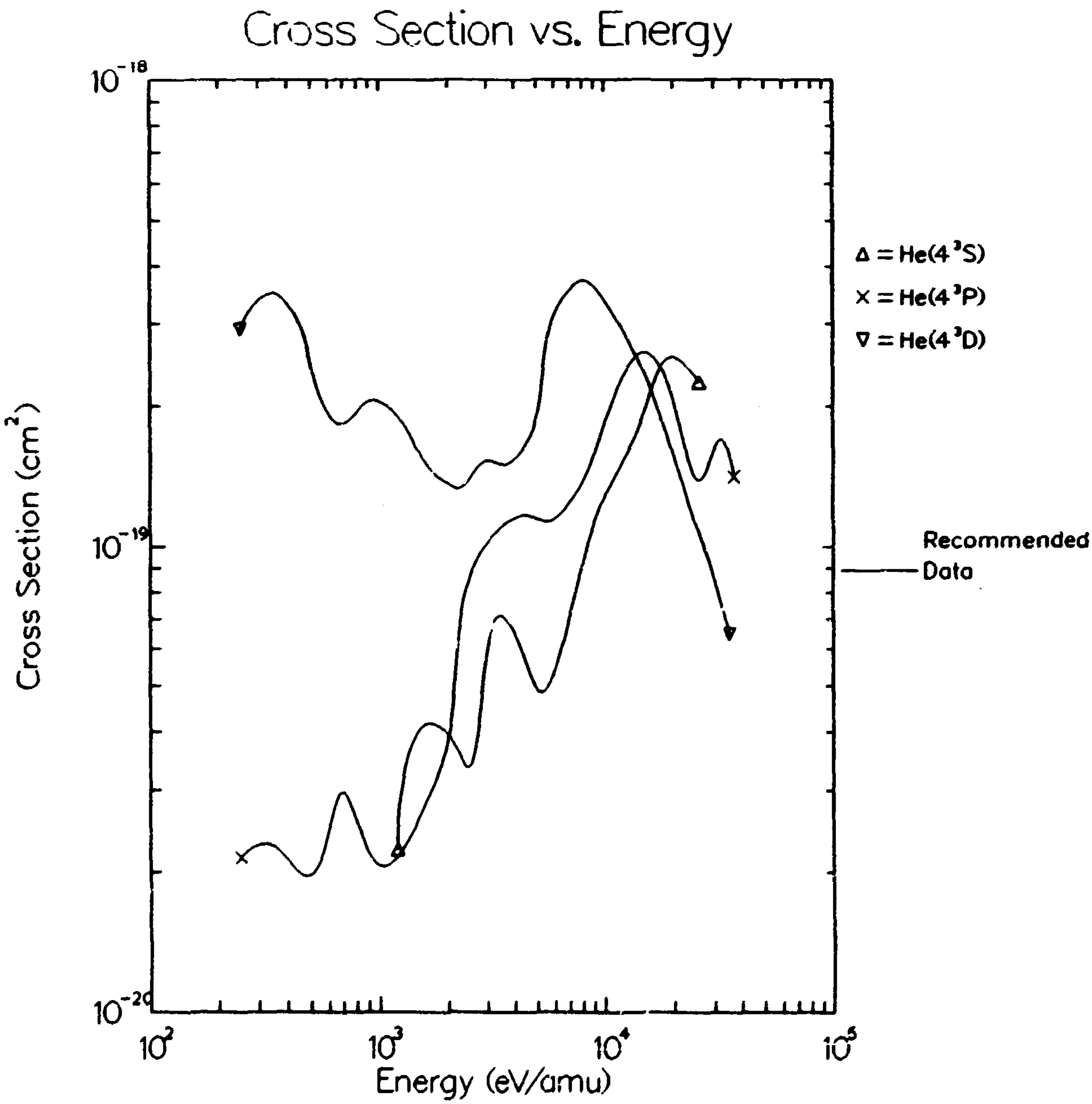
<u>Notes:</u> (1) Relative cross sections may be found in Refs. 705 and 708. (2) Accuracies reported in Refs. 204 and 696 are: systematic error < 10%; random error < 5% on each; however, results differ by a factor of 2 at some energies common to both experiments. (3) Acceptable polynomial fits to these data were not possible.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

No fits to the cross sections.

See appendix for Chebyshev fit details.

$He^{+} + He \rightarrow He^{+} + He(4^3S, 4^3P, 4^3D)$



Projectile Excitation Cross Sections for

$He^+ + He \rightarrow He^+(n=2) + He$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+03	4.39E+07	3.84E-18
1.7E+03	5.73E+07	8.16E-18
2.0E+03	6.21E+07	7.62E-18
3.0E+03	7.61E+07	5.30E-18
4.0E+03	8.79E+07	4.35E-18
5.0E+03	9.82E+07	3.80E-18
6.0E+03	1.08E+08	3.43E-18
7.0E+03	1.16E+08	3.16E-18
8.0E+03	1.24E+08	2.96E-18
9.0E+03	1.32E+08	2.80E-18
1.0E+04	1.39E+08	2.68E-18
2.0E+04	1.96E+08	2.30E-18
2.5E+04	2.20E+08	2.11E-18
3.0E+04	2.41E+08	1.91E-18
4.0E+04	2.78E+08	1.55E-18

References: 699, 704, 705, 713, 714

Accuracy: E < 70%

Notes: (1) See Ref. 705 for relative cross sections for excitation of He^+ 2^2P. (2) For combined excitation of target and projectile see Ref. 714.

Chebyshev Fitting Parameters for Cross Sections

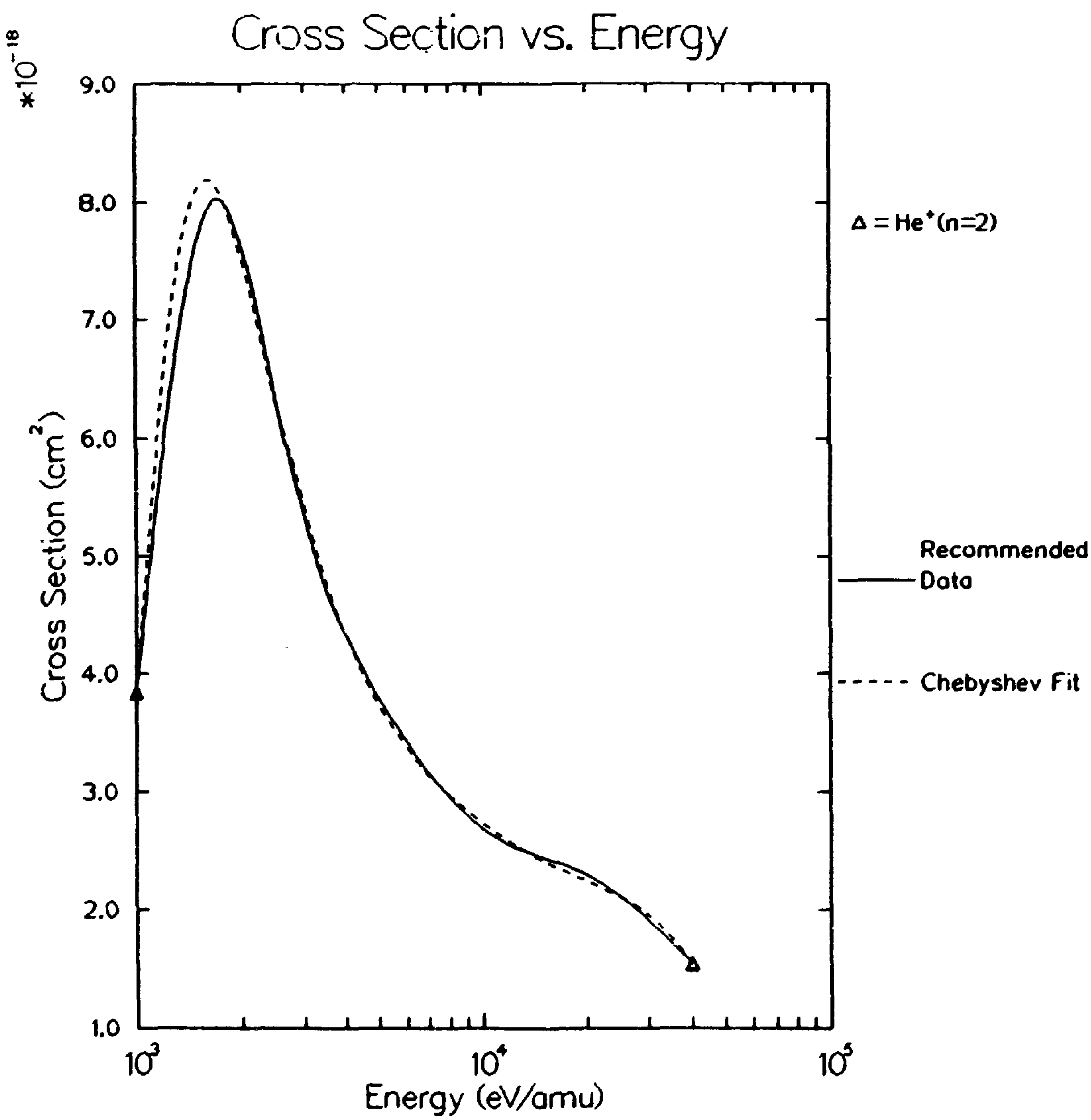
E_{min} = 1.0E+03 eV/amu, E_{max} = 4.0E+04 eV/amu

A0	A1	A2	A3	A4	A5	A6
-80 4224	-.698320	-.116751	.174729	-.194669	.0663496	-.0346561

The fit represents the above cross section with an rms deviation of 1.4%. The maximum deviation is 2.7% at 3.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$He^+ + He \rightarrow He^+(n=2) + He$



Projectile Excitation Cross Sections for

$He^{+} + He \rightarrow He^{+}(n=3) + He$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
7.4E+03	1.19E+08	2.93E-19
8.0E+03	1.24E+08	4.13E-19
9.0E+03	1.32E+08	6.76E-19
1.0E+04	1.39E+08	8.88E-19
1.5E+04	1.70E+08	1.66E-18
2.0E+04	1.96E+08	2.43E-18
2.5E+04	2.20E+08	3.54E-18

References: 705, 713

Accuracy: Unknown

Note: Ref. 705 gives relative cross sections for excitation of 3^2P level.

Chebyshev Fitting Parameters for Cross Sections

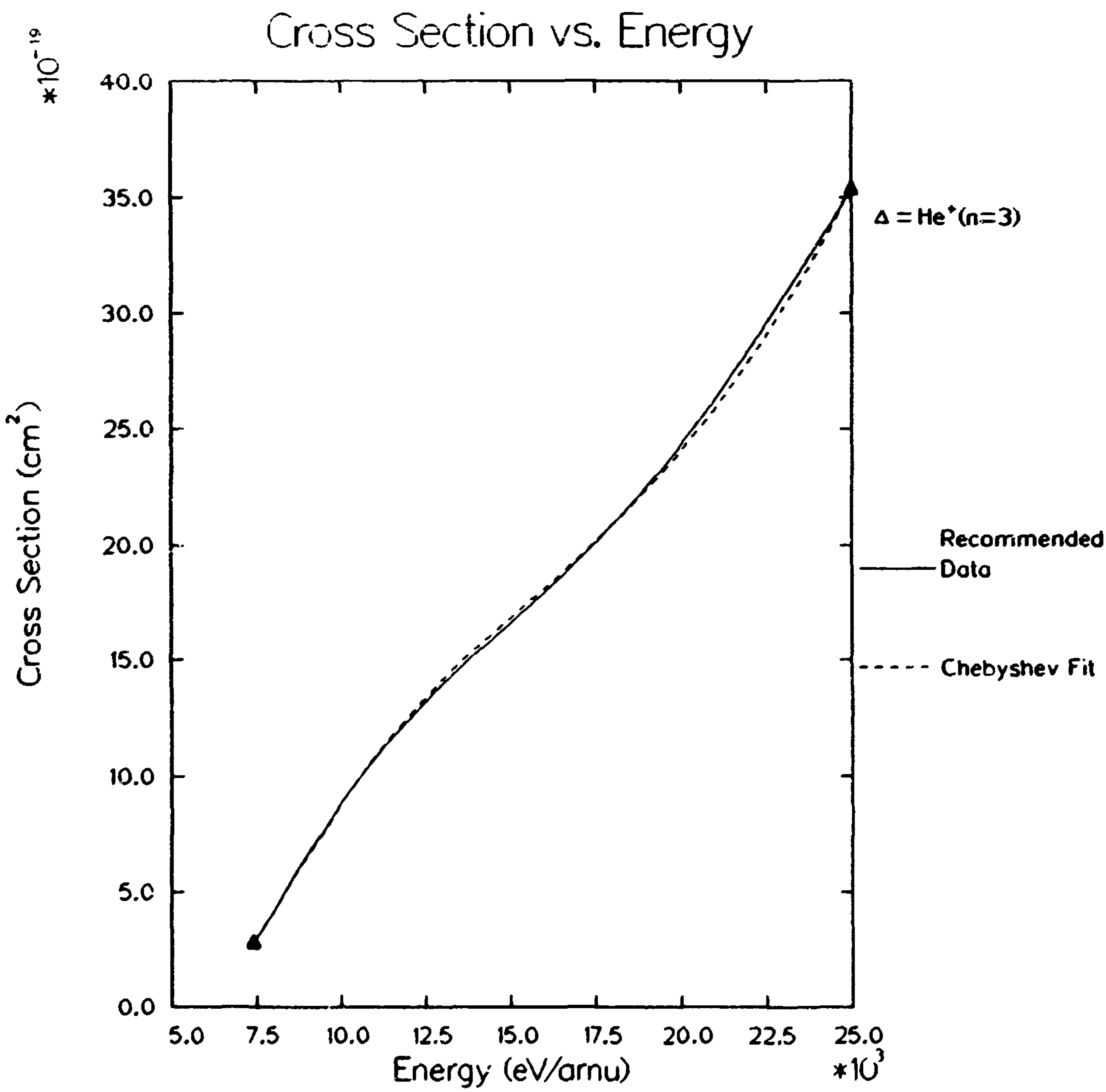
E_{min} = 7.4E+03 eV/amu, E_{max} = 2.5E+04 eV/amu

A0	A1	A2	A3	A4	A5	A6
-82.4466	1.12862	-.190981	.124483	-.0202534		

The fit represents the above cross section with an rms deviation of 1.4%. The maximum deviation is 2.9% at 8.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$He^{+} + He \rightarrow He^{+}(n=3) + He$



Spectral Line Emission Cross Sections for

He + H_2 -> H(Balmer-α,Balmer-β)

H(Balmer-α) Energy (eV/amu)	H(Balmer-α) Cross Section (cm^2)	H(Balmer-β) Energy (eV/amu)	H(Balmer-β) Cross Section (cm^2)
1.5E+02	6.77E-19	1.2E+02	6.93E-20
2.0E+02	7.82E-19	1.5E+02	1.34E-19
3.0E+02	9.61E-19	2.0E+02	2.18E-19
4.0E+02	1.08E-18	3.0E+02	3.34E-19
5.0E+02	1.18E-18	4.0E+02	4.11E-19
6.0E+02	1.26E-18	5.0E+02	4.56E-19
7.0E+02	1.34E-18	6.0E+02	4.85E-19
8.0E+02	1.40E-18	7.0E+02	5.07E-19
9.0E+02	1.45E-18	8.0E+02	5.25E-19
1.0E+03	1.51E-18	9.0E+02	5.35E-19
2.0E+03	1.80E-18	1.0E+03	5.44E-19
3.0E+03	1.89E-18	1.3E+03	5.52E-19
4.0E+03	1.89E-18	2.0E+03	5.47E-19
5.0E+03	1.84E-18	3.0E+03	5.24E-19
6.0E+03	1.76E-18	4.0E+03	4.97E-19
7.0E+03	1.65E-18	5.0E+03	4.75E-19
7.6E+03	1.58E-18	6.0E+03	4.54E-19
		7.0E+03	4.36E-19
		8.0E+03	4.20E-19

Reference: 461

Accuracy: Unknown

Notes: (1) The hydrogen Balmer line emission results from dissociative excitation of H_2. (2) The Balmer-α emission is the n=3->2 transition (656.28nm). (3) The Balmer-β emission is the n=4->2 transition (486.13nm).

Chebyshev Fitting Parameters for Cross Sections

H(Balmer-α) E_{min} = 1.5E+02 eV/amu, E_{max} = 7.6E+03 eV/amu
H(Balmer-β) E_{min} = 1.2E+02 eV/amu, E_{max} = 8.0E+03 eV/amu

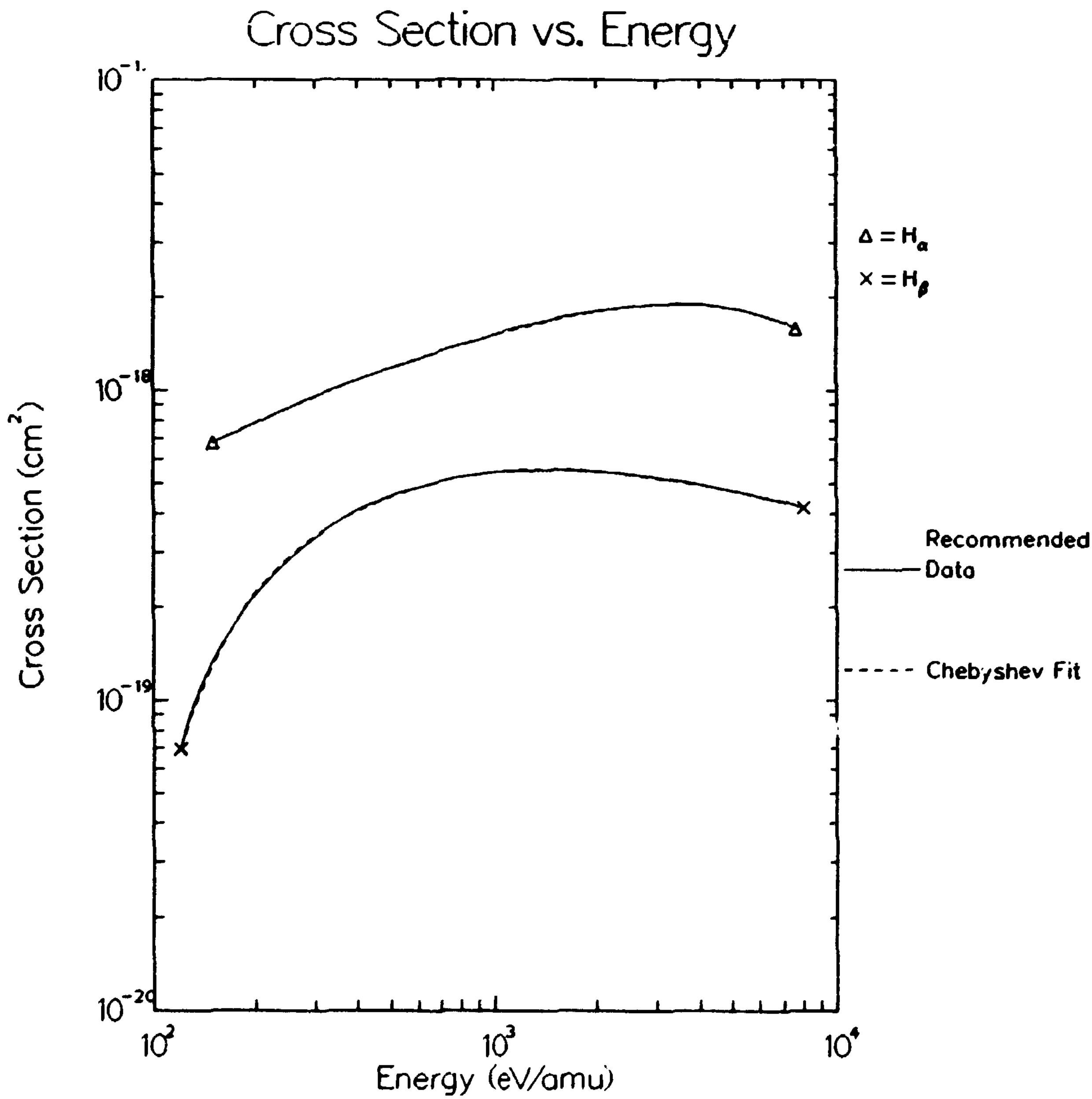
	A0	A1	A2	A3	A4	A5	A6
H(Balmer-α)	-82.3960	.472324	-.197315	-.0438413	-.0176366	-.00308248	5.34250E-05
H(Balmer-β)	-85.1264	.678943	-.561863	.182560	-.0716643	.0321037	-.0158573

The fit represents the H(Balmer-α) cross section with an rms deviation of 0.3%. The maximum deviation is 0.5% at 2.0E+02 eV/amu.

The fit represents the H(Balmer-β) cross section with an rms deviation of 0.9%. The maximum deviation is 1.4% at 2.0E+02 eV/amu.

See appendix for Chebyshev fit details.

$He + H_2 \rightarrow H(\text{Balmer-}\alpha, \text{Balmer-}\beta)$



Excitation Cross Sections for

He + He -> He(2^1S,2^1P)

He(2^1S) Energy (eV/amu)	He(2^1S) Cross Section (cm^2)	He(2^1P) Energy (eV/amu)	He(2^1P) Cross Section (cm^2)
1.6E+01	1.00E-19	1.3E+01	4.83E-18
2.0E+01	6.25E-19	1.5E+01	7.85E-18
2.5E+01	1.17E-18	2.0E+01	1.52E-17
3.0E+01	1.52E-18	2.5E+01	2.39E-17
3.5E+01	1.73E-18	3.0E+01	3.03E-17
4.0E+01	1.90E-18	3.5E+01	3.59E-17
4.5E+01	2.07E-18	4.0E+01	4.05E-17
5.0E+01	2.20E-18	5.0E+01	4.70E-17
5.5E+01	2.33E-18	6.0E+01	5.25E-17
6.0E+01	2.44E-18	7.0E+01	5.62E-17
7.0E+01	2.65E-18	8.0E+01	5.95E-17
7.4E+01	2.72E-18	9.0E+01	6.19E-17
		1.0E+02	6.39E-17
		1.5E+02	7.24E-17

References: 719, 721, 722

Accuracy: Unknown

Notes: (1) The data for 2^1S state are theoretical data of Olson et al. (Ref. 721). The 2^1P state data are the experimental data of Kempter et al. (Ref. 719) and are approximately a factor of 2 greater than those of Olson et al. (2) The experimental data were determined by measuring emission line intensities and correcting for branching ratios using known transition probabilities. With He, cascading contributions should be less than 3%.

Chebyshev Fitting Parameters for Cross Sections

He(2^1S) E_{min} = 1.6E+01 eV/amu, E_{max} = 7.4E+01 eV/amu
He(2^1P) E_{min} = 1.3E+01 eV/amu, E_{max} = 1.5E+02 eV/amu

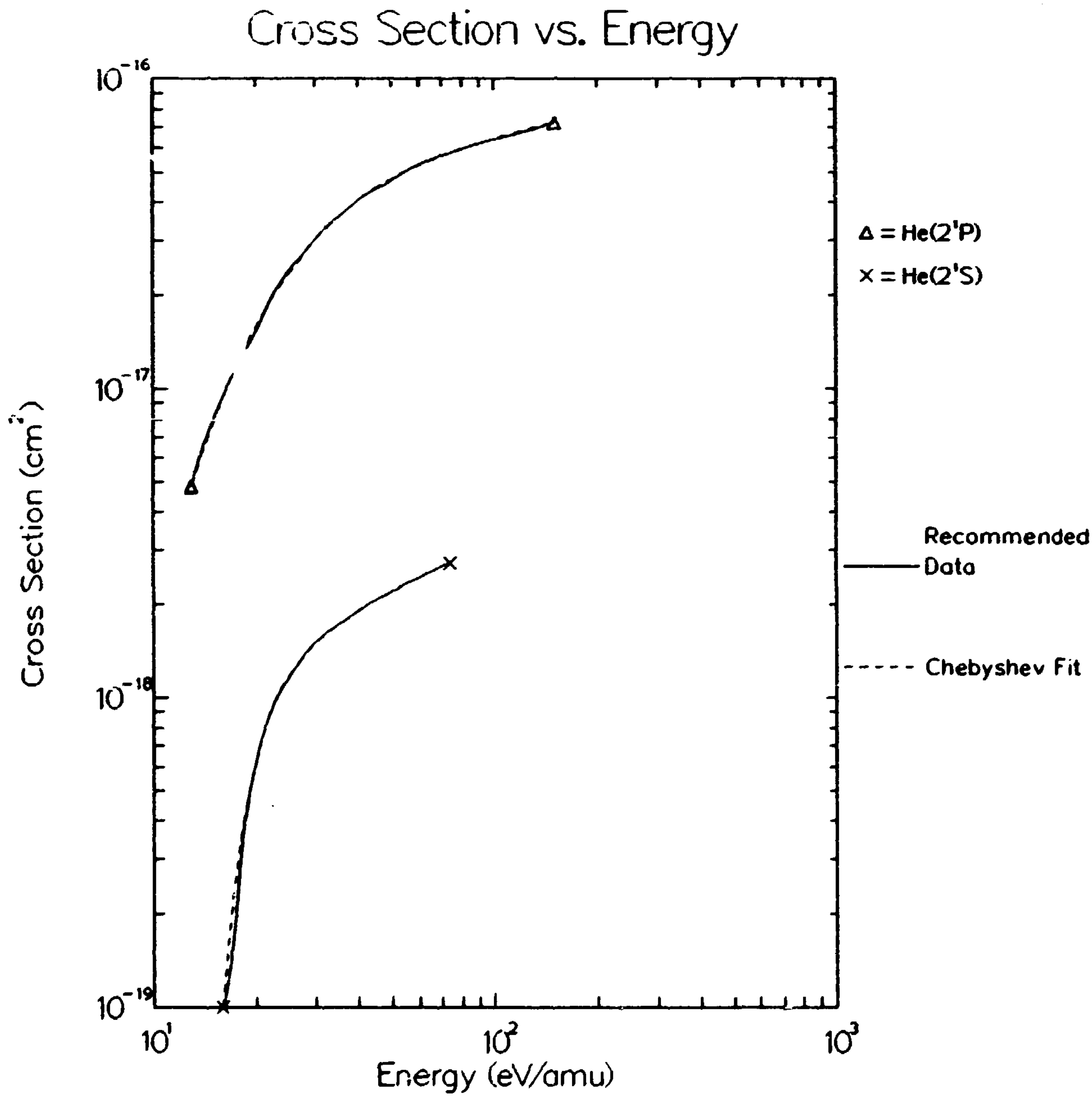
	A0	A1	A2	A3	A4	A5	A6
He(2^1S)	-82.7427	1.30331	-.579333	.299739	-.133372	.0473667	-.0142447
He(2^1P)	-76.1505	1.23531	-.420131	.116081	-.0158137	-.00167796	-.0033629

The fit represents the He(2^1S) cross section with an rms deviation of 0.5%. The maximum deviation is 0.9% at 2.5E+01 eV/amu.

The fit represents the He(2^1P) cross section with an rms deviation of 1.2%. The maximum deviation is 3.0% at 2.0E+01 eV/amu.

See appendix for Chebyshev fit details.

He + He -> He(2'S,2'P)


Cross Section vs. Energy
Cross Section (cm²)
Energy (eV/amu)
10⁻¹⁶
10⁻¹⁷
10⁻¹⁸
10⁻¹⁹
10¹
10²
10³
Δ = He(2'P)
× = He(2'S)
Recommended Data
Chebyshev Fit

Excitation Cross Section for

He + He -> He(3^1P,3^1D,3^3P,3^3D)

He(3^1P)		He(3^1D)		He(3^3P)		He(3^3D)	
Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)
2.5E+02	2.27E-18	2.5E+01	1.12E-19	2.5E+01	1.49E-19	2.5E+01	1.67E-19
3.0E+02	2.12E-18	3.0E+01	2.23E-19	4.0E+01	9.97E-19	3.0E+01	4.68E-19
4.0E+02	1.93E-18	4.0E+01	5.21E-19	7.0E+01	2.45E-18	4.0E+01	1.09E-18
5.0E+02	1.83E-18	5.0E+01	9.01E-19	1.0E+02	2.68E-18	5.0E+01	1.55E-18
6.0E+02	1.77E-18	6.0E+01	1.33E-18	2.0E+02	2.20E-18	6.0E+01	1.98E-18
7.0E+02	1.76E-18	7.0E+01	1.71E-18	4.0E+02	1.58E-18	7.0E+01	2.39E-18
8.0E+02	1.76E-18	8.0E+01	1.92E-18	7.0E+02	1.35E-18	8.0E+01	2.68E-18
9.0E+02	1.76E-18	9.0E+01	1.81E-18	1.0E+03	1.47E-18	9.0E+01	2.80E-18
1.0E+03	1.77E-18	1.0E+02	1.74E-18	1.2E+03	1.64E-18	1.0E+02	2.77E-18
1.2E+03	1.80E-18	1.1E+02	1.74E-18			1.5E+02	2.44E-18
		1.5E+02	2.31E-18				

References: 718, 719, 723

Accuracy: Unknown

Note: The recommended data for 3^3P state have been interpolated between the data of Kimura et al. (Ref. 718) ($E > 2.5 \times 10^2$ eV/amu) and the low-energy data of Kempter et al. (Ref. 719). This extrapolation is uncertain due to different energy dependencies.

Chebyshev Fitting Parameters for Cross Sections

He(3^1P)	E_{min}	=	2.5E+02	eV/amu,	E_{max}	=	1.2E+03	eV/amu
He(3^1D)	E_{min}	=	2.5E+01	eV/amu,	E_{max}	=	1.5E+02	eV/amu
He(3^3P)	E_{min}	=	2.5E+01	eV/amu,	E_{max}	=	1.2E+03	eV/amu
He(3^3D)	E_{min}	=	2.5E+01	eV/amu,	E_{max}	=	1.5E+02	eV/amu

	A0	A1	A2	A3	A4	A5	A6
He(3^1P)	-81.5965	-.116911	.0573167	8.08164E-04	-.00364047	6.11763E-05	.00187028
He(3^1D)	-83.4302	1.37998	-.506774	.0626383	.0986308	.0721865	3.46628E-04
He(3^3P)	-82.5431	.625566	-.782070	.545218	-.100346	.0310014	.00459533
He(3^3D)	-82.5242	1.15604	-.602651	.117602	-.0538056	.0673126	.0230997

The fit represents the He(3^1P) cross section with an rms deviation of 0.1%. The maximum deviation is 0.3% at 6.0E+02 eV/amu.

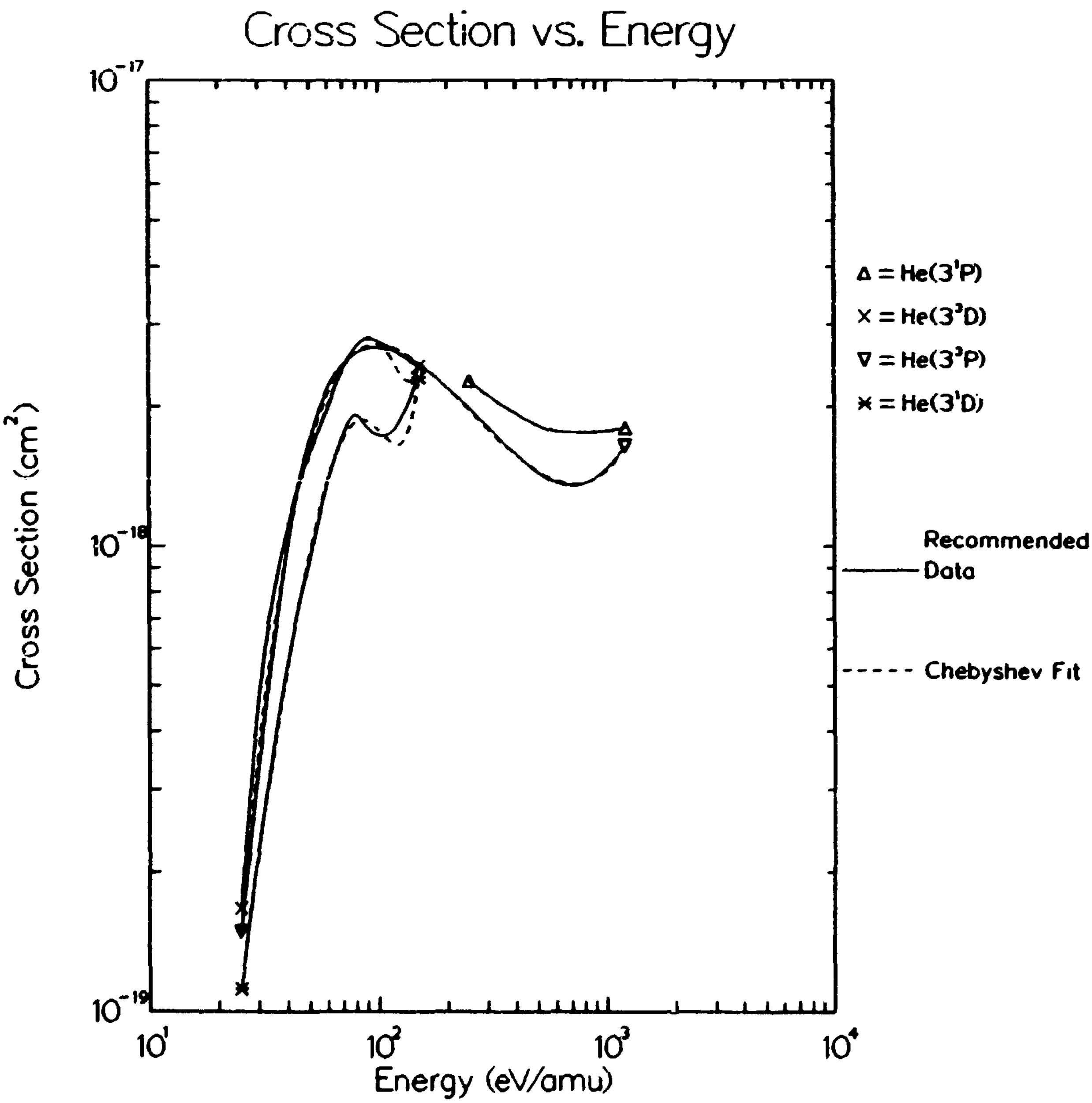
The fit represents the He(3^1D) cross section with an rms deviation of 1.9%. The maximum deviation is 2.8% at 9.0E+01 eV/amu.

The fit represents the He(3^3P) cross section with an rms deviation of 0.7%. The maximum deviation is 1.1% at 1.0E+02 eV/amu.

The fit represents the He(3^3D) cross section with an rms deviation of 0.1%. The maximum deviation is 0.3% at 9.0E+01 eV/amu.

See appendix for Chebyshev fit details.

He + He -> He(3^1P,3^1D,3^3P,3^3D)



Excitation Cross Sections for

He + He -> He(4^1S,4^1P)

He(4^1S) Energy (eV/amu)	σ (cm^2)	He(4^1S) cont. Energy (eV/amu)	σ (cm^2)	He(4^1P) Energy (eV/amu)	σ (cm^2)
1.7E+01	2.00E-20	5.0E+03	2.96E-19	5.0E+03	3.65E-19
2.0E+01	2.98E-20	6.0E+03	3.37E-19	5.5E+03	3.88E-19
3.0E+01	9.53E-20	7.0E+03	3.78E-19	6.0E+03	4.06E-19
4.0E+01	2.37E-19	8.0E+03	4.11E-19	7.0E+03	4.23E-19
5.0E+01	4.71E-19	9.0E+03	4.40E-19	8.0E+03	4.06E-19
6.0E+01	7.06E-19	1.0E+04	4.61E-19	9.0E+03	3.85E-19
7.0E+01	8.91E-19	1.5E+04	5.11E-19	1.0E+04	3.60E-19
7.9E+01	1.05E-18	2.0E+04	4.72E-19	1.5E+04	2.61E-19
9.0E+01	1.19E-18	2.5E+04	4.22E-19	2.0E+04	1.88E-19
1.0E+02	1.33E-18			2.4E+04	1.50E-19
1.5E+02	1.90E-18				
1.8E+02	2.15E-18				

References: 703, 719, 723

Accuracy: Unknown

Note: The 4^1S data in the low and high energy ranges are plotted individually to indicate the problems involved in comparing and interpolating between low and high energy data. Use these data with caution.

Chebyshev Fitting Parameters for Cross Sections

He(4^1S) E_{min} = 1.7E+01 eV/amu, E_{max} = 1.8E+02 eV/amu
He(4^1S) E_{min} = 5.0E+03 eV/amu, E_{max} = 2.5E+04 eV/amu
He(4^1P) E_{min} = 5.0E+03 eV/amu, E_{max} = 2.4E+04 eV/amu

	A0	A1	A2	A3	A4	A5	A6
He(4^1S)	-85.2188	2.41501	-.487597	-.0727179	.111514	-.00381501	-.0352846
He(4^1S)	-84.6731	.196616	-.160691	-.0239012	.00732614	.00447306	.00338388
He(4^1D)	-85.4091	-.479796	-.191704	.0341683	-.0126641	.00116120	.00977808

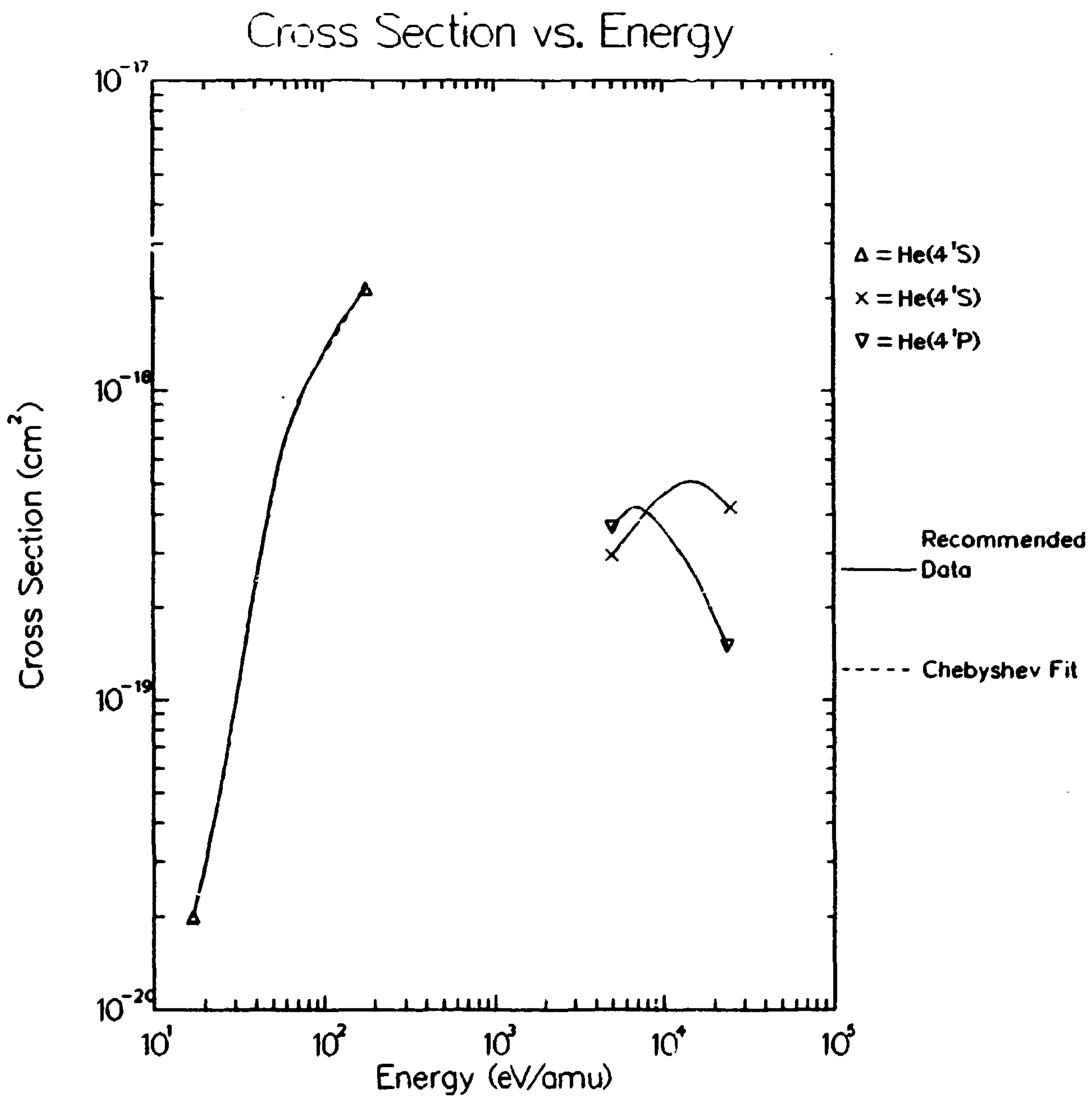
The fit represents the He(4^1S) cross section with an rms deviation of 1.2%. The maximum deviation is 2.3% at 4.0E+01 eV/amu.

The fit represents the He(4^1S) cross section with an rms deviation of 0.2%. The maximum deviation is 0.4% at 7.1E+03 eV/amu.

The fit represents the He(4^1P) cross section with an rms deviation of 0.3%. The maximum deviation is 0.6% at 8.0E+03 eV/amu.

See appendix for Chebyshev fit details.

He + He -> He(4 ¹S,4 ¹P)



Excitation Cross Sections for

He + He -> He(4^3S,4^3P)

He(4^3S) Energy (eV/amu)	σ (cm^2)	He(4^3S) cont. Energy (eV/amu)	σ (cm^2)	He(4^3P) Energy (eV/amu)	σ (cm^2)
2.4E+01	2.53E-20	5.0E+03	4.37E-19	2.5E+02	2.78E-18
2.5E+01	2.90E-20	5.5E+03	4.47E-19	4.0E+02	1.38E-18
3.0E+01	5.97E-20	6.0E+03	4.66E-19	7.0E+02	8.79E-19
3.5E+01	1.07E-19	7.0E+03	4.90E-19	1.0E+03	8.23E-19
4.0E+01	1.59E-19	8.0E+03	5.29E-19	2.0E+03	7.68E-19
4.5E+01	2.08E-19	9.0E+03	5.47E-19	4.0E+03	7.14E-19
5.0E+01	2.62E-19	1.0E+04	5.14E-19	7.0E+03	7.07E-19
5.5E+01	3.15E-19	1.1E+04	4.88E-19	1.0E+04	5.62E-19
6.0E+01	3.65E-19	1.5E+04	5.30E-19	1.5E+04	3.11E-19
7.0E+01	4.61E-19	2.0E+04	6.12E-19	2.0E+04	1.95E-19
8.0E+01	5.43E-19	2.5E+04	6.77E-19		
8.8E+01	5.95E-19				

References: 703, 718, 719, 720, 723

Accuracy: Unknown

Note: No attempt has been made to interpolate between the low and high energy data for the 4^3S state. Use these data with caution.

Chebyshev Fitting Parameters for Cross Sections

He(4^3S)	E_{min} = 2.4E+01 eV/amu,	E_{max} = 8.8E+01 eV/amu
He(4^3S)	E_{min} = 5.0E+03 eV/amu,	E_{max} = 2.5E+04 eV/amu
He(4^3P)	E_{min} = 2.5E+02 eV/amu,	E_{max} = 2.0E+04 eV/amu

	A0	A1	A2	A3	A4	A5	A6
He(4^3S)	-86.5334	1.37661	-.301332	.0231287	.0147011	-.0218801	.0103488
He(4^3S)	-84.1641	.186801	.0274621	.0565092	-.00857002	-.0283410	.0102453
He(4^3P)	-83.4554	-.954640	-.0267074	-.366176	-.0251284	-.0183797	.0210686

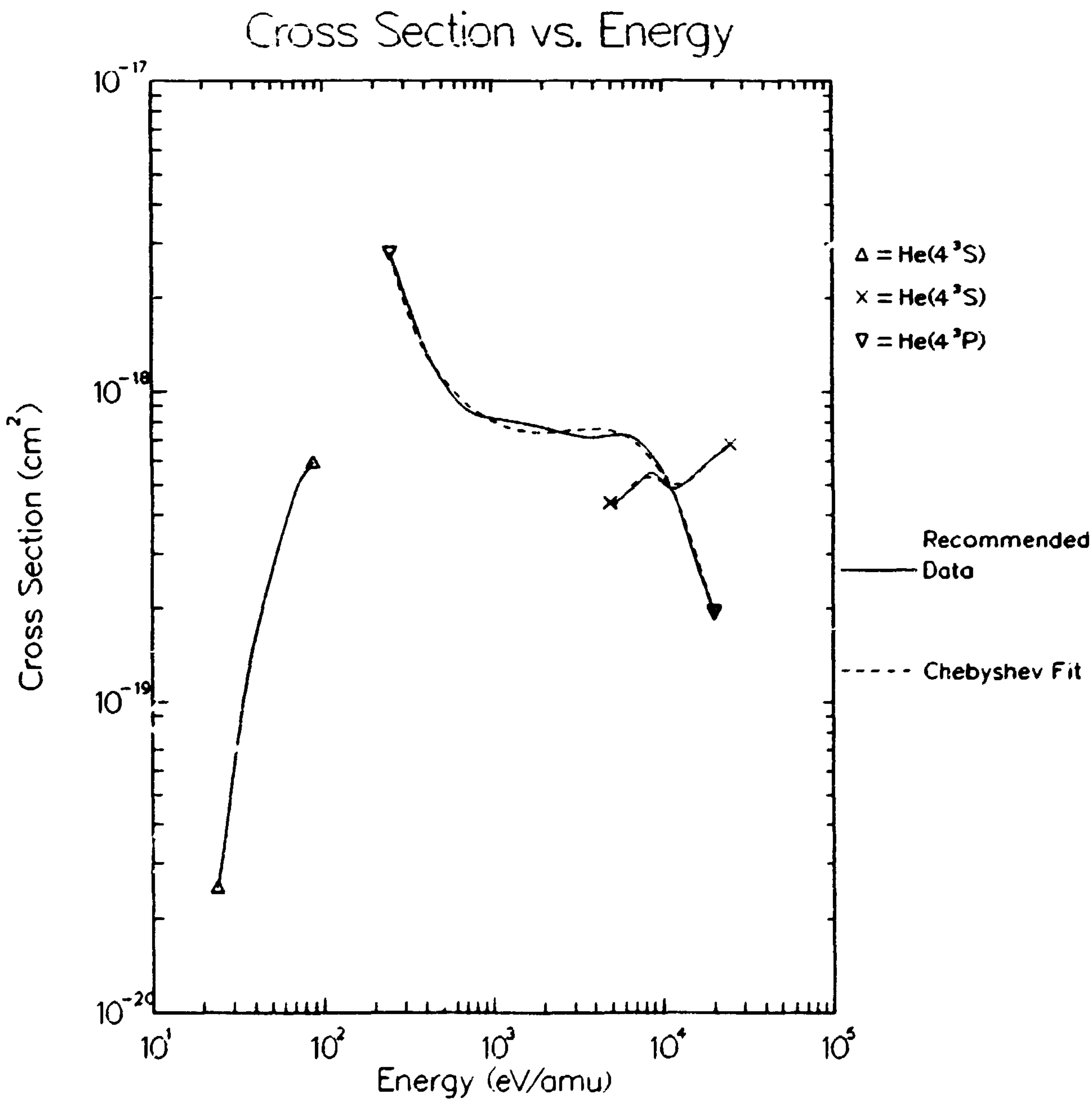
The fit represents the He(4^3S) cross section with an rms deviation of 0.4%. The maximum deviation is 1.0% at 4.5E+01 eV/amu.

The fit represents the He(4^3S) cross section with an rms deviation of 2.1%. The maximum deviation is 3.6% at 1.1E+04 eV/amu.

The fit represents the He(4^3P) cross section with an rms deviation of 3.5%. The maximum deviation is 6.2% at 4.0E+03 eV/amu.

See appendix for Chebyshev fit details.

He + He -> He(4^3S,4^3P)



Excitation and Ion-Pair Production Cross Sections for He + He -> Autoionizing States

$2s^2\ ^1S$		$2s2p\ ^3P$		$2p^2\ ^1D$		$2s2p\ ^1P$		$He^-(1s2s^2)\ ^2S$	
Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)
2.5E+03	6.83E-20	2.5E+03	1.72E-20	2.5E+03	2.01E-19	2.5E+03	1.13E-19	3.7E+03	2.45E-19
3.0E+03	8.84E-20	3.0E+03	2.04E-20	3.0E+03	2.55E-19	3.0E+03	1.52E-19	4.0E+03	2.60E-19
4.0E+03	1.32E-19	4.0E+03	2.70E-20	4.0E+03	3.57E-19	4.0E+03	2.27E-19	5.0E+03	3.05E-19
5.0E+03	1.80E-19	5.0E+03	3.37E-20	5.0E+03	4.42E-19	5.0E+03	2.91E-19	6.0E+03	3.43E-19
6.0E+03	2.28E-19	6.0E+03	4.01E-20	6.0E+03	5.18E-19	6.0E+03	3.48E-19	7.0E+03	3.76E-19
7.0E+03	2.82E-19	7.0E+03	4.74E-20	7.0E+03	5.74E-19	7.0E+03	4.05E-19	7.7E+03	3.83E-19
8.0E+03	3.37E-19	8.0E+03	5.42E-20	8.0E+03	6.16E-19	8.0E+03	4.53E-19	8.0E+03	3.80E-19
9.0E+03	3.90E-19	9.0E+03	6.16E-20	9.0E+03	6.49E-19	9.0E+03	5.05E-19	9.0E+03	3.41E-19
1.0E+04	4.33E-19	.0E+04	6.96E-20	1.0E+04	6.72E-19	1.0E+04	5.49E-19	1.0E+04	2.80E-19
1.4E+04	5.20E-19	1.5E+04	1.30E-19	1.2E+04	6.89E-19	1.3E+04	6.18E-19	1.5E+04	8.38E-20
1.5E+04	5.19E-19	2.0E+04	2.51E-19	1.5E+04	5.58E-19	1.5E+04	5.92E-19	2.0E+04	3.76E-20
2.0E+04	4.54E-19	3.0E+04	4.28E-19	2.0E+04	3.42E-19	2.0E+04	4.82E-19	3.0E+04	2.22E-20
3.0E+04	3.31E-19	3.5E+04	4.92E-19	3.0E+04	1.57E-19	3.0E+04	3.38E-19	3.5E+04	1.99E-20
3.5E+04	2.86E-19			3.5E+04	1.22E-19	3.5E+04	2.89E-19		

<u>**References:**</u> 724, 725, 726

<u>**Accuracy:**</u> Unknown

<u>**Note:**</u> The $1s2s^2\ ^2S$ state is the autodetaching state of He^-.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

$2s^2\ ^1S$	E_{min} = 2.5E+03 eV/amu,	E_{max} = 3.5E+04 eV/amu
$2s2p\ ^3P$	E_{min} = 2.5E+03 eV/amu,	E_{max} = 3.5E+04 eV/amu
$2p^2\ ^1D$	E_{min} = 2.5E+03 eV/amu,	E_{max} = 3.5E+04 eV/amu
$2s2p\ ^1P$	E_{min} = 2.5E+03 eV/amu,	E_{max} = 3.5E+04 eV/amu
$He^-(1s2s^2)^2S$	E_{min} = 3.7E+03 eV/amu,	E_{max} = 3.5E+04 eV/amu

	A0	A1	A2	A3	A4	A5	A6
$2s^2\ ^1S$	-85.8524	799247	-.526341	-.114359	.0439092	.0371210	-.00499344
$2s2p\ ^3P$	-87.8698	1.74012	.165859	-.0382066	-.0794670	-.0352277	.0132924
$2p^2\ ^1D$	-85.2799	-.217724	-.729656	-.0810841	.0662609	.0581753	.00536077
$2s2p\ ^1P$	-85.2994	.497649	-.530222	-.0630468	.0249202	.0444313	-5.43766E-04
$He^-(1s2s^2)^2S$	-87.4403	-1.52170	-.498463	.350749	.157944	-.0929551	-.0455722

The fit represents the $2s^2\ ^1S$ cross section with an rms deviation of 1.1%. The maximum deviation is 2.2% at 2.0E+04 eV/amu.

The fit represents the $2s2p\ ^3P$ cross section with an rms deviation of 2.4%. The maximum deviation is 5.2% at 1.5E+04 eV/amu.

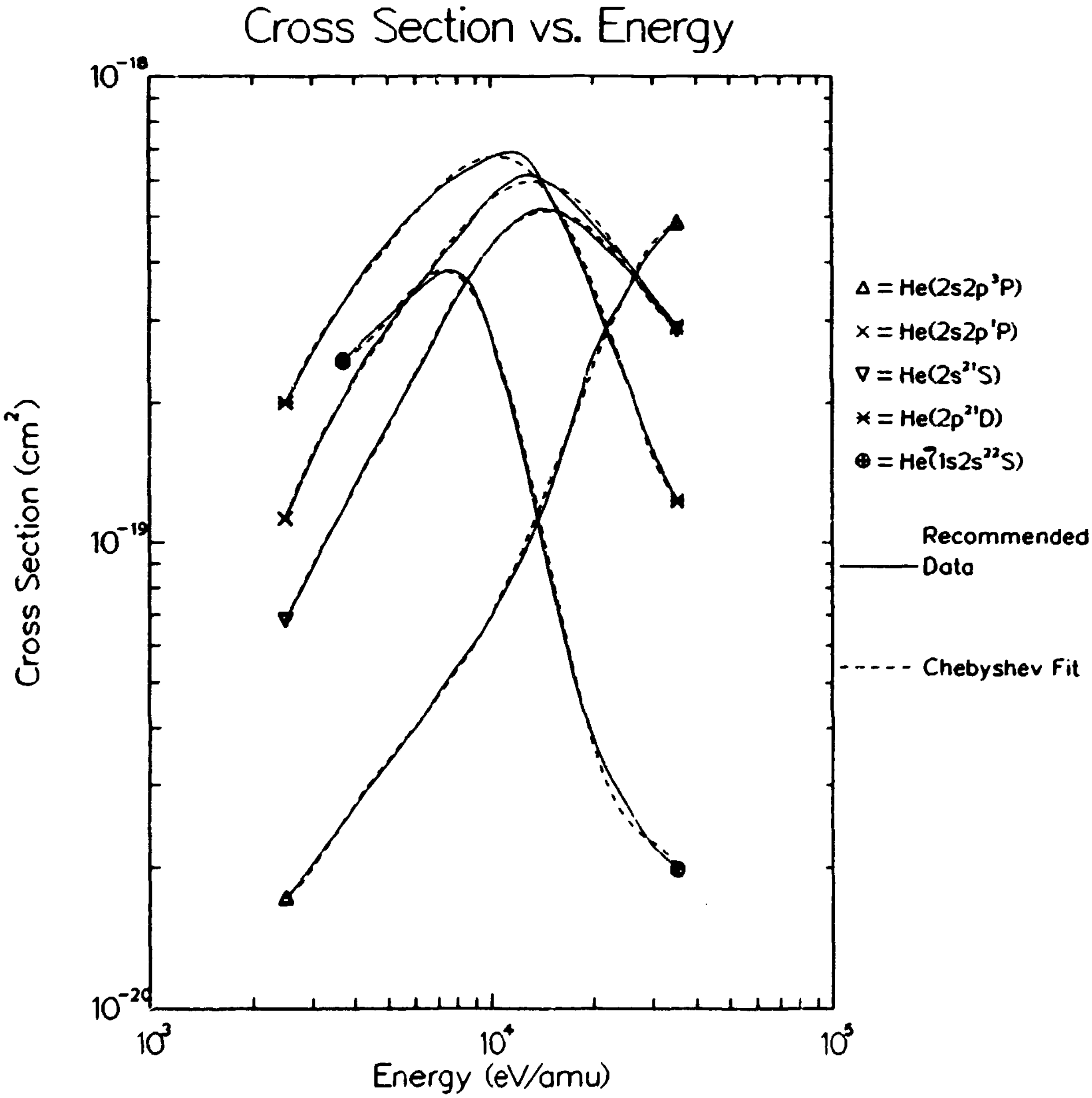
The fit represents the $2p^2\ ^1D$ cross section with an rms deviation of 2.0%. The maximum deviation is 3.6% at 2.0E+04 eV/amu.

The fit represents the $2s2p\ ^1P$ cross section with an rms deviation of 1.8%. The maximum deviation is 3.7% at 2.0E+04 eV/amu.

The fit represents the $He^-(1s2s^2)^2S$ cross section with an rms deviation of 1.9%. The maximum deviation is 3.4% at 1.5E+04 eV/amu.

See appendix for Chebyshev fit details.

He + He –> He(2s2p^{2}P, 2s2p^{1}P, 2s^{21}S, 2p^{21}D)
He + He –> He$^-$(1s2s^{22}S)



Excitation Cross Sections for

$He^{2+} + H \rightarrow H(2s,2p)$

H(2s) Energy (eV/amu)	H(2s) Cross Section (cm^2)	H(2p) Energy (eV/amu)	H(2p) Cross Section (cm^2)
2.5E+04	1.41E-16	2.5E+04	1.68E-16
3.0E+04	1.16E-16	3.0E+04	1.75E-16
4.0E+04	8.70E-17	4.0E+04	1.84E-16
5.0E+04	6.97E-17	5.0E+04	1.92E-16
6.0E+04	5.77E-17	6.0E+04	1.97E-16
7.0E+04	4.98E-17	7.0E+04	2.01E-16
8.0E+04	4.37E-17	8.0E+04	2.05E-16
9.0E+04	3.86E-17	9.0E+04	2.06E-16
1.0E+05	3.50E-17	1.0E+05	2.08E-16
1.5E+05	2.35E-17	1.5E+05	2.07E-16
2.0E+05	1.79E-17	2.0E+05	1.97E-16
3.0E+05	1.22E-17	3.0E+05	1.69E-16
4.0E+05	9.42E-18	4.0E+05	1.45E-16
5.0E+05	7.75E-18	5.0E+05	1.31E-16
5.6E+05	7.06E-18	5.4E+05	1.29E-16

Reference: 174

Accuracy: Unknown

Note: The curves are results of theoretical calculations for the excitation of H(1s) by He^{2+} inpact. Ref. 174 compares the results of calculations using alternative basis sets together with a full explanation of the estimated accuracy at different He^{2+} energies.

Chebyshev Fitting Parameters for Cross Sections

H(2s) E_{min} = 2.5E+04 eV/amu, E_{max} = 5.6E+05 eV/amu
H(2p) E_{min} = 2.5E+04 eV/amu, E_{max} = 5.4E+05 eV/amu

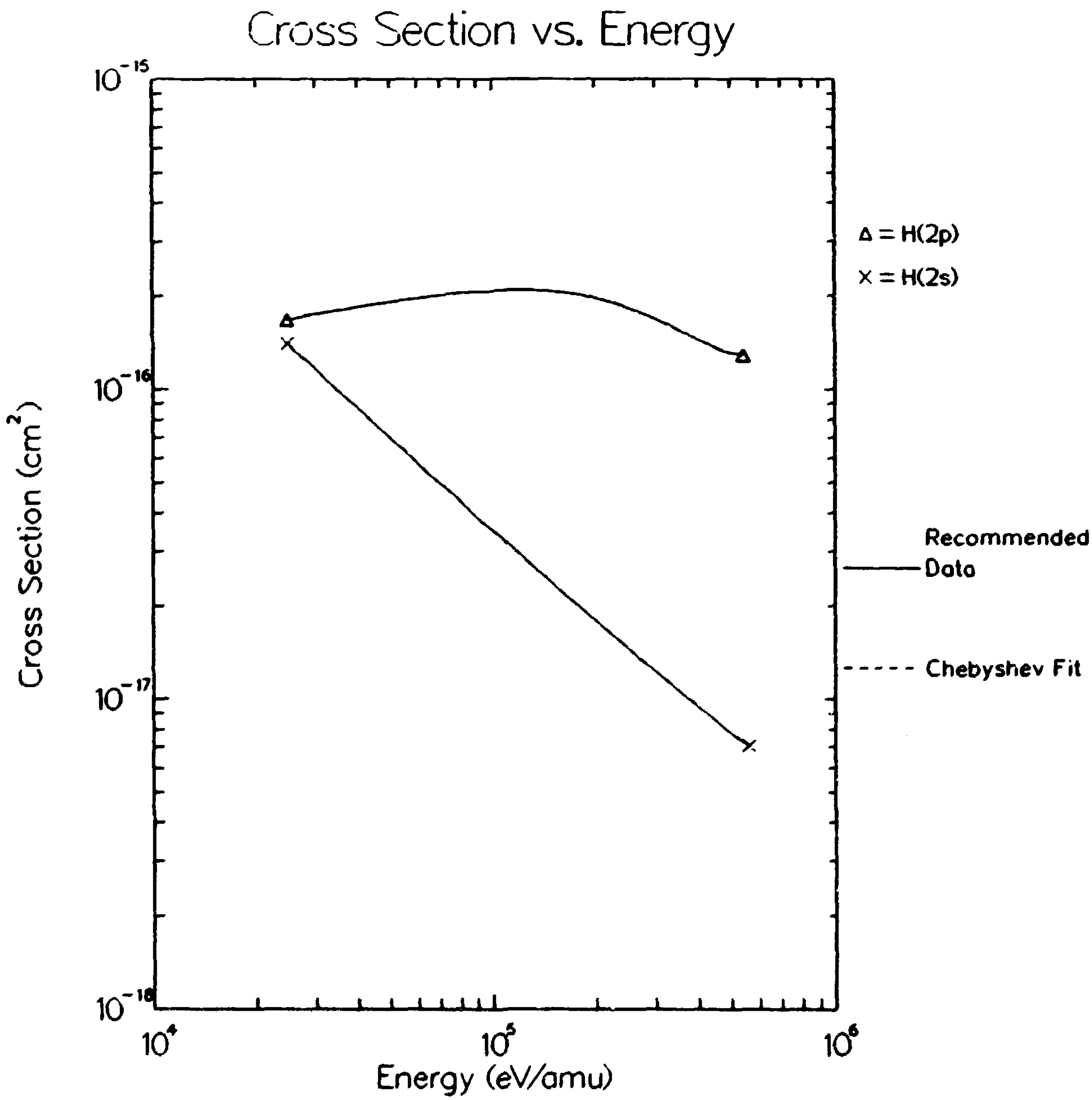
	A0	A1	A2	A3	A4	A5	A6
H(2s)	-76.0595	-1.50152	.0300296	.00522842	.00296312	-4.05387E	04.00159517
H(2p)	-72.5902	-.122617	-.180664	-.0249549	.0157733	.0139456	.00499314

The fit represents H(2s) cross section with an rms deviation of 0.2%. The maximum deviation is 0.5% at 6.0E+04 eV/amu.

The fit represents H(2p) cross section with an rms deviation of 0.2%. The maximum deviation is 0.3% at 4.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^{2+} + H \rightarrow H(2s,2p)$



Projectile Excitation Cross Sections for

$He(2^3S) + He(1^1S) \rightarrow He(3^1P) + He$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
5.0E+01	9.82E+06	3.44E-18
6.0E+01	1.08E+07	4.55E-18
7.0E+01	1.16E+07	5.27E-18
8.0E+01	1.24E+07	5.66E-18
9.0E+01	1.32E+07	5.84E-18
1.0E+02	1.39E+07	5.93E-18
1.5E+02	1.70E+07	4.63E-18
2.0E+02	1.96E+07	3.94E-18
2.5E+02	2.20E+07	4.44E-18
3.0E+02	2.41E+07	5.57E-18
4.0E+02	2.78E+07	6.82E-18
5.0E+02	3.11E+07	6.97E-18
6.0E+02	3.40E+07	6.76E-18
7.0E+02	3.68E+07	6.35E-18
8.0E+02	3.93E+07	5.88E-18
9.0E+02	4.17E+07	5.35E-18
1.0E+03	4.39E+07	4.80E-18
1.2E+03	4.81E+07	3.50E-18

References: 728, 729

Accuracy: Unknown

Notes: (1) Results from Ref. 728 correspond to projectile emission measurements and no corrections were made for contamination of metastable atomic beam with ground state atoms. Results have been normalized by the authors to previous results on excitation. (2) Experimental details of Ref. 729 are unknown.

Chebyshev Fitting Parameters for Cross Sections

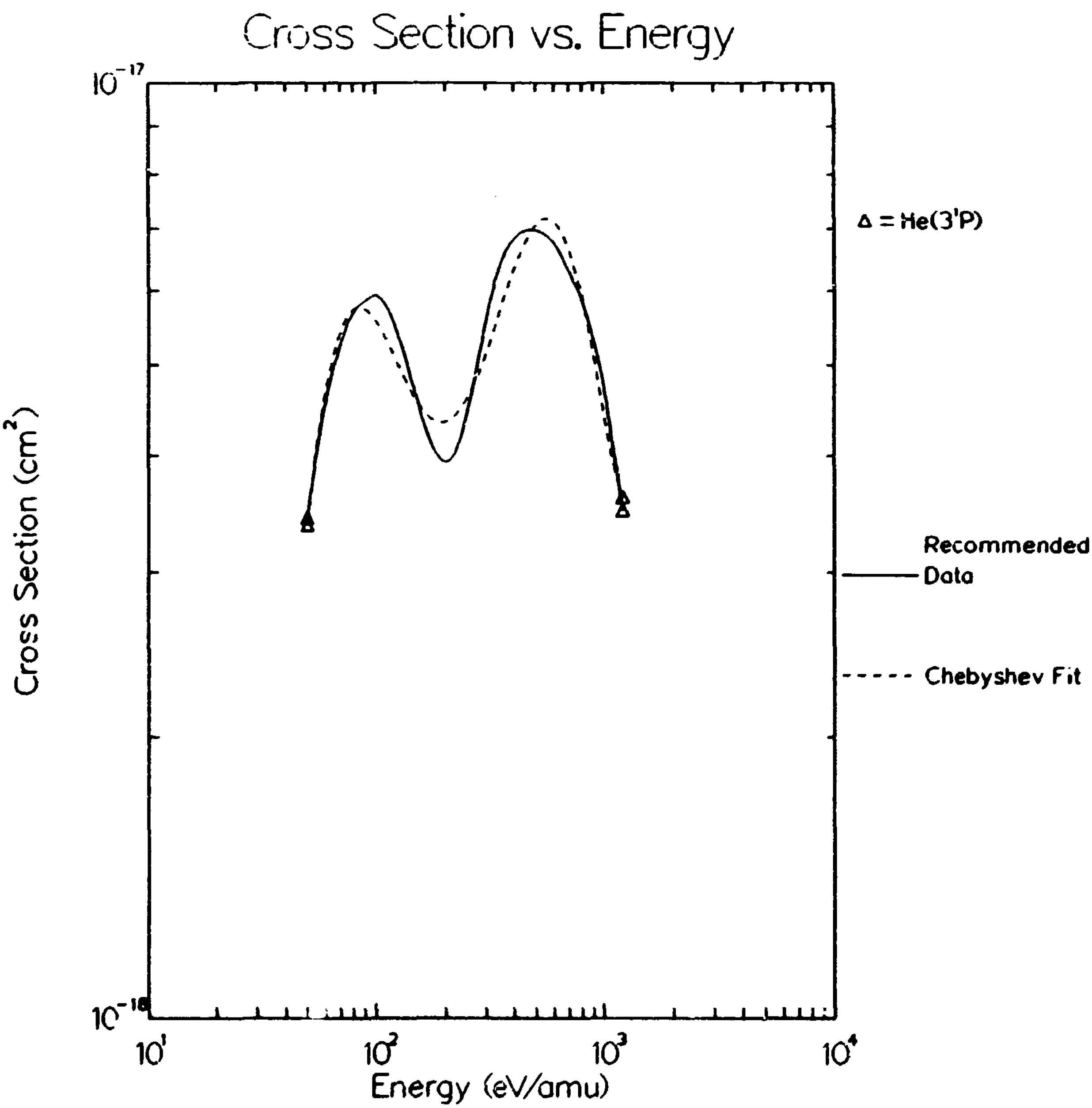
E_{min} = 5.0E+01 eV/amu, E_{max} = 1.2E+03 eV/amu

A0	A1	A2	A3	A4	A5	A6
-79.7131	.0521928	-.176441	-.0874202	-.203462	.0710365	.0424143

The fit represents the above cross section with an rms deviation of 4.9%. The maximum deviation is 10.5% at 2.0E+02 eV/amu.

See appendix for Chebyshev fit details.

$He(2^3S) + He(1^1S) \rightarrow He(3^1P) + He$



Projectile Excitation Cross Sections for

$He(2^3S) + He(1^1S) \rightarrow He(3^3P) + He$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
3.5E+01	8.22E+06	3.51E-17
4.0E+01	8.79E+06	4.07E-17
5.0E+01	9.82E+06	5.05E-17
6.0E+01	1.08E+07	5.96E-17
7.0E+01	1.16E+07	6.67E-17
8.0E+01	1.24E+07	7.23E-17
9.0E+01	1.32E+07	7.70E-17
1.0E+02	1.39E+07	8.11E-17
1.5E+02	1.70E+07	9.36E-17
2.0E+02	1.96E+07	9.94E-17
2.5E+02	2.20E+07	1.02E-16
3.0E+02	2.41E+07	1.03E-16
4.0E+02	2.78E+07	1.02E-16
5.0E+02	3.11E+07	1.00E-16
6.0E+02	3.40F+07	9.93E-17
7.0E+02	3.68E+07	9.82E-17
8.0E+02	3.93E+07	9.68E-17
9.0E+02	4.17E+07	9.49E-17
1.0E+03	4.39E+07	9.35E-17
1.3E+03	5.01E+07	8.48E-17

<u>References:</u> 728, 729

<u>Accuracy:</u> Unknown

<u>Notes:</u> (1) Results from Ref. 728 correspond to projectile emission measurements and no corrections were made for contamination of metastable atomic beam with ground state atoms. (2) Results have been normalized by the authors to previous results on excitation. (3) Experimental details of Ref. 729 are unknown.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

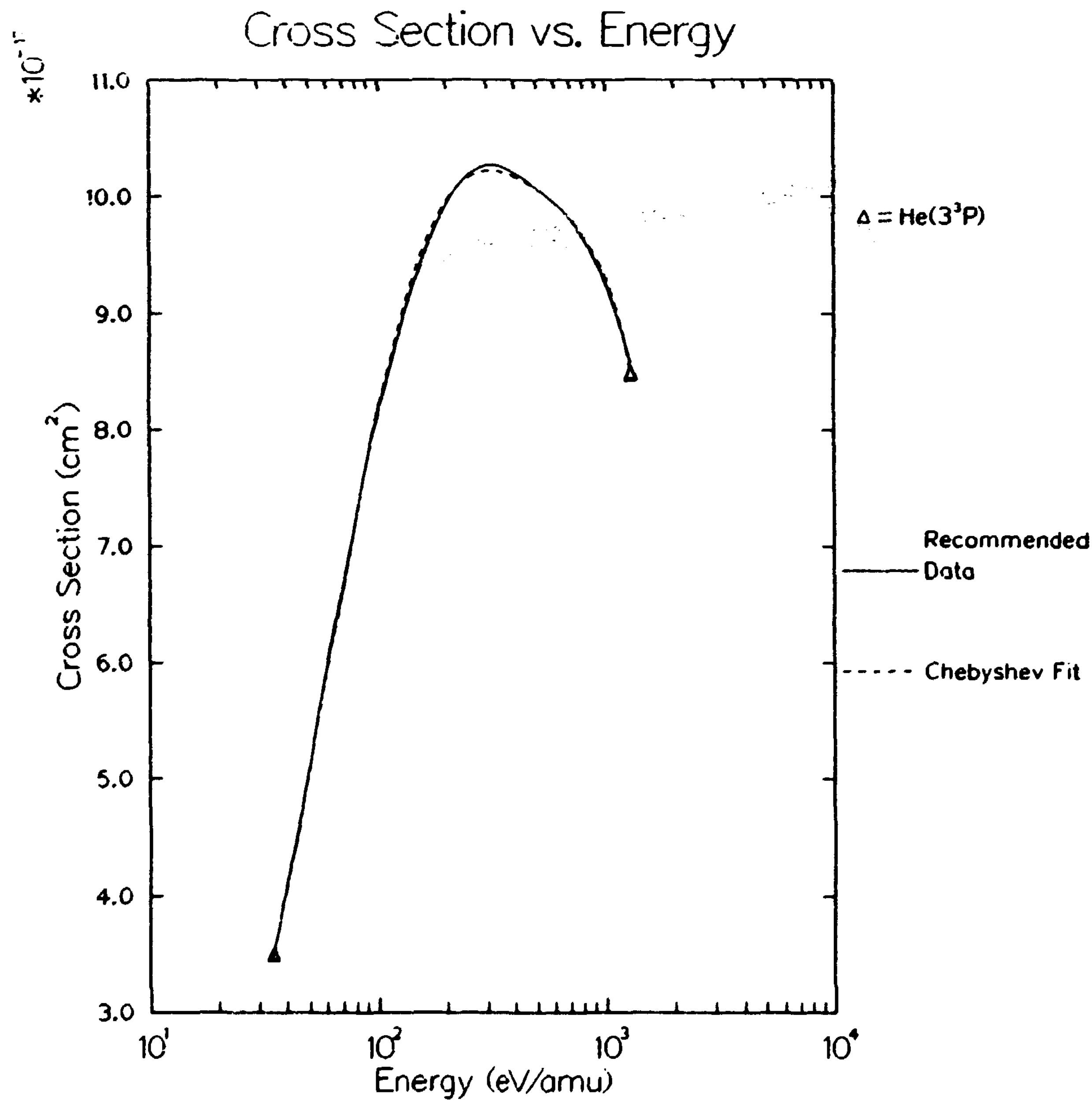
E_{min} = 3.5E+01 eV/amu, E_{max} = 1.3E+03 eV/amu

A0	A1	A2	A3	A4	A5	A6
-74.2632	.399374	-.300481	.0525981	-.0111543	-.00859422	-.00474980

The fit represents the above cross section with an rms deviation of 0.4%. The maximum deviation is 0.8% at 5.0E+01 eV/amu.

See appendix for Chebyshev fit details.

$He(2^3S) + He(1^1S) \rightarrow He(3^3P) + He$



Projectile Excitation Cross Sections for

$He(2^3S) + He(1^1S) \rightarrow He(4^3S, 4^3D) + He$

$He(4^3S)$ Energy (eV/amu)	$He(4^3S)$ Cross Section (cm^2)	$He(4^3D)$ Energy (eV/amu)	$He(4^3D)$ Cross Section (cm^2)
7.0E+01	1.17E-18	6.0E+01	6.96E-18
8.0E+01	9.49E-19	7.0E+01	7.98E-18
9.0E+01	8.39E-19	8.0E+01	9.02E-18
1.0E+02	7.81E-19	9.0E+01	9.94E-18
1.5E+02	1.22E-18	1.0E+02	1.07E-17
2.0E+02	1.62E-18	1.5E+02	1.36E-17
3.0E+02	1.99E-18	2.0E+02	1.49E-17
1.0E+04	2.70E-18	2.5E+02	1.52E-17
1.5E+04	2.16E-18	3.0E+02	1.42E-17
2.0E+04	1.76E-18	4.0E+02	1.16E-17
2.5E+04	1.49E-18	5.0E+02	1.05E-17
2.7E+04	1.39E-18	6.0E+02	1.09E-17
		7.0E+02	1.16E-17
		8.0E+02	1.21E-17
		9.0E+02	1.26E-17
		1.0E+03	1.29E-17
		1.5E+03	1.39E-17
		2.0E+03	1.39E-17
		3.0E+03	1.33E-17
		4.0E+03	1.22E-17
		5.0E+03	1.11E-17
		6.0E+03	1.00E-17
		7.0E+03	9.02E-18
		8.0E+03	8.13E-18
		9.0E+03	7.36E-18
		1.0E+04	6.61E-18
		1.5E+04	3.87E-18
		2.0E+04	2.28E-18
		2.5E+04	1.41E-18

<u>References:</u> 727, 728, 729, 730

<u>Accuracy:</u> Unknown

<u>Notes:</u> (1) Results from Ref. 728 correspond to projectile emission cross sections and no correction was made for contamination of metastable atomic beam with ground state atoms. (2) Results have been normalized by the authors to previous results on excitation. (3) Experimental details of Ref. 729 are unknown. (4) Dotted curve for 4^3S excitation between .3 and 10 keV/amu represents an interpolation between the data of Ref. 727 and Ref. 729, and has a large uncertainty.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

$He(4^3S)$ E_{min} = 7.0E+01 eV/amu, E_{max} = 2.7E+04 eV/amu
$He(4^3D)$ E_{min} = 6.0E+01 eV/amu, E_{max} = 2.5E+04 eV/amu

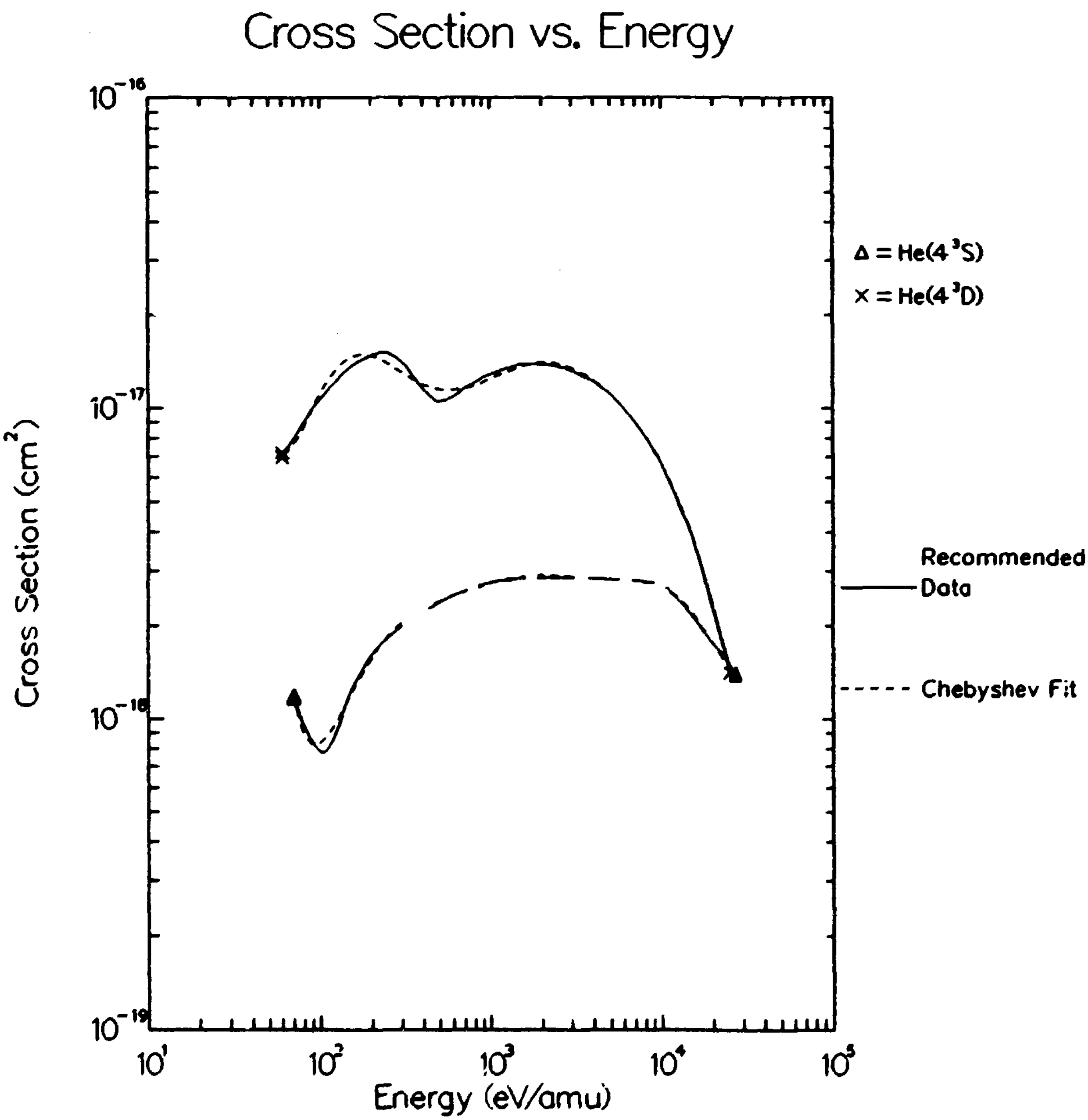
	A0	A1	A2	A3	A4	A5	A6	A7	A8
$He(4^3S)$	-81.7091	.309903	-.473244	-.0741860	.0175929	-.112721	.0812889	-.0416811	.0437011
$He(4^3D)$	-78.8400	-.637167	-.719668	-.186552	-.198706	.0689624	.0116222	-.0618008	.0358345

The fit represents the $He(4^3S)$ cross section with an rms deviation of 2.6%. The maximum deviation is 7.0% at 1.0E+02 eV/amu.

The fit represents the $He(4^3D)$ cross section with an rms deviation of 3.7%. The maximum deviation is 9.8% at 5.0E+02 eV/amu.

See appendix for Chebyshev fit details.

$He(2^3S) + He \rightarrow He(4^3S, 4^3D) + He$



Target Excitation Crosss Sections for

$He(2^3S)$ + $He(1^1S)$ -> He + $He(4^3S, 4^3D)$

$He(4^3S)$

Energy (eV/amu)	Cross Section (cm^2)
5.0E+03	6.41E-18
6.0E+03	7.20E-18
7.0E+03	7.72E-18
8.0E+03	7.92E-18
9.0E+03	8.01E-18
1.0E+04	7.89E-18
1.5E+04	5.87E-18
2.0E+04	3.35E-18
2.5E+04	1.50E-18

$He(4^3D)$

Energy (eV/amu)	Cross Section (cm^2)
5.0E+03	1.17E-17
6.0E+03	1.39E-17
7.0E+03	1.48E-17
7.5E+03	1.49E-17
8.0E+03	1.47E-17
9.0E+03	1.38E-17
1.0E+04	1.22E-17
1.2E+04	6.16E-18
1.5E+04	3.51E-18
2.0E+04	1.74E-18
2.3E+04	1.28E-18

<u>References:</u> 727, 730

<u>Accuracy:</u> 40%

<u>Note:</u> Data are for excitation of the ground state He target atom by the metastable $He(2^3S)$ projectile atom.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

He + $He(4^3S)$ E_{min} = 5.0E+03 eV/amu, E_{max} = 2.5E+04 eV/amu
He + $He(4^3D)$ E_{min} = 5.0E+03 eV/amu, E_{max} = 2.3E+04 eV/amu

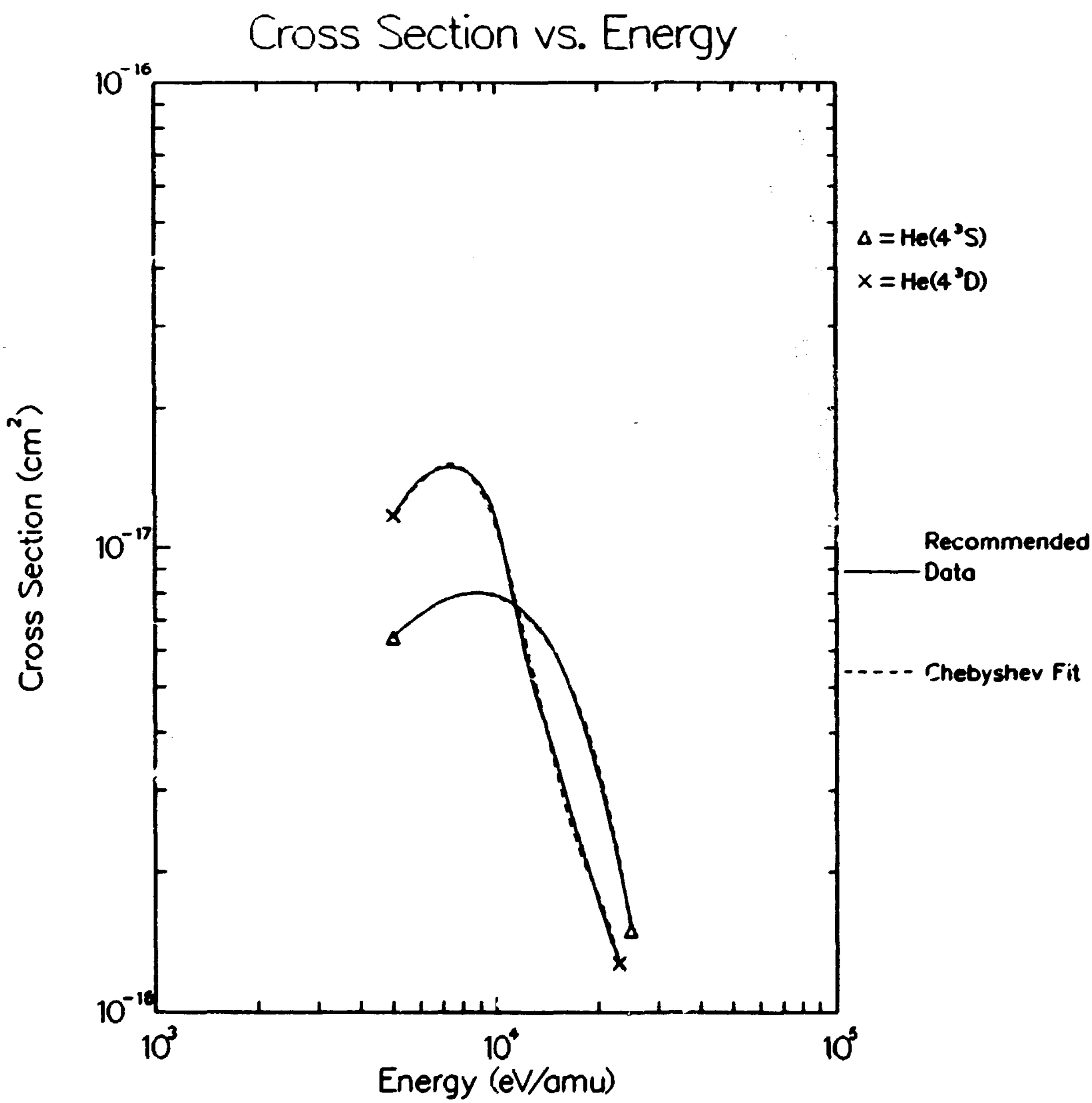
	A0	A1	A2	A3	A4	A5	A6
He + $He(4^3S)$	-79.6926	-.631297	-.445191	-.0910388	-.0216050	-.00467890	.00182959
He + $He(4^3D)$	-79.4099	-1.23537	-.423173	.177825	.0609486	-.0537149	-.0270941

The fit represents He + $He(4^3S)$ cross section with an rms deviation of 0.2%. The maximum deviation is 0.4% at 8.0E+03 eV/amu.

The fit represents He + $He(4^3D)$ cross section with an rms deviation of 4.4%. The maximum deviation is 10.7% at 1.2E+04 eV/amu.

See appendix for Chebyshev fit details.

$He(2^3S) + He(1^1S) \rightarrow He(4^3S, 4^3D) + He$



Excitation and Spectral Line Emission Cross Sections for

$H^{+} + Li(2s) \rightarrow H^{+} + Li(2p)$
$\rightarrow H^{+} + Li(670.8nm)$

Li(2p)

Energy (eV/amu)	Cross Section (cm^2)
5.0E+02	9.56E-16
7.0E+02	1.20E-15
1.0E+03	1.50E-15
1.5E+03	1.91E-15
2.0E+03	2.25E-15
4.0E+03	3.06E-15
7.0E+03	3.62E-15
1.0E+04	3.96E-15
1.3E+04	3.99E-15
2.0E+04	3.88E-15
4.0E+04	2.38E-15
7.0E+04	1.42E-15
1.0E+05	1.03E-15
1.3E+05	8.17E-16

Li(670.8nm)

Energy (eV/amu)	Cross Section (cm^2)
2.0E+03	2.97E-15
2.5E+03	3.35E-15
3.0E+03	3.69E-15
4.0E+03	4.04E-15
5.0E+03	4.27E-15
6.0E+03	4.43E-15
7.0E+03	4.53E-15
8.0E+03	4.60E-15
9.0E+03	4.65E-15
1.0E+04	4.69E-15
1.5E+04	4.73E-15
2.0E+04	4.55E-15

References: Li(2p); 257, 285
Li(670.8nm) emission; 258, 732, 734

Accuracy: Unknown

Notes: (1) The ground state of Li is the 2s state. (2) The resonance line of Li is the 2p -> 2s transition at a wavelength of 670.8nm. (3) Myers et al. (Ref. 734) have also measured emission cross sections for this reaction in the energy region 100-1500 eV/amu. Their results are more than an order of magnitude lower than the recommended data in the energy overlap region.

Chebyshev Fitting Parameters for Cross Sections

Li(2p) E_{min} = 5.0E+02 eV/amu, E_{max} = 1.3E+05 eV/amu
Li(670.8 nm) E_{min} = 2.0E+03 eV/amu, E_{max} = 2.0E+04 eV/amu

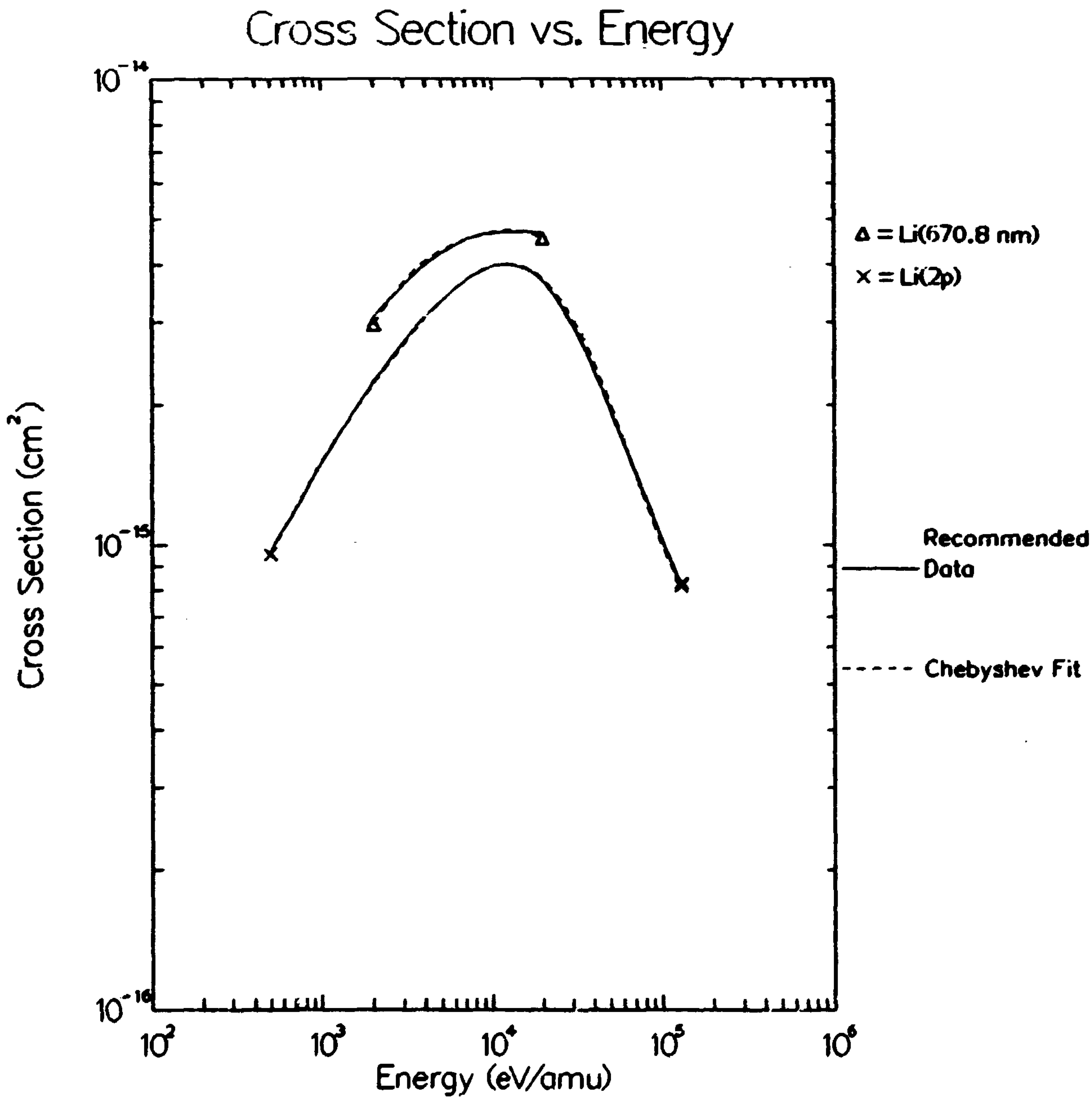
	A0	A1	A2	A3	A4	A5	A6
Li(2p)	-67.9437	-.00943077	-.745522	-.112088	.0453106	.0512591	.0155081
Li(670.8 nm)	-66.2671	.208208	-.0976231	.00780915	-.00712239	-.00227550	.00106025

The fit represents Li(2p) cross section with an rms deviation of 1.9%.
The maximum deviation is 3.6% at 4.0E+04 eV/amu.

The fit represents Li(670.8 nm) cross section with an rms deviation of 0.3%.
The maximum deviation is 0.4% at 2.5E+03 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + Li(2s) \rightarrow Li(2p, 670.8\ nm\ emission)$



Total Spectral Line Emission Cross Sections for

$He^+ + Li(2s) \rightarrow He^+ + Li(670.8nm)$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
5.0E+02	3.11E+07	5.58E-16
6.0E+02	3.40E+07	6.55E-16
7.0E+02	3.68E+07	7.48E-16
8.0E+02	3.93E+07	8.43E-16
9.0E+02	4.17E+07	9.33E-16
1.0E+03	4.39E+07	1.03E-15
1.5E+03	5.38E+07	1.47E-15
2.0E+03	6.21E+07	1.93E-15
2.5E+03	6.95E+07	2.43E-15
3.0E+03	7.61E+07	2.90E-15
4.0E+03	8.79E+07	3.39E-15
4.5E+03	9.32E+07	3.51E-15
5.0E+03	9.82E+07	3.52E-15

References: 267, 732, 734

Accuracy: Unknown

Notes: (1) The 2p -> 2s transition at 670.8nm is the resonance transition of Li. (2) The emission cross section includes cascading into the 2p state from the upper levels. (3) As far as we are aware no data for the cross sections for the 2p state excitation exist. (4) Myers et al. (Ref. 734) obtained data for the emission cross sections in the energy range 50-375 eV/amu. Their measurements are an order of magnitude less than the recommended data at 400 eV/amu.

Chebyshev Fitting Parameters for Cross Sections

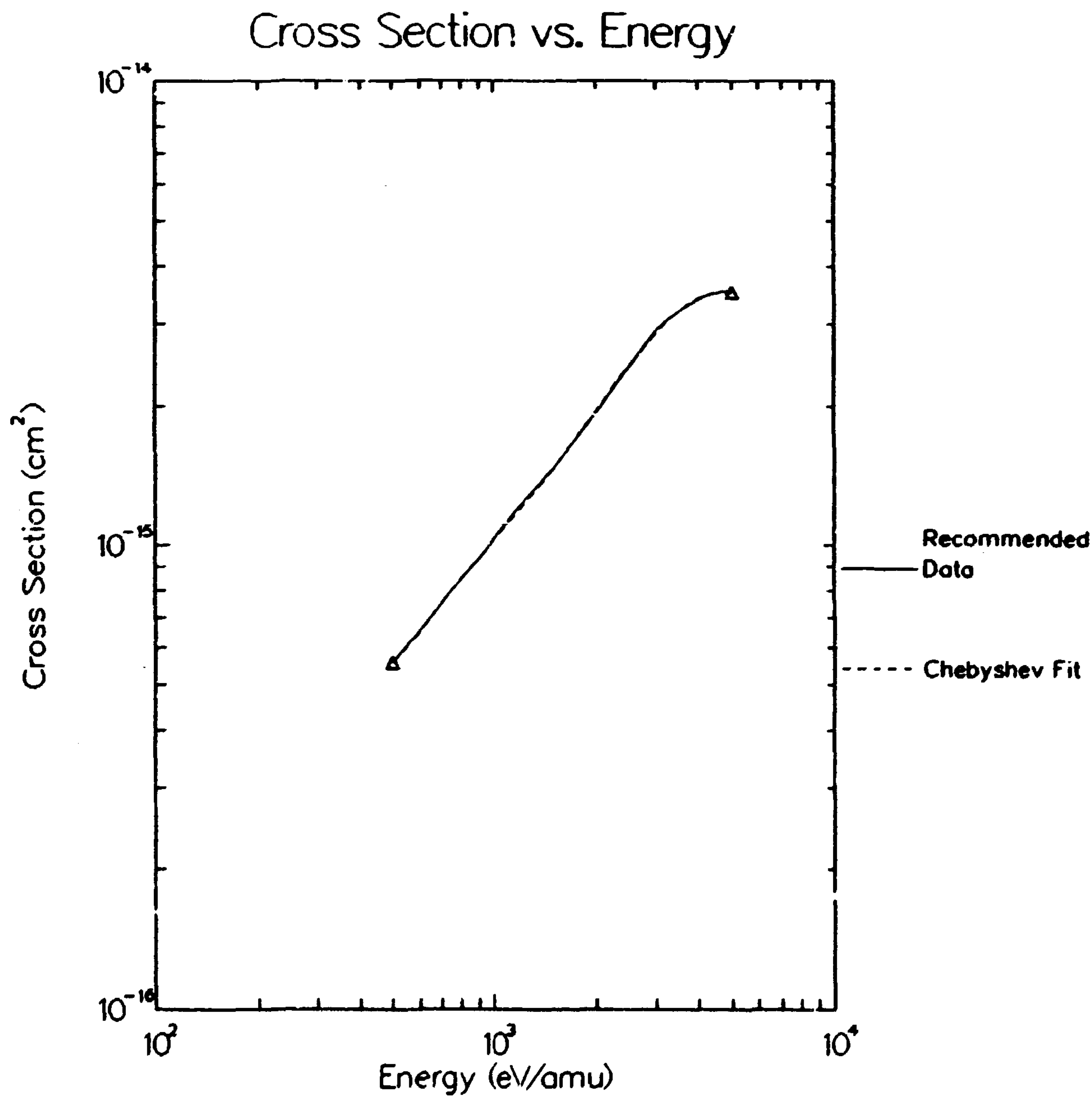
E_{min} = 5.0E+02 eV/amu, E_{max} = 5.0E+03 eV/amu

A0	A1	A2	A3	A4	A5	A6
-68.2494	.976730	-.0528574	-.0520709	-.0299645	-.00494558	.00671922

The fit represents the above cross section with an rms deviation of 0.5%. The maximum deviation is 0.8% at 2.0E+03 eV/amu.

See appendix for Chebyshev fit details.

He^{+} + Li(2s) -> Li(2p) (670.8 nm emission)



Excitation and Spectral Line Emission Cross Sections for

$He^{2+} + Li(2s) \rightarrow He^{2+} + Li(2p)$
$\rightarrow He^{2+} + Li(670.8nm)$

Li(2p) Energy (eV/amu)	Li(2p) σ (cm^2)	Li(2p) (cont.) Energy (eV/amu)	Li(2p) (cont.) σ (cm^2)	Li(670.8nm) Energy (eV/amu)	Li(670.8nm) σ (cm^2)
1.4E+02	3.90E-17	3.8E+03	2.79E-15	3.7E+03	2.92E-15
2.0E+02	6.43E-17	4.0E+03	2.94E-15	4.0E+03	3.13E-15
3.0E+02	1.11E-16	7.0E+03	4.93E-15	7.0E+03	5.21E-15
4.0E+02	1.62E-16	1.0E+04	6.57E-15	1.0E+04	6.96E-15
5.0E+02	2.18E-16	2.0E+04	7.93E-15	1.5E+04	8.45E-15
6.0E+02	2.73E-16	2.6E+04	8.12E-15	2.0E+04	9.07E-15
7.0E+02	3.28E-16	4.0E+04	7.50E-15	2.6E+04	9.21E-15
8.0E+02	3.84E-16	7.0E+04	6.04E-15	4.0E+04	8.69E-15
9.0E+02	4.36E-16	1.0E+05	5.10E-15	7.0E+04	6.94E-15
1.0E+03	4.90E-16	2.0E+05	3.25E-15	1.0E+05	5.81E-15
1.5E+03	7.52E-16	4.0E+05	1.82E-15	1.5E+05	4.70E-15
2.0E+03	9.89E-16	7.0E+05	1.09E-15		
		1.0E+06	7.68E-16		
		2.0E+06	3.93E-16		
		2.7E+06	2.95E-16		

References: Li(2p); 731, 733, 735
Li(670.8nm) emission; 259, 733, 735

Accuracy: Unknown

Notes: (1) The 2p -> 2s is the resonance transition of Li with λ = 670.8nm. (2) No attempt has been made to join the low energy data of Barrett and Leventhal (Ref. 259) to the data of Kadota et al. (Ref. 733). (3) The data of Kadota et al. have been extended to 2.5×10^6 eV/amu using the theoretical data of Ermolaev et al. (Ref. 731).

Chebyshev Fitting Parameters for Cross Sections

Li(2p) E_{min} = 1.4E+02 eV/amu, E_{max} = 2.0E+03 eV/amu
Li(2p) E_{min} = 3.8E+03 eV/amu E_{max} = 2.7E+06 eV/amu
Li(670.8 nm) E_{min} = 3.7E+03 eV/amu, E_{max} = 1.5E+05 eV/amu

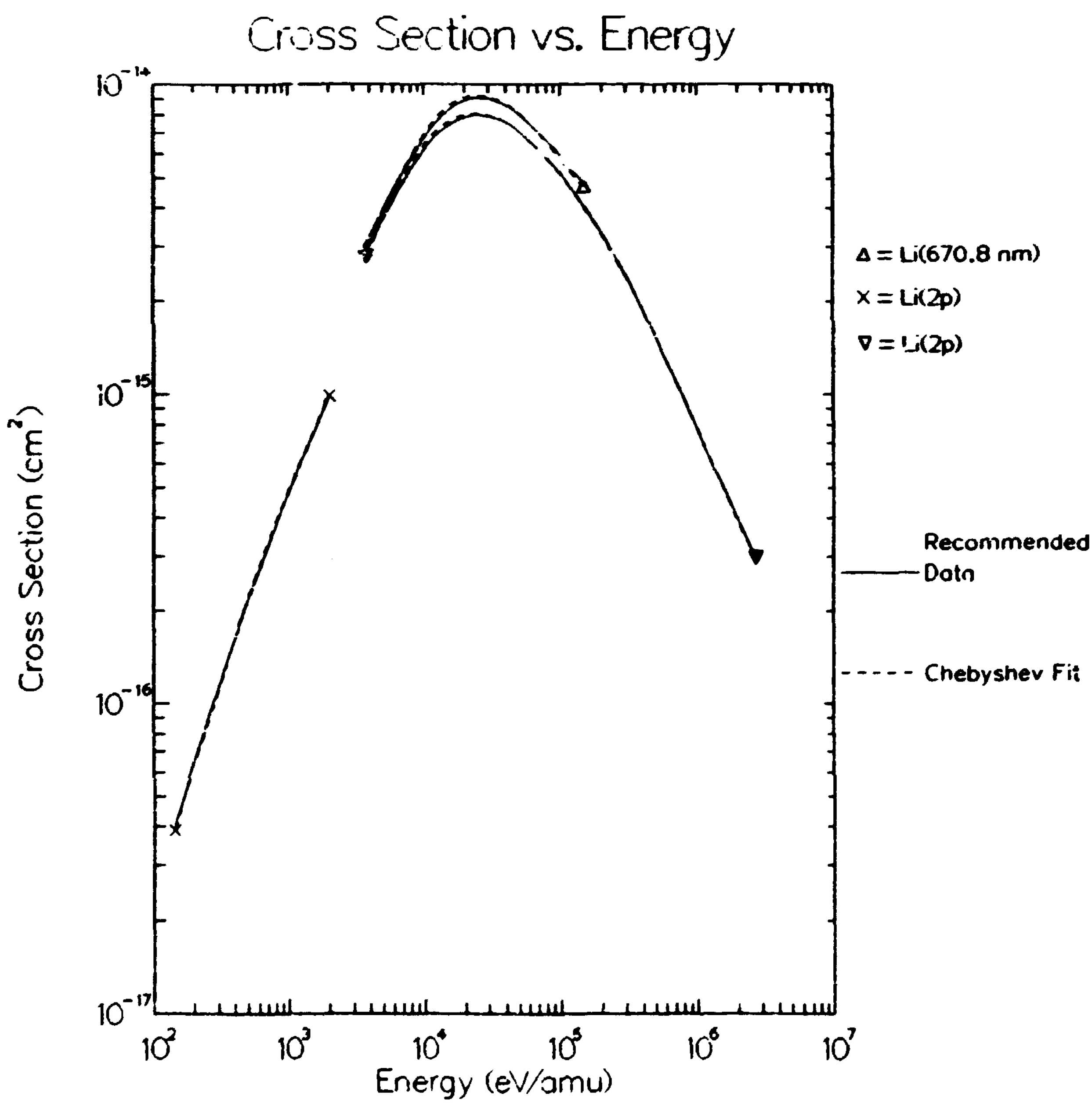
	A0	A1	A2	A3	A4	A5	A6
Li(2p)	-72.1632	1.62490	-.0826001	-.0110092	.00206946	.00278599	-.00427450
Li(2p)	-67.5365	-1.31752	-.867548	.198289	-.0106036	.00118819	.0110240
Li(670.8 nm)	-65.6114	.210669	-.460211	.0351576	.0330529	-.00874795	.00505234

The fit represents Li(2p) excitation cross section with an rms deviation of 0.2%.
The maximum deviation is 0.4% at 4.0E+02 eV/amu.

The fit represents Li(2p) cross section with an rms deviation of 1.1%.
The maximum deviation is 2.3% at 7.0E+03 eV/amu.

The fit represents Li(670.8 nm) cross section with an rms deviation of 0.4%.
The maximum deviation is 0.5% at 7.0E+04 eV/amu.

$He^{2+} + Li(2s) \rightarrow Li(2p, 670.8\ nm\ emission)$



D. Cross Sections for Ionization and Production of Charged Particles

(* denotes rate coefficient data also)

D. (Cont'd)

Cross Sections for Slow Positive-Ion and Electron Production in Collisions of Hydrogen Atoms with Molecular Hydrogen

H + H_2 -> Total Slow Positive Ion Prod.
H + H_2 -> Total Slow Electron Prod.

Slow Positive Ion Production		Electron Production	
Energy (eV/amu)	Cross Section (cm^2)	Energy (eV/amu)	Cross Section (cm^2)
4.0E+01	5.51E-19	8.0E+01	2.83E-19
7.0E+01	1.65E-18	1.0E+02	5.71E-19
1.0E+02	2.51E-18	2.0E+02	2.65E-18
2.0E+02	3.37E-18	4.0E+02	9.67E-18
3.0E+02	3.17E-18	7.0E+02	2.38E-17
4.0E+02	3.26E-18	1.0E+03	3.98E-17
7.0E+02	4.73E-18	2.0E+03	9.33E-17
1.0E+03	7.28E-13	3.0E+03	1.24E-16
2.0E+03	1.97E-17	4.0E+03	1.29E-16
4.0E+03	5.06E-17	5.0E+03	1.32E-16
1.0E+04	1.27E-16	7.0E+03	1.50E-16
2.0E+04	1.75E-16	1.0E+04	2.00E-16
4.0E+04	1.60E-16	2.0E+04	2.90E-16
1.0E+05	1.15[illegible]6	3.0E+04	3.08E-16
2.0E+05	8.14E-[illegible]7	4.0E+04	2.98E-16
4.0E+05	5.02E-17	7.0E+04	2.56E-16
		1.0E+05	2.26E-16
		2.0E+05	1.58E-16
		4.0E+05	1.02E-16

References: 28, 30, 143, 287, 315, 323, 324

Accuracy: 20%

Notes: (1) The slow positive charge formation cross section is the sum of the ionization cross section and the electron capture cross section. $\sigma^+ = \sigma_1 (H_2^+ + e) + \sigma_{0-1} (H^- + H_2^+)$. The dissociative ionization cross section ($H + H_2 \rightarrow H + H^+ + H + e$) is only 2-5% of the H_2^+ formation cross section in this energy range. (2) At low energies most of the H_2^+ arises from electron capture collisions. (3) The electron production cross section is the sum of ionization and the electron loss or stripping cross section $\sigma^+ = \sigma_1 (H_2^+ + e) + \sigma_{01} (H^+ + e)$.

Chebyshev Fitting Parameters for Cross Sections

Positive Ions E_{min} = 4.0E+01 eV/amu, E_{max} = 4.0E+05 eV/amu
Electrons E_{min} = 8.0E+01 eV/amu, E_{max} = 4.0E+05 eV/amu

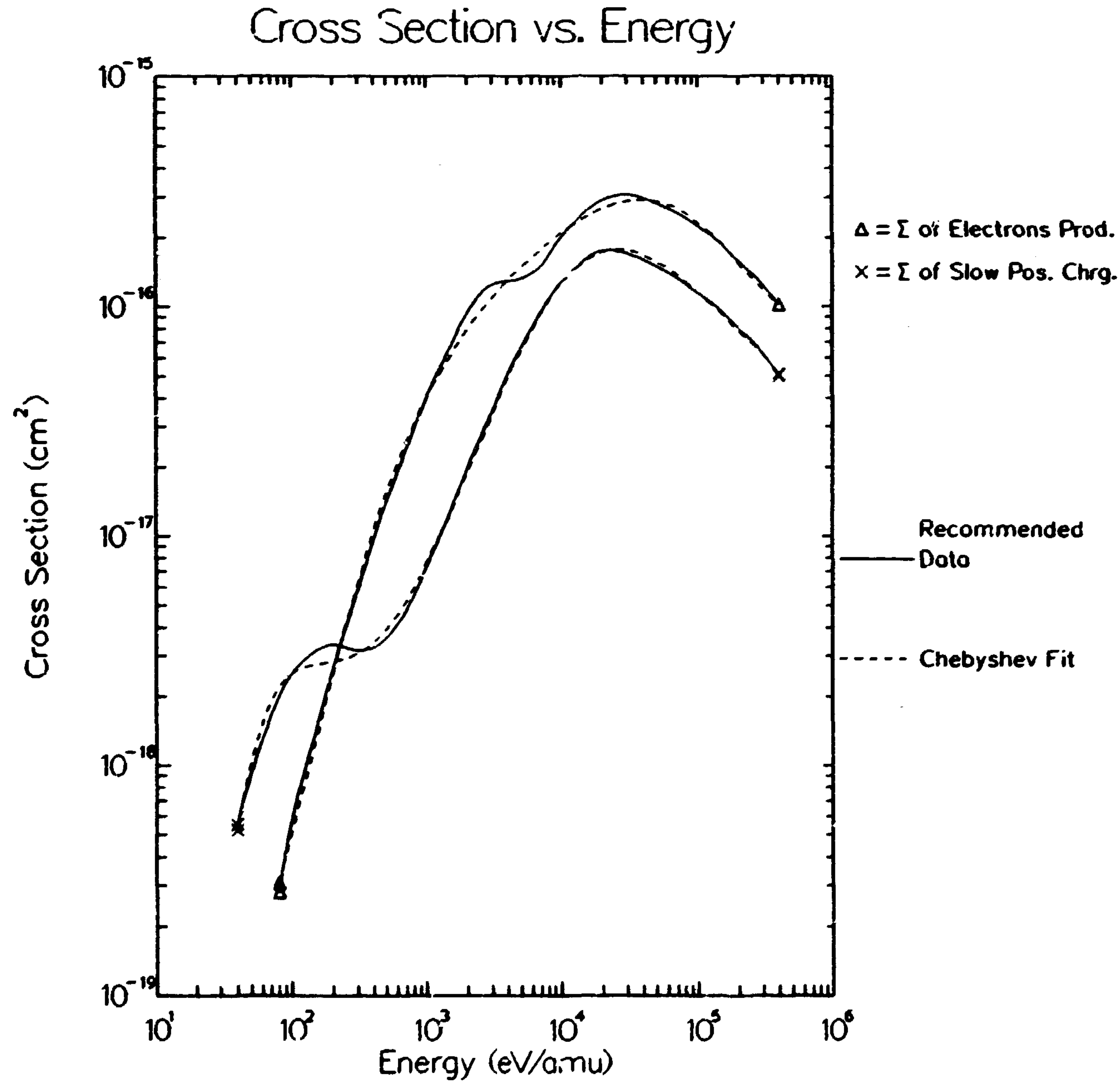
	A0	A1	A2	A3	A4	A5	A6
Pos. Ions	-77.2533	2.45645	-.972849	-.533057	-.0537388	.365771	-.154454
Electrons	-75.9790	2.77048	-1.73727	.139659	-.0624901	-.00991339	.0680936

The fit represents the Positive Ions cross section with an rms deviation of 6.7%. The maximum deviation is 14.9% at 7.0E+01 eV/amu.

The fit represents the Electrons cross section with an rms deviation of 8.5%. The maximum deviation is 17.8% at 7.0E+03 eV/amu.

See appendix for Chebyshev fit details.

H + H_2 -> Sum of Slow Positive Charges
H + H_2 -> Sum of Electrons Produced



Ionization Cross Sections for

$H + H_2 \rightarrow H + H_2^+ + e$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.0E+02	1.96E+07	4.04E-19
4.0E+02	2.78E+07	1.42E-18
7.0E+02	3.68E+07	3.32E-18
1.0E+03	4.39E+07	5.48E-18
2.0E+03	6.21E+07	1.49E-17
4.0E+03	8.79E+07	3.71E-17
7.0E+03	1.16E+08	6.72E-17
1.0E+04	1.39E+08	9.30E-17
2.0E+04	1.96E+08	1.45E-16
2.8E+04	2.32E+08	1.54E-16
4.0E+04	2.78E+08	1.46E-16
7.0E+04	3.68E+08	1.23E-16
1.0E+05	4.39E+08	1.08E-16
2.0E+05	6.21E+08	8.13E-17
4.0E+05	8.78E+08	4.99E-17

References: 28, 30, 143, 308, 315, 323, 325

Accuracy: 30%

Notes: (1) The ionization cross section is determined from either of two relations: $\sigma_i = \sigma^- - \sigma_{01}$ or $\sigma_i = \sigma^+ - \sigma_{0-1}$, where σ^- is the cross section for formation of electrons, σ_{01} is the loss or stripping cross section, σ^+ is the cross section for slow ion formation, and σ_{0-1} is the electron capture cross section. (2) There is considerable scatter in the data among the various investigators.

Chebyshev Fitting Parameters for Cross Sections

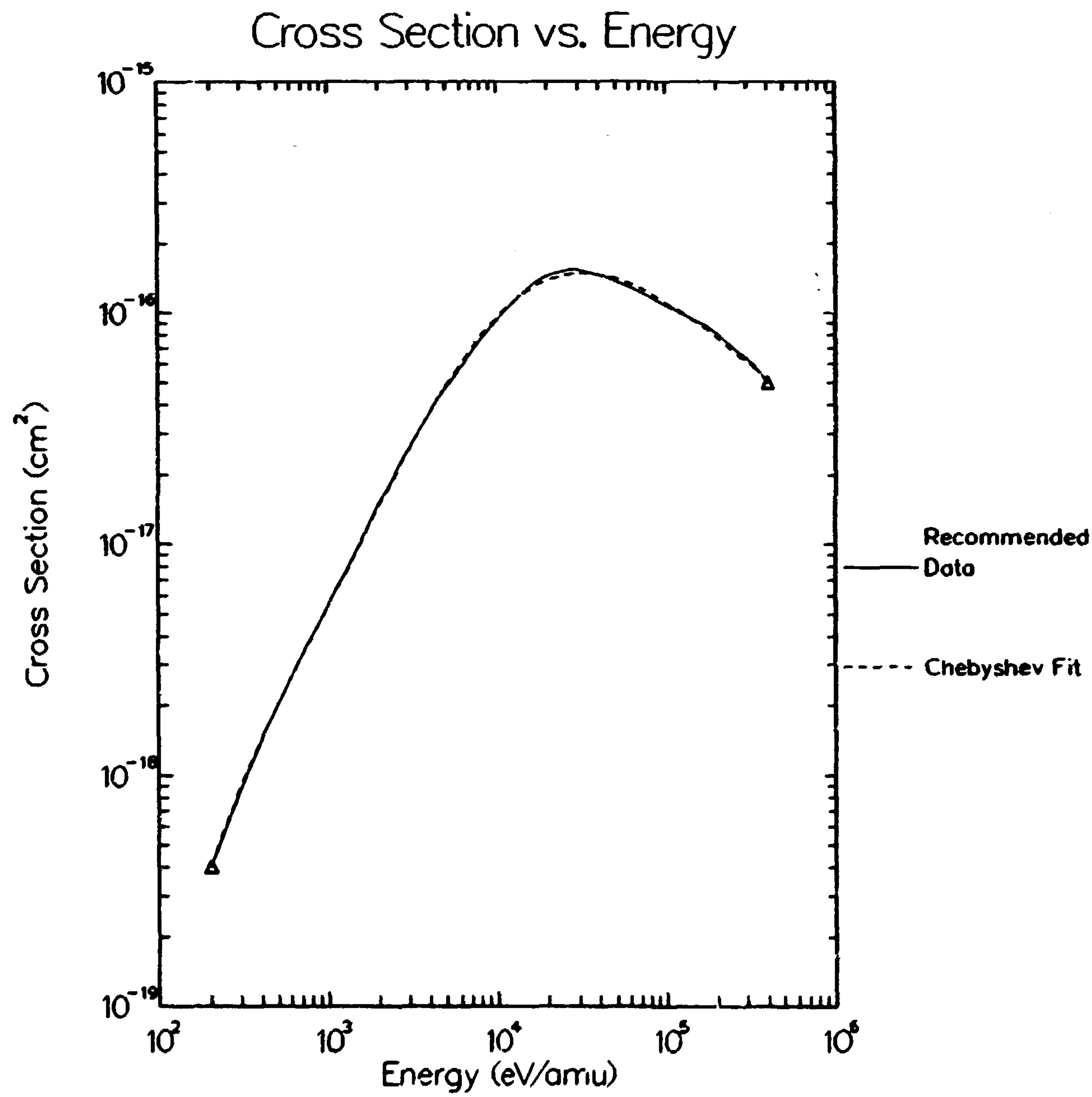
E_{min} = 2.0E+02 eV/amu, E_{max} = 4.0E+05 eV/amu

A0	A1	A2	A3	A4	A5	A6
-77.1205	2.47663	-1.43551	-.126243	.100447	.0662120	-.0477593

The fit represents the above cross section with an rms deviation of 2.7%. The maximum deviation is 4.1% at 7.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$H + H_2 \rightarrow H + H_2^+ + e$



Ionization Cross Sections for

$H^+ + H \rightarrow H^+ + H^+ + e$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
9.4E+03	1.35E+08	1.62E-17
1.0E+04	1.39E+08	1.84E-17
1.5E+04	1.70E+08	4.21E-17
2.0E+04	1.96E+08	7.20E-17
3.0E+04	2.41E+08	1.21E-16
4.0E+04	2.78E+08	1.39E-16
4.5E+04	2.95E+08	1.41E-16
5.0E+04	3.11E+08	1.40E-16
6.0E+04	3.40E+08	1.37E-16
7.0E+04	3.68E+08	1.30E-16
8.0E+04	3.93E+08	1.23E-16
9.0E+04	4.17E+08	1.16E-16
1.0E+05	4.39E+08	1.10E-16
1.5E+05	5.38E+08	8.72E-17
2.0E+05	6.21E+08	7.14E-17
3.0E+05	7.61E+08	5.14E-17
4.0E+05	8.78E+08	4.04E-17
7.0E+05	1.16E+09	2.54E-17
1.0E+06	1.39E+09	1.88E-17
1.5E+06	1.70E+09	1.34E-17

References: 4, 261, 335, 336, 337, 338, 339, 340, 341, 342, 383, 586

Accuracy: $E > 4\times10^4$ eV/amu - 25%
$E < 4\times10^4$ eV/amu - Unknown

Notes: (1) Data above 4×10^4 eV/amu are the recommended data of Rudd, et al. (Ref. 335). Below this energy, the recent data of Shah et al. (Ref. 336) indicate a marked departure from the evaluated data of Rudd. The data plotted here in the low energy range are the recent results of Shah et al. (Ref. 336). (2) For a hydrogen atom target, the cross sections for slow electron production (σ^-) are equal to the ionization cross sections (σ_1). For slow ion production (σ^+) the cross sections are the sum of the electron capture cross sections (σ_{01}) and the ionization cross sections at high energies $\sigma^- = \sigma^+ = \sigma_1$.

Chebyshev Fitting Parameters for Cross Sections

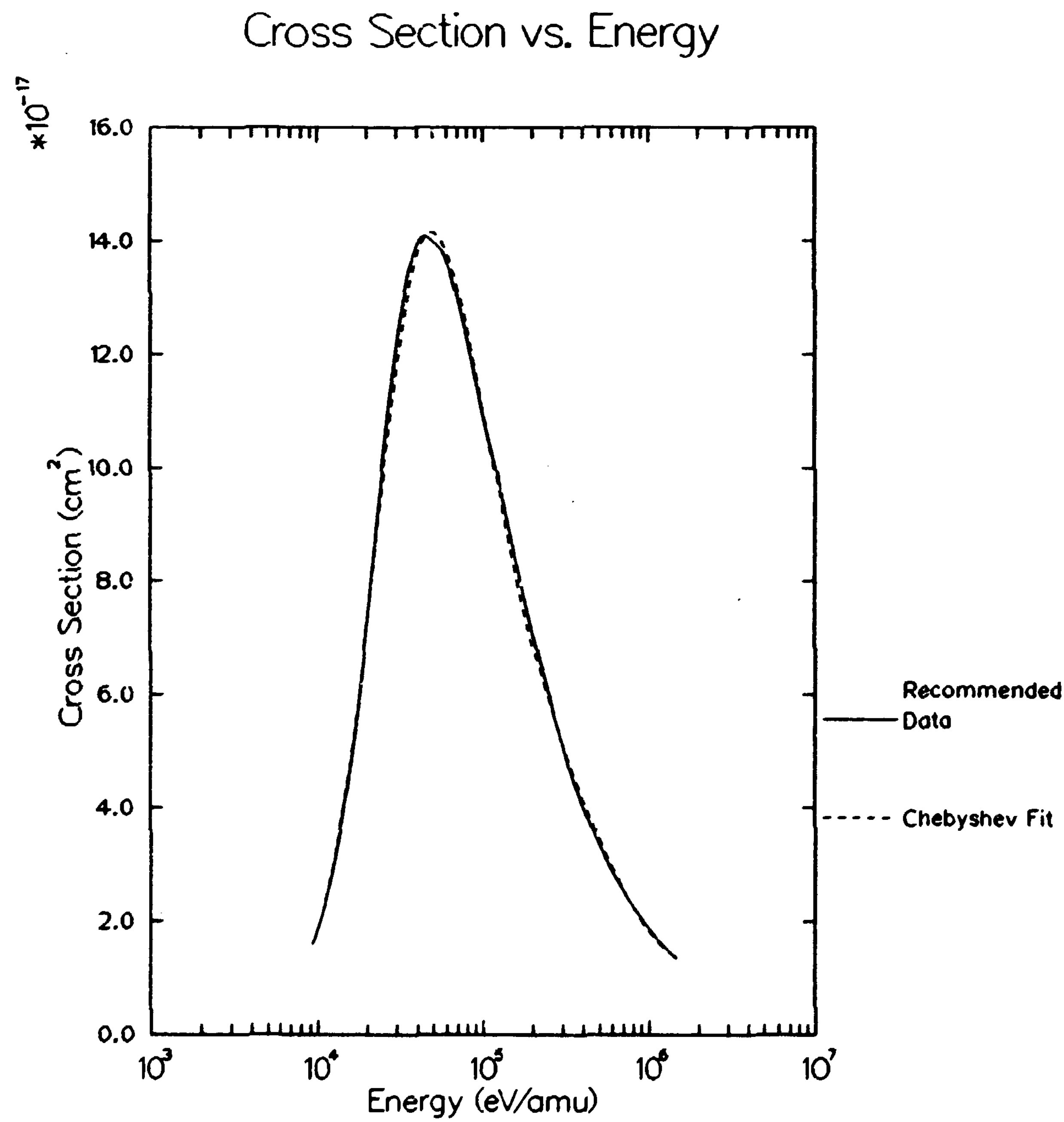
E_{min} = 9.4E+03 eV/amu, E_{max} = 1.5E+06 eV/amu

A0	A1	A2	A3	A4	A5	A6
-75.5053	-.409785	-.996553	.355360	-.049000	-.0349984	.0437825

The fit represents the above cross section with an rms deviation of 1.7%. The maximum deviation is 2.7% at 4.0E+05 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + H \rightarrow H^+ + H^+ + \epsilon$



Ionization Rate Coefficients for

$$H^+ + H \rightarrow H^+ + H^+ + e$$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	Equal Temp.	H^+ Temp. (eV) 1000.	2000.	4000.	7000.	10000.	15000.	20000.
1.0E+03	9.60E-11#	9.60E-11#	5.16E-10#	2.35E-09*	6.44E-09*	1.08E-08	1.74E-08	2.25E-08
1.5E+03	5.16E-10#	2.59E-10#	8.64E-10#	2.96E-09*	7.18E-09	1.16E-08	1.79E-08	2.30E-08
2.0E+03	1.29E-09*	5.16E-10#	1.29E-09*	3.61E-09*	7.92E-09	1.23E-08	1.85E-08	2.34E-08
2.5E+03	2.35E-09*	8.64E-10#	1.79E-09*	4.29E-09*	8.66E-09	1.29E-08	1.91E-08	2.38E-08
3.0E+03	3.61E-09*	1.29E-09*	2.35E-09*	4.99E-09*	9.40E-09	1.36E-08	1.96E-08	2.42E-08
3.5E+03	4.99E-09*	1.79E-09*	2.96E-09*	5.71E-09*	1.01E-08	1.43E-08	2.01E-08	2.46E-08
4.0E+03	6.44E-09*	2.35E-09*	3.61[illegible]9*	6.44E-09*	1.08E-08	1.49E-08	2.06E-08	2.50E-08
4.5E+03	7.92E-09	2.96E-09*	4.29E-09*	7.18E-09	1.16E-08	1.56E-08	2.11E-08	2.54E-08
5.0E+03	9.40E-09	3.61E-09*	4.99E-09*	7.92E-09	1.23E-08	1.62E-08	2.16E-08	2.58E-08
5.5E+03	1.08E-08	4.29E-09*	5.71E-09*	8.66E-09	1.29E-08	1.68E-08	2.21E-08	2.61E-08
6.0E+03	1.23E-08	4.99E-09*	6.44E-09*	9.40E-09	1.36E-08	1.74E-08	2.25E-08	2.65E-08
8.0E+03	1.74E-08	7.92E-09	9.40E-09	1.23E-08	1.62E-08	1.96E-08	2.42E-08	2.78E-08
1.0E+04	2.16E-08	1.08E-08	1.23E-08	1.49E-08	1.85E-08	2.16E-08	2.58E-08	2.90E-08
1.2E+04	2.50E-08	1.36E-08	1.49E-08	1.74E-08	2.06E-08	2.34E-08	2.72E-08	3.01E-08
1.4E+04	2.78E-08	1.62E-08	1.74E-08	1.96E-08	2.25E-08	2.50E-08	2.84E-08	3.10E-08
1.6E+04	3.01E-08	1.85E-08	1.96E-08	2.16E-08	2.42E-08	2.65E-08	2.95E-08	3.19E-08
1.8E+04	3.19E-08	2.06E-08	2.16E-08	2.34E-08	2.58E-08	2.78E-08	3.06E-08	3.27E-08
2.0E+04	3.35E-08	2.25E-08	2.34E-08	2.50E-08	2.72E-08	2.90E-08	3.15E-08	3.35E-08

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

Chebyshev Fitting Parameters for Rate Coefficients

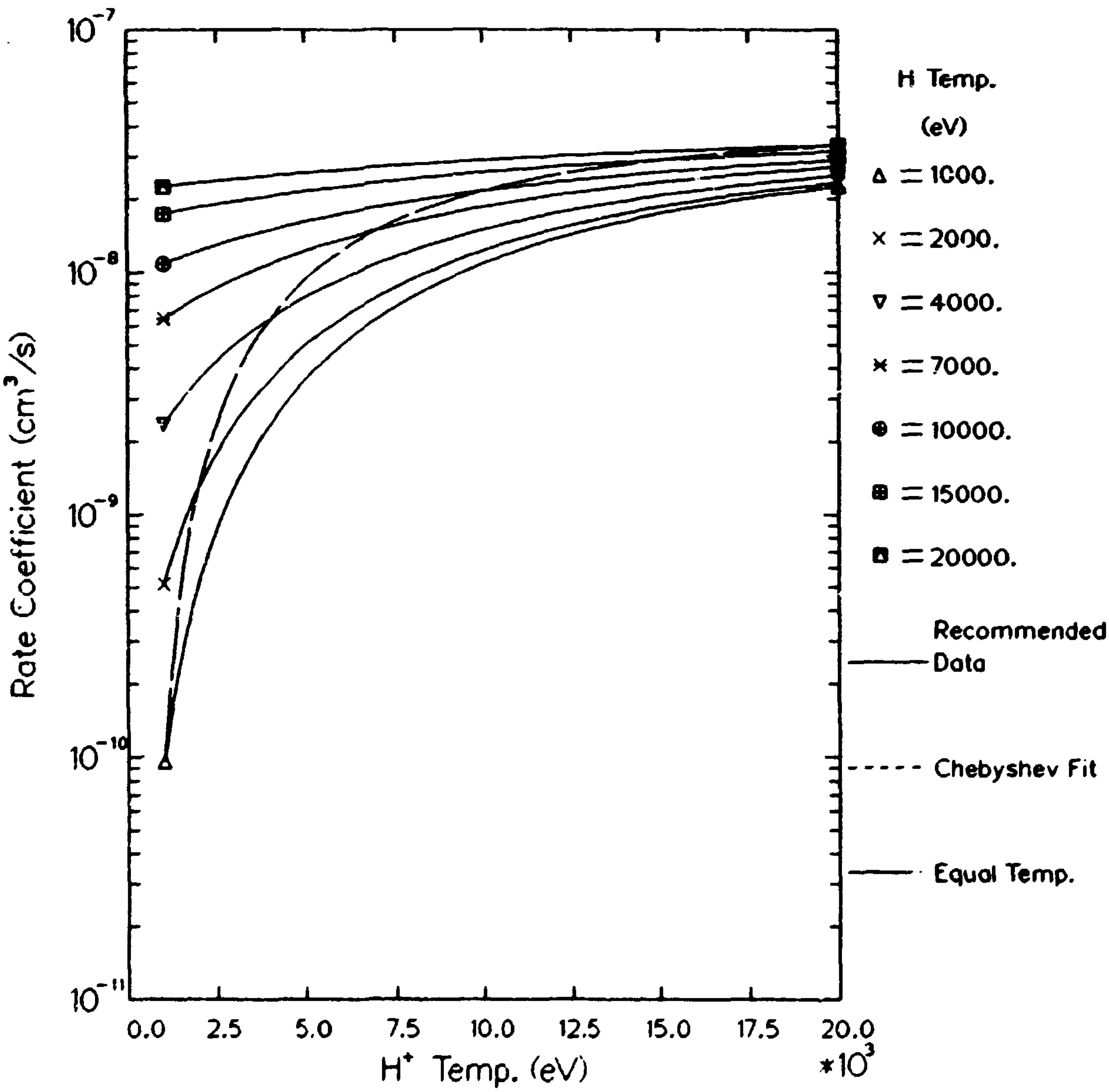
$$E_{min} = 1.0E+03 \text{ eV}, \quad E_{max} = 2.0E+04 \text{ eV}$$

H Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
1000.	-40.0051	2.76605	-.344647	-.0369496	.00899170	-3.564719E-04	4.064999E-04
2000.	-38.7629	1.97055	-.100798	-.0656769	.0461132	.00211656	-1.279077E-04
4000.	-37.4352	1.22903	.0356592	-.0490361	-.00390032	.00203472	2.011422E-04
7000.	-36.4087	.743427	.0691035	-.0248017	-.00589077	5.652350E-04	3.380127E-04
10000.	-35.8193	.504234	.0663753	-.0124429	-.00494956	-1.095647E-04	2.357336E-04
15000.	-35.2398	.301656	.0518339	-.00363904	-.00313907	-4.112259E-04	8.863478E-05
20000.	-34.8966	.198907	.0391475	-5.009330E-04	-.00198385	-3.886616E-04	1.159612E-05
Equal Temp.	-38.7626	2.81265	-.736000	.106667	-.0206816	.00733904	-.00185096

See appendix for Chebyshev fit details.

$H^+ + H \rightarrow H^+ + H^+ + e$

Maxwellian – Maxwellian



Ionization Rate Coefficients for

$H + H^+ \rightarrow H^+ + H^+ + e$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	2.56E-09	1.41E-08	3.86E-08	4.78E-08	4.83E-08	4.43E-08	3.30E-08
2.0E+00	2.56E-09	1.41E-08	3.86E-08	4.78E-08	4.83E-08	4.43E-08	3.30E-08
4.0E+00	2.53E-09	1.41E-08	3.85E-08	4.78E-08	4.83E-08	4.43E-08	3.30E-08
7.0E+00	2.47E-09	1.41E-08	3.85E-08	4.78E-08	4.83E-08	4.43E-08	3.30E-08
1.0E+01	2.40E-09	1.41E-08	3.85E-08	4.78E-08	4.83E-08	4.43E-08	3.30E-08
2.0E+01	2.27E-09*	1.41E-08	3.85E-08	4.77E-08	4.83E-08	4.43E-08	3.30E-08
4.0E+01	2.19E-09*	1.41E-08	3.84E-08	4.77E-08	4.83E-08	4.43E-08	3.30E-08
7.0E+01	2.18E-09*	1.41E-08	3.84E-08	4.77E-08	4.83E-08	4.43E-08	3.30E-08
1.0E+02	2.22E-09*	1.42E-08	3.83E-08	4.77E-08	4.83E-08	4.43E-08	3.30E-08
2.0E+02	2.42E-09*	1.44E-08	3.82E-08	4.77E-08	4.82E-08	4.43E-08	3.30E-08
4.0E+02	2.88E-09*	1.49E-08	3.81E-08	4.76E-08	4.82E-08	4.42E-08	3.30E-08
7.0E+02	3.58E-09*	1.56E-08	3.79E-08	4.75E-08	4.81E-08	4.42E-08	3.30E-08
1.0E+03	4.25E-09*	1.63E-08	3.77E-08	4.73E-08	4.81E-08	4.41E-08	3.30E-08
2.0E+03	6.40E-09	1.81E-08	3.74E-08	4.69E-08	4.79E-08	4.40E-08	3.30E-08
4.0E+03	1.02E-08	2.09E-08	3.71E-08	4.62E-08	4.76E-08	4.38E-08	3.30E-08
7.0E+03	1.49E-08	2.40E-08	3.70E-08	4.52E-08	4.70E-08	4.36E-08	3.29E-08
1.0E+04	1.86E-08	2.64E-08	3.72E-08	4.45E-08	4.64E-08	4.33E-08	3.29E-08
2.0E+04	2.73E-08	3.18E-08	3.82E-08	4.31E-08	4.47E-08	4.26E-08	3.29E-08

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

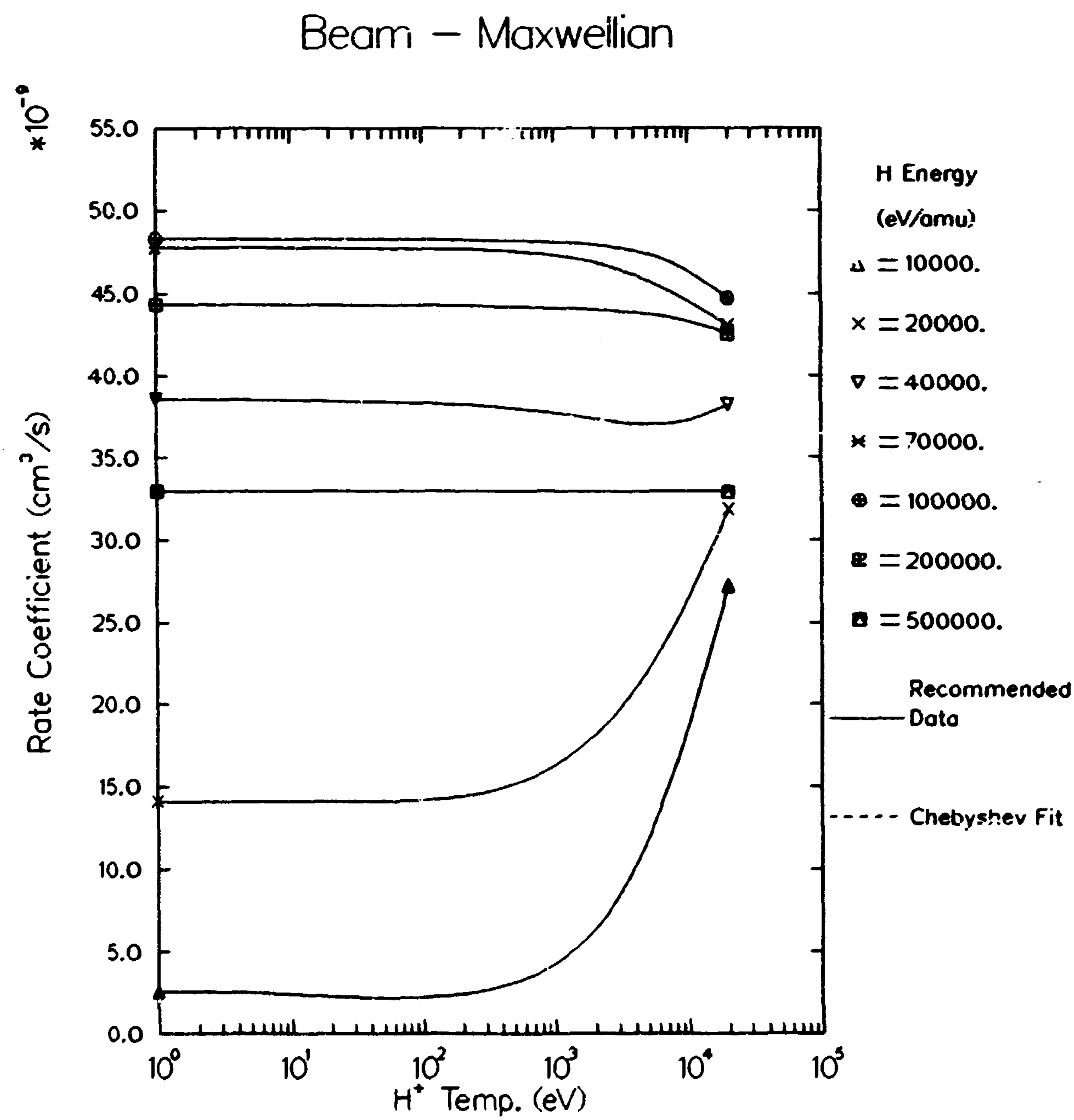
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

H Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-38.2968	1.12152	.644681	.100717	-.100166	-.0395957	.00265964
20000.	-35.7290	.356274	.202092	.0620743	-.00276894	-.0115918	-.00410154
40000.	-34.1679	-.0162401	3.246363E-04	.00754856	.00728055	.00420183	.00124748
70000.	-33.7606	-.0400418	-.0258461	-.0120904	-.00336001	2.548592E-04	9.663075E-04
100000.	-33.7204	-.0256605	-.0180094	-.0107132	-.00535053	-.00208862	-4.645604E-04
200000.	-33.8801	-.0146171	-.00902218	-.00477874	-.00229897	-9.828762E-04	-3.658987E-04
500000.	-34.4565	-7.913823E-04	-5.710595E-04	-3.486254E-04	-1.820028E-04	-8.154704E-05	-3.512063E-05

See appendix for Chebyshev fit details.

$H + H^+ \rightarrow H^+ + H^+ + e$



Associative Detachment Cross Sections for

$$H^+ + H^- \rightarrow H_2^+ + e$$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.0E-03	6.21E+04	5.12E-14
4.0E-03	8.79E+04	2.23E-14
7.0E-03	1.16E+05	1.36E-14
1.0E-02	1.39E+05	1.08E-14
2.0E-02	1.96E+05	6.77E-15
4.0E-02	2.78E+05	3.77E-15
7.0E-02	3.68E+05	2.19E-15
1.0E-01	4.39E+05	1.55E-15
2.0E-01	6.21E+05	8.79E-16
4.0E-01	8.79E+05	4.96E-16
7.0E-01	1.16E+06	3.25E-16
1.0E+00	1.39E+06	2.32E-16
2.0E+00	1.96E+06	1.27E-16
4.0E+00	2.78E+06	5.13E-17
7.0E+00	3.68E+06	2.37E-17

References: 417, 418, 419

Accuracy: 30%

Notes: (1) The theoretical data of (Ref. 417) are within a few percent of the experimental data of (Ref. 418). (2) Measurements of $D^+ + D^- \rightarrow D_2^+ + e$ are consistently 30-50% below those for $H^+ + H^-$. At energies greater than 1 eV/amu the fluctuations in the data mask this difference.

Chebyshev Fitting Parameters for Cross Sections

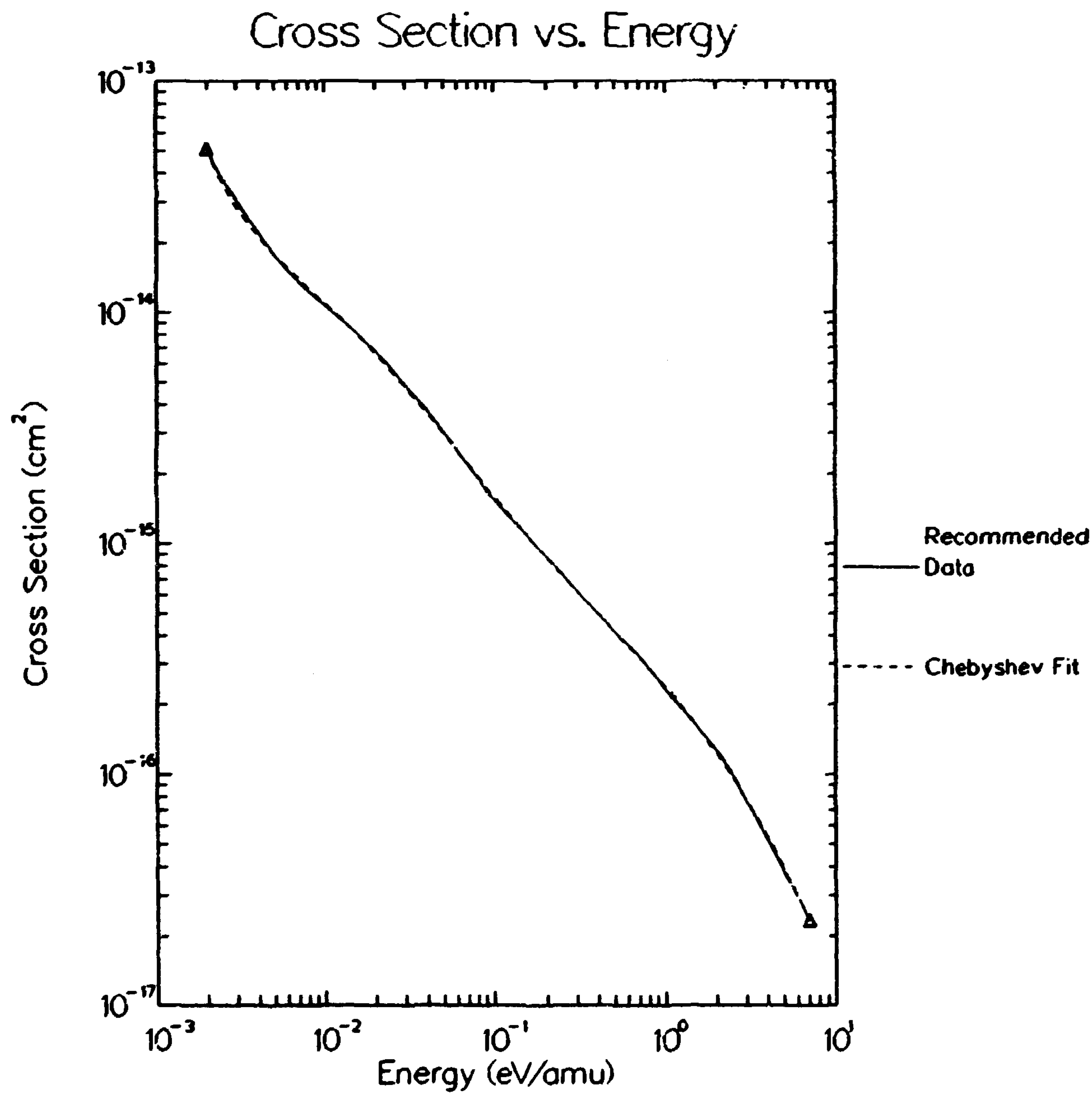
E_{min} = 2.0E-03 eV/amu, E_{max} = 7.0E+00 eV/amu

A0	A1	A2	A3	A4	A5	A6
-68.6095	-3.63490	.153293	-0.133084	-.0284174	-.0787410	.0439445

The fit represents the above cross section with an rms deviation of 2.2%. The maximum deviation is 3.4% at 7.0E-03 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + H \rightarrow H_2^+ + e$



Total Slow Electron Production Cross Sections for

$$H^+ + H_2 \rightarrow \Sigma\ e$$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
5.0E+02	3.11E+07	1.44E-18
7.0E+02	3.68E+07	2.15E-18
1.0E+03	4.39E+07	3.32E-18
2.0E+03	6.21E+07	7.85E-18
4.0E+03	8.79E+07	1.84E-17
7.0E+03	1.16E+08	3.67E-17
1.0E+04	1.39E+08	5.66E-17
2.0E+04	1.96E+08	1.18E-16
4.0E+04	2.78E+08	1.96E-16
6.5E+04	3.54E+08	2.19E-16
7.0E+04	3.68E+08	2.19E-16
1.0E+05	4.39E+08	1.96E-16
2.0E+05	6.21E+08	1.33E-16
4.0E+05	8.78E+08	7.96E-17
7.0E+05	1.16E+09	5.08E-17
1.0E+06	1.39E+09	3.74E-17
2.0E+06	1.96E+09	2.07E-17
4.0E+06	2.77E+09	1.15E-17
5.0E+06	3.09E+09	9.50E-18

References: 30, 36, 42, 45, 89, 217, 315, 335, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 366

Accuracy: 25%

Notes: (1) The data are the recommended data of Rudd et al. (Ref. 335). See this reference for an analytical fit to the data at low and high energies. (2) The slow electron production cross sections are the sum of four reactions: (a) $H^+ + H_2 \rightarrow H^+ + H_2^+ + e$ (pure ionization); (b) $\rightarrow H^+ + H + H^+ + e$ (ionization with dissociation); (c) $\rightarrow H^+ + H^+ + e$ (double ionization); (d) $\rightarrow H + 2H^+ + e$ (electron capture with ionization).

Chebyshev Fitting Parameters for Cross Sections

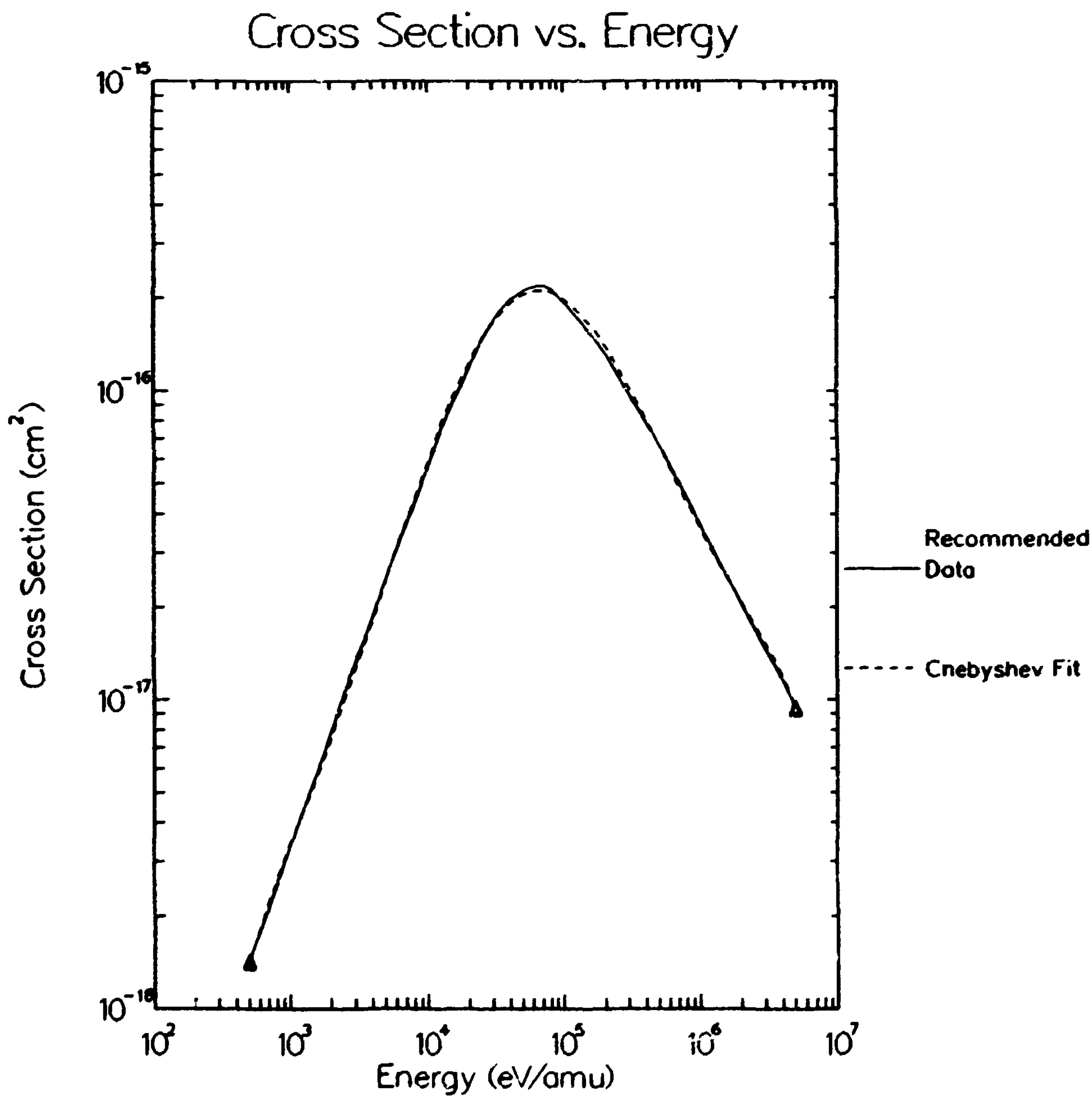
E_{min} = 5.0E+02 eV/amu, E_{max} = 5.0E+06 eV/amu

A0	A1	A2	A3	A4	A5	A6
-76.9159	.969378	-1.91735	-.0245092	.313763	-.000351145	-.0992103

The fit represents the above cross section with an rms deviation of 3.1%. The maximum deviation is 6.2% at 2.0E+05 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + H_2 \to \Sigma e$



Cross Sections for the Formation of Positive Ions in Collisions of H^+ with H_2

$H^+ + H_2 \rightarrow H^+ + H_2^+ + e$ (Single Ionization)
$H^+ + H_2 \rightarrow$ Total Production of H_2^+ (or Total Ion Formation)
$H^+ + H_2 \rightarrow$ Total Production of H^+

Single Ionization		H_2^+ Production		H^+ Production	
Energy (eV/amu)	Cross Section (cm^2)	Energy (eV/amu)	Cross Section (cm^2)	Energy (eV/amu)	Cross Section (cm^2)
5.0E+03	1.23E-17	6.0E+03	8.23E-16	5.0E+03	3.71E-17
7.0E+03	1.78E-17	7.0E+03	8.37E-16	6.0E+03	4.93E-17
1.0E+04	2.63E-17	1.0E+04	8.[illegible]E-16	7.0E+03	6.11E-17
1.5E+04	4.24E-17	2.0E+04	6.09E-16	8.0E+03	7.25E-17
2.0E+04	6.23E-17	4.0E+04	4.13E-16	9.0E+03	8.29E-17
3.0E+04	1.30E-16	7.0E+04	2.93E-16	1.0E+04	9.16E-17
4.0E+04	1.83E-16	1.0E+05	2.32E-16	1.5E+04	1.17E-16
6.0E+04	2.20E-16	1.5E+05	1.75E-16	1.7E+04	1.20E-16
7.0E+04	2.17E-16	2.0E+05	1.43E-16	2.0E+04	1.17E-16
1.0E+05	2.04E-16	4.0E+05	8.69E-17	2.5E+04	1.02E-16
1.5E+05	1.74E-16	7.0E+05	5.51E-17	3.0E+04	8.36E-17
2.0E+05	1.44E-16	1.0E+06	4.05E-17	3.5E+04	7.03E-17
4.0E+05	8.71E-17	1.5E+06	2.85E-17	4.0E+04	6.03E-17
7.0E+05	5.54E-17	2.0E+06	2.24E-17	4.5E+04	5.24E-17
1.0E+06	4.07E-17	3.0E+06	1.56E-17	5.0E+04	4.62E-17
2.0E+06	2.24E-17	3.5E+06	1.37E-17		
3.0E+06	1.57E-17				
3.5E+06	1.37E-17				
3.8E+06	1.28E-17				

References: 30, 36, 40, 89, 315, 346, 348, 350, 353, 354, 356, 360, 361, 362, 363, 364, 365, 366

Accuracy: 30%

Notes: (1) The interaction of H^+ with H_2 to produce H_2^+ ions may follow one of two pathways: (a) $H^+ + H_2 \rightarrow H^+ + H_2^+ + e$, single ionization; (b) $H^+ + H_2 \rightarrow H + H_2^+$, electron capture. Five reactions are involved in the production of H^+ ions; (c) $H^+ + H_2^+ \rightarrow H^+ + H + H^+ + e$, dissociative ionization; (d) $\rightarrow H^+ + H^+ + H^+ + 2e$, double ionization; (e) $\rightarrow H + H + H^+$, electron capture with dissociation; (f) $\rightarrow H + H^+ + H^+ + e$, transfer ionization; (g) $\rightarrow H^- + 2H^+$, double electron capture. (2) At energies less than 150 keV/amu the total charge production cross sections (σ_t^+) are dominated by electron capture. (3) Within the experimental error the total charge production cross section is the same as the total cross sec ion for producing H_2^+. (4) Above 150 keV the single ionization cross sectio. (reaction a) is the dominant process to form positive charges or H_2^+. (5) Cross sections are available for the double ionization (Ref. 36, 348, 356, 360, 365) (reaction c). However there are large discrepancies and these data are not included here. The cross sections are at least an order of magnitude smaller than the single ionization cross sections.

Chebyshev Fitting Parameters for Cross Sections

Sing. Ion. E_{min} = 5.0E+03 eV/amu, E_{max} = 3.8E+06 eV/amu
H_2^+ Prod. E_{min} = 6.0E+03 eV/amu, E_{max} = 3.5E+06 eV/amu
H^+ Prod. E_{min} = 5.0E+03 eV/amu, E_{max} = 5.0E+04 eV/amu

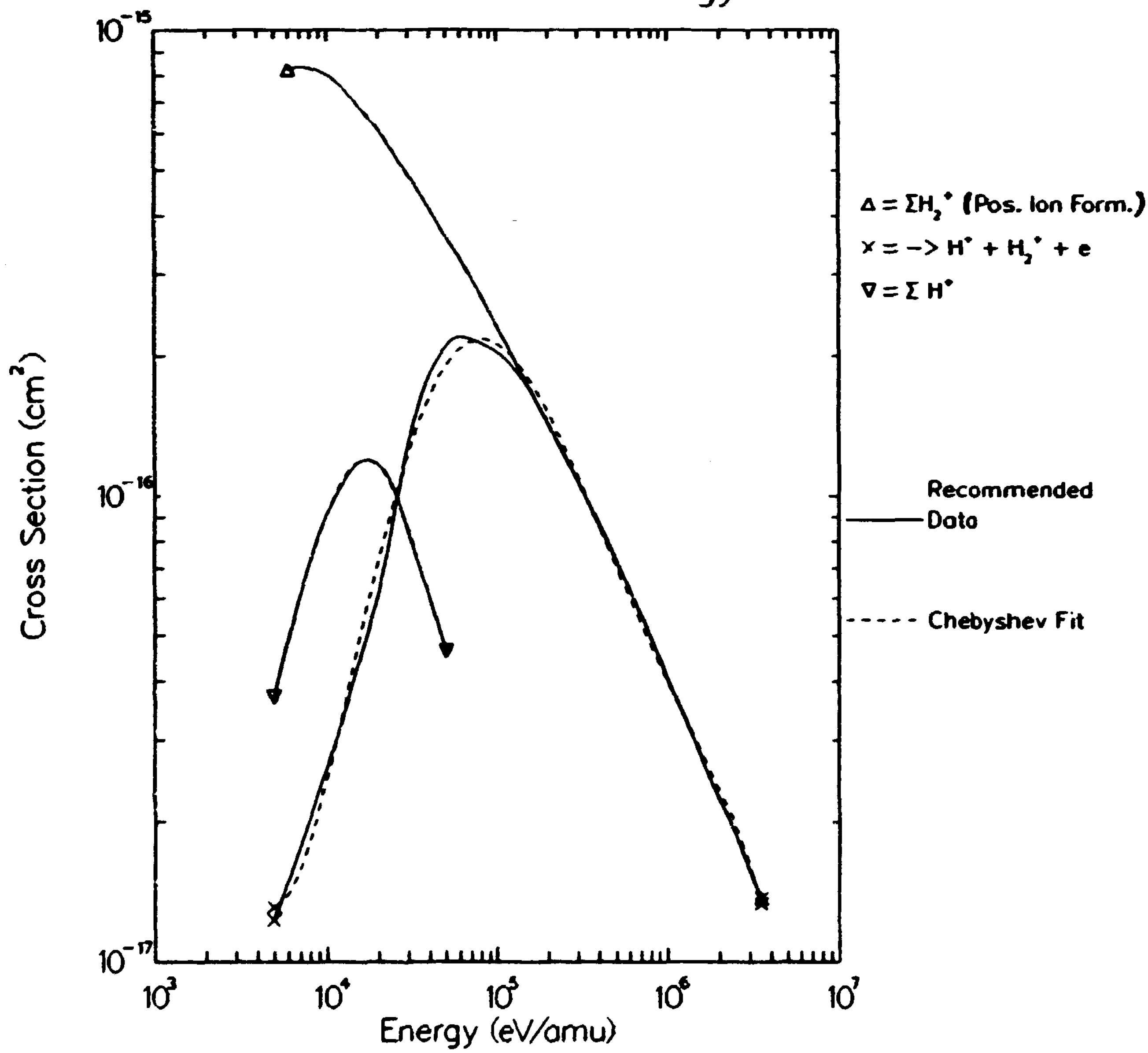
	A0	A1	A2	A3	A4	A5	A6
Sing. Ion	-75.4752	-.100192	-1.35816	.230586	.187780	-.157087	.0102380
H_2^+ Prod.	-72.9773	-2.12495	-.260502	.0542968	-.0279667	.0221059	-.00372930
H^+ Prod.	-74.4647	.0986066	-.525436	.00183837	.0396132	.0121041	-.00373826

The fit represents the Single Ion. cross section with an rms deviation of 7.1%.
The maximum deviation is 17.3% at 2.0E+04 eV/amu.
The fit represents the H_2^+ Prod. cross section with an rms deviation of 0.4%.
The maximum deviation is 0.7% at 2.0E+05 eV/amu.
The fit represente the H^+ Prod. cross section with an rms deviation of 0.6%.
The maximum deviation is 1.2% at 3.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + H_2 \rightarrow H^+ + H_2^+ + e$
$He^- + H_2 \rightarrow$ Total H^+ Production
$He^- + H_2 \rightarrow$ Total H_2^+ Production

Cross Section vs. Energy



Slow Negative Charge Production Cross Sections for

$H^+ + He \rightarrow$ electrons and H^-

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
4.4E+02	2.91E+07	9.65E-20
5.0E+02	3.11E+07	1.16E-19
7.0E+02	3.68E+07	1.92E-19
1.0E+03	4.39E+07	3.28E-19
2.0E+03	6.21E+07	9.40E-19
4.0E+03	8.79E+07	2.73E-18
7.0E+03	1.16E+08	6.35E-18
1.0E+04	1.39E+08	1.09E-17
2.0E+04	1.96E+08	2.96E-17
4.0E+04	2.78E+08	6.68E-17
7.0E+04	3.68E+08	9.07E-17
1.0E+05	4.39E+08	9.28E-17
2.0E+05	6.21E+08	6.86E-17
4.0E+05	8.78E+08	4.24E-17
7.0E+05	1.16E+09	2.77E-17
1.0E+06	1.39E+09	2.09E-17
1.5E+06	1.70E+09	1.53E-17
2.0E+06	1.96E+09	1.20E-17
4.0E+06	2.77E+09	6.79E-18
5.0E+06	3.09E+09	5.63E-18

<u>References:</u> 40, 83, 89, 315, 335, 347, 353, 354, 355, 357, 358, 359, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380

<u>Accuracy:</u> $E > 4 \times 10^4$ eV/amu - 20%
$E < 4 \times 10^4$ eV/amu - Unknown - see note (1)

<u>Notes:</u> (1) These data are the recommended data of Rudd et al. (Ref. 335). The data below 4×10^4 eV/amu are strongly weighted by the experimental results of Rudd et al. (Ref. 83) taken in 1983. Several investigators have investigated the low energy region, all of them reporting cross sections higher than the recommended data. (2) Reactions that produce slow negative charges are: (a) $H^+ + He \rightarrow H^+ + He^+ + e$, single ionization; (b) $H^+ + He \rightarrow H^+ + He^{2+} + 2e$, double ionization; (c) $H^+ + He \rightarrow H + He^+ \rightarrow H^+ + He^+ + e$, capture with ionization or transfer ionization; (d) $H^+ + He \rightarrow H^- + He^{2+}$ double electron capture.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

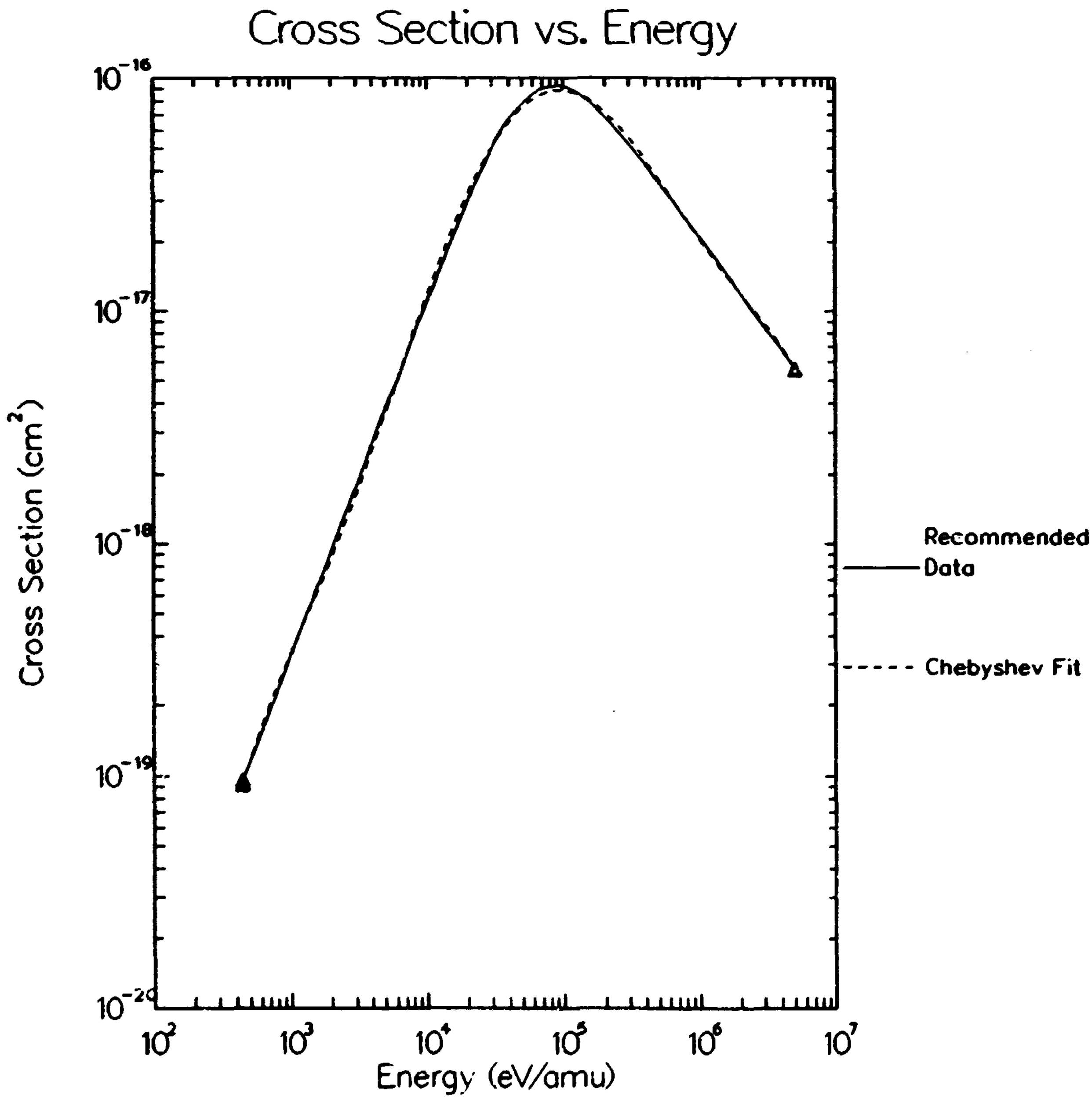
E_{min} = 4.4E+02 eV/amu, E_{max} = 5.0E+06 eV/amu

A0	A1	A2	A3	A4	A5	A6
-79.6795	2.14499	-2.18192	-.146158	.362843	.0528127	-.123316

The fit represents the above cross section with an rms deviation of 4.4%. The maximum deviation is 7.3% at 2.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + He \rightarrow$ electrons $+ H^-$



Slow Negative Charge Production Rate Coefficients for

$H^+ + He \rightarrow$ electrons and H^-

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

H Temp. (eV)	Equal Temp.	He Temp. (eV) 10.	750.	1000.	1250.	5000.	15000.	20000.
1.0E+02	3.59E-13#	1.61E-13#	3.94E-12*	6.17E-12*	8.83E-12*	1.02E-10	3.79E-10	1.39E-09
7.5E+02	4.86E-11	3.10E-11	4.86E-11	5.54E-11	6.26E-11	2.24E-10	5.88E-10	1.74E-09
1.0E+03	8.71E-11	5.57E-11	7.85E-11	8.71E-11	9.61E-11	2.84E-10	6.79E-10	1.87E-09
1.3E+03	1.37E-10	8.74E-11	1.16E-10	1.26E-10	1.37E-10	3.50E-10	7.76E-10	2.02E-09
1.5E+03	1.97E-10	1.26E-10	1.60E-10	1.72E-10	1.84E-10	4.23E-10	8.75E-10	2.16E-09
1.8E+03	2.69E-10	1.72E-10	2.11E-10	2.24E-10	2.39E-10	5.02E-10	9.87E-10	2.31E-09
2.0E+03	3.50E-10	2.25E-10	2.69E-10	2.84E-10	3.00E-10	5.88E-10	1.10E-09	2.47E-09
3.0E+03	7.76E-10	5.03E-10	5.66E-10	5.88E-10	6.10E-10	9.87E-10	1.60E-09	3.11E-09
4.0E+03	1.34E-09	8.80E-10	9.59E-10	9.87E-10	1.01E-09	1.47E-09	2.16E-09	3.78E-09
5.0E+03	2.03E-09	1.34E-09	1.44E-09	1.47E-09	1.50E-09	2.02E-09	2.78E-09	4.48E-09
6.0E+03	2.78E-09	1.88E-09	1.98E-09	2.02E-09	2.05E-09	2.62E-09	3.44E-09	5.20E-09
7.0E+03	3.61E-09	2.47E-09	2.58E-09	2.62E-09	2.66E-09	3.27E-09	4.13E-09	5.93E-09
8.0E+03	4.48E-09	3.11E-09	3.23E-09	3.27E-09	3.31E-09	3.95E-09	4.84E-09	6.66E-09
9.0E+03	5.38E-09	3.78E-09	3.91E-09	3.95E-09	3.99E-09	4.66E-09	5.56E-09	7.40E-09
1.0E+04	6.30E-09	4.48E-09	4.61E-09	4.66E-09	4.70E-09	5.38E-09	6.30E-09	8.13E-09
1.2E+04	8.13E-09	5.93E-09	6.07E-09	6.11E-09	6.16E-09	6.85E-09	7.76E-09	9.57E-09
1.5E+04	1.08E-08	8.13E-09	8.27E-09	8.31E-09	8.36E-09	9.04E-09	9.92E-09	1.17E-08
2.0E+04	1.48E-08	1.17E-08	1.18E-08	1.18E-08	1.19E-08	1.25E-08	1.33E-08	1.48E-08

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

Chebyshev Fitting Parameters for Rate Coefficients

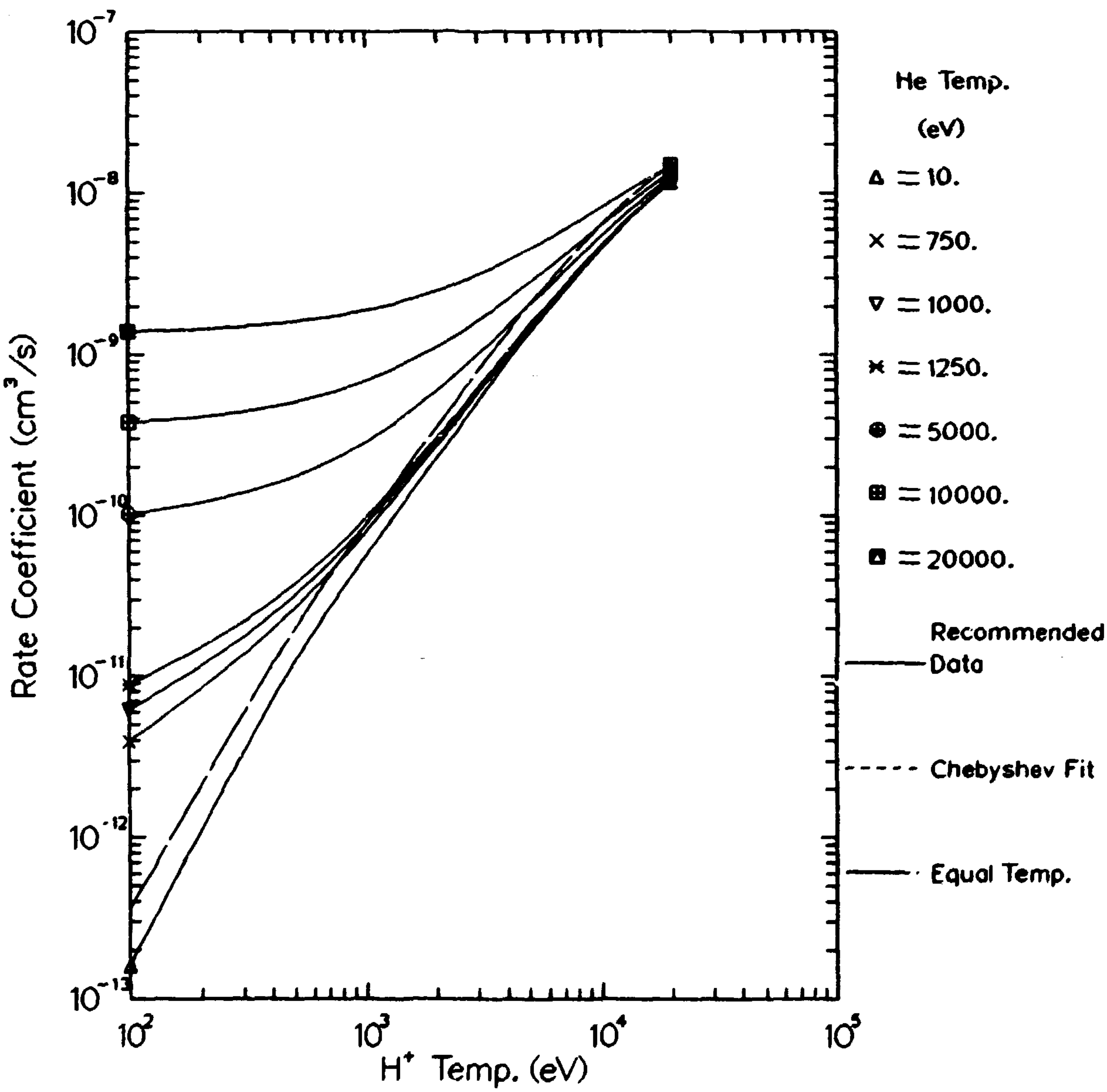
$$E_{min} = 1.0E+02 \text{ eV}, \quad E_{max} = 2.0E+04 \text{ eV}$$

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
10.	-46.5650	5.49971	-.475864	.0795255	-.103842	.0146906	5.701499E-04
750.	-44.8867	4.19397	.198206	-.184815	-.014624	-.00795734	.00438872
1000.	-44.5760	3.97780	.272829	-.192799	-.0215899	-.00569587	.00394217
1250.	-44.3093	3.79820	.326679	-.193047	-.0272627	-.00347223	.00358121
5000.	-42.1265	2.50907	.515276	-.0994986	-.0616701	-.00489874	.00584793
10000.	-40.7163	1.83020	.481655	-.0331261	-.0467863	-.0183645	.00768600
20000.	-39.1385	1.18831	.377951	.0154712	-.0231939	-.0206727	.00437997
Equal Temp.	-45.6407	5.29550	-.441278	.00871718	-.0827904	.0101600	.00309937

See appendix for Chebyshev fit details.

$H^+ + He \rightarrow electrons + H^-$

Maxwellian – Maxwellian



Slow Negative Charge Production Rate Coefficients for

He + H^+ -> electrons and H^-

Beam - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	150000.	200000.
1.0E+00	1.51E-09	5.59E-09	1.84E-08	3.11E-08	4.07E-08	4.18E-08	4.26E-08
2.0E+00	1.51E-09	5.80E-09	1.85E-08	3.32E-08	4.07E-08	4.18E-08	4.26E-08
4.0E+00	1.52E-09	5.81E-09	1.85E-08	3.33E-08	4.07E-08	4.18E-08	4.26E-08
7.0E+00	1.52E-09	5.81E-09	1.85E-08	3.32E-08	4.07E-08	4.18E-08	4.26E-08
1.0E+01	1.52E-09	5.81E-09	1.85E-08	3.32E-08	4.06E-08	4.18E-08	4.26E-08
2.0E+01	1.53E-09	5.81E-09	1.84E-08	3.32E-08	4.06E-08	4.18E-08	4.25E-08
4.0E+01	1.54E-09	5.82E-09	1.84E-08	3.31E-08	4.05E-08	4.18E-08	4.25E-08
7.0E+01	1.56E-09	5.85E-09	1.84E-08	3.31E-08	4.05E-08	4.18E-08	4.25E-08
1.0E+02	1.58E-09	5.87E-09	1.83E-08	3.30E-08	4.04E-08	4.18E-08	4.25E-08
2.0E+02	1.65E-09	5.97E-09	1.83E-08	3.30E-08	4.02E-08	4.18E-08	4.24E-08
4.0E+02	1.80E-09	6.17E-09	1.84E-08	3.28E-08	4.01E-08	4.18E-08	4.23E-08
7.0E+02	2.03E-09	6.48E-09	1.85E-08	3.28E-08	3.99E-08	4.18E-08	4.22E-08
1.0E+03	2.26E-09	6.80E-09	1.87E-08	3.27E-08	3.97E-08	4.18E-08	4.22E-08
2.0E+03	3.04E-09	7.83E-09	1.92E-08	3.27E-08	3.93E-08	4.18E-08	4.20E-08
4.0E+03	4.66E-09	9.70E-09	2.04E-08	3.26E-08	3.87E-08	4.17E-08	4.17E-08
7.0E+03	7.06E-09	1.21E-08	2.19E-08	3.25E-08	3.82E-08	4.13E-08	4.14E-08
1.0E+04	9.37E-09	1.43E-08	2.31E-08	3.25E-08	3.77E-08	4.09E-08	4.11E-08
2.0E+04	1.59E-08	1.98E-08	2.62E-08	3.29E-08	3.69E-08	3.98E-08	4.02E-08

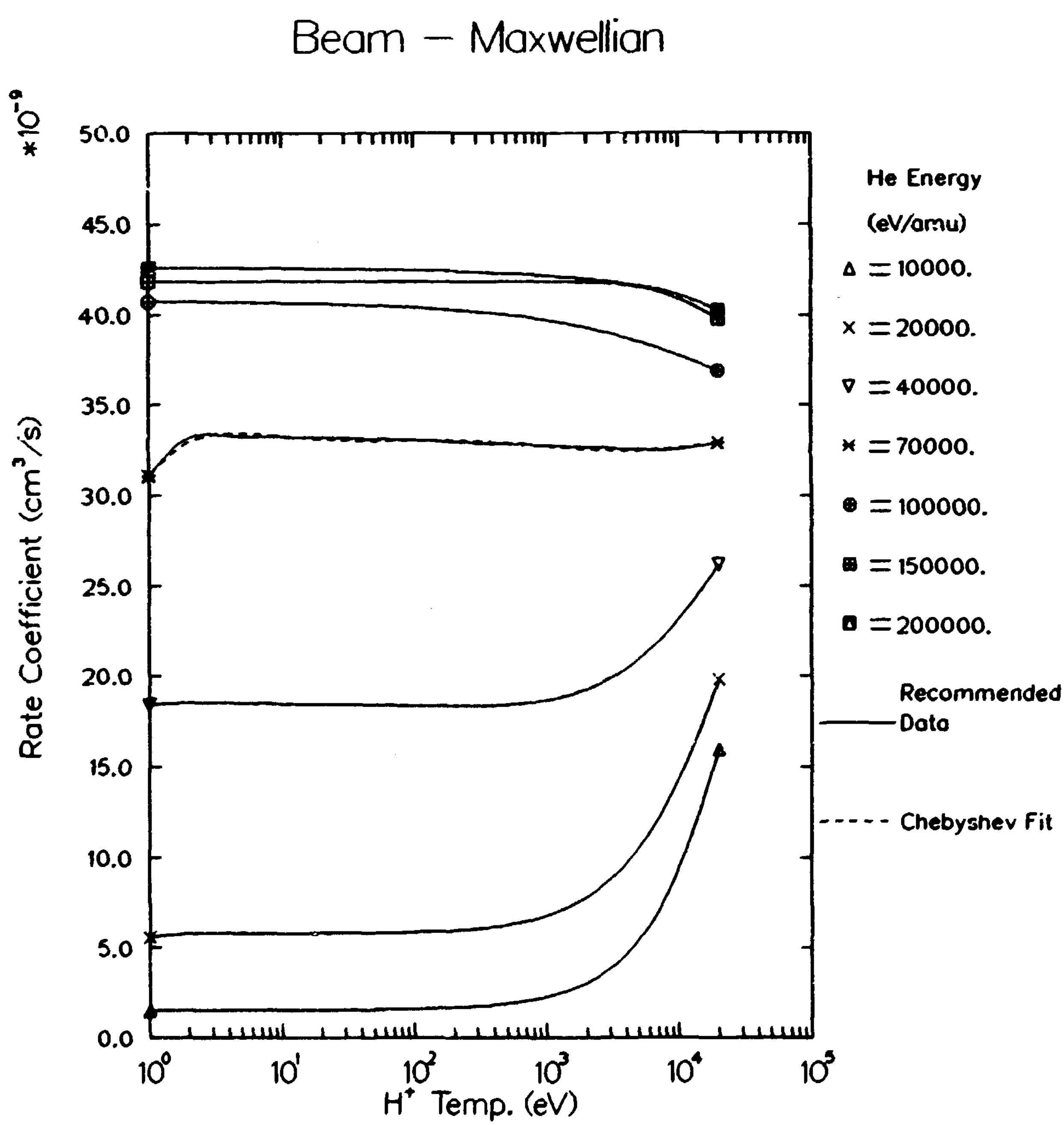
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-39.3816	1.02698	.576534	.188719	4.425971E-05	-.0355917	-.0198253
20000.	-37.3350	.517958	.301257	.123942	.00937576	-.0100372	-.0129438
40000.	-35.4715	.129405	.0937138	.0477169	.0118588	-4.888201E-04	-.003254337E-03
70000.	-34.4703	.00355792	-.0123483	.0153783	-.00669156	.00817185	-.00392000
100000.	-34.0898	-.0436120	-.0204578	-.00631264	-9.902555E-04	3.700060E-04	5.42[illegible]520E-04
150000.	-33.9953	-.0150052	-.0121264	-.00832720	-.00470324	-.00198547	-3.364408E-04
200000.	-33.9705	-.0219825	-.0119088	-.00528740	-.00226756	-.00102041	-4.501627E-04

See appendix for Chebyshev fit details.

He + H^+ -> electrons + H^-



Ionization and Total He^+ Production Cross Sections for

$H^+ + He \rightarrow H^+ + He^+ + e$

$H^+ + He \rightarrow (H + He^+)$ or $(H^+ + He^+ + e)$

Ionization		Total He^+ Production	
Energy (eV/amu)	Cross Section (cm^2)	Energy (eV/amu)	Cross Section (cm^2)
1.0E+04	2.04E-17	5.0E+03	3.82E-17
1.5E+04	3.49E-17	7.0E+03	7.64E-17
2.0E+04	4.94E-17	1.0E+04	1.33E-16
3.0E+04	6.61E-17	2.0E+04	2.39E-16
4.0E+04	7.37E-17	2.3E+04	2.43E-16
7.0E+04	8.28E-17	4.0E+04	2.17E-16
9.0E+04	8.42E-17	7.0E+04	1.58E-16
1.0E+05	8.38E-17	1.0E+05	1.22E-16
1.5E+05	7.65E-17	2.0E+05	7.14E-17
2.0E+05	6.69E-17	4.0E+05	4.27E-17
4.0E+05	4.26E-17	7.0E+05	2.84E-17
7.0E+05	2.82E-17	1.0E+06	2.18E-17
1.0E+06	2.18E-17	1.5E+06	1.61E-17
1.5E+06	1.61E-17	2.0E+06	1.29E-17
2.0E+06	1.29E-17	4.0E+06	6.75E-18
3.0E+06	8.92E-18	5.0E+06	5.31E-18
4.0E+06	6.71E-18		
5.0E+06	5.32E-18		

References: 83, 87, 89, 315, 353, 354, 359, 368, 371, 372, 375, 376, 381, 382, 383, 384, 385, 386, 387, 388

Accuracy: 30%

Notes: (1) The total cross section for slow He^+ ion production is the sum of the electron capture cross ($H^+ + He \rightarrow H + He^+$) and the ionization cross section ($H^+ + He \rightarrow H^+ + H^+ + e$). (2) The cross section for production of He^{2+} is two orders of magnitude less than that for He^+ and contributes a negligible amount to the slow ion formation. (3) At energies less than 2×10^5 eV/amu the electron capture cross section is the dominant reaction in producing slow ions. Above this energy the cross section for He^+ formation is the same as the ionization cross section to form He^+. (4) For cross sections involving the formation of slow He^{2+} see the following set of data.

Chebyshev Fitting Parameters for Cross Sections

Ionization E_{min} = 1.0E+04 eV/amu, E_{max} = 5.0E+06 eV/amu

Tot. He^+ Prod. E_{min} = 5.0E+03 eV/amu, E_{max} = 5.0E+06 eV/amu

	A0	A1	A2	A3	A4	A5	A6
Ionization	-76.3648	-.874453	-.884552	.221104	-.0292448	-.0234184	-.0152807
Tot. He^+ Prod.	-75.4062	-1.41315	-.923745	.441895	-.193224	-.00636635	.0315740

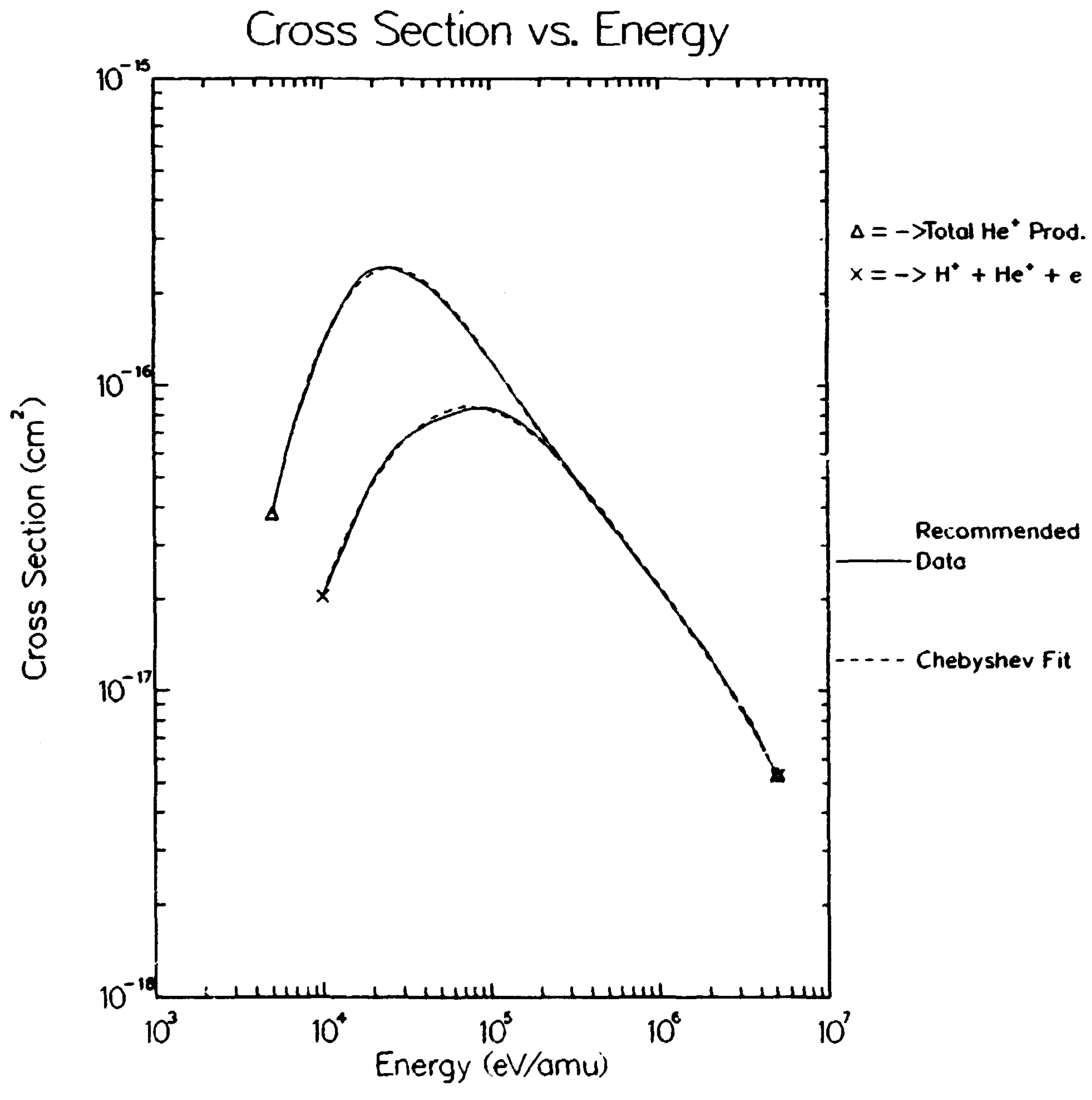
The fit represents the Ionization cross section with an rms deviation of 1.6%. The maximum deviation is 2. at 7.0E+04 eV/amu.

The fit represents the Tot. He^+ Prod. cross section with an rms deviation of 1.3%. The maximum deviation is 1.7% at 1.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + He \rightarrow H^+ + He^+ + e$

$H^+ + He \rightarrow (H + He^+)$ or $(H^+ + He^+ + e)$



Ionization Rate Coefficients for

$H^+ + He \rightarrow H^+ + He^+ + e$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	Equal Temp.	He Temp. (eV) 5000.	6000.	7000.	8000.	10000.	15000.	20000.
1.0E+03	4.07E-12#	1.33E-10#	2.07E-10#	2.99E-10#	4.08E-10#	6.69E-10#	1.51E-09*	2.50E-09*
1.5E+03	5.51E-11#	2.99E-10#	4.08E-10#	5.31E-10#	6.69E-10#	9.78E-10#	1.89E-09*	2.92E-09*
2.0E+03	2.07E-10#	5.31E-10#	6.69E-10#	8.18E-10#	9.78E-10#	1.32E-09#	2.30E-09*	3.35E-09*
2.5E+03	4.68E-10#	8.18E-10#	9.78E-10#	1.15E-09#	1.32E-09#	1.70E-09*	2.71E-09*	3.77E-09*
3.0E+03	8.18E-10#	1.15E-09#	1.32E-09#	1.51E-09*	1.70E-09*	2.09E-09*	3.13E-09*	4.20E-09*
3.5E+03	1.24E-09#	1.51E-09*	1.70E-09*	1.89E-09*	2.09E-09*	2.50E-09*	3.56E-09*	4.62E-09*
4.0E+03	1.70E-09*	1.89E-09*	2.09E-09*	2.30E-09*	2.50E-09*	2.92E-09*	3.99E-09*	5.05E-09*
4.5E+03	2.20E-09*	2.30E-09*	2.50E-09*	2.71E-09*	2.92E-09*	3.35E-09*	4.41E-09*	5.47E-09*
5.0E+03	2.71E-09*	2.71E-09*	2.92E-09*	3.13E-09*	3.35E-09*	3.77E-09*	4.84E-09*	5.89E-09*
5.5E+03	3.24E-09*	3.13E-09*	3.35E-09*	3.56E-09*	3.77E-09*	4.20E-09*	5.26E-09*	6.30E-09*
6.0E+03	3.77E-09*	3.56E-09*	3.77E-09*	3.99E-09*	4.20E-09*	4.62E-09*	5.68E-09*	6.72E-09*
8.0E+03	5.89E-09*	5.26E-09*	5.47E-09*	5.68E-09*	5.89E-09*	6.30E-09*	7.32E-09	8.29E-09
1.0E+04	7.91E-09	6.92E-09*	7.12E-09*	7.32E-09	7.52E-09	7.91E-09	8.87E-09	9.79E-09
1.2E+04	9.79E-09	8.48E-09	8.68E-09	8.87E-09	9.06E-09	9.43E-09	1.03E-08	1.12E-08
1.4E+04	1.15E-08	9.97E-09	1.01E-08	1.03E-08	1.05E-08	1.08E-08	1.17E-08	1.25E-08
1.6E+04	1.31E-08	1.14E-08	1.15E-08	1.17E-08	1.19E-08	1.22E-08	1.30E-08	1.37E-08
1.8E+04	1.46E-08	1.27E-08	1.28E-08	1.30E-08	1.31E-08	1.34E-08	1.42E-08	1.49E-08
2.0E+04	1.60E-08	1.39E-08	1.40E-08	1.42E-08	1.43E-08	1.46E-08	1.53E-08	1.60E-08

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

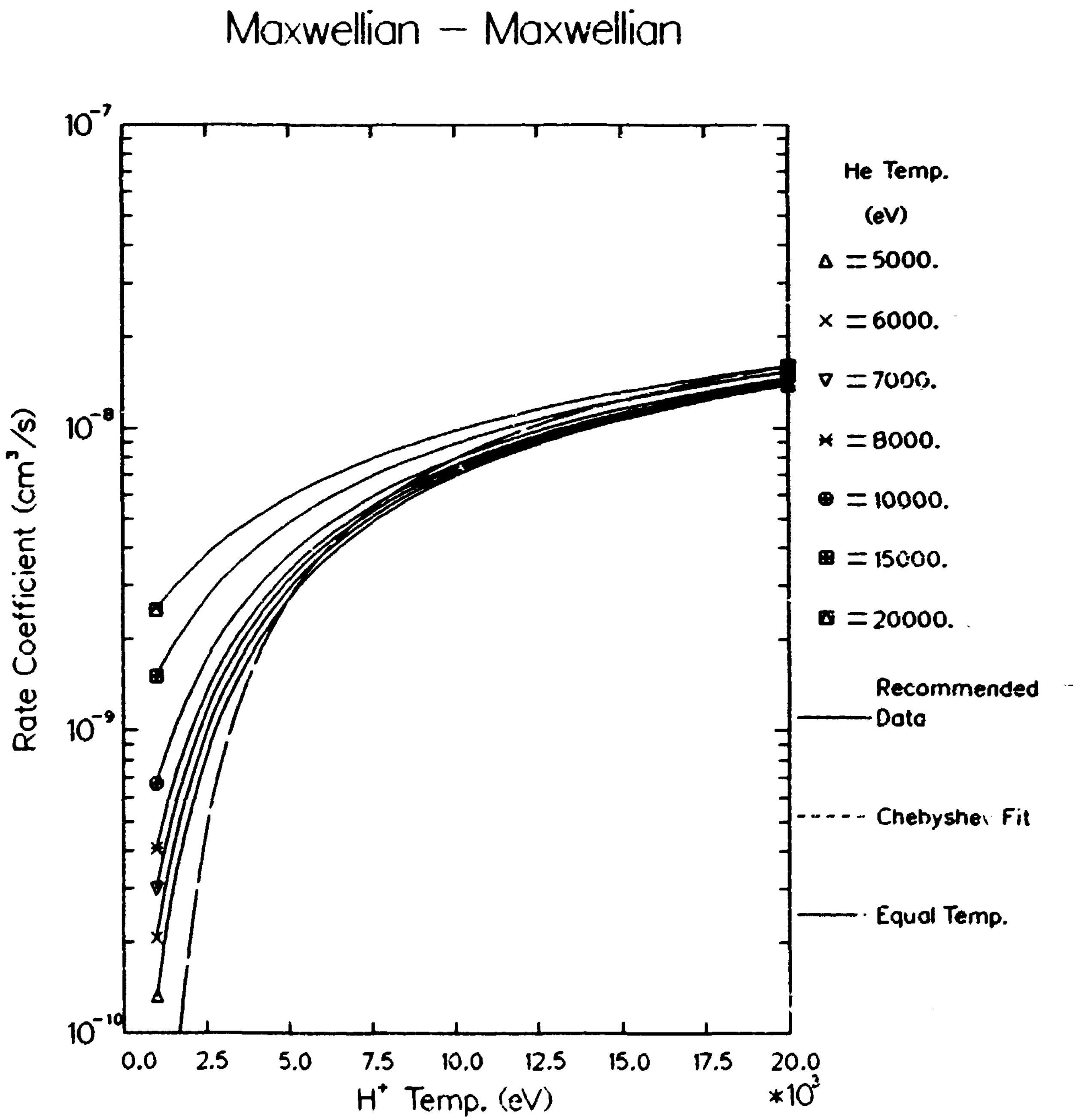
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+03 eV, E_{max} = 2.0E+04 eV

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
5000.	-40.3451	2.34883	-.257537	-.0218607	.0131131	-.00170960	-2.72133E-04
6000.	-40.0282	2.14145	-.186832	-.0325594	.0117041	-7.73826E-04	-3.91919E-04
7000.	-39.7552	1.96806	-.132538	-.0385303	.00991961	-1.95606E-05	-4.64455E-04
8000.	-39.5164	1.82079	-.0901635	-.0415358	.00805275	5.25545E-04	-4.72996E-04
10000.	-39.1158	1.58360	-.0298040	-.0424986	.00463640	.00112196	-3.85570E-04
15000.	-38.3952	1.19217	.0455887	-.0345519	-.00101950	.00132410	-2.81514E-05
20000.	-37.8995	.951741	.0744487	-.0255952	-.00350613	8.71591E-04	-4.39401E-05
Equal Temp.	-41.9272	3.86757	-1.06890	.261511	-.0564975	.00926856	-.00119300

See appendix for Chebyshev fit details

$H^{+} + He \rightarrow H^{+} + He^{+} + e$



Ionization Rate Coefficients for

$He + H^{+} \rightarrow He^{+} + H^{+} + e$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	1.45E-09*	9.69E-09	2.05E-08	3.04E-08	3.68E-08	4.15E-08	3.55E-08
2.0E+00	1.47E-09*	9.68E-09	2.05E-08	3.04E-08	3.68E-08	4.15E-08	3.55E-08
4.0E+00	1.49E-09*	9.67E-09	2.05E-08	3.04E-08	3.68E-08	4.15E-08	3.55E-08
7.0E+00	1.52E-09*	9.66E-09	2.05E-08	3.04E-08	3.68E-08	4.15E-08	3.55E-08
1.0E+01	1.54E-09*	9.66E-09	2.04E-08	3.04E-08	3.68E-08	4.15E-08	3.55E-08
2.0E+01	1.60E-09*	9.65E-09	2.04E-08	3.04E-08	3.68E-08	4.15E-08	3.55E-08
4.0E+01	1.68E-09*	9.64E-09	2.04E-08	3.04E-08	3.67E-08	4.15E-08	3.55E-08
7.0E+01	1.77E-09*	9.64E-09	2.04E-08	3.04E-08	3.67E-08	4.15E-08	3.55E-08
1.0E+02	1.85E-09*	9.65E-09	2.04E-08	3.04E-08	3.67E-08	4.15E-08	3.55E-08
2.0E+02	2.08E-09*	9.71E-09	2.04E-08	3.04E-08	3.66E-08	4.14E-08	3.55E-08
4.0E+02	2.45E-09*	9.85E-09	2.05E-08	3.04E-08	3.66E-08	4.13E-08	3.55E-08
7.0E+02	2.91E-09*	1.01E-08	2.06E-08	3.04E-08	3.65E-08	4.13E-08	3.54E-08
1.0E+03	3.33E-09*	1.03E-08	2.06E-08	3.04E-08	3.65E-08	4.12E-08	3.55E-08
2.0E+03	4.53E-09*	1.10E-08	2.09E-08	3.05E-08	3.63E-08	4.11E-08	3.55E-08
4.0E+03	6.51E-09*	1.23E-08	2.15E-08	3.07E-08	3.62E-08	4.08E-08	3.55E-08
7.0E+03	8.99E-09	1.42E-08	2.25E-08	3.09E-08	3.60E-08	4.05E-08	3.54E-08
1.0E+04	1.12E-08	1.58E-08	2.34E-08	3.11E-08	3.58E-08	4.02E-08	3.54E-08
2.0E+04	1.70E-08	2.04E-08	2.59E-08	3.18E-08	3.55E-08	3.94E-08	3.53E-08

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

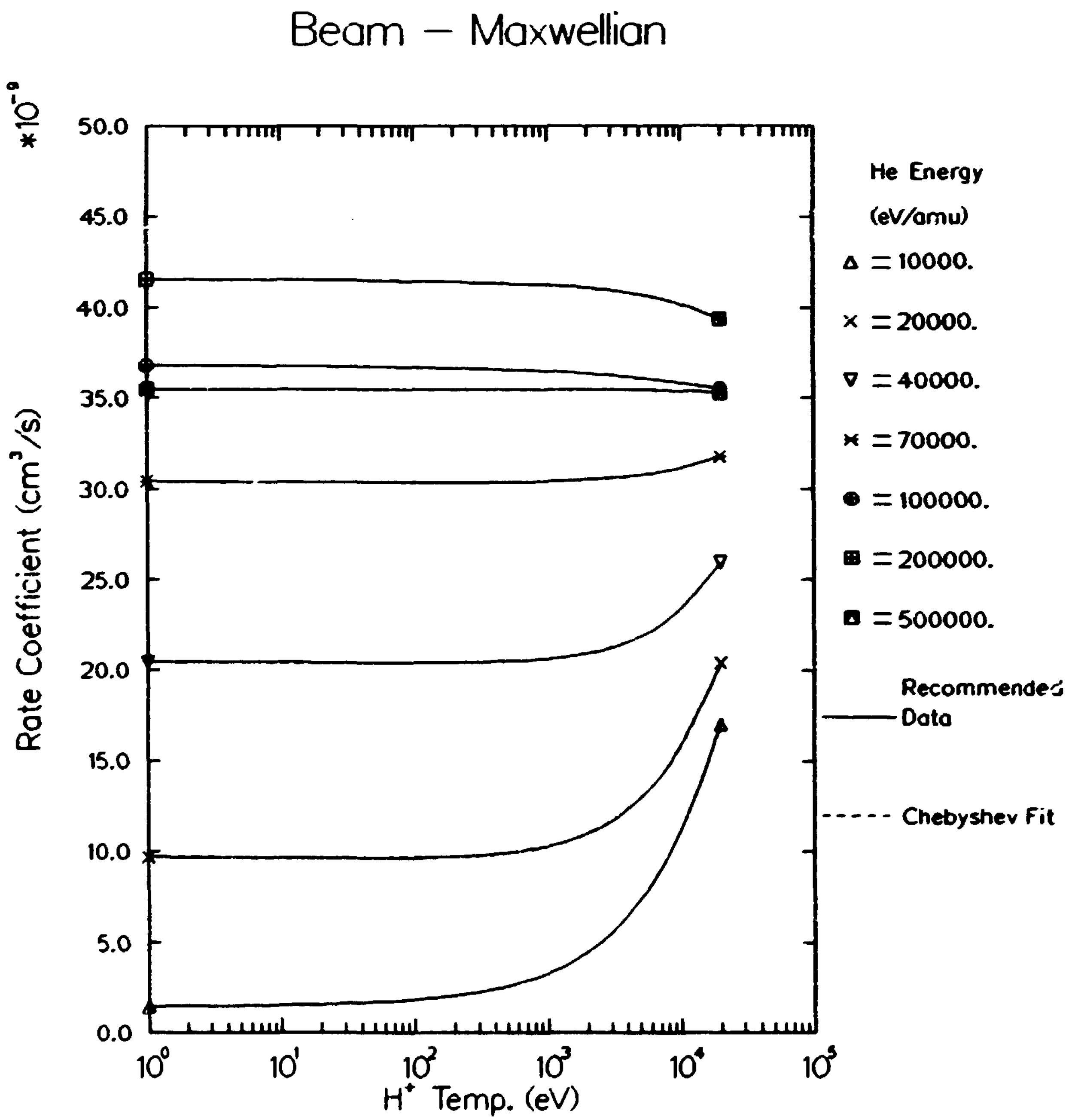
Chebyshev Fitting Parameters for Rate Coefficients

$$E_{min} = 1.0E+00 \text{ eV}, \quad E_{max} = 2.0E+04 \text{ eV}$$

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-39.1279	1.16505	.469737	.0813519	-.0228287	-.0182847	-.00258180
20000.	-36.5805	.285887	.190126	.0869452	.0237093	4.34865E-04	-3.87928E-03
40000.	-35.3193	.0816359	.0597659	.0332395	.0137513	.00383099	1.22161E-04
70000.	-34.6011	.0145540	.0116645	.00621244	.00251084	6.[illegible]3786E-04	4.47956E-04
100000.	-34.2559	-.0155100	-.00743994	-.00254453	-6.97240E-04	-1.61490E-04	2.33078E-05
200000.	-34.0175	-.0200973	-.0118588	-.00542167	-.00256996	-9.8[illegible]558E-04	-2.32402E-04
500000.	-34.3105	-.00181505	-.00131097	-8.28718E-04	-5.05268E-04	-2.95214E-04	-1.01434E-04

See appendix for Chebyshev fit details

He + H$^+$ -> He$^+$ + H$^+$ + e


Beam – Maxwellian
*10^{-9}
Rate Coefficient (cm^3/s)
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
10^0
10^1
10^2
10^3
10^4
10^5
H$^+$ Temp. (eV)
He Energy
(eV/amu)
△ = 10000.
× = 20000.
▽ = 40000.
✕ = 70000.
● = 100000.
⊞ = 200000.
■ = 500000.
Recommended Data
Chebyshev Fit

Total He+ Production Rate Coefficients for

$H^{+} + He \rightarrow (H + He^{+})$ or $(H^{+} + He^{+} + e)$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

H^{+} Temp. (eV)	Equal Temp.	He Temp. (eV) 1000.	2000.	4000.	7000.	10000.	15000.	20000.
1.0E+03	3.32E-10#	3.32E-10#	6.71E-10#	1.68E-09#	3.78E-09*	6.26E-09*	1.06E-08*	1.49E-08
1.5E+03	1.39E-09#	1.13E-09#	1.68E-09#	3.02E-09*	5.41E-09*	8.00E-09*	1.24E-08	1.65E-08
2.0E+03	3.62E-09*	2.32E-09*	3.02E-09*	4.58E-09*	7.12E-09*	9.77E-09*	1.41E-08	1.81E-08
2.5E+03	4.90E-09*	3.78E-09*	4.58E-09*	6.26E-09*	8.88E-09*	1.15E-08	1.57E-08	1.96E-08
3.0E+03	7.12E-09*	5.41E-09*	6.26E-09*	8.00E-09*	1.06E-08*	1.32E-08	1.73E-08	2.10E-08
3.5E+03	9.33E-09*	7.12E-09*	8.00E-09*	9.77E-09*	1.24E-08	1.49E-08	1.88E-08	2.24E-08
4.0E+03	1.15E-08	8.88E-09*	9.77E-09*	1.15E-08	1.41E-08	1.65E-08	2.03E-08	2.37E-08
4.5E+03	1.37E-08	1.06E-08*	1.15E-08	1.32E-08	1.57E-08	1.81E-08	2.17E-08	2.49E-08
5.0E+03	1.57E-08	1.24E-08	1.32E-08	1.49E-08	1.73E-08	1.96E-08	2.30E-08	2.61E-08
5.5E+03	1.77E-08	1.41E-08	1.49E-08	1.65E-08	1.88E-08	2.10E-08	2.43E-08	2.72E-08
6.0E+03	1.96E-08	1.57E-08	1.65E-08	1.81E-08	2.03E-08	2.24E-08	2.55E-08	2.83E-08
8.0E+03	2.61E-08	2.17E-08	2.24E-08	2.37E-08	2.55E-08	2.72E-08	2.98E-08	3.20E-08
1.0E+04	3.12E-08	2.67E-08	2.72E-08	2.83E-08	2.98E-08	3.12E-08	3.32E-08	3.51E-08
1.2E+04	3.51E-08	3.07E-08	3.12E-08	3.20E-08	3.32E-08	3.44E-08	3.61E-08	3.76E-08
1.4E+04	3.82E-08	3.40E-08	3.44E-08	3.51E-08	3.61E-08	3.70E-08	3.84E-08	3.97E-08
1.6E+04	4.06E-08	3.67E-08	3.70E-08	3.76E-08	3.84E-08	3.92E-08	4.04E-08	4.14E-08
1.8E+04	4.25E-08	3.90E-08	3.92E-08	3.97E-08	4.04E-08	4.10E-08	4.19E-08	4.28E-08
2.0E+04	4.40E-08	4.08E-08	4.10E-08	4.14E-08	4.19E-08	4.25E-08	4.33E-08	4.40E-08

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

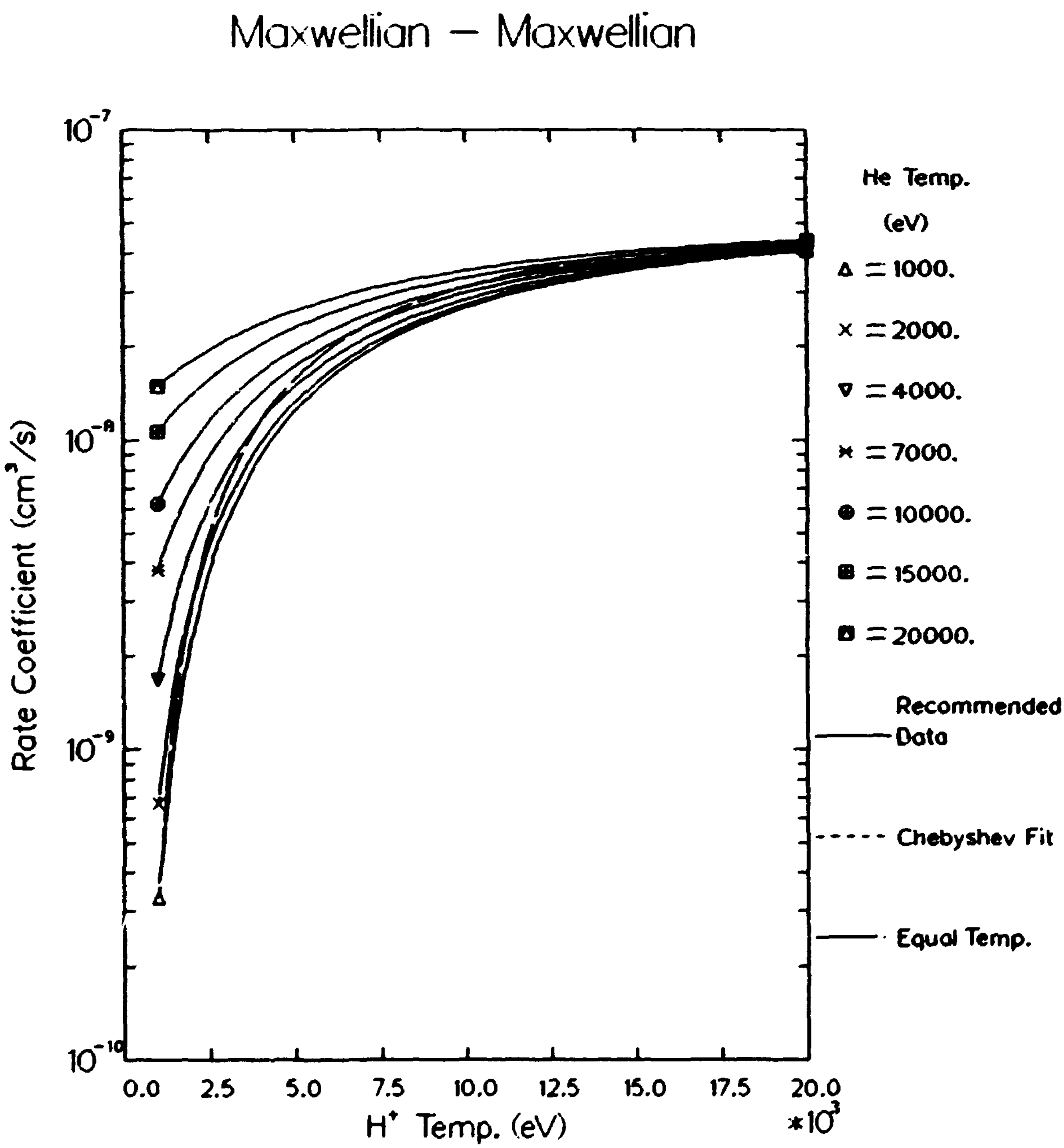
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+03 eV, E_{max} = 2.0E+04 eV

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
1000.	-37.7759	2.35765	-.526776	.0461542	-.00599557	.00186274	5.61892E-05
2000.	-37.3613	2.05214	-.389347	.00372548	.00380397	3.22896E-04	1.92742E-07
4000.	-36.7649	1.63391	-.227162	-.0328342	.00799982	4.62850E-04	-3.57204E-04
7000.	-36.1737	1.24696	-.108095	-.0449948	.00515942	.00147386	-4.77249E-04
10000.	-35.7678	.998971	-.0496155	-.0432215	.00174125	.00180493	-2.03326E-04
15000.	-35.3028	.734516	-.00387920	-.0346346	-.00171864	.00144813	-1.44086E-05
20000.	-34.9844	.566598	.0150211	-.0267530	-.00313077	.00108401	2.07674E-04
Equal Temp.	-37.4591	2.34257	-.631509	.0945062	-.0203712	.00642863	-.00134327

See appendix for Chebyshev fit details

$H^{+} + He \rightarrow (H + He^{+})$ or $(H^{+} + He^{+} + e)$



Total He^+ Production Rate Coefficients for

$He + H^+ \rightarrow (He^+ + H)$ or $(He^+ + H^+ + e)$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	1.84E-08	4.68E-08	6.02E-08	5.80E-08	5.36E-08	4.44E-08	3.56E-08
2.0E+00	1.84E-08	4.68E-08	6.02E-08	5.80E-08	5.36E-08	4.44E-08	3.56E-08
4.0E+00	1.84E-08	4.67E-08	6.02E-08	5.80E-08	5.36E-08	4.44E-08	3.56E-08
7.0E+00	1.83E-08	4.66E-08	6.01E-08	5.80E-08	5.36E-08	4.44E-08	3.56E-08
1.0E+01	1.83E-08	4.66E-08	6.01E-08	5.80E-08	5.36E-08	4.44E-08	3.56E-08
2.0E+01	1.83E-08	4.64E-08	6.00E-08	5.80E-08	5.36E-08	4.44E-08	3.56E-08
4.0E+01	1.83E-08	4.62E-08	5.99E-08	5.79E-08	5.36E-08	4.44E-08	3.56E-08
7.0E+01	1.83E-08	4.60E-08	5.98E-08	5.79E-08	5.35E-08	4.44E-08	3.56E-08
1.0E+02	1.84E-08	4.59E-08	5.97E-08	5.79E-08	5.35E-08	4.44E-08	3.56E-08
2.0E+02	1.87E-08	4.55E-08	5.94E-08	5.78E-08	5.35E-08	4.44E-08	3.56E-08
4.0E+02	1.95E-08	4.51E-08	5.91E-08	5.77E-08	5.35E-08	4.43E-08	3.56E-08
7.0E+02	2.07E-08	4.48E-08	5.87E-08	5.75E-08	5.34E-08	4.44E-08	3.56E-08
1.0E+03	2.18E-08	4.46E-08	5.85E-08	5.74E-08	5.34E-08	4.44E-09	3.56E-08
2.0E+03	2.51E-08	4.44E-08	5.76E-08	5.71E-08	5.32E-08	4.44E-08	3.56E-08
4.0E+03	3.00E-08	4.47E-08	5.62E-08	5.64E-08	5.30E-08	4.44E-08	3.56E-06
7.0E+03	3.50E-08	4.56E-08	5.46E-08	5.54E-08	5.25E-08	4.44E-08	3.56E-08
1.0E+04	3.86E-08	4.64E-08	5.35E-08	5.45E-08	5.21E-08	4.44E-08	3.56E-08
2.0E+04	4.53E-08	4.85E-08	5.16E-08	5.21E-08	5.05E-08	4.42E-08	3.56E-08

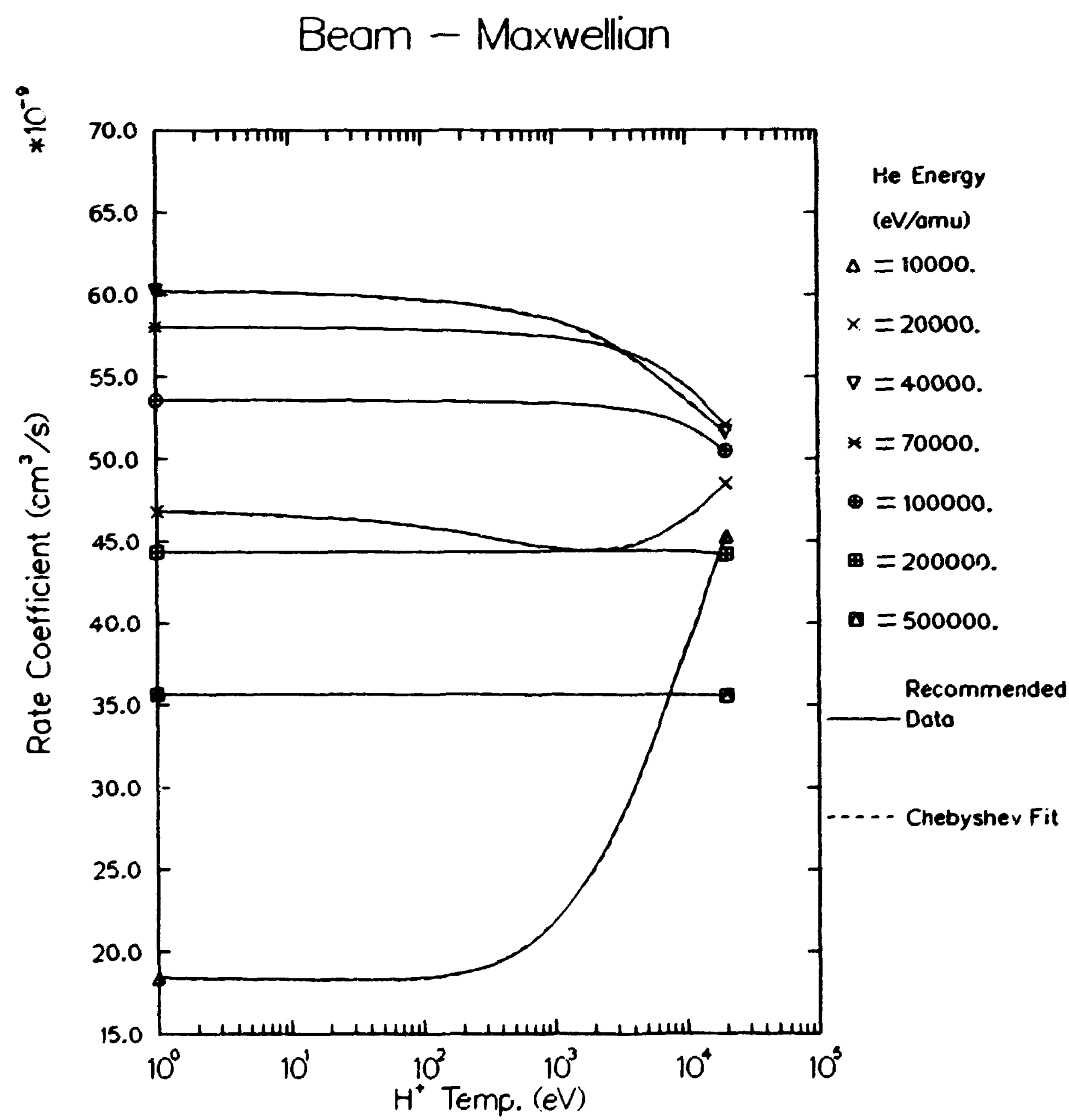
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-35.1311	.412881	.228878	.0583838	-.0173875	-.0216039	-.00620616
20000.	-33.7784	-.00396664	.0221013	.0208873	.00921146	.00114081	-.00146388
40000.	-33.3338	-.0658860	-.0346993	-.0127985	-.00242907	.00117581	.00179130
70000.	-33.3704	-.0391288	-.0249648	-.0133215	-.00605125	-.00211349	-2.49745E-04
100000.	-33.5061	-.0193669	-.0135261	-.00817621	-.00432298	-.00189118	-6.09453E-04
200000.	-33.8626	-6.29120E-04	-9.61867E-04	-9.42621E-04	-7.21387E-04	-4.47888E-04	-2.11683E-04
500000.	-34.3009	-7.64617E-04	-4.54422E-04	-2.24604E-04	-1.49745E-04	-1.31679E-04	-5.40513E-05

See appendix for Chebyshev fit details

$He + H^+ \rightarrow (He^+ + H)$ or $(He^+ + H^+ + e)$



Ionization and Total He^{2+} Production Cross Sections for

$H^+ + He \rightarrow H^+ + He^{2+} + 2e$
$H^+ + He \rightarrow (H^- + He^{2+})$ or $(H^+ + He^{2+} + 2e)$

Ionization		Total He^{2+} Production	
Energy (eV/amu)	Cross Section (cm^2)	Energy (eV/amu)	Cross Section (cm^2)
2.0E+04	1.40E-19	1.0E+04	4.97E-19
3.0E+04	4.46E-19	1.5E+04	9.85E-19
4.0E+04	6.68E-19	2.0E+04	1.49E-18
6.0E+04	9.69E-19	3.0E+04	2.17E-18
8.0E+04	1.07E-18	4.0E+04	2.38E-18
1.0E+05	9.95E-19	5.0E+04	2.41E-18
1.5E+05	7.42E-19	7.0E+04	2.30E-18
2.0E+05	5.59E-19	1.0E+05	1.80E-18
3.0E+05	3.67E-19	1.5E+05	1.04E-18
4.0E+05	2.52E-19	2.0E+05	6.71E-19
6.0E+05	1.38E-19	3.0E+05	3.83E-19
8.0E+05	9.63E-20	4.0E+05	2.52E-19
1.0E+06	7.49E-20	7.0E+05	1.14E-19
1.5E+06	4.95E-20	1.0E+06	7.54E-20
2.0E+06	3.72E-20	1.5E+06	4.98E-20
3.0E+06	2.46E-20	2.0E+06	3.74E-20
4.0E+06	1.85E-20	4.0E+06	1.86E-20
5.0E+06	1.46E-20	5.0E+06	1.48E-20

References: 83, 87, 89, 315, 353, 354, 359, 368, 371, 372, 375, 376, 381, 382, 383, 384, 385, 386, 387, 388

Accuracy: 20%

Notes: (1) The total cross section for producing slow He^{2+} ions is the sum of the double ionization cross section ($H^+ + He \rightarrow H^+ + He^{2+} + 2e$) and the electron capture cross section ($H^+ + He \rightarrow H^- + He^{2+}$). (2) At energies less than 3×10^5 eV/amu the production of He^{2+} is dominated by double electron capture collisions. (3) For cross sections involving the formation of He^+ see the preceding set of data.

Chebyshev Fitting Parameters for Cross Sections

Ionization E_{min} = 2.0E+04 eV/amu, E_{max} = 5.0E+06 eV/amu
Tot. He^{2+} Prod. E_{min} = 1.0E+04 eV/amu, E_{max} = 5.0E+06 eV/amu

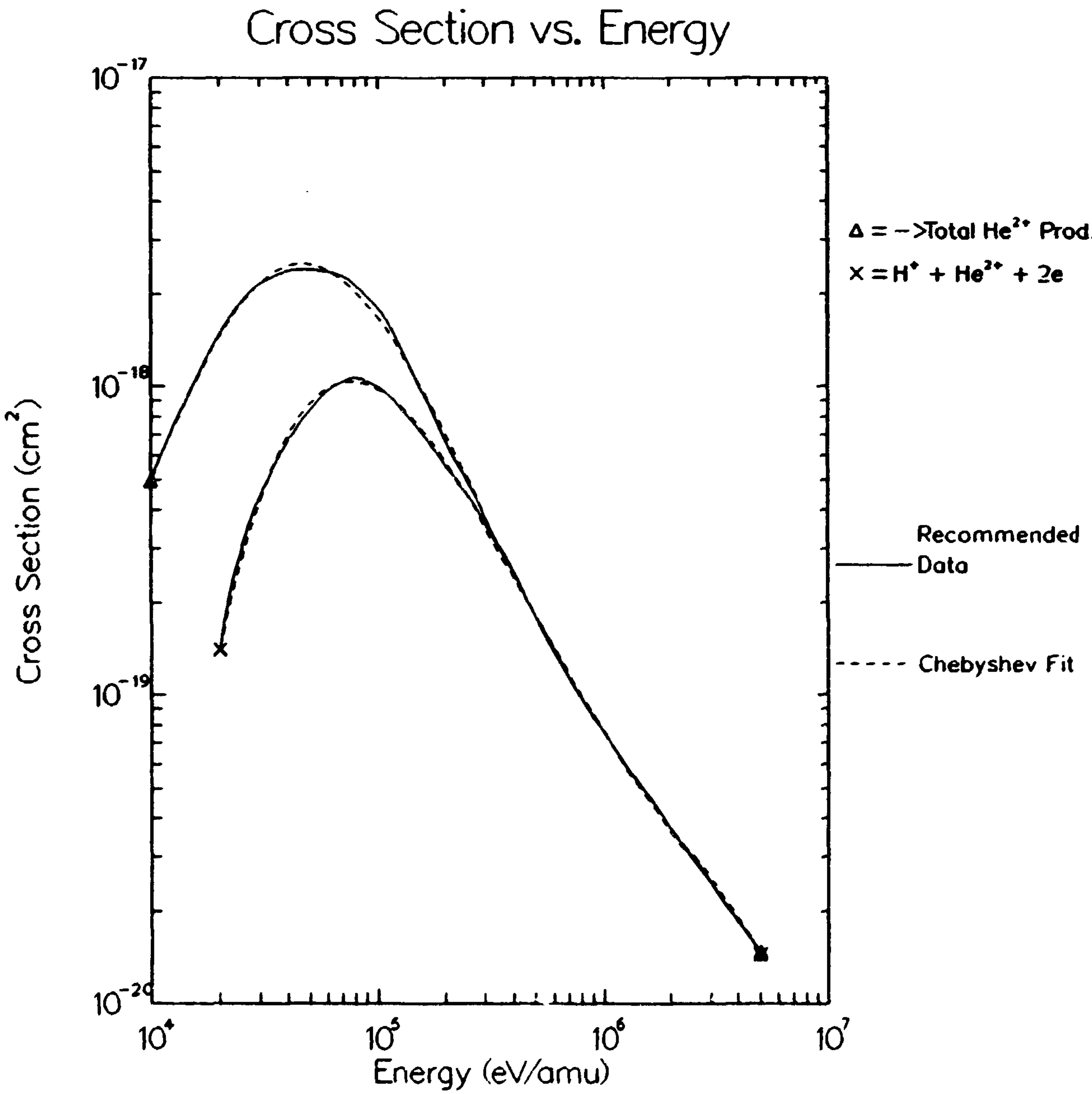
	A0	A1	A2	A3	A4	A5	A6
Ionization	-86.8125	-1.69704	-.988419	.579481	-.140358	-.0229323	-.00915691
Tot. He^{2+} Prod.	-85.7168	-2.26739	-.987093	.602380	-.0759791	-.104008	.0149516

The fit represents the Ionization cross section with an rms deviation of 2.5%. The maximum deviation is 4.3% at 4.0E+04 eV/amu.

The fit represents the Tot. He^{2+} Prod. cross section with an rms deviation of 2.7%. The maximum deviation is 4.8% at 2.0E+05 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + He \rightarrow H^+ + He^{2+} + 2e$
$H^+ + He \rightarrow (H^- + He^{2+})$ or $(H^+ + He^{2+} + 2e)$



Double Ionization Rate Coefficients for

$He + H^{+} \rightarrow He^{2+} + H^{+} + 2e$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H^{+} Temp. (eV)	He Energy (eV/amu) 20000.	40000.	60000.	80000.	100000.	200000.	500000.
1.0E+00	1.42E-11*	1.85E-10	3.29E-10	4.20E-10	4.37E-10	3.47E-10	1.78E-10
2.0E+00	1.44E-11*	1.85E-10	3.29E-10	4.20E-10	4.37E-10	3.47E-10	1.78E-10
4.0E+00	1.46E-11*	1.85E-10	3.29E-10	4.19E-10	4.36E-10	3.47E-10	1.78E-10
7.0E+00	1.49E-11*	1.85E-10	3.29E-10	4.19E-10	4.36E-10	3.47E-10	1.78E-10
1.0E+01	1.52E-11*	1.85E-10	3.28E-10	4.19E-10	4.36E-10	3.47E-10	1.78E-10
2.0E+01	1.58E-11*	1.85E-10	3.28E-10	4.18E-10	4.36E-10	3.47E-10	1.78E-10
4.0E+01	1.68E-11*	1.85E-10	3.27E-10	4.17E-10	4.35E-10	3.47E-10	1.78E-10
7.0E+01	1.80E-11*	1.85E-10	3.27E-10	4.16E-10	4.34E-10	3.47E-10	1.78E-10
1.0E+02	1.90E-11*	1.85E-10	3.26E-10	4.15E-10	4.34E-10	3.47E-10	1.78E-10
2.0E+02	2.20E-11*	1.85E-10	3.26E-10	4.13E-10	4.32E-10	3.47E-10	1.78E-10
4.0E+02	2.70E-11*	1.87E-10	3.25E-10	4.10E-10	4.31E-10	3.46E-10	1.78E-10
7.0E+02	3.34E-11*	1.89E-10	3.25E-10	4.07E-10	4.28E-10	3.47E-10	1.78E-10
1.0E+03	3.90E-11*	1.92E-10	3.25E-10	4.04E-10	4.26E-10	3.46E-10	1.78E-10
2.0E+03	5.50E-11*	2.00E-10	3.24E-10	3.97E-10	4.19E-10	3.46E-10	1.78E-10
4.0E+03	8.11E-11*	2.15E-10	3.23E-10	3.85E-10	4.08E-10	3.45E-10	1.78E-10
7.0E+03	1.13E-10	2.32E-10	3.21E-10	3.73E-10	3.94E-10	3.42E-10	1.79E-10
1.0E+04	1.40E-10	2.44E-10	3.20E-10	3.64E-10	3.83E-10	3.39E-10	1.79E-10
2.0E+04	2.03E-10	2.71E-10	3.18E-10	3.45E-10	3.58E-10	3.28E-10	1.80E-10

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

Chebyshev Fitting Parameters for Rate Coefficients

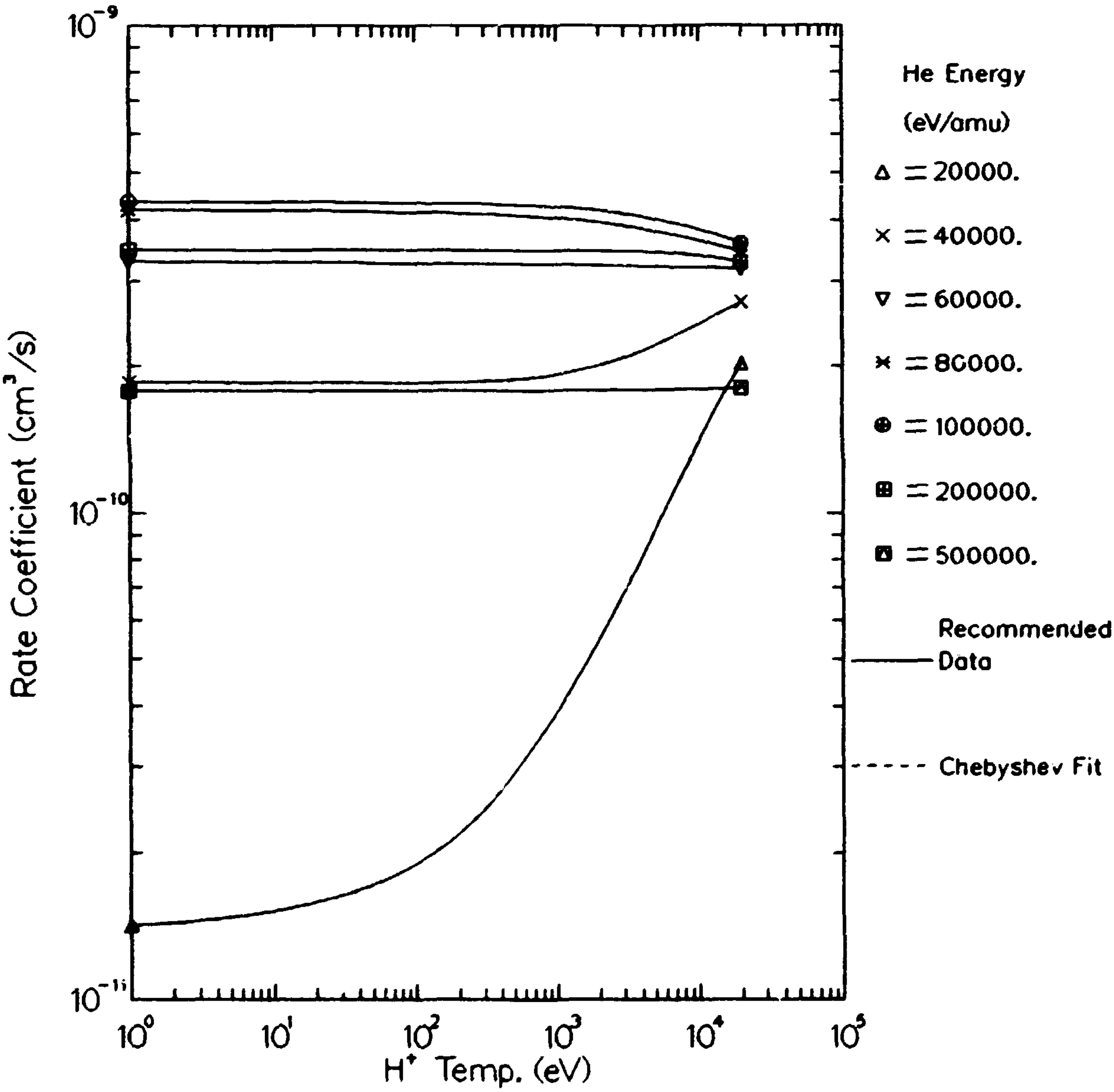
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
20000.	-48.1754	1.30300	.485174	.0480600	-.0457483	-.0219390	-7.65210E-04
40000.	-44.6402	.155683	.100721	.0406747	.00551141	-.00485389	-.00420546
60000.	-43.6938	.0163921	-.00478529	-.00179360	-.00131646	-1.05431E-04	8.93568E-04
80000.	-43.2865	-.0824386	-.0435066	-.0165975	-.00387115	5.14172E-04	1.18040E-03
100000.	-43.1958	-.0767199	-.0463123	-.0215537	-.00727208	-9.94415E-04	8.20812E-04
200000.	-43.5811	-.0170301	-.0127181	-.00866682	-.00530410	-.00278153	-1.19855E-03
500000.	-44.8971	.00488974	.00333081	.00168204	5.29597E-04	-3.67440E-06	-7.7215[illegible]E-05

See appendix for Chebyshev fit details

$He + H^+ \rightarrow He^{2+} + H^+ + 2e$

Beam – Maxwellian



Total He^{2+} Production Rate Coefficients for

$H^{+} + He \rightarrow (H^{-} + He^{2+}) + (H^{+} + He^{2+} + 2e)$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	Equal Temp.	He Temp. (eV) 5000.	7500.	10000.	12500.	15000.	17500.	20000.
7.5E+02	7.68E-15#	2.03E-12#	6.81E-12#	1.47E-11#	2.53E-11#	3.80E-11*	5.22E-11*	6.75E-11*
1.0E+03	1.04E-13#	3.55E-12#	9.61E-12#	1.87E-11#	3.01E-11#	4.35E-11*	5.82E-11*	7.38E-11*
1.3E+03	5.03E-13#	5.59E-12#	1.29E-11#	2.30E-11#	3.53E-11*	4.92E-11*	6.44E-11*	8.03E-11*
1.5E+03	1.45E-12#	8.15E-12#	1.65E-11#	2.77E-11#	4.07E-11*	5.52E-11*	7.07E-11*	8.68E-11*
1.8E+03	3.12E-12#	1.12E-11#	2.08E-11#	3.27E-11#	4.63E-11*	6.12E-11*	7.70E-11*	9.33E-11*
2.0E+03	5.59E-12#	1.47E-11#	2.53E-11#	3.80E-11*	5.22E-11*	6.75E-11*	8.35E-11*	1.00E-10*
3.0E+03	2.30E-11#	3.27E-11#	4.63E-11*	6.12E-11*	7.70E-11*	9.33E-11*	1.10E-10*	1.27E-10*
4.0E+03	4.92E-11*	5.52E-11*	7.07E-11*	8.68E-11*	1.03E-10*	1.20E-10*	1.37E-10*	1.54E-10*
5.0E+03	8.03E-11*	8.03E-11*	9.66E-11*	1.13E-10*	1.30E-10*	1.47E-10*	1.63E-10*	1.80E-10*
6.0E+03	1.13E-10*	1.07E-10*	1.23E-10*	1.40E-10*	1.57E-10*	1.73E-10*	1.89E-10*	2.05E-10
7.0E+03	1.47E-10*	1.33E-10*	1.50E-10*	1.67E-10*	1.83E-10*	1.99E-10	2.14E-10	2.30E-10
8.0E+03	1.80E-10*	1.60E-10*	1.76E-10*	1.92E-10*	2.08E-10	2.24E-10	2.38E-10	2.53E-10
9.0E+03	2.11E-10	1.86E-10*	2.02E-10	2.18E-10	2.33E-10	2.47E-10	2.61E-10	2.75E-10
1.0E+04	2.41E-10	2.11E-10	2.27E-10	2.41E-10	2.56E-10	2.70E-10	2.83E-10	2.96E-10
1.2E+04	2.96E-10	2.59E-10	2.72E-10	2.86E-10	2.99E-10	3.12E-10	3.24E-10	3.35E-10
1.5E+04	3.66E-10	3.21E-10	3.33E-10	3.44E-10	3.55E-10	3.66E-10	3.76E-10	3.86E-10
2.0E+04	4.50E-10	4.04E-10	4.12E-10	4.21E-10	4.29E-10	4.36E-10	4.44E-10	4.50E-10

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

Chebyshev Fitting Parameters for Rate Coefficients

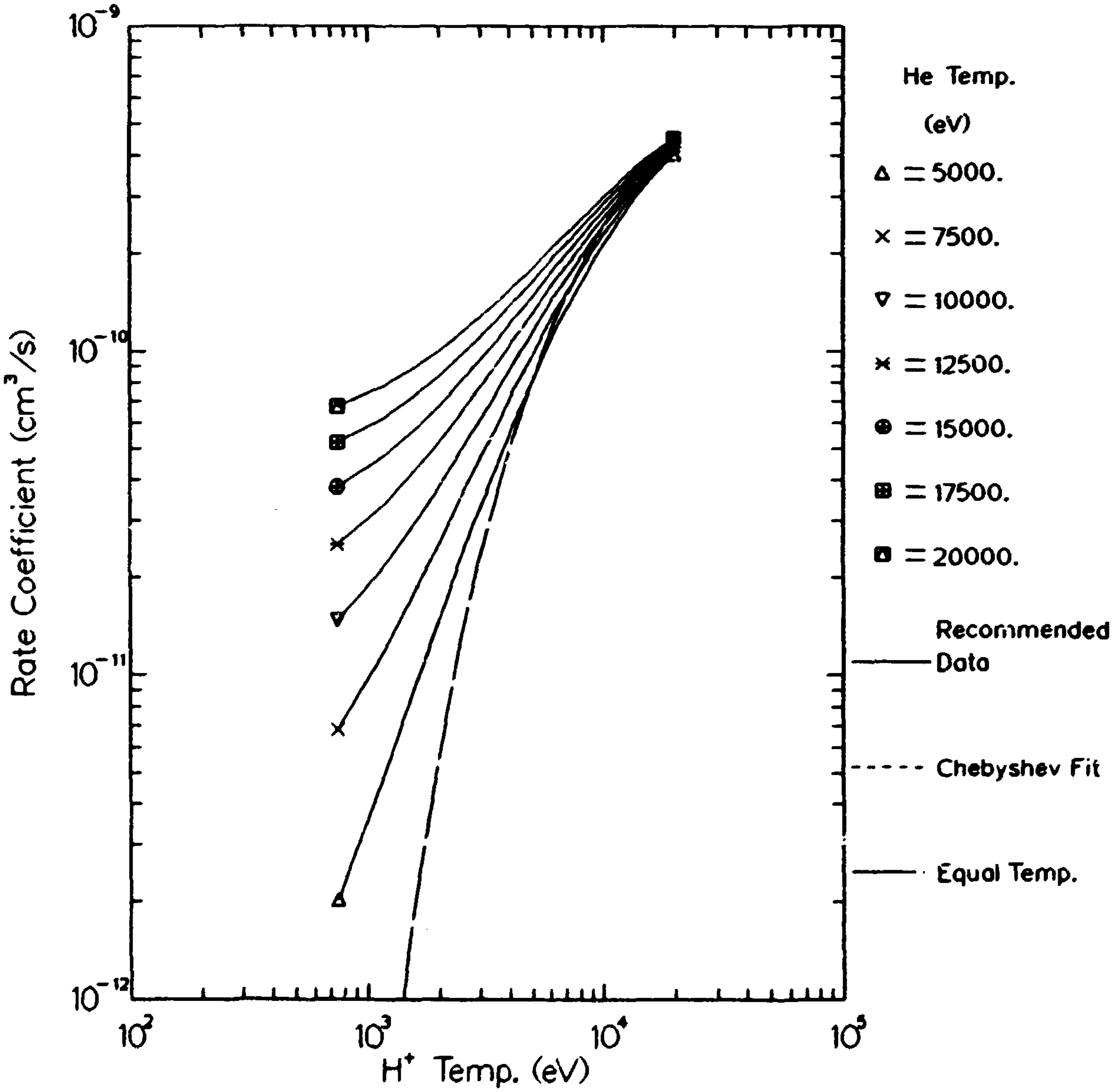
E_{min} = 7.5E+02 eV, E_{max} = 2.0E+04 eV

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
5000.	-47.9855	2.71190	-.299562	-.0631734	.0152650	-.00140966	-4.92425E-04
7500.	-47.0952	2.12886	-.119977	-.0784054	.00701306	.00151172	-6.61029E-04
10000.	-46.4732	1.74892	-.0292041	-.0751534	3.23238E-04	.00245385E-03	-3.15620E-04
12500.	-46.0040	1.47944	.0203814	-.0667770	-.00376242	.00232506	5.55977E-05
15000.	-45.6322	1.27684	.0490457	-.0581142	-.00655132	.00195763	1.43604E-04
17500.	-45.3276	1.11863	.0651645	-.0499554	-.00809607	.00145805	3.73270E-04
20000.	-45.0718	.991107	.0746366	-.0430706	-.00880789	.00106692	2.57551E-04
Equal Temp.	-50.6204	5.07900	-1.59808	.393560	-.101018	.0175307	-.00147330

See appendix for Chebyshev fit details

$H^+ + He \rightarrow (H^- + He^{2+}) + (H^+ + He^{2+} + 2e)$

Maxwellian – Maxwellian



Total He^{2+} Production Rate Coefficients for

$He + H^{+} \rightarrow (He^{2+} + H^{-}) + (He^{2+} + H^{+} + 2e)$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	150000.	200000.
1.0E+00	3.56E-11*	2.92E-10	6.61E-10	8.44E-10	7.90E-10	5.59E-10	4.17E-10
2.0E+00	3.60E-11*	2.92E-10	6.61E-10	8.44E-10	7.89E-10	5.59E-10	4.17E-10
4.0E+00	3.67E-11*	2.92E-10	6.60E-10	8.43E-10	7.89E-10	5.59E-10	4.17E-10
7.0E+00	3.74E-11*	2.92E-10	6.60E-10	8.43E-10	7.88E-10	5.59E-10	4.17E-10
1.0E+01	3.80E-11*	2.91E-10	6.60E-10	8.42E-10	7.88E-10	5.59E-10	4.17E-10
2.0E+01	3.96E-11*	2.91E-10	6.59E-10	8.41E-10	7.86E-10	5.59E-10	4.17E-10
4.0E+01	4.20E-11*	2.91E-10	6.59E-10	8.39E-10	7.85E-10	5.59E-10	4.17E-10
7.0E+01	4.49E-11*	2.91E-10	6.58E-10	8.37E-10	7.83E-10	5.58E-10	4.17E-10
1.0E+02	4.73E-11*	2.92E-10	6.58E-10	8.36E-10	7.81E-10	5.58E-10	4.18E-10
2.0E+02	5.41E-11*	2.95E-10	6.57E-10	8.32E-10	7.78E-10	5.58E-10	4.18E-10
4.0E+02	6.55E-11*	3.01E-10	6.56E-10	8.26E-10	7.72E-10	5.57E-10	4.19E-10
7.0E+02	8.03E-11*	3.10E-10	6.55E-10	8.20E-10	7.66E-10	5.57E-10	4.19E-10
1.0E+03	9.37E-11*	3.18E-10	6.53E-10	8.15E-10	7.62E-10	5.57E-10	4.20E-10
2.0E+03	1.33E-10*	3.43E-10	6.50E-10	8.00E-10	7.48E-10	5.56E-10	4.22E-10
4.0E+03	1.99E-10	3.84E-10	6.46E-10	7.73E-10	7.26E-10	5.54E-10	4.24E-10
7.0E+03	2.77E-10	4.32E-10	6.41E-10	7.40E-10	6.98E-10	5.49E-10	4.27E-10
1.0E+04	3.39E-10	4.69E-10	6.36E-10	7.12E-10	6.74E-10	5.42E-10	4.28E-10
2.0E+04	4.75E-10	5.41E-10	6.21E-10	6.47E-10	6.14E-10	5.17E-10	4.24E-10

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

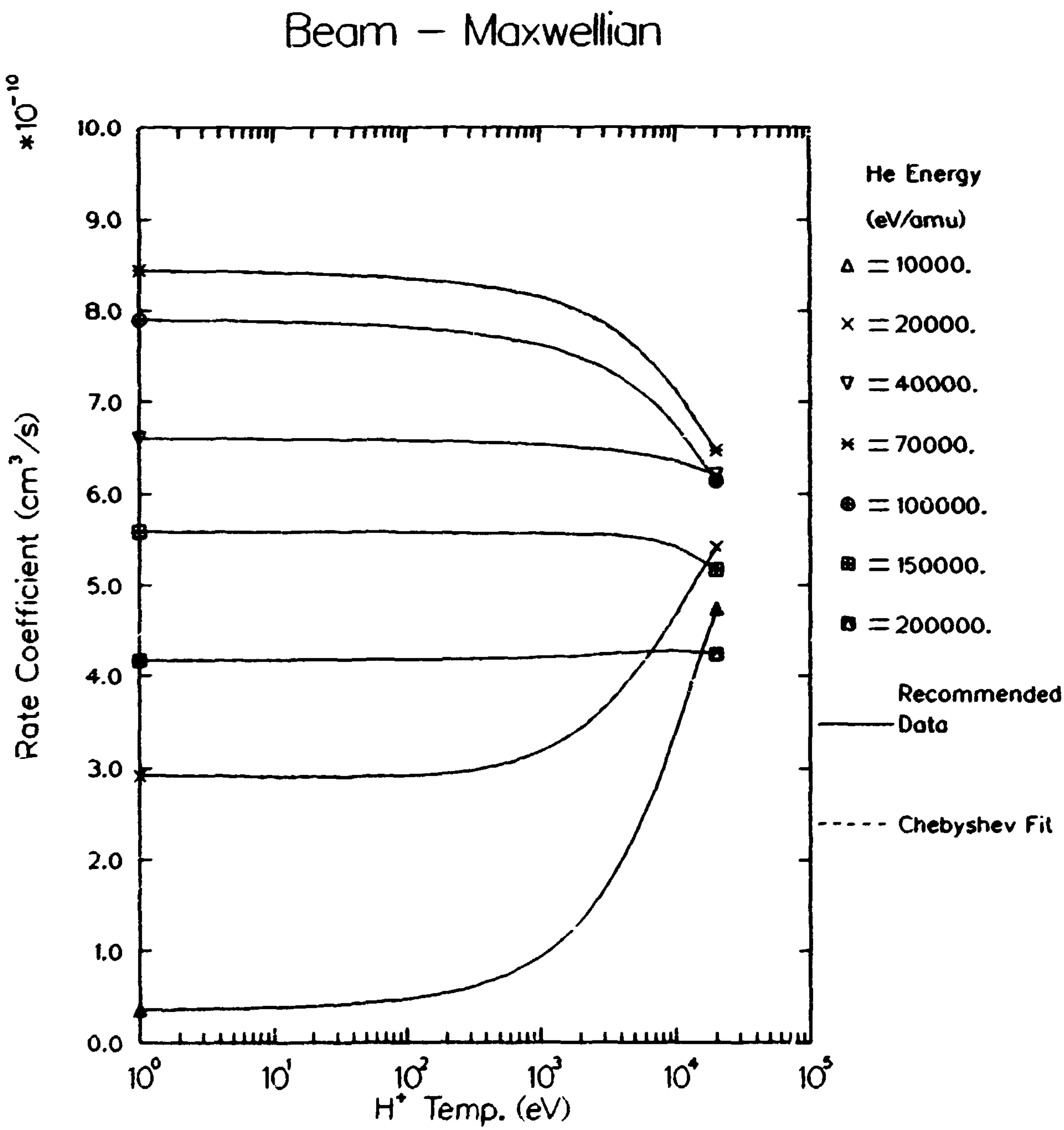
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-46.3757	1.27650	.480627	.0489252	-.0511164	-.0308841	-.00542828
20000.	-43.5984	.264368	.158736	.0549494	.00162732	-.00969406	-.00629046
40000.	-42.3060	-.0238894	-.0125884	-.00618733	-.00280784	-.00102524	-4.84730E-04
70000.	-41.9087	-.101626	-.0604596	-.0289603	-.0112319	-.00285512	3.95976E-04
100000.	-42.0360	-.0958542	-.0558944	-.0266235	-.0108604	-.00350631	-4.83059E-04
150000.	-42.6352	-.0233424	-.0167110	-.0116669	-.00760143	-.00419389	-.00181500
200000.	-43.1811	.0113231	.00418441	-8.73051E-04	-.00251835	-.00215399	-.00136312

See appendix for Chebyshev fit details

$He + H^+ \rightarrow (He^{2+} + H^-)$ or $(He^{2+} + H^+ + 2e)$



Penning, Associative, and Total Ionization Cross Sections for

$He(2^1S) + H \rightarrow He + H^+ + e$ (σ_{PI})
$He(2^1S) + H \rightarrow HeH^+ + e$ (σ_{AI})
$He(2^1S) + H \rightarrow (\sigma_{PI}) + (\sigma_{AI})$ (Total Ion.)

Total Ion. (TI)		Penn. Ion. (PI)		Assoc. Ion. (AI)	
Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)
2.0E-02	7.93E-15	1.8E-02	6.02E-15	1.9E-02	1.83E-15
2.5E-02	7.35E-15	2.0E-02	5.89E-15	2.0E-02	1.77E-15
3.0E-02	6.85E-15	3.0E-02	5.34E-15	2.5E-02	1.51E-15
4.0E-02	6.19E-15	4.0E-02	4.93E-15	3.0E-02	1.29E-15
6.0E-02	5.16E-15	6.0E-02	4.29E-15	4.0E-02	9.78E-16
8.0E-02	4.51E-15	8.0E-02	3.83E-15	6.0E-02	5.79E-16
1.0E-01	4.02E-15	1.0E-01	3.47E-15	8.0E-02	3.75E-16
1.3E-01	3.49E-15	1.3E-01	3.11E-15	1.0E-01	2.60E-16
				1.3E-01	1.80E-16

<u>References:</u> 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433

<u>Accuracy:</u> 100%

<u>Notes:</u> (1) The total ionization of H by low energy $He(2^1S)$ is the sum of Penning ionization $He(2^1S) + H \rightarrow He + H^+ + e$ and associative ionization $He(2^1S) + H \rightarrow HeH^+ + e$. (2) All data have been normalized to theory at an interaction energy of 0.04 eV. (3) Total ionization is sometimes referred to as chemionization. (4) The energy of the 2^1S state is 20.61 eV with a lifetime of 2×10^{-2} sec.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

Total Ion. (TI) E_{min} = 2.0E-02 eV/amu, E_{max} = 1.3E-01 eV/amu
Penn. Ion. (PI) E_{min} = 1.8E-02 eV/amu, E_{max} = 1.3E-01 eV/amu
Assoc. Ion. (AI) E_{min} = 1.9E-02 eV/amu, E_{max} = 1.3E-01 eV/amu

	A0	A1	A2	A3	A4	A5	A6
Total Ion. (TI)	-65.7017	-.409875	-.0288546	.000799090	.000526085	-.00141688	.000701497
Penn. Ion. (PI)	-66.0843	-.332960	-.0347058	.00142222	.00272425	.00118710	.000264732
Assoc. Ion. (AI)	-69.9529	-1.18775	-.135804	.0232877	.0173897	.00454102	.000920812

The fit represents the (TI) cross section with an rms deviation of 0.1%. The maximum deviation is 0.2% at 3.0E-02 eV/amu.

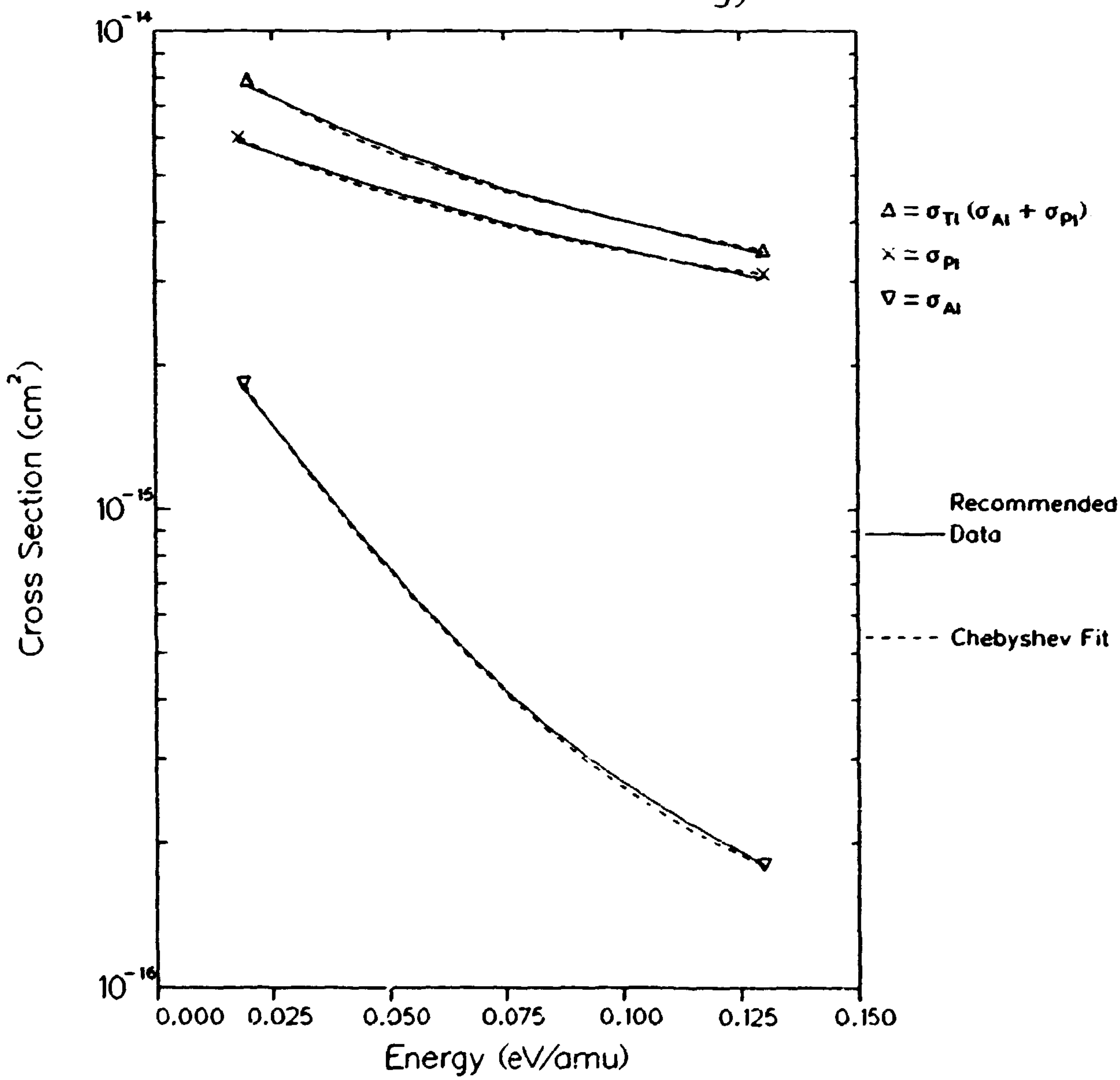
The fit represents the (PI) cross section with an rms deviation of 0.1%. The maximum deviation is 0.1% at 6.0E-02 eV/amu.

The fit represents the (AI) cross section with an rms deviation of 0.3%. The maximum deviation is 0.4% at 3.0E-02 eV/amu.

See appendix for Chebyshev fit details.

$He(2^1S) + H \rightarrow He + H^+ + e \ (\sigma_{PI})$
$He(2^1S) + H \rightarrow HeH^+ + e \ (\sigma_{AI})$

Cross Section vs. Energy



Penning, Associative, and Total Ionization Cross Sections for

$He(2^3S) + H \rightarrow He + H^+ + e$ (σ_{PI})
$He(2^3S) + H \rightarrow HeH^+ + e$ (σ_{AI})
$He(2^3S) + H \rightarrow$ (σ_{PI}) + (σ_{AI}) (Total Ion.)

Total Ion. (TI)		Penn. Ion. (PI)		Assoc. Ion. (AI)	
Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)
1.3E-02	4.26E-15	1.2E-02	2.95E-15	1.2E-02	1.34E-15
1.5E-02	4.12E-15	1.5E-02	2.80E-15	1.5E-02	1.25E-15
2.0E-02	3.84E-15	2.0E-02	2.61E-15	2.0E-02	1.13E-15
4.0E-02	3.05E-15	4.0E-02	2.20E-15	4.0E-02	8.08E-16
6.0E-02	2.55E-15	6.0E-02	1.95E-15	6.0E-02	6.14E-16
8.0E-02	2.24E-15	8.0E-02	1.77E-15	8.0E-02	4.90E-16
1.0E-01	2.02E-15	1.0E-01	1.61E-15	1.0E-01	3.99E-16
1.5E-01	1.64E-15	1.5E-01	1.36E-15	1.5E-01	2.67E-16
2.0E-01	1.40E-15	2.0E-01	1.19E-15	2.0E-01	1.95E-16
4.0E-01	9.79E-16	3.0E-01	9.77E-16	4.0E-01	9.18E-17
6.0E-01	7.72E-16	5.0E-01	7.58E-16	6.0E-01	5.98E-17
8.0E-01	6.31E-16	7.0E-01	6.13E-16	8.0E-01	4.54E-17
1.0E+00	5.25E-16	1.0E+00	4.88E-16	1.0E+00	3.69E-17
1.5E+00	3.92E-16	1.5E+00	3.87E-16	1.5E+00	2.53E-17
2.0E+00	3.44E-16	2.0E+00	3.36E-16	2.0E+00	1.93E-17
4.0E+00	2.54E-16	4.0E+00	2.49E-16	4.0E+00	9.51E-18
6.0E+00	2.13E-16	6.0E+00	2.10E-16	6.0E+00	6.12E-18
8.0E+00	1.89E-16	8.0E+00	1.86E-16	8.0E+00	4.11E-18
1.0E+01	1.71E-16	1.0E+01	1.71E-16	1.0E+01	2.17E-18
1.3E+01	1.53E-16	1.3E+01	1.51E-16	1.3E+01	9.08E-19

References: 420, 421, 422, 423, 424, 423, 425, 426, 427, 428, 429, 430, 431, 432, 433

Accuracy: 100%

Notes: (1) The total ionization of H by low energy metastable $He(2^3S)$ is the sum of the cross section for Penning ionization σ_{PI} - $He(2^3S) + H \rightarrow He + H^+ + e$ and associative ionization σ_{AI} - $He(2^3S) + H \rightarrow HeH^+ + e$. (2) Much of the data have been taken such that the entire metastable beam is in the 2^3S state. Measurements have shown that the ratio of singlet to triplet states in ion beams is approximately 0.1. This assumption results in an error well within the experimental errors. (3) Total ionization is also referred to as chemionization. (4) The energy level of the 2^3S is 19.82 eV with a lifetime of 7900 sec.

Chebyshev Fitting Parameters for Cross Sections

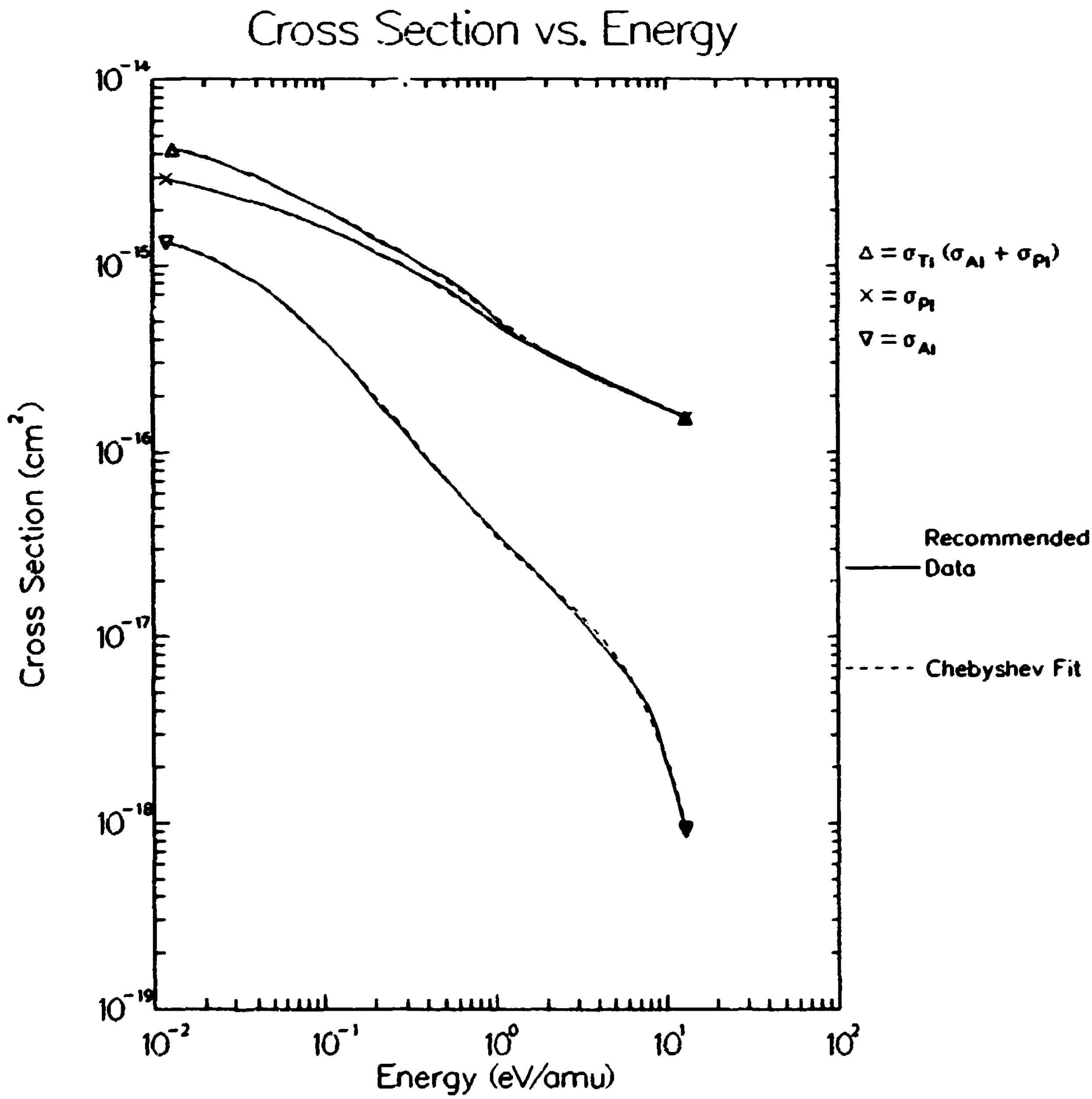
Total Ion. (TI) E_{min} = 1.3E-02 eV/amu, E_{max} = 1.3E+01 eV/amu
Penn. Ion. (PI) E_{min} = 1.2E-02 eV/amu, E_{max} = 1.3E+01 eV/amu
Assoc. Ion. (AI) E_{min} = 1.2E-02 eV/amu, E_{max} = 1.3E+01 eV/amu

	A0	A1	A2	A3	A4	A5	A6
Total Ion. (TI)	-69.3748	-1.75540	-.0609031	.106912	.0109231	-.0140956	-.0257512
Penn. Ion. (PI)	-69.6823	-1.55608	-.107728	.0932212	.0140800	-.0224249	-.0110671
Assoc. Ion. (AI)	-74.3566	-1.45106	-.466805	-.0598336	-.211902	-.116545	-.0298545

The fit represents the (TI) cross section with an rms deviation of 1.9%.
The maximum deviation is 4.7% at 1.5E+00 eV/amu.
The fit represents the (PI) cross section with an rms deviation of 0.9%.
The maximum deviation is 1.5% at 1.5E+00 eV/amu.
The fit represents the (AI) cross section with an rms deviation of 3.2%.
The maximum deviation is 8.6% at 4.0E+00 eV/amu.

See appendix for Chebyshev fit details.

$He(2^3S) + H \rightarrow He + H^+ + e \ (\sigma_{PI})$
$He(2^3S) + H \rightarrow HeH^+ + e \ (\sigma_{AI})$



Total, Penning, and Rearrangement Ionization Cross Sections for $He(2^3S) + H_2 \rightarrow$ Ion Formation

Total Ionization (TI) Energy (eV/amu)	Total Ionization (TI) Cross Section (cm^2)	Rearrangement Ionization (RI) Energy (eV/amu)	Rearrangement Ionization (RI) Cross Section (cm^2)
2.0E-02	6.19E-17	3.0E-02	1.12E-17
3.0E-02	1.02E-16	4.0E-02	1.22E-17
4.0E-02	1.45E-16	5.0E-02	1.37E-17
5.0E-02	1.89E-16	6.0E-02	1.55E-17
6.0E-02	2.36E-16	7.0E-02	1.74E-17
7.0E-02	2.84E-16	8.0E-02	1.92E-17
8.0E-02	3.34E-16	9.0E-02	2.06E-17
9.0E-02	3.86E-16	1.0E-01	2.19E-17
1.0E-01	4.39E-16	1.5E-01	2.79E-17
1.5E-01	7.21E-16	2.0E-01	3.35E-17
1.7E-01	8.04E-16	3.0E-01	4.47E-17
		4.0E-01	5.55E-17
		5.0E-01	6.58E-17
		6.0E-01	7.62E-17
		7.0E-01	8.70E-17
		7.5E-01	9.18E-17

<u>References:</u> 412, 421, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456

<u>Accuracy:</u> Unknown

<u>Notes:</u> (1) The measurement of metastable helium in H_2 is very difficult and the experimental results are inconsistent. Therefore the data should not be taken as absolute. The total ionization cross sections at thermal energies which are plotted at 0.03 eV/amu vary by a factor of six among eight measurements in glow discharges, flowing afterglow and merged beams. (2) The processes to form ions are: (a) Penning ionization (PI), $He(2^3S) + H_2 \rightarrow He + H^{2+} + e$; (b) associative ionization (AI) $He(2^3S) + H_2 \rightarrow HeH^+ + e$; (c) dissociative ionization (DI) $He(2^3S) + H_2 \rightarrow He + H^+ + H + e$; (d) Rearrangement ionization (RI) $He(2^3S) + H_2 \rightarrow HeH^+ + H + e$; (e) Ion pair production (IPP) $He(2^3S) + H_2 \rightarrow He + H^+ + H^-$. The sum of these processes is know as total ionization or chemionization; (3) Note that the total ionization is the same as Penning ionization within the experimental errors; (4) The energy level of the 2^3S is 19.82 eV with a lifetime of 7900 sec.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

Total Ion. (TI) E_{min} = 2.0E-02 eV/amu, E_{max} = 1.7E-01 eV/amu
Rearrang. Ion. (RI) E_{min} = 3.0E-02 eV/amu, E_{max} = 7.5E-01 eV/amu

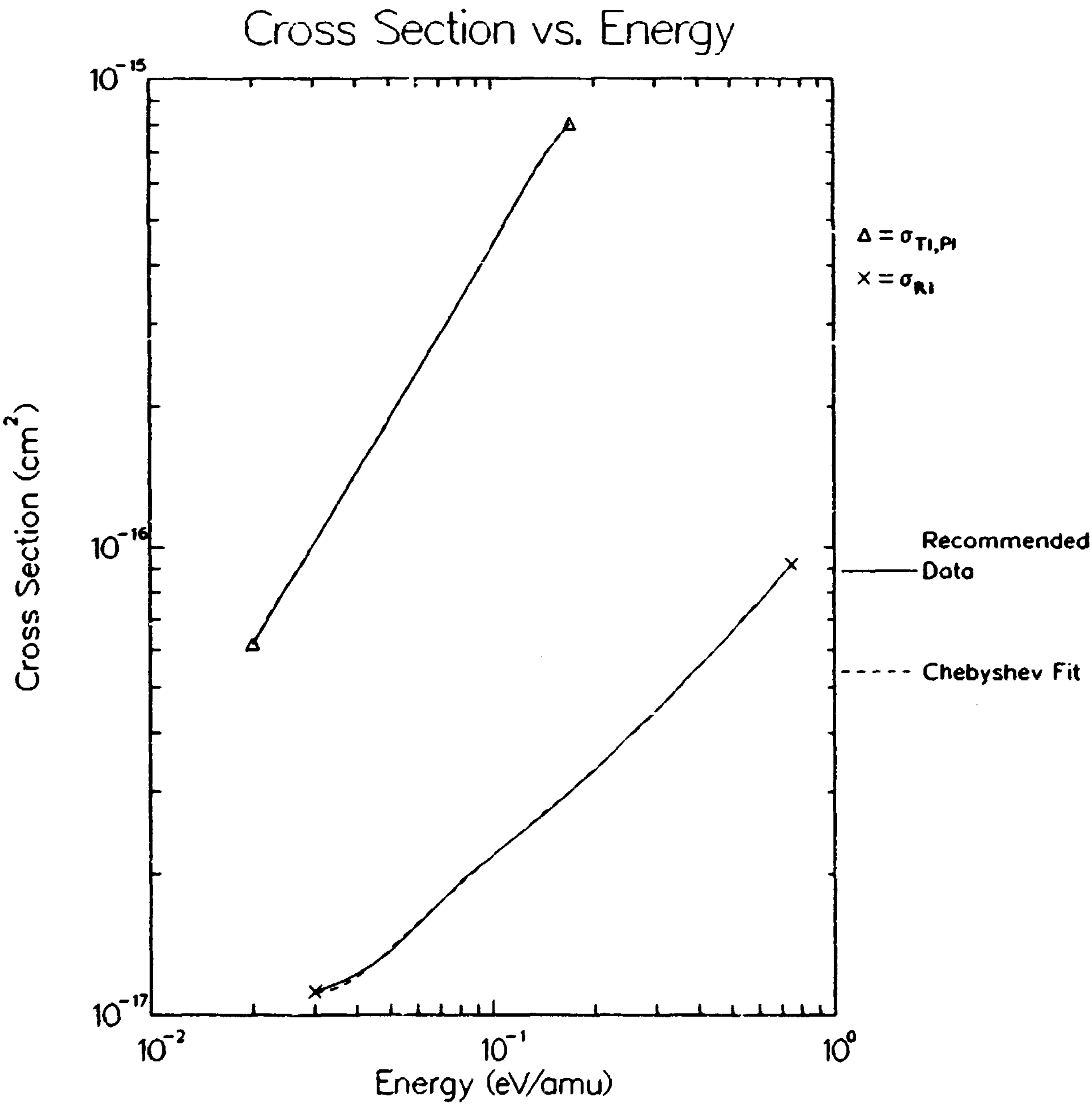
	A0	A1	A2	A3	A4	A5	A6
Total Ion. (TI)	-72.0362	1.29388	-.00614640	-.00568072	-.00984080	-.00595660	-.00475204
Rearrang. Ion. (RI)	-76.1234	1.06951	.0610251	-.000279924	.0164987	-.0176903	.00723031

The fit represents the (TI) cross section with an rms deviation of 0.2%. The maximum deviation is 0.3% at 5.0E-02 eV/amu.

The fit represents the (RI) cross section with an rms deviation of 0.5%. The maximum deviation is 0.9% at 6.0E-02 eV/amu.

See appendix for Chebyshev fit details.

$He(2^3S) + H_2$ -> Ion Formation



Total, Penning, and Rearrangement Ionization Cross Sections for $He(2^1S) + H_2 \rightarrow$ Ion Formation

Total Ionization (TI) Energy (eV/amu)	Total Ionization (TI) Cross Section (cm^2)	Rearrangement Ionization (RI) Energy (eV/amu)	Rearrangement Ionization (RI) Cross Section (cm^2)
2.8E-02	9.97E-17	3.0E-02	1.19E-17
3.0E-02	1.11E-16	4.0E-02	1.47E-17
3.5E-02	1.35E-16	5.0E-02	1.69E-17
4.0E-02	1.58E-16	6.0E-02	1.90E-17
5.0E-02	2.04E-16	7.0E-02	2.08E-17
6.0E-02	2.50E-16	8.0E-02	2.26E-17
7.0E-02	2.94E-16	9.0E-02	2.41E-17
8.0E-02	3.40E-16	1.0E-01	2.51E-17
9.0E-02	3.77E-16	1.1E-01	2.55E-17
1.0E-01	4.07E-16	1.5E-01	2.19E-17
1.5E-01	5.00E-16	2.0E-01	1.83E-17
1.8E-01	5.39E-16	2.5E-01	1.57E-17
		3.0E-01	1.38E-17
		4.0E-01	1.12E-17
		5.0E-01	9.61E-18
		6.0E-01	8.38E-18
		7.0E-01	7.47E-18
		7.5E-01	7.12E-18

<u>References:</u> 412, 421, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456

<u>Accuracy:</u> Unknown

<u>Notes:</u> (1) The measurement of metastable helium in H_2 is very difficult and the results are inconsistent. Therefore, the data should not be taken as absolute. (2) The processes to form ions are: (a) Penning ionization (PI) $He(2^1S) + H_2 \rightarrow He + H_2^+ + e$; (b) Associative ionization (AI) $He(2^1S) + H_2 \rightarrow HeH_2^+ + e$; (c) Dissociative ionization (DI) $He(2^1S) + H_2 \rightarrow He + H^+ + H + e$; (d) Rearrangement ionization (RI) $He(2^1S) + H_2 \rightarrow HeH^+ + H + e$; (e) Ion pair production (IPP) $He(2^1S) + H_2 \rightarrow He + H^+ + H^-$. The sum of these processes is known as total ionization or chemionization. (3) Note that the Penning ionization and the total ionization are the same within experimental errors; (4) The energy of the 2^1S state is 20.61 eV with a lifetime of 2×10^{-2} sec.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

Total Ion. (TI) E_{min} = 2.8E-02 eV/amu, E_{max} = 1.8E-01 eV/amu
Rearrang. Ion. (RI) E_{min} = 3.0E-02 eV/amu, E_{max} = 7.5E-01 eV/amu

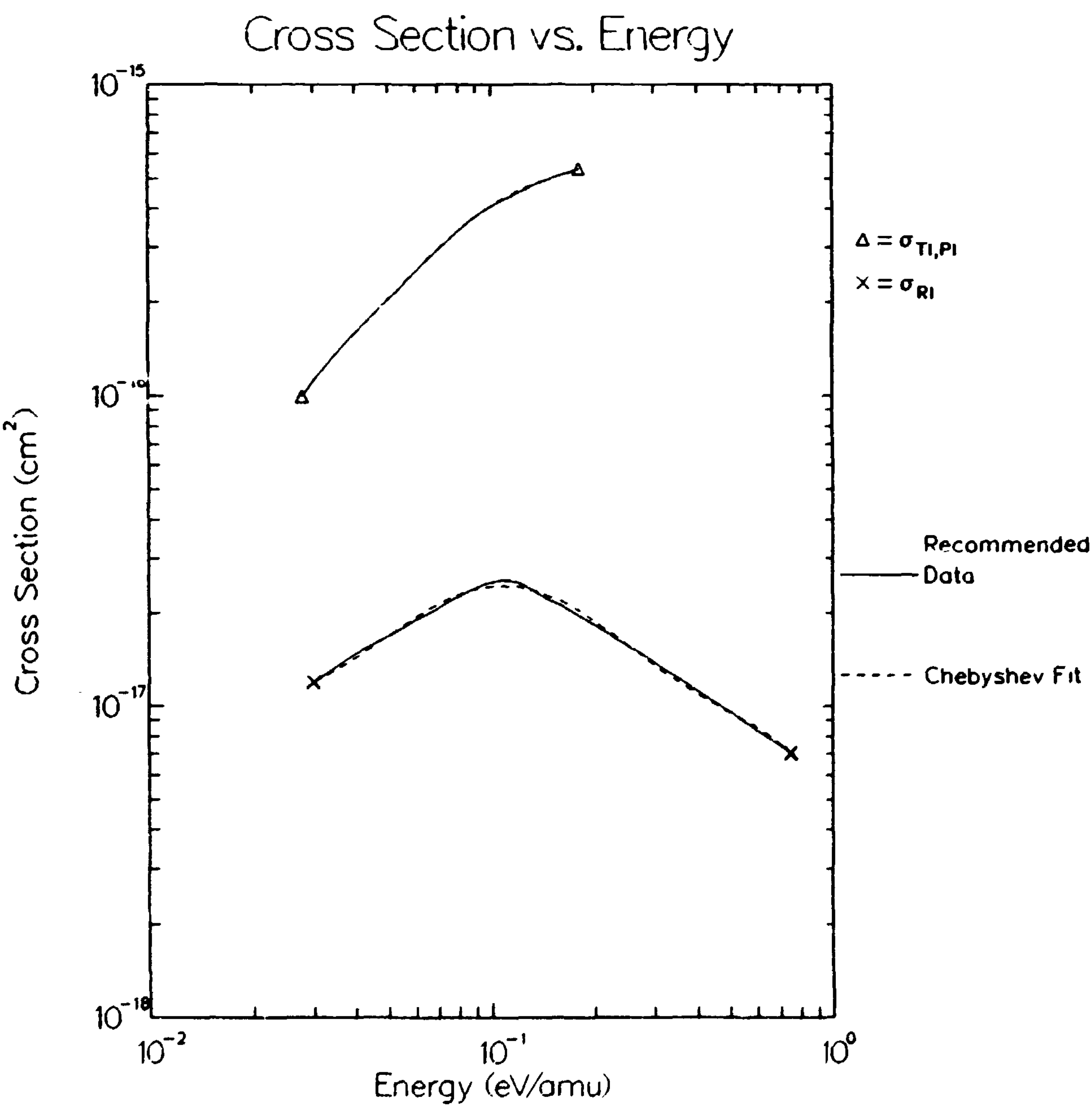
	A0	A1	A2	A3	A4	A5	A6
Total Ion. (TI)	-71.7445	.851023	-.128729	-.0202443	.00116383	.0124597	-.000179356
Rearrang. Ion. (RI)	-77.6786	-.311173	-.434644	.0826330	.0582759	-.0400365	-.0150564

The fit represents the (TI) cross section with an rms deviation of 0.3%. The maximum deviation is 0.6% at 7.0E-02 eV/amu.

The fit represents the (RI) cross section with an rms deviation of 2.1%. The maximum deviation is 2.9% at 7.0E-02 eV/amu.

See appendix for Chebyshev fit details.

He(2¹S) + H_2 -> Ion Formation



Ionization and He^{2+} Production Cross Sections for

$H^+ + He^+ \to (H^+ + He^{2+} + e)$ (σ_i)
$H^+ + He^+ \to (H^+ + He^{2+} + e)$ or $(H^0 + He^{2+})$ $(\sigma_{He}{}^{2+})$

Ionization		He^{2+} Production	
Energy (eV/amu)	Cross Section (cm^2)	Energy (eV/amu)	Cross Section (cm^2)
2.0E+04	4.20E-19	3.7E+03	9.25E-20
2.5E+04	7.50E-19	4.0E+03	1.08E-19
3.0E+04	1.18E-18	5.0E+03	1.62E-19
3.5E+04	1.67E-18	6.0E+03	2.41E-19
4.0E+04	2.21E-18	7.0E+03	3.55E-19
4.5E+04	2.80E-18	8.0E+03	5.35E-19
5.0E+04	3.42E-18	9.0E+03	7.92E-19
6.0E+04	4.69E-18	1.0E+04	1.12E-18
7.0E+04	5.92E-18	1.5E+04	4.31E-18
8.0E+04	6.98E-18	2.0E+04	9.33E-18
9.0E+04	8.00E-18	2.5E+04	1.44E-17
1.0E+05	8.97E-18	3.0E+04	1.89E-17
1.5E+05	1.09E-17	4.0E+04	2.52E-17
2.0E+05	1.01E-17	4.5E+04	2.71E-17
3.0E+05	7.74E-18	5.0E+04	2.86E-17
4.0E+05	6.36E-18	6.0E+04	2.96E-17
5.0E+05	5.19E-18	7.0E+04	2.93E-17
		8.0E+04	2.81E-17
		9.0E+04	2.64E-17
		1.0E+05	2.42E-17
		1.5E+05	1.75E-17
		2.0E+05	1.36E-17
		3.0E+05	8.97E-18
		4.0E+05	6.56E-18
		5.0E+05	5.12E-18

References: 69, 73, 75, 76, 77, 81, 278, 279, 458

Accuracy: Ionization - 60%
He^{2+} Production - 30%

Notes: (1) The production of He^{2+} arises from two processes: (a) Charge exchange ($H^+ + He^+ \to H + He^{2+}$) and (b) Ionization ($H^+ + He^+ \to H^+ + He^{2+} + e$). (2) At energies less than approximately 2.0 - 3.0×10^5 eV/amu the charge exchange process is dominant. Above this energy the ionization reaction dominates.

Chebyshev Fitting Parameters for Cross Sections

Ionization E_{min} = 2.0E+04 eV/amu, E_{max} = 5.0E+05 eV/amu
He^{2+} Production E_{min} = 3.7E+03 eV/amu, E_{max} = 5.0E+05 eV/amu

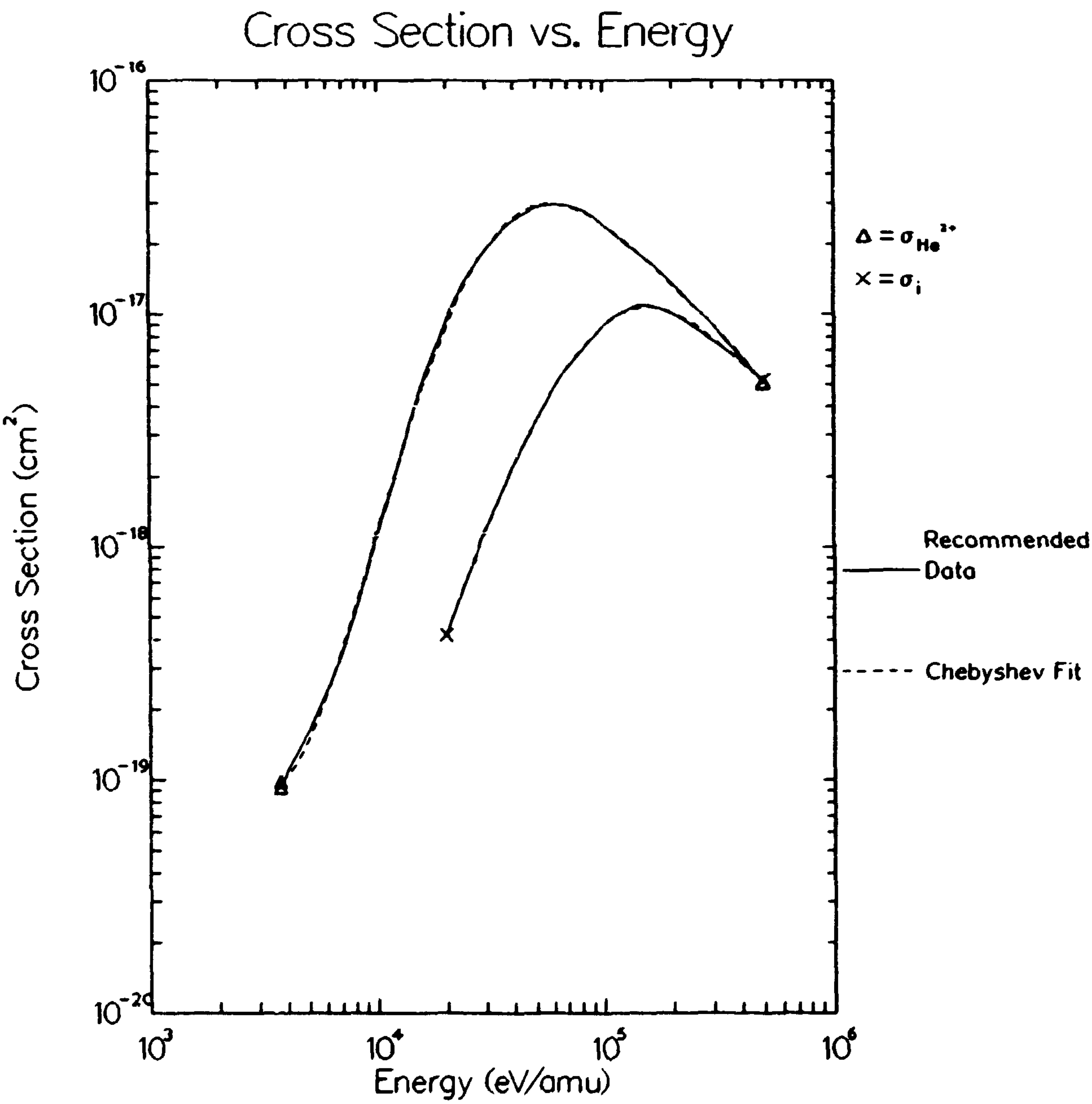
	A0	A1	A2	A3	A4	A5	A6
Ionization	-80.4308	1.24048	-.890202	.00345922	.0570045	.0193037	-.00746147
He^{2+} Production	-80.5893	2.10007	-1.81896	-.00398887	.325128	-.125749	-.00793823

The fit represents the Ionization cross section with an rms deviation of 1.1%. The maximum deviation is 2.1% at 3.0E+05 eV/amu.

The fit represents the He^{2+} Production cross section with an rms deviation of 3.2%. The maximum deviation is 6.2% at 3.7E+03 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + He^+ \rightarrow (H^+ + He^{2+} + e)$ or $(H + He^{2+})$ $(\sigma_{He}{}^{2+})$
$H^+ + He^+ \rightarrow H^+ + He^{2+} + e$ (σ_i)



Ionization Rate Coefficients for

$He^{+} + H^{+} \rightarrow He^{2+} + H^{+} + e$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	He$^+$ Energy (eV/amu) 20000.	40000.	60000.	80000.	100000.	200000.	500000.
1.0E+00	4.25E-11*	6.14E-10	1.60E-09	2.70E-09	3.89E-09	6.27E-09	2.55E-09#
2.0E+00	4.30E-11*	6.14E-10	1.60E-09	2.74E-09	3.93E-09	6.27E-09	2.55E-09#
4.0E+00	4.37E-11*	6.14E-10	1.59E-09	2.74E-09	3.93E-09	6.27E-09	2.55E-09#
7.0E+00	4.46E-11*	6.14E-10	1.59E-09	2.74E-09	3.93E-09	6.27E-09	2.55E-09#
1.0E+01	4.52E-11*	6.15E-10	1.59E-09	2.74E-09	3.93E-09	6.26E-09	2.55E-09#
2.0E+01	4.70E-11*	6.16E-10	1.60E-09	2.74E-09	3.92E-09	6.26E-09	2.55E-09#
4.0E+01	4.98E-11*	6.18E-10	1.60E-09	2.74E-09	3.92E-09	6.25E-09	2.55E-09#
7.0E+01	5.30E-11*	6.21E-10	1.60E-09	2.75E-09	3.91E-09	6.25E-09	2.54E-09#
1.0E+02	5.57E-11*	6.24E-10	1.60E-09	2.75E-09	3.91E-09	6.24E-09	2.54E-09#
2.0E+02	6.36E-11*	6.35E-10	1.61E-09	2.76E-09	3.90E-09	6.23E-09	2.54E-09#
4.0E+02	7.68E-11*	6.56E-10	1.63E-09	2.78E-09	3.89E-09	6.21E-09	2.54E-09#
7.0E+02	9.48E-11*	6.87E-10	1.67E-09	2.81E-09	3.89E-09	6.19E-09	2.54E-09#
1.0E+03	1.12E-10*	7.17E-10	1.70E-09	2.83E-09	3.89E-09	6.18E-09	2.54E-09#
2.0E+03	1.69E-10*	8.17E-10	1.80E-09	2.89E-09	3.91E-09	6.13E-09	2.53E-09#
4.0E+03	2.88E-10	1.01E-09	1.98E-09	3.01E-09	3.96E-09	6.05E-09	2.52E-09#
7.0E+03	4.80E-10	1.27E-09	2.22E-09	3.17E-09	4.02E-09	5.95E-09	2.51E-09#
1.0E+04	6.80E-10	1.51E-09	2.42E-09	3.30E-09	4.07E-09	5.86E-09	2.49E-09#
2.0E+04	1.34E-09	2.16E-09	2.93E-09	3.62E-09	4.21E-09	5.60E-09	2.44E-09#

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

Chebyshev Fitting Parameters for Rate Coefficients

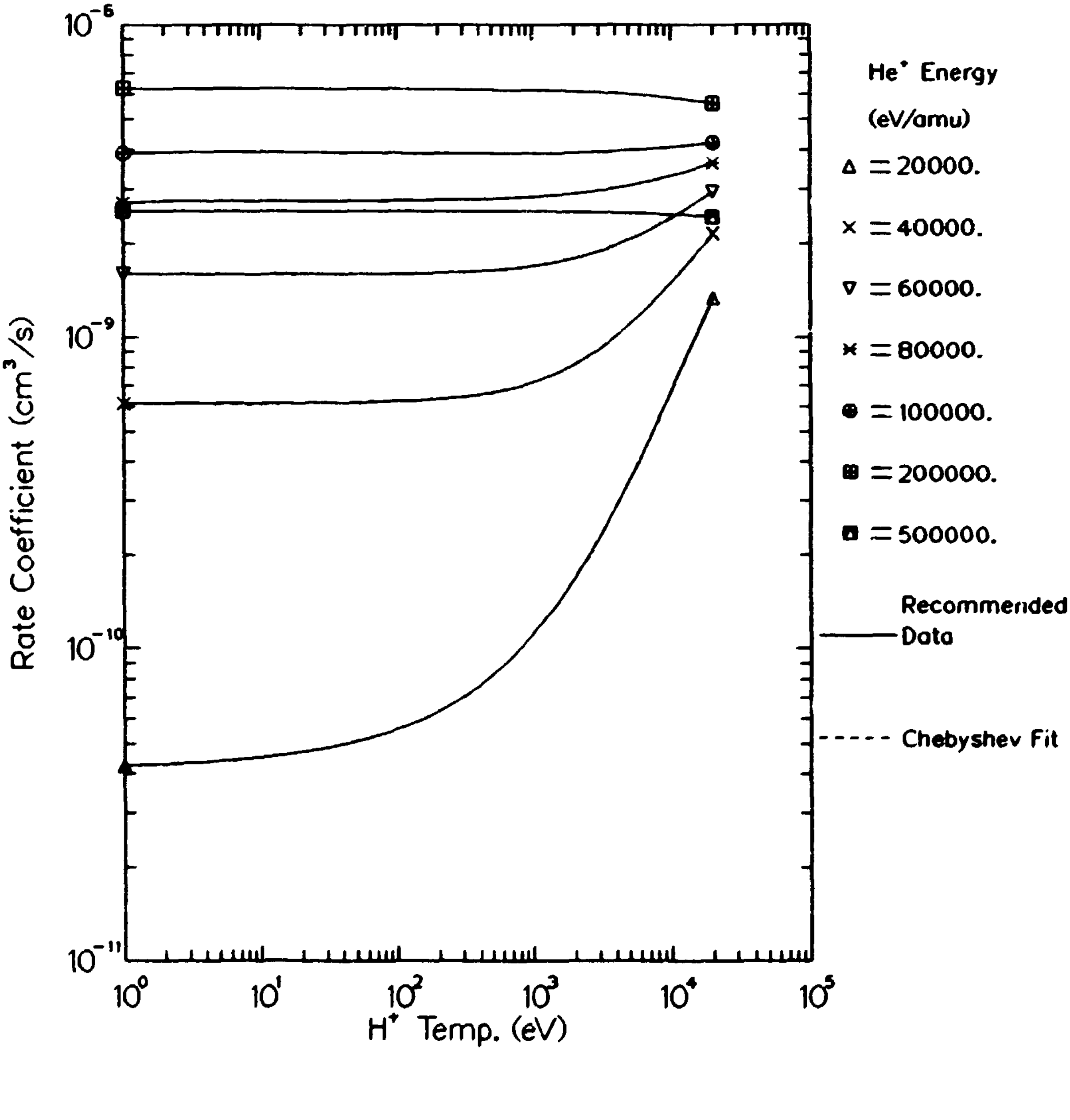
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

He$^+$ Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
20000.	-45.6943	1.57907	.710583	.175768	-.00705451	-.0284130	-.0139117
40000.	-41.8177	.512347	.311944	.126340	.0238811	-.00849678	-.00968659
60000.	-40.2324	.239690	.153320	.0661005	.0168871	-.00195984	-.00376827
80000.	-39.3054	.111744	.0654773	.0331289	.00699774	.00254954	-.00222373
100000.	-38.6923	.0227031	.0195819	.0149078	.00271827	.00119878	-.00147599
200000.	-37.8257	-.0418823	-.0248902	-.0123878	-.00550012	-.00208690	-5.276582E-04
500000.	-39.5936	-.0146717	-.00937139	-.00524336	-.00267631	-.00119132	-4.070685E-04

See appendix for Chebyshev fit details

$He^{+} + H^{+} \rightarrow He^{2+} + H^{+} + e$

Beam – Maxwellian



He^{2+} Production Rate Coefficients for

$H^{+} + He^{+} \rightarrow (H^{+} + He^{2+} + e)$ or $(H + He^{2+})$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	Equal Temp.	He$^+$ Temp. (eV) 1000.	2000.	4000.	7000.	10000.	15000.	20000.
3.0E+02	1.95E-15#	4.34E-14#	3.74E-13#	3.02E-12#	1.65E-11*	4.93E-11	1.62E-10	3.47E-10
5.0E+02	9.77E-14#	2.70E-13#	1.04E-12#	5.22E-12*	2.30E-11*	6.23E-11	1.87E-10	3.83E-10
7.0E+02	5.74E-13#	8.33E-13#	2.21E-12#	8.32E-12*	3.11E-11*	7.71E-11	2.14E-10	4.20E-.0
9.0E+02	1.70E-12#	1.86E-12#	4.02E-12*	1.25E-11*	4.08E-11	9.39E-11	2.42E-10	4.59E-10
1.0E+03	2.59E-12#	2.59E-12#	5.22E-12*	1.51E-11*	4.64E-11	1.03E-10	2.57E-10	4.78E-10
1.3E+03	6.08E-12*	5.22E-12*	9.26E-12*	2.30E-11*	6.23E-11	1.28E-10	2.97E-10	5.29E-10
1.5E+03	1.19E-11*	9.26E-12*	1.51E-11*	3.34E-11	8.11E-11	1.56E-10	3.39E-10	5.82E-10
1.8E+03	2.08E-11*	1.51E-11*	2.30E-11*	4.64E-11	1.03E-10	1.87E-10	3.83E-10	6.36E-10
2.0E+03	3.34E-11	2.30E-11*	3.34E-11	6.23E-11	1.28E-10	2.21E-10	4.30E-10	6.92E-10
4.0E+03	2.97E-10	1.87E-10	2.21E-10	2.97E-10	4.30E-10	5.82E-10	8.68E-10	1.18E-09
6.0E+03	8.08E-10	5.29E-10	5.82E-10	6.92E-10	8.68E-10	1.05E-09	1.38E-09	1.72E-09
8.0E+03	1.45E-09	9.92E-10	1.05E-09	1.18E-09	1.38E-09	1.58E-09	1.92E-09	2.25E-09
1.0E+04	2.12E-09	1.51E-09	1.58E-09	1.72E-09	1.92E-09	2.12E-09	2.45E-09	2.77E-09
1.2E+04	2.77E-09	2.05E-09	2.12E-09	2.25E-09	2.45E-09	2.65E-09	2.96E-09	3.27E-09
1.4E+04	3.38E-09	2.58E-09	2.65E-09	2.77E-09	2.96E-09	3.14E-09	3.44E-09	3.72E-09
1.6E+04	3.94E-09	3.08E-09	3.14E-09	3.27E-09	3.44E-09	3.61E-09	3.89E-09	4.15E-09
1.8E+04	4.44E-09	3.56E-09	3.61E-09	3.72E-09	3.89E-09	4.04E-09	4.30E-09	4.54E-09
2.0E+04	4.89E-09	3.99E-09	4.04E-09	4.15E-09	4.30E-09	4.44E-09	4.67E-09	4.89E-09

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

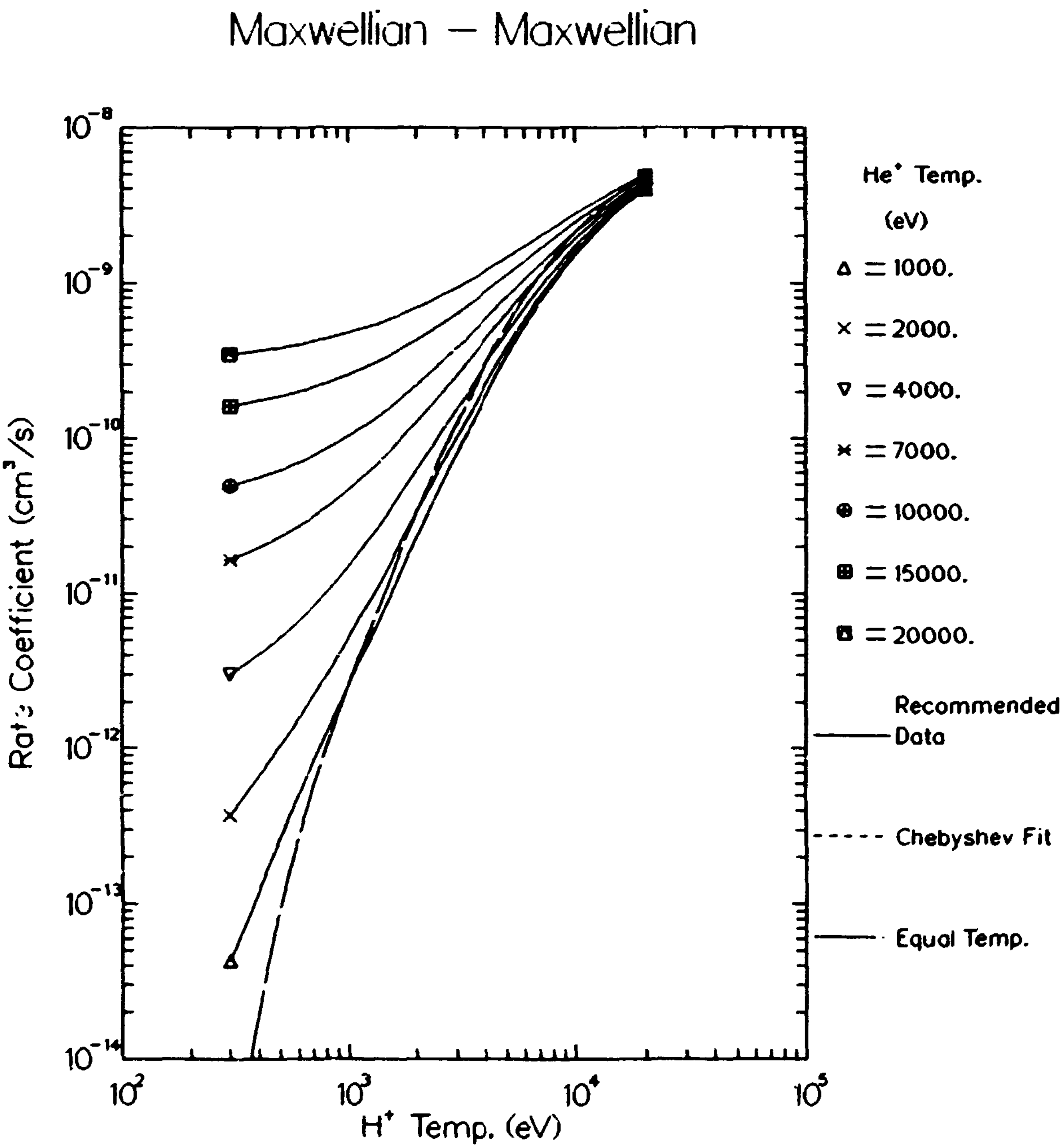
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 3.0E+02 eV, E_{max} = 2.0E+04 eV

He$^+$ Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
1000.	-48.8313	5.83309	-.599670	-.148905	-.0411485	.0351803	.00376359
2000.	-47.5113	4.87892	-.205206	-.261188	-.00849826	.0291892	-3.733670E-04
4000.	-45.9304	3.85019	.0664286	-.260544	-.0126575	.0232481	-8.770358E-04
7000.	-44.4276	2.96296	.192841	-.194359	-.0273665	.0145816	.00158914
10000.	-43.3804	2.38527	.238913	-.143127	-.0314989	.00836597	.00280697
15000.	-42.1743	1.76616	.255545	-.0870174	-.0337594	.00196449	.00271327
20000.	-41.3491	1.37656	.243899	-.0536024	-.0298721	-.00120071	.00208341
Equal Temp.	-49.5753	7.04496	-1.51108	.221849	-.184942	.102821	-.0193609

See appendix for Chebysnev fit details.

$H^+ + He^+ \rightarrow (H^+ + He^{2+} + e)$ or $(H + He^{2+})$



He^{2+} Production Rate Coefficients for

$He^{+} + H^{+} \rightarrow (He^{2+} + H^{+} + e)$ or $(He^{2+} + H)$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H^{+} Temp. (eV)	He^{+} Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	1.56E-10	1.83E-09	6.99E-09	1.08E-08	1.06E-08	8.45E-09	2.51E-09#
2.0E+00	1.56E-10	1.83E-09	6.99E-09	1.08E-08	1.06E-08	8.45E-09	2.51E-09#
4.0E+00	1.57E-10	1.83E-09	6.99E-09	1.08E-08	1.06E-08	8.44E-09	2.51E-09#
7.0E+00	1.57E-10	1.82E-09	6.98E-09	1.08E-08	1.06E-08	8.44E-09	2.51E-09#
1.0E+01	1.58E-10	1.82E-09	6.98E-09	1.08E-08	1.06E-08	8.44E-09	2.52E-09#
2.0E+01	1.61E-10	1.83E-09	6.98E-09	1.07E-08	1.06E-08	8.44E-09	2.52E-09#
4.0E+01	1.66E-10	1.83E-09	6.97E-09	1.07E-08	1.06E-08	8.44E-09	2.52E-09#
7.0E+01	1.74E-10	1.85E-09	6.97E-09	1.07E-08	1.06E-08	8.43E-09	2.52E-09#
1.0E+02	1.83E-10	1.86E-09	6.97E-09	1.07E-08	1.06E-08	8.43E-09	2.52E-09#
2.0E+02	2.12E-10	1.92E-09	6.97E-09	1.07E-08	1.06E-08	8.42E-09	2.52E-09#
4.0E+02	2.73E-10	2.02E-09	6.99E-09	1.06E-08	1.06E-08	8.41E-09	2.52E-09#
7.0E+02	3.69E-10	2.18E-09	7.01E-09	1.06E-08	1.06E-08	8.40E-09	2.53E-09#
1.0E+03	4.69E-10	2.32E-09	7.03E-09	1.05E-08	1.06E-08	8.40E-09	2.53E-09#
2.0E+03	8.12E-10	2.76E-09	7.11E-09	1.03E-08	1.05E-08	8.37E-09	2.53E-09#
4.0E+03	1.49E-09	3.47E-09	7.24E-09	1.00E-08	1.03E-08	8.33E-09	2.54E-09#
7.0E+03	2.42E-09	4.29E-09	7.40E-09	9.66E-09	1.00E-08	8.29E-09	2.55E-09#
1.0E+04	3.24E-09	4.92E-09	7.52E-09	9.41E-09	9.77E-09	8.24E-09	2.56E-09#
2.0E+04	5.23E-09	6.29E-09	7.81E-09	8.92E-09	9.18E-09	8.01E-09	2.58E-09#

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

Chebyshev Fitting Parameters for Rate Coefficients

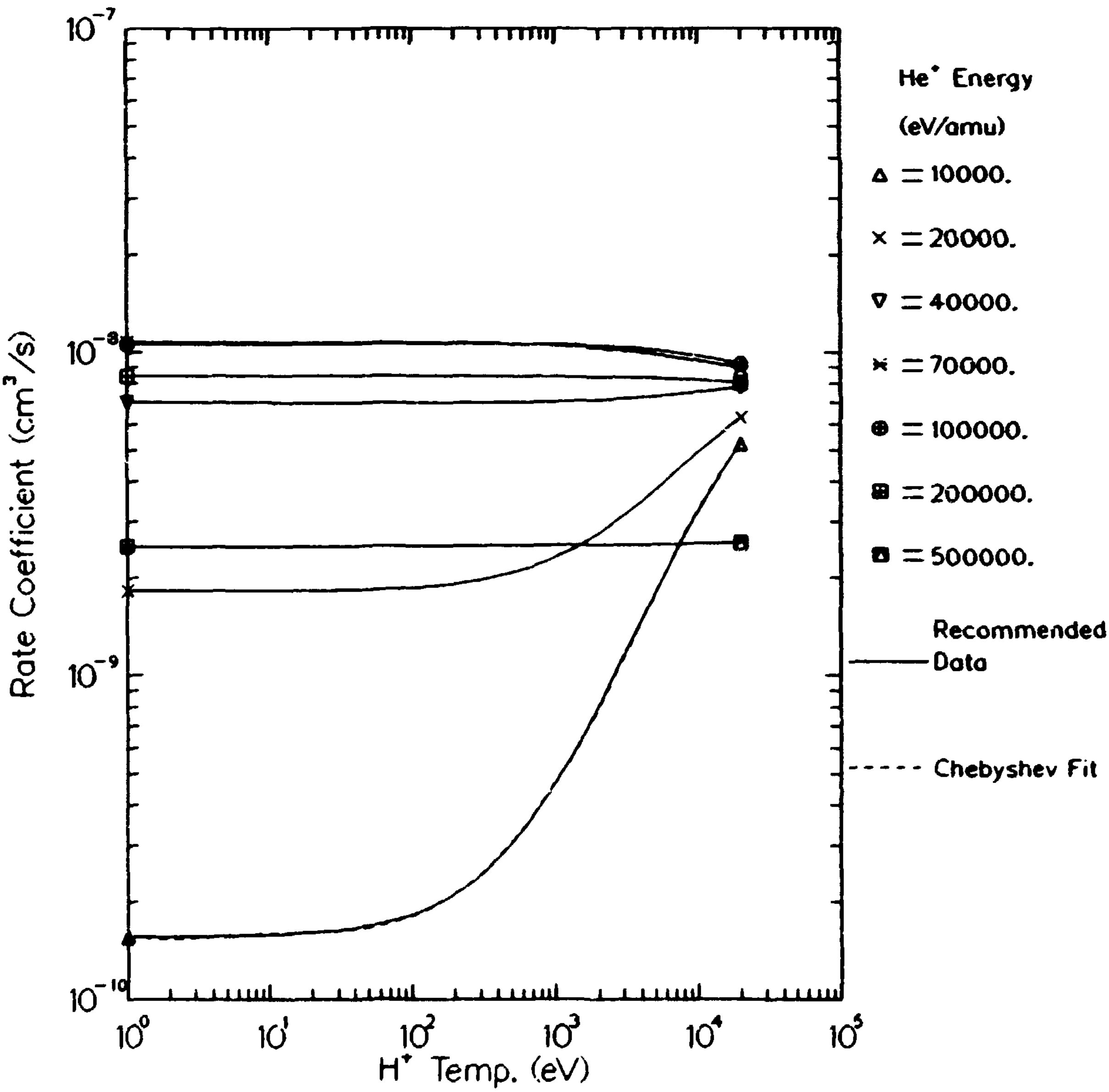
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

He^{+} Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-42.9783	1.71856	.769214	.0945643	-.105175	-.0612282	-1.282705E-04
20000.	-39.5695	.556768	.303458	.0843952	-.0122473	-.0224889	-.00919993
40000.	-37.5112	.0421662	.0299866	.0131929	.00299530	-2.171997E-04	-6.745161E-04
70000.	-36.7855	-.0761446	-.0461124	-.0196107	-.00417912	.00142605	.00181386
100000.	-36.7766	-.0515173	-.0368252	-.0201855	-.00804421	-.00194056	1.214410E-04
200000.	-37.2003	-.0177798	-.0110628	-.00629544	-.00355051	-.00193013	-.00100821
500000.	-39.5894	.0104222	.00514715	.00174490	3.638925E-04	-8.415182E-06	-5.520857E-05

See appendix for Chebyshev fit details.

$He^{+} + H^{+} \rightarrow (He^{2+} + H^{+} + e)$ or $(He^{2+} + H)$

Beam – Maxwellian



Ionization and He^{2+} Production Cross Sections for

$He^+ + He^+ \rightarrow (He^+ + He^{2+} + e)$ (σ_i)
$He^+ + He^+ \rightarrow (He + He^{2+})$ or $(He^+ + He^{2+} + e)$ $(\sigma_{He}{}^{2+})$

Ionization Energy (eV/amu)	Ionization Cross Section (cm^2)	He^{2+} Production Energy (eV/amu)	He^{2+} Production Cross Section (cm^2)
1.0E+04	6.35E-19	5.9E+03	3.46E-18
1.5E+04	1.72E-18	6.0E+03	3.67E-18
2.0E+04	3.12E-18	7.0E+03	4.94E-18
2.5E+04	4.75E-18	8.0E+03	6.38E-18
3.0E+04	6.72E-18	9.0E+03	7.84E-18
3.5E+04	8.79E-18	1.0E+04	9.34E-18
4.0E+04	1.08E-17	1.5E+04	1.55E-17
4.5E+04	1.32E-17	2.0E+04	1.98E-17
5.0E+04	1.56E-17	2.5E+04	2.25E-17
5.5E+04	1.81E-17	3.0E+04	2.50E-17
5.8E+04	1.99E-17	3.5E+04	2.69E-17
		4.0E+04	2.82E-17
		4.5E+04	2.94E-17
		5.0E+04	3.00E-17
		5.5E+04	3.02E-17
		6.0E+04	3.03E-17
		6.7E+04	2.98E-17

References: 69, 277, 457

Accuracy: σ_i - Factor of 2
$\sigma_{He}{}^{2+}$ - 50%

Notes: (1) The production of He^{2+} arises from two processes: (a) Charge exchange ($He^+ + He^+ \rightarrow He + He^{2+}$); (b) Ionization ($He^+ + He^+ \rightarrow He^+ + He^{2+} + e$). (2) At energies less than 2.0 - 3.0×10^5 eV/amu the charge exchange reaction dominates. (3) The incident He^+ energy in eV/amu is plotted vs. the stationary He^+ target.

Chebyshev Fitting Parameters for Cross Sections

Ionization E_{min} = 1.0E+04 eV/amu, E_{max} = 5.8E+04 eV/amu
He^{2+} Prod. E_{min} = 5.9E+03 eV/amu, E_{max} = 6.7E+04 eV/amu

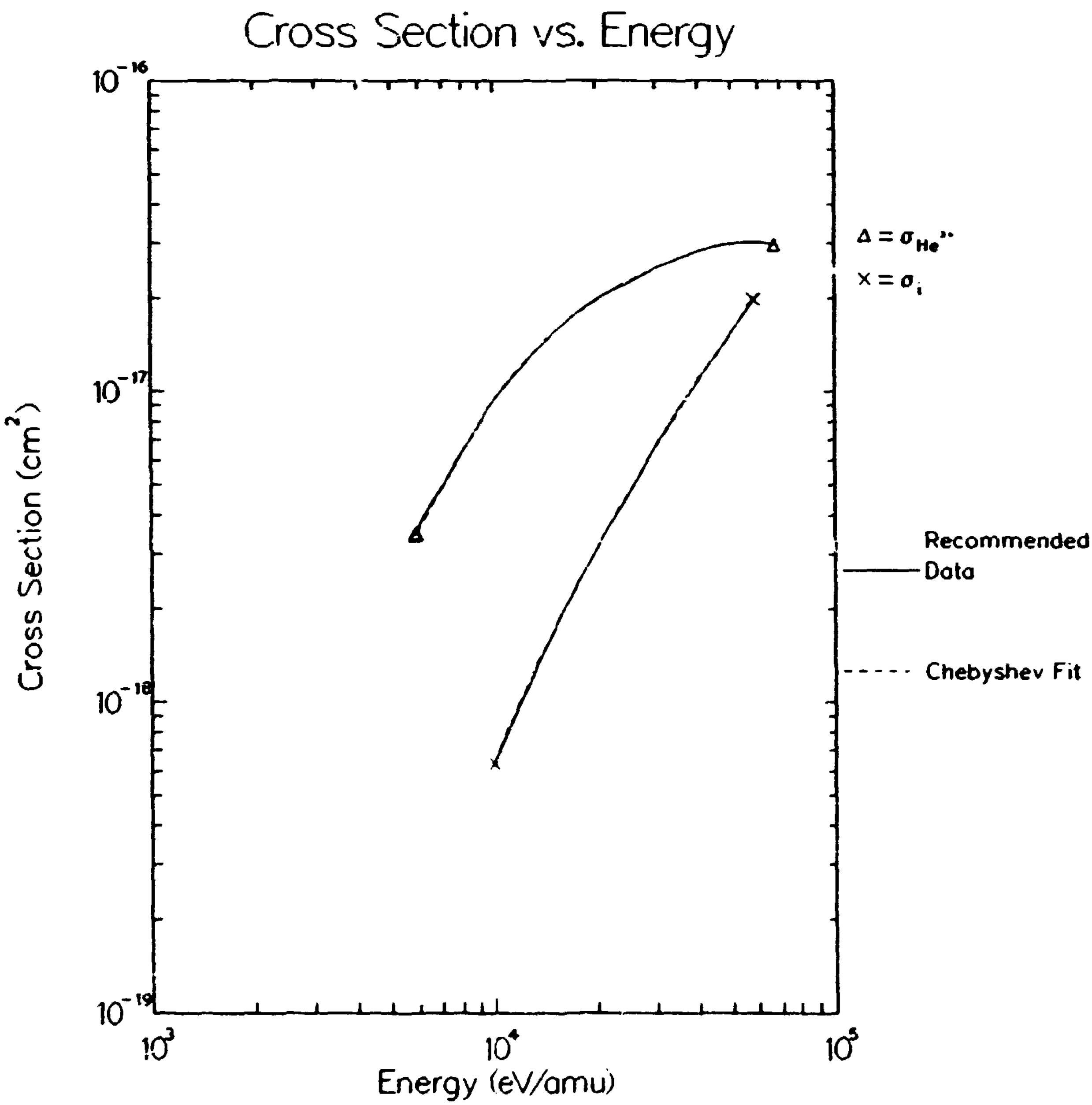
	A0	A1	A2	A3	A4	A5	A6
Ionization	-80.1208	1.69568	-.114597	.0198330	-.00494221	.00648764	.00123081
He^{2+} Prod.	-77.5761	1.04465	-.328288	.0385208	-.00883058	-.0130928	.00201232

The fit represents the Ionization cross section with an rms deviation of 0.5%. The maximum deviation is 1.0% at 4.0E+04 eV/amu.

The fit represents the He^{2+} Prod. cross section with an rms deviation of 0.5%. The maximum deviation is 1.2% at 5.9E+03 eV/amu.

See appendix for Chebyshev fit details.

$He^{+} + He^{+} \rightarrow (He^{+} + He^{2+} + e)$ or $(He + He^{2+})$ $(\sigma_{He^{2+}})$
$He^{+} + He^{+} \rightarrow He^{+} + He^{2+} + e$ (σ_{i})



Single Ionization Rate Coefficients for

$He^{+} + He^{+} \rightarrow He^{+} + He^{2+} + e$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{+} Temp. (eV)	He^{+} Energy (eV/amu) 10000.	20000.	30000.	40000.	50000.	52000.	55000.
1.0E+00	4.50E-11*	5.85E-10	1.62E-09	2.96E-09	4.85E-09	5.18E-09	5.62E-09
2.0E+00	4.53E-11*	6.12E-10	1.62E-09	3.00E-09	4.85E-09	5.25E-09	5.89E-09
4.0E+00	4.59E-11*	6.13E-10	1.62E-09	3.00E-09	4.85E-09	5.25E-09	5.90E-09
7.0E+00	4.65E-11*	6.13E-10	1.62E-09	3.00E-09	4.85E-09	5.25E-09	5.90E-09
1.0E+01	4.69E-11*	6.13E-10	1.62E-09	3.00E-09	4.85E-09	5.25E-09	5.90E-09
2.0E+01	4.82E-11*	6.13E-10	1.62E-09	3.01E-09	4.85E-09	5.26E-09	5.91E-09
4.0E+01	5.00E-11*	6.14E-10	1.62E-09	3.01E-09	4.85E-09	5.26E-09	5.90E-09
7.0E+01	5.22E-11*	6.15E-10	1.62E-09	3.01E-09	4.85E-09	5.26E-09	5.81E-09
1.0E+02	5.39E-11*	6.16E-10	1.62E-09	3.02E-09	4.86E-09	5.27E-09	5.67E-09
2.0E+02	5.89E-11*	6.21E-10	1.63E-09	3.03E-09	4.87E-09	5.24E-09	5.20E-09*
4.0E+02	6.68E-11*	6.31E-10	1.64E-09	3.06E-09	4.84E-09	5.05E-09	4.60E-09*
7.0E+02	7.70E-11*	6.46E-10	1.67E-09	3.09E-09	4.68E-09	4.70E-09*	4.10E-09*
1.0E+03	8.64E-11*	6.62E-10	1.69E-09	3.12E-09	4.49E-09*	4.40E-09*	3.79E-09*
2.0E+03	1.15E-10*	7.16E-10	1.76E-09	3.18E-09	3.93E-09*	3.75E-09*	3.24E-09*
4.0E+03	1.71E-10*	8.25E-10	1.91E-09	3.11E-09	3.28E-09*	3.10E-09*	2.74E-09#
7.0E+03	2.60E-10*	9.89E-10	2.04E-09	2.86E-09*	2.75E-09*	2.62E-09#	2.36E-09#
1.0E+04	3.57E-10	1.14E-09	2.07E-09*	2.62E-09*	2.44E-09#	2.33E-09#	2.13E-09#
2.0E+04	6.89E-10	1.42E-09*	1.95E-09*	2.09E-09*	1.88E-09#	1.81E-09#	1.69E-09#

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

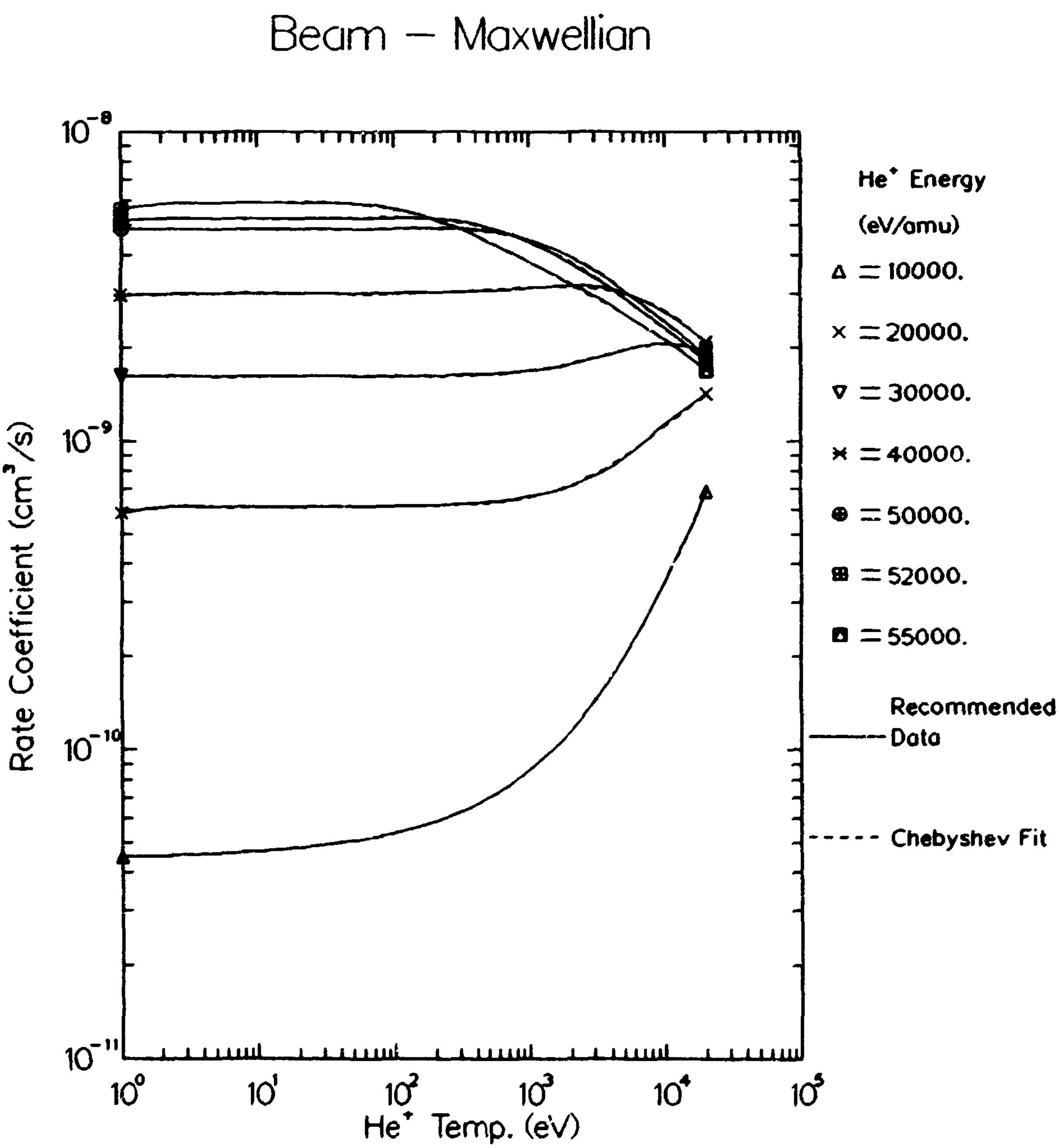
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

He^{+} Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-46.1185	1.19034	.579487	.183843	.0279275	-.00786851	-.00843904
20000.	-42.0417	.348208	.209457	.102371	.0130005	-.00449377	-.0168872
30000.	-40.3424	.114393	.0591680	.00327281	-.0216154	-.0232829	-.0142410
40000.	-39.3369	-.0868409	-.0958221	-.0743825	-.0480228	-.0161228	-1.557744E-05
50000.	-38.7358	-.388572	-.250357	-.102423	-.00799043	.0201351	.00955123
52000.	-38.6794	-.462898	-.271231	-.0815950	.00845828	.0221265	-7.913020E-04
55000.	-38.6693	-.588564	-.267081	-.0118366	.0203911	-.00168618	-.0171873

See appendix for Chebyshev fit details.

$He^{+} + He^{+} \rightarrow He^{+} + He^{2+} + e$



He^{2+} Production Rate Coefficients for

$He^{+} + He^{+} \rightarrow (He^{+} + He^{2+} + e)$ or $(He + He^{2+})$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{+} Temp. (eV)	He^{+} Energy (eV/amu) 10000.	20000.	30000.	40000.	50000.	60000.	65000.
1.0E+00	1.30E-09	3.89E-09	5.71E-09	7.84E-09	9.32E-09	1.03E-08	1.06E-08
2.0E+00	1.30E-09	3.89E-09	5.99E-09	7.83E-09	9.32E-09	1.03E-08	1.06E-08
4.0E+00	1.30E-09	3.89E-09	6.01E-09	7.83E-09	9.32E-09	1.03E-08	1.06E-08
7.0E+00	1.29E-09	3.88E-09	6.01E-09	7.83E-09	9.31E-09	1.03E-08	1.06E-08
1.0E+01	1.29E-09	3.88E-09	6.01E-09	7.84E-09	9.31E-09	1.03E-08	1.06E-08
2.0E+01	1.29E-09	3.88E-09	6.01E-09	7.84E-09	9.31E-09	1.03E-08	1.05E-08
4.0E+01	1.29E-09	3.88E-09	6.01E-09	7.84E-09	9.31E-09	1.03E-08	1.02E-08
7.0E+01	1.30E-09	3.88E-09	6.01E-09	7.84E-09	9.31E-09	1.03E-08	9.57E-09*
1.0E+02	1.30E-09	3.88E-09	6.01E-09	7.84E-09	9.31E-09	1.03E-08	9.11E-09*
2.0E+02	1.31E-09	3.88E-09	6.02E-09	7.85E-09	9.30E-09	1.03E-08	8.19E-09*
4.0E+02	1.33E-09	3.89E-09	6.03E-09	7.85E-09	9.30E-09	9.99E-09	7.34E-09*
7.0E+02	1.36E-09	3.90E-09	6.04E-09	7.86E-09	9.29E-09	9.46E-09	6.76E-09*
1.0E+03	1.39E-09	3.92E-09	6.06E-09	7.87E-09	9.28E-09	9.00E-09*	6.44E-09*
2.0E+03	1.49E-09	3.98E-09	6.10E-09	7.89E-09	9.11E-09	7.96E-09*	5.87E-09*
4.0E+03	1.70E-09	4.11E-09	6.20E-09	7.87E-09	8.50E-09	6.90E-09*	5.36E-09*
7.0E+03	1.99E-09	4.31E-09	6.30E-09	7.63E-09	7.66E-09*	6.10E-09*	4.95E-09#
1.0E+04	2.26E-09	4.50E-09	6.32E-09	7.29E-09*	7.02E-09*	5.60E-09*	4.67E-09#
2.0E+04	3.05E-09	4.89E-09	6.01E-09*	6.26E-09*	5.71E-09*	4.67E-09#	4.08E-09#

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

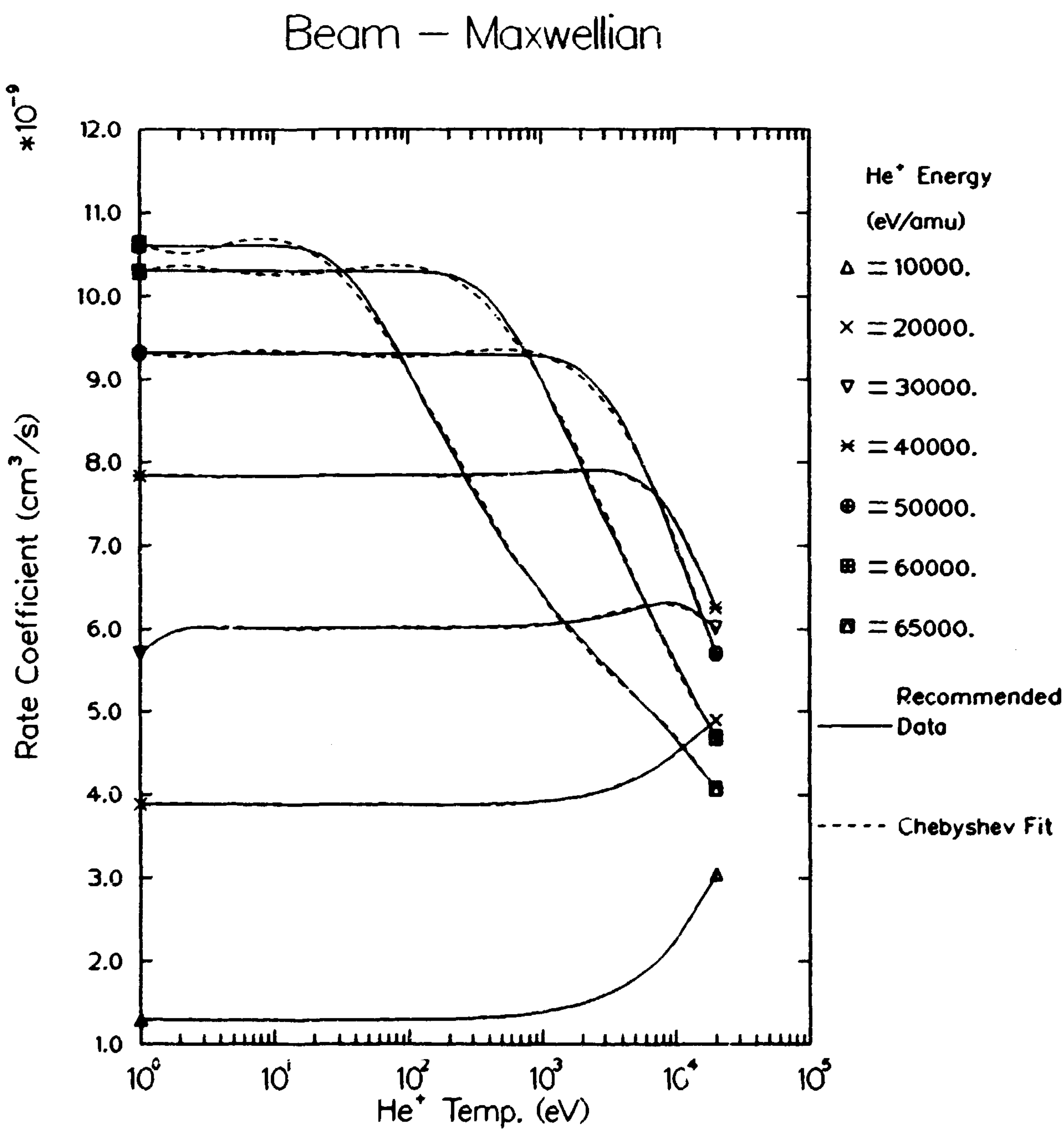
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

He^{+} Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-40.5559	.324800	.215507	.101128	.0305437	.00225930	-.00348368
20000.	-38.6393	.0830639	.0600817	.0314309	.0105748	.00101472	-.00206469
30000.	-37.8497	.0259326	-.00436636	.00382678	-.0161047	-.00327000	-.00929120
40000.	-37.3876	-.0574256	-.0510653	-.0409152	-.0269282	-.0144190	-.00522979
50000.	-37.1678	-.166608	-.125810	-.0745545	-.0317364	-.00593417	.00489997
60000.	-37.1929	-.348477	-.198373	-.0604564	.00910326	.0165438	4.816223E-04
65000.	-37.4160	-.490762	-.135825	.0331097	.00708503	-.0235912	-.00325326

See appendix for Chebyshev fit details

$He^{+} + He^{+} \rightarrow (He^{+} + He^{2+} + e)$ or $(He + He^{2+})$



Cross Sections for Producting Slow Ions and Electrons for

He + H_2 -> Σ slow ions (σ^+)
He + H_2 -> Σ slow electrons (σ^-)

(σ^+) Energy (eV/amu)	Cross Section (cm^2)	(σ^-) Energy (eV/amu)	Cross Section (cm^2)
7.6E+02	3.28E-17	1.2E+00	2.30E-20
8.0E+02	3.45E-17	1.3E+00	2.00E-19
1.0E+03	4.21E-17	1.4E+00	5.36E-19
2.0E+03	6.90E-17	1.5E+00	4.86E-19
4.0E+03	1.02E-16	1.7E+00	4.08E-19
6.0E+03	1.26E-16	2.0E+00	8.65E-19
8.0E+03	1.46E-16	2.5E+00	2.36E-18
1.0E+04	1.63E-16	3.0E+00	3.97E-18
2.0E+04	2.17E-16	4.0E+00	6.94E-18
4.0E+04	2.54E-16	5.0E+00	1.02E-17
6.0E+04	2.50E-16	6.0E+00	1.35E-17
8.0E+04	2.35E-16	7.0E+00	1.75E-17
1.0E+05	2.18E-16	8.0E+00	2.07E-17
2.0E+05	1.43E-16	9.0E+00	2.31E-17
2.5E+05	1.17E-16	1.0E+01	2.47E-17
		4.0E+01	5.52E-17
		7.0E+01	7.17E-17
		1.0E+02	8.42E-17
		4.0E+02	1.46E-16
		7.0E+02	1.77E-16
		1.0E+03	2.00E-16
		4.0E+03	3.06E-16
		7.0E+03	3.53E-16
		1.0E+04	3.77E-16
		4.0E+04	4.46E-16
		7.0E+04	4.15E-16
		1.0E+05	3.66E-16
		2.5E+05	2.06E-16

<u>References:</u> σ^+ - 143, 459, 463
σ^- - 143, 460

<u>Accuracy:</u> σ^+ - 20%
σ^- - 1.0 eV/amu to 12 eV/amu - 20%
12 eV/amu to 3.7×10^4 eV/amu - Unknown
3.7×10^4 eV/amu to 2.5×10^4 eV/amu - 20%

<u>Notes:</u> (1) Note the small resonance at 1.4 eV/amu results from metastable He. (2) The cross section σ^+ is defined as the sum of cross sections for all processes producing slow singly-charged ions plus twice the cross section for producing doubly-charged slow ions. Similarly the σ^- cross section is defined as the cross section for ionization plus the cross section for electron loss or stripping. In those reactions where electron capture is important, the σ^+ cross section is the sum of the ionization cross section and the electron capture cross section.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

σ^+ E_{min} = 7.6E+02 eV/amu, E_{max} = 2.5E+05 eV/amu
σ^- E_{min} = 1.2E+00 eV/amu, E_{max} = 2.5E+05 eV/amu

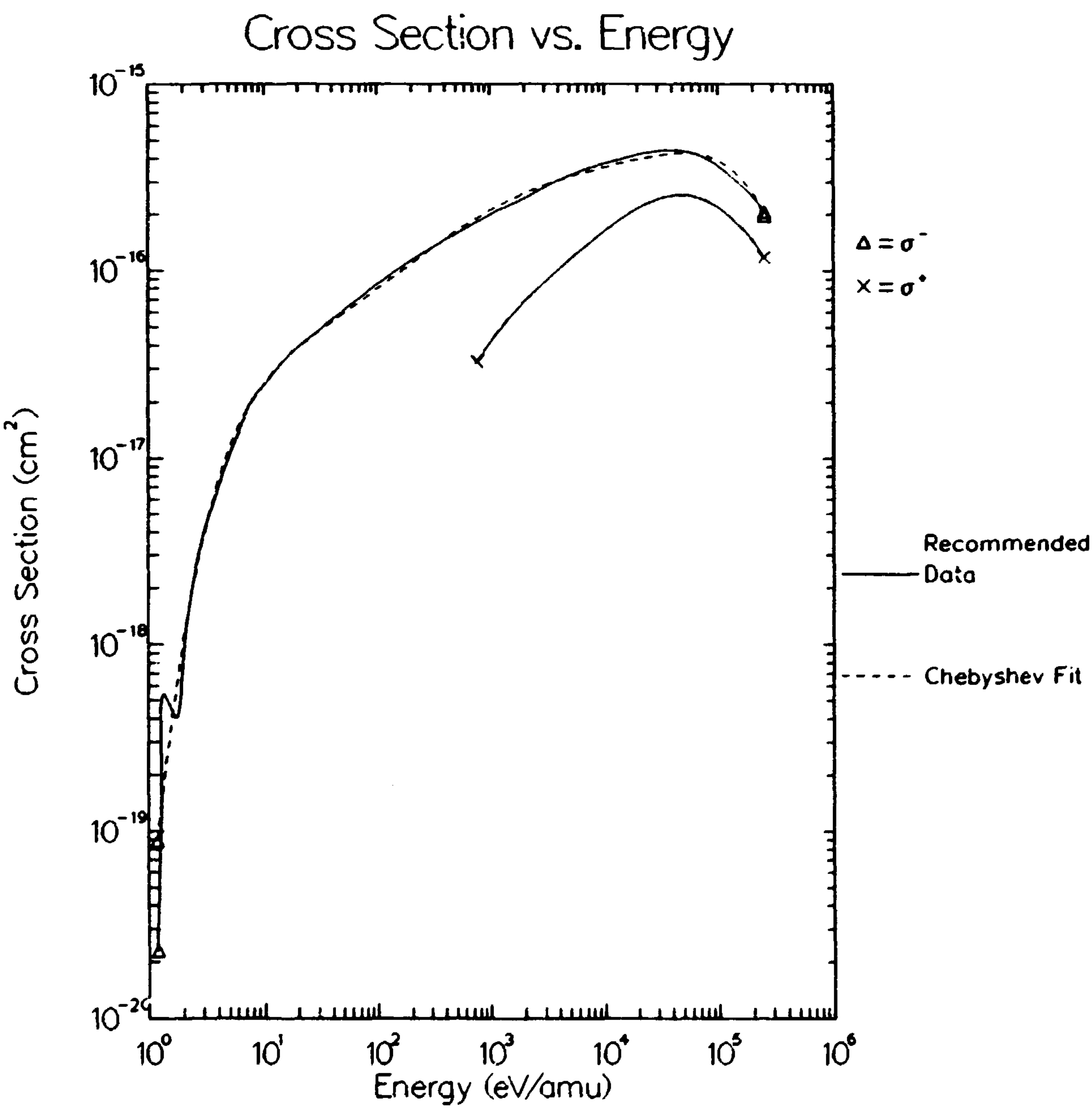
	A0	A1	A2	A3	A4	A5	A6
σ^+	-73.4532	.742441	-.556022	-.126285	-.0371599	.0218408	.000323040
σ^-	-75.1363	3.03724	-1.67952	.577117	-.601974	.234746	-.168549

The fit represents the σ^+ cross section with an rms deviation of 0.3%. The maximum deviation is 0.4% at 8.0E+04 eV/amu.

The fit represents the σ^- cross section with an rms deviation of 52.2%. The maximum deviation is 286.3% at 1.2E+00 eV/amu.

See appendix for Chebyshev fit details.

$He^+ + He^+ \rightarrow \Sigma$ Slow Ions (σ^+)
$He^+ + He^+ \rightarrow \Sigma$ Slow Electrons (σ^-)



Ionization and H^+ Production Cross Sections for

$$He + H_2 \rightarrow He + H_2^+ + e$$
$$He + H_2 \rightarrow \Sigma H^+$$

Ionization (H_2^+ Production)		H^+ (Production)	
Energy (eV/amu)	Cross Section (cm^2)	Energy (eV/amu)	Cross Section (cm^2)
7.4E+02	1.64E-17	7.4E+02	2.17E-17
8.0E+02	1.75E-17	8.0E+02	2.19E-17
9.0E+02	1.93E-17	9.0E+02	2.23E-17
1.0E+03	2.11E-17	1.0E+03	2.28E-17
1.5E+03	2.97E-17	1.5E+03	2.52E-17
2.0E+03	3.81E-17	2.0E+03	2.78E-17
3.0E+03	5.24E-17	3.0E+03	3.32E-17
4.0E+03	6.55E-17	4.0E+03	3.69E-17
5.0E+03	7.72E-17	4.3E+03	3.74E-17
6.0E+03	8.71E-17	5.0E+03	3.67E-17
7.0E+03	9.55E-17	6.0E+03	3.55E-17
8.0E+03	1.03E-16	7.0E+03	3.52E-17
9.0E+03	1.10E-16	8.0E+03	3.55E-17
1.0E+04	1.15E-16	9.0E+03	3.68E-17
1.2E+04	1.24E-16	1.0E+04	3.87E-17
		1.1E+04	4.20E-17

__References:__ 459, 461, 462, 463, 464

__Accuracy:__ Unknown

__Notes:__ (1) The data of Refs. 461, 462, 463, and 464 are approximately a factor of 2-3 less than that of Ref. 459 for the production of H^+ ions. The data presented follows closely the results of Ref. 459.

__Chebyshev Fitting Parameters for Cross Sections__

H_2^+ Prod. E_{min} = 7.4E+02 eV/amu, E_{max} = 1.2E+04 eV/amu
H^+ Prod. E_{min} = 7.4E+02 eV/amu, E_{max} = 1.1E+04 eV/amu

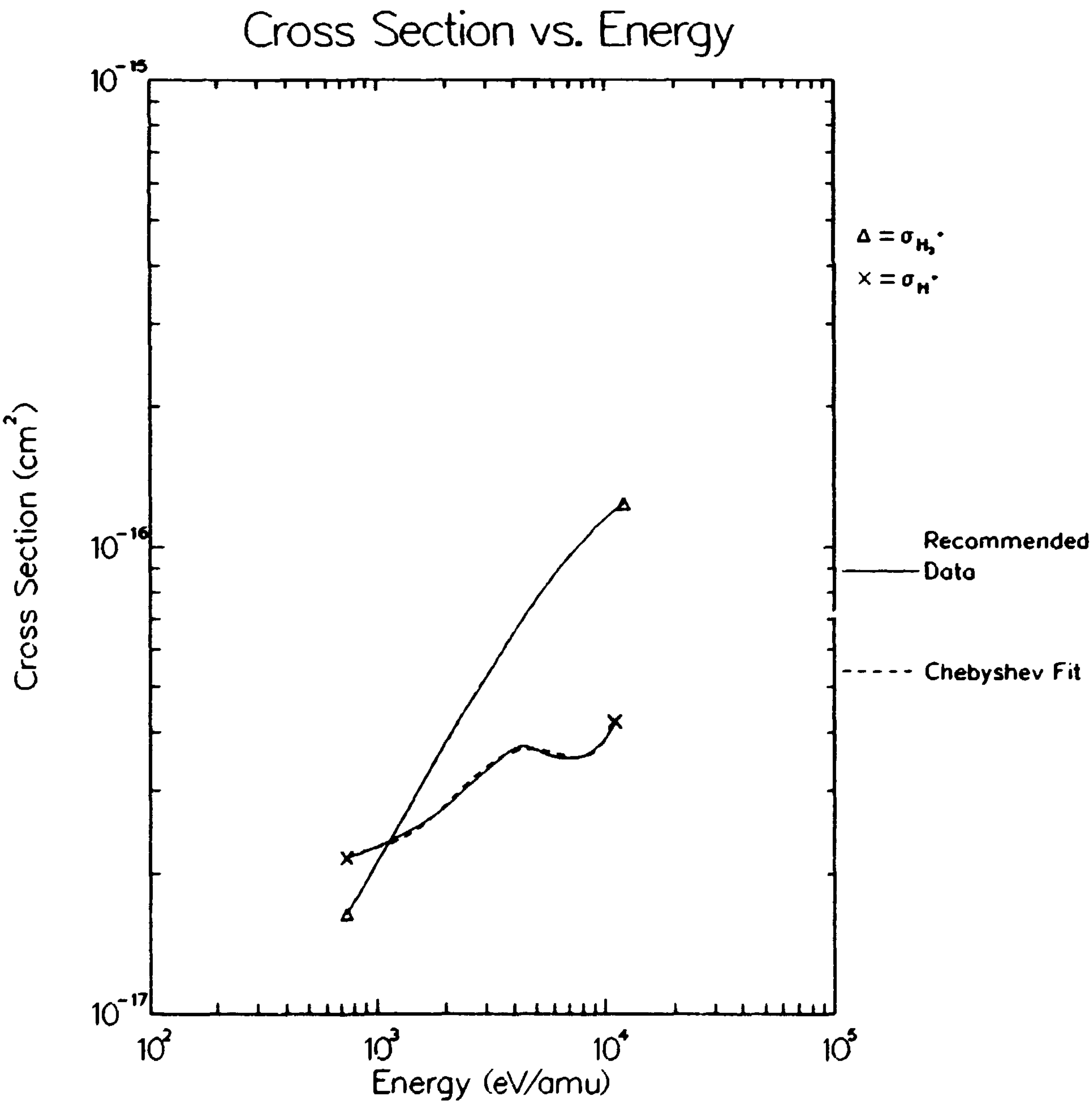
	A0	A1	A2	A3	A4	A5	A6
H_2^+ Prod.	-75.1222	1.03406	-.0748886	-.0222039	-.00237843	-.000779509	.000954515
H^+ Prod.	-76.0878	.319638	-.0448970	-.0183961	.0505953	.0349869	-.000131466

The fit represents the H_2^+ cross section with an rms deviation of 0.2%. The maximum deviation is 0.4% at 1.5E+03 eV/amu.

The fit represents the H^+ cross section with an rms deviation of 1.0%. The maximum deviation is 1.8% at 6.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$He + H_2 \rightarrow He + H_2^+ + e\ (\sigma_{H_2^+})$
$He + H_2 \rightarrow \Sigma H^+\ (\sigma_{H^+})$



Electron and Slow Positive Ion Production Cross Sections for

He + He -> Σ slow electrons (σ^-)
He + He -> Σ slow ions (σ^+)

σ^+		σ^- (Lower Energy)		σ^- (Higher Energy)	
Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)
5.0E+03	4.45E-17	2.7E+01	2.56E-20	3.7E+04	2.47E-16
6.0E+03	5.23E-17	3.0E+01	1.34E-19	4.0E+04	2.50E-16
7.0E+03	5.88E-17	3.5E+01	3.31E-19	5.0E+04	2.50E-16
8.0E+03	6.49E-17	4.0E+01	4.86E-19	6.0E+04	2.47E-16
9.0E+03	7.07E-17	5.0E+01	7.66E-19	7.0E+04	2.43E-16
1.0E+04	7.55E-17	6.0E+01	1.06E-18	8.0E+04	2.35E-16
1.5E+04	9.74E-17	7.0E+01	1.33E-18	9.0E+04	2.33E-16
2.0E+04	1.10E-16	8.0E+01	1.61E-18	1.0E+05	2.25E-16
3.0E+04	1.23E-16	9.0E+01	1.88E-18	1.5E+05	1.91E-16
4.0E+04	1.28E-16	1.0E+02	2.16E-18	2.0E+05	1.67E-16
5.0E+04	1.29E-16	1.5E+02	3.52E-18	2.5E+05	1.43E-16
6.0E+04	1.28E-16	2.0E+02	4.77E-18		
7.0E+04	1.26E-16	2.5E+02	5.89E-18		
8.0E+04	1.22E-16	3.0E+02	6.96E-18		
9.0E+04	1.19E-16				
1.0E+05	1.16E-16				
1.5E+05	9.91E-17				
2.0E+05	8.49E-17				
2.5E+05	7.44E-17				

References: 143, 403, 462, 463, 472, 473, 474, 475

Accuracy: Unknown

Notes: (1) The processes to form slow positive ions and electrons are: (a) He + He -> He^+ + He + e, electron loss; (b) He + He -> He^+ + He^+ + 2e (electron loss with target ionization); (c) He + He -> He + He^+ + e, single ionization; (d) He + He -> He + He^{2+} + 2e, double ionization; (e) He + He -> He^- + He^+, electron capture. (2) Cross sections for slow positive ion formation (σ^+) are the sum of reactions σ(b) + σ(c) + σ(d) + σ(e). (3) For electrons, (σ^-) is the sum of σ(a) + 2σ(b) + σ(c) + 2σ(d). For higher energies σ(e) is very small and thus σ^+ is approximately equal to the sum of the single and double ionization cross sections. (4) No attempt has been made to interpolate between the high-energy σ^- and the low-energy data (E < 300 eV/amu).

Chebyshev Fitting Parameters for Cross Sections

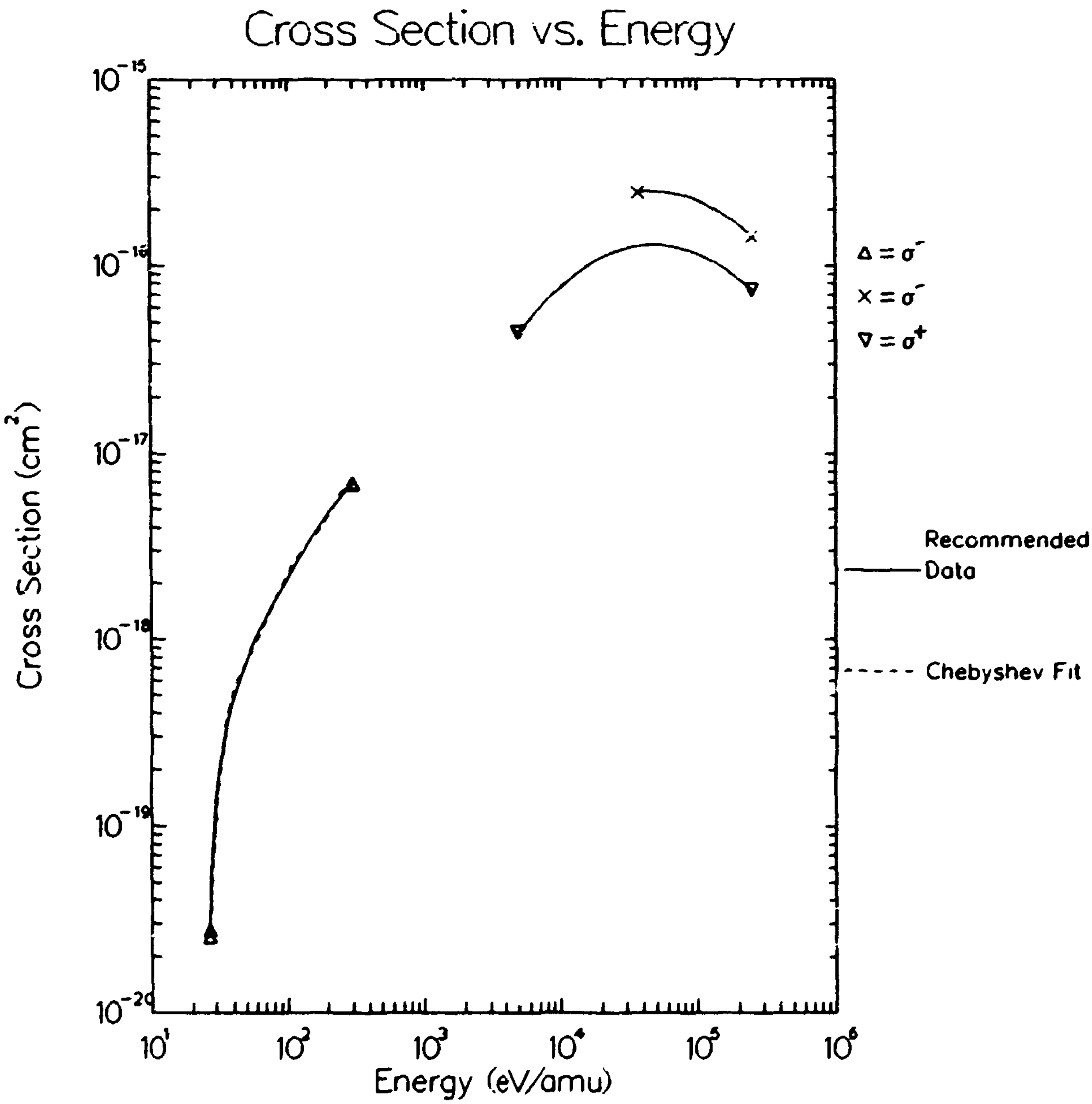
σ^+ E_{min} = 5.0E+03 eV/amu, E_{max} = 2.5E+05 eV/amu
σ^- (lower E) E_{min} = 2.7E+01 eV/amu, E_{max} = 3.0E+02 eV/amu
σ^- (Higher E) E_{min} = 3.7E+04 eV/amu, E_{max} = 2.5E+05 eV/amu

	A0	A1	A2	A3	A4	A5	A6
σ^+	-74.0092	.259096	-.395285	-.00216683	.00569771	-.00263905	.00150963
σ^- (lower E)	-82.5433	2.19805	-.641453	.385156	-.256300	.170524	-.106115
σ^- (Higher E)	-72.2261	-.269539	-.0908126	-.000390444	-.000723589	-.00319421	-.00598024

The fit represents the σ^+ cross section with an rms deviation of 0.4%.
The maximum deviation is 0.9% at 1.0E+04 eV/amu.
The fit represents the σ^- (lower E) cross section with an rms deviation of 6.3%.
The maximum deviation is 10.0% at 4.0E+01 eV/amu.
The fit represents the σ^- (Higher E) cross section with an rms deviation of 0.1%.
The maximum deviation is 0.2% at 8.0E+04 eV/amu.

See appendix for Chebyshev fit details.

He + He –> ΣSlow Electrons (σ^-)
He + He –> ΣSlow Ions (σ^+)



Single and Double Ionization Cross Sections for

$He + He \rightarrow He + He^{+} + e$
$He + He \rightarrow He + He^{2+} + 2e$

Single Ionization Energy (eV/amu)	Single Ionization Cross Section (cm^2)	Double Ionization Energy (eV/amu)	Double Ionization Cross Section (cm^2)
1.2E+04	8.26E-17	1.3E+04	9.93E-19
1.5E+04	1.03E-16	1.5E+04	1.40E-18
2.0E+04	1.32E-16	2.0E+04	2.14E-18
2.5E+04	1.58E-16	2.5E+04	2.69E-18
3.0E+04	1.80E-16	3.0E+04	3.15E-18
3.5E+04	1.99E-16	3.5E+04	3.59E-18
4.0E+04	2.13E-16	4.0E+04	4.03E-18
4.5E+04	2.25E-16	4.5E+04	4.44E-18

References: 462, 463

Accuracy: Unknown

Notes: None

Chebyshev Fitting Parameters for Cross Sections

Single Ion. E_{min} = 1.2E+04 eV/amu, E_{max} = 4.5E+04 eV/amu
Double Ion. E_{min} = 1.3E+04 eV/amu, E_{max} = 4.5E+04 eV/amu

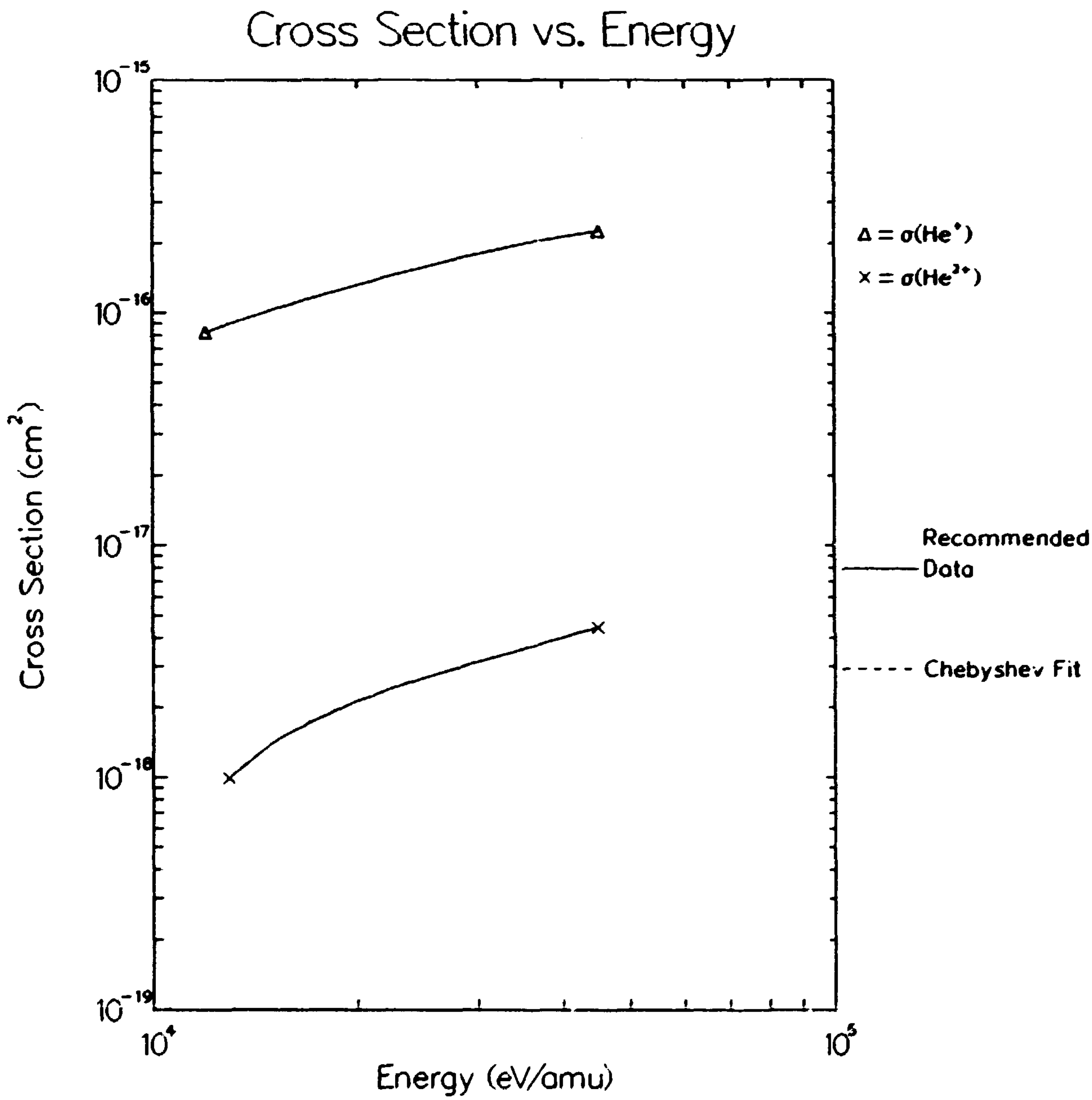
	A0	A1	A2	A3	A4	A5	A6
Single Ion.	-72.9678	.503766	-.0453017	-.00416573	-.00286603	.00135469	.000526378
Double Ion.	-81.1695	.703077	-.106105	.0433845	-.0115100	.00236396	-.00233450

The fit represents the Single Ion. cross section with an rms deviation of 0.1%. The maximum deviation is 0.2% at 3.0E+04 eV/amu.

The fit represents the Double Ion. cross section with an rms deviation of 0.1%. The maximum deviation is 0.1% at 3.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$He + He \rightarrow He + He^{+} + e$
$He + He \rightarrow He + He^{2+} + 2e$



Ionization Cross Sections for

$He^{+} + H \rightarrow He^{+} + H^{+} + e$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
6.3E+03	1.10E+08	1.28E-17
7.0E+03	1.16E+08	1.47E-17
8.0E+03	1.24E+08	1.75E-17
9.0E+03	1.32E+08	2.07E-17
1.0E+04	1.39E+08	2.45E-17
1.5E+04	1.70E+08	4.80E-17
2.0E+04	1.96E+08	8.07E-17
3.0E+04	2.41E+03	1.46E-16
4.0E+04	2.78E+08	1.98E-16
5.0E+04	3.11E+08	2.16E-16
6.0E+04	3.40E+08	2.18E-16
7.0E+04	3.68E+08	2.10E-16
8.0E+04	3.93E+08	2.00E-16
9.0E+04	4.17E+08	1.91E-16
1.0E+05	4.39E+08	1.78E-16
1.5E+05	5.38E+08	1.36E-16
2.0E+05	6.21E+08	1.10E-16
3.0E+05	7.61E+08	8.04E-17
4.0E+05	8.78E+08	6.41E-17
5.0E+05	9.82E+08	5.36E-17
6.0E+05	1.08E+09	4.56E-17
7.0E+05	1.16E+09	4.04E-17
8.0E+05	1.24E+09	3.61E-17
9.0E+05	1.32E+09	3.26E-17
1.0E+06	1.39E+09	2.94E-17
2.0E+06	1.96E+09	1.59E-17
3.0E+06	2.40E+09	1.09E-17
4.0E+06	2.77E+09	8.33E-18
5.0E+06	3.09E+09	6.74E-18
6.0E+06	3.39E+09	5.76E-18
7.0E+06	3.65E+09	4.97E-18
8.0E+06	3.90E+09	4.39E-18

References: 564, 565, 566

Accuracy: Unknown

Notes: (1) As far as we know no published experimental data exist. The data plotted are theoretical results. (2) For energies less than 10^5 eV/amu the data of Ref. 566 has been plotted. The classical Monte Carlo calculations have been quite accurate in predicting similar collisional processes where experimental data is available for comparison. (3) For energies greater than 10^5 eV/amu data of Ref. 565 is plotted. These calculations are Born approximations which should be good at these high energies. At lower energies the cross sections are much higher than those given in Ref. 566.

Chebyshev Fitting Parameters for Cross Sections

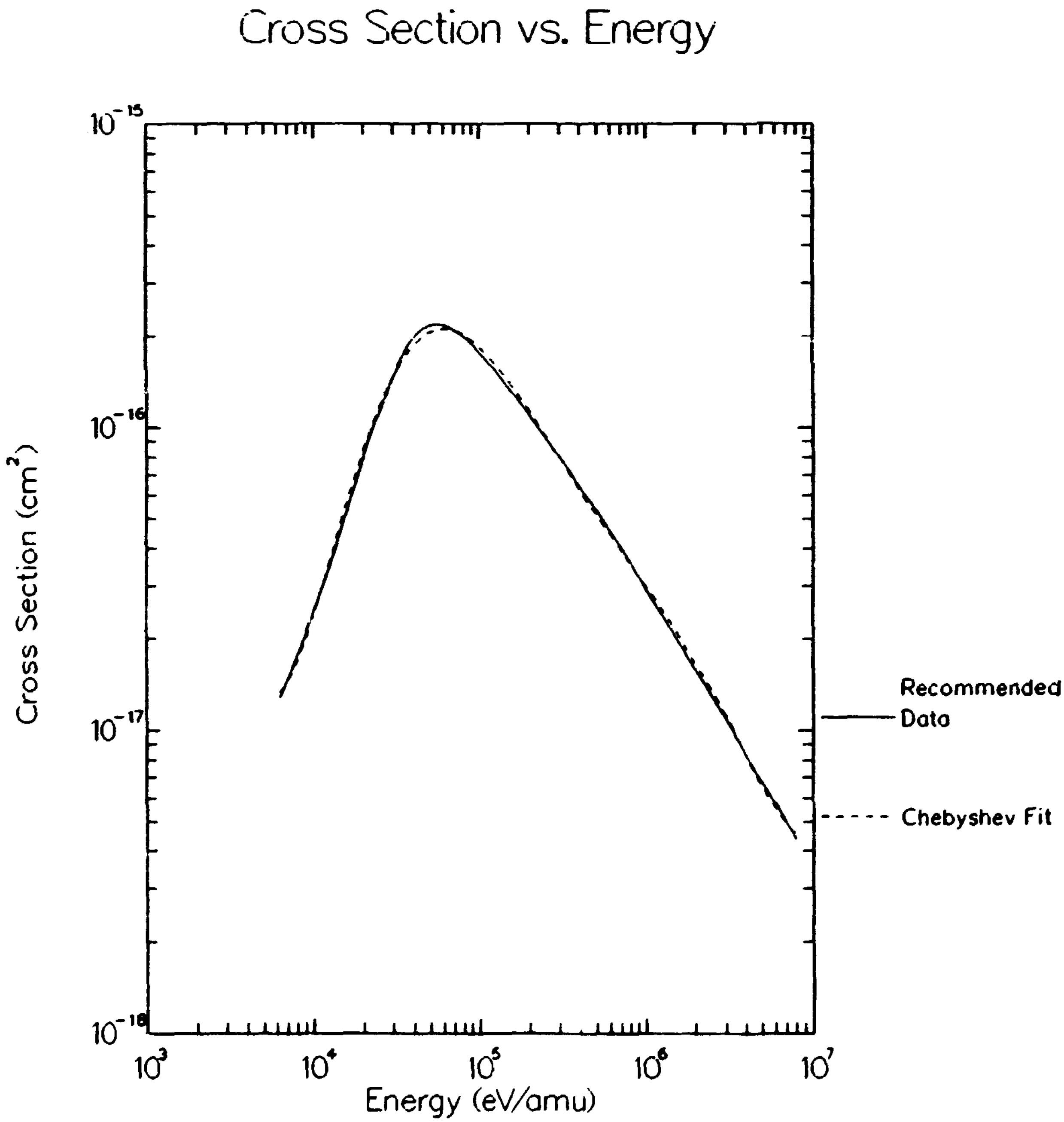
E_{min} = 6.3E+03 eV/amu, E_{max} = 8.0E+06 eV/amu

A0	A1	A2	A3	A4	A5	A6
-76.1808	-.896422	-1.40016	.494799	-.0137803	-.135113	.110603

The fit represents the above cross section with an rms deviation of 3.2%. The maximum deviation is 6.7% at 1.5E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^{+} + H \rightarrow He^{+} + H^{+} + e$



Ionization Rate Coefficients for

$H + He^{+} \rightarrow H^{+} + He^{+} + e$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{+} Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	3.41E-09	1.58E-08	5.49E-08	7.72E-08	7.82E-08	6.83E-08	5.26E-08
2.0E+00	3.41E-09	1.58E-08	5.49E-08	7.71E-08	7.82E-08	6.83E-08	5.26E-08
4.0E+00	3.41E-09	1.58E-08	5.48E-08	7.71E-08	7.82E-08	6.83E-08	5.26E-08
7.0E+00	3.42E-09	1.58E-08	5.48E-08	7.71E-08	7.82E-08	6.83E-08	5.26E-08
1.0E+01	3.43E-09	1.58E-08	5.47E-08	7.71E-08	7.82E-08	6.83E-08	5.26E-08
2.0E+01	3.45E-09	1.58E-08	5.46E-08	7.71E-08	7.82E-08	6.83E-08	5.26E-08
4.0E+01	3.49E-09	1.59E-08	5.45E-08	7.71E-08	7.82E-08	6.83E-08	5.26E-08
7.0E+01	3.55E-09	1.60E-08	5.43E-08	7.70E-08	7.82E-08	6.83E-08	5.26E-08
1.0E+02	3.61E-09	1.61E-08	5.43E-08	7.70E-08	7.82E-08	6.83E-08	5.26E-08
2.0E+02	3.81E-09	1.64E-08	5.41E-08	7.69E-08	7.81E-08	6.83E-08	5.26E-08
4.0E+02	4.20E-09	1.72E-08	5.40E-08	7.67E-08	7.81E-08	6.82E-08	5.26E-08
7.0E+02	4.84E-09	1.83E-08	5.39E-08	7.65E-08	7.79E-08	6.82E-08	5.25E-08
1.0E+03	5.52E-09	1.93E-08	5.39E-08	7.62E-08	7.77E-08	6.82E-08	5.25E-08
2.0E+03	7.93E-09	2.25E-08	5.41E-08	7.52E-08	7.72E-08	6.81E-08	5.25E-08
4.0E+03	1.29E-08	2.76E-08	5.46E-08	7.34E-08	7.62E-08	6.80E-08	5.24E-08
7.0E+03	1.97E-08	3.34E-08	5.55E-08	7.14E-08	7.48E-08	6.78E-08	5.23E-08
1.0E+04	2.56E-08	3.78E-08	5.63E-08	6.99E-08	7.35E-08	6.75E-08	5.23E-08
2.0E+04	3.99E-08	4.76E-08	5.86E-08	6.73E-08	7.03E-08	6.66E-08	5.21E-08

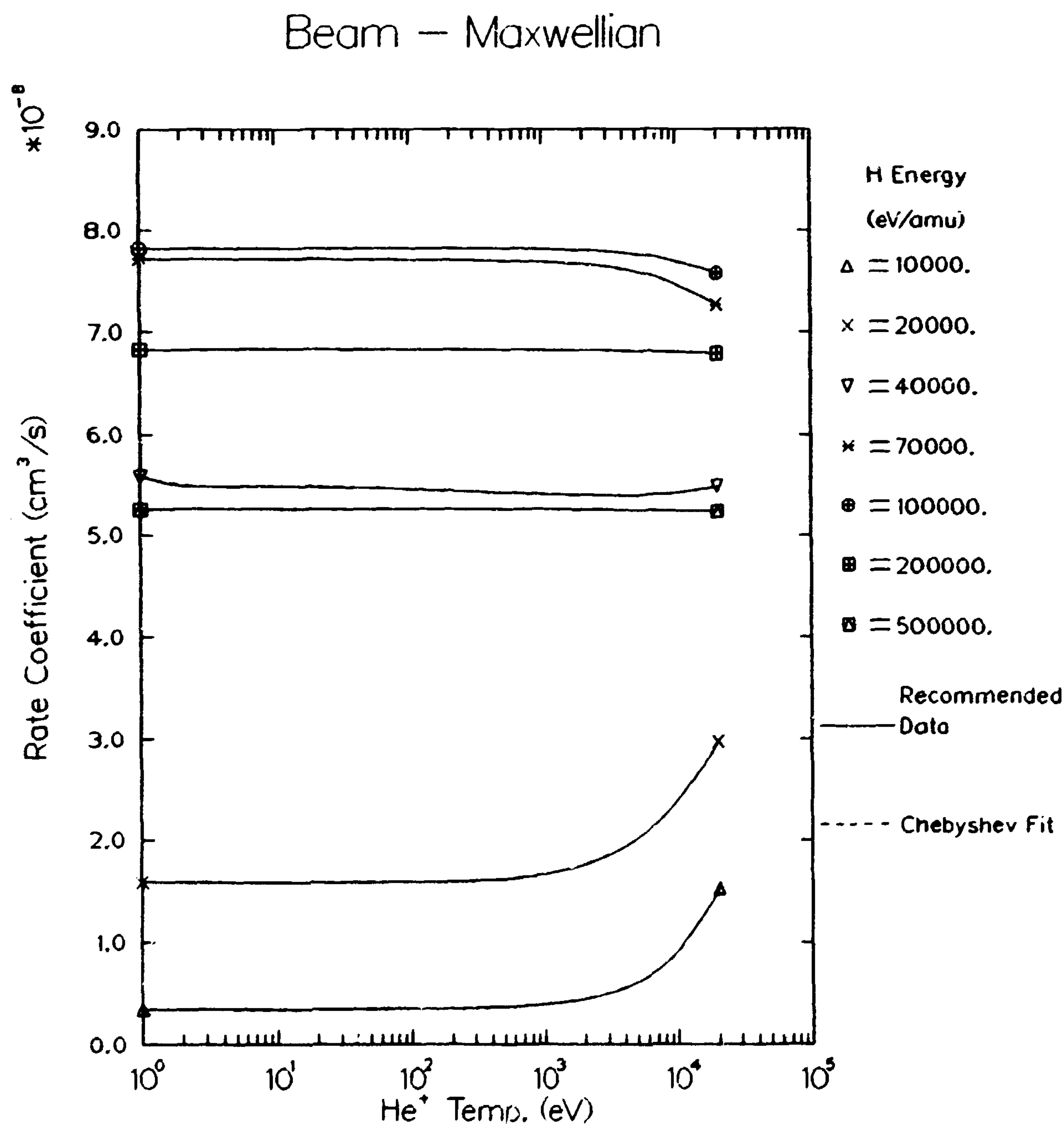
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

H Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-37.6259	1.12300	.601815	.164371	-.0334027	-.0580916	-.0243672
20000.	-35.3341	.489409	.271922	.0807229	-.00815166	-.0204835	-.00815012
40000.	-33.4270	.0164455	.02281157	.0149114	.00585597	.00147262	-3.367767E-06
70000.	-32.8194	-.0548059	-.0346997	-.0154134	-.00335201	.00137249	.00185552
100000.	-32.7709	-.0377570	-.0264510	-.0142784	-.00575226	-.00155112	-3.572900E-05
200000.	-33.0075	-.00828099	-.00567988	-.00349931	-.00201522	-.00104778	-4.638534E-04
500000.	-33.5256	-.00412902	-.00205167	-6.187466E-04	-2.150041E-04	-7.937795E-05	-1.271717E-04

See appendix for Chebyshev fit details.

$H + He^{+} \rightarrow He^{+} + H^{+} + e$



Cross Sections for the Production of Slow Positive Ions and Electrons for He^+ Passing Through H_2

$He^+ + H_2 \rightarrow \Sigma$ Slow Ions σ^+
$\rightarrow \Sigma$ Electrons σ^-

Slow Ions σ^+ Energy (eV/amu)	Cross Section (cm^2)	Electrons σ^- Energy (eV/amu)	Cross Section (cm^2)
7.5E+02	1.28E-16	2.5E+03	4.19E-17
8.0E+02	1.24E-16	3.0E+03	4.59E-17
1.0E+03	1.15E-16	4.0E+03	5.36E-17
1.3E+03	1.11E-16	7.0E+03	7.38E-17
1.5E+03	1.14E-16	1.0E+04	9.89E-17
2.0E+03	1.34E-16	1.5E+04	1.52E-16
4.0E+03	2.66E-16	2.0E+04	2.01E-16
7.0E+03	3.72E-16	4.0E+04	3.30E-16
1.0E+04	4.20E-16	6.0E+04	3.61E-16
1.5E+04	4.65E-16	7.0E+04	3.63E-16
2.0E+04	4.92E-16	1.0E+05	3.36E-16
3.0E+04	5.08E-16	1.5E+05	2.84E-16
4.0E+04	5.03E-16	2.0E+05	2.46E-16
7.0E+04	4.11E-16	4.0E+05	1.67E-16
1.0E+05	3.41E-16	5.0E+05	1.46E-16
1.5E+05	2.70E-16		
2.0E+05	2.29E-16		
4.0E+05	1.46E-16		
5.0E+05	1.24E-16		

References: 96, 104, 105, 353, 355, 364, 462, 463, 478, 479, 480, 481

Accuracy: 50%

Notes: (1) The reactions that produce slow ions and electrons as reaction products are: (a) $He^+ + H_2 \rightarrow He^+ + H_2^+ + e$, single ionization; (b) $He^+ + H_2 \rightarrow He + H_2^+$, single capture; (c) $He^+ + H_2 \rightarrow He^+ + H^+ + H + e$, dissociative ionization; (d) $He^+ + H_2 \rightarrow He^+ + H^+ + H^+ + 2e$, double ionization; (e) $He^+ + H_2 \rightarrow He + H^+ + H$, dissociative electron capture; (f) $He^+ + H_2 \rightarrow He + H^+ + H^+ + e$, electron capture with ionization. σ^+ is equal to the sum $\sigma(a) + \sigma(b) + \sigma(c) + 2\sigma(d) + \sigma(e) + 2\sigma(f)$. σ^- is equal to $\sigma(a) + \sigma(c) + 2\sigma(d) + \sigma(f)$. (2) For energies less than 10^5 eV/amu the electron capture cross sections to form H_2^+ dominate the σ^+ cross sections. (3) the σ^- cross sections of Ref. 355 are not plotted below 2.5×10^3 eV/amu due to the small energy dependence of the cross sections.

Chebyshev Fitting Parameters for Cross Sections

Slow Ions σ^+ E_{min} = 7.5E+02 eV/amu, E_{max} = 5.0E+05 eV/amu
Electrons σ^- E_{min} = 2.5E+03 eV/amu, E_{max} = 5.0E+05 eV/amu

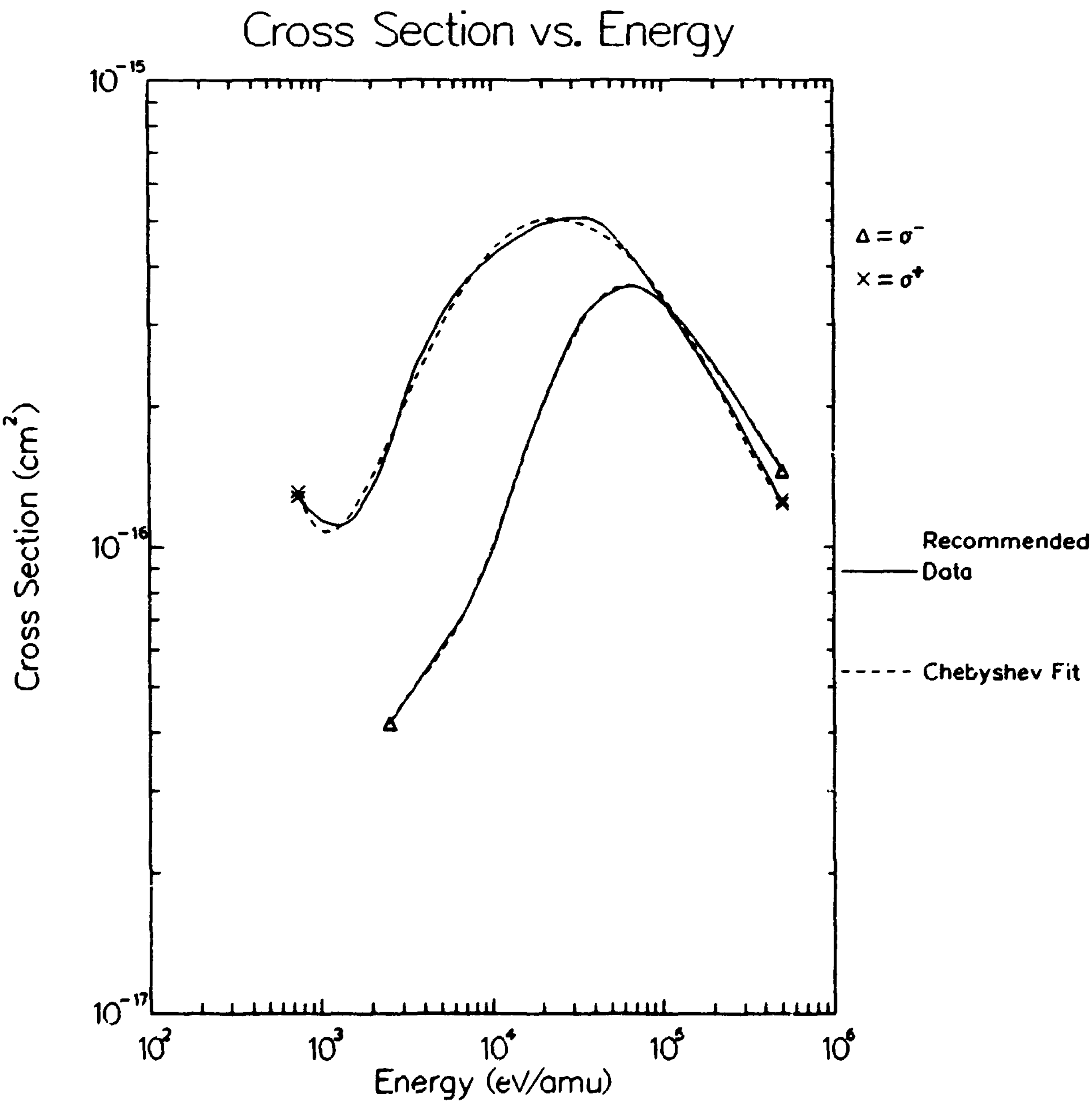
	A0	A1	A2	A3	A4	A5	A6
Slow Ions σ^+	-72.1635	.175055	-.713665	-.133412	.172753	-.0619895	.0345550
Electrons σ^-	-73.0711	.770468	-.649678	-.176586	.134550	.0300410	-.0402778

The fit represents the σ^+ cross section with an rms deviation of 3.2%. The maximum deviation is 5.5% at 2.0E+03 eV/amu.

The fit represents the σ^- cross section with an rms deviation of 0.7%. The maximum deviation is 1.6% at 1.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^{+} + H_2 \rightarrow \Sigma$Slow Ions ($\sigma^{+}$)
$He^{+} + H_2 \rightarrow \Sigma$Electrons ($\sigma^{-}$)



Cross Sections for the Formation of H_2^+, H^+, and for Double Ionization for He^+ in H_2

$$He^+ + H_2 \rightarrow He + H_2^+$$
$$\rightarrow He^+ + H_2^+ + e \quad [\sigma(H_2^+)]$$

$$He^+ + H_2 \rightarrow \Sigma\, H^+ \quad [\sigma(H^+)]$$

$$He^+ + H_2 \rightarrow He^+ + H^+ + H^+ + 2e \quad \text{(Double Ionization)}$$

H_2^+ Production		H^+ Production		Double Ionization	
Energy (eV/amu)	Cross Section (cm^2)	Energy (eV/amu)	Cross Section (cm^2)	Energy (eV/amu)	Cross Section (cm^2)
7.3E+02	3.08E-17	7.4E+02	9.39E-17	2.5E+04	4.77E-18
8.0E+02	3.23E-17	8.0E+02	8.99E-17	3.0E+04	4.53E-18
1.0E+03	3.55E-17	9.0E+02	8.45E-17	4.0E+04	3.68E-18
1.5E+03	4.45E-17	1.0E+03	8.00E-17	5.0E+04	2.86E-18
2.0E+03	5.45E-17	1.5E+03	6.92E-17	6.0E+04	2.31E-18
4.0E+03	1.04E-16	2.0E+03	6.71E-17	7.0E+04	1.92E-18
7.0E+03	1.84E-16	2.5E+03	6.65E-17	8.0E+04	1.52E-18
1.0E+04	2.83E-16	3.0E+03	6.70E-17	9.0E+04	1.40E-18
1.5E+04	3.96E-16	4.0E+03	6.93E-17	1.0E+05	1.2[illegible]E-18
2.0E+04	4.21E-16	5.0E+03	7.50E-17	1.5E+05	6.79E-19
4.0E+04	3.93E-16	6.0E+03	8.29E-17	2.0E+05	4.23E-19
7.0E+04	3.37E-16	7.0E+03	9.05E-17	3.0E+05	2.26E-19
1.0E+05	2.83E-16	8.0E+03	1.02E-16	4.0E+05	1.42E-19
1.5E+05	2.22E-16	8.6E+03	1.05E-16	5.0E+05	1.00E-19
2.0E+05	1.86E-16	9.0E+03	1.04E-16	6.0E+05	7.31E-20
4.0E+05	1.25E-16	1.0E+04	9.64E-17	7.0E+05	5.83E-20
7.0E+05	9.17E-17	1.2E+04	8.49E-17	8.0E+05	4.73E-20
8.0E+05	8.51E-17			9.0E+05	4.09E-20

<u>References:</u> 360, 365, 462, 463, 481, 482

<u>Accuracy:</u> $\sigma(H_2^+)$ - 20%
$\sigma(H^+)$ - Unknown
σ(Double Ion.) - 20%

<u>Notes:</u> (1) H_2^+ is formed from ionization of H_2 by He^+ and from electron capture collisions. (2) H^+ is formed from dissociative ionization, $He^+ + H_2 \rightarrow He^+ + H^+ + H + e$; from double ionization, $He^+ + H_2 \rightarrow He^+ + H^+ + H^+ + 2e$; and from transfer ionization, $He^+ + H_2 \rightarrow He + H^+ + H^+ + e$.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

H_2^+ Prod. E_{min} = 7.3E+02 eV/amu, E_{max} = 8.0E+05 eV/amu
H^+ Prod. E_{min} = 7.4E+02 eV/amu, E_{max} = 1.2E+04 eV/amu
Double Ion. E_{min} = 2.5E+04 eV/amu, E_{max} = 9.0E+05 eV/amu

	A0	A1	A2	A3	A4	A5	A6
H_2^+ Prod.	-73.3806	.601066	-1.00967	-.0679372	.247157	-.0416476	-.0640838
H^+ Prod.	-74.0876	.0639707	.162049	-.0778454	-.0615354	-.0437939	-.0172413
Double Ion.	-84.0918	-2.48636	-.206129	.0854195	-.00909082	.0148658	-.00608471

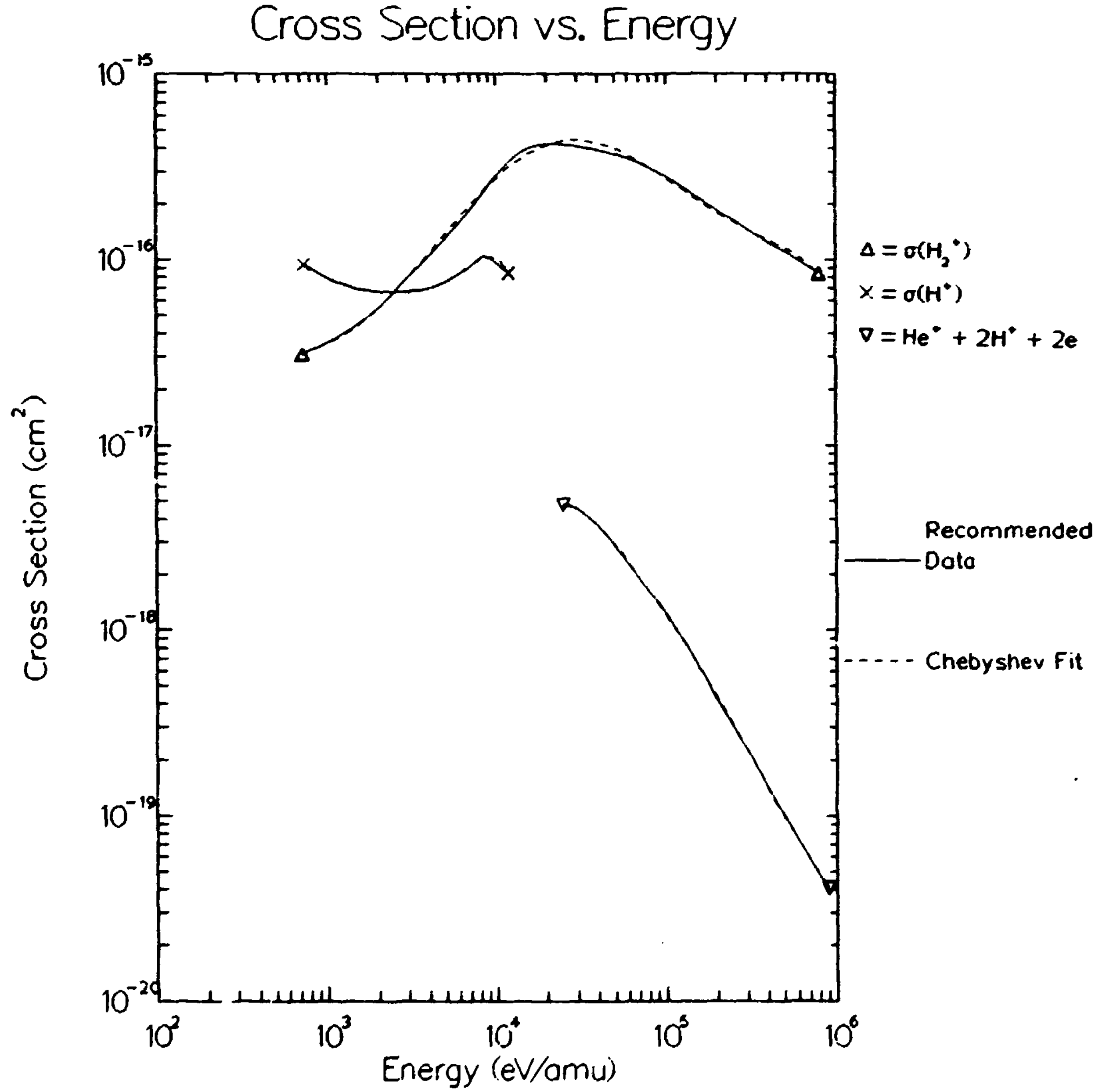
The fit represents the H_2^+ Prod. cross section with an rms deviation of 3.7%. The maximum deviation is 9.0% at 4.0E+04 eV/amu.

The fit represents the H Prod. cross section with an rms deviation of 1.3%. The maximum deviation is 5.7% at 1.0E+04 eV/amu.

The fit represents the Double Ion. cross section with an rms deviation of 1.1%. The maximum deviation is 2.5% at 2.0E+05 eV/amu.

See appendix for Chebyshev fit details.

$He^+ + H_2 \rightarrow \sigma(H_2^+)$
$He^+ + H_2 \rightarrow \sigma(H^+)$
$He^+ + H_2 \rightarrow He^+ + 2H^+ + 2e$



Cross Sections for Production of Slow Positive Charges (σ^+) and Slow Electrons (σ^-) for He^+ Passing Through He.

$$He^+ + He \rightarrow \sigma^+, \sigma^-$$

$He^+ + He$ (σ^+)

Energy (eV/amu)	Cross Section (cm^2)
2.5E+03	6.13E-16
4.0E+03	5.83E-16
7.0E+03	5.05E-16
1.0E+04	4.49E-16
2.0E+04	3.49E-16
4.0E+04	2.68E-16
7.0E+04	2.12E-16
1.0E+05	1.84E-16
2.0E+05	1.30E-16
4.0E+05	7.58E-17
7.0E+05	4.72E-17
1.0E+06	3.53E-17
2.0E+06	1.94E-17
2.8E+06	1.45E-17

$He^+ + He$ (σ^-)

Energy (eV/amu)	Cross Section (cm^2)
2.5E+03	1.40E-17
4.0E+03	2.15E-17
7.0E+03	3.3[illegible]E-17
1.0E+04	4.46E-17
2.0E+04	7.56E-17
4.0E+04	1.19E-16
7.0E+04	1.59E-16
1.0E+05	1.81E-16
1.1E+05	1.83E-16
2.0E+05	1.51E-16
4.0E+05	9.77E-17
5.0E+05	8.39E-17

<u>References:</u> 96, 104, 105, 355, 364, 388, 463, 472, 478, 479, 480, 487, 493, 497, 498, 499, 500, 579

<u>Accuracy:</u> $E > 3\text{-}4 \times 10^4$ eV/amu - 20%
$E < 3\text{-}4 \times 10^4$ eV/amu Unknown

Notes: (1) σ^+ and σ^- are the sum of the cross sections for processes producing slow ions and electrons, respectively. (2) The reaction channels contributing to these processes are (a) single electron capture; (b) single and double ionization of the target atom; (c) single capture plus ionization of the target; (d) capture into the continuum; (e) electron loss; (f) electron loss plus ionization of the target. For $He^+ + He$ collisions, proceses (c, d and f) are believed to contribute a factor of ten less than the other processes especially at low energies. (3) For He^+ energies less than 10^5 eV/amu, the low-energy σ^- data of Refs. 104, 105, 355, 364, 463, 480, 487, 498, and 500 are not included in the present compilation. These data are questionable since the cross sections are only slightly dependent on energy. (4) For low energies the σ^+ cross sections are dominated by single electron capture collisions.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

$He^+ + He$ (σ^+) E_{min} = 2.5E+03 eV/amu, E_{max} = 2.8E+06 eV/amu
$He^+ + He$ (σ^-) E_{min} = 2.5E+03 eV/amu, E_{max} = 5.0E+05 eV/amu

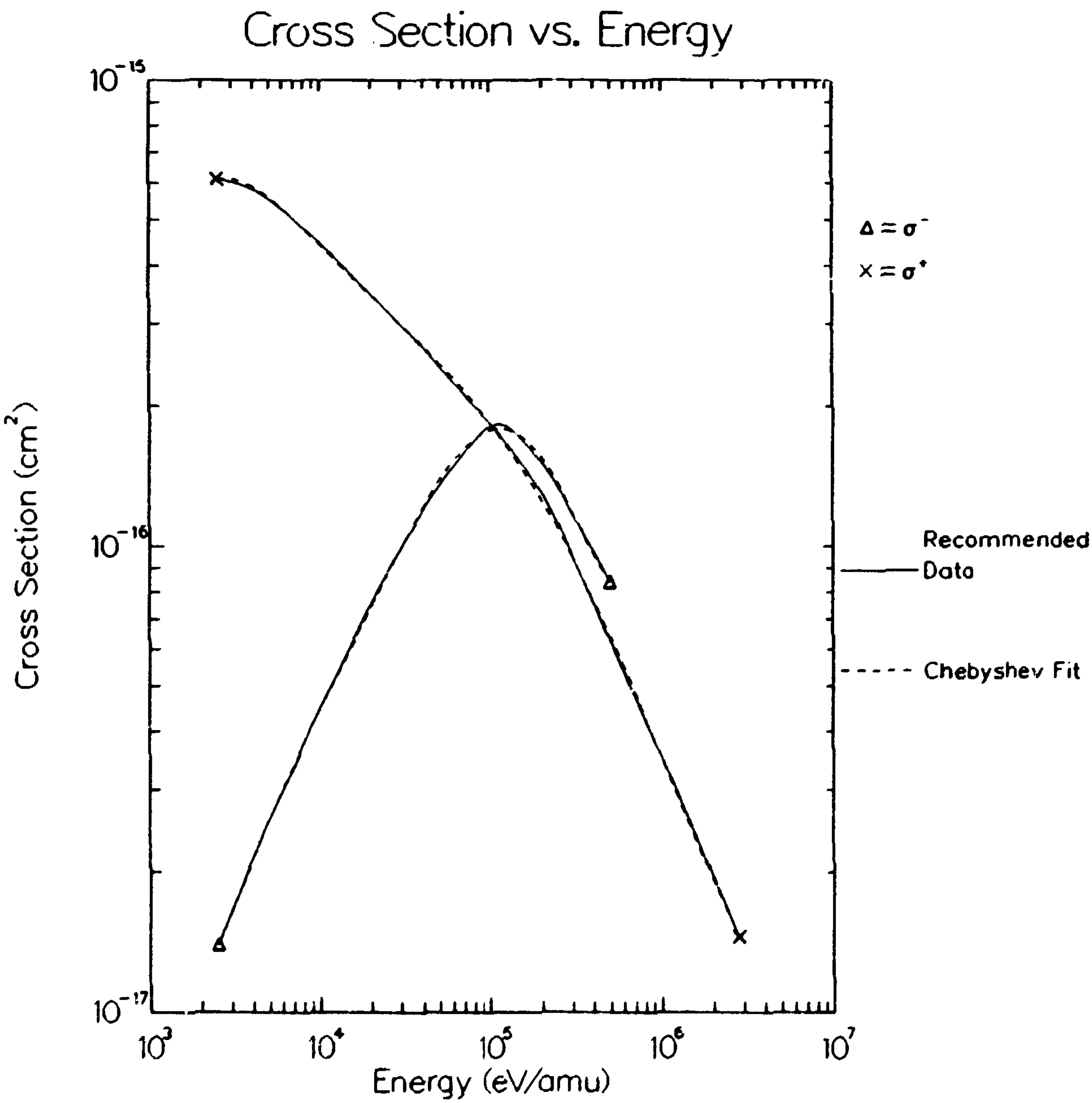
	A0	A1	A2	A3	A4	A5	A6
$He^+ + He$ (σ^+)	-73.0794	-1.87553	-.368452	-.0292343	.0164797	.0394079	-.00613696
$He^+ + He$ (σ^-)	-74.6255	1.02842	-.609151	-.175413	-.00862801	.0447902	.0224536

The fit represents the $He^+ + He$ (σ^+) cross section with an rms deviation of 1.5%. The maximum deviation is 2.1% at 7.0E+05 eV/amu.

The fit represents the $He^+ + He$ (σ^-) cross section with an rms deviation of 1.5%. The maximum deviation is 2.5% at 2.0E+05 eV/amu.

See appendix for Chebyshev fit details.

$He^{+} + He \rightarrow \sigma^{+}$
$He^{+} + He \rightarrow \sigma^{-}$



Ionization Rate Coefficients for

He^{+} + He -> o^{+}

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

He^{+} Temp. (eV)	Equal Temp.	He Temp. (eV) 5000.	6000.	8000.	10000.	12000.	15000.	20000.
1.0E+03	8.49E-10#	1.73E-08#	2.12E-08*	2.70E-08*	3.30E-08*	3.71E-08*	4.20E-08*	4.76E-08*
1.5E+03	3.93E-09#	1.93E-08*	2.30E-08*	2.*2E-08*	3.41E-08*	3.81E-08*	4.26E-08*	4.81E-08*
2.0E+03	8.30E-09#	2.12E-08*	2.47E-08*	3.06E-08*	3.52E-08*	3.89E-08*	4.33E-08*	4.85E-08*
2.5E+03	1.29E-08#	2.30E-08*	2.63E-08*	3.18E-08*	3.62E-08*	3.97E-08*	4.39E-08*	4.90E-08*
3.0E+03	1.73E-08#	2.47E-08*	2.70E-08*	3.30E-08*	3.71E-08*	4.05E-08*	4.45E-08*	4.94E-08*
3.5E+03	2.12E-08*	2.63E-08*	2.92E-08*	3.41E-08*	3.81E-08*	4.13E-08*	4.51E-08-	4.98E-08*
4.0E+03	2.47E-08*	2.78E-08*	3.06E-08*	3.52E-08*	3.89E-08*	4.20E-08*	4.56E-08*	5.02E-08
4.5E+03	2.78E-08*	2.92E-08*	3.18E-08*	3.62E-08*	3.97E-08*	4.26E-08*	4.62E-08*	5.06E-08
5.0E+03	3.06E-08*	3.06E-08*	3.30E-08*	3.71E-08*	4.05E-08*	4.33E-08*	4.67E-08*	5.09E-08
5.5E+03	3.30E-08*	3.18E-08*	3.41E-08*	3.81E-08*	4.13E-08*	4.39E-08*	4.72E-08*	5.13E-08
6.0E+03	3.52E-08*	3.30E-08*	3.52E-08*	3.89E-08*	4.20E-08*	4.45E-08*	4.76E-08*	5.16E-08
8.0E+03	4.20E-08*	3.71E-08*	3.89E-08*	4.20E-08*	4.45E-08*	4.67E-08*	4.94E-08*	5.29E-08
1.0E+04	4.67E-08*	4.05E-08*	4.20E-08*	4.45E-08*	4.67E-08*	4.85E-08*	5.09E-08	5.40E-08
1.2E+04	5.02E-08	4.33E-08*	4.45E-08*	4.67E-08*	4.85E-08*	5.02E-08	5.23E-08	5.51E-08
1.4E+04	5.29E-08	4.56E-08*	4.67E-08*	4.85E-08*	5.02E-08	5.16E-08	5.35E-08	5.60E-08
1.6E+04	5.51E-08	4.76E-08*	4.85E-08*	5.02E-08	5.16E-08	5.29E-08	5.46E-08	5.69E-08
1.8E+04	5.69E-08	4.94E-08*	5.02E-08	5.16E-08	5.29E-08	5.40E-08	5.56E-08	5.77E-08
2.0E+04	5.84E-08	5.09E-08	5.16E-08	5.29E-08	5.40E-08	5.51E-08	5.65E-08	5.84E-08

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

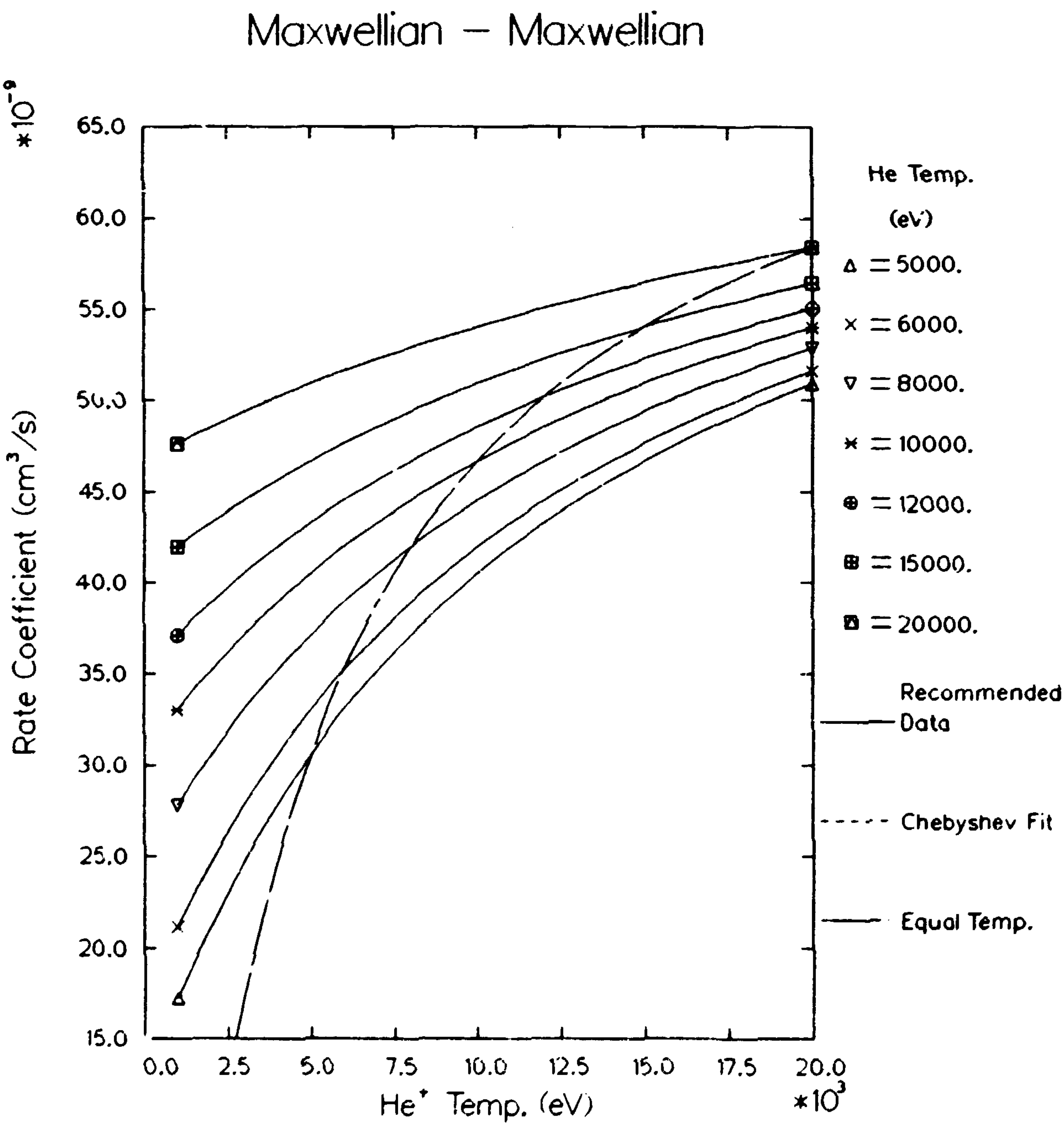
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+03 eV, E_{max} = 2.0E+04 eV

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
5000.	-34.6840	.561425	.00846562	-.0219365	-2.039967E-04	.00120158	-1.325802E-05
6000.	-34.4871	.460985	.0203888	-.0170479	-.00123903	8.950819E-04	7.412802E-05
8000.	-34.2085	.331032	.0296262	-.0101056	-.00187431	4.167700E-04	1.213301E-04
10000.	-34.0188	.252148	.0310288	-.00582488	-.00180584	1.394312E-04	1.072709E-04
12000.	-33.8797	.200089	.0298230	-.00316385	-.00155179	-8.216817E-06	8.115796E-05
15000.	-33.7274	.149363	.0266925	-8.769851E-04	-.00114857	-1.026825E-04	4.607830E-05
20000.	-33.5570	.101222	.0215477	7.809161E-04	-6.525756E-04	-1.278772E-04	1.216316E-05
Equal Temp.	-26.1071	1.93272	-.683257	.177855	-.0338898	.00493571	-5.499191E-04

See appendix for Chebyshev fit details.

$He^+ + He \rightarrow \sigma^+$



Ionization Rate Coefficients for

$He + He^{+} \rightarrow \sigma^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	6.24E-08	6.86E-08	7.45E-08	7.79E-08	8.08E-08	8.07E-08	6.16E-08
2.0E+00	6.24E-08	6.86E-08	7.44E-08	7.79E-08	8.08E-08	8.07E-08	6.16E-08
4.0E+00	6.24E-08	6.86E-08	7.44E-08	7.79E-08	8.08E-08	8.07E-08	6.16E-08
7.0E+00	6.24E-08	6.86E-08	7.44E-08	7.79E-08	8.08E-08	8.07E-08	6.16E-08
1.0E+01	6.24E-08	6.86E-08	7.44E-08	7.79E-08	8.08E-08	8.07E-08	6.16E-08
2.0E+01	6.23E-08	6.86E-08	7.44E-08	7.79E-08	8.08E-08	8.07E-08	6.16E-08
4.0E+01	6.23E-08	6.85E-08	7.44E-08	7.79E-08	8.08E-08	8.07E-08	6.16E-08
7.0E+01	6.23E-08	6.85E-08	7.44E-08	7.79E-08	8.08E-08	8.06E-08	6.16E-08
1.0E+02	6.23E-08	6.85E-08	7.44E-08	7.79E-08	8.07E-08	8.06E-08	6.16E-08
2.0E+02	6.23E-08	6.85E-08	7.44E-08	7.79E-08	8.07E-08	8.05E-08	6.16E-08
4.0E+02	6.23E-08	6.85E-08	7.44E-08	7.79E-08	8.07E-08	8.05E-08	6.16E-08
7.0E+02	6.23E-08	6.85E-08	7.44E-08	7.80E-08	8.06E-08	8.04E-08	6.16E-08
1.0E+03	6.23E-08	6.86E-08	7.43E-08	7.80E-08	8.06E-08	8.03E-08	6.16E-08
2.0E+03	6.23E-08	6.86E-08	7.43E-08	7.80E-08	8.05E-08	8.01E-08	6.16E-08
4.0E+03	6.21E-08	6.87E-08	7.43E-08	7.81E-08	8.04E-08	7.98E-08	6.16E-08
7.0E+03	6.19E-08	6.88E-08	7.43E-08	7.81E-08	8.02E-08	7.95E-08	6.16E-08
1.0E+04	6.19E-08	6.88E-08	7.43E-08	7.81E-08	8.01E-08	7.93E-08	6.16E-08
2.0E+04	6.28E-08	6.90E-08	7.44E-08	7.82E-08	7.99E-08	7.87E-08	6.16E-08

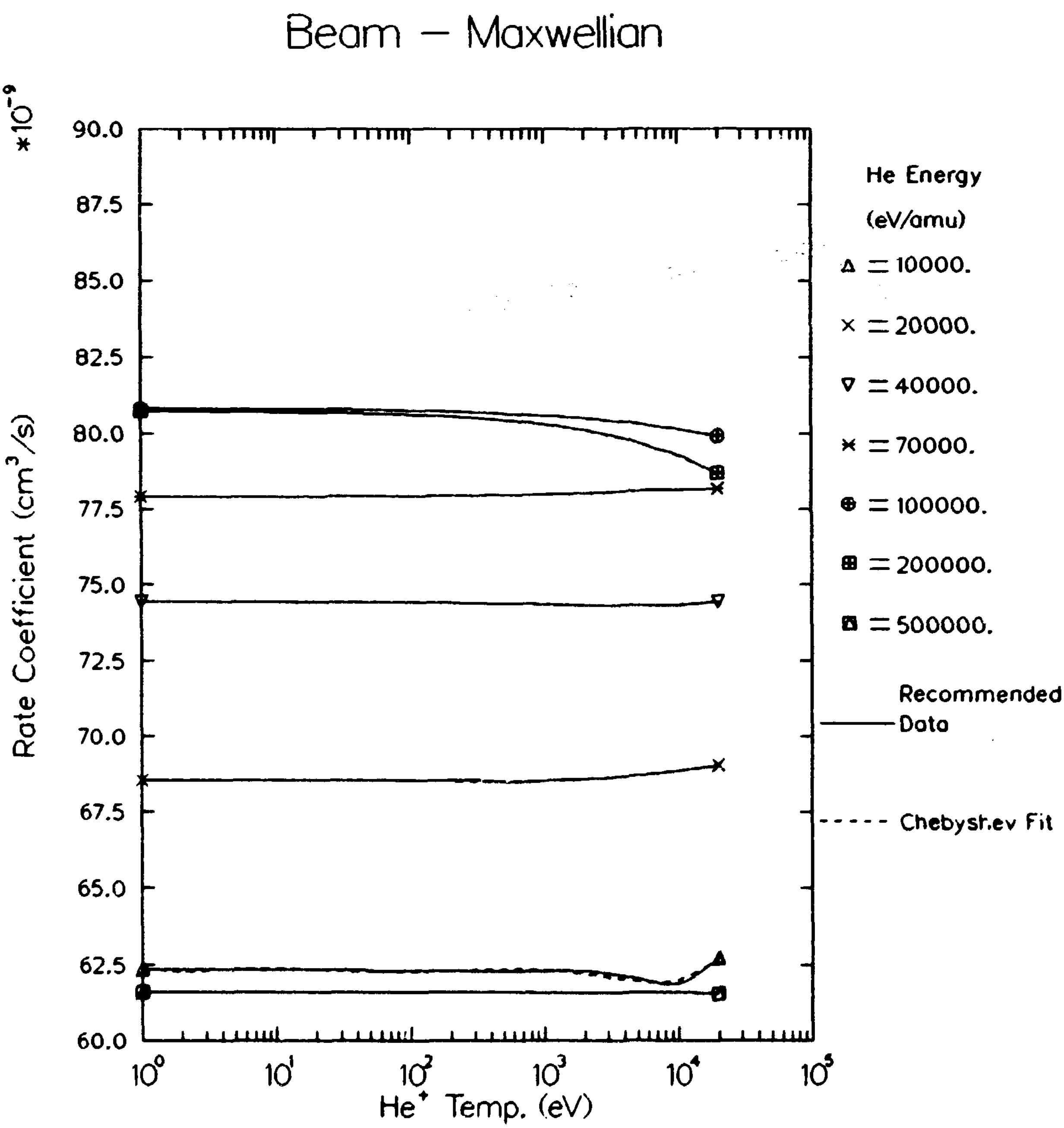
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-33.1826	-8.447088E-04	4.379986E-04	.00153621	.00196721	.00191297	.00165579
20000.	-32.9886	.00246657	.00200537	.00110670	3.142096E-04	-7.069038E-05	-9.257167E-05
40000.	-32.8276	-7.087943E-04	1.614074E-04	4.588808E-04	3.529485E-04	1.836710E-04	9.755263E-05
70000.	-32.7333	.00154471	7.127662E-04	1.336512E-04	-9.932012E-05	-1.253244E-04	-7.595796E-05
100000.	-32.6686	-.00490652	-.00228784	-7.224299E-04	-1.313023E-04	-2.878208E-05	1.350276E-05
200000.	-32.6778	-.0107031	-.00545996	-.00203612	-5.571363E-04	-8.996061E-05	1.739583E-05
500000.	-33.2050	-2.649854E-04	-1.908228E-04	-1.196480E-04	-6.719115E-05	-3.770261E-05	-2.551690E-05

See appendix for Chebyshev fit details.

He + He^+ -> σ^+



Beam – Maxwellian
*10^-9
Rate Coefficient (cm^3/s)
90.0
87.5
85.0
82.5
80.0
77.5
75.0
72.5
70.0
67.5
65.0
62.5
60.0
10^0
10^1
10^2
10^3
10^4
10^5
He^+ Temp. (eV)
He Energy
(eV/amu)
= 10000.
= 20000.
= 40000.
= 70000.
= 100000.
= 200000.
= 500000.
Recommended Data
Chebyshev Fit

Ionization Rate Coefficients for

He^{+} + He -> σ^{-}

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

He^{+} Temp. (eV)	Equal Temp.	He Temp. (eV) 5000.	6000.	8000.	10000.	12000.	15000.	20000.
1.0E+03	2.40E-11#	7.15E-10*	9.55E-10*	1.46E-09*	1.99E-09*	2.54E-09	3.39E-09	4.87E-09
1.5E+03	1.23E-10#	8.33E-10*	1.08E-09*	1.59E-09*	2.13E-09*	2.68E-09	3.54E-09	5.02E-09
2.0E+03	2.86E-10#	9.55E-10*	1.20E-09*	1.73E-09*	2.27E-09*	2.82E-09	3.68E-09	5.17E-09
2.5E+03	4.89E-10*	1.08E-09*	1.33E-09*	1.86E-09*	2.40E-09	2.97E-09	3.83E-09	5.32E-09
3.0E+03	7.15E-10*	1.20E-09*	1.46E-09*	1.99E-09*	2.54E-09	3.11E-09	3.98E-09	5.48E-09
3.5E+03	9.55E-10*	1.33E-09*	1.59E-09*	2.13E-09*	2.68E-09	3.25E-09	4.12E-09	5.63E-09
4.0E+03	1.20E-09*	1.46E-09*	1.73E-09*	2.27E-09*	2.82E-09	3.39E-09	4.27E-09	5.78E-09
4.5E+03	1.46E-09*	1.59E-09*	1.86E-09*	2.40E-09	2.97E-09	3.54E-09	4.42E-09	5.93E-09
5.0E+03	1.73E-09*	1.73E-09*	1.99E-09*	2.54E-09	3.11E-09	3.68E-09	4.57E-09	6.09E-09
5.5E+03	1.99E-09*	1.86E-09*	2.13E-09*	2.68E-09	3.25E-09	3.83E-09	4.72E-09	6.24E-09
6.0E+03	2.27E-09*	1.99E-09*	2.27E-09*	2.82E-09	3.39E-09	3.98E-09	4.87E-09	6.40E-09
8.0E+03	3.39E-09	2.54E-09	2.82E-09	3.39E-09	3.98E-09	4.57E-09	5.48E-09	7.02E-09
1.0E+04	4.57E-09	3.11E-09	3.39E-09	3.98E-09	4.57E-09	5.17E-09	6.09E-09	7.64E-09
1.2E+04	5.78E-09	3.68E-09	3.98E-09	4.57E-09	5.17E-09	5.78E-09	6.71E-09	8.27E-09
1.4E+04	7.02E-09	4.27E-09	4.57E-09	5.17E-09	5.78E-09	6.40E-09	7.33E-09	8.91E-09
1.6E+04	8.27E-09	4.87E-09	5.17E-09	5.78E-09	6.40E-09	7.02E-09	7.96E-09	9.54E-09
1.8E+04	9.54E-09	5.48E-09	5.78E-09	6.40E-09	7.02E-09	7.64E-09	8.59E-09	1.02E-08
2.0E+04	1.08E-08	6.09E-09	6.40E-09	7.02E-09	7.64E-09	8.27E-09	9.22E-09	1.08E-08

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

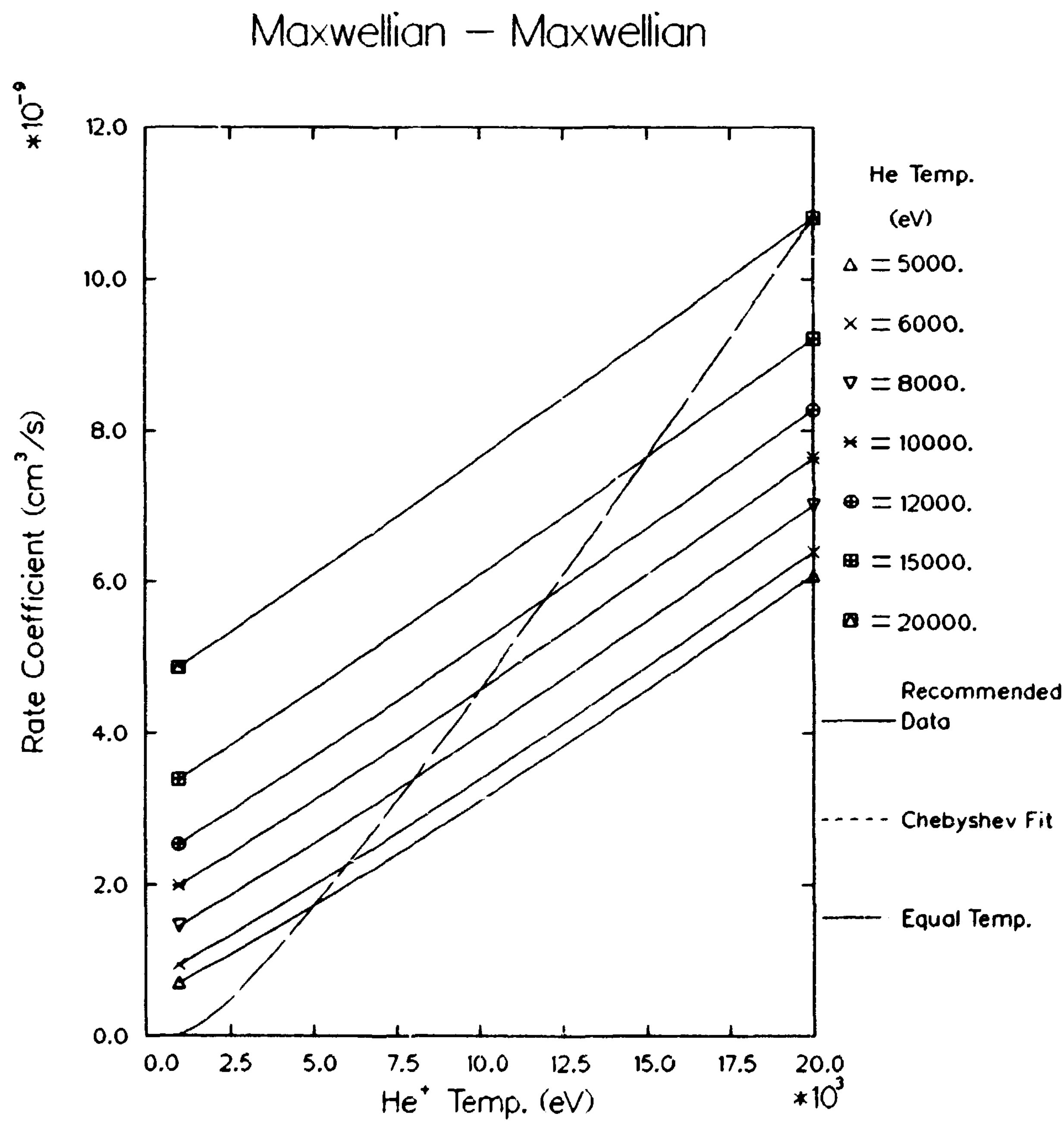
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+03 eV, E_{max} = 2.0E+04 eV

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
5000.	-40.2457	1.08016	..17224	-.00960777	-.00225681	.00426467	-3.707387E-05
6000.	-39.9198	.955399	.. 4445	-.00462863	-.00297856	1.656917E-04	3.638382E-05
8000.	-39.4021	.782041	.165020	.00249323	-.00313214	-2.249516E-04	6.938838E-05
10000.	-38.9951	.665607	.138788	.00682158	-.00268049	-4.285723E-04	4.558085E-05
12000.	-38.6575	.580938	.130790	.00942419	-.00211989	-5.139889E-04	1.312445E-05
15000.	-38.2374	.488850	.118758	.0114760	-.00136912	-5.313647E-04	-2.876352E-05
20000.	-37.6842	.386897	.101410	.0124848	-5.096408E-04	-4.658120E-04	-7.014682E-05
Equal Temp.	-41.6708	2.88394	-.522363	.167306	-.0405614	.00499358	-2.402961E-04

See appendix for Chebyshev fit details.

$He^{+} + He \rightarrow \sigma^{-}$



Ionization Rate Coefficients for

$He + He^{+} \rightarrow \sigma^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	400000.
1.0E+00	8.99E-09	3.51E-09	2.12E-08	5.88E-08	8.73E-08	9.38E-08	8.59E-08
2.0E+00	7.46E-09	9.85E-09	2.88E-08	5.91E-08	8.45E-08	9.38E-08	8.58E-08
4.0E+00	6.44E-09	1.40E-08	3.24E-08	5.84E-08	8.03E-08	9.38E-08	8.58E-08
7.0E+00	6.22E-09	1.48E-08	3.30E-08	5.84E-08	7.95E-08	9.37E-08	8.58E-08
1.0E+01	6.20E-09	1.48E-08	3.30E-08	5.84E-08	7.94E-08	9.37E-08	8.58E-08
2.0E+01	6.20E-09	1.48E-08	3.30E-08	5.84E-08	7.94E-08	9.37E-08	8.58E-08
4.0E+01	6.21E-09	1.48E-08	3.30E-08	5.84E-08	7.94E-08	9.37E-08	8.58E-08
7.0E+01	6.22E-09	1.49E-08	3.30E-08	5.84E-08	7.94E-08	9.36E-08	8.58E-08
1.0E+02	6.23E-09	1.49E-08	3.30E-08	5.84E-08	7.93E-08	9.36E-08	8.58E-08
2.0E+02	6.26E-09	1.49E-08	3.30E-08	5.84E-08	7.93E-08	9.35E-08	8.58E-08
4.0E+02	6.33E-09	1.49E-08	3.31E-08	5.84E-08	7.92E-08	9.34E-08	8.58E-08
7.0E+02	6.43E-09	1.50E-08	3.31E-08	5.84E-08	7.91E-08	9.33E-08	8.58E-08
1.0E+03	6.53E-09	1.51E-08	3.32E-08	5.84E-08	7.90E-08	9.32E-08	8.57E-08
2.0E+03	6.87E-09	1.55E-08	3.35E-08	5.86E-08	7.87E-08	9.30E-08	8.57E-08
4.0E+03	7.56E-09	1.62E-08	3.41E-08	5.89E-08	7.83E-08	9.27E-08	8.56E-08
7.0E+03	8.57E-09	1.72E-08	3.50E-08	5.94E-08	7.78E-08	9.22E-08	8.51E-08
1.0E+04	9.57E-09	1.82E-08	3.56E-08	5.99E-08	7.74E-08	9.20E-08	8.39E-08
2.0E+04	1.29E-08	2.15E-08	3.87E-08	6.11E-08	7.66E-08	9.13E-08	7.91E-08

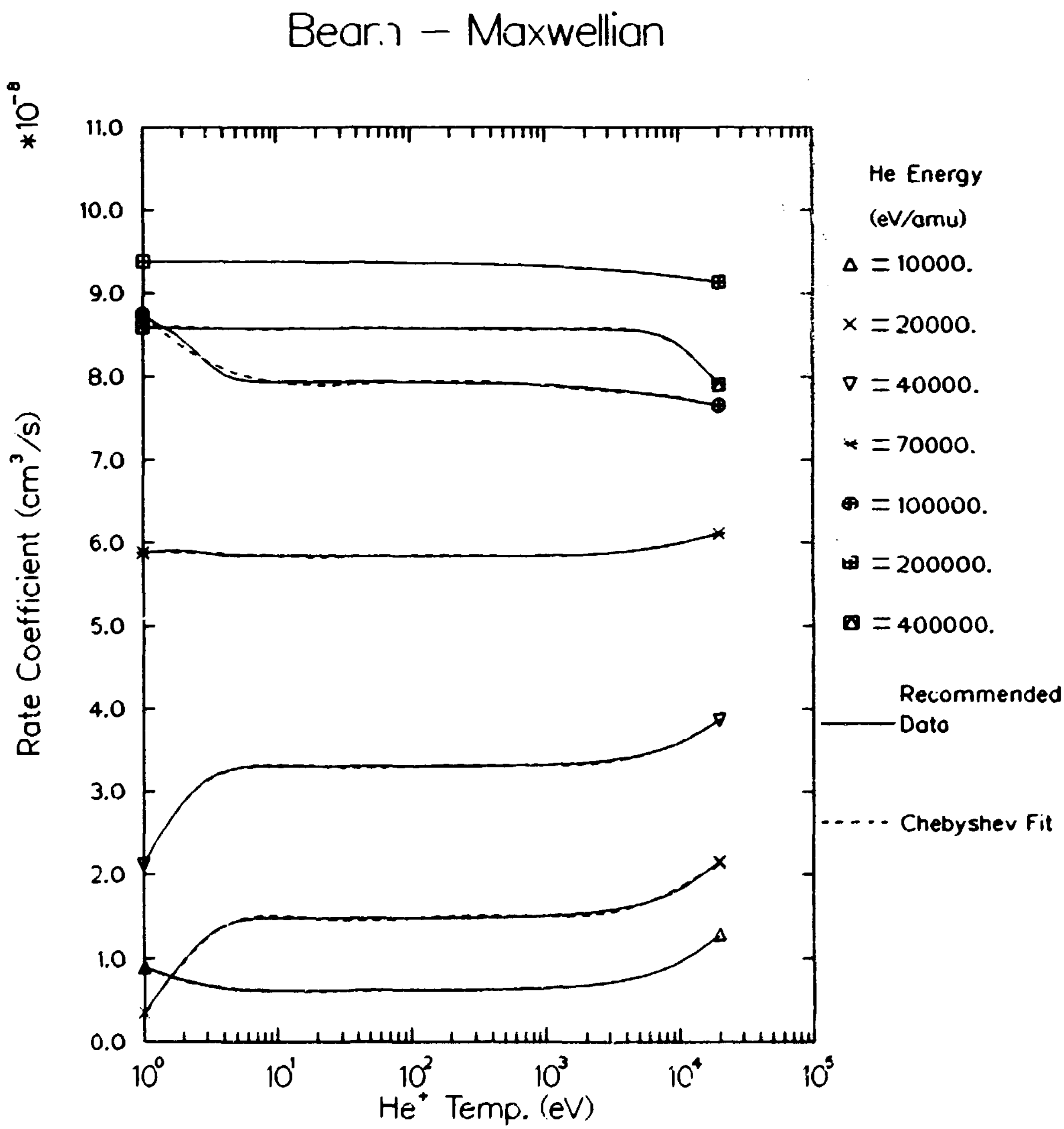
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-37.3[illegible]67	.152586	.271251	.0286627	.0720550	-.00417899	1.885647E-04
20000.	-36.2921	.498746	-.223651	.296885	-.142577	.103860	-.0465049
40000.	-34.5146	.168467	-.0600577	.0991481	-.0398571	.0325305	-.0123581
70000.	-33.2915	.0119357	.0143042	.00553446	.00283829	.00124894	-.00136315
100000.	-32.6810	-.0457164	.0165590	-.0198832	.00750636	-.00146373	-.00200726
200000.	-32.3792	-.0113032	-.00566531	-.00204888	-5.329708E-04	-7.815125E-05	1.640098E-05
400000.	-32.5635	-.0211742	-.0170066	-.0140215	-.00943770	-.00589724	-.00293363

See appendix for Chebyshev fit details.

He + He$^+$ -> σ^-



Beam – Maxwellian
*10^-8
Rate Coefficient (cm^3/s)
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
10^0
10^1
10^2
10^3
10^4
10^5
He^+ Temp. (eV)
He Energy
(eV/amu)
= 10000.
= 20000.
= 40000.
= 70000.
= 100000.
= 200000.
= 400000.
Recommended Data
Chebyshev Fit

Single and Double Ionization Cross Sections for He^+ in He

$$He^+ + He \rightarrow He^+ + He^+ + e$$
$$\rightarrow He^+ + He^{2+} + 2e$$

$He^+ + He^+ + e$		$He^+ + He^{2+} + 2e$	
Energy (eV/amu)	Cross Section (cm^2)	Energy (eV/amu)	Cross Section (cm^2)
1.2E+04	4.09E-16	1.2E+04	2.16E-18
1.5E+04	3.57E-16	1.5E+04	2.87E-18
2.0E+04	3.07E-16	2.0E+04	3.88E-18
3.0E+04	2.52E-16	3.0E+04	5.82E-18
4.0E+04	2.19E-16	4.0E+04	7.76E-18
6.0E+04	1.80E-16	6.0E+04	9.74E-18
8.0E+04	1.54E-16	8.0E+04	9.08E-18
1.0E+05	1.36E-16	1.0E+05	7.69E-18
1.5E+05	1.08E-16	1.5E+05	4.95E-18
2.0E+05	9.12E-17	2.0E+05	3.32E-18
3.0E+05	7.02E-17	3.0E+05	1.81E-18
4.0E+05	5.85E-17	4.0E+05	1.19E-18
6.0E+05	4.53E-17	6.0E+05	7.14E-19
7.8E+05	3.82E-17	7.5E+05	5.60E-19

References: 388, 462, 463, 494, 495, 496

Accuracy: 20%

Note: At lower energies the formation of He^+ is dominated by single electron capture.

Chebyshev Fitting Parameters for Cross Sections

$He^+ + He^+ + e$ E_{min} = 1.2E+04 eV/amu, E_{max} = 7.8E+05 eV/amu
$He^+ + He^{2+} + 2e$ E_{min} = 1.2E+04 eV/amu, E_{max} = 7.5E+05 eV/amu

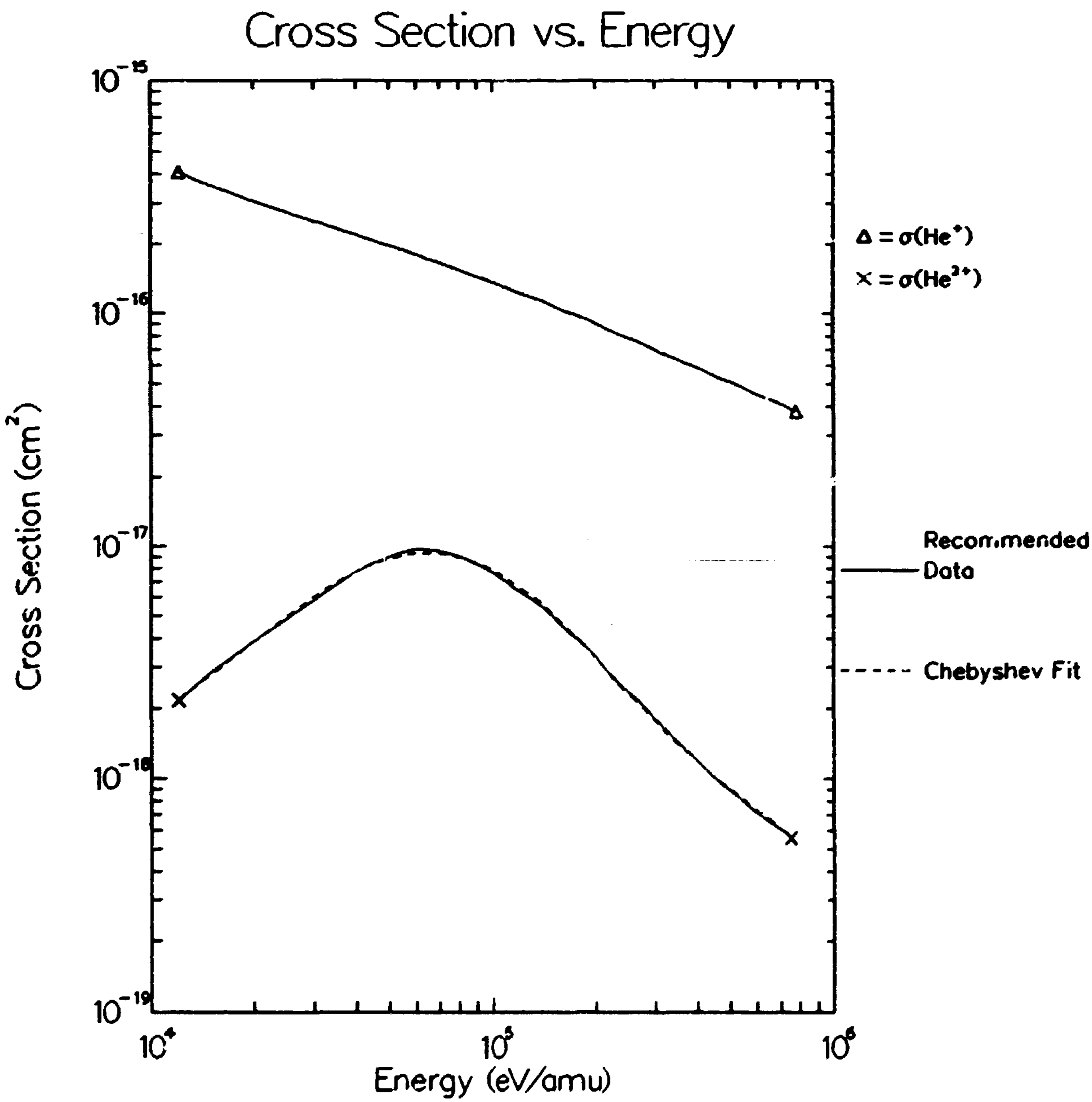
	A0	A1	A2	A3	A4	A5	A6
$He^+ + He^+ + e$	-73.1564	-1.17268	-.0534400	-.00896703	.0130892	-.00303440	.000546481
$He^+ + He^{2+} + 2e$	-80.9940	-.809711	-.972278	.157207	.149794	-.0339390	-.0320888

The fit represents the $He^+ + He^+ + e$ cross section with an rms deviation of 0.2%. The maximum deviation is 0.3% at 1.0E+05 eV/amu.

The fit represents the $He^+ + He^{2+} + 2e$ cross section with an rms deviation of 2.0%. The maximum deviation is 3.3% at 3.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^{+} + He \rightarrow He^{+} + He^{+} + e \quad \sigma(He^{+})$
$He^{+} + He \rightarrow He^{+} + He^{2+} + 2e \quad \sigma(He^{2+})$



Single Ionization Rate Coefficients for

$He + He^{+} \rightarrow He^{+} + He^{+} + e$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{+} Temp. (eV)	He Energy (eV/amu) 15000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	6.07E-08	6.03E-08	6.08E-08	6.08E-08	5.97E-08	5.66E-08	4.99E-08
2.0E+00	6.08E-08	6.03E-08	6.08E-08	6.08E-08	5.97E-08	5.66E-08	4.99E-08
4.0E+00	6.08E-08	6.03E-08	6.08E-08	6.08E-08	5.97E-08	5.66E-08	4.99E-08
7.0E+00	6.08E-08	6.03E-08	6.08E-08	6.08E-08	5.97E-08	5.66E-08	4.99E-08
1.0E+01	6.08E-08	6.03E-08	6.08E-08	6.08E-08	5.97E-08	5.66E-08	4.99E-08
2.0E+01	6.08E-08	6.03E-08	6.08E-08	6.08E-08	5.97E-08	5.66E-08	4.99E-08
4.0E+01	6.08E-08	6.03E-08	6.08E-08	6.08E-08	5.97E-08	5.66E-08	4.99E-08
7.0E+01	6.08E-08	6.03E-08	6.08E-08	6.08E-08	5.97E-08	5.66E-08	4.99E-08
1.0E+02	6.08E-08	6.04E-08	6.08E-08	6.08E-08	5.97E-08	5.66E-08	4.99E-08
2.0E+02	6.06E-08	6.04E-08	6.08E-08	6.08E-08	5.97E-08	5.66E-08	4.99E-08
4.0E+02	5.91E-08	6.04E-08	6.09E-08	6.08E-08	5.97E-08	5.66E-08	4.99E-08
7.0E+02	5.65E-08	6.04E-08	6.09E-08	6.08E-08	5.97E-08	5.66E-08	4.99E-08
1.0E+03	5.45E-08*	6.04E-08	6.08E-08	6.08E-08	5.97E-08	5.66E-08	4.99E-08
2.0E+03	5.05E-08*	5.96E-08	6.09E-08	6.08E-08	5.97E-08	5.65E-08	4.99E-08
4.0E+03	4.73E-08*	5.73E-08	6.09E-08	6.07E-08	5.97E-08	5.65E-08	4.99E-08
7.0E+03	4.59E-08*	5.49E-08	6.08E-08	6.07E-08	5.96E-08	5.64E-08	4.99E-08
1.0E+04	4.55E-08*	5.36E-08*	6.07E-08	6.06E-08	5.96E-08	5.64E-08	4.99E-08
2.0E+04	4.61E-08*	5.18E-08*	5.98E-08	6.03E-08	5.95E-08	5.63E-08	4.99E-08

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

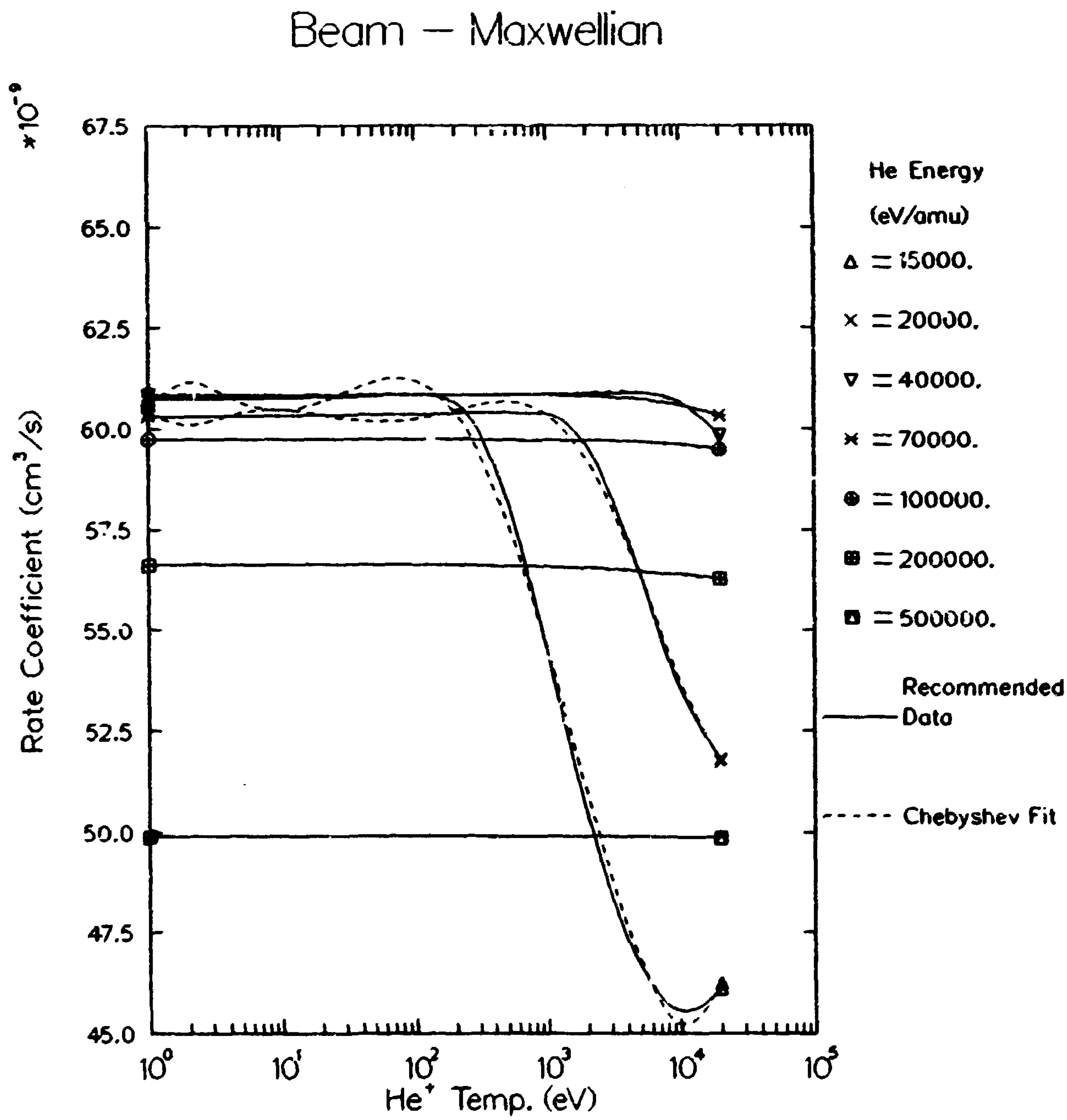
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
15000.	-33.4287	-.158108	-.0677688	.0633240	.0303214	.0168471	-.00235247
20000.	-33.3167	-.0613195	-.0460891	-.0209720	-.00324850	.00492917	.00599209
40000.	-33.2337	-.00382566	-.00347023	-.00301869	-.00227878	-.00145508	-3.331803E-04
70000.	-33.2330	-.00284092	-.00208988	-.00125435	-6.089006E-04	-2.360207E-04	-6.070840E-05
100000.	-33.2684	-.00150867	-9.658744E-04	-5.35351E-04	-2.92897E-04	-1.57790E-04	-6.49004E-05
200000.	-33.3763	-.00257819	-.00151167	-4.93380E-04	-2.11497E-04	5.23848E-05	-7.73477E-06
500000.	-33.6268	-2.54059E-04	-1.85372E-04	-1.19077E-04	-7.06237E-05	-4.19110E-05	-3.05576E-05

See appendix for Chebyshev fit details

He + He^+ -> He^+ + He^+ + e


Beam — Maxwellian
*10⁻⁹
67.5
65.0
62.5
60.0
57.5
55.0
52.5
50.0
47.5
45.0
Rate Coefficient (cm³/s)
10⁰
10¹
10²
10³
10⁴
10⁵
He⁺ Temp. (eV)
He Energy
(eV/amu)
= 15000.
= 20000.
= 40000.
= 70000.
= 100000.
= 200000.
= 500000.
Recommended Data
Chebyshev Fit

Double Ionization Rate Coefficients for

$He + He^{+} \rightarrow He^{+} + He^{2+} + e$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{+} Temp. (eV)	He Energy (eV/amu) 15000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	4.90E-10	7.62E-10	2.15E-09	3.45E-09	3.38E-09	2.06E-09	8.82E-10
2.0E+00	4.88E-10	7.62E-10	2.15E-09	3.45E-09	3.38E-09	2.06E-09	8.82E-10
4.0E+00	4.88E-10	7.62E-10	2.15E-09	3.45E-09	3.38E-09	2.06E-09	8.82E-10
7.0E+00	4.88E-10	7.62E-10	2.15E-09	3.45E-09	3.38E-09	2.06E-09	8.82E-10
1.0E+01	4.88E-10	7.62E-10	2.15E-09	3.45E-09	3.37E-09	2.06E-09	8.82E-10
2.0E+01	4.88E-10	7.62E-10	2.15E-09	3.45E-09	3.37E-09	2.06E-09	8.82E-10
4.0E+01	4.88E-10	7.63E-10	2.15E-09	3.45E-09	3.37E-09	2.06E-09	8.82E-10
7.0E+01	4.88E-10	7.64E-10	2.15E-09	3.45E-09	3.37E-09	2.06E-09	8.82E-10
1.0E+02	4.89E-10	7.64E-10	2.15E-09	3.45E-09	3.37E-09	2.06E-09	8.82E-10
2.0E+02	4.89E-10	7.67E-10	2.14E-09	3.45E-09	3.36E-09	2.06E-09	8.82E-10
4.0E+02	4.86E-10	7.72E-10	2.14E-09	3.45E-09	3.36E-09	2.06E-09	8.82E-10
7.0E+02	4.81E-10	7.81E-10	2.14E-09	3.45E-09	3.35E-09	2.06E-09	8.82E-10
1.0E+03	4.80E-10	7.89E-10	2.14E-09	3.44E-09	3.35E-09	2.06E-09	8.82E-10
2.0E+03	4.91E-10*	8.12E-10	2.16E-09	3.42E-09	3.33E-09	2.06E-09	8.82E-10
4.0E+03	5.35E-10*	8.60E-10	2.19E-09	3.38E-09	3.30E-09	2.06E-09	8.82E-10
7.0E+03	6.15E-10*	9.36E-10	2.22E-09	3.32E-09	3.27E-09	2.06E-09	8.83E-10
1.0E+04	6.93E-10	1.01E-09	2.25E-09	3.26E-09	3.23E-09	2.06E-09	8.83E-10
2.0E+04	9.42E-10	1.25E-09	2.32E-09	3.12E-09	3.12E-09	2.05E-09	8.85E-10

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

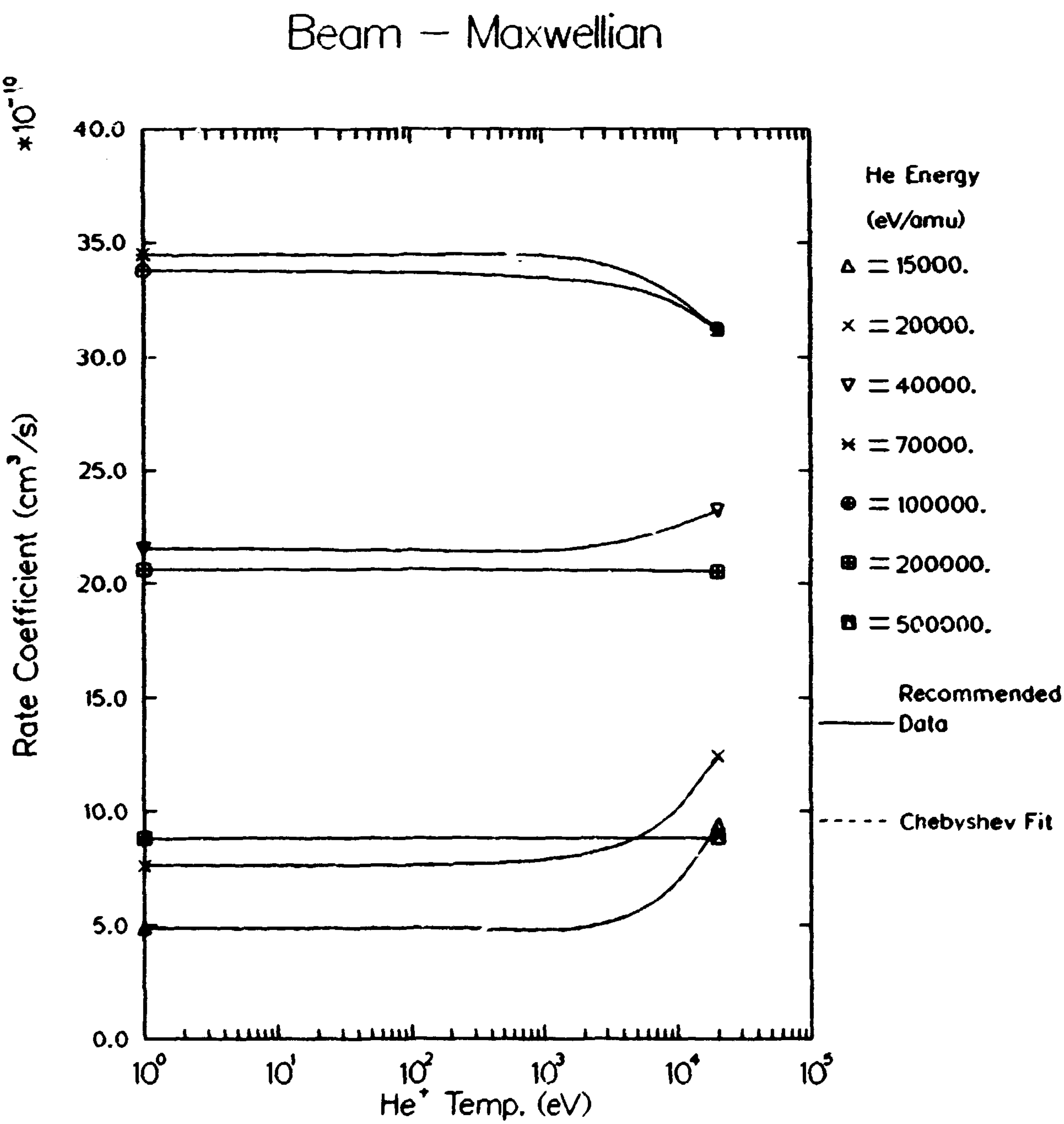
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
15000.	-42.6506	.210697	.170191	.107504	.0517361	.0113452	-.00599787
20000.	-41.7921	.173873	.139280	.0639172	.0267485	.00833917	.00105484
40000.	-39.8862	.0257832	.0210619	.0122377	.00362207	-2.35724E-04	-9.66877E-04
70000.	-39.0084	-.0336772	-.0251731	-.0147490	-.00625255	-.00143355	2.795328E-04
100000.	-39.0462	-.0279022	-.0171564	-.00916918	-.00454775	-.00203657	-7.514507E-04
200000.	-40.0019	-.00189800	-6.33043E-04	-1.62792E-04	-2.09259E-04	-7.95723E-05	-1.42798E-04
500000.	-41.6965	9.43319E-04	7.29142E-04	4.97094E-04	2.96459E-04	1.50204E-04	6.26450E-05

See appendix for Chebyshev fit details.

$He + He^{+} \rightarrow He^{+} + He^{2+} + 2e$



Ionization Cross Sections for

$He^{2+} + H \rightarrow He^{2+} + H^{+} + e$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
3.1E+04	2.45E+08	2.31E-16
4.0E+04	2.78E+08	3.39E-16
5.0E+04	3.11E+08	4.05E-16
6.0E+04	3.40E+08	4.29E-16
7.0E+04	3.68E+08	4.22E-16
8.0E+04	3.93E+08	4.07E-16
9.0E+04	4.17E+08	3.90E-16
1.0E+05	4.39E+08	3.77E-16
1.5E+05	5.38E+08	3.04E-16
2.0E+05	6.21E+08	2.53E-16
3.0E+05	7.61E+08	1.90E-16
4.0E+05	8.78E+08	1.53E-16
5.0E+05	9.82E+08	1.28E-16
5.5E+05	1.03E+09	1.18E-16

References: 506, 507, 508, 509, 510, 522, 512, 653

Accuracy: 30%

Notes: (1) As far as we are aware only one experimental measurement has been reported (Ref. 510). Above 100 keV/amu the theoretical results of Crothers and McCann (Ref. 507) are within 10% of the experimental results. At energies less than 100 keV/amu the theoretical data (Refs. 506, 507, 508, 509, 511, 512) vary by as much as an order of magnitude.

Chebyshev Fitting Parameters for Cross Sections

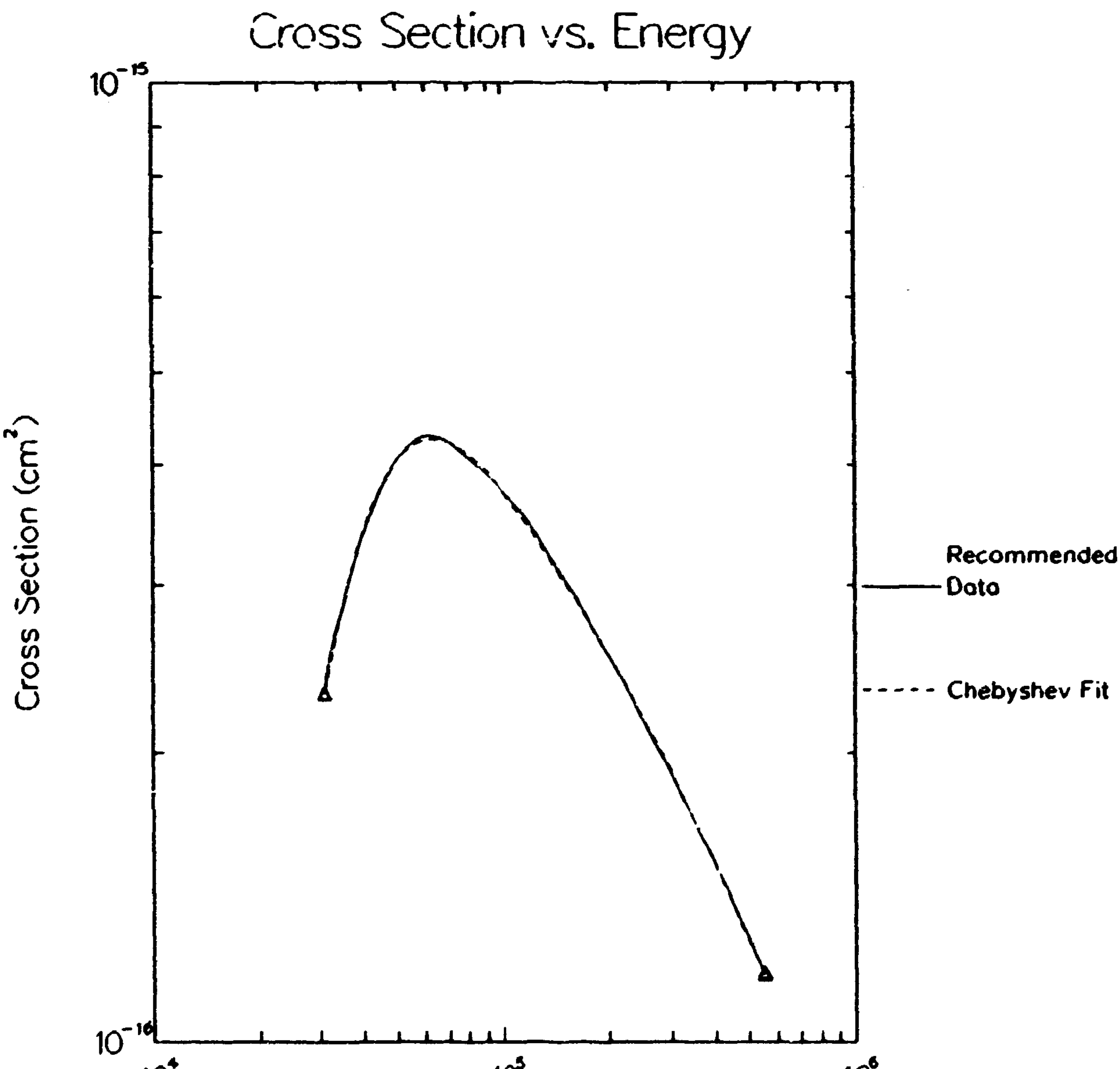
E_{min} = 3.1E+04 eV/amu, E_{max} = 5.5E+05 eV/amu

A0	A1	A2	A3	A4	A5	A6
-71.9027	-.471110	-.344985	.128260	-.0459123	.00932704	.00279820

The fit represents the above cross section with an rms deviation of 0.5%. The maximum deviation is 0.8% at 9.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^{2+} + H \rightarrow He^{2+} + H^{+} + e$



Ionization Rate Coefficients for

$H + He^{2+} \rightarrow H^{+} + He^{2+} + e$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{2+} Temp. (eV)	H Energy (eV/amu) 35000.	40000.	60000.	80000.	100000.	200000.	500000.
1.0E+00	7.21E-08	9.41E-08	1.46E-07	1.60E-07	1.66E-07	1.57E-07	1.26E-07
2.0E+00	7.21E-08	9.40E-08	1.46E-07	1.60E-07	1.66E-07	1.57E-07	1.26E-07
4.0E+00	7.21E-08	9.40E-08	1.46E-07	1.60E-07	1.66E-07	1.57E-07	1.26E-07
7.0E+00	7.21E-08	9.39E-08	1.46E-07	1.60E-07	1.66E-07	1.57E-07	1.26E-07
1.0E+01	7.21E-08	9.39E-08	1.46E-07	1.60E-07	1.65E-07	1.57E-07	1.26E-07
2.0E+01	7.21E-08	9.38E-08	1.46E-07	1.60E-07	1.65E-07	1.57E-07	1.26E-07
4.0E+01	7.22E-08	9.37E-08	1.46E-07	1.60E-07	1.65E-07	1.57E-07	1.26E-07
7.0E+01	7.22E-08	9.35E-08	1.45E-07	1.60E-07	1.65E-07	1.57E-07	1.26E-07
1.0E+02	7.23E-08	9.35E-08	1.45E-07	1.60E-07	1.65E-07	1.57E-07	1.26E-07
2.0E+02	7.19E-08	9.33E-08	1.45E-07	1.60E-07	1.65E-07	1.57E-07	1.26E-07
4.0E+02	7.01E-08	9.31E-08	1.45E-07	1.60E-07	1.65E-07	1.57E-07	1.26E-07
7.0E+02	6.80E-08	9.29E-08	1.44E-07	1.60E-07	1.65E-07	1.57E-07	1.26E-07
1.0E+03	6.67E-08*	9.25E-08	1.44E-07	1.59E-07	1.65E-07	1.57E-07	1.25E-07
2.0E+03	6.54E-08*	9.10E-08	1.43E-07	1.59E-07	1.64E-07	1.57E-07	1.24E-07
4.0E+03	6.66E-08*	8.96E-08	1.42E-07	1.59[illegible]07	1.64E-07	1.57E-07	1.18E-07
7.0E+03	6.96E-08*	8.96E-08	1.40E-07	1.58[illegible]7	1.63E-07	1.56E-07	1.10E-07*
1.0E+04	7.26E-08*	9.04E-08*	1.38E-07	1.56E-07	1.62E-07	1.56E-07	1.04E-07*
2.0E+04	8.06E-08*	9.43E-08*	1.34E-07	1.53E-07	1.60E-07	1.56E-07	9.36E-08*

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

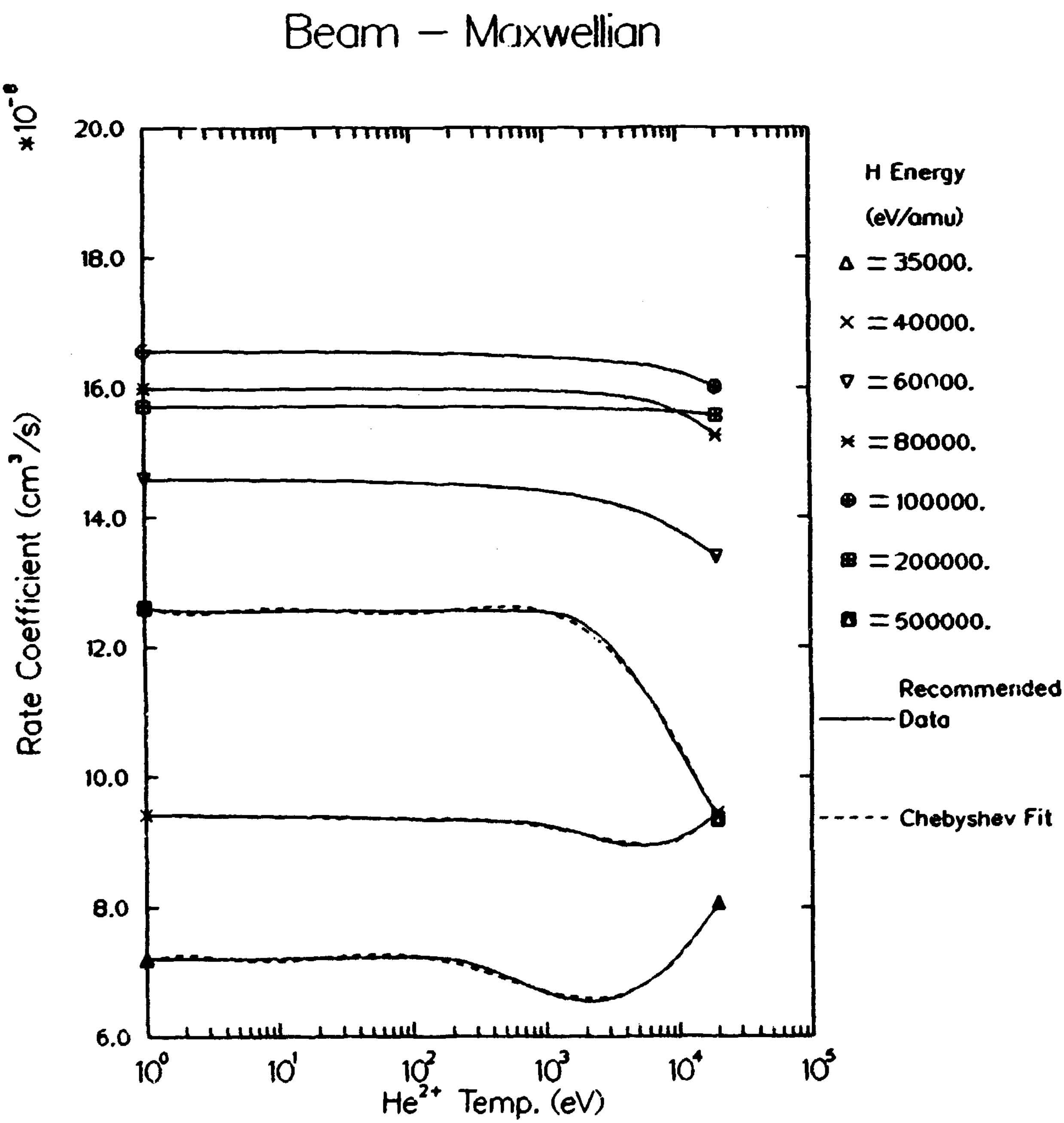
<u>Chebyshev Fitting Parameters for Rate Coefficients</u>

$E_{min} = 1.0E+00$ eV, $E_{max} = 2.0E+04$ eV

H Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
35000.	-32.9985	.00549401	.0364412	.0474517	.0313047	.00563515	-.00840841
40000.	-32.3844	-.0158075	6.87620E-04	.00939742	.0108456	.00801907	.00326444
60000.	-31.5217	-.0331828	-.0190037	-.00885517	-.00343877	-9.09107E-04	9.58875E-05
80000.	-31.3145	-.0148657	-.0105289	-.00656864	-.00357109	-.00159023	-5.08065E-04
100000.	-31.2432	-.0124344	-.00696173	-.00342119	-.00172670	-9.03335E-04	-4.39816E-04
200000.	-31.3365	-.00345476	-.00195[illegible]	-3.10531E-04	-3.44995E-04	-1.21204E-04	-2.21966E-05
500000.	-31.8962	-.105965	-.0779255	-.0443668	-.0153954	-4.90580E-04	.00568340

See appendix for Chebyshev fit details.

$H + He^{2+} \rightarrow H^+ + He^{2+} + e$



Cross Sections for the Production of Slow Positive Ions and Electrons for He^{2+} Colliding with H_2 Molecules

$He^{2+} + H_2 \rightarrow \Sigma$ (H_2^+ and H^+ Prod.) σ^+
$\rightarrow \Sigma$ Electrons σ^-

$He^{2+} + H_2$ (σ^+)

Energy (eV/amu)	Cross Section (cm^2)
2.0E+03	3.82E-15
4.0E+03	6.17E-16
7.0E+03	8.79E-16
1.0E+04	1.11E-15
1.5E+04	1.37E-15
2.0E+04	1.47E-15
2.3E+04	1.49E-15
4.0E+04	1.28E-15
7.0E+04	9.83E-16
1.0E+05	7.90E-16
1.5E+05	6.21E-16
2.0E+05	5.15E-16
3.0E+05	4.01E-16

$He^{2+} + H_2$ (σ^-)

Energy (eV/amu)	Cross Section (cm^2)
2.5E+03	9.15E-17
4.0E+03	7.80E-17
5.0E+03	7.52E-17
7.0E+03	8.35E-17
1.0E+04	1.18E-16
1.5E+04	2.12E-16
2.0E+04	3.17E-16
4.0E+04	6.19E-16
7.0E+04	7.00E-16
1.0E+05	6.97E-16
1.5E+05	6.01E-16
2.0E+05	4.94E-16
4.0E+05	2.51E-16
5.0E+05	1.90E-16

References: 95, 143, 144, 346, 479, 532, 533, 534

Accuracy: 25%

Notes: (1) The seven reactions producing slow ions and electrons are: (a) $He^{2+} + H_2 \rightarrow He^{2+} + H_2^+ + e$ (single ionization), (b) $He^{2+} + H_2 \rightarrow He^{2+} + H^+ + H + e$ (dissociative ionization), (c) $He^{2+} + H_2 \rightarrow He^{2+} + H^+ + H^+ + 2e$ (double ionization), (d) $He^{2+} + H_2 \rightarrow He^+ + H_2^+$ (single electron capture), (e) $He^{2+} + H_2 \rightarrow He^+ + H^+ + H$ (dissociative electron capture), (f) $He^{2+} + H_2 \rightarrow He^+ + H^+ + H^+ + e$ (electron capture with ionization), (g) $He^{2+} + H_2 \rightarrow He + H^+ + H^+$ (double electron capture). (2) Afrosimov et al. (Ref. 95) have made a detailed study of these reactions in the energy region 2.3×10^3 to 2.5×10^4 eV/amu. (3) The cross section for slow electron production (σ^-) is the sum of $\sigma(a) + \sigma(b) + 2\sigma(c) + \sigma(f)$. (4) The cross section for slow positive ion production is the sum of $\sigma(a) + \sigma(b) + 2\sigma(c) + \sigma(d) + \sigma(e) + 2\sigma(f) + 2\sigma(g)$.

Chebyshev Fitting Parameters for Cross Sections

$He^{2+} + H_2$ (σ^+) E_{min} = 2.0E+03 eV/amu, E_{max} = 3.0E+05 eV/amu
$He^{2+} + H_2$ (σ^-) E_{min} = 2.5E+03 eV/amu, E_{max} = 5.0E+05 eV/amu

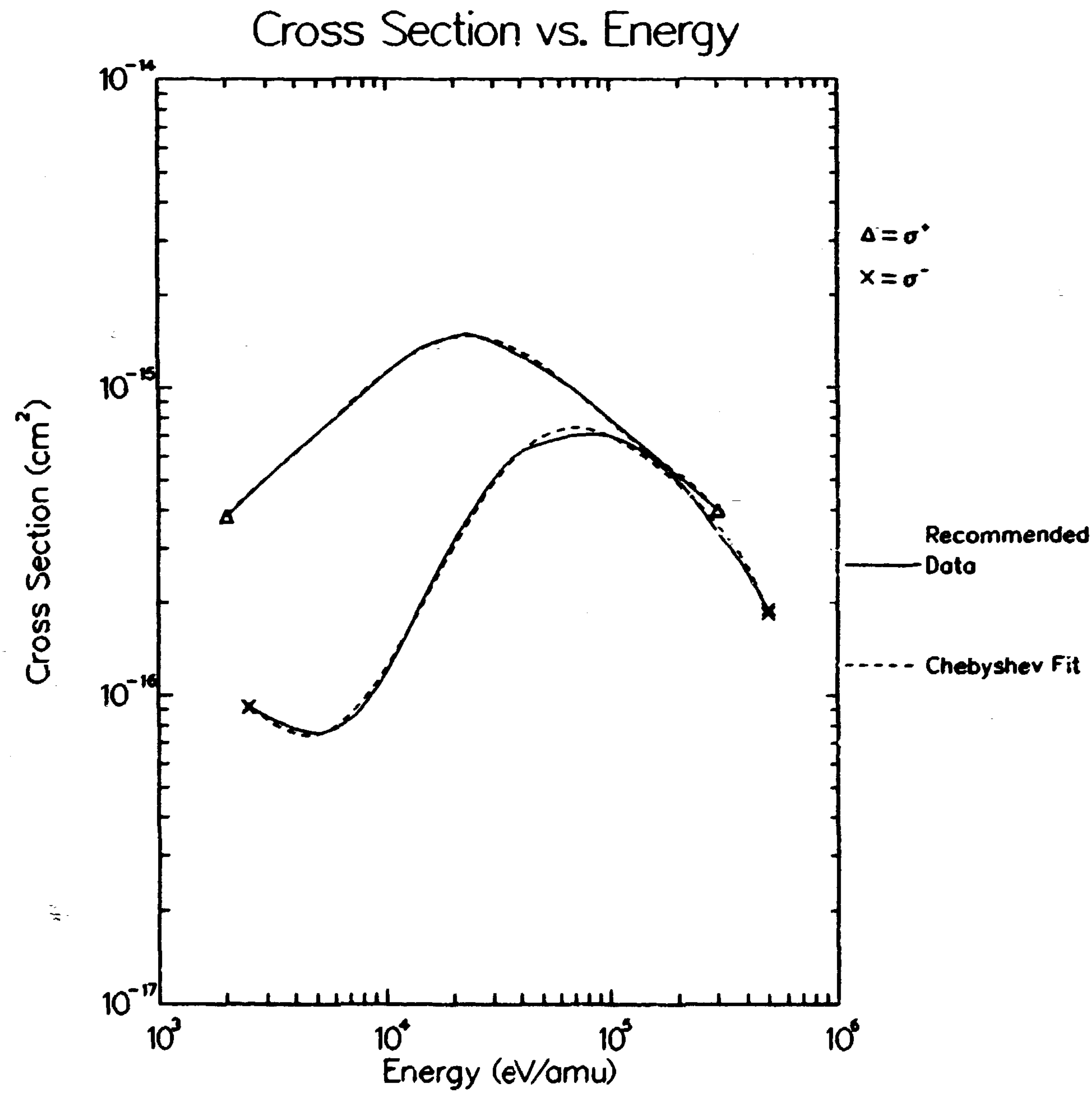
	A0	A1	A2	A3	A4	A5	A6
$He^{2+} + H_2$ (σ^+)	-69.8186	.0111387	-.631977	.0179570	.0939313	-.00776735	-.0310932
$He^{2+} + H_2$ (σ^-)	-72.0755	.794419	-.668306	-.447465	.196243	-.000576099	-.0629005

The fit represents the (σ^+) cross section with an rms deviation of 1.3%. The maximum deviation is 3.0% at 4.0E+04 eV/amu.

The fit represents the (σ^-) cross section with an rms deviation of 3.2%. The maximum deviation is 5.8% at 7.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^{2+} + H_2 \rightarrow \Sigma(H_2^+ + H^+)\ \sigma^+$
$He^{2+} + H_2 \rightarrow \Sigma\, e\ \ \sigma^-$



Cross Sections for the Production of H^+ and H_2^+ Ions for He^{2+} Incident On H_2

$$He^{2+} + H_2 \rightarrow \sigma(H^+)$$
$$\rightarrow \sigma(H_2^+)$$

(Curve A) Total H_2^+ Prod.		(Curve B) Single Ion. H_2^+ Prod.		(Curve C) Total H^+ Prod.		(Curve D) Ion. H^+ Prod.	
Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)
2.1E+03	9.68E-17	2.5E+03	9.97E-18	2.3E+03	2.17E-16	2.3E+03	1.66E-16
7.0E+03	6.30E-16	1.0E+04	5.30E-17	7.0E+03	1.91E-16	7.0E+03	1.12E-16
1.0E+04	7.92E-16	1.5E+04	1.36E-16	1.0E+04	2.15E-16	1.0E+04	1.29E-16
1.5E+04	9.00E-16	2.0E+04	2.90E-16	1.5E+04	2.51E-16	1.5E+04	1.60E-16
2.0E+04	9.95E-16	3.0E+04	1.50E-15	2.0E+04	2.86E-16	2.0E+04	1.79E-16
3.0E+04	1.48E-15	4.0E+04	3.20E-15	4.0E+04	4.53E-16	2.5E+04	1.90E-16
4.0E+04	3.18E-15	8.4E+04	5.19E-15	7.0E+04	6.35E-16	4.0E+04	1.76E-16
7.0E+04	5.07E-15	1.0E+05	5.18E-15	8.0E+04	6.43E-16	7.0E+04	1.36E-16
8.4E+04	5.21E-15	1.5E+05	4.77E-15	1.0E+05	6.32E-16	1.0E+05	1.06E-16
1.0E+05	5.18E-15	2.0E+05	4.26E-15	1.5E+05	5.59E-16	1.5E+05	7.51E-17
1.5E+05	4.80E-15	4.0E+05	2.97E-15	2.0E+05	4.87E-16	2.0E+05	[illegible]
2.0E+05	4.29E-15	5.4E+05	2.50E-15	4.0E+05	3.20E-16	4.0E+05	[illegible]
4.0E+05	2.97E-15			4.6E+05	2.92E-16	6.0E+05	1.50E-17
5.4E+05	2.50E-15						

References: 95, 346, 553

Accuracy: 25%

Notes: (1) The seven reactions producing reaction products H^+ and H_2^+ are: (a) $He^{2+} + H_2 \rightarrow He^{2+} + H_2^+ + e$, single ionization; (b) $He^{2+} + H_2 \rightarrow He^{2+} + H^+ + H + e$, dissociative ionization; (c) $He^{2+} + H_2 \rightarrow He^{2+} + H^+ + H^+ + 2e$, double ionization; (d) $He^{2+} + H_2 \rightarrow He^+ + H_2^+$, electron capture; (e) $He^{2+} + H_2 \rightarrow He^+ + H^+ + H$, dissociative electron capture; (f) $He^{2+} + H_2 \rightarrow He^+ + H^+ + H^+ + e$, electron capture with ionization; (g) $He^{2+} + H_2 \rightarrow He + H^+ + H^+$, double electron capture. (2) Afrosimov et al. (Ref. 96) have made detailed studies of these reactions. (3) Shown as curve A is the total cross section for producing H_2^+ and is the sum of $\sigma(a)$ and $\sigma(d)$. (4) Curve B is the single ionization cross section for producing H_2^+, $\sigma(a)$. (5) Curve C is the total cross section for producing H^+ and is the sum of $\sigma(b) + 2\sigma(c) + \sigma(e) + 2\sigma(f)$. (6) Curve D is the cross section for producing H^+ by ionization collisions, $\sigma(b) + 2\sigma(c)$.

Chebyshev Fitting Parameters for Cross Sections

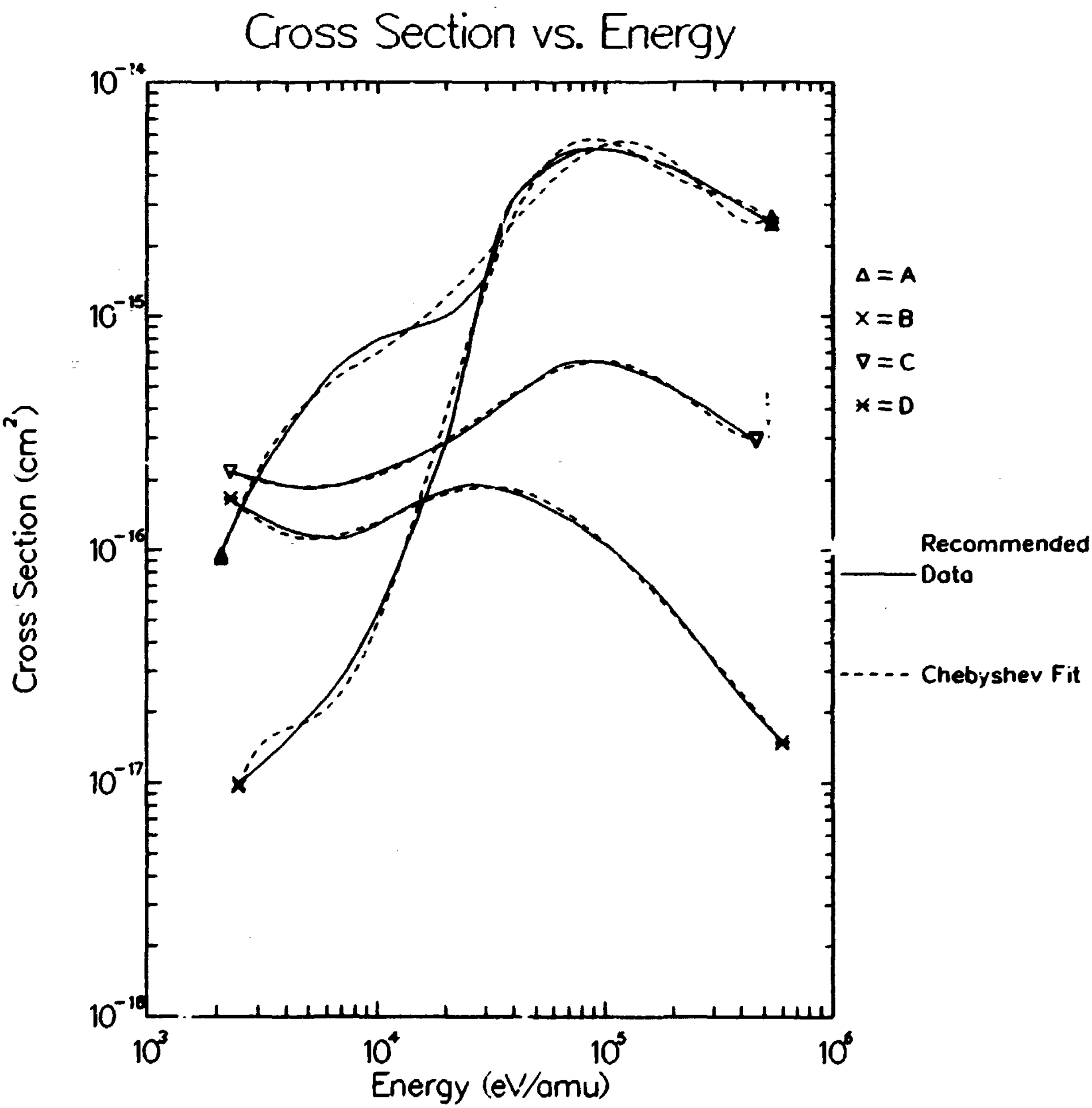
Curve A E_{min} = 2.1E+03 eV/amu, E_{max} = 5.4E+05 eV/amu
Curve B E_{min} = 2.5E+03 eV/amu, E_{max} = 5.4E+05 eV/amu
Curve C E_{min} = 2.3E+03 eV/amu, E_{max} = 4.6E+05 eV/amu
Curve D E_{min} = 2.3E+03 eV/amu, E_{max} = 6.0E+05 eV/amu

	A0	A1	A2	A3	A4	A5	A6
Curve A	-68.8191	1.63697	-.768285	-.163048	-.111162	.206844	.0545283
Curve B	-70.9500	3.23148	-1.12038	-.650292	.397513	.189249	-.208238
Curve C	-71.4299	.407648	-.257736	-.323208	.0419822	.0784881	.0252954
Curve D	-74.1448	-.984730	-.626797	-.217335	.186783	-.0134584	-.0263402

The fit represents the Curve A cross section with an rms deviation of 12.0%.
The maximum deviation is 23.3% at 3.0E+04 eV/amu.
The fit represents the Curve B cross section with an rms deviation of 12.7%.
The maximum deviation is 31.9% at 2.0E+04 eV/amu.
The fit represents the Curve C cross section with an rms deviation of 2.3%.
The maximum deviation is 3.3% at 1.5E+05 eV/amu.
The fit represents the Curve D cross section with an rms deviation of 3.2%.
The maximum deviation is 4.4% at 7.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^{2+} + H_2 \rightarrow \sigma(H^+), \sigma(H_2^+)$



Cross Sections for the Production of Slow Positive Ions and Electrons for He^{2+} Ions Interacting with He.

$He^{2+} + He \rightarrow \sigma^{+}$
$He^{2+} + He \rightarrow \sigma^{-}$

$He^{2+} + He$ (σ^{+})		$He^{2+} + He$ (σ^{-})	
Energy (eV/amu)	Cross Section (cm^2)	Energy (eV/amu)	Cross Section (cm^2)
9.0E+03	3.72E-16	5.0E+03	1.59E-18
1.0E+04	4.03E-16	7.0E+03	4.68E-18
1.5E+04	5.30E-16	1.0E+04	1.29E-17
2.0E+04	5.87E-16	1.5E+04	3.07E-17
3.0E+04	6.03E-16	2.0E+04	5.11E-17
4.0E+04	5.91E-16	4.0E+04	1.30E-16
7.0E+04	4.98E-16	7.0E+04	2.20E-16
1.0E+05	4.19E-16	1.0E+05	2.74E-16
1.5E+05	3.29E-16	1.3E+05	2.88E-16
2.0E+05	2.73E-16	1.5E+05	2.84E-16
4.0E+05	1.70E-16	2.0E+05	2.51E-16
7.0E+05	1.14E-16	4.0E+05	1.62E-16
1.0E+06	8.54E-17	7.0E+05	1.06E-16
1.5E+06	6.10E-17	1.0E+06	7.96E-17
2.0E+06	4.74E-17	1.5E+06	5.57E-17
2.9E+06	3.41E-17	2.0E+06	4.31E-17
		2.8E+06	3.29E-17

<u>References:</u> 143, 144, 148, 375, 381, 382, 479, 495, 532, 534, 537, 538, 539, 540

<u>Accuracy:</u> σ^{+} - 30%
σ^{-} - 50%

<u>Notes:</u> (1) The reactions occurring when He^{2+} reacts with He are: (a) $He^{2+} + He \rightarrow He + He^{2+}$, double electron capture; (b) $He^{2+} + He \rightarrow He^{+} + He^{+}$, single electron capture; (c) $He^{2+} + He \rightarrow He^{2+} + He^{2+} + 2e$, double ionization; (d) $He^{2+} + He \rightarrow He^{2+} + He^{+} + e$, single ionization; (e) $He^{2+} + He \rightarrow He^{+} + He^{2+} + e$, single capture with single ionization. The cross sections for slow electron production σ^{-} is $2\sigma(c) + \sigma(d) + \sigma(e)$. The cross sections for slow ion production σ^{+} is $\sigma(a) + \sigma(b) + \sigma(c) + \sigma(d) + \sigma(e)$. (2) For energies less than 10^5 eV/amu electron capture dominates overionization.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

σ^{+} E_{min} = 9.0E+03 eV/amu, E_{max} = 2.9E+06 eV/amu
σ^{-} E_{min} = 5.0E+03 eV/amu, E_{max} = 2.8E+06 eV/amu

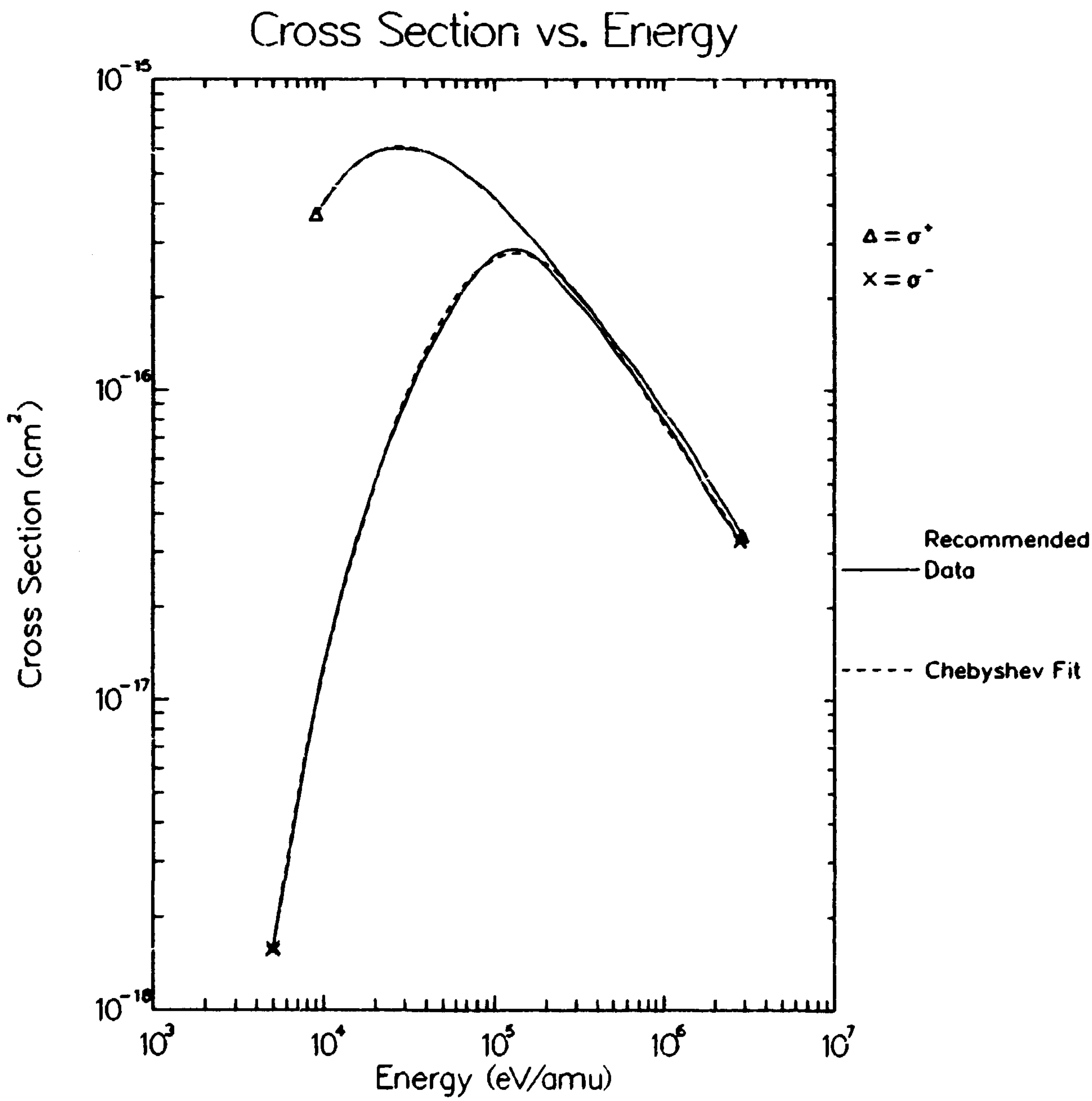
	A0	A1	A2	A3	A4	A5	A6
σ^{+}	-72.3312	-1.34390	-.519938	.150932	-.0442699	-.00102101	.00498217
σ^{-}	-75.4418	1.18618	-1.77854	.310230	.0670546	.0236438	-.0500356

The fit represents the σ^{+} cross section with an rms deviation of 0.6%. The maximum deviation is 1.3% at 3.0E+04 eV/amu.

The fit represents the σ^{-} cross section with an rms deviation of 2.9%. The maximum deviation is 5.1% at 7.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$He^{2+} + He \rightarrow \sigma^-$
$He^{2+} + He \rightarrow \sigma^+$



Slow Positive Ion Production Rate Coefficients for

He^{2+} + He -> σ^{+}

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

He^{2+} Temp. (eV)	Equal Temp.	He Temp. (eV) 5000.	6000.	8000.	10000.	12000.	15000.	20000.
3.5E+03	1.01E-09#	2.40E-09#	3.68E-09#	6.95E-09#	1.09E-08#	1.53E-08#	2.22E-08#	3.37E-08*
4.0E+03	1.86E-09#	3.01E-09#	4.42E-09#	7.89E-09#	1.20E-08#	1.64E-08#	2.33E-08*	3.48E-08*
4.5E+03	3.01E-09#	3.68E-09#	5.22E-09#	8.86E-09#	1.31E-08#	1.75E-08#	2.45E-08*	3.59E-08*
5.0E+03	4.42E-09#	4.42E-09#	6.06E-09#	9.86E-09#	1.42E-08#	1.87E-08#	2.57E-08*	3.70E-08*
5.5E+03	6.06E-09#	5.22E-09#	6.95E-09#	1.09E-08#	1.53E-08#	1.99E-08#	2.68E-08*	3.81E-08*
6.0E+03	7.89E-09#	6.06E-09#	7.89E-09#	1.20E-08#	1.64E-08#	2.10E-08#	2.80E-08*	3.92E-08*
8.0E+03	1.64E-08#	9.86E-09#	1.20E-08#	1.64E-08#	2.10E-08#	2.57E-08*	3.25E-08*	4.35E-08*
1.0E+04	2.57E-08*	1.42E-08#	1.64E-08#	2.10E-08#	2.57E-08*	3.03E-08*	3.70E-08*	4.76E-08*
1.2E+04	3.48E-08*	1.87E-08#	2.10E-08#	2.57E-08*	3.03E-08*	3.48E-08*	4.14E-08*	5.15E-08*
1.4E+04	4.35E-08*	2.33E-08*	2.57E-08*	3.03E-08*	3.48E-08*	3.92E-08*	4.55E-08*	5.53E-08*
1.6E+04	5.15E-08*	2.80E-08*	3.03E-08*	3.48E-08*	3.92E-08*	4.35E-08*	4.95E-08*	5.89E-08*
1.8E+04	5.89E-08*	3.26E-08*	3.48E-08*	3.92E-08*	4.35E-08*	4.76E-08*	5.34E-08*	6.24E-08*
2.0E+04	6.57E-08*	3.70E-08*	3.92E-08*	4.35E-08*	4.76E-08*	5.15E-08*	5.71E-08*	6.57E-08*

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

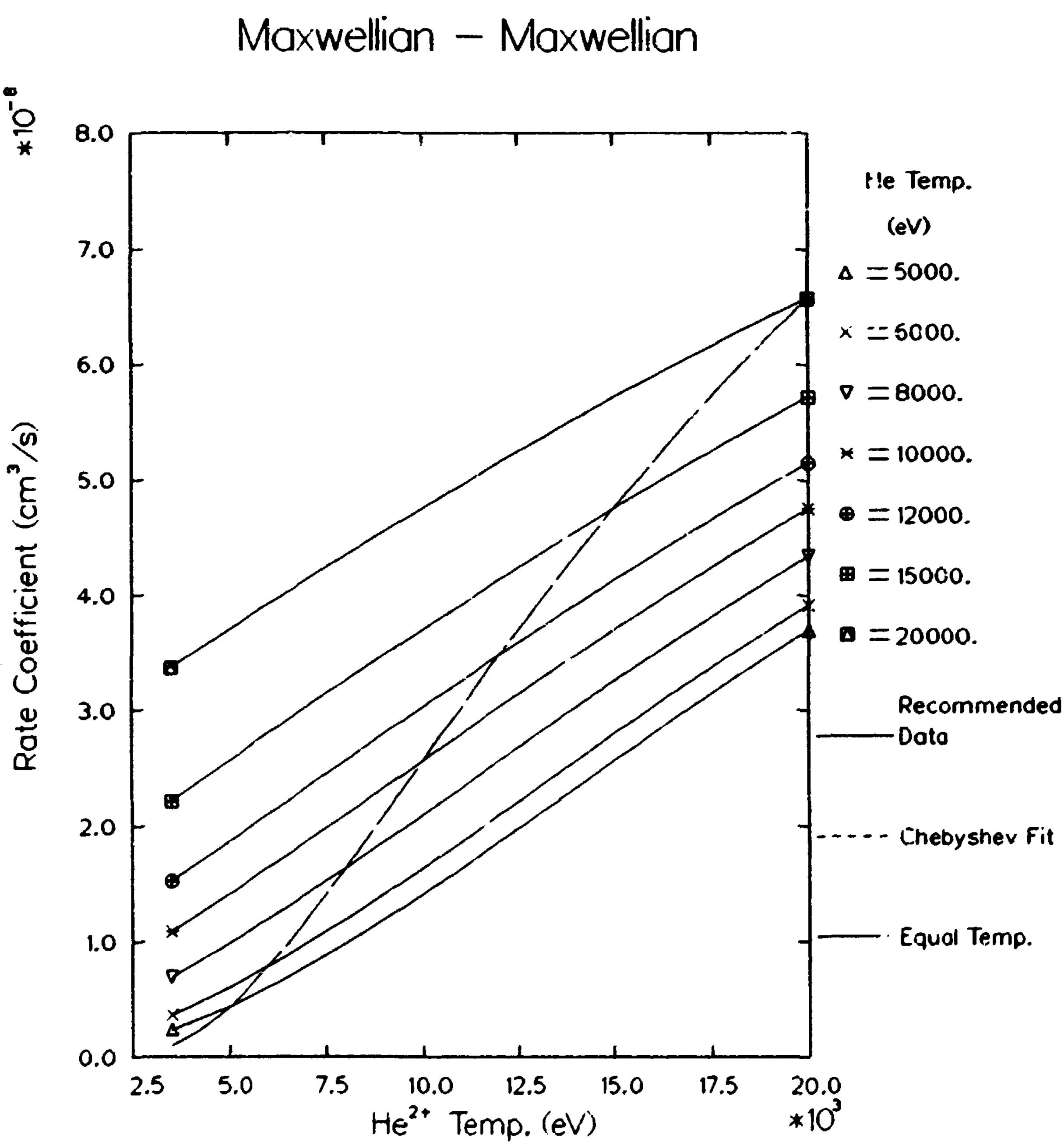
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 3.5E+03 eV, E_{max} = 2.0E+04 eV

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
5000.	-36.8434	1.38333	-.0598328	-.0157120	.00186832	1.83603E-04	6.05353E-05
6000.	-36.4161	1.19746	-.0301418	-.0151798	9.78258E-04	1.15739E-04	-3.58181E-05
8000.	-35.7440	.928769	.00411079	-.0126285	1.55066E-04	2.07816E-04	1.37906E-04
10000.	-35.2350	.745842	.0204872	-.00979258	-3.75639E-04	2.38560E-04	-3.33682E-05
12000.	-34.8337	.615060	.0278881	-.00727889	-6.44358E-04	-3.66627E-05	4.09092E-05
15000.	-34.3648	.477864	.0321621	-.00474753	-6.70690E-04	1.26091E-04	-4.23094E-05
20000.	-33.8047	.336327	.0310835E-02	-.00214049	-6.33145E-04	-5.04160E-05	-1.09705E-04
Equal Temp.	-36.4417	2.02992	-.399477	.0593303	-.00723537	5.77470E-04	-3.03527E-05

See appendix for Chebyshev fit details.

$He^{2+} + He \rightarrow \sigma^{+}$



Slow Positive Ion Production Rate Coefficients for

$He + He^{2+} \rightarrow \sigma^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{2+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	5.60E-08	1.15E-07	1.64E-07	1.83E-07	1.84E-07	1.69E-07	1.42E-07
2.0E+00	5.60E-08	1.15E-07	1.64E-07	1.83E-07	1.84E-07	1.70E-07	1.42E-07
4.0E+00	5.60E-08	1.15E-07	1.64E-07	1.83E-07	1.84E-07	1.70E-07	1.42E-07
7.0E+00	5.60E-08	1.15E-07	1.64E-07	1.83E-07	1.84E-07	1.70E-07	1.42E-07
1.0E+01	5.60E-08	1.15E-07	1.64E-07	1.83E-07	1.84E-07	1.70E-07	1.42E-07
2.0E+01	5.60E-08	1.15E-07	1.64E-07	1.83E-07	1.84E-07	1.70E-07	1.42E-07
4.0E+01	5.55E-08	1.15E-07	1.64E-07	1.83E-07	1.84E-07	1.70E-07	1.42E-07
7.0E+01	5.42E-08	1.15E-07	1.64E-07	1.83E-07	1.84E-07	1.70E-07	1.42E-07
1.0E+02	5.29E-08	1.15E-07	1.64E-07	1.83E-07	1.84E-07	1.70E-07	1.42E-07
2.0E+02	4.99E-08*	1.15E-07	1.63E-07	1.83E-07	1.84E-07	1.70E-07	1.42E-07
4.0E+02	4.75E-08*	1.14E-07	1.63E-07	1.82E-07	1.84E-07	1.69E-07	1.42E-07
7.0E+02	4.67E-08*	1.14E-07	1.63E-07	1.82E-07	1.83E-07	1.69E-07	1.42E-07
1.0E+03	4.68E-08*	1.14E-07	1.63E-07	1.82E-07	1.83E-07	1.69E-07	1.42E-07
2.0E+03	4.90E-08*	1.14E-07	1.62E-07	1.82E-07	1.83E-07	1.69E-07	1.42E-07
4.0E+03	5.40E-08*	1.15E-07	1.62E-07	1.81E-07	1.83E-07	1.69E-07	1.42E-07
7.0E+03	6.06E-08*	1.15E-07	1.61E-07	1.80E-07	1.82E-07	1.69E-07	1.42E-07
1.0E+04	6.62E-08*	1.16E-07	1.60E-07	1.80E-07	1.82E-07	1.69E-07	1.42E-07
2.0E+04	8.14E-08*	1.20E-07	1.59E-07	1.78E-07	1.80E-07	1.69E-07	1.42E-07

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

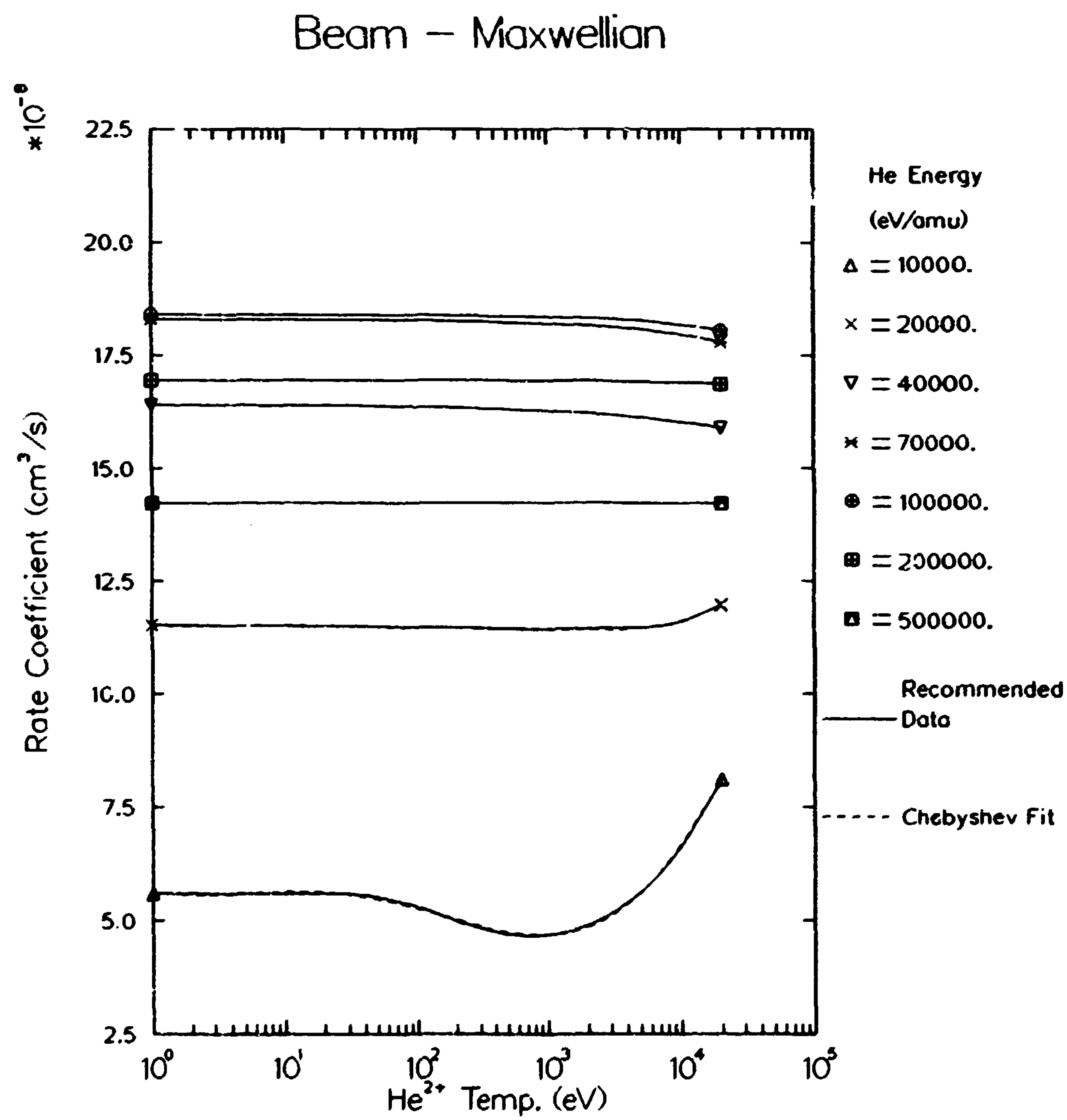
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-33.3528	.0888838	.145456	.115375	.0287771	-.0197504	-.00975561
20000.	-31.9486	.00733446	.0104567	.00658353	.00508869	.00265079	.00155039
40000.	-31.2633	-.0136989	-.00614936	-.00195506	-5.61861E-04	-2.03312E-04	-6.59434E-05
70000.	-31.0470	-.0112913	-.0059297	-.00253976	-.00106355	- 4.84457E-04	-2.29325E-04
100000.	-31.0255	-.00737792	-.00415937	-.00198048	-9.12662E-04	-4.31500E-04	-1.81183E-04
200000.	-31.1826	-.00193461	-.00125764	-4.52646E-04	-2.53650E-04	2.30595E-05	-3.75081E-05
500000.	-31.5305	-2.56726E-04	-1.78746E-04	-1.04195E-04	-5.27594E-05	-2.69854E-05	-1.83293E-05

See appendix for Chebyshev fit details

He + He^{2+} -> σ^+



Beam – Maxwellian
*10^-8
Rate Coefficient (cm^3/s)
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
10^0
10^1
10^2
10^3
10^4
10^5
He^2+ Temp. (eV)
He Energy
(eV/amu)
= 10000.
= 20000.
= 40000.
= 70000.
= 100000.
= 200000.
= 500000.
Recommended Data
Chebyshev Fit

Slow Electron Production Rate Coefficients for

He^{2+} + He -> e^-

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

He^{2+} Temp. (eV)	Equal Temp.	He Temp. (eV) 5000.	6000.	8000.	10000.	12000.	15000.	20000.
1.5E+03	1.17E-12#	6.45E-11#	1.11E-10*	2.47E-10*	4.44E-10*	6.99E-10	1.18E-09	2.24E-09
2.0E+03	6.87E-12#	8.57E-11*	1.39E-10*	2.91E-10*	5.02E-10*	7.72E-10	1.28E-09	2.36E-09
2.5E+03	2.11E-11#	1.11E-10*	1.71E-10*	3.38E-10*	5.64E-10*	8.48E-10	1.37E-09	2.48E-09
3.0E+03	4.68E-11#	1.39E-10*	2.07E-10*	3.89E-10*	6.30E-10*	9.27E-10	1.47E-09	2.61E-09
3.5E+03	8.57E-11*	1.71E-10*	2.47E-10*	4.44E-10*	6.99E-10	1.01E-09	1.57E-09	2.73E-09
4.0E+03	1.39E-10*	2.07E-10*	2.91E-10*	5.02E-10*	7.72E-10	1.10E-09	1.68E-09	2.86E-09
4.5E+03	2.07E-10*	2.47E-10*	3.38E-10*	5.64E-10*	8.48E-10	1.18E-09	1.78E-09	3.00E-09
5.0E+03	2.91E-10*	2.91E-10*	3.89E-10*	6.30E-10*	9.27E-10	1.28E-09	1.89E-09	3.13E-09
5.5E+03	3.89E-10*	3.38E-10*	4.44E-10*	6.99E-10	1.01E-09	1.37E-09	2.00E-09	3.27E-09
6.0E+03	5.02E-10*	3.89E-10*	5.02E-10*	7.72E-10	1.10E-09	1.47E-09	2.12E-09	3.41E-09
8.0E+03	1.10E-09	6.30E-10*	7.72E-10	1.10E-09	1.47E-09	1.89E-09	2.61E-09	3.99E-09
1.0E+04	1.89E-09	9.27E-10	1.10E-09	1.47E-09	1.89E-09	2.36E-09	3.13E-09	4.60E-09
1.2E+04	2.86E-09	1.28E-09	1.47E-09	1.89E-09	2.36E-09	2.86E-09	3.69E-09	5.24E-09
1.4E+04	3.99E-09	1.68E-09	1.89E-09	2.36E-09	2.86E-09	3.41E-09	4.29E-09	5.91E-09
1.6E+04	5.24E-09	2.12E-09	2.36E-09	2.86E-09	3.41E-09	3.99E-09	4.92E-09	6.60E-09
1.8E+04	6.60E-09	2.61E-09	2.86E-09	3.41E-09	3.99E-09	4.60E-09	5.57E-09	7.32E-09
2.0E+04	8.06E-09	3.13E-09	3.41E-09	3.99E-09	4.60E-09	5.24E-09	6.25E-09	8.06E-09

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

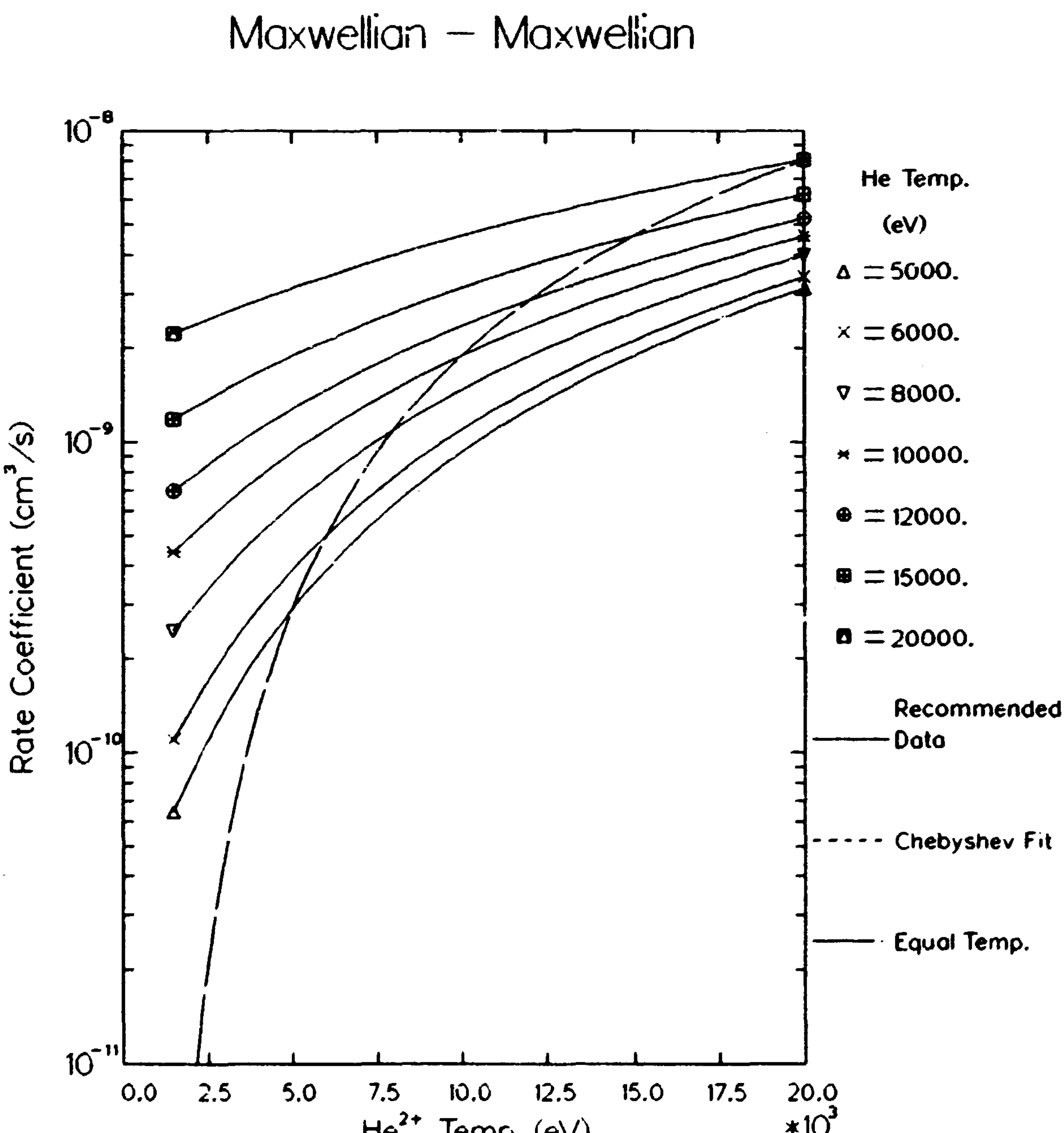
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.5E+03 eV, E_{max} = 2.0E+04 eV

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
5000.	43.3317	1.97188	.145899	-.0314858	-.00292157	9.87310E-04	6.59233E-05
6000.	-42.7445	1.73787	.165098	-.0242892	-.00406700	7.29676E-04	1.18519E-04
8000.	-41.8072	1.40305	.177579	-.0125933	-.00472104	2.21088E-04	1.43982E-04
10000.	-41.0752	1.17389	.175396	-.00453799	-.00443211	-1.26246E-04	1.20206E-04
12000.	-40.4766	1.00680	.167979	8.55383E-04	-.00385784	-3.27458E-04	8.43893E-05
15000.	-39.7464	.826618	.154121	.00577291	-.00294670	-4.58815E-04	3.46633E-05
20000.	-38.8140	.631796	.131790	.00946407	-.00174398	-4.77146E-04	-1.78125E-05
Equal Temp.	-44.6706	4.27088	-.685712	.139921	-.0311302	.00607534	-8.51332E-04

See appendix for Chebyshev fit details.

$He^{2+} + He \rightarrow \sigma^-$



Slow Electron Production Rate Coefficients for

He + He^{2+} -> e^-

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{2+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	1.06E-09	1.04E-08	6.65E-08	3.41E-08	5.31E-08	1.56E-07	1.34E-07
2.0E+00	1.60E-09	1.00E-08	4.88E-08	6.09E-08	9.79E-08	1.56E-07	1.34E-07
4.0E+00	1.78E-09	1.00E-08	3.86E-08	7.70E-08	1.18E-07	1.56E-07	1.34E-07
7.0E+00	1.79E-09	1.00E-08	3.63E-08	8.04E-08	1.20E-07	1.56E-07	1.34E-07
1.0E+01	1.78E-09	1.00E-08	3.61E-08	8.07E-08	1.20E-07	1.56E-07	1.34E-07
2.0E+01	1.78E-09	1.00E-08	3.60E-08	8.07E-08	1.20E-07	1.56E-07	1.34E-07
4.0E+01	1.79E-09	1.00E-08	3.60E-08	8.07E-08	1.20E-07	1.56E-07	1.34E-07
7.0E+01	1.79E-09	1.00E-08	3.60E-08	8.07E-08	1.20E-07	1.56E-07	1.34E-07
1.0E+02	1.80E-09	1.00E-08	3.60E-08	8.06E-08	1.20E-07	1.56E-07	1.34E-07
2.0E+02	1.83E-09	1.00E-08	3.60E-08	8.06E-08	1.20E-07	1.56E-07	1.34E-07
4.0E+02	1.90E-09	1.01E-08	3.60E-08	8.06E-08	1.20E-07	1.56E-07	1.34E-07
7.0E+02	2.01E-09	1.03E-08	3.61E-08	8.06E-08	1.19E-07	1.55E-07	1.34E-07
1.0E+03	2.13E-09	1.04E-08	3.62E-08	8.06E-08	1.19E-07	1.55E-07	1.34E-07
2.0E+03	2.51E-09	1.09E-08	3.67E-08	8.09E-08	1.19E-07	1.55E-07	1.34E-07
4.0E+03	3.27E-09	1.20E-08	3.79E-08	8.16E-08	1.19E-07	1.55E-07	1.34E-07
7.0E+03	4.44E-09	1.37E-08	3.97E-08	8.28E-08	1.19E-07	1.54E-07	1.34E-07
1.0E+04	5.63E-09	1.54E-08	4.14E-08	8.38E-08	1.19E-07	1.54E-07	1.34E-07
2.0E+04	9.85E-09	2.08E-08	4.70E-08	8.69E-08	1.19E-07	1.52E-07	1.34E-07

Chebyshev Fitting Parameters for Rate Coefficients

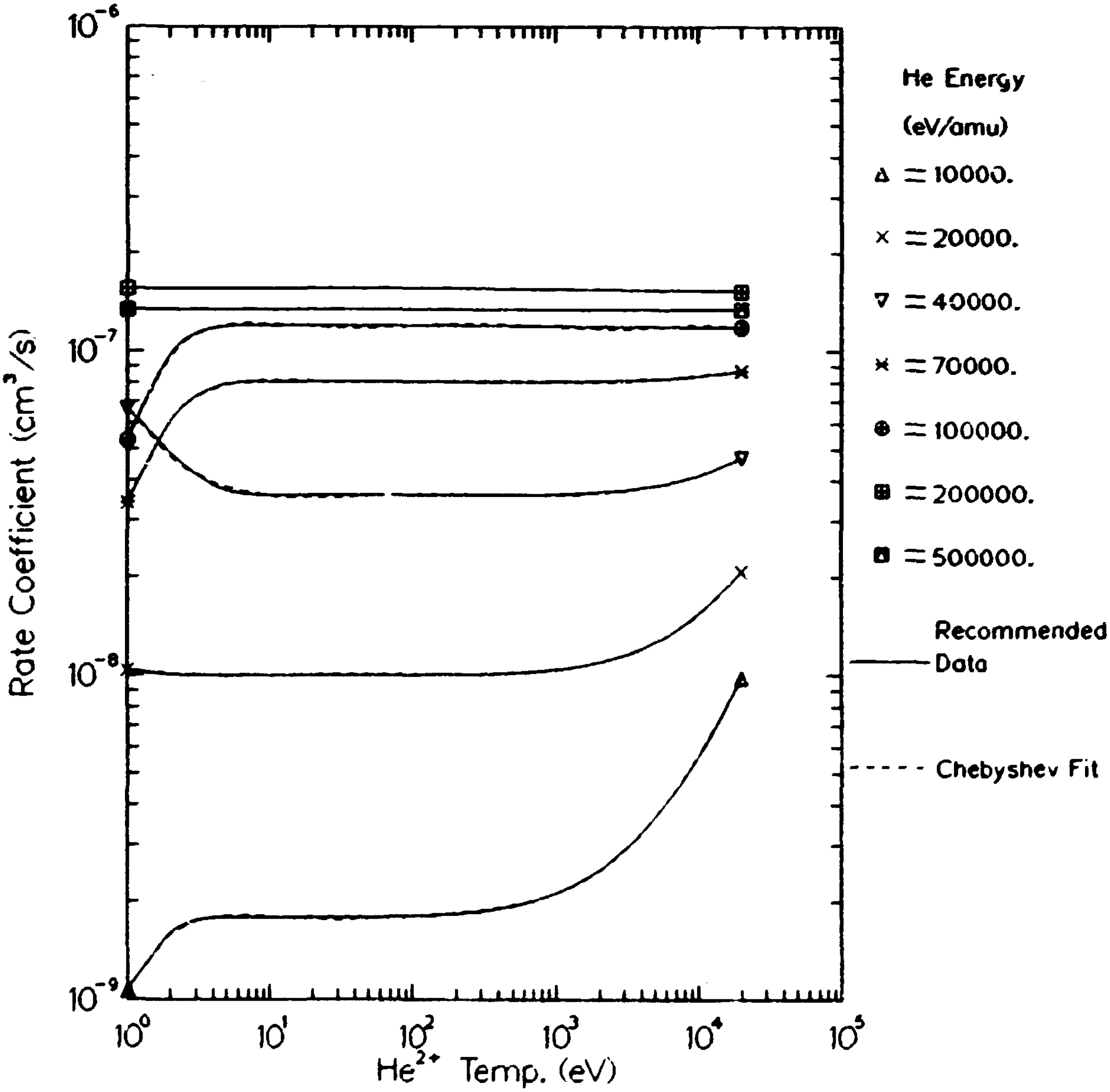
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-39.6384	.794564	.318341	.275468	-.0163980	.0386510	-.0302765
20000.	-36.5385	.251533	.188617	.0914015	.0423640	.00564777	.00225398
40000.	-33.9830	-.0965962	.217818	-.0655465	.0766555	-.0163273	5.77974E-04
70000.	-32.8790	.252448	-.174234	.159512	-.0904273	.0541651	-.0228943
100000.	-32.0888	.196302	-.176198	.140458	-.0957365	.0592874	-.0318816
200000.	-31.3593	-.00872687	-.00490003	-.00214295	-9.76224E-04	-3.39591E-04	-1.98244E-04
500000.	-31.6466	-3.56481E-04	-2.64796E-04	-1.77709E-04	-1.07797E-04	-6.25087E-05	-4.02042E-05

See appendix for Chebyshev fit details.

$He + He^{2+} \rightarrow \sigma^-$

Beam – Maxwellian



Single and Double Ionization Cross Sections for He^{2+} + He Collisions

$$He^{2+} + He \rightarrow He^{2+} + He^{+} + e$$
$$He^{2+} + He \rightarrow He^{2+} + He^{2+} + 2e$$

Single Ionization		Double Ionization	
Energy (eV/amu)	Cross Section (cm^2)	Energy (eV/amu)	Cross Section (cm^2)
1.5E+03	2.72E-18	1.4E+04	4.43E-19
2.0E+03	2.85E-18	1.5E+04	4.70E-19
4.0E+03	3.41E-18	2.0E+04	6.21E-19
7.0E+03	4.73E-18	4.0E+04	1.32E-18
1.0E+04	5.96E-18	7.0E+04	2.76E-18
1.5E+04	8.11E-18	1.0E+05	6.06E-18
2.0E+04	1.10E-17	1.4E+05	7.60E-18
4.0E+04	2.92E-17	1.5E+05	7.50E-18
7.0E+04	1.28E-16	2.0E+05	6.65E-18
1.0E+05	1.85E-16	4.0E+05	3.01E-18
1.5E+05	2.09E-16	7.0E+05	1.27E-18
2.0E+05	2.05E-16	1.0E+06	7.13E-19
4.0E+05	1.50E-16	1.5E+06	3.51E-19
7.0E+05	1.03E-16	2.0E+06	2.53E-19
1.0E+06	8.17E-17	2.7E+06	2.06E-19
1.5E+06	6.10E-17		
2.0E+06	4.97E-17		
2.4E+06	4.46E-17		

<u>References:</u> 148, 282, 381, 382, 383, 384, 387, 537, 538, 540

<u>Accuracy:</u> $\sigma(He^{+})$ - 30%
$\sigma(He^{2+})$ - 50%

<u>Note:</u> The data of DuBois (Ref. 538) supercede earlier results (Ref. 282) due to recalibration of the slow recoil ion detector. These corrected data are consistent with those of Afrosimov et al. (Ref. 148), which define the low-energy behavior of the cross section.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

$\sigma(He^{+})$ E_{min} = 1.5E+03 eV/amu, E_{max} = 2.4E+06 eV/amu
$\sigma(He^{2+})$ E_{min} = 1.4E+04 eV/amu, E_{max} = 2.7E+06 eV/amu

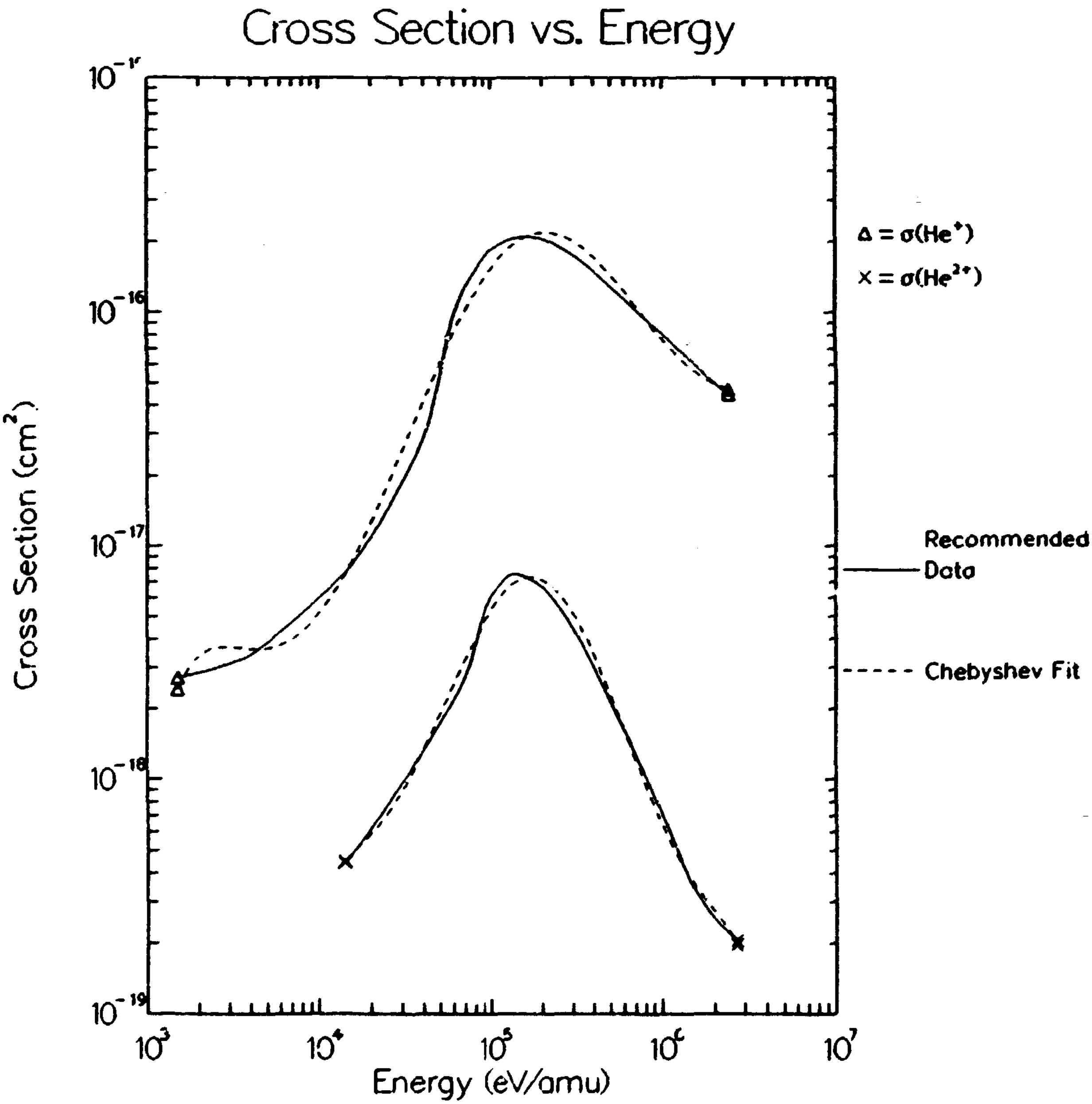
	A0	A1	A2	A3	A4	A5	A6
$\sigma(He^{+})$	-76.5996	1.88840	-.913101	-.705245	.237700	.295143	-.101724
$\sigma(He^{2+})$	-82.9537	-.441854	-1.49781	.0576939	.413751	-.0249295	-.0956323

The fit represents the $\sigma(He^{+})$ cross section with an rms deviation of 15.4%. The maximum deviation is 44.5% at 4.0E+04 eV/amu.

The fit represents the $\sigma(He^{2+})$ cross section with an rms deviation of 8.4%. The maximum deviation is 18.4% at 7.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^{2+} + He \rightarrow He^{2+} + He^{+} + e \quad \sigma(He^{+})$
$He^{2+} + He \rightarrow He^{2+} + He^{2+} + 2e \quad \sigma(He^{2+})$



Single Ionization Rate Coefficients for

$He^{2+} + He \rightarrow He^{2+} + He^{+} + e$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

He^{2+} Temp. (eV)	Equal Temp.	He Temp. (eV) 1000.	2000.	4000.	7000.	10000.	15000.	20000.
1.0E+03	2.02E-11#	2.02E-11#	5.26E-11#	1.21E-10*	2.21E-10*	3.23E-10	5.15E-10	7.50E-10
1.5E+03	5.26E-11#	3.57E-11#	6.99E-11*	1.38E-10*	2.38E-10*	3.41E-10	5.36E-10	7.76E-10
2.0E+03	8.72E-11*	5.26E-11#	8.72E-11*	1.55E-10*	2.54E-10*	3.59E-10	5.58E-10	8.04E-10
2.5E+03	1.21E-10*	6.99E-11*	1.04E-10*	1.71E-10*	2.71E-10*	3.77E-10	5.80E-10	8.31E 10
3.0E+03	1.55E-10*	8.72E-11*	1.21E-10*	1.88E-10*	2.88E-10	3.96E-10	6.03E-10	8.60E-10
3.5E+03	1.88E-10*	1.04E-10*	1.38E-10*	2.04E-10*	3.06E-10	4.15E-10	6.26E-10	8.89E-10
4.0E+03	2.21E-10*	1.21E-10*	1.55E-10*	2.21E-10*	3.23E-10	4.34E-10	6.50E-10	9.19E-10
4.5E+03	2.54E-10*	1.38E-10*	1.71E-10*	2.38E-10*	3.41E-10	4.54E-10	6.74E-10	9.50E-10
5.0E+03	2.88E-10	1.55E-10*	1.88E-10*	2.54E-10*	3.59E-10	4.74E-10	6.99E-10	9.81E-10
5.5E+03	3.23E-10	1.71E-10*	2.04E-10*	2.71E-10*	3.77E-10	4.94E-10	7.24E-10	1.01E-09
6.0E+03	3.59E-10	1.88E-10*	2.21E-10*	2.88E-10	3.96E-10	5.15E-10	7.50E-10	1.05E-09
8.0E+03	5.15E-10	2.54E-10*	2.88E-10	3.59E-10	4.74E-10	6.03E-10	8.60E-10	1.19E-09
1.0E+04	6.99E-10	3.23E-10	3.59E-10	4.34E-10	5.58E-10	6.99E-10	9.81E-10	1.34E-09
1.2E+04	9.19E-10	3.96E-10	4.34E-10	5.15E-10	6.50E-10	8.04E-10	1.11E-09	1.51E-09
1.4E+04	1.19E-09	4.74E-10	5.15E-10	6.03E-10	7.50E-10	9.19E-10	1.26E-09	1.69E-09
1.6E+04	1.51E-09	5.58E-10	6.03E-10	6.99E-10	8.60E-10	1.05E-09	1.42E-09	1.90E-09
1.8E+04	1.90E-09	6.50E-10	6.99E-10	8.04E-10	9.81E-10	1.19E-09	1.60E-09	2.12E-09
2.0E+04	2.36E-09	7.50E-10	8.04E-10	9.19E-10	1.11E-09	1.34E-09	1.79E-09	2.36E-09

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

Chebyshev Fitting Parameters for Rate Coefficients

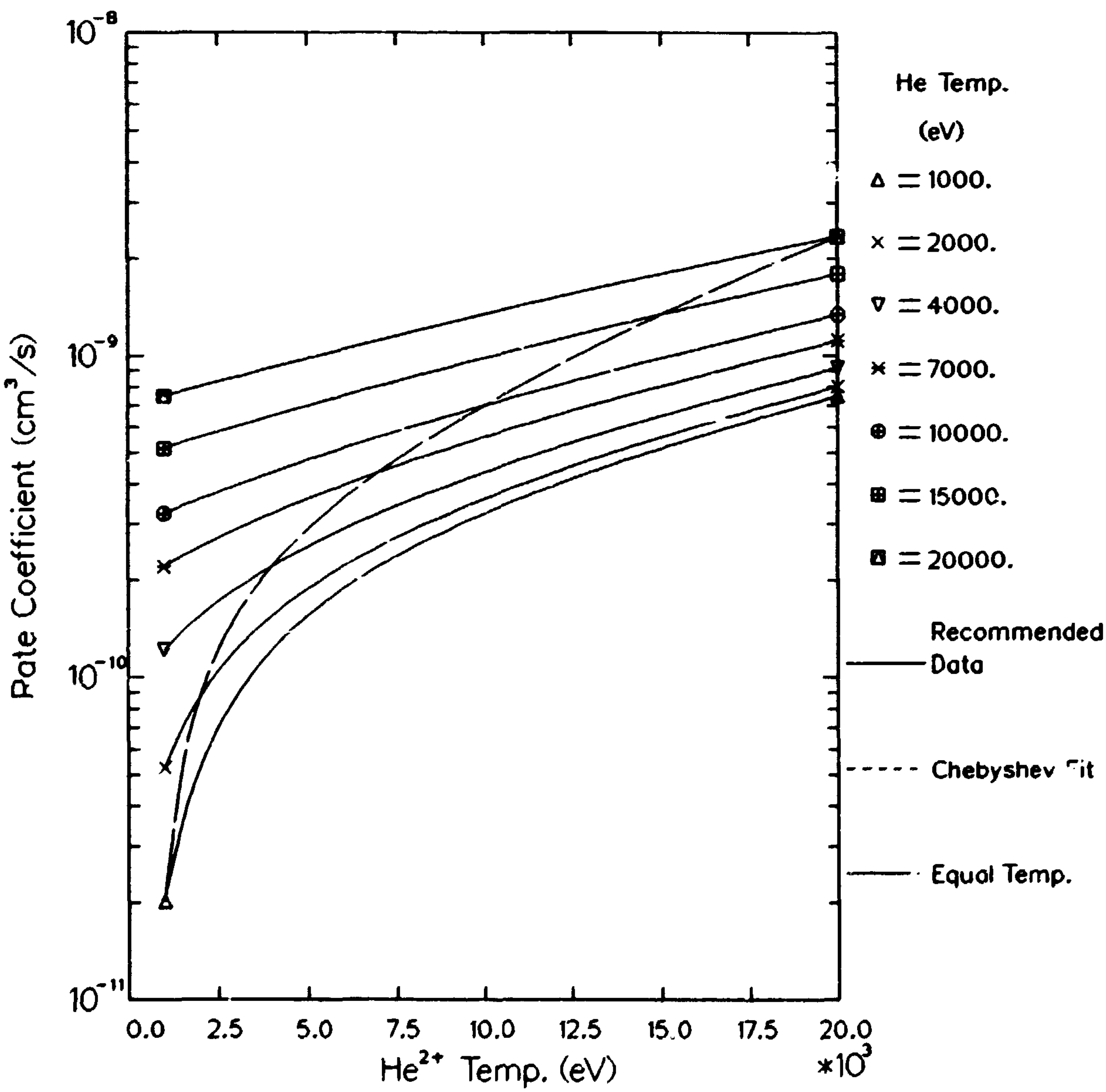
E_{min} = 1.0E+03 eV, E_{max} = 2.0E+04 eV

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
1000.	-45.5517	1.76637	-.0538507	.0411721	.0121873	-.00162780	4.71335E-04
2000.	-44.8184	1.34639	.0940426	.0160336	.0100615	7.61162E-04	-5.25995E-06
4000.	-43.9954	.993020	.171815	.0181703	.00532378	.00150693	1.33413E-04
7000.	-43.2344	.780722	.188817	.0272646	.00407424	.00107015	2.33342E-04
10000.	-42.6662	.678316	.186986	.0320032	.00435983	7.84218E-04	1.42277E-04
15000.	-41.8920	.588941	.178679	.0346782	.00461614	3.94516E-04	-9.31127E-05
20000.	-41 2236	.538493	.169263	.0338729	.00410893	1.87221E-05	-2.35709E-04
Equal Temp.	-44.3188	2.21934	-.0710730	.154144	-.0123650	.00522272	-.00149471

See appendix for Chebyshev fit details.

$He^{2+} + He \rightarrow He^{2+} + He^{+} + e$

Maxwellian — Maxwellian



Single Ionization Rate Coefficients for

$He + He^{2+} \rightarrow He^{+} + He^{2+} + e$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{2+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	7.33E-11	1.69E-10	9.57E-09	1.61E-08	7.23E-08	1.27E-07	1.27E-07
2.0E+00	3.50E-10	9.12E-10	9.31E-09	3.37E-08	8.37E-08	1.27E-07	1.27E-07
4.0E+00	6.77E-10	1.78E-09	8.43E-09	4.44E-08	8.29E-08	1.27E-07	1.27E-07
7.0E+00	8.03E-10	2.10E-09	8.17E-09	4.66E-08	8.17E-08	1.27E-07	1.27E-07
1.0E+01	8.25E-10	2.16E-09	8.16E-09	4.68E-08	8.13E-08	1.27E-07	1.27E-07
2.0E+01	8.30E-10	2.17E-09	8.18E-09	4.67E-08	8.10E-08	1.27E-07	1.27E-07
4.0E+01	8.31E-10	2.18E-09	8.22E-09	4.66E-08	8.09E-08	1.27E-07	1.27E-07
7.0E+01	8.33E-10	2.18E-09	8.26E-09	4.64E-08	8.08E-08	1.27E-07	1.27E-07
1.0E+02	8.35E-10	2.19E-09	8.30E-09	4.63E-08	8.08E-08	1.27E-07	1.27E-07
2.0E+02	8.40E-10	2.20E-09	8.40E-09	4.61E-08	8.06E-08	1.27E-07	1.27E-07
4.0E+02	8.50E-10	2.23E-09	8.57E-09	4.59E-08	8.04E-08	1.27E-07	1.27E-07
7.0E+02	8.65E-10	2.28E-09	8.79E-09	4.57E-08	8.01E-08	1.27E-07	1.27E-07
1.0E+03	8.80E-10	2.32E-09	9.01E-09	4.56E-08	8.00E-08	1.26E-07	1.27E-07
2.0E+03	9.34E-10	2.46E-09	9.68E-09	4.56E-08	7.97E-08	1.26E-07	1.27E-07
4.0E+03	1.05E-09	2.73E-09	1.10E-08	4.61E-08	7.95E-08	1.26E-07	1.27E-07
7.0E+03	1.26E-09	3.20E-09	1.30E-08	4.71E-08	7.94E-08	1.25E-07	1.27E-07
1.0E+04	1.50E-09	3.78E-09	1.48E-08	4.81E-08	7.94E-08	1.24E-07	1.27E-07
2.0E+04	2.65E-09	6.33E-09	2.04E-08	5.15E-08	7.99E-08	1.23E-07	1.27E-07

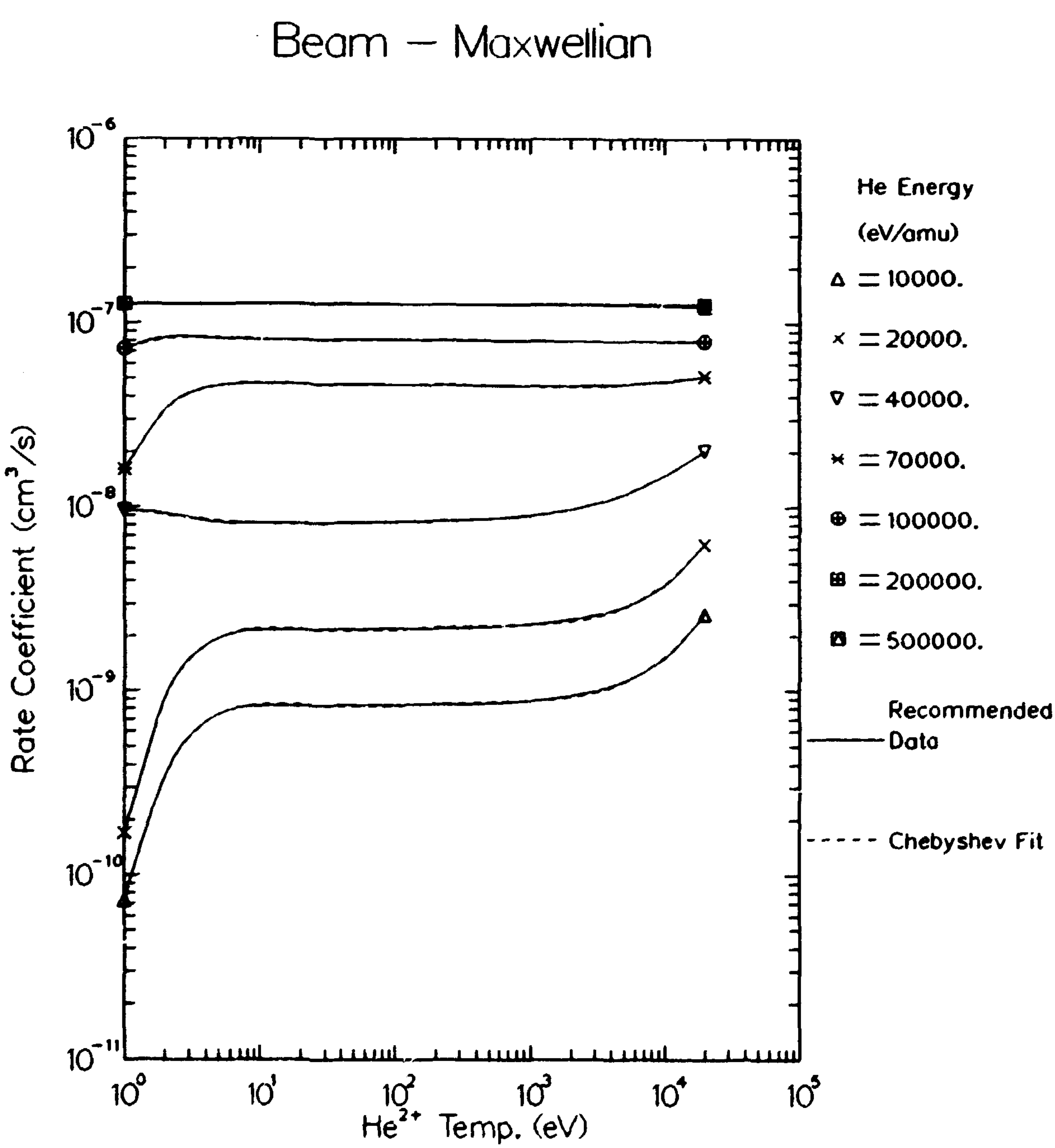
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-42.0879	1.05416	-.278168	.571603	-.178692	.163417	-.0427310
20000.	-40.2183	1.05217	-.325687	.576861	-.203701	.175474	-.0514200
40000.	-36.7712	.292755	.267604	.0744621	.0454617	.00691932	-.0124274
70000.	-34.0338	.300282	-.207456	.207032	-.108795	.0715453	-.0312105
100000.	-32.6844	.00402251	-.0177396	.0232129	-.0175932	.0185648	-.0137519
200000.	-31.7707	-.0135888	-.00673208	-.00257568	-7.31948E-04	-2.50136E-04	-2.83646E-05
500000.	-31.7621	-4.22604E-04	-3.26343E-04	-2.33365E-04	-1.51845E-04	-9.21185E-05	-5.83670E-05

See appendix for Chebyshev fit details.

$He + He^{2+} \rightarrow He^{+} + He^{2+} + e$



Double Ionization Rate Coefficients for

$He + He^{2+} \rightarrow He^{2+} + He^{2+} + e$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{2+} Temp. (eV)	He Energy (eV/amu) 15000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	9.35E-11	1.13E-10	1.86E-10	1.74E-09	1.73E-09	4.13E-09	2.09E-09
2.0E+00	8.19[illegible]-11	1.21E-10	3.04E-10	1.26E-09	2.49E-09	4.13E-09	2.09E-09
4.0E+00	8.0[illegible]E-11	1.22E-10	3.59E-10	1.05E-09	2.65E-09	4.13E-09	2.09E-09
7.0E+00	8.[illegible]0E-11	1.22E-10	3.67E-10	1.02E-09	2.65E-09	4.13E-09	2.09E-09
1.0E+01	8.01E-11	1.22E-10	3.67E-10	1.02E-09	2.65E-09	4.12E-09	2.09E-09
2.0E+01	7.98E-11	1.22E-10	3.67E-10	1.02E-09	2.65E-09	4.12E-09	2.09E-09
4.0E+01	7.81E-11	1.22E-10	3.68E-10	1.02E-09	2.64E-09	4.12E-09	2.09E-09
7.0E+01	7.50E-11	1.23E-10	3.68E-10	1.02E-09	2.63E-09	4.11E-09	2.09E-09
1.0E+02	7.25E-11*	1.23E-10	3.69E-10	1.03E-09	2.63E-09	4.11E-09	2.09E-09
2.0E+02	6.79E-11*	1.23E-10	3.70E-10	1.03E-09	2.62E-09	4.10E-09	2.10E-09
4.0E+02	6.47E-11*	1.24E-10	3.73E-10	1.04E-09	2.60E-09	4.09E-09	2.10E-09
7.0E+02	6.39E-11*	1.26E-10	3.76E-10	1.06E-09	2.59E-09	4.08E-09	2.10E-09
1.0E+03	6.45E-11*	1.27E-10	3.79E-10	1.07E-09	2.58E-09	4.07E-09	2.10E-09
2.0E+03	6.87E-11*	1.30E-10	3.90E-10	1.11E-09	2.56E-09	4.05E-09	2.10E-09
4.0E+03	7.87E-11*	1.37E-10	4.10E-10	1.18E-09	2.56E-09	4.01E-09	2.10E-09
7.0E+03	9.41E-11*	1.52E-10	4.43E-10	1.26E-09	2.56E-09	3.97E-09	2.10E-09
1.0E+04	1.10E-10*	1.69E-10	4.78E-10	1.34E-09	2.58E-09	3.94E-09	2.10E-09
2.0E+04	1.66E-10*	2.34E-10	6.12E-10	1.54E-09	2.62E-09	3.84E-09	2.10E-09

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

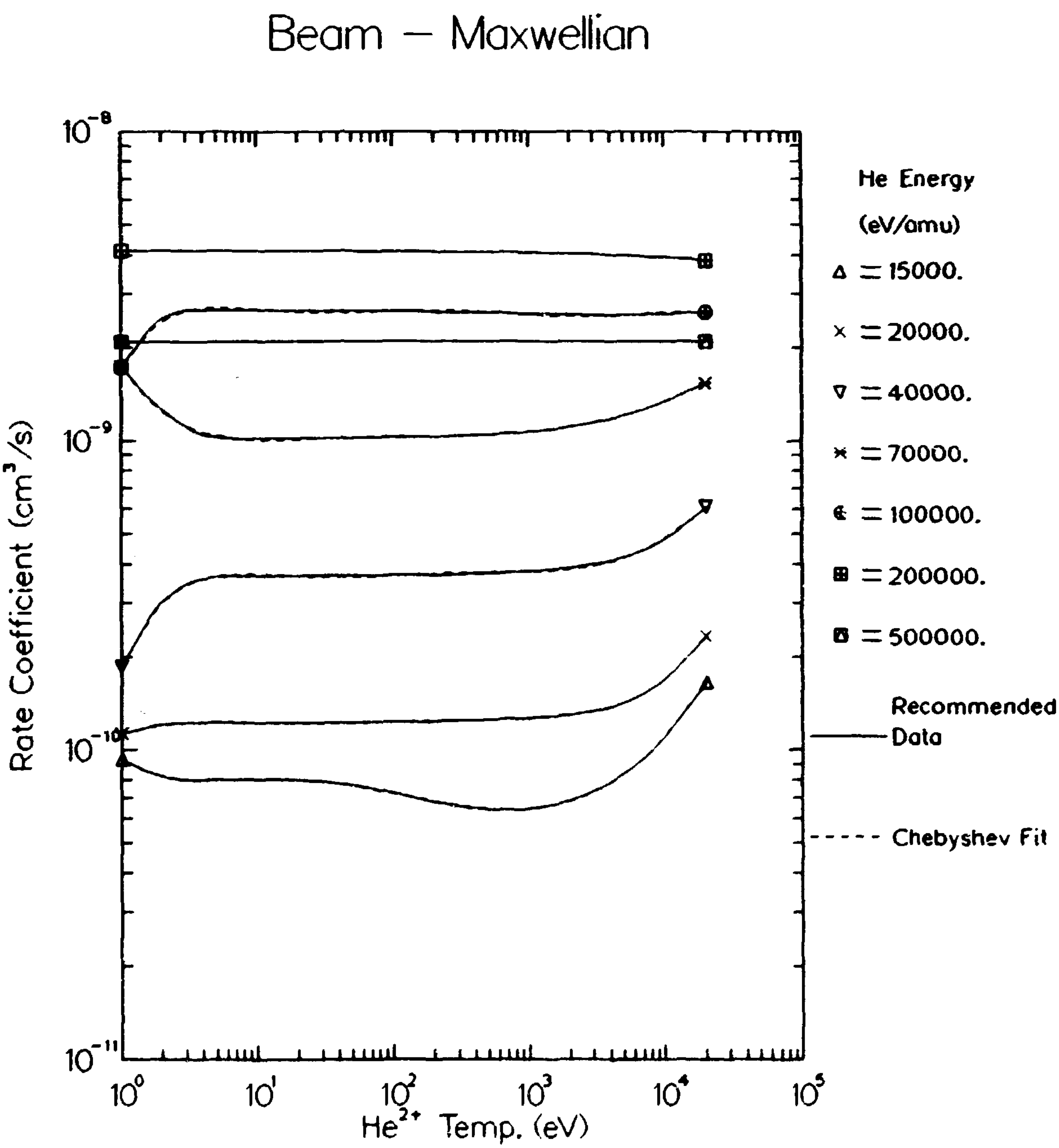
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
15000.	-46.3312	.153224	.279715	.156829	.0725151	.0242560	.00705852
20000.	-45.4317	.231432	.136168	.105908	.0379291	.0289022	.00177492
40000.	-43.4356	.345707	-.0276535	.185072	-.0448587	.0604026	-.0183190
70000.	-41.0648	.0136654	.223879	-.0488164	.0714513	-.0272212	.00699819
100000.	-39.6220	.0822767	-.0834305	.0811386	-.0492265	.0386945	-.0239545
200000.	-38.6471	-.0288702	-.0153708	-.00634634	-.00248827	-8.91443E-04	-4.33357E-04
500000.	-39.9659	.00135586	8.97190E-04	4.16825E-04	1.05292E-04	-2.86625E-05	-6.55320E-05

See appendix for Chebyshev fit details.

$He + He^{2+} \rightarrow He^{2+} + He^{2+} + e$



Cross Sections for the Ionization of Li by Proton Impact

$H^+ + Li \rightarrow H^+ + Li^+ + e$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.5E+04	2.20E+08	1.20E-15
4.0E+04	2.78E+08	7.56E-16
7.0E+04	3.68E+08	4.49E-16
1.0E+05	4.39E+08	3.22E-16
1.5E+05	5.38E+08	2.24E-16
2.0E+05	6.21E+08	1.73E-16
4.0E+05	8.78E+08	9.48E-17
7.0E+05	1.16E+09	5.79E-17
1.0E+06	1.39E+09	4.21E-17
1.5E+06	1.70E+09	2.98E-17
2.0E+06	1.96E+09	2.36E-17
2.3E+06	2.10E+09	2.12E-17

References: 232, 234, 737, 738

Accuracy: 30%

Note: Cross sections for double ionization and electron transfer ionization may be found in Ref. 234.

Chebyshev Fitting Parameters for Cross Sections

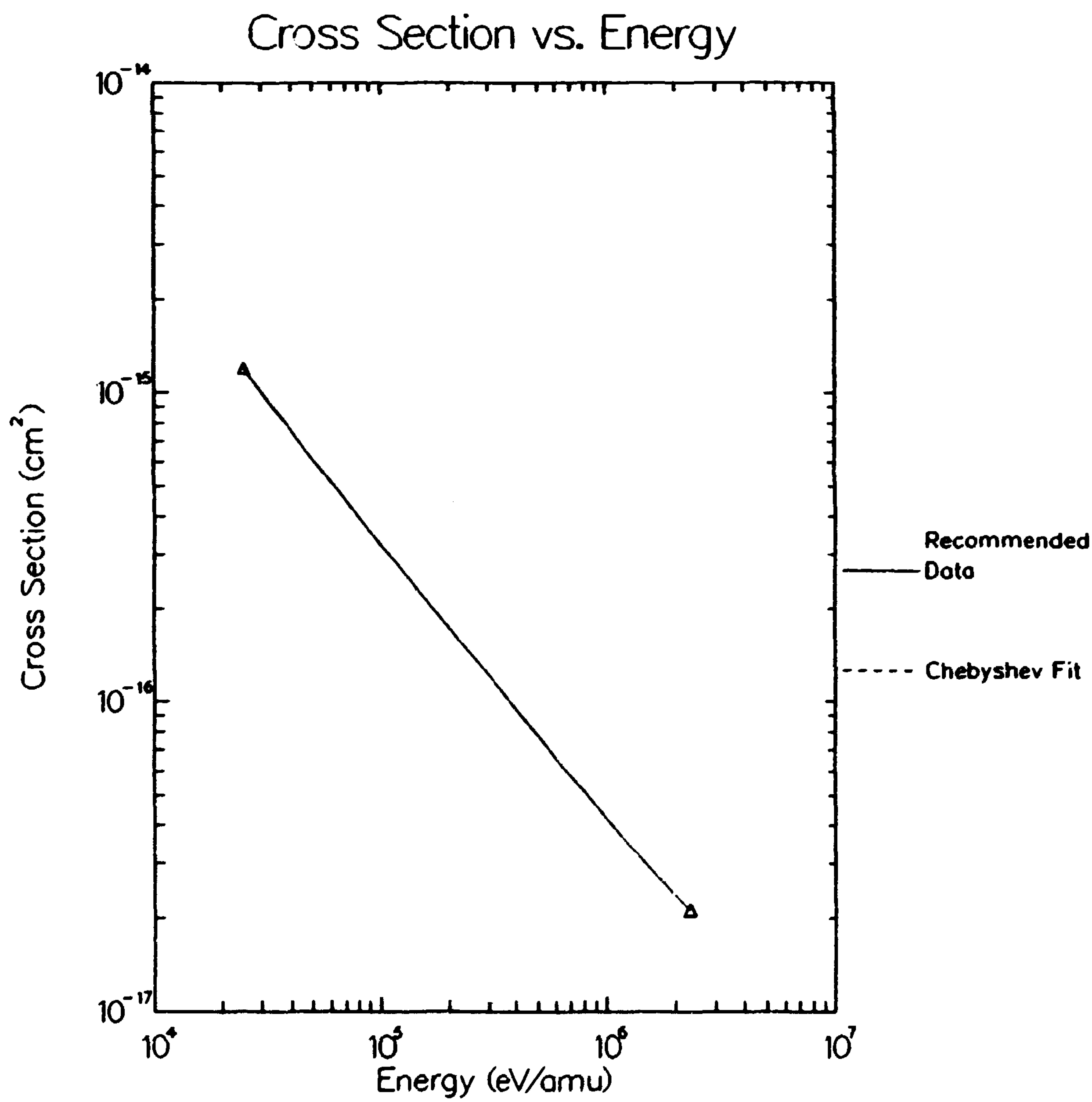
E_{min} = 2.5E+04 eV/amu, E_{max} = 2.3E+06 eV/amu

A0	A1	A2	A3	A4	A5	A6
-72.8380	-2.01716	.0360083	-.00414961	.00683897	.00418712	.00222666

The fit represents the above cross section with an rms deviation of 0.2%. The maximum deviation is 0.4% at 1.0E+06 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + Li \rightarrow H^+ + Li^+ + e$



Ionization Rate Coefficients for

$Li + H^+ \rightarrow Li^+ + H^+ + e$

Beam - Maxwellian Rate Coefficients (cm^3/s)

H^+ Temp. (eV)	Li Energy (eV/amu) 25000.	30000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	1.32E-07*	2.41E-07	2.10E-07	1.65E-07	1.41E-07	1.07E-07	7.65E-08
2.0E+00	1.32E-07*	2.41E-07	2.10E-07	1.65E-07	1.41E-07	1.07E-07	7.65E-08
4.0E+00	1.32E-07*	2.41E-07	2.10E-07	1.65E-07	1.41E-07	1.07E-07	7.65E-08
7.0E+00	1.32E-07*	2.41E-07	2.10E-07	1.65E-07	1.41E-07	1.07E-07	7.65E-08
1.0E+01	1.32E-07*	2.41E-07	2.10E-07	1.65E-07	1.41E-07	1.07E-07	7.65E-08
2.0E+01	1.32E-07*	2.41E-07	2.10E-07	1.65E-07	1.41E-07	1.07E-07	7.65E-08
4.0E+01	1.32E-07*	2.41E-07	2.10E-07	1.65E-07	1.41E-07	1.07E-07	7.65E-08
7.0E+01	1.32E-07*	2.40E-07	2.10E-07	1.65E-07	1.42E-07	1.07E-07	7.65E-08
1.0E+02	1.32E-07*	2.37E-07	2.10E-07	1.65E-07	1.42E-07	1.07E-07	7.65E-08
2.0E+02	1.32E-07*	2.26E-07	2.10E-07	1.65E-07	1.41E-07	1.08E-07	7.65E-08
4.0E+02	1.32E-07*	2.07E-07*	2.10E-07	1.65E-07	1.42E-07	1.07E-07	7.65E-08
7.0E+02	1.32E-07*	1.91E-07*	2.08E-07	1.65E-07	1.42E-07	1.08E-07	7.64E-08
1.0E+03	1.32E-07*	1.81E-07*	2.05E-07	1.65E-07	1.42E-07	1.08E-07	7.65E-08
2.0E+03	1.33E-07*	1.66E-07*	1.92E-07	1.65E-07	1.42E-07	1.08E-07	7.65E-08
4.0E+03	1.33E-07*	1.54E-07*	1.75E-07*	1.64E-07	1.42E-07	1.08E-07	7.64E-08
7.0E+03	1.34E-07*	1.47E-07*	1.63E-07*	1.59E-07	1.41E-07	1.08E-07	7.64E-08
1.0E+04	1.35E-07*	1.44E-07*	1.55E-07*	1.55E-07	1.40E-07	1.08E-07	7.64E-08
2.0E+04	1.36E-07*	1.39E-07*	1.44E-07*	1.43E-07	1.35E-07	1.07E-07	7.63E-08

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

Chebyshev Fitting Parameters for Rate Coefficients

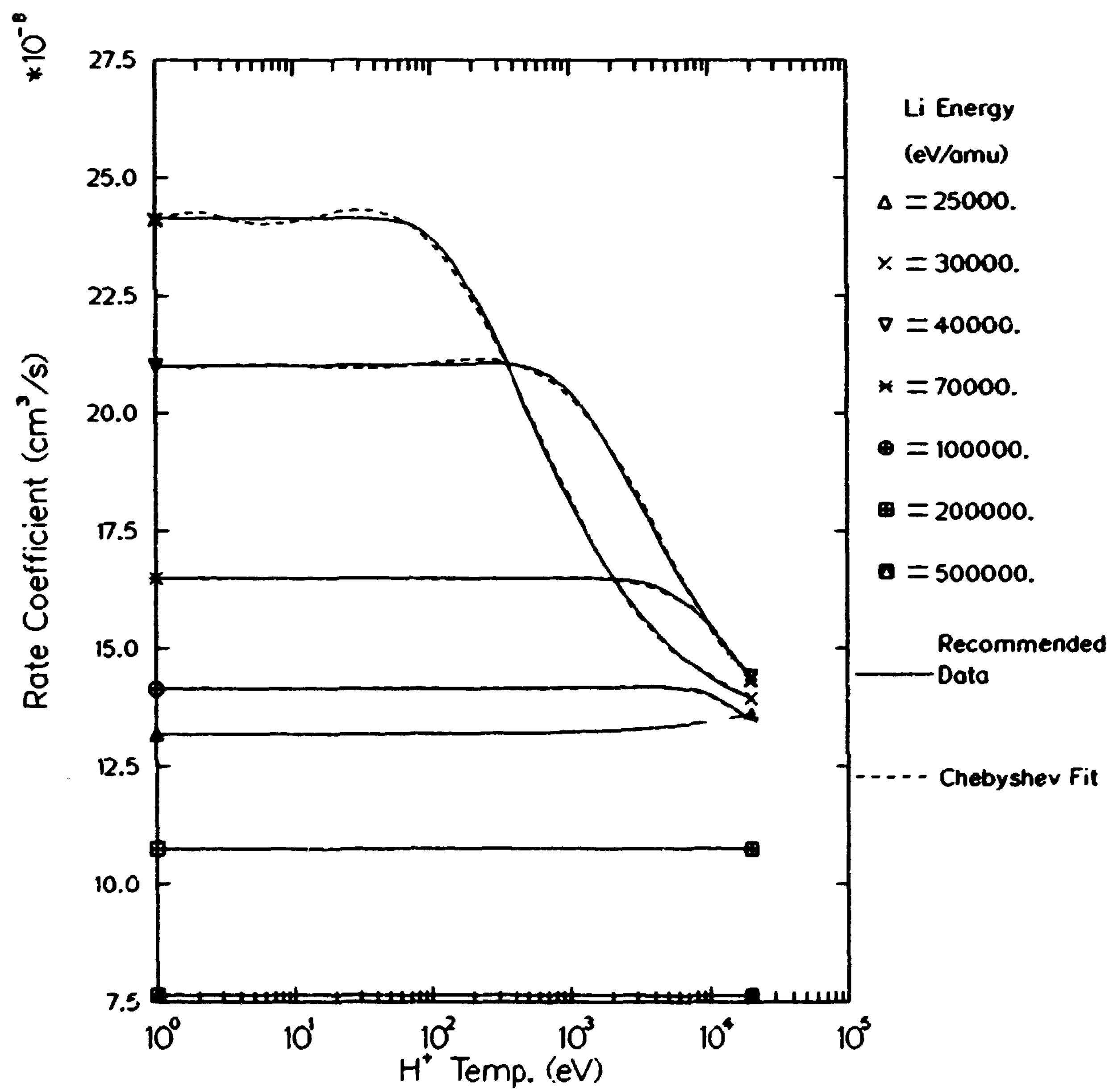
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Li Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
25000.	-31.6698	.0118975	.00739492	.00353790	.00119300	1.935930E-04	-1.149263E-04
30000.	-30.8686	-.300540	-.102787	.0265566	.03755728	4.406779E-04	-.0128332
40000.	-30.9410	-.164365	-.104816	-.0390710	.00300641	.0148191	.00812484
70000.	-31.2792	-.0415852	-.0337922	-.0234716	-.0135033	-.00588597	-.00106044
100000.	-31.5530	-.0108539	-.0102585	-.00887341	-.00653162	-.00400398	-.00213914
200000.	-32.0915	3.788109E-04	-1.517981E-04	-3.574076E-04	-3.435617E-04	-2.366813E-04	-1.024141E-04
500000.	-32.7738	-8.388920E-04	-5.417499E-04	-3.069308E-04	-2.075953E-04	-1.598618E-04	-6.145641E-05

See appendix for Chebyshev fit details

$Li + H^+ \rightarrow Li^+ + H^+ + e$

Beam – Maxwellian



Cross Sections for the Ionization of Li by He^+ Ions.

$$He^+ + Li \rightarrow He^+ + Li^+ + e$$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
8.2E+03	1.26E+08	1.67E-15
9.0E+03	1.32E+08	1.66E-15
1.0E+04	1.39E+08	1.65E-15
1.5E+04	1.70E+08	1.53E-15
2.0E+04	1.96E+08	1.38E-15
2.5E+04	2.20E+08	1.17E-15
3.0E+04	2.41E+08	9.31E-16
3.4E+04	2.56E+08	7.58E-16

References: 232, 739

Accuracy: Unknown

Notes: (1) The theoretical cross section of Tiwary et al. (Ref. 739) continues to increase at energies less than 10^4 eV/amu. (2) The experimental data of DuBois (Ref. 232) indicate a maximum in the cross section at 10^4 eV/amu.

Chebyshev Fitting Parameters for Cross Sections

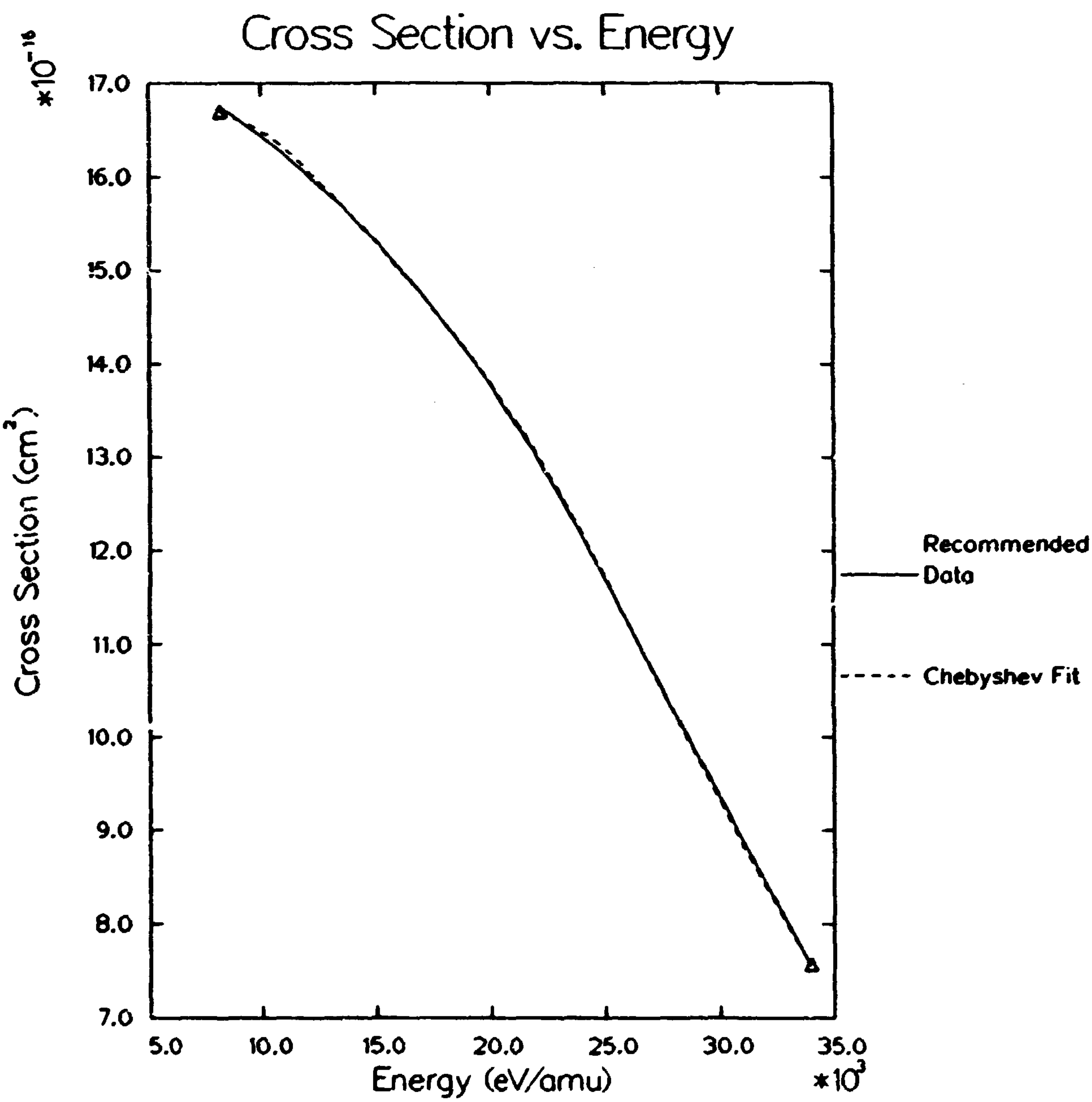
E_{min} = 8.2E+03 eV/amu, E_{max} = 3.4E+04 eV/amu

A0	A1	A2	A3	A4	A5	A6
-68.5495	-.358317	-.141101	-.0391361	-.00786217	.00262636	.00278367

The fit represents the above cross section with an rms deviation of 0.0%. The maximum deviation is 0.1% at 2.5E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^+ + Li \rightarrow He^+ + Li^+ + e$



Cross Sections for Ionization of Li by He^{2+} Ions

$$He^{2+} + Li \rightarrow He^{2+} + Li^{+} + e$$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
6.6E+03	1.13E+08	5.62E-16
7.0E+03	1.15E+08	6.85E-16
1.0E+04	1.39E+08	1.42E-15
1.5E+04	1.70E+08	2.77E-15
2.0E+04	1.96E+08	3.80E-15
2.4E+04	2.15E+08	4.06E-15
4.0E+04	2.78E+08	3.02E-15
7.0E+04	3.68E+08	1.86E-15
1.0E+05	4.39E+08	1.35E-15
1.5E+05	5.38E+08	9.43E-16
2.0E+05	6.21E+08	7.36E-16
4.0E+05	8.78E+08	4.01E-16
7.0E+05	1.16E+09	2.51E-16
1.0E+06	1.39E+09	1.84E-16
1.5E+06	1.70E+09	1.28E-16

__References:__ 232, 234, 264, 731, 735, 737

__Accuracy:__ $E > 2x10^4$ eV/amu - 30%
$E < 2x10^4$ eV/amu - Unknown

__Notes:__ (1) The theoretical data of Shipsey, et al. (Ref. 264) have been used to extend the experimental data below $2x10^4$ eV/amu. At higher energies the theoretical data of this paper are approximately 50% below the experimental data. (2) See Shah, et al. (Ref. 234) for double ionization and transfer ionization.

__Chebyshev Fitting Parameters for Cross Sections__

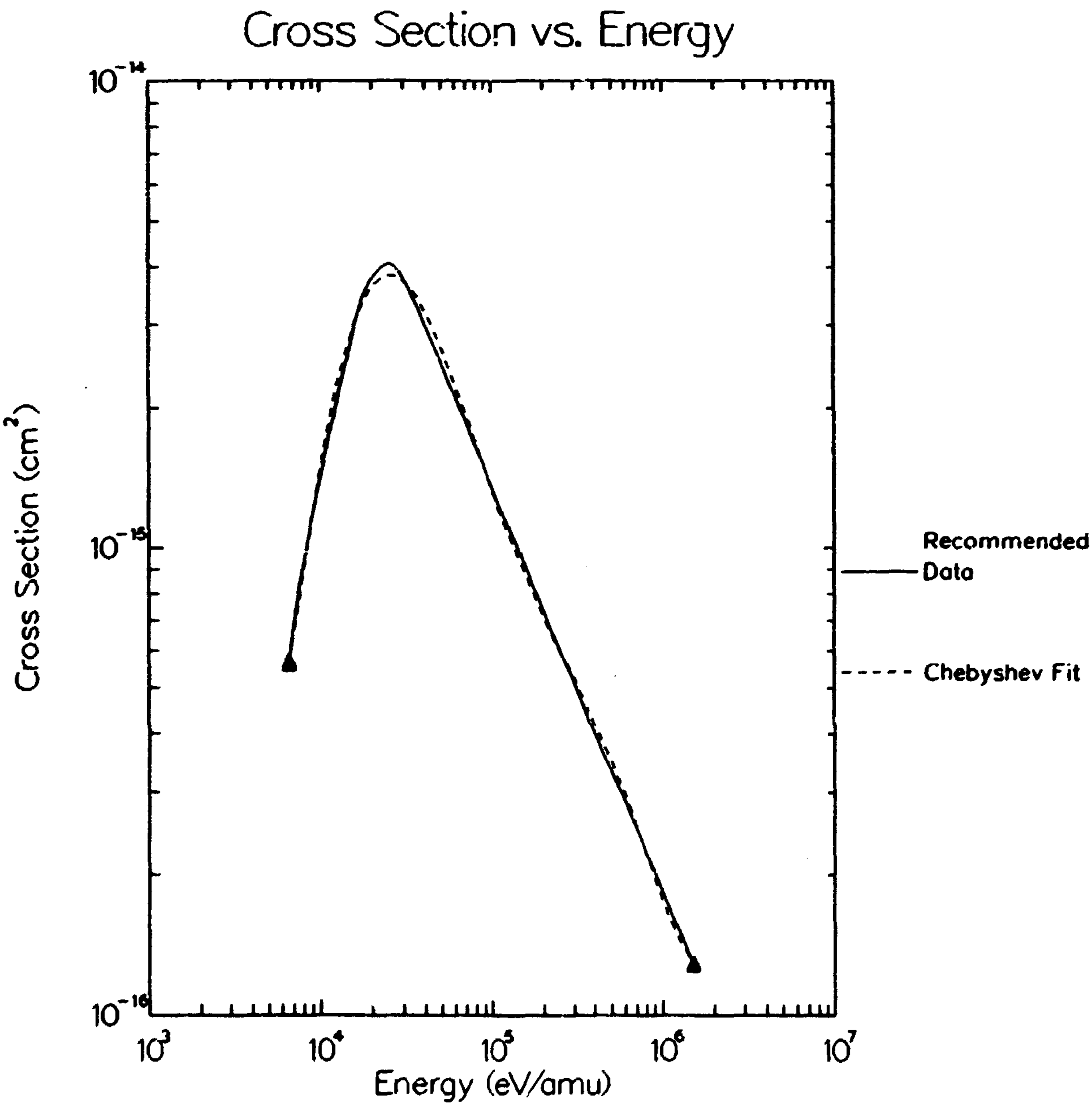
E_{min} = 6.6E+03 eV/amu, E_{max} = 1.5E+06 eV/amu

A0	A1	A2	A3	A4	A5	A6
-69.7410	-1.20403	-.864397	.480069	-.171618	-.0181494	.0678290

The fit represents the above cross sections with an rms deviation of 3.8%. The maximum deviation is 6.5% at 4.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^{2+} + Li \rightarrow He^{2+} + Li^{+} + e$



Ionization Rate Coefficients for

$Li + He^{2+} \rightarrow Li^{+} + He^{2+} + e$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{2+} Temp. (eV)	Li Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	1.97E-07	7.45E-07	8.39E-07	6.84E-07	5.93E-07	4.57E-07	3.27E-07
2.0E+00	1.97E-07	7.45E-07	8.39E-07	6.84E-07	5.93E-07	4.57E-07	3.27E-07
4.0E+00	1.97E-07	7.44E-07	8.38E-07	6.84E-07	5.93E-07	4.57E-07	3.27E-07
7.0E+00	1.97E-07	7.44E-07	8.38E-07	6.84E-07	5.93E-07	4.57E-07	3.27E-07
1.0E+01	1.97E-07	7.43E-07	8.38E-07	6.83E-07	5.93E-07	4.57E-07	3.27E-07
2.0E+01	1.97E-07	7.42E-07	8.37E-07	6.83E-07	5.93E-07	4.57E-07	3.27E-07
4.0E+01	1.97E-07	7.40E-07	8.37E-07	6.83E-07	5.93E-07	4.57E-07	3.27E-07
7.0E+01	1.98E-07	7.39E-07	8.36E-07	6.83E-07	5.93E-07	4.57E-07	3.27E-07
1.0E+02	1.98E-07	7.38E-07	8.36E-07	6.83E-07	5.93E-07	4.57E-07	3.27E-07
2.0E+02	2.01E-07	7.35E-07	8.34E-07	6.83E-07	5.93E-07	4.57E-07	3.27E-07
4.0E+02	2.06E-07	7.32E-07	8.32E-07	6.83E-07	5.93E-07	4.57E-07	3.27E-07
7.0E+02	2.13E-07	7.28E-07	8.30E-07	6.83E-07	5.93E-07	4.57E-07	3.27E-07
1.0E+03	2.20E-07	7.23E-07	8.28E-07	6.83E-07	5.93E-07	4.57E-07	3.27E-07
2.0E+03	2.44E-07	7.12E-07	8.23E-07	6.82E-07	5.93E-07	4.57E-07	3.27E-07
4.0E+03	2.87E-07	6.95E-07	8.15E-07	6.82E-07	5.93E-07	4.57E-07	3.27E-07
7.0E+03	3.38E-07	6.81E-07	8.03E-07	6.81E-07	5.93E-07	4.56E-07	3.27E-07
1.0E+04	3.77E-07	6.72E-07	7.89E-07	6.79E-07	5.93E-07	4.56E-07	3.27E-07
2.0E+04	4.63E-07	6.57E-07	7.52E-07	6.72E-07	5.92E-07	4.56E-07	3.27E-07

Chebyshev Fitting Parameters for Rate Coefficients

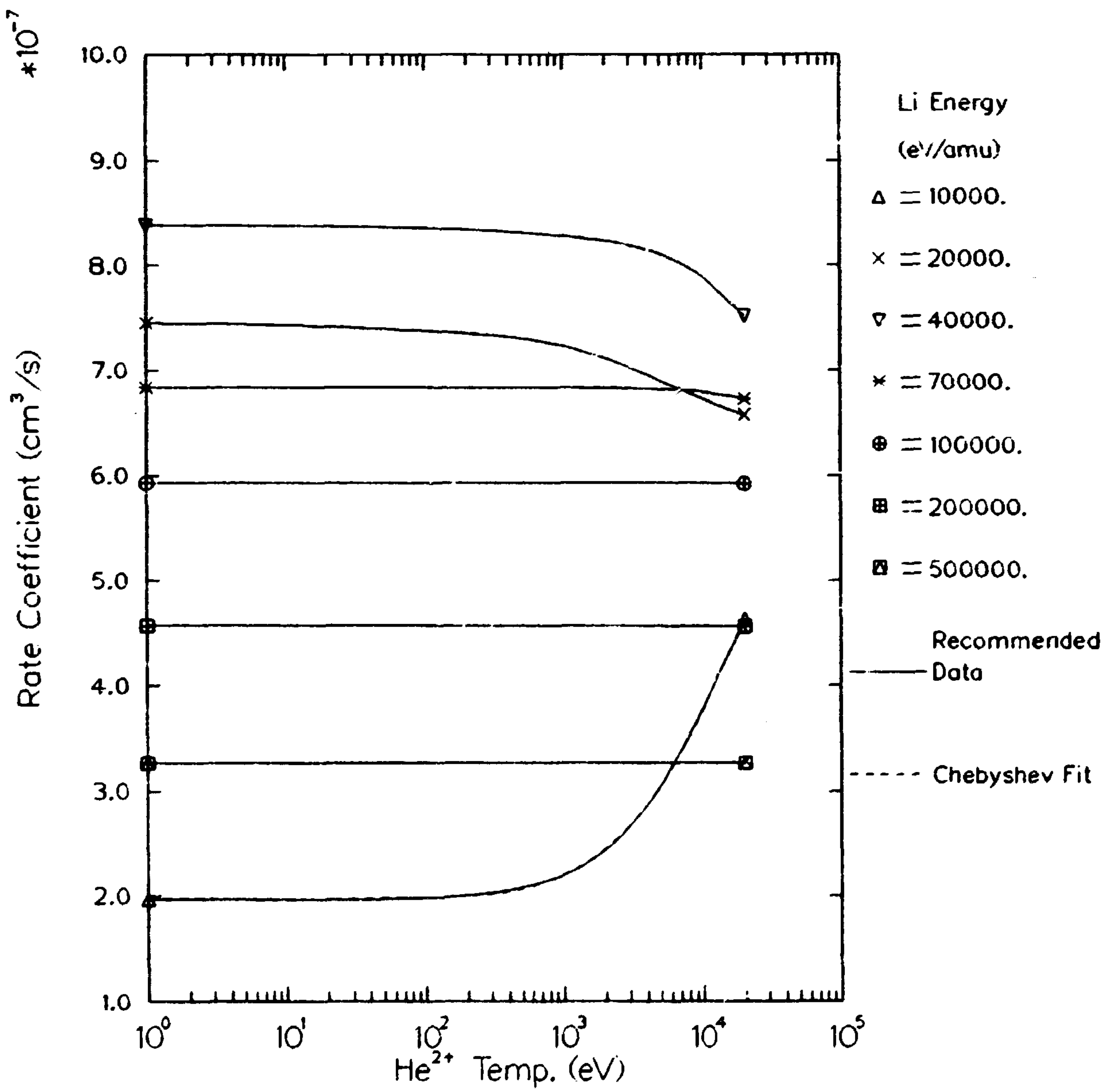
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Li Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-30.4517	.363146	.218568	.0797980	.30504386	-.0143333	-.0104786
20000.	-28.2941	-.0576610	-.0273357	-.00812937	3.616003E-04	.00260866	.00171889
40000.	-28.0291	-.0386370	-.0241107	-.0131556	-.00664902	-.00299352	-.00102071
70000.	-28.3978	-.00517514	-.00356459	-.00231958	-.00145198	-8.487303E-04	-4.870846E-04
100000.	-28.6764	-3.661189E-04	-4.106187E-04	-3.730240E-04	-2.606518E-04	-1.714793E-04	-7.710836E-05
200000.	-29.1978	-8.814731E-04	-6.105531E-04	-1.205126E-04	-7.285731E-05	1.063444E-04	7.216290E-06
500000.	-29.8691	-1.603658E-04	-9.779805E-05	-3.825455E-05	-5.564509E-06	2.962654E-06	-4.029762E-07

See appendix for Chebyshev fit details.

$Li + He^{2+} \rightarrow Li^{+} + He^{2+} + e$

Beam – Maxwellian



E. Projectile Electron Loss or Stripping Cross Sections

(* denotes rate coefficient data also)

Projectile Electron Loss or Stripping Cross Sections for

$H + H \rightarrow H^{+} + H + e$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.2E+03	4.81E+07	2.89E-18
2.0E+03	6.21E+07	1.50E-17
4.0E+03	8.79E+07	3.65E-17
6.0E+03	1.08E+08	5.22E-17
7.0E+03	1.16E+08	5.87E-17
1.0E+04	1.39E+08	7.68E-17
1.5E+04	1.70E+08	1.07E-16
2.0E+04	1.96E+08	1.26E-16
4.0E+04	2.78E+08	9.64E-17
7.0E+04	3.68E+08	7.35E-17
1.0E+05	4.39E+08	5.98E-17
1.5E+05	5.38E+08	4.49E-17
2.0E+05	6.21E+08	3.57E-17
4.0E+05	8.78E+08	1.96E-17
7.0E+05	1.16E+09	1.27E-17
1.0E+06	1.39E+09	9.67E-18
1.5E+06	1.70E+09	7.08E-18
2.0E+06	1.96E+09	5.76E-18
3.5E+06	2.59E+09	3.88E-18

References: 33, 34, 209, 296, 297, 298, 299, 300, 301

Accuracy: 20%

Note: To our knowledge there are no known experimental ionization cross sections for H interacting with H atoms.

Chebyshev Fitting Parameters for Cross Sections

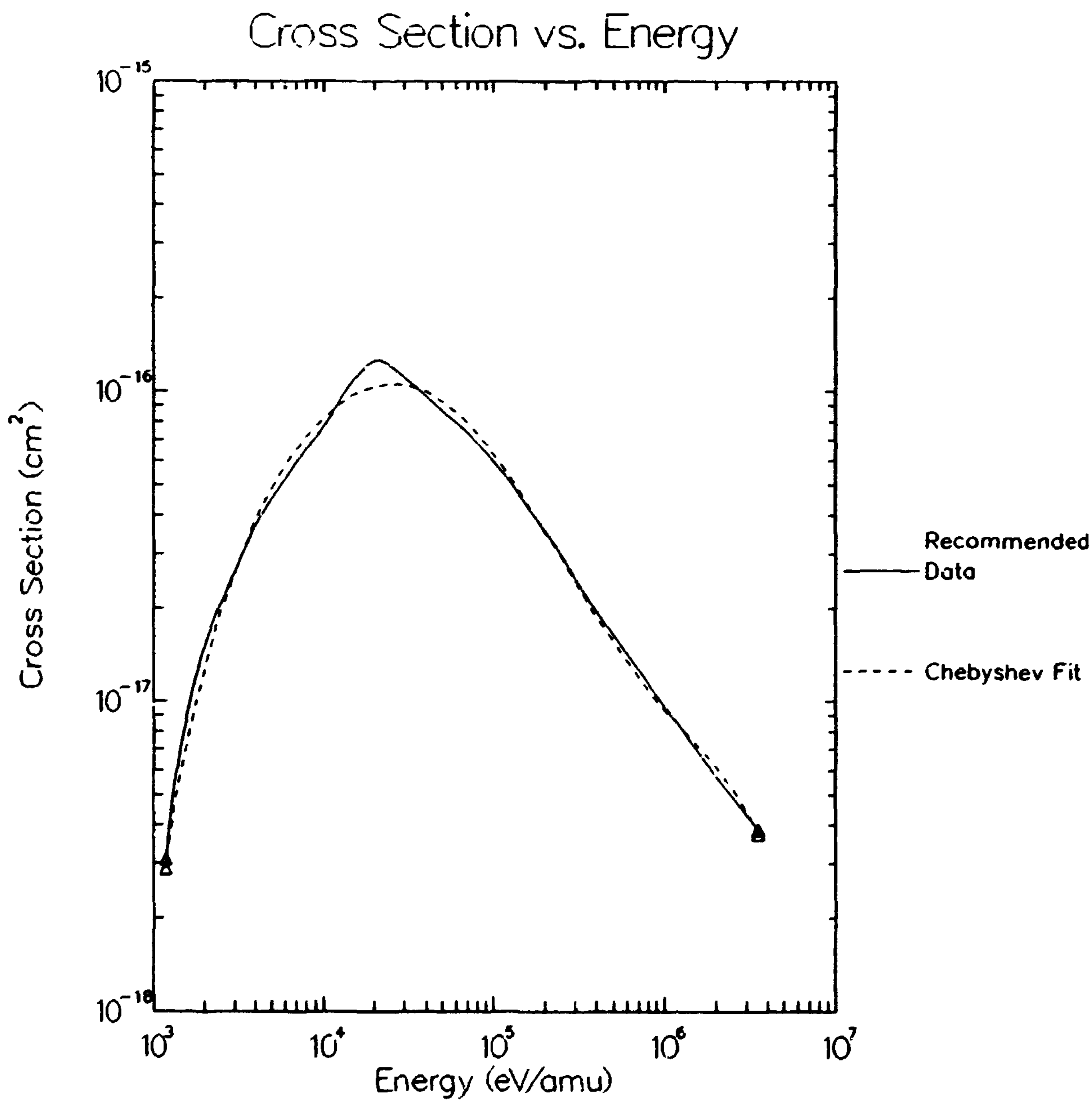
E_{min} = 1.2E+03 eV/amu, E_{max} = 3.5E+06 eV/amu

A0	A1	A2	A3	A4	A5	A6
-77.1794	-.451408	-1.51760	.543975	-.0355154	.00258954	-.0750900

The fit represents the above cross section with an rms deviation of 8.0%. The maximum deviation is 10.3% at 7.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$H + H \rightarrow H^+ + H + e$



Projectile Electron Loss or Stripping Cross Sections for

$H(2s) + H(1s) \rightarrow H^{+} + H + e$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
5.0E+03	9.82E+07	2.24E-16
6.0E+03	1.08E+08	2.39E-16
7.0E+03	1.16E+08	2.51E-16
8.0E+03	1.24E+08	2.62E-16
9.0E+03	1.32E+08	2.69E-16
1.0E+04	1.39E+08	2.75E-16
1.5E+04	1.70E+08	2.95E-16
2.0E+04	1.96E+08	2.94E-16
3.0E+04	2.41E+08	2.60E-16
4.0E+04	2.78E+08	2.29E-16
5.0E+04	3.11E+08	2.10E-16
6.0E+04	3.40E+08	1.99E-16
7.0E+04	3.68E+08	1.91E-16
8.0E+04	3.93E+08	1.84E-16
9.0E+04	4.17E+08	1.79E-16
1.0E+05	4.39E+08	1.74E-16

References: 33, 285, 302

Accuracy: Unknown

Note: The experimental data of Hill, et al. (Ref. 33) have been extrapolated from 20 keV/amu to 100 keV/amu using the theoretical data of Abrines and Percival (Ref. 285), and Prasad and Unnikrishnan (Ref. 302). In the energy range of overlap the experimental and theoretical data agree to within 25%.

Chebyshev Fitting Parameters for Cross Sections

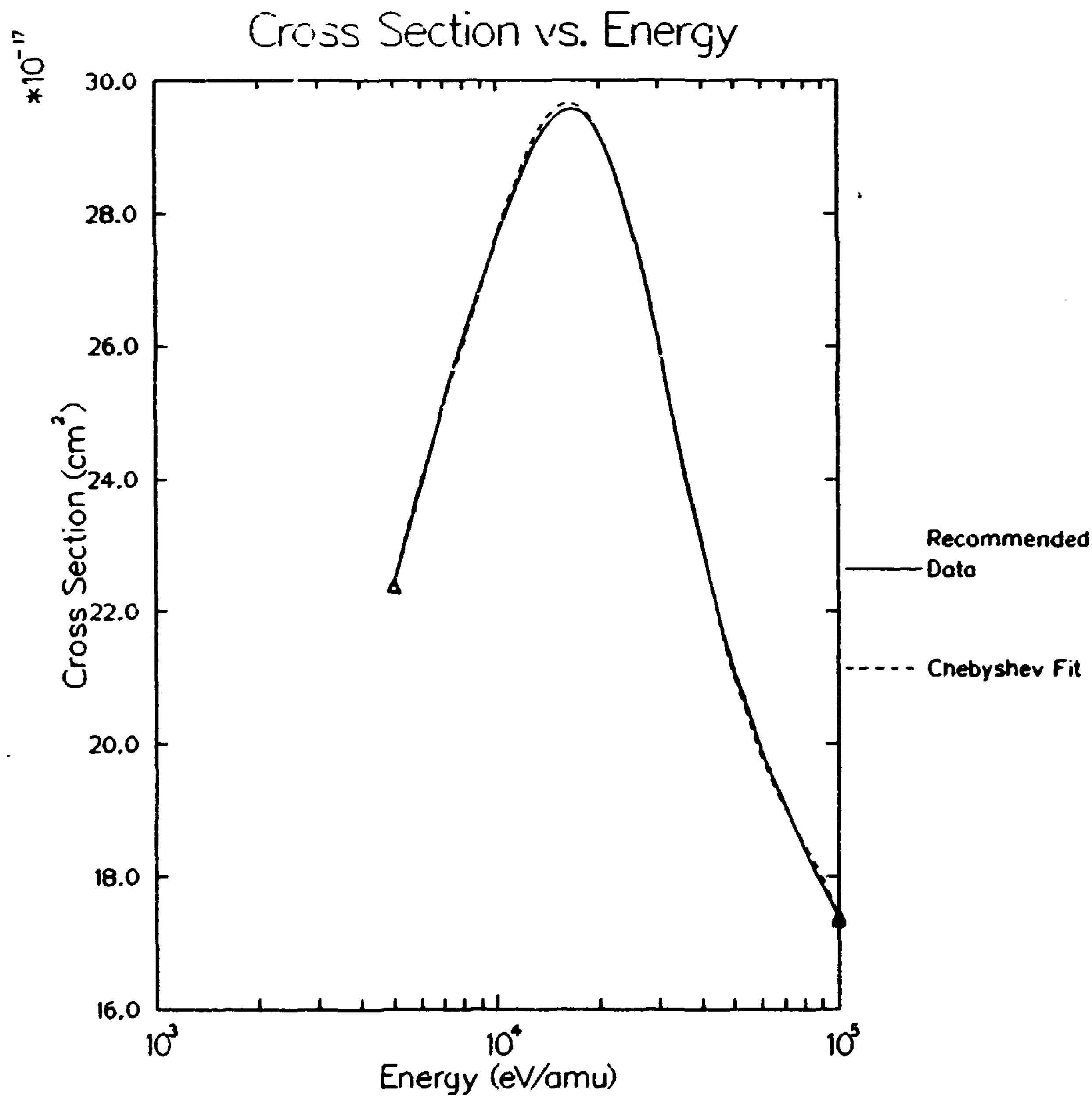
E_{min} = 5.0E+03 eV/amu, E_{max} = 1.0E+05 eV/amu

A0	A1	A2	A3	A4	A5	A6
-72.0121	-.164818	-.174972	.0460650	.0293401	-.00879104	-.0113468

The fit represents the above cross section with an rms deviation of 0.4%. The maximum deviation is 0.5% at 4.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$H(2s) + H \rightarrow H^+ + H + e$



Projectile Electron Loss or Stripping Cross Sections for

$H + H_2 \rightarrow H^+ + H_2 + e$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
6.0E+01	1.08E+07	1.17E-19
7.0E+01	1.16E+07	1.91E-19
1.0E+02	1.39E+07	5.24E-19
1.5E+02	1.70E+07	1.37E-18
2.0E+02	1.96E+07	2.39E-18
4.0E+02	2.78E+07	8.32E-18
7.0E+02	3.68E+07	2.09E-17
1.0E+03	4.39E+07	3.37E-17
1.5E+03	5.38E+07	5.08E-17
2.0E+03	6.21E+07	6.36E-17
4.0E+03	8.79E+07	8.63E-17
7.0E+03	1.16E+08	9.09E-17
1.0E+04	1.39E+08	9.21E-17
1.5E+04	1.70E+08	1.06E-16
2.0E+04	1.96E+08	1.36E-16
4.0E+04	2.78E+08	1.54E-16
7.3E+04	3.75E+08	1.34E-16
1.0E+05	4.39E+08	1.10E-16
1.5E+05	5.38E+08	8.61E-17
2.0E+05	6.21E+08	7.04E-17
4.0E+05	8.78E+08	4.20E-17
7.0E+05	1.16E+09	2.63E-17
1.0E+06	1.39E+09	1.91E-17
1.5E+06	1.70E+09	1.30E-17
2.0E+06	1.96E+09	9.74E-18
4.0E+06	2.77E+09	4.60E-18
7.0E+06	3.65E+09	2.46E-18
1.0E+07	4.36E+09	1.65E-18
1.5E+07	5.32E+09	1.02E-18
2.0E+07	6.11E+09	7.34E-19

<u>References:</u> 26, 27, 28, 29, 31, 33, 37, 45, 47, 49, 51, 143, 269, 270, 296, 298, 299, 301, 303, 304, 305, 306, 307, 308, 310, 313, 315, 316, 321

<u>Accuracy:</u> 30%

<u>Note:</u> Many Investigators have been involved in these measurements. Consequently there is large scatter in the data, but most of the measurements are within the quoted accuracy of 30%.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

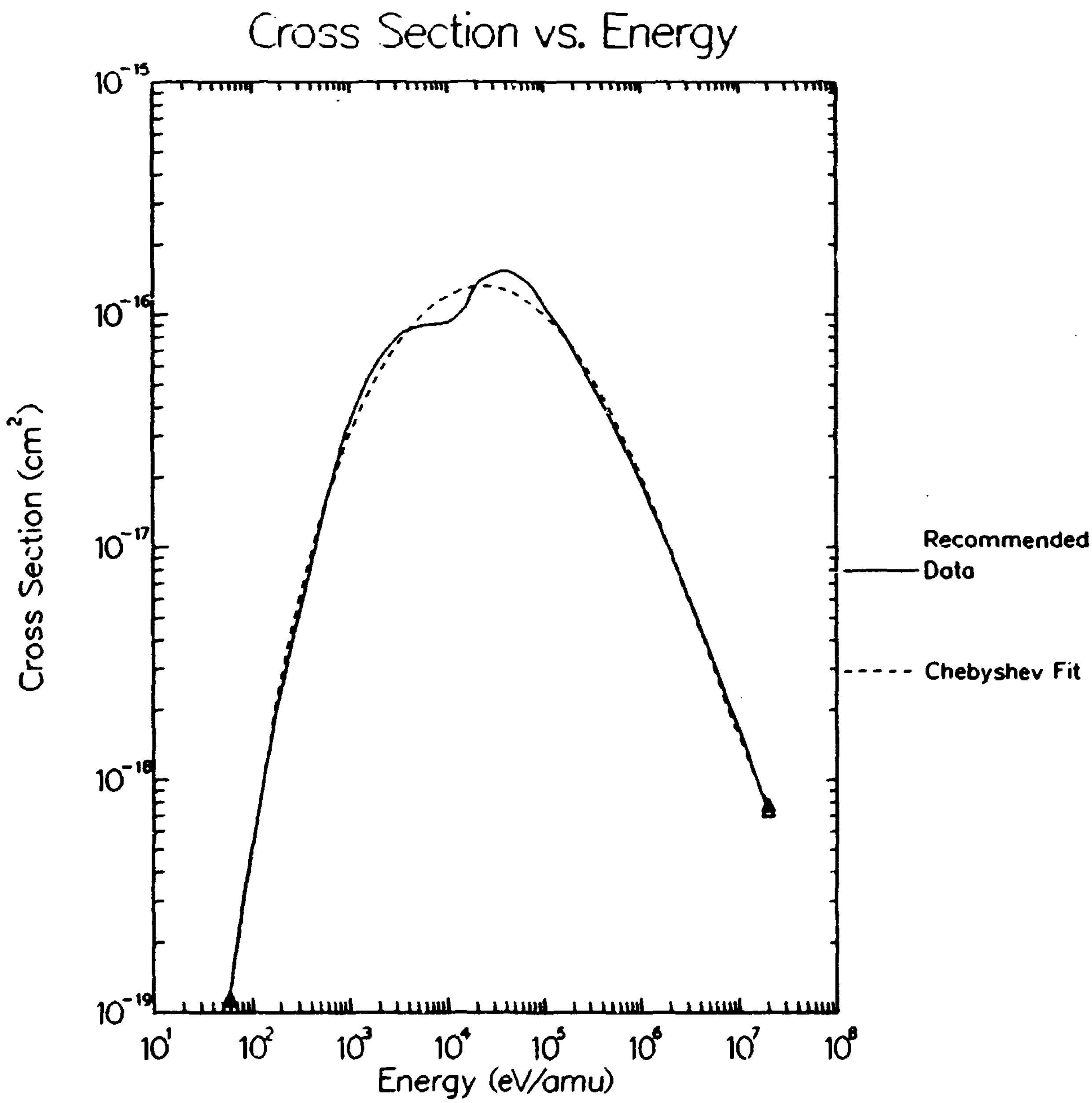
E_{min} = 6.0E+01 eV/amu, E_{max} = 2.0E+07 eV/amu

A0	A1	A2	A3	A4	A5	A6
-79.0892	.346403	-3.04496	.508490	-.0758661	.108006	.00593450

The fit represents the above cross section with an rms deviation of 10.7%. The maximum deviation is 29.8% at 1.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$H + H_2 \rightarrow H^+ + H_2 + e$



Projectile Electron Loss or Stripping Cross Sections for

$H(2s) + H_2 \rightarrow H^+ + H_2 + e$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
5.0E+02	3.11E+07	6.14E-17
7.0E+02	3.68E+07	1.09E-16
1.0E+03	4.39E+07	1.90E-16
1.5E+03	5.38E+07	2.89E-16
2.0E+03	6.21E+07	3.33E-16
4.0E+03	8.79E+07	4.05E-16
7.0E+03	1.16E+08	4.36E-16
1.0E+04	1.39E+08	4.50E-16
1.5E+04	1.70E+08	4.63E-16
2.0E+04	1.96E+08	4.76E-16
4.0E+04	2.78E+08	4.00E-16
7.0E+04	3.68E+08	3.00E-16
1.0E+05	4.39E+08	2.48E-16
1.5E+05	5.38E+08	1.95E-16
2.0E+05	6.21E+08	1.59E-16
4.0E+05	8.78E+08	9.56E-17
5.0E+05	9.82E+08	8.13E-17

References: 27, 33, 306, 326, 327, 328, 329, 331, 332

Accuracy: 50%

Note: Due to the uncertainties in measuring the H(2s) metastable fraction, the errors in measuring the cross sections may be large.

Chebyshev Fitting Parameters for Cross Sections

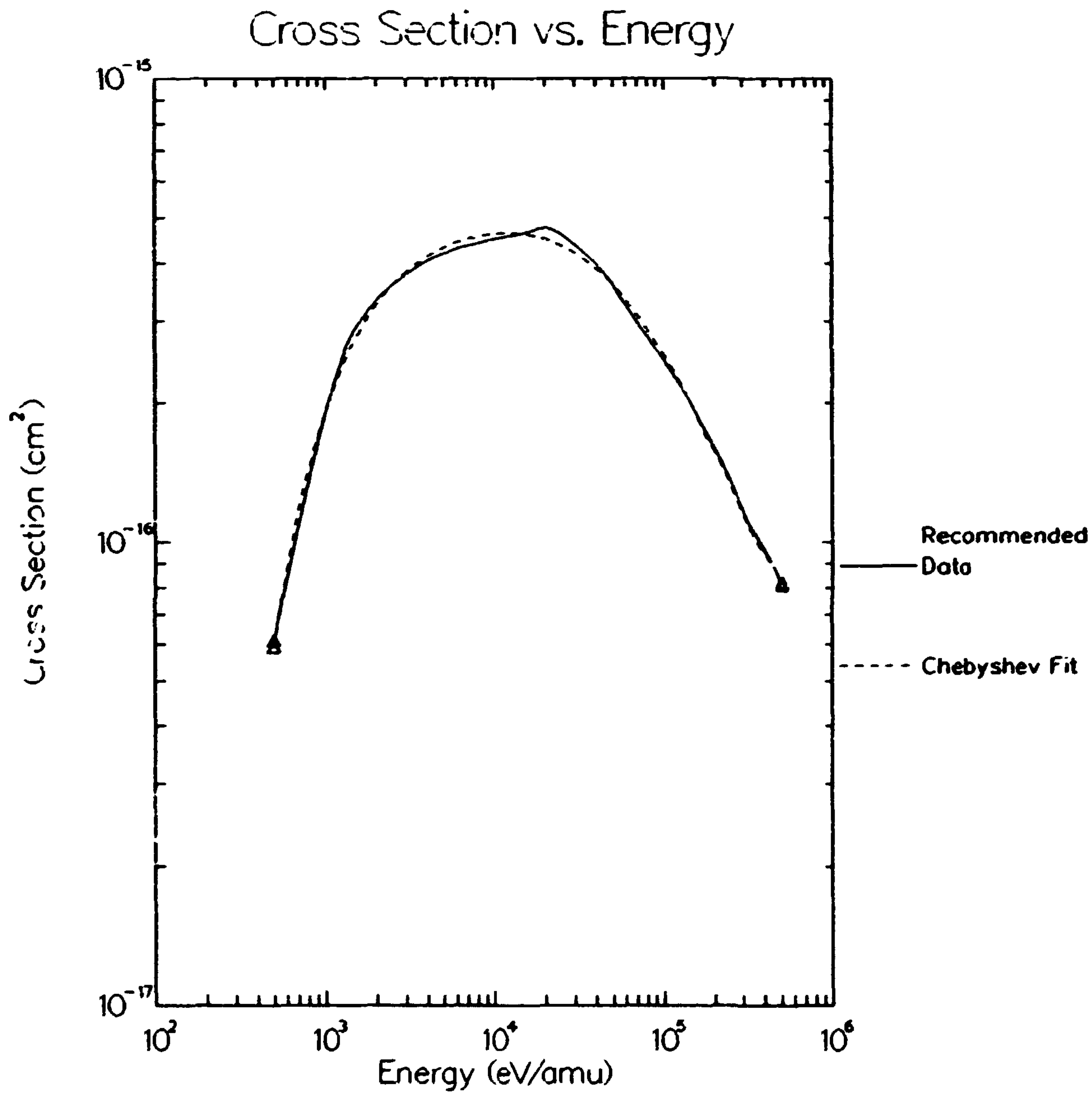
E_{min} = 5.0E+02 eV/amu, E_{max} = 5.0E+05 eV/amu

A0	A1	A2	A3	A4	A5	A6
-72.3651	-.0686522	-.939077	.160670	-.0746703	.0714502	-.00310738

The fit represents the above cross section with an rms deviation of 3.2%. The maximum deviation is 7.0% at 7.0E+02 eV/amu.

See appendix for Chebyshev fit details.

$H(2s) + H_2 \rightarrow H^+ + H_2 + e$



Projectile Electron Loss or Stripping Cross Sections for

$H + He \rightarrow H^{+} + He + e$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
5.0E+01	9.82E+06	2.25E-19
7.0E+01	1.16E+07	5.27E-19
1.0E+02	1.39E+07	1.08E-18
2.0E+02	1.96E+07	3.40E-18
4.0E+02	2.78E+07	9.54E-18
7.0E+02	3.68E+07	2.06E-17
1.0E+03	4.39E+07	3.31E-17
2.0E+03	6.21E+07	6.83E-17
4.0E+03	8.79E+07	1.07E-16
7.0E+03	1.16E+08	1.28E-16
1.0E+04	1.39E+08	1.33E-16
2.0E+04	1.96E+08	1.30E-16
4.0E+04	2.78E+08	1.21E-16
7.0E+04	3.68E+08	1.05E-16
1.0E+05	4.39E+08	8.77E-17
2.0E+05	6.21E+08	5.41E-17
4.0E+05	8.78E+08	3.12E-17
7.0E+05	1.16E+09	1.91E-17
1.0E+06	1.39E+09	1.38E-17
2.0E+06	1.96E+09	7.20E-18
4.0E+06	2.77E+09	3.68E-18
7.0E+06	3.65E+09	2.13E-18
1.0E+07	4.36E+09	1.49E-18
2.0E+07	6.11E+09	7.31E-19

References: 26, 27, 28, 29, 47, 49, 51, 103, 268, 269, 270, 286, 287 296, 299, 300, 303, 307, 309, 313, 314, 316, 317, 318, 319, 320, 321, 322

Accuracy: 15%

Notes: None

Chebyshev Fitting Parameters for Cross Sections

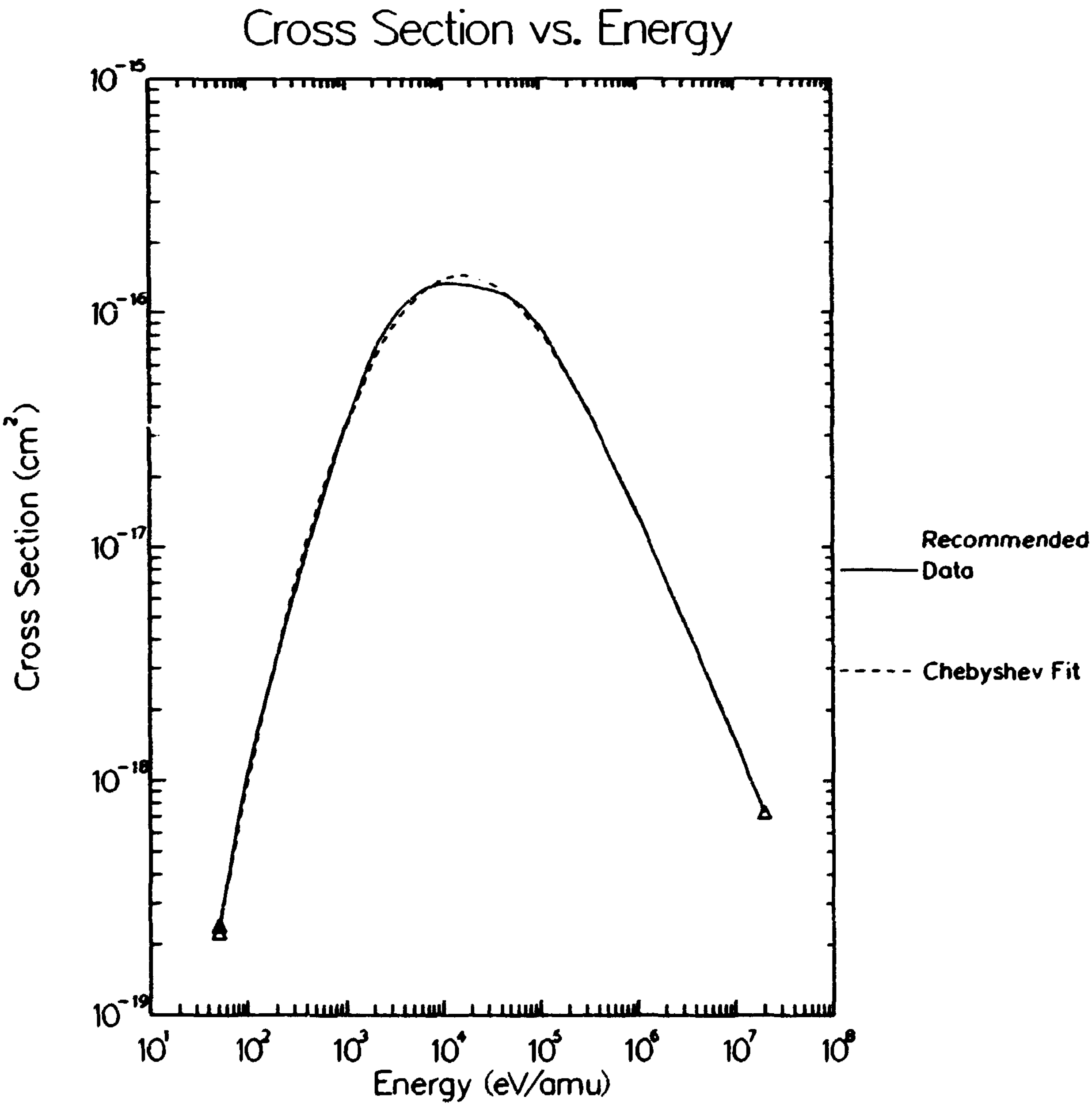
E_{min} = 5.0E+01 eV/amu, E_{max} = 2.0E+07 eV/amu

A0	A1	A2	A3	A4	A5	A6
-79.0638	.107432	-2.86460	.477451	.0989948	-.0319510	-.0136705

The fit represents the above cross section with an rms deviation of 4.7%. The maximum deviation is 9.9% at 2.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$H + He \rightarrow H^+ + He + e$



Projectile Electron Loss or Stripping Rate Coefficients for

$H + He \rightarrow H^{+} + He + e$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

H Temp. (eV)	Equal Temp.	He Temp. (eV) 10.	100.	500.	1000.	5000.	10000.	20000.
1.0E+01	7.25E-13#	2.29E-13#	6.10E-12*	1.09E-10	3.69E-10	3.81E-09	7.66E-09	1.30E-08
2.0E+01	2.53E-12*	1.86E-12*	1.10E-11	1.25E-10	3.94E-10	3.84E-09	7.69E-09	1.30E-08
4.0E+01	1.40E-11	9.69E-12	2.48E-11	1.60E-10	4.47E-10	3.91E-09	7.74E-09	1.30E-08
6.0E+01	3.35E-11	2.28E-11	4.34E-11	1.98E-10	5.01E-10	3.98E-09	7.80E-09	1.31E-08
8.0E+01	6.03E-11	4.08E-11	6.64E-11	2.40E-10	5.58E-10	4.05E-09	7.85E-09	1.31E-08
1.0E+02	9.38E-11	6.33E-11	9.38E-11	2.84E-10	6.16E-10	4.12E-09	7.90E-09	1.31E-08
2.0E+02	3.44E-10	2.35E-10	2.84E-10	5.43E-10	9.27E-10	4.46E-09	8.16E-09	1.33E-08
4.0E+02	1.09E-09	7.76E-10	8.47E-10	1.18E-09	1.62E-09	5.12E-09	8.67E-09	1.36E-08
6.0E+02	1.97E-09	1.45E-09	1.53E-09	1.88E-09	2.34E-09	5.76E-09	9.15E-09	1.40E-08
8.0E+02	2.88E-09	2.16E-09	2.25E-09	2.61E-09	3.06E-09	6.[illegible]6E-09	9.62E-09	1.43E-08
1.0E+03	3.77E-09	2.89E-09	2.97E-09	3.33E-09	3.77E-09	6.95E-09	1.01E-08	1.46E-08
2.0E+03	7.64E-09	6.22E-09	6.29E-09	6.58E-09	6.95E-09	9.50E-09	1.21E-08	1.60E-08
4.0E+03	1.30E-08	1.11E-08	1.12E-03	1.14E-08	1.16E-08	1.34E-08	1.53E-08	1.83E-08
6.0E+03	1.66E-08	1.46E-08	1.46E-08	1.48E-08	1.49E-08	1.63E-08	1.78E-08	2.03E-08
8.0E+03	1.93E-08	1.72E-08	1.72E-08	1.73E-08	1.75E-08	1.86E-08	1.98E-08	2.19E-08
1.0E+04	2.15E-08	1.93E-08	1.94E-08	1.95E-08	1.96E-08	2.05E-08	2.15E-08	2.33E-08
1.5E+04	2.55E-08	2.33E-08	2.33E-08	2.34E-08	2.35E-08	2.41E-08	2.48E-08	2.61E-08
2.0E+04	2.81E-08	2.61E-08	2.61E-08	2.61E-08	2.62E-03	2.66E-06	2.71E-08	2.81E-08

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

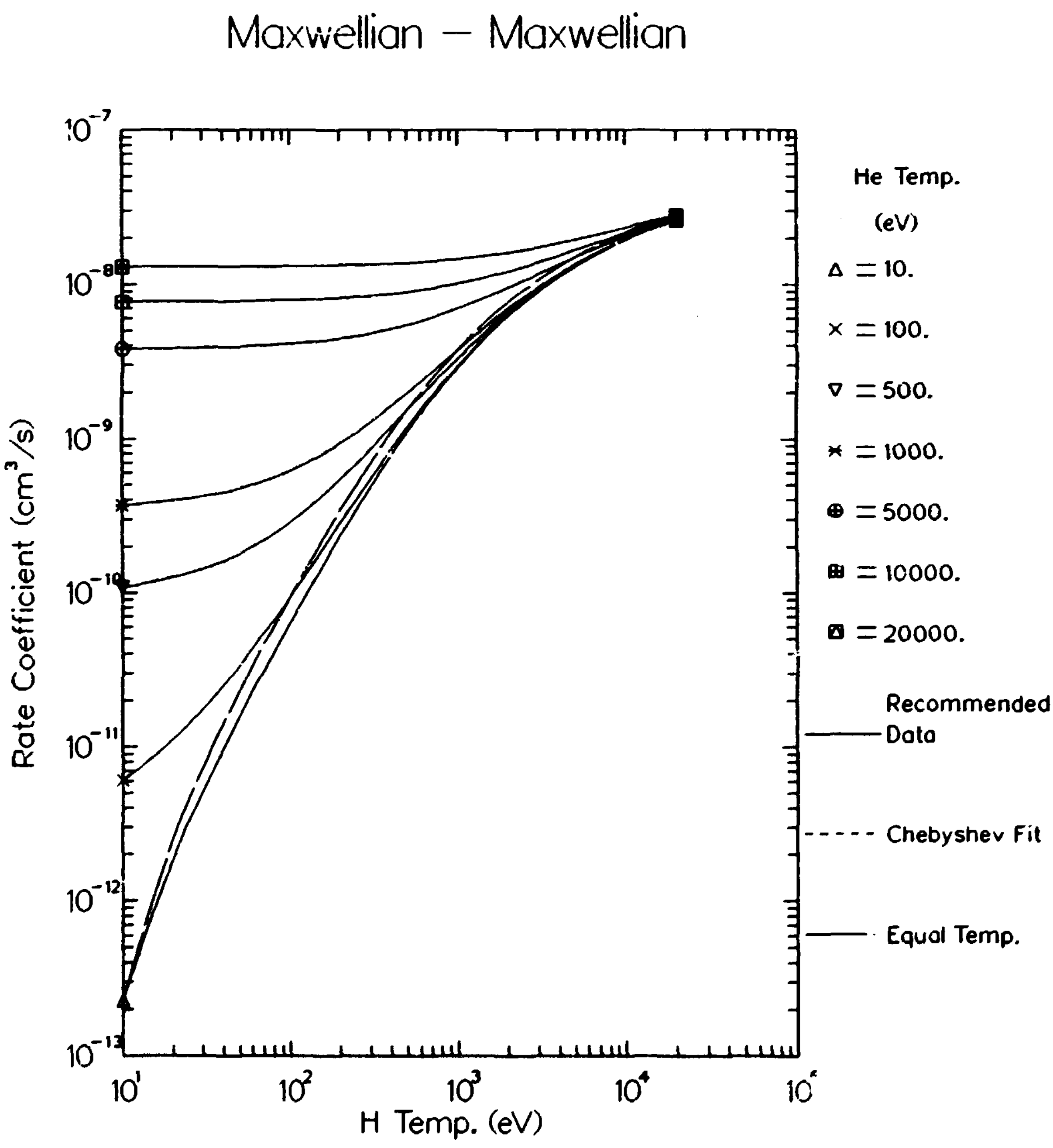
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+01 eV, E_{max} = 2.0E+04 eV

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
10.	-44.0257	5.73463	-1.21932	.0247503	-.0292957	.0619373	-.0219438
100.	-42.5585	4.48698	-.446257	-.330879	.0963671	.0257805	-.0137058
500.	-40.6373	3.03270	.121804	-.344684	.00515230	.0559208	-.00813670
1000.	-39.6384	2.34972	.269827	-.258791	-.0440918	.0450062	.00550612
5000.	-37.3658	1.00814	.315318	-.0289392	-.0542988	-.00704923	.00822057
10000.	-36.5490	.622335	.247753	.0221122	-.0286150	-.0130702	4.392519E-04
20000.	-35.8634	.357047	.168697	.0373094	-.00809424	-.00961802	-.00307060
Equal Temp.	-43.5995	5.66872	-1.35443	.109372	-.0570829	.0766441	-.0349995

See appendix for Chebyshev fit details.

H + He -> H^+ + He + e



Maxwellian — Maxwellian
Rate Coefficient (cm^3/s)
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^1
10^2
10^3
10^4
10^5
H Temp. (eV)
He Temp.
(eV)
△ = 10.
× = 100.
▽ = 500.
✳ = 1000.
⊕ = 5000.
⊞ = 10000.
⊠ = 20000.
Recommended Data
Chebyshev Fit
Equal Temp.

Projectile Electron Loss or Stripping Cross Sections for

$H(2s) + He \rightarrow H^{+} + He + e$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
5.0E+02	3.11E+07	3.08E-17
7.0E+02	3.68E+07	8.29E-17
1.0E+03	4.39E+07	1.37E-16
1.5E+03	5.38E+07	1.94E-16
2.0E+03	6.21E+07	2.39E-16
4.0E+03	8.79E+07	3.28E-16
7.0E+03	1.16E+08	3.42E-16
1.0E+04	1.39E+08	3.42E-16
1.5E+04	1.70E+08	3.32E-16
2.0E+04	1.96E+08	3.07E-16
4.0E+04	2.78E+08	2.23E-16
7.0E+04	3.68E+08	1.61E-16
1.0E+05	4.39E+08	1.26E-16
1.5E+05	5.38E+08	9.97E-17
2.0E+05	6.21E+08	8.78E-17
4.0E+05	8.78E+08	6.97E-17
5.0E+05	9.6[illegible]E+08	6.72E-17

<u>References:</u> 29, 324, 326, 327, 329, 332

<u>Accuracy:</u> 50%

<u>Note:</u> Due to the uncertainties in measuring the H(2s) metastable fraction the errors in measuring the cross section may be large. For energies less than 1 keV/amu the data should by used with caution.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

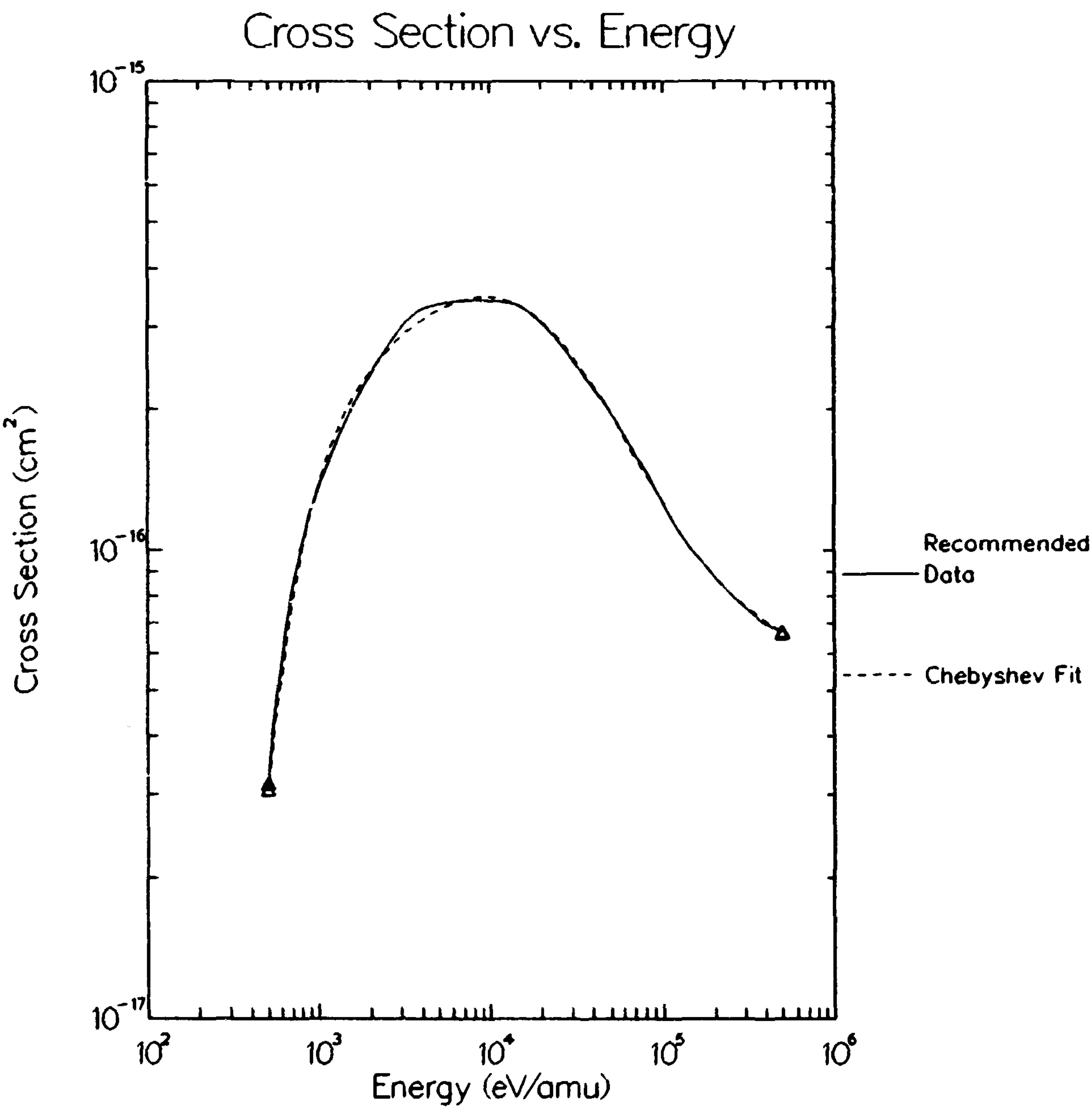
E_{min} = 5.0E+02 eV/amu, E_{max} = 5.0E+05 eV/amu

A0	A1	A2	A3	A4	A5	A6
-73.2008	-.0752112	-.927667	.363861	-.0349147	.08236627	-.0565338

The fit represents the above cross section with an rms deviation of 2.6%. The maximum deviation is 4.8% at 1.5E+03 eV/amu.

See Appendix for Chebyshev fit details.

H(2s) + He -> H^+ + He + e



Cross Section vs. Energy
10^{-15}
10^{-16}
10^{-17}
Cross Section (cm^2)
10^2
10^3
10^4
10^5
10^6
Energy (eV/amu)
Recommended Data
Chebyshev Fit

Projectile Electron Loss or Stripping Cross Sections for

$He + H \rightarrow He^{+} + H + e$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
5.0E+04	3.11E+08	1.56E-16
6.0E+04	3.40E+08	1.42E-16
7.0E+04	3.68E+08	1.31E-16
8.0E+04	3.93E+08	1.23E-16
9.0E+04	4.17E+08	1.15E-16
1.0E+05	4.39E+08	1.09E-16
1.5E+05	5.38E+08	8.49E-17
2.0E+05	6.21E+08	6.87E-17
3.0E+05	7.61E+08	4.80E-17
4.0E+05	8.78E+08	3.68E-17
5.0E+05	9.82E+08	2.93E-17
6.0E+05	1.08E+09	2.44E-17
7.0E+05	1.16E+09	2.07E-17
8.0E+05	1.24E+09	1.85E-17
9.0E+05	1.32E+09	1.65E-17
1.0E+06	1.39E+09	1.49E-17
1.2E+06	1.52E+09	1.23E-17

References: 301, 398

Accuracy: 15%

Notes: None

Chebyshev Fitting Parameters for Cross Sections

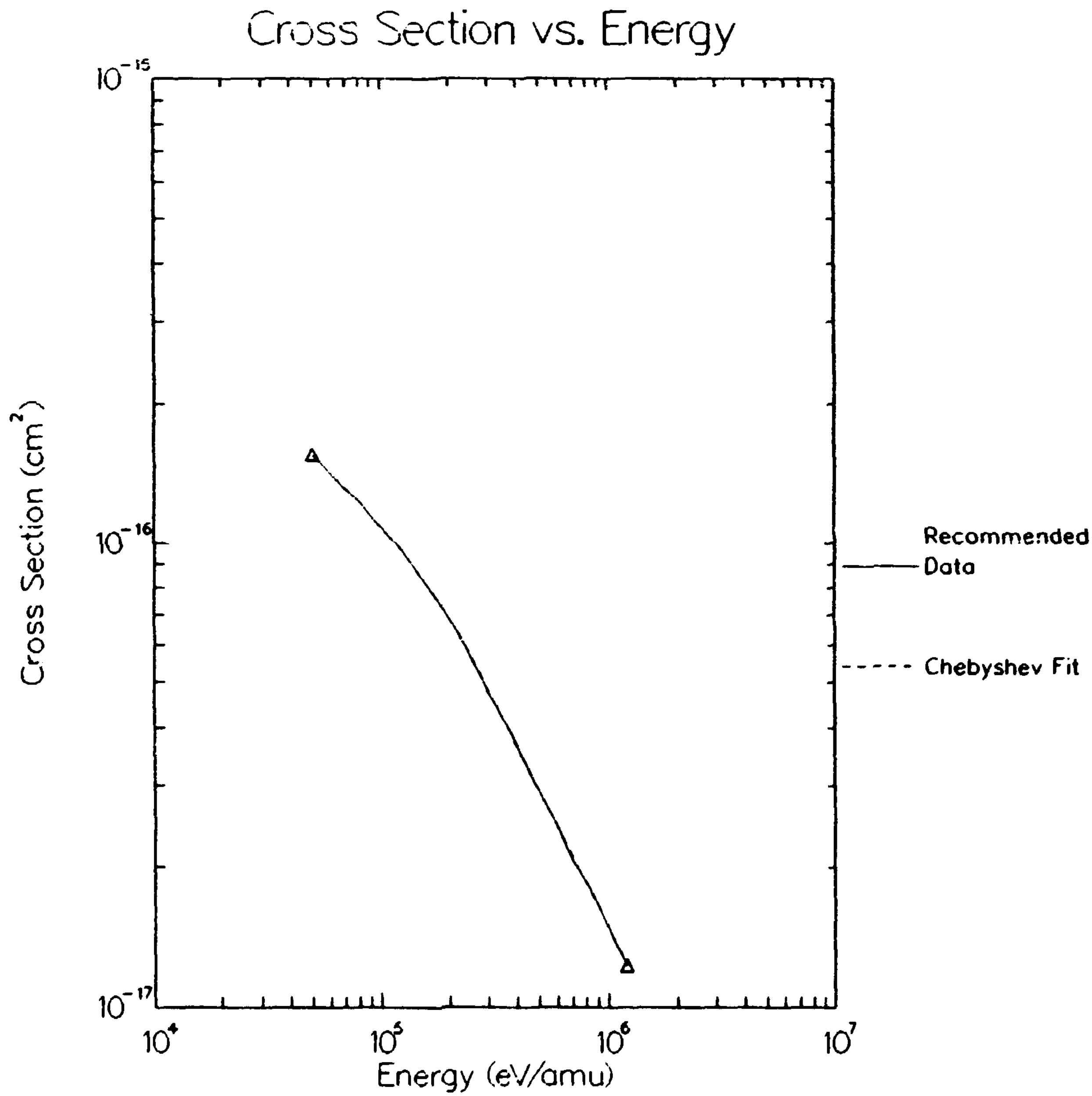
E_{min} = 5.0E+04 eV/amu, E_{max} = 1.2E+06 eV/amu

A0	A1	A2	A3	A4	A5	A6
-75.0809	-1.28466	-.136342	.022920	.0144810	-.00700300	-.00377068

The fit represents the above cross section with an rms deviation of 0.4%. The maximum deviation is 1.3% at 7.0E+05 eV/amu.

See appendix for Chebyshev fit details.

He + H -> He^{+} + H + e



Cross Section vs. Energy
Cross Section (cm^2)
10^{-15}
10^{-16}
10^{-17}
10^4
10^5
10^6
10^7
Energy (eV/amu)
Recommended Data
Chebyshev Fit

Single and Double Projectile Electron Loss or Stripping Cross Sections for

$He + H_2 \rightarrow He^+ + H_2 + e \ \sigma_{01}$
$He + H_2 \rightarrow He^{2+} + H_2 + 2e \ \sigma_{02}$

(σ_{01}) Energy (eV/amu)	Cross Section (cm^2)	(σ_{02}) Energy (eV/amu)	Cross Section (cm^2)
5.0E+02	9.96E-19	5.0E+04	2.59E-18
7.0E+02	2.13E-18	6.0E+04	3.14E-18
1.0E+03	4.68E-18	7.0E+04	3.51E-18
1.5E+03	9.24E-18	8.0E+04	3.78E-18
2.0E+03	1.33E-17	9.0E+04	3.98E-18
4.0E+03	2.73E-17	1.0E+05	4.07E-18
7.0E+03	4.26E-17	1.2E+05	4.10E-18
1.0E+04	5.33E-17	1.5E+05	3.93E-18
1.5E+04	6.75E-17	2.0E+05	3.46E-18
2.0E+04	7.93E-17	3.0E+05	2.44E-18
4.0E+04	1.11E-16	4.0E+05	1.75E-18
7.0E+04	1.27E-16	5.0E+05	1.31E-18
1.0E+05	1.23E-16	6.0E+05	1.09E-18
1.5E+05	1.08E-16	7.0E+05	9.38E-19
2.0E+05	9.38E-17	8.0E+05	8.21E-19
4.0E+05	6.08E-17		
7.0E+05	4.01E-17		
1.0E+06	3.00E-17		

<u>References:</u> (Single Stripping) 94, 97, 99, 102, 103, 143, 198, 301, 316, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409
(Double Stripping) 400, 405

<u>Accuracy:</u> σ_{01} - 15%
σ_{02} - Unknown

<u>Notes:</u> (1) The stripping cross sections are measured in two ways: (a) by the attenuation of the He beam in the H_2 gas cell; (b) by the formation of He^+. The attenuation method gives the sum of the single and double stripping cross sections. Since the double-stripping cross section is at least a factor of 30 less than that for single-stripping, the two methods give the same cross sections within the measurement errors. (2) The data for double stripping do not permit an error evaluation.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

σ_{01} E_{min} = 5.0E+02 eV/amu, E_{max} = 1.0E+06 eV/amu
σ_{02} E_{min} = 5.0E+04 eV/amu, E_{max} = 8.0E+05 eV/amu

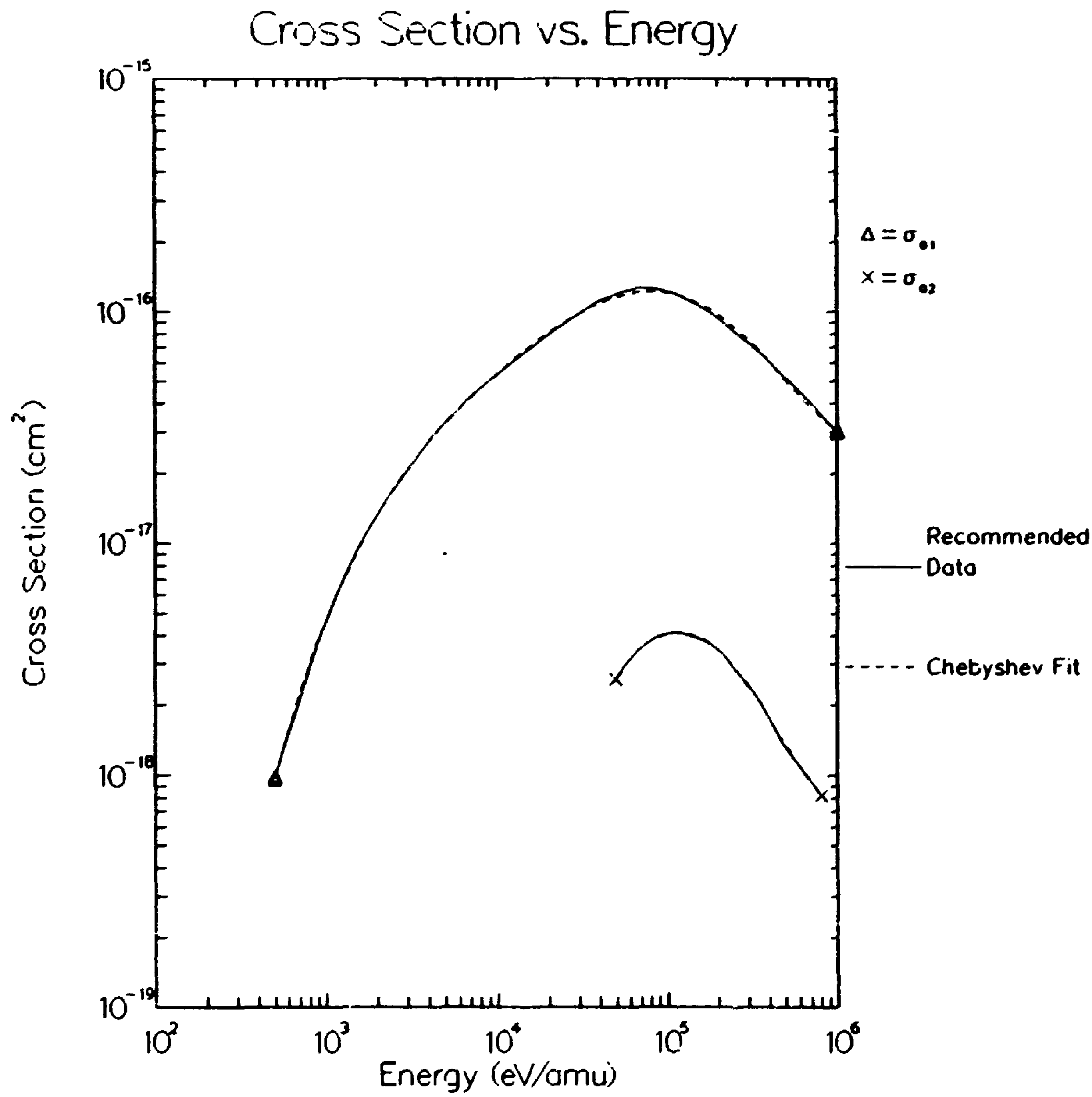
	A0	A1	A2	A3	A4	A5	A6
σ_{01}	-76.5793	1.58478	-1.39956	.0511448	-.0845579	.0891012	.0231543
σ_{02}	-81.3267	-.669570	-.425168	.0911177	.0266527	.00757867	-.00546826

The fit represents the σ_{01} cross section with an rms deviation of 2.5%. The maximum deviation is 5.4% at 7.0E+02 eV/amu.

The fit represents the σ_{02} cross section with an rms deviation of 0.7%. The maximum deviation is 1.8% at 5.0E+05 eV/amu.

See appendix for Chebyshev fit details.

$He + H_2 \rightarrow He^+ + H_2 + e \quad \sigma_{01}$
$He + H_2 \rightarrow He^{2+} + H_2 + 2e \quad \sigma_{02}$



Total Metastable Destruction, Electron Stripping, and De-excitation Cross Sections for

$He^{*} + H_2 \rightarrow He \text{ or } He^{+}$ (σ_T)
$He^{*} + H_2 \rightarrow He^{+} + H_2 + e$ ($\sigma_{0 \cdot 1}$)
$He^{*} + H_2 \rightarrow He + H_2$ ($\sigma_{0 \cdot 0}$)

σ_T		$\sigma_{0\cdot 1}$		$\sigma_{0\cdot 0}$	
Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)
1.8E+03	3.72E-16	2.5E+03	2.34E-16	6.3E+03	2.09E-16
2.0E+03	3.94E-16	4.0E+03	3.81E-16	7.0E+03	2.09E-16
4.0E+03	6.16E-16	7.0E+03	5.41E-16	1.0E+04	2.01E-16
7.0E+03	7.49E-16	8.6E+03	5.53E-16	1.5E+04	1.77E-16
8.4E+03	7.63E-16	1.0E+04	5.48E-16	2.0E+04	1.52E-16
1.0E+04	7.54E-16	1.5E+04	4.88E-16	4.0E+04	8.20E-17
1.5E+04	6.69E-16	2.0E+04	4.43E-16	7.0E+04	3.66E-17
2.0E+04	5.98E-16	4.0E+04	3.38E-16	1.0E+05	1.84E-17
4.0E+04	4.32E-16	7.0E+04	2.66E-16	1.2E+05	1.21E-17
7.0E+04	3.13E-16	1.0E+05	2.23E-16		
1.0E+05	2.49E-16	1.3E+05	1.90E-16		
1.2E+05	2.26E-16				

References: 102, 198, 402, 408, 410, 411, 412, 413, 414, 415, 416

Accuracy: 50%

Notes: (1) Tawara (Ref. 102) has listed the excited state lifetimes for He as: (a) 2^1P - 5.6×10^{-10} sec; (b) 2^3P - 1.05×10^{-7} sec; (c) 2^1S - 0.14 sec; (d) 2^3S - 10^5 sec. (2) $\sigma_T = \sigma_{0\cdot 1} + \sigma_{0\cdot 0}$. (3) Benton, et al. (Ref. 412) found the total destruction cross sections of the triplet metastable state to be $6.0\times10^{-16} cm^2$ at thermal energies. For electron stripping cross sections of other excited states see Pedersen (Ref. 414).

Chebyshev Fitting Parameters for Cross Sections

σ_T E_{min} = 1.8E+03 eV/amu, E_{max} = 1.2E+05 eV/amu
$\sigma_{0\cdot 1}$ E_{min} = 2.5E+03 eV/amu, E_{max} = 1.3E+05 eV/amu
$\sigma_{0\cdot 0}$ E_{min} = 6.3E+03 eV/amu, E_{max} = 1.2E+05 eV/amu

	A0	A1	A2	A3	A4	A5	A6
σ_T	-70.7481	-.310880	-.437383	.0856563	.022775	-.0286798	.0139816
$\sigma_{0\cdot 1}$	-71.3457	-.218099	-.407518	.142300	-.0331160	-.0270893	.0189680
$\sigma_{0\cdot 0}$	-74.1810	-1.38382	-.434191	-.0390903	-.00312428	-.00143317	-.000970525

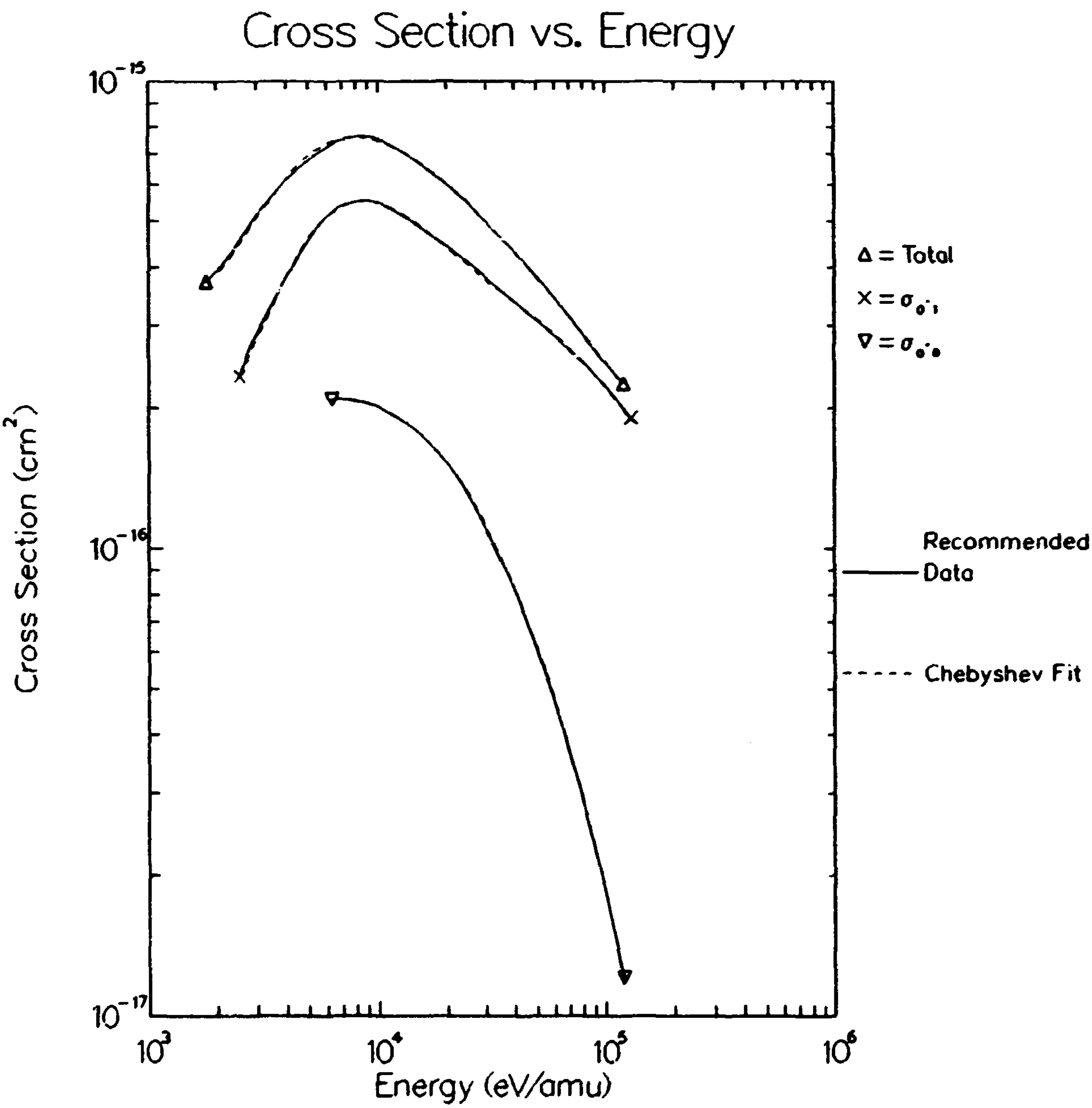
The fit represents the σ_T cross section with an rms deviation of 0.6%. The maximum deviation is 0.6% at 1.8E+03 eV/amu.

The fit represents the $\sigma_{0\cdot 1}$ cross section with an rms deviation of 0.5%. The maximum deviation is 0.9% at 1.5E+04 eV/amu.

The fit represents the $\sigma_{0\cdot 0}$ cross section with an rms deviation of 0.0%. The maximum deviation is 0.1% at 7.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^{*} + H_2 \rightarrow He^{+} + H_2 + e \; (\sigma_{0^{*}1})$
$He^{*} + H_2 \rightarrow He + H_2 \quad (\sigma_{0^{*}0})$



Single and Double Projectile Electron Loss or Stripping Cross Sections for

$He + He \rightarrow He^{+} + He + e$ (σ_{01})
$He + He \rightarrow He^{2+} + He + 2e$ (σ_{02})

σ_{01}

Energy (eV/amu)	Cross Section (cm^2)
5.0E+01	1.19E-19
7.0E+01	2.30E-19
1.0E+02	3.40E-19
1.5E+02	4.19E-19
2.0E+02	4.37E-19
4.0E+02	1.37E-18
7.0E+02	3.36E-18
1.0E+03	5.79E-18
1.5E+03	1.07E-17
2.0E+03	1.64E-17
4.0E+03	3.77E-17
7.0E+03	5.37E-17
1.0E+04	6.74E-17
1.5E+04	8.16E-17
2.0E+04	9.21E-17
4.0E+04	1.08E-16
7.0E+04	1.00E-16
1.0E+05	9.31E-17
1.5E+05	8.37E-17
2.0E+05	7.40E-17
4.0E+05	4.89E-17
5.0E+05	4.18E-17

σ_{02}

Energy (eV/amu)	Cross Section (cm^2)
5.0E+04	3.92E-18
7.0E+04	5.00E-18
1.0E+05	5.85E-18
1.5E+05	5.04E-18
2.0E+05	3.83E-18
4.0E+05	1.72E-18
7.0E+05	8.71E-19
1.0E+06	5.50E-19

<u>References:</u> σ_{01} - 97, 99, 103, 198, 304, 316, 399, 400, 401, 404, 405, 407, 408, 410, 465, 466, 467, 468, 469, 470, 471
σ_{02} - 94, 400, 401, 405, 470, 471

<u>Accuracy:</u> σ_{01} $E > 1\times10^{3}$ eV/amu - 20%
$E < 1\times10^{3}$ eV/amu - 100%
σ_{02} 100%

<u>Note:</u> Most of the data have been taken for a mixed beam of ground state and metastable states of incident He.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

σ_{01} E_{min} = 5.0E+01 eV/amu, E_{max} = 5.0E+05 eV/amu
σ_{02} E_{min} = 5.0E+04 eV/amu, E_{max} = 1.0E+06 eV/amu

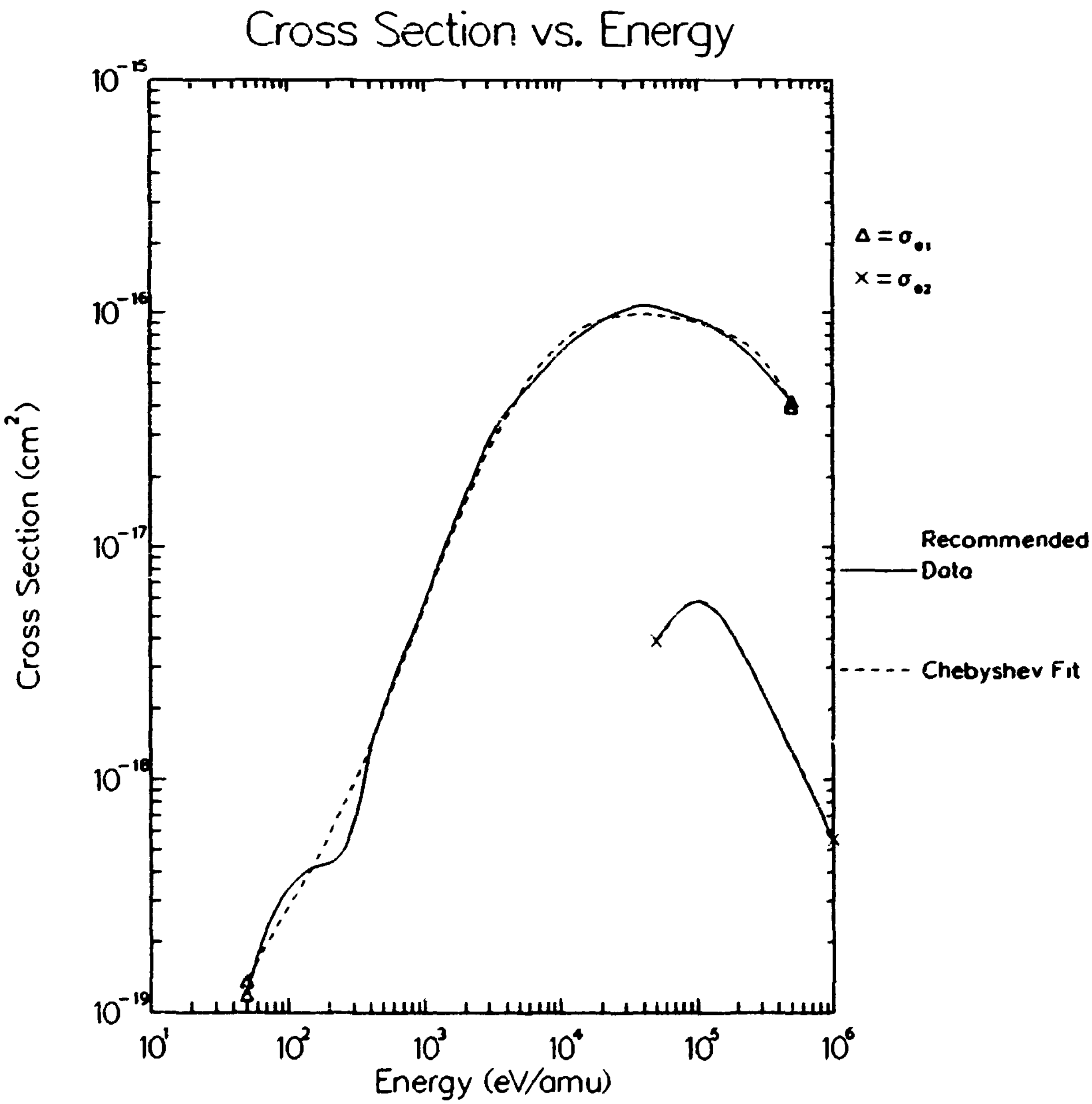
	A0	A1	A2	A3	A4	A5	A6
σ_{01}	-78.6347	3.20546	-1.37570	-.359168	.188553	-.0115646	-.0973845
σ_{02}	-81.2673	-1.09626	-.438191	.146687	-.0102958	-.0324691	.0197680

The fit represents the σ_{01} cross section with an rms deviation of 10.2%. The maximum deviation is 32.7% at 2.0E+02 eV/amu.

The fit represents the σ_{02} cross section with an rms deviation of 0.1%. The maximum deviation is 0.2% at 2.0E+05 eV/amu.

See appendix for Chebyshev fit details.

$He + He \rightarrow He^{+} + He + e\ (\sigma_{01})$
$He + He \rightarrow He^{2+} + He + 2e\ (\sigma_{02})$



Single Projectile Electron Loss or Stripping Rate Coefficients for

$He + He \rightarrow He^{+} + He + e$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

He Temp. (eV)	Equal Temp.	He Temp. (eV) 10.	100.	500.	1000.	5000.	10000.	20000.
1.0E+01	2.56E-16#	2.56E-16#	9.95E-13*	1.53E-11	5.98E-11	1.13E-09	2.96E-09	6.52E-09
2.0E+01	3.55E-14#	6.78E-15#	1.19E-12*	1.58E-11	6.10E-11	1.14E-09	2.96E-09	6.52E-09
4.0E+01	4.65E-13#	9.72E-14#	1.59E-12*	1.70E-11	6.34E-11	1.14E-09	2.97E-09	6.53E-09
6.0E+01	1.19E-12*	3.17E-13#	2.02E-12*	1.83E-11	6.59E-11	1.15E-09	2.98E-09	6.54E-09
8.0E+01	2.02E-12*	6.30E-13*	2.46E-12*	1.96E-11	6.85E-11	1.16E-09	2.98E-09	6.54E-09
1.0E+02	2.93E-12*	9.95E-13*	2.93E-12*	2.10E-11	7.10E-11	1.17E-09	2.99E-09	6.55E-09
2.0E+02	9.61E-12	3.17E-12*	5.75E-12	2.85E-11	8.46E-11	1.20E-09	3.03E-09	6.58E-09
4.0E+02	3.73E-11	1.01E-11	1.47E-11	4.74E-11	1.15E-10	1.27E-09	3.10E-09	6.65E-09
6.0E+02	8.46E-11	2.17E-11	2.85E-11	7.10E-11	1.50E-10	1.34E-09	3.18E-09	6.72E-09
8.0E+02	1.50E-10	3.83E-11	4.74E-11	9.93E-11	1.88E-10	1.41E-09	3.25E-09	6.78E-09
1.0E+03	2.31E-10	5.98E-11	7.10E-11	1.32E-10	2.31E-10	1.48E-09	3.32E-09	6.85E-09
2.0E+03	7.94E-10	2.33E-10	2.53E-10	3.50E-10	4.87E-10	1.85E-09	3.69E-09	7.18E-09
4.0E+03	2.21E-09	7.97E-10	8.27E-10	9.60E-10	1.13E-09	2.58E-09	4.42E-09	7.83E-09
6.0E+03	3.69E-09	1.49E-09	1.52E-09	1.67E-09	1.85E-09	3.32E-09	5.13E-09	8.47E-09
8.0E+03	5.13E-09	2.22E-09	2.25E-09	2.40E-09	2.58E-09	4.06E-09	5.83E-09	9.08E-09
1.0E+04	6.52E-09	2.96E-09	2.99E-09	3.14E-09	3.32E-09	4.77E-09	6.52E-09	9.69E-09
1.5E+04	9.69E-09	4.78E-09	4.81E-09	4.95E-09	5.13E-09	6.52E-09	8.15E-09	1.11E-06
2.0E+04	1.25E-08	6.52E-09	6.55E-09	6.68E-09	6.85E-09	8.15E-09	9.69E-09	1.25E-08

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

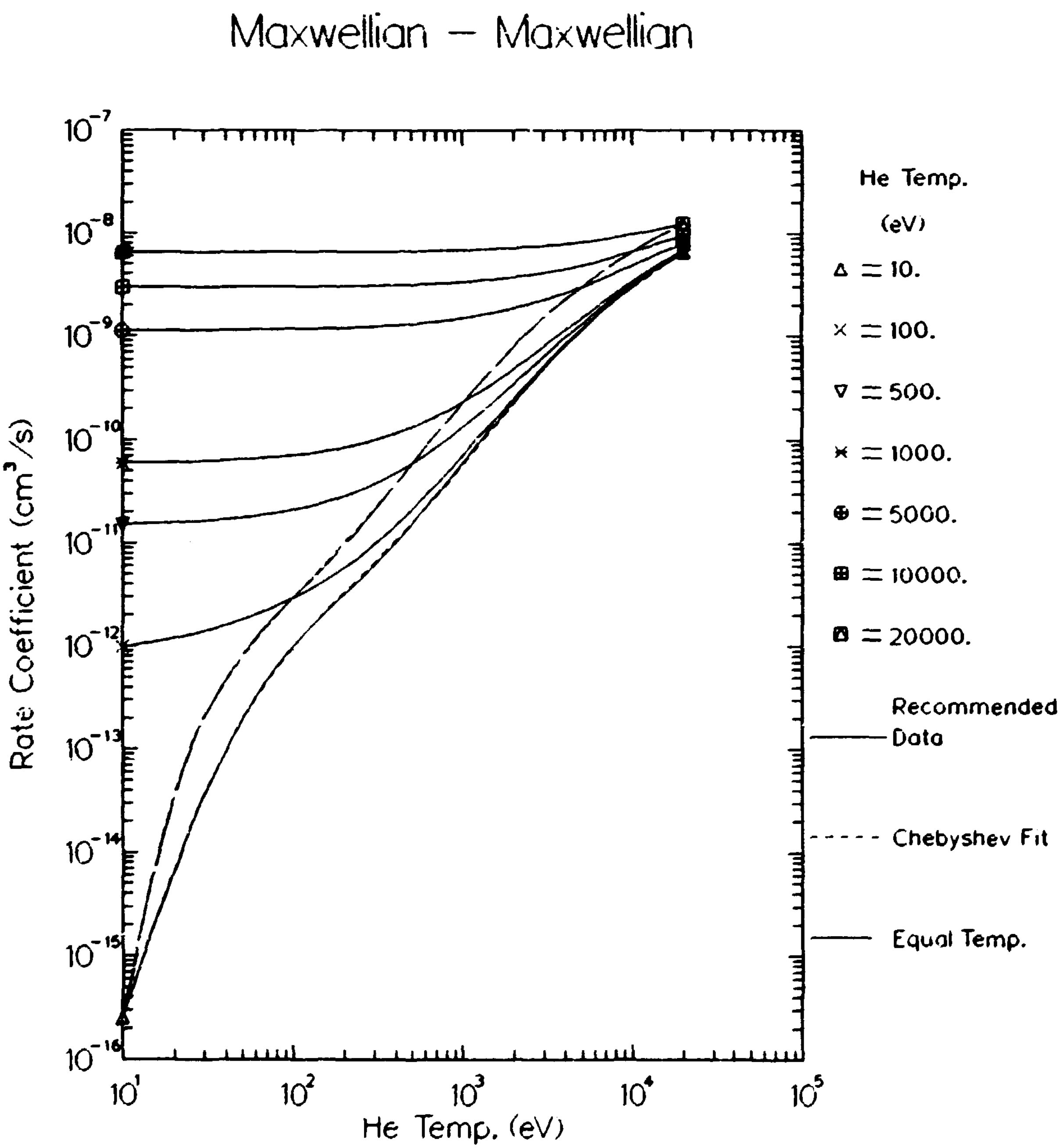
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+01 eV, E_{max} = 2.0E+04 eV

He Temp. (eV)	A0	A1	A2	A3	A4	A5	A6
10.	-51.7583	8.06294	-1.24558	.480900	-.345667	.00168045	.0989086
100.	-47.7268	4.71689	.727833	-.356780	-.134711	.0403620	.0326103
500.	-45.2262	3.19352	.872249	-.155633	-.153319	.00295441	.0304174
1000.	-43.7465	2.41883	.806189	-.0302189	-.122890	-.0208521	.0205933
5000.	-40.0684	.892003	.435779	.111572	-.00729485	-.0179737	-.00576743
10000.	-38.6577	.504603	.274535	.0948483	.0137433	-.00755328	-.00472901
20000.	-37.3817	.261777	.152417	.0618891	.0157868	5.99102E-04	-.00183208
Equal Temp.	-49.6803	7.93762	-1.58981	.635046	-.579197	.290394	-.0450460

See appendix for Chebyshev fit details.

He + He -> He^+ + He + e


Maxwellian - Maxwellian
Rate Coefficient (cm^3/s)
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-15}
10^{-16}
10^1
10^2
10^3
10^4
10^5
He Temp. (eV)
He Temp.
(eV)
△ = 10.
× = 100.
▽ = 500.
✱ = 1000.
⊕ = 5000.
⊞ = 10000.
⊠ = 20000.
Recommended Data
Chebyshev Fit
Equal Temp.

Single Projectile Electron Loss or Stripping Rate Coefficients for

$He + He \rightarrow He^{+} + He + e$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	8.89E-09	2.37E-08	3.00E-08	3.68E-08	4.09E-08	4.60E-08	2.05E-08#
2.0E+00	9.34E-09	1.90E-08	3.00E-08	3.57E-08	4.09E-08	4.59E-08	2.05E-08#
4.0E+00	9.36E-09	1.81E-08	3.00E-08	3.67E-08	4.09E-08	4.60E-08	2.05E-08#
7.0E+00	9.35E-09	1.81E-08	3.00E-08	3.67E-08	4.09E-08	4.60E-08	2.05E-08#
1.0E+01	9.35E-09	1.81E-08	3.00E-08	3.67E-08	4.09E-08	4.59E-08	2.05E-08#
2.0E+01	9.35E-09	1.81E-08	2.99E-08	3.67E-08	4.09E-08	4.59E-08	2.05E-08#
4.0E+01	9.35E-09	1.81E-08	2.99E-08	3.67E-08	4.09E-08	4.59E-08	2.05E-08#
7.0E+01	9.35E-09	1.81E-08	2.99E-08	3.67E-08	4.09E-08	4.59E-08	2.05E-08#
1.0E+02	9.36E-09	1.80E-08	2.99E-08	3.67E-08	4.09E-08	4.59E-08	2.05E-08#
2.0E+02	9.38E-09	1.80E-08	2.98E-08	3.67E-08	4.09E-08	4.59E-08	2.05E-08#
4.0E+02	9.43E-09	1.81E-08	2.97E-08	3.67E-08	4.09E-08	4.59E-08	2.04E-08#
7.0E+02	9.51E-09	1.81E-08	2.97E-08	3.67E-08	4.08E-08	4.58E-08	2.04E-08#
1.0E+03	9.60E-09	1.81E-08	2.96E-08	3.67E-08	4.08E-08	4.58E-08	2.04E-08#
2.0E+03	9.91E-09	1.83E-08	2.95E-08	3.67E-08	4.08E-08	4.57E-08	2.03E-08#
4.0E+03	1.05E-08	1.86E-08	2.95E-08	3.67E-08	4.08E-08	4.57E-08	2.02E-08#
7.0E+03	1.14E-08	1.91E-08	2.95E-08	3.68E-08	4.08E-08	4.55E-08	2.01E-08#
1.0E+04	1.22E-08	1.96E-08	2.95E-08	3.68E-08	4.08E-08	4.55E-08	2.00E-08#
2.0E+04	1.46E-08	2.11E-08	2.98E-08	3.69E-08	4.08E-08	4.52E-08	1.98E-08#

Accuracy: * - Possible Error Greater Than 10%
- Possible Error Greater Than 100%

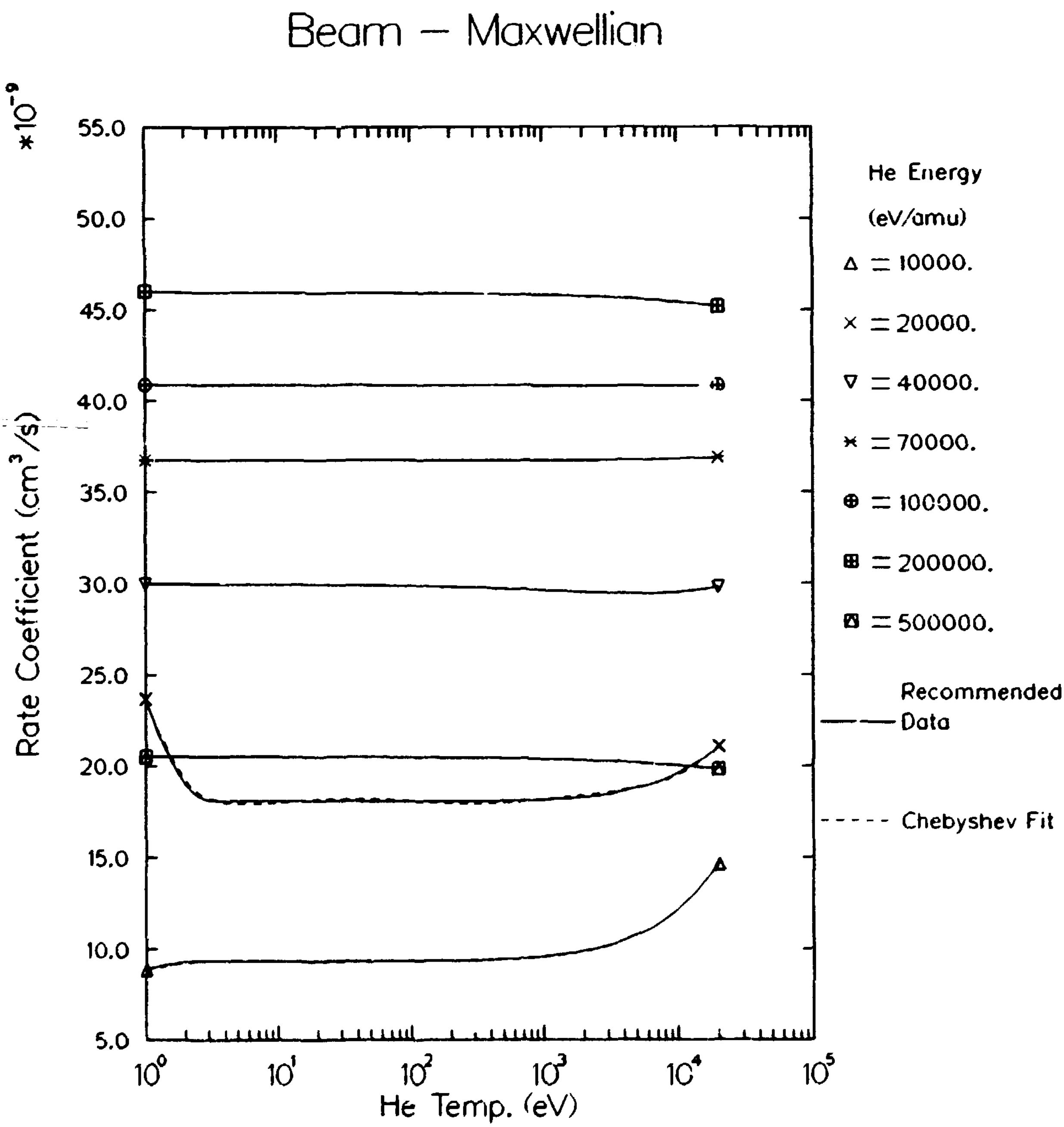
Chebyshev Fitting Parameters for Rate Coefficients

E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-36.8050	.170883	.101708	.0672106	.0156617	.0105796	-.00356384
20000.	-35.5374	-.0131879	.0937563	-.0235657	.0434438	-.0195503	.0142526
40000.	-34.6583	-.00778924	6.32056E-04	.00349830	.00265169	.00125371	4.62226E-04
70000.	-34.2378	9.38356E-04	.00134041	9.62664E-04	4.31072E-04	6.92929E-05	-2.31386E-05
100000.	-34.0260	-6.94332E-04	3.47489E-05	2.89415E-04	6.86603E-05	-2.08349E-05	-8.09043E-05
200000.	-33.7994	-.00708522	-.00341665	-.00168503	-3.16686E-04	-3.04255E-04	1.04496E-04
500000.	-35.4225	-.0144815	-.00746534	-.00291476	-9.54856E-04	-2.93045E-04	-9.76578E-05

See appendix for Chebyshev fit details.

$He + He \rightarrow He^{+} + He + e$



Electron Projectile Loss or Stripping Cross Sections for

$He^{+} + H \rightarrow He^{2+} + H + e$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.2E+04	1.52E+08	1.66E-19
1.5E+04	1.70E+08	4.71E-19
2.0E+04	1.96E+08	1.15E-18
4.0E+04	2.78E+08	7.03E-18
7.0E+04	3.68E+08	1.11E-17
1.0E+05	4.39E+08	1.04E-17
1.5E+05	5.38E+08	9.34E-18
2.0E+05	6.21E+08	8.17E-18
4.0E+05	8.78E+08	5.26E-18
7.0E+05	1.16E+09	3.63E-18
9.0E+05	1.32E+09	3.04E-18

References: 301, 476

Accuracy: 20%

Notes: None

Chebyshev Fitting Parameters for Cross Sections

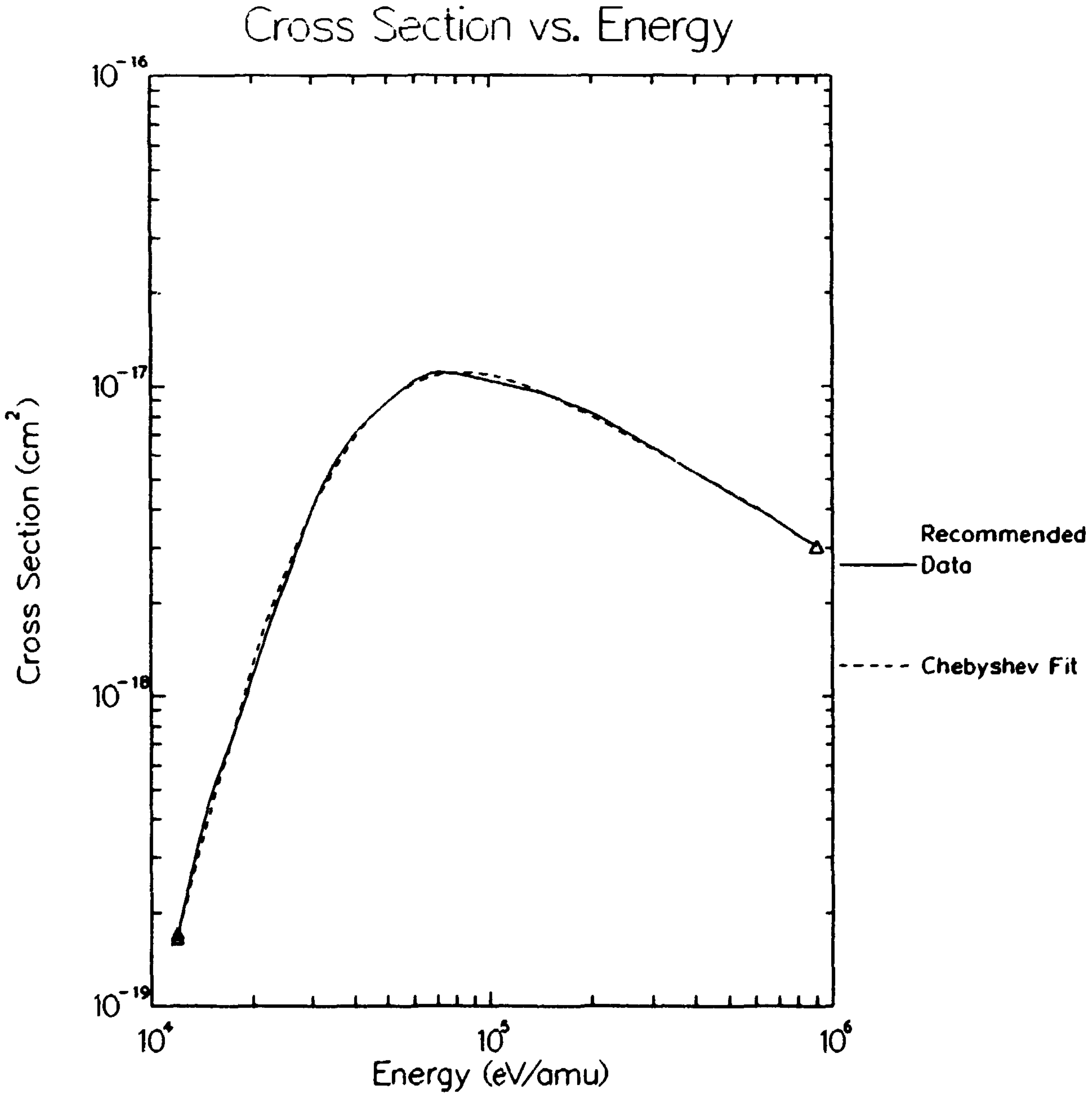
E_{min} = 1.2E+04 eV/amu, E_{max} = 9.0E+05 eV/amu

A0	A1	A2	A3	A4	A5	A6
-80.7839	1.04755	-1.36971	.441034	-.0292764	-.0527228	.0184479

The fit reprerents the above cross section with an rms deviation of 4.3%
The maximum devation is 8.7% at 2.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^{+} + H \rightarrow He^{2+} + H + e$



Projectile Electron Loss or Stripping Cross Sections for

$He^{+} + H_2 \rightarrow He^{2+} + H_2 + e$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
5.0E+03	9.82E+07	1.29E-19
7.0E+03	1.16E+08	1.99E-19
1.0E+04	1.39E+08	3.25E-19
1 5E+04	1.70E+08	6.18E-19
2.0E+04	1.96E+08	1.06E-18
4.0E+04	2.78E+08	5.77E-18
7.0E+04	3.68E+08	1.45E-17
1.0E+05	4.39E+08	2.02E-17
1.3E+05	5.01E+08	2.16E-17
1.5E+05	5.38E+08	2.16E-17
2.0E+05	6.21E+08	1.85E-17
4.0E+05	8.78E+08	1.13E-17
7.0E+05	1.16E+09	7.81E-18
9.5E+05	1.35E+09	6.29E-18

References: 94, 96, 97, 100, 101, 296, 301, 464, 476, 478

Accuracy: $E < 3x10^4$ eV/amu - 40%
$E > 3x10^4$ eV/amu - 20%

Notes: None

Chebyshev Fitting Parameters for Cross Sections

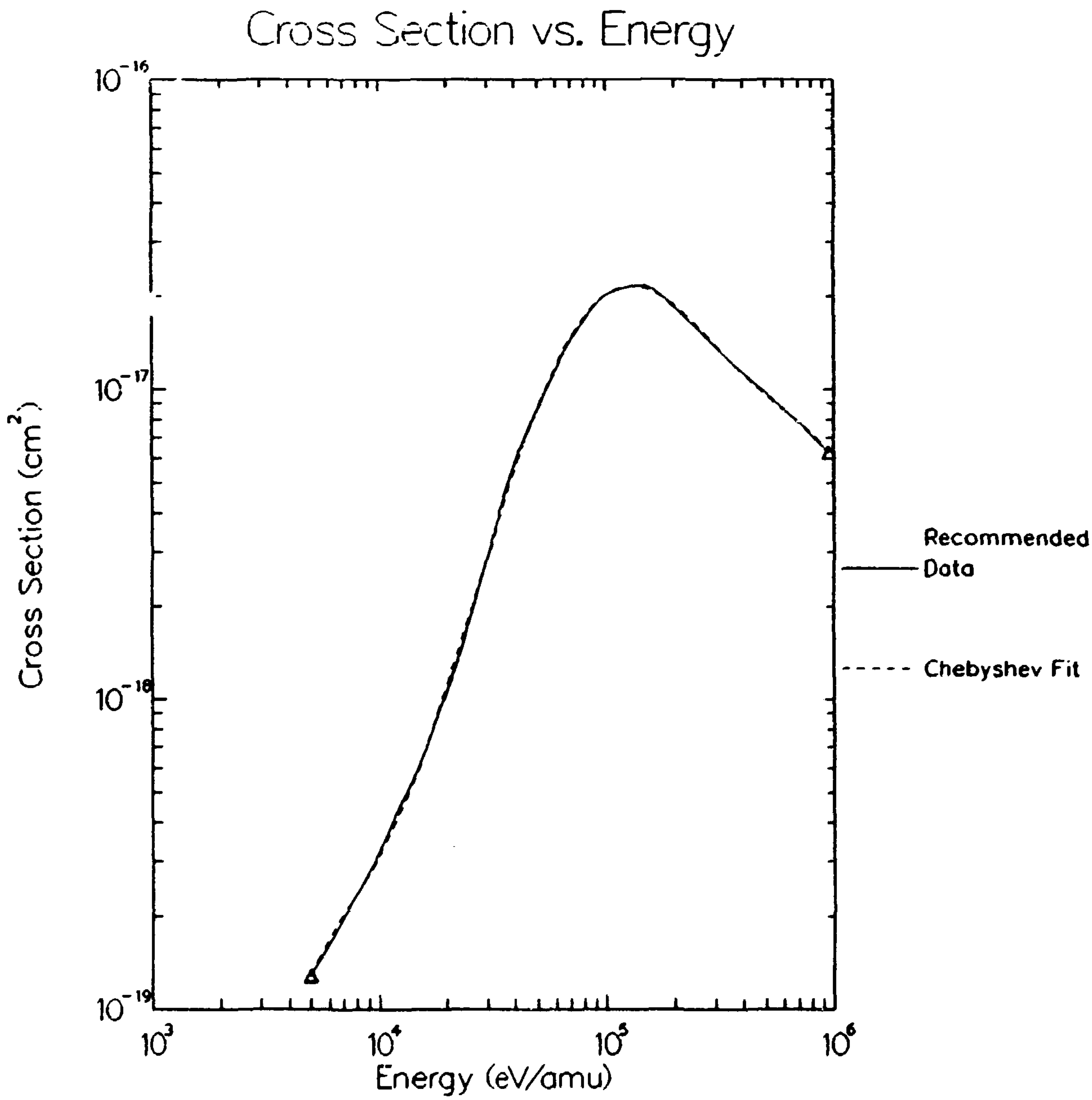
E_{min} = 5.0E+03 eV/amu, E_{max} = 9.5E+05 eV/amu

A0	A1	A2	A3	A4	A5	A6
-80.9631	2.17474	-1.29222	-.291348	.317779	.0620566	-.0993825

The fit represents the above cross section with an rms deviation of 2.3%.
The maximum deviation is 5.1% at 2.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^{+} + H_2 \rightarrow He^{2+} + H_2 + e$



Cross Sections for Projectile Electron Loss or Stripping for He^{+} Passing Through Helium

$He^{+} + He \rightarrow He^{2+} + He + e$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
3.5E+03	8.22E+07	2.63E-19
4.0E+03	8.79E+07	3.68E-19
7.0E+03	1.16E+08	1.02E-18
1.0E+04	1.39E+08	1.64E-18
1.5E+04	1.70E+08	2.74E-18
2.0E+04	1.96E+08	3.87E-18
4.0E+04	2.78E+08	8.89E-18
7.0E+04	3.68E+08	1.67E-17
1.0E+05	4.39E+08	2.14E-17
1.5E+05	5.38E+08	2.35E-17
1.7E+05	5.73E+08	2.36E-17
2.0E+05	6.21E+08	2.34E-17
4.0E+05	8.78E+08	1.69E-17
7.0E+05	1.16E+09	1.07E-17
1.0E+06	1.39E+09	7.73E-18
1.5E+06	1.70E+09	5.21E-18
2.0E+06	1.96E+09	3.91E-18
4.0E+06	2.77E+09	1.98E-18

References: 94, 96, 97, 101, 296, 375, 471, 477, 480, 481, 483, 485, 486, 487, 488, 489, 490, 491, 492, 493

Accuracy: 20%

Notes: None

Chebyshev Fitting Parameters for Cross Sections

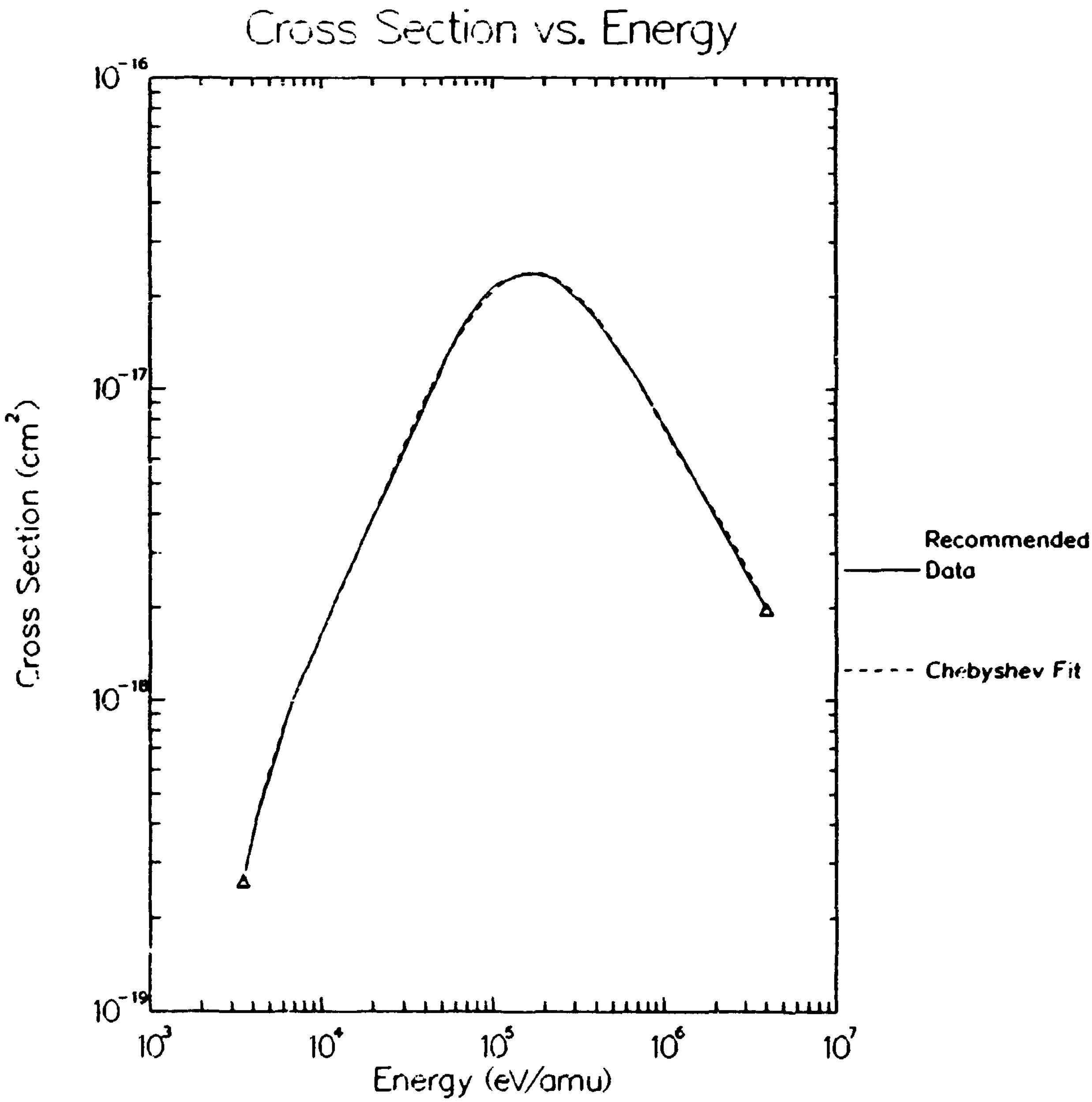
E_{min} = 3.5E+03 eV/amu, E_{max} = 4.0E+06 eV/amu

A0	A1	A2	A3	A4	A5	A6
-80.4254	.937124	-1.62973	.00297670	.154841	.0696031	-.0892584

The fit represents the above cross section with an rms deviation of 1.6%. The maximum deviation is 3.5% at 4.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^{+} + He \rightarrow He^{2+} + He + e$



Projectile Electron Loss or Stripping Rate Coefficients for

$He + He^{+} \rightarrow He^{2+} + He + e$

Beam - Maxwellian Rate Coefficients (cm^3/s)

He^{+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	2.93E-10	1.20E-09	8.75E-10	4.39E-09	1.06E-08	1.45E-08	1.38E-08
2.0E+00	2.38E-10	8.92E-10	1.82E-09	5.65E-09	9.90E-09	1.45E-08	1.38E-08
4.0E+00	2.28E-10	7.71E-10	2.39E-09	5.99E-09	9.37E-09	1.45E-08	1.38E-08
7.0E+00	2.28E-10	7.60E-10	2.47E-09	6.09E-09	9.37E-09	1.45E-08	1.38E-08
1.0E+01	2.28E-10	7.61E-10	2.47E-09	6.12E-09	9.38E-09	1.45E-08	1.38E-08
2.0E+01	2.28E-10	7.61E-10	2.47E-09	6.13E-09	9.38E-09	1.45E-08	1.38E-08
4.0E+01	2.28E-10	7.62E-10	2.47E-09	6.12E-09	9.38E-09	1.45E-08	1.38E-08
7.0E+01	2.29E-10	7.63E-10	2.47E-09	6.12E-09	9.37E-09	1.45E-08	1.38E-08
1.0E+02	2.30E-10	7.64E-10	2.47E-09	6.12E-09	9.36E-09	1.45E-08	1.38E-08
2.0E+02	2.32E-10	7.67E-10	2.48E-09	6.11E-09	9.35E-09	1.45E-08	1.38E-08
4.0E+02	2.36E-10	7.74E-10	2.49E-09	6.10E-09	9.34E-09	1.45E-08	1.38E-08
7.0E+02	2.43E-10	7.85E-10	2.50E-09	6.10E-09	9.32E-09	1.44E-08	1.38E-08
1.0E+03	2.50E-10	7.96E-10	2.52E-09	6.11E-09	9.31E-09	1.44E-08	1.38E-08
2.0E+03	2.72E-10	8.32E-10	2.57E-09	6.13E-09	9.29E-09	1.44E-08	1.38E-08
4.0E+03	3.19E-10	9.05E-10	2.68E-09	6.19E-09	9.29E-09	1.43E-08	1.38E-08
7.0E+03	3.92E-10	1.02E-09	2.83E-09	6.28E-09	9.30E-09	1.42E-08	1.38E-08
1.0E+04	4.70E-10	1.13E-09	2.99E-09	6.38E-09	9.32E-09	1.42E-08	1.38E-08
2.0E+04	7.54E-10	1.52E-09	3.46E-09	6.67E-09	9.41E-09	1.40E-08	1.38E-08

Chebyshev Fitting Parameters for Rate Coefficients

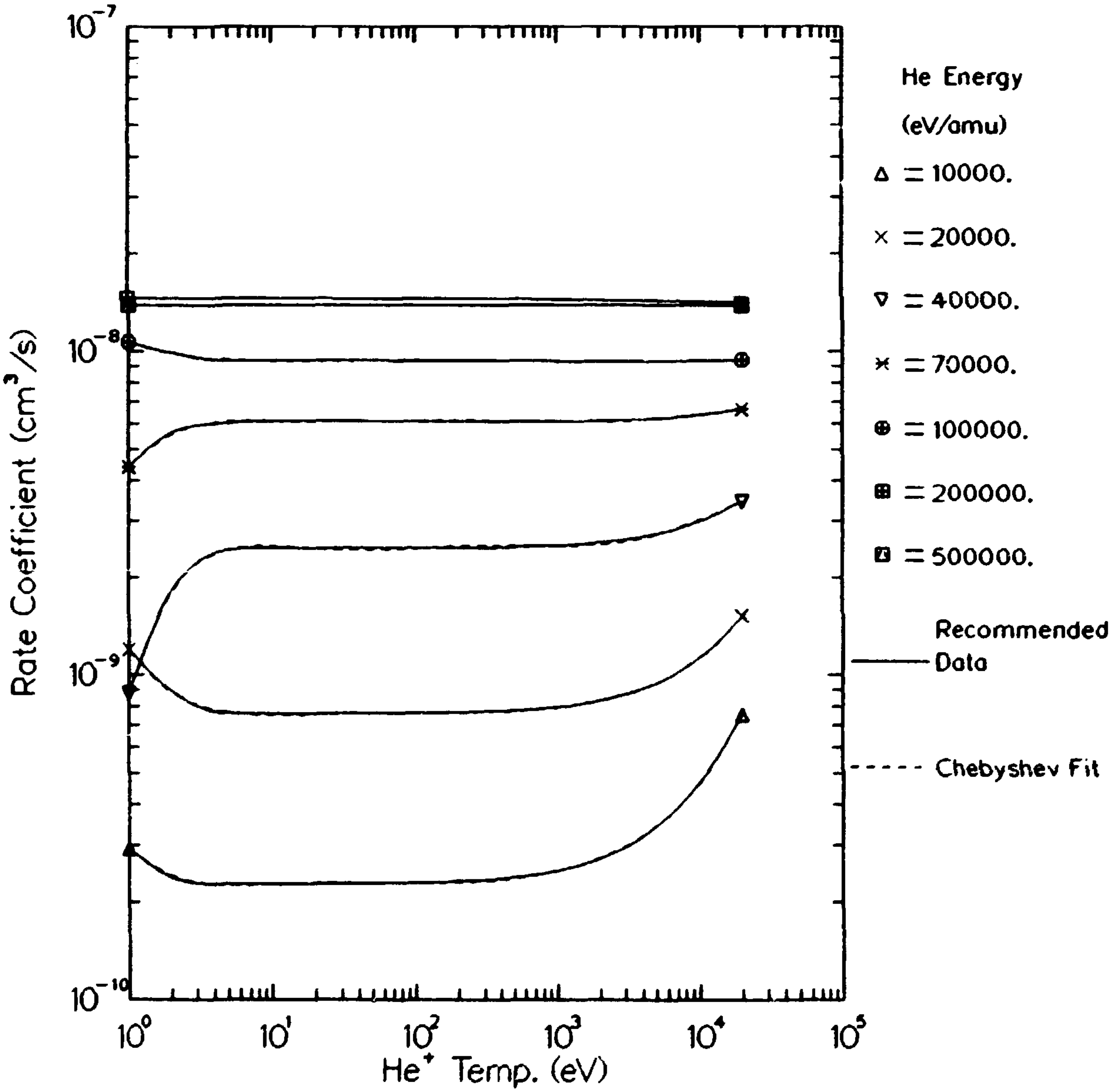
$E_{min} = 1.0E+00$ eV, $E_{max} = 2.0E+04$ eV

He Energy (eV/amu)	A0	A1	A2	A3	A4	A5	A6
10000.	-43.0442	.378813	.344057	.105569	.0867559	-.00821300	.0129056
20000.	-41.5896	.123902	.270872	.0115805	.0807436	-.0161519	.0126729
40000.	-39.7835	.385155	-.145042	.223297	-.0998296	.0753339	-.0326980
70000.	-37.8827	.110612	-.0493705	.0701363	-.0309008	.0252250	-.0129206
100000.	-36.9382	-.0374325	.0312796	-.0188116	.0166130	-.00628486	.00207752
200000.	-36.1132	-.0149848	-.00760145	-.00280029	-8.61479E-04	-1.69493E-04	-3.20142E-05
500000.	-36.1937	-5.70799E-04	-4.55366E-04	-3.44110E-04	-2.36175E-04	-1.47246E-04	-9.193766E-05

See appendix for Chebyshev fit details.

$He + He^{+} \rightarrow He^{2+} + He + e$

Beam – Maxwellian



F. Electron Detachment Cross Sections

Cross Section for Single Electron Detachment
and Total H^0 Formation from H^- on H

$H^- + H \rightarrow H + H + e$
$H^- + H \rightarrow (H + H + e)$ or $(H + H^-)$ [Total H Prod.]

H + H + e		Total H Prod.	
Energy (eV/amu)	Cross Section (cm^2)	Energy (eV/amu)	Cross Section (cm^2)
1.1E+02	8.65E-16	6.0E+01	6.64E-15
2.0E+02	1.28E-15	7.0E+01	6.75E-15
4.0E+02	1.44E-15	1.0E+02	6.79E-15
7.0E+02	1.39E-15	1.5E+02	6.48E-15
1.0E+03	1.32E-15	2.0E+02	6.11E-15
1.5E+03	1.19E-15	4.0E+02	4.92E-15
2.0E+03	1.11E-15	7.0E+02	3.83E-15
4.0E+03	1.01E-15	1.0E+03	3.13E-15
7.0E+03	9.75E-16	1.5E+03	2.45E-15
1.0E+04	8.72E-16	2.0E+03	2.03E-15
1.5E+04	7.18E-16	4.0E+03	1.26E-15
2.0E+04	6.26E-16	7.0E+03	1.01E-15
4.0E+04	4.25E-16	1.0E+04	8.74E-16
7.0E+04	2.90E-16	1.5E+04	7.18E-16
1.0E+05	2.21E-16	2.0E+04	6.26E-16
1.5E+05	1.61E-16	4.0E+04	4.25E-16
2.0E+05	1.27E-16	7.0E+04	2.90E-16
4.0E+05	7.04E-17	1.0E+05	2.21E-16
7.0E+05	4.24E-17	1.5E+05	1.61E-16
1.0E+06	2.99E-17	2.0E+05	1.27E-16
1.5E+06	2.09E-17	4.0E+05	7.04E-17
2.0E+06	1.59E-17	7.0E+05	4.24E-17
4.0E+06	8.23E-18	1.0E+06	2.99E-17
		1.5E+06	2.09E-17
		2.0E+06	1.59E-17
		4.0E+06	8.23E-18

References: 162, 281, 301, 395, 524, 525, 554, 555

Accuracy: 30%

Note: Data for total H^0 formation represent the sum of the cross sections for collisional detachment and charge exchange. The charge exchange contribution is negligible at energies above 10 keV/amu.

Chebyshev Fitting Parameters for Cross Sections

H + H + e E_{min} = 1.1E+02 eV/amu, E_{max} = 4.0E+06 eV/amu
Total H Prod. E_{min} = 6.0E+01 eV/amu, E_{max} = 4.0E+06 eV/amu

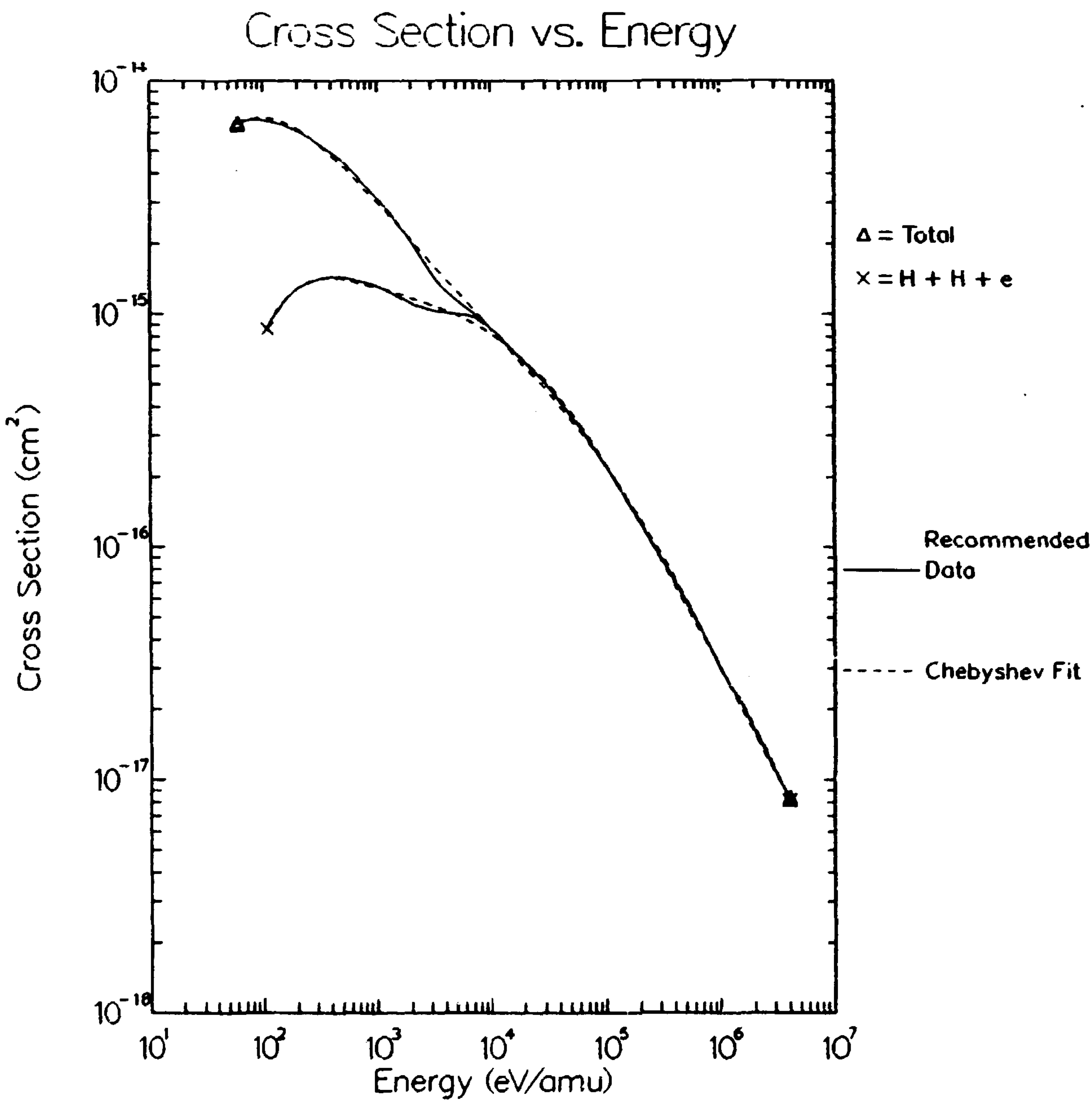
	A0	A1	A2	A3	A4	A5	A6
H + H + e	-72.0699	-2.47924	-.936325	.0886530	.0175392	.0545278	-.0645320
Total H Prod.	-70.7835	-3.41032	-.545568	.00370195	-.0606176	.0839778	.00626877

The fit represents H + H + e cross section with an rms deviation of 2.7%.
The maximum deviation is 5.4% at 2.0E+03 eV/amu.

The fit repreents Total H Prod. cross section with an rms deviation of 3.7%.
The maximum deviation is 12.4% at 4.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$H^- + H \rightarrow (H + H + e)$ or $(H + H^-)$
$H^- + H \rightarrow H + H + e$



Cross Sections for Double Electron Detachment of H^- in H

$$H^- + H \rightarrow H^+ + H + 2e$$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.8E+03	5.89E+07	3.11E-18
2.0E+03	6.21E+07	3.57E-18
4.0E+03	8.79E+07	9.35E-18
7.0E+03	1.16E+08	1.50E-17
1.0E+04	1.39E+08	1.77E-17
1.5E+04	1.70E+08	1.87E-17
2.0E+04	1.96E+08	1.85E-17
4.0E+04	2.78E+08	1.43E-17
7.0E+04	3.68E+08	9.40E-18
1.0E+05	4.39E+08	6.79E-18
1.5E+05	5.38E+08	4.61E-18
2.0E+05	6.21E+08	3.51E-18
3.0E+05	7.61E+08	2.50E-18

References: 524, 525

Accuracy: 20%

Note: There is only one set of experimental measurements.

Chebyshev Fitting Parameters for Cross Sections

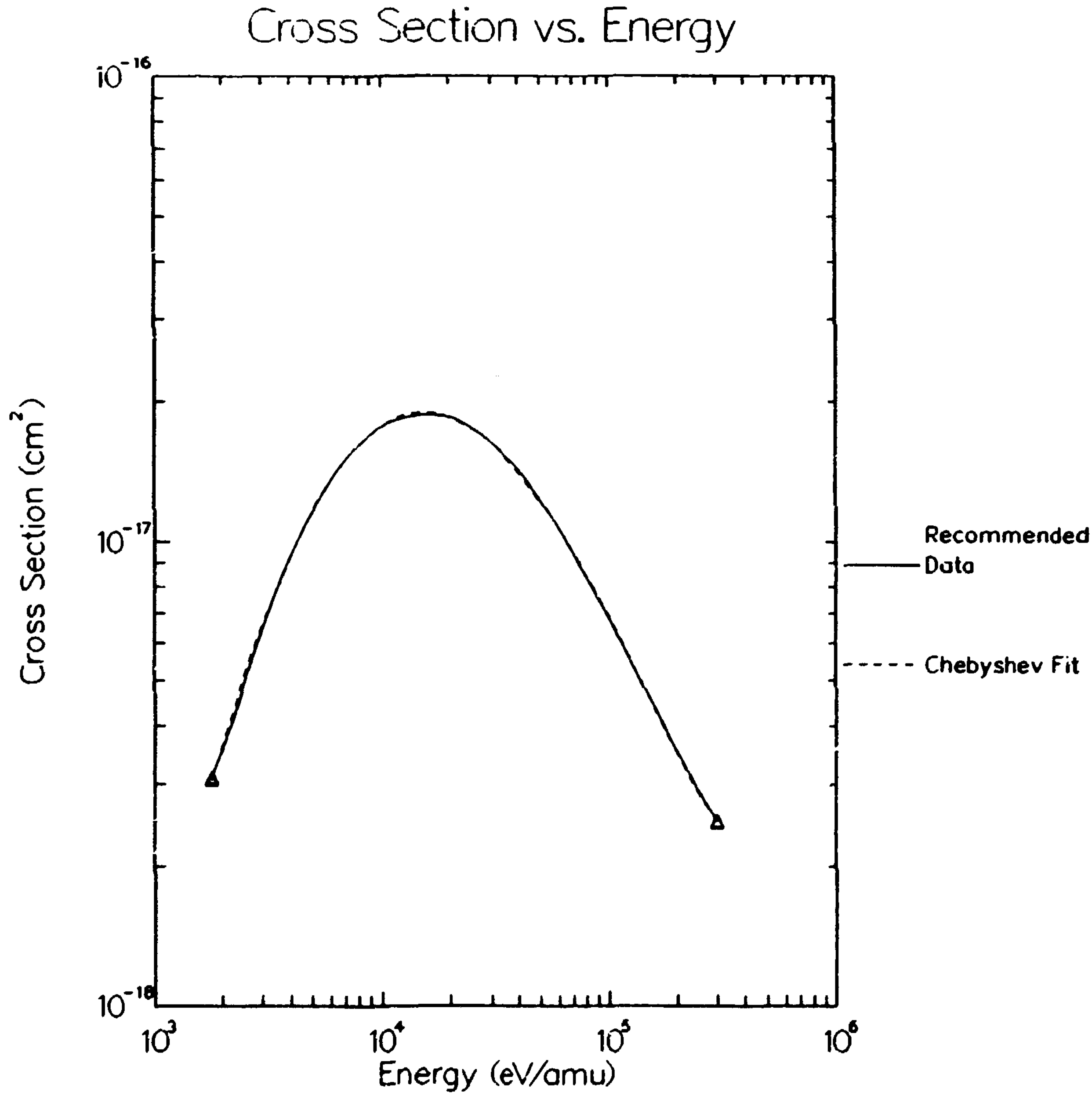
E_{min} = 1.8E+03 eV/amu, E_{max} = 3.0E+05 eV/amu

A0	A1	A2	A3	A4	A5	A6
-79.0633	-.259790	-.938476	.154218	.0364114	.00411484	.00724986

The fit represents the above cross section with an rms deviation of 0.9%.
The maximum deviation is 1.8% at 2.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$H^- + H \rightarrow H^+ + H + 2e$



Cross Sections for Single Electron Detachment of H^- Colliding with H^+

$$H^- + H^+ \rightarrow H + H^+ + e$$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.8E+03	7.35E+07	3.99E-16
3.0E+03	7.61E+07	6.57E-16
4.0E+03	8.79E+07	1.55E-15
5.0E+03	9.82E+07	2.24E-15
6.0E+03	1.08E+08	2.73E-15
7.0E+03	1.16E+08	3.11E-15
8.0E+03	1.24E+08	3.40E-15
9.0E+03	1.32E+08	3.64E-15
1.0E+04	1.39E+08	3.82E-15
1.5E+04	1.70E+08	4.23E-15
2.0E+04	1.96E+08	4.18E-15
3.0E+04	2.41E+08	3.88E-15
4.0E+04	2.78E+08	3.51E-15
5.0E+04	3.11E+08	3.19E-15
6.0E+04	3.40E+08	2.92E-15
7.0E+04	3.68E+08	2.66E-15

References: 69, 569, 572, 573

Accuracy: 40%

Note: Accuracy taken from the only experimental data available. Theoretical calculations presented by Fussen and Claeys (Ref. 572), and Ermolaev (Ref. 573) agree very well with experimental data.

Chebyshev Fitting Parameters for Cross Sections

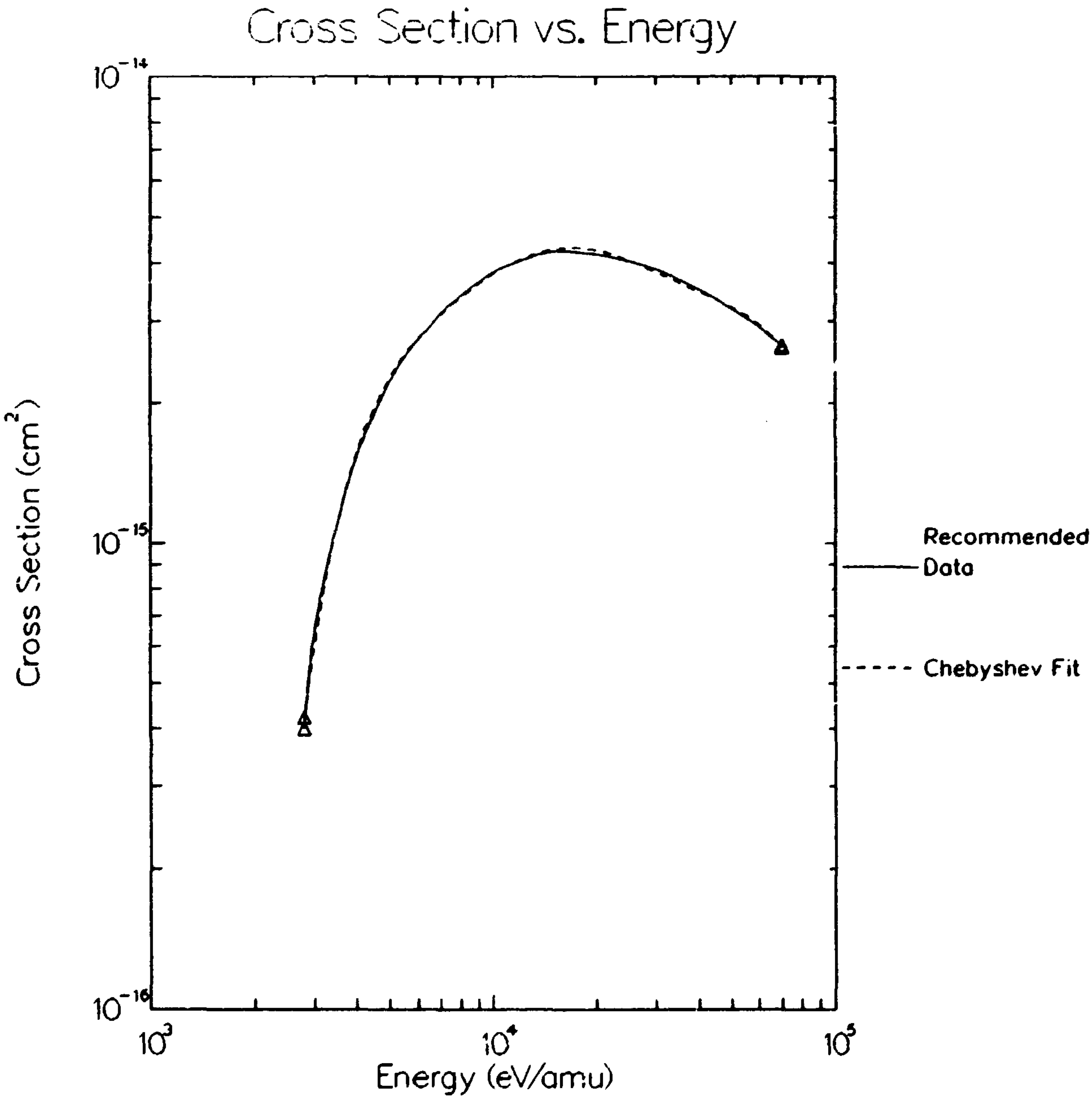
E_{min} = 2.8E+03 eV/amu, E_{max} = 7.0E+04 eV/amu

A0	A1	A2	A3	A4	A5	A6
-67.3879	.650676	-.658353	.211309	-.0972717	.0547639	-.0359904

The fit represents the above cross section with an rms deviation of 2.6%. The maximum deviation is 5.7% at 2.8E+03 eV/amu.

See appendix for Chebyshev fit details.

$H^- + H^+ \rightarrow H + H^+ + e$



Cross Sections for Single Electron Detachment of H^- in H_2

$$H^- + H_2 \rightarrow H + H_2 + e$$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.3E+00	2.11E+06	8.91E-17
4.0E+00	2.78E+06	1.92E-16
7.0E+00	3.68E+06	3.18E-16
1.0E+01	4.39E+06	3.68E-16
1.5E+01	5.38E+06	4.14E-16
2.0E+01	6.21E+06	4.28E-16
4.0E+01	8.79E+06	4.15E-16
7.0E+01	1.16E+07	4.36E-16
1.0E+02	1.39E+07	4.80E-16
1.5E+02	1.70E+07	5.60E-16
2.0E+02	1.96E+07	6.29E-16
4.0E+02	2.78E+07	8.41E-16
7.0E+02	3.68E+07	1.00E-15
1.0E+03	4.39E+07	1.06E-15
1.4E+03	5.20E+07	1.10E-15
2.0E+03	6.21E+07	1.13E-15
4.0E+03	8.79E+07	1.14E-15
7.0E+03	1.16E+08	1.09E-15
1.0E+04	1.39E+08	1.02E-15
1.5E+04	1.70E+08	9.24E-16
2.0E+04	1.96E+08	8.36E-16
4.0E+04	2.78E+08	6.33E-16
7.0E+04	3.68E+08	4.82E-16
1.0E+05	4.39E+08	3.95E-16
1.5E+05	5.38E+08	3.06E-16
2.0E+05	6.21E+08	2.51E-16
4.0E+05	8.78E+08	1.43E-16
7.0E+05	1.16E+09	9.02E-17
1.0E+06	1.39E+09	6.43E-17
1.5E+06	1.70E+09	4.41E-17
2.0E+06	1.96E+09	3.29E-17
4.0E+06	2.77E+09	1.55E-17
7.0E+06	3.65E+09	8.13E-18
1.0E+07	4.36E+09	5.16E-18
1.5E+07	5.32E+09	3.17E-18
1.7E+07	5.65E+09	2.72E-18

References: 27, 32, 82, 269, 299, 301, 303, 307, 321, 395, 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 526, 527, 541, 542, 544

Accuracy: 25%

Note: For total detachment cross sections ($\sigma_{-10} + \sigma_{-11}$) see: Muschlitz, Jr. et al., (Ref. 514, 516); Stedeford and Hasted (Ref. 82); Hasted and Smith (Ref. 515); Risley and Geballe (Ref. 520); Risley (Ref. 544); Jorgensen, Jr. et al. (Ref. 32); Lichtenbert et al. (Ref. 523)

Chebyshev Fitting Parameters for Cross Sections

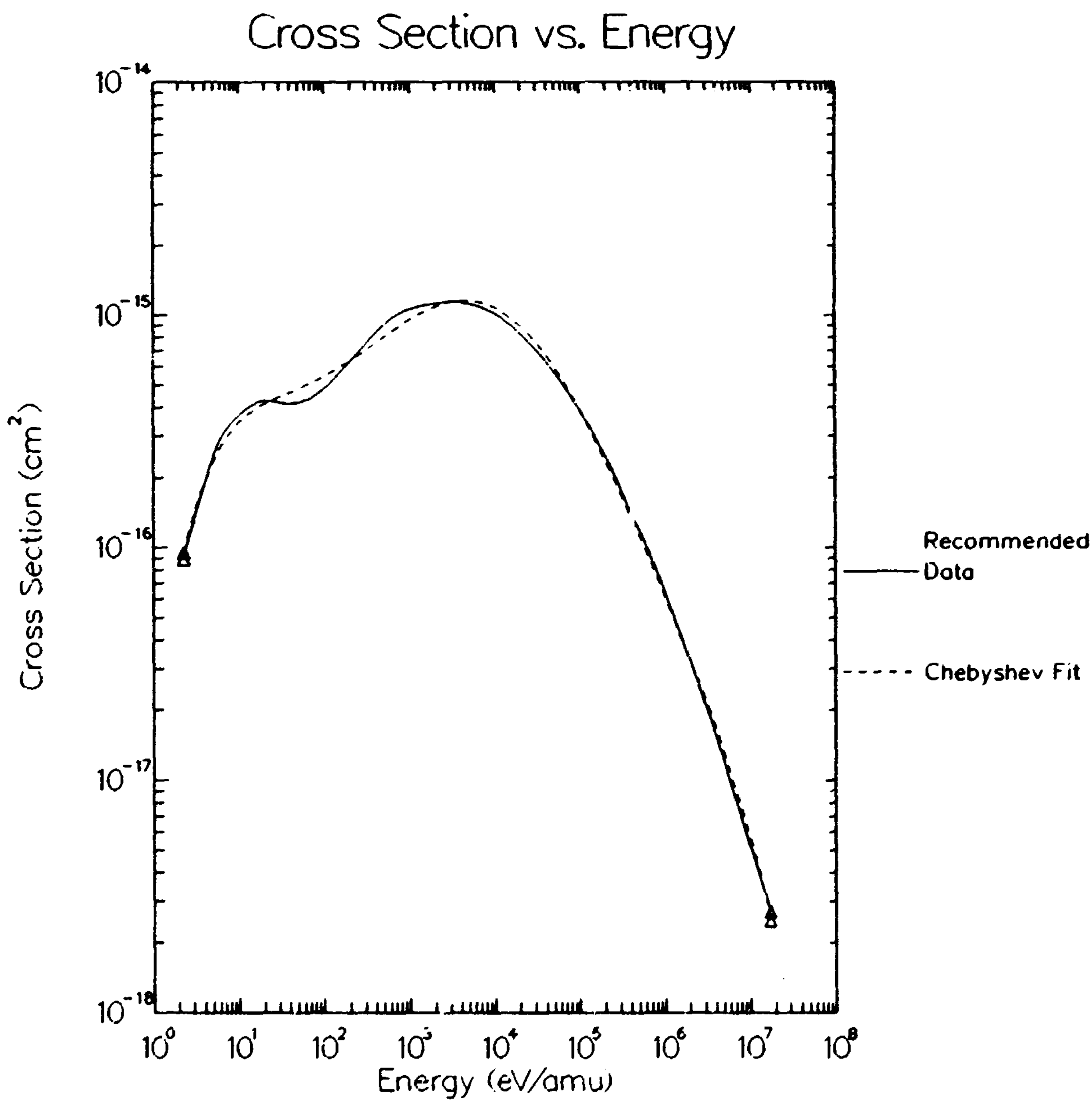
E_{min} = 2.3E+00 eV/amu, E_{max} = 1.7E+07 eV/amu

A0	A1	A2	A3	A4	A5	A6
-73.1506	-1.75695	-2.00168	-.190280	.0171353	.127083	-.152313

The fit represents the above cross section with an rms deviation of 7.2%. The maximum deviation is 16.6% at 7.0E+01 eV/amu.

See appendix for Chebyshev fit details.

$H^- + H_2 \rightarrow H + H_2 + e$



Cross Sections for Double Electron Detachment of H^- in H_2

$$H^- + H_2 \rightarrow H^+ + H_2 + 2e$$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+03	4.39E+07	1.48E-17
2.0E+03	6.21E+07	2.31E-17
4.0E+03	8.79E+07	3.24E-17
7.0E+03	1.16E+08	3.79E-17
1.0E+04	1.39E+08	4.03E-17
1.5E+04	1.70E+08	4.16E-17
2.0E+04	1.96E+08	4.11E-17
4.0E+04	2.78E+08	3.97E-17
7.0E+04	3.68E+08	3.36E-17
1.0E+05	4.39E+08	2.84E-17
1.5E+05	5.38E+08	2.20E-17
2.0E+05	6.21E+08	1.76E-17
4.0E+05	8.78E+08	8.71E-18
7.0E+05	1.16E+09	4.98E-18
1.0E+06	1.39E+09	3.42E-18
1.5E+06	1.70E+09	2.23E-18
2.0E+06	1.96E+09	1.67E-18
4.0E+06	2.77E+09	8.12E-19
7.0E+06	3.65E+09	4.52E-19
1.0E+07	4.36E+09	3.13E-19

<u>References:</u> 269, 299, 303, 307, 321, 518, 521, 522, 524, 525, 526, 556, 563, 567

<u>Accuracy:</u> 30%

<u>Note:</u> There are no experimental or theoretical data for energies below 1 keV/amu.

Chebyshev Fitting Parameters for Cross Sections

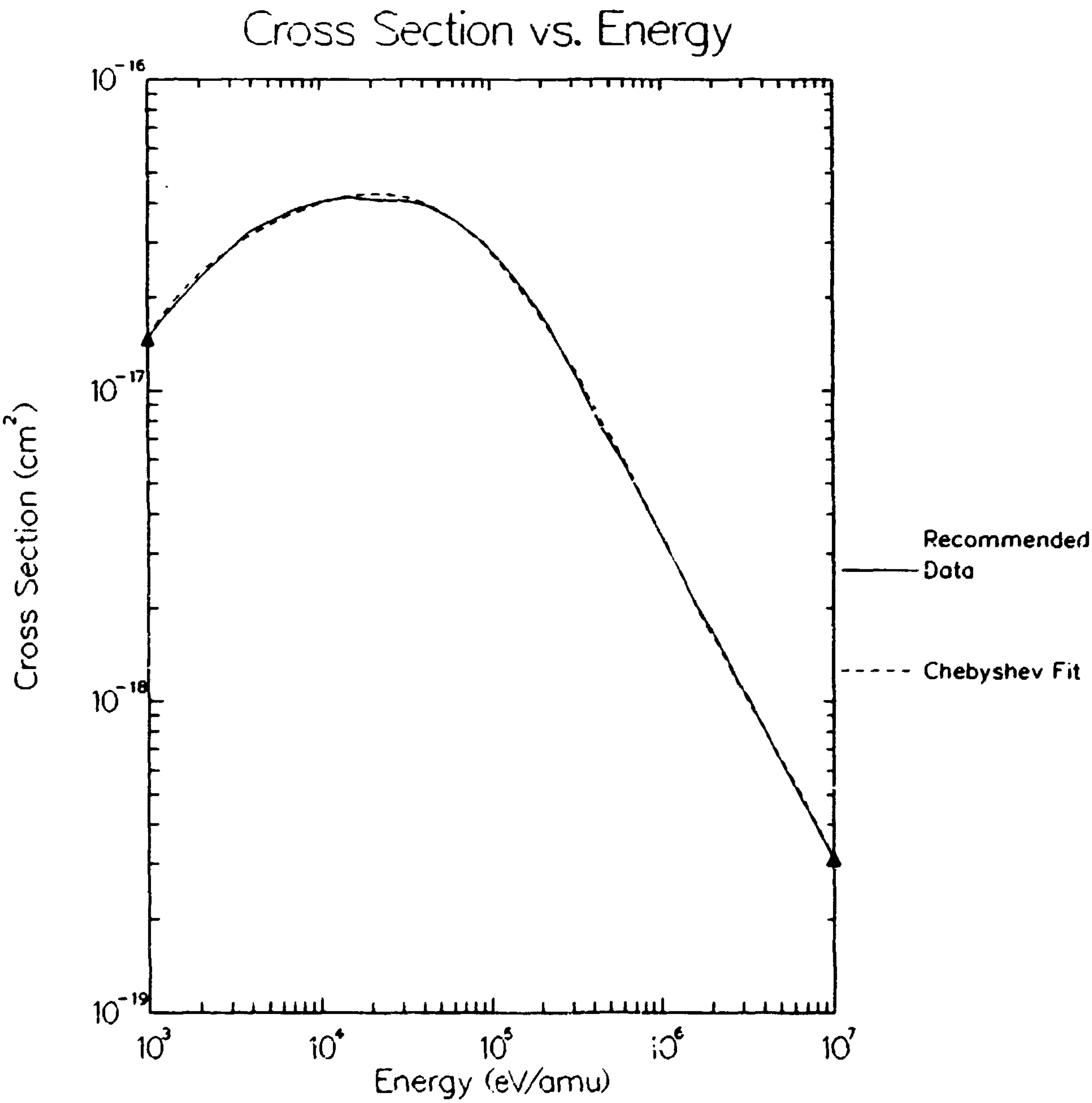
E_{min} = 1.0E+03 eV/amu, E_{max} = 1.0E+07 eV/amu

A0	A1	A2	A3	A4	A5	A6
-79.0159	-2.10252	-1.24073	.174799	.106249	-.000434273	-0.0465674

The fit represents the above cross section with an rms deviation of 2.0%. The maximum deviation is 4.3% at 4.0E+05 eV/amu.

See appendix for Chebyshev fit details.

$H^- + H_2 \rightarrow H^+ + H_2 + 2e$



Cross Sections for Single Electron Detachment of H^- in He

$H^- + He \rightarrow H + He + e$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+00	1.39E+06	6.13E-17
2.0E+00	1.96E+06	1.25E-16
4.0E+00	2.78E+06	2.33E-16
7.0E+00	3.68E+06	2.94E-16
1.0E+01	4.39E+06	3.03E-16
1.5E+01	5.38E+06	3.14E-16
2.0E+01	6.21E+06	3.22E-16
4.0E+01	8.79E+06	3.42E-16
7.0E+01	1.16E+07	3.70E-16
1.0E+02	1.39E+07	3.91E-16
1.5E+02	1.70E+07	4.21E-16
2.0E+02	1.96E+07	4.48E-16
4.0E+02	2.78E+07	5.10E-16
7.0E+02	3.68E+07	5.60E-16
1.0E+03	4.39E+07	6.02E-16
1.5E+03	5.38E+07	6.38E-16
2.0E+03	6.21E+07	6.53E-16
3.4E+03	8.10E+07	6.78E-16
4.0E+03	8.79E+07	6.73E-16
7.0E+03	1.16E+08	6.34E-16
1.0E+04	1.39E+08	6.08E-16
1.5E+04	1.70E+08	5.50E-16
2.0E+04	1.96E+08	5.01E-16
4.0E+04	2.78E+08	3.83E-16
7.0E+04	3.68E+08	2.80E-16
1.0E+05	4.39E+08	2.24E-16
1.5E+05	5.38E+08	1.72E-16
2.0E+05	6.21E+08	1.42E-16
4.0E+05	8.78E+08	8.33E-17
7.0E+05	1.16E+09	5.27E-17
1.0E+06	1.39E+09	4.00E-17
1.5E+06	1.70E+09	2.92E-17
2.0E+06	1.96E+09	2.27E-17
4.0E+06	2.77E+09	1.23E-17
7.0E+06	3.65E+09	6.98E-18
1.0E+07	4.36E+09	4.63E-18
1.5E+07	5.32E+09	2.82E-18

<u>References:</u> 27, 82, 269, 299, 300, 303, 307, 318, 321, 518, 519, 520, 521, 522, 523, 525, 527, 529, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 584

<u>Accuracy:</u> 25%

<u>Notes:</u> (1) For total detachment cross sections ($\sigma_{T0} + 2\sigma_{T1}$) see: Stedeford and Hasted (Ref. 82); Lichtenberg et al. (Ref. 523); Risley (Ref. 544); Hasted (Ref. 553); Bailey et al. (Ref. 543); Risley and Geballe (Ref. 520); Champion et al. (Ref. 545); Andersen et al. (Ref. 551); Anderson et al. (Ref. 547); Huq et al. (Ref. 548); Risley and Olson (Ref. 549); Risley (Ref. 318).

(2) For $D^- + He \rightarrow D$ see: Risley (Ref. 544); Berkner et al. (Ref. 307); Champion et al. (Ref. 545); Anderson et al. (Ref. 547); Huq et al. (Ref. 548).

<u>Chebyshev Fitting Parameters for Cross Sections</u>

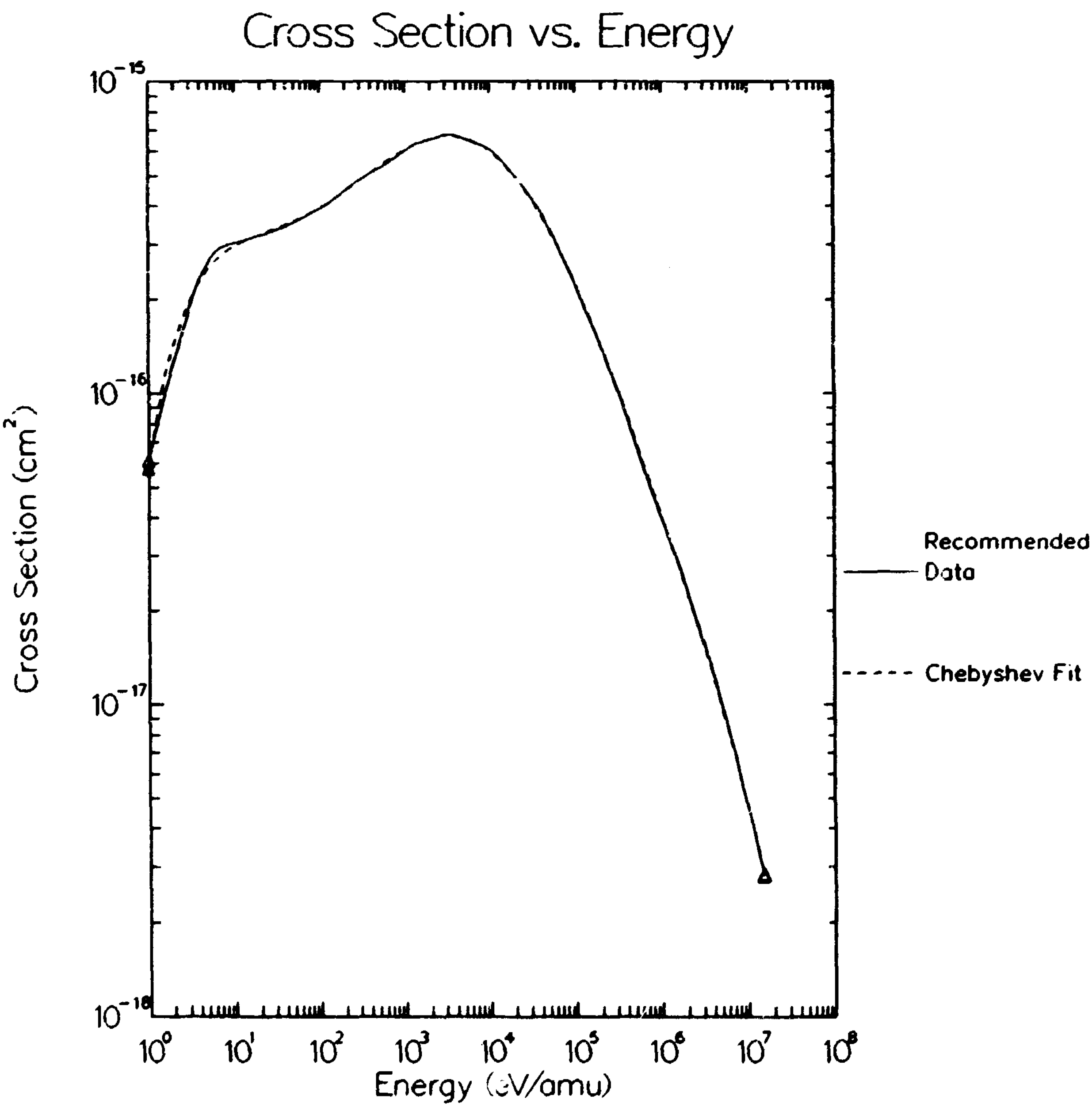
E_{min} = 1.0E+00 eV/amu, E_{max} = 1.5E+07 eV/amu

A0	A1	A2	A3	A4	A5	A6
-73.7795	-1.54839	-1.84526	-.140437	-.0282087	.183809	-.132562

The fit represents the above cross section with an rms deviation of 3.0%. The maximum deviation is 14.4% at 2.0E+00 eV/amu.

See appendix for Chebychev fit details.

$H^- + He \rightarrow H + He + e$



Cross Sections for Double Electron Detachment of H^- on He

$$H^- + He \rightarrow H^+ + He + 2e$$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
4.0E+02	2.78E+07	2.03E-18
7.0E+02	3.68E+07	7.10E-18
1.0E+03	4.39E+07	1.30E-17
1.5E+03	5.38E+07	2.32E-17
2.0E+03	6.21E+07	3.16E-17
4.0E+03	8.79E+07	4.96E-17
7.0E+03	1.16E+08	5.51E-17
1.0E+04	1.39E+08	5.46E-17
1.5E+04	1.70E+08	5.12E-17
2.0E+04	1.96E+08	4.66E-17
4.0E+04	2.78E+08	3.25E-17
7.0E+04	3.68E+08	2.01E-17
1.0E+05	4.39E+08	1.37E-17
1.5E+05	5.38E+08	8.92E-18
2.0E+05	6.21E+08	6.54E-18
4.0E+05	8.78E+08	3.16E-18
7.0E+05	1.16E+09	1.75E-18
1.0E+06	1.39E+09	1.19E-18
1.5E+06	1.70E+09	7.74E-19
2.0E+06	1.96E+09	5.59E-19
4.0E+06	2.77E+09	2.68E-19
7.0E+06	3.65E+09	1.48E-19
1.0E+07	4.36E+09	1.01E-19
1.5E+07	5.32E+09	6.53E-20
2.0E+07	6.11E+09	4.89E-20
2.3E+07	6.54E+09	4.16E-20

References: 268, 269, 299, 303, 307, 318, 321, 518, 521, 522, 523, 525, 552, 556, 561, 568, 584

Accuracy: 30%

Note: There are no experimental data for energies below 400 eV/amu. Theoretical calculations extend down to 100 eV/amu.

Chebyshev Fitting Parameters for Cross Sections

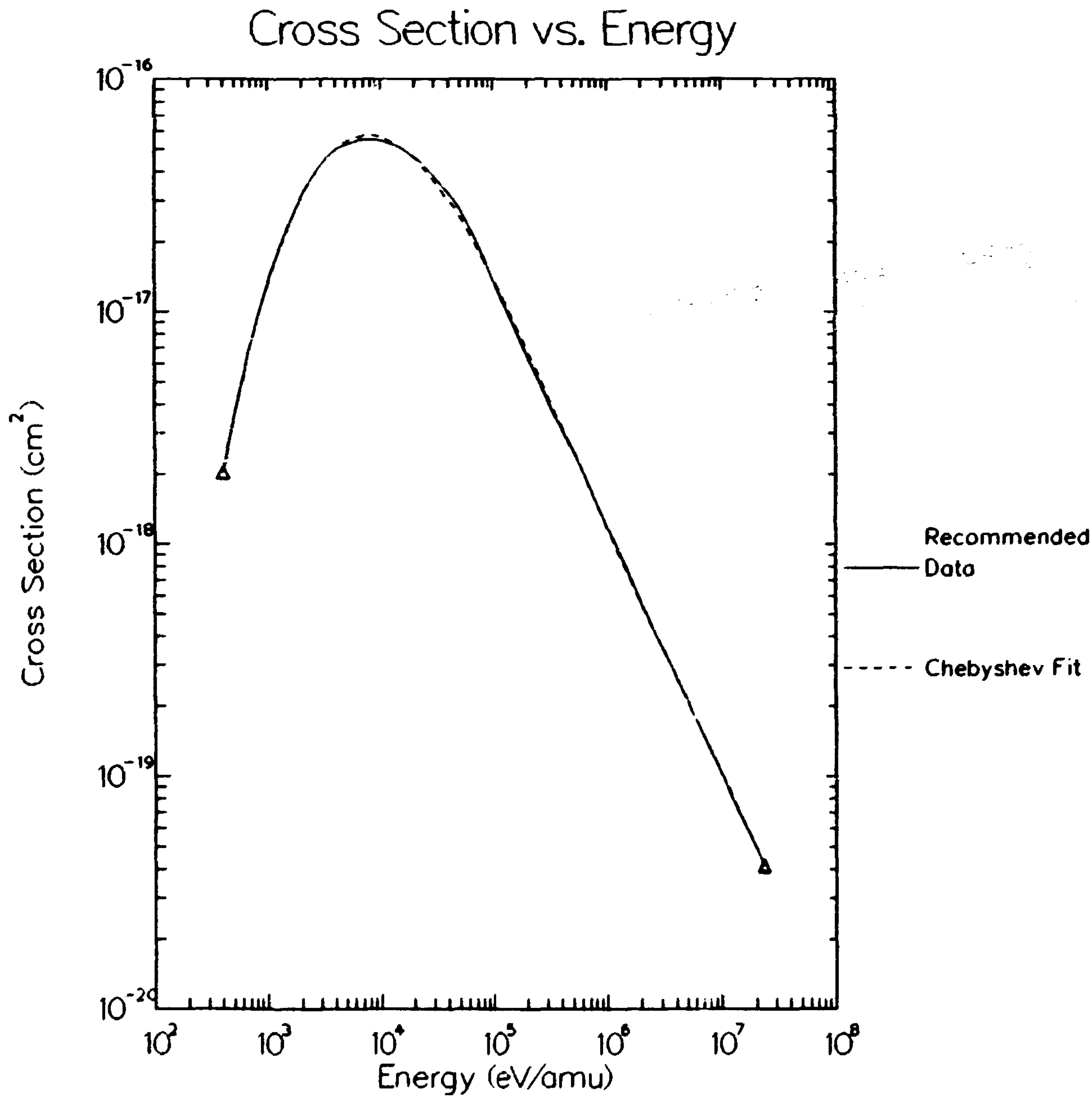
E_{min} = 4.0E+02 eV/amu, E_{max} = 2.3E+07 eV/amu

A0	A1	A2	A3	A4	A5	A6
-81.1984	-2.71121	-1.94690	.784427	-.131737	.0264605	-.00697915

The fit represents the above cross section with an rms deviation of 2.6%. The maximum deviation is 5.1% at 2.0E+05 eV/amu.

See appendix for Chebyshev fit details.

$H^- + He \rightarrow H^+ + He + 2e$



Cross Sections for Single Electron Detachment of He^- in H

$He^- + H \rightarrow He + H + e$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
3.7E+05	8.45E+08	6.39E-16
4.0E+05	8.78E+08	6.16E-16
7.0E+05	1.16E+09	4.29E-16
1.0E+06	1.39E+09	3.29E-16
1.5E+06	1.70E+09	2.39E-16
2.0E+06	1.96E+09	1.88E-16
4.0E+06	2.77E+09	1.04E-16
7.0E+06	3.65E+09	6.34E-17
9.0E+06	4.14E+09	4.99E-17

References: 301, 583

Accuracy: 40%

Note: There is only one set of experimental measurements.

Chebyshev Fitting Parameters for Cross Sections

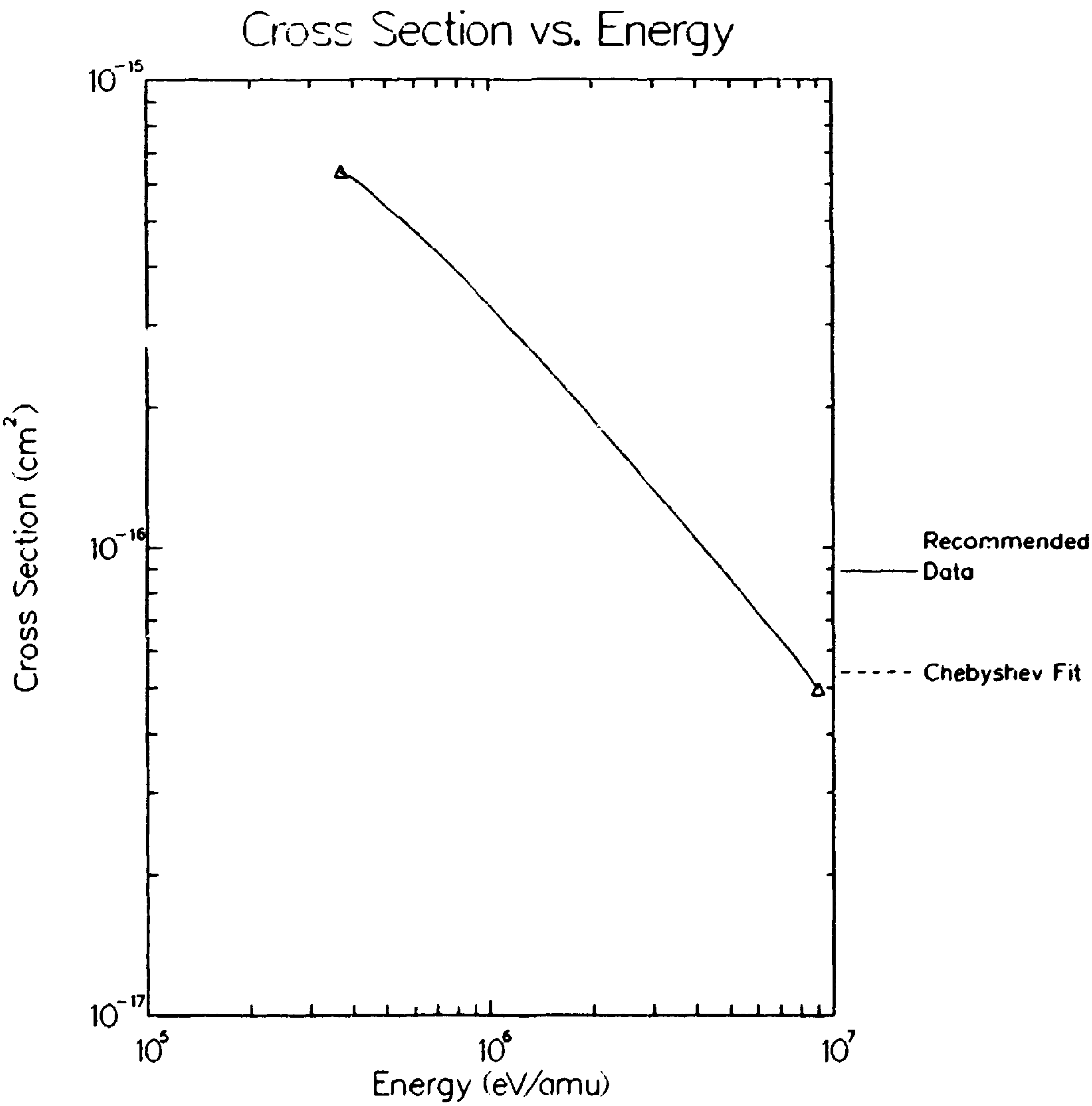
E_{min} = 3.7E+05 eV/amu, E_{max} = 9.0E+06 eV/amu

A0	A1	A2	A3	A4	A5	A6
-72.3804	-1.28777	-.0622952	.0122474	-.00652473	.000145452	-.00224648

The fit represents the above cross section with an rms deviation of 0.1%. The maximum deviation is 0.2% at 2.0E+06 eV/amu.

See appendix for Chebyshev fit details.

$He^- + H \rightarrow He + H + e$



Cross Sections for Single and Double Electron Detachment of He^- in H_2

$$He^- + H_2 \rightarrow He + H_2 + e$$
$$\rightarrow He^+ + H_2 + 2e$$

$He + H_2 + e$

Energy (eV/amu)	Cross Section (cm^2)
1.3E+02	2.15E-15
2.0E+02	2.17E-15
4.0E+02	2.14E-15
7.0E+02	2.09E-15
1.0E+03	2.06E-15
1.5E+03	2.02E-15
2.0E+03	1.97E-15
4.0E+03	1.84E-15
7.0E+03	1.69E-15
1.0E+04	1.56E-15
1.5E+04	1.41E-15
2.0E+04	1.30E-15
4.0E+04	9.76E-16
7.0E+04	7.15E-16
1.0E+05	5.67E-16
1.5E+05	4.27E-16
2.0E+05	3.44E-16
4.0E+05	1.97E-16
7.0E+05	1.24E-16
8.0E+05	1.11E-16

$He^+ + H_2 + 2e$

Energy (eV/amu)	Cross Section (cm^2)
2.6E+04	3.86E-17
3.0E+04	3.89E-17
4.0E+04	3.92E-17
5.0E+04	3.94E-17
6.0E+04	3.91E-17
7.0E+04	3.91E-17
8.0E+04	3.86E-17
9.0E+04	3.82E-17
1.0E+05	3.73E-17
1.5E+05	3.31E-17
2.0E+05	2.96E-17
3.0E+05	2.42E-17
4.0E+05	2.01E-17
5.0E+05	1.72E-17
6.0E+05	1.50E-17
7.0E+05	1.33E-17
8.0E+05	1.19E-17

References: 32, 301, 519, 521, 522, 525, 577, 580, 582, 583

Accuracy: 30%

Notes: (1) The total electron detachment cross section (single and double) has been measured by Jorgensen and Kuyatt (Ref. 32).

(2) For single detachment see: Ryding et al. (Ref. 577); Simpson and Gilbody (Ref. 519); Heinemeier et al. (Ref. 581); Heinemeier et al. (Ref. 521); Coggiola (Ref. 582); Hvelplund and Andersen (Ref. 301).

(3) For double detachment see: Ryding et al. (Ref. 577); Heinemeier et al. (Ref. 581); Heinemeier et al. (Ref. 521).

Chebyshev Fitting Parameters for Cross Sections

Single det. E_{min} = 1.3E+02 eV/amu, E_{max} = 8.0E+05 eV/amu
Double det. E_{min} = 2.6E+04 eV/amu, E_{max} = 8.0E+05 eV/amu

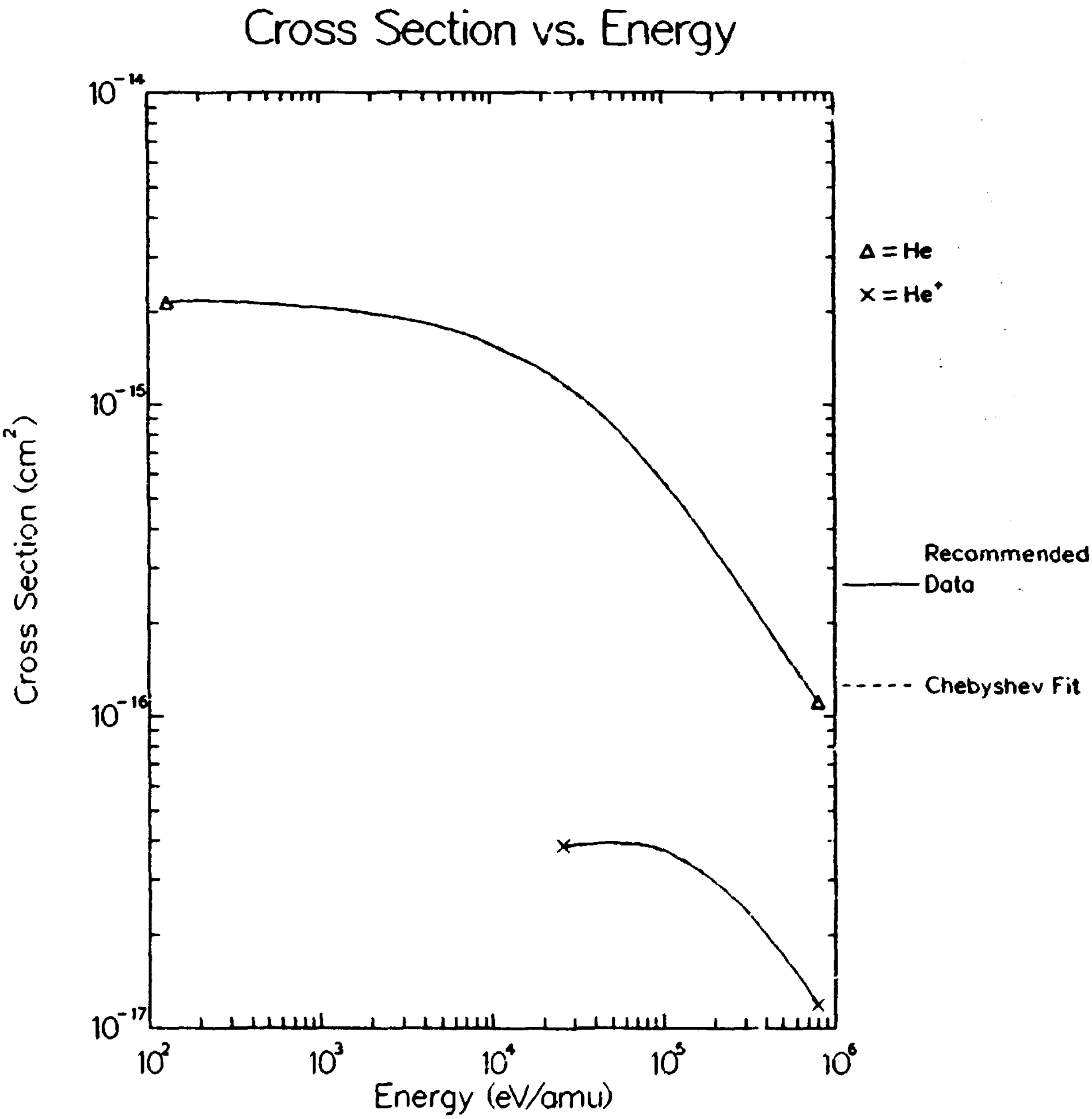
	A0	A1	A2	A3	A4	A5	A6
Single det.	-69.4085	-1.41471	-.581942	-.0905120	.0321529	.0250996	.000363782
Double det.	-76.3306	-.578433	-.226903	-.00774557	.0112528	-.00347756	.000402148

The fit represents the single detachment cross section with an rms deviation of 0.4%. The maximum deviation is 0.8% at 1.0E+04 eV/amu.

The fit represents the double detachment cross section with an rms deviation of 0.4%. The maximum deviation is 0.7% at 6.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^- + H_2 \rightarrow He + H_2 + e$
$He^- + H_2 \rightarrow He^+ + H_2 + 2e$



Cross Sections for Single and Double Electron Detachment of He^- in He

$$He^- + He \rightarrow He + He + e$$
$$\rightarrow He^+ + He + 2e$$

He + He + e

Energy (eV/amu)	Cross Section (cm^2)
1.2E+02	1.27E-15
2.0E+02	1.29E-15
3.0E+02	1.32E-15
4.0E+02	1.33E-15
7.0E+02	1.35E-15
1.0E+03	1.35E-15
2.0E+03	1.32E-15
4.0E+03	1.23E-15
7.0E+03	1.12E-15
1.0E+04	1.04E-15
2.0E+04	8.07E-16
4.0E+04	5.72E-16
7.0E+04	4.07E-16
1.0E+05	3.22E-16
2.0E+05	1.94E-16
4.0E+05	1.11E-16
7.0E+05	6.98E-17

He^+ + He + 2e

Energy (eV/amu)	Cross Section (cm^2)
2.7E+04	4.1PE-17
3.0E+04	4.16E-17
4.0E+04	4.05E-17
5.0E+04	3.90E-17
6.0E+04	3.82E-17
7.0E+04	3.71E-17
8.0E+04	3.58E-17
9.0E+04	3.47E-17
1.0E+05	3.37E-17
1.5E+05	2.98E-17
2.0E+05	2.66E-17
3.0E+05	2.23E-17
4.0E+05	1.93E-17
5.0E+05	1.72E-17
6.0E+05	1.58E-17
7.0E+05	1.47E-17
8.0E+05	1.36E-17

<u>**References:**</u> 519, 521, 522, 525, 575, 576, 577, 578, 581, 582, 583

<u>**Accuracy:**</u> 25%

<u>**Notes:**</u> (1) The total electron detachment cross section (single and double) has been measured by Windham et al. (Ref. 575); Nicholas et al. (Ref. 578); Simpson and Gilbody (Ref. 519).

(2) For single detachment see: Sweetman (Ref. 576); Ryding et al. (Ref. 577); Heinemeier et al. (Ref. 581); Heinemeier et al. (Ref. 521); Coggiola (Ref. 582).

(3) For double detachment see: Ryding et al. (Ref. 577); Heinemeier et al. (Ref. 521).

<u>Chebyshev Fitting Parameters for Cross Sections</u>

Single det. E_{min} = 1.2E+02 eV/amu, E_{max} = 7.0E+05 eV/amu
Double det. E_{min} = 2.7E+04 eV/amu, E_{max} = 8 [illegible]+05 eV/amu

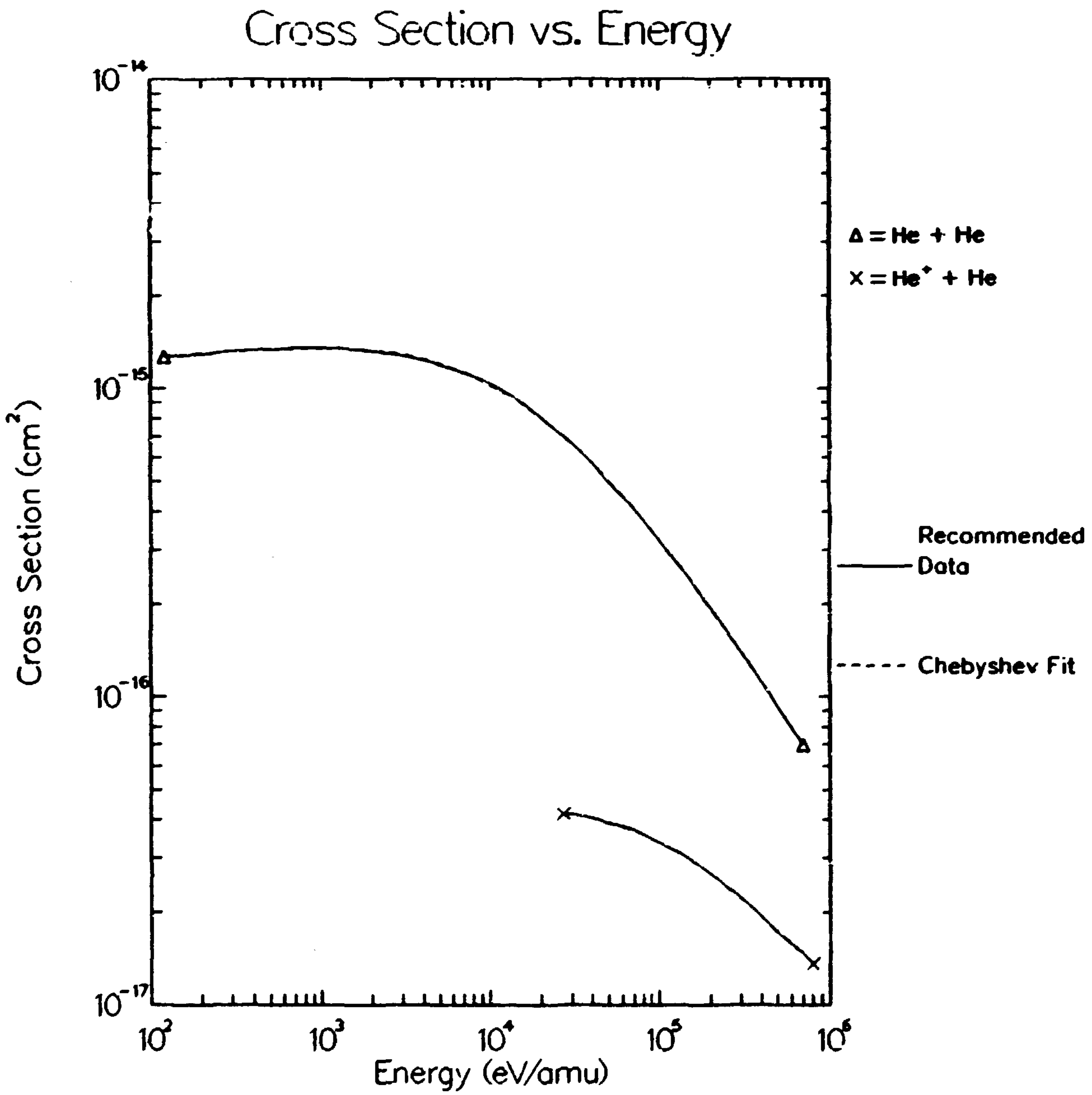
	A0	A1	A2	A3	A4	A5	A6
Single det.	-70.3313	-1.40200	-.626470	-.0569330	.0458639	.0102379	-.00527677
Double det.	-76.3309	-.571055	-.112122	.0109146	.00565444	.000461742	-.00146987

The fit represents the single detachment cross section with an rms deviation of 0.5%. The maximum deviation is 1.1% at 4.0E+03 eV/amu.

The fit represents the double detachment cross section with an rms deviation of 0.4%. The maximum deviation is 0.6% at 5.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^- + He \rightarrow He + He + e$
$He^- + He \rightarrow He^+ + He + 2e$



Cross Sections for Single and Double Electron Detachment of Li^- in H_2

$$Li^- + H_2 \rightarrow Li + H_2 + e$$
$$\rightarrow Li^+ + H_2 + 2e$$

$Li + H_2 + e$

Energy (eV/amu)	Cross Section (cm^2)
1.5E+03	1.89E-15
2.0E+03	1.91E-15
4.0E+03	1.81E-15
7.0E+03	1.64E-15
1.0E+04	1.50E-15
1.5E+04	1.34E-15
2.0E+04	1.23E-15
4.0E+04	9.45E-16
7.0E+04	7.43E-16
1.0E+05	6.30E-16
1.5E+05	5.15E-16
2.0E+05	4.46E-16
4.0E+05	3.10E-16

$Li^+ + H_2 + 2e$

Energy (eV/amu)	Cross Section (cm^2)
1.5E+04	1.00E-16
2.0E+04	8.79E-17
3.0E+04	7.40E-17
4.0E+04	6.67E-17
5.0E+04	6.27E-17
6.0E+04	5.98E-17
7.0E+04	5.76E-17
8.0E+04	5.55E-17
9.0E+04	5.43E-17
1.0E+05	5.28E-17
1.5E+05	4.83E-17
1.8E+05	4.67E-17

References: 250, 522, 583, 588

Accuracy: 25%

Note: For total electron detachment (single and double) see: Allision et al. (Ref. 250). For both single and double detachment see: McCullough et al. (Ref. 588).

Chebyshev Fitting Parameters for Cross Sections

Single det. E_{min} = 1.5E+03 eV/amu, E_{max} = 4.0E+05 eV/amu
Double det. E_{min} = 1.5E+04 eV/amu, E_{max} = 1.8E+05 eV/amu

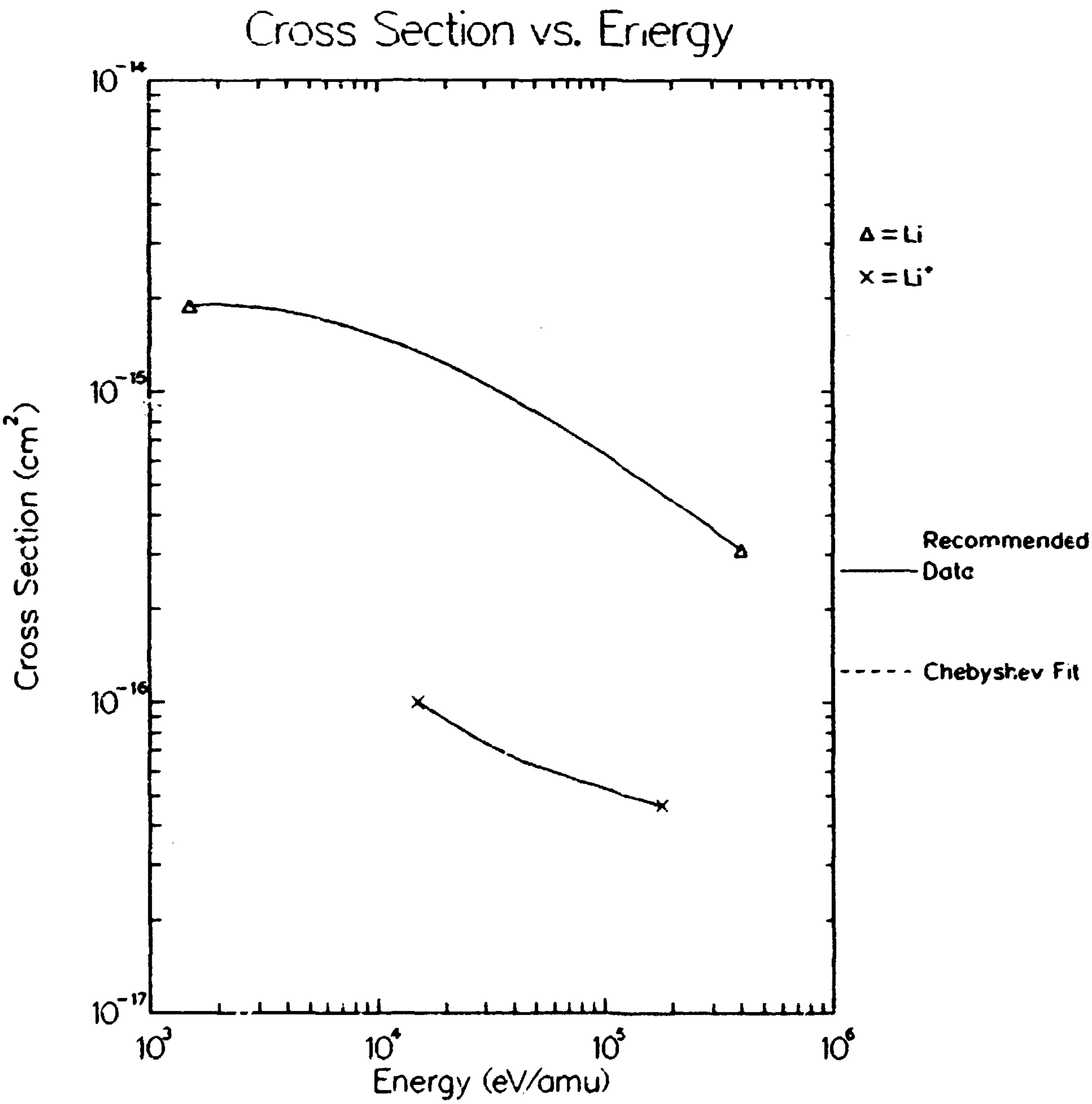
	A0	A1	A2	A3	A4	A5	A6
Single det.	-69.2100	-.932154	-.198400	.0257913	-.00111248	.00258484	-.00164526
Double det.	-74.5383	-.376194	.0491243	-.00831956	-.00149259	.00388870	-.000530605

The fit represents the single detachment cross section with an rms deviation of 0.2%. The maximum deviation is 0.3% at 1.0E+04 eV/amu.

The fit represents the double detachment cross section with an rms deviation of 0.2%. The maximum deviation is 0.4% at 8.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$Li^- + H_2 \rightarrow Li + H_2 + e$
$Li^- + H_2 \rightarrow Li^+ + H_2 + 2e$



Cross Sections for Total Electron Detachment of Li^- on He

$Li^- + He \rightarrow Li,\ Li^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.8E+02	1.86E+07	4.22E-16
2.0E+02	1.96E+07	4.56E-16
4.0E+02	2.78E+07	6.65E-16
7.0E+02	3.68E+07	8.07E-16
1.0E+03	4.39E+07	8.83E-16
1.5E+03	5.38E+07	9.57E-16
2.0E+03	6.21E+07	9.93E-16
4.0E+03	8.79E+07	1.05E-15
7.0E+03	1.16E+08	1.04E-15
1.0E+04	1.39E+08	1.00E-15
1.5E+04	1.70E+08	9.42E-16
2.0E+04	1.96E+08	8.87E-16
4.0E+04	2.78E+08	7.43E-16
6.0E+04	3.40E+08	6.46E-16

<u>References:</u> 250, 522, 551, 583, 587

<u>Accuracy:</u> 25%

<u>Note:</u> Reported values for cross sections correspond to the sum of those for single and double detachment.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

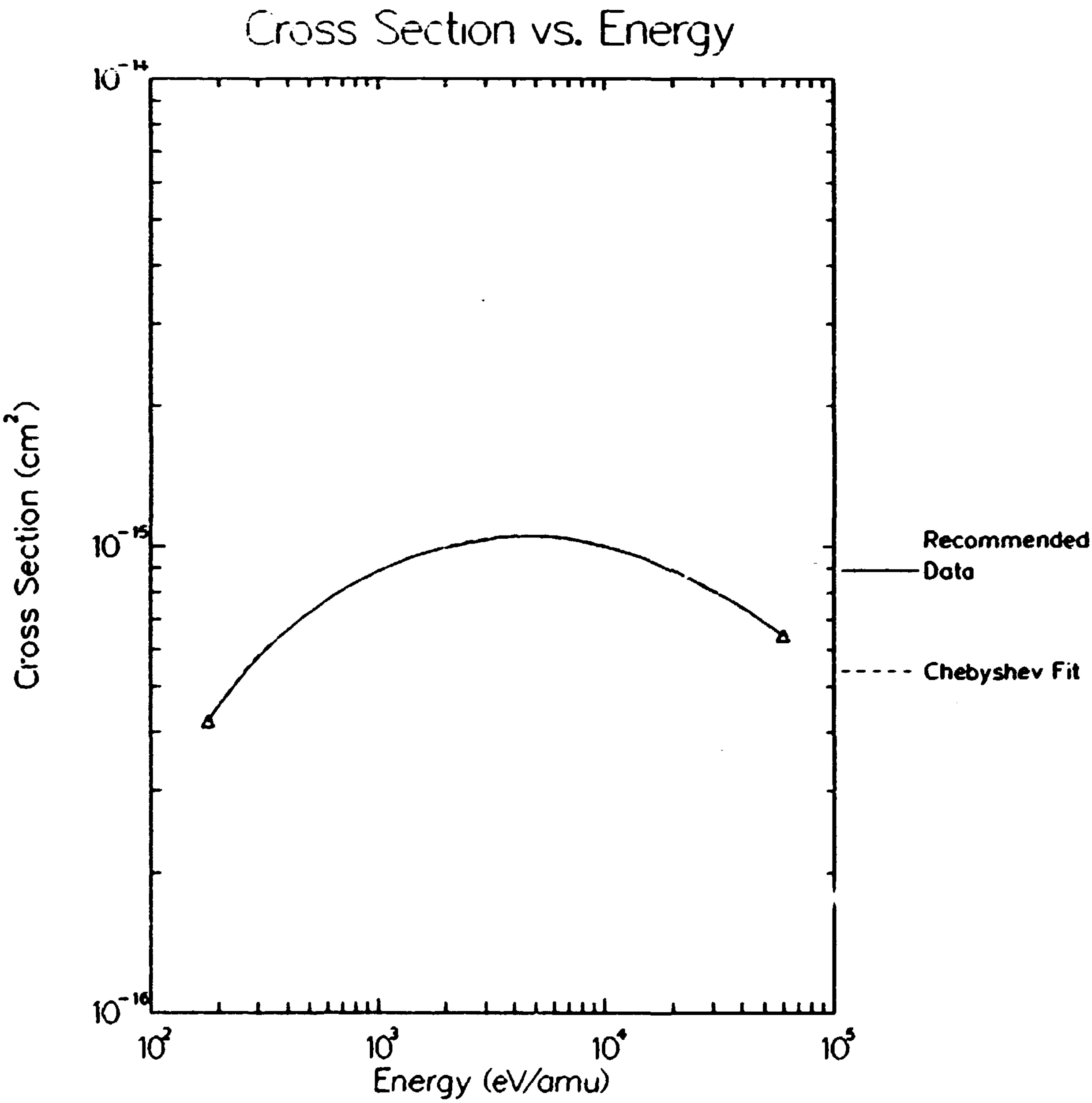
E_{min} = 1.8E+02 eV/amu, E_{max} = 6.0E+04 eV/amu

A0	A1	A2	A3	A4	A5	A6
-69.6625	.18135	-.342099	.0241112	-.0117377	.00823347	-.00361753

The fit represents the above cross section with an rms deviation of 0.2%. The maximum deviation is 0.4% at 2.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$Li^- + He \rightarrow Li, Li^+$



G. Cross Sections for Dissociation of Molecules and Molecular Ions

G. (Cont'd)

Cross Sections for Double (Dissociative) Ionization, Double Ionization with Stripping, and Electron Capture with Ionization for H-Atom Impact on H_2

$$H + H_2 \rightarrow H + (H^+ + H^+) + 2e$$
$$H + H_2 \rightarrow H^+ + (H^+ + H^+) + 3e$$
$$H + H_2 \rightarrow H^- + (H^+ + H^+) + e$$

$(H + 2H^+ + 2e)$		$(H^+ + 2H^+ + 3e)$		$(H^- + 2H^+ + e)$	
Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)
5.0E+03	1.62E-19	5.7E+03	1.06E-20	4.7E+03	2.18E-20
6.0E+03	2.59E-19	7.0E+03	1.65E-20	7.0E+03	6.65E-20
7.0E+03	3.90E-19	1.0E+04	3.87E-20	8.5E+03	1.00E-19
8.0E+03	5.40E-19	1.3E+04	9.90E-20	9.0E+03	1.17E-19
9.0E+03	7.04E-19	1.5E+04	1.38E-19	1.0E+04	1.51E-19
1.0E+04	8.88E-19	2.0E+04	2.79E-19	1.5E+04	3.22E-19
1.5E+04	1.91E-18	2.5E+04	4.68E-19	2.0E+04	3.69E-19
2.0E+04	2.58E-18	3.0E+04	6.32E-19	2.5E+04	3.47E-19
3.0E+04	3.22E-18	3.5E+04	7.82E-19	3.0E+04	3.05E-19
4.0E+04	3.35E-18	4.0E+04	9.19E-19	3.5E+04	2.70E-19
5.0E+04	3.11E-18	4.5E+04	1.00E-18	4.0E+04	2.43E-19
		5.0E+04	1.14E-18	4.5E+04	2.22E-19
		5.2E+04	1.17E-18	5.0E+04	2.05E-19

Reference: 30

Accuracy: Unknown

Note: Kinetic energy of the slow H^+ ions is approximately 9 eV.

Chebyshev Fitting Parameters for Cross Sections

$(H + 2H^+ + 2e)$ E_{min} = 5.0E+03 eV/amu, E_{max} = 5.0E+04 eV/amu
$(H^+ + 2H^+ + 3e)$ E_{min} = 5.7E+03 eV/amu, E_{max} = 5.2E+04 eV/amu
$(H^- + 2H^+ + e)$ E_{min} = 4.7E+03 eV/amu, E_{max} = 5.0E+04 eV/amu

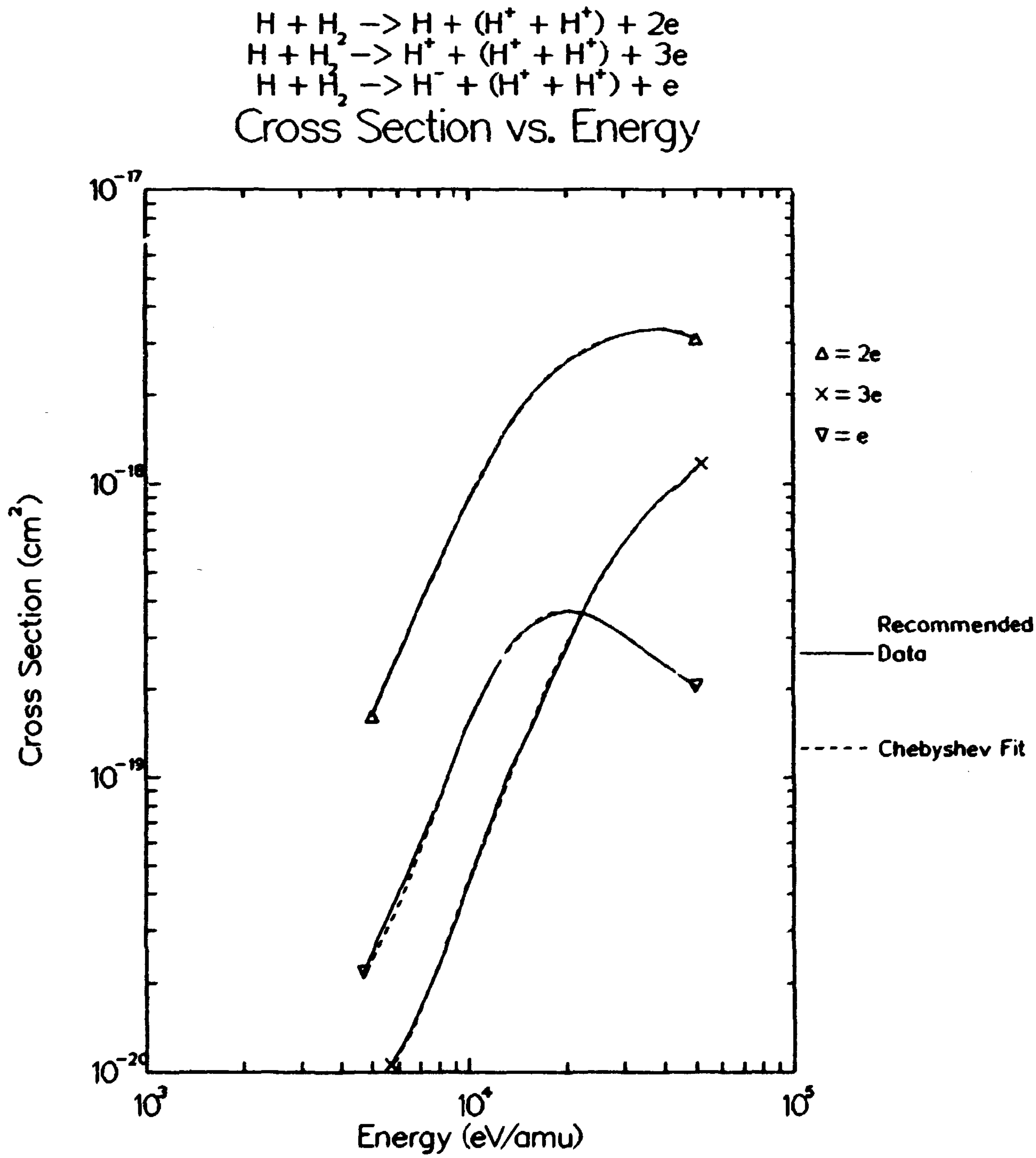
	A0	A1	A2	A3	A4	A5	A6
$(H + 2H^+ + 2e)$	-82.5844	1.50087	-.514162	-.0138263	.0274858	-.00853833	-.0116637
$(H^+ + 2H^+ + 3e)$	-86.7735	2.46227	-.301192	-.105842	.0379990	-.00417294	.0122290
$(H^- + 2H^+ + e)$	-86.8910	1.09636	-.754871	-.00932842	.0855477	.0300822	-.0393792

The fit represents the $(H + 2H^+ + 2e)$ cross section with an rms deviation of 0.8%. The maximum deviation is 1.1% at 6.0E+03 eV/amu.

The fit represents the $(H^+ + 2H^+ + 3e)$ cross section with an rms deviation of 1.8%. The maximum deviation is 2.9% at 1.0E+04 eV/amu.

The fit represents the $(H^- + 2H^+ + e)$ cross section with an rms deviation of 1.3%. The maximum deviation is 3.0% at 8.5E+03 eV/amu.

See appendix for Chebyshev fit details.



H + H2 -> H + (H+ + H+) + 2e
H + H2 -> H+ + (H+ + H+) + 3e
H + H2 -> H- + (H+ + H+) + e
Cross Section vs. Energy
Cross Section (cm2)
10-17
10-18
10-19
10-20
10^3
10^4
10^5
Energy (eV/amu)
Δ = 2e
X = 3e
∇ = e
Recommended Data
Chebyshev Fit

Cross Sections for Dissociative Ionization of H_2 in Collisions with Hydrogen Atoms.

$$H + H_2 \rightarrow H + (H + H^+) + e$$

via $1s\sigma_g$ State (Curve 1)		via $2p\sigma_u$ State (Curve 2)	
Energy (eV/amu)	Cross Section (cm^2)	Energy (eV/amu)	Cross Section (cm^2)
5.0E+03	6.40E-19	5.0E+03	2.25E-18
6.0E+03	8.21E-19	6.0E+03	3.23E-18
7.0E+03	9.67E-19	7.0E+03	4.12E-18
8.0E+03	1.09E-18	8.0E+03	4.97E-18
9.0E+03	1.18E-18	9.0E+03	5.76E-18
1.0E+04	1.25E-18	1.0E+04	6.47E-18
1.5E+04	1.40E-18	1.5E+04	8.07E-18
2.0E+04	1.38E-18	2.0E+04	7.49E-18
2.5E+04	1.31E-18	2.5E+04	6.24E-18
3.0E+04	1.23E-18	3.0E+04	5.13E-18
3.5E+04	1.17E-18	3.5E+04	4.11E-18
4.0E+04	1.12E-18	4.0E+04	3.24E-18
4.5E+04	1.06E-18	4.5E+04	2.51E-18
5.0E+04	1.00E-18	5.0E+04	1.97E-18

Reference: 30

Accuracy: Unknown

Notes: (1) Cross section values plotted in curve 1 refer to the dissociation of the H_2^+ ion from the $1s\sigma_g$ state. Energy of the slow ion is Approximately zero. (2) Cross section values plotted in curve 2 refer to the electron transitions to the $2p\sigma_u$ state and also to all the excited electron states of the H_2^+ ion. Energy of the slow ion is approximately 7 eV.

Chebyshev Fitting Parameters for Cross Sections

(via $1s\sigma_g$ state) E_{min} = 5.0E+03 eV/amu, E_{max} = 5.0E+04 eV/amu
(via $2p\sigma_u$ state) E_{min} = 5.0E+03 eV/amu, E_{max} = 5.0E+04 eV/amu

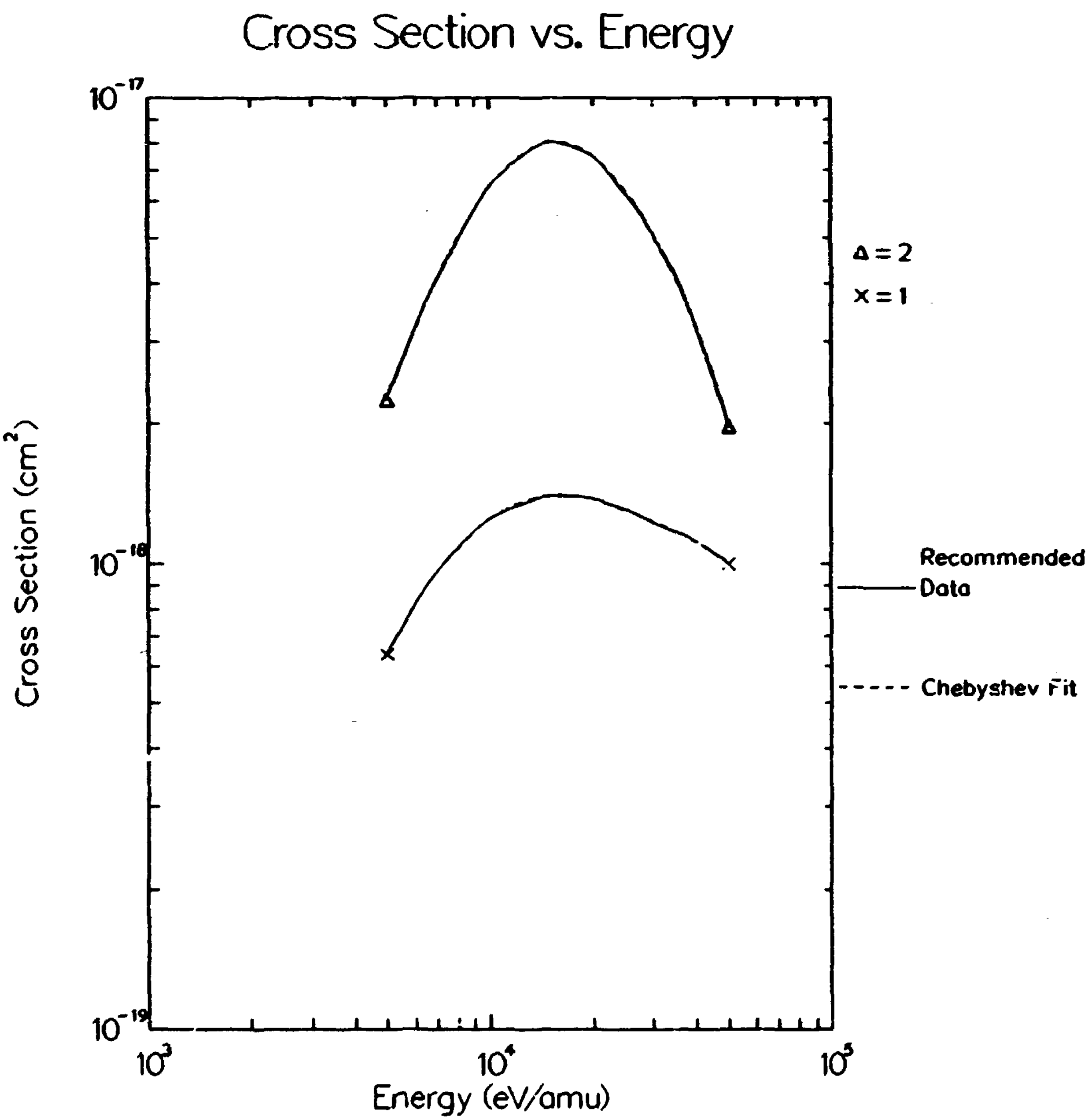
	A0	A1	A2	A3	A4	A5	A6
(via $1s\sigma_g$ state)	-82.7739	.176787	-.277606	.0497140	-.000803387	-.00277426	-.00425677
(via $2p\sigma_u$ state)	-80.0822	-.050777	-.663490	-.0140905	.00850407	-.00531411	-.00795596

The fit represents the cross section (via $1s\sigma_g$ state) with an rms deviation of 0.2%. The maximum deviation is 0.4% at 3.0E+04 eV/amu.

The fit represents the cross section (via $2p\sigma_u$ state) with an rms deviation of 0.6%. The maximum deviation is 1.2% at 4.5E+04 eV/amu.

See appendix for Chebyshev fit details.

$H + H_2 \rightarrow H + (H + H^+) + e$



Cross Sections for Dissociative Ionization of H_2 by H-Atom Impact Accompanied by Stripping of the H Projectile

$$H + H_2 \rightarrow H^+ + (H + H^+) + 2e$$

via $1s\sigma_g$ state (Curve 1)		via $2p\sigma_u$ state (Curve 2)	
Energy (eV/amu)	Cross Section (cm^2)	Energy (eV/amu)	Cross Section (cm^2)
5.0E+03	2.49E-20	5.0E+03	2.38E-20
6.0E+03	3.27E-20	6.0E+03	5.83E-20
7.0E+03	4.07E-20	7.0E+03	1.07E-19
8.0E+03	4.91E-20	8.0E+03	1.66E-19
9.0E+03	5.77E-20	9.0E+03	2.34E-19
1.0E+04	6.68E-20	1.0E+04	3.07E-19
1.5E+04	1.15E-19	1.5E+04	6.88E-19
2.0E+04	1.66E-19	2.0E+04	1.04E-18
3.0E+04	2.73E-19	2.5E+04	1.26E-18
4.0E+04	3.65E-19	3.0E+04	1.37E-18
5.0E+04	4.10E-19	3.5E+04	1.37E-18
		4.0E+04	1.32E-18
		4.5E+04	1.23E-18
		5.0E+04	1.13E-18

Reference: 30

Accuracy: Unknown

Notes: (1) Cross section values plotted in curve 1 refer to the dissociation of the H_2^+ ion via the $1s\sigma_g$ state of H_2^+. Energy of the slow ion is approximately zero. (2) Cross section values plotted in curve 2 refer to the dissociation of the H_2^+ ion via the $2p\sigma_u$ state and also all higher excited electronic states of the H_2^+ ion. Energy of the slow ion is approximately 7 eV.

Chebyshev Fitting Parameters for Cross Sections

(via $1s\sigma_g$ state) E_{min} = 5.0E+03 eV/amu, E_{max} = 5.0E+04 eV/amu
(via $2p\sigma_u$ state) E_{min} = 5.0E+03 eV/amu, E_{max} = 5.0E+04 eV/amu

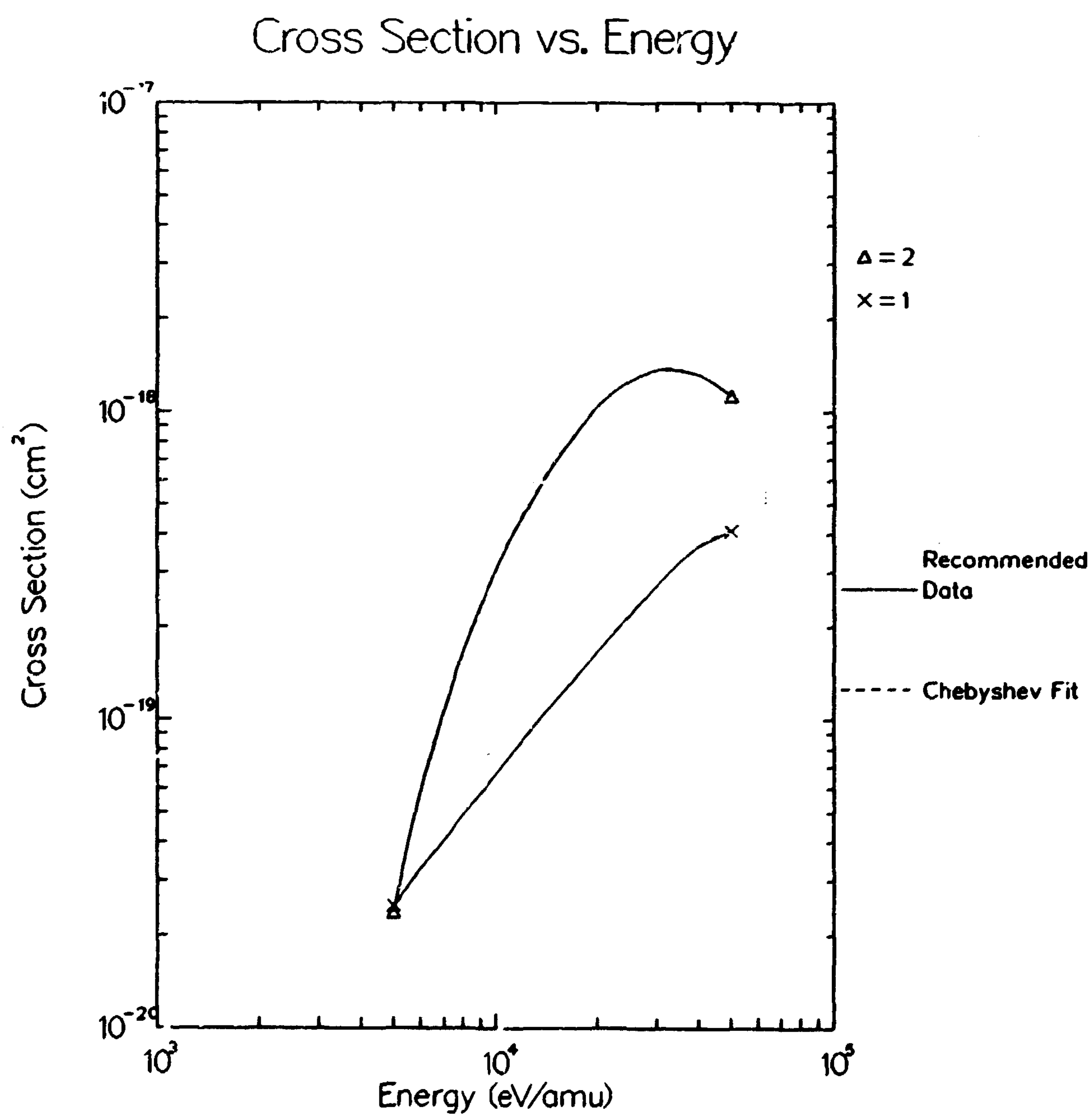
	A0	A1	A2	A3	A4	A5	A6
(via $1s\sigma_g$ state)	-87.2426	1.43882	-.0948243	-.0308580	-.0190257	-.00744929	-.00364561
(via $2p\sigma_u$ state)	-86.8972	1.86566	-.764017	.0497586	-.0434187	.0151155	.00206675

The fit represents cross section (via $1s\sigma_g$ state) with an rms deviation of 0.1%. The maximum deviation is 0.1% at 2.0E+04 eV/amu.

The fit represents cross section (via $2p\sigma_u$ state) with an rms deviation of 0.3%. The maximum deviation is 0.6% at 1.5E+04 eV/amu.

See appendix for Chebyshev fit details.

$H + H_2 \rightarrow H^+ + (H + H^+) + 2e$



Cross Sections for Dissociative Electron Capture from H_2 by H-Atoms

$$H + H_2 \rightarrow H^- + (H^+ + H)$$

via $1s\sigma_g$ state (Curve 1) Energy (eV/amu)	Cross Section (cm^2)	via $2p\sigma_u$ state (Curve 2) Energy (eV/amu)	Cross Section (cm^2)
5.0E+03	8.20E-20	5.0E+03	2.91E-19
6.0E+03	1.05E-19	6.0E+03	4.72E-19
7.0E+03	1.26E-19	7.0E+03	6.57E-19
8.0E+03	1.45E-19	8.0E+03	8.34E-19
9.0E+03	1.63E-19	9.0E+03	9.97E-19
1.0E+04	1.79E-19	1.0E+04	1.15E-18
1.5E+04	2.18E-19	1.5E+04	1.45E-18
2.0E+04	1.81E-19	2.0E+04	1.13E-18
2.5E+04	1.31E-19	2.5E+04	7.75E-19
3.0E+04	1.02E-19	3.0E+04	5.33E-19
3.5E+04	8.51E-20	3.5E+04	3.51E-19
4.0E+04	7.39E-20	4.0E+04	2.48E-19
4.5E+04	6.68E-20	4.5E+04	1.78E-19
5.0E+04	6.17E-20	5.0E+04	1.27E-19

__Reference:__ 30

__Accuracy:__ Unknown

__Notes:__ (1) Cross section values plotted in curve 1 refer to the dissociation of the H_2^+ ion via the $1s\sigma_g$ state of H_2^+. The energy of the slow particles is approximately zero. (2) Cross section values plotted in curve 2 refer to the dissociation of the H_2^+ ion via the $2p\sigma_u$ and also all excited electronic states of the H_2^+ ion. The energy of the slow particles is approximately 7 eV.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

(via $1s\sigma_g$ state) E_{min} = 5.0E+03 eV/amu, E_{max} = 5.0E+04 eV/amu
(via $2p\sigma_u$ state) E_{min} = 5.0E+03 eV/amu, E_{max} = 5.0E+04 eV/amu

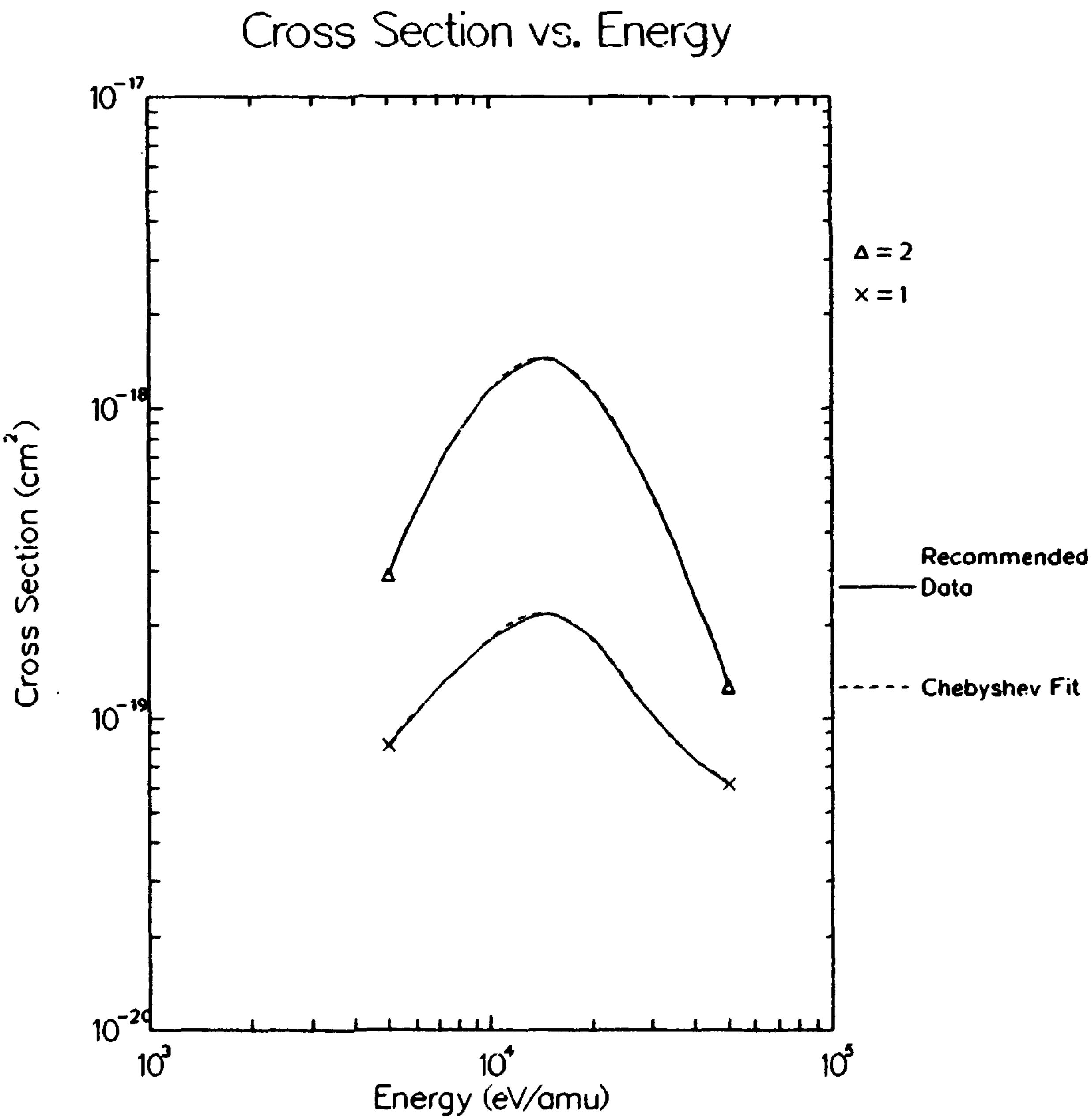
	A0	A1	A2	A3	A4	A5	A6
(via $1s\sigma_g$ state)	-87.2731	-.218951	-.522211	.0736627	.0971637	.00270336	-.0307172
(via $2p\sigma_u$ state)	-84.2975	-.438944	-.978064	.0211660	.0476037	.00159449	-.0175091

The fit represents cross section (via $1s\sigma_g$ state) with an rms deviation of 0.8%. The maximum deviation is 1.5% at 2.5E+04 eV/amu.

The fit represents cross section (via $2p\sigma_u$ state) with an rms deviation of 0.8%. The maximum deviation is 1.1% at 4.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$H + H_2 \rightarrow H^- + (H + H^+)$



Dissociative Double Ionization Cross Sections for

$H^+ + H_2 \rightarrow H^+ + H^+ + H^+ + 2e$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+05	4.39E+08	3.96E-19
1.5E+05	5.38E+08	1.79E-19
2.0E+05	6.21E+08	1.02E-19
3.0E+05	7.61E+08	4.90E-20
7.0E+05	1.16E+09	1.17E-20
1.0E+06	1.39E+09	7.16E-21
1.5E+06	1.70E+09	4.30E-21
2.0E+06	1.96E+09	3.26E-21
3.0E+06	2.40E+09	2.49E-21

Reference: 365

Accuracy: Within factor of 4

Note: The data are reported for the H_2 internuclear axis oriented at 90° and 30° relative to the ion beam direction and no apparent difference was found between the measured cross section values.

Chebyshev Fitting Parameters for Cross Sections

E_{min} = 1.0E+05 eV/amu, E_{max} = 3.0E+06 eV/amu

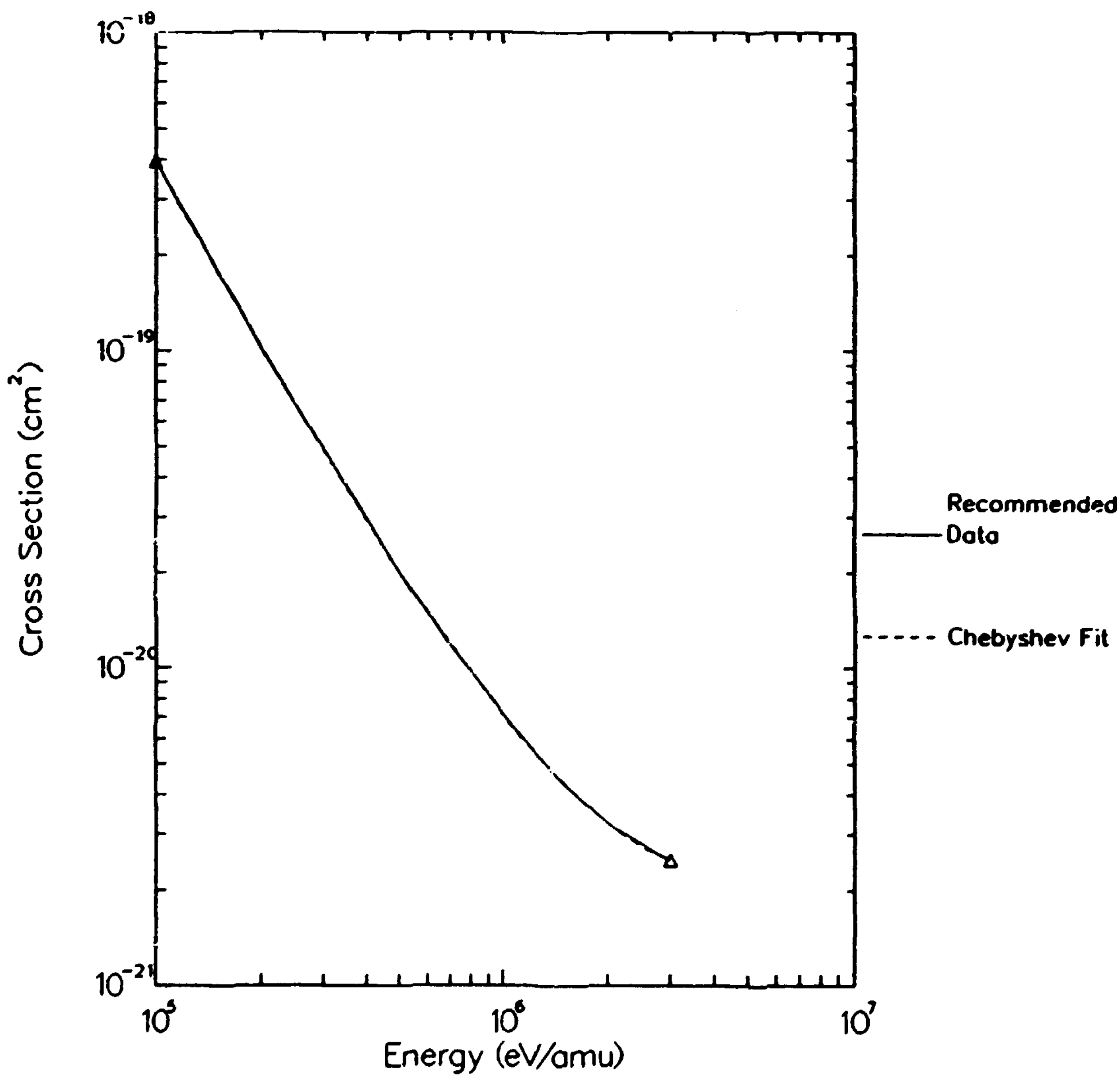
A0	A1	A2	A3	A4	A5	A6
-90.4247	-2.58979	.296205	.0536430	.00747606	.00133207	.00152342

The fit represents the above cross section with an rms deviation of 0.6%. The maximum deviation is 0.9% at 2.0E+05 eV/amu.

See appendix for Chebyshev fit details.

$H^+ + H_2 \rightarrow H^+ + H^+ + H^+ + 2e$

Cross Section vs. Energy



Cross Sections for the Dissociative Double Ionization of H_2 By Fast He^+

$He^+ + H_2 \rightarrow He^+ + H^+ + H^+ + 2e$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.5E+03	6.95E+07	5.00E-18
3.0E+03	7.61E+07	4.22E-18
4.0E+03	8.79E+07	3.12E-18
7.0E+03	1.16E+08	1.62E-18
1.0E+04	1.39E+08	1.02E-18
1.5E+04	1.70E+08	5.89E-19
2.0E+04	1.96E+08	3.91E-19
4.0E+04	2.78E+08	1.40E-19
7.0E+04	3.68E+08	5.95E-20
9.0E+04	4.17E+08	4.02E-20

Reference: 482

Accuracy: The absolute cross section values are estimated to within a factor of 4.

Note: The data are reported for the H_2 internuclear axis oriented at 90° and 30° relative to the ion beam direction, and no apparent difference was found between the cross section values.

Chebyshev Fitting Parameters for Cross Sections

E_{min} = 2.5E+03 eV/amu, E_{max} = 9.0E+04 eV/amu

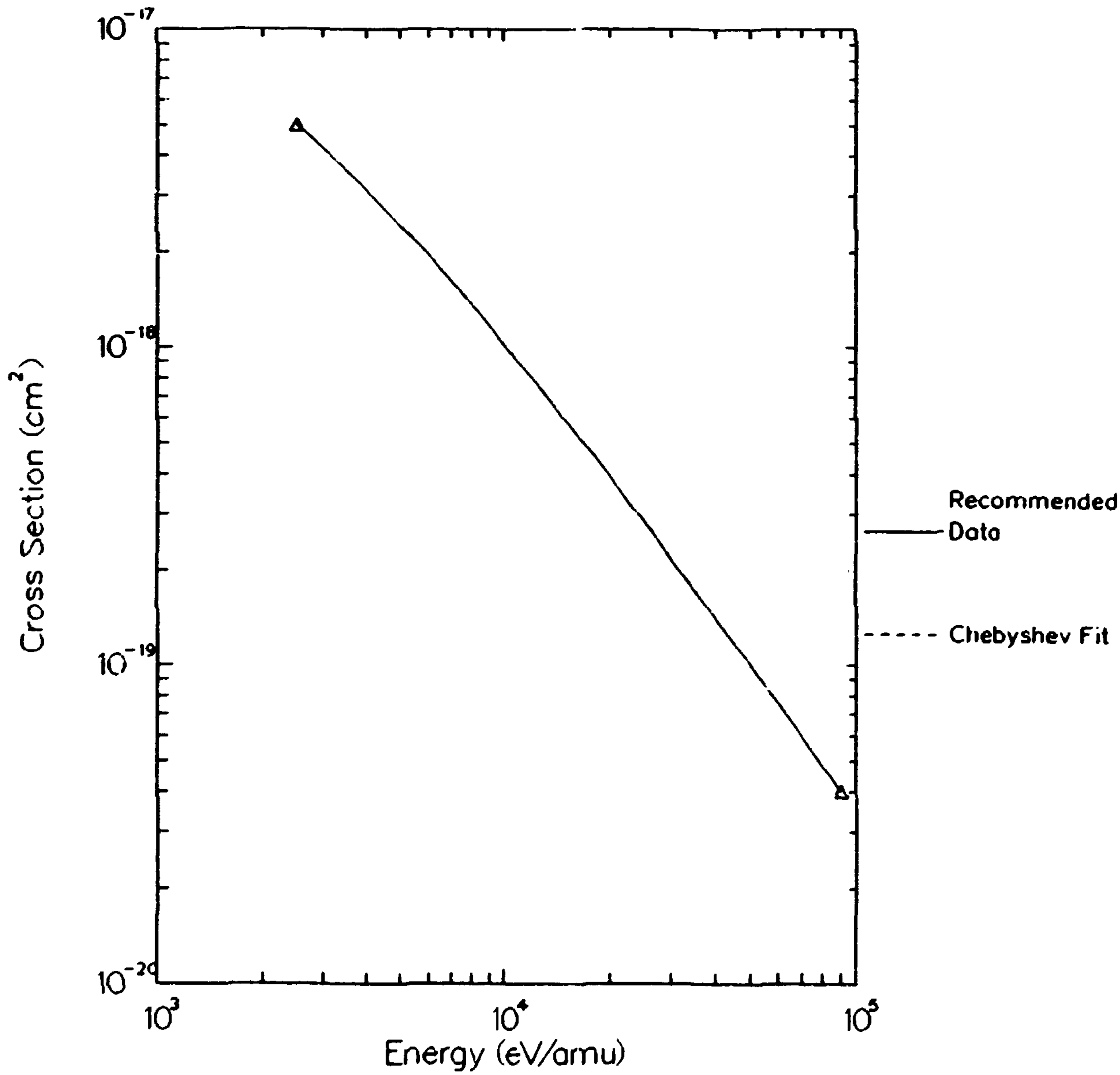
A0	A1	A2	A3	A4	A5	A6
-84.2206	-2.43620	-.134853	.0237772	-.00240081	.000622206	-.00103783

The fit represents the above cross section with an rms deviation of 0.1%. The maximum deviation is 0.2% at 1.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^{+} + H_2 \rightarrow He^{+} + H^{+} + H^{+} + 2e$

Cross Section vs. Energy



Cross Sections for the Dissociative Ionization of H_2 by Fast He^{2+}

$$He^{2+} + H_2 \rightarrow He^{2+} + (H^+ + H) + e$$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
3.8E+03	8.56E+07	1.10E-19
4.0E+03	8.79E+07	1.38E-19
5.0E+03	9.82E+07	2.74E-19
6.0E+03	1.08E+08	4.31E-19
7.0E+03	1.16E+08	5.63E-19
8.0E+03	1.24E+08	6.27E-19
9.0E+03	1.32E+08	6.48E-19
1.0E+04	1.39E+08	6.57E-19
1.5E+04	1.70E+08	6.65E-19
2.0E+04	1.96E+08	1.04E-18
2.5E+04	2.20E+08	1.81E-18

Reference: 95

Accuracy: 20%

Note: These cross sections values refer to the ionization with dissociation of H_2 via the $1s\sigma_g$ state of the H_2^+ ion.

Chebyshev Fitting Parameters for Cross Sections

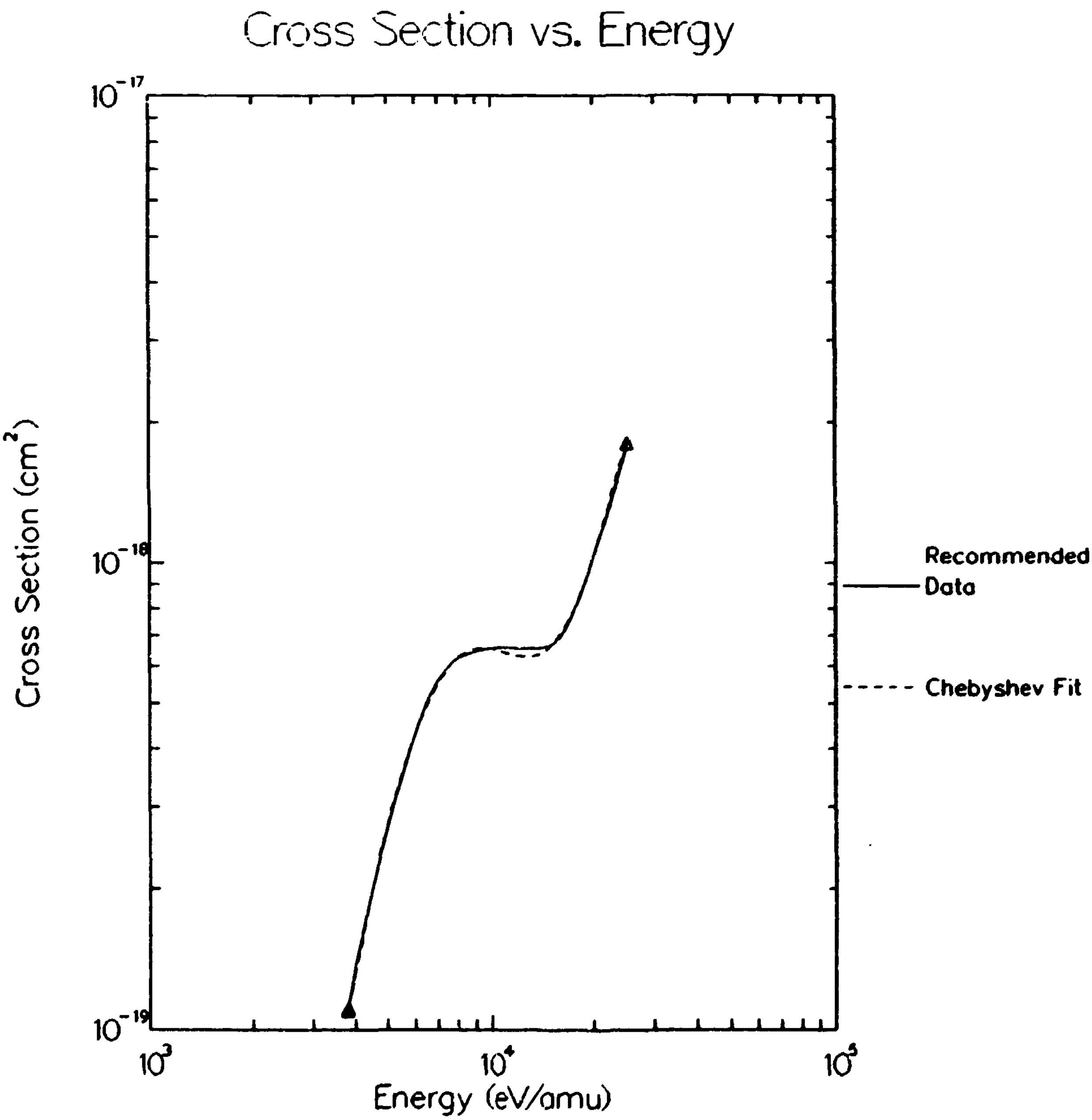
E_{min} = 3.8E+03 eV/amu, E_{max} = 2.5E+04 eV/amu

A0	A1	A2	A3	A4	A5	A6
-84.1813	1.12091	-.170391	.319582	.0335842	-.0467173	-.0198799

The fit represents the above cross section with an rms deviation of 1.0%. The maximum deviation is 1.3% at 5.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$He^{2+} + H_2 \rightarrow He^{2+} + (H^+ + H) + e$



Cross Sections for the Dissociative Ionization of H_2 by Fast He^{2+}

$$He^{2+} + H_2 \rightarrow He^{2+} + (H^+ + H) + e$$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.5E+03	6.95E+07	1.46E-19
3.0E+03	7.61E+07	2.05E-19
4.0E+03	8.79E+07	4.28E-19
5.0E+03	9.82E+07	7.94E-19
6.0E+03	1.08E+08	1.05E-18
7.0E+03	1.16E+08	1.23E-18
8.0E+03	1.24E+08	1.35E-18
9.0E+03	1.32E+08	1.42E-18
1.0E+04	1.39E+08	1.46E-18
1.5E+04	1.70E+08	1.53E-18
2.0E+04	1.96E+08	2.23E-18
2.5E+04	2.20E+08	3.13E-18
3.0E+04	2.41E+08	4.22E-18

Reference: 95

Accuracy: 30%

Notes: (1) The cross section values are for the ionization with dissociation of H_2 via the $2p\sigma_u$ state of H_2^+. See reference 95. (2) The measured energy of the slow ion is approximately 7 eV.

Chebyshev Fitting Parameters for Cross Sections

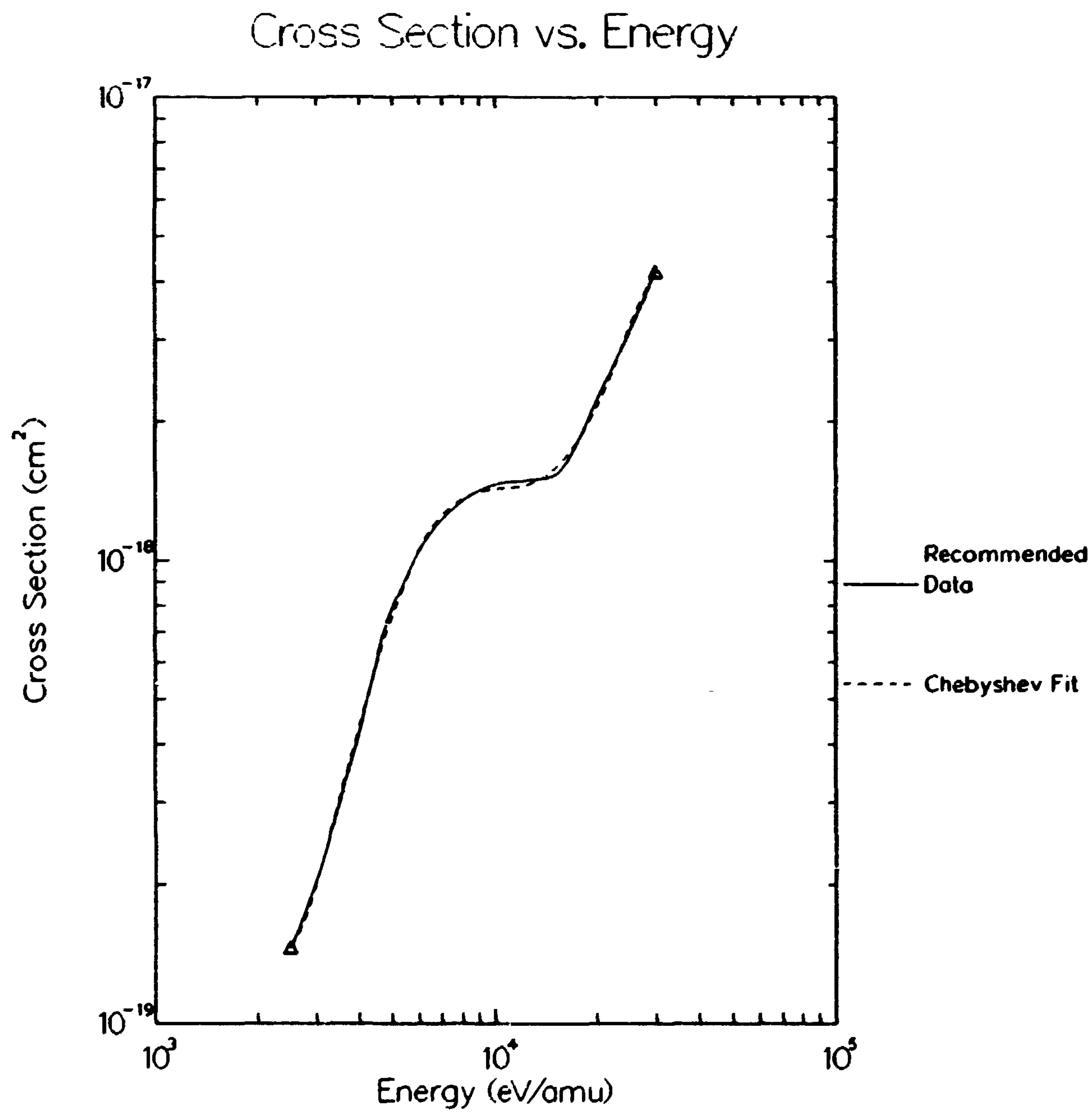
E_{min} = 2.5E+03 eV/amu, E_{max} = 3.0E+04 eV/amu

A0	A1	A2	A3	A4	A5	A6
-82.9850	1.52994	-.280153	.246249	.0922114	-.0977812	-.00881272

The fit represents the above cross section with an rms deviation of 2.1%. The maximum deviation is 2.9% at 1.5E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^{2+} + H_2 \rightarrow He^{2+} + (H^+ + H) + e$



Cross Sections for Dissociative Electron Capture from H_2 By Fast He^{2+}

$$He^{2+} + H_2 \rightarrow He^{+} + (H^{+} + H)$$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.3E+03	5.01E+07	2.77E-18
1.5E+03	5.38E+07	3.01E-18
2.0E+03	6.21E+07	3.47E-18
3.0E+03	7.61E+07	4.37E-18
4.0E+03	8.79E+07	5.25E-18
5.0E+03	9.82E+07	6.17E-18
6.0E+03	1.08E+08	6.96E-18
7.0E+03	1.16E+08	7.79E-18
8.0E+03	1.24E+08	8.51E-18
9.0E+03	1.32E+08	9.31E-18
1.0E+04	1.39E+08	1.02E-17
1.5E+04	1.70E+08	1.27E-17
2.0E+04	1.96E+08	1.29E-17
2.5E+04	2.20E+08	1.29E-17

Reference: 95

Accuracy: 20%

Note: The cross section values are for capture with dissociation from the $1s\sigma_g$ state of the H_2^{+} ion.

Chebyshev Fitting Parameters for Cross Sections

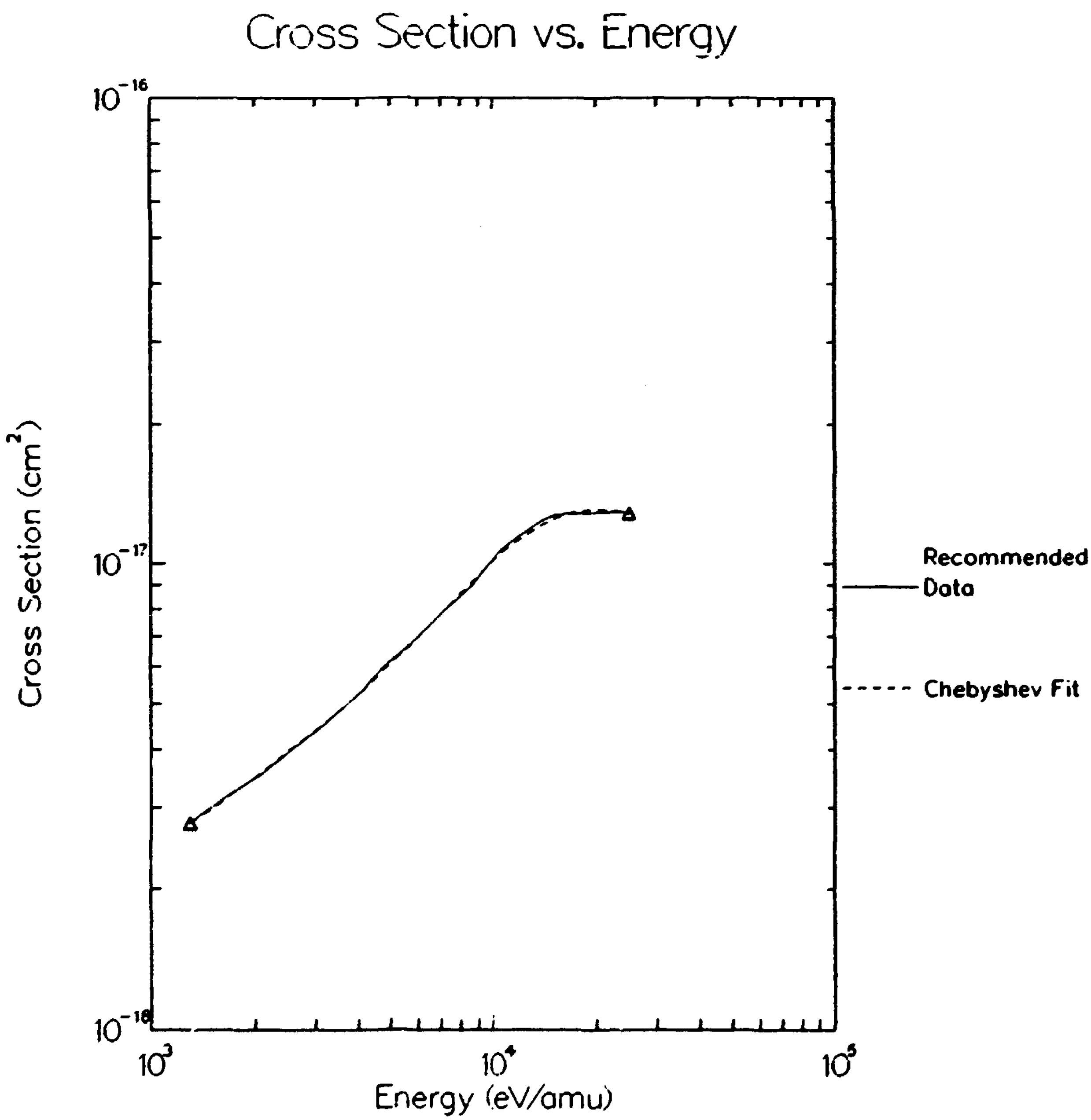
E_{min} = 1.3E+03 eV/amu, E_{max} = 2.5E+04 eV/amu

A0	A1	A2	A3	A4	A5	A6
-79.1499	.840316	-.0633082	-.0781071	-.0271766	.00205805	.00727217

The fit represents the above cross section with an rms deviation of 1.0%. The maximum deviation is 1.5% at 2.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$He^{2+} + H_2 \rightarrow He^{+} + (H^{+} + H)$



Cross Sections for Dissociative Electron Capture with Ionization in Collisions of Fast He^{2+} with H_2

$$He^{2+} + H_2 \rightarrow He^{+} + (H^{+} + H^{+}) + e$$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.2E+03	4.81E+07	1.10E-16
1.5E+03	5.38E+07	1.01E-16
2.0E+03	6.21E+07	8.84E-17
2.5E+03	6.95E+07	8.01E-17
3.0E+03	7.61E+07	7.47E-17
3.5E+03	8.22E+07	6.84E-17
4.0E+03	8.79E+07	6.01E-17
5.0E+03	9.82E+07	5.04E-17
6.0E+03	1.08E+08	4.90E-17
7.0E+03	1.16E+08	5.11E-17
8.0E+03	1.24E+08	5.53E-17
9.0E+03	1.32E+08	6.10E-17
1.0E+04	1.39E+08	6.54E-17
1.5E+04	1.70E+08	7.88E-17
2.0E+04	1.96E+08	8.57E-17
2.5E+04	2.20E+08	8.70E-17

Reference: 95

Accuracy: 30%

Note: The measured energy of the slow H^{+} ions is approximately 9 eV.

Chebyshev Fitting Parameters for Cross Sections

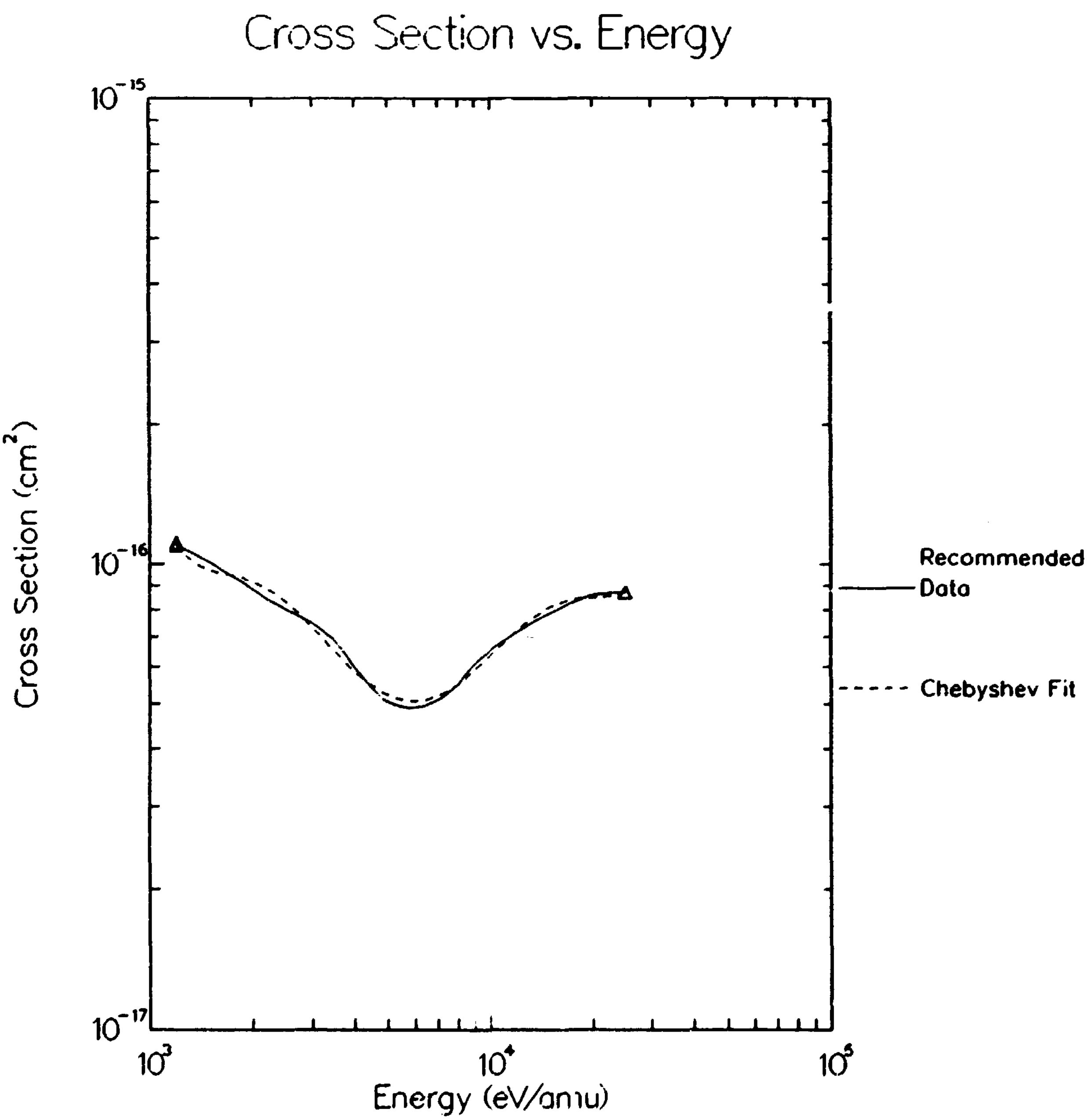
E_{min} = 1.2E+03 eV/amu, E_{max} = 2.5E+04 eV/amu

A0	A1	A2	A3	A4	A5	A6
-74.1562	-.104398	.277805	.00632922	-.107311	-.0247870	.0511068

The fit represents the above cross section with an rms deviation of 2.9%. The maximum deviation is 3.9% at 2.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$He^{2+} + H_2 \rightarrow He^{+} + (H^{+} + H^{+}) + e$



Cross Sections for Double (Dissociative) Ionization of H_2 By Fast He^{2+}

$$He^{2+} + H_2 \rightarrow He^{2+} + (H^+ + H^+) + 2e$$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.5E+03	6.95E+07	1.44E-19
3.0E+03	7.61E+07	2.15E-19
4.0E+03	8.79E+07	4.24E-19
5.0E+03	9.82E+07	7.90E-19
6.0E+03	1.08E+08	1.07E-18
7.0E+03	1.16E+08	1.25E-18
8.0E+03	1.24E+08	1.35E-18
9.0E+03	1.32E+08	1.39E-18
1.0E+04	1.39E+08	1.44E-18
1.5E+04	1.70E+08	1.52E-18
2.0E+04	1.96E+08	2.24E-18
3.0E+04	2.41E+08	4.23E-18

Reference: 95

Accuracy: 30%

Note: The measured energy of the slow H^+ ions is approximately 9 eV.

Chebyshev Fitting Parameters for Cross Sections

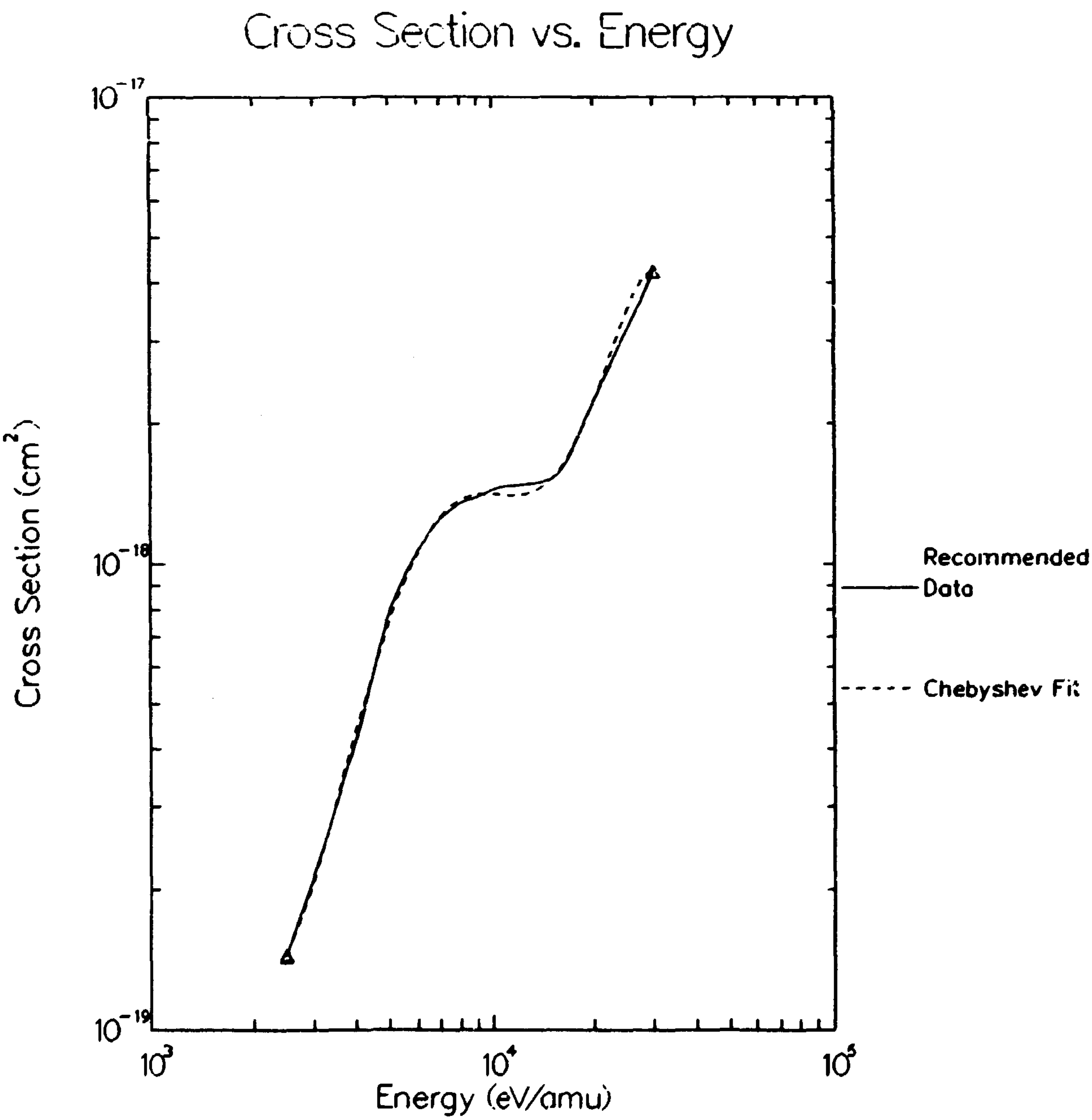
E_{min} = 2.5E+03 eV/amu, E_{max} = 3.0E+04 eV/amu

A0	A1	A2	A3	A4	A5	A6
-82.9515	1.54494	-.254833	.255864	.0749613	-.113726	-.0359609

The fit represents the above cross section with an rms deviation of 2.0%. The maximum deviation is 4.4% at 4.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$He^{2+} + H_2 \rightarrow He^{2+} + (H^+ + H^+) + 2e$



Cross Sections for (Dissociative) Double Electron Capture from H_2 By Fast He^{2+}

$$He^{2+} + H_2 \rightarrow He + (H^+ + H^+)$$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.1E+03	4.61E+07	5.15E-17
1.5E+03	5.38E+07	3.00E-17
2.0E+03	6.21E+07	1.70E-17
2.5E+03	6.95E+07	1.45E-17
3.0E+03	7.61E+07	1.42E-17
4.0E+03	8.79E+07	1.68E-17
5.0E+03	9.82E+07	2.14E-17
6.0E+03	1.08E+08	2.55E-17
7.0E+03	1.16E+08	2.90E-17
8.0E+03	1.24E+08	3.23E-17
9.0E+03	1.32E+08	3.49E-17
1.0E+04	1.39E+08	3.75E-17
1.5E+04	1.70E+08	4.42E-17
2.0E+04	1.96E+08	4.59E-17
2.5E+04	2.20E+08	4.48E-17

<u>Reference:</u> 95

<u>Accuracy:</u> 15%

<u>Notes:</u> None

<u>Chebyshev Fitting Parameters for Cross Sections</u>

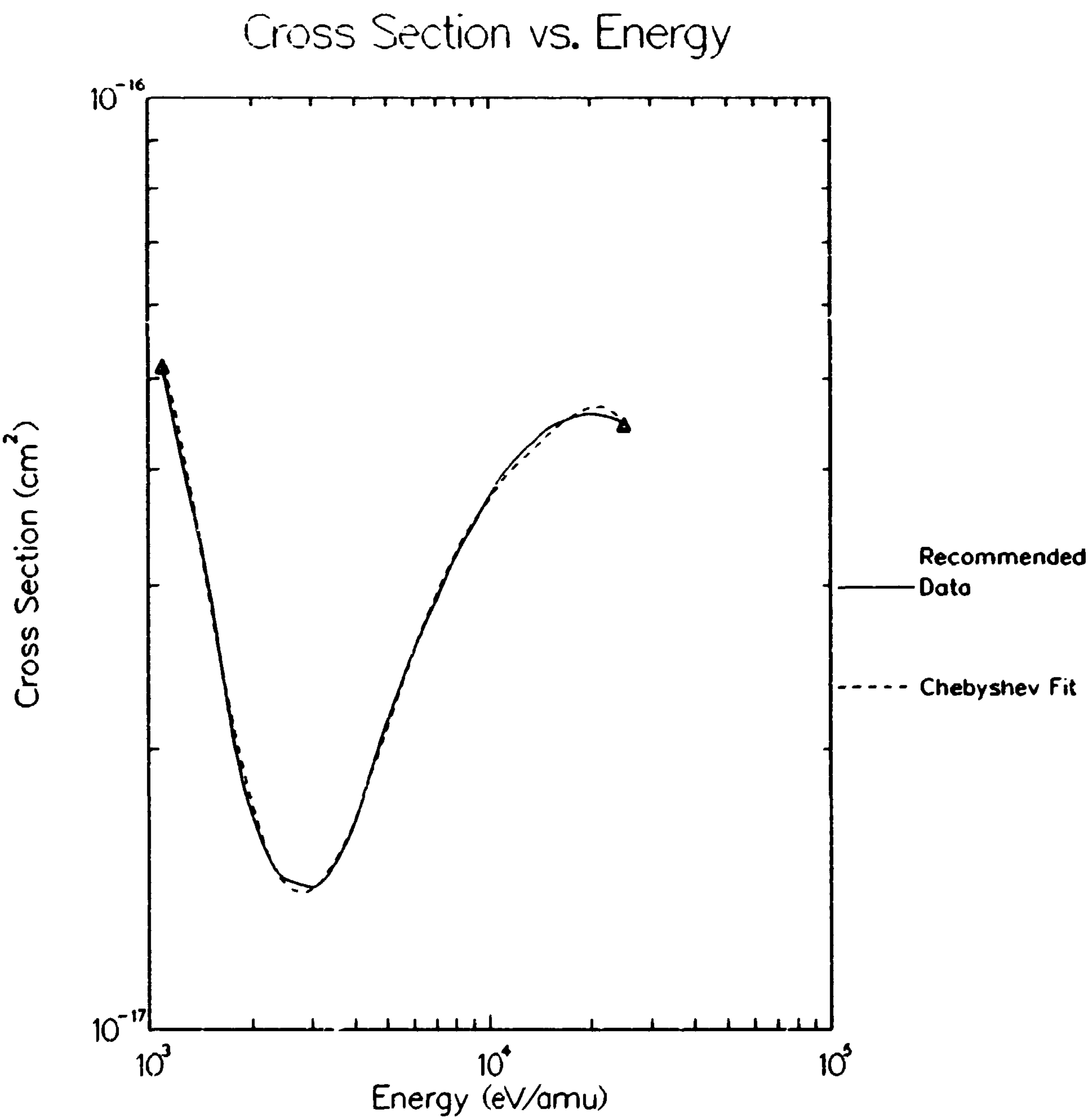
E_{min} = 1.1E+03 eV/amu, E_{max} = 2.5E+04 eV/amu

A0	A1	A2	A3	A4	A5	A6
-75.9688	.211347	.437455	-.355845	.0231353	.0708411	-.0517123

The fit represents the above cross section with an rms deviation of 1.7%. The maximum deviation is 2.9% at 2.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$He^{2+} + H_2 \rightarrow He + (H^+ + H^+)$



Cross Sections for the Conversion of Fast H_2^+ Ions Into Fast Protons in Passage Through H_2

$$H_2^+ + H_2 \rightarrow H^+_{Proj.}$$

Low Energy		High Energy	
Energy (eV/amu)	Cross Section (cm^2)	Energy (eV/amu)	Cross Section (cm^2)
1.6E+00	3.31E-17	1.5E+03	2.09E-16
2.0E+00	6.46E-17	2.0E+03	2.26E-16
2.5E+00	8.09E-17	4.0E+03	2.42E-16
3.0E+00	8.66E-17	7.0E+03	2.31E-16
3.5E+00	8.67E-17	1.0E+04	2.13E-16
4.0E+00	8.58E-17	1.5E+04	1.88E-16
4.5E+00	8.33E-17	1.8E+04	1.80E-16
5.0E+00	7.96E-17	2.0E+04	1.86E-16
		3.0E+04	2.23E-16
		4.0E+04	2.30E-16
		5.0E+04	2.26E-16
		8.0E+04	1.99E-16
		1.0E+05	1.80E-16
		1.5E+05	1.46E-16
		2.0E+05	1.21E-16
		4.0E+05	7.43E-17
		7.0E+05	4.22E-17
		1.0E+06	2.70E-17
		1.5E+06	1.46E-17
		2.0E+06	1.11E-17
		4.0E+06	6.21E-18
		7.0E+06	4.11E-18
		1.0E+07	3.28E-18

References: 86, 208, 210, 214, 218, 219, 527, 528, 531, 557, 558, 559, 571, 590

Accuracy: 25%

Note: No attempt has been made to interpolate between the low-energy data and the data taken at higher energies.

Chebyshev Fitting Parameters for Cross Sections

Low Energy E_{min} = 1.6E+00 eV/amu, E_{max} = 5.0E+00 eV/amu
High Energy E_{min} = 1.5E+03 eV/amu, E_{max} = 1.0E+07 eV/amu

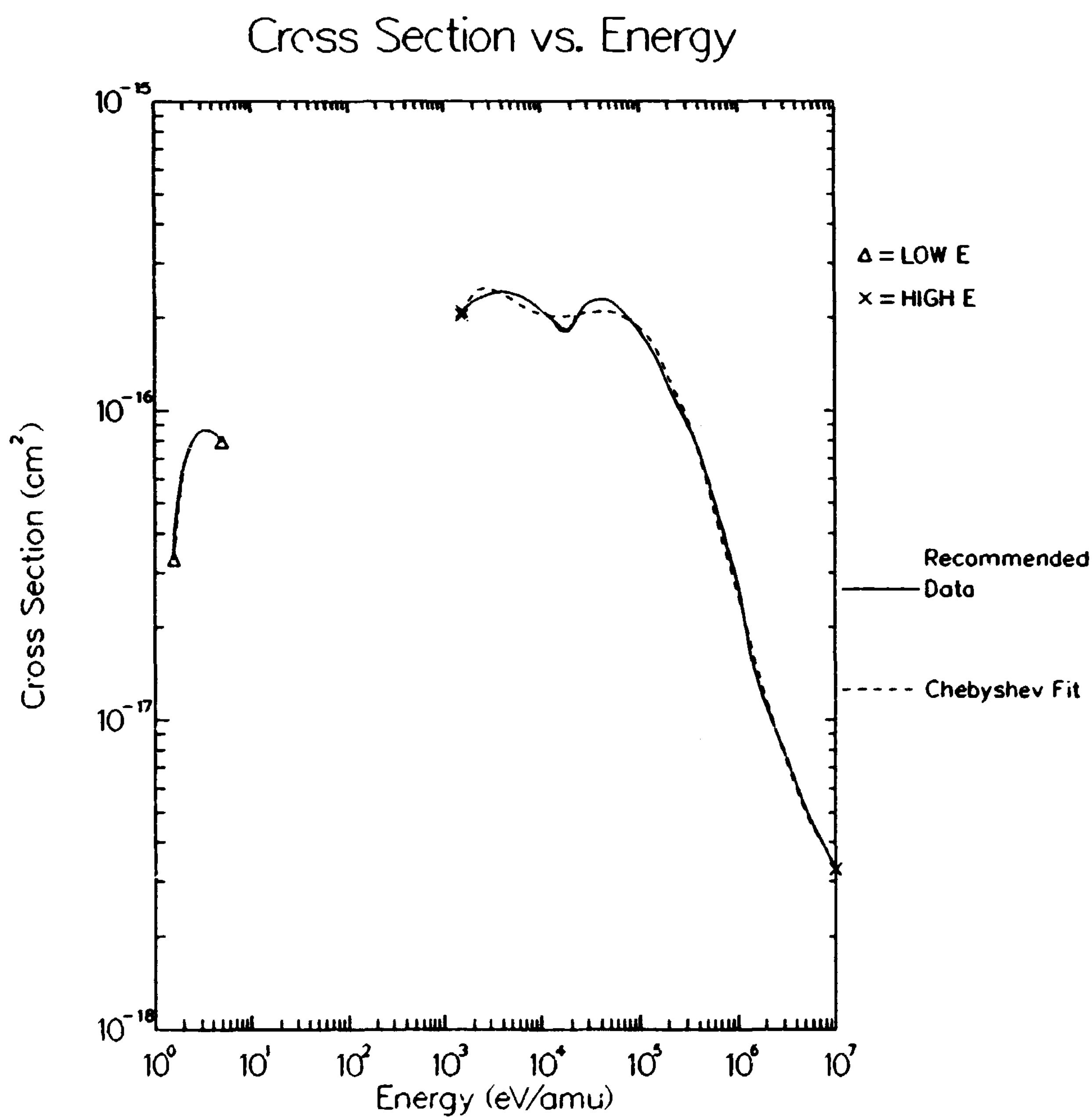
	A0	A1	A2	A3	A4	A5	A6
Low Energy	-74.4493	.351878	-.249279	.0781924	-.0295527	.00853617	-.00490330
High Energy	-74.9261	-2.19443	-.855834	.0421307	.216227	.0921147	-.0893079

The fit represents the Low Energy cross section with an rms deviation of 0.2%. The maximum deviation is 0.3% at 3.5E+00 eV/amu.

The fit represents the High Energy cross section with an rms deviation of 6.3%. The maximum deviation is 12.4% at 1.8E+04 eV/amu.

See appendix for Chebyshev fit details.

$H_2^+ + H_2 \rightarrow H^+_{Proj.}$



Cross Sections for the Conversion of Fast H_2^+ Ions Into Fast Protons in Passage Through H Atoms

$H_2^+ + H \rightarrow H^+_{Proj.}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.5E+03	5.38E+07	1.60E-16
2.0E+03	6.21E+07	1.83E-16
4.0E+03	8.79E+07	2.16E-16
7.0E+03	1.16E+08	2.20E-16
1.0E+04	1.39E+08	2.15E-16
1.5E+04	1.70E+08	2.06E-16
2.0E+04	1.96E+08	1.96E-16
4.0E+04	2.78E+08	1.69E-16
5.0E+04	3.11E+08	1.59E-16

Reference: 599

Accuracy: 25%

Notes: None

Chebyshev Fitting Parameters for Cross Sections

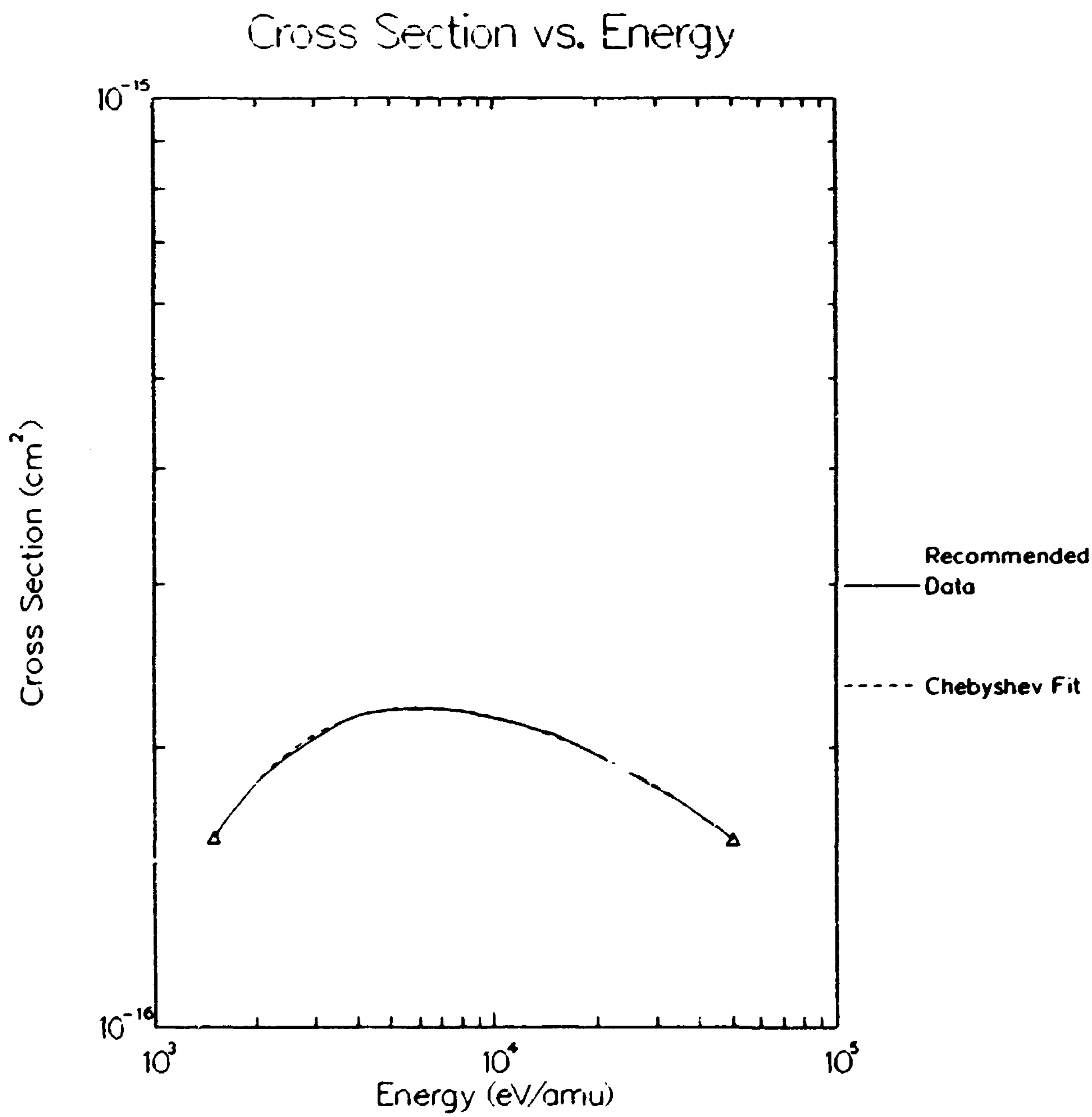
E_{min} = 1.5E+03 eV/amu, E_{max} = 5.0E+04 eV/amu

A0	A1	A2	A3	A4	A5	A6
-72.4228	-.0319629	-.156039	.0287214	-.00752456	.000228203	.000526627

The fit represents the above cross section with an rms deviation of 0.1%. The maximum deviation is 0.2% at 2.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$H_2^+ + H \rightarrow H^+_{Proj.}$



Cross Section for the Formation of Fast H Atoms by Passage of H_2^+ Through H_2

$H_2^+ + H_2 \rightarrow H_{proj.}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.0E+03	6.21E+07	4.98E-16
4.0E+03	8.79E+07	7.09E-16
7.0E+03	1.16E+08	8.12E-16
1.0E+04	1.39E+08	8.22E-16
1.5E+04	1.70E+08	8.05E-16
2.0E+04	1.96E+08	7.44E-16
4.0E+04	2.78E+08	4.70E-16
7.0E+04	3.68E+08	2.21E-16
1.0E+05	4.39E+08	1.21E-16

References: 208, 210, 214, 218, 219, 271

Accuracy: 20%

Note: The data refer to the sum of the cross sections for $H_2^+ + H_2 \rightarrow (H^+ + H)_{proj.}$ and $H_2^+ + H_2 \rightarrow (H + H)_{proj.}$.

Chebyshev Fitting Parameters for Cross Sections

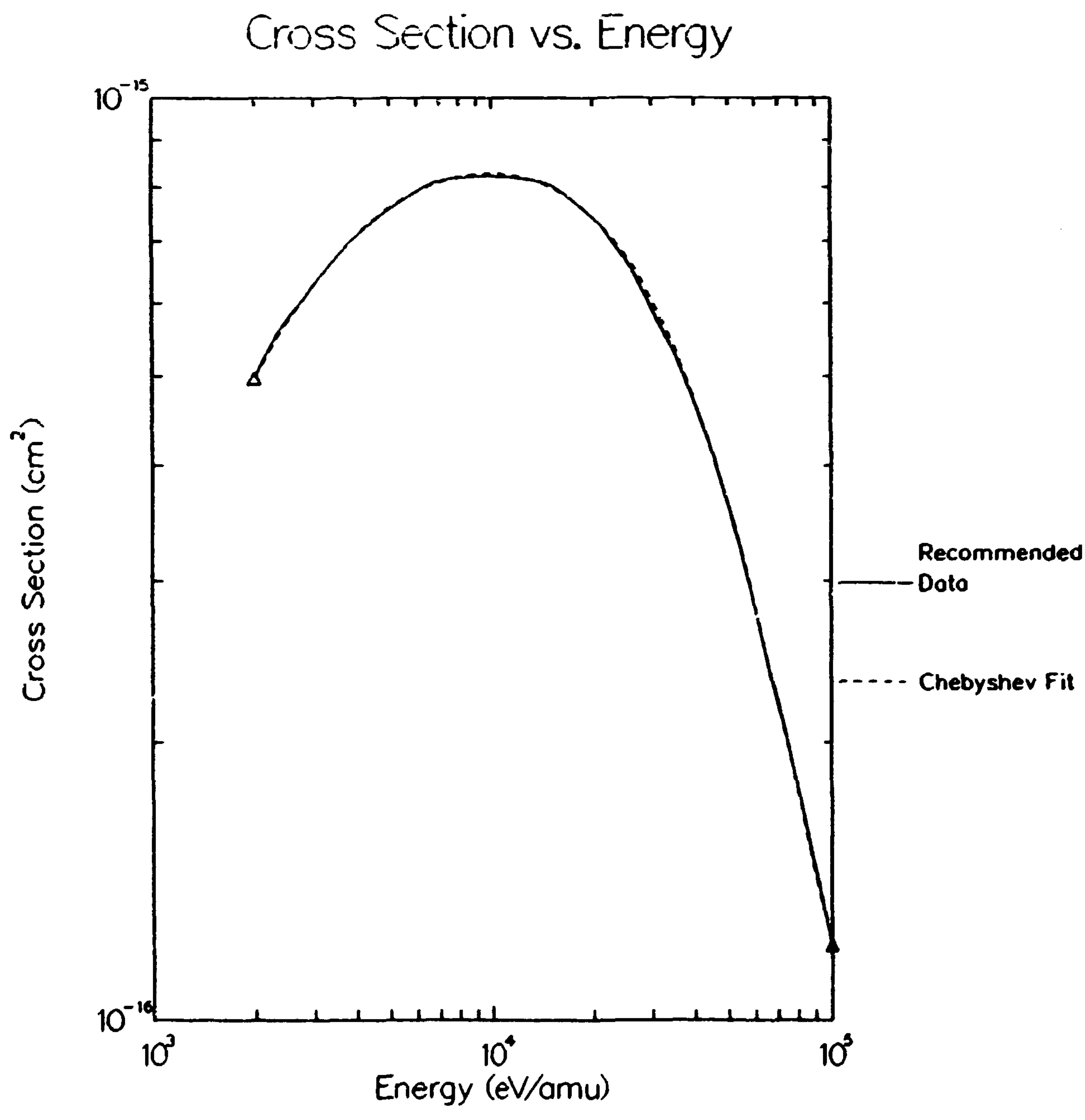
E_{min} = 2.0E+03 eV/amu, E_{max} = 1.0E+05 eV/amu

A0	A1	A2	A3	A4	A5	A6
-70.6702	-.632612	-.606521	-.0915143	-.0121710	.0168179	.0104797

The fit represents the above cross section with an rms deviation of 0.3%. The maximum deviation is 0.6% at 1.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$H_2^+ + H_2 \rightarrow H_{Proj.}$



Partial Cross Sections for Dissociation of Fast H_2^+ Ions in Passage Through H_2

$$H_2^+ + H_2 \rightarrow (H^+ + H) + H_2$$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+01	4.39E+06	6.14E-17
2.0E+01	6.21E+06	6.58E-17
4.0E+01	8.79E+06	6.96E-17
7.0E+01	1.16E+07	7.64E-17
1.0E+02	1.39E+07	8.16E-17
1.5E+02	1.70E+07	9.19E-17
2.0E+02	1.96E+07	1.01E-16
4.0E+02	2.78E+07	1.24E-16
7.0E+02	3.68E+07	1.47E-16
1.0E+03	4.39E+07	1.60E-16
1.5E+03	5.38E+07	1.65E-16
2.0E+03	6.21E+07	1.67E-16
4.0E+03	8.79E+07	1.68E-16
7.0E+03	1.16E+08	1.67E-16
1.0E+04	1.39E+08	1.65E-16
1.5E+04	1.70E+08	1.55E-16
2.0E+04	1.96E+08	1.47E-16
4.0E+04	2.78E+08	1.13E-16
7.0E+04	3.68E+08	8.34E-17
1.0E+05	4.39E+08	6.73E-17
1.5E+05	5.38E+08	5.12E-17
2.0E+05	6.21E+08	4.22E-17
4.0E+05	8.78E+08	2.58E-17
7.0E+05	1.16E+09	1.74E-17
1.0E+06	1.39E+09	1.34E-17

<u>References:</u> 271, 527, 528, 529, 560, 589, 591

<u>Accuracy:</u> $E < 5\times10^4$ eV/amu, 40%
$E > 5\times10^4$ eV/amu, 20%

<u>Notes:</u> (1) At the lower impact energies, the results of the various investigators depend on the initial vibrational-state distributions of the H_2^+ ion. (2) In the eV range, H_2^+ projectiles were used with D_2 target and D_2^+ projectiles with H_2 target (see Ref. 589).

<u>Chebyshev Fitting Parameters for Cross Sections</u>

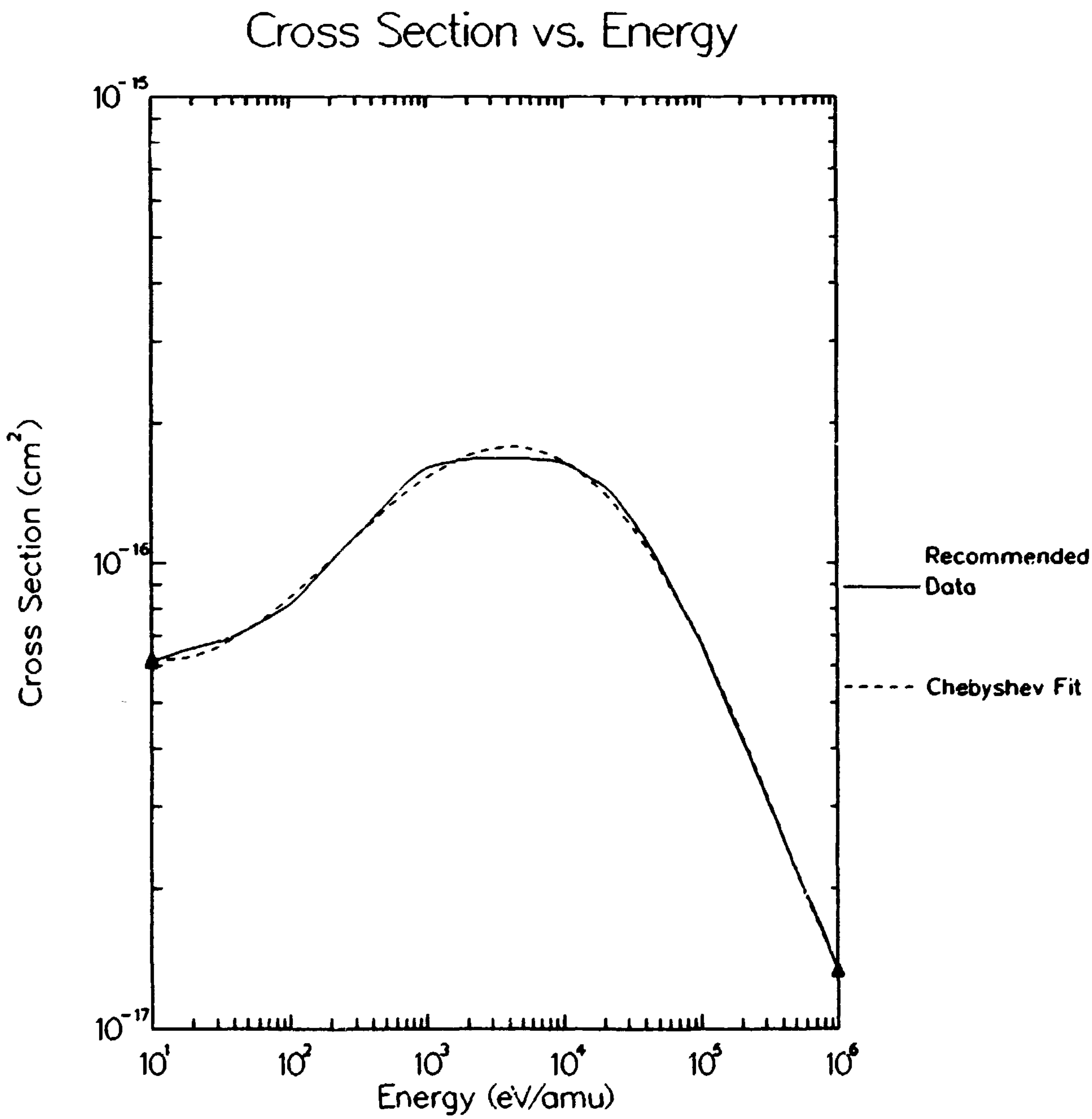
E_{min} = 1.0E+01 eV/amu, E_{max} = 1.0E+06 eV/amu

A0	A1	A2	A3	A4	A5	A6
-74.5723	-.555602	-.906658	-.238001	.110022	.0251065	.00343160

The fit represents the above cross section with an rms deviation of 2.6%. The maximum deviation is 5.8% at 4.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$H_2^+ + H_2 \rightarrow (H^+ + H) + H_2$



Cross Sections for the Formation of Fast Protons from H_2^+ in He

H_2^+ + He -> Total H^+

$\sigma_{H^+}(He)$

Energy (eV/amu)	Cross Section (cm^2)
1.0E+03	3.69E-17
1.5E+03	5.75E-17
2.0E+03	7.43E-17
4.0E+03	1.17E-16
7.0E+03	1.53E-16
1.0E+04	1.72E-16
1.5E+04	1.86E-16
2.0E+04	1.94E-16
3.0E+04	2.01E-16
3.5E+04	2.01E-16
4.0E+04	2.00E-16
7.0E+04	1.84E-16
1.0E+05	1.57E-16
1.5E+05	1.22E-16
2.0E+05	9.81E-17
4.0E+05	5.21E-17
6.0E+05	3.35E-17
6.5E+05	3.06E-17

References: 86, 527, 528, 531, 562, 570

Accuracy: 20%

Notes: (1) More recent cross-section data from Ref. 562 (between $2x10^3$ to $8x10^3$ eV/amu) exceed the earlier data by approximately 40% at $8x10^3$ eV/amu to approximately 360% at $2x10^3$ eV/amu. (2) $\sigma_{H^+}(He)$ refers to the sum: $\sigma(H^+ + H)_{Proj.} + 2\sigma(H^+ + H^+)_{Proj.}$

Chebyshev Fitting Parameters for Cross Sections

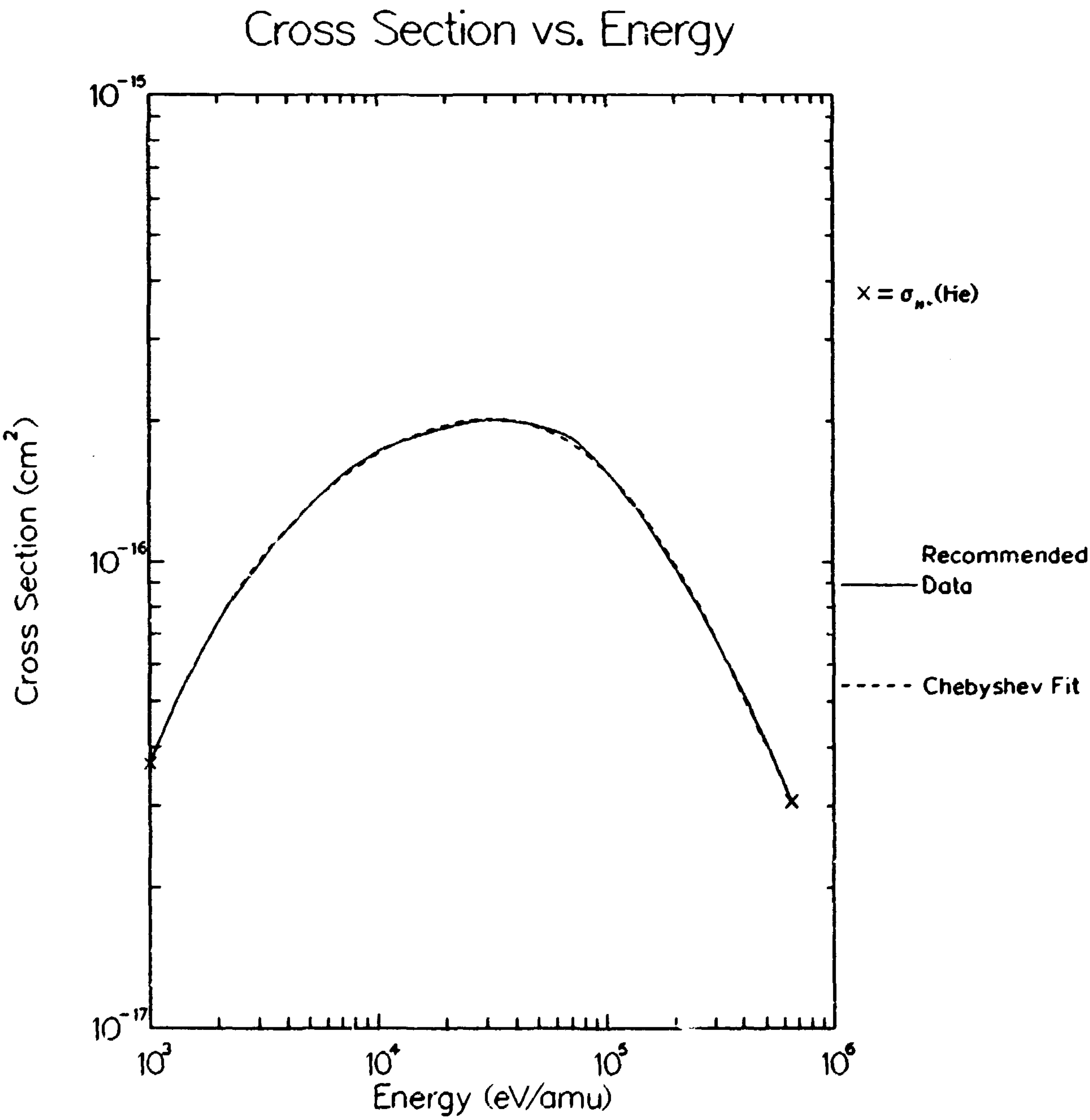
$\sigma_{H^+}(He)$ E_{min} = 1.0E+03 eV/amu, E_{max} = 6.5E+05 eV/amu

	A0	A1	A2	A3	A4	A5	A6
$\sigma_{H^+}(He)$	-74.0323	-.0812968	-.900960	-.0399950	-.0205556	.0309465	.00869410

The fit represents the σ_{H^+} cross section with an rms deviation of 1.0%. The maximum deviation is 1.4% at 2.0E+05 eV/amu.

See appendix for Chebyshev fit details.

$H_2^+ + He \rightarrow H^+$



Cross Sections for Dissociation of Fast H_2^+ Ions in Passage Through He

$$H_2^+ + He \rightarrow (H^+ + H) + He$$

Low Energy

Energy (eV/amu)	Cross Section (cm^2)
9.7E+00	6.55E-17
1.1E+01	6.55E-17
1.2E+01	6.55E-17
1.3E+01	6.56E-17
1.3E+01	6.56E-17
1.5E+01	6.56E-17
1.5E+01	6.56E-17
1.6E+01	6.56E-17
1.7E+01	6.61E-17
1.8E+01	6.57E-17
1.9E+01	6.55E-17
2.0E+01	6.59E-17
2.1E+01	6.59E-17
2.2E+01	6.58E-17
2.3E+01	6.57E-17
2.4E+01	6.55E-17

High Energy

Energy (eV/amu)	Cross Section (cm^2)
2.0E+03	2.11E-16
4.0E+03	1.93E-16
7.0E+03	1.69E-16
1.0E+04	1.46E-16
1.5E+04	1.22E-16
2.0E+04	1.07E-16
4.0E+04	7.35E-17
7.0E+04	5.39E-17
1.0E+05	4.46E-17
1.5E+05	3.35E-17
2.0E+05	2.68E-17
4.0E+05	1.51E-17
7.0E+05	8.82E-18
1.0E+06	6.37E-18

<u>References:</u> 527, 528, 560, 562

<u>Accuracy:</u> $E > 5x10^4$ eV/amu, 20%
$2x10^3 < E < 8x10^3$ eV/amu, 15% (see Ref. 562)
$E < 10^2$ eV/amu, Unknown

<u>Notes:</u> (1) At lower impact energies the results of the various investigators depend on the initial vibrational state distribution of the H_2^+ ion. (2) The data at 10 to 25 eV/amu were taken with D_2^+ instead of H_2^+ as the projectile. (3) No attempt has been made to interpolate between the low and high energy data.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

Low Energy E_{min} = 9.7E+00 eV/amu, E_{max} = 2.4E+01 eV/amu
High Energy E_{min} = 2.0E+03 eV/amu, E_{max} = 1.0E+06 eV/amu

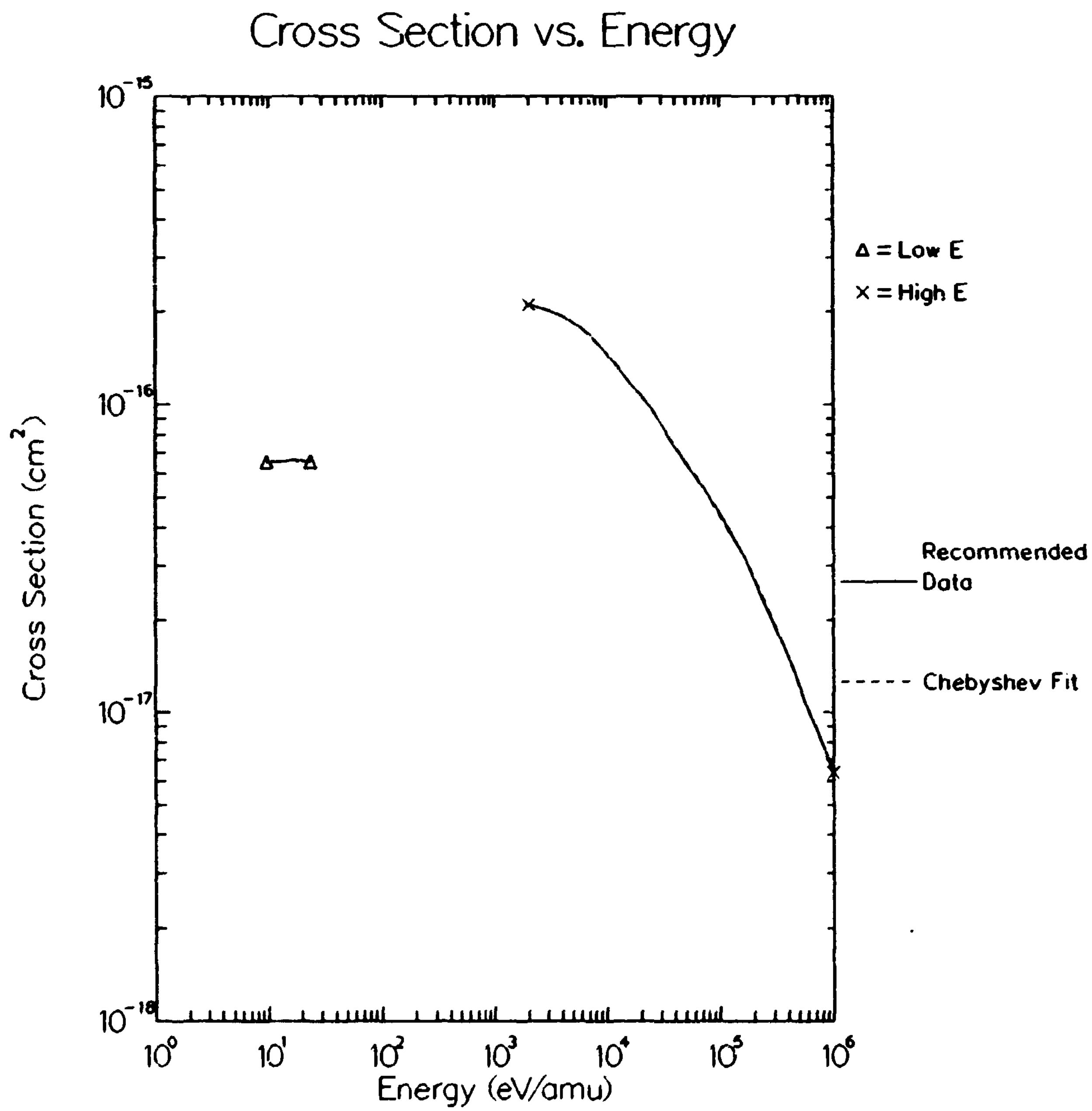
	A0	A1	A2	A3	A4	A5	A6
Low Energy	-74.5250	.00171327	-.000929677	-.00133213	-.000620656	-.000378036	-.000458557
High Energy	-75.0072	-1.76360	-.334933	.000919287	-.0200220	.0135139	.0139802

The fit represents the Low Energy cross section with an rms deviation of 0.2%. The maximum deviation is 0.4% at 1.9E+01 eV/amu.

The fit represents the High Energy cross section with an rms deviation of 0.8%. The maximum deviation is 1.3% at 2.0E+05 eV/amu.

See appendix for Chebyshev fit details.

$H_2^+ + He \rightarrow (H^+ + H) + He$



Cross Sections for Formation of Fast H^+ for Fast H_2 Projectiles Passing Through H_2

$H_2 + H_2 \rightarrow H^+$ (Fast,Total)

Low E Energy (eV/amu)	Low E Cross Section (cm^2)	High E Energy (eV/amu)	High E Cross Section (cm^2)
2.5E+03	2.04E-17	1.5E+05	6.13E-17
4.0E+03	2.62E-17	2.0E+05	4.61E-17
7.0E+03	3.61E-17	2.5E+05	3.70E-17
1.0E+04	4.52E-17	3.0E+05	3.13E-17
1.5E+04	5.74E-17	4.0E+05	2.56E-17
2.0E+04	6.71E-17	5.0E+05	2.25E-17
2.4E+04	6.89E-17	6.0E+05	2.12E-17
3.0E+04	6.25E-17		
4.0E+04	4.34E-17		
5.0E+04	2.80E-17		

References: 31, 535

Accuracy: Unknown

Notes: (1) The low energy data are from Ref. 31, while the high energy data are taken from Ref. 535. (2) This data involves the sum of the cross sections for the products: $\sigma(H^+ + H)_{Proj.} + 2\sigma(H^+ + H^+)_{Proj.} + \sigma(H^+ + H^-)_{Proj.}$. (3) No attempt has been made to join the high and low energy data sets.

Chebyshev Fitting Parameters for Cross Sections

Low E E_{min} = 2.5E+03 eV/amu, E_{max} = 5.0E+04 eV/amu
High E E_{min} = 1.5E+05 eV/amu, E_{max} = 6.0E+05 eV/amu

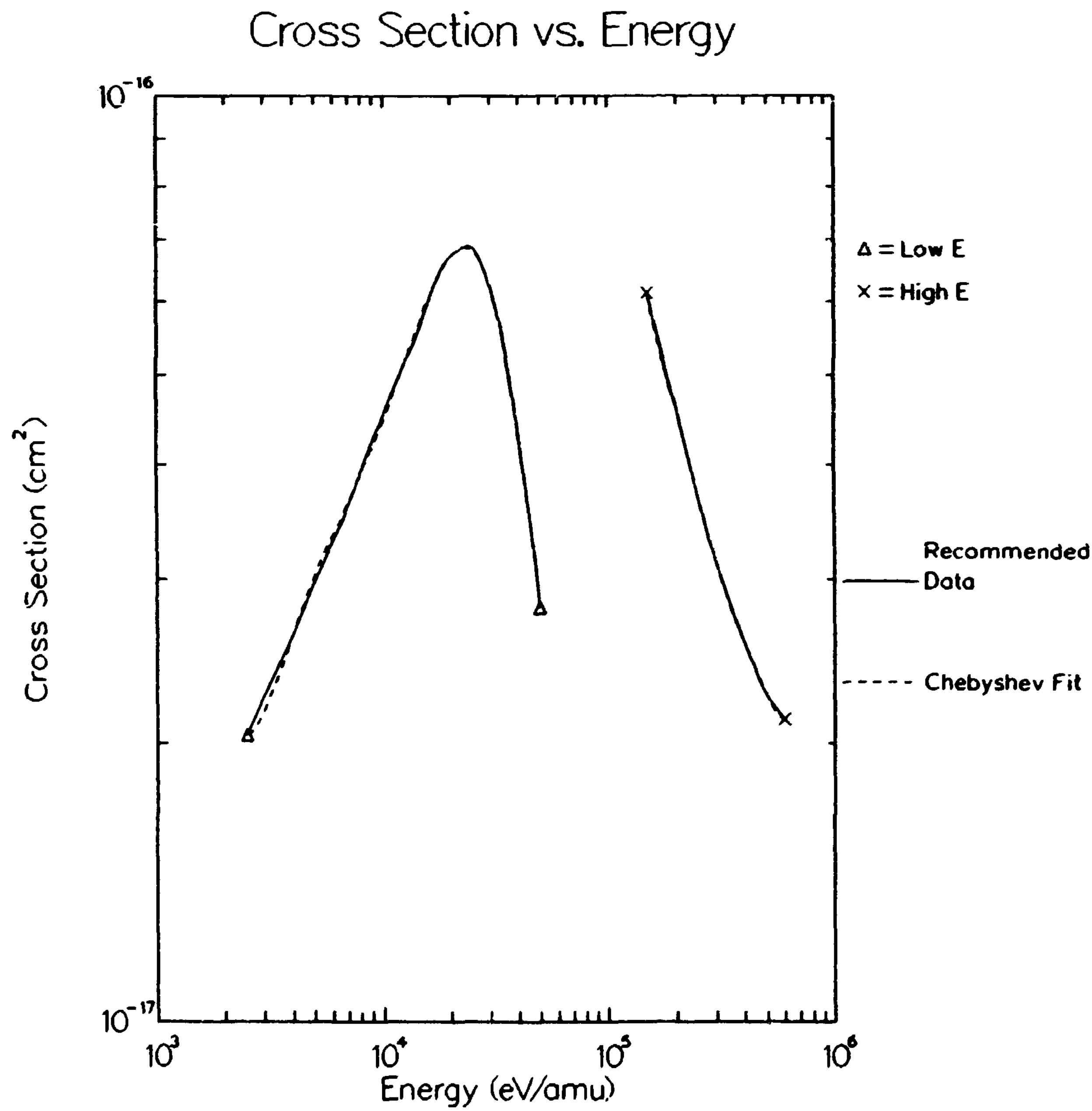
	A0	A1	A2	A3	A4	A5	A6
Low E	-75.7161	.371301	-.373363	-.209805	-.0677263	-.00389719	.0259767
High E	-75.8616	-.542987	.0642733	.0118753	-.00148111	.000221649	.00636358

The fit represents the Low E cross section with an rms deviation of 0.7%. The maximum deviation is 1.2% at 1.5E+04 eV/amu.

The fit represents the High E cross section with an rms deviation of 0.0%. The maximum deviation is 0.0% at 4.0E+05 eV/amu.

See appendix for Chebyshev fit details.

$H_2 + H_2 \rightarrow H^+$ (Fast, Total)



Cross Sections for the Formation of Fast H from Fast H_2 Projectiles Passing Through H_2

$H_2 + H_2 \rightarrow H$ (Fast,Total)

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.5E+03	6.95E+07	2.62E-16
3.0E+03	7.61E+07	2.89E-16
4.0E+03	8.79E+07	3.08E-16
5.0E+03	9.82E+07	3.08E-16
6.0E+03	1.08E+08	2.95E-16
7.0E+03	1.16E+08	2.85E-16
8.0E+03	1.24E+08	2.93E-16
9.0E+03	1.32E+08	3.13E-16
1.0E+04	1.39E+08	3.32E-16
1.3E+04	1.58E+08	3.46E-16
1.5E+04	1.70E+08	3.43E-16
2.0E+04	1.96E+08	3.16E-16
3.0E+04	2.41E+08	2.49E-16
4.0E+04	2.78E+08	2.00E-16
5.0E+04	3.11E+08	1.65E-16

References: 31, 536

Accuracy: 40%

Note: This data involves the sum of the cross sections for the products: $\sigma(H^+ + H)_{Proj.} + 2\sigma(H + H)_{Proj.}$. Variations in ion source conditions produce changes up to 10% in the measured values (see Ref. 536).

Chebyshev Fitting Parameters for Cross Sections

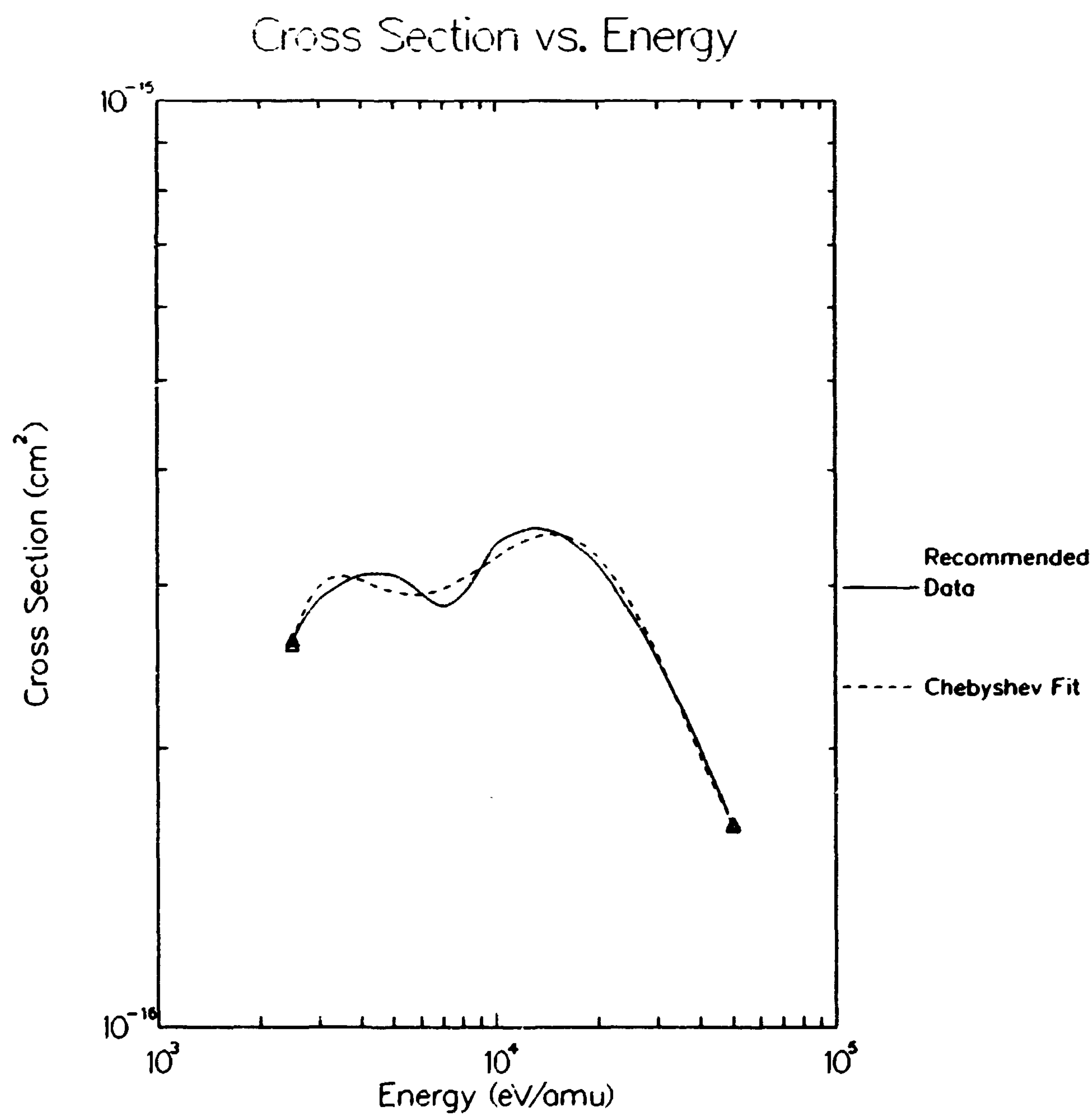
E_{min} = 2.5E+03 eV/amu, E_{max} = 5.0E+04 eV/amu

A0	A1	A2	A3	A4	A5	A6
-71.7329	-.200109	-.223241	-.0773361	-.0140887	.0563185	-.00955263

The fit represents the above cross section with an rms deviation of 2.5%. The maximum deviation is 4.4% at 7.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$H_2 + H_2 \rightarrow H$ (Fast, Total)



Total Destruction Cross Sections for Fast H_2 Projectile in H_2

$H_2 + H_2 \rightarrow$ Total Destruction of Fast H_2 Projectile

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.3E+03	5.01E+07	1.59E-16
1.5E+03	5.38E+07	1.64E-16
2.0E+03	6.21E+07	1.76E-16
4.0E+03	8.79E+07	2.16E-15
7.0E+03	1.16E+08	2.64E-16
1.0E+04	1.39E+08	3.09E-16
1.5E+04	1.70E+08	3.45E-16
2.0E+04	1.96E+08	3.52E-16
4.0E+04	2.78E+08	3.17E-16
5.0E+04	3.11E+08	2.92E-16

__Reference:__ 536

__Accuracy:__ 20%

__Notes:__ (1) This cross section is the sum of cross sections for all reactions that destroy the fast H_2 molecule in passage through H_2, i.e. those producing fast H_2^+, (H+H), ($H+H^+$), and ($H^+ + H^+$) products. (2) Large variations in ion source operating conditions were found to produce changes up to 10% in the measured cross section (see Ref. 536).

__Chebyshev Fitting Parameters for Cross Sections__

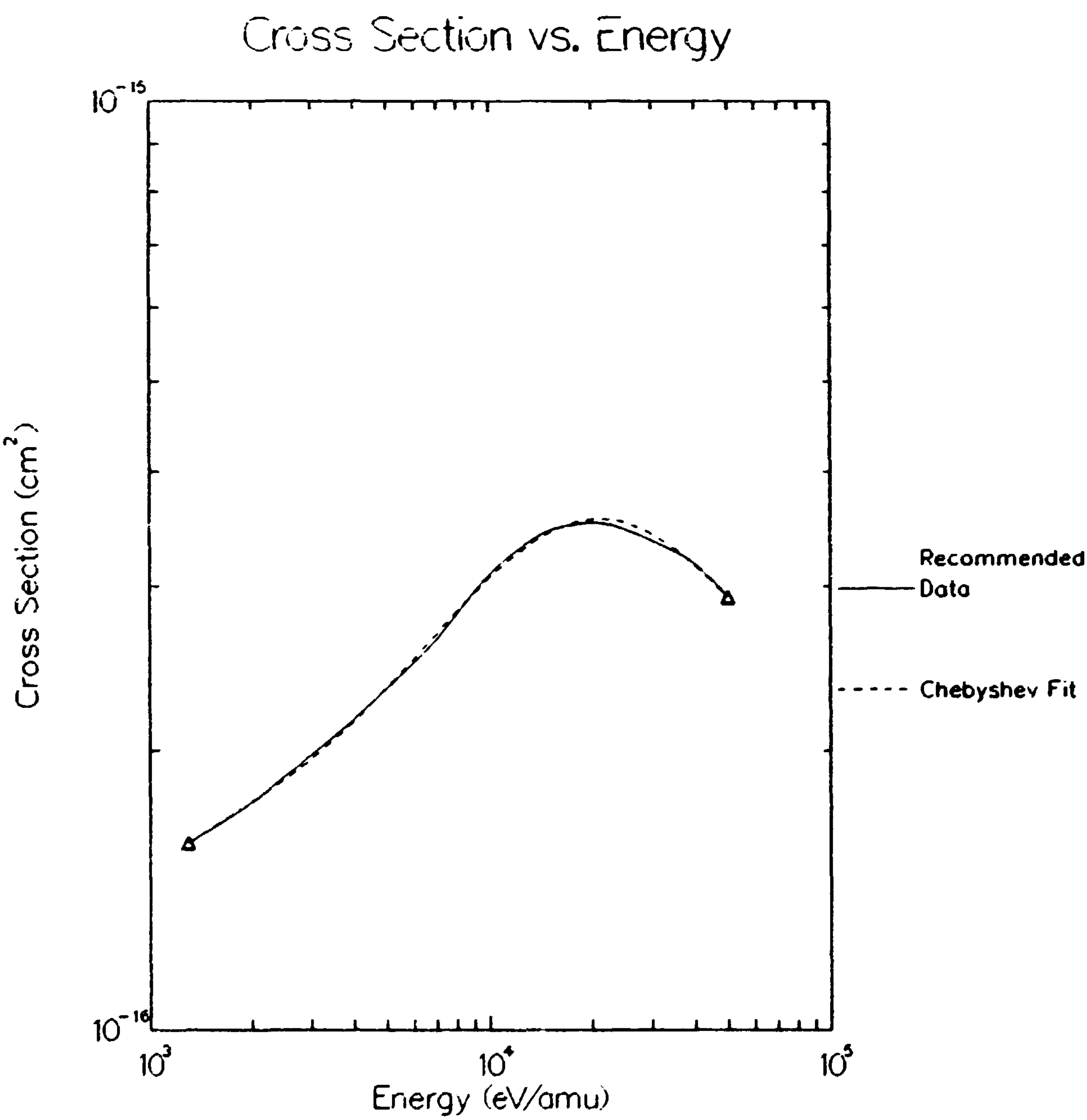
E_{min} = 1.3E+03 eV/amu, E_{max} = 5.0E+04 eV/amu

A0	A1	A2	.3	A4	A5	A6
-71.8671	.380700	-.137630	-.0886297	-.00459765	.0134628	.00197498

The fit represents the above cross section with an rms deviation of 0.6%. The maximum deviation is 1.2% at 7.0E+03 eV/amu.

See appendix for Chebyshev fit details.

$H_2 + H_2$ –> Total Destruction of Fast H_2 Projectiles



Total Destruction Cross Sections for H_3^+ Projectile Ions in H_2

$H_3^+ + H_2 \rightarrow$ Total Destruction of H_3^+

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.6E+03	5.56E+07	3.39E-16
2.0E+03	6.21E+07	3.78E-16
4.0E+03	8.79E+07	5.07E-16
7.0E+03	1.16E+08	6.10E-16
1.0E+04	1.39E+08	6.65E-16
1.5E+04	1.70E+08	7.06E-16
2.0E+04	1.96E+08	6.81E-16
3.0E+04	2.41E+08	5.93E-16
3.5E+04	2.60E+08	5.58E-16

Reference: 536

Accuracy: 20%

Notes: (1) This cross section is the sum of cross sections for all reactions that destroy the H_3^+ molecular ion in passage through H_2. (2) Large variations in ion source operating conditions were found to produce changes up to 10% in the measured cross sections (see Ref. 536).

Chebyshev Fitting Parameters for Cross Sections

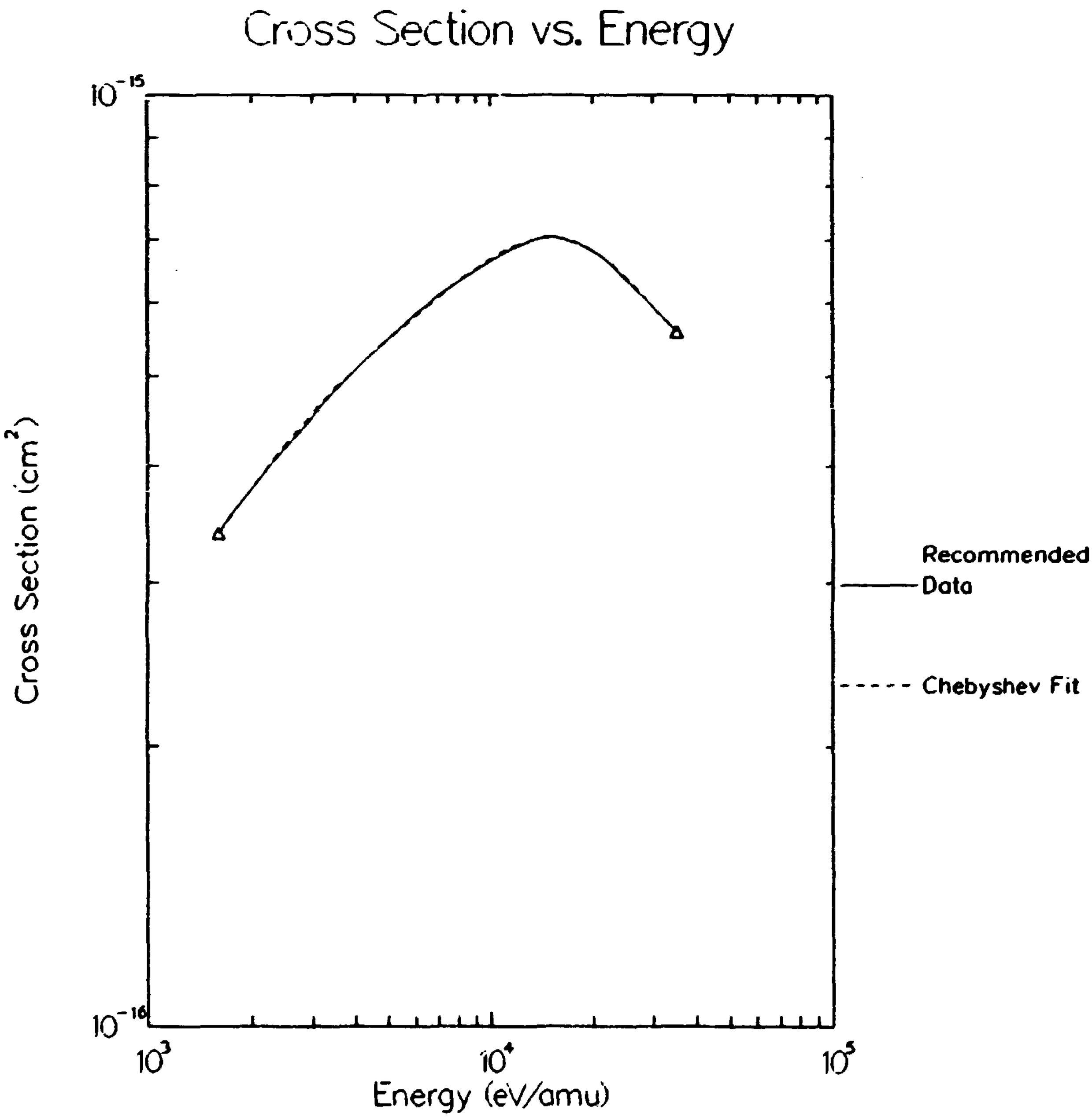
E_{min} = 1.6E+03 eV/amu, E_{max} = 3.5E+04 eV/amu

A0	A1	A2	A3	A4	A5	A6
-70.3701	.284601	-.184305	-.0425670	-.00921848	.00698594	.00725332

The fit represents the above cross section with an rms deviation of 0.3%. The maximum deviation is 0.5% at 1.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$H_3^+ + H_2$ –> Total Destruction of H_3^+ Projectiles



Total Destruction Cross Sections for H_2^+ Projectile Ions in H_2

$H_2^+ + H_2 \rightarrow$ Total Destruction of H_2^+

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.5E+03	5.38E+07	8.12E-16
2.0E+03	6.21E+07	8.18E-16
4.0E+03	8.79E+07	8.30E-16
7.0E+03	1.16E+08	8.15E-16
1.0E+04	1.39E+08	8.18E-16
1.5E+04	1.70E+08	8.46E-16
2.0E+04	1.96E+08	7.75E-16
4.0E+04	2.78E+08	4.69E-16
5.0E+04	3.11E+08	3.81E-16

References: 536, 589

Accuracy: 20%

Notes: (1) This cross section is the sum of cross sections for all reactions that destroy the H_2^+ molecular ion in passage through H_2. (2) Large variations in ion source operating conditions were found to produce changes up to 10% in the measure cross sections (see Ref. 536).

Chebyshev Fitting Parameters for Cross Sections

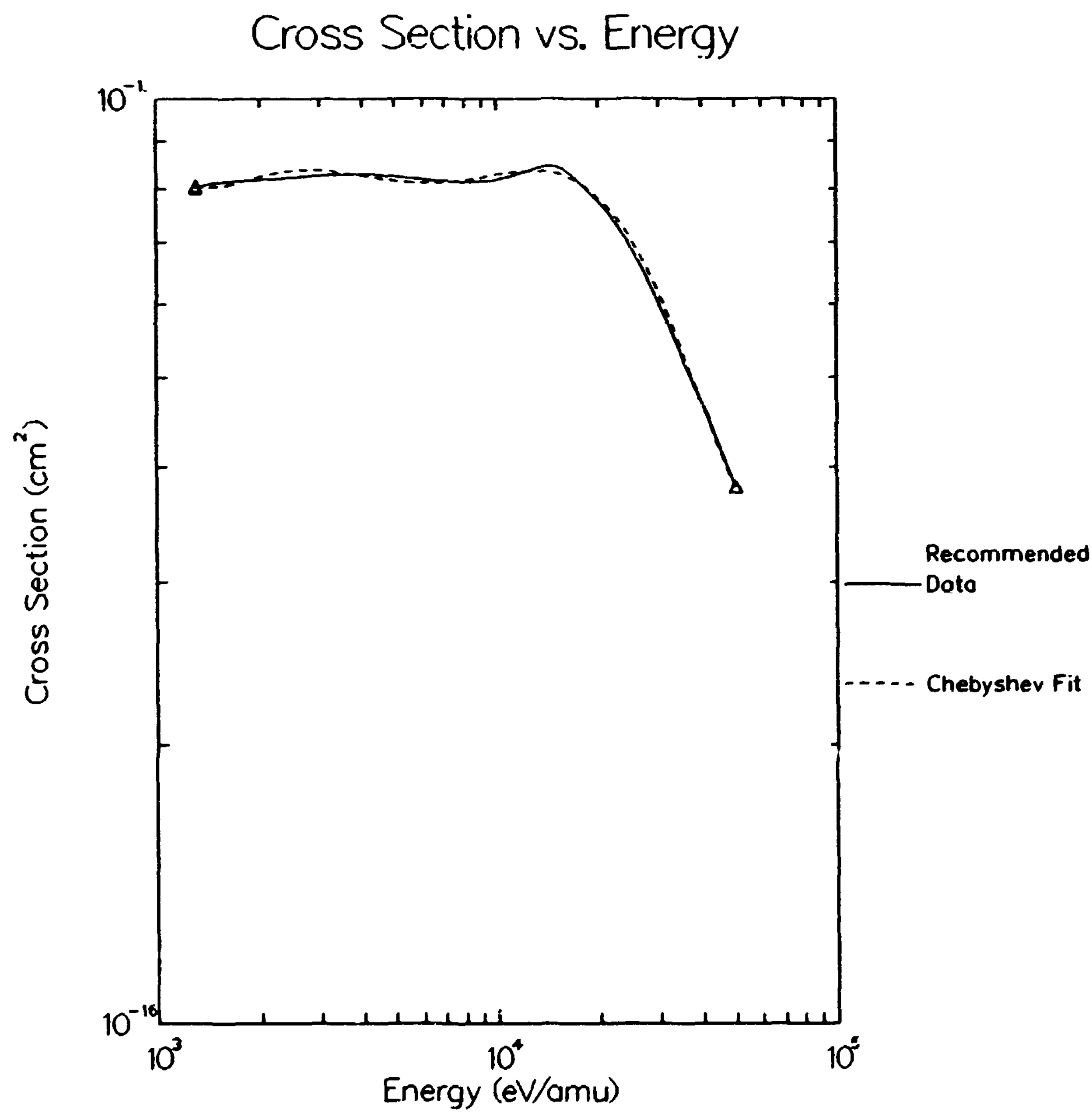
E_{min} = 1.3E+03 eV/amu, E_{max} = 5.0E+04 eV/amu

A0	A1	A2	A3	A4	A5	A6
-69.7995	-.288081	-.216489	-.102343	-.0344599	.0155290	.0223268

The fit represents the above cross section with an rms deviation of 0.9%. The maximum deviation is 1.3% at 1.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$H_2^+ + H_2$ -> Total Destruction of H_2^+ Projectiles



Cross Sections for Production of Fast H^+ From H_3^+ Projectiles in H_2

$H_3^+ + H_2 \rightarrow H^+$ (Total,Projectile)

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
4.0E+01	8.84E+06	6.00E-18
7.0E+01	1.16E+07	6.91E-18
1.0E+02	1.39E+07	7.61E-18
2.0E+02	1.96E+07	8.89E-18
4.0E+02	2.78E+07	1.19E-17
7.0E+02	3.68E+07	1.78E-17
1.0E+03	4.39E+07	2.49E-17
1.5E+03	5.38E+07	3.99E-17
2.0E+03	6.21E+07	5.41E-17
4.0E+03	8.79E+07	9.80E-17
7.0E+03	1.16E+08	1.42E-16
1.0E+04	1.39E+08	1.77E-16
2.0E+04	1.96E+08	2.14E-16
4.0E+04	2.78E+08	2.33E-16
7.0E+04	3.68E+08	2.39E-16
1.0E+05	4.39E+08	2.28E-16
2.0E+05	6.21E+08	1.74E-16
4.0E+05	8.78E+08	1.08E-16
6.0E+05	1.08E+09	7.15E-17

References: 86, 214, 535, 574

Accuracy: 30%

Note: Large variations in measured dissociation cross sections have been ascribed to the influence of H_3^+ ions formed in ion sources with varying degrees of vibrational excitation.

Chebyshev Fitting Parameters for Cross Sections

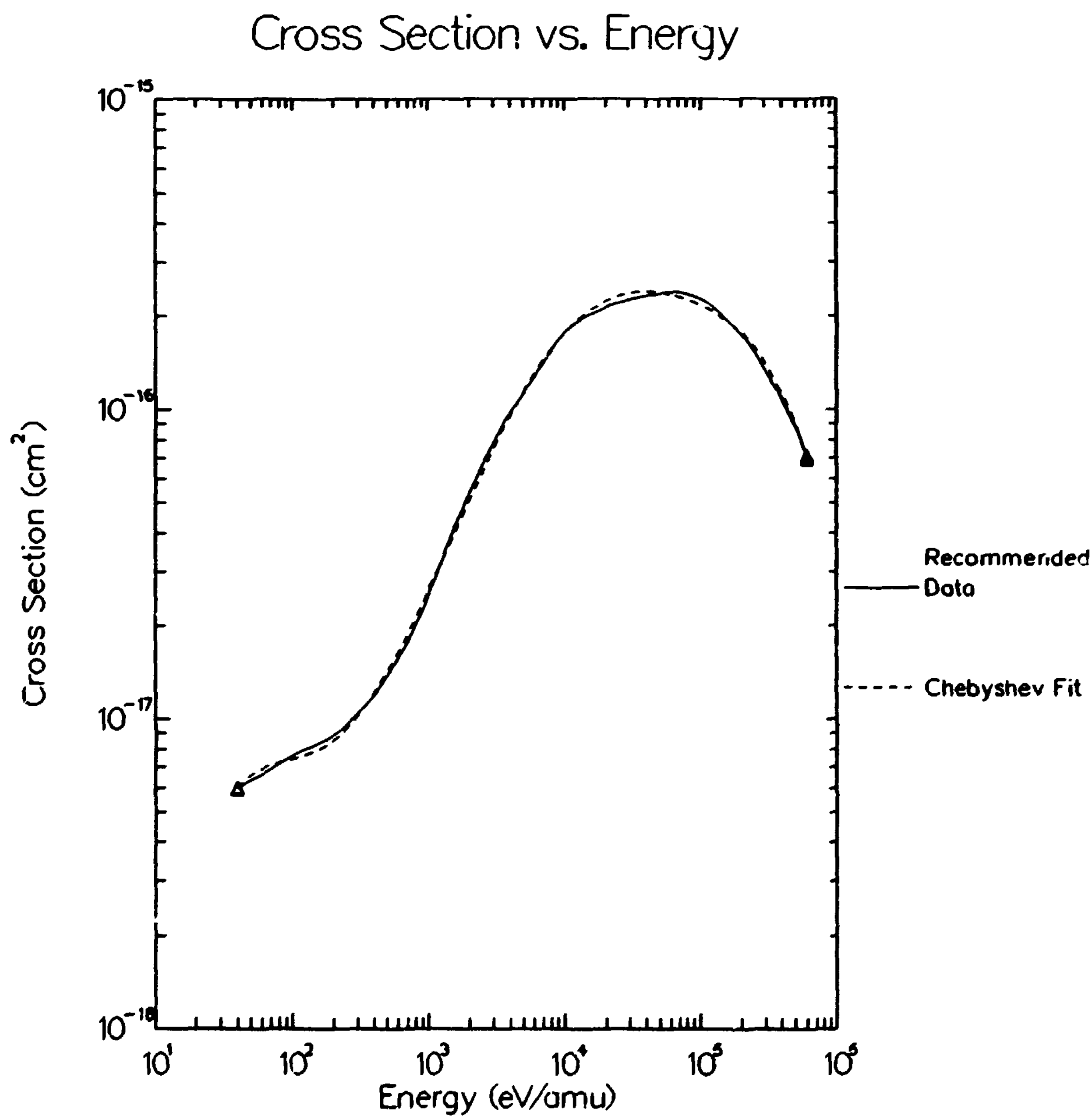
E_{min} = 4.0E+01 eV/amu, E_{max} = 6.0E+05 eV/amu

A0	A1	A2	A3	A4	A5	A6
-75.3369	1.74367	-.759749	-.559135	.0918355	.0438106	-.0940811

The fit represents the above cross section with an rms deviation of 3.4%. The maximum deviation is 5.3% at 7.0E+02 eV/amu.

See appendix for Chebyshev fit details.

$H_3^+ + H_2$ -> H^+ (Total, Projectile)



Cross Sections for Production of Fast H_2^+ From H_3^+ Projectiles in H_2

$H_3^+ + H_2 \rightarrow H_2^+$ (Total,Projectile)

Energy (eV/amu)	Cross Section (cm^2)
1.1E+02	1.34E-17
2.0E+02	1.99E-17
4.0E+02	2.93E-17
7.0E+02	4.17E-17
1.0E+03	5.09E-17
1.5E+03	6.53E-17
2.0E+03	7.96E-17
4.0E+03	1.18E-16
7.0E+03	1.29E-16
1.0E+04	1.29E-16
2.0E+04	1.18E-16
4.0E+04	9.62E-17
7.0E+04	7.75E-17
1.0E+05	6.62E-17
2.0E+05	4.69E-17
4.0E+05	2.86E-17
6.0E+05	2.03E-17

<u>References:</u> 86, 214, 535, 574

<u>Accuracy:</u> 30%

<u>Note:</u> Large variations in measured dissociation cross sections have been ascribed to the influence of H_3^+ ions formed in ion sources with varying degrees of vibrational excitation.

<u>Chebyshev Fitting Parameters for Cross Sections</u>

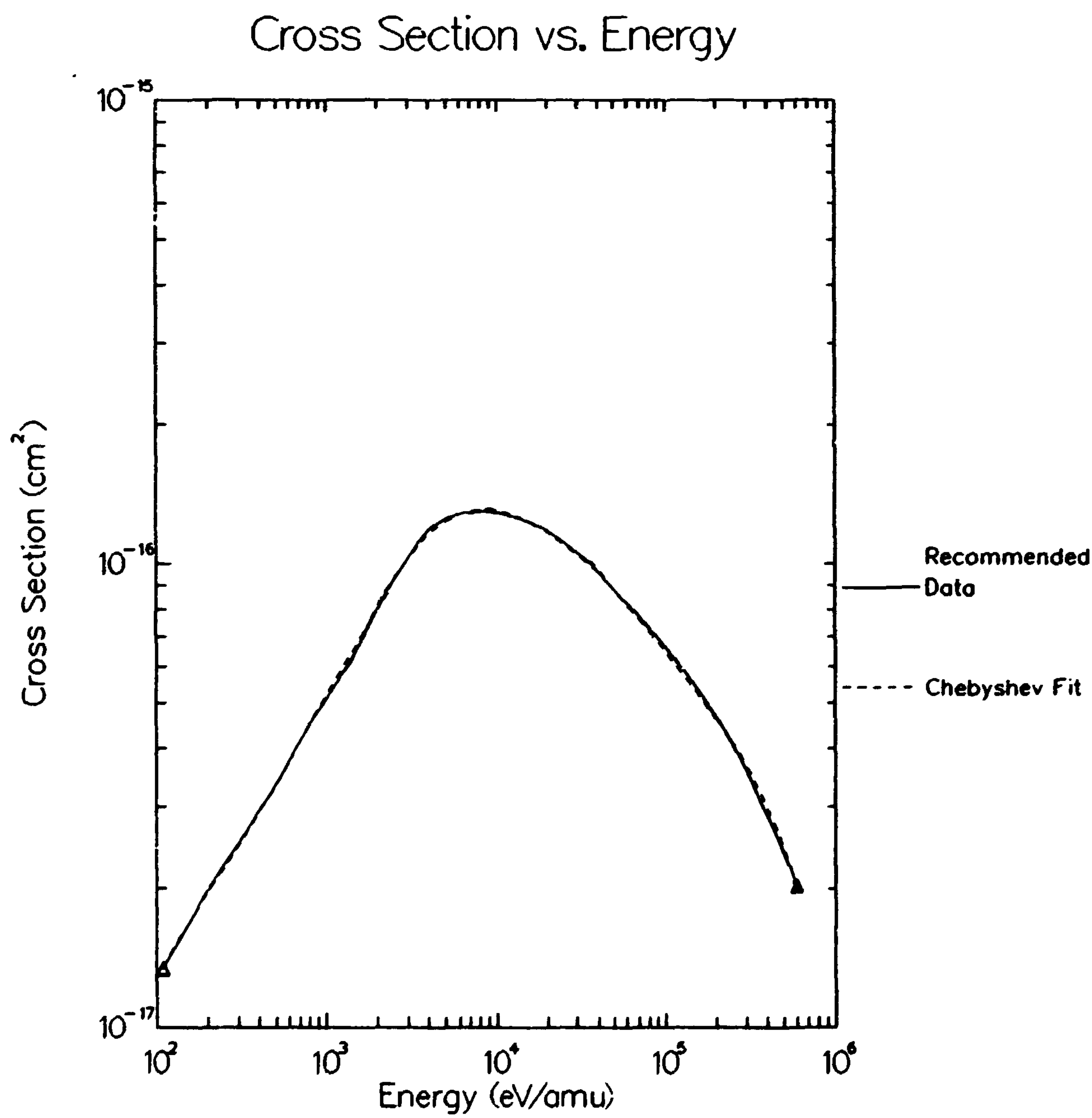
E_{min} = 1.1E+02 eV/amu, E_{max} = 6.0E+05 eV/amu

A0	A1	A2	A3	A4	A5	A6
-75.4231	.295854	-.985779	-.0762360	.0980699	-.0248092	-.0512818

The fit represents the cross section with an rms deviation of 2.4%. The maximum deviation is 4.1% at 4.0E+05 eV/amu.

See appendix for Chebyshev fit details.

$H_3^+ + H_2 \rightarrow H^{2+}$ (Total, Projectile)



Cross Sections for Production of Fast H from H_3^+ Projectiles in H_2

$H_3^+ + H_2 \rightarrow H$ (Total, Projectile)

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.5E+03	5.42E+07	3.20E-16
2.0E+03	6.21E+07	4.26E-16
4.0E+03	8.79E+07	6.94E-16
7.0E+03	1.16E+08	8.90E-16
1.0E+04	1.39E+08	9.69E-16
1.3E+04	1.58E+08	9.96E-16
2.0E+04	1.96E+08	9.02E-16
4.0E+04	2.78E+08	5.77E-16
7.0E+04	3.68E+08	3.56E-16
1.0E+05	4.39E+08	2.62E-16
2.0E+05	6.21E+08	1.45E-16
4.0E+05	8.78E+08	7.79E-17
6.0E+05	1.08E+09	5.48E-17

References: 214, 535

Accuracy: 30%

Note: Large variations in measured dissociation cross sections have been ascribed to the influence of H_3^+ ions formed in ion sources with varying degrees of vibrational excitation.

Chebyshev Fitting Parameters for Cross Sections

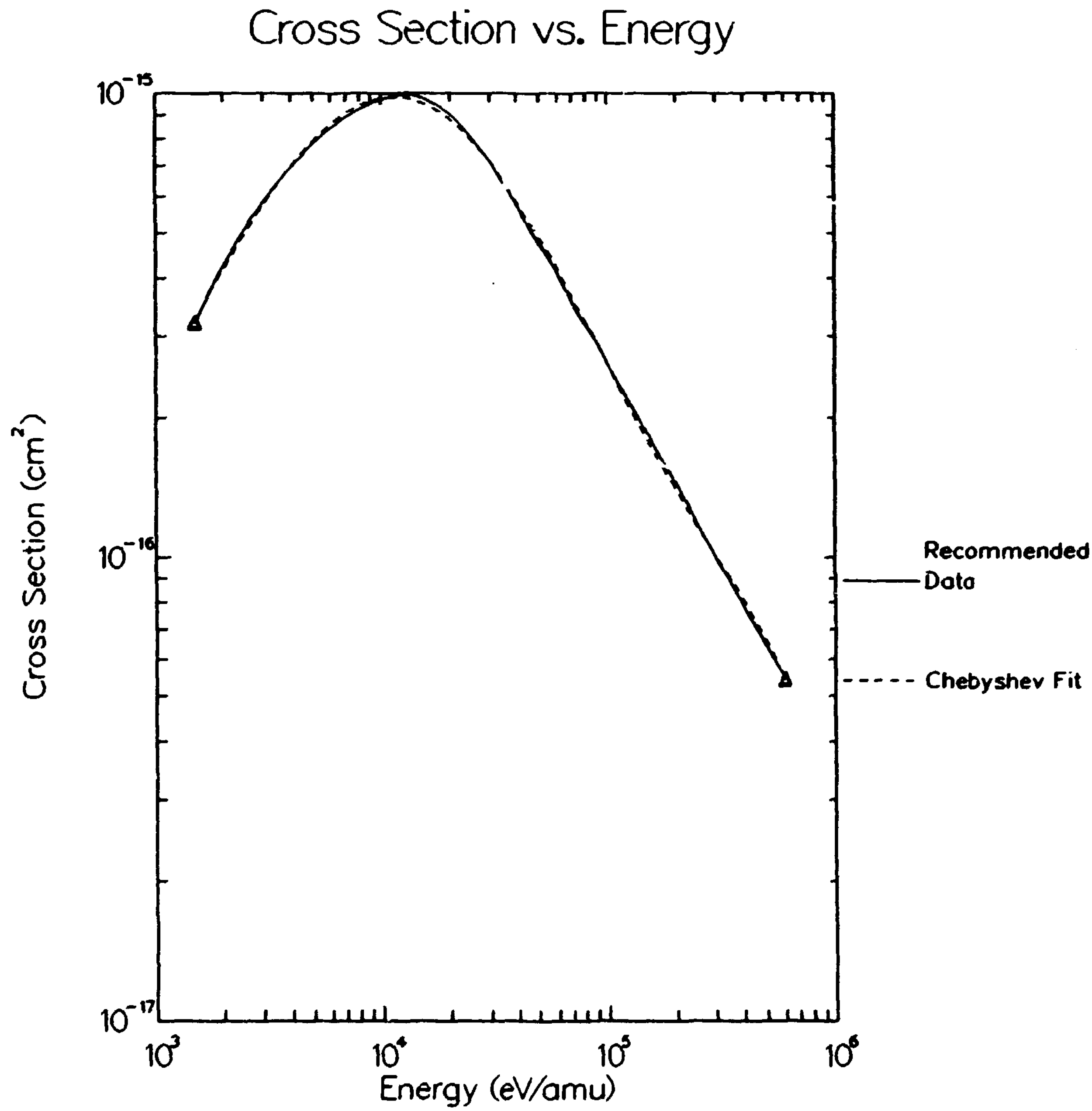
E_{min} = 1.5E+03 eV/amu, E_{max} = 6.0E+05 eV/amu

A0	A1	A2	A3	A4	A5	A6
-71.5391	-1.05347	-.826342	.203507	.0536140	-.0425785	-.0185315

The fit represents the above cross section with an rms deviation of 1.8%. The maximum deviation is 2.9% at 4.0E+05 eV/amu.

See appendix for Chebyshev fit details.

$H_3^+ + H_2 \rightarrow H$ (Total, Projectile)



Cross Sections for Production of Fast H_2 from H_3^+ Projectiles in H_2

$H_3^+ + H_2 \rightarrow H_2$ (Total,Projectile)

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
3.0E+01	7.61E+06	5.03E-17
4.0E+01	8.79E+06	5.18E-17
7.0E+01	1.16E+07	5.74E-17
1.0E+02	1.39E+07	6.29E-17
1.5E+02	1.70E+07	7.07E-17
2.0E+02	1.96E+07	7.82E-17
4.0E+02	2.78E+07	1.10E-16
7.0E+02	3.68E+07	1.48E-16
1.0E+03	4.39E+07	1.81E-16
1.5E+03	5.38E+07	2.25E-16
2.0E+03	6.21E+07	2.63E-16
4.0E+03	8.79E+07	3.64E-16
7.0E+03	1.16E+08	4.26E-16
8.0E+03	1.24E+08	4.31E-16
1.0E+04	1.39E+08	4.30E-16
1.5E+04	1.70E+08	3.83E-16
2.0E+04	1.96E+08	3.22E-16
4.0E+04	2.78E+08	1.50E-16
7.0E+04	3.68E+08	6.49E-17
1.0E+05	4.39E+08	3.65E-17
1.5E+05	5.38E+08	1.98E-17
2.0E+05	6.21E+08	1.34E-17
4.0E+05	8.78E+08	6.90E-18
6.0E+05	1.08E+09	6.09E-18

References: 214, 535, 585

Accuracy: 30%

Note: Large variations in measured dissociation cross sections have been ascribed to the influence of H_3^+ ions formed in ion sources with varying degrees of vibrational excitation.

Chebyshev Fitting Parameters for Cross Sections

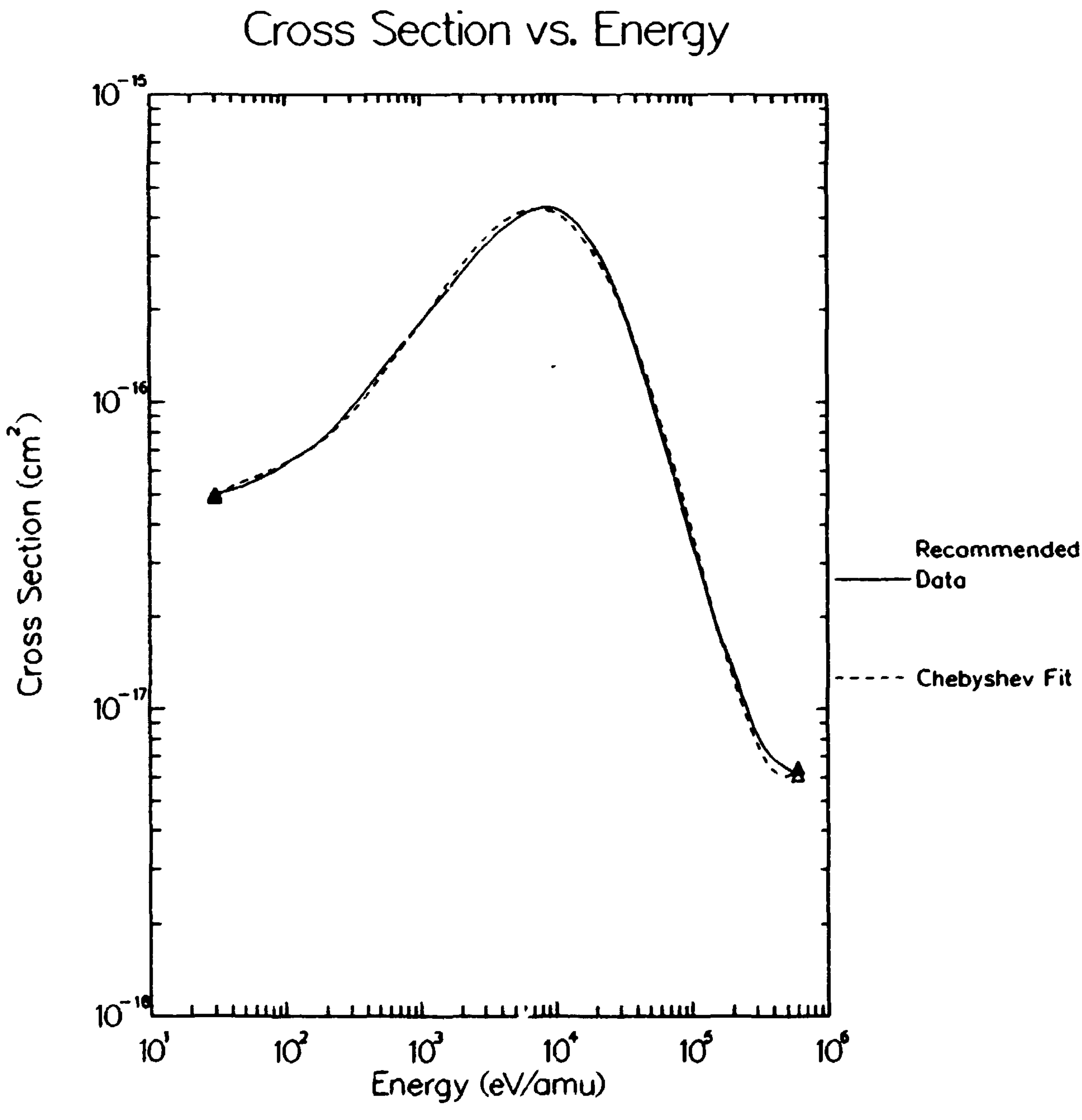
E_{min} = 3.0E+01 eV/amu, E_{max} = 6.0E+05 eV/amu

A0	A1	A2	A3	A4	A5	A6
-74.8168	-.899995	-1.57067	-.379862	.384429	.264557	.0263143

The fit represents the above cross section with an rms deviation of 4.1%. The maximum deviation is 6.5% at 1.0E+05 eV/amu.

See appendix for Chebyshev fit details.

$H_3^+ + H_2 \rightarrow H_2$ (Total, Projectile)



Cross Sections for the Formation of Fast H^+ From the Dissociation of H_3^+ Projectiles in He

$H_3^+ + He \rightarrow H^+$ (Total)

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+03	4.39E+07	2.19E-17
1.5E+03	5.38E+07	3.20E-17
2.0E+03	6.21E+07	4.18E-17
4.0E+03	8.79E+07	7.20E-17
7.0E+03	1.16E+08	1.02E-16
1.0E+04	1.39E+08	1.20E-16
1.5E+04	1.70E+08	1.36E-16
1.7E+04	1.81E+08	1.39E-16

Reference: 86

Accuracy: 20%

Notes: None

Chebyshev Fitting Parameters for Cross Sections

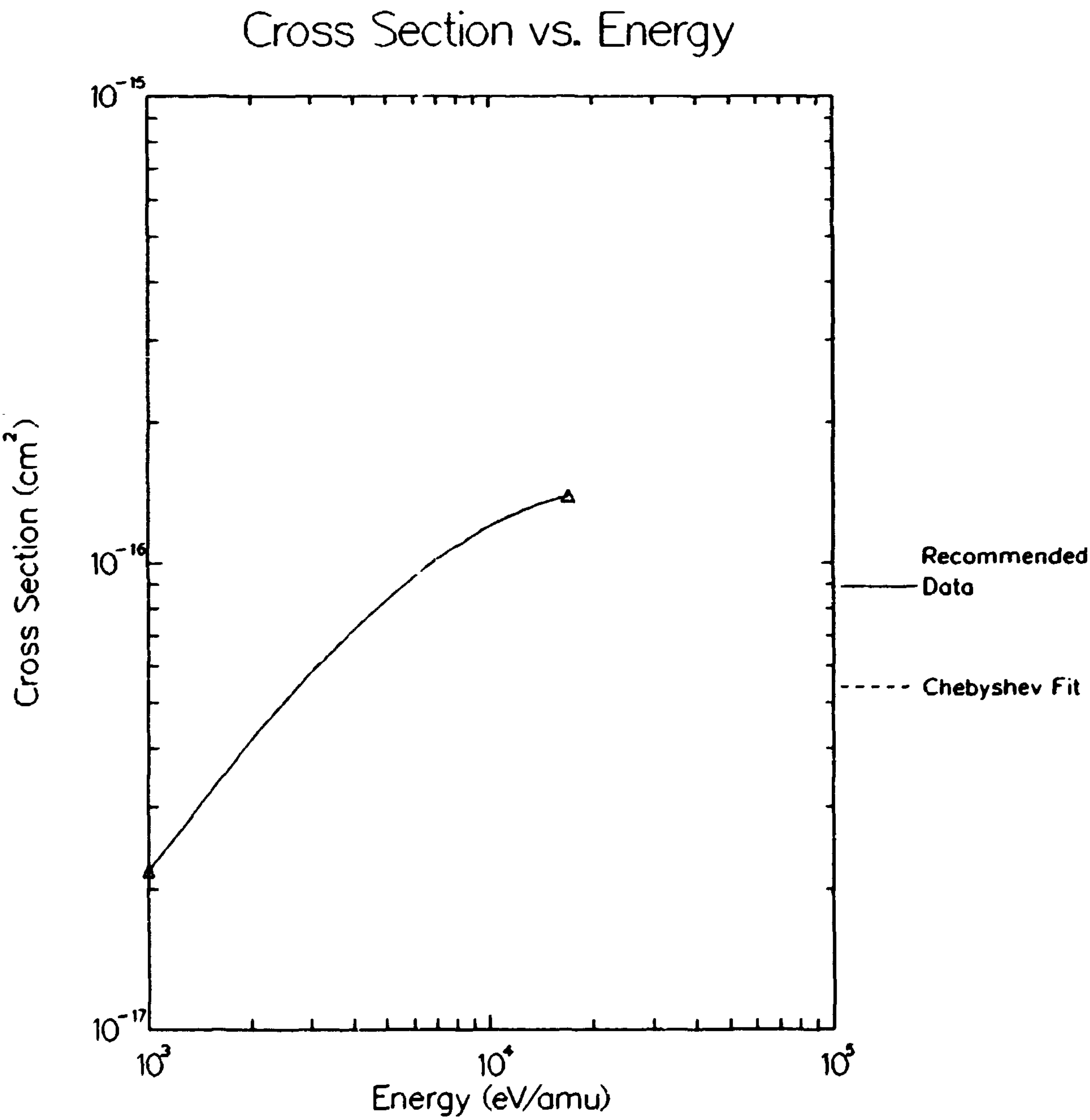
E_{min} = 1.0E+03 eV/amu, E_{max} = 1.7E+04 eV/amu

A0	A1	A2	A3	A4	A5	A6
-74.5849	.941781	-.146192	-.0143319	.000599232	-.00304737	.00231477

The fit represents the above cross section with an rms deviation of 0.1%. The maximum deviation is 0.2% at 1.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$H_3^+ + He \rightarrow H^+$ (Total)



Cross Sections for the Formation of Fast H_2^+ From the Dissociation of H_3^+ Projectiles in He

$H_3^+ + He \rightarrow H_2^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+03	4.39E+07	1.67E-17
1.5E+03	5.38E+07	2.50E-17
2.0E+03	6.21E+07	3.25E-17
4.0E+03	8.79E+07	5.48E-17
7.0E+03	1.16E+08	7.57E-17
1.0E+04	1.39E+08	9.00E-17
1.5E+04	1.70E+08	1.06E-16
1.7E+04	1.81E+08	1.10E-16

Reference: 86

Accuracy: 20%

Notes: None

Chebyshev Fitting Parameters for Cross Sections

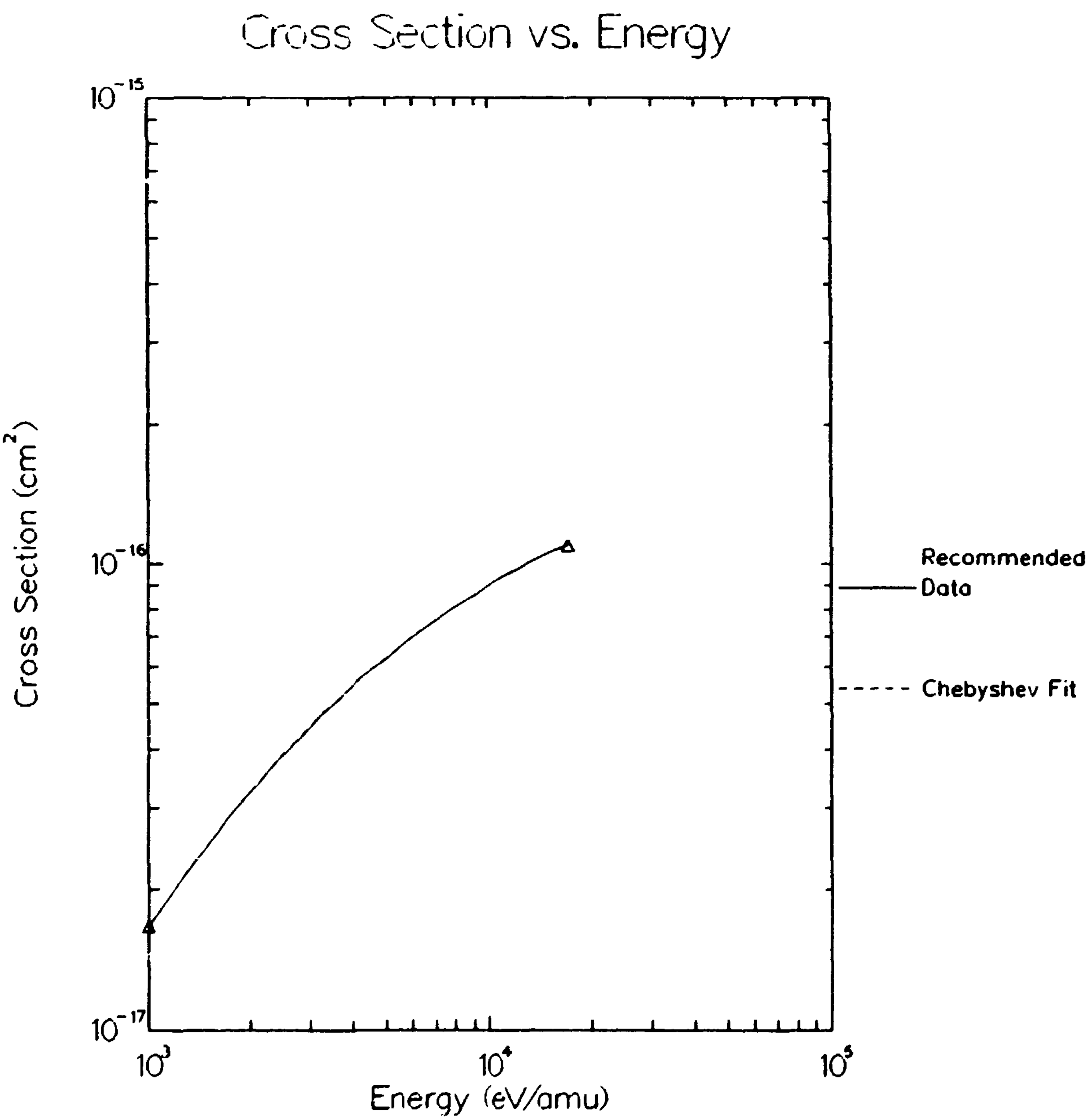
E_{min} = 1.0E+03 eV/amu, E_{max} = 1.7E+04 eV/amu

A0	A1	A2	A3	A4	A5	A6
-75.1127	.939201	-.132028	.00680760	.000497736	-.00339960	-.000620124

The fit represents the above cross section with an rms deviation of 0.0%. The maximum deviation is 0.0% at 1.0E+04 eV/amu.

See appendix for Chebyshev fit details.

$H_3^+ + He \rightarrow H_2^+$



Total Cross Sections for the Dissociation of HeH^+ in H_2

$HeH^+ + H_2 \rightarrow$ Total HeH^+ Dissociation Products

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+04	1.39E+08	6.85E-16
1.5E+04	1.70E+08	6.33E-16
2.0E+04	1.96E+08	5.59E-16
4.0E+04	2.78E+08	3.65E-16
7.0E+04	3.68E+08	2.14E-16
1.0E+05	4.39E+08	1.41E-16
1.5E+05	5.38E+08	1.05E-16
2.0E+05	6.21E+08	9.07E-17

Reference: 610

Accuracy: 20%

Notes: (1) This reaction involves the total dissociation cross section obtained from the sum of the partial cross sections for the formation of fast projectile fragments, i.e. (He+H), (He^++H), (He+H^+) and (He^++H^+). (2) See Ref. 610 for partial cross sections in the 1-2 x 10^5 eV/amu energy range.

Chebyshev Fitting Parameters for Cross Sections

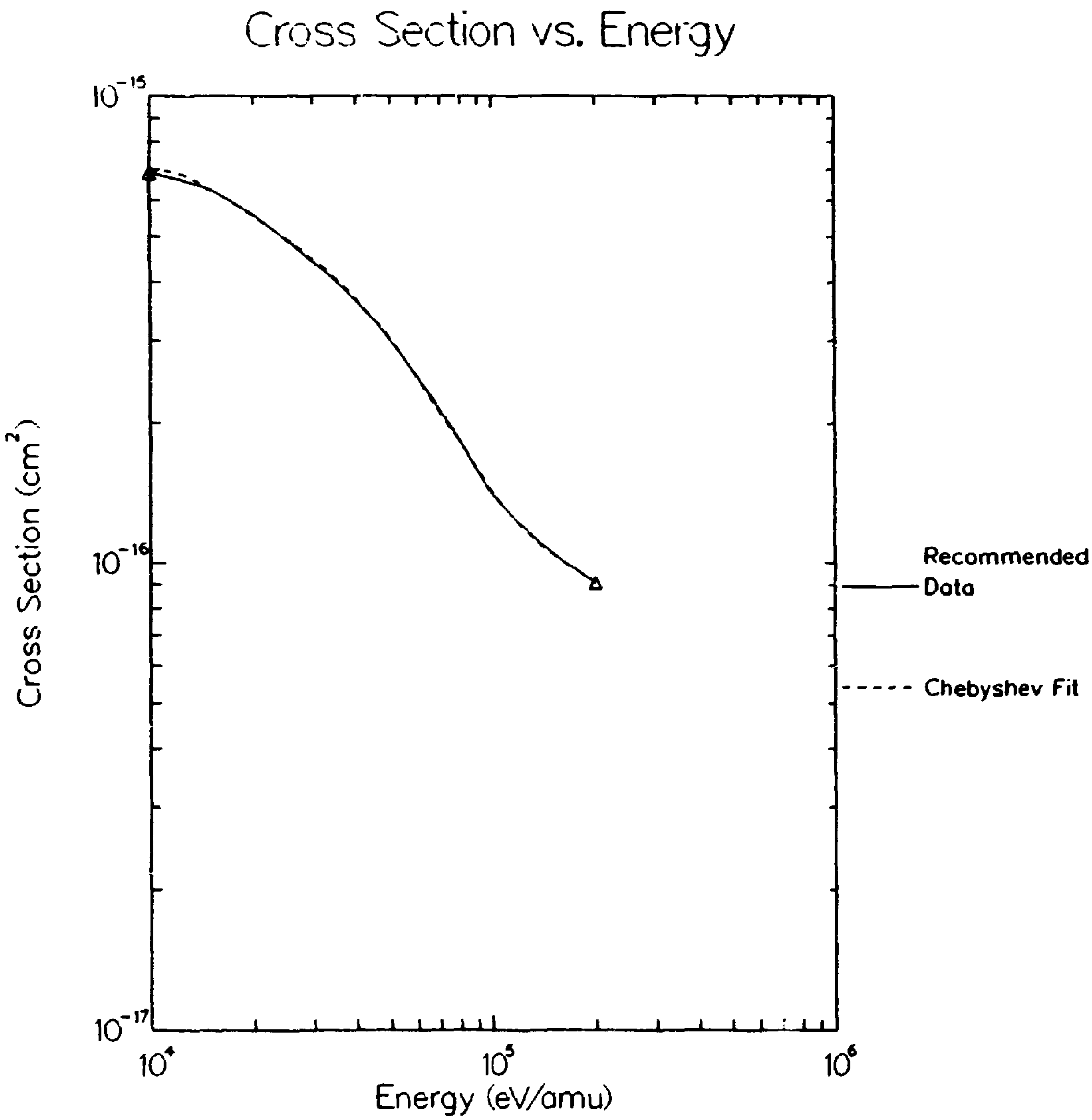
E_{min} = 1.0E+04 eV/amu, E_{max} = 2.0E+05 eV/amu

A0	A1	A2	A3	A4	A5	A6
-71.6345	-1.10463	-.128721	.0876009	.0373958	.00719887	-.0189657

The fit represents the above cross section with an rms deviation of 0.9%. The maximum deviation is 1.5% at 1.0E+05 eV/amu.

See appendix for Chebyshev fit details.

$HeH^+ + H_2$ –> Total HeH^+ Dissociation



Total Cross Sections for the Dissociation of HeH^+ in He

HeH^+ + He -> Total HeH^+ Dissociation Products

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+04	1.39E+08	2.09E-16
1.5E+04	1.70E+08	2.98E-16
2.0E+04	1.96E+08	3.14E-16
3.0E+04	2.41E+08	3.00E-16
4.0E+04	2.78E+08	2.73E-16
5.0E+04	3.11E+08	2.44E-16
6.0E+04	3.40E+08	2.15E-16
7.0E+04	3.68E+08	1.93E-16
8.0E+04	3.93E+08	1.73E-16
9.0E+04	4.17E+08	1.58E-16
1.0E+05	4.39E+08	1.44E-16
1.5E+05	5.38E+08	1.03E-16
2.0E+05	6.21E+08	8.54E-17

Reference: 610

Accuracy: 20%

Notes: (1) This reaction involves the total dissociation cross section obtained from the sum of the partial cross sections for the formation of fast projectile fragments, i.e. (H_2+H), (He^++H), (He+H^+) and (He^++H^+). (2) See Ref. 610 for partial cross sections in the 1-2 x 10^5 eV/amu energy range.

Chebyshev Fitting Parameters for Cross Sections

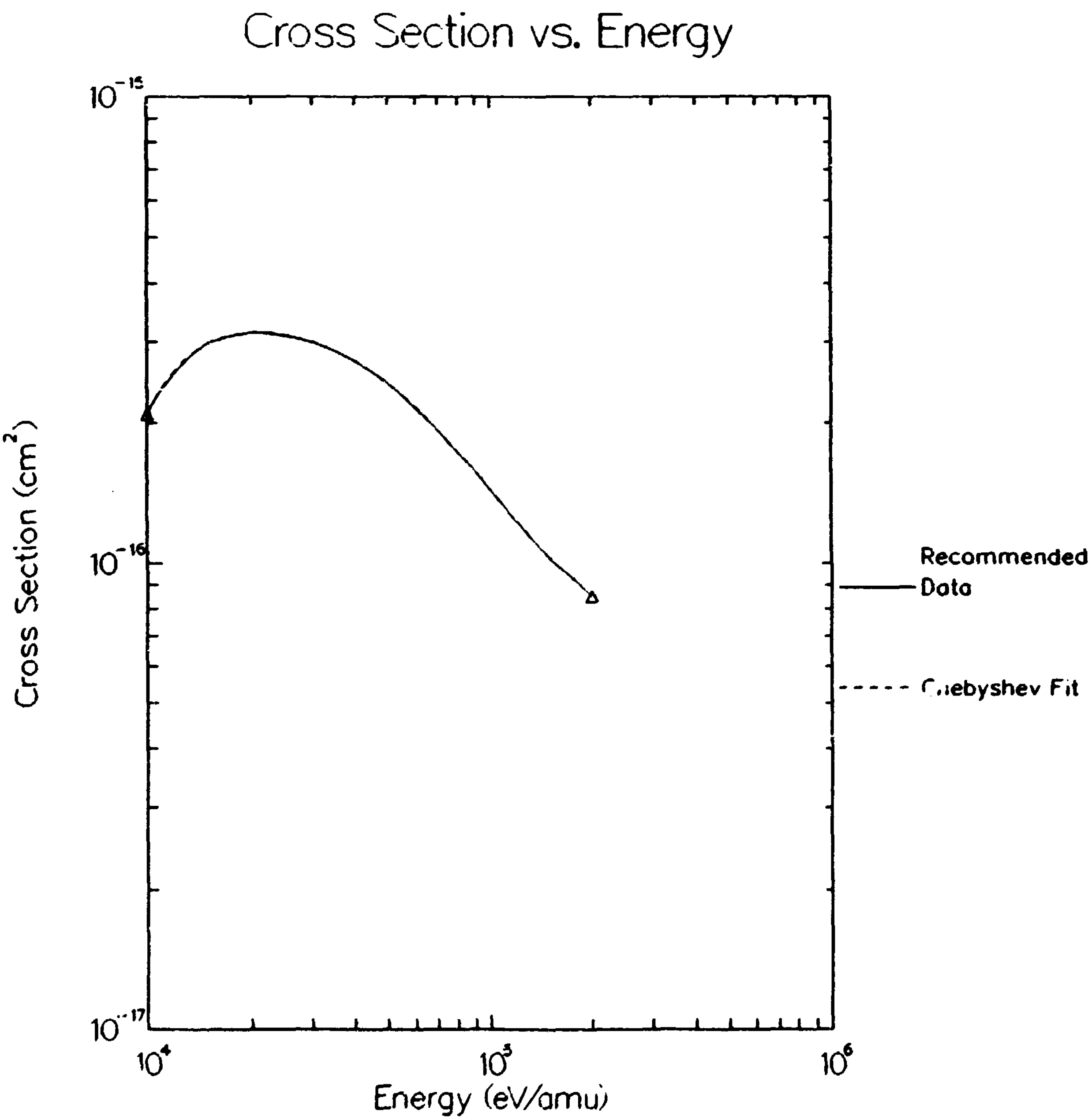
E_{min} = 1.0E+04 eV/amu, E_{max} = 2.0E+05 eV/amu

A0	A1	A2	A3	A4	A5	A6
-72.4377	-.561126	-.322720	.0959965	-.00323223	.017197	-.00704447

The fit represents the above cross section with an rms deviation of 0.3%. The maximum deviation is 0.6% at 6.0E+04 eV/amu.

See appendix for Chebyshev fit details.

HeH$^+$ + He -> Total HeH$^+$ Dissociation



H. Cross Sections for Interchange Reactions

Cross Reactions for Interchange Reactions Between Protons and D_2

$$H^+ + D_2 \rightarrow D^+ + HD$$
$$\rightarrow HD^+ + D$$

$D^+ + HD$

Energy (eV/amu)	Cross Section (cm^2)
4.5E-01	1.18E-15
7.0E-01	7.38E-16
1.0E+00	4.69E-16
1.5E+00	2.59E-16
2.0E+00	1.59E-16
4.0E+00	4.15E-17
7.0E+00	1.47E-17
1.0E+01	1.10E-17
1.5E+01	9.80E-18
2.0E+01	8.78E-18
4.0E+01	5.18E-18
7.0E+01	2.90E-18
1.0E+02	2.01E-18

$HD^+ + D$

Energy (eV/amu)	Cross Section (cm^2)
2.2E+00	4.67E-18
4.0E+00	2.22E-17
4.5E+00	2.26E-17
7.0E+00	1.29E-17
1.0E+01	4.03E-18
1.5E+01	1.28E-18
2.0E+01	6.95E-19
4.0E+01	2.72E-19
7.0E+01	1.87E-19
1.0E+02	1.67E-19

References: 602, 603, 604, 605, 606, 620

Accuracy: Unknown

Notes: (1) For proton energies about 5 eV the production of D^+ may proceed also via $H^+ + D_2 \rightarrow D^+ + D + H$. (2) For total reaction cross sections see: Maier (Ref. 602); Ochs and Teloy (Ref. 604); Schlier et al. (Ref. 605); and Holliday et al. (Ref. 603). (3) For relative yields of D^+ and HD^+ see: Krenos and Wolfgang (Ref. 620). (4) Rate coefficient for thermal energy is: $k = 3.7 \times 10^{-10}$ cm^3/s from Fehsenfeld et al. (Ref. 606).

Chebyshev Fitting Parameters for Cross Sections

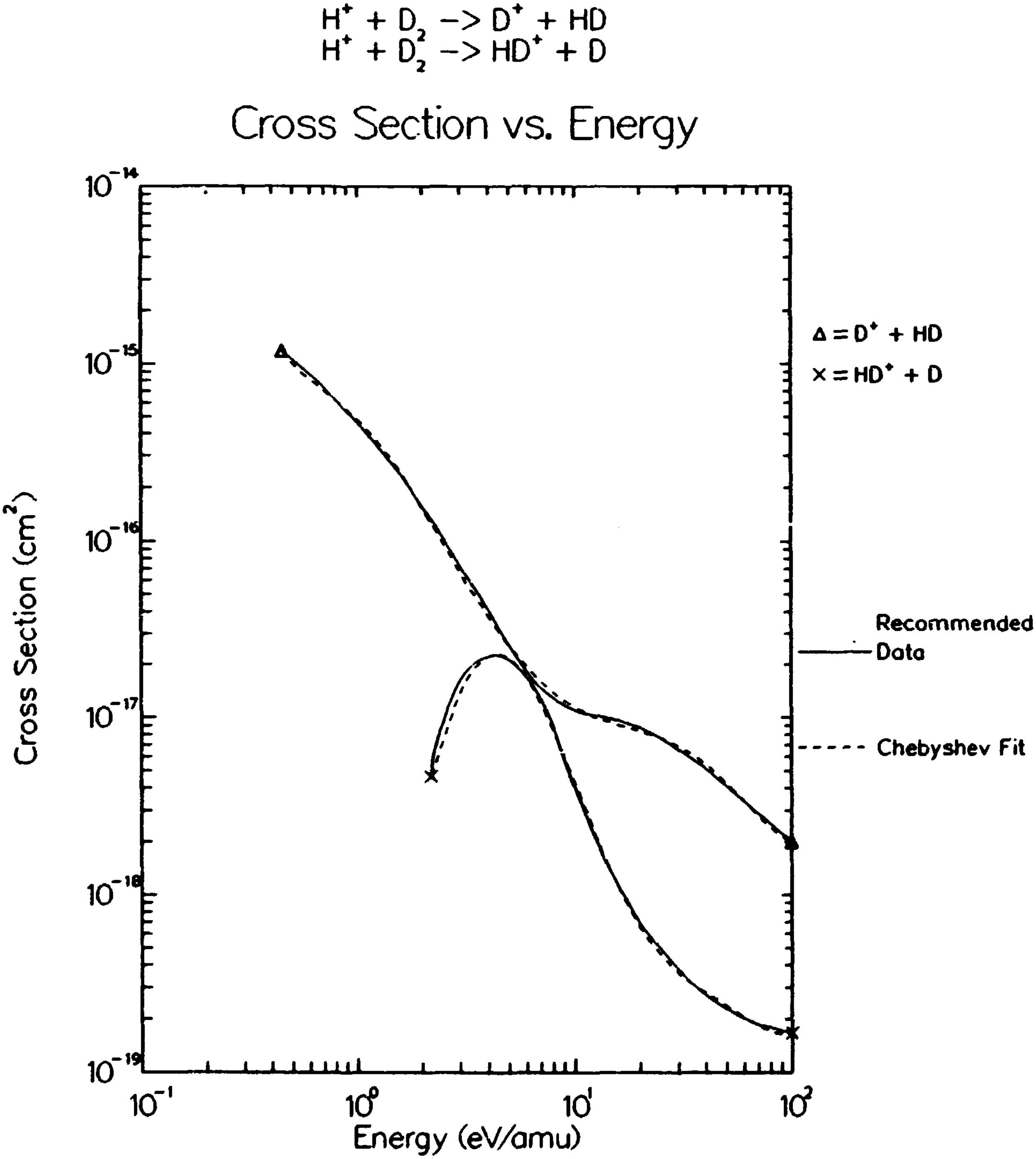
$D^+ + HD$ E_{min} = 4.5E-01 eV/amu, E_{max} = 1.0E+02 eV/amu
$HD^+ + D$ E_{min} = 2.2E+00 eV/amu, E_{max} = 1.0E+02 eV/amu

	A0	A1	A2	A3	A4	A5	A6
$D^+ + HD$	-75.6468	-3.22911	.412113	.0393398	-.261749	.00129512	.120885
$HD^+ + D$	-82.0488	-2.46136	-.299817	.833081	-.341103	-.0343948	.0959803

The fit represents the $D^+ + HD$ cross section with an rms deviation of 4.9%. The maximum deviation is 9.3% at 7.0E+00 eV/amu.

The fit represents the $HD^+ + D$ cross section with an rms deviation of 3.5%. The maximum deviation is 7.0% at 1.0E+01 eV/amu.

See appendix for Chebyshev fit details.


H+ + D2 -> D+ + HD
H+ + D2 -> HD+ + D
Cross Section vs. Energy
10^-14
10^-15
10^-16
10^-17
10^-18
10^-19
Cross Section (cm^2)
10^-1
10^0
10^1
10^2
Energy (eV/amu)
Δ = D+ + HD
× = HD+ + D
Recommended Data
Chebyshev Fit

Cross Sections for Interchange Reactions Between HD^+ and D_2

$$HD^+ + D_2 \rightarrow HD_2^+ + D$$
$$\rightarrow D_3^+ + H$$

$HD_2^+ + D$		$D_3^+ + H$	
Energy (eV/amu)	Cross Section (cm^2)	Energy (eV/amu)	Cross Section (cm^2)
6.0E-03	1.17E-14	6.0E-03	6.52E-15
7.0E-03	1.10E-14	7.0E-03	5.99E-15
1.0E-02	9.45E-15	1.0E-02	5.03E-15
1.5E-02	7.92E-15	1.5E-02	4.15E-15
2.0E-02	6.93E-15	2.0E-02	3.58E-15
4.0E-02	5.08E-15	4.0E-02	2.48E-15
7.0E-02	4.11E-15	7.0E-02	1.80E-15
1.0E-01	3.58E-15	1.0E-01	1.47E-15
1.5E-01	3.07E-15	1.5E-01	1.14E-15
2.0E-01	2.70E-15	2.0E-01	9.55E-16
4.0E-01	1.85E-15	4.0E-01	5.78E-16
7.0E-01	1.11E-15	7.0E-01	3.54E-16
1.0E+00	7.05E-16	1.0E+00	2.30E-16
1.5E+00	3.49E-16	1.5E+00	1.20E-16
2.0E+00	1.82E-16	2.0E+00	6.60E-17
4.0E+00	1.47E-17	4.0E+00	6.33E-18
4.3E+00	9.62E-18	4.3E+00	4.59E-18

<u>References:</u> 607, 608

<u>Accuracy:</u> Unknown

<u>Notes:</u> None

<u>Chebyshev Fitting Parameters for Cross Sections</u>

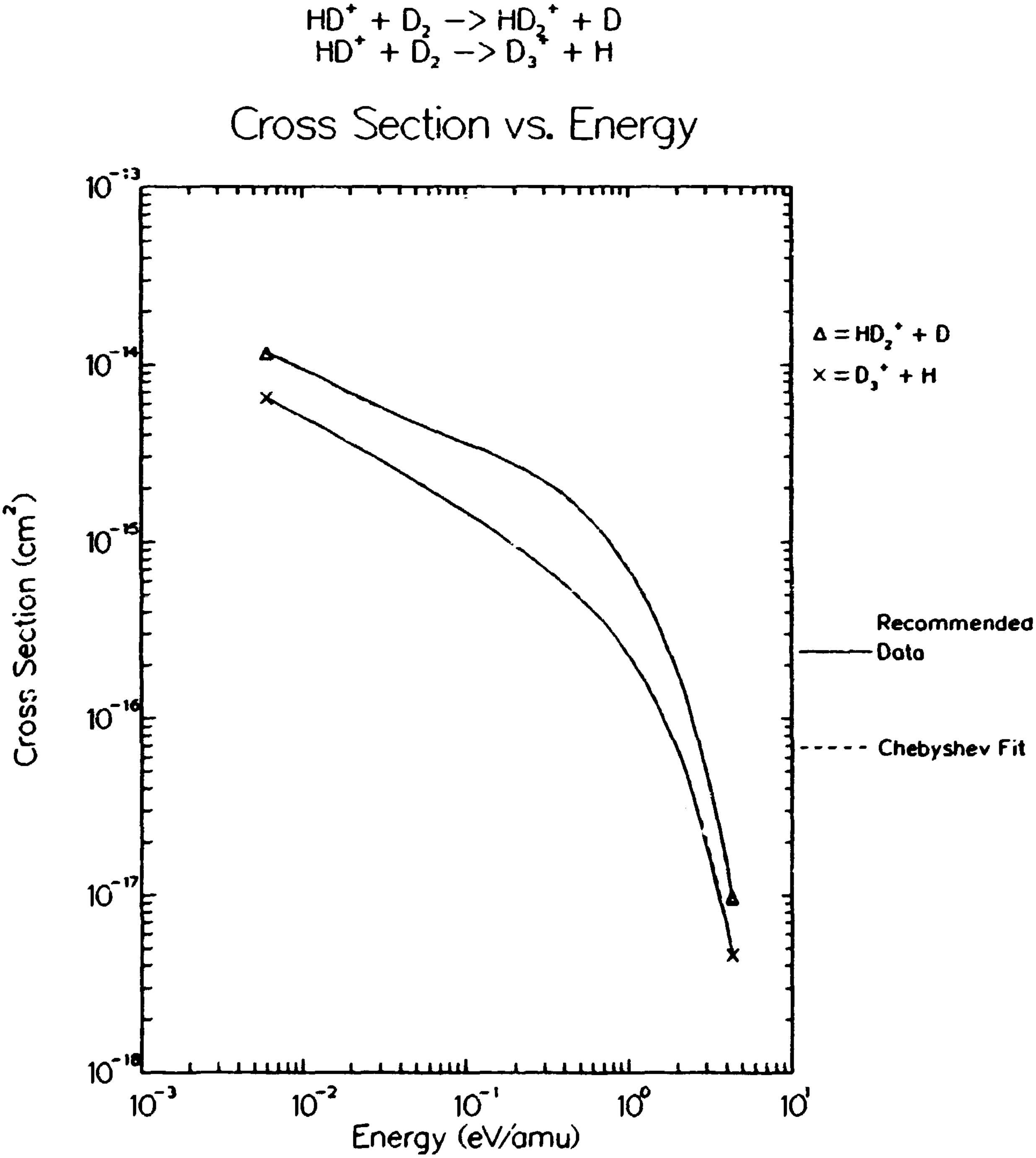
$HD_2^+ + D$ $\quad E_{min}$ = 6.0E-03 eV/amu, $\quad E_{max}$ = 4.3E+00 eV/amu
$D_3^+ + H$ $\quad E_{min}$ = 6.0E-03 eV/amu, $\quad E_{max}$ = 4.3E+00 eV/amu

	A0	A1	A2	A3	A4	A5	A6
$HD_2^+ + D$	-68.6683	-2.92522	-1.06891	-.570210	-.198731	-.0387800	-.0184986
$D_3^+ + H$	-70.3595	-3.11828	-.916067	-.449998	-.194126	-.0628098	-.00822327

The fit represents the $HD_2^+ + D$ cross section with an rms deviation of 1.3%. The maximum deviation is 2.9% at 4.3E+00 eV/amu.

The fit represents the $D_3^+ + H$ cross section with an rms deviation of 0.5%. The maximum deviation is 0.9% at 4.0E+00 eV/amu.

See appendix for Chebyshev fit details.



HD+ + D2 -> HD2+ + D
HD+ + D2 -> D3+ + H
Cross Section vs. Energy
Cross Section (cm2)
Energy (eV/amu)
10-13
10-14
10-15
10-16
10-17
10-18
10-3
10-2
10-1
100
101
Δ = HD2+ + D
× = D3+ + H
Recommended Data
Chebyshev Fit

Cross Sections for Interchange Reactions Between HD^+ and He

$$HD^+(v) + He \rightarrow HeH^+ + D$$

v = 0 Energy (eV/amu)	v = 0 σ (cm^2)	v = 1 Energy (eV/amu)	v = 1 σ (cm^2)	v = 2 Energy (eV/amu)	v = 2 σ (cm^2)	v = 3 Energy (eV/amu)	v = 3 σ (cm^2)	v = 4 Energy (eV/amu)	v = 4 σ (cm^2)
1.8E-01	7.76E-18	1.9E-01	2.53E-17	2.0E-01	6.15E-17	2.0E-01	1.25E-16	1.8E-01	2.25E-16
2.0E-01	7.71E-18	2.0E-01	2.44E-01	3.0E-01	3.82E-17	2.5E-01	1.03E-16	2.0E-01	2.06E-16
3.0E-01	7.36E-18	3.0E-01	1.84E-17	4.0E-01	2.48E-17	3.0E-01	8.06E-17	3.0E-01	1.26E-16
4.0E-01	6.79E-18	4.0E-01	1.46E-17	5.0E-01	1.71E-17	4.0E-01	4.[illegible]-17	4.0E-01	8.05E-17
5.0E-01	6.27E-18	5.0E-01	1.22E-17	6.0E-01	1.27E-17	5.0E-01	2.54E-17	5.0E-01	5.29E-17
6.0E-01	5.79E-18	6.0E-01	1.04E-17	7.0E-01	1.04E-17	6.0E-01	1.78E-17	6.0E-01	3.54E-17
7.0E-01	5.37E-18	7.0E-01	9.22E-18	8.0E-01	8.98E-18	7.0E-01	1.42E-17	7.0E-01	2.44E-17
8.0E-01	5.00E-18	8.0E-01	8.26E-18	9.0E-01	8.08E-18	8.0E-01	1.23E-17	8.0E-01	1.69E-17
9.0E-01	4.68E-18	9.0E-01	7.52E-18	1.0E+00	7.45E-18	9.0E-01	1.13E-17	9.0E-01	1.22E-17
1.0E+00	4.37E-18	1.0E+00	6.94E-18	1.5E+00	6.51E-18	1.0E+00	1.06E-17	1.0E+00	8.94E-18
1.5E+00	3.31E-18	1.5E+00	5.29E-18			1.5E+00	1.01E-17	1.5E+00	2.36E-18
1.7E+00	3.08E-18								

References: 609, 611

Accuracy: Unknown

Notes: (1) Cross sections are presented as a function of initial vibrational quantum number v. (2) The HD^+ ion beam was prepared in a given vibrational state by selective photoionization of HD (Turner et al. Ref. 611). (3) The thermal-energy (~0.1 eV) rate coefficient k for the HD^+ + He reaction leading to all products in Smith et al. (Ref. 609) is: $k = (1.25 \pm 0.1)\times 10^{-10}$ cm^3/s.

Chebyshev Fitting Parameters for Cross Sections

v = 0 E_{min} = 1.8E-01 eV/amu, E_{max} = 1.7E+00 eV/amu
v = 1 E_{min} = 1.9E-01 eV/amu, E_{max} = 1.5E+00 eV/amu
v = 2 E_{min} = 2.0E-01 eV/amu, E_{max} = 1.5E+00 eV/amu
v = 3 E_{min} = 2.0E-01 eV/amu, E_{max} = 1.5E+00 eV/amu
v = 4 E_{min} = 1.8E-01 eV/amu, E_{max} = 1.5E+00 eV/amu

	A0	A1	A2	A3	A4	A5	A6
v = 0	-79.5223	-.474196	-.106022	.00910711	.00412170	.00308534	.00343162
v = 1	-78.0058	-.802720	.000681956	.0202372	.00181675	.000208519	.00196596
v = 2	-77.1958	-1.20851	.141092	.101616	-.00786021	-.0159891	.0143204
v = 3	-76.1495	-1.42278	.227207	.182149	-.0607895	-.0178064	.0326454
v = 4	-75.8801	-2.27104	-.369722	-.00864579	.00647117	.00107548	-.00589532

The fit represents the v = 0 cross section with an rms deviation of 0.1%. The maximum deviation is 0.1% at 4.0E-01 eV/amu.

The fit represents the v = 1 cross section with an rms deviation of 0.2%. The maximum deviation is 0.4% at 6.0E-01 eV/amu.

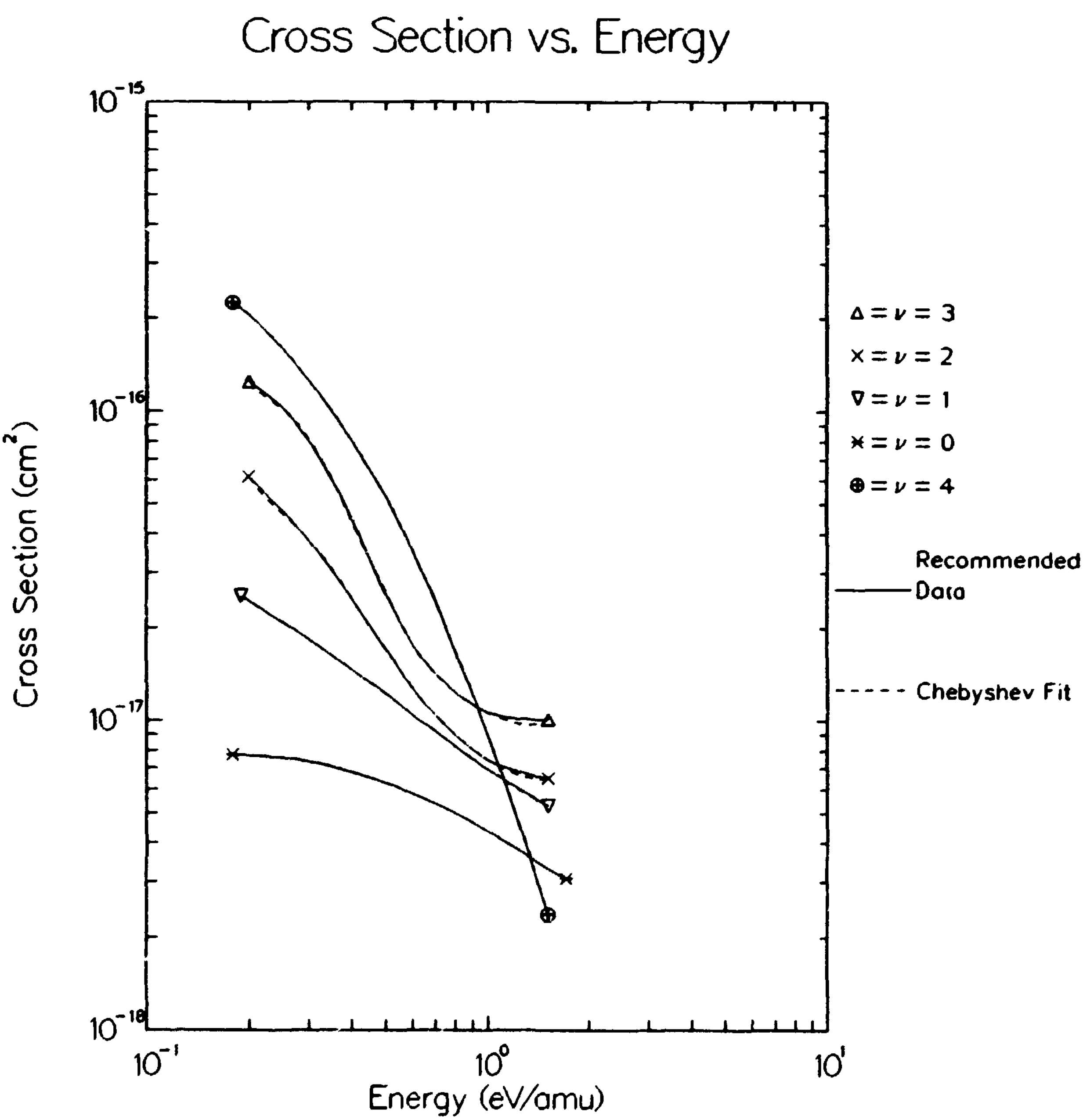
The fit represents the v = 2 cross section with an rms deviation of 0.2%. The maximum deviation is 0.5% at 6.0E-01 eV/amu.

The fit represents the v = 3 cross section with an rms deviation of 0.8%. The maximum deviation is 1.4% at 5.0E-01 eV/amu.

The fit represents the v = 4 cross section with an rms deviation of 0.2%. The maximum deviation is 0.6% at 8.0E-01 eV/amu.

See appendix for Chebyshev fit details.

$HD^+(\nu) + He \rightarrow HeH^+ + D, HeD^+ + H$



Cross Sections for Interchange Reactions Between H_2^+ and He

$$H_2^+ + He \rightarrow HeH^+ + H$$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
5.6E-01	1.04E+06	5.13E-16
6.0E-01	1.08E+06	4.81E-16
7.0E-01	1.16E+06	4.17E-16
8.0E-01	1.24E+06	3.67E-16
9.0E-01	1.32E+06	3.24E-16
1.0E+00	1.39E+06	2.86E-16
1.5E+00	1.70E+06	1.66E-16
2.0E+00	1.96E+06	1.04E-16
3.0E+00	2.41E+06	4.91E-17
4.0E+00	2.78E+06	3.07E-17
5.0E+00	3.11E+06	2.23E-17
6.0E+00	3.40E+06	1.77E-17
7.0E+00	3.68E+06	1.49E-17
8.0E+00	3.93E+06	1.29E-17
9.0E+00	4.17E+06	1.16E-17
1.0E+01	4.39E+06	1.05E-17

References: 609, 611, 612, 613, 614, 615, 616, 617, 618, 619

Accuracy: Unknown

Notes: (1) For relative total cross sections see: Neynaber and Magnuson (Ref. 618). (2) For absolute cross sections as a function of vibrational states of H_2^+ see: Chupka and Russell (Ref. 616); Chupka et al. (Ref. 617); Turner et al. (Ref. 611); and Govers and Guyon (Ref. 619). (3) For absolute rate constants for production of HeH^+ as a function of the energy see: Von Koch and Friedman (Ref. 615); and Smith et al. (Ref. 609). (4) Rate coefficient k, at thermal energy for HeH^+ production is: $k = [1.4 \pm .15]\times10^{-10}$ cm^3/mol s. (5) For data on $D_2^+ + He \rightarrow HeD^+$ see: Smith et al. (Ref. 609). (6) Rate coefficient k at thermal energy for HeD^+ production is: $k = [1.15 \pm 0.1]\times10^{-10}$ cm^3/mol.s.

Chebyshev Fitting Parameters for Cross Sections

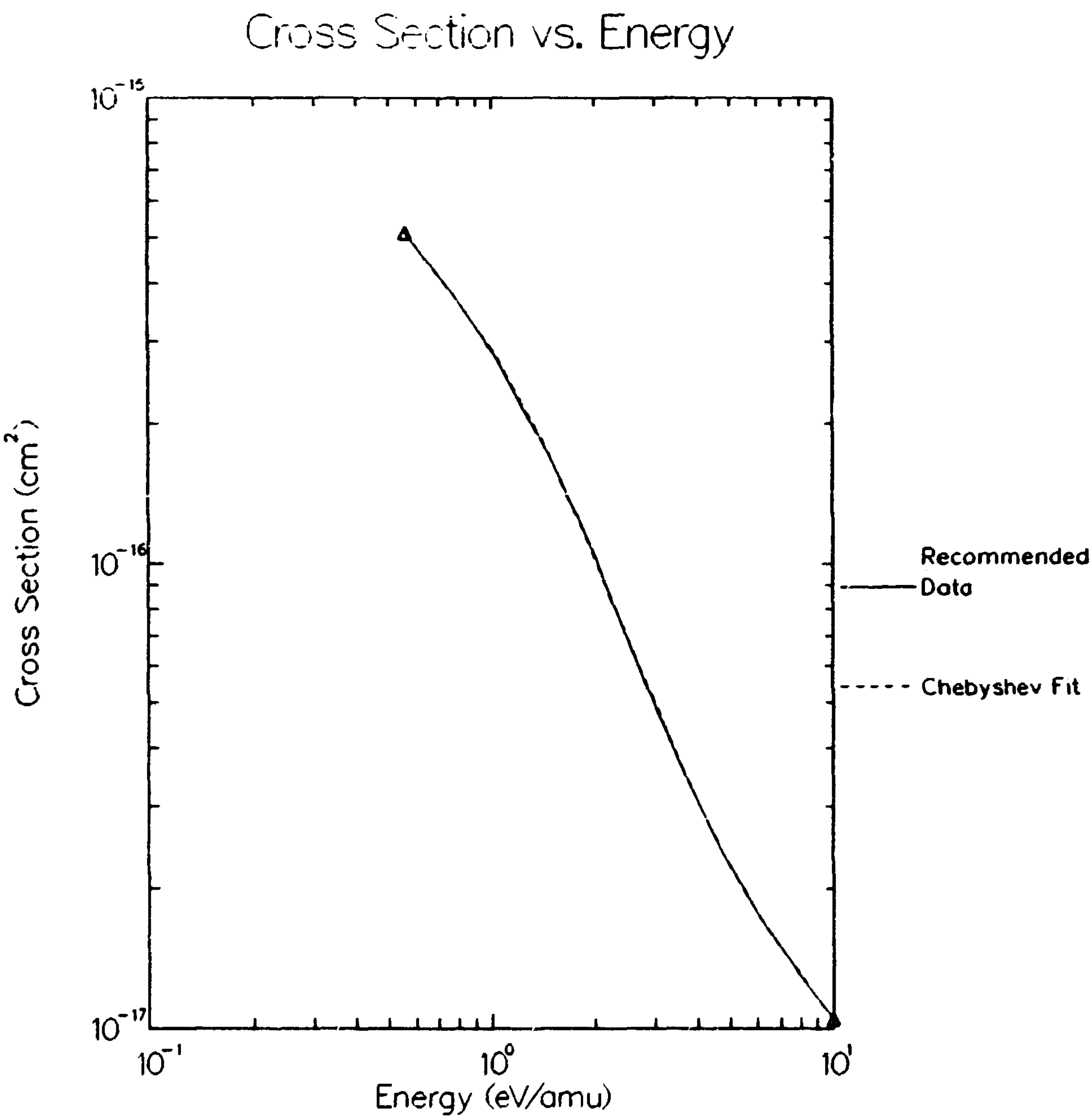
E_{min} = 5.6E-01 eV/amu, E_{max} = 1.0E+01 eV/amu

A0	A1	A2	A3	A4	A5	A6
-74.2766	-2.05811	-.0177676	.136014	.00555409	-.0251696	-.000631817

The fit represents the above cross section with an rms deviation of 0.6%. The maximum deviation is 1.4% at 3.0E+00 eV/amu.

See appendix for Chebyshev fit details.

$H_2^+ + He \rightarrow HeH^+ + H$



Cross Sections for Interchange Reactions Between H_2^+ and H_2

$$H_2^+ + H_2 \rightarrow H_3^+ + H$$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E-02	1.39E+05	1.16E-14
2.0E-02	1.96E+05	1.03E-14
4.0E-02	2.78E+05	8.63E-15
7.0E-02	3.68E+05	7.20E-15
1.0E-01	4.39E+05	6.23E-15
2.0E-01	6.21E+05	4.62E-15
4.0E-01	8.79E+05	3.27E-15
7.0E-01	1.16E+06	2.43E-15
1.0E+00	1.39E+06	1.87E-15
1.5E+00	1.70E+06	1.25E-15
2.0E+00	1.96E+06	8.51E-16
4.0E+00	2.78E+06	2.09E-16
7.0E+00	3.68E+06	2.22E-17

References: 607, 612, 613, 621, 622, 623, 624, 625, 626, 627, 628, 629, 631, 632, 633, 636, 637

Accuracy: ± 45%

Notes: (1) For relative total cross sections see: Clow and Futrell (Ref. 625); and Vance and Bailey (Ref. 628). (2) For absolute rate constants as a function of the energy see: Clow and Futrell (Ref. 625); Bowers et al. (Ref. 626); and Reuben and Friedman (Ref. 627). (3) For energy distributions of H_3^+ see: Lees and Rol (Ref. 638); and Gentry et al. (Ref. 621). (4) For cross sections as a function of v see: Chupka et al. (Ref. 629); and Koyano and Tanaka (Ref. 633). (5) For k as a function of υ see: Theard and Huntress (Ref. 613). (6) Rate coefficient k at thermal energy for production of H_3^+ is: $k = (2.0 \pm .15) \times 10^{-9}$ cm^3/s, from Refs. 613, 621, 623, 625, 626, 627, 631, 637.

Chebyshev Fitting Parameters for Cross Sections

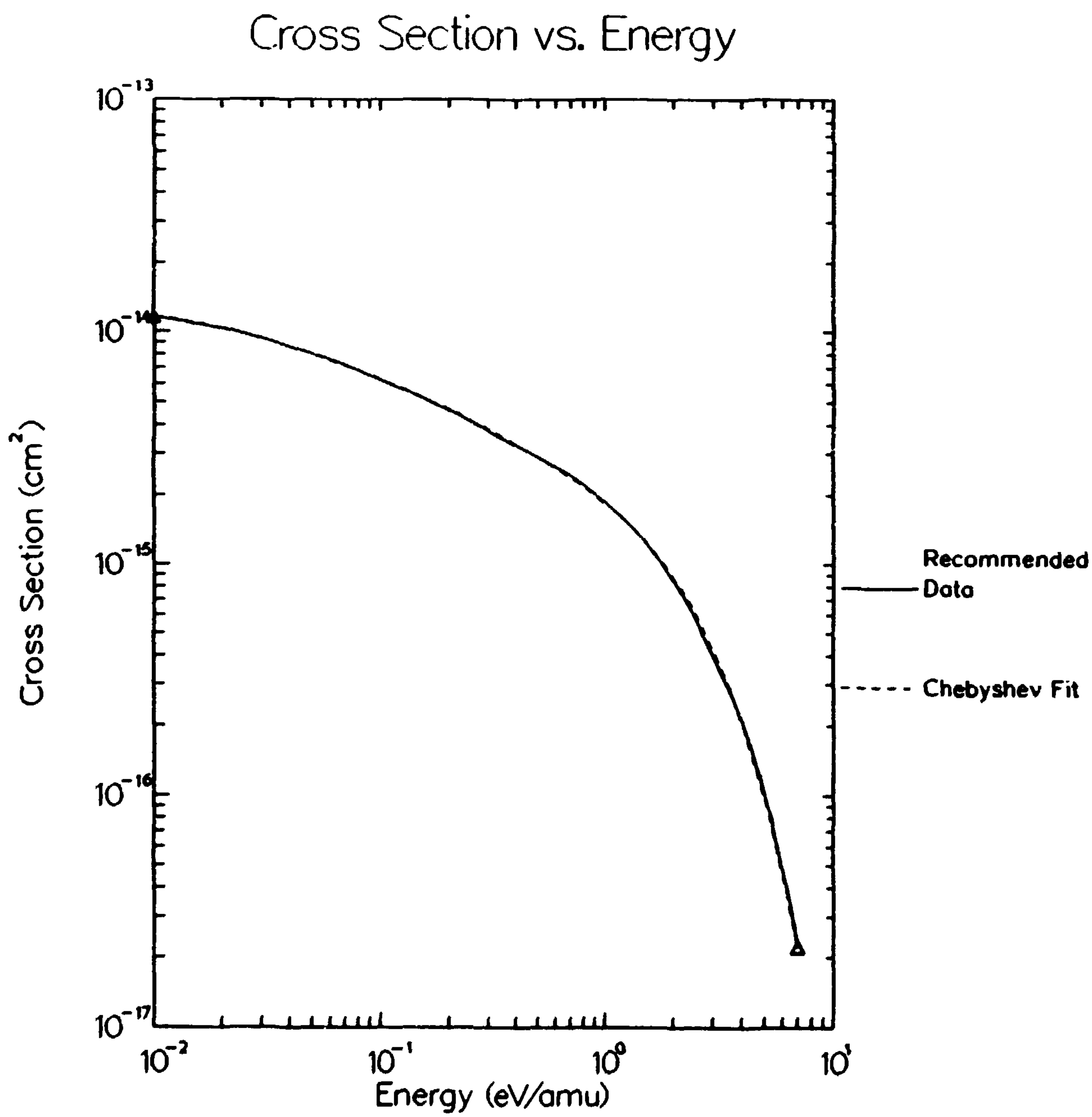
E_{min} = 1.0E-02 eV/amu, E_{max} = 7.0E+00 eV/amu

A0	A1	A2	A3	A4	A5	A6
-67.8902	-2.58783	-1.02353	-.461932	-.229219	-.0763343	-.0170793

The fit represents the above cross section with an rms deviation of 1.2%. The maximum deviation is 2.7% at 2.0E+00 eV/amu.

See appendix for Chebyshev fit details.

$H_2^+ + H_2 \rightarrow H_3^+ + H$



Cross Sections for Interchange reactions Between D_2^+ and D_2

$$D_2^+ + D_2 \rightarrow D_3^+ + D$$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.6E-01	5.56E+05	2.60E-15
2.0E-01	6.21E+05	2.43E-15
3.0E-01	7.61E+05	2.00E-15
4.0E-01	8.79E+05	1.69E-15
5.0E-01	9.82E+05	1.45E-15
6.0E-01	1.08E+06	1.29E-15
7.0E-01	1.16E+06	1.16E-15
8.0E-01	1.24E+06	1.06E-15
9.0E-01	1.32E+06	9.77E-16
1.0E+00	1.39E+06	9.07E-16
1.5E+00	1.70E+06	6.90E-16
2.0E+00	1.96E+06	5.55E-16
3.0E+00	2.41E+06	4.01E-16
4.0E+00	2.78E+06	3.15E-16
4.2E+00	2.85E+06	3.04E-16

__References:__ 623, 625, 626, 627, 631, 647

__Accuracy:__ Unknown

__Notes:__ (1) For relative cross sections see: Clow and Futrell (Ref. 625). (2) For absolute rate constants as a function of energy see: Drewitz (Ref. 631); Harrison et al. (Ref. 623); Reuben and Friedman (Ref. 627); Clow and Futrell (Ref. 625); and Bowers et al. (Ref. 626). (3) For kinetic energy distributions of D_3^+ products see: Doverspike and Champion (Ref. 647). (4) Rate coefficient for production of D_3^+ is: $k = 1.55 \times 10^{-9}$ cm^3/mol s from Refs. 623, 625, 626, 627, 631. The states of reactants are unknown.

__Chebyshev Fitting Parameters for Cross Sections__

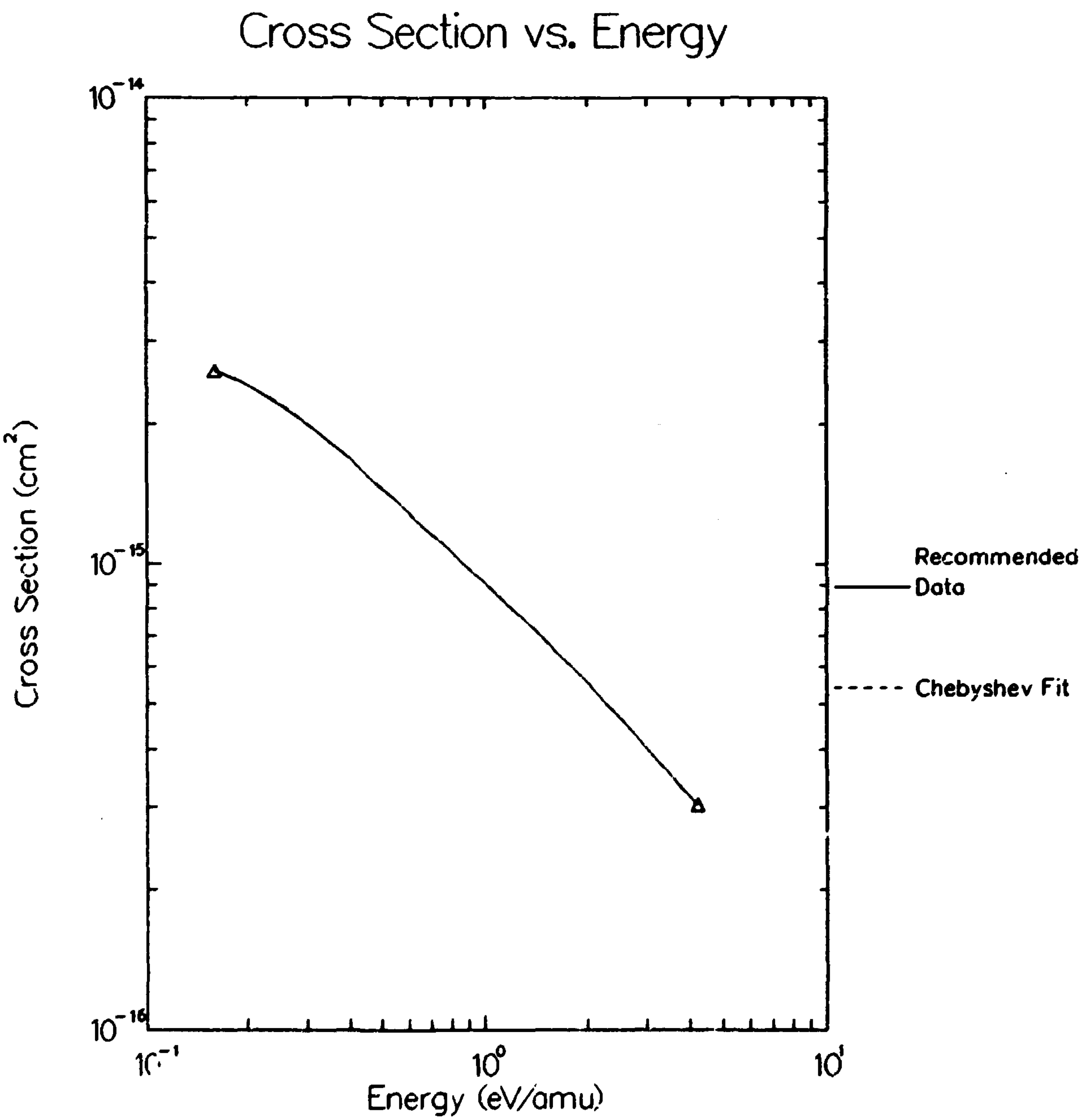
E_{min} = 1.6E-01 eV/amu, E_{max} = 4.2E+00 eV/amu

A0	A1	A2	A3	A4	A5	A6
-69.1270	-1.09264	-.0827553	.0133959	-.0140139	.00530178	.00343451

The fit represents the above cross section with an rms deviation of 0.2%. The maximum deviation is .4% at 1.0E+00 eV/amu.

See appendix for Chebyshev fit details.

$D_2^+ + D_2 \rightarrow D_3^+ + D$



Cross Sections for Interchange Reactions Between D_2^+ and H_2

$$D_2^+(v) + H_2 \rightarrow HD_2^+ + H$$

$v = 0$ Energy (eV/amu)	$v = 0$ σ (cm^2)	$v = 1$ Energy (eV/amu)	$v = 1$ σ (cm^2)	$v = 2$ Energy (eV/amu)	$v = 2$ σ (cm^2)	$v = 3$ Energy (eV/amu)	$v = 3$ σ (cm^2)
5.8E-02	1.88E-15	5.7E-02	2.03E-15	5.8E-02	2.01E-15	5.8E-02	1.93E-15
6.0E-02	1.84E-15	6.0E-02	1.92E-15	6.0E-02	1.96E-15	6.0E-02	1.90E-15
7.0E-02	1.52E-15	7.0E-02	1.61E-15	7.0E-02	1.76E-15	7.0E-02	1.78E-15
8.0E-02	1.20E-15	8.0E-02	1.29E-15	8.0E-02	1.57E-15	8.0E-02	1.62E-15
9.0E-02	9.67E-16	9.0E-02	1.10E-15	9.0E-02	1.42E-15	9.0E-02	1.49E-15
1.0E-01	8.31E-16	1.0E-01	9.66E-16	1.0E-01	1.28E-15	1.0E-01	1.36E-15
1.5E-01	5.70E-16	1.5E-01	6.93E-16	1.5E-01	8.29E-16	1.5E-01	8.81E-16
2.0E-01	4.29E-16	2.0E-01	5.25E-16	2.0E-01	5.66E-16	2.0E-01	5.70E-16
3.0E-01	2.47E-16	2.5E-01	3.78E-16	2.5E-01	3.79E-16	2.5E-01	3.75E-16
3.5E-01	1.81E-16	3.0E-01	2.79E-16	3.0E-01	2.77E-16	3.0E-01	2.46E-16
4.0E-01	1.52E-16	3.5E-01	2.00E-16	3.5E-01	2.01E-16	3.5E-01	1.65E-16
4.6E-01	1.15E-16	4.0E-01	1.44E-16	4.0E-01	1.47E-16	4.0E-01	1.12E-16
		4.5E-01	1.04E-16	4.5E-01	1.04E-16	4.5E-01	7.55E-17
		4.6E-01	9.61E-17	4.6E-01	9.58E-17	4.6E-01	6.93E-17

References: 625, 626, 627, 634, 638, 647, 652

Accuracy: 25%

Notes: (1) For relative cross sections see: Clow and Futrell (Ref. 625). (2) For rate constants, energy dependence see: Bowers et al. (Ref. 626); and Clow and Futrell (Ref. 625). (3) For kinetic energy distributions of HD_2^+ products see: Lees and Rol (Ref. 638); Doverspike and Champion (Ref. 647), and Krenos et al. (Ref. 652). (4) Rate coeficient for reaction $D_2^+ + H_2 \rightarrow$ products is: $k = (3.0 \pm 0.6) \times 10^{-9}$ cm^3/mols from Clow and Futrell (Ref. 625). (5) Data are presented as a function of v, as reported in Anderson et al. (Ref. 634).

Chebyshev Fitting Parameters for Cross Sections

$v = 0$ E_{min} = 5.8E-02 eV/amu, E_{max} = 4.6E-01 eV/amu
$v = 1$ E_{min} = 5.7E-02 eV/amu, E_{max} = 4.6E-01 eV/amu
$v = 2$ E_{min} = 5.8E-02 eV/amu, E_{max} = 4.6E-01 eV/amu
$v = 3$ E_{min} = 5.8E-02 eV/amu, E_{max} = 4.6E-01 eV/amu

	A0	A1	A2	A3	A4	A5	A6
$v = 0$	-70.4879	-1.34605	-.0400746	-.0884724	.00327275	.0410225	-.0238082
$v = 1$	-70.3174	-1.41371	-.174436	-.131909	-.00594907	.0250115	-.0190350
$v = 2$	-70.1696	-1.46820	-.256068	-.0411502	-.0107313	-.00889023	-.0110482
$v = 3$	-70.3104	-1.61386	-.377596	-.0473991	-.00736333	.000736757	-.00411866

The fit represents the $v = 0$ cross section with an rms deviation of 1.3%. The maximum deviation is 3.3% at 3.5E-01 eV/amu.

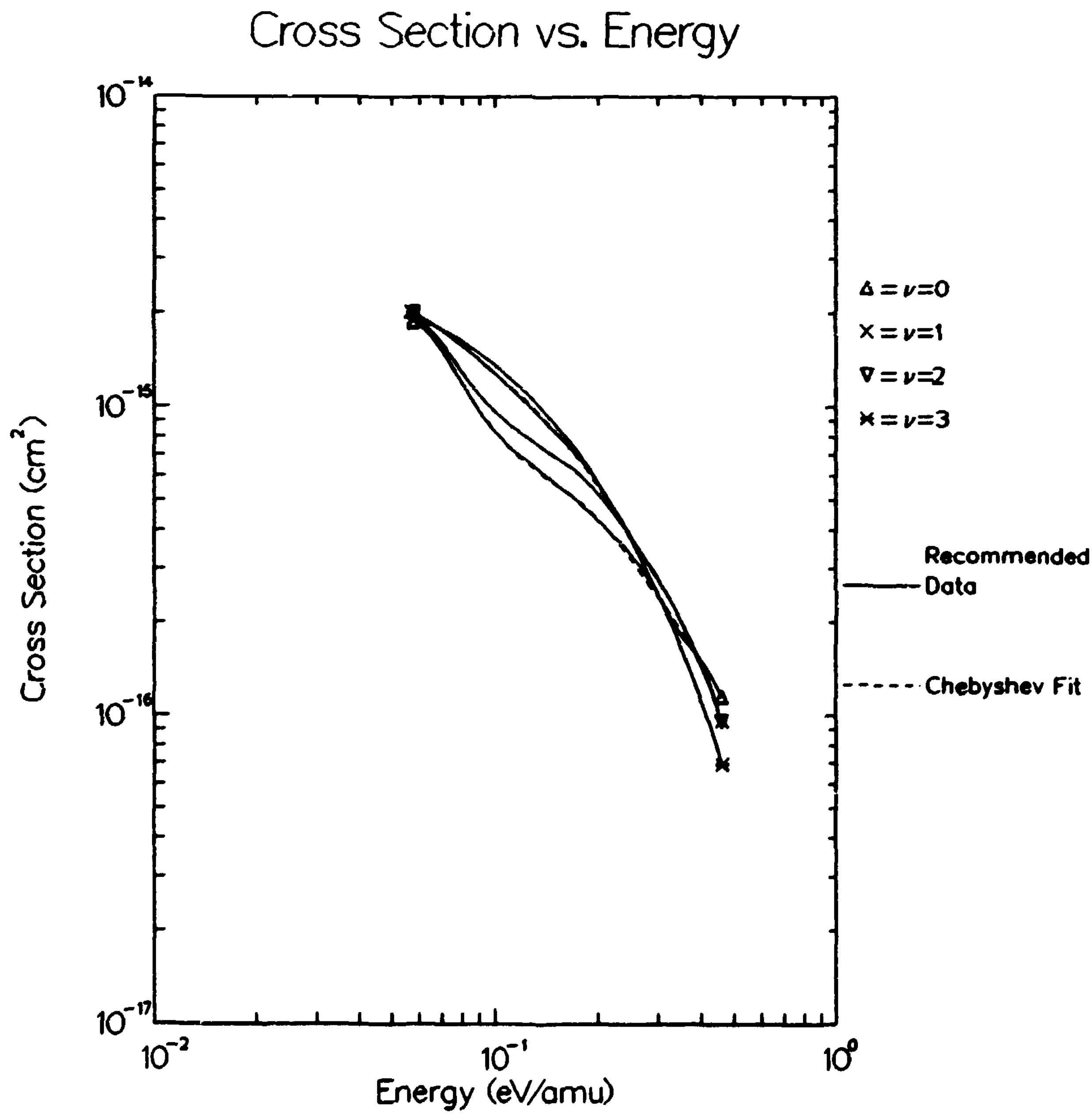
The fit represents the $v = 1$ cross section with an rms deviation of 0.7%. The maximum deviation is 1.3% at 6.0E-02 eV/amu.

The fit represents the $v = 2$ cross section with an rms deviation of 0.7%. The maximum deviation is 1.4% at 2.5E-01 eV/amu.

The fit represents the $v = 3$ cross section with an rms deviation of 0.3%. The maximum deviation is 0.4% at 8.0E-02 eV/amu.

See appendix for Chebyshev fit details.

$D^{2+}(\nu) + H_2 \rightarrow HD_2^+ + H$



Cross Sections for Interchange Reactions Between H_2^+ and D_2

$$H_2^+(\upsilon) + D_2 \rightarrow HD_2^+ + H$$

υ = 0		υ = 1		υ = 2		υ = 3		υ = 4	
Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)	Energy (eV/amu)	σ (cm^2)
1.7E-01	2.92E-15	1.7E-01	2.53E-15	1.7E-01	2.46E-15	1.8E-01	2.45E-15	1.8E-01	2.47E-15
2.0E-01	2.91E-15	2.0E-01	2.43E-15	2.0E-01	2.41E-15	2.0E-01	2.39E-15	2.0E-01	2.40E-15
3.0E-01	2.64E-15	3.0E-01	2.15E-15	3.0E-01	2.12E-15	3.0E-01	2.13E-15	3.0E-01	2.14E-15
4.0E-01	2.26E-15	4.0E-01	1.91E-15	4.0E-01	1.91E-15	4.0E-01	1.91E-15	4.0E-01	1.95E-15
5.0E-01	1.92E-15	5.0E-01	1.72E-15	5.0E-01	1.71E-15	5.0E-01	1.71E-15	5.0E-01	1.80E-15
6.0E-01	1.62E-15	5.0E-01	1.68E-15	6.0E-01	1.54E-15	6.0E-01	1.58E-15	6.0E-01	1.67E-15
7.0E-01	1.36E-15	6.0E-01	1.49E-15	7.0E-01	1.42E-15	7.0E-01	1.46E-15	7.0E-01	1.56E-15
8.0E-01	1.14E-15	7.0E-01	1.32E-15	8.0E-01	1.30E-15	8.0E-01	1.37E-15	8.0E-01	1.47E-15
9.0E-01	9.72E-16	8.0E-01	1.19E-15	9.0E-01	1.21E-15	9.0E-01	1.29E-15	9.0E-01	1.39E-15
1.0E+00	8.51E-16	9.0E-01	1.08E-15	1.0E+00	1.13E-15	1.0E+00	1.23E-15	1.0E+00	1.32E-15
1.5E+00	5.48E-16	1.0E+00	9.81E-16	1.5E+00	[illegible].39E-16	1.5E+00	9.64E-16	1.5E+00	1.06E-15
2.0E+00	4.24E-16	1.5E+00	6.61E-16	2.0E+00	6.65E-16	2.0E+00	7.74E-16	2.0E+00	8.60E-16
3.0E+00	3.02E-16	2.0E+00	5.13E-16	3.0E+00	4.65E-16	3.0E+00	5.21E-16	3.0E+00	5.53E-16
4.0E+00	2.39E-16	3.0E+00	3.71E-16	4.0E+00	3.58E-16	4.0E+00	3.73E-16	4.0E+00	3.55E-16
4.5E+00	2.19E-16	4.0E+00	3.07E-16	5.0E+00	2.90E-16	5.0E+00	2.85E-16	4.5E+00	2.84E-16
		5.0E+00	2.74E-16	5.4E+00	2.70E-16	5.2E+00	2.80E-16		

References: 625, 626, 627, 634, 638, 652

Accuracy: 25%

Notes: (1) For energy dependence of rate constants see: Bowers et al. (Ref. 626); Clow and Futrell (Ref. 625); and Reuben and Friedman (Ref. 627). (2) For kinetic energy distributions of HD_2^+ products see: Lees and Rol (Ref. 638); and Krenos et al. (Ref. 652). (3) For relative cross sections see: Clow and Futrell (Ref. 625). (4) Rate coefficient for reaction: $H_2^+ + D_2 \rightarrow$ Products is: $k = (3.2 \pm 0.6) \times 10^{-9}$ cm^3/mol.s from Clow and Futrell (Ref. 625). (5) Data are presented as a function of υ, as reported in Anderson et al. (Ref. 634).

Chebyshev Fitting Parameters for Cross Sections

υ = 0 E_{min} = 1.7E-01 eV/amu, E_{max} = 4.5E+00 eV/amu
υ = 1 E_{min} = 1.7E-01 eV/amu, E_{max} = 5.0E+00 eV/amu
υ = 2 E_{min} = 1.7E-01 eV/amu, E_{max} = 5.4E+00 eV/amu
υ = 3 E_{min} = 1.8E-01 eV/amu, E_{max} = 5.2E+00 eV/amu
υ = 4 E_{min} = 1.8E-01 eV/amu, E_{max} = 4.5E+00 eV/amu

	A0	A1	A2	A3	A4	A5	A6
υ = 0	-69.2456	-1.40946	-.128223	.139770	-.0170479	-.0330555	.00606671
υ = 1	-69.2502	-1.19199	-.116093	.0911706	.0198857	-.0118162	-.000510451
υ = 2	-69.1336	-1.12492	-.176104	.0165999	.000760447	.00273290	-.000454869
υ = 3	-69.0426	-1.06802	-.213967	-.0360351	-.00493123	.0161013	.00775590
υ = 4	-68.8659	-.092859	-.258499	-.0853432	-.0286104	-.00372291	.00520865

The fit represents the υ = 0 cross section with an rms deviation of 1.3%. The maximum deviation is 2.0% at 1.0E+00 eV/amu.

The fit represents the υ = 1 cross section with an rms deviation of 0.6%. The maximum deviation is 0.8% at 7.0E-01 eV/amu.

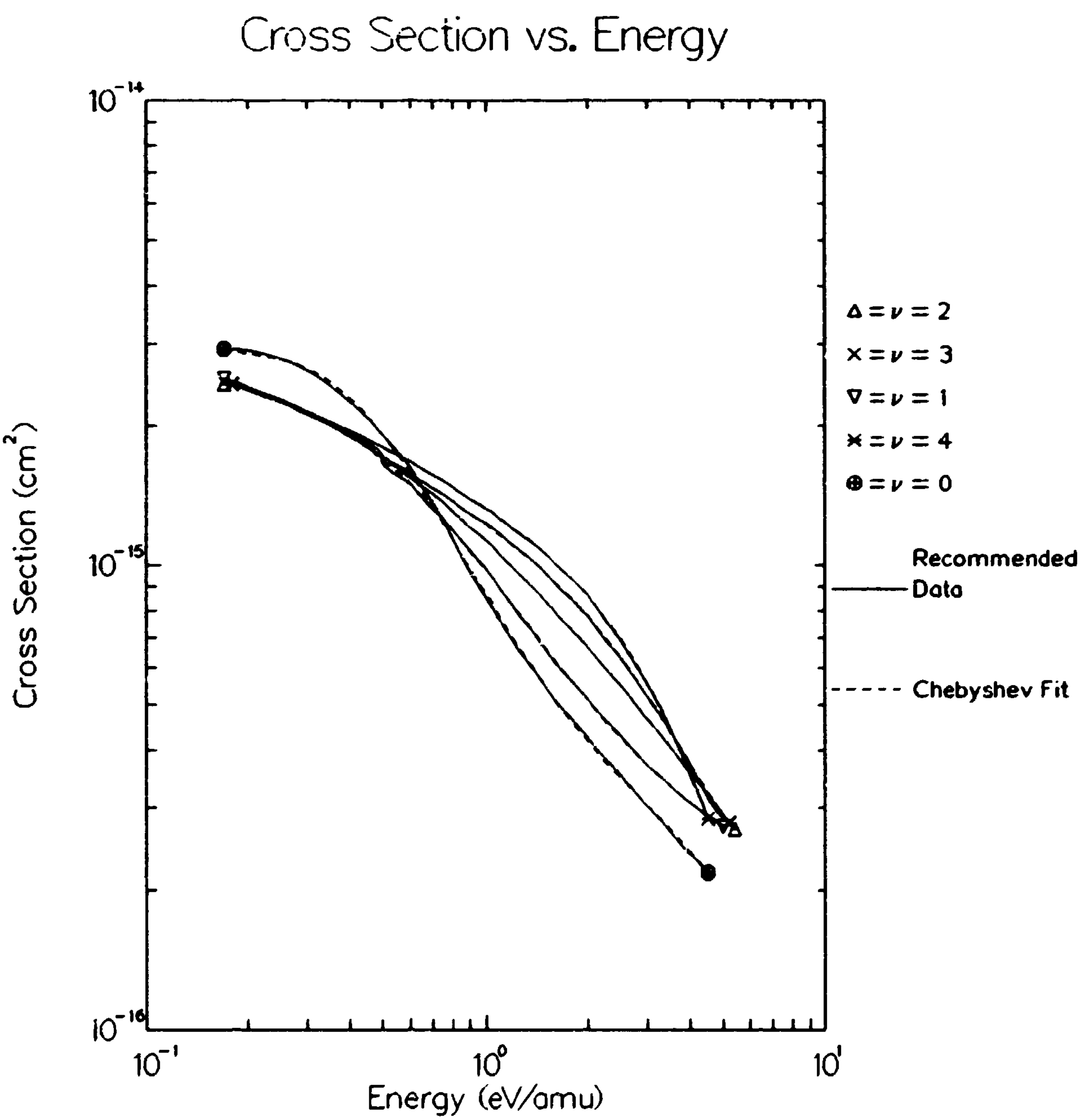
The fit represents the υ = 2 cross section with an rms deviation of 0.3%. The maximum deviation is 0.7% at 3.0E-01 eV/amu.

The fit represents the υ = 3 cross section with an rms deviation of 0.5%. The maximum deviation is 1.3% at 5.0E+00 eV/amu.

The fit represents the υ = 4 cross section with an rms deviation of 0.2%. The maximum deviation is 0.3% at 1.0E+00 eV/amu.

See appendix for Chebyshev fit details.

$H_2^+(\nu) + D_2 \rightarrow HD_2^+ + H$



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APPENDIX 1

Calculation of Cross Sections and Rate Coefficients from Chebyshev Fitting Parameters

APPENDIX 1

Calculation of Cross Sections and Rate Coefficients from Chebyshev Fitting Parameters

For ease of numerical data retrieval, the method of least-squares fitting to the recommended cross sections and rate coefficients using the Chebyshev orthogonal polynomials has been used throughout this compilation. In general, it produced high accuracy fits to the recommended data.

A measure of the accuracy of the Chebyshev fit representation to the recommended cross sections has been calculated and appears at the bottom of each cross section page as a relative rms error with a maximum deviation. In a handful of cases, the recommended cross sections had associated Chebyshev fits with an error of greater than 100% rms error. These fits have not been included and only the recommended cross section data is presented.

The recommended cross-section and rate coefficient data have been fitted to the following analytical expression:

$$\ell n[\sigma(E)] = A_0/2 + \sum_{i=1}^{k} A_i T_i(X) \ ,$$

where k is the smallest number of coefficients that provides an accurate fit (usually k=6), and

$$X = [(\ell nE - \ell nE_{min}) - (\ell nE_{max} - \ell nE)] \ / \ (\ell nE_{max} - \ell nE_{min}),$$

and where $T_i(X)$ are the Chebyshev orthogonal polynomials. Fitting to the natural logarithms of the cross section and energy values increases the Chebyshev fit accuracy by reducing the ranges of values for the cross section and energy by several orders of magnitude.

The values of fitting parameters A_i, E_{min}, and E_{max} are given for each reaction after each cross-section or rate-coefficient table. In each case, the minimum number of parameters A_i are listed which are required to produce a satisfactory fit to the data. The cross section σ is given in units of cm^2, with collision energies E in units of eV/amu. The rate coefficient α is in units of cm^3/s, with Maxwellian temperatures T in units of eV. (We follow the convention used frequently in plasma physics of expressing temperature in eV energy units, recognizing that kT is understood, where k is Boltzmann's constant.) The analytic representation of the cross section or rate coefficient should be used only in the region between E_{min} and E_{max}. The expressions for the Chebyshev polynomials are reproduced below for convenience.

$T_1(X) = X$
$T_2(X) = 2\ X^2 - 1$
$T_3(X) = 4\ X^3 - 3\ X$
$T_4(X) = 8\ X^4 - 8\ X^2 + 1$
$T_5(X) = 16\ X^5 - 20\ X^3 + 5\ X$
$T_6(X) = 32\ X^6 - 48\ X^4 + 18\ X^2 - 1$
$T_7(X) = 64\ X^7 - 112\ X^5 + 56\ X^3 - 7\ X$
$T_8(X) = 128\ X^8 - 256\ X^6 + 160\ X^4 - 32\ X^2 + 1$

All the rate-coefficient and cross-section data in this volume may be reproduced by using either of the model Chebyshev fitting programs listed at the end of this Appendix. For each reaction and pair of reactants there are given Chebyshev fitting parameters to be used as input to the CHEBFOR Fortran or CHEB Basic code.

In the plots of recommended data the Chebyshev or alternative fits have been added as dashed lines to give a visual inspection of the accuracy of the fit. Also, the pages containing cross section tables include rms deviations of the fit to the recommended data over the energy range from E_{min} to E_{max}.

The sample programs listed below utilize recursion relations to rapidly generate the Chebyshev polynomials and require input of the parameters E_{min}, E_{max}, and the Chebyshev coefficients A0, A1, A2, ... to enable calculation of a rate coefficient or cross section at a given energy. The programs direct the user to input these parameters at the proper time during program execution. To simplify data input, the tabulations of coefficients contain the minimum number of significant digits required to produce an accurate representation of the polynomial fit.

The ALADDIN database system may also be used to generate the cross-section data directly from the fitting coefficients. See Appendix 2 for details.

Sample FORTRAN Program

```
      Program CHEBFOR
C     This Fortran program is derived from a program in 'Elementary Numerical Analysis: An
C     Algorithmic Approach' , S. D. Conte and C. de Boor, McGraw-Hill, Inc., P.254, 1972.
      DIMENSION D(10)
      REAL*4 ANS, ANS2
1000  TYPE 14
14    FORMAT('   IS THIS A FIT TO RATE COEFFICIENTS? ; ENTER "Y" FOR YES, "N" FOR NO')
      ACCEPT 199, ANS
199   FORMAT(A1)
1010  TYPE 15
15    FORMAT('   ENTER THE NUMBER OF COEFFICIENTS')
      ACCEPT 200, NTERMS
200   FORMAT(I2)
```

Sample FORTRAN Program (Cont'd.)

```
      IF(ANS .EQ. 'N') GO TO 16
      TYPE 1
1     FORMAT(' **** ENTER Emin (eV) *****')
      ACCEPT *, EMIN
      TYPE 9
9     FORMAT(' **** ENTER Emax (eV) *****')
      ACCEPT *, EMAX
      GO TO 25
19    FORMAT(' **** ENTER Emin (eV/amu) ****')
16    TYPE 19
      ACCEPT *, EMIN
      TYPE 29
29    FORMAT(' **** ENTER Emax (eV/amu) ****')
      ACCEPT *, EMAX
25    EMINL=ALOG(EMIN)
      EMAXL=ALOG(EMAX)
      TYPE 2, NTERMS
2     FORMAT('  ENTER ', I2, ' COEFFICIENTS ')
      ACCEPT *, (D(J), J=1,NTERMS)
100   IF (ANS .EQ. 'N')GO TO 24
      TYPE 3, EMIN, EMAX
3     FORMAT('  INPUT TEMPERATURE (eV) BETWEEN ',1PE10.1,' AND ',1PE10.1,' FOR THE RATE
     & COEFFICIENT CALCULATION  ')
      GO TO 26
24    TYPE 23, EMIN, EMAX
23    FORMAT('  INPUT ENERGY (eV/amu) BETWEEN ',1PE10.1,' AND ',1PE10.1,' FOR THE CROSS SECTION
     & CALCULATION  ')
C     TAKE ENERGY FOR CALCULATION AND USE THREE TERM RECURRENCE RELATION
26    K=NTERMS
      CHEB=D(K)
      ACCEPT *, X
      IF(X .LT. 0.) GO TO 101
      X=ALOG(X)
      K=K-1
      XNORM=(X-EMINL-(EMAXL-X))/(EMAXL-EMINL)
      TWOX=2.*XNORM
      PREV2=0.
10    PREV=CHEB
      IF(K .EQ. 1)  GO TO 20
      CHEB=D(K)+TWOX*PREV-PREV2
      PREV2=PREV
      K=K-1
      GO TO 10
20    CHEB=.5*D(1)+XNORM*PREV-PREV2
      IF(ANS .EQ. 'Y') TYPE 69, EXP(CHEB)
69    FORMAT('  RATE COEFFICIENT (CM3/S) = ',1PE12.4)
      IF(ANS .EQ. 'N') TYPE 45, EXP(CHEB)
45    FORMAT('  CROSS SECTION (CM2) = ',1PE12.4)
      TYPE 48
48    FORMAT('  DO YOU WANT ANOTHER CALCULATION FOR THIS FIT?, ENTER "Y" FOR YES; "N" FOR NO')
      ACCEPT 199, ANS2
      IF(ANS2 .EQ. 'Y') GO TO 100
      TYPE 49
49    FORMAT('  DO YOU WANT A DIFFERENT FIT CALCULATION?, ENTER "Y" FOR YES;  "N" FOR NO')
      ACCEPT 199, ANS2
      IF(ANS2 .EQ. 'Y') GO TO 1000
101   END
```

Sample BASIC Program

```
5 REM CHEB.BAS
10 REM CHEB PROGRAM IS A BASIC PROGRAM DERIVED FROM A FORTRAN
20 REM PROGRAM IN "ELEMENTARY NUMERICAL ANALYSIS: AN ALGORITHMIC
30 REM APPROACH", S. D. CONTE AND C. de BOOR, 30 REM McGRAW-HILL, INC., P
40 REM 254, 1972.
50    DIM D(10)
60    INPUT "IS THE A RATE FIT?; ENTER 'Y' FOR YES, 'N' FOR NO   ",ANS$
70    IF ANS$="Y" THEN INPUT "ENTER Emin (eV)  ",EMIN
80    IF ANS$="Y" THEN INPUT "ENTER Emax (eV)  ",EMAX
90    IF ANS$="N" THEN INPUT "ENTER Emin (eV/amu)  ",EMIN
100    IF ANS$="N" THEN INPUT "ENTER Emax (eV/amu)  ",EMAX
110    INPUT "HOW MANY COEFFICIENTS FOR THIS FIT?";NTERMS
120   EMINL=LOG(EMIN)
130   EMAXL=LOG(EMAX)
140   PRINT USING"ENTER # COEFFICIENTS";NTERMS
150   FOR J=1 TO NTERMS
160   INPUT D(J):NEXT J
170   IF ANS$="Y" THEN PRINT USING "INPUT ENERGY (eV/amu) BETWEEN ###.# AND #.#^^^^ FOR THE RATE
COEFFICIENT CALCULATION";EMIN;EMAX
180   IF ANS$="N" THEN PRINT USING "INPUT ENERGY (eV/amu) BETWEEN ###.# AND #.#^^^^ FOR THE CROSS
SECTION CALCULATION";EMIN;EMAX
190 REM GET ENERGY FOR CALCULATION AND USE THREE TERM RECURRENCE
200 REM RELATION
210   INPUT X
220   K=NTERMS
230   CHEB=D(K)
240   IF X<0 THEN END
250   X=LOG(X)
260   K=K-1
270   IF K=0 THEN END
280   XNORM=(X-EMINL-(EMAXL-X))/(EMAXL-EMINL)
290   TWOX=2*XNORM
300   PREV2=0
310   PREV=CHEB
320   IF K=1 GOTO 370
330   CHEB=D(K)+TWOX*PREV-PREV2
340   PREV2=PREV
350   K=K-1
360   GOTO 310
370   CHEB=.5*D(1)+XNORM*PREV-PREV2
380   IF ANS$="Y" THEN PRINT USING"##.##^^^^ = RATE COEFFICIENT (CM3/S)";EXP(CHEB)
390   IF ANS$="N" THEN PRINT USING"##.##^^^^ = CROSS SECTION (CM2)";EXP(CHEB)
400   GOTO 170
410   END
```

APPENDIX 2

ALADDIN Database System and Data Files

APPENDIX 2

ALADDIN Database System and Data Files

ALADDIN[1,2] is an atomic physics database system which has been developed by R. A. Hulse of Princeton Plasma Physics Laboratory in conjunction with the Atomic and Molecular Data Unit of the International Atomic Energy Agency (IAEA) to provide a broadly-based standard medium for the exchange and management of atomic data. ALADDIN has been adopted by the IAEA as the standard international atomic physics data exchange format for magnetic confinement fusion applications.

ALADDIN consists of a data format definition together with supporting software for both interactive searches and access to the data by plasma modelling and other computer codes. The ALADDIN software has been written in strict FORTRAN-77 to ensure compatibility with the widest possible range of scientific computers. The data are stored in straightforward ASCII text files either in tabular x,y or parametrized format. Provision has been made within ALADDIN to incorporate the subroutines which are needed to extract the atomic data from each ALADDIN data entry. The Chebyshev polynomial fits which are presented for the data in this volume are one example of such a parametrization.

All recommended cross-section data from the compilations in the **Atomic Data for Fusion** series are available in ALADDIN format (including those from this volume). Table 2.1 contains a sample ALADDIN data entry from each chapter of this volume. Each entry contains a page-number label to expedite locating specific data within the file. Complete ALADDIN data files for this series and a copy of the ALADDIN Database program are available on PC-DOS-formatted diskettes from:

Controlled Fusion Atomic Data Center
Oak Ridge National Laboratory
P. O. Box 2008
MS-6372
Oak Ridge, TN 37831-6372, U.S.A.

A copy of the ALADDIN Manual[2] which contains instructions for its use and a dictionary of abbreviations and symbolic notations for collision processes is also available from the above address. The ALADDIN code and reference material are also available directly from the IAEA (see address below).

The ALADDIN data files and FORTRAN program may also be transmitted readily by electronic mail, and are available by contacting:

phaneuf@orn.MFENET or **phaneuf@orph01.BITNET**

With input from a number of international data centers, the Atomic and Molecular Data Unit of the IAEA is assembling a larger ALADDIN data base of atomic and molecular processes relevant to fusion applications, and is providing officially recommended data in ALADDIN format. Further information may be obtained by contacting:

Atomic and Molecular Data Unit
Nuclear Data Section
International Atomic Energy Agency
P. O. Box 100
A-1400 Vienna, Austria

or by electronic mail at:

RNDS@IAEA1.BITNET

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1. R. A. Hulse, "The ALADDIN Atomic Physics Database System," pp. 63-72 in **Atomic Processes in Plasmas**, AIP Conference Proceedings 206, ed. Y. K. Kim and R. C. Elton, AIP, New York, 1990.

2. **ALADDIN Manual, A System for Storage, Exchange and Management of Atomic and Molecular Data for Fusion**, IAEA-NDS-AM-17, Atomic and Molecular Data Unit, Nuclear Data Section, International Atomic Energy Agency, Vienna, June 1989.

TABLE 2.1

Sample ALADDIN Data File

```
$ CX  H [+1]  H [+0]   H [+0]  H [+1]
& XS   EVAL  ACC-B  ORNL-CFADC  DOC-ORNL-6086  A-22  6/90  #CHEB
-72.6656        -5.49142        -3.42948       -1.98377       -0.878009
 -0.198932       0.0837431      0.121252        0.0827182  0.12  630000.

$ CXSS  He [+2]  H [+0] (G)   He [+1] (2s)  H [+1]
& XS   EVAL  ACC-C  ORNL-CFADC  DOC-ORNL-6086  B-89  6/90  #CHEB
-89.4268        -0.438776       -8.73454        0.130314        -0.0101210
  0.0343355      0.227699       -0.188121      -0.130396   23.  2500000.

$ EXC  H [+0] (G)  H [+0] (G)   H [+0] (2s)  H [+0]
& XS   EVAL  ACC-?  ORNL-CFADC  DOC-ORNL-6086  C-2  8/89  #CHEB
-79.1098        -0.784062       -0.651723       0.0462865       0.114234
 -0.00487654    -0.0114391      0.0             0.0      2000.   90000.

$ ION  H [+1]  H [+0]   H [+1]  H [+1]  e
& XS   EVAL  ACC-B  ORNL-CFADC  DOC-ORNL-6086  D-6  5/90  #CHEB
-75.505348206  -0.409784913  -0.996553540   0.355360299  -0.049000371
 -0.034998417   0.043782476  0.0            0.0    9400.     1500000.

$ STRIP  H [+0]  H [+0]   H [+1]  H [+0]  e
& XS   EVAL  ACC-B  ORNL-CFADC  DOC-ORNL-6086  E-2  5/90  #CHEB
-77.1793823242 -0.4514082074 -1.5175991058  0.5439749956 -0.0355154276
  0.0025895320 -0.0750899166  0.0           0.0      1200. 3500000.

$ ELDET  H [-1]  H [+0]   H [+0]  H [+0]  e
& XS   EVAL  ACC-C  ORNL-CFADC  DOC-ORNL-6086  F-2  5/90  #CHEB
-72.0698776245 -2.4792380333 -0.9363254905  0.0886530057  0.0175392255
  0.0545278080 -0.0645320490  0.0           0.0       110. 4000000.

$ DISION2  H [+0]  H(2) [+0]   H [+0]  H [+1]  H [+1]  2e
& XS   EVAL  ACC-?  ORNL-CFADC  DOC-ORNL-6086  G-2  6/90  #CHEB
-82.5844192505  1.5008718967 -0.5141620040 -0.0138262566  0.0274858437
 -0.0085383281 -0.0116637163  0.0           0.0      5000. 50000.

$ PX  H [+1]  D(2) [+0]   D [+1]  HD [+0]
& XS   EVAL  ACC-?  ORNL-CFADC  DOC-ORNL-6086  H-2  9/89  #CHEB
-75.6467819214 -3.2291088104  0.4121128917  0.0393397696 -0.2617489398
  0.0012951158  0.1208853275  0.0           0.0      0.45     100.
```

APPENDIX 3

Atomic Physics

Handy Conversion Units and Formulas

APPENDIX 3

Atomic Physics

Handy Conversion Units and Formulas

Conversion Units

1 electron volt = 1 eV = 8065.76 cm^{-1} = 23.069 kcal/mol = 1.6022 × 10^{-12} ergs = 1.6022 × 10^{-19} joules

1 atomic unit = 1 a.u. = 2 Rydbergs = 27.21 eV = 1 Hartree

1 atomic mass unit = 1 a.m.u. = 1.6605 × 10^{-24} gm

Atomic velocity = velocity of 13.6 eV electron = 2.18 × 10^{8} cm/sec = velocity of 24.97 keV proton

Atomic radius = radius of first Bohr orbit of H^{o} = 5.29 × 10^{-9} cm

1 angstrom = 1 Å = 1 × 10^{-8} cm

Electron mass, m_e = 9.110 × 10^{-28} gm

Electron charge, e = 4.8032 × 10^{-10} statcoulomb, or 1.6011 × 10^{-19} coulombs

Proton mass = 1.673 × 10^{-24} gm

Atomic unit of time = atomic radius/atomic velocity = 2.42 × 10^{-17} sec

Boltzmann constant, k = 1.331 × 10^{-16} erg/°K

1 mm Hg = 133.3 pascals = 1 torr; 1 mBar = 100 pascals

Atomic cross section = π × (atomic radius)^2 = πa_o^2 = 8.797 × 10^{-17} cm^2

1 mol = 6.022169 × 10^{23} molecules = Avogadro's number

Loschmidt's number = number of molecules at 1 mm Hg at 0°C = 2.687 × 10^{16} cm^{-3}

Formulas

Velocity (non-relativistic) (cm/sec) = $1.38 \times 10^6 (E/m)^{1/2}$, where E = energy of the particle in eV, of mass m in a.m.u.

Energy levels in hydrogen-like atoms,

$$E_n(\text{eV}) = \frac{-13.6\ Z^2}{n^2};$$

where Z is the atomic number and n is the total quantum number.

Wavelength of a photon,

$$\lambda(\text{Å}) = \frac{1.2398 \times 10^4}{E},$$

where E is the photon energy in eV.

Wavelength of a non-relativistic electron,

$$\lambda(\text{Å}) = \frac{17.34}{T^{1/2}},$$

where T is the temperature of the electrons in eV.

Relative velocity (cm/s) = $V_r = (V_1^2 + V_2^2 - 2V_1V_2\cos\theta)^{1/2}$, where V_1 = velocity of particle 1 in cm/sec, V_2 = velocity of particle 2, and θ = angle of approach.

Energy (center of mass) (eV) =

$$\frac{M_1M_2}{M_1+M_2}\left[\frac{E_1}{M_1}+\frac{E_2}{M_2}\cdot 2\left(\frac{E_1E_2}{M_1M_2}\right)^{1/2}\cos\Theta\right]$$

where M_1, E_1 are the mass and energy of particle 1 and M_2, E_2 are the mass and energy of particle 2, respectively, and θ is the angle of approach.

Plasma Physics

Handy Formulas

*Gaussian units are used in the formulas below except for the following: Temperatures, T_e of electrons, and T_i of ions in eV. Mass of ions, m_i is expressed in units of proton mass, m_p by $\mu = m_i/m_p$; B in gauss; k is Boltzmann's constant; n_e and n_i are number densities of electrons and ions, respectively, in cm^{-3}; Z is the charge state of an ion; λ is wavelength in Å; c is the speed of light in vacuum (3×10^{10} cm/sec); and frequency is ω (rad/sec) = $2\pi \cdot f$(cycles/sec)

For Electrons:

Plasma frequency, ω_{pe} (rad/sec) = $5.64 \times 10^4\ n_e^{1/2}$
Gyrofrequency, ω_{ce} (rad/sec) = 1.76×10^7 B
Gyroradius, r_e (cm) = $2.38\ T_e^{1/2}\ B^{-1}$
Electron thermal velocity, v_{te} (cm/sec) = $4.19 \times 10^7\ T_e^{1/2}$

Electron deBroglie length, λ (Å) = $\frac{17.34}{T_e^{1/2}}$

For Ions:

Plasma frequency, ω_{pi} (rad/sec) = $1.32 \times 10^3\ Z\ \mu^{-1/2}\ n_i^{1/2}$
Gyrofrequency, ω_{ci} (rad/sec) = $9.58 \times 10^3\ Z\ \mu^{-1}$ B
Gyroradius, r_i (cm) = $1.02 \times 10^2\ \mu^{1/2}\ Z^{-1/2}\ T_i^{1/2}\ B^{-1}$
Ion thermal velocity, v_{ti} (cm/sec) = $9.79 \times 10^5\ \mu^{-1/2}\ T_i^{1/2}$

Drift velocity of particles in a constant electric field, E (volts/cm), perpendicular to a constant magnetic field, B (gauss), independent of mass m, or charge Z, of the particle is given by:

$$v_E\ (\text{cm/sec}) = 1 \times 10^8\ \frac{E}{B}$$

Phase velocity, v_ϕ (cm/sec) = ω/k, where ω is in rad/sec and k is the wavenumber in cm^{-1}.

Group velocity, v_g (cm/sec) = $d\omega/dk$

Alfven velocity, v_A (cm/sec) = $2.18 \times 10^{11}\ \mu^{-1/2}\ n_i^{-1/2}$ B

Debye length, λ_D (cm) = $7.43 \times 10^2\ T_e^{1/2}\ n_e^{-1/2}$

Maxwellian velocity distribution for a constant temperature plasma, for one-dimension:

$$F_{max}(v)\ (cm^{-3}) = n\cdot (m/2\pi kt)^{1/2} \exp(-mv^2/2kt)\ ,$$

where t is in °K, m is the particle's mass in gm, n is the number density (cm^{-3}), k is Boltzmann's constant (1.38×10^{-16} erg/°K), and v is the particle's velocity (cm/sec) for one-dimension.

Saha thermal equilibrium:

$$n_i/n_n \approx 2.4 \times 10^{15}\ (t^{3/2}/n_i) \exp(-U_i/kt)\ ,$$

where n_n is the number density of neutrals in cm^{-3}, U_i is the ionization energy of the gas in ergs, and t is the temperature of the gas in °K.