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RECOMMENDED VALUES OF TRANSPORT CROSS SECTIONS FOR ELASTIC COLLISION AND TOTAL COLLISION CROSS SECTION FOR ELECTRONS IN ATOMIC AND MOLECULAR GASES

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Recommended values are presented for the integral, momentum-transfer and viscosity cross sections for elastic collisions and total collision cross section of electrons in He, Ne, Ar, Kr, Xe, H_2, N_2, O_2, CO and CO_2. A wide range of electron energies (10^{-3} to 10^4 eV) is considered, but emphasis is placed on the 1 - 10^3 eV range. A comprehensive list of references for the relevant cross sections is given.

In an analysis of various phenomena in ionized gases, a fundamental role is played by a set of integral (q_t), momentum-transfer (q_m) and viscosity (q_v) cross sections for elastic collisions, as well as every kind of inelastic collision cross section. The three transport cross sections for electrons with kinetic energy E are defined by

$$q_t(E) = 2\pi\int_0^{\pi} \sigma(E,\theta) \sin\theta \, d\theta, \qquad (1)$$

$$q_m(E) = 2\pi\int_0^{\pi} \sigma(E,\theta)(1 - \cos\theta) \sin\theta \, d\theta, \qquad (2)$$

$$q_v(E) = 2\pi\int_0^{\pi} \sigma(E,\theta)(1 - \cos^2\theta) \sin\theta \, d\theta, \qquad (3)$$

where $\sigma(E,\theta)$ is the differential cross section for elastic scattering and θ is the scattering angle. Another important quantity is the total collision cross section Q_T defined by

$$Q_T(E) = q_t(E) + \Sigma q_{inel}(E), \qquad (4)$$

where the second term on the right side denotes the summation of all the inelastic collision cross sections. In the present report, available data on these four kinds of cross sections are critically reviewed and the recommended values of them are given for rare gas atoms and several simple molecules.

The present task of data compilation was started primarily for an application to the calculation of swarm parameters for medium to high X/N, where X is the electric field applied and N is the gas number density. The calculations have been carried out for He, Ne, Ar, Kr, Xe, H_2, N_2 and O_2, and partly reported elsewhere[1]. To do the calculations, accurate values of q_m are needed for a wide range of electron energy. Rather widely different values, however, have been used for q_m in the swarm parameter calculation by different authors. Fig. I shows an example for H_2[2]. Thus, an effort had to be made to determine our own recommended values for q_m. The effort has been extended to other transport cross sections and Q_T, and results are given here.

For q_m at low electron energies ($E < 10$ eV), accurate values can be obtained by swarm experiments[3,4]. Those values have been reviewed by Itikawa[5]. The best swarm data, therefore, were adopted for q_m at low collision energies.

The values of Q_T have been obtained by Ramsauer-type experiments by many authors. Recent experiments can give Q_T within an error of 2-3 %. For atomic species, Q_T should equal q_t below the threshold of the first excited state. Above the threshold, Q_T of high accuracy is quite useful in the evaluation of q_t.

In the last ten years a beam method has been applied extensively to the determination of differential cross sections. Furthermore many elaborate theoretical calculations of $\sigma(\theta)$ have been made. Here we adopt, in principle, the most reliable experimental data on $\sigma(\theta)$ to obtain q_v for all the energies and q_m and q_t for higher energies. A similar procedure has been followed by de Heer et al.[6] in their determination of best values of q_t and Q_T for 20 to 3×10^3 eV in inert gases. In the present report, available data are searched more thoroughly and q_m and q_v are calculated as well.

In the calculation of the transport cross sections from $\sigma(\theta)$, two problems arise. Usually beam methods can not give $\sigma(\theta)$ for very small angles (near 0°) and for very large angles ($\sim$180°). With the aid of theoretical cross sections, an extrapolation of $\sigma(\theta)$ to smaller or larger angles is made in the present caluculations. Beam methods are less reliable in providing absolute magnitudes of cross sections and hence some normalization procedure is often invoked. Some original data are renormalized here so as to give more consistent results. One example of renormalization is shown in Fig. II. This figure shows the differential cross section of nitrogen molecules measured by Trajmar's group[7]. They obtained absolute values with a normalization to the differential cross section for He.

We renormalized their values to the newly measured $\sigma(\theta)$ for He[8]. The result is also shown in Fig. II. The renormalized value is very close to the recent experimental data by Shyn[9]. This renormalization reduces the value of q_m by about 30 % and makes it agree with our recommeded value as shown in Fig. III. Fig. IV shows a comparison of the renormalized values of q_m with other experimental and theoretical results. It turns out that all the experimental values agree within about 10 %.

The recommended values of q_t, q_m, q_v and Q_T thus determined are given in Tables 1-10 and Figs. 1-10. The accuracy of the present q_m is roughly estimated to be shown in Table 11. At the end of this report, a rather comprehensive list of references for the relevant cross sections is given. The list is arranged separately for each species considered here. For the reader's convenience, each entry has a short description of the information contained in the paper. The present recommended values of corss sections are based mostly on the papers with an asterisk.

In future, recommended values will be determined for differential cross sections. For that purpose, measurements should be made over a wide range of scattering angles. In particular data on large-angle scattering (for $\theta \sim 150°$) are improtant in the determination of q_m for the electron energies less than about 100 eV.

The author wishes to thank Professors K. Takayanagi, Y. Itikawa and L.H. Fisher for their advice and encouragement. Thanks are also due to Professors A.V. Phelps and S. Trajmar. They kindly provided the author with unpublished data obtained by them and other researchers. This work was supported in part by a Grant-in-Aid by the Ministry of Education. Numerical calculations were performed with the assistance of many students.

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Figures of the Text

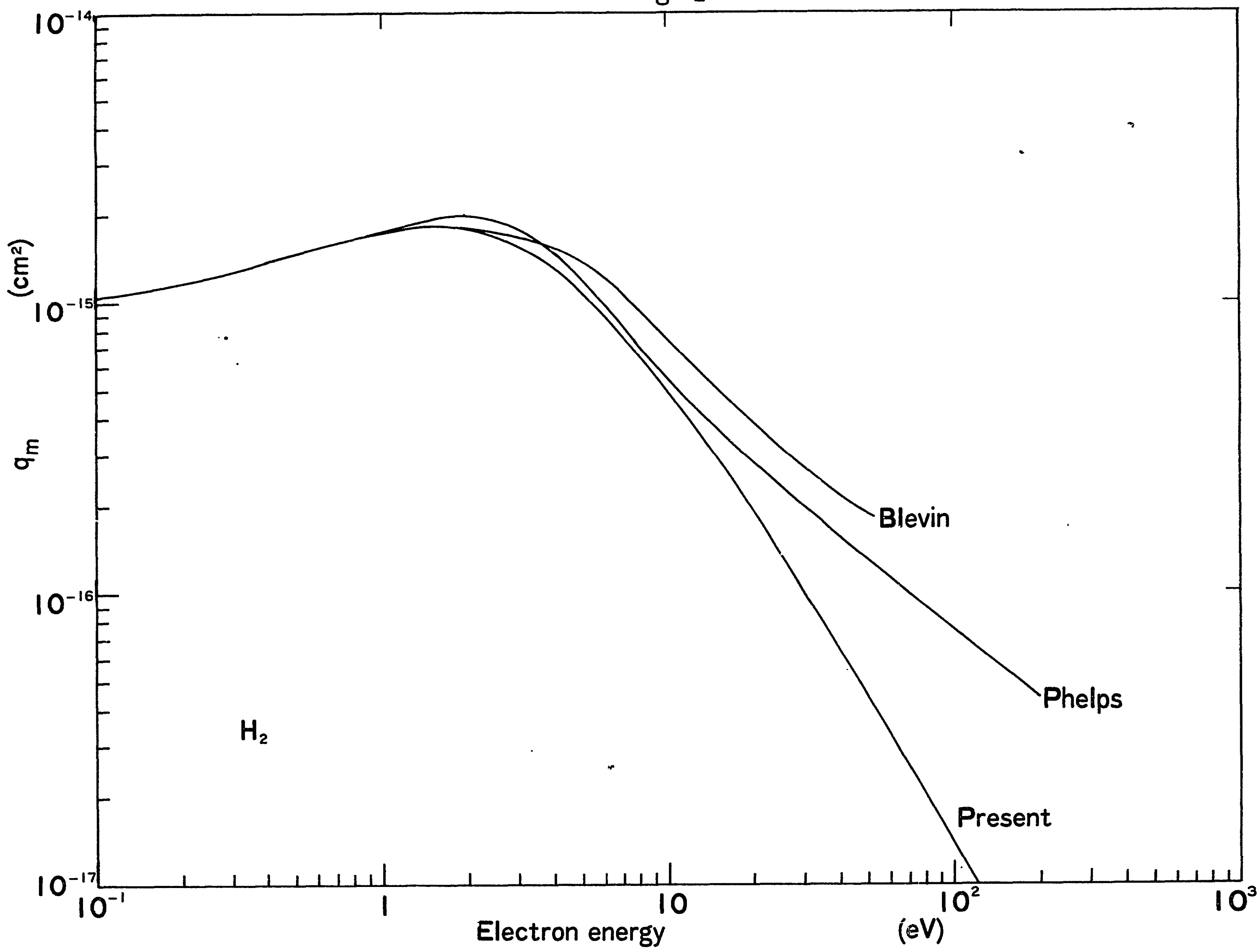
Fig. I. Momentum transfer cross sections, q_m, adopted in the previous swarm analysis for hydrogen molecules[2], compared with the recommended values of this report.

Fig. II. Differential elastic scattering cross section for nitrogen molecules at the electron energy of 50 eV. The upper curve at the large scattering angles is the original DCS reported by Srivastava et al.[7] and the lower curve is the one renormalized to the more accurate DCS measured recently for He.

Fig. III. Original and renomalized values of momentum transfer cross sections for N_2 as a function of electron energy, E. The present recommended values are also shown.

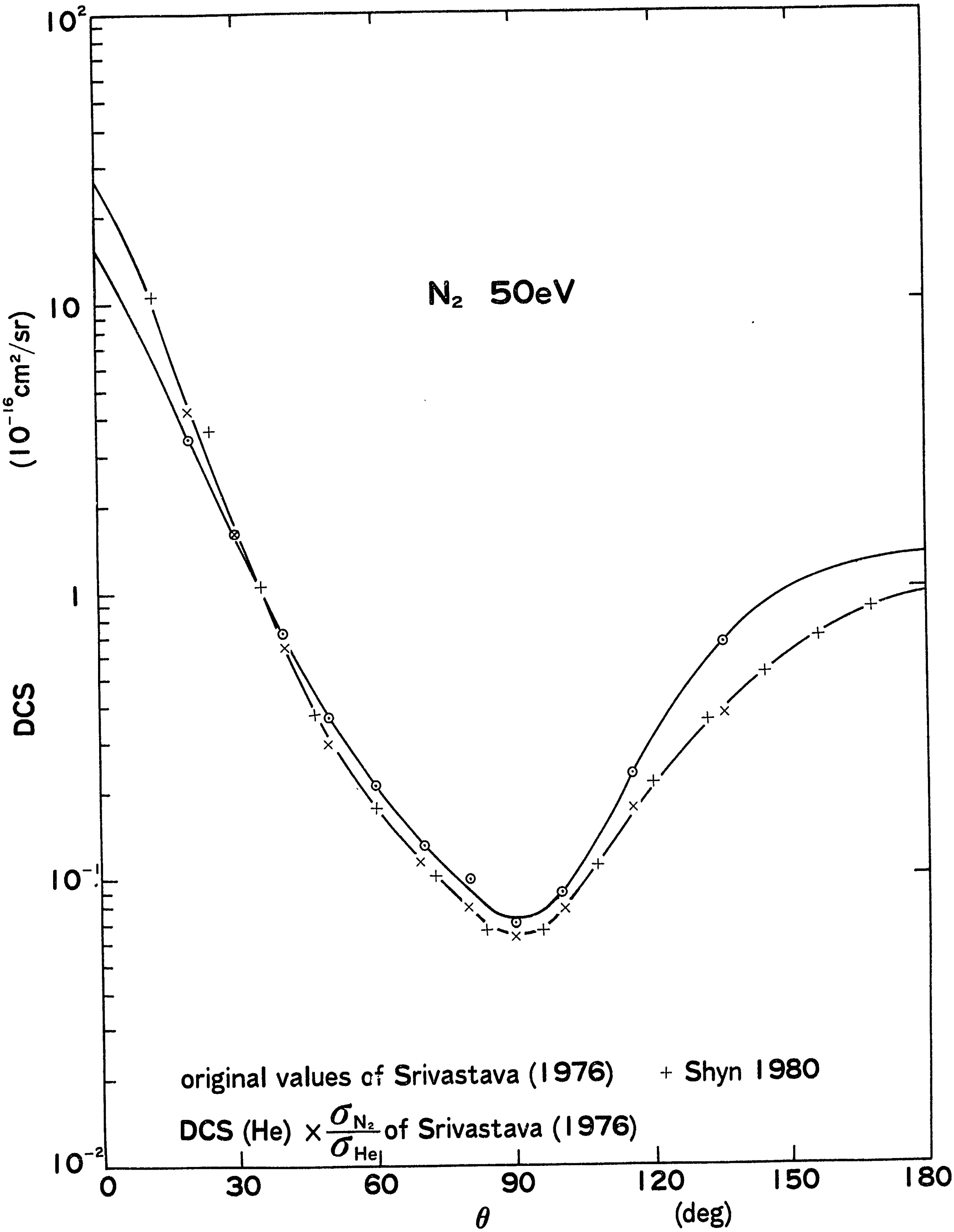
Fig. IV. Recent experimental and theoretical values of q_m for N_2 over a wide energy range. Srivastava's values are the renormalized ones as shown in Fig. III. For references, see the list of papers at the end of the report.

Fig. I



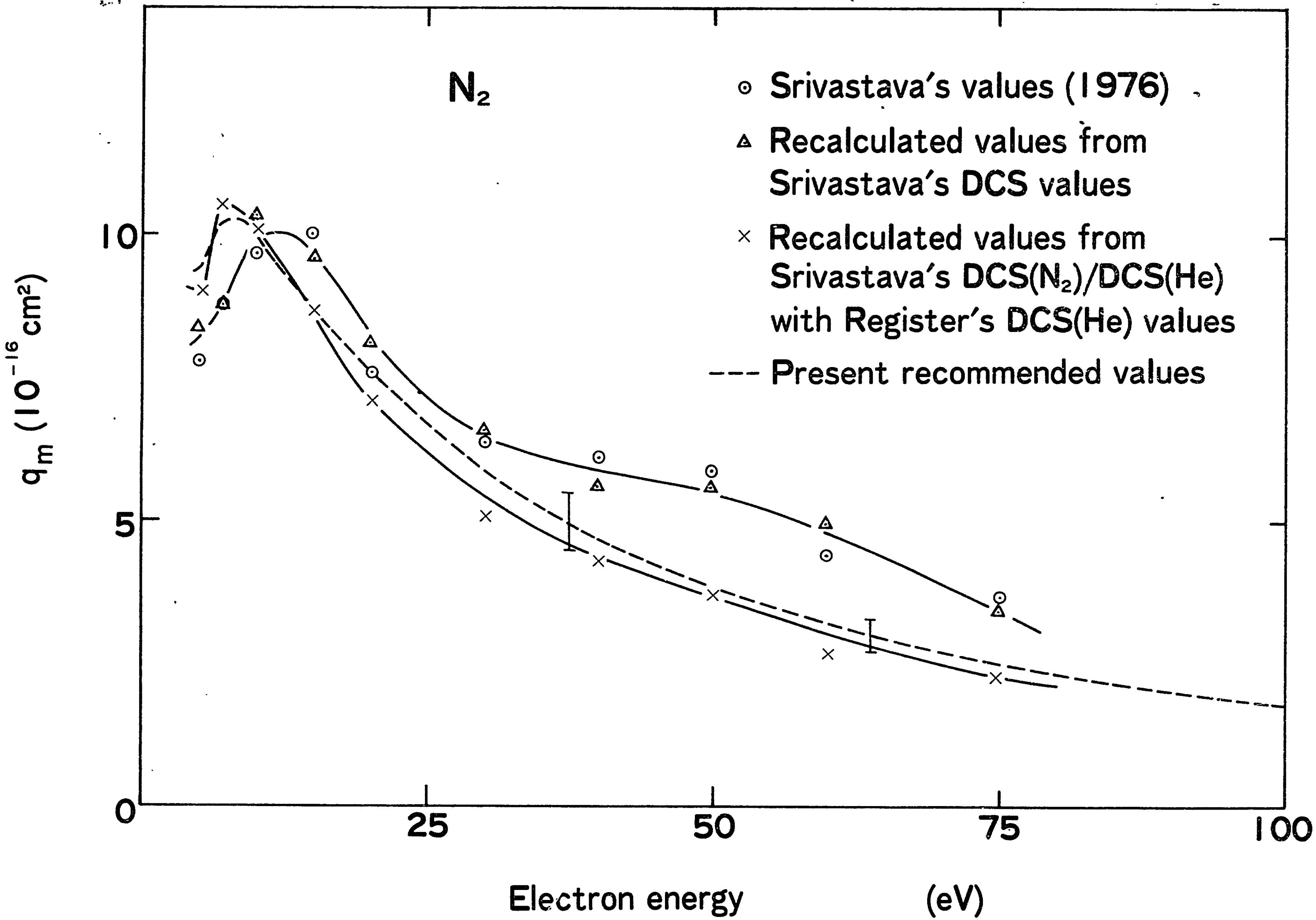
10^{-14}
10^{-15}
10^{-16}
10^{-17}
q_m
(cm²)
10^{-1}
1
10
10^2
10^3
Electron energy
(eV)
H_2
Blevin
Phelps
Present

Fig. II



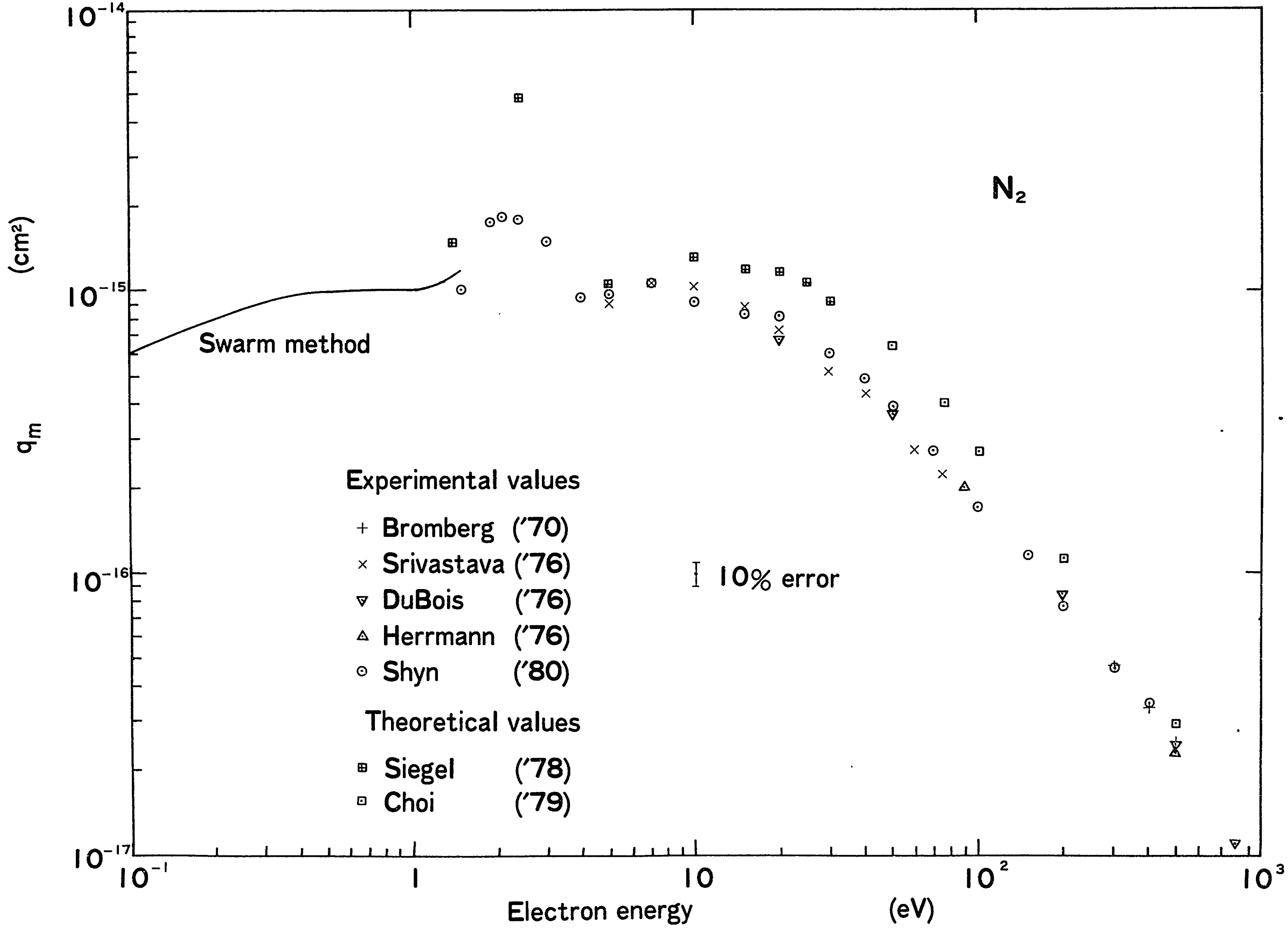
N₂ 50eV
DCS
(10⁻¹⁶cm²/sr)
10²
10
1
10⁻¹
10⁻²
0
30
60
90
120
150
180
θ
(deg)
original values of Srivastava (1976)
+ Shyn 1980
DCS (He) × σN₂/σHe of Srivastava (1976)

Fig. III



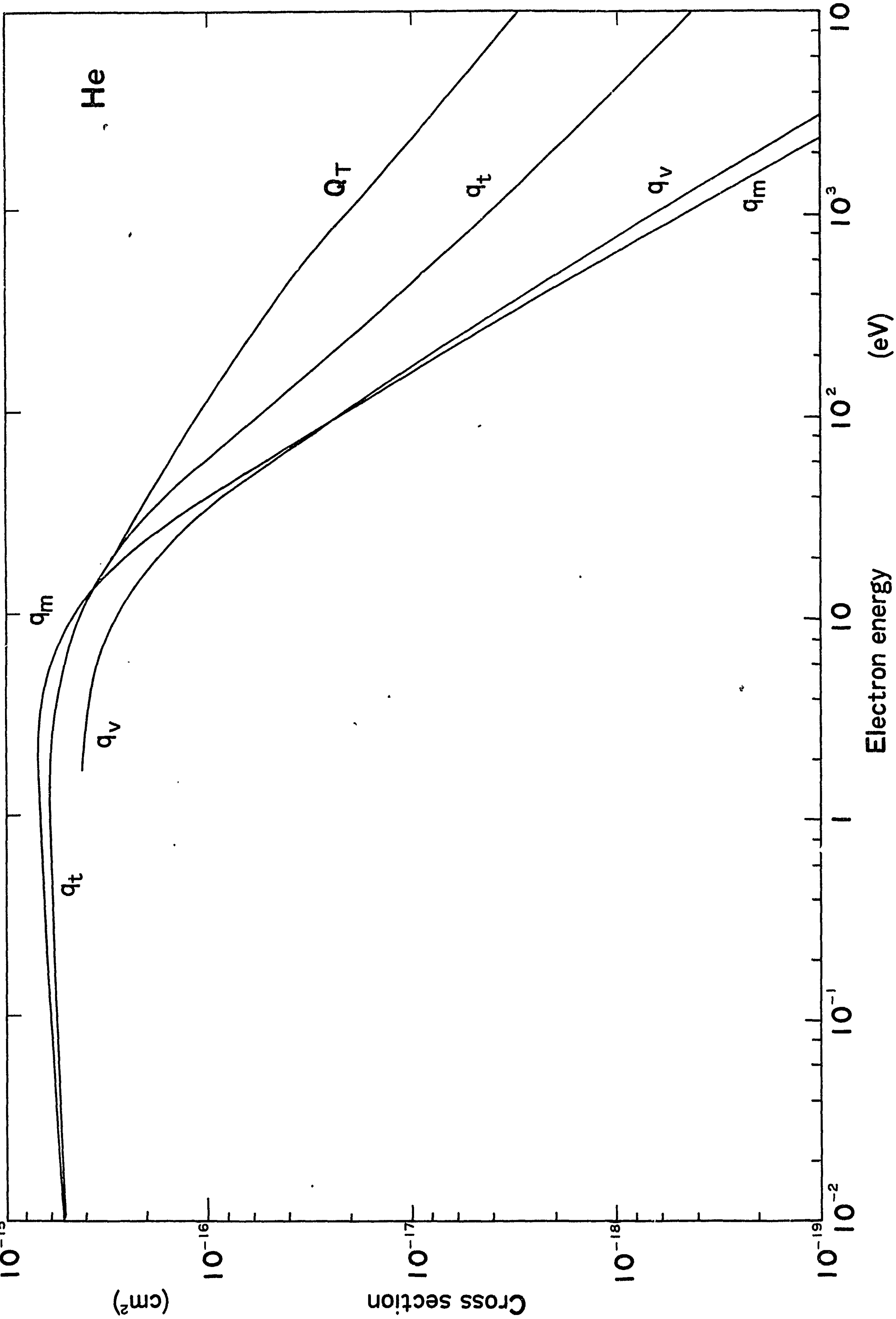
N2
Srivastava's values (1976)
Recalculated values from Srivastava's DCS values
Recalculated values from Srivastava's DCS(N2)/DCS(He) with Register's DCS(He) values
Present recommended values
qm (10^-16 cm^2)
10
5
0
25
50
75
100
Electron energy (eV)

Fig. IV



N_2
Swarm method
10% error
Experimental values
+ Bromberg ('70)
× Srivastava ('76)
▽ DuBois ('76)
△ Herrmann ('76)
⊙ Shyn ('80)
Theoretical values
⊞ Siegel ('78)
⊡ Choi ('79)
q_m (cm²)
10^{-14}
10^{-15}
10^{-16}
10^{-17}
10^{-1}
1
10
10^2
10^3
Electron energy (eV)

Recommended Values of Transport Cross Sections and Total Collision Cross Section



He
Q_T
q_t
q_v
q_m
10^{-2}
10^{-1}
1
10
10^2
10^3
10^4
Electron energy (eV)
10^{-15}
10^{-16}
10^{-17}
10^{-18}
10^{-19}
Cross section (cm^2)

Fig. 1

Table 1. He

E(ev)	$q_t(cm^2)$	$q_m(cm^2)$	$q_v(cm^2)$	$Q_T(cm^2)$	E(ev)	$q_t(cm^2)$	$q_m(cm^2)$	$q_v(cm^2)$	$Q_T(cm^2)$
0	5.03(-16)	5.03(-16)			100	5.6 (-17)	2.18(-17)	2.28(-17)	1.09(-16)
0.01	5.15(-16)	5.21(-16)			120	4.64(-17)	1.63(-17)	1.77(-17)	9.7 (-17)
0.03	5.37(-16)	5.46(-16)			150	3.58(-17)	1.13(-17)	1.28(-17)	8.5 (-17)
0.1	5.67(-16)	5.86(-16)			200	2.58(-17)	6.9 (-18)	8.0 (-18)	7.09(-17)
0.3	5.95(-16)	6.35(-16)			250	2.01(-17)	4.84(-18)	5.7 (-18)	6.11(-17)
1.0	6.16(-16)	6.85(-16)			300	1.63(-17)	3.50(-18)	4.3 (-18)	5.42(-17)
1.2	6.14(-16)	6.90(-16)		the	400	1.19(-17)	2.20(-18)	2.80(-18)	4.40(-17)
1.5	6.10(-16)	6.96(-16)		same	500	9.2 (-18)	1.54(-18)	1.95(-18)	3.75(-17)
2.0	6.02(-16)	6.99(-16)	4.2 (-16)	as	600	7.5 (-18)	1.13(-18)	1.49(-18)	3.26(-17)
2.5	5.91(-16)	6.94(-16)	4.1 (-16)	q_t	800	5.3 (-18)	6.8 (-19)	9.3 (-19)	2.55(-17)
3.0	5.80(-16)	6.90(-16)	4.0 (-16)		1000	4.23(-18)	4.72(-19)	6.8 (-19)	2.08(-17)
4.0	5.55(-16)	6.62(-16)	3.8 (-16)		1200	3.50(-18)	3.42(-19)	5.0 (-19)	1.85(-17)
5.0	5.35(-16)	6.31(-16)	3.65(-16)		1500	2.75(-18)	2.30(-19)	3.43(-19)	1.50(-17)
6.0	5.14(-16)	6.00(-16)	3.45(-16)		2000	2.12(-18)	1.39(-19)	2.12(-19)	1.19(-17)
8.0	4.76(-16)	5.35(-16)	3.1 (-16)		2500	1.68(-18)	9.3 (-20)	1.43(-19)	9.9 (-18)
10	4.40(-16)	4.72(-16)	2.8 (-16)		3000	1.40(-18)	6.7 (-20)	1.03(-19)	8.37(-18)
12	4.02(-16)	4.20(-16)	2.57(-16)		4000	1.07(-18)	4.01(-20)	6.4 (-20)	6.56(-18)
15	3.60(-16)	3.50(-16)	2.2 (-16)		5000	8.4 (-19)	2.69(-20)	4.3 (-20)	5.44(-18)
20	2.95(-16)	2.58(-16)	1.77(-16)	3.01(-16)	6000	7.0 (-19)	1.92(-20)	3.1 (-20)	4.65(-18)
25	2.51(-16)	1.95(-16)	1.40(-16)	2.61(-16)	8000	5.4 (-19)	1.14(-20)	1.89(-20)	3.64(-18)
30	2.10(-16)	1.51(-16)	1.15(-16)	2.33(-16)	10000	4.2 (-19)	7.6 (-21)	1.29(-20)	2.99(-18)
40	1.61(-16)	9.8 (-17)	8.3 (-17)	1.94(-16)					
50	1.24(-16)	7.02(-17)	6.2 (-17)	1.70(-16)					
60	1.02(-16)	5.04(-17)	4.9 (-17)	1.52(-16)					
80	7.2 (-17)	3.15(-17)	3.15(-17)	1.25(-16)					

He

Fig. 2

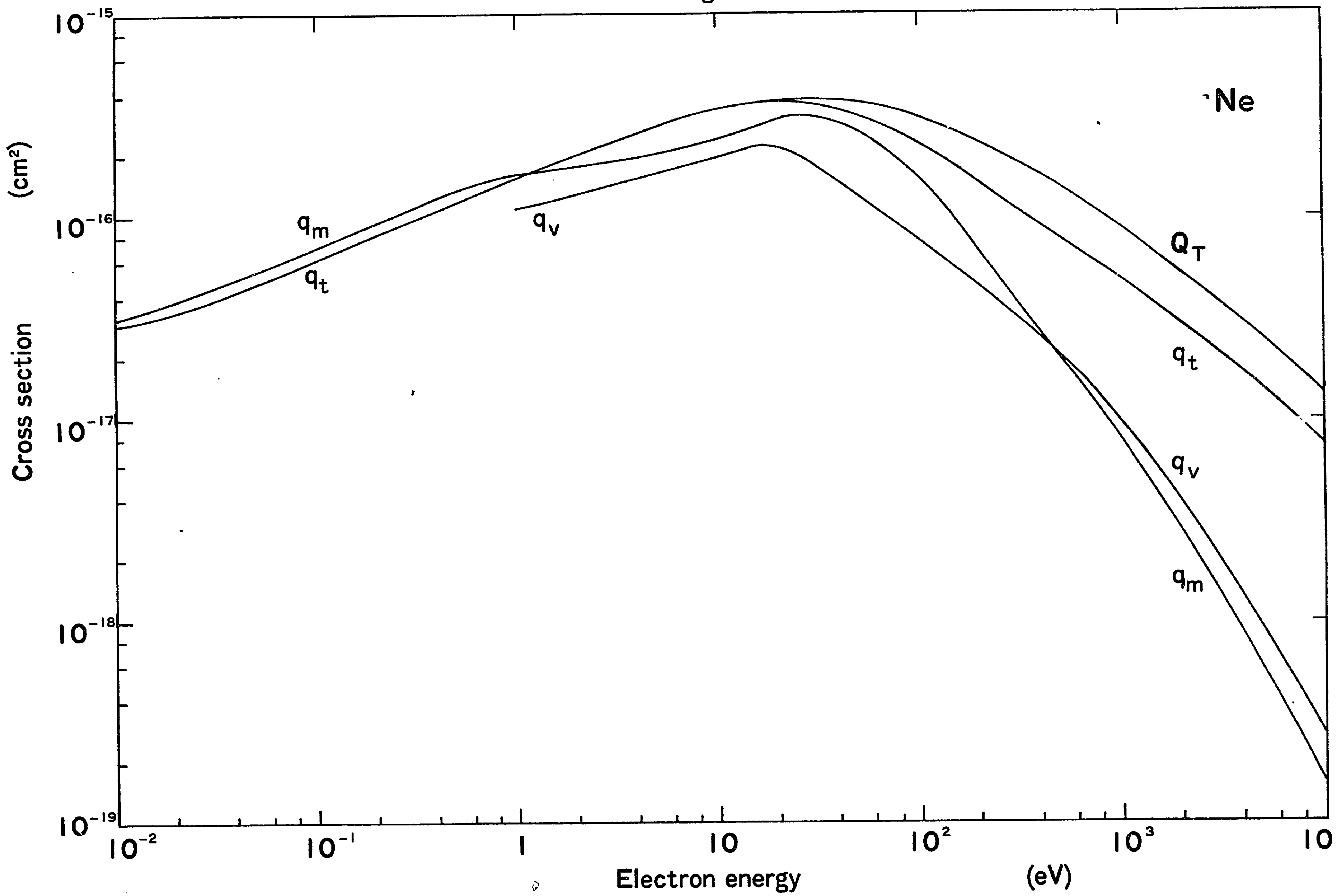
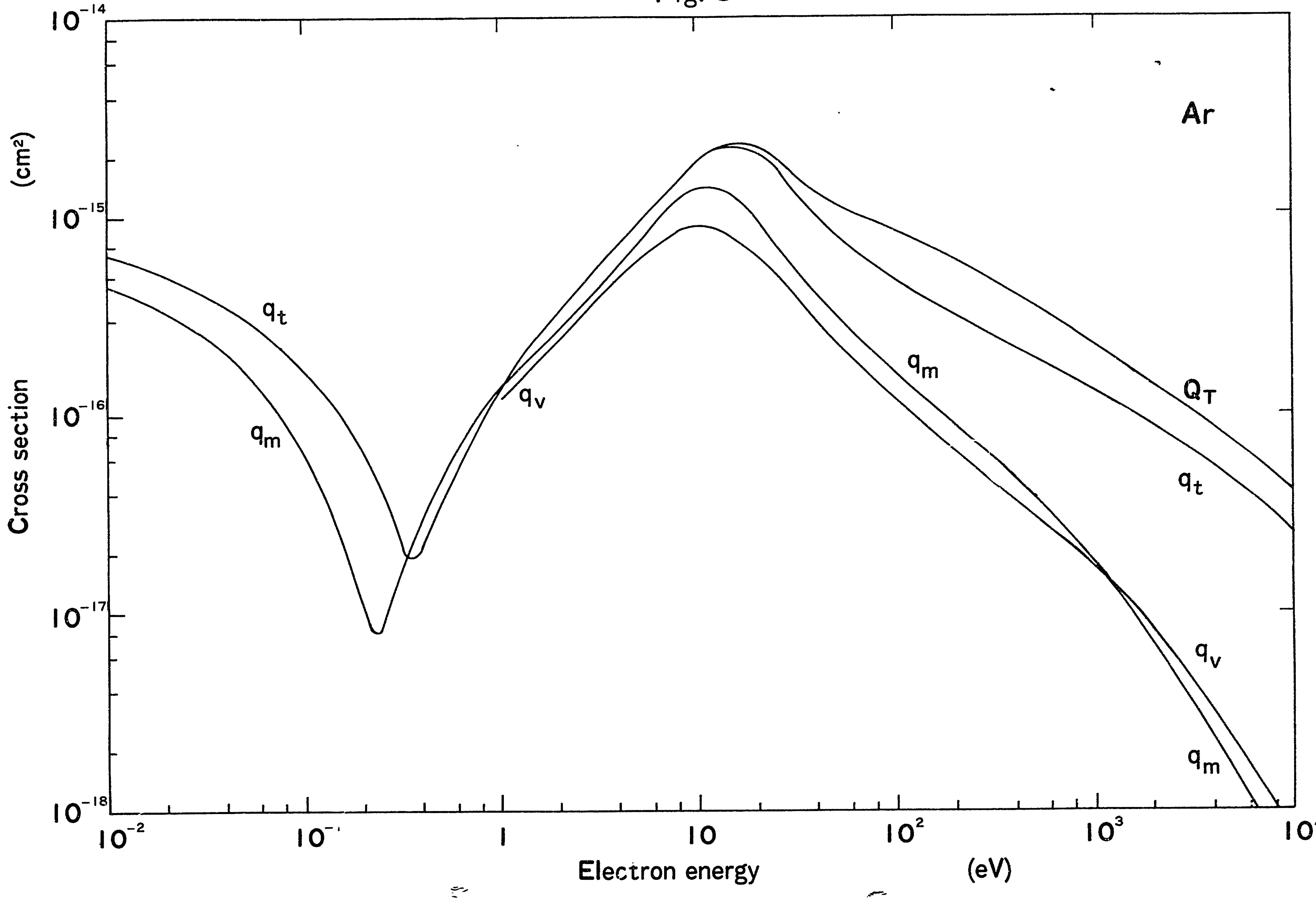

Ne
Q_T
q_t
q_v
q_m
10^{-15}
10^{-16}
10^{-17}
10^{-18}
10^{-19}
Cross section (cm²)
10^{-2}
10^{-1}
1
10
10^2
10^3
10^4
Electron energy (eV)

Table 2. Ne

E(ev)	$q_t(cm^2)$	$q_m(cm^2)$	$q_v(cm^2)$	$Q_T(cm^2)$	E(ev)	$q_t(cm^2)$	$q_m(cm^2)$	$q_v(cm^2)$	$Q_T(cm^2)$
0	1.61(-17)	1.61(-17)			60	2.89(-16)	2.30(-16)	1.11(-16)	3.52(-16)
0.001	2.1 (-17)	2.2 (-17)			80	2.53(-16)	1.86(-16)	9.0 (-17)	3.29(-16)
0.003	2.27(-17)	2.41(-17)			100	2.25(-16)	1.54(-16)	7.6 (-17)	3.08(-16)
0.01	2.87(-17)	3.14(-17)			120	2.00(-16)	1.30(-16)	6.6 (-17)	2.87(-16)
0.03	3.92(-17)	4.42(-17)			150	1.75(-16)	9.5 (-17)	5.5 (-17)	2.63(-16)
0.1	6.13(-17)	6.93(-17)		the	200	1.45(-16)	6.5 (-17)	4.4 (-17)	2.31(-16)
0.3	9.7 (-17)	1.08(-16)		same	250	1.25(-16)	4.9 (-17)	3.7 (-17)	2.06(-16)
1	1.57(-16)	1.59(-16)	1.10(-16)	as	300	1.09(-16)	3.9 (-17)	3.1 (-17)	1.86(-16)
1.2	1.67(-16)	1.66(-16)	1.15(-16)	q_t	400	9.1 (-17)	2.65(-17)	2.4 (-17)	1.57(-16)
1.5	1.82(-16)	1.72(-16)	1.20(-16)		500	7.8 (-17)	2.0 (-17)	1.95(-17)	1.36(-16)
2	2.02(-16)	1.80(-16)	1.29(-16)		600	6.9 (-17)	1.6 (-17)	1.6 (-17)	1.20(-16)
2.5	2.18(-16)	1.85(-16)	1.37(-16)		800	5.6 (-17)	1.05(-17)	1.18(-17)	9.8 (-17)
3	2.31(-16)	1.89(-16)	1.43(-16)		1000	4.8 (-17)	7.7 (-18)	9.2 (-18)	8.3 (-17)
4	2.54(-16)	1.96(-16)	1.54(-16)		1200	4.2 (-17)	6.0 (-18)	7.3 (-18)	7.2 (-17)
5	2.74(-16)	2.05(-16)	1.63(-16)		1500	3.55(-17)	4.2 (-18)	5.5 (-18)	6.1 (-17)
6	2.89(-16)	2.12(-16)	1.72(-16)		2000	2.9 (-17)	2.6 (-18)	3.6 (-18)	5.0 (-17)
8	3.18(-16)	2.26(-16)	1.85(-16)		2500	2.45(-17)	1.82(-18)	2.65(-18)	4.2 (-17)
10	3.40(-16)	2.40(-16)	1.95(-16)		3000	2.13(-17)	1.34(-18)	1.96(-18)	3.65(-17)
12	3.54(-16)	2.52(-16)	2.05(-16)		4000	1.66(-17)	8.2 (-19)	1.22(-18)	2.89(-17)
15	3.68(-16)	2.72(-16)	2.17(-16)	3.68(-16)	5000	1.34(-17)	5.5 (-19)	8.3 (-19)	2.36(-17)
16	3.71(-16)	2.80(-16)	2.20(-16)	3.71(-16)	6000	1.15(-17)	4.0 (-19)	6.2 (-19)	2.03(-17)
18	3.74(-16)	2.89(-16)	2.24(-16)	3.77(-16)	8000	9.0 (-18)	2.4 (-19)	3.83(-19)	1.59(-17)
20	3.75(-16)	2.95(-16)	2.20(-16)	3.80(-16)	10000	7.3 (-18)	1.6 (-19)	2.65(-19)	1.30(-17)
25	3.68(-16)	3.06(-16)	2.00(-16)	3.80(-16)					
30	3.57(-16)	3.04(-16)	1.79(-16)	3.78(-16)					
40	3.33(-16)	2.81(-16)	1.48(-16)	3.71(-16)					
50	3.12(-16)	2.55(-16)	1.25(-16)	3.64(-16)					

Ne

Fig. 3



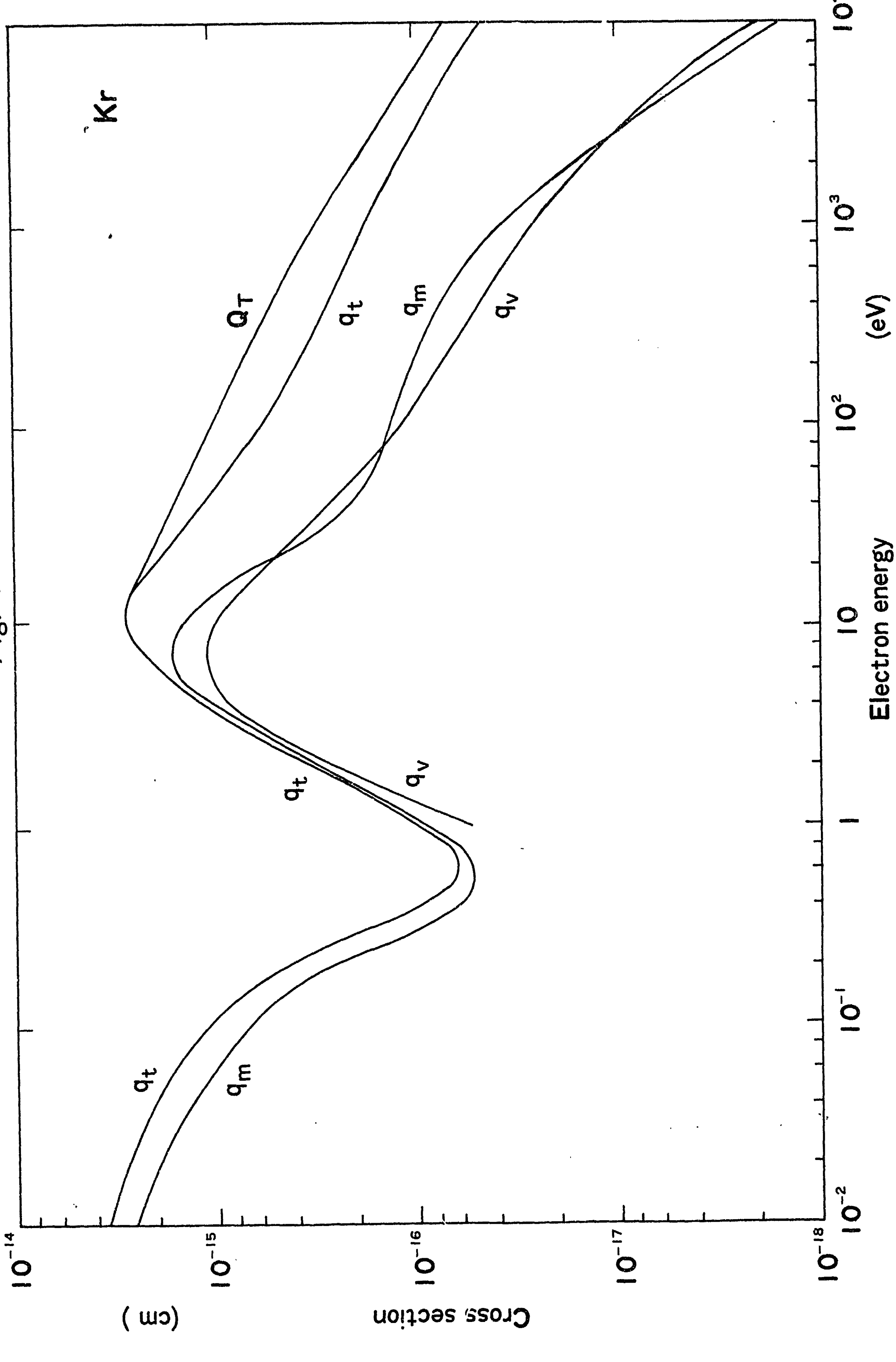
Ar
Cross section (cm²)
Electron energy (eV)
q_t
q_m
q_v
Q_T
10^{-14}
10^{-15}
10^{-16}
10^{-17}
10^{-18}
10^{-2}
10^{-1}
1
10
10^{2}
10^{3}
10^{4}

Table 3. Ar

E(ev)	$q_t(cm^2)$	$q_m(cm^2)$	$q_v(cm^2)$	$Q_T(cm^2)$	E(ev)	$q_t(cm^2)$	$q_m(cm^2)$	$q_v(cm^2)$	$Q_T(cm^2)$
0	1 (-15)	1 (-15)							
0.01	6.5 (-16)	4.5 (-16)			100	4.75(-16)	1.62(-16)	1.17(-16)	8.2 (-16)
0.03	4.1 (-16)	2.57(-16)			120	4.35(-16)	1.36(-16)	9.9 (-17)	7.5 (-16)
0.1	1.63(-16)	6.2 (-17)			150	3.75(-16)	1.10(-16)	8.1 (-17)	6.9 (-16)
0.3	2.3 (-17)	1.51(-17)		the	200	3.10(-16)	8.7 (-17)	6.3 (-17)	5.9 (-16)
1	1.55(-16)	1.37(-16)	1.2 (-16)	same	250	2.78(-16)	7.1 (-17)	5.3 (-17)	5.2 (-16)
1.2	1.88(-16)	1.66(-16)	1.45(-16)	as	300	2.50(-16)	6.0 (-17)	4.5 (-17)	4.7 (-16)
1.5	2.42(-16)	2.05(-16)	1.8 (-16)	q_t	400	2.12(-16)	4.6 (-17)	3.6 (-17)	4.0 (-16)
2	3.35(-16)	2.70(-16)	2.45(-16)		500	1.89(-16)	3.7 (-17)	3.0 (-17)	3.5 (-16)
2.5	4.25(-16)	3.43(-16)	3.05(-16)		600	1.70(-16)	3.1 (-17)	2.6 (-17)	3.1 (-16)
3	5.2 (-16)	4.20(-16)	3.7 (-16)		800	1.46(-16)	2.25(-17)	2.0 (-17)	2.55(-16)
4	7.15(-16)	5.70(-16)	4.8 (-16)		1000	1.28(-16)	1.7 (-17)	1.68(-17)	2.23(-16)
5	9.1 (-16)	7.5 (-16)	6.0 (-16)		1200	1.15(-16)	1.35(-17)	1.4 (-17)	1.97(-16)
6	1.10(-15)	9.0 (-16)	6.9 (-16)		1500	1.00(-16)	9.8 (-18)	1.1 (-17)	1.69(-16)
8	1.54(-15)	1.20(-15)	8.3 (-16)		2000	8.4 (-17)	6.5 (-18)	7.8 (-18)	1.38(-16)
10	1.85(-15)	1.40(-15)	9.0 (-16)	1.85(-15)	2500	7.2 (-17)	4.65(-18)	5.9 (-18)	1.20(-16)
12	2.10(-15)	1.39(-15)	8.7 (-16)	2.10(-15)	3000	6.4 (-17)	3.5 (-18)	4.6 (-18)	1.05(-16)
15	2.23(-15)	1.24(-15)	7.8 (-16)	2.25(-15)	4000	5.3 (-17)	2.20(-18)	3.1 (-18)	8.4 (-17)
20	2.07(-15)	9.2 (-16)	6.2 (-16)	2.19(-15)	5000	4.5 (-17)	1.52(-18)	2.1 (-18)	7.1 (-17)
25	1.70(-15)	6.9 (-16)	5.0 (-16)	1.90(-15)	6000	3.95(-17)	1.13(-18)	1.68(-18)	6.2 (-17)
30	1.37(-15)	5.6 (-16)	4.1 (-16)	1.63(-15)	8000	3.1 (-17)	7.0 (-19)	1.06(-18)	4.9 (-17)
40	9.7 (-16)	4.1 (-16)	2.9 (-16)	1.29(-15)	10000	2.57(-17)	4.9 (-19)	7.6 (-19)	4.1 (-17)
50	7.7 (-16)	3.15(-16)	2.3 (-16)	1.11(-15)					
60	6.7 (-16)	2.65(-16)	1.92(-16)	1.02(-15)					
80	5.4 (-16)	2.0 (-16)	1.42(-16)	9.0 (-16)					

Ar

Fig. 4



Kr
Q_T
q_t
q_m
q_v
q_t
q_v
q_t
q_m
10^{-14}
10^{-15}
10^{-16}
10^{-17}
10^{-18}
Cross section (cm)
10^{-2}
10^{-1}
1
10
10^{2}
10^{3}
10^{4}
Electron energy (eV)

Table 4. Kr

E(ev)	$q_t(cm^2)$	$q_m(cm^2)$	$q_v(cm^2)$	$Q_T(cm^2)$	E(ev)	$q_t(cm^2)$	$q_m(cm^2)$	$q_v(cm^2)$	$Q_T(cm^2)$
0	3.1 (-15)	3.1 (-15)			50	9.9 (-16)	1.8 (-16)	2.15(-16)	1.45(-15)
0.001		3.0 (-15)			60	8.6 (-16)	1.65(-16)	1.8 (-16)	1.32(-15)
0.003		2.95(-15)			80	6.9 (-16)	1.47(-16)	1.42(-16)	1.16(-15)
0.01		2.6 (-15)			100	5.8 (-16)	1.36(-16)	1.20(-16)	1.03(-15)
0.03		1.6 (-15)			120	5.2 (-16)	1.26(-16)	1.05(-16)	9.4 (-16)
0.1		6.80(-16)		the	150	4.5 (-16)	1.16(-16)	9.1 (-17)	8.4 (-16)
0.3		9.8 (-17)		same	200	3.8 (-16)	1.05(-16)	7.5 (-17)	7.4 (-16)
1	1.0 (-16)	9.6 (-17)	5.7 (-17)	as	250	3.4 (-16)	9.6 (-17)	6.5 (-17)	6.6 (-16)
1.2	1.38(-16)	1.3 (-16)	8.5 (-17)	q_t	300	3.1 (-16)	8.7 (-17)	5.8 (-17)	6.0 (-16)
1.5	2.05(-16)	1.9 (-16)	1.39(-16)		400	2.70(-16)	7.4 (-17)	4.8 (-17)	5.2 (-16)
2	3.4 (-16)	3.1 (-16)	2.65(-16)		500	2.40(-16)	6.4 (-17)	4.2 (-17)	4.6 (-16)
2.5	5.3 (-16)	4.6 (-16)	4.2 (-16)		600	2.20(-16)	5.6 (-17)	3.7 (-17)	4.2 (-16)
3	7.4 (-16)	6.3 (-16)	5.8 (-16)		800	1.90(-16)	4.5 (-17)	2.95(-17)	3.6 (-16)
4	1.13(-15)	1.00(-15)	8.6 (-16)		1000	1.71(-16)	3.6 (-17)	2.5 (-17)	3.05(-16)
5	1.52(-15)	1.37(-15)	9.8 (-16)		1200	1.54(-16)	3.0 (-17)	2.15(-17)	2.7 (-16)
6	1.90(-15)	1.58(-15)	1.05(-15)		1500	1.37(-16)	2.3 (-17)	1.8 (-17)	2.35(-16)
8	2.45(-15)	1.62(-15)	1.1 (-15)		2000	1.19(-16)	1.6 (-17)	1.39(-17)	1.97(-16)
10	2.73(-15)	1.47(-15)	1.02(-15)	2.73(-15)	2500	1.06(-16)	1.20(-17)	1.13(-17)	1.73(-16)
12	2.79(-15)	1.25(-15)	9.1 (-16)	2.80(-15)	3000	9.7 (-17)	9.1 (-18)	9.3 (-18)	1.54(-16)
15	2.55(-15)	9.4 (-16)	7.5 (-16)	2.60(-15)	4000	8.3 (-17)	6.0 (-18)	6.8 (-18)	1.29(-16)
20	2.05(-15)	6.0 (-16)	5.5 (-16)	2.24(-15)	5000	7.2 (-17)	4.3 (-18)	5.2 (-18)	1.11(-16)
25	1.69(-15)	4.1 (-16)	4.4 (-16)	1.98(-15)	6000	6.5 (-17)	3.2 (-18)	4.2 (-18)	9.9 (-17)
30	1.48(-15)	3.0 (-16)	3.6 (-16)	1.85(-15)	8000	5.5 (-17)	2.0 (-18)	2.7 (-18)	8.2 (-17)
40	1.17(-15)	2.2 (-16)	2.7 (-16)	1.60(-15)	10000	4.7 (-17)	1.49(-18)	2.0 (-18)	7.0 (-17)

Kr

Fig. 5

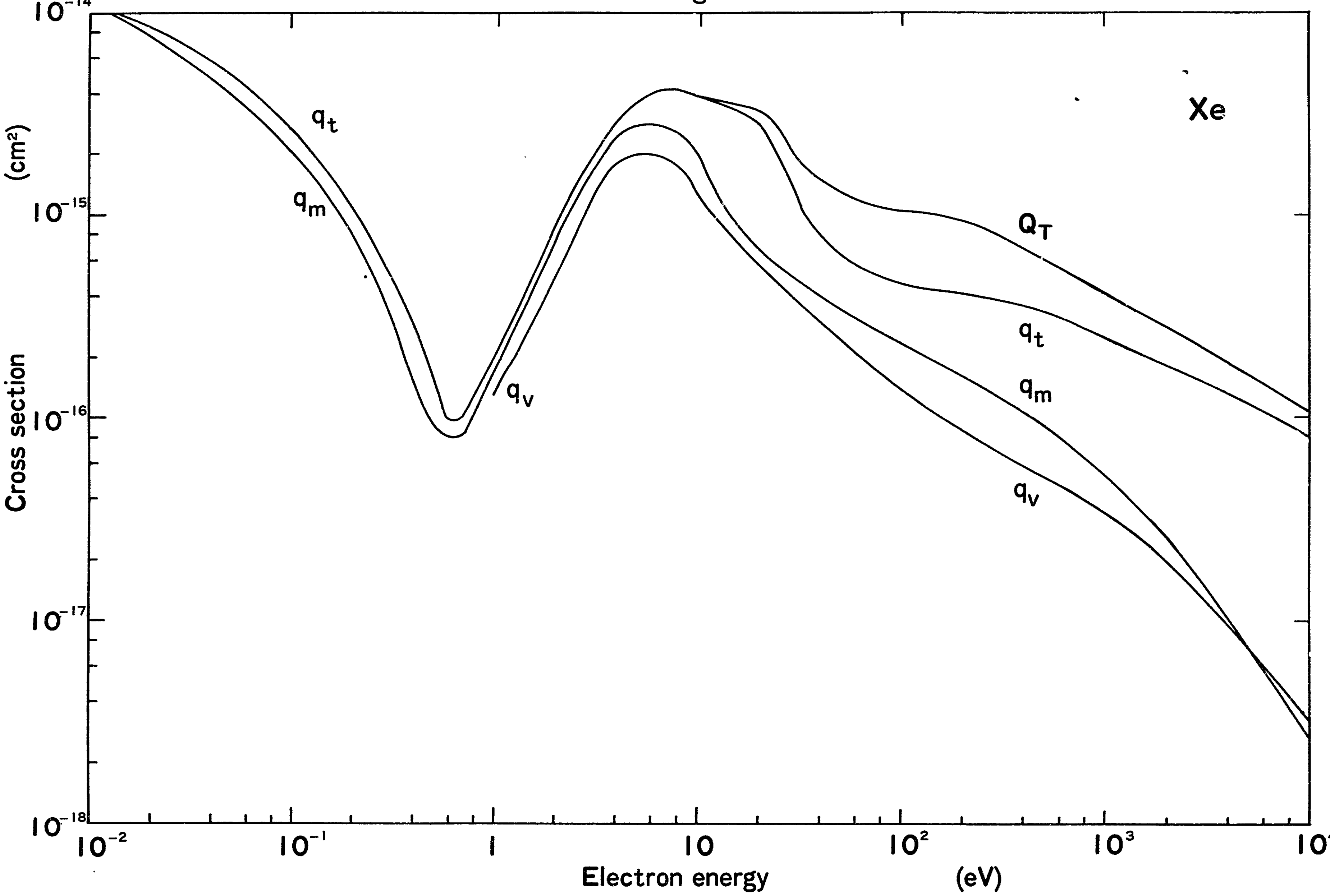
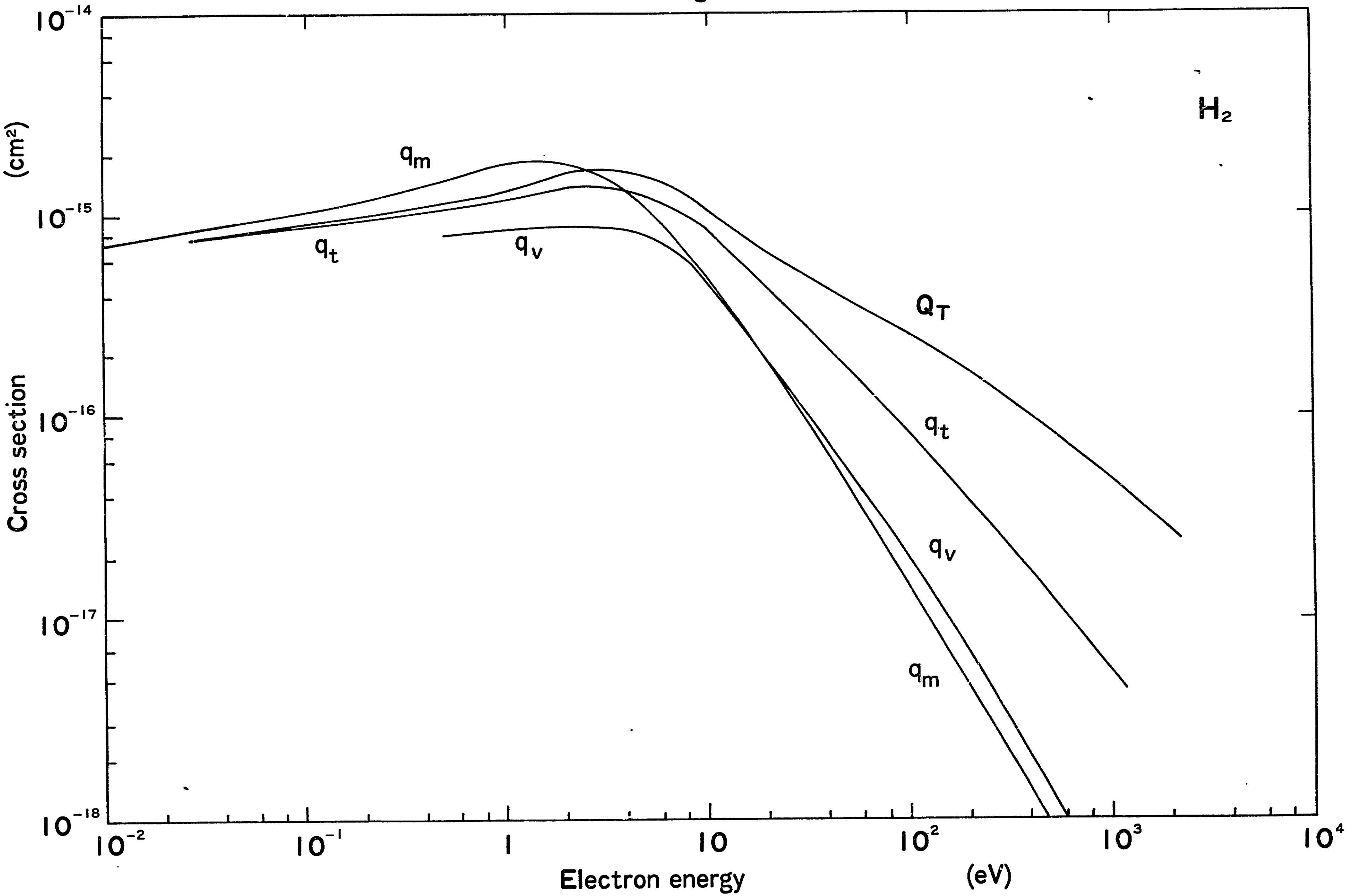

Xe
Q_T
q_t
q_m
q_v
Cross section (cm²)
10^{-14}
10^{-15}
10^{-16}
10^{-17}
10^{-18}
10^{-2}
10^{-1}
1
10
10^2
10^3
10^4
Electron energy (eV)

Table 5. X_e

E(ev)	$q_t(cm^2)$	$q_m(cm^2)$	$q_v(cm^2)$	$Q_T(cm^2)$	E(ev)	$q_t(cm^2)$	$q_m(cm^2)$	$q_v(cm^2)$	$Q_T(cm^2)$
0	1.7 (-14)	1.7 (-14)			100	4.6 (-16)	2.4 (-16)	1.4 (-16)	1.07(-15)
0.001	1.4 (-14)	1.4 (-14)			120	4.5 (-16)	2.15(-16)	1.25(-16)	1.03(-15)
0.003	1.3 (-14)	1.3 (-14)			150	4.3 (-16)	1.9 (-16)	1.05(-16)	1.00(-15)
0.01	1.2 (-14)	1.16(-14)		the	200	4.1 (-16)	1.6 (-16)	8.7 (-17)	9.5 (-16)
0.03	6.8 (-15)	6.13(-15)		same	250	3.95(-16)	1.42(-16)	7.6 (-17)	8.7 (-16)
0.1	2.65(-15)	2.04(-15)		as	300	3.85(-16)	1.3 (-16)	7.0 (-17)	8.1 (-16)
0.3	5.55(-16)	3.3 (-16)		q_t	400	3.6 (-16)	1.08(-16)	5.9 (-17)	7.1 (-16)
1	2.0 (-16)	1.7 (-16)	1.3 (-16)		500	3.35(-16)	9.2 (-17)	5.2 (-17)	6.4 (-16)
1.2	3.0 (-16)	2.55(-16)	1.85(-16)		600	3.1 (-16)	8.1 (-17)	4.7 (-17)	5.8 (-16)
1.5	4.8 (-16)	4.0 (-16)	2.8 (-16)		800	2.78(-16)	6.4 (-17)	4.0 (-17)	4.95(-16)
2	8.9 (-16)	7.5 (-16)	5.0 (-16)		1000	2.55(-16)	5.3 (-17)	3.4 (-17)	4.35(-16)
2.5	1.33(-15)	1.15(-15)	8.3 (-16)		1200	2.36(-16)	4.5 (-17)	3.0 (-17)	3.9 (-16)
3	1.84(-15)	1.6 (-15)	1.2 (-15)		1500	2.11(-16)	3.55(-17)	2.5 (-17)	3.4 (-16)
4	2.90(-15)	2.45(-15)	1.8 (-15)		2000	1.84(-16)	2.5 (-17)	2.0 (-17)	2.9 (-16)
5	3.62(-15)	2.8 (-15)	2.0 (-15)		2500	1.66(-16)	1.9 (-17)	1.65(-17)	2.53(-16)
6	3.98(-15)	2.8 (-15)	2.0 (-15)		3000	1.51(-16)	1.5 (-17)	1.35(-17)	2.27(-16)
8	4.12(-15)	2.6 (-15)	1.7 (-15)		4000	1.33(-16)	1.0 (-17)	1.0 (-17)	1.92(-16)
10	3.87(-15)	2.0 (-15)	1.25(-15)	3.88(-15)	5000	1.18(-16)	7.5 (-18)	7.7 (-18)	1.69(-16)
12	3.71(-15)	1.35(-15)	1.03(-15)	3.74(-15)	6000	1.07(-16)	5.7 (-18)	6.2 (-18)	1.52(-16)
15	3.40(-15)	9.5 (-16)	8.0 (-16)	3.56(-15)	8000	9.3 (-17)	3.8 (-18)	4.4 (-18)	1.28(-16)
20	2.88(-15)	7.0 (-16)	5.9 (-16)	3.33(-15)	10000	8.2 (-17)	2.7 (-18)	3.3 (-18)	1.12(-16)
25	2.00(-15)	5.9 (-16)	4.7 (-16)	2.70(-15)					
30	1.33(-15)	5.1 (-16)	4.0 (-16)	1.98(-15)					
40	8.14(-16)	4.2 (-16)	3.05(-16)	1.49(-15)					
50	6.45(-16)	3.6 (-16)	2.5 (-16)	1.30(-15)					
60	5.66(-16)	3.2 (-16)	2.1 (-16)	1.20(-15)					
80	5.00(-16)	2.7 (-16)	1.7 (-16)	1.11(-15)					

Xe

Fig. 6



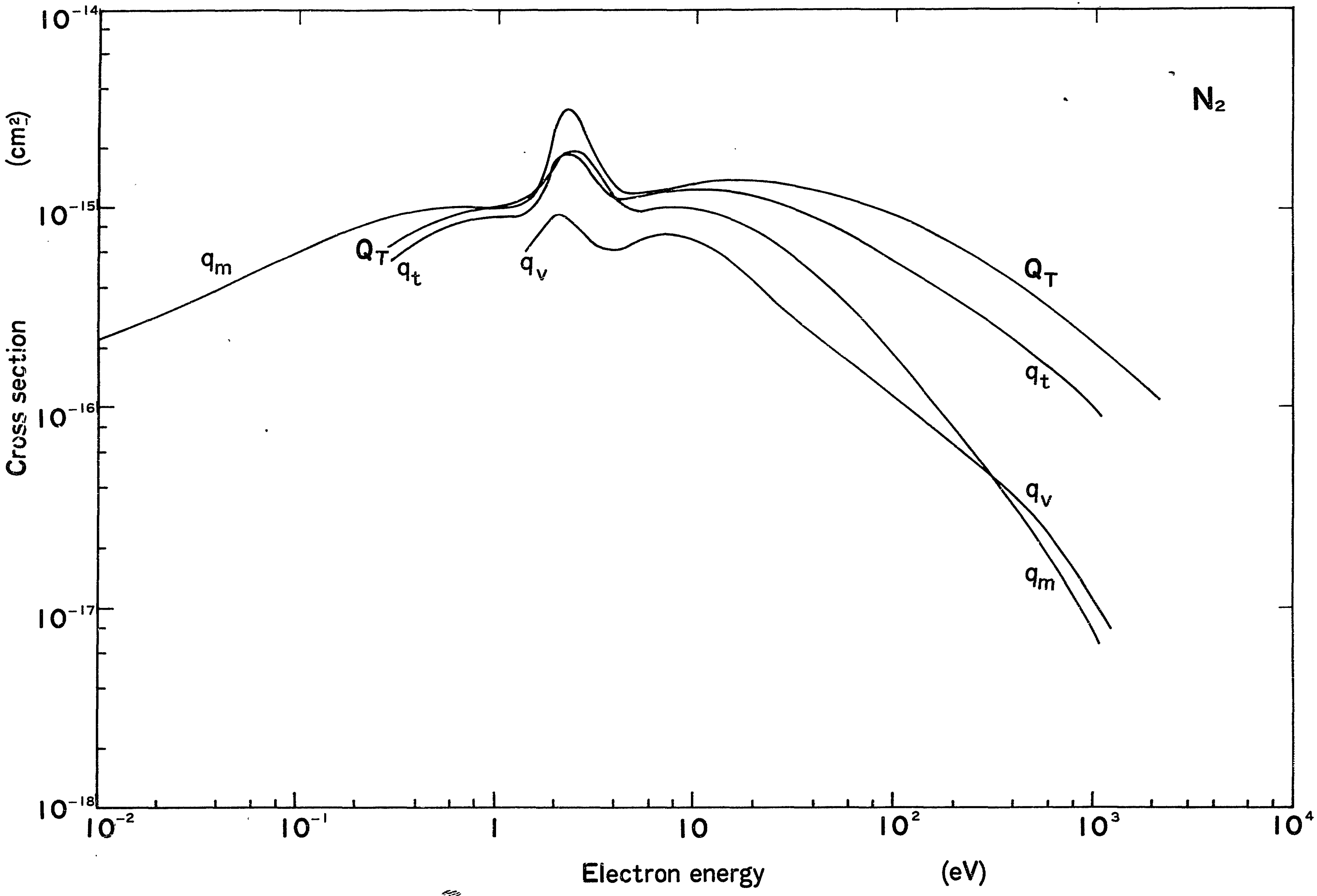
H₂
Q_T
q_t
q_v
q_m
Cross section (cm²)
Electron energy (eV)
10^{-14}
10^{-15}
10^{-16}
10^{-17}
10^{-18}
10^{-2}
10^{-1}
1
10
10^{2}
10^{3}
10^{4}

Table 6. H_2

E(ev)	$q_t(cm^2)$	$q_m(cm^2)$	$q_v(cm^2)$	$Q_T(cm^2)$	E(ev)	$q_t(cm^2)$	$q_m(cm^2)$	$q_v(cm^2)$	$Q_T(cm^2)$
0	6.4 (-16)	6.4 (-16)			100	7.9 (-17)	1.32(-17)	1.92(-17)	2.52(-16)
0.001		6.55(-16)			120	6.5 (-17)	1.04(-17)	1.47(-17)	2.25(-16)
0.003		6.75(-16)			150	5.1 (-17)	7.3 (-18)	1.07(-17)	2.00(-16)
0.01		7.3 (-16)			200	3.7 (-17)	4.5 (-18)	6.6 (-18)	1.62(-16)
0.03	7.8 (-16)	8.5 (-16)		7.8 (-16)	250	2.85(-17)	3.05(-18)	4.5 (-18)	1.38(-16)
0.1	9.1 (-16)	1.05(-15)		9.2 (-16)	300	2.3 (-17)	2.2 (-18)	3.3 (-18)	1.21(-16)
0.3	1.00(-15)	1.30(-15)		1.03(-15)	400	1.62(-17)	1.35(-18)	2.0 (-18)	9.7 (-17)
1	1.20(-15)	1.74(-15)	8.3 (-16)	1.32(-15)	500	1.22(-17)	9.1 (-19)	1.36(-18)	8.3 (-17)
1.2	1.23(-15)	1.80(-15)	8.4 (-16)	1.39(-15)	600	9.9 (-18)	6.6 (-19)	1.00(-18)	7.1 (-17)
1.5	1.28(-15)	1.82(-15)	8.5 (-16)	1.47(-15)	800	6.9 (-18)	4.0 (-19)	6.1 (-19)	5.7 (-17)
2	1.35(-15)	1.80(-15)	8.6 (-16)	1.57(-15)	1000	5.3 (-18)	2.7 (-19)	4.2 (-19)	4.7 (-17)
2.5	1.38(-15)	1.69(-15)	8.8 (-16)	1.65(-15)	1200				4.0 (-17)
3	1.38(-15)	1.54(-15)	8.7 (-16)	1.70(-15)	1500				3.35(-17)
4	1.33(-15)	1.30(-15)	8.4 (-16)	1.63(-15)	2000				2.65(-17)
5	1.22(-15)	1.06(-15)	8.0 (-16)	1.52(-15)					
6	1.10(-15)	8.9 (-16)	7.3 (-16)	1.42(-15)					
8	9.5 (-16)	6.5 (-16)	5.8 (-16)	1.22(-15)					
10	8.2 (-16)	5.0 (-16)	4.7 (-16)	1.04(-15)					
12	7.0 (-16)	3.9 (-16)	3.8 (-16)	9.4 (-16)					
15	5.7 (-16)	2.9 (-16)	2.9 (-16)	8.0 (-16)					
20	4.3 (-16)	1.88(-16)	1.95(-16)	6.5 (-16)					
25	3.4 (-16)	1.35(-16)	1.40(-16)	5.5 (-16)					
30	2.8 (-16)	1.00(-16)	1.07(-16)	4.9 (-16)					
40	2.05(-16)	6.2 (-17)	7.0 (-17)	4.2 (-16)					
50	1.65(-16)	4.4 (-17)	5.1 (-17)	3.7 (-16)					
60	1.35(-16)	3.1 (-17)	4.0 (-17)	3.3 (-16)					
80	1.00(-16)	1.95(-17)	2.66(-17)	2.8 (-16)					

H_2

Fig. 7



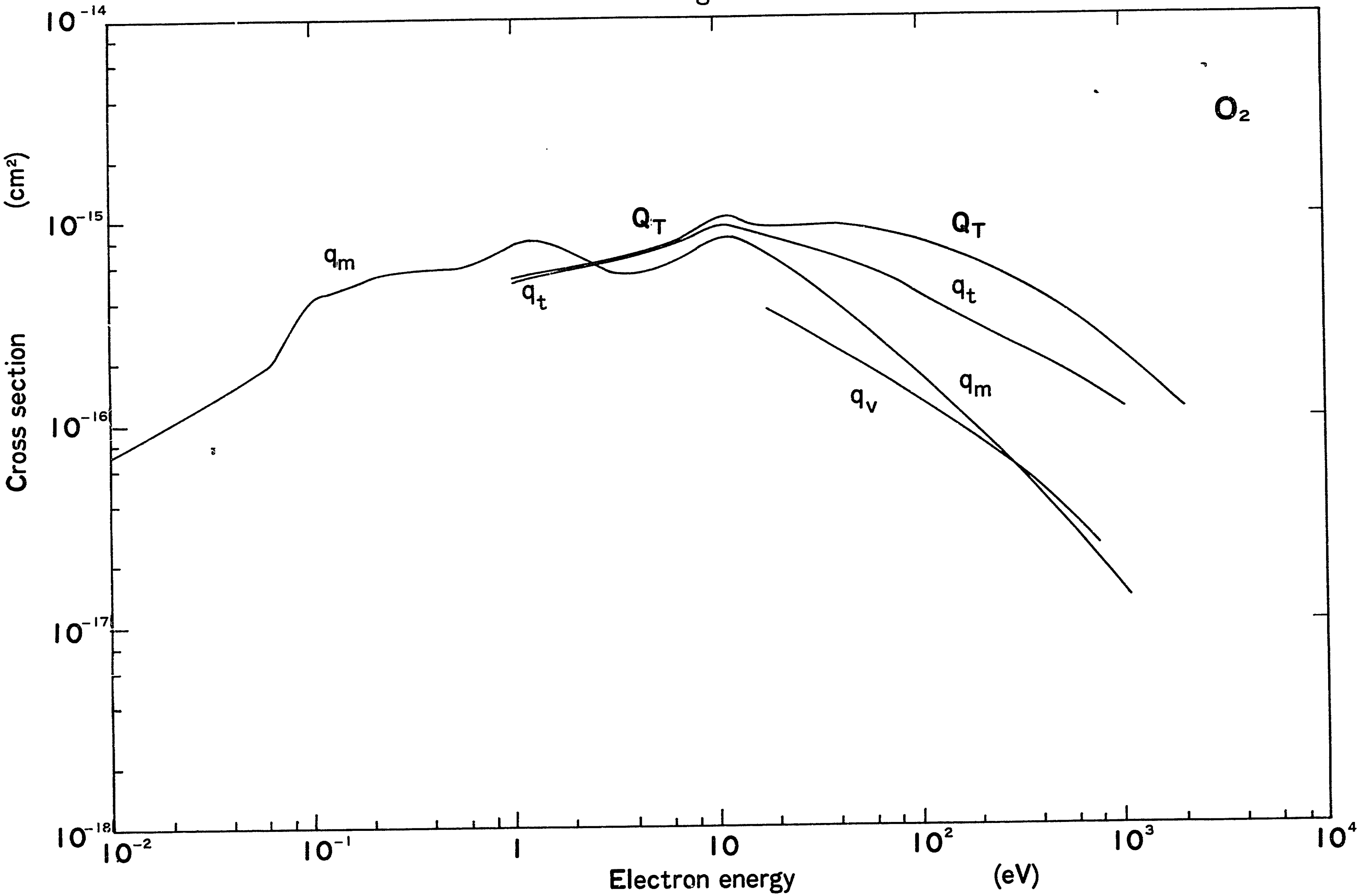
N₂
Q_T
q_t
q_v
q_m
Cross section (cm²)
Electron energy (eV)
10⁻¹⁴
10⁻¹⁵
10⁻¹⁶
10⁻¹⁷
10⁻¹⁸
10⁻²
10⁻¹
1
10
10²
10³
10⁴

Table 7. N_2

E(ev)	$q_t(cm^2)$	$q_m(cm^2)$	$q_v(cm^2)$	$Q_T(cm^2)$	E(ev)	$q_t(cm^2)$	$q_m(cm^2)$	$q_v(cm^2)$	$Q_T(cm^2)$
0	1.10(-16)	1.10(-16)			60	7.2 (-16)	3.2 (-16)	1.7 (-16)	1.08(-15)
0.001		1.36(-16)			80	6.1 (-16)	2.35(-16)	1.33(-16)	9.9 (-16)
0.003		1.62(-16)			100	5.5 (-16)	1.80(-16)	1.12(-16)	9.1 (-16)
0.01		2.19(-16)			120	4.8 (-16)	1.46(-16)	9.7 (-17)	8.5 (-16)
0.03		3.40(-16)			150	4.2 (-16)	1.13(-16)	8.2 (-17)	7.5 (-16)
0.1		5.95(-16)			200	3.5 (-16)	8.0 (-17)	6.5 (-17)	6.5 (-16)
0.3	5.5 (-16)	9.0 (-16)		6.5 (-16)	250	3.05(-16)	6.0 (-17)	5.4 (-17)	5.8 (-16)
1	9.0 (-16)	1.00(-15)		1.00(-15)	300	2.6 (-16)	4.8 (-17)	4.7 (-17)	5.1 (-16)
1.2	9.1 (-16)	1.03(-15)		1.02(-15)	400	2.15(-16)	3.3 (-17)	3.6 (-17)	4.3 (-16)
1.5	9.7 (-16)	1.17(-15)	6.4 (-16)	1.12(-15)	500	1.85(-16)	2.3 (-17)	2.8 (-17)	3.7 (-16)
2	1.75(-15)	1.70(-15)	9.2 (-16)	2.5 (-15)	600	1.60(-16)	1.75(-17)	2.3 (-17)	3.2 (-16)
2.5	1.9 (-15)	1.95(-15)	8.0 (-16)	2.9 (-15)	800	1.25(-16)	1.1 (-17)	1.6 (-17)	2.6 (-16)
3	1.5 (-15)	1.7 (-15)	6.8 (-16)	2.0 (-15)	1000	1.00(-16)	7.7 (-18)	1.1 (-17)	2.1 (-16)
4	1.11(-15)	1.1 (-15)	6.1 (-16)	1.3 (-15)	1200				1.85(-16)
5	1.12(-15)	9.5 (-16)	6.7 (-16)	1.18(-15)	1500				1.50(-16)
6	1.18(-15)	9.8 (-16)	7.2 (-16)	1.20(-15)	2000				1.16(-16)
8	1.22(-15)	1.02(-15)	7.3 (-16)	1.24(-15)					
10	1.20(-15)	9.9 (-16)	6.8 (-16)	1.30(-15)					
12	1.19(-15)	9.5 (-16)	6.3 (-16)	1.34(-15)					
15	1.18(-15)	8.7 (-16)	5.4 (-16)	1.34(-15)					
20	1.13(-15)	7.6 (-16)	4.3 (-16)	1.32(-15)					
25	1.04(-15)	6.7 (-16)	3.5 (-16)	1.31(-15)					
30	9.8 (-16)	5.9 (-16)	3.0 (-16)	1.28(-15)					
40	8.8 (-16)	4.7 (-16)	2.3 (-16)	1.21(-15)					
50	8.2 (-16)	3.8 (-16)	1.95(-16)	1.13(-15)					

N_2

Fig. 8



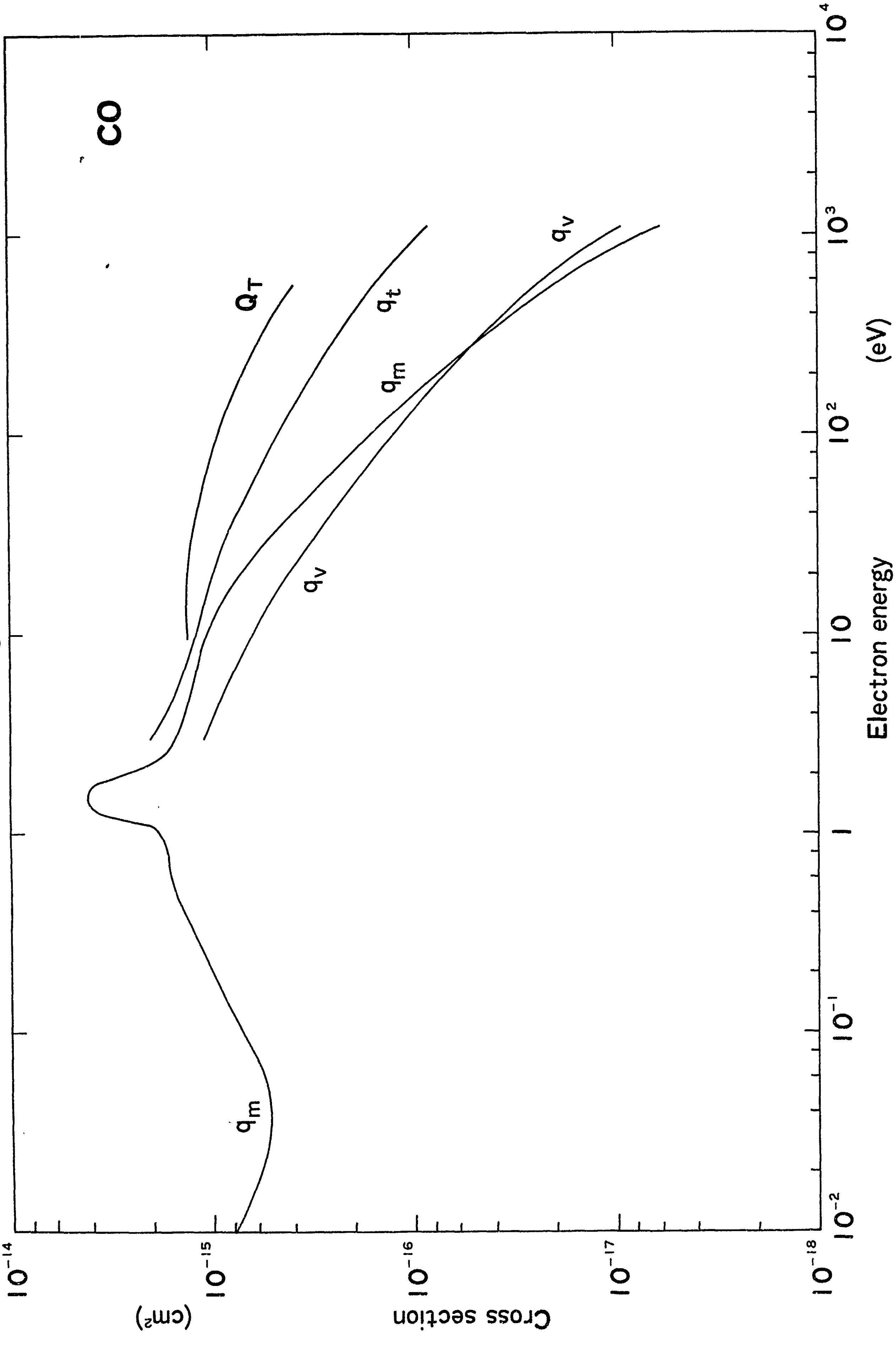
O_2
Q_T
q_t
q_m
q_v
Cross section (cm²)
10^{-14}
10^{-15}
10^{-16}
10^{-17}
10^{-18}
10^{-2}
10^{-1}
1
10
10^{2}
10^{3}
10^{4}
Electron energy (eV)

Table 8. O_2

E(ev)	$q_t(cm^2)$	$q_m(cm^2)$	$q_v(cm^2)$	$Q_T(cm^2)$	E(ev)	$q_t(cm^2)$	$q_m(cm^2)$	$q_v(cm^2)$	$Q_T(cm^2)$
0	3.5 (-17)	3.5 (-17)			100	4.2 (-16)	1.71(-16)	1.26(-16)	7.7 (-16)
0.001		3.5 (-17)			120	3.85(-16)	1.45(-16)	1.12(-16)	7.2 (-16)
0.003		4.0 (-17)			150	3.4 (-16)	1.17(-16)	9.7 (-17)	6.7 (-16)
0.01		7.0 (-17)			200	2.95(-16)	9.0 (-17)	7.9 (-17)	6.0 (-16)
0.03		1.25(-16)			250	2.6 (-16)	7.2 (-17)	6.7 (-17)	5.4 (-16)
0.1		4.2 (-16)			300	2.35(-16)	5.9 (-17)	5.9 (-17)	4.9 (-16)
0.3		5.7 (-16)			400	2.04(-16)	4.3 (-17)	4.6 (-17)	4.2 (-16)
1	5.0 (-16)	7.4 (-16)		5.2 (-16)	500	1.80(-16)	3.4 (-17)	3.7 (-17)	3.6 (-16)
1.2	5.25(-16)	7.8 (-16)		5.5 (-16)	600	1.62(-16)	2.7 (-17)	3.1 (-17)	3.2 (-16)
1.5	5.5 (-16)	7.7 (-16)		5.8 (-16)	800	1.35(-16)	1.9 (-17)		2.6 (-16)
2	5.8 (-16)	6.8 (-16)		6.2 (-16)	1000	1.18(-16)	1.5 (-17)		2.12(-16)
2.5	6.0 (-16)	6.1 (-16)		6.4 (-16)	1200				1.80(-16)
3	6.3 (-16)	5.7 (-16)		6.6 (-16)	1500				1.48(-16)
4	6.7 (-16)	5.5 (-16)		6.9 (-16)	2000				1.15(-16)
5	7.1 (-16)	5.6 (-16)		7.2 (-16)					
6	7.5 (-16)	6.1 (-16)		7.6 (-16)					
8	8.4 (-16)	7.2 (-16)		8.7 (-16)					
10	9.3 (-16)	7.9 (-16)		1.00(-15)					
12	9.1 (-16)	8.0 (-16)		1.02(-15)					
15	8.6 (-16)	7.6 (-16)		9.6 (-16)					
20	8.0 (-16)	6.3 (-16)	3.4 (-16)	9.4 (-16)					
25	7.5 (-16)	5.4 (-16)	3.0 (-16)	9.3 (-16)					
30	7.1 (-16)	4.75(-16)	2.7 (-16)	9.3 (-16)					
40	6.5 (-16)	3.75(-16)	2.3 (-16)	9.3 (-16)					
50	5.9 (-16)	3.12(-16)	2.0 (-16)	9.2 (-16)					
60	5.5 (-16)	2.67(-16)	1.8 (-16)	8.8 (-16)					
80	4.8 (-16)	2.07(-16)	1.47(-16)	8.2 (-16)					

O_2

Fig. 9



CO
Q_T
q_t
q_m
q_v
q_v
q_m
Cross section (cm²)
10^{-14}
10^{-15}
10^{-16}
10^{-17}
10^{-18}
10^{-2}
10^{-1}
1
10
10^{2}
10^{3}
10^{4}
Electron energy (eV)

Table 9. CO

E(ev)	$q_t(cm^2)$	$q_m(cm^2)$	$q_v(cm^2)$	$Q_T(cm^2)$
0		6.0 (-15)		
0.001		4.0 (-15)		
0.003		1.77(-15)		
0.01		7.8 (-16)		
0.03		5.4 (-16)		
0.1		7.3 (-16)		
0.3		1.21(-15)		
1		1.85(-15)		
1.2		2.8 (-15)		
1.3		3.7 (-15)		
1.5		4.2 (-15)		
1.7		4.0 (-15)		
2		2.73(-15)		
2.5		1.75(-15)		
3	1.9 (-15)	1.54(-15)	1.1 (-15)	2.0 (-15)
4	1.7 (-15)	1.38(-15)	9.7 (-16)	1.73(-15)
5	1.55(-15)	1.29(-15)	8.9 (-16)	1.55(-15)
6	1.45(-15)	1.23(-15)	8.2 (-16)	1.45(-15)
8	1.31(-15)	1.16(-15)	7.1 (-16)	1.32(-15)
10	1.24(-15)	1.04(-15)	6.3 (-16)	1.35(-15)
12	1.17(-15)	9.6 (-16)	5.7 (-16)	1.35(-15)
15	1.10(-15)	8.5 (-16)	5.0 (-16)	1.36(-15)
20	1.01(-15)	7.1 (-16)	4.2 (-16)	1.33(-15)
25	9.4 (-16)	6.0 (-16)	3.6 (-16)	1.30(-15)
30	8.6 (-16)	5.1 (-16)	3.1 (-16)	1.26(-15)
40	7.6 (-16)	4.1 (-16)	2.5 (-16)	1.20(-15)
50	6.8 (-16)	3.3 (-16)	2.1 (-16)	1.14(-15)
60	6.2 (-16)	2.75(-16)	1.82(-16)	1.09(-15)
80	5.4 (-16)	2.05(-16)	1.46(-16)	1.01(-15)
100	4.8 (-16)	1.60(-16)	1.20(-16)	9.4 (-16)
120	4.3 (-16)	1.30(-16)	1.03(-16)	8.8 (-16)
150	3.75(-16)	1.03(-16)	8.6 (-17)	8.1 (-16)
200	3.1 (-16)	7.5 (-17)	6.7 (-17)	7.0 (-16)
250	2.75(-16)	5.7 (-17)	5.5 (-17)	6.3 (-16)
300	2.45(-16)	4.6 (-17)	4.7 (-17)	5.8 (-16)
400	2.0 (-16)	3.3 (-17)	3.6 (-17)	4.9 (-16)
500	1.7 (-16)	2.4 (-17)	2.8 (-17)	4.3 (-16)
600	1.48(-16)	1.8 (-17)	2.25(-17)	
800	1.15(-16)	1.15(-17)	1.5 (-17)	
1000	9.4 (-17)	7.5 (-18)	1.05(-17)	

CO

Fig. 10

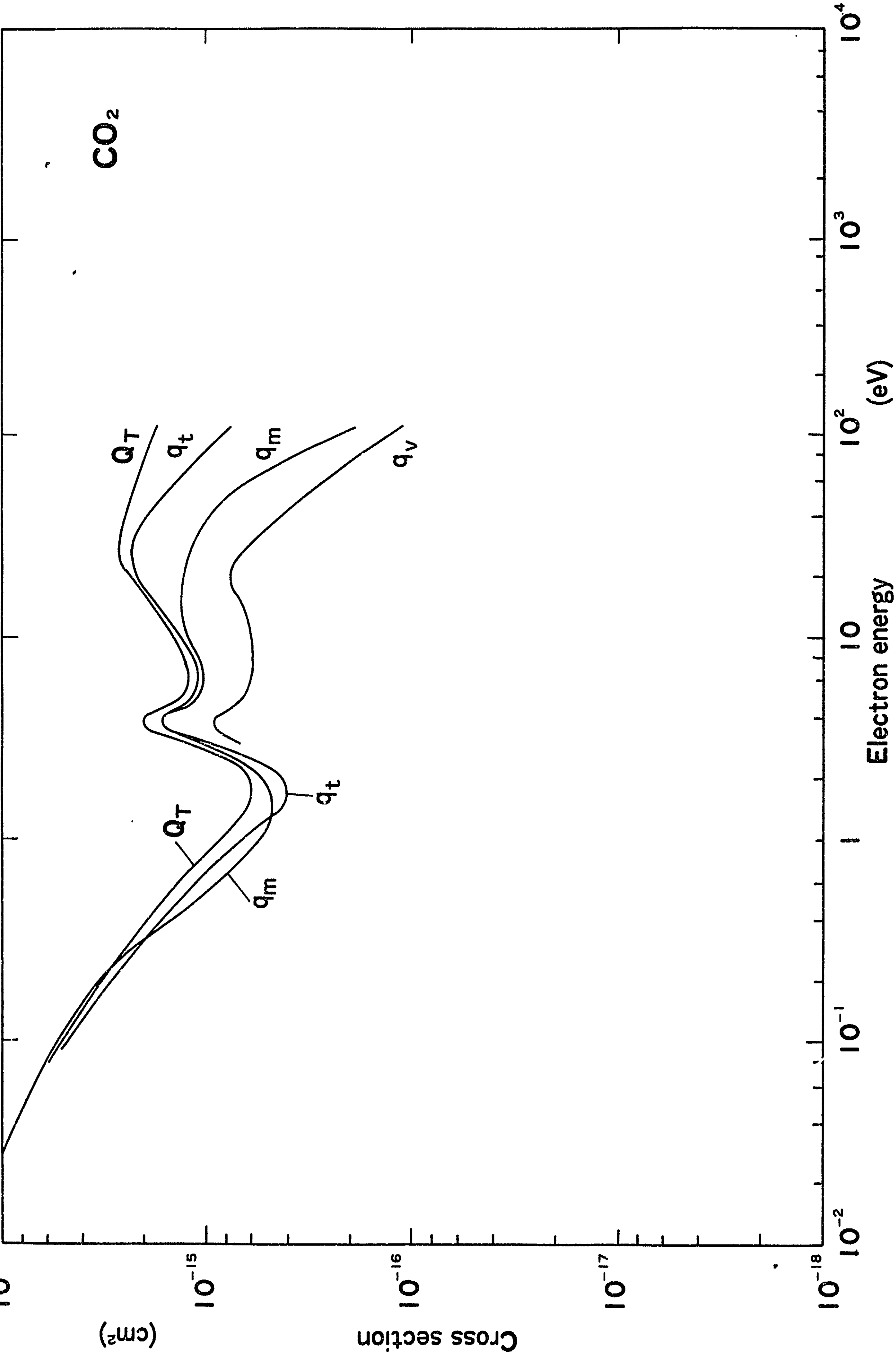

CO₂
Q_T
q_t
q_m
q_v
10^-14
10^-15
10^-16
10^-17
10^-18
Cross section (cm²)
10^-2
10^-1
1
10
10^2
10^3
10^4
Electron energy (eV)

Table 10. CO_2

E(ev)	$q_t(cm^2)$	$q_m(cm^2)$	$q_v(cm^2)$	$Q_T(cm^2)$	E(cm)	$q_t(cm^2)$	$q_m(cm^2)$	$q_v(cm^2)$	$Q_T(cm^2)$
0.03		9.5 (-15)			60	1.36(-15)	6.0 (-16)	2.6 (-16)	2.19(-15)
0.1	4.8 (-15)	5.1 (-15)		5.1 (-15)	80	1.04(-15)	3.4 (-16)	1.8 (-16)	1.95(-15)
0.3	2.1 (-15)	2.2 (-15)		2.3 (-15)	100	8.4 (-16)	1.7 (-16)	1.27(-16)	1.80(-15)
1	6.3 (-16)	5.5 (-16)		8.5 (-16)					
1.2	5.1 (-16)	4.9 (-16)		7.2 (-16)					
1.5	4.2 (-16)	4.8 (-16)		6.3 (-16)					
1.7	4.0 (-16)	4.9 (-16)		6.0 (-16)					
2	4.3 (-16)	5.2 (-16)		6.1 (-16)					
2.5	6.4 (-16)	7.0 (-16)		8.3 (-16)					
3	1.05(-15)	1.08(-15)	6.9 (-16)	1.3 (-15)					
3.5	1.5 (-15)	1.5 (-15)	8.8 (-16)	1.9 (-15)					
4	1.6 (-15)	1.6 (-15)	9.0 (-16)	2.0 (-15)					
4.5	1.35(-15)	1.3 (-15)	7.4 (-16)	1.6 (-15)					
5	1.22(-15)	1.13(-15)	6.7 (-16)	1.37(-15)					
6	1.12(-15)	1.05(-15)	6.2 (-16)	1.23(-15)					
8	1.19(-15)	1.12(-15)	6.0 (-16)	1.32(-15)					
10	1.36(-15)	1.25(-15)	6.1 (-16)	1.44(-15)					
12	1.52(-15)	1.30(-15)	6.2 (-16)	1.58(-15)					
15	1.80(-15)	1.35(-15)	6.7 (-16)	1.88(-15)					
20	2.20(-15)	1.32(-15)	8.0 (-16)	2.40(-15)					
25	2.30(-15)	1.25(-15)	6.9 (-16)	2.65(-15)					
30	2.20(-15)	1.15(-15)	5.7 (-16)	2.65(-15)					
40	1.92(-15)	9.5 (-16)	4.2 (-16)	2.53(-15)					
50	1.60(-15)	7.8 (-16)	3.3 (-16)	2.34(-15)					

Table 11. Roughly estimated error of q_m (%)

E(ev)	$1 \sim 10$	$10 \sim 10^2$	$10^2 \sim 10^3$	$10^3 \sim 10^4$
He	$2 \sim 5$	10	5	5
Ne	$3 \sim 5$	10	$5 \sim 10$	5
Ar	$5 \sim 10$	20	10	5
Kr	$10 \sim 20$	20	10	5
Xe	$20 \sim 30$	20	$10 \sim 20$	5
H_2	$5 \sim 10$	10	10	—
N_2	$5 \sim 10$	10	10	—
O_2	10	$10 \sim 20$	10	—
CO	10	20	10	—
CO_2	10	30	—	—

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(1) He

(2) Ne

(3) Ar

(4) Kr

(5) Xe

(6) H_2

(7) N_2

(8) O_2

(9) CO

(10) CO_2

Each entry has a short description of the contents of the paper: types of cross sections, ranges of electron energies considered, errors estimated, and range of scattering angles when differential cross sections (DCS) are given. Theoretical papers are denoted by "Theory". Otherwise experimental data are given. Papers with an asterisk provide the basis on which the present recommended cross sections are determined.

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5.5) K. Schackert: Ph D Thesis, Univ. Mainz (1968)
DCS, relative, 50 ∿ 150 eV, 30 ∿ 150°

5.6) C.R. Hoffmann and H.M. Skarsgard
Phys. Rev. 178 168 (1969)
q_m, 4 x 10^{-2} ∿ 2 eV

5.7) R.A. Berg. J.E. Purcell and A.E.S. Green
Phys. Rev. A 3 508 (1971)
Theory, DCS, 100 ∿ 300 eV

5.8)* J.P. Bromberg
J. Chem. Phys. 61 963 (1974)
DCS, 300 ∿ 700 eV. 3 ∿ 25°

5.9) B.R. Lewis, I.E. McCarthy, P.J.O. Teubner and E. Weigold
J. Phys. B 7 2549 (1974)
DCS, 60 eV, 15 ∿ 140°

5.10)* J.F. Williams and A. Crowe
J. Phys. B 8 2233 (1975)
DCS, 20 ∿ 400 eV, 20 ∿ 150°

5.11)* M.E. Riley, C.J. MacCallum and F. Biggs
Atomic Data and Nucl. Data Tables 15 443 (1975)
Theory, DCS, 1 ∿ 256 keV

5.12) T. Heindorff, J. Hofft and P. Dabkiewicz
J. Phys. B 9 89 (1975)
DCS, relative, 3 ∿ 10.5 eV, 30 ∿ 130°

5.13) R.H.J. Jansen and F.J. de Heer
J. Phys. B 9 213 (1976)
DCS, 10^2 ∿ 3 x 10^3eV 5 ∿ 54°

5.14)* I.E. McCarthy, C.J. Noble, B.A. Phillips and A.D. Turnbull
Phys. Rev. A 15 2173 (1977)
Theory, 20 ∿ 3 x 10^3 eV

5.15)* F.J. de Heer, R.H.J. Jansen and W. van der Kaay
J. Phys. B 12 979 (1979)
Analysis, Q_T, q_t, 20 ∿ 3000 eV

5.16) M. Klewer, M.J.M. Beerlarge and M.J. van der Wiel
J. Phys. B 13 571 (1980)
DCS, relative, 2 ∿ 300 eV

5.17)* M.S. Dababneh, W.E. Kauppila, J.P. Downing, F. Laperriere, V. Pol, J.H. Smart and T.S. Stein
Phys. Rev. A 22 1872 (1980)
Q_T, 2.8 ∿ 49.6 eV

(6) H_2

6.1) D.E. Golden, H.W. Bandel and J.A. Salerno
Phys. Rev. 146 40 (1966)
Q_T, 0.25 ∿ 15 eV, ± 3%

6.2) K.G. Williams
6th ICPEAC, p735 (1969)
DCS, 30 ∿ 200 eV, 20 ∿ 130°

6.3)* R.W. Crompton, D.K. Gibson and A.I. McIntosh
Aust. J. Phys. 22 715 (1969)
q_m from swarm data, 0 ∿ 2 eV, 5%

6.4) R.J.W. Henry and N.F. Lane
Phys. Rev. 183 221 (1969)
Theory

6.5)* F. Linder and H. Schmidt
Z.f. Naturforsh. A 26 1603 (1971)
DCS, 0.6 ∿ 10.8 eV, 20 ∿ 120°

6.6) D.G. Truhlar and J.K. Rice
J. Chem. Phys. 52 4480 (1970), Erratum 55 2005 (1971)
Theory

6.7) S. Trajmar, D.G. Truhlar and J.K. Rice
J. Chem. Phys. 52 4502 (1970), Erratum 55 2004 (1971)

6.8) S. Trajmar, D. G. Truhlar, J.K. Rice and A. Kupperman
J. Chem. Phys. 52 4516 (1970)

6.9) C.R. Lloyd, P.J.O. Teubner, E. Weigold and B.R. Lewis
Phys. Rev. A 10 175 (1974)
DCS, 30 ∿ 200 eV, 15 ∿ 135°

6.10) D.G. Truhlar and J.K. Rice
Phys. Lett. 47A 372 (1974)
Theory, 30 ∿ 200 eV

6.11)* S.K. Srivastava, A. Chutjian and S. Trajmar
J. Chem. Phys. 63 2659 (1975)
DCS, 3 ∿ 75 eV

6.12) M. Fink, K. Jost and D. Herrmann
Phys. Rev. A 12 1374 (1975)
DCS, relative, 10^2 ∿ 10^3 eV, 3 ∿ 130°

6.13) P.K. Bhattacharyya and A.S. Ghosh
Phys. Rev. A 12 480 (1975)
Theory, DCS, 9.4 ∿ 100 eV

6.14) S. Hayashi and K. Kuchitsu
J. Phys. Soc. Japan 42 1316 (1977)
Theory, DCS, 50 ∿ 400 eV

6.15) B. van Wingerden, E. Weigold, F.J. de Heer and K.J. Nygaard
J. Phys. B 10 1345 (1977)
DCS, 10^2 ∿ 2 x 10^3 eV

6.16)* B. van Wingerden, R.W. Wagenaar and F.J. de Heer
J. Phys. B 13 3481 (1980)
Q_T, 25 ∿ 750 eV, 4%

6.17) J. Ferch, W. Raith and K. Schröder
J. Phys. B 13 1481 (1980)
q_t, 0.02 ∿ 2 eV, 2.5%

6.18)* G. Dalba, P. Fornasini, I. Lazzizzera, G. Ranieri and A. Zecca
J. Phys. B 13 2839 (1980)
Q_T, 0.2 ∿ 100 eV, 1.7 ∿ 5%

(7) N_2

7.1)* A.G. Engelhardt and A.V. Phelps
Phys. Rev. 135A 1566 (1964)
q_m from swarm data, $1.6 \times 10^{-3} \sim 40$ eV

7.2) D.G. Truhlar and S. Trajmar
J. Chem. Phys. 57 3250 (1972)

7.3)* J.P. Bromberg
J. Chem. Phys. 52 1243 (1970)
DCS, $300 \sim 500$ eV, $2 \sim 110°$

7.4) T.W. Shyn, R.S. Stolarski and G.R. Carignan
Phys. Rev. A 6 1002 (1972)
DCS, $5 \sim 90$ eV, $18 \sim 160°$

7.5) H. Kambara and K. Kuchitsu
Jap. J. App. Phys. 11 609 (1972)
DCS, relative, $50 \sim 500$ eV, $4 \sim 150°$

7.6) T.G. Finn and J.P. Doering
J. Chem, Phys. 63 4399 (1975)
DCS, $13 \sim 100$ eV, $5 \sim 90°$

7.7) R.H.J. Jansen, F.J. de Heer, H.J. Luyken, B. van Wingerden and H.J. Blaauw
J. Phys. B 9 185 (1976)
DCS, $10^2 \sim 3 \times 10^3$ eV, $5 \sim 55°$

7.8) E.M.A. Peixoto and J.C. Nogueira
Phys. Rev. A 13 1352 (1976)
DCS of Q_T, $5 \times 10^2 \sim 10^3$ eV

7.9)* R.D. DuBois and H.E. Rudd
J. Phys. D 9 2657 (1976)
DCS, $20 \sim 800$ eV, $2 \sim 150°$, $12 \sim 32\%$

7.10) D. Herrmann
J. Chem. Phys. 64 1 (1976)
DCS, relative, $90 \sim 10^3$ eV

7.11)* S.K. Srivastava, A. Chutjian and S. Trajmar
J. Chem. Phys. 64 1340 (1976)
DCS, 5 ∿ 75 eV, 20 ∿ 135°

7.12) D. Dill and J.L. Dehmer
Phys. Rev. A 16 1423 (1977)
Theory, 0 ∿ 10^3 eV

7.13) H.J. Blaauw, F.J. de Heer, R.W. Wagenaar and D.H. Barends
J. Phys. B 10 L299 (1977)
Q_T, 15 ∿ 750 eV

7.14) K. Rohr
J. Phys. B 10 2215 (1977)

7.15) R.W. Wagenaar: Thesis (1978)
Q_T, 17.5 ∿ 750 eV

7.16) J. Siegel, D. Dill and J.L. Dehmer
Phys. Rev. A 17 2106 (1978)
Theory, 1.4 ∿ 30 eV

7.17) B.H. Choi, R.T. Poe and J.C. Sun
Phys. Rev. A 19 116 (1979)
Theory, DCS, 50 ∿ 500 eV

7.18) R.E. Kennerly
Phys. Rev. A 21 1876 (1980)
Q_T, 0.5 ∿ 50 eV, 3%

7.19)* T.W. Shyn and G.R. Carignan
Phys. Rev. A 22 923 (1980)
DCS, 1.5 ∿ 400 eV, 6 or 12 ∿ 156°

7.20) G. Dalba, P. Fornasini, R. Grisenti, G. Ranieri and
A. Zecca
J. Phys. B 13 4695 (1980)
Q_T, 100 ∿ 1600 eV, 2.5%

(8) O_2

8.1) G. Sunshine, B.B. Aubrey and B. Bederson
Phys. Rev. 154 1 (1967)
Q_T, 0.5 ∿ 10^2 eV

8.2) R.D. Hake, Jr. and A.V. Phelps
Phys. Rev. 158 70 (1967)
q_m from swarm data, 10^{-2} ∿ 10^2 eV

8.3) A. Salop and H.H. Nakano
Phys. Rev. A 2 127 (1970); Erratum A 5, 2696 (1972)
Q_T, 2.35 ∿ 21 eV

8.4)* S. Trajmar, D.C. Cartwright and W.Williams
Phys. Rev. A 4 1482 (1971)
elastic DCS, 4 ∿ 45 eV, 10 ∿ 90°

8.5) S. Trajmar, W. Williams and A. Kuppermann
J. Chem. Phys. 56 3759 (1972)
elastic DCS, 20 ∿ 45 eV, 20 ∿ 90°

8.6) D.R. Nelson and F.J. Davis
J. Chem. Phys. 57 4079 (1972)
swarm exp., q_m, 2.58 x 10^{-2} eV

8.7) J.P. Bromberg
J. Chem. Phys. 60 1717 (1974)
DCS, 300 ∿ 500 eV, 2 ∿ 40°

8.8) N.L.S. Martin and A. von Engel
Proc. 12th ICPIG, p.10 (1975)
exp. of q_m, 0.1 ∿ 14 eV

8.9) R.C. Dehmel, M.A. Fineman and D.R. Miller
Phys. Rev. A 13 115 (1976)
DCS of Q_T, 5, 15 eV, 15 ∿ 150°

8.10) A.V. Phelps
Proc. of US-Japan Seminar, Boulder p. 20 (1977)
q_m, $10^{-2} \sim 10^{2}$ eV

8.11)* S.A. Lawton and A.V. Phelps
J. Chem. Phys. 69 1055 (1978)
q_m, $10^{-2} \sim 10^{2}$ eV

8.12)* K. Wakiya
J. Phys. B 11 3913 (1978)
DCS, 20 ∿ 500 eV, 5 ∿ 130°

8.13) G. Dalba, P. Fornasini, R. Grisenti, G. Ranieri and A. Zecca
J. Phys. B 13 4695 (1980)
Q_T, $10^{2} \sim 1.6 \times 10^{3}$ eV, 2.5%

(9) CO

9.1) R.D. Hake, Jr. and A.V. Phelps
Phys. Rev. 158 70 (1967)
q_m from swarm data, $10^{-2} \sim 10^{2}$ eV

9.2)* J.P. Bromberg
J. Chem. Phys. 52 1243 (1970)
DCS, 30 ∿ 500 eV, 2 ∿ 110°

9.3) N. Chandra
Phys. Rev. A 12 2342 (1975)
Theory, q_m, $10^{-1} \sim 10$ eV

9.4)* R.D. DuBois and M.E. Rudd
J. Phys. B 9 2657 (1976)
DCS, 200 ∿ 800 eV, 3 ∿ 150°, 12%

9.5) N. Chandra
Phys. Rev. A 16 80 (1977)
Theory, q_m, $10^{-2} \sim 10$ eV

9.6)* J.E. Land
J. App. Phys. 49 5716 (1978)
q_m from swarm data, 0 ∿ 100 eV, 10% below 3 eV

9.7)* H. Tanaka, S.K. Srivastava and A. Chutjian
J. Chem. Phys. 69 5329 (1978)
DCS, 3 ∿ 100 eV

9.8) C. Szmytkowski and M. Zubek
Chem. Phys. Lett. 57 105 (1978)
Q_T, 1.5 ∿ 5.5 eV

9.9) R.T. Poe
Symp. on Electron-Molecule Collisions, P. 49 (1979)
Theory, DCS

(10) CO_2

10.1)* R.D. Hake, Jr. and A.V. Phelps
Phys. Rev. 158 70 (1967)
q_m from swarm data, 10^{-2} 10^2 eV

10.2) D. Spence, J.L. Mauer and G.J. Schulz
J. Chem. Phys. 57 5516 (1972)
Σq_{inel}, 3.8 eV

10.3)* J.J. Lowke, A.V. Phelps and B.W. Irwin
J. App. Phys. 44 4664 (1973)
q_m from swarm data, $2 \times 10^{-2} \sim 10^2$ eV

10.4) M.A. Morrison, L.A. Collins and N.F. Lane
Chem. Phys. Lett. 42 356 (1976)
Theory

10.5) M.A. Morrison, N.F. Lane and L.A. Collins
Phys. Rev. A 15 2186 (1977)
Theory

10.6)* T.W. Shyn, W.E. Sharp and G.R. Ca ignan
Phys. Rev. A 17 1855 (1978)
DCS, 3 90 eV, -105 ∼ 156°

10.7) C. Szmytokowski and M. Zubek
Chem. Phys. Lett. 57 105 (1978)
Q_T, 1.5 ∼ 8 eV

10.8) M.g. Lynch and D. Dill
J. Chem. Phys. 71 4249 (1979)
Theory, Q_T, 0 ∼ 100 eV

10.9) R.T. Poe
Sympo. on Electorn-Molecule Collisions, P. 49 (1979)
Theory, DCS, 50 ∼ 500 eV

10.10) K. Onda and D.G. Truhlar
J. Phys. B 12 283 (1979)
Theory

10.11)* D.F. Register, H. Nishimura and S. Trajmar
J. Phys. B 13 1651 (1980)
DCS, 4 $\sim$ 50 eV, 15 $\sim$ 140°, 15%

10.12) D. Thirumalai, K. Onda and D.G. Truhlar
J. Chem. Phys. 74, 6792 (1981)
Theory, 10 eV

LIST OF IPPJ-AM REPORTS

IPPJ-AM-1* "Gross Sections for Charge Transfer of Hydrogen Beams in Gases and Vapors in the Energy Range 10 eV - 10 keV" by Tawara (1977)

IPPJ-AM-2* "Ionization and Excitation of Ions by Electron Impact -Review of Empirical Formulae-" by T. Kato (1977)

IPPJ-AM-3 "Grotriam Diagrams of Highly Ionized Iron FeVIII-FeXXVI" by K. Mori, M. Otsuka and T. Kato (1977)

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IPPJ-AM-6* "Free-Free Transition in a Plasma -Review of Cross Sections and Spectra-" by T. Kato and H. Narumi (1978)

IPPJ-AM-7* "Bibliography on Electron Collisions with Atomic Positive Ions: 1940 Through 1977" by K. Takayanagi and T. Iwai (1978)

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IPPJ-AM-9 "Charge Changing Cross Sections for Heavy-Particle Collision in the Energy Range from 0.1 eV to 10 MeV I. Incidence of He, Li, Be, B and Their Ions" by Kazuhiko Okuno (1978)

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IPPJ-AM-11 "Charge Changing Cross Sections for Heavy-Particle Collision in the Energy Range from 0.1 eV to 10 Mev III. Incidence of F, Ne, Na and Their Ions" by Kazuhiko Okuno (1978)

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by S. Nakazaki and T. Hashino (1979)

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IPPJ-AM-14 "Energy Dependence of Sputtering Yields of Monatomic Solids"
N. Matsunami, Y. Yamamura, Y. Itikawa, N. Itoh, Y. Kazumata, S. Miyagawa, K. Morita and R. Shimizu (1980)

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Y. Kaneko, T. Arikawa, Y. Itikawa, T. Iwai T. Kato, M. Matsuzawa, Y. Nakai, K. Okuno H. Ryufuku, H. Tawara and T. Watanabe (1980)

IPPJ-AM-16 "Two-Centre Coulomb Phaseshifts and Radial Functions"
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IPPJ-AM-17 "Empirical Formulas for Ionization cross Section of Atomic Ions for Electron Collisions -Critical Review with Compilation of Experimental Data-"
by Y. Itikawa and T. Kato (1981)

IPPJ-AM-18 "Data on the Backscattering Coefficients of Light Ions from Solids"
T. Tabata, R. Ito, Y. Itikawa, N. Itoh and K. Morita (1981)

IPPJ-AM-19 "Recommended Values of Transport Cross Sections for Elastic Collision and Total Collision Cross Section for Electrons in Atomic and Molecular Gases"
M. Hayashi (1981)

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