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Electron Impact Excitation Cross Sections and Effective Collision Strengths of N Atom and N-Like Ions
– A Review of Available Data and Recommendations –

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Electron impact excitation cross sections and effective collision strengths of N atom and N-like ions
- A review of available data and recommendations -

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Abstract

The cross sections and/or the effective collision strengths for excitation of N atom and N-like ions by electron impact are reviewed. Main sources for data are listed and the recommended data sources are selected for each ion. The comparison of the cross sections is shown in Graphs. The fit parameters are given for the recommended effective collision strengths in a table; the effective collision strengths calculated therefrom are shown graphically.

Key words

excitation cross section, electron impact, N atom, N-like ions
recommended data

Contents

Introduction

The cross sections and/or the effective collision strengths for excitation of N-like ions by electron impact are reviewed. Main sources for data are listed in Table I along the published year for each atom and the recommended data sources are selected for each ion in Table II. The comparison of the cross sections is shown in Graph I. In order to obtain the effective collision strength, the energy dependence of the collision strength in a wide energy region needs to be known. Since most of the results are given as collision strengths, it is necessary the collision strength is first fitted to an analytical function before the effective collision strengths are calculated. The data points are not sufficient to derive the effective collision strength for N-like ions. Then we give here the only original effective collision strength for N atom and Fe XX ions as recommended data.

The effective collision strengths for N atoms and Fe XX ions are fitted to an analytical formula assuming that the collision strength Ω is expressed by the formula

$$\Omega = A + B/X + C/X^2 + D/X^3 + E \ln X , \qquad (1)$$

where $X = E0/\Delta E$, E0 the energy of the incident electron, ΔE the excitation energy. Correspondingly then, the effective collision strength γ is given as

$$\gamma = y\{(A/y + C) + (D/2)(1 - y) + e^y E_1(y)(B - Cy + Dy^2/2 + E/y)\} \qquad (2)$$

where $y = \Delta E/kT_e$, T_e is the electron temperature, and

$$E_1(y) = \int_y^\infty \frac{e^{-t}}{t} dt \qquad (3)$$

For the dipole allowed transitions, we fit γ with a fixed value $E = 4\omega_i f_{ij} / \Delta E$ for the parameter E in eq.(2) where f_{ij} is the absorption oscillator strength and ΔE the excitation energy in Rydbergs, ω_i the statistical weight of the initial state[1]. The fit parameters are given in Table II with the excitation energy and the effective collision strengths γ are plotted in Graph II.

The rate coefficient is derived with γ as

$$C = \frac{8.010 \times 10^{-8}}{\omega\sqrt{T_e(eV)}} e^{-\Delta E/kT_e} \gamma \qquad cm^3 s^{-1} \qquad (4)$$

The first excited configuration of N atoms is $2s^2 2p^2 3s$. The levels with the configuration $2s2p^4$ appear as the first excited states for OII and FIII ions below the energy levels from the $2s^2 2p^2 3s$ configuration. For ions heavier than NaV the first, second and third excited configurations are $2s2p^4$, $2p^5$ and $2s^2 2p^2 3s$. Thus the cross sections for $2s^2 2p^2 3s$ are often given for N atoms whereas $2s2p^4$ and $2p^5$ for heavier ions, besides those among the levels of the ground state configuration.

1.1. N atoms

Doering and Goembel[2] measured the absolute differential and integral cross section for the $2s^2 2p^3\ {}^4S$ - $2p^2 3s\ {}^4P$ transition with electron scattering techniques. Their values are lower by a factor of two than the fluorescence cross section of Stone and Zipf[3,4] corrected to reflect the recent change in the H_2 dissociative excitation reference cross section. The values by ref.4 and 5 include the contribution of cascade. Spence and Burrow[5] measured the cross sections for the $2s^2 2p^3\ {}^4S$ - $2p^2 3s\ {}^4P$, $2s^2 p^4\ {}^4P$ transition by the electron energy loss spectra near threshold. They observed a strong peak near threshold for $2s^2 2p^3\ {}^4S$ - $2p^2 3s\ {}^4P$ transition. The only available theoretical data for this transition are by Ormond et al[6] and their values are smaller than the experimental values.

Most of the theoretical calculations give the data for transitions among the ground state $2s^22p^3\ ^4S$, ^2D and ^2P. Berrington et al.[7] calculated cross sections using R-matrix method with 8 states for n = 2 - 2 transitions. Ref.5 used the data of ref. 7 for the $2s^22p^3\ ^4S$ - $2s2p^4\ ^4P$ transition to obtain the absolute values for the $2s^22p^3\ ^4S$ - $2p^23s\ ^4P$ transition. The effective collision strengths by R-matrix calculations are given in ref. 8 for the transitions between the $2s^22p^3\ ^4S$, ^2D and ^2P in the temperature range from 500 to 10^5K. The data by ref. 8 are fitted analytical formula of eq.(2) and the fitting parameters are given in Table II. They are plotted in Graph II.

1. 2. O II ions

McLaughlin et al.[9] calculated the cross sections for the $2p^3\ ^4S$, ^2D, ^2P - $2p^23s\ ^4P$, ^2P transitions using both a 9 state and a 34 state R-matrix approximation. The collision strengths exhibit strong resonance structure in the energy region between the $2s^22p^23s\ ^2P$ and $2s2p^4\ ^2P$ thresholds. The importance of the resonances will decrease as the nuclear charge increases. Itikawa et al[10] gave the recommended data and recommended values are fitted to an analytical formula for carbon and oxygen ions. They included the calculations of Henry[11], Ho and Henry[12], Pradhan[13,14]. Ref.12 calculated the collision strengths from the ground state to the $2s2p^4\ ^4P$ and $2s^22p^23s$ ^4P excited states in a two state close coupling approximation. Ref.9 obtains the higher values than ref.12 near the threshold, although the two results at 26 eV are almost similar. Effective collision strengths are obtained using the close coupling approximation by ref.14 for the fine structure transitions within the ground configuration. The results in ref. 13 and 14 are in good agreement with those of Martins et al.[15] for energies above the ^2P threshold but about 10% higher at the ^2D threshold[13]. The results given by Saraph et al[16] agree within 10 % with those by ref.13.

1.3. F III

There are few results for F III ions. ref.16 gave numerical calculations for the first four ions for the configurations

$2s^2 2p^q$(q= 1 - 5) in the approximation of neglecting coupling to configurations other than $2s^2 2p^q$. Martins et al[15] gave the collision strengths among fine structure levels including resonances converging onto the ^2P level by similar method as ref.16. We recommend data by ref..15 and 16, since their data for OII ions are in agreement within 10 % comparing to the recent calculations as shown in the previous section, .

1.5 .Ne IV

Giles[17] presented the rate coefficients for transitions between fine structure levels in the ground configurations. The inclusion of the next excited configuration in the close coupling expansion gives rise to near threshold resonances comparing to those of ref.16. Bhatia and Kastner[18] calculated the collision strength between the 72 levels of the six configurations $2s^2 2p^3$ - $2s^2 2p^3$, $2s2p^4$, $2p^5$, $2p^2 3s$, $2p^2 3p$, $2p^2 3d$. The numerical values of the collision strength for each transitions are given for only one incident electron energy, 7 Ryd. It is required to give the energy dependence of the collision strengths.

1.5. Na V

Same as F III ions.

1.6.Mg VI

Bhatia and Mason[19] calculated collision strengths including the $2s^2 2p^3$, $2s2p^4$ and $2p^5$ configurations for Mg VI, Si VIII, S X, Ar XII and Ca XIV using a computer package developed at University College, London. The data for the configurations $2s^2 2p^3$, $2s2p^4$ are given at 10, 15 and 20 Ryd. incident electron energies and the results connected with the $2p^5$ term and within the $2s2p^4$ term are available on request. According to their paper, their results are in good agreement with the previous calculation by Davis et al[20] .

1.7. Si VIII

The DW results by ref.19, 20 and 21 are available.

1.8. S X

The data by Ref.19 is the only available source.

1.9 .Ar XII

Bhatia et al[22] calculated the collision strengths including 72 levels of $2s^22p^3$, $2s2p^4$, $2p^5$, $2s^22p^33s$, $2s^22p^23p$ and $2s^22p^23d$ for Ar XII, Ti XVI, Fe XX, Zn XXIV and Kr XXX ions. The values of the collision strengths for one impact electron energy point are given for a limited number of transitions for which the radiative transition probabilities exceed a certain value. The collision strengths for spin exchange transitions are not given.

1.10. Ca XIV

Same as S X.

1.11. Ti XVI

Bhatia et al[23] presented the calculations of the collision strength for the Li- through F - like titanium ions. For Ti XVI ions, the collision strengths at 15, 20 and 25 Ryd. are given for all the transitions among $2s^22p^3$, $2s2p^4$, $2p^5$ fine structure levels.

1.12.Mn XIX

Bhatia[24] calculated the collision strengths for the configurations $2s^22p^k$, $2s2p^{k+1}$ and $2s2p^{k+2}$ of Mn ions of the Li - through F - like sequences as calculated for Ti ions in ref.23. For N-like Mn XIX ions, the collision strengths for the impact electron energies of 20, 40 and 60 Ryd. are given for the transitions among 15 levels with the configurations of $2s^22p^3$, $2s2p^4$, $2p^5$.

1.13.Fe XX

Ref.25 presented the collision strengths of Fe XX ions for the fine structure transitions among $2s^22p^3$ and $2s2p^4$ including the configurations $2s^22p^3$, $2s2p^4$ and $2p^5$ in the calculation. Mason and Bhatia[26] extended these calculations to include transitions from $2s^22p^3$ up to $2s^22p^23s$ and

$2s^2 2p^2 3d$. Kingston and Lennon[27] presented polynomial fit coefficients for recommended rate coefficient of iron ions based on the data of Robb(1980)[28] and Bhatia. Sometimes their rate coefficients derived fit parameters give wrong values due to the mis-printing of the fit coefficients. Bhatia et al[22] calculated new data including 72 levels. The values of radiative decay and the collision strength by ref.26 and ref.22 are almost similar. But some differences are found due to the difference of the order of the energy levels; e.g. the order of the energy levels of $2p^2 3d\ ^2P_{1/2}$ and $2p^2 3d\ ^4P_{1/2}$. This discrepancy is due to the naming of the levels. The effective collision strengths[28] based on ref.25 are fitted to analytical formula and plotted in Graph II. The cross sections are not plotted for all the data but only for comparison in Graph I.

1.14 Summary

For the N atom and O II ions there are few results involving transitions to n = 3 levels. For ions from Ne IV to Kr XXX, DW calculations have been carried out for n = 2 (Mg VI, Si VIII, S X, Ca XIV) and n = 2 and 3 (Ne IV, Ar XII, Ti XVI, Mn XIX, Fe XX, Zn XXIV, Kr XXX) for the transitions among fine structure levels.

As the next step, it is necessary to calculate the effective collision strengths from the recommended collision strengths. DW calculations by Bhatia et al. give the collision strengths for no more than three incident electron energies. It is required to calculate the cross sections for more several energy points in order to know the energy dependence.

Since there are so many transitions among fine structure levels, it will be useful to consider a standard database for excitation processes. The problems include the format how to store the configuration of the levels, identification of the transition, fitting formulae and parameters, transition energies etc.

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References

1. Kato, T., and Nakazaki, S., Atomic Data and Nuclear Data Tables 42, 313 (1989)
2. Doering J.P., Goembel, L. J. Geophy. Res. 96, 16021 (1991)
3. Stone, E.J. and Zipf, E.C., Phys. Rev A, 4, 610 (1971)
4. Stone, E.J. and Zipf, E.C., J. Chem. Phys., 58, 4278(1973)
5. Spence, D and Burrow, P.D., J. Phys. B, 13, 2809 (1980)
6. Ormonde, S., Smith, K., Torres, B.W., Davies, A.R., Phys. Rev. A, 8, 262(1973)
7. Berrington, K.A., Burke,P.G. and Robb, W.D. J. Phys. B, 8, 2500 (1975)
8. Berrington, K.A. and Burke,P.G., Planet Space Sci, 29, 377(1981)
9. McLaughlin, B.M., Burke, P.G. and Kingston, A.E. J. Phys. B. 20, L55 (1987)
10. Itikawa, Y., Hara, S., Kato, T., Nakazaki, S., Pindzola, M.S., Crandall, D.H., A.D.N.D.T., 33, 149(1985)
11. Henry R. J., Burke, P.G., Sinfailam A. -L., Phys. Rev., 178, 218-217 (1969)
12. Ho, Y.K. and Henry, R.J.W., Astrophys. J. 264, 733(1983)
13. Pradhan, A.K., J. Phys. B, 9, 433(1976a)
14. Pradhan, A.K., Mon. Not. R. astr. Soc., 177, 31(1976b)
15. Martins, P.A., Saraph, H.E., Seaton, M.J., J. Phys. B. 2, 427(1969)
16. Saraph, H.E., Seaton, M.J. and Shemming, J., Phil. Trans. Roy. Soc. 264, 77(1969)
17. Giles, K., Mon. Not. R. astr. Soc.,195, 63(1981)
18. Bhatia, A.K., Kastner, S.O., Astrophysical J. 332, 1063(1988)
19. Bhatia, A.K. and Mason, H.E. , Mon. Not. R. astr. Soc.,190, 925(1980a)
20. Davis,J., Kepple, P.C. and Blaha, M., J. Quant. Radiat. Transfer, 16, 1043 (1976)
21. Davis,J., Kepple, P.C. and Blaha, M., J. Quant. Radiat. Transfer, 18, 535 (1977)
22. Bhatia,A.K., Seely,J.F. and Feldman,U. Atomic Data and Nuclear Data Tables, 43,99(1989)
23. Bhatia, A.K., Feldman, U. and Doschek, G.A., J. Appl. Phys. 51, 1464(1980)
24. Bhatia, A.K., J. Appl. Phys. 53, 59(1982)
25. Bhatia, A.K. and Mason, H.E. Astron. Astrophys. 83, 380 (1980b)
26. Mason, H.E. and Bhatia, A.K., Astron. Astrophys. Suppl. Ser. 52, 181 (1983)
27. Kingston, A.E., Lennon, M.A. , Nuclear Fusion, Special Suppl.,43(1987)

28. Robb, W.D., Los Alamos Rep. LA-8267-MS(1980)
29. Mason, H. E, private communication(1992)

Explanation of Tables

Table I. Available data sources.

Author(year)	The author of the reference and the published year
Transition	Transition from the initial(left) to the final(wright) state.
(fine str.)	transitions among fine structure levels
Data	
σ	Cross section
Ω	Collision strength
γ	Effective collision strength
C	Rate coefficient
(par. fit)	Fit parameters are given
Energy(Temp.)	The energy or temperature range spanned by the data
(thre.)	Threshold energy

Method

R-matrix	R-matrix calculation
CC	Close-coupling calculation
DW	Distorted wave calculation
beam	Experiment using electron beam
(electron)	Electron energy loss measurement
(optical)	Optical line emission measurement
Evaluation	Data are evaluated

Table II Sources and energy(temperature) ranges for recommended data.

Table III Fit parameters for recommended effective collision strengths.

Fit parameters are tabulated for each excitation process of N atom[7] and Fe XX[29]. The notation, $2s^2 2p^3\ {}^4S^o$ - $2p^2 2p^3\ {}^2D^o$, for example, means the excitation from the lower state to the upper state.

ΔE	Excitation energy in eV
A,B,C,D,E	Fit parameters for the effective collision strengths γ in eq.(2).

Explanation of Graphs

Graph I Comparison of the cross sections.

The excitation cross sections (cm^2) are plotted as a function of energy (eV) for each transitions. A letter "T" or "E" (after the authors and the year of publication in the legend) indicates a theoretical or an experimental paper, respectively. Since there are many transitions among fine structure levels, only part of them are shown.

Graph II The recommended effective collision strengths.

The effective collision strengths are plotted as a function of temperature T_e in Kelvin degree for N atom and Fe XX ions. Their fit parameters are listed in Table III. The symbols and solid lines indicate the original points from ref. 4 and ref.29, and calculated values from the fit parameters in Table III, respectively.

References for Table I and Graph I

Berrington, K.A., Burke,P.G. and Robb, W.D. J. Phys. B, 8, 2500 (1975)
Berrington, K.A. and Burke,P.G., Planet Space Sci, 29, 377(1981)
Bhatia, A.K., J. Appl. Phys. 53, 59(1982)
Bhatia, A.K., Feldman, U. and Doschek, G.A., J. Appl. Phys. 51, 1464(1980)
Bhatia, A.K., Kastner, S.O., Astrophysical J. 332, 1063(1988)
Bhatia, A.K. and Mason, H.E. , Mon. Not. R. astr. Soc.,190, 925(1980a)
Bhatia, A.K. and Mason, H.E. Astron. Astrophys. 83, 380 (1980b)
Bhatia,A.K., Seely,J.F. and Feldman,U. Atomic Data and Nuclear Data Tables, 43,99(1989)
Burke, P.G. Comput. Phys. Commun. 6, 275 - 287 (1974)
Cohn A J. Chem. Phys. 57, 2456 (1972)
Davis,J., Kepple, P.C. and Blaha, M., J. Quant. Radiat. Transfer, 15, 1145 (1975)
Davis,J., Kepple, P.C. and Blaha, M., J. Quant. Radiat. Transfer, 16, 1043 (1976)
Davis,J., Kepple, P.C. and Blaha, M., J. Quant. Radiat. Transfer, 18, 535 (1977)
Doering J.P., Goembel, L. J. Geophy. Res. 96, 16021 (1991)
Ganas P. S., J. Chem. Phys. 59, 5411-5414 (1973)
Giles, K., Mon. Not. R. astr. Soc.,195, 63(1981)
Henry R. J., Burke, P.G., Sinfailam A. -L., Phys. Rev., 178, 218-217 (1969)
Henry,R.J., Williams, R.E., Publ. Astron. Soc. Pac. 80, 669-679 (1968)
Ho, Y.K. and Henry, R.J.W., Astrophys. J. 264, 733(1983)
Itikawa, Y., Hara, S., Kato, T., Nakazaki, S., Pindzola, M.S., Crandall, D.H., A.D.N.D.T., 33, 149(1985)
Kingston, A.E., Lennon, M.A. , Nuclear Fusion, Special Suppl.,43(1987)
Le Dourneuf, M. Vo Ky Lan, Berrington, K.A. and Burke, P.G., IX ICPEAC, 634 (1975)
Mann, J.B., Atomic Data and Nuclear Data Tables, 29, 407(1983)
Mason, H.E. and Bhatia, A.K., Astron. Astrophys. Suppl. Ser. 52, 181 (1983)
Martins, P.A., Saraph, H.E., Seaton, M.J., J. Phys. B. 2, 427(1969)
McLaughlin, B.M., Burke, P.G. and Kingston, A.E. J. Phys. B. 20, L55 (1987)
Ormonde, S., Smith, K., Torres, B.W., Davies, A.R., Phys. Rev. A, 8, 262(1973)
Robb, W.D., Los Alamos Rep. LA-8267-MS(1980)
Pradhan, A.K., J. Phys. B, 9, 433(1976a)
Pradhan, A.K., Mon. Not. R. astr. Soc., 177, 31(1976b)
Saraph, H.E., Seaton, M.J. and Shemming, J., Phil. Trans. Roy. Soc. 264, 77(1969)

Seaton (1955) Ann. Geophys. 24,167(1968) Aurora
Smith A C Phys. Rev. 127 1647 (1962)
Smith K, Conneely, M J, Morgan, L A Phys. Rev., 177, 196-203 (1969)
Smith, K., Henry, R.J.W. and Burke, P.G., Phys. Rev. 157, 51-68 (1967)
Spence, D and Burrow, P.D., J. Phys. B, 13, 2809 (1980)
Stone, E.J. and Zipf, E.C., Phys. Rev A, 4, 610 (1971)
Stone, E.J. and Zipf, E.C., J. Chem. Phys., 58, 4278(1973)
Thomas, L.D. and Nesbet, R.K. Phys. Rev. A 12, 2369-2377 (1975)

Table I. Available Data Sources

Author(year)	Transition	Data, Energy(Temp.) range	Method
N atom			
Smith et al(1967)	among $2s^22p^3$ $^4S, ^2D, ^2P$	σ(threshold - 4Ryd.)	CC
Henry and Williams(1968)	among $2s^22p^3$ $^4S, ^2D, ^2P$	γ(500 - 10^5 K, par. fit)	CC
Henry et al(1969)	among $2s^22p^3$ $^4S, ^2D, ^2P$	σ(thre. - 50eV)	CC
Stone and Zipf(1971)	$2s^22p^3$ ^4S - $2p^23s$ ^4P	σ(threshold - 15eV)	beam(optical)
Stone and Zipf(1973)	$2s^22p^3$ ^4S - $2s2p^4(^4P)$, $2s^22p^3$ - $2p^23s$,3p	σ(17 - 32eV)	beam(optical)
Ganas(1973)	2p - ns (n=7), 2p-np(n=4), 2p-nd(n=5)	σ(thre.-1000eV)	Born
Ormond et al(1973)	among $2s^22p^3$ $^4S, ^2D, ^2P$	Ω(0.3-1.4 Ryd.)	CC
	$2s^22p^3$ - $2p^23s$ ^4P	Ω(1.0 - 1.4 Ryd.)	
Davis et al(1975)	$2s^22p^3$ - $2p^23s$	σ(1.14 - 6.08 Ryd.)	DW
Thomas and Nesbet(1975)	among $2s^22p^3$ $^4S, ^2D, ^2P$	σ(3.4 - 11.0 eV)	matrix variational
Le Dourneuf(1975)	$2s^22p^3$ ^2D - ^2P	σ	R-matrix
Berrington et al(1975)	among $2s^22p^3$ $^4S, ^2D, ^2P$	σ(thre. - 2.5 Ryd.)	R-matrix
	$2s^22p^3$ - $2s2p^4$ $^4P, ^2D, ^2S, ^2P$		
Spence and Burrow(1980)	$2s^22p^3$ - $2s^22p^3$ $^4S, ^2D, ^2P$	σ(10.3-11.1 eV)	beam(electron)
Berrington and Burke(1981)	among $2s^22p^3$ $^4S, ^2D, ^2P$	γ(500 - 10^5 K, par. fit)	R-matrix
Doering and Goembel(1991)	$2s^22p^3$ ^4S - $2p^23s$ ^4P	σ(30-100 eV)	beam(electron)
O II ions			
Henry et al(1969)	among $2s^22p^3$ $^4S, ^2D, ^2P$	σ(thre. - 50eV)	CC
Saraph et al(1969)	among $2s^22p^3$ $^4S, ^2D, ^2P$	Ω(thre.-.91Ryd.)	exact resonance, DW
	^2D - $^2D, ^2P$ (fine str.)		
Martins et al(1969)	among $2s^22p^3$ (fine str.)	Ω(0.3 - 0.47 Ryd.)	exact resonance
Ormond et al(1973)	$2s^22p^3$ ^4S- $2s2p^4$ ^4P	Ω(1.16 - 2.6 Ryd.)	CC
Davis et al(1975)	$2s^22p^3$ - $2s2p^4$, $2p^23s$	σ(1.1-13.5 Ryd.)	DW
Pradhan(1976a)	among $2s^22p^3$ $^4S, ^2D, ^2P$	Ω(thre.)	CC
	^2D - ^2D (fine structures)		
Pradhan(1976b)	among $2s^22p^3$ $^4S, ^2D, ^2P$	Ω(thre.), γ(5×10^3- 2×10^4K)	CC
	^2D - $^2D, ^2P$ - ^2P (fine str.)	γ(5×10^3- 2×10^4K)	
Ho and Henry(1983)	$2s^22p^3$ ^4S - $2s2p^4$ ^4P, $2p^23s$ ^4P	Ω, γ (par. fit, <10^6K)	CC

Table I. Available Data Sources (continued)

Author(year)	Transition	Data, Energy(Temp.) range	Method
Itikawa et al(1985)	among $2s^2 2p^3\ ^4S, ^2D, ^2P$ $2s^2 2p^3\ ^4S$ - $2s2p^4\ ^4P$, $2p^2 3s\ ^4P$	γ(0.3 - 100eV, par.fit)	Evaluation
McLaughlin et al(1987)	$2p^3\ ^4S, ^2D, ^2P$ - $2p^2 3s\ ^4P, ^2P$	Ω(thre. -2 Ryd.)	R -matrix
F III			
Saraph et al(1969)	among $2s^2 2p^3\ ^4S, ^2D, ^2P$ ^2D - $^2D, ^2P$ (fine str.)	Ω	exact resonance, DW
Martins et al(1969)	among $2s^2 2p^3$ (fine str.)	Ω(0.1 - 0.22 Ryd.)	exact resonance
Ne IV			
Saraph et al(1969)	among $2s^2 2p^3\ ^4S, ^2D, ^2P$ ^2D - $^2D, ^2P$ (fine str.)	Ω	exact resonance, DW
Martins et al(1969)	among $2s^2 2p^3$ (fine str.)	Ω(0.08 - 0.2 Ryd)	exact resonance
Giles(1981)	among $^4S, ^2D, ^2P$(fine str.)	γ(6×10^3 - 2×10^4K)	CC
Bhatia and Kastner(1988)	$2s^2 2p^3$ - $2s^2 2p^3$, $2s2p^4$, $-2p^5$, $2p^2 3s$, $2p^2 3p$, $2p^2 3d$ (fine str.)	Ω(7Ryd.)	DW
Na V			
Saraph et al(1969)	among $2s^2 2p^3\ ^4S, ^2D, ^2P$ ^2D - $^2D, ^2P$ (fine str.)	Ω	exact resonance, DW
Martins et al(1969)	among $2s^2 2p^3$ (fine str.)	Ω(0.05 - 1.7 Ryd.)	exact resonance
Mg VI			
Saraph et al(1969)	among $2s^2 2p^3\ ^4S, ^2D, ^2P$ ^2D - $^2D, ^2P$ (fine str.)	Ω	exact resonance, DW
Davis et al(1976)	$2s^2 2p^3\ ^4S_{3/2}$ - $2s2p^4\ ^4P_{1/2}$ $2s^2 2p^3\ ^2P_{3/2}$ - $2s2p^4\ ^2P_{1/2}$	C(par. fit)	DW
Bhatia and Mason(1980a)	$2s^2 2p^3$ - $2s^2 2p^3$, $2s2p^4$ (fine str.)	Ω(10, 15, 20 Ryd.)	DW

Table I. Available Data Sources (continued)

Author(year)	Transition	Data, Energy(Temp.) range	Method
Si VIII			
Davis et al(1976)	$2s^22p^3\ {}^4S_{3/2}$ - $2s2p^4\ {}^4P_{1/2}$	C(par. fit)	DW
	$2s^22p^3\ {}^2D_{3/2}$ - $2s2p^4\ {}^2D_{3/2}$		
Davis et al(1977)	$2s^22p^3\ {}^4S$ - $2p^23s\ {}^4P$, $2p^23d\ {}^4P$	C(par. fit), Ω	DW
Bhatia and Mason(1980a)	$2s^22p^3$ - $2s^22p^3$, $2s2p^4$(fine str.)	Ω(10, 15, 20Ryd.)	DW
S X.			
Bhatia and Mason(1980a)	$2s^22p^3$ - $2s^22p^3$, $2s2p^4$(fine str.)	Ω (15,20,30 Ryd.)	DW
Ar XII			
Bhatia and Mason(1980a)	$2s^22p^3$ - $2s^22p^3$, $2s2p^4$(fine str.)	Ω(15, 30, 45Ryd.)	DW
Bhatia et al(1989)	among $2s^22p^3$, $2s2p^4$, $2p^5$, $2p^23s$, $2p^23p$, $2p^23d$ (fine str.)	Ω(32 Ryd.) DW,CB	
Ca XIV			
Bhatia and Mason(1980a)	$2s^22p^3$ - $2s^22p^3$, $2s2p^4$	Ω(15, 30, 45 Ryd.)	DW
Ti XVI			
Bhatia et al(1980c)	among $2s^22p^3$, $2s2p^4$, $2p^5$ (fine str.)	Ω(15, 20, 25 Ryd.)	DW
Bhatia et al(1989)	among $2s^22p^3$, $2s2p^4$, $2p^5$, $2p^23s$, $2p^23p$, $2p^23d$(fine str.)	Ω(32 Ryd.)	DW, CB
Mn XIX			
Bhatia(1982)	among $2s^22p^3$, $2s2p^4$, $2p^5$ (fine str.)	Ω(20, 40, 60 Ryd.)	DW
Fe XX			
Davis et al(1976)	$2s^22p^3$ - $2s2p^4$, $2p^3$ - $2p^23d$, $2s2p^4$ - $2p^5$	C(par. fit)	DW
Bhatia and Mason(1980b)	$2s^22p^3$ - $2s2p^4$ (fine str.)	Ω(20, 50,100 Ryd.)	DW
Mason and Bhatia(1983)	$2s^22p^3$ - $2p^23s$, $2p^23d$(fine str.)	Ω(80 Ryd.)	DW
Mann(1983)	$2s^22p^3$ (${}^4S$) - $2s2p^4$ (${}^4P$,${}^2D$,${}^2S$,${}^2P$)	Ω (x=1 - 50, par. fit)	DW
Kingston and Lennon(1987)	among $2s^22p^3$, $2s2p^4$ (fine str.)	C(par. fit)	Evaluation
Bhatia et al(1989)	among $2s^22p^3$, $2s2p^4$, $2p^5$, $2p^23s$, $2p^23p$, $2p^23d$(fine str.)	Ω(80 Ryd.)	DW, CB
Zn XXIV			
Bhatia et al(1989)	among $2s^22p^3$, $2s2p^4$, $2p^5$, $2p^23s$, $2p^23p$ and $2p^23d$(fine str.)	Ω(110 Ryd.)	DW, CB
Kr XXX			
Bhatia et al(1989)	among $2s^22p^3$, $2s2p^4$, $2p^5$, $2p^23s$, $2p^23p$ and $2p^23d$(fine str.)	Ω(160 Ryd.)	DW, CB

Table II Sources for Recommended Data

Transition	Data, Energy(Temp.) range	References
N atom		
among $2s^22p^3\ ^4S, ^2D, ^2P$	γ (500 - 105 K, par. fit)	Berrington and Burk(1981)
$2s^22p^3\ ^4S, ^2D, ^2P$ -$2s2p^4\ ^4P, ^2D, ^2S, ^2D$	σ(thre. - 2.5 Ryd..)	Berrington et al(1975)
$2s^22p^3\ ^4S$ - $2p^23s\ ^4P$	σ(30 - 100 eV)	Doering and Goembel(1991)
O II		
$2p^3$ ($^4S, ^2D, ^2P$) - $2p^23s$ (^4P, ^2P)	Ω(thre. -2 Ryd.)	McLaughlin et al(1987)
$2s^22p^3\ ^4S$ - $2p^23s\ ^4P$, $2s2p^4\ ^4P$	γ(0.3 - 100eV)	Itikawa et al(1985)
among $2s^22p^3\ ^4S, ^2D, ^2P$	γ(0.3 - 100eV)	Itikawa et al(1985)
^2D - ^2D, ^2P - ^2P (fine structures)	γ(5×10^3-2×10^4K)	Pradhan(1976b)
F III		
among $2s^22p^3\ ^4S, ^2D, ^2P$	Ω	Saraph et al(1969)
among $2s^22p^3\ ^4S, ^2D, ^2P$(fine structure)	Ω(0.1 - 0.22 Ryd.)	Martins et al(1969)
Ne IV		
among $2s^22p^3\ ^4S, ^2D, ^2P$ (fine structure)	γ(6×10^3 - 2×10^4K)	Giles(1981)
$2s^22p^3$ - $2s2p^4$, $2p^5$, $2p^23s$, $2p^23p$, $2p^23d$ (fine structure)	Ω(7Ryd)	Bhatia and Kastner(1988)
Na V		
among $2s^22p^3\ ^4S, ^2D, ^2P$	Ω	Saraph et al(1969)
among $2s^22p^3\ ^4S, ^2D, ^2P$(fine structure)	Ω(0.027 - 0.15 Ryd.)	Martins et al(1969)
Mg VI		
$2s^22p^3$ - $2s^22p^3$, $2s2p^4$(fine structures)	Ω(10, 15, 20 Ryd.)	Bhatia and Mason(1980a)
Si VIII		
$2s^22p^3$ - $2s^22p^3$, $2s2p^4$(fine structures)	Ω(10, 15, 20Ryd.)	Bhatia and Mason(1980a)
S X		
$2s^22p^3$ - $2s^22p^3$, $2s2p^4$(fine structures)	Ω (15,20,30 Ryd.)	Bhatia and Mason(1980a)
Ar XII		
$2s^22p^3$ - $2s^22p^3$, $2s2p^4$ (fine structure)	Ω(15, 30, 45Ryd.)	Bhatia and Mason(1980a)
among $2s^22p^3$, $2s2p^4$, $2p^5$, $2s^22p^33s$, $2s^22p^23p$ and $2s^22p^23d$(fine structure)	Ω(32 Ryd.)	Bhatia et al(1989)

Table II Sources for Recommended data (continued)

Transition	Data, Energy(Temp.) range	References
Ca XIV		
$2s^22p^3$ - $2s^22p^3$, $2s2p^4$ (fine structure)	Ω(15, 30, 45 Ryd.)	Bhatia and Mason(1980a)
Ti XVI		
among $2s^22p^3$, $2s2p^4$, $2p^5$ (fine structure)	Ω(15, 30, 45 Ryd.)	Bhatia et al(1980)
among $2s^22p^3$, $2s2p^4$, $2p^5$, $2p^23s$, $2p^23p$, $2p^23d$(fine structure)	Ω(55 Ryd.)	Bhatia et al(1989)
Mn XIX		
among $2s^22p^3$, $2s2p^4$, $2p^5$ (fine structure)	Ω(20, 40, 60 Ryd.)	Bhatia(1982)
Fe XX		
among $2s^22p^3$ - $2s2p^4$ (fine structure), including forbidden transitions	Ω (20, 50 and100 Ryd.)	Bhatia and Mason(1980b)
$2s^22p^3$ - $2p^23s$, $2p^23d$(fine structure)	Ω(80 Ryd.)	Mason and Bhatia(1983)
among $2s^22p^3$, $2s2p^4$, $2p^5$, $2p^23s$, $2p^23p$ and $2p^23d$(fine structure)	Ω(80 Ryd.)	Bhatia et al(1989)

TABLE III. Fit Parameters for the recommended effective collision strength

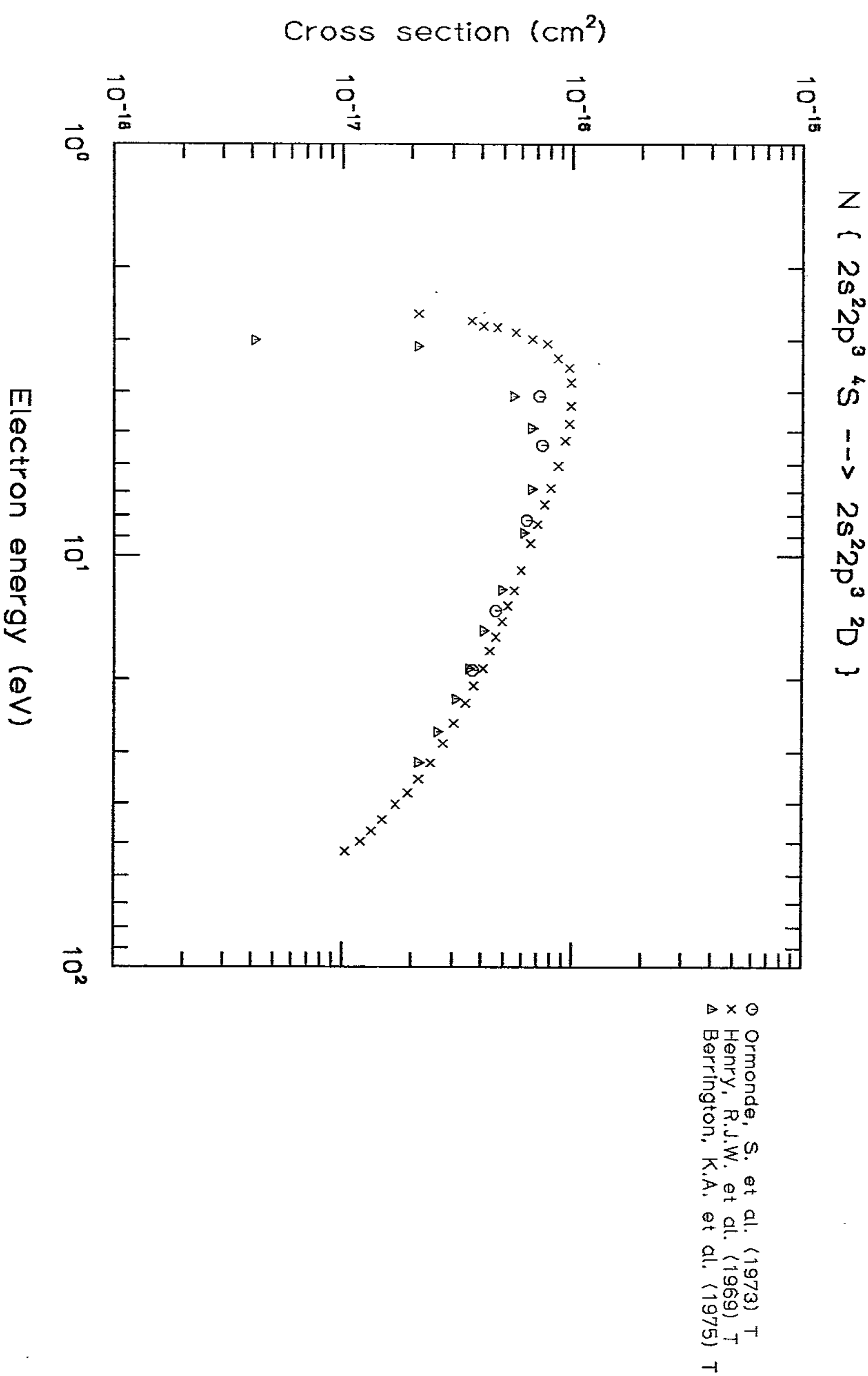
N		ΔE(eV)	A	B	C	D	E
$2s^22p^3\ ^4S^o$ -	$2s^22p^3\ ^{2z}D^o$	2.38E+00	-2.07E+00	1.04E+01	-1.53E+01	6.94E+00	1.55E+00
$2s^22p^3\ ^4S^o$ -	$2s^22p^3\ ^2P^o$	3.57E+00	-2.52E+00	8.74E+00	-1.05E+01	4.30E+00	1.16E+00
$2s^22p^3\ ^2D^o$ -	$2s^22p^3\ ^2P^o$	1.19E+00	1.73E+00	-5.93E+00	8.23E+00	-3.96E+00	1.11E+00

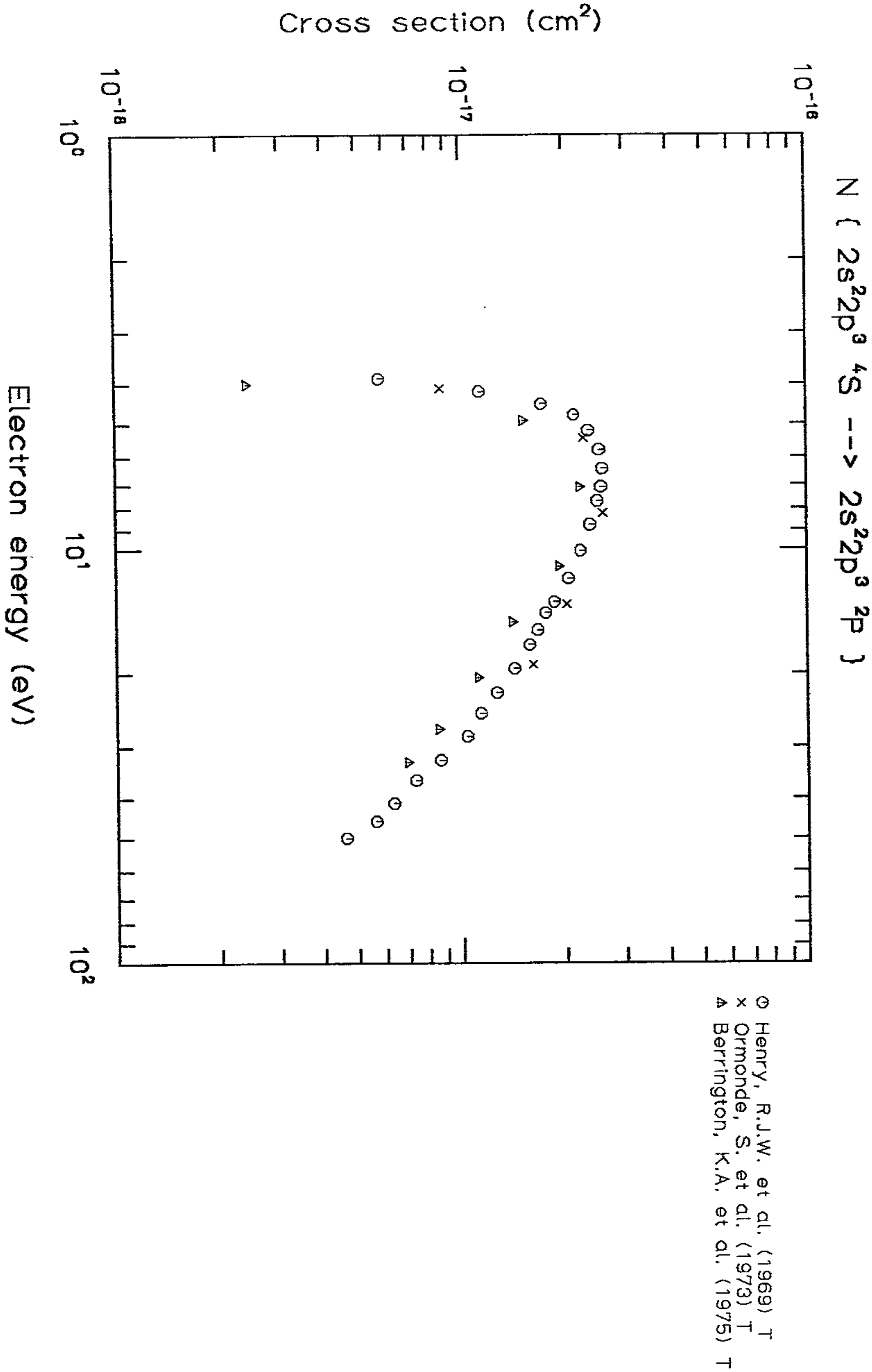
Fe^{19+}		ΔE(eV)	A	B	C	D	E
$2s^22p^3\ ^4S_{3/2}$ -	$2s^22p^3\ ^2D_{3/2}$	1.74E+01	4.07E-02	2.87E-01	-7.68E-01	5.12E-01	-5.96E-03
$2s^22p^3\ ^4S_{3/2}$ -	$2s^22p^3\ ^2D_{5/2}$	2.22E+01	5.10E-02	1.49E-01	-3.75E-01	2.42E-01	-7.46E-03
$2s^22p^3\ ^4S_{3/2}$ -	$2s^22p^3\ ^2P_{1/2}$	3.19E+01	5.03E-03	1.37E-01	-3.16E-01	2.00E-01	-8.17E-04
$2s^22p^3\ ^4S_{3/2}$ -	$2s^22p^3\ ^2P_{3/2}$	3.97E+01	9.62E-03	8.47E-02	-1.85E-01	1.13E-01	-1.78E-03
$2s^22p^3\ ^4S_{3/2}$ -	$2s2p^4\ ^4P_{5/2}$	9.29E+01	2.88E-01	-3.91E-02	5.65E-01	-3.94E-01	1.25E-01
$2s^22p^3\ ^4S_{3/2}$ -	$2s2p^4\ ^4P_{3/2}$	1.01E+02	1.94E-01	2.50E-02	2.46E-01	-1.74E-01	8.94E-02
$2s^22p^3\ ^4S_{3/2}$ -	$2s2p^4\ ^4P_{1/2}$	1.04E+02	1.16E-01	-1.17E-01	4.30E-01	-2.75E-01	4.63E-02
$2s^22p^3\ ^4S_{3/2}$ -	$2s2p^4\ ^2D_{3/2}$	1.30E+02	8.00E-03	6.66E-03	3.69E-03	-4.78E-03	3.78E-03
$2s^22p^3\ ^4S_{3/2}$ -	$2s2p^4\ ^2D_{5/2}$	1.32E+02	-1.44E-05	1.21E-03	-1.13E-03	4.19E-04	5.71E-05
$2s^22p^3\ ^4S_{3/2}$ -	$2s2p^4\ ^2S_{1/2}$	1.49E+02	2.25E-03	1.57E-02	-2.14E-02	1.07E-02	1.37E-03
$2s^22p^3\ ^4S_{3/2}$ -	$2s2p^4\ ^2P_{3/2}$	1.55E+02	9.18E-03	5.00E-02	-6.83E-02	3.44E-02	5.74E-03
$2s^22p^3\ ^4S_{3/2}$ -	$2s2p^4\ ^2P_{1/2}$	1.67E+02	4.77E-04	4.43E-03	-2.48E-03	1.36E-04	6.30E-05
$2s^22p^3\ ^2D_{3/2}$ -	$2s^22p^3\ ^2D_{5/2}$	4.76E+00	7.69E-02	3.91E-01	-1.94E+00	1.77E+00	-9.02E-03
$2s^22p^3\ ^2D_{3/2}$ -	$2s^22p^3\ ^2P_{1/2}$	1.45E+01	2.45E-02	4.23E-02	-1.22E-01	8.68E-02	-1.04E-03
$2s^22p^3\ ^2D_{3/2}$ -	$2s^22p^3\ ^2P_{3/2}$	2.22E+01	3.02E-02	9.95E-02	-2.52E-01	1.61E-01	-4.36E-03
$2s^22p^3\ ^2D_{3/2}$ -	$2s2p^4\ ^4P_{5/2}$	7.55E+01	2.59E-02	4.85E-02	-5.33E-02	2.32E-02	1.03E-02
$2s^22p^3\ ^2D_{3/2}$ -	$2s2p^4\ ^4P_{3/2}$	8.36E+01	4.60E-03	4.10E-02	-7.24E-02	3.87E-02	-8.19E-04
$2s^22p^3\ ^2D_{3/2}$ -	$2s2p^4\ ^4P_{1/2}$	8.63E+01	3.38E-03	1.79E-02	-3.12E-02	1.61E-02	-5.42E-04
$2s^22p^3\ ^2D_{3/2}$ -	$2s2p^4\ ^2D_{3/2}$	1.12E+02	3.11E-01	1.67E-01	1.74E-01	-1.60E-01	1.51E-01
$2s^22p^3\ ^2D_{3/2}$ -	$2s2p^4\ ^2D_{5/2}$	1.15E+02	1.08E-03	2.80E-02	-4.22E-02	2.12E-02	1.15E-04
$2s^22p^3\ ^2D_{3/2}$ -	$2s2p^4\ ^2S_{1/2}$	1.31E+02	1.11E-01	-5.01E-02	2.95E-01	-1.95E-01	4.98E-02
$2s^22p^3\ ^2D_{3/2}$ -	$2s2p^4\ ^2P_{3/2}$	1.38E+02	6.14E-02	-3.03E-03	1.05E-01	-7.19E-02	3.01E-02
$2s^22p^3\ ^2D_{3/2}$ -	$2s2p^4\ ^2P_{1/2}$	1.50E+02	4.85E-02	-3.34E-02	1.56E-01	-1.02E-01	2.22E-02

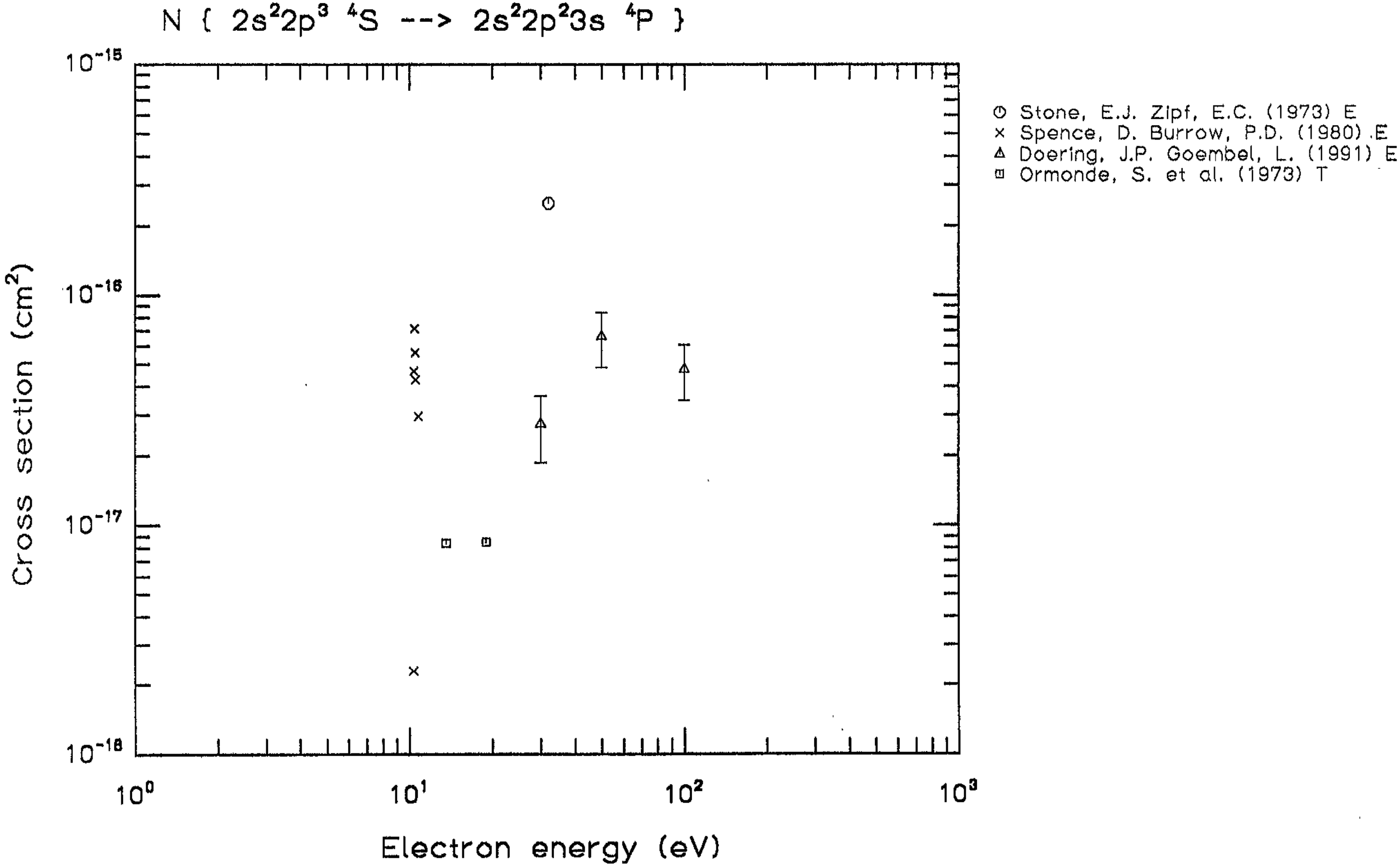
TABLE III. (continued)

Fe^{19+}		ΔE(eV)	A	B	C	D	E
$2s^22p^3\ ^2D_{5/2}$ -	$2s^22p^3\ ^2P_{1/2}$	9.74E+00	2.74E-02	5.08E-02	-1.84E-01	1.45E-01	-1.82E-03
$2s^22p^3\ ^2D_{5/2}$ -	$2s^22p^3\ ^2P_{3/2}$	1.75E+01	6.24E-02	7.53E-02	-2.08E-01	1.42E-01	-3.79E-03
$2s^22p^3\ ^2D_{5/2}$ -	$2s2p^4\ ^4P_{5/2}$	7.07E+01	1.17E-02	1.16E-01	-2.16E-01	1.21E-01	5.40E-03
$2s^22p^3\ ^2D_{5/2}$ -	$2s2p^4\ ^4P_{3/2}$	7.88E+01	7.02E-04	2.73E-02	-3.65E-02	1.54E-02	4.90E-04
$2s^22p^3\ ^2D_{5/2}$ -	$2s2p^4\ ^4P_{1/2}$	8.15E+01	2.98E-04	2.85E-03	-4.86E-03	2.54E-03	-5.62E-05
$2s^22p^3\ ^2D_{5/2}$ -	$2s2p^4\ ^2D_{3/2}$	1.08E+02	2.34E-03	2.82E-02	-3.07E-02	1.10E-02	2.01E-04
$2s^22p^3\ ^2D_{5/2}$ -	$2s2p^4\ ^2D_{5/2}$	1.10E+02	4.05E-01	-1.77E-02	7.10E-01	-5.02E-01	1.89E-01
$2s^22p^3\ ^2D_{5/2}$ -	$2s2p^4\ ^2S_{1/2}$	1.26E+02	3.64E-05	2.51E-03	-3.93E-03	1.95E-03	-8.97E-06
$2s^22p^3\ ^2D_{5/2}$ -	$2s2p^4\ ^2P_{3/2}$	1.33E+02	4.86E-01	-3.07E-01	1.45E+00	-9.48E-01	2.21E-01
$2s^22p^3\ ^2D_{5/2}$ -	$2s2p^4\ ^2P_{1/2}$	1.45E+02	5.40E-05	4.09E-03	-5.69E-03	2.65E-03	-1.63E-05
$2s^22p^3\ ^2P_{1/2}$ -	$2s^22p^3\ ^2P_{3/2}$	7.73E+00	2.48E-02	2.35E-01	-8.50E-01	6.81E-01	-2.72E-03
$2s^22p^3\ ^2P_{1/2}$ -	$2s2p^4\ ^4P_{5/2}$	6.10E+01	4.13E-04	7.00E-03	-1.42E-02	8.29E-03	-6.91E-05
$2s^22p^3\ ^2P_{1/2}$ -	$2s2p^4\ ^4P_{3/2}$	6.91E+01	8.24E-04	1.89E-02	-3.06E-02	1.58E-02	6.01E-05
$2s^22p^3\ ^2P_{1/2}$ -	$2s2p^4\ ^4P_{1/2}$	7.18E+01	2.23E-03	5.95E-02	-1.18E-01	6.75E-02	1.61E-03
$2s^22p^3\ ^2P_{1/2}$ -	$2s2p^4\ ^2D_{3/2}$	9.79E+01	4.00E-02	-2.78E-03	7.68E-02	-5.48E-02	1.64E-02
$2s^22p^3\ ^2P_{1/2}$ -	$2s2p^4\ ^2D_{5/2}$	1.00E+02	1.72E-03	1.88E-02	-3.14E-02	1.60E-02	-3.29E-04
$2s^22p^3\ ^2P_{1/2}$ -	$2s2p^4\ ^2S_{1/2}$	1.17E+02	1.41E-01	-1.44E-02	2.78E-01	-1.96E-01	6.07E-02
$2s^22p^3\ ^2P_{1/2}$ -	$2s2p^4\ ^2P_{3/2}$	1.23E+02	5.61E-02	-1.32E-02	1.24E-01	-8.51E-02	2.48E-02
$2s^22p^3\ ^2P_{1/2}$ -	$2s2p^4\ ^2P_{1/2}$	1.35E+02	1.06E-02	-6.26E-03	2.85E-02	-1.85E-02	4.71E-03
$2s^22p^3\ ^2P_{3/2}$ -	$2s2p^4\ ^4P_{5/2}$	5.32E+01	3.36E-03	2.35E-02	-5.57E-02	3.41E-02	-5.95E-04
$2s^22p^3\ ^2P_{3/2}$ -	$2s2p^4\ ^4P_{3/2}$	6.14E+01	2.32E-02	-6.16E-03	1.41E-02	-8.23E-03	6.86E-04
$2s^22p^3\ ^2P_{3/2}$ -	$2s2p^4\ ^4P_{1/2}$	6.41E+01	2.13E-03	1.35E-02	-8.00E-03	1.95E-04	1.90E-04
$2s^22p^3\ ^2P_{3/2}$ -	$2s2p^4\ ^2D_{3/2}$	9.02E+01	1.09E-02	4.80E-02	-7.16E-02	3.68E-02	5.08E-03
$2s^22p^3\ ^2P_{3/2}$ -	$2s2p^4\ ^2D_{5/2}$	9.23E+01	1.50E-01	-5.98E-02	3.70E-01	-2.49E-01	6.01E-02
$2s^22p^3\ ^2P_{3/2}$ -	$2s2p^4\ ^2S_{1/2}$	1.09E+02	1.28E-02	3.42E-02	-3.44E-02	1.40E-02	5.95E-03
$2s^22p^3\ ^2P_{3/2}$ -	$2s2p^4\ ^2P_{3/2}$	1.16E+02	7.20E-02	-7.14E-03	1.36E-01	-9.54E-02	3.21E-02
$2s^22p^3\ ^2P_{3/2}$ -	$2s2p^4\ ^2P_{1/2}$	1.27E+02	2.68E-01	-1.10E-01	7.22E-01	-4.93E-01	1.21E-01

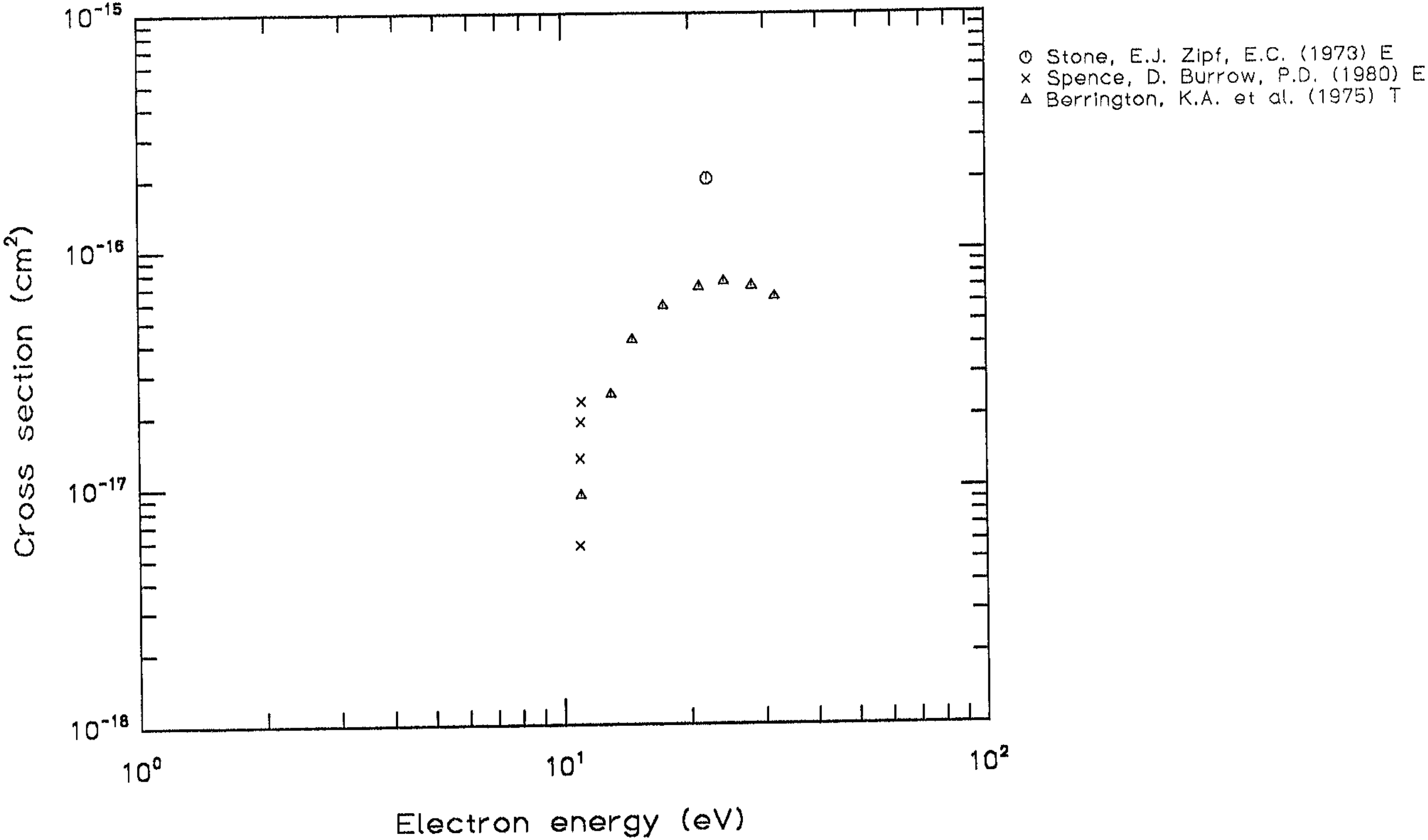
Graphs I. Comparison of the cross sections

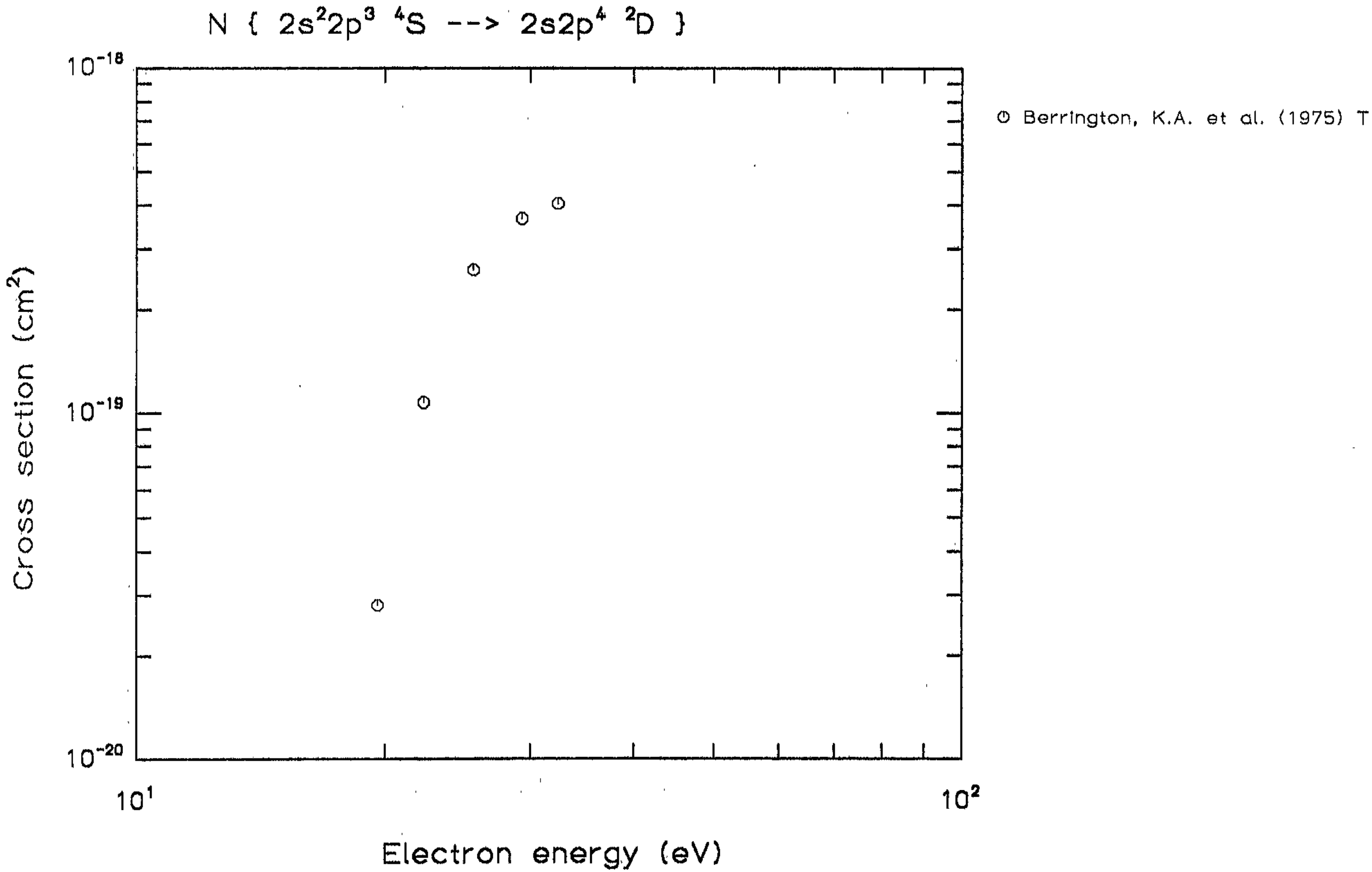

N (2s²2p³ ⁴S --> 2s²2p³ ²D)
Cross section (cm²)
10⁻¹⁸
10⁻¹⁷
10⁻¹⁶
10⁻¹⁵
10⁰
10¹
10²
Electron energy (eV)
Θ Ormonde, S. et al. (1973) T
× Henry, R.J.W. et al. (1969) T
▵ Berrington, K.A. et al. (1975) T


N ($2s^22p^3$ ^4S --> $2s^22p^3$ ^2P)
Cross section (cm^2)
10^{-18}
10^{-17}
10^{-16}
Electron energy (eV)
10^0
10^1
10^2
⊖ Henry, R.J.W. et al. (1969) T
× Ormonde, S. et al. (1973) T
▵ Berrington, K.A. et al. (1975) T

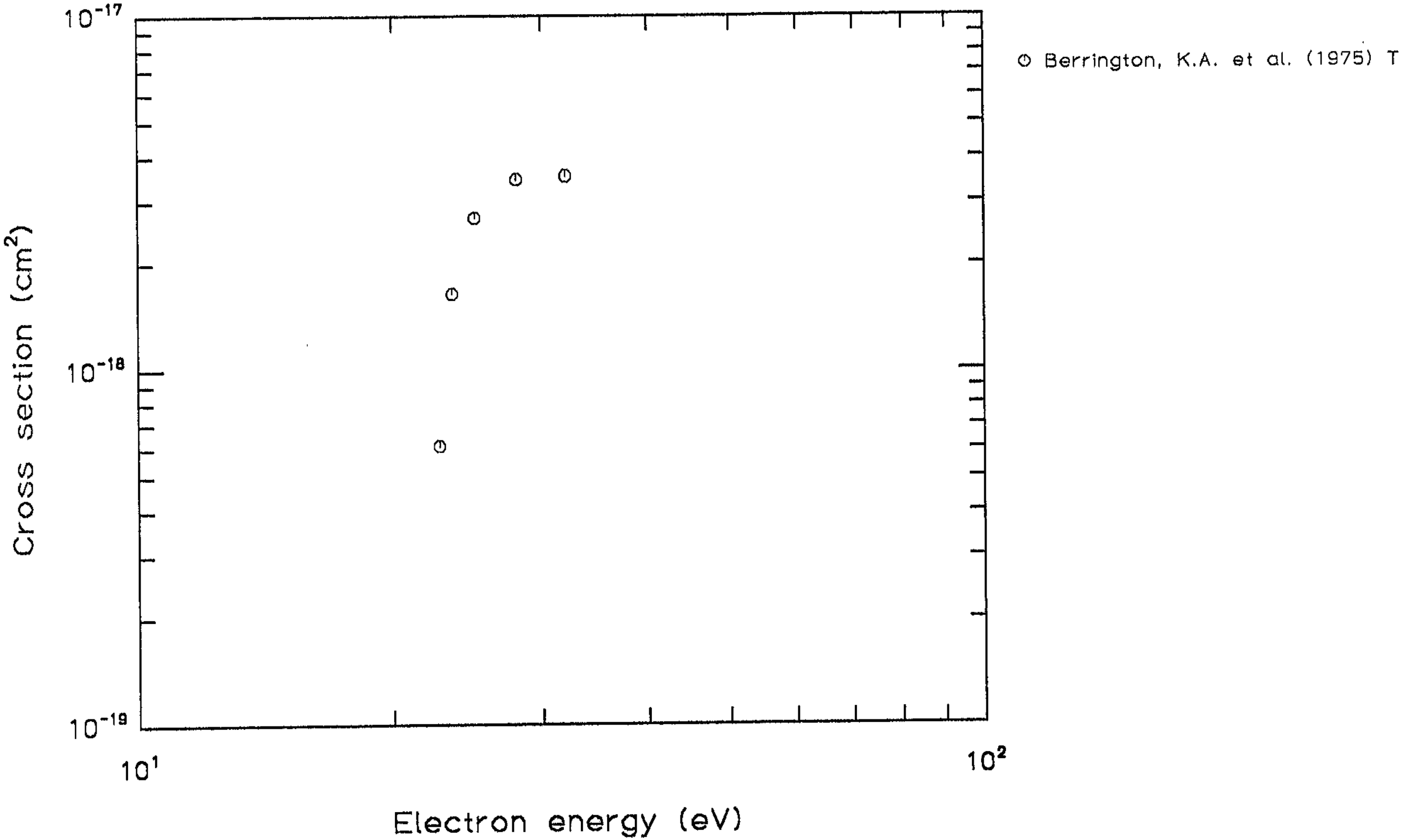

N { 2s²2p³ ⁴S --> 2s²2p²3s ⁴P }
Cross section (cm²)
10⁻¹⁵
10⁻¹⁶
10⁻¹⁷
10⁻¹⁸
10⁰
10¹
10²
10³
Electron energy (eV)
Stone, E.J. Zipf, E.C. (1973) E
Spence, D. Burrow, P.D. (1980) E
Doering, J.P. Goembel, L. (1991) E
Ormonde, S. et al. (1973) T

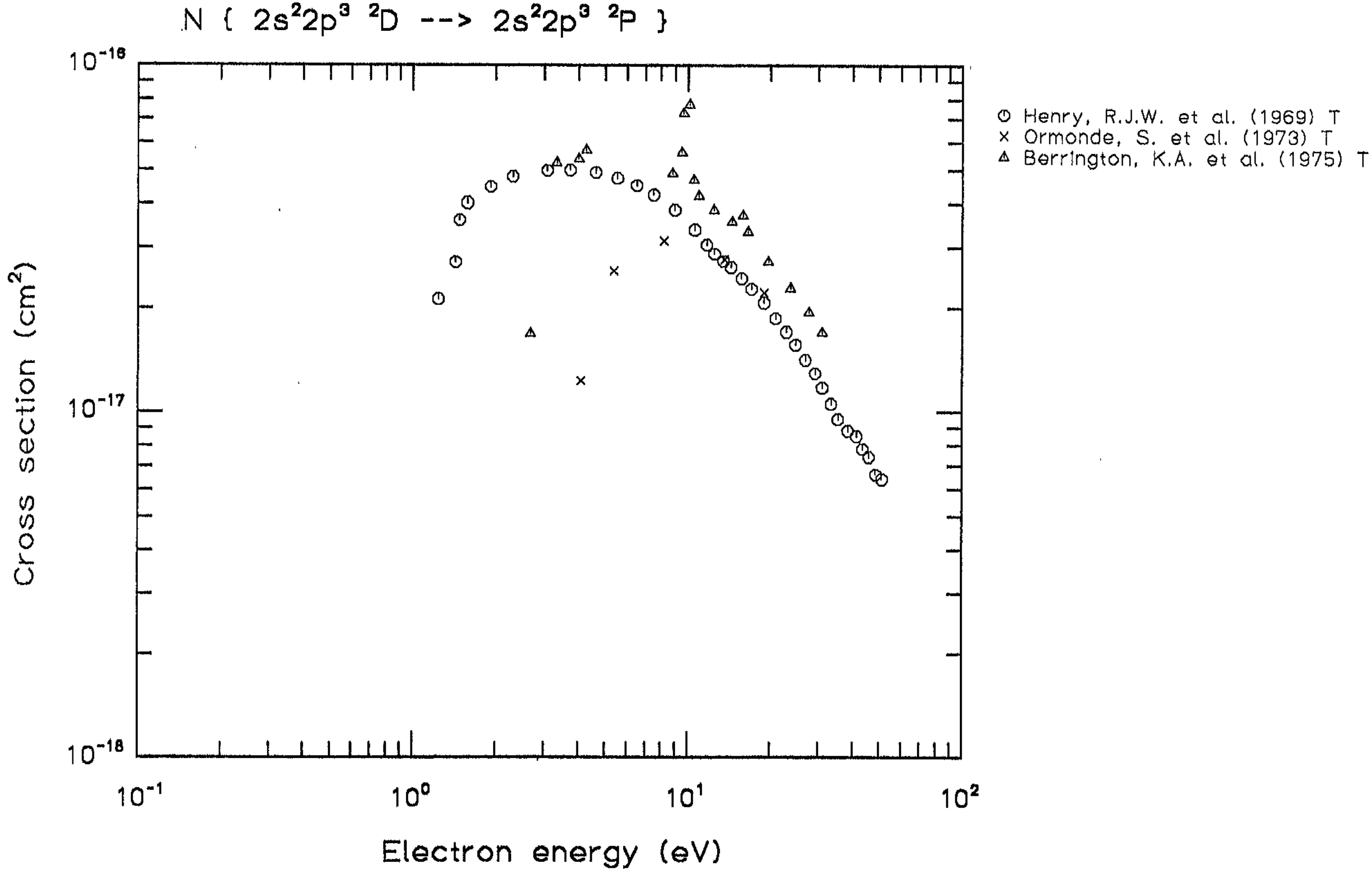
N { $2s^2 2p^3\ ^4S$ --> $2s2p^4\ ^4P$ }



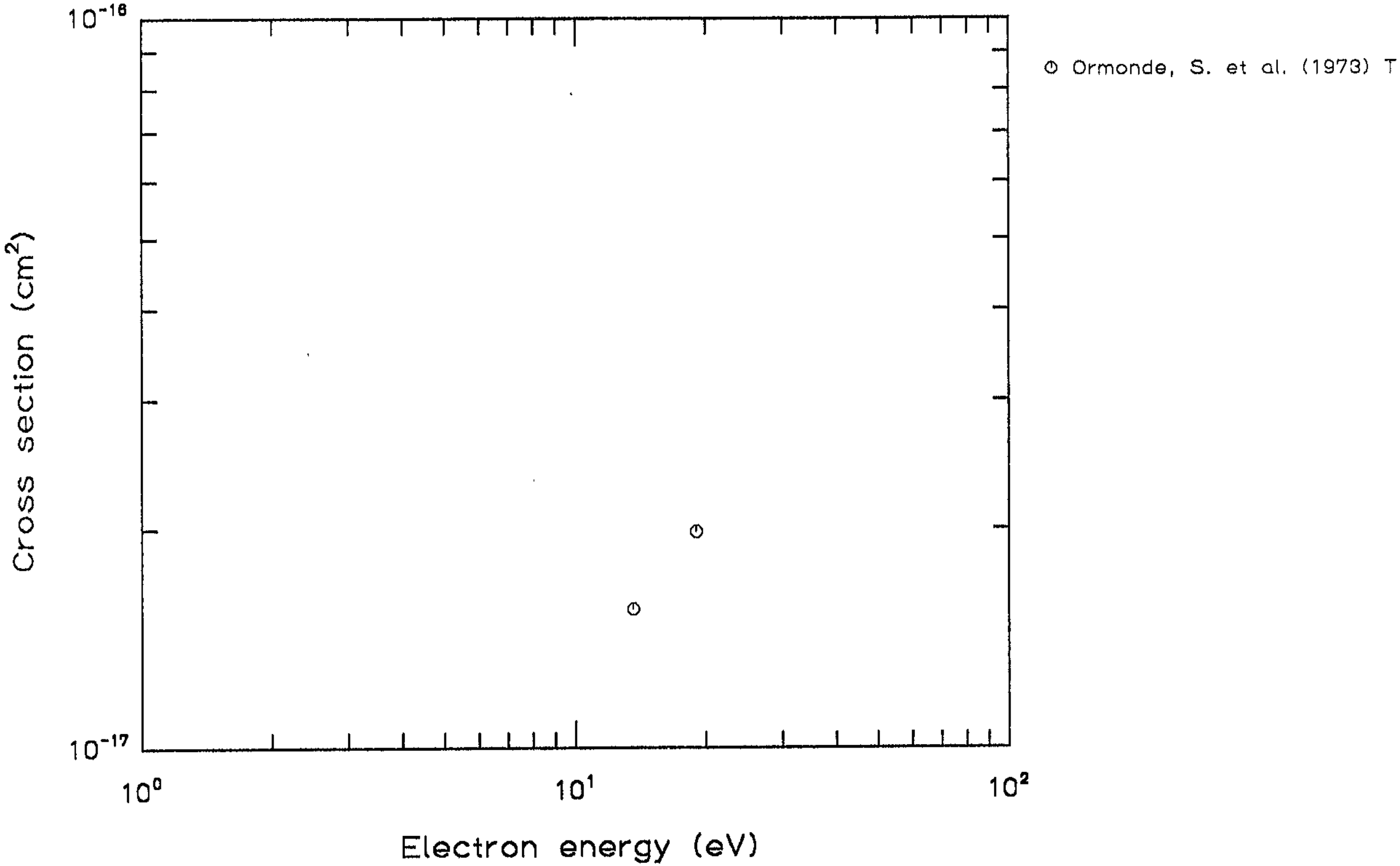

N { 2s²2p³ ⁴S --> 2s2p⁴ ²D }
10⁻¹⁸
10⁻¹⁹
10⁻²⁰
Cross section (cm²)
10¹
10²
Electron energy (eV)
Berrington, K.A. et al. (1975) T

N { $2s^22p^3\ ^4S$ --> $2s2p^4\ ^2P$ }

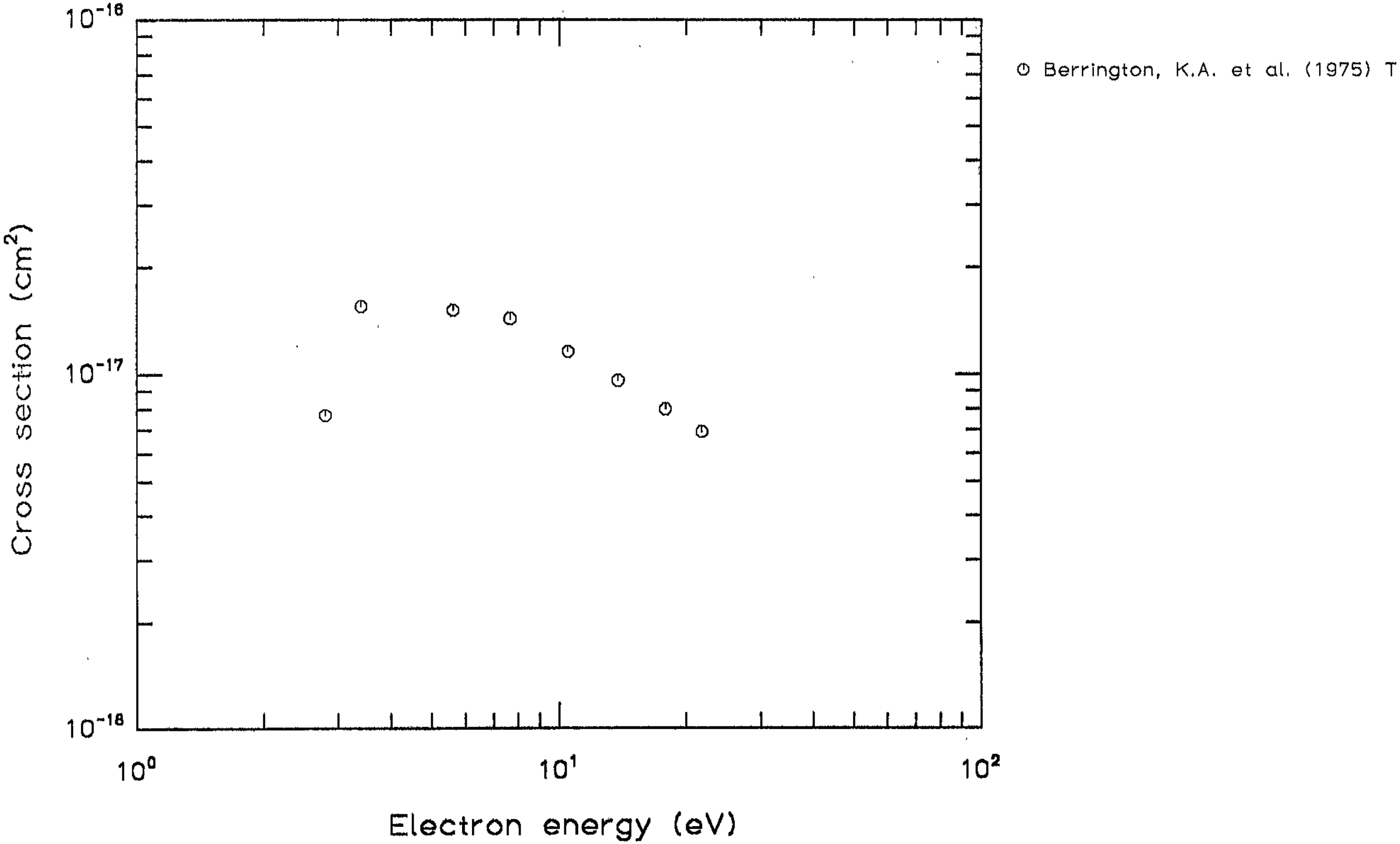


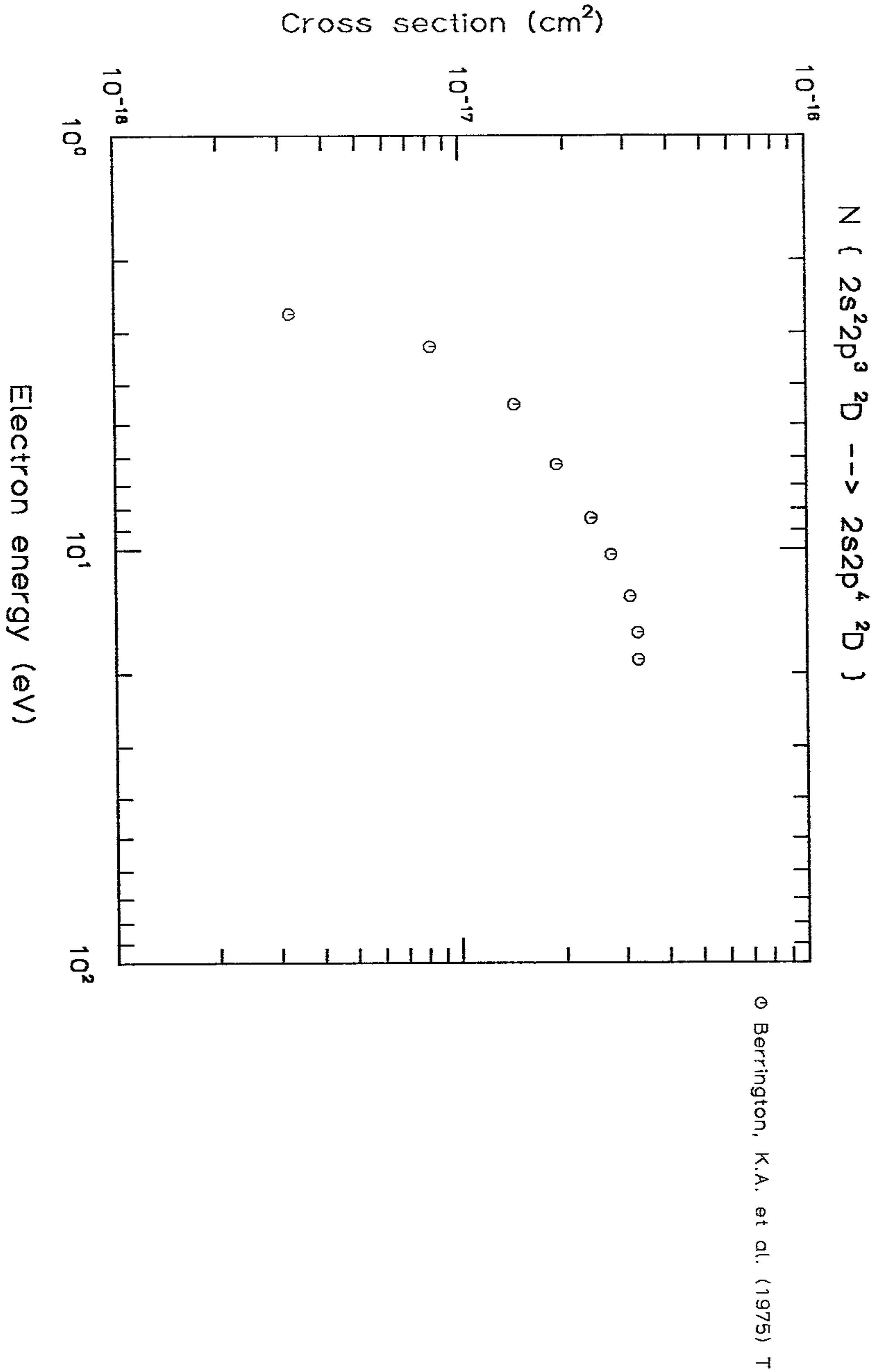

N { 2s²2p³ ²D --> 2s²2p³ ²P }
Cross section (cm²)
10⁻¹⁶
10⁻¹⁷
10⁻¹⁸
10⁻¹
10⁰
10¹
10²
Electron energy (eV)
Henry, R.J.W. et al. (1969) T
Ormonde, S. et al. (1973) T
Berrington, K.A. et al. (1975) T

N { $2s^22p^3\ ^2D \rightarrow 2s^22p^23s\ ^4P$ }

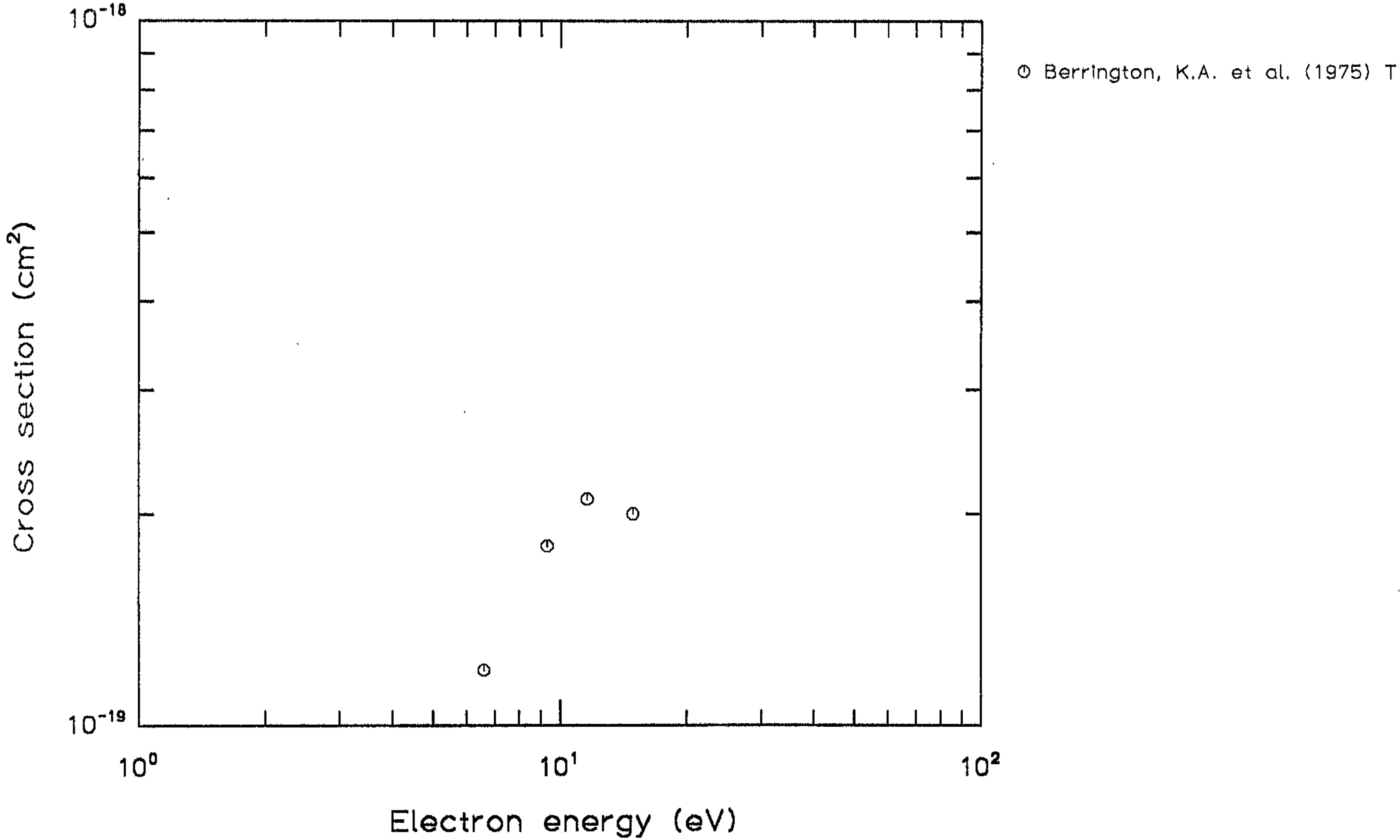


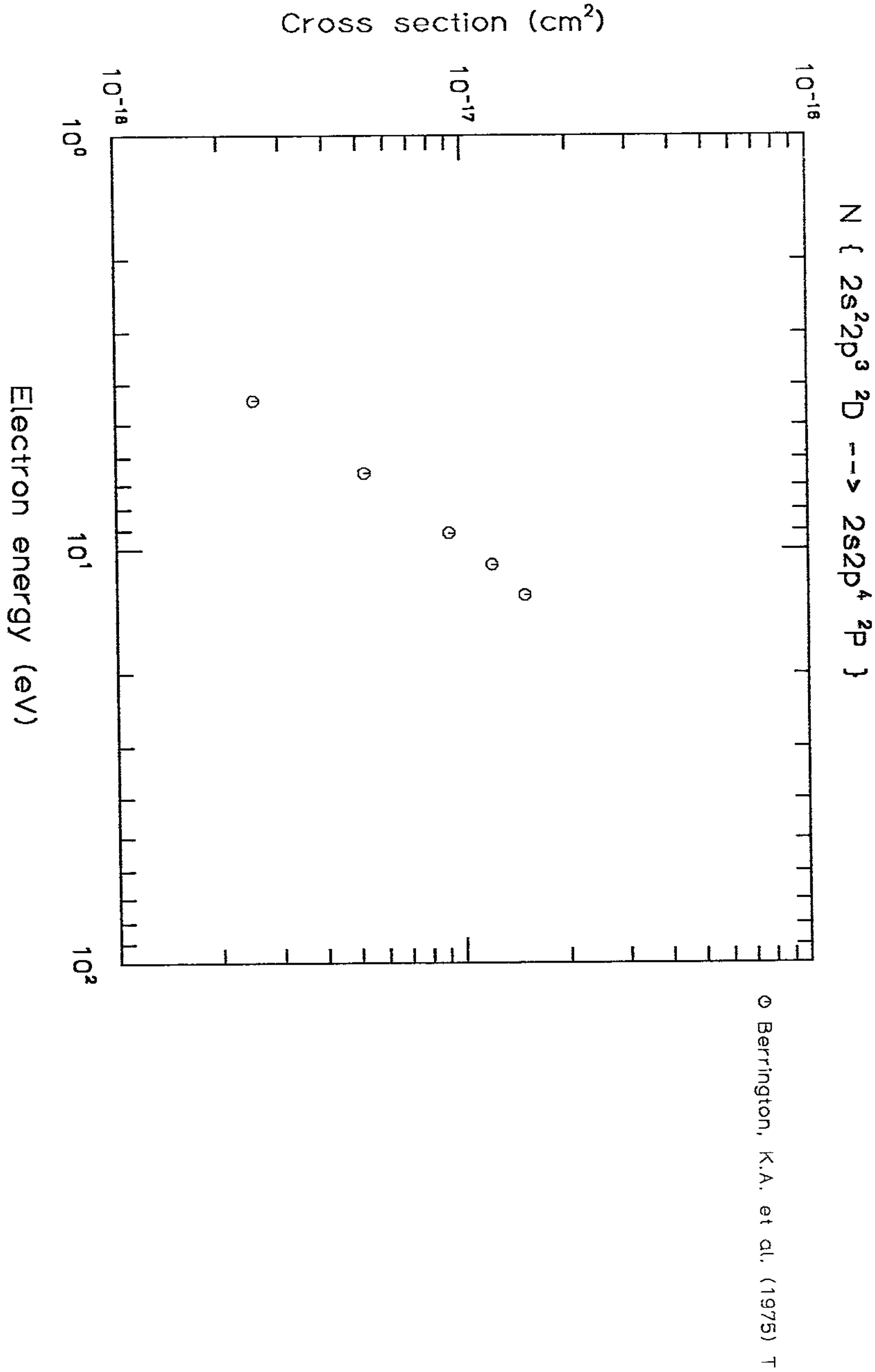
N { $2s^2 2p^3\ ^2D$ --> $2s2p^4\ ^4P$ }



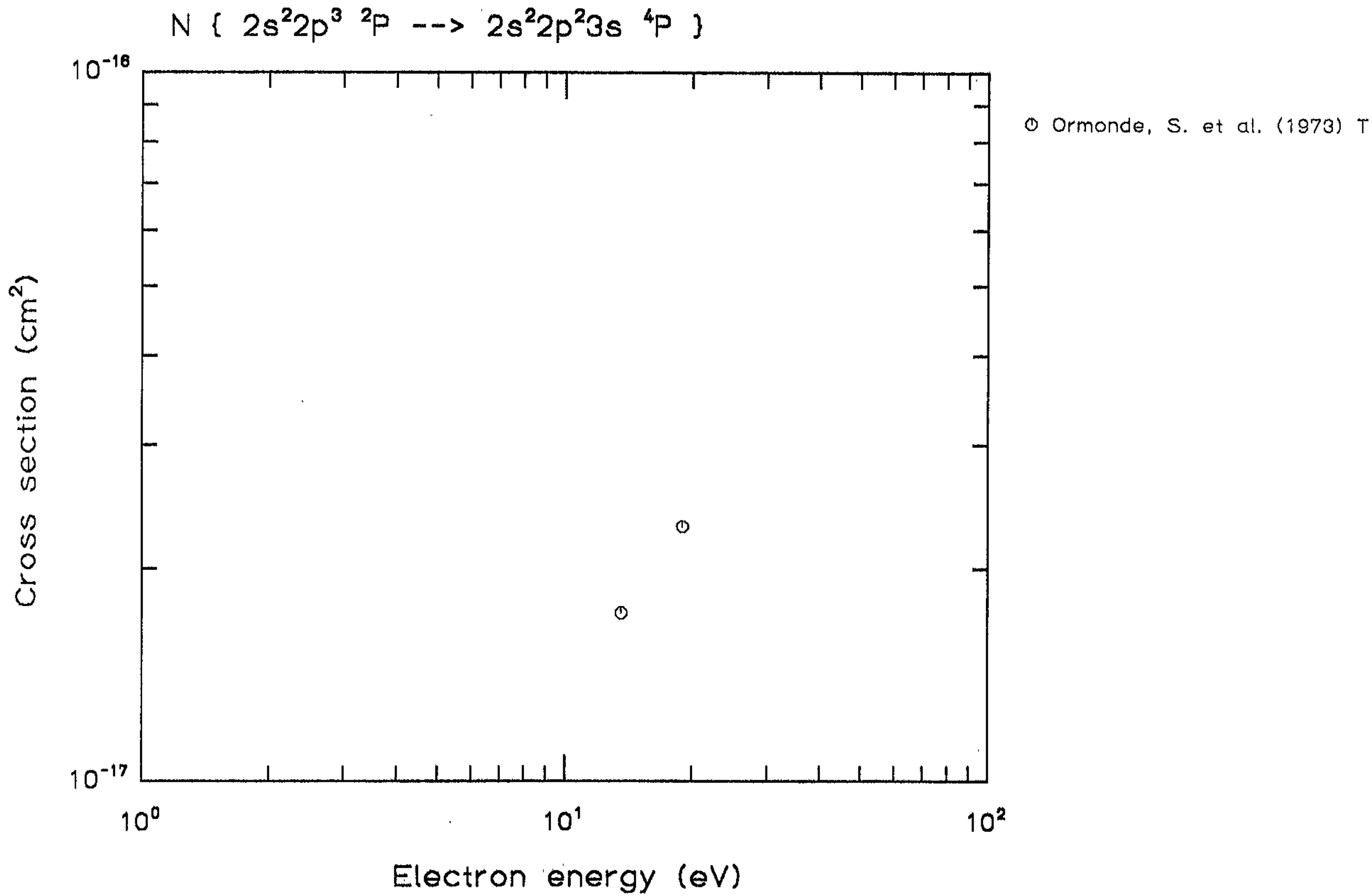

N (2s²2p³ ²D --> 2s2p⁴ ²D)
Cross section (cm²)
10⁻¹⁸
10⁻¹⁷
10⁻¹⁶
Electron energy (eV)
10⁰
10¹
10²
Θ Berrington, K.A. et al. (1975) T

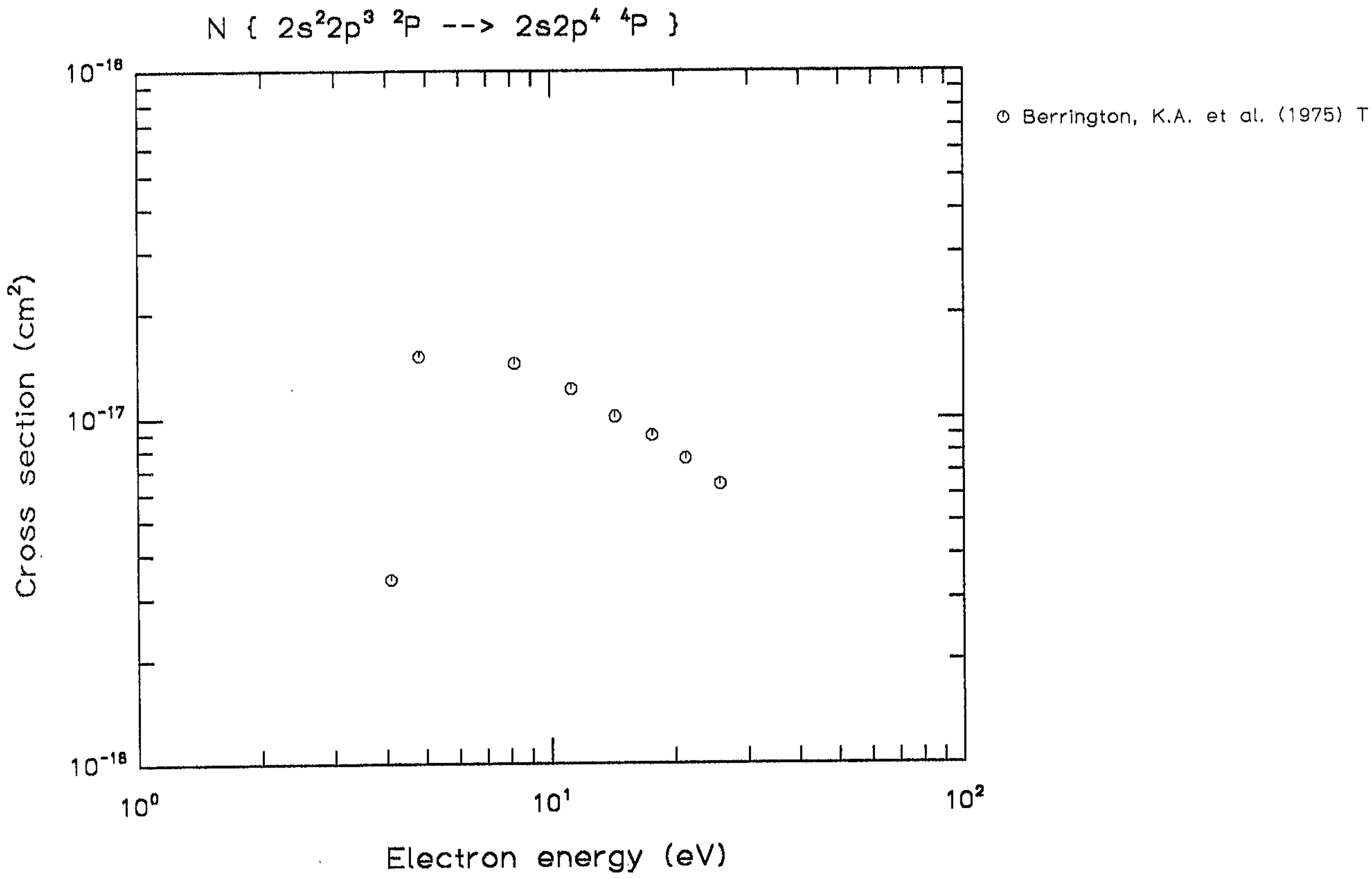
N { $2s^2 2p^3\ ^2D$ --> $2s2p^4\ ^2S$ }

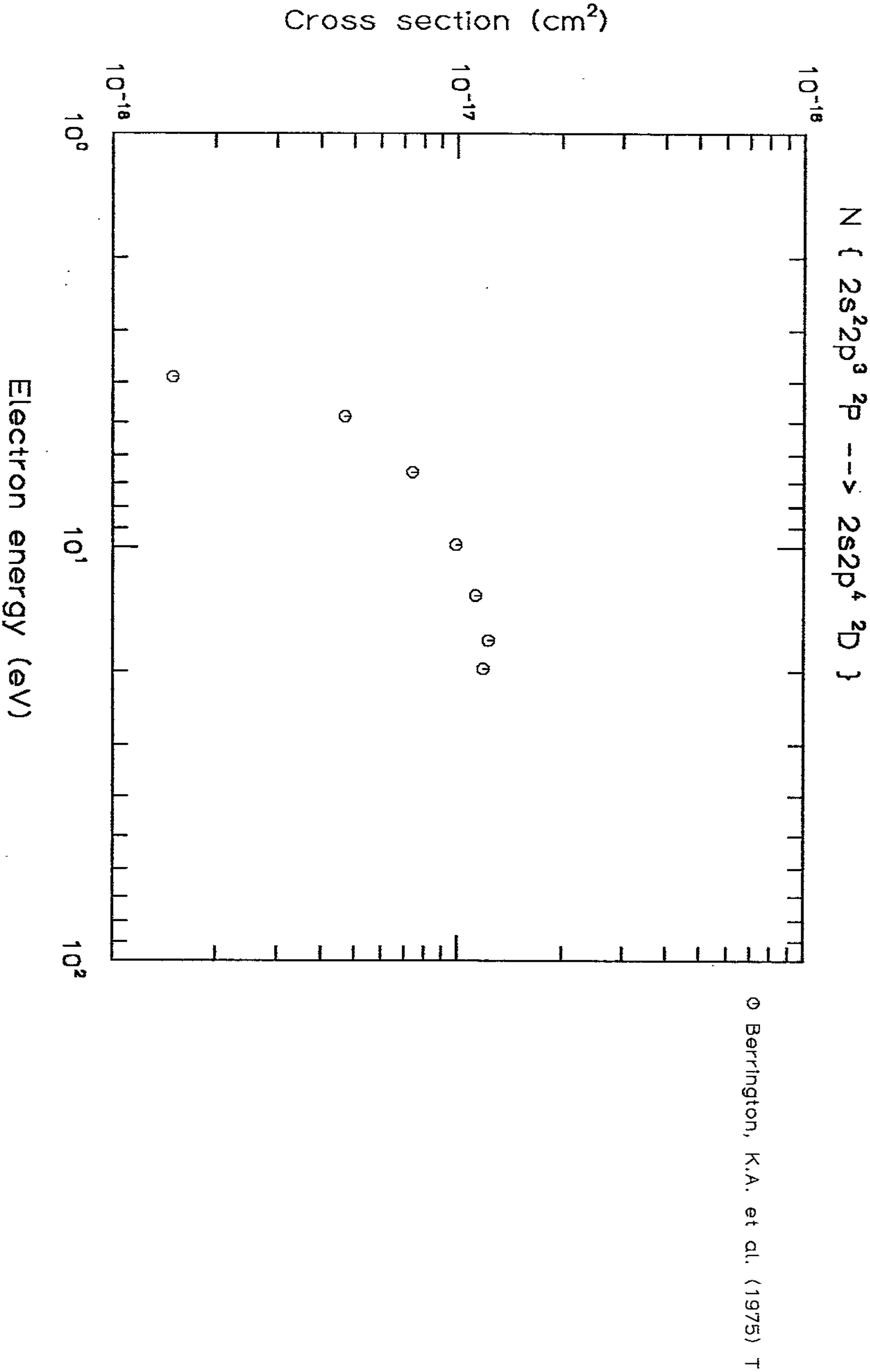


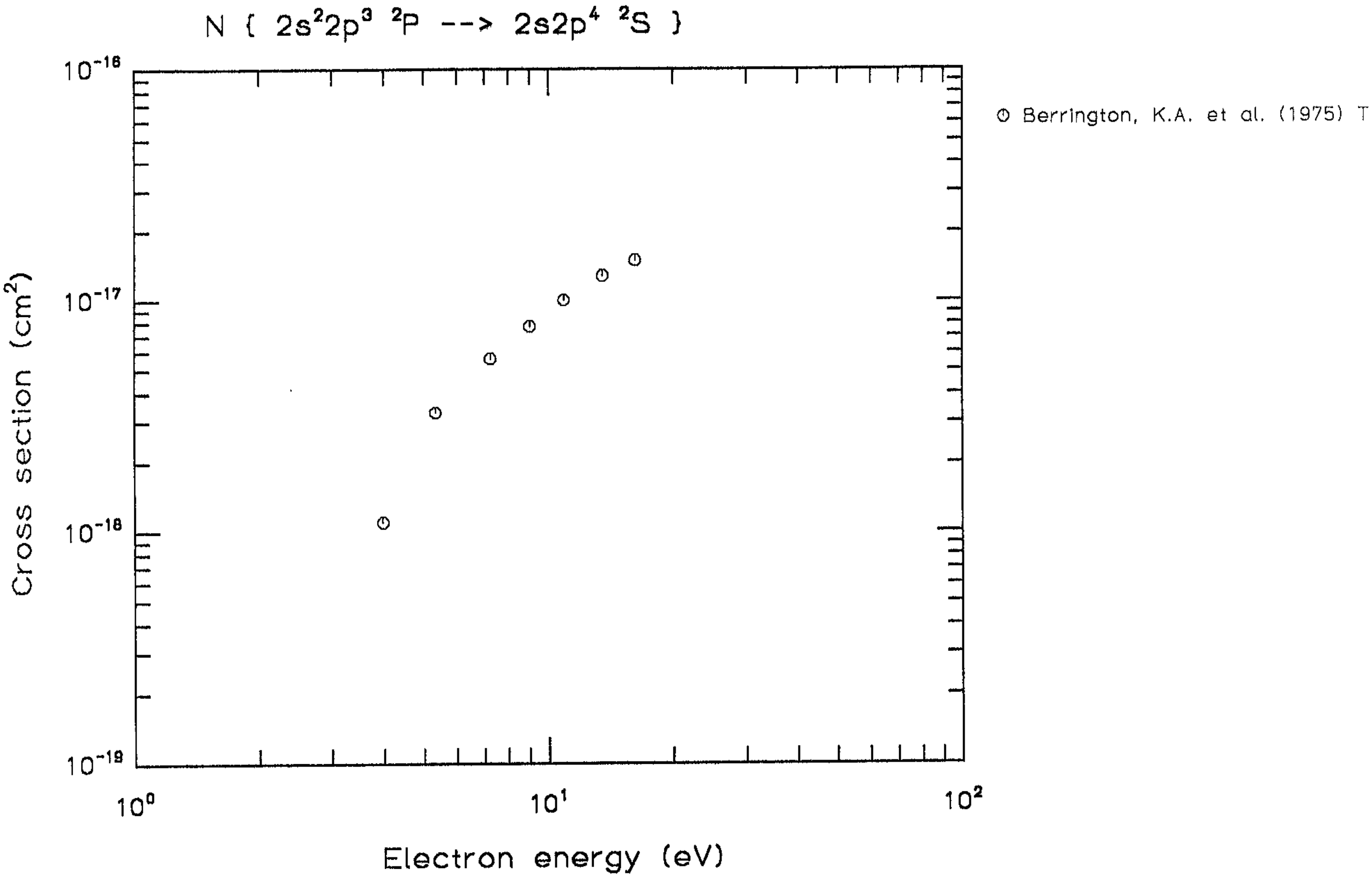


Cross section (cm^2)
10^{-18}
10^{-17}
10^{-16}
10^0
10^1
10^2
N { $2s^22p^3$ ^2D --> $2s2p^4$ ^2P }
Electron energy (eV)
Θ Berrington, K.A. et al. (1975) T

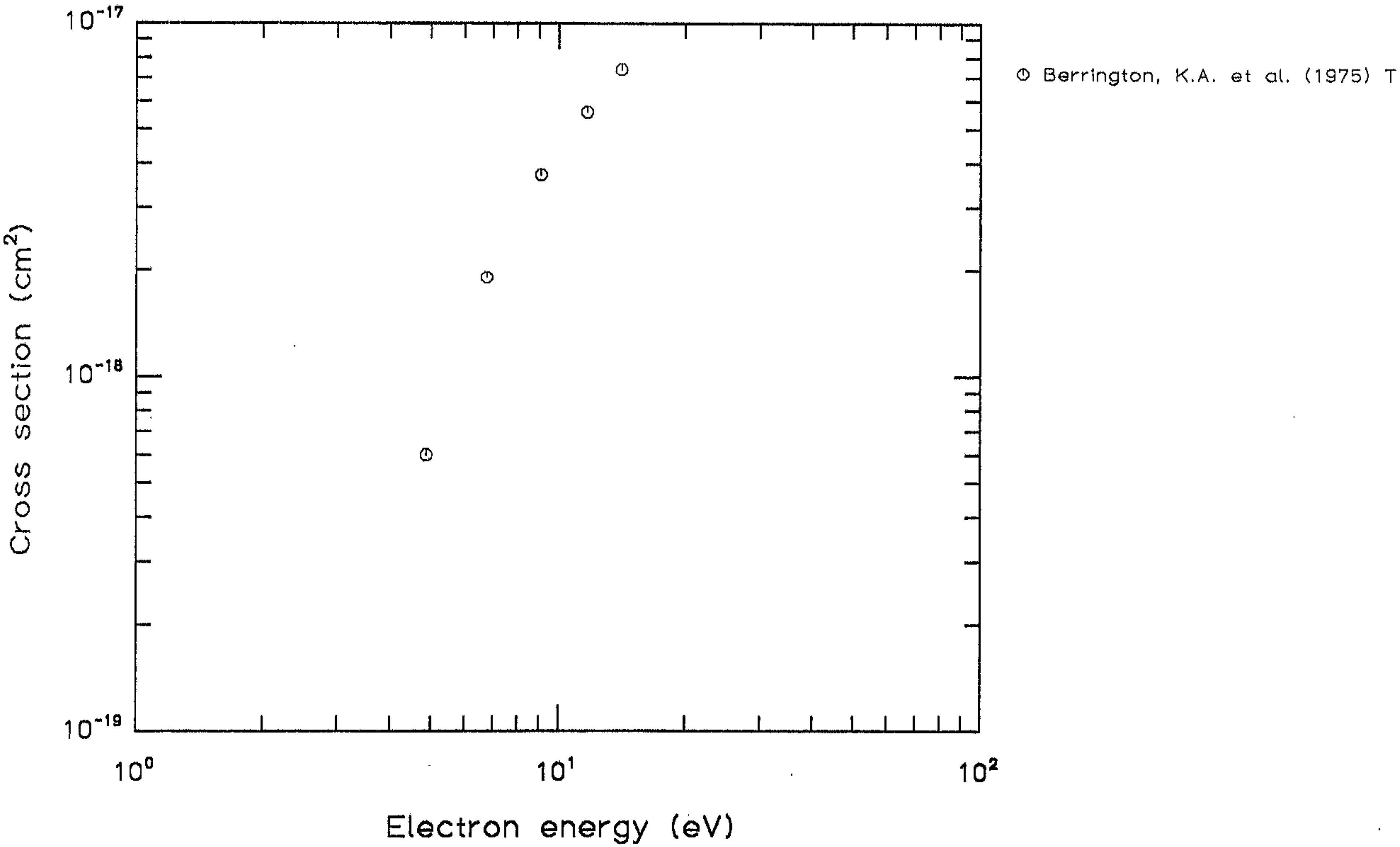

N { 2s²2p³ ²P --> 2s²2p²3s ⁴P }
Cross section (cm²)
10⁻¹⁶
10⁻¹⁷
10⁰
10¹
10²
Electron energy (eV)
Ormonde, S. et al. (1973) T

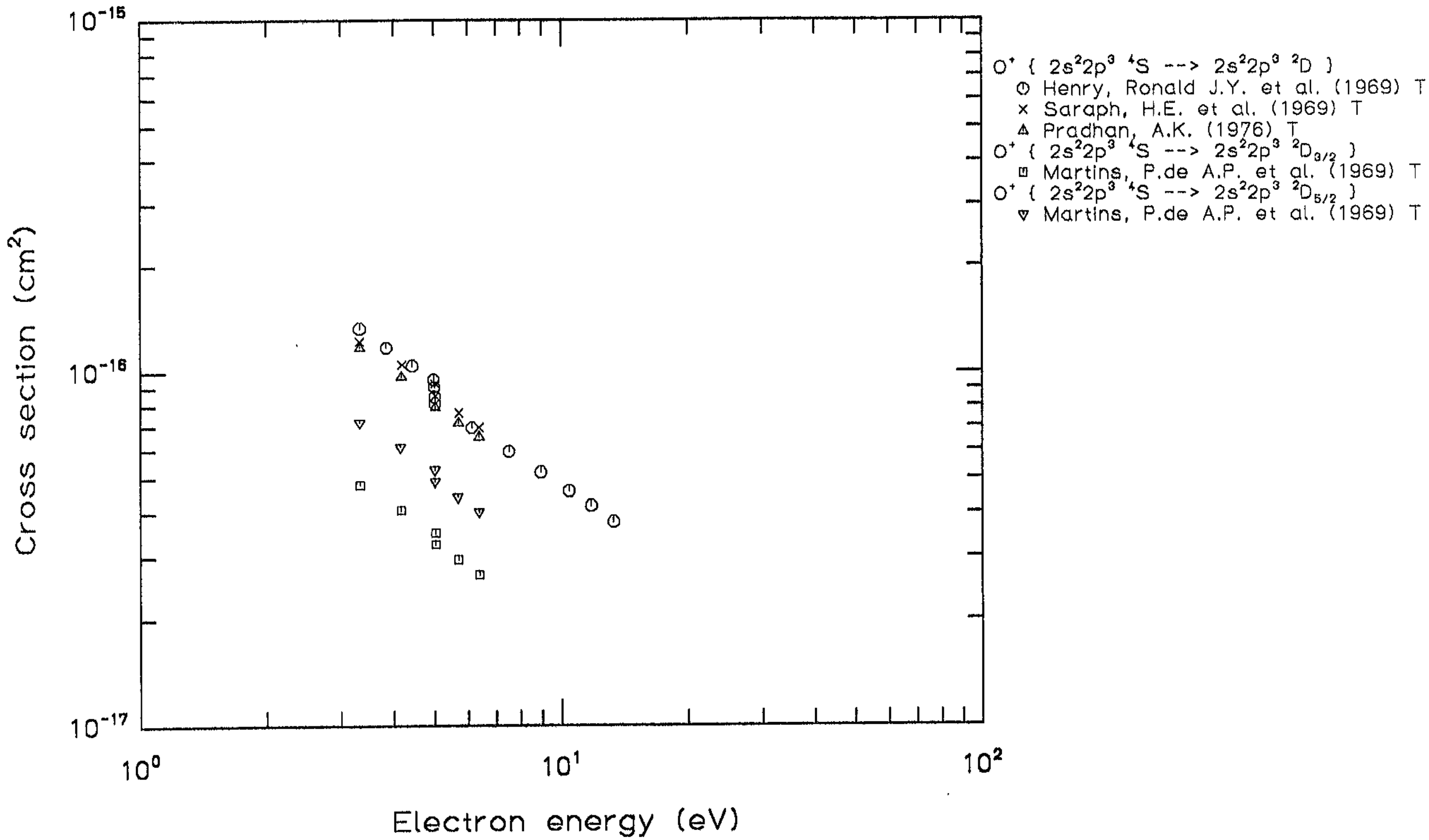

N { $2s^22p^3$ ^2P --> $2s2p^4$ ^4P }
10^{-16}
10^{-17}
10^{-18}
Cross section (cm^2)
10^0
10^1
10^2
Electron energy (eV)
Berrington, K.A. et al. (1975) T


N { 2s²2p³ ²P --> 2s2p⁴ ²D }
Cross section (cm²)
10⁻¹⁸
10⁻¹⁷
10⁻¹⁶
Electron energy (eV)
10⁰
10¹
10²
Θ Berrington, K.A. et al. (1975) T

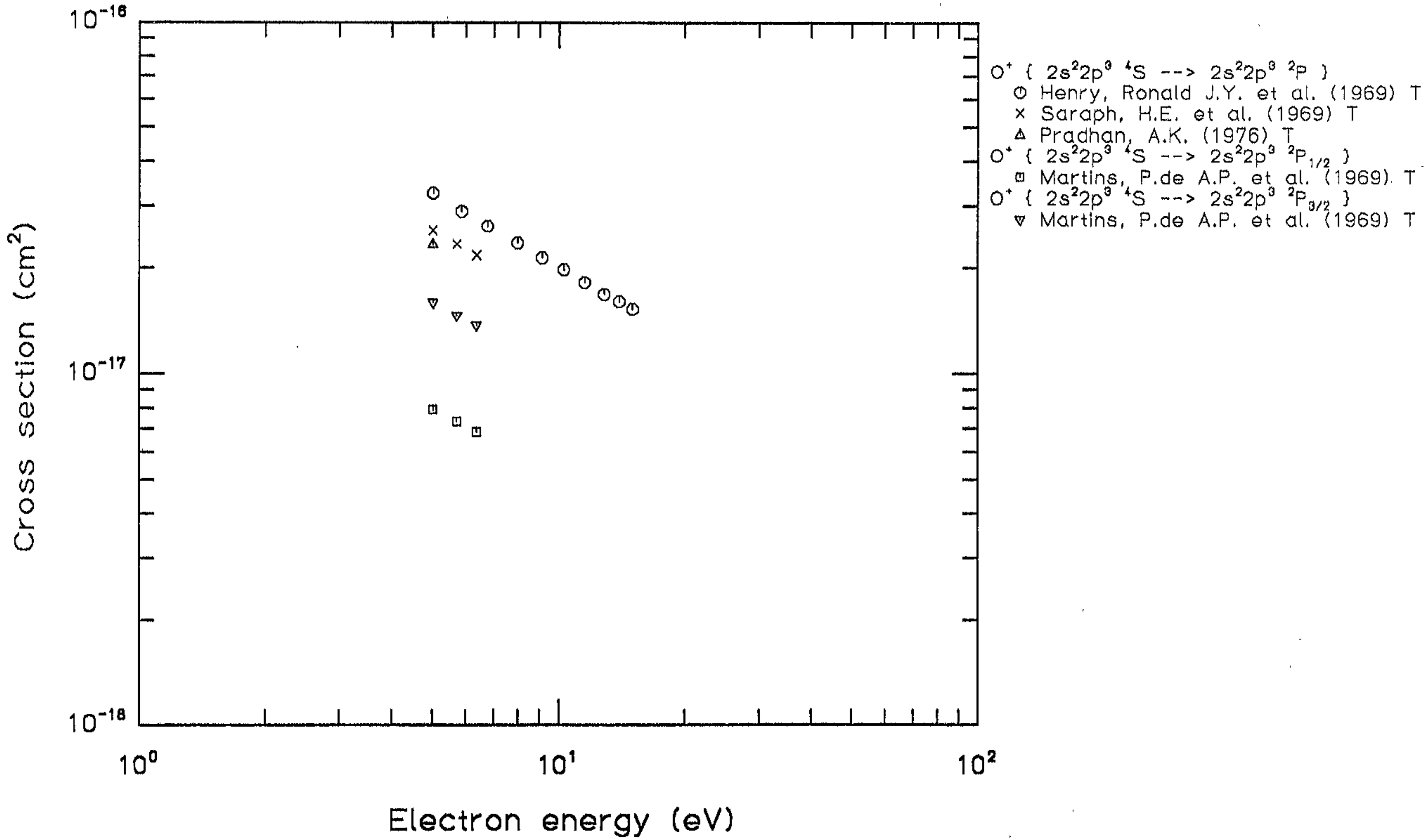

N { 2s²2p³ ²P --> 2s2p⁴ ²S }
Cross section (cm²)
10⁻¹⁶
10⁻¹⁷
10⁻¹⁸
10⁻¹⁹
10⁰
10¹
10²
Electron energy (eV)
Θ Berrington, K.A. et al. (1975) T

N { $2s^2 2p^3\ ^2P$ --> $2s2p^4\ ^2P$ }

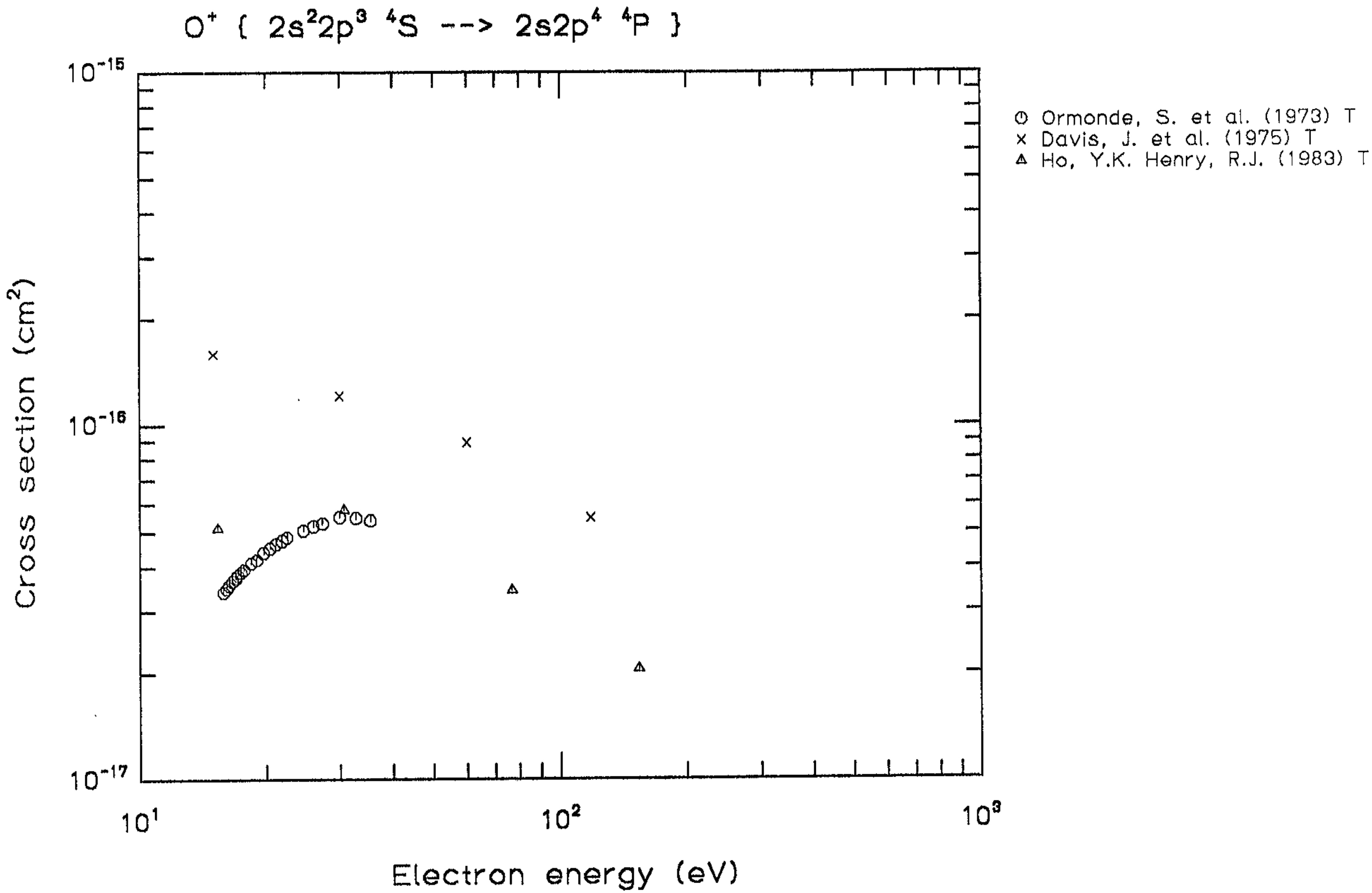


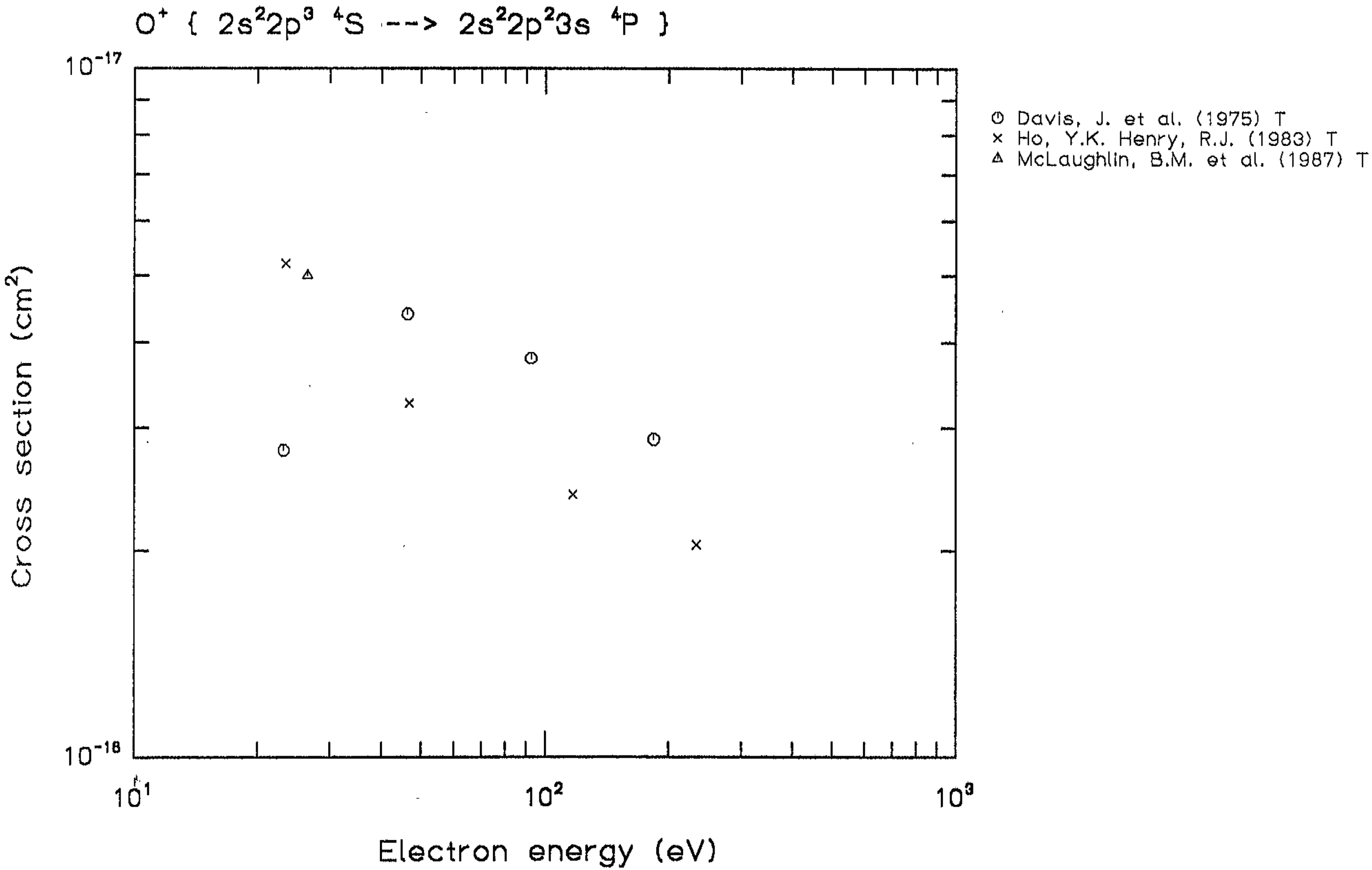


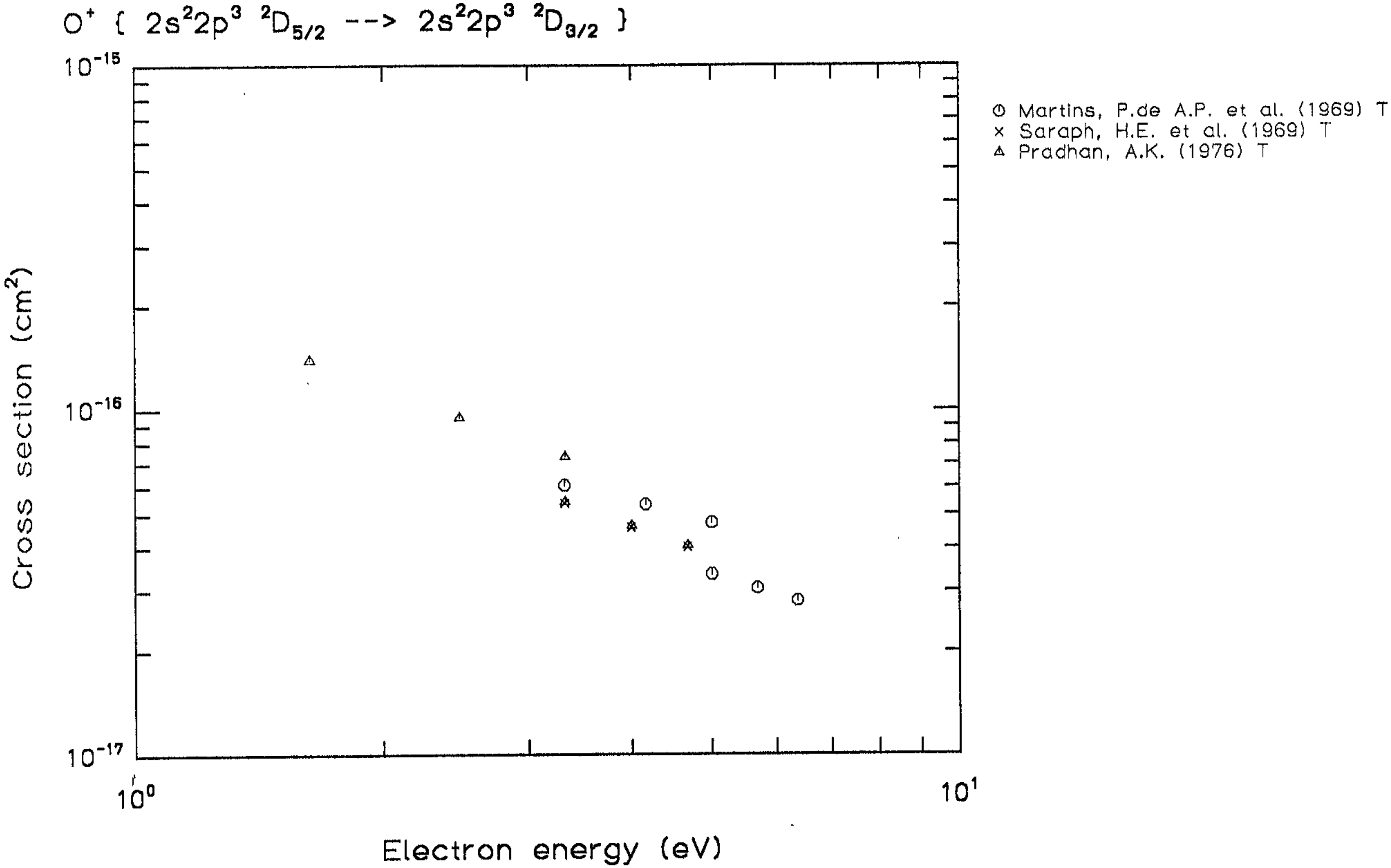
Cross section (cm2)
10-15
10-16
10-17
100
101
102
Electron energy (eV)
O+ { 2s22p3 4S --> 2s22p3 2D }
Henry, Ronald J.Y. et al. (1969) T
Saraph, H.E. et al. (1969) T
Pradhan, A.K. (1976) T
O+ { 2s22p3 4S --> 2s22p3 2D3/2 }
Martins, P.de A.P. et al. (1969) T
O+ { 2s22p3 4S --> 2s22p3 2D5/2 }
Martins, P.de A.P. et al. (1969) T

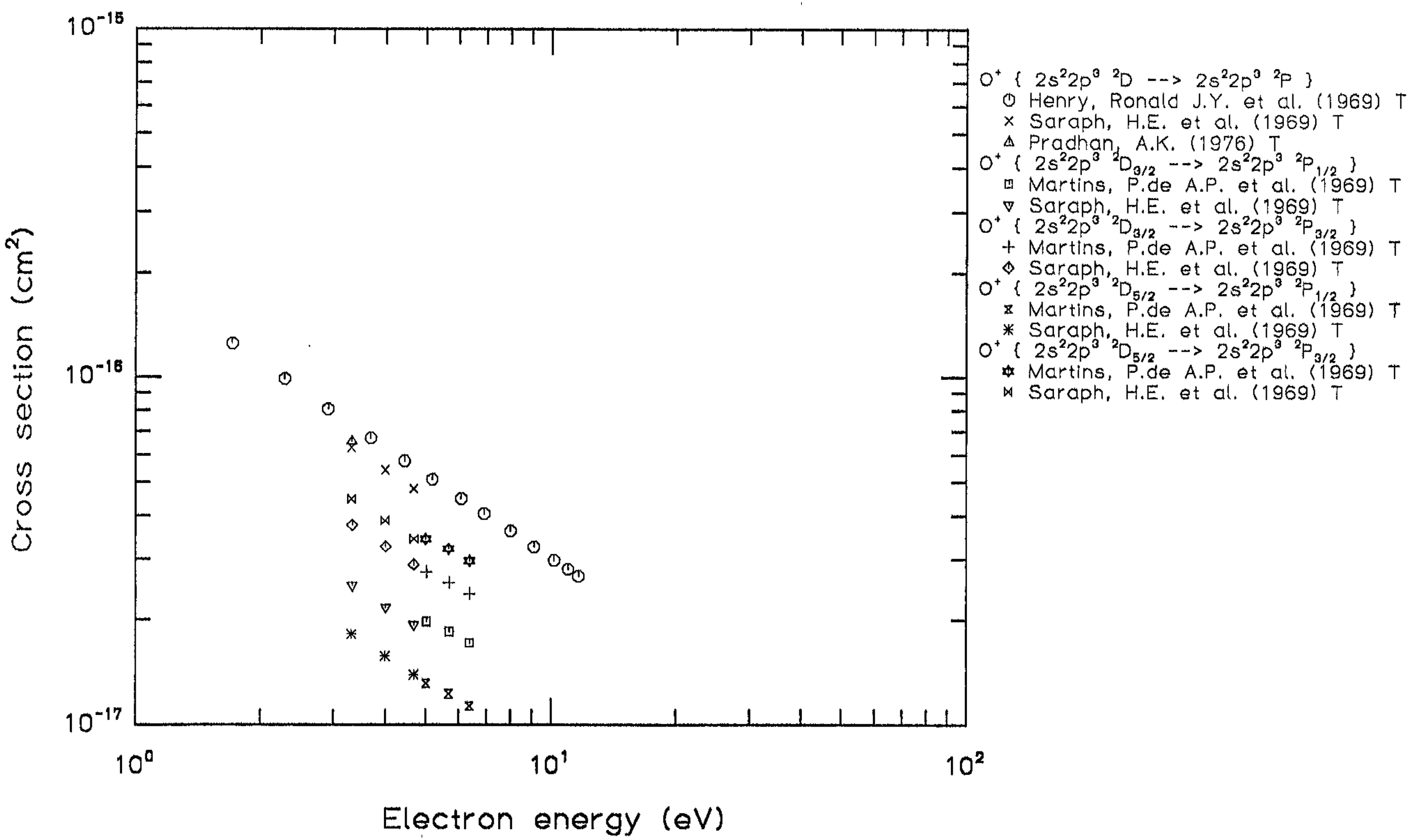


Cross section (cm²)
10⁻¹⁶
10⁻¹⁷
10⁻¹⁸
10⁰
10¹
10²
Electron energy (eV)
O⁺ { 2s²2p³ ⁴S --> 2s²2p³ ²P }
Henry, Ronald J.Y. et al. (1969) T
Saraph, H.E. et al. (1969) T
Pradhan, A.K. (1976) T
O⁺ { 2s²2p³ ⁴S --> 2s²2p³ ²P1/2 }
Martins, P.de A.P. et al. (1969) T
O⁺ { 2s²2p³ ⁴S --> 2s²2p³ ²P3/2 }
Martins, P.de A.P. et al. (1969) T

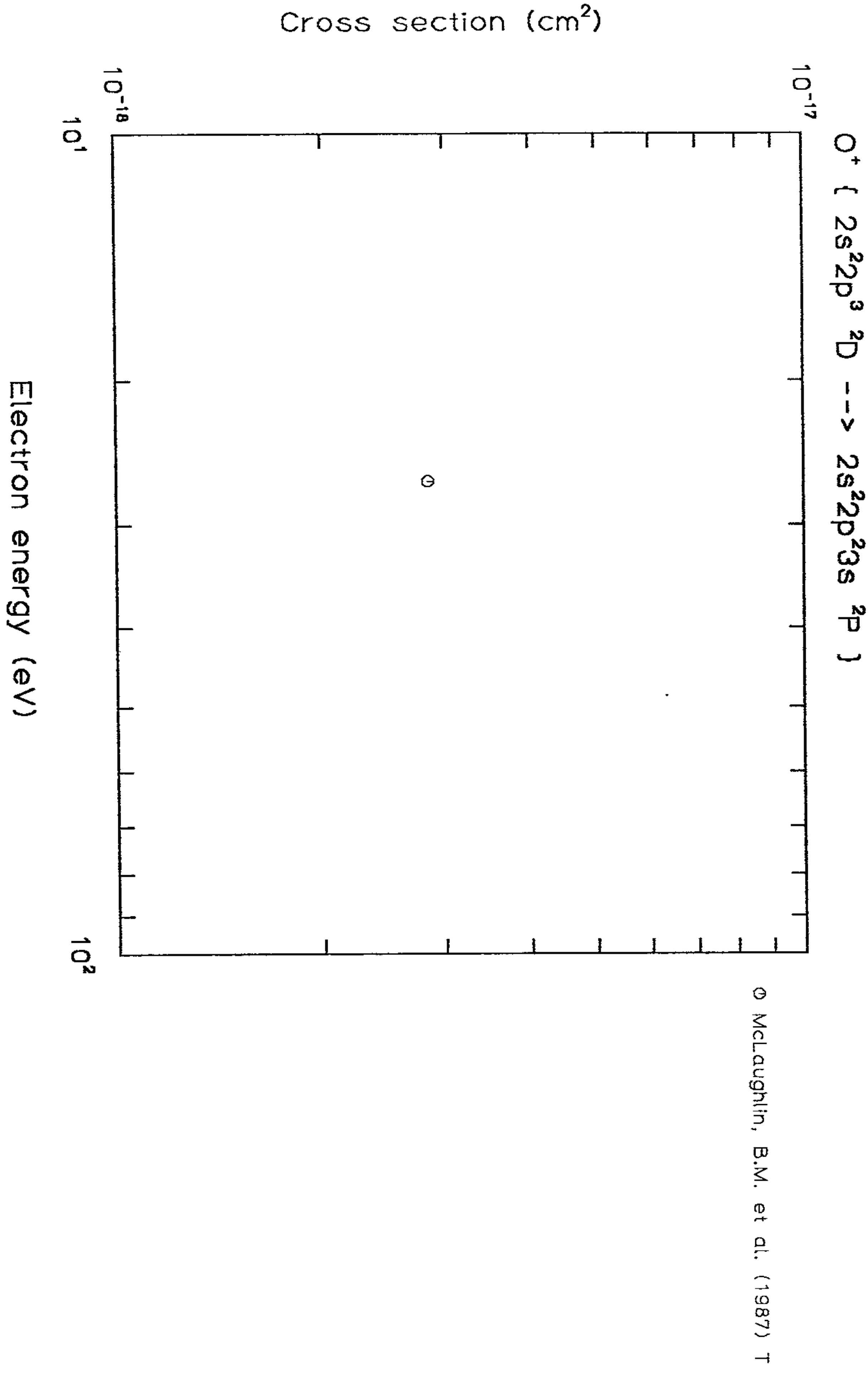

O+ { 2s22p3 4S --> 2s2p4 4P }
Cross section (cm2)
10-15
10-16
10-17
Electron energy (eV)
101
102
103
Ormonde, S. et al. (1973) T
Davis, J. et al. (1975) T
Ho, Y.K. Henry, R.J. (1983) T


O+ { 2s2 2p3 4S --> 2s2 2p2 3s 4P }
Cross section (cm2)
10-17
10-18
101
102
103
Electron energy (eV)
Davis, J. et al. (1975) T
Ho, Y.K. Henry, R.J. (1983) T
McLaughlin, B.M. et al. (1987) T

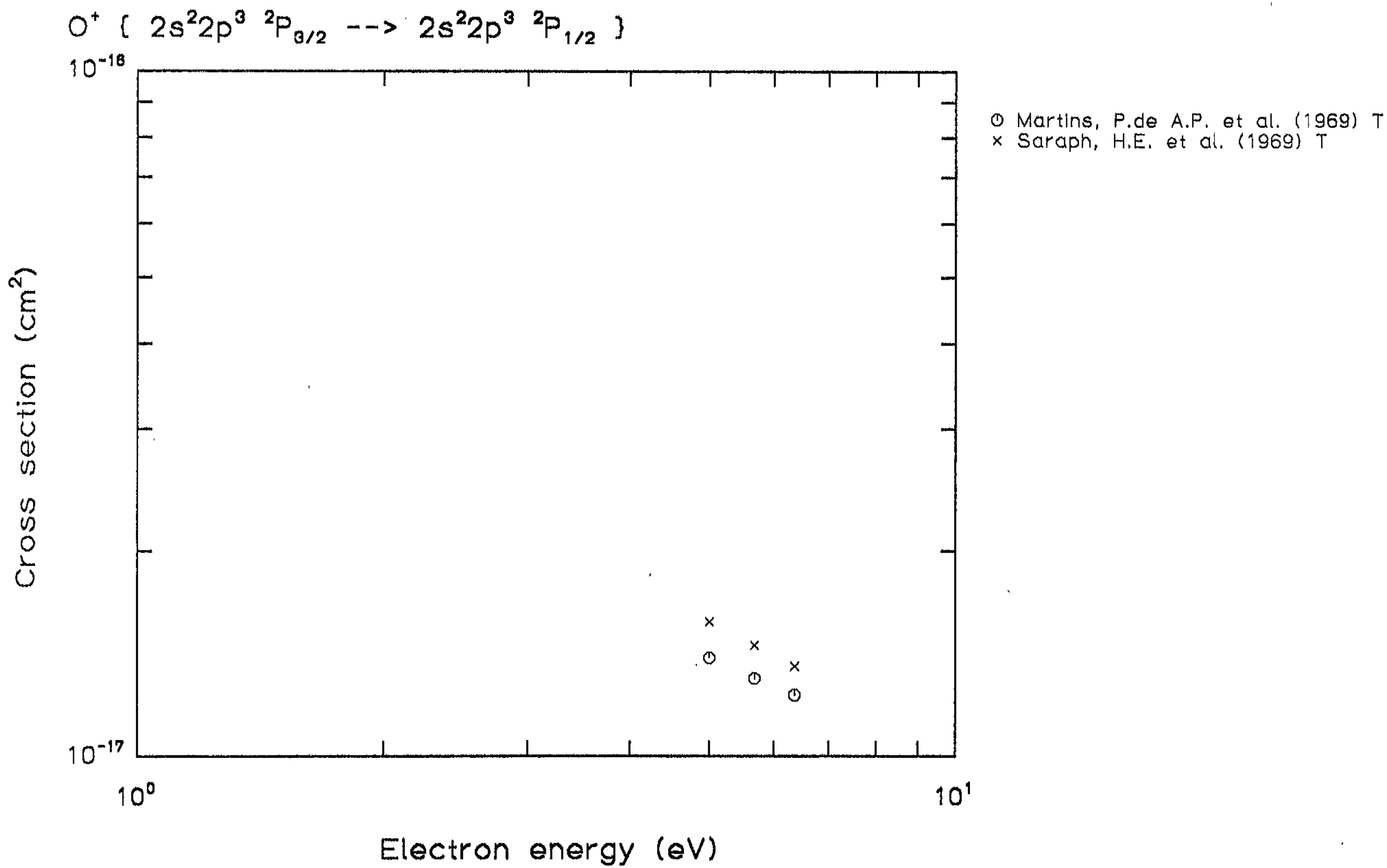

O+ { 2s²2p³ ²D5/2 --> 2s²2p³ ²D3/2 }
Cross section (cm²)
10-15
10-16
10-17
10⁰
10¹
Electron energy (eV)
Martins, P.de A.P. et al. (1969) T
Saraph, H.E. et al. (1969) T
Pradhan, A.K. (1976) T



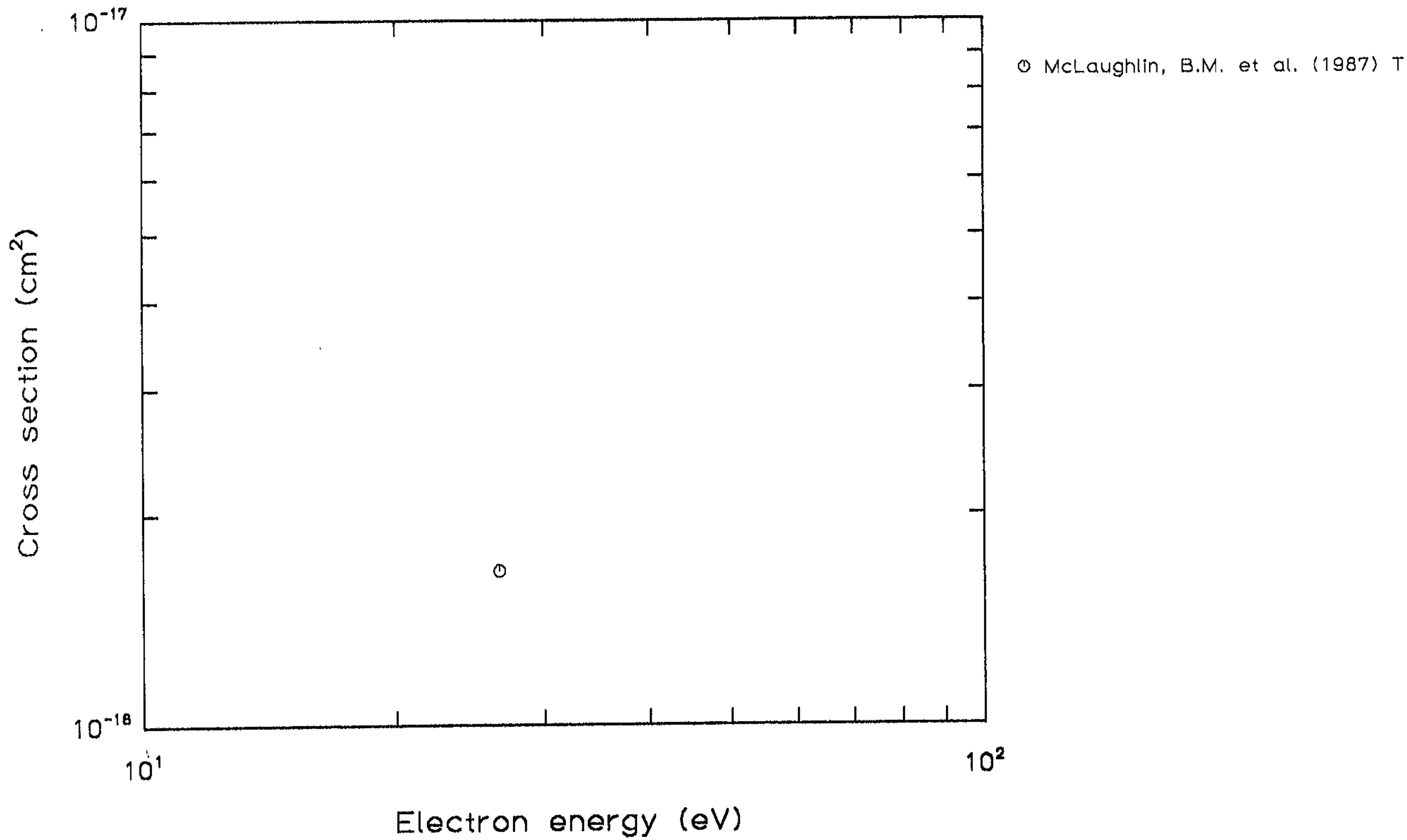
Cross section (cm²)
10⁻¹⁵
10⁻¹⁶
10⁻¹⁷
10⁰
10¹
10²
Electron energy (eV)
O⁺ { 2s²2p³ ²D --> 2s²2p³ ²P }
Henry, Ronald J.Y. et al. (1969) T
Saraph, H.E. et al. (1969) T
Pradhan, A.K. (1976) T
O⁺ { 2s²2p³ ²D3/2 --> 2s²2p³ ²P1/2 }
Martins, P.de A.P. et al. (1969) T
Saraph, H.E. et al. (1969) T
O⁺ { 2s²2p³ ²D3/2 --> 2s²2p³ ²P3/2 }
Martins, P.de A.P. et al. (1969) T
Saraph, H.E. et al. (1969) T
O⁺ { 2s²2p³ ²D5/2 --> 2s²2p³ ²P1/2 }
Martins, P.de A.P. et al. (1969) T
Saraph, H.E. et al. (1969) T
O⁺ { 2s²2p³ ²D5/2 --> 2s²2p³ ²P3/2 }
Martins, P.de A.P. et al. (1969) T
Saraph, H.E. et al. (1969) T

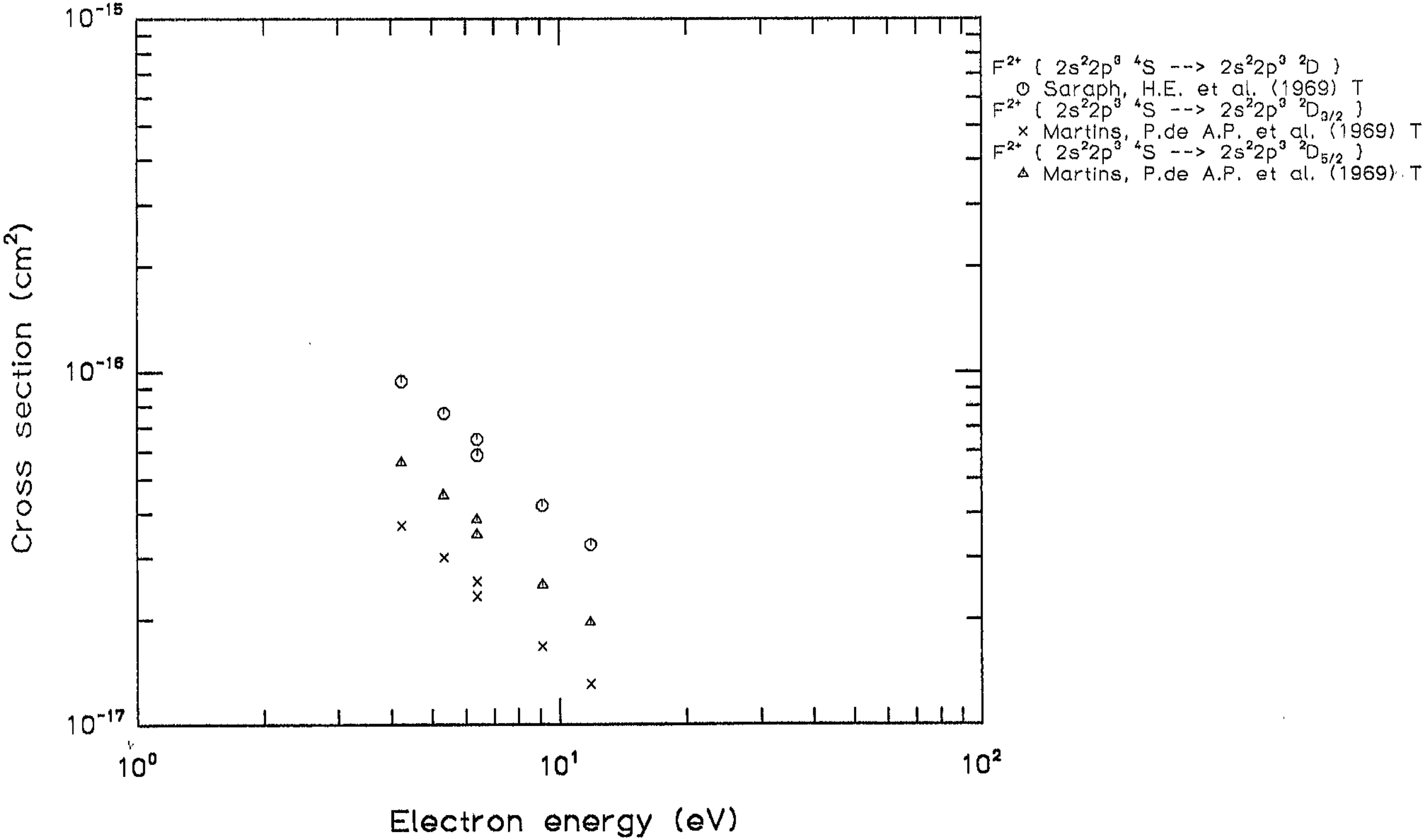


Cross section (cm²)
10⁻¹⁸
10⁻¹⁷
O⁺ { 2s²2p³ ²D --> 2s²2p²3s ²P }
10¹
10²
Electron energy (eV)
⊖ McLaughlin, B.M. et al. (1987) T

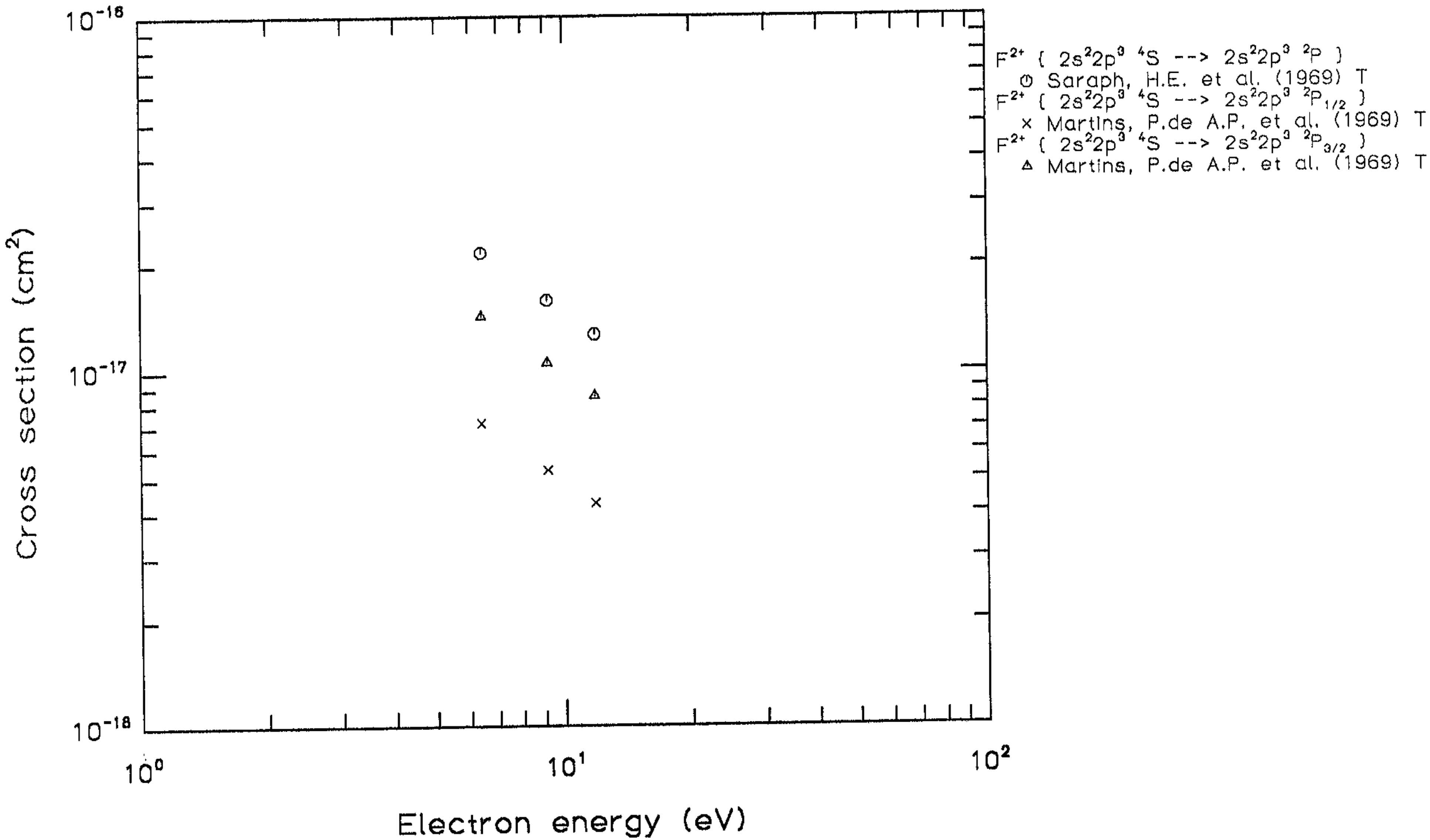

O^+ { $2s^22p^3\ ^2P_{3/2}$ --> $2s^22p^3\ ^2P_{1/2}$ }
10^{-16}
10^{-17}
Cross section (cm^2)
10^0
10^1
Electron energy (eV)
Θ Martins, P.de A.P. et al. (1969) T
× Saraph, H.E. et al. (1969) T

$O^+ \{ 2s^2 2p^3\ ^2P \rightarrow 2s^2 2p^2 3s\ ^2P \}$

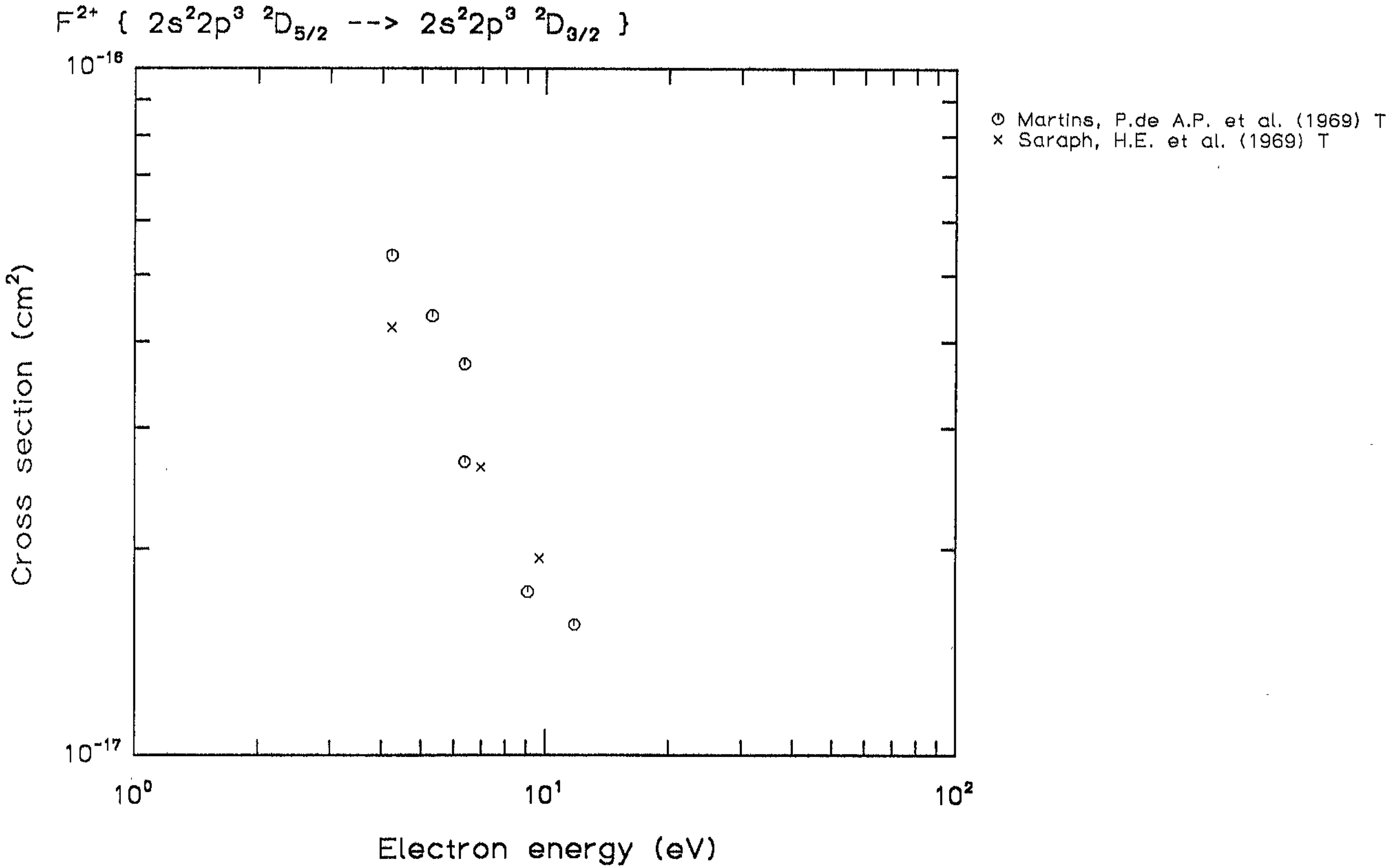


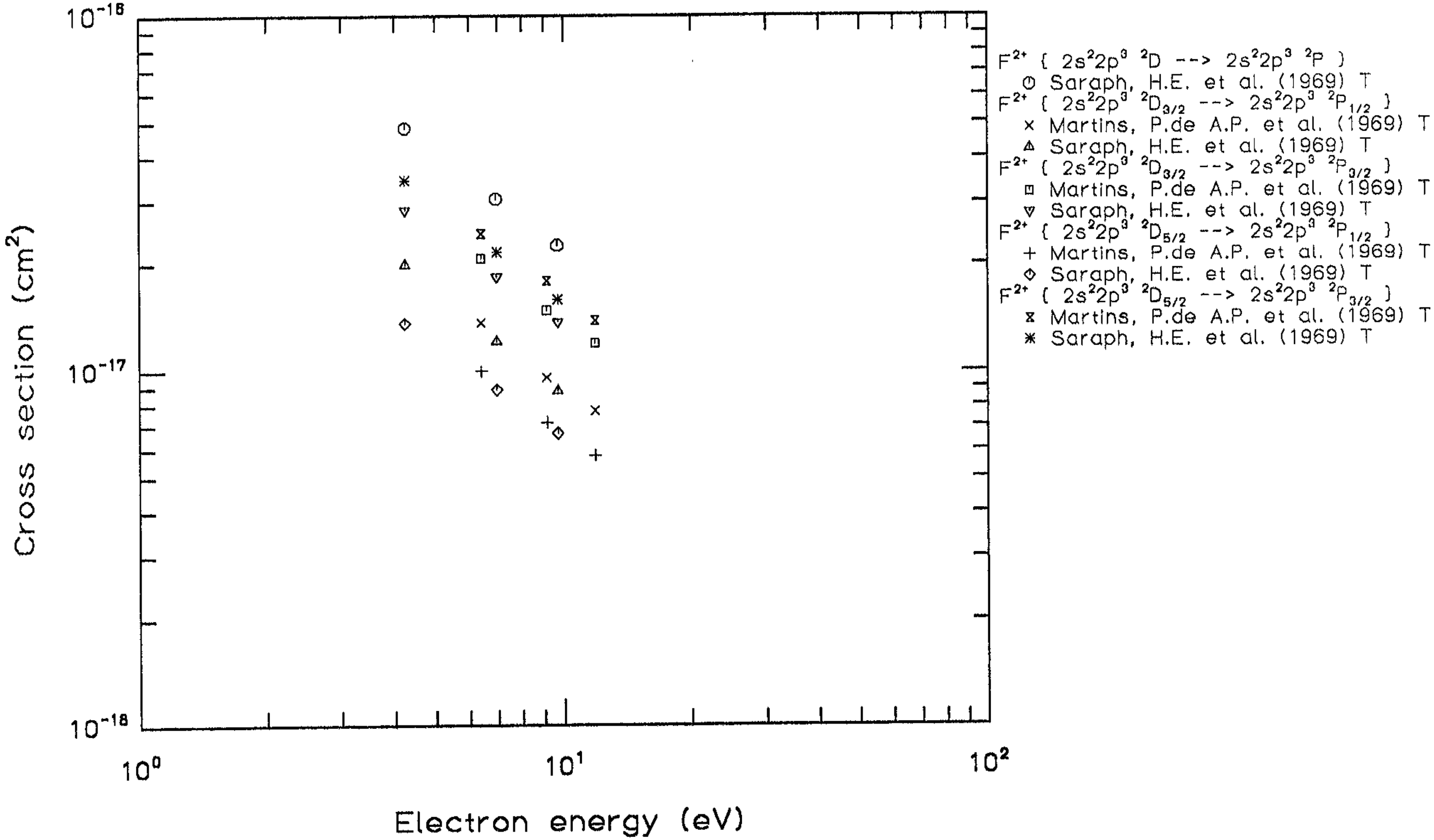


Cross section (cm2)
10-15
10-16
10-17
10^0
10^1
10^2
Electron energy (eV)
F2+ (2s22p3 4S --> 2s22p3 2D)
Θ Saraph, H.E. et al. (1969) T
F2+ (2s22p3 4S --> 2s22p3 2D3/2)
× Martins, P.de A.P. et al. (1969) T
F2+ (2s22p3 4S --> 2s22p3 2D5/2)
Δ Martins, P.de A.P. et al. (1969) T

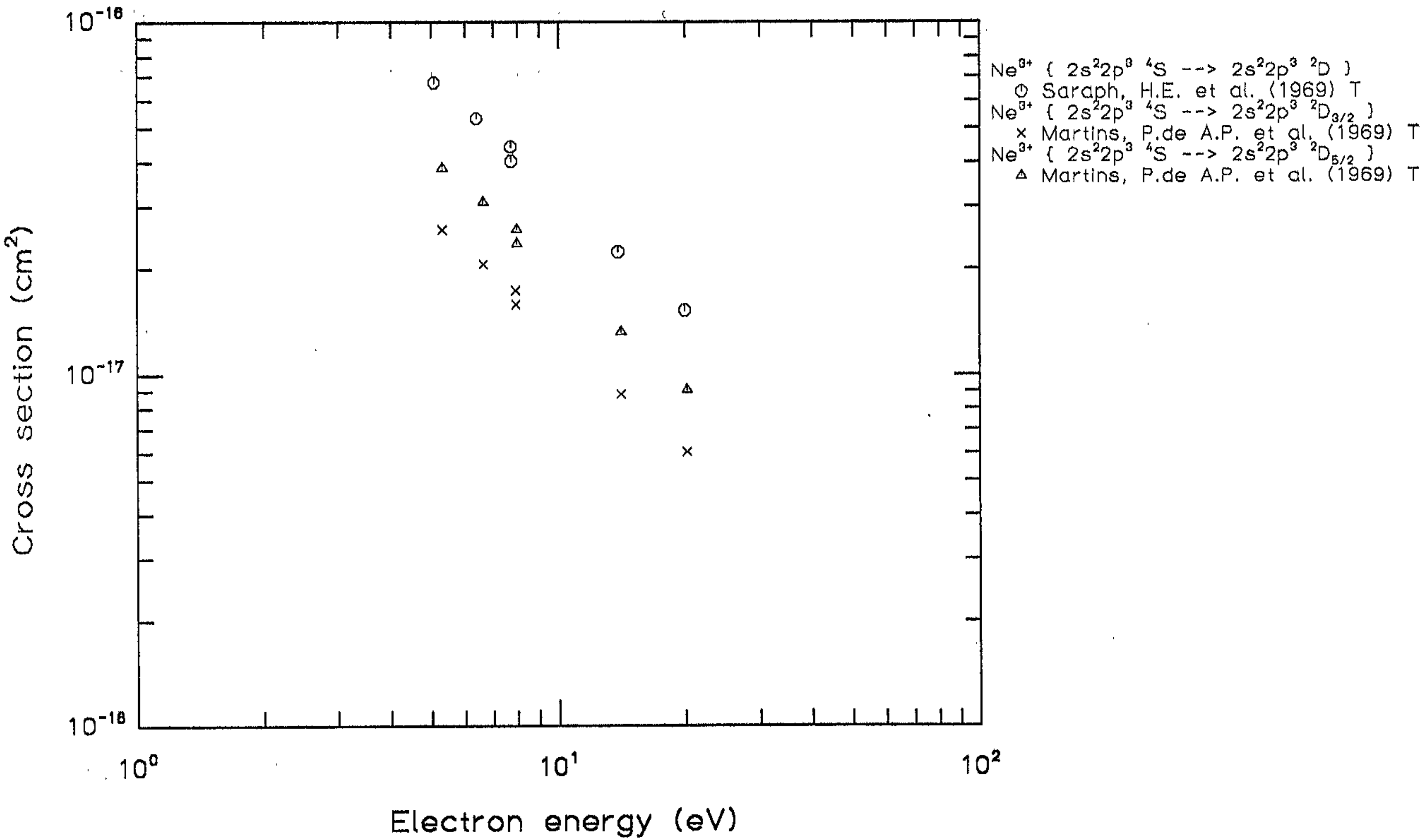


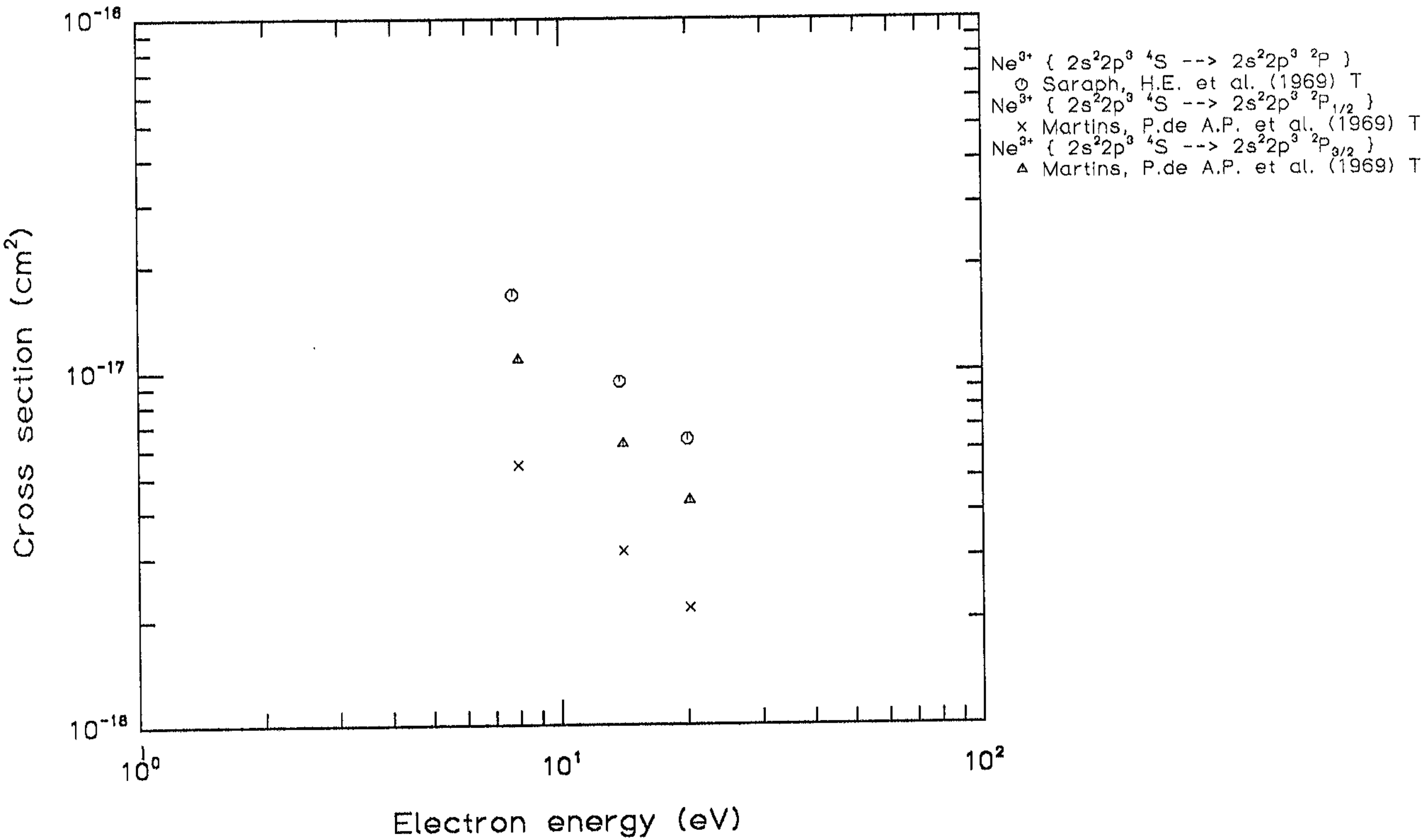
10^{-16}
10^{-17}
10^{-18}
Cross section (cm^2)
10^0
10^1
10^2
Electron energy (eV)
F^{2+} ($2s^22p^3$ ^4S --> $2s^22p^3$ ^2P)
⊖ Saraph, H.E. et al. (1969) T
F^{2+} ($2s^22p^3$ ^4S --> $2s^22p^3$ $^2P_{1/2}$)
× Martins, P.de A.P. et al. (1969) T
F^{2+} ($2s^22p^3$ ^4S --> $2s^22p^3$ $^2P_{3/2}$)
△ Martins, P.de A.P. et al. (1969) T

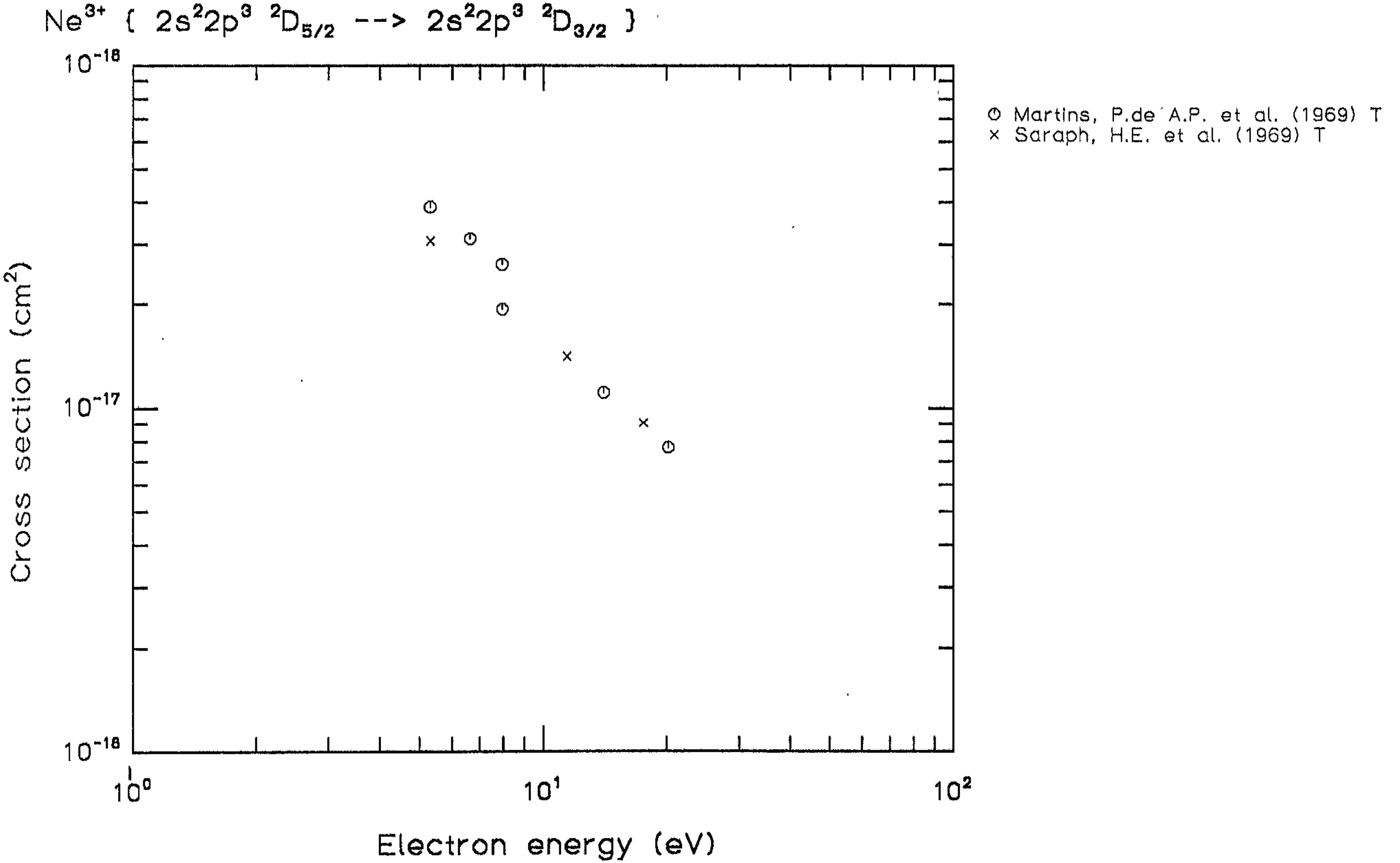

F^{2+} { $2s^22p^3\ ^2D_{5/2}$ --> $2s^22p^3\ ^2D_{3/2}$ }
Cross section (cm^2)
10^{-16}
10^{-17}
10^0
10^1
10^2
Electron energy (eV)
Martins, P.de A.P. et al. (1969) T
× Saraph, H.E. et al. (1969) T



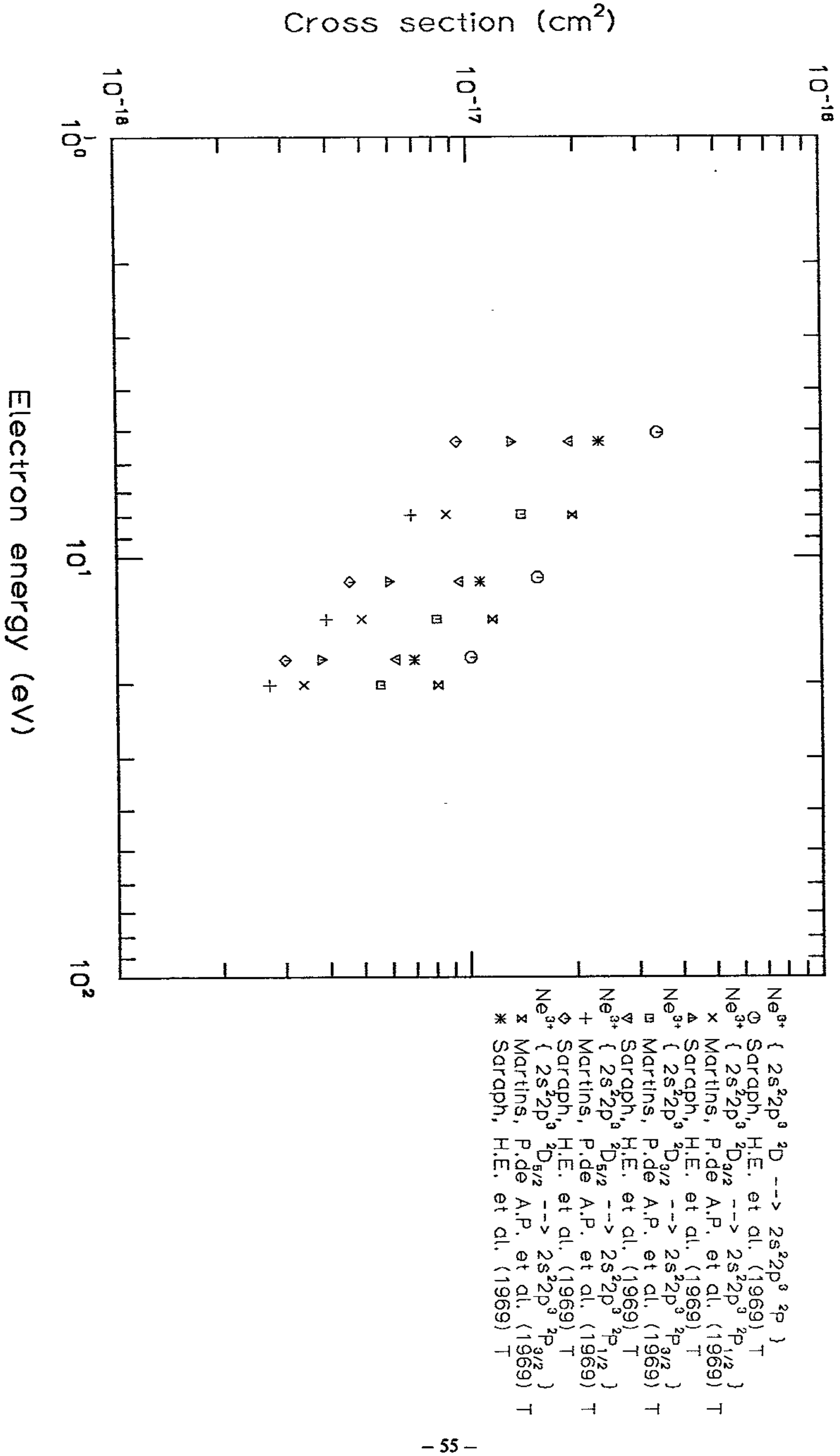
Cross section (cm2)
10-16
10-17
10-18
10^0
10^1
10^2
Electron energy (eV)
F2+ { 2s22p3 2D --> 2s22p3 2P }
Saraph, H.E. et al. (1969) T
F2+ { 2s22p3 2D3/2 --> 2s22p3 2P1/2 }
Martins, P.de A.P. et al. (1969) T
Saraph, H.E. et al. (1969) T
F2+ { 2s22p3 2D3/2 --> 2s22p3 2P3/2 }
Martins, P.de A.P. et al. (1969) T
Saraph, H.E. et al. (1969) T
F2+ { 2s22p3 2D5/2 --> 2s22p3 2P1/2 }
Martins, P.de A.P. et al. (1969) T
Saraph, H.E. et al. (1969) T
F2+ { 2s22p3 2D5/2 --> 2s22p3 2P3/2 }
Martins, P.de A.P. et al. (1969) T
Saraph, H.E. et al. (1969) T

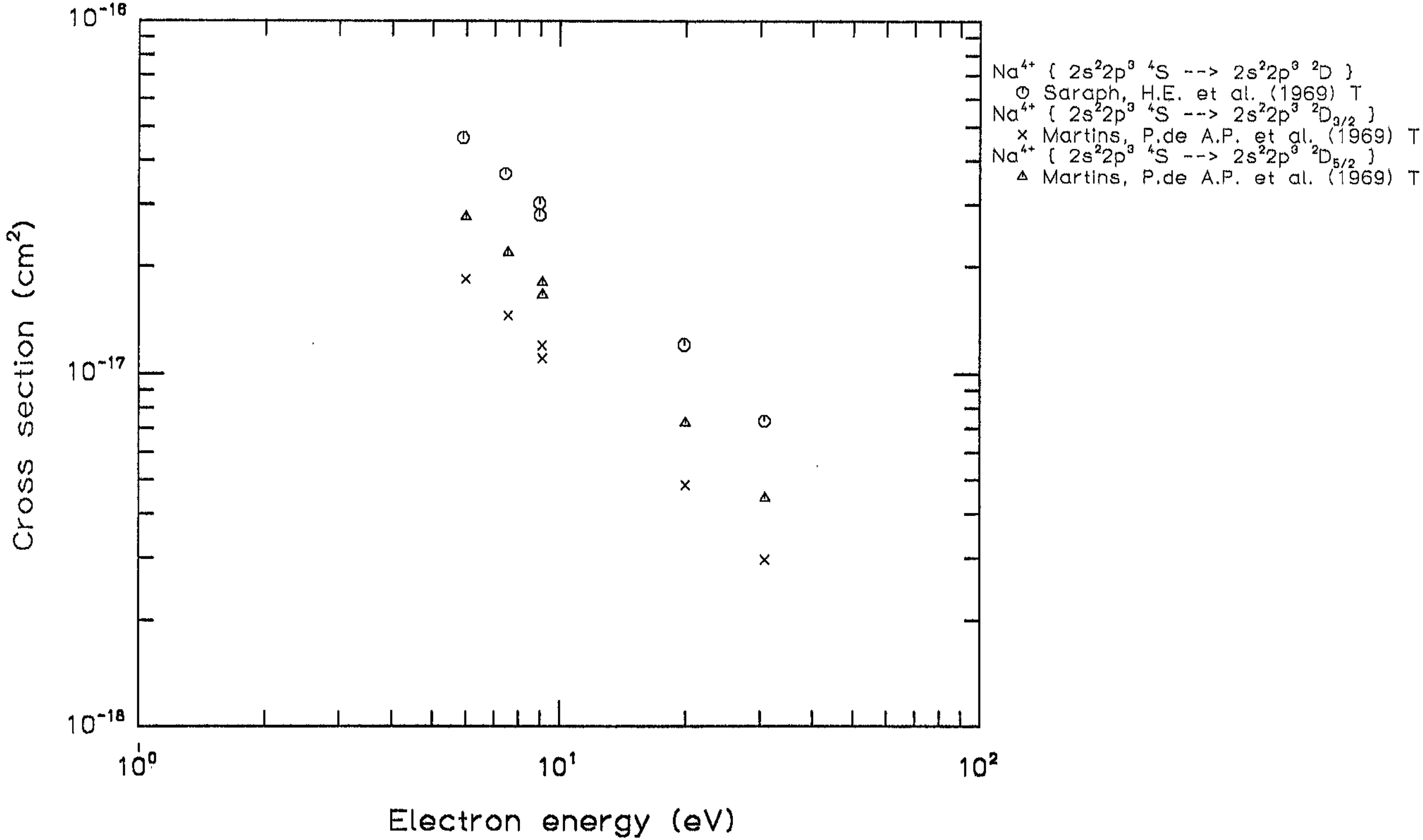

Cross section (cm²)
Electron energy (eV)
10⁻¹⁶
10⁻¹⁷
10⁻¹⁸
10⁰
10¹
10²
Ne³⁺ { 2s²2p³ ⁴S --> 2s²2p³ ²D }
Saraph, H.E. et al. (1969) T
Ne³⁺ { 2s²2p³ ⁴S --> 2s²2p³ ²D3/2 }
× Martins, P.de A.P. et al. (1969) T
Ne³⁺ { 2s²2p³ ⁴S --> 2s²2p³ ²D5/2 }
Δ Martins, P.de A.P. et al. (1969) T


Cross section (cm²)
10^{-16}
10^{-17}
10^{-18}
10^{0}
10^{1}
10^{2}
Electron energy (eV)
Ne^{3+} { $2s^22p^3\ ^4S$ --> $2s^22p^3\ ^2P$ }
⊖ Saraph, H.E. et al. (1969) T
Ne^{3+} { $2s^22p^3\ ^4S$ --> $2s^22p^3\ ^2P_{1/2}$ }
× Martins, P.de A.P. et al. (1969) T
Ne^{3+} { $2s^22p^3\ ^4S$ --> $2s^22p^3\ ^2P_{3/2}$ }
△ Martins, P.de A.P. et al. (1969) T

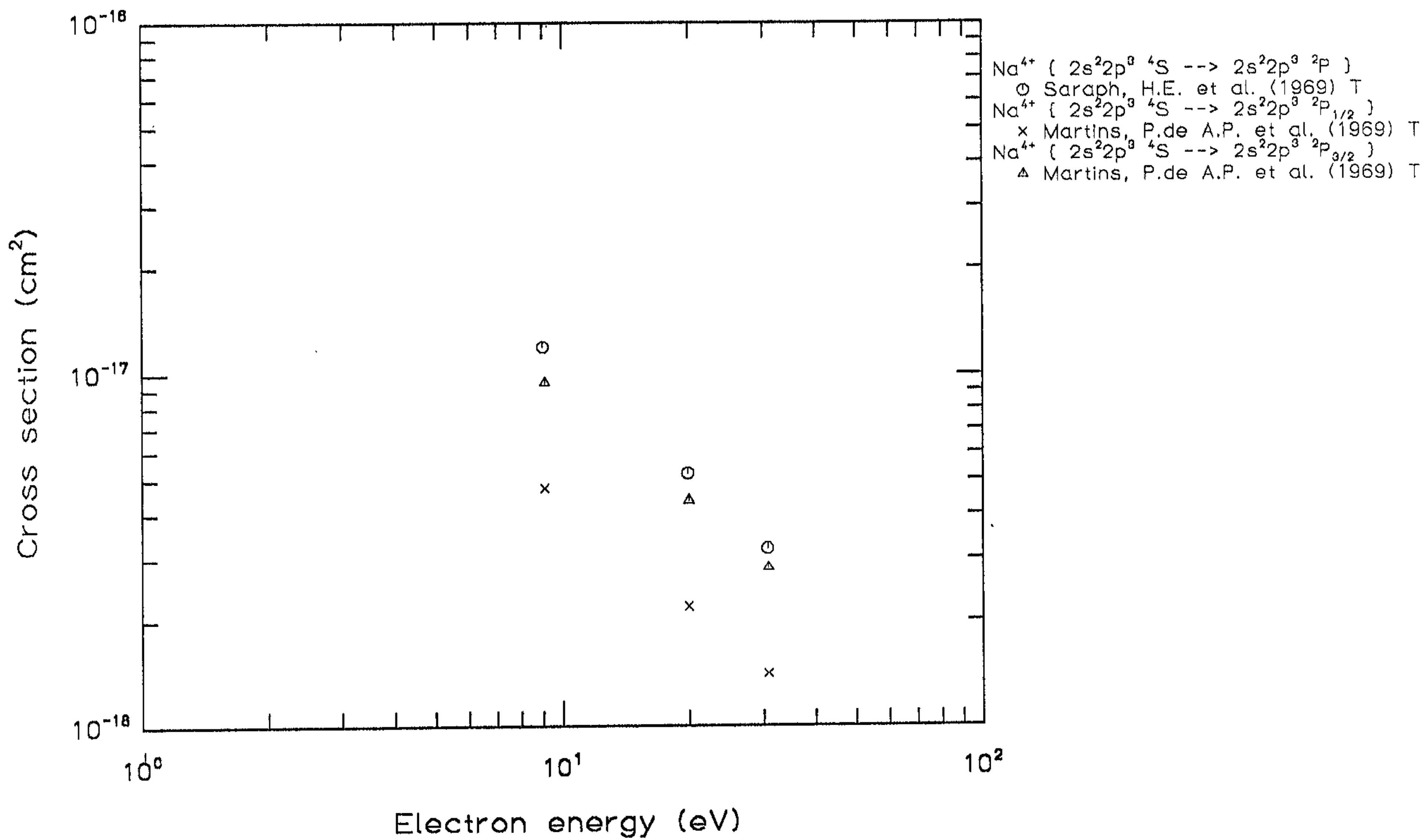


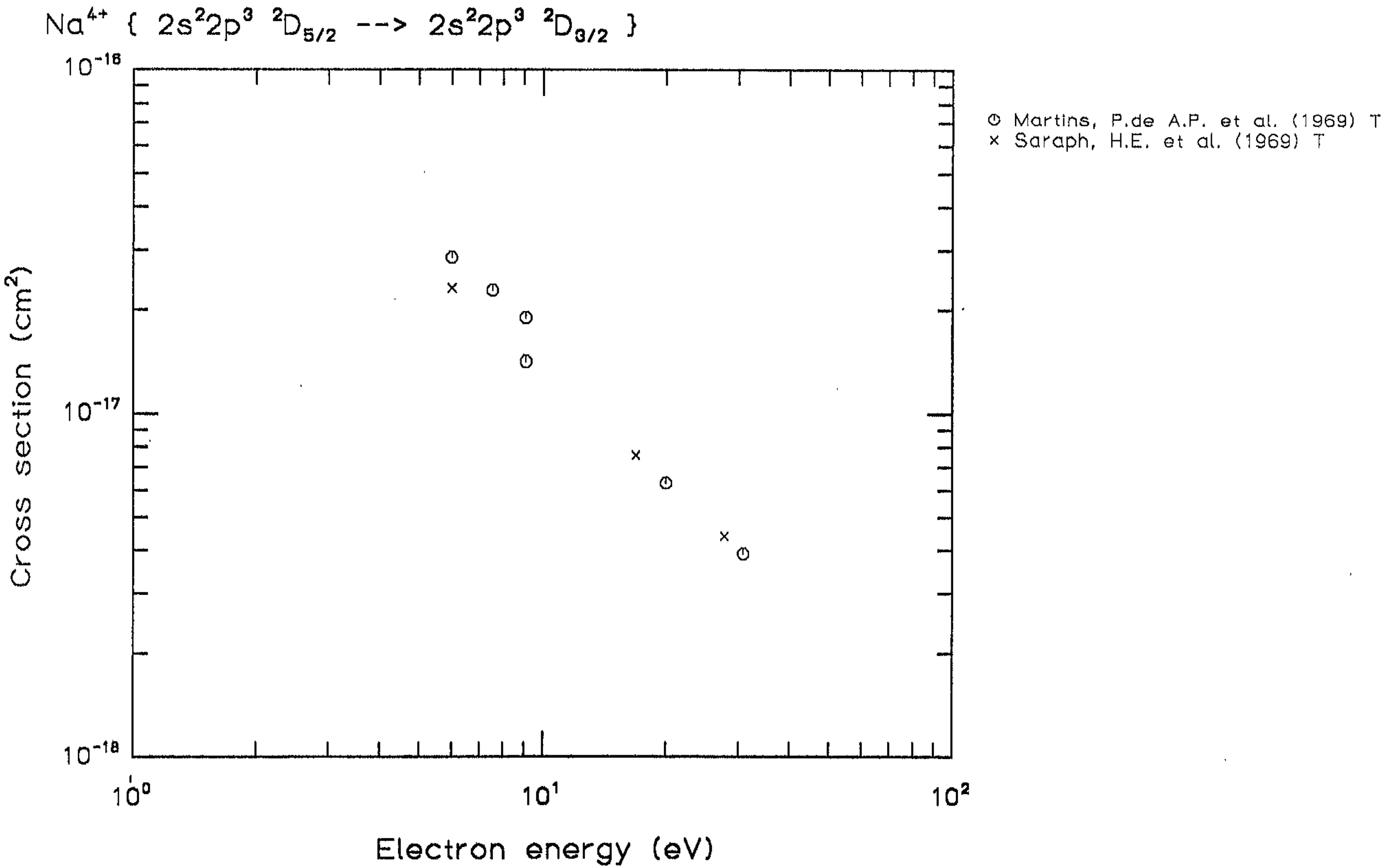
Ne3+ { 2s22p3 2D5/2 --> 2s22p3 2D3/2 }
Cross section (cm2)
10-16
10-17
10-18
100
101
102
Electron energy (eV)
Θ Martins, P.de´A.P. et al. (1969) T
× Saraph, H.E. et al. (1969) T


Cross section (cm^2)
10^{-18}
10^{-17}
10^{-16}
10^0
10^1
10^2
Electron energy (eV)
Ne^{3+} { $2s^22p^3$ ^2D --> $2s^22p^3$ ^2P }
Θ Saraph, H.E. et al. (1969) T
Ne^{3+} { $2s^22p^3$ $^2D_{3/2}$ --> $2s^22p^3$ $^2P_{1/2}$ }
× Martins, P.de A.P. et al. (1969) T
△ Saraph, H.E. et al. (1969) T
Ne^{3+} { $2s^22p^3$ $^2D_{3/2}$ --> $2s^22p^3$ $^2P_{3/2}$ }
⊡ Martins, P.de A.P. et al. (1969) T
▽ Saraph, H.E. et al. (1969) T
Ne^{3+} { $2s^22p^3$ $^2D_{5/2}$ --> $2s^22p^3$ $^2P_{1/2}$ }
+ Martins, P.de A.P. et al. (1969) T
◇ Saraph, H.E. et al. (1969) T
Ne^{3+} { $2s^22p^3$ $^2D_{5/2}$ --> $2s^22p^3$ $^2P_{3/2}$ }
⧖ Martins, P.de A.P. et al. (1969) T
* Saraph, H.E. et al. (1969) T

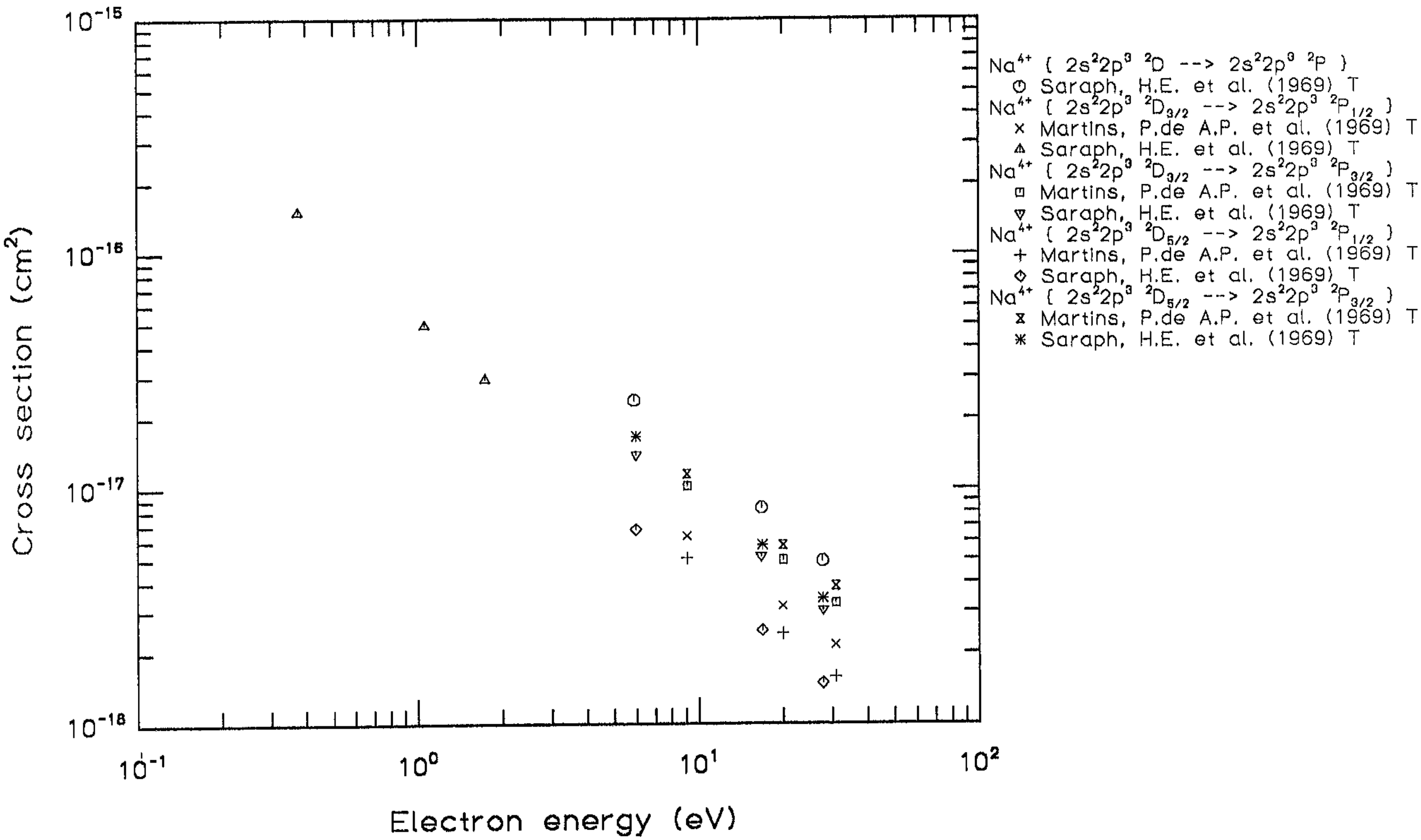


Cross section (cm²)
10⁻¹⁶
10⁻¹⁷
10⁻¹⁸
10⁰
10¹
10²
Electron energy (eV)
Na⁴⁺ { 2s²2p³ ⁴S --> 2s²2p³ ²D }
Saraph, H.E. et al. (1969) T
Na⁴⁺ { 2s²2p³ ⁴S --> 2s²2p³ ²D3/2 }
Martins, P.de A.P. et al. (1969) T
Na⁴⁺ { 2s²2p³ ⁴S --> 2s²2p³ ²D5/2 }
Martins, P.de A.P. et al. (1969) T


Cross section (cm²)
10⁻¹⁶
10⁻¹⁷
10⁻¹⁸
10⁰
10¹
10²
Electron energy (eV)
Na⁴⁺ (2s²2p³ ⁴S --> 2s²2p³ ²P)
Θ Saraph, H.E. et al. (1969) T
Na⁴⁺ (2s²2p³ ⁴S --> 2s²2p³ ²P1/2)
× Martins, P.de A.P. et al. (1969) T
Na⁴⁺ (2s²2p³ ⁴S --> 2s²2p³ ²P3/2)
Δ Martins, P.de A.P. et al. (1969) T

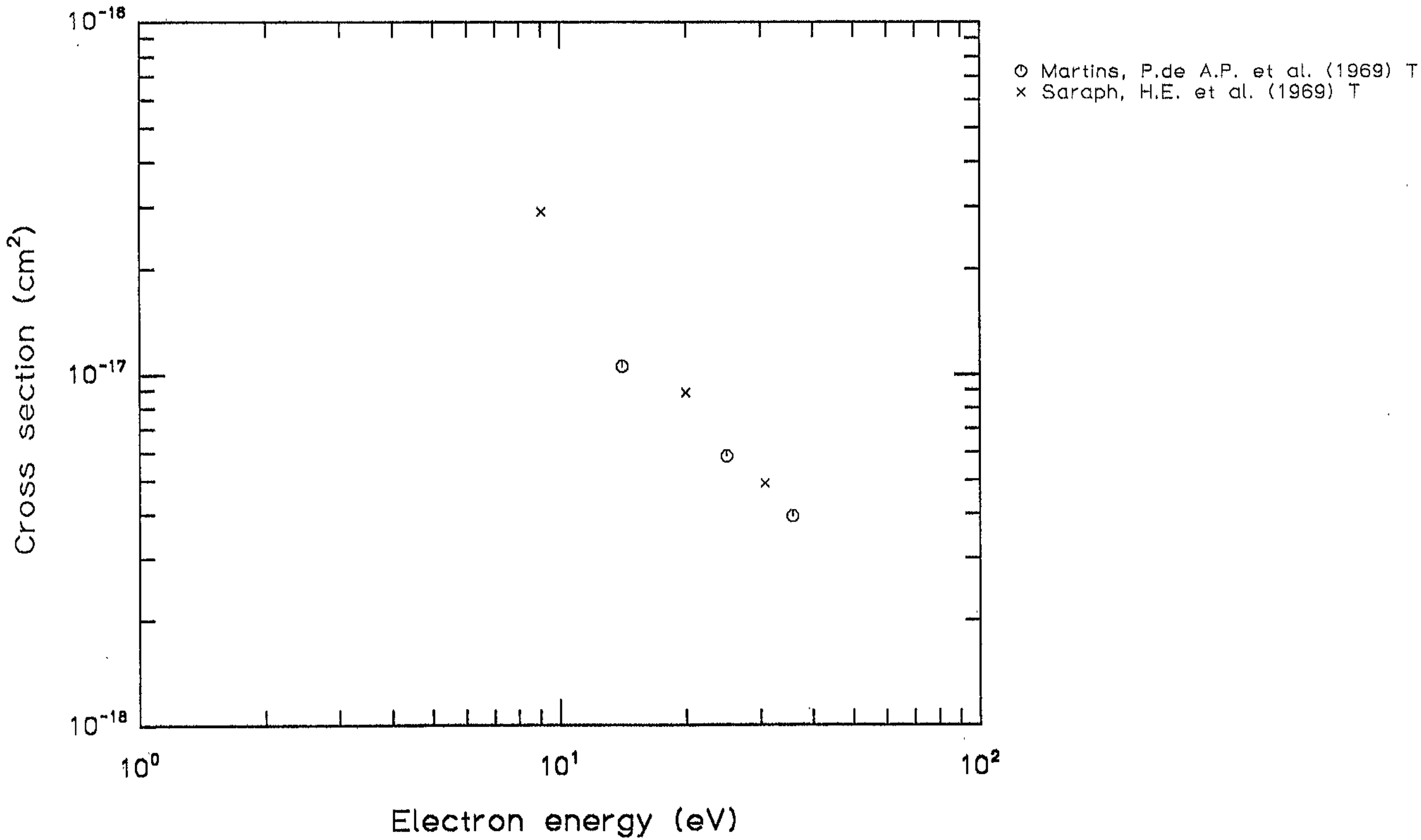


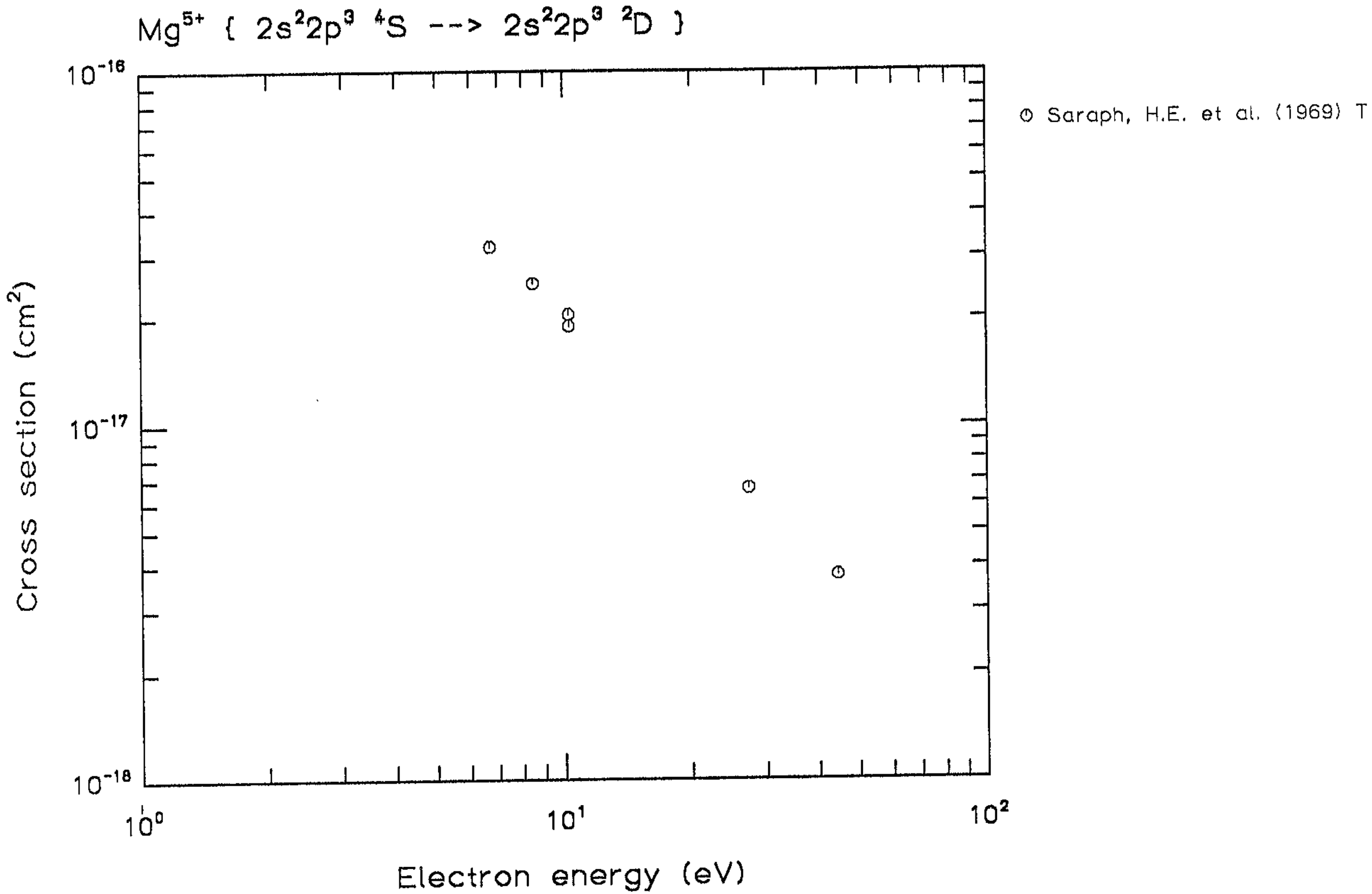
Na4+ { 2s22p3 2D5/2 --> 2s22p3 2D3/2 }
10-16
10-17
10-18
Cross section (cm2)
100
101
102
Electron energy (eV)
Θ Martins, P.de A.P. et al. (1969) T
× Saraph, H.E. et al. (1969) T



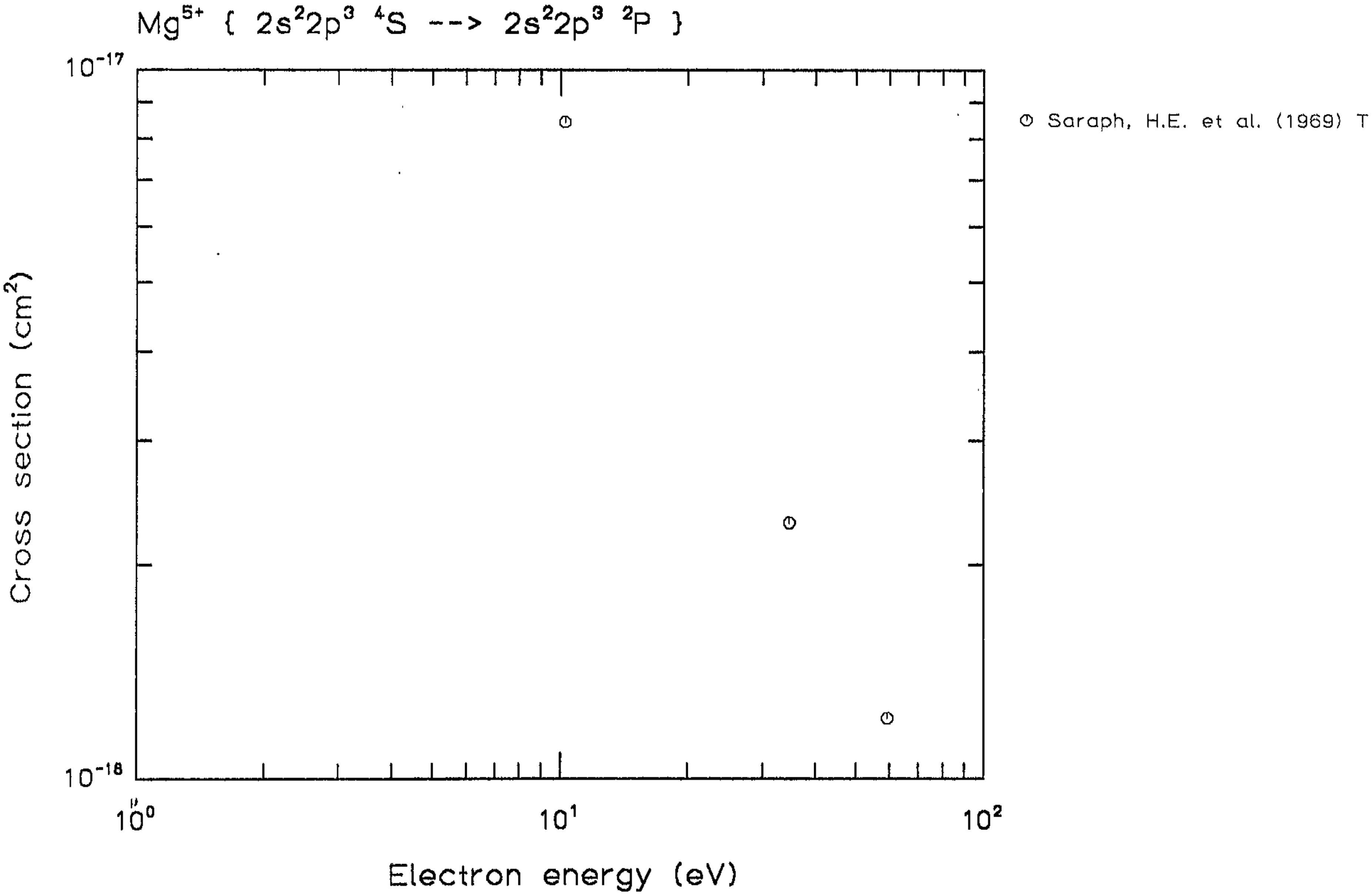
Cross section (cm^2)
10^{-15}
10^{-16}
10^{-17}
10^{-18}
10^{-1}
10^{0}
10^{1}
10^{2}
Electron energy (eV)
Na^{4+} { $2s^22p^3$ ^2D --> $2s^22p^3$ ^2P }
Saraph, H.E. et al. (1969) T
Na^{4+} { $2s^22p^3$ $^2D_{3/2}$ --> $2s^22p^3$ $^2P_{1/2}$ }
Martins, P.de A.P. et al. (1969) T
Saraph, H.E. et al. (1969) T
Na^{4+} { $2s^22p^3$ $^2D_{3/2}$ --> $2s^22p^3$ $^2P_{3/2}$ }
Martins, P.de A.P. et al. (1969) T
Saraph, H.E. et al. (1969) T
Na^{4+} { $2s^22p^3$ $^2D_{5/2}$ --> $2s^22p^3$ $^2P_{1/2}$ }
Martins, P.de A.P. et al. (1969) T
Saraph, H.E. et al. (1969) T
Na^{4+} { $2s^22p^3$ $^2D_{5/2}$ --> $2s^22p^3$ $^2P_{3/2}$ }
Martins, P.de A.P. et al. (1969) T
Saraph, H.E. et al. (1969) T

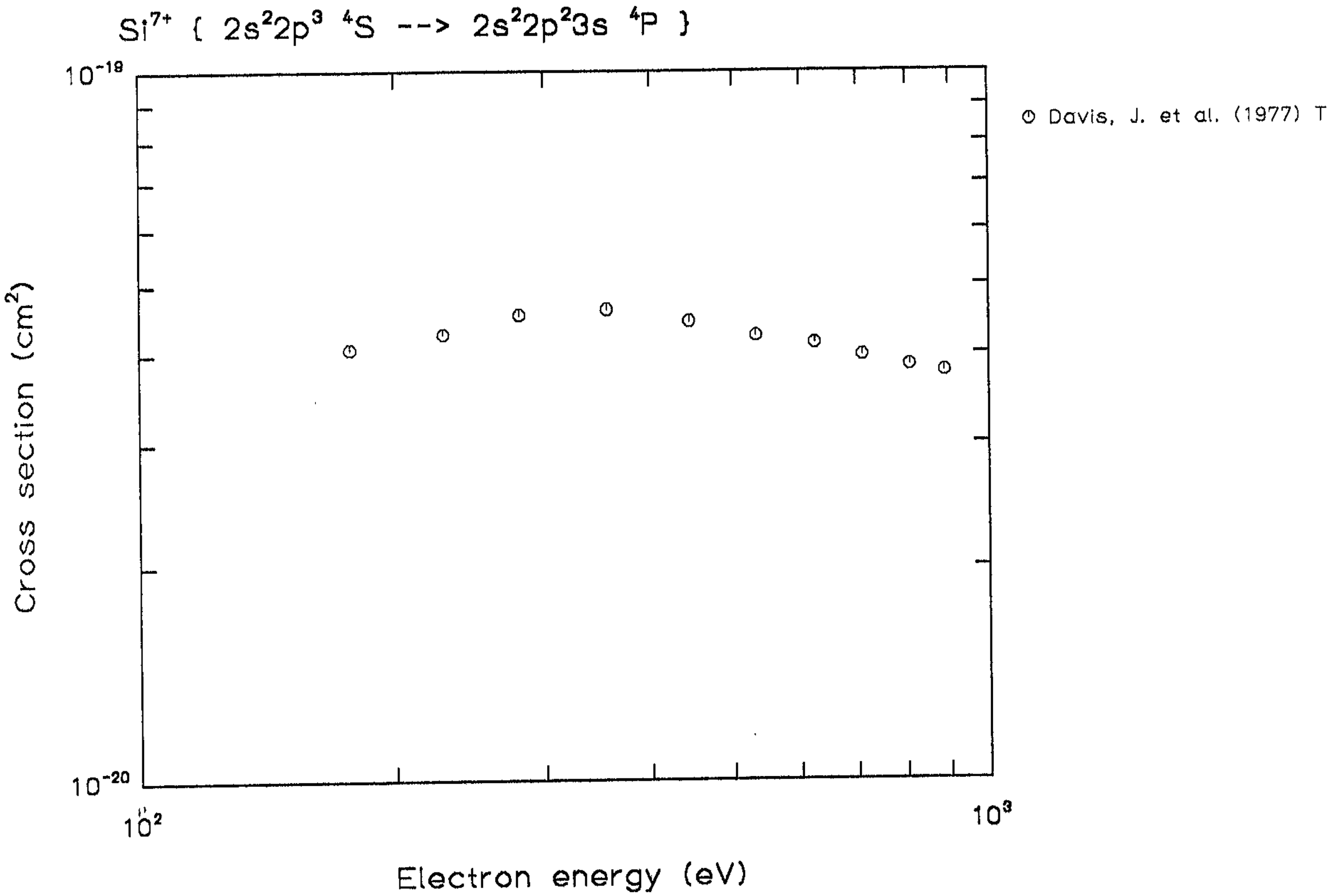
Na^{4+} { $2s^2 2p^3\ ^2P_{1/2}$ --> $2s^2 2p^3\ ^2P_{3/2}$ }





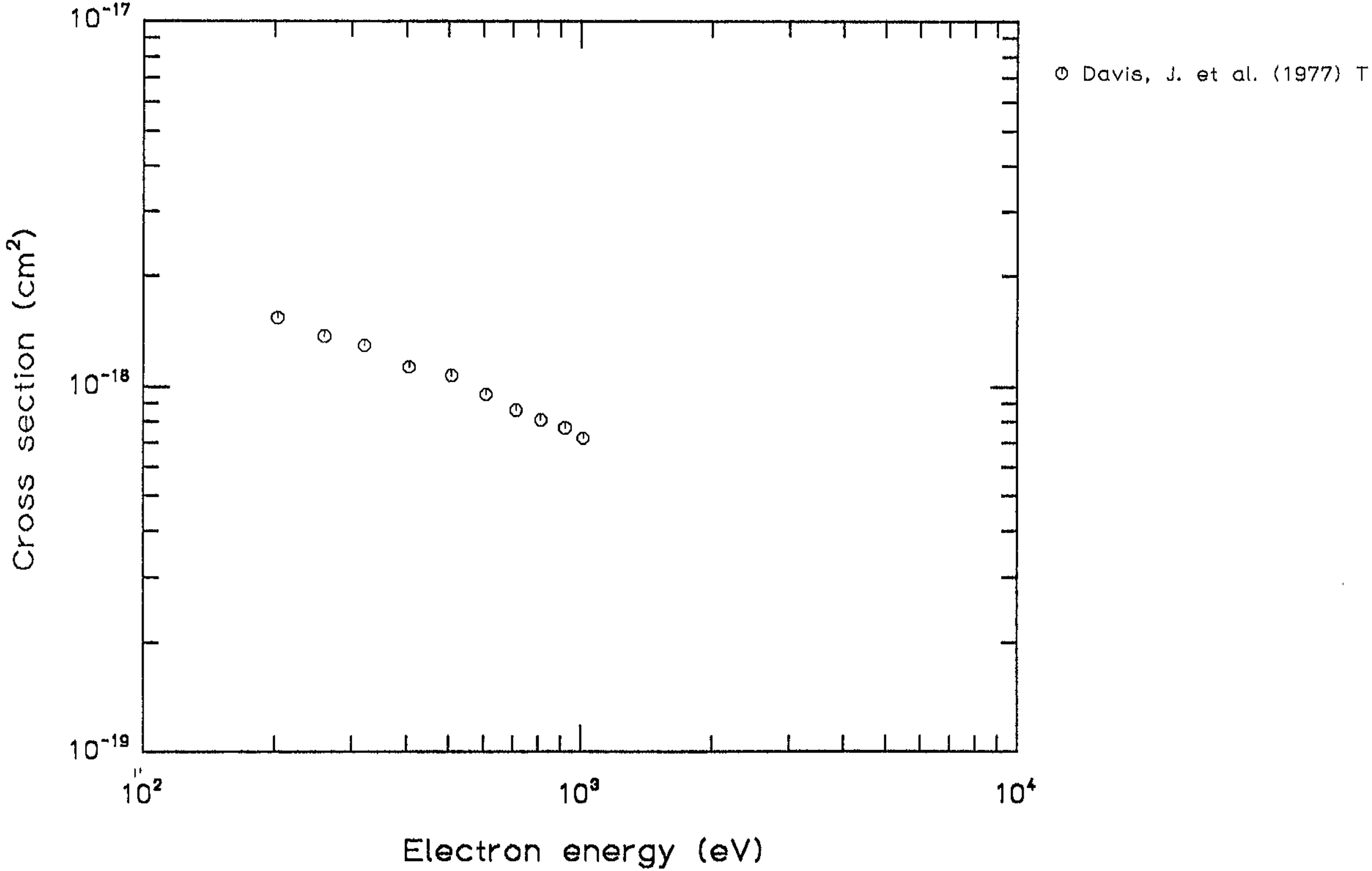
Mg5+ { 2s2 2p3 4S --> 2s2 2p3 2D }
10-16
10-17
10-18
Cross section (cm2)
100
101
102
Electron energy (eV)
Saraph, H.E. et al. (1969) T

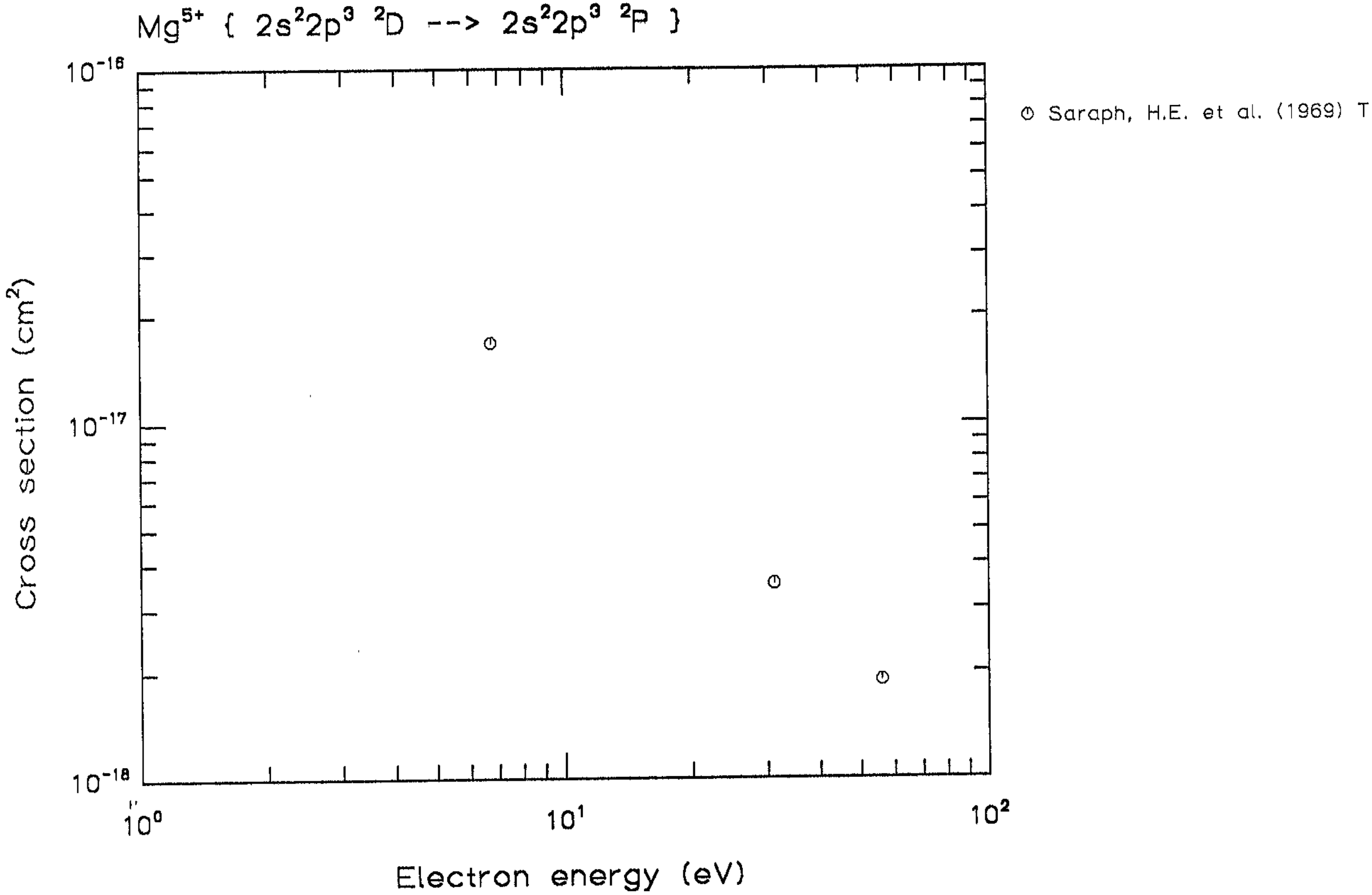

Mg5+ { 2s22p3 4S --> 2s22p3 2P }
10-17
10-18
Cross section (cm2)
100
101
102
Electron energy (eV)
Saraph, H.E. et al. (1969) T



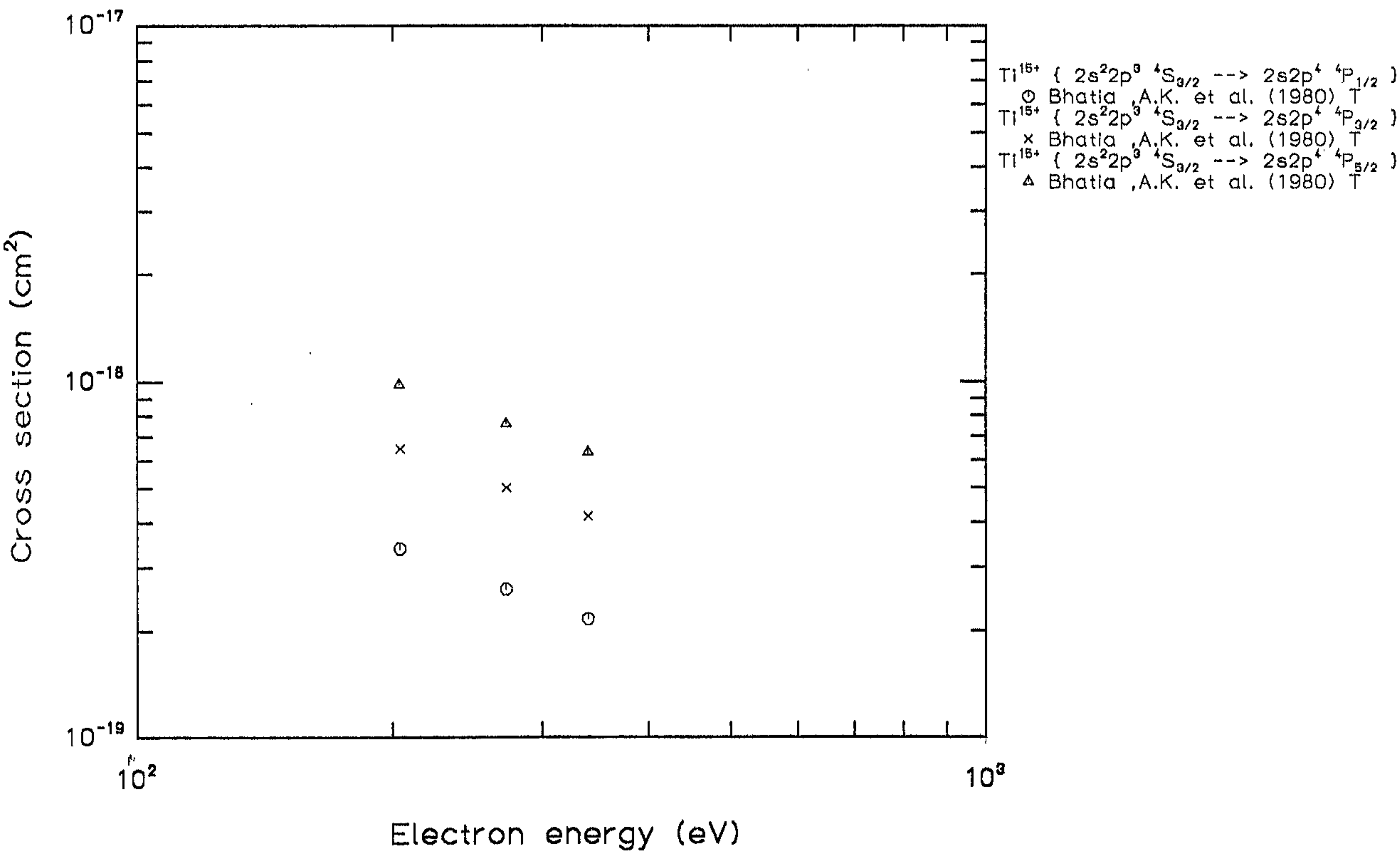
Si^{7+} { $2s^22p^3$ ^4S --> $2s^22p^23s$ ^4P }
10^{-19}
10^{-20}
Cross section (cm^2)
10^2
10^3
Electron energy (eV)
Davis, J. et al. (1977) T

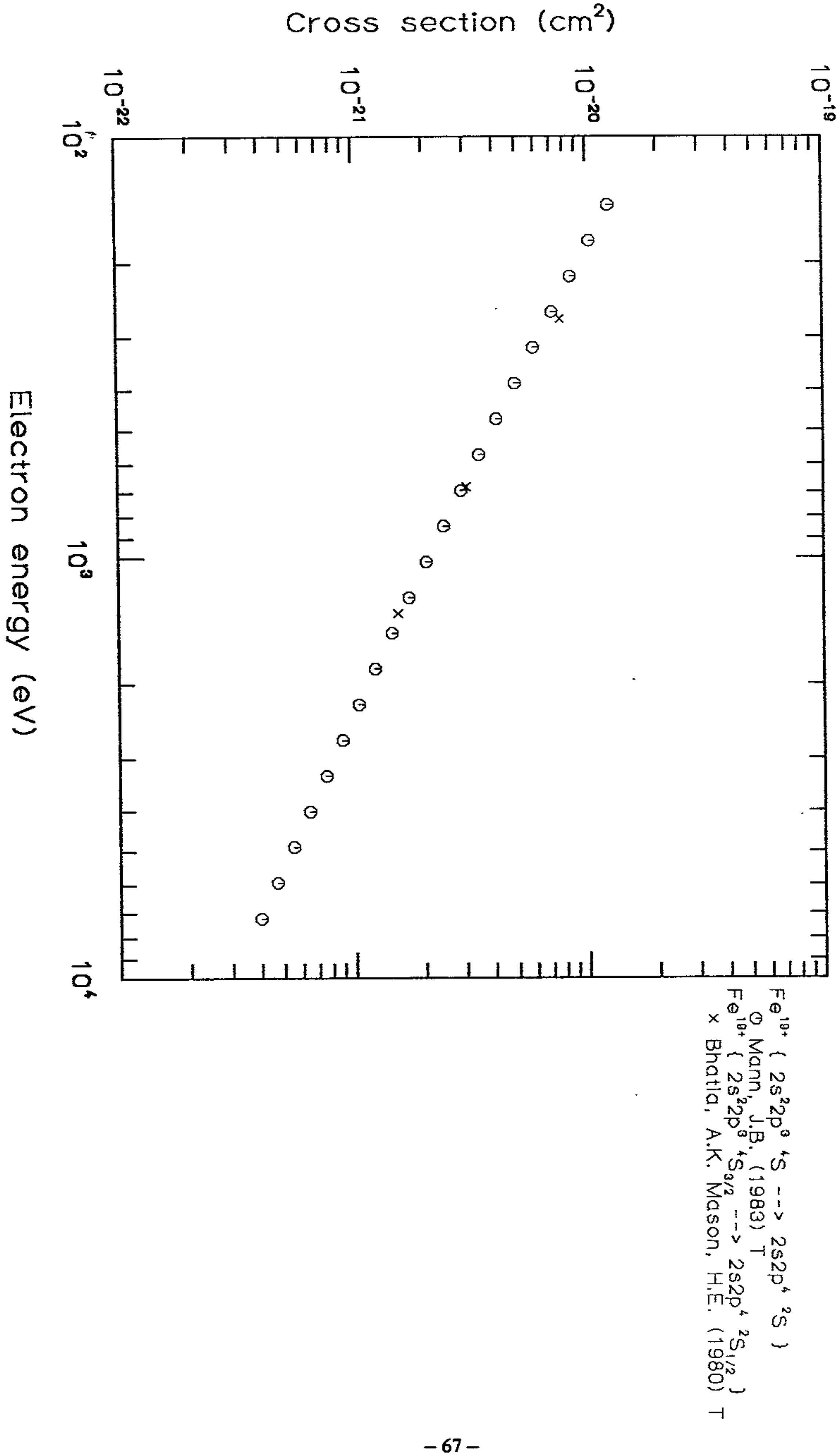
Si^{7+} { $2s^2 2p^3\ ^4S \rightarrow 2s^2 2p^2 3d\ ^4P$ }

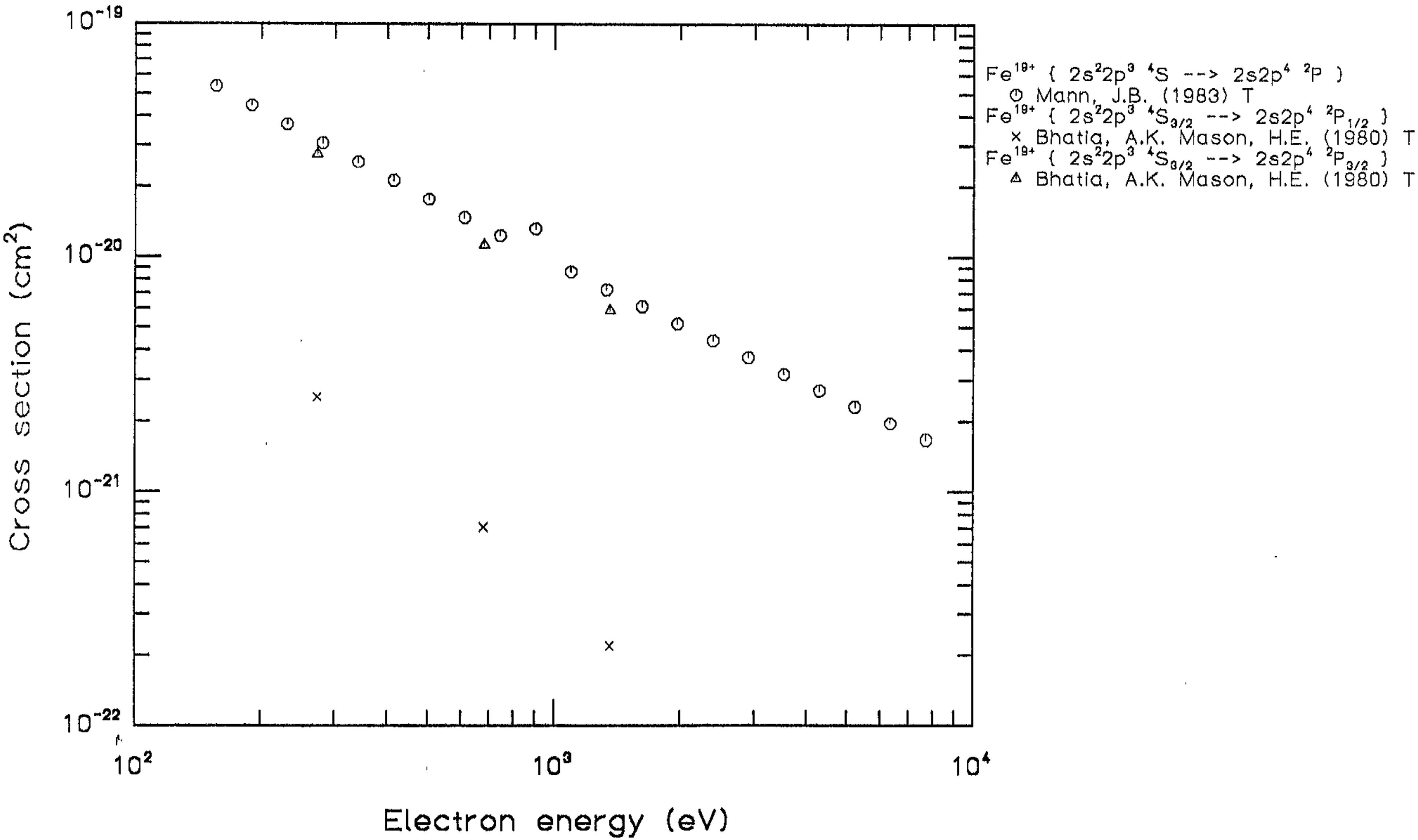


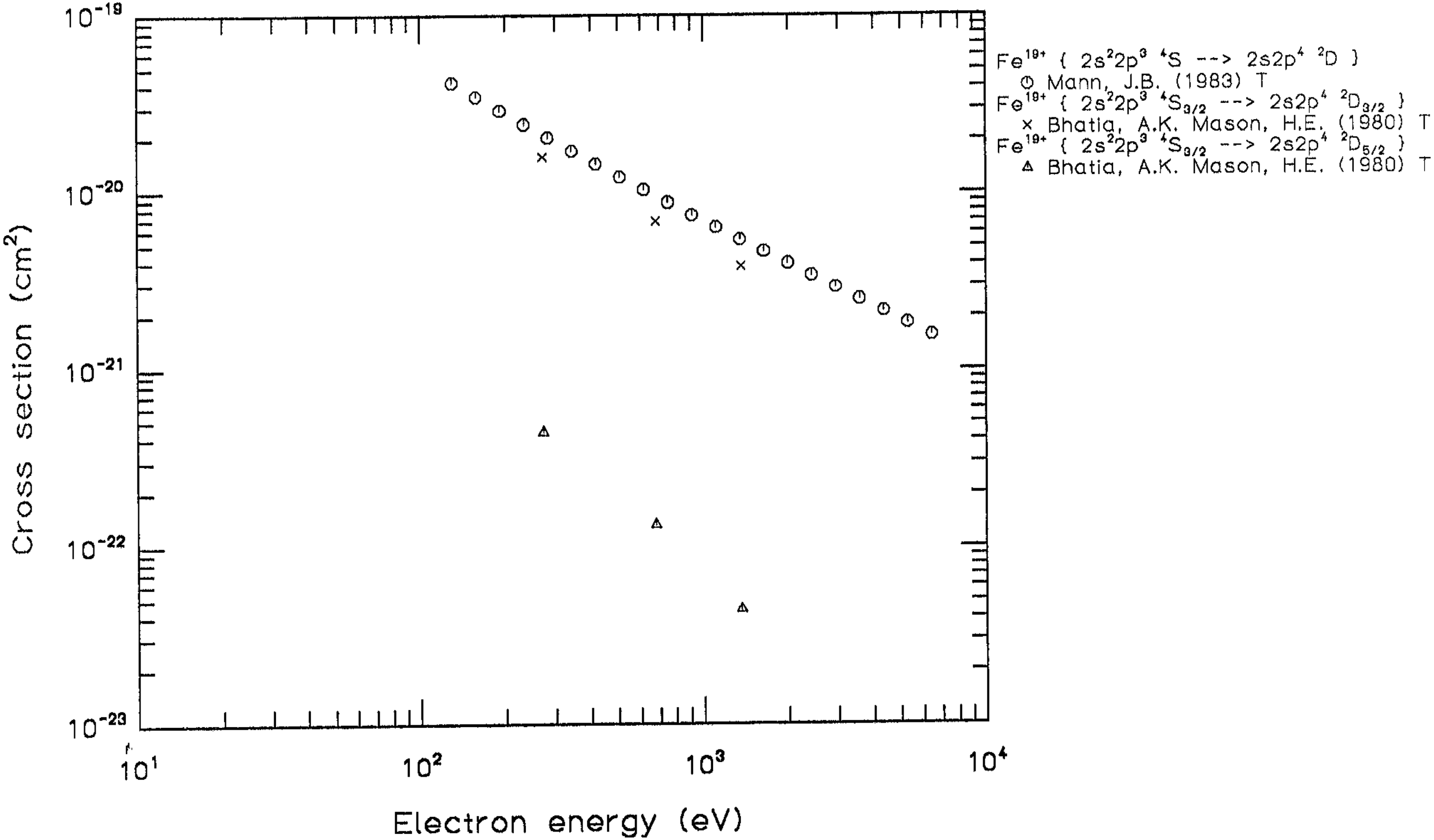


Mg^{5+} { $2s^22p^3\ ^2D$ --> $2s^22p^3\ ^2P$ }
10^{-16}
10^{-17}
10^{-18}
Cross section (cm^2)
10^0
10^1
10^2
Electron energy (eV)
Saraph, H.E. et al. (1969) T

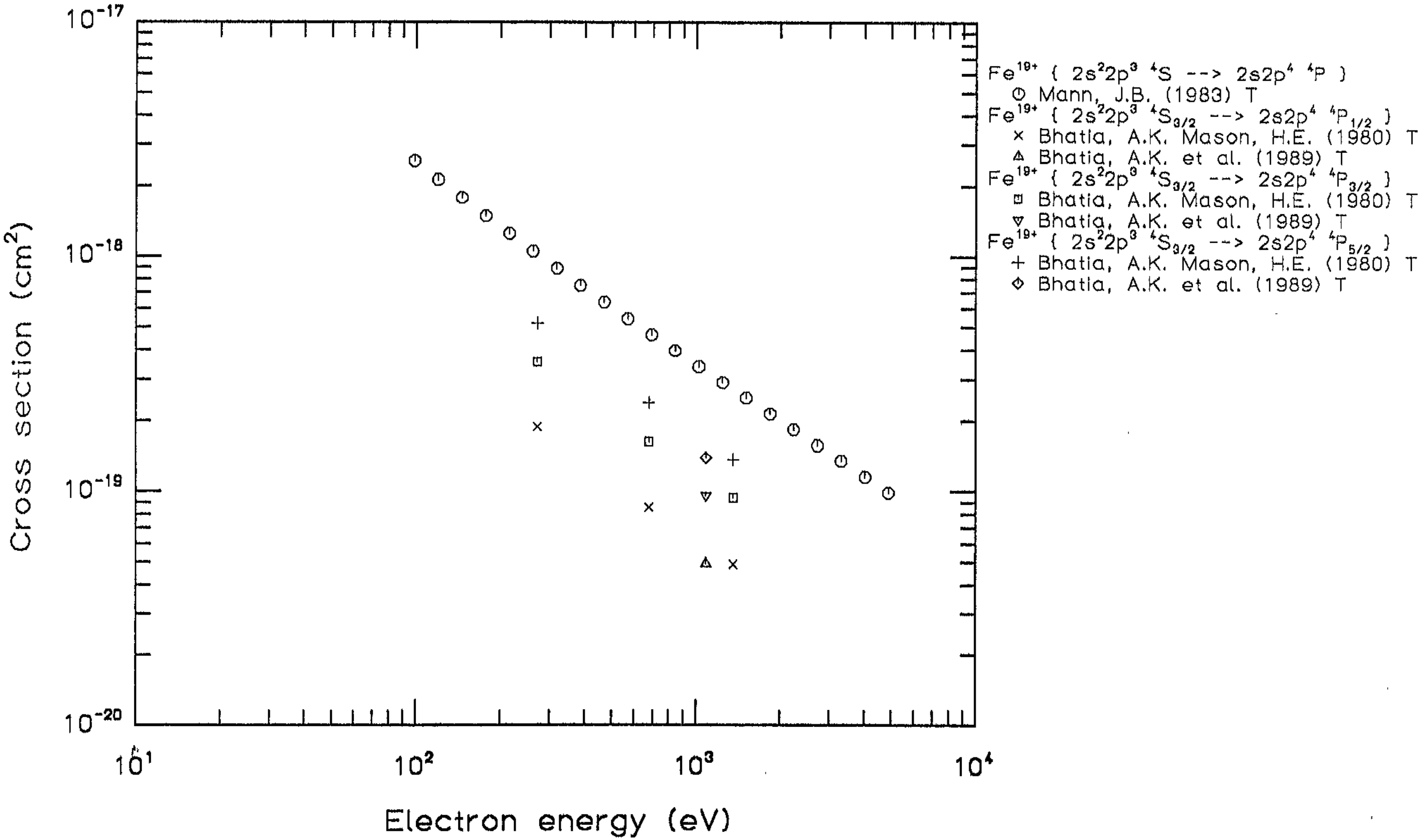

Cross section (cm²)
10⁻¹⁷
10⁻¹⁸
10⁻¹⁹
10²
10³
Electron energy (eV)
Ti¹⁵⁺ { 2s²2p³ ⁴S3/2 --> 2s2p⁴ ⁴P1/2 }
Θ Bhatia ,A.K. et al. (1980) T
Ti¹⁵⁺ { 2s²2p³ ⁴S3/2 --> 2s2p⁴ ⁴P3/2 }
× Bhatia ,A.K. et al. (1980) T
Ti¹⁵⁺ { 2s²2p³ ⁴S3/2 --> 2s2p⁴ ⁴P5/2 }
△ Bhatia ,A.K. et al. (1980) T

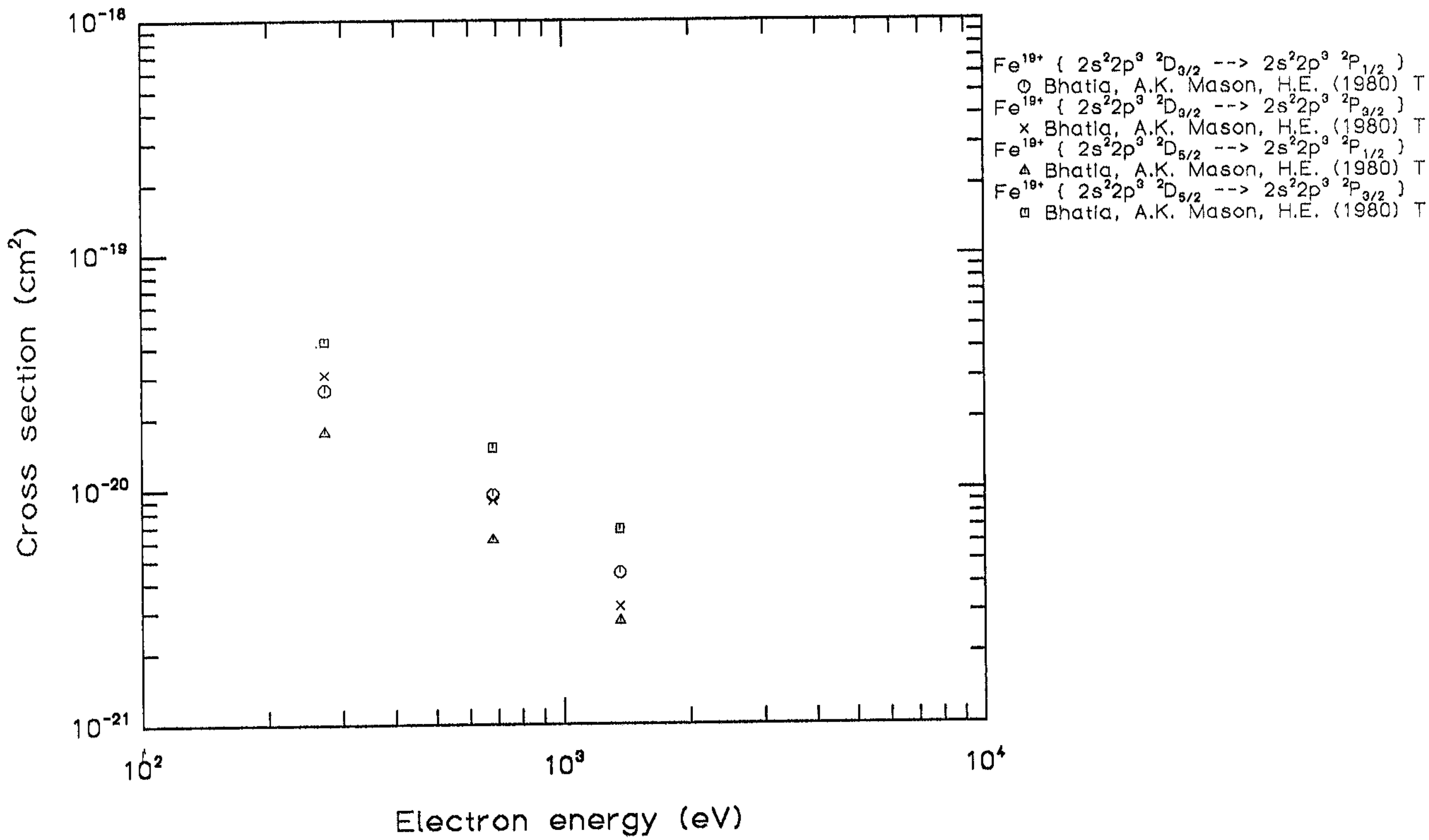

Cross section (cm^2)
10^{-22}
10^{-21}
10^{-20}
10^{-19}
10^2
10^3
10^4
Electron energy (eV)
Fe^{19+} ($2s^22p^3$ ^4S --> $2s2p^4$ ^2S)
Θ Mann, J.B. (1983) T
Fe^{19+} ($2s^22p^3$ $^4S_{3/2}$ --> $2s2p^4$ $^2S_{1/2}$)
× Bhatia, A.K. Mason, H.E. (1980) T


Cross section (cm²)
10⁻¹⁹
10⁻²⁰
10⁻²¹
10⁻²²
10²
10³
10⁴
Electron energy (eV)
Fe¹⁹⁺ { 2s²2p³ ⁴S --> 2s2p⁴ ²P }
Mann, J.B. (1983) T
Fe¹⁹⁺ { 2s²2p³ ⁴S3/2 --> 2s2p⁴ ²P1/2 }
× Bhatia, A.K. Mason, H.E. (1980) T
Fe¹⁹⁺ { 2s²2p³ ⁴S3/2 --> 2s2p⁴ ²P3/2 }
Bhatia, A.K. Mason, H.E. (1980) T

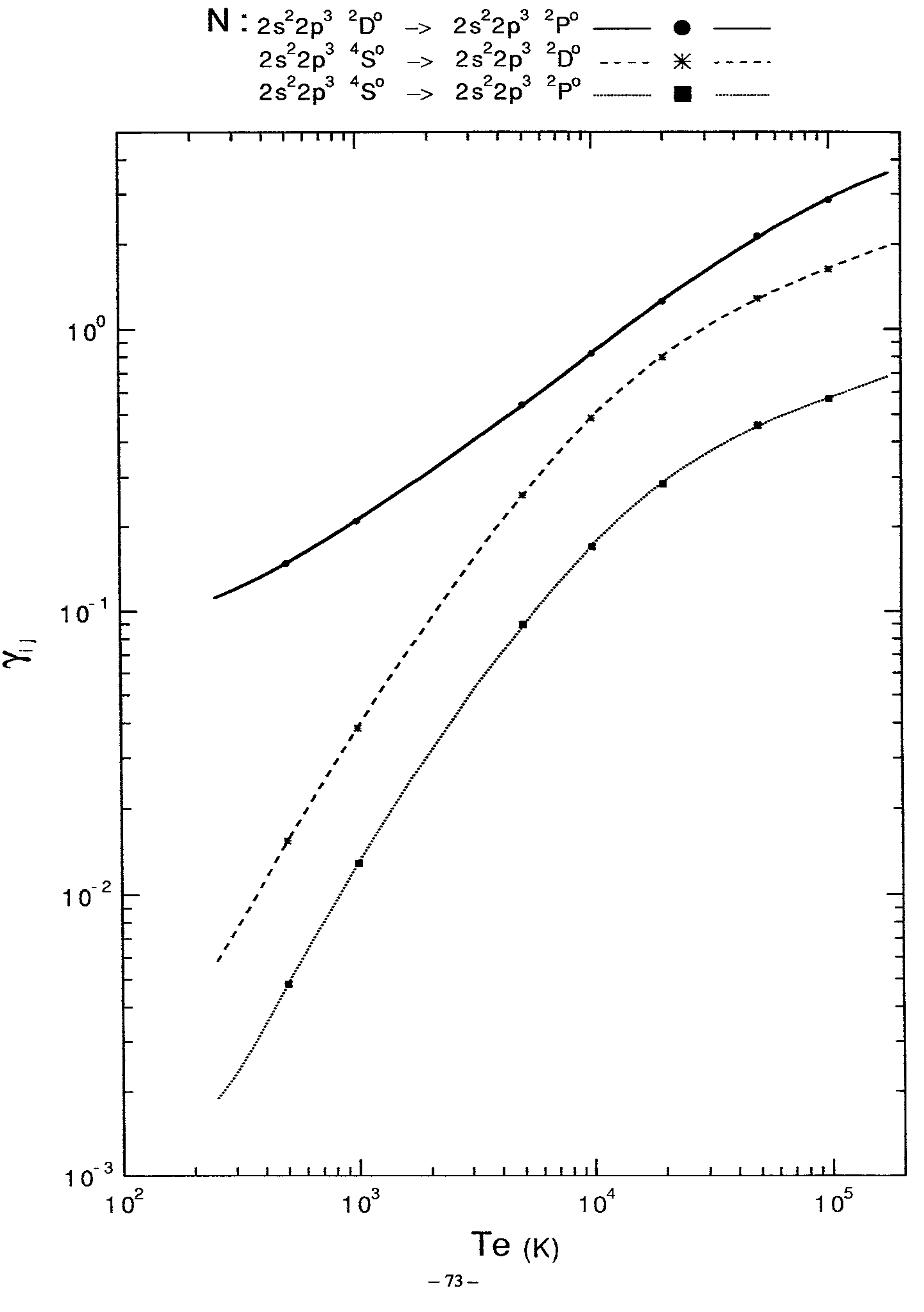


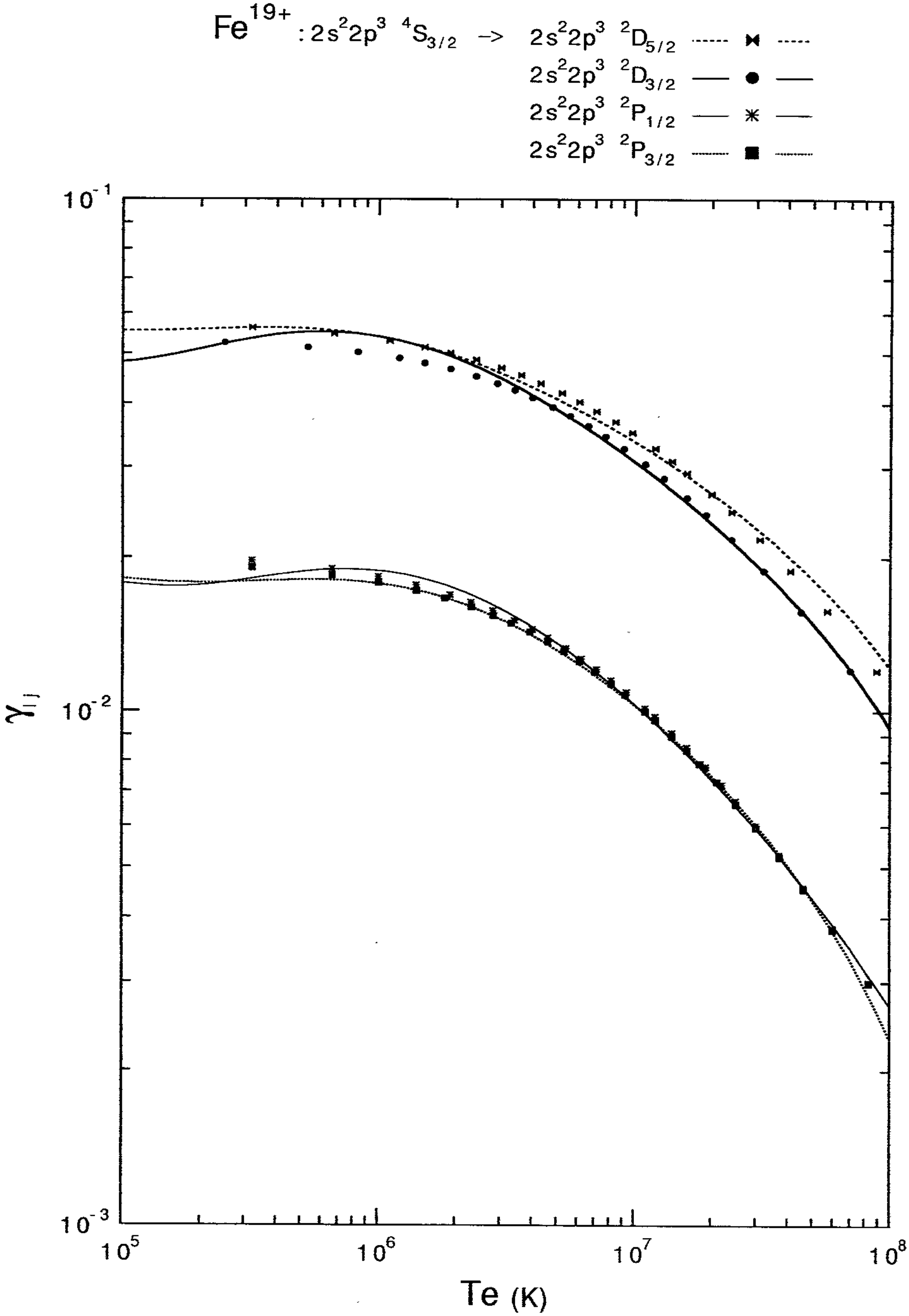
Fe^{19+} { $2s^22p^3\ ^4S$ --> $2s2p^4\ ^2D$ }
Mann, J.B. (1983) T
Fe^{19+} { $2s^22p^3\ ^4S_{3/2}$ --> $2s2p^4\ ^2D_{3/2}$ }
× Bhatia, A.K. Mason, H.E. (1980) T
Fe^{19+} { $2s^22p^3\ ^4S_{3/2}$ --> $2s2p^4\ ^2D_{5/2}$ }
Bhatia, A.K. Mason, H.E. (1980) T
Cross section (cm^2)
10^{-19}
10^{-20}
10^{-21}
10^{-22}
10^{-23}
10^1
10^2
10^3
10^4
Electron energy (eV)


Cross section (cm^2)
10^{-17}
10^{-18}
10^{-19}
10^{-20}
10^1
10^2
10^3
10^4
Electron energy (eV)
Fe^{19+} { $2s^22p^3$ ^4S --> $2s2p^4$ ^4P }
Mann, J.B. (1983) T
Fe^{19+} { $2s^22p^3$ $^4S_{3/2}$ --> $2s2p^4$ $^4P_{1/2}$ }
Bhatia, A.K. Mason, H.E. (1980) T
Bhatia, A.K. et al. (1989) T
Fe^{19+} { $2s^22p^3$ $^4S_{3/2}$ --> $2s2p^4$ $^4P_{3/2}$ }
Bhatia, A.K. Mason, H.E. (1980) T
Bhatia, A.K. et al. (1989) T
Fe^{19+} { $2s^22p^3$ $^4S_{3/2}$ --> $2s2p^4$ $^4P_{5/2}$ }
Bhatia, A.K. Mason, H.E. (1980) T
Bhatia, A.K. et al. (1989) T

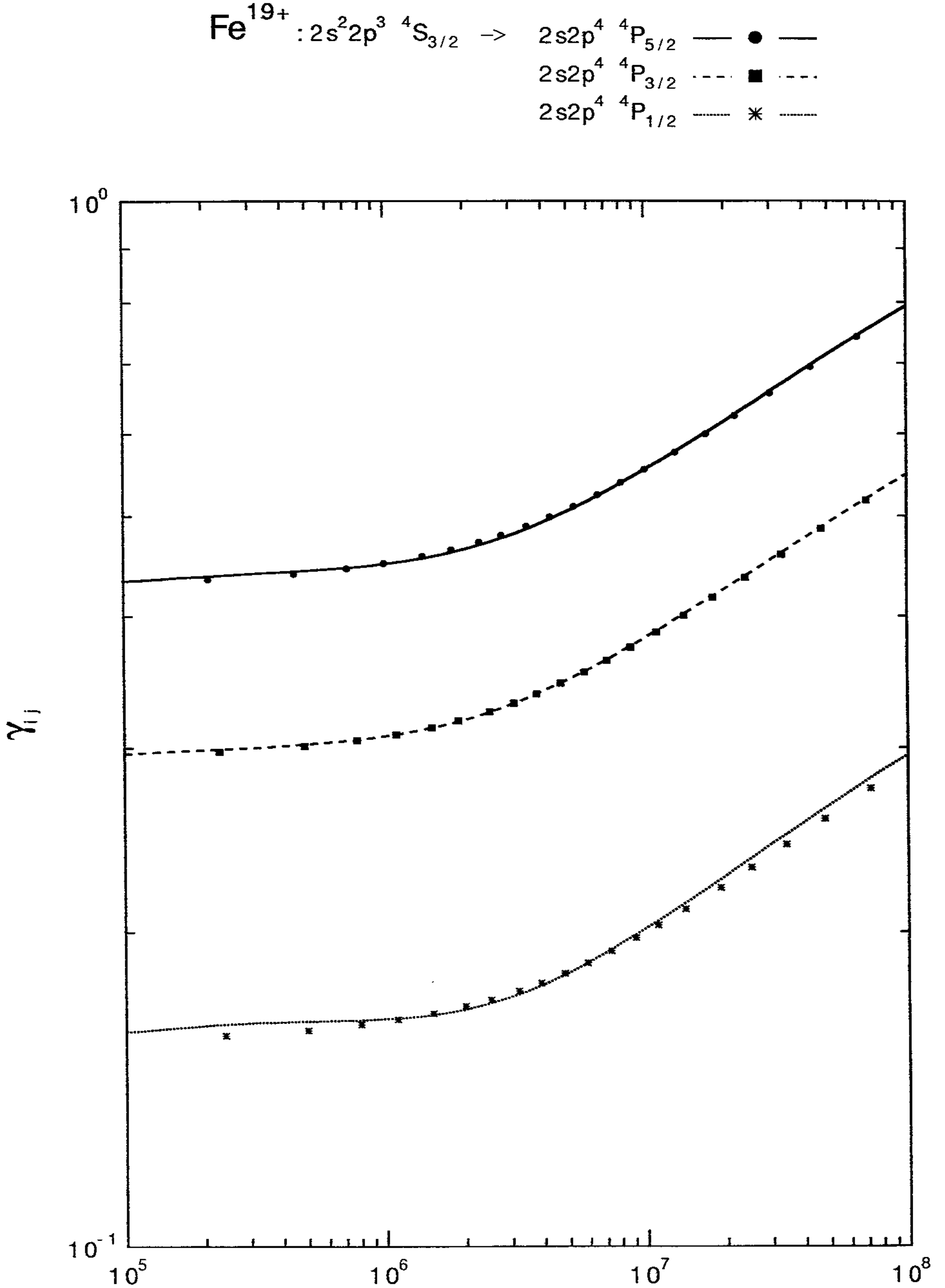

Cross section (cm^2)
10^{-18}
10^{-19}
10^{-20}
10^{-21}
10^2
10^3
10^4
Electron energy (eV)
Fe^{19+} { $2s^22p^3\ ^2D_{3/2}$ --> $2s^22p^3\ ^2P_{1/2}$ }
Φ Bhatia, A.K. Mason, H.E. (1980) T
Fe^{19+} { $2s^22p^3\ ^2D_{3/2}$ --> $2s^22p^3\ ^2P_{3/2}$ }
× Bhatia, A.K. Mason, H.E. (1980) T
Fe^{19+} { $2s^22p^3\ ^2D_{5/2}$ --> $2s^22p^3\ ^2P_{1/2}$ }
Δ Bhatia, A.K. Mason, H.E. (1980) T
Fe^{19+} { $2s^22p^3\ ^2D_{5/2}$ --> $2s^22p^3\ ^2P_{3/2}$ }
⊡ Bhatia, A.K. Mason, H.E. (1980) T

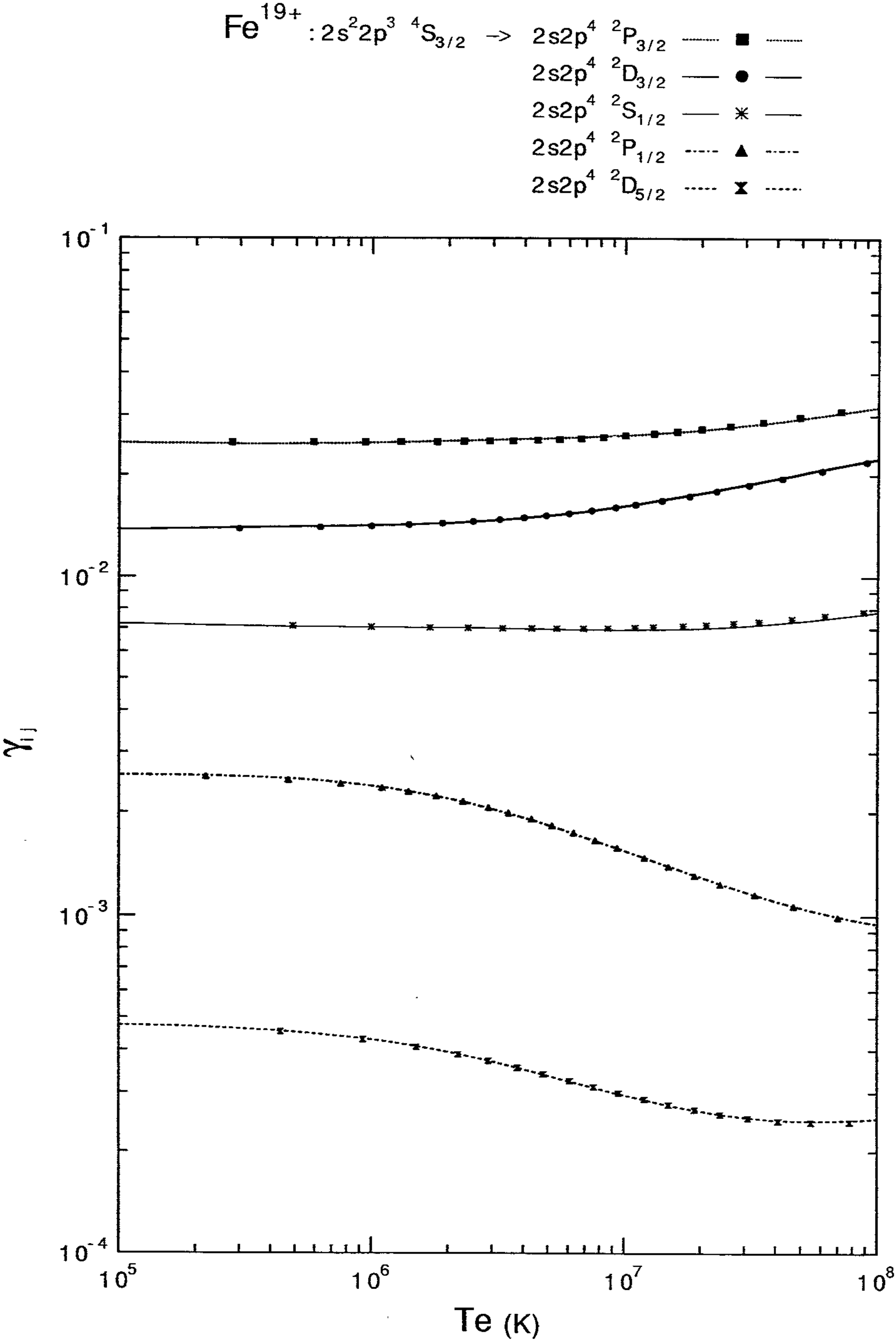
Graphs II. Recommended effective collision strengths

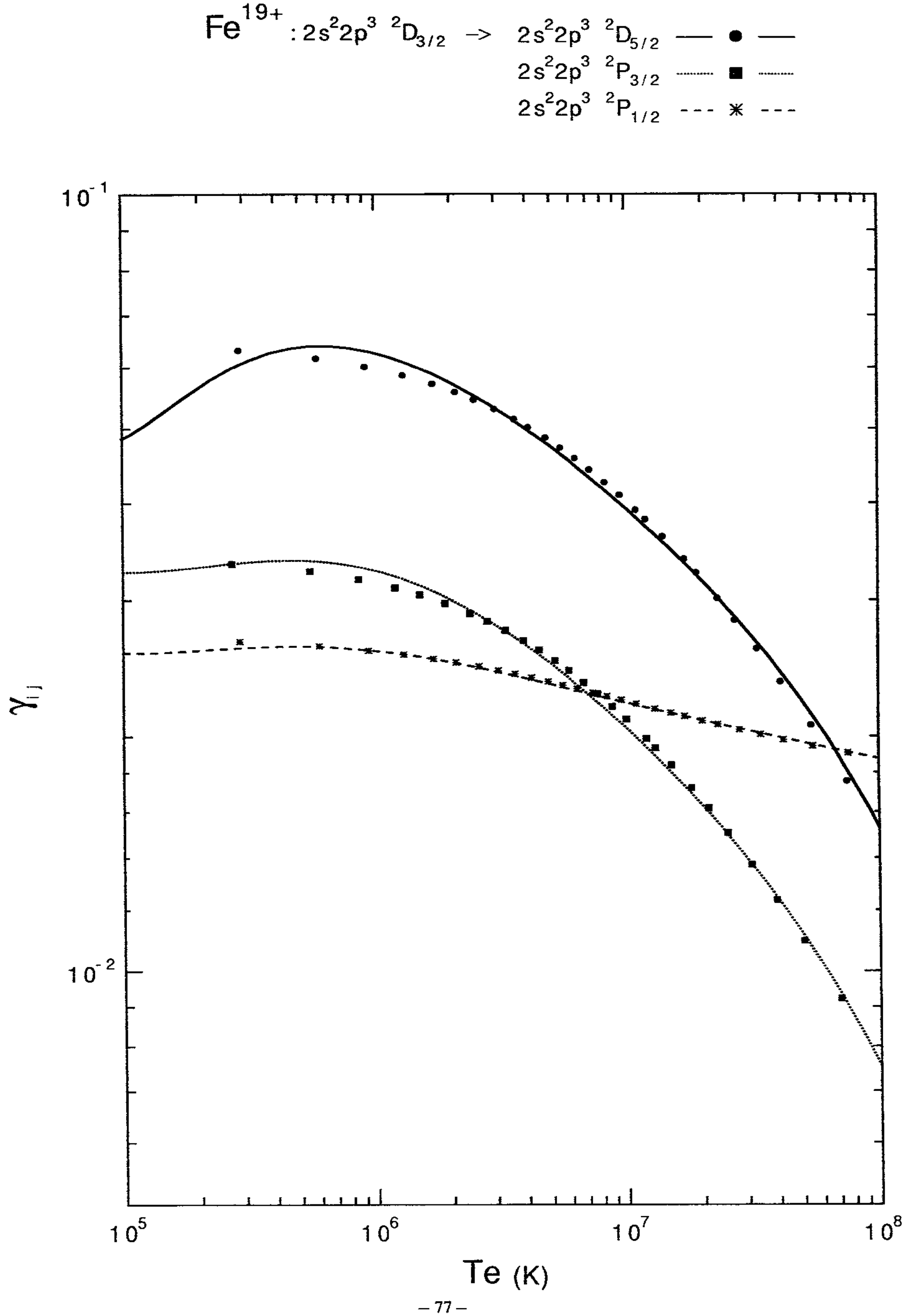

N : $2s^22p^3\ ^2D^o$ -> $2s^22p^3\ ^2P^o$
$2s^22p^3\ ^4S^o$ -> $2s^22p^3\ ^2D^o$
$2s^22p^3\ ^4S^o$ -> $2s^22p^3\ ^2P^o$
10^0
10^{-1}
10^{-2}
10^{-3}
γ_{ij}
10^2
10^3
10^4
10^5
Te (K)

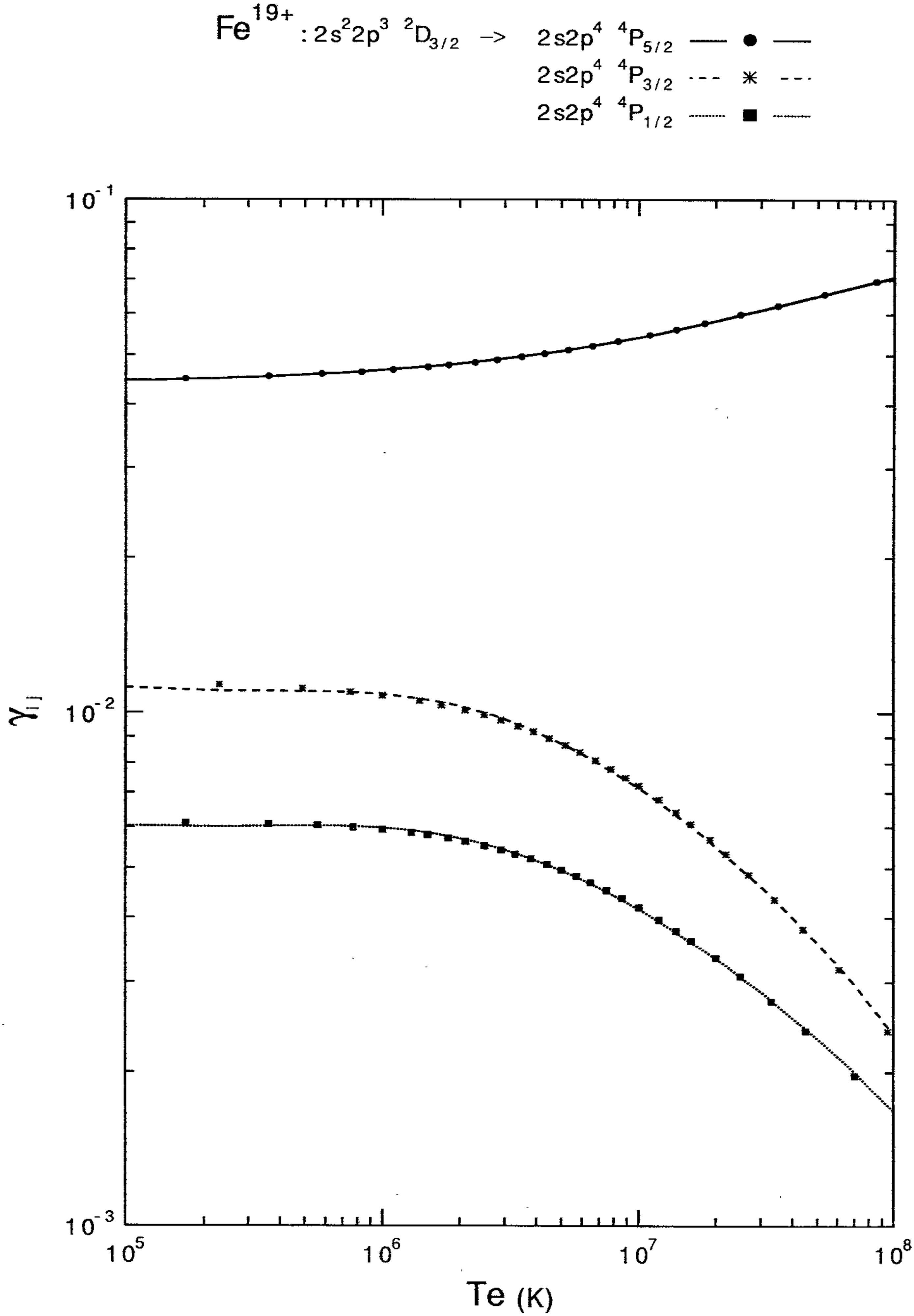


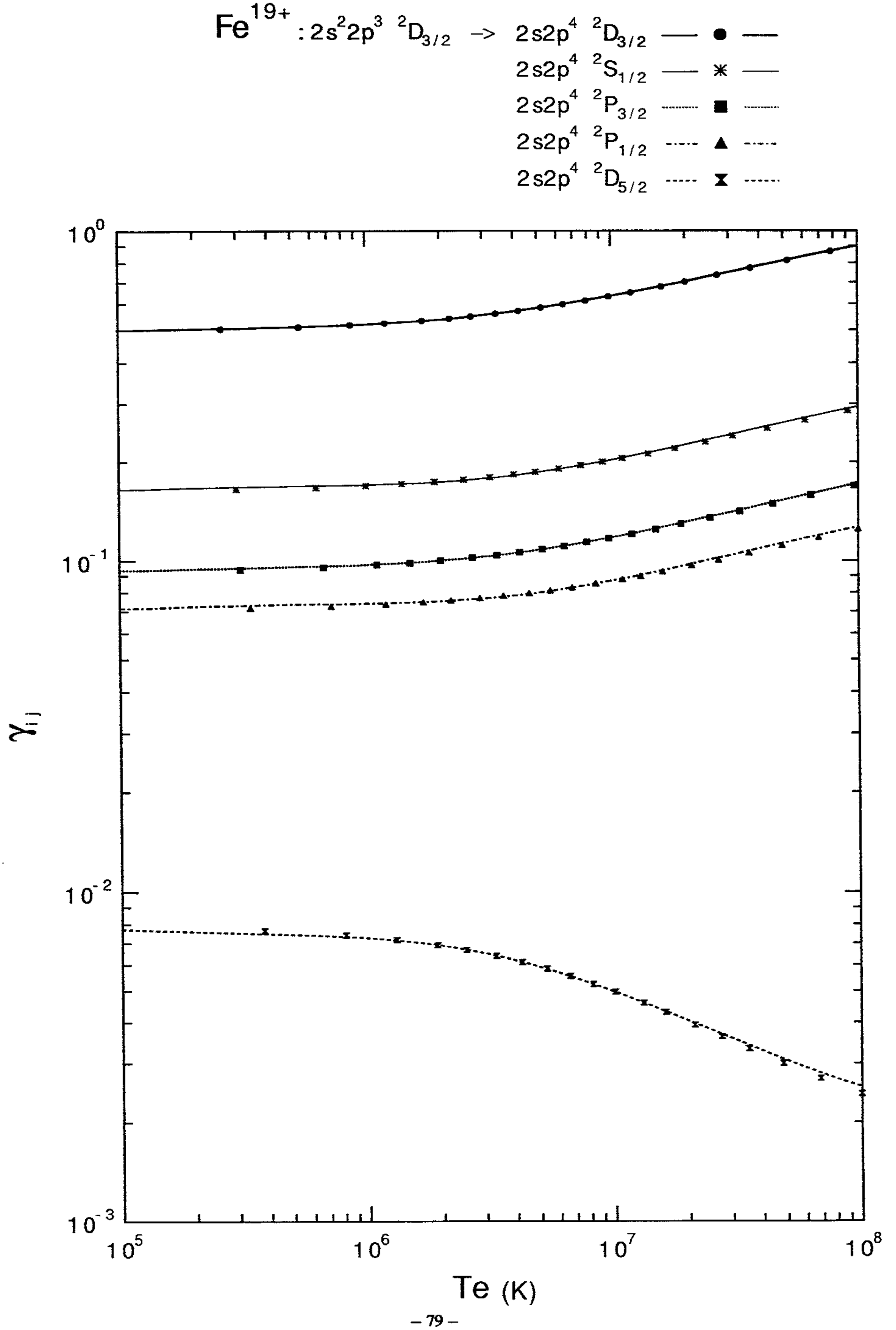
$Fe^{19+}: 2s^2 2p^3\ ^4S_{3/2} \rightarrow$
$2s^2 2p^3\ ^2D_{5/2}$
$2s^2 2p^3\ ^2D_{3/2}$
$2s^2 2p^3\ ^2P_{1/2}$
$2s^2 2p^3\ ^2P_{3/2}$
γ_{ij}
10^{-1}
10^{-2}
10^{-3}
10^5
10^6
10^7
10^8
Te (K)

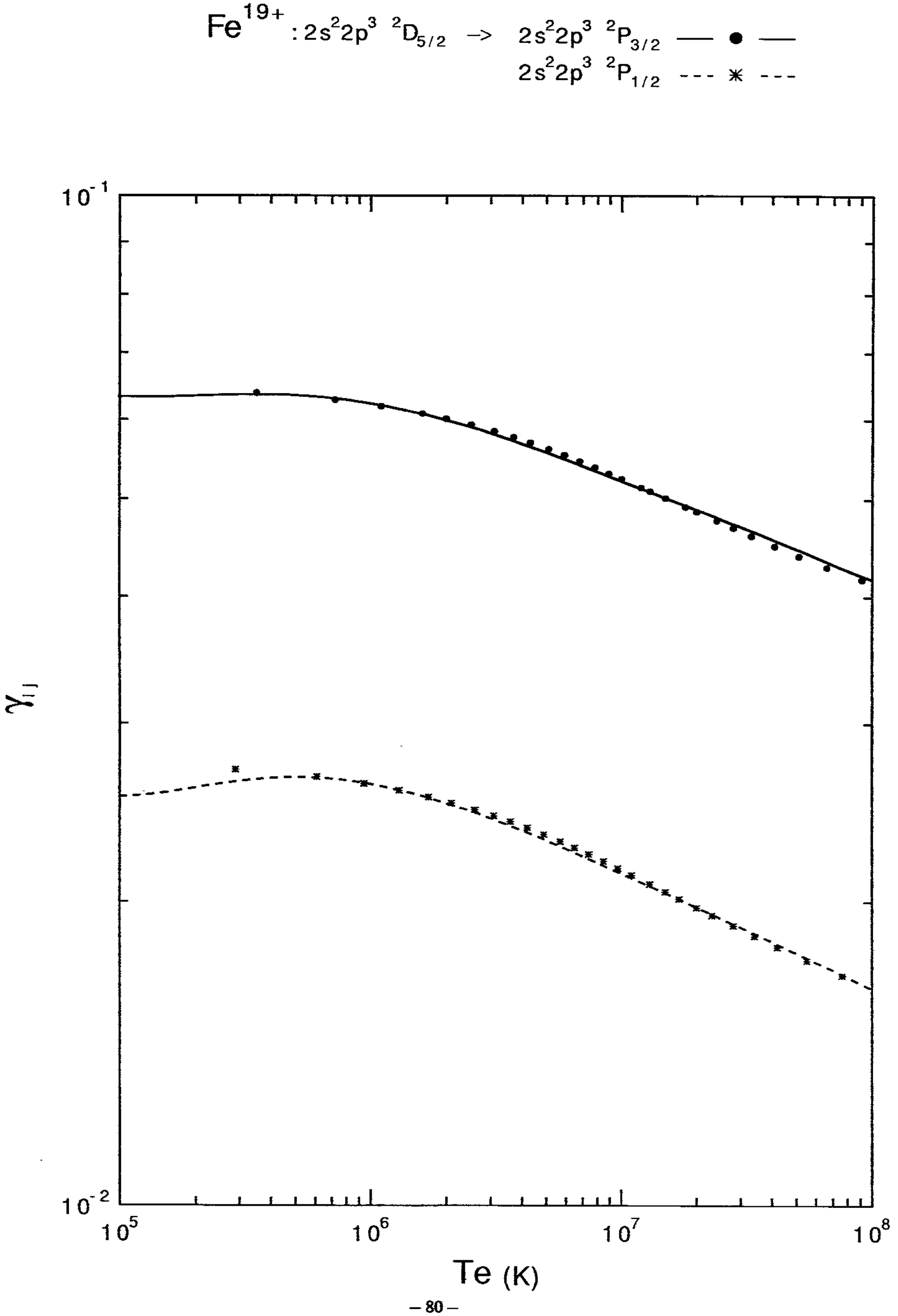

Fe^{19+} : $2s^2 2p^3\ ^4S_{3/2}$ -> $2s2p^4\ ^4P_{5/2}$
$2s2p^4\ ^4P_{3/2}$
$2s2p^4\ ^4P_{1/2}$
10^0
10^{-1}
γ_{ij}
10^5
10^6
10^7
10^8
Te (K)

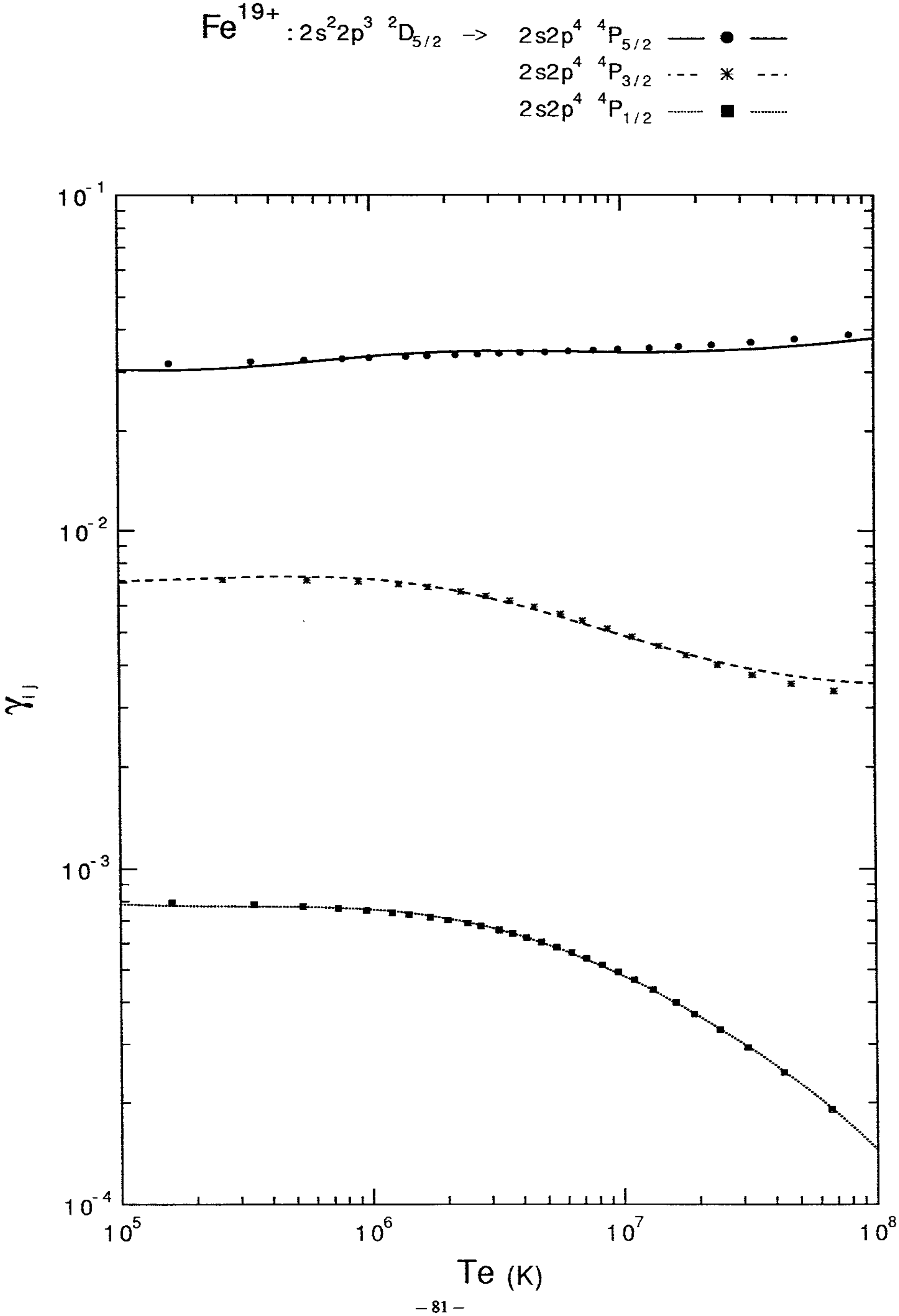

Fe19+ : 2s²2p³ ⁴S3/2 -> 2s2p⁴ ²P3/2
2s2p⁴ ²D3/2
2s2p⁴ ²S1/2
2s2p⁴ ²P1/2
2s2p⁴ ²D5/2
10-1
10-2
10-3
10-4
γij
10⁵
10⁶
10⁷
10⁸
Te (K)

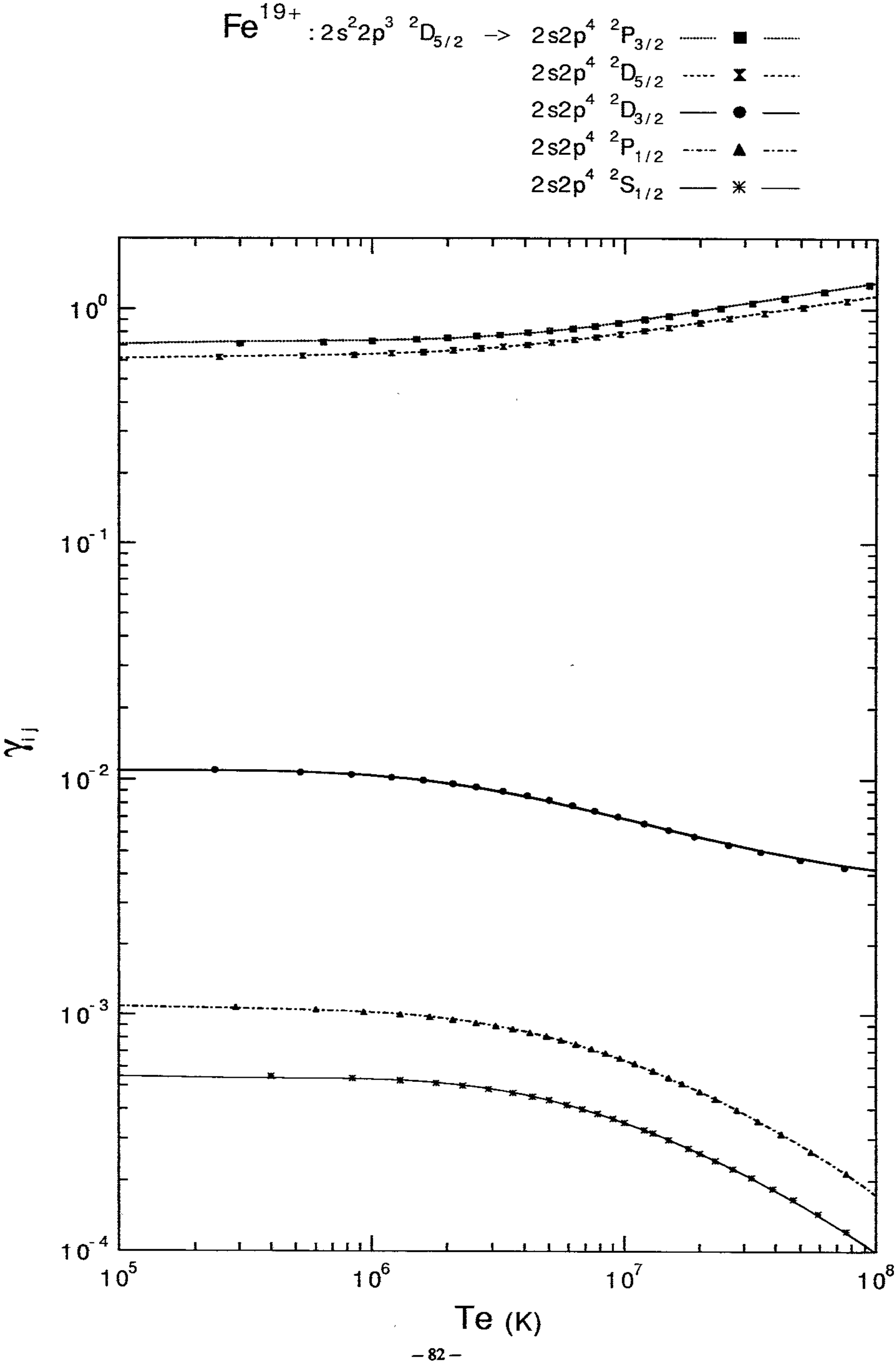

Fe19+ : 2s2 2p3 2D3/2 -> 2s2 2p3 2D5/2
2s2 2p3 2P3/2
2s2 2p3 2P1/2
10-1
10-2
γij
10^5
10^6
10^7
10^8
Te (K)


Fe^{19+} : $2s^2 2p^3\ ^2D_{3/2}$ -> $2s2p^4\ ^4P_{5/2}$
$2s2p^4\ ^4P_{3/2}$
$2s2p^4\ ^4P_{1/2}$
γ_{ij}
10^{-1}
10^{-2}
10^{-3}
10^5
10^6
10^7
10^8
Te (K)

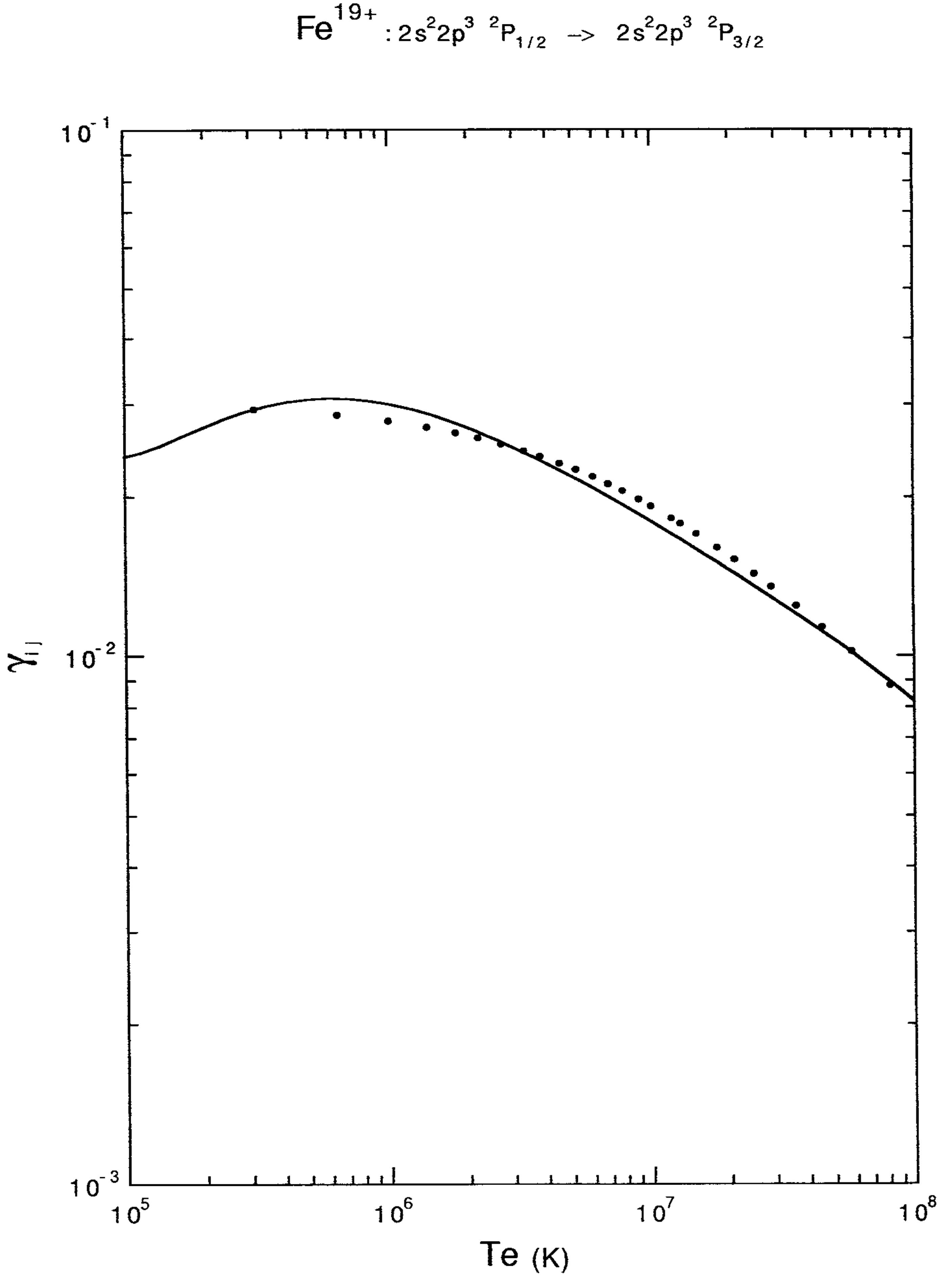

Fe^{19+} : $2s^2 2p^3\ ^2D_{3/2}$ -> $2s2p^4\ ^2D_{3/2}$
$2s2p^4\ ^2S_{1/2}$
$2s2p^4\ ^2P_{3/2}$
$2s2p^4\ ^2P_{1/2}$
$2s2p^4\ ^2D_{5/2}$
10^0
10^{-1}
10^{-2}
10^{-3}
γ_{ij}
10^5
10^6
10^7
10^8
Te (K)

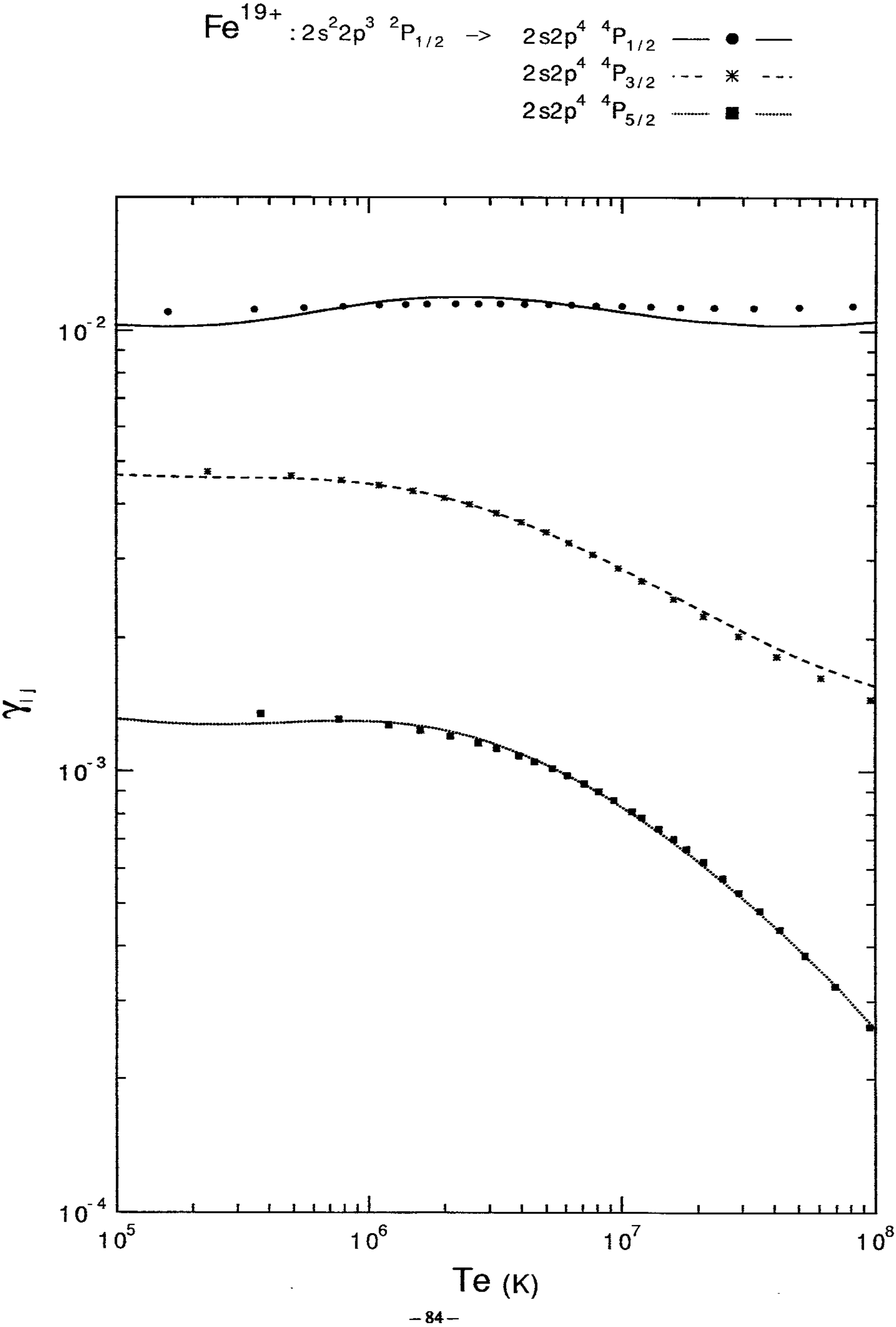

Fe^{19+} : $2s^2 2p^3\ ^2D_{5/2}$ -> $2s^2 2p^3\ ^2P_{3/2}$
$2s^2 2p^3\ ^2P_{1/2}$
10^{-1}
10^{-2}
γ_{ij}
10^5
10^6
10^7
10^8
Te (K)


Fe^{19+} : $2s^2 2p^3\ ^2D_{5/2}$ -> $2s2p^4\ ^4P_{5/2}$
$2s2p^4\ ^4P_{3/2}$
$2s2p^4\ ^4P_{1/2}$
γ_{ij}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^5
10^6
10^7
10^8
Te (K)

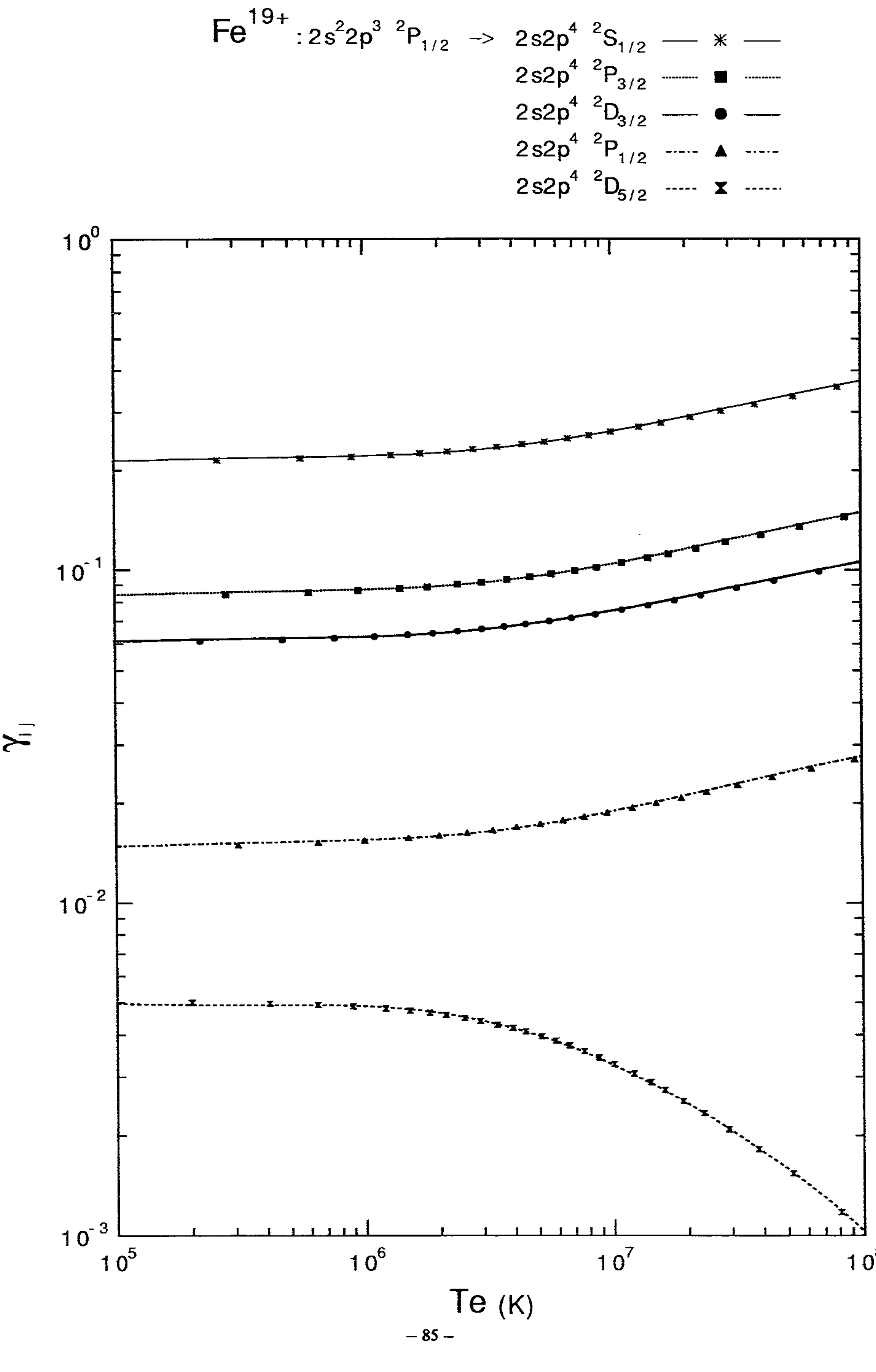


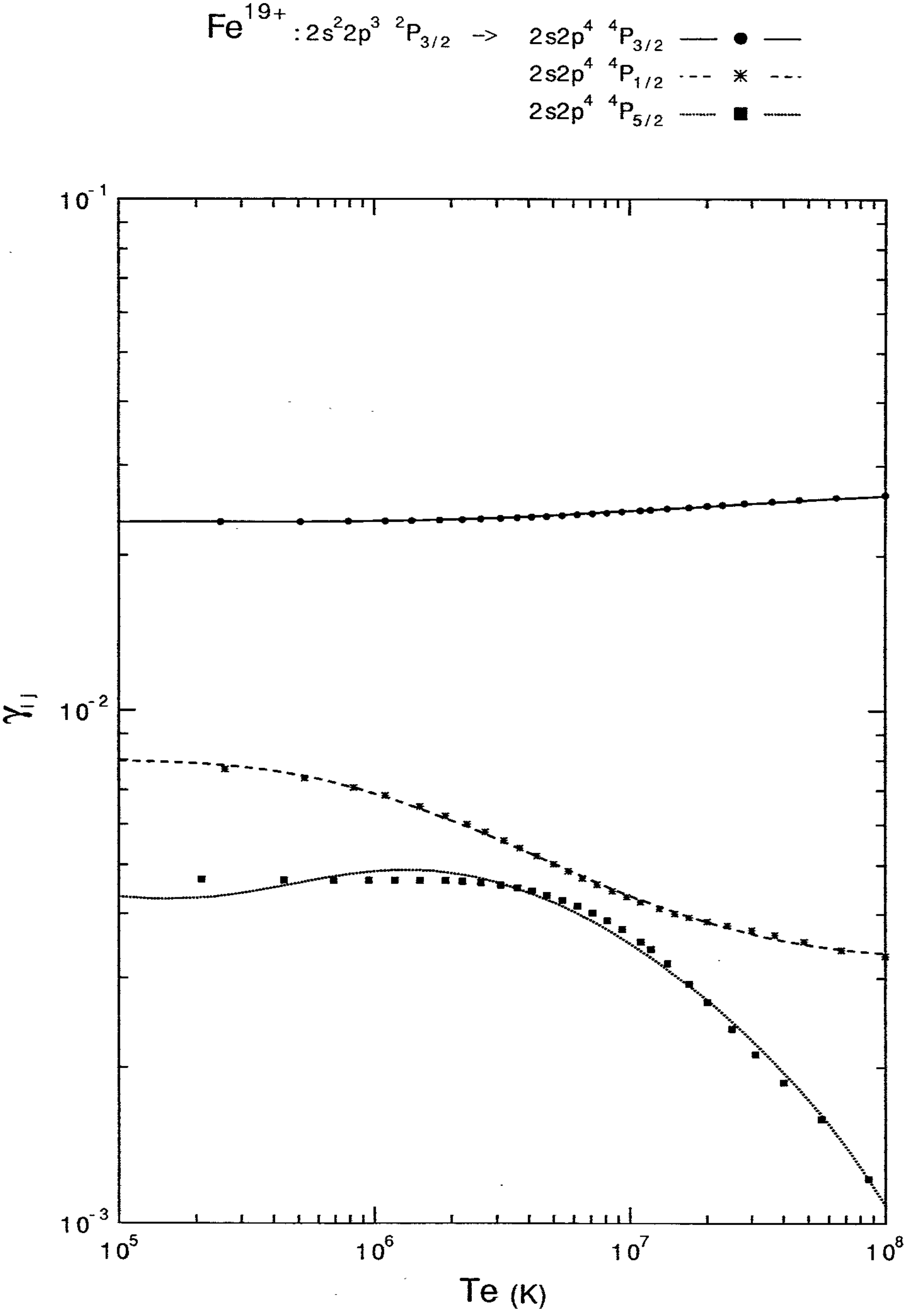
Fe^{19+} : $2s^2 2p^3\ ^2D_{5/2}$ ->
$2s2p^4\ ^2P_{3/2}$
$2s2p^4\ ^2D_{5/2}$
$2s2p^4\ ^2D_{3/2}$
$2s2p^4\ ^2P_{1/2}$
$2s2p^4\ ^2S_{1/2}$
γ_{ij}
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^5
10^6
10^7
10^8
Te (K)


Fe^{19+} : $2s^2 2p^3\ ^2P_{1/2}$ -> $2s^2 2p^3\ ^2P_{3/2}$
10^{-1}
10^{-2}
10^{-3}
γ_{ij}
10^5
10^6
10^7
10^8
Te (K)

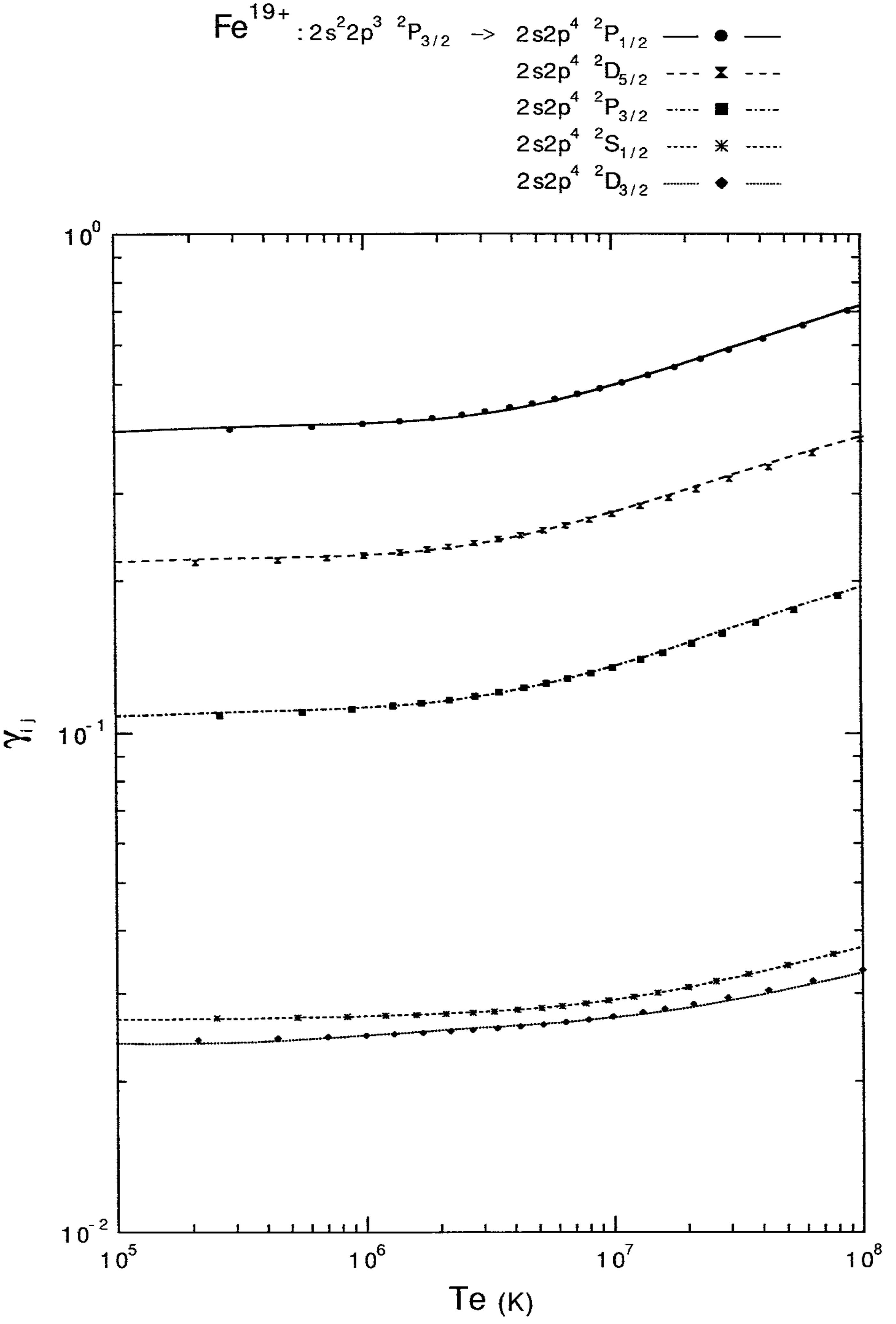


Fe^{19+} : $2s^2 2p^3\ ^2P_{1/2}$ -> $2s2p^4\ ^4P_{1/2}$
$2s2p^4\ ^4P_{3/2}$
$2s2p^4\ ^4P_{5/2}$
γ_{ij}
10^{-2}
10^{-3}
10^{-4}
10^5
10^6
10^7
10^8
Te (K)


Fe^{19+} : $2s^22p^3\ ^2P_{1/2}$ -> $2s2p^4\ ^2S_{1/2}$
$2s2p^4\ ^2P_{3/2}$
$2s2p^4\ ^2D_{3/2}$
$2s2p^4\ ^2P_{1/2}$
$2s2p^4\ ^2D_{5/2}$
10^0
10^{-1}
10^{-2}
10^{-3}
γ_{ij}
10^5
10^6
10^7
10^8
Te (K)



Fe^{19+} : $2s^2 2p^3\ ^2P_{3/2}$ -> $2s2p^4\ ^4P_{3/2}$
$2s2p^4\ ^4P_{1/2}$
$2s2p^4\ ^4P_{5/2}$
10^{-1}
10^{-2}
10^{-3}
γ_{ij}
10^5
10^6
10^7
10^8
Te (K)


Fe^{19+} : $2s^2 2p^3\ ^2P_{3/2}$ -> $2s2p^4\ ^2P_{1/2}$
$2s2p^4\ ^2D_{5/2}$
$2s2p^4\ ^2P_{3/2}$
$2s2p^4\ ^2S_{1/2}$
$2s2p^4\ ^2D_{3/2}$
10^0
10^{-1}
10^{-2}
γ_{ij}
10^5
10^6
10^7
10^8
Te (K)

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