Total and partial cross sections for electron scattering on atoms and molecules

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IAEA –AMD, Vienna, 27/11/2019

Rationale: edge and divertor plasma

Influence of atomic physics on EDGE2D-EIRENE simulations of JET divertor detachment with carbon and beryllium/tungsten plasma-facing components

Table 3. Atomic and molecular reactions included in the physics models used in EIRENE (also valid for D).

NIMBUS-like model	Kotov-2008 model
(1) $e + H^0 \rightarrow 2e + H^+$	Same reactions as default plus:
(2) $H^+ + H^0 \rightarrow H^0 + H^+$	(9) $H_2 + H^+ \rightarrow H^+ + H_2$
(3) $e + C^0 \rightarrow 2e + C^+$	(10) $H_2 + H^+ \rightarrow H_2^+ + H^0$
(4) $e + H_2 \rightarrow 3e + 2H^+$	(11) $e + H_2 \rightarrow 2e + H_2^+$
(5) $e + H_2 \rightarrow e + 2H^0$	(replacing (4))
(6) $e + H_2 \rightarrow 2e + H^+ + H^0$	(12) $e + H_2^+ \rightarrow e + H^0 + H^+$
(7) $e + H^+ \rightarrow H^0$	(13) $e + H_2^+ \rightarrow 2e + 2H^+$
(8) $2e + H^+ \rightarrow e + H^0$	(14) $e + H_2^+ \rightarrow 2H^0$
No CRM[a] for (4), (5) and (6)	CRM[a] for (11), (5) and (6)

[a] Collisional Radiative Model.

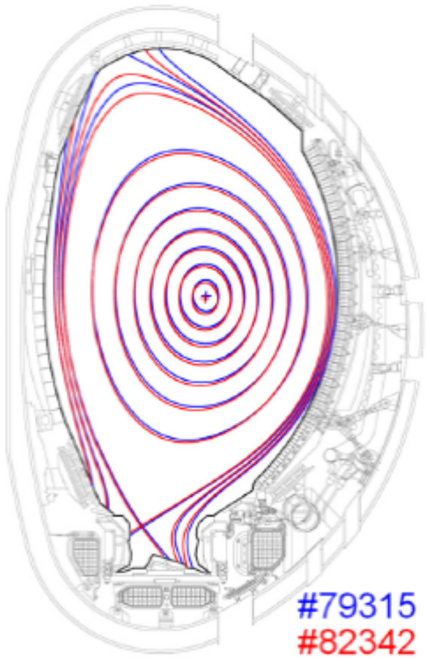


Figure 1. Magnetic equilibria for the shots #79315 and #82342 at 20 s and 13 s, respectively.

Guillemaut et al. Nucl.Fusion **54** (2014) 093012

Data needed:

I Neutrals (H, C, C_2, Be, BeH_2, CH_4)

1. Total cross section

2. Partial cross sections:

elastic scattering $e+A \rightarrow e+A$

rotational excitation $e+CH_4\ (J=0) \rightarrow e+CH_4\ (J=2)$

vibrational excitation $e+AB(v=0) \rightarrow e+AB(v>0)$

electron attachment (dissociative) $e+AB \rightarrow A^- + B$

electronic excitation $e+A \rightarrow e+A^*$

emission lines: $A^* \rightarrow A + hv$

neutral dissociation $e+AB \rightarrow A + B + e$

emission from dissociation $e + AB \rightarrow A^* + B + e + hv$

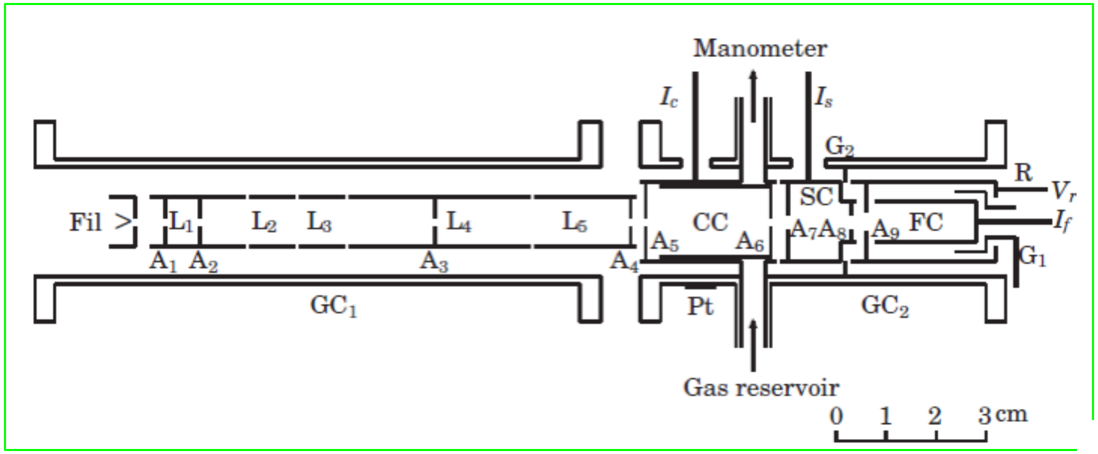
ionization $e+A \rightarrow A^+ + 2e$

dissociative ionization $e+AB \rightarrow A + B^+ + 2e$

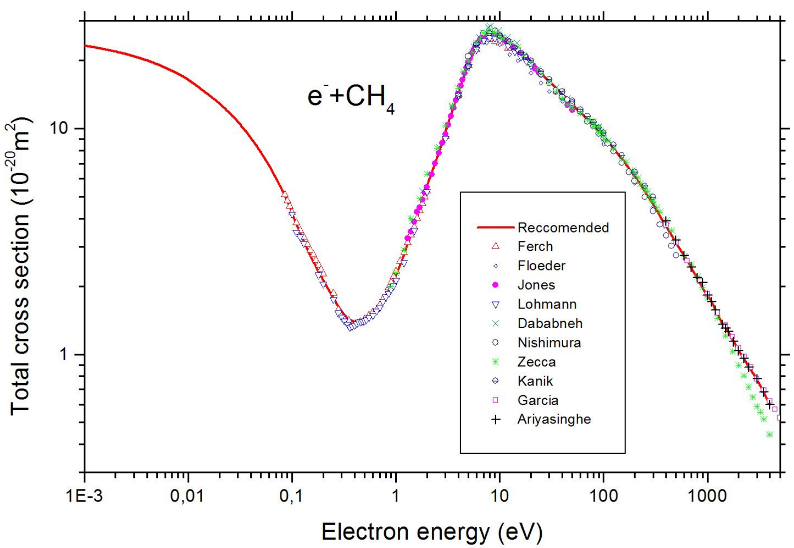
ionization into excited states $e + A \rightarrow (A^+)^* + 2e$

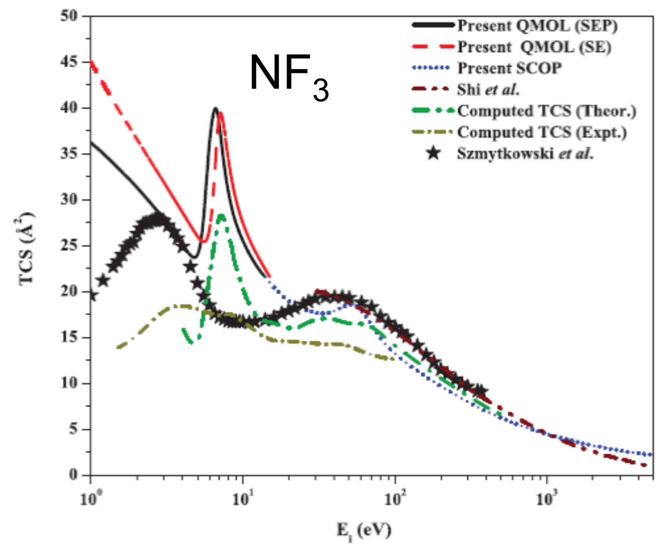
Experimental methods: total

attenuation method $I = I_0 \exp(-\sigma n L)$; precision <5%



H. Nishimura et al., J.Phys. Soc. Japan **72** (2003) 1080



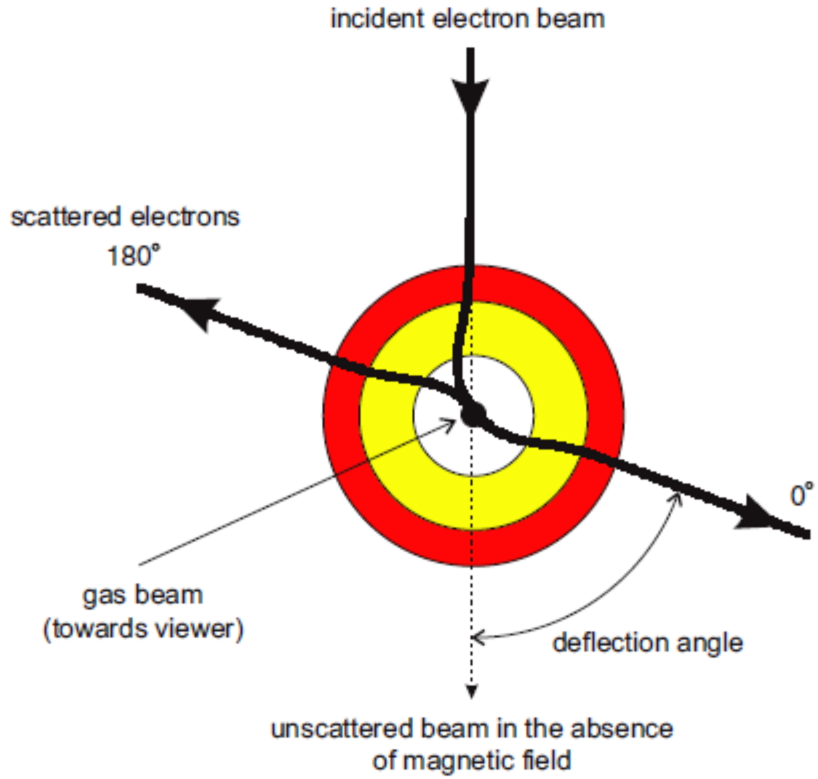


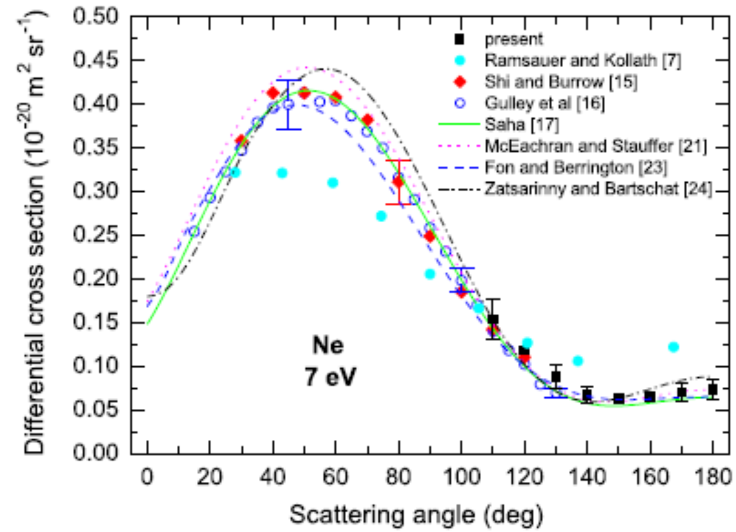
M.-Y. Song et al., JCPRD 44 (2015) 023101

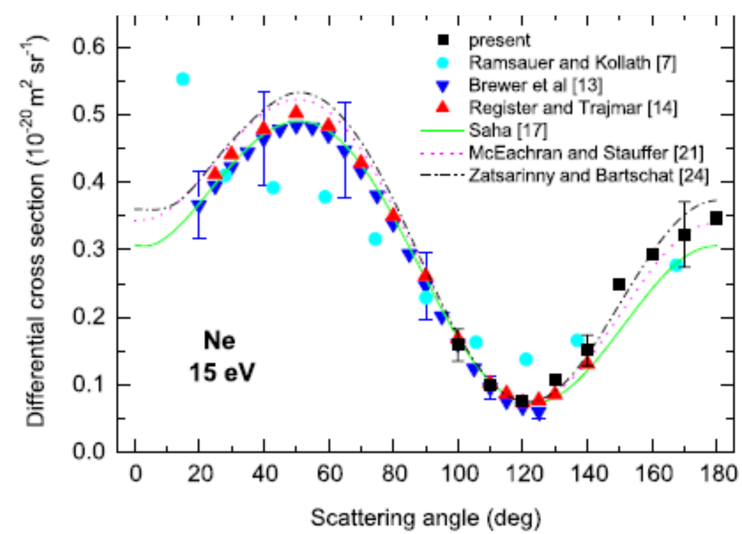
B. Goswami et al. PRA **88** (2013) 032707

Experimental methods: elastic

PHYSICAL REVIEW A 74, 042701 (2006)

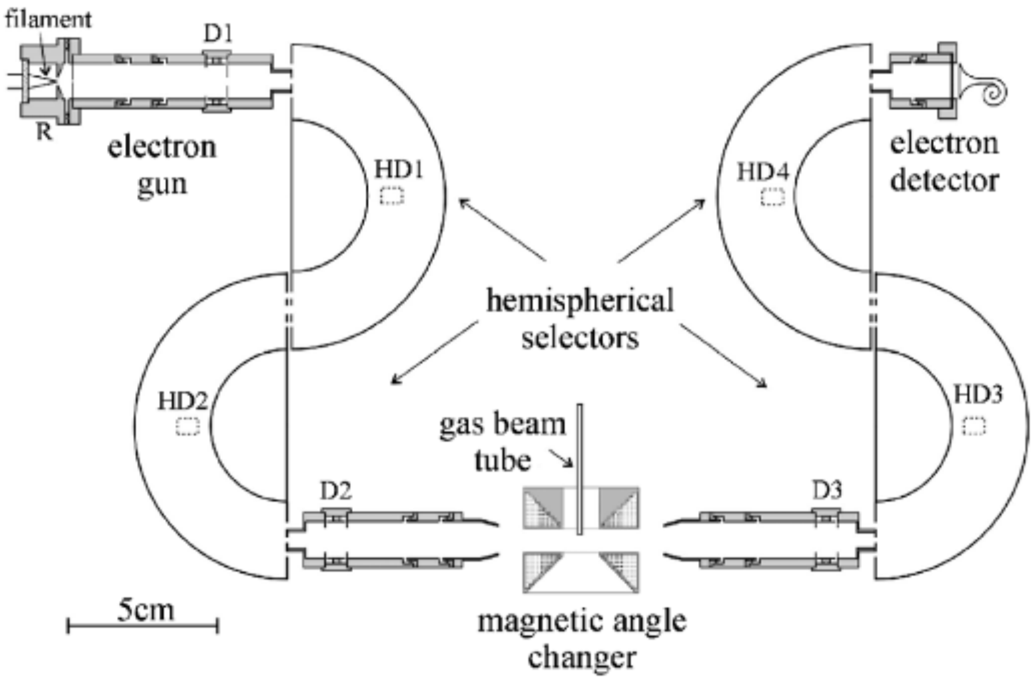


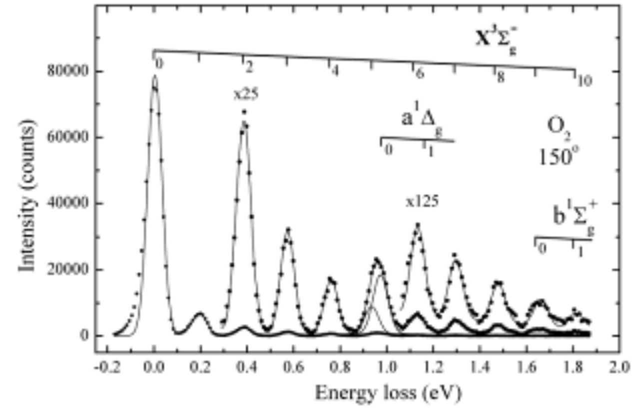


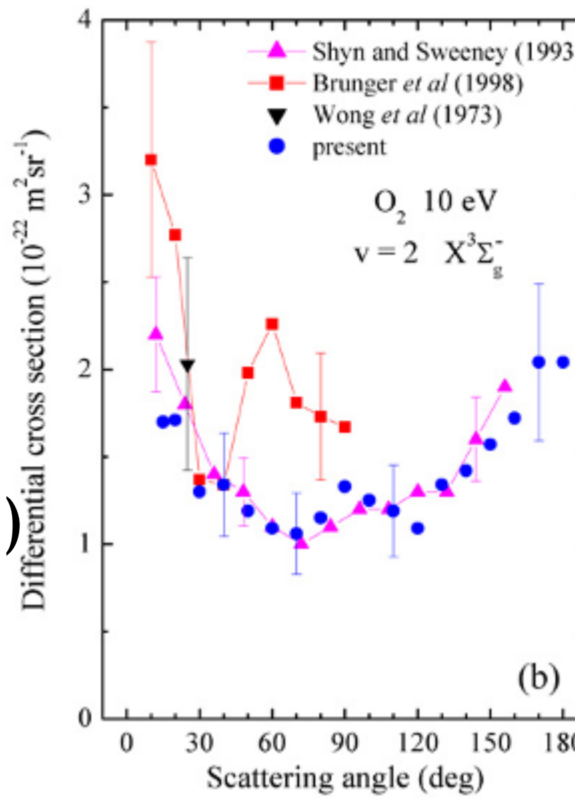


I. Linert, B. Mielewska, G. King, and M. Zubek, PRA (2006)

Experimental methods: excitation (electronic, vibrational)







$e^- + O_2$ (v=0) – $e^- + O_2$ (v=0, 1, 2, etc.)

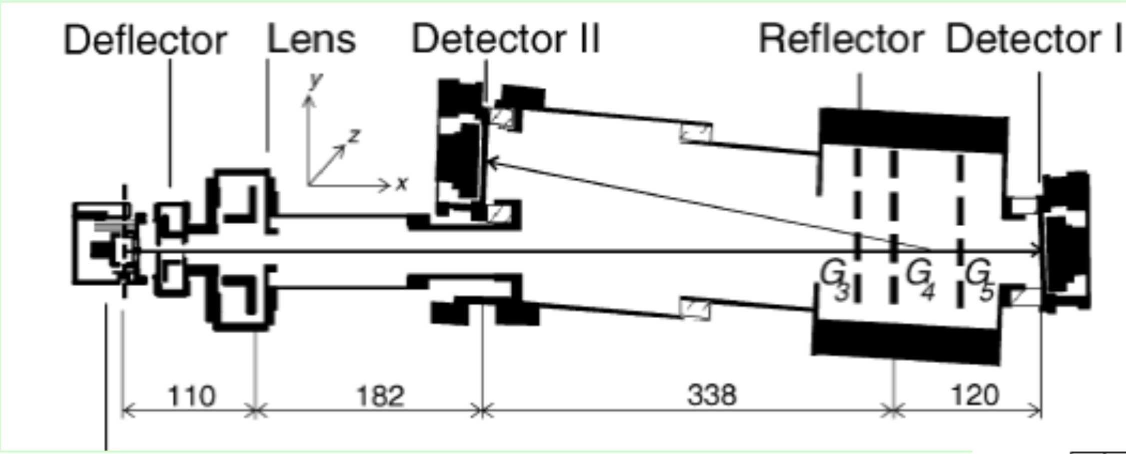
Experiments by:

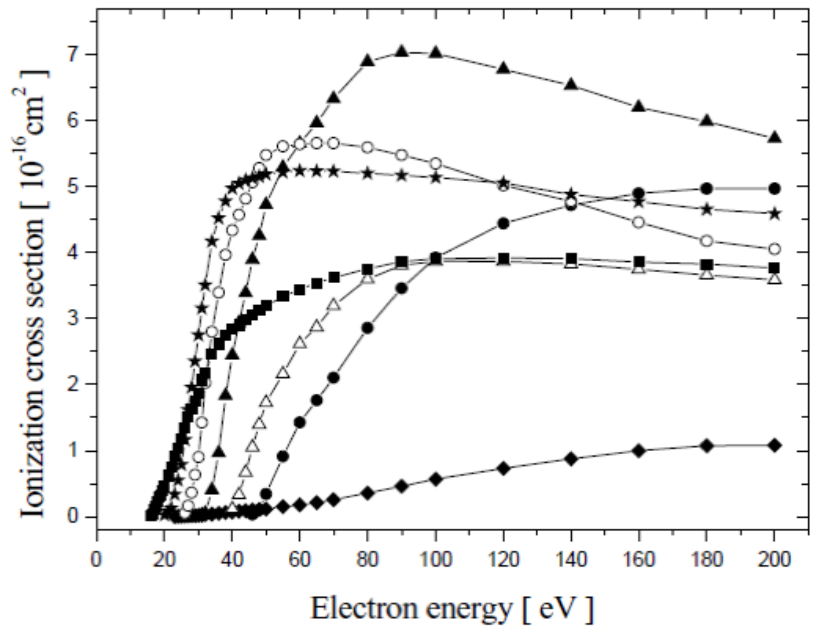
I. Linert, M. Zubek (Gdansk) J. Phys. B **39** (2006)

M. Khakoo et al. (Fullerton California)

M. Allan, (Freiburg University)

Experimental methods: ionization

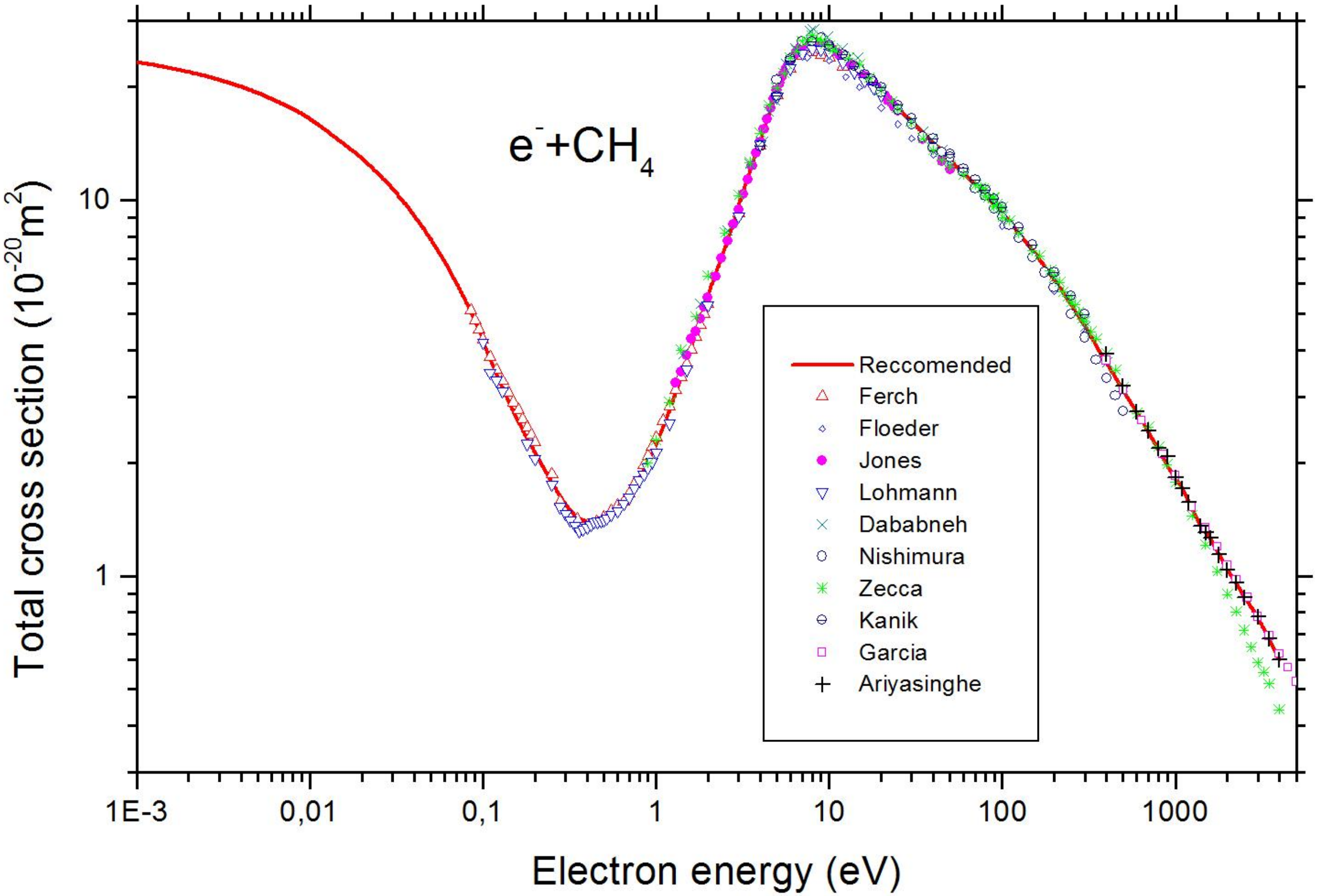




If two ions are formed
(for example $CH_4 \rightarrow CH_3^+ + H^+ + 2e$)
the ionization is counted twice

R. Basner, M. Schmidt, K. Becker, Int. J. Mass Spectr. 233 (2004) 25

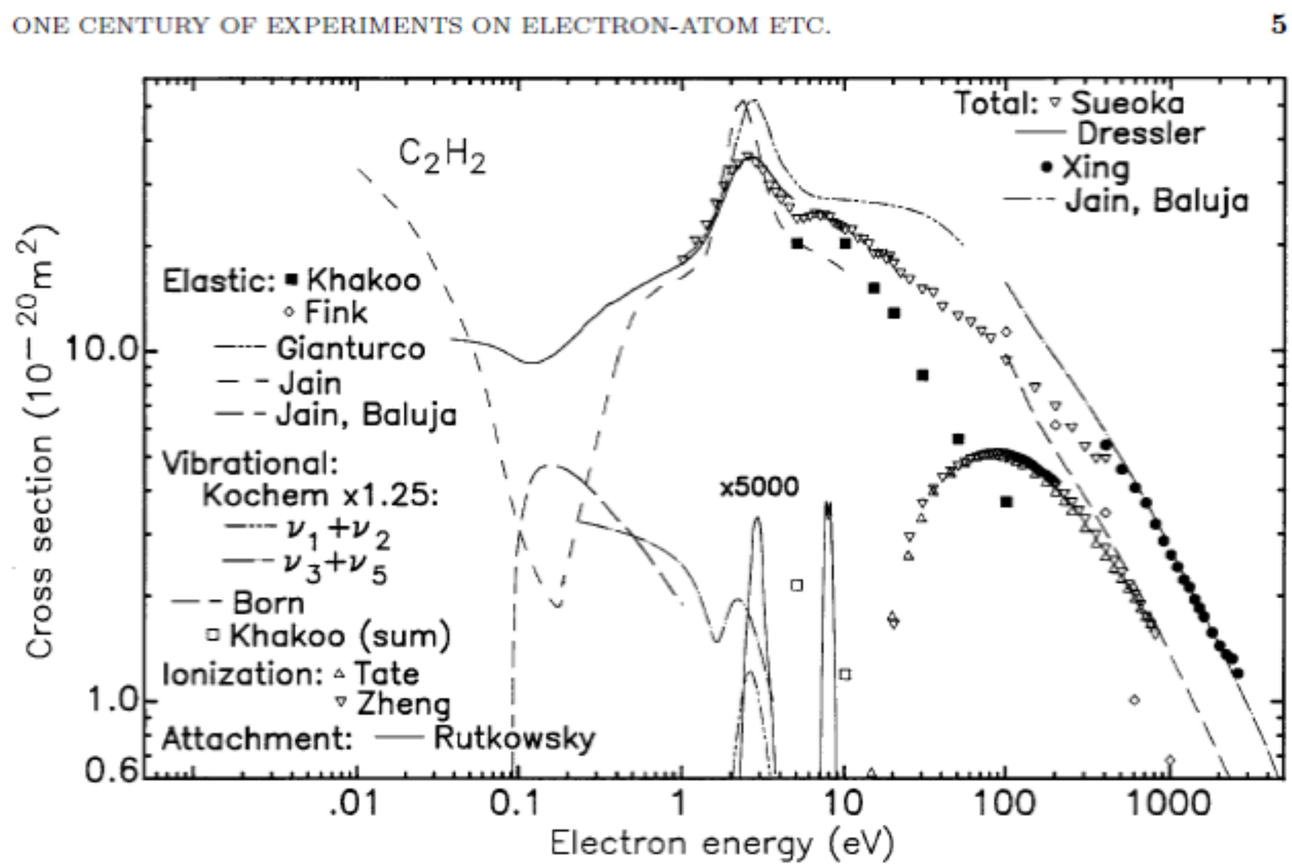
Total cross sections: beam (±5%)



M.-Y. Song, Y.-S. Yoon, H. Cho, Y. Itikawa, G. P. Karwasz, V. Kokoouline, Y, Nakamura, J. Tennyson, Journal of Physical and Chemical Reference Data **44**, 023101 (2015)

„One century experiments on electron-atom and molecule scattering (2001)

3 volumes, some 50 molecules



G.P. Karwasz, R.S. Brusa, A. Zecca, *Riv. Nuovo Cimento*, 24, no.1 (2001)

3 volumes,
some 50 molecules

G.P. Karwasz,
R.S. Brusa, A. Zecca,
Riv. Nuovo Cimento,

Vol. 19, No. 3 (1996)
atoms & diatomic

Vol. 24, no.1 (2001)
triatomic etc.

Vol. no 4. (2001)
hydrocabons

One century of experiments on electron-atom and molecule scattering: a critical review of integral cross-sections

II. – Polyatomic molecules

GRZEGORZ P. KARWASZ, ROBERTO S. BRUSA and ANTONIO ZECCA

Istituto Nazionale per la Fisica della Materia and Dipartimento di Fisica Università degli Studi di Trento, I-38050 Povo (Trento), Italy

(ricevuto il 29 Marzo 2000)

Compared,
checked,
not recommended

Table I. – *Integral cross-sections for electron scattering on methane (in 10^{-20} m^2 units).*

Energy	Elastic	Vibrational	Electronic excitation	Ionization	Neutral dissociation	Summed	Total
0.6	0.92 S 1.1 BU	0.34 B				1.26 1.44	1.49 L 1.54 F
1.0	1.66 S 1.78 BU	0.24 B				1.90 2.16	2.13 L 2.34 F
2.0	5.61 BO 4.64 BU	0.21 B 0.28 BU				5.82 4.92	5.24 L 5.5 J 6.3 Z
2.5	6.06 S	0.18 B				6.24	8.2 Z
3.0	9.25 BO 7.70 BU 7.4 TA	0.46 T 0.45 BU				9.71 8.15 7.85	9.06 L 9.4 J 10.3 Z
5.0	18.0 BO 17.5 BU 13.7 TA	0.83 T 1.32 BU				18.8 18.8	18.9 K 19.9 Z
8.0	26.3 BO 19.6* TA	1.33 T				27.6	26.4 K 27.4 Z
10	23.0 BO 19.8 SH 18.4 TA	1.02 T			0.31 N	24.3	25.9 K
15	18.3 BO 17.6 SH 15.7 TA	0.45 T	1.1 KA	0.21 NI	(1.3) N	20.1	23.0 Z
20	14.4 BO 15.3 SH 17.6 V 14.3 TA	0.31 T	1.75 KA (1.5 VT)	1.22 NI	(2.0) N	17.7 18.6 20.6	20.0 K

Electron-scattering database – UMK (2013)

ELECTRON SCATTERING CROSS SECTIONS

Interactive data base (K. Fedus, K. Służewski, 2013) based on Rivista del Nuovo Cimento (G.P. Karwasz, R.S. Brusa, A. Zecca, 1996-2001)

Atoms	Diatomic molecules	Hydrides	Triatomic molecules	Hydrocarbons	Halides
H	H_2	CH_4	CO_2	C_2H_2	CF_4
He	N_2	SiH_4	N_2O	C_6H_6	CF_3Cl
Li	CO	GeH_4	NO_2	C_2H_4	CF_2Cl_2
O	O_2	NH_3	O_3	C_2H_6	$CFCl_3$
Ne	NO	H_2O	OCS	C_3H_8	CCl_4
Na		PH_3	SO_2		CH_3F
Ar		H_2S	ClO_2		CH_3Cl
K		HCl	CS_2		CH_3Br
Kr		HF			CH_3I
Rb		HBr			NF_3
Xe					C_2F_6
Cs					C_3F_8
Hg					C_6F_6
					SF_6
					UF_6
					WF_6
					SiF_4

http://dydaktyka.fizyka.umk.pl/ESCS/

Electron-scattering database – UMK (2013)

Niezabezpieczona | dydaktyka.fizyka.umk.pl/ESCS/Hydrides/H2O/index.html

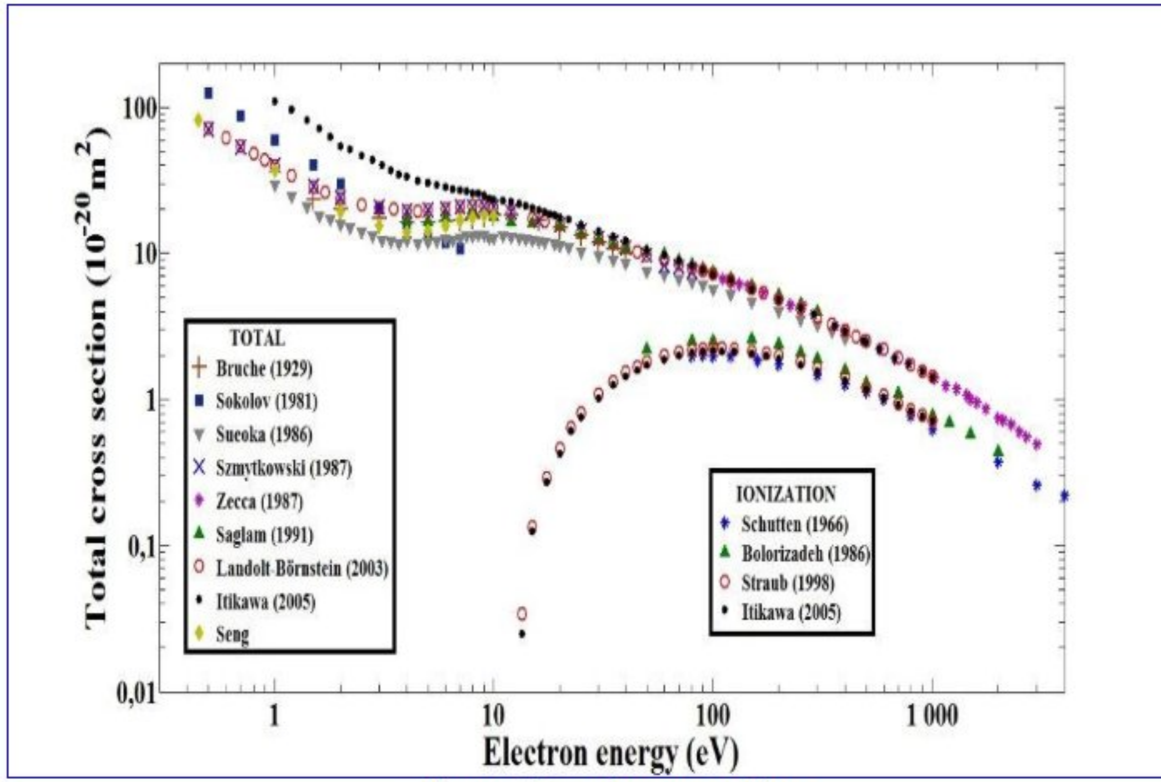
ELECTRON SCATTERING CROSS SECTIONS

H_2O

Main Menu

Total
Elastic
Momentum transfer
Vibrational excitation
Rotational excitation
Electronic excitation
Ionization
Electron attachment

www:
A. Karbowski
K. Fedus



Chosen integral cross sections

http://dydaktyka.fizyka.umk.pl/ESCS/

Electron-scattering database – UMK (2013)

Niezabezpieczona | dydaktyka.fizyka.umk.pl/ESCS/Hydrides/H2O/Ionization/index.html

ELECTRON SCATTERING CROSS SECTIONS

H_2O
Total
Elastic
Momentum transfer
Vibrational excitation
Rotational excitation
Electronic excitation
Ionization
Electron attachment

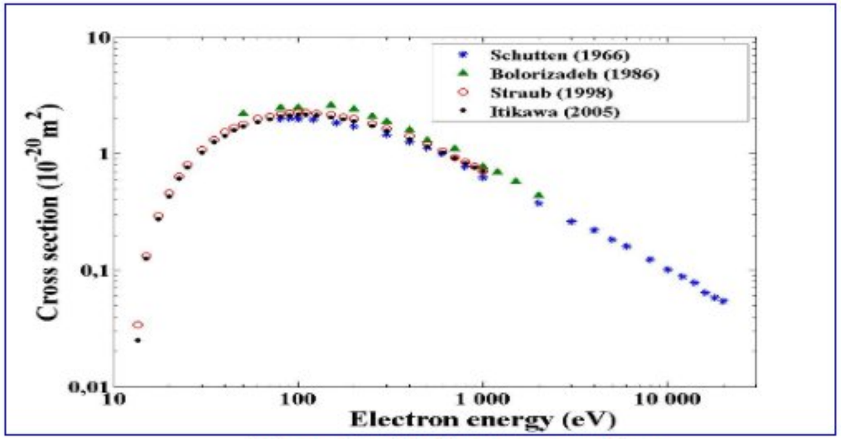
Main Menu

Data

Integral and partial ionization

H_2O. Ionization – intergal cross sections

Graph



Integral ionization cross sections

References:

SCHUTTEN J., de Heer F. J., Moustafa H. R., Boerboom A. J. H. and Kistemaker J., J. Chem. Phys., 44 (1966) 3924.
BOLORIZADEH M. A. and Rudd M. E., Phys. Rev. A, 33 (1986) 882.
STRAUB H. C., Lindsay B. G., Smith K. A., and Stebbings R. F., J. Chem. Phys. 108, 109 (1998).
ITIKAWA Y. and Mason N., J. Phys. Chem. Ref. Data 34, (2005) 1.

http://dydaktyka.fizyka.umk.pl/ESCS/

Electron-scattering database – UMK (2013)

H_2O. elastic – differential cross sections

Microsoft Excel - H2O_elastic_DCS.xls

Katase86	energy (ev)	energy (ev)	energy (ev)	energy (ev)	energy (ev)	energy (ev)	energy (ev)
angle(deg.)	100	200	300	400	500	700	1000
0	9,71	12	8,54	8,71	6,53	5,9	4,47
5	8,34	9,7	6,99	6,88	5,23	4,74	3,67
10	5,44	4,09	3,29	2,91	2,28	1,95	1,25
15	2,96	2,02	1,64	1,27	0,957	0,767	0,5
20	1,59	1,03	0,727	0,597	0,487	0,357	0,246
30	0,573	0,329	0,232	0,204	0,17	0,125	0,0751
40	0,228	0,158	0,114	0,0874	0,0744	0,0524	0,03
50	0,129	0,0822	0,0595	0,046	0,0403	0,026	0,0148
60	0,0785	0,0489	0,0381	0,0308	0,0255	0,0162	0,00872
70	0,0498	0,0326	0,0283	0,0219	0,0163	0,0106	0,00534
80	0,0286	0,0263	0,0218	0,0157	0,012	0,00724	0,00372
90	0,0251	0,0254	0,0187	0,0128	0,00973	0,00535	0,00267
100	0,0287	0,0245	0,0158	0,011	0,00831	0,00427	0,00214
110	0,0388	0,0246	0,0151	0,0102	0,00711	0,00353	0,00172
120	0,0531	0,0242	0,0145	0,00953	0,00629	0,00303	0,00148
130	0,068	0,0245	0,0142	0,0091	0,00607	0,00269	0,00136
140	0,0984	0,0293	0,0155	0,00915	0,00577	0,00255	0,0013
150	0,132	0,0356	0,017	0,00924	0,00571	0,0025	0,001
160	0,167	0,0429	0,0186	0,00938	0,00572	0,00251	0,00134
170	0,192	0,0487	0,0198	0,00949	0,00575	0,00253	0,00137
180	0,202	0,051	0,0203	0,00953	0,00576	0,00254	0,00138

Shyn87	energy (ev)	energy (ev)	energy (ev)	energy (ev)
angle(deg.)	2.2	4.0	6.0	8.0
15	7,44	7,21	8,43	9
30	2,77	3,37	3,36	3,17
45	1,38	1,44	1,6	1,46
60	0,74	0,99	1,05	1,12
75	0,58	0,67	0,78	0,82
90	0,44	0,49	0,55	0,54
105	0,36	0,31	0,45	0,4
120	0,35	0,29	0,37	0,42
135	0,33	0,38	0,5	0,62
150	0,46	0,58	1	1,25
165	0,68	0,88	1,95	1,95

http://dydaktyka.fizyka.umk.pl/ESCS/

Landolt-Börstein Data (2003)

G.P.Karwasz, A.Zecca, R.S.Brusa, Electron Scattering with Molecules. Total. (in:) Landolt-Börnstein. Numerical Data and Functional Relationships in Science and Technology. *New Series* / Editor in Chief: W. Martienssen. Group I: Elementary Particles, Nuclei and Atoms. Volume 17. Photon and Electron Interactions with Atoms, Molecules and Ions. Subvolume C. Interactions of Photons and Electrons with Molecules. Chapter VI.1 , p. 6.1-6.51, Springer-Verlag, Berlin, Heidelberg, 2003

LB-SEARCH (Springer)

LB-CONTENTS

GROUP I: Elementary Particles, Nuclei and Atoms

VOLUME 17
Photon and Electron Interactions with Atoms, Molecules and Ions

SUBVOLUME C
Interactions of Photons and Electrons with Molecules

Landolt-Börstein Data (2003)

6-14 6.1 Total scattering cross sections [Ref. p. 6-4

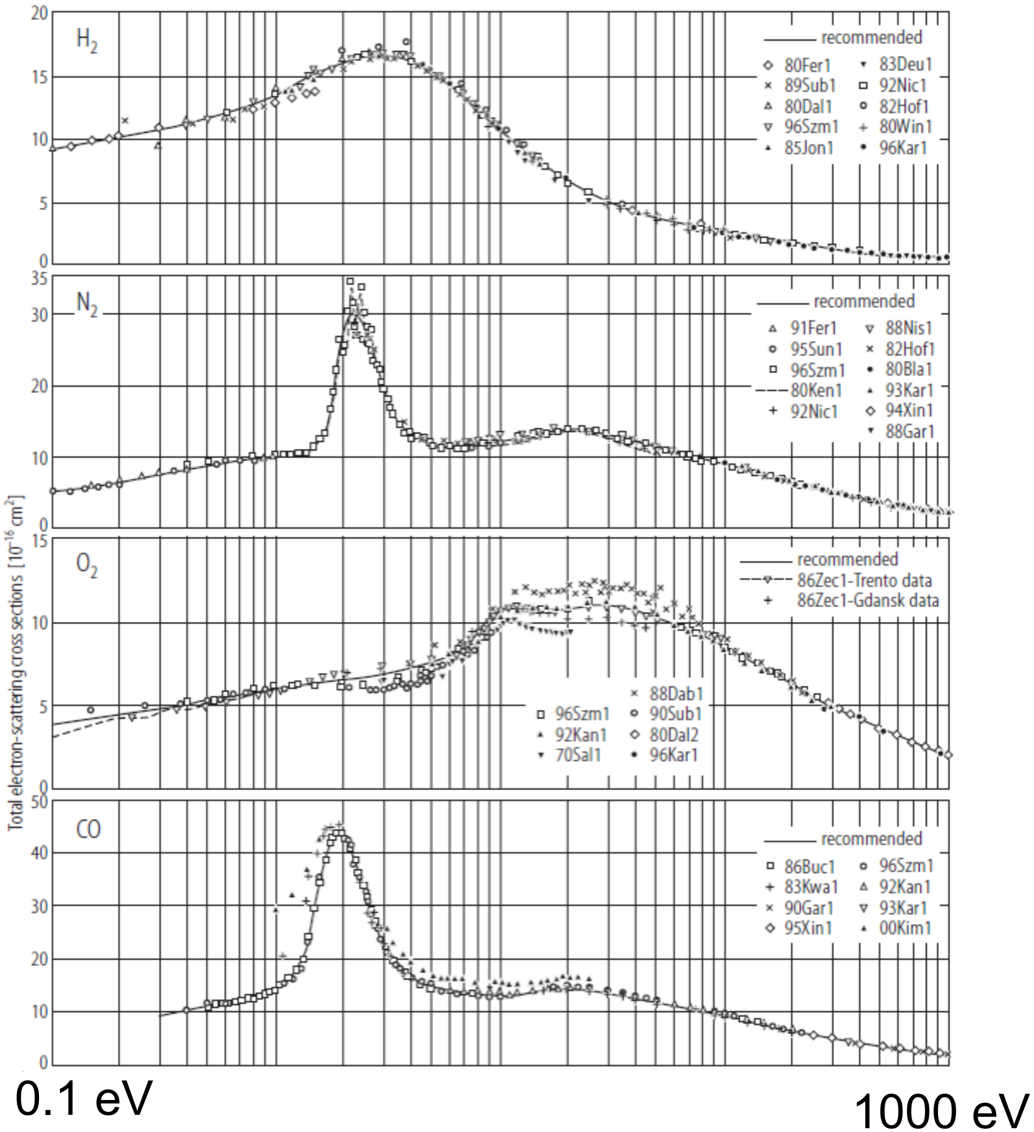


Table 6.1.2. Recommended total cross sections for diatomic molecules.

Energy [eV]	Cross section [10^{-16} cm^2]				
	H_2	N_2	O_2	CO	NO
0.1	9.23	4.88	3.83 (c1)		
0.12	9.47	5.13	4.02	(d1)	
0.15	9.76	5.56	4.22		(e1)
0.17	9.93	5.85	4.33		
0.2	10.1	6.25	4.47		
0.25	10.5	6.84	4.65		
0.3	10.7	7.32	4.79	9.13	
0.35	11.0	7.72	4.91	9.69	
0.4	11.2	8.06	5.07	10.2	
0.45	11.4	8.33	5.20	10.6	
0.5	11.6	8.61	5.31 (c2)	10.9	
0.6	11.9	8.96	5.49	11.7	
0.7	12.3	9.25	5.64	12.2	
0.8	12.8	9.48	5.77	12.7	
0.9	13.2	9.66	5.87	13.3	
1.0	13.5 (a1)	9.85	5.97	14.1	
1.2	14.2	10.2	6.18	16.7	
1.5	15.0	11.2	6.36	29.1	
1.7	15.5	13.3	6.45	38.9	
2.0	16.0	25.7	6.56 (c3)	43.3 (d2)	
2.5	16.5	28.5 (b1)	6.68	33.3	9.70
3.0	16.6	21.0	6.84	23.8	9.47
3.5	16.6	14.6	7.01	18.9	9.32
4.0	16.3	13.2	7.18	16.4	9.25
4.5	15.9	12.3	7.36	15.2	9.22
5.0	15.4	11.8	7.55	14.5	9.23
6.0	14.4	11.4	7.93	13.7	9.32
7.0	13.3	11.4	8.39	13.5	9.48
8.0	12.4	11.5	9.16	13.6	9.68
9.0	11.6	11.7	9.91	13.5	9.92
10	10.9	12.0	10.4	13.2	10.2
12	9.61	12.4	10.8	13.3	11.0
15	8.19	13.2	10.7	13.9	11.5
17	7.46	13.5	10.7	14.3	11.6
20	6.60	13.7	10.8	14.5	11.4

„Recommended" cross sections for electron scattering with molecules

Mi-Young Song, Jung-Sik Yoon,
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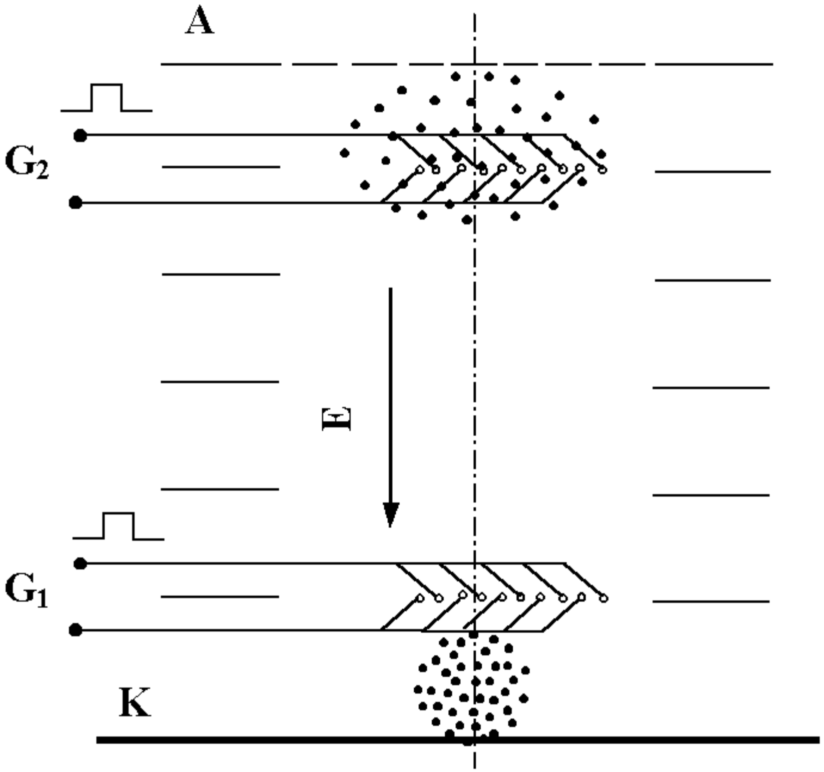
Swarm experiments: diffusion coefficients → cross sections

$$\frac{\partial}{\partial t} n_e(\mathbf{r},t) = -w \frac{\partial}{\partial z} n_e(\mathbf{r},t) + D_T \left[\frac{\partial^2}{\partial x^2} n_e(\mathbf{r},t) + \frac{\partial^2}{\partial y^2} n_e(\mathbf{r},t) \right] + D_L \frac{\partial^2}{\partial z^2} n_e(\mathbf{r},t)$$



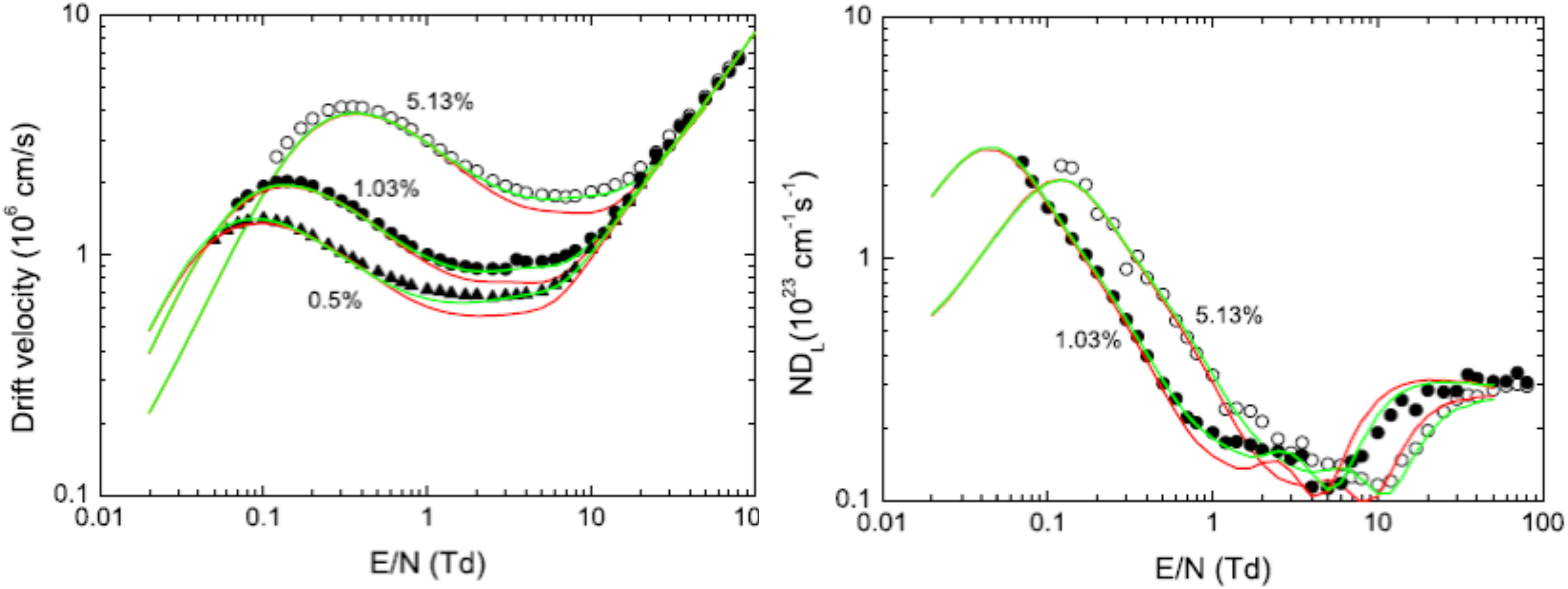
$$w = -\left(\frac{2}{m}\right)^{1/2} \frac{eF}{3N} \int_0^\infty \frac{E}{\sigma_m(E)} \frac{df_0(E)}{dE} dE$$

$$D_T = \left(\frac{2}{m}\right)^{1/2} \frac{1}{3N} \int_0^\infty \frac{E}{\sigma_m(E)} f_0(E) dE$$

Experiment is simple, but requires guessing cross sections, that can form a non-unique set

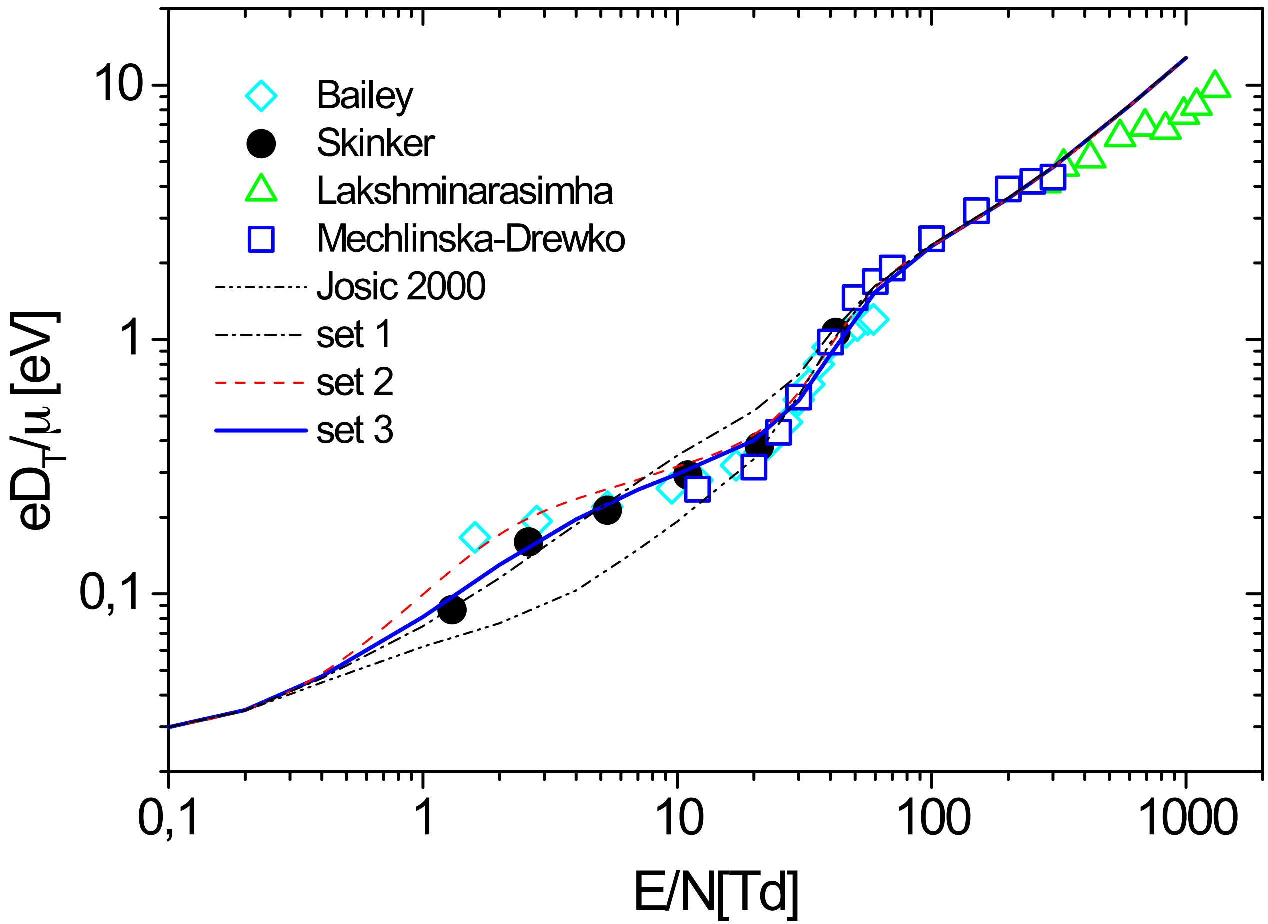
Vibrational: swarm cross-check

CH_4



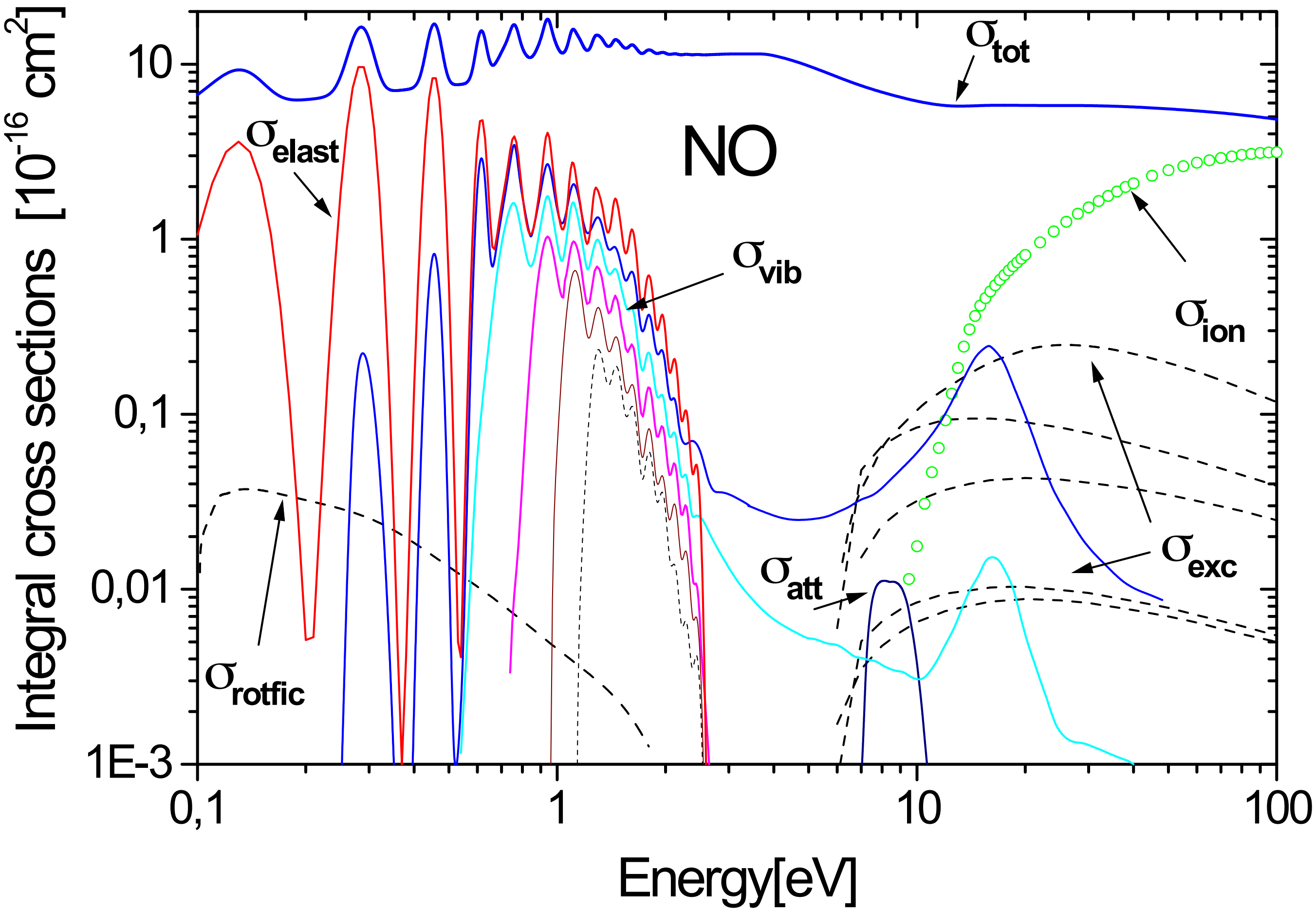
M.-Y. Song et al., J. Phys. Chem Ref. Data (2015)

NO swarm data



L. Josić, T. Wróblewski, Z.Lj. Petrović, J. Mechlińska-Drewko, G. Karwasz
Chem. Phys. Lett. 350 (2001) 318

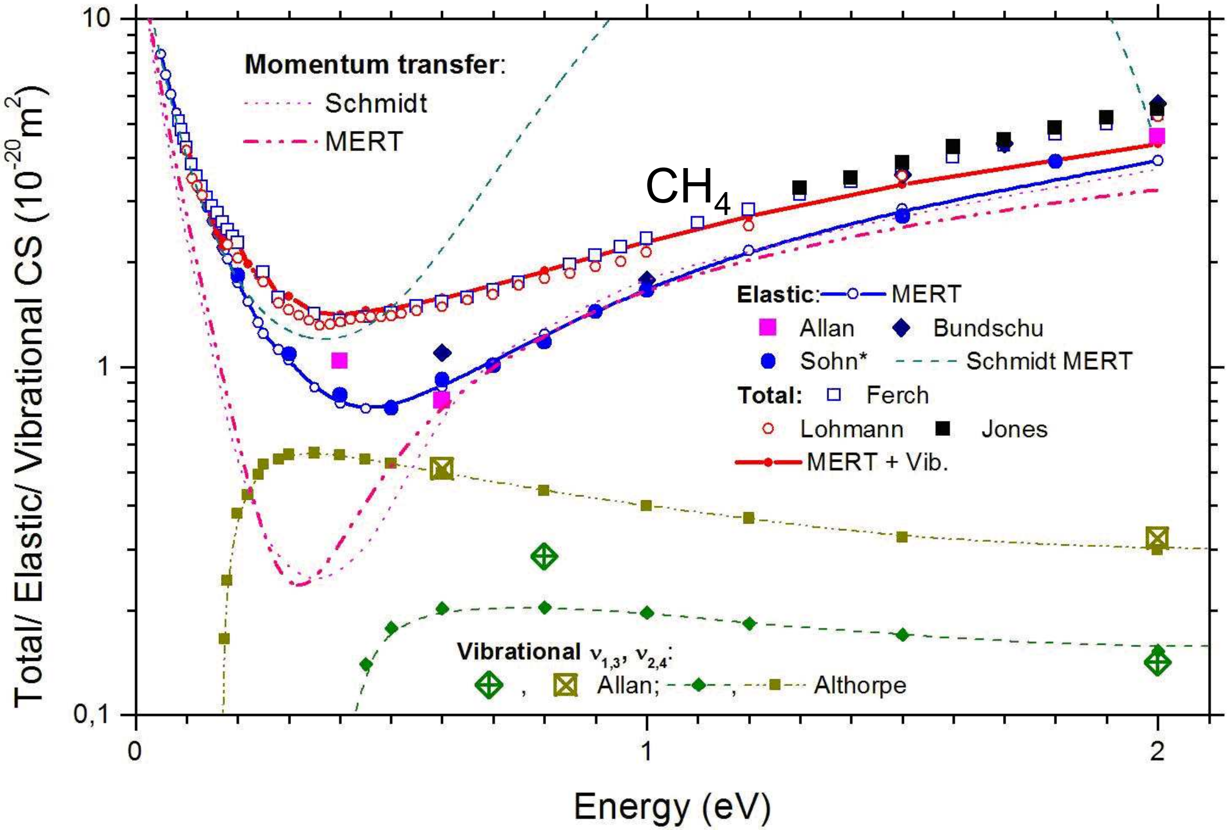
NO – congruent set of cross sections



Confirmed by beam experiments (ANU Canberra, Fribourg Uni)

Semi-empirical methods: elastic (MERT)

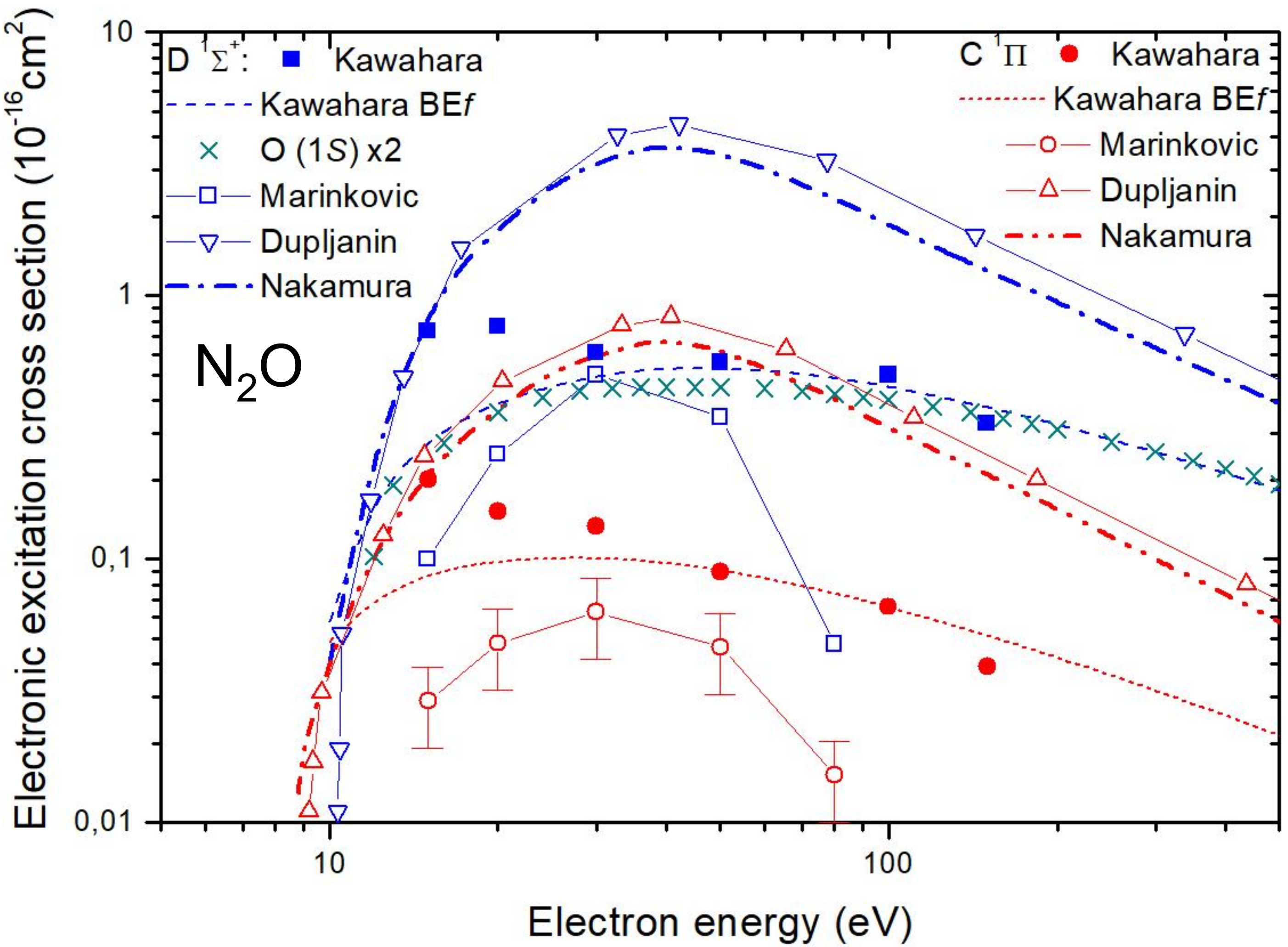
Link between elastic, total, MTCS: in some simple cases, and low energies



MERT allows to **inks elastic, total, MTCS:**
for atoms, spherical molecules @ energies <1 eV

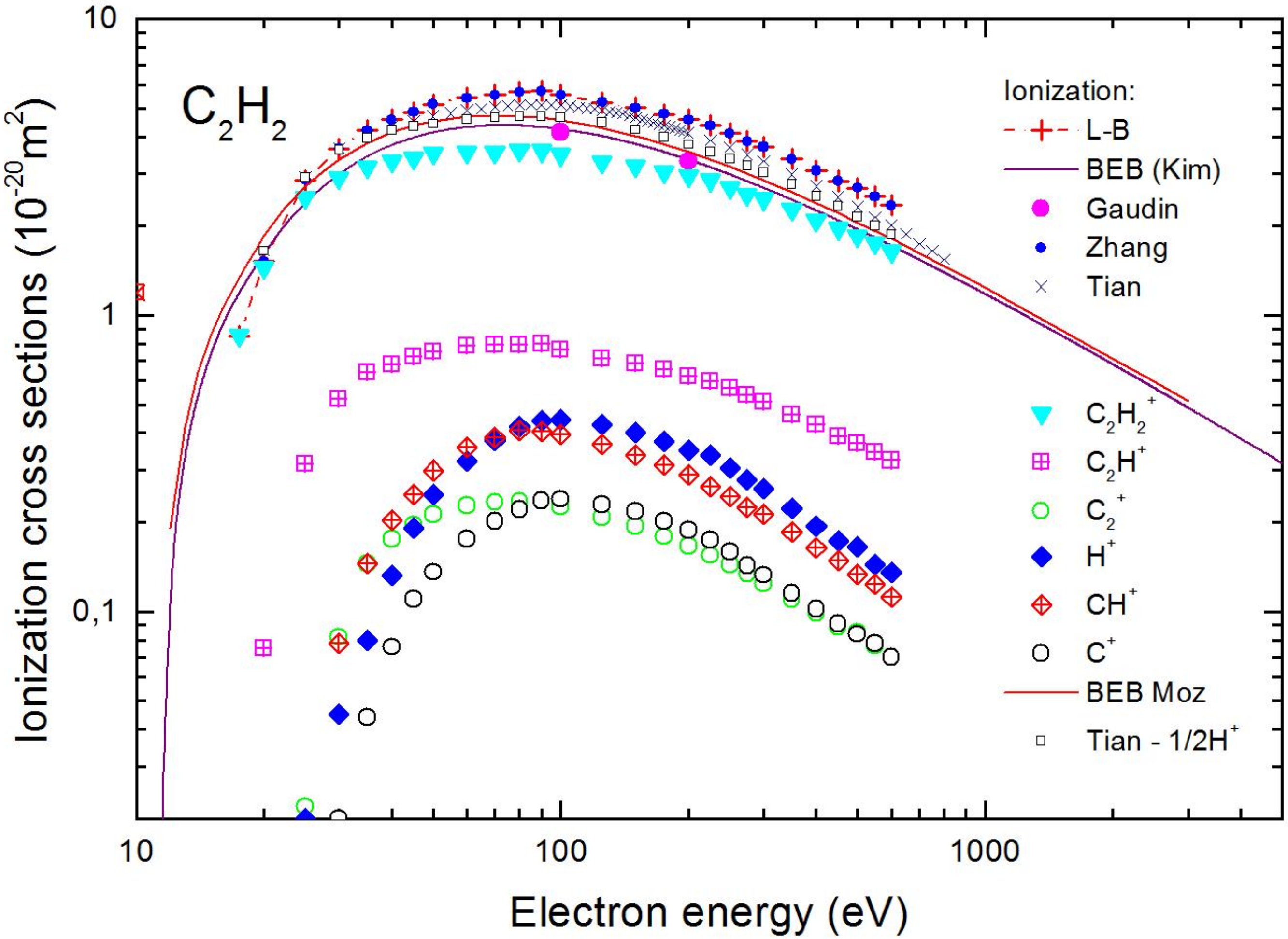
K. Fedus, G. Karwasz, Eur. J. Phys. D (2014)

Electronic excitation: swarm, beam, theory



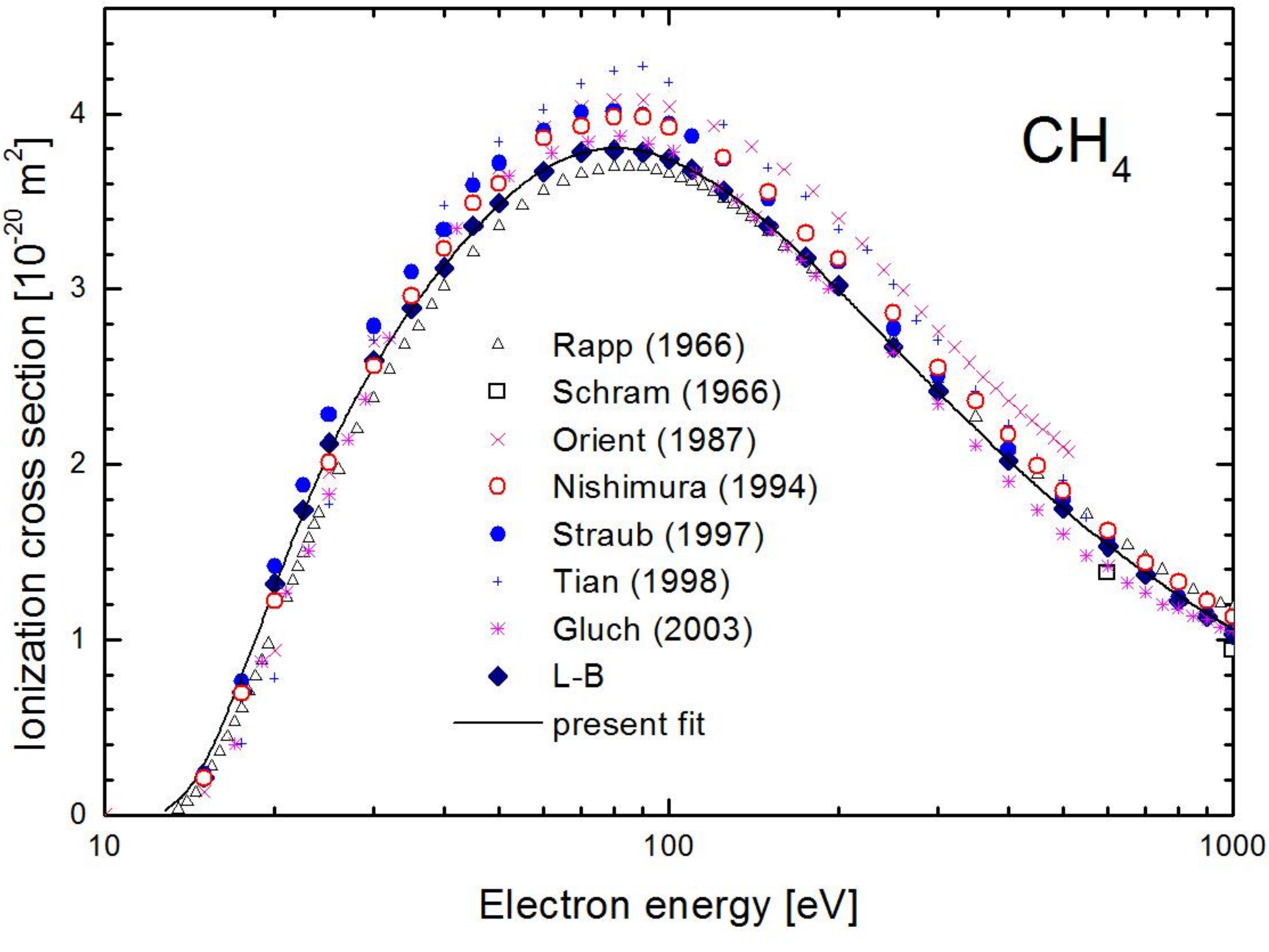
M.-Y. Song et al., J. Phys. Chem. Ref. Data, submitted

Ionization: partial

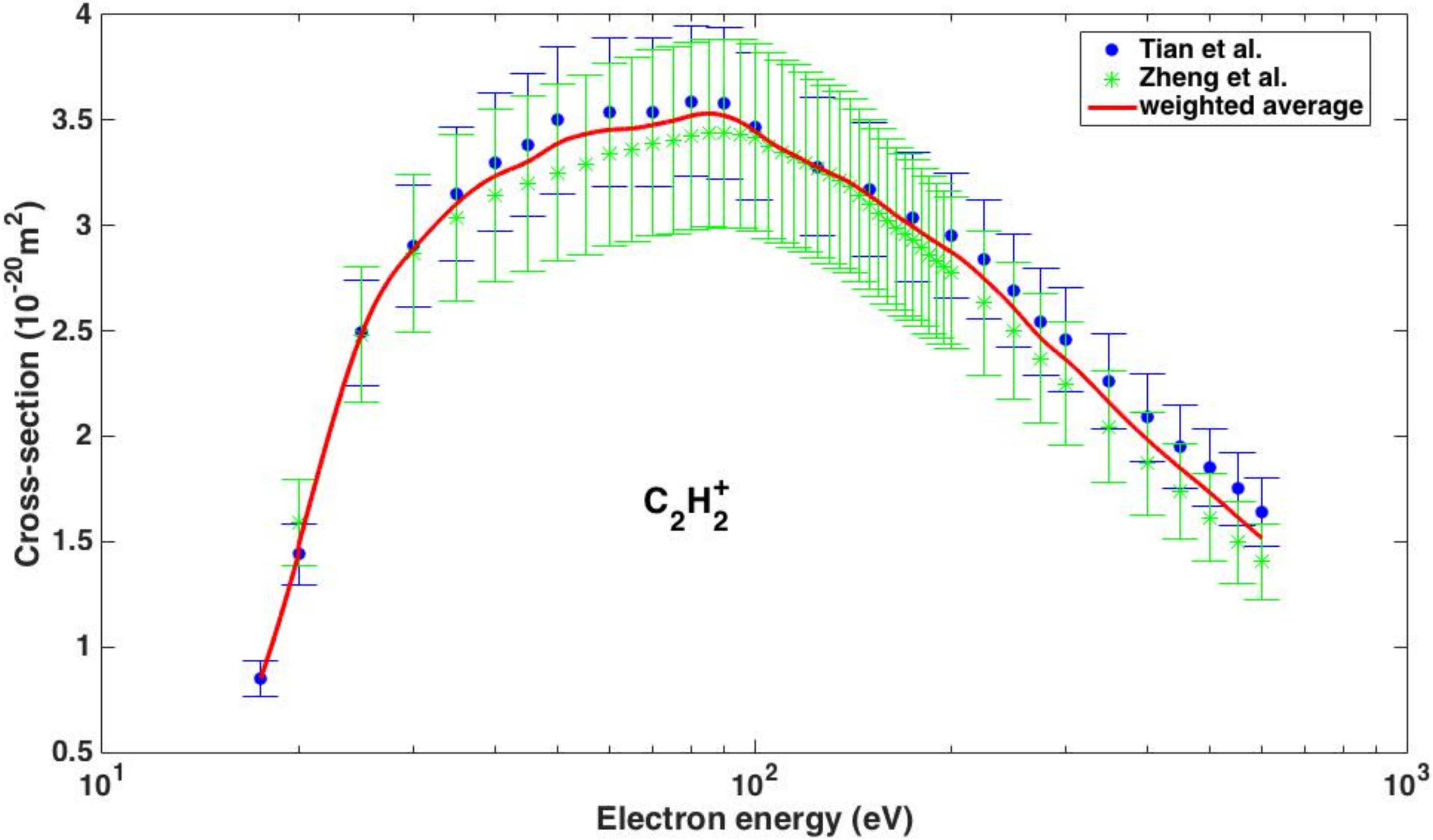


These data are from L-B, based on Tian and Vidal.
Data by Feil et al. and King/Price change little on this picture

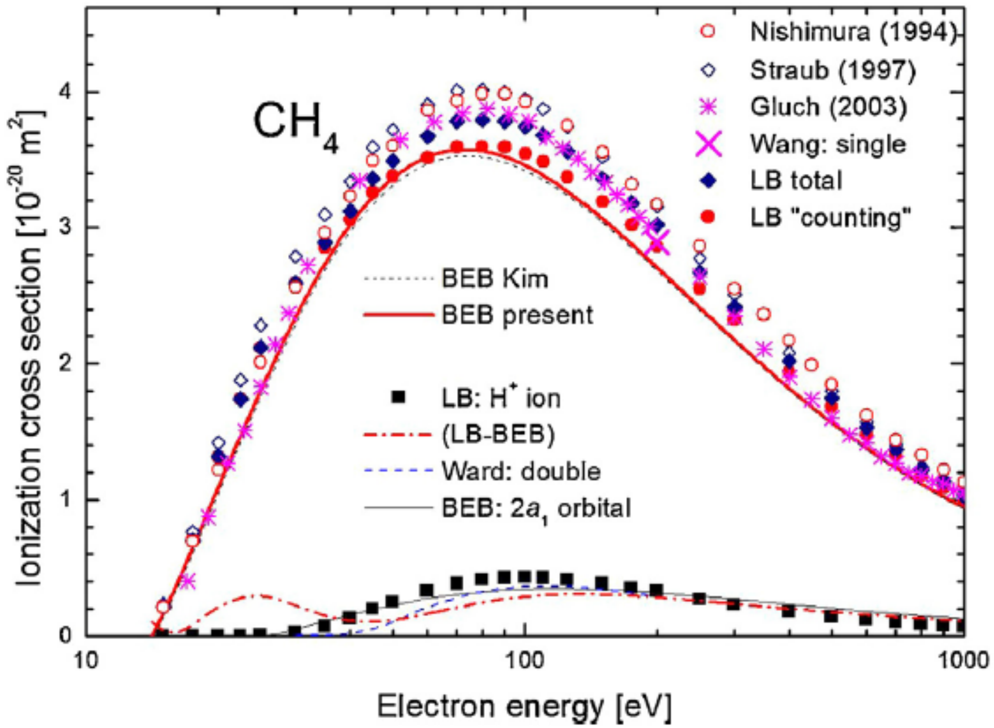
Ionization: total (±5%)



Ionization: partial (±15%)



Ionization: BEB formula



Experiment overestimes t*counting* ionization (due to dissociative ionization)

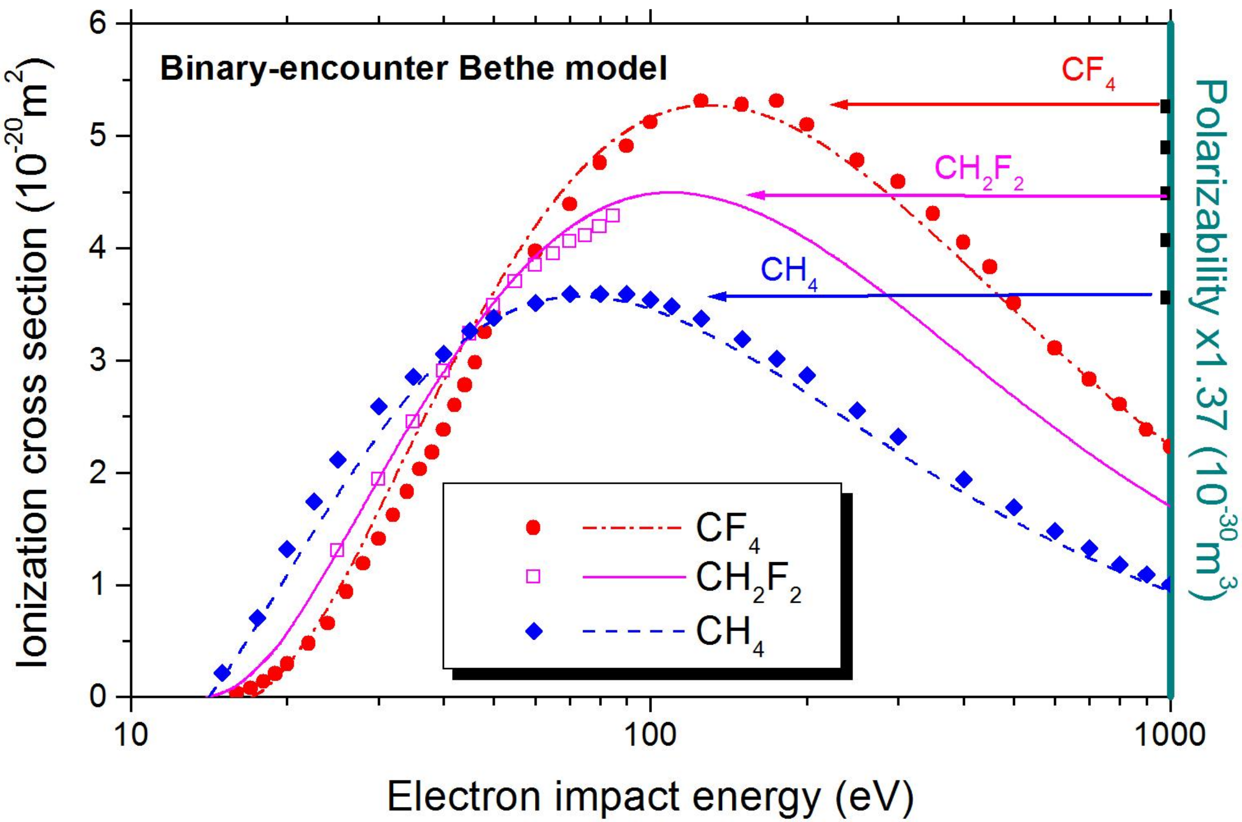
$$\sigma = \sum_n 4\pi a_0^2 \xi_n \left(\frac{R}{I_n}\right)^2 \frac{1}{t+u_n+1}\left\{1-\frac{1}{t}+\frac{\ln t}{2}\left(1-\frac{1}{t^2}\right)-\frac{\ln t}{t+1}\right\}$$

Normalized energies: $t = E/I_n$, $u_n = E_{kin}/I_n$

Only two values needed from QCh

G. Karwasz, P. Mozejko, M.-Y. Song, Int. J. Mass Spectrometry365/366 (2014) 23 (2014)

Ionization (BEB): CH_4, CH_3F, ... CF_4

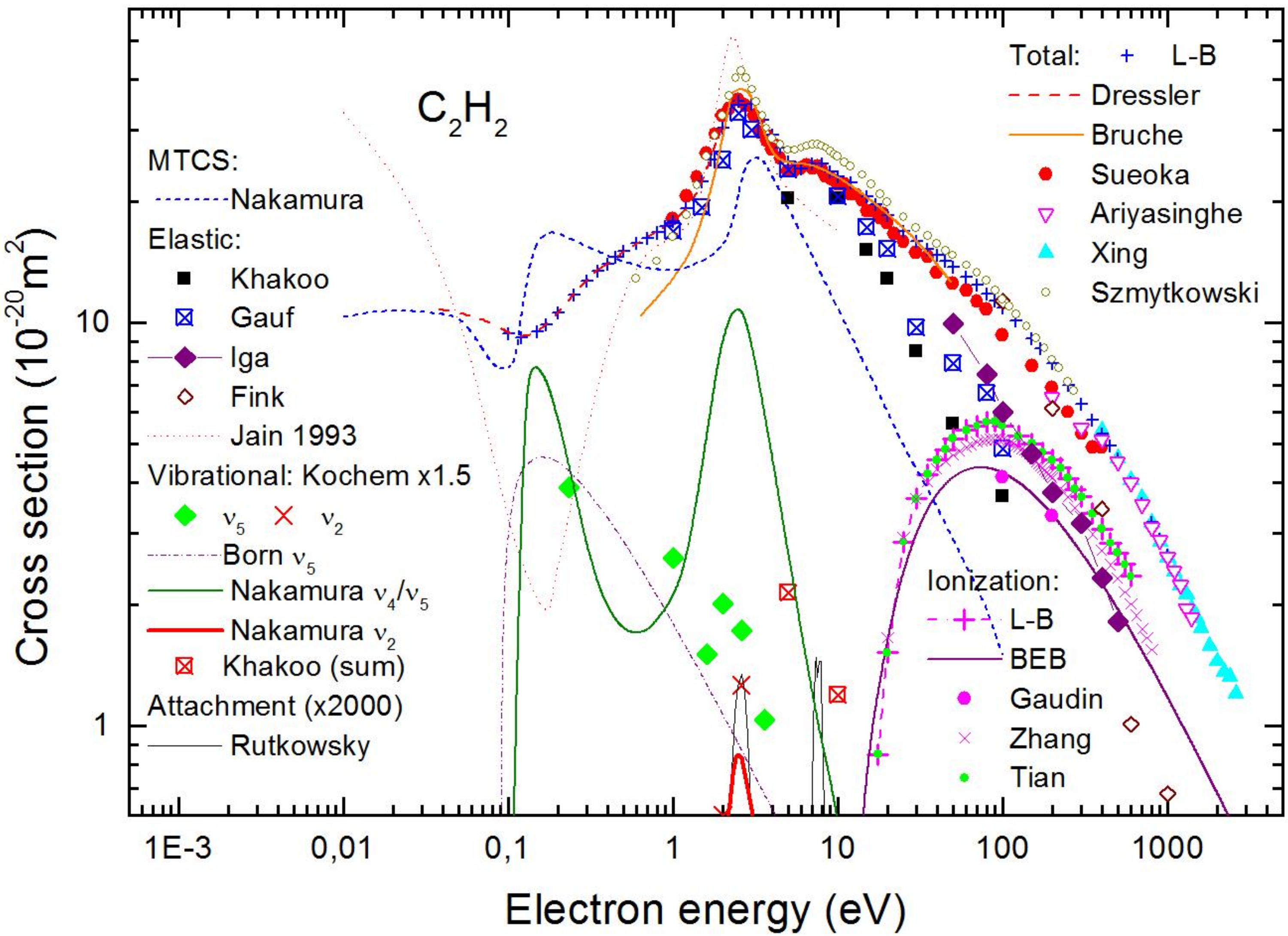


Thumb rule (?)

$\sigma_{max} = 4/3\ \alpha$

G. Karwasz, P. Mozejko, M.-Y. Song, Int. J. Mass Spectrometry 365 (2014) 232

Total and partial: C_2H_2



A+M Data Center Activities in National Fusion Research Institute

Mi-Young Song with Team Members

Plasma Technology Research Center
National Fusion Research Institute

http://www.adas.ac.uk/2016talks/2016_ADAS_MSong.pdf

NFRI – Republic of Korea

Evaluated data (2007 ~ 2015)

구분		total scattering	eleastic scattering	momentum transfer	DCS	total ionization	partial ionization	TDCS	Neutral dissociation	Total attachment	Dissociative attachment	vibrational excitation	rotational excitation	electronical excitation
		TCS	ES	MT	DCS	TICS	PICS	TDCS	NDCS	TACS	DACS	VI	RO	EX
1	H2	C	V	V	D	Q	Q			Q		V	Q	Q
2	O2	Q	Q	Q	D	Q	V	Q			V	Q		V
3	N2	Q	Q	V	D	Q	V	Q				Q	Q	Q
4	Ar	V	Q	Q	D	V	V							
5	Xe	V	Q	Q	D	V	V							
6	CF4	V	V	V	V	V	Q	Q	Q	Q				
7	C2F6	V	Q	Q	V	V	V	Q		Q				
8	C3F8-2013	V	Q	Q	V	V	Q	Q		Q				
9	C4F8-2013	V	V	V	V	Q	Q	Q		Q				
10	CF3I-2013	V			D	Q	Q							
11	CHF3		V	V	D	V	Q	Q						
12	CCl2F2	Q	Q		D	V	Q							
13	SF6	V	Q	Q	D	Q	Q							
14	CCl4	V			D	V	V							
15	SiF4	V			D	Q	Q		Q					
16	SiF3					Q	Q							
17	SiF2					Q	Q							
18	SiF					Q	Q							
19	Si					Q	Q							
20	SiH4	V	Q	Q	D	V	V	Q						
21	Si2H6	Q	Q	Q	D			Q						
22	NF3	Q	Q	Q	D	Q	Q				Q			
23	NH3	V	Q	Q	D	Q	Q							
24	N2O					V	Q			Q	Q			
25	NO2					Q	Q							
26	NO		Q			Q	Q			Q				
27	C					Q	Q							
28	O					Q	Q							
29	N					Q	Q							
30	F					Q	Q							
31	Cl					Q	Q							
32	Br					Q	Q							

Cross Sections for Electron Collisions with Methane

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Cross section data are compiled from the literature for electron collision (CH_4) molecules. Cross sections are collected and reviewed for total sca scattering, momentum transfer, excitations of rotational and vibrational state ionization, and dissociative attachment. The data derived from swarm exper considered. For each of these processes, the recommended values of the cro presented. The literature has been surveyed through early 2014. © 2015 A LLC. [http://dx.doi.org/10.1063/1.4918630]

Cross Sections for Electron Collisions with Acetylene

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(Revised 18 November 2015)

Cross section data are compiled from the literature for electron collisions with acetylene (HCCH) molecules. Cross sections are collected and reviewed for total scattering, elastic scattering, momentum transfer, excitations of rotational and vibrational states, dissociation, ionization, and dissociative attachment. The data derived from swarm experiments are also considered. For each of these processes, the recommended values of the cross sections are presented. The literature has been surveyed through early 2016.

PACS numbers: 34.80.Bm, 52.20.Fs
Keywords: electron collisions, total cross sections, ionization, dissociation, attachment, evaluation

I. INTRODUCTION

Acetylene (HCCH) is the

The accuracy for the measured cross section data for processes involving ground state species is

II. TOTAL SCATTERING CROSS SECTION

III. ELASTIC SCATTERING CROSS SECTION

Since the last review of electron-acetylene collisions by Nakamura[1], theoretical cross sections for excitation of

IV. MOMENTUM TRANSFER CROSS SECTION

The momentum-transfer cross-section for electron-acetylene collisions has been determined in several recent studies in which elastic differential cross sections were measured or calculated. Similarly to the recommended data for differential elastic cross sections discussed above, the recommended momentum-transfer cross section is from the recent study by Gauf *et al.*[3]. The agreement of the data by Gauf with a previous experimental work by Iga *et al.*[4] is very good. Theoretical cross sections determined in the same work by Gauf *et al.*[3], and also by Jain[5], and Gianturco and Stoecklin[6] agree with each other within 5-10% above 1 eV. However, they are larger than experimental data by about 20% over the whole

http://www.adas.ac.uk/2016talks/2016_ADAS_MSong.pdf

Nitrogen oxides (2019)

Journal of Physical and Chemical Reference Data ARTICLE scitation.org/journal/jpr

Cross Sections for Electron Collisions with NO, N_2O, and NO_2

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Nitrogen oxides (2019)

TABLE 7. Recommended total and partial cross sections for electron-impact ionization of nitric oxide, NO in 10^{-16} cm^2. Energy in eV

Energy	NO^+	N^+	O^+	NO^{2+}	Total
12.5	0.048				0.048
15	0.21				0.21
17.5	0.48				0.48
20	0.59				0.59
22.5	0.75				0.76
25	0.98	0.014	0.004		0.99
30	1.20	0.054	0.013		1.27
35	1.37	0.132	0.022		1.53
40	1.51	0.191	0.046	0.000 17	1.75
45	1.67	0.252	0.073	0.001 5	2.00
50	1.74	0.317	0.104	0.004 2	2.16
55	1.84	0.315	0.140	0.007 6	2.31
60	1.89	0.375	0.158	0.011 3	2.43
70	1.92	0.444	0.170	0.015 8	2.55
80	1.96	0.479	0.199	0.025 0	2.67
90	1.97	0.481	0.251	0.029 5	2.74
100	1.97	0.506	0.247	0.029 5	2.75
125	1.92	0.499	0.286	0.032 1	2.73
150	1.84	0.502	0.274	0.029 5	2.65
200	1.69	0.438	0.267	0.030 6	2.43
250	1.55	0.406	0.246	0.028 4	2.23
300	1.40	0.385	0.191	0.023 3	2.00
400	1.24	0.309	0.168	0.023 2	1.74
500	1.11	0.265	0.139	0.020 3	1.53
600	0.98	0.228	0.139	0.014 7	1.36
800	0.81	0.190	0.100	0.013 2	1.11
1000	0.70	0.169	0.076	0.006 9	0.95

recommended total and partial cross sections in NO are shown in Fig. 17 and given in Table 7, respectively.

2.10. Electron attachment (DEA) cross section

Rapp and Briglia[70] measured the absolute TCS's for negative-ion formation in NO by electron impact in a total ionization tube. The dissociative electron attachment (DEA) channel forming this negative ion is O^- from NO. Orient and Chutjian[71] identified three channels forming $O^-(^2P)$, but did not present the absolute cross sections. Rapp and Briglia[70] is the only available measured DEA cross sections and

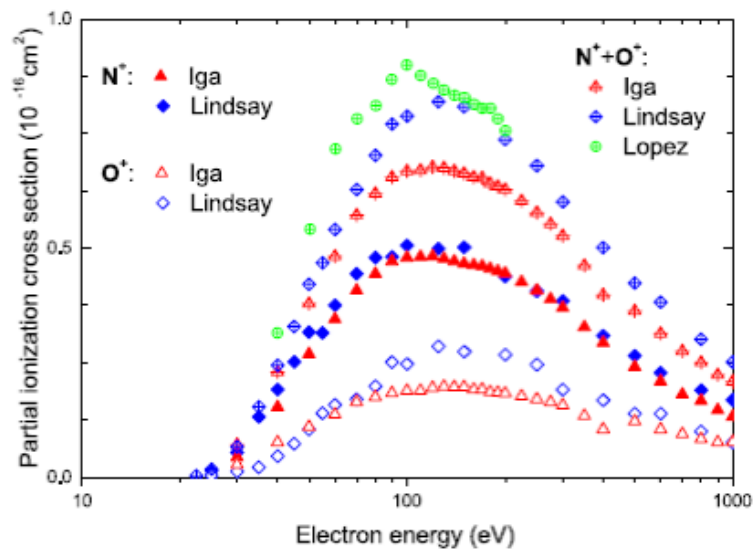
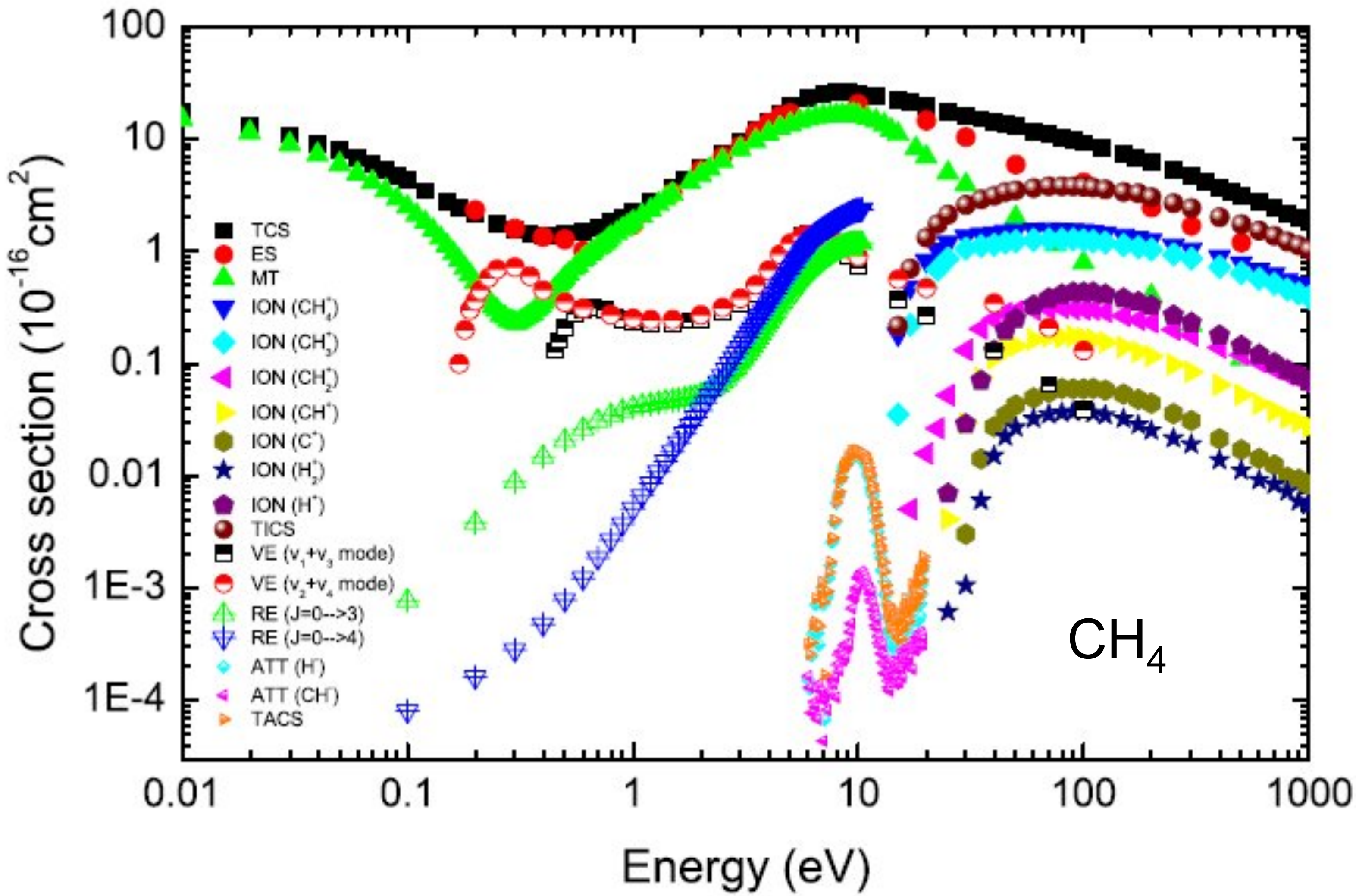


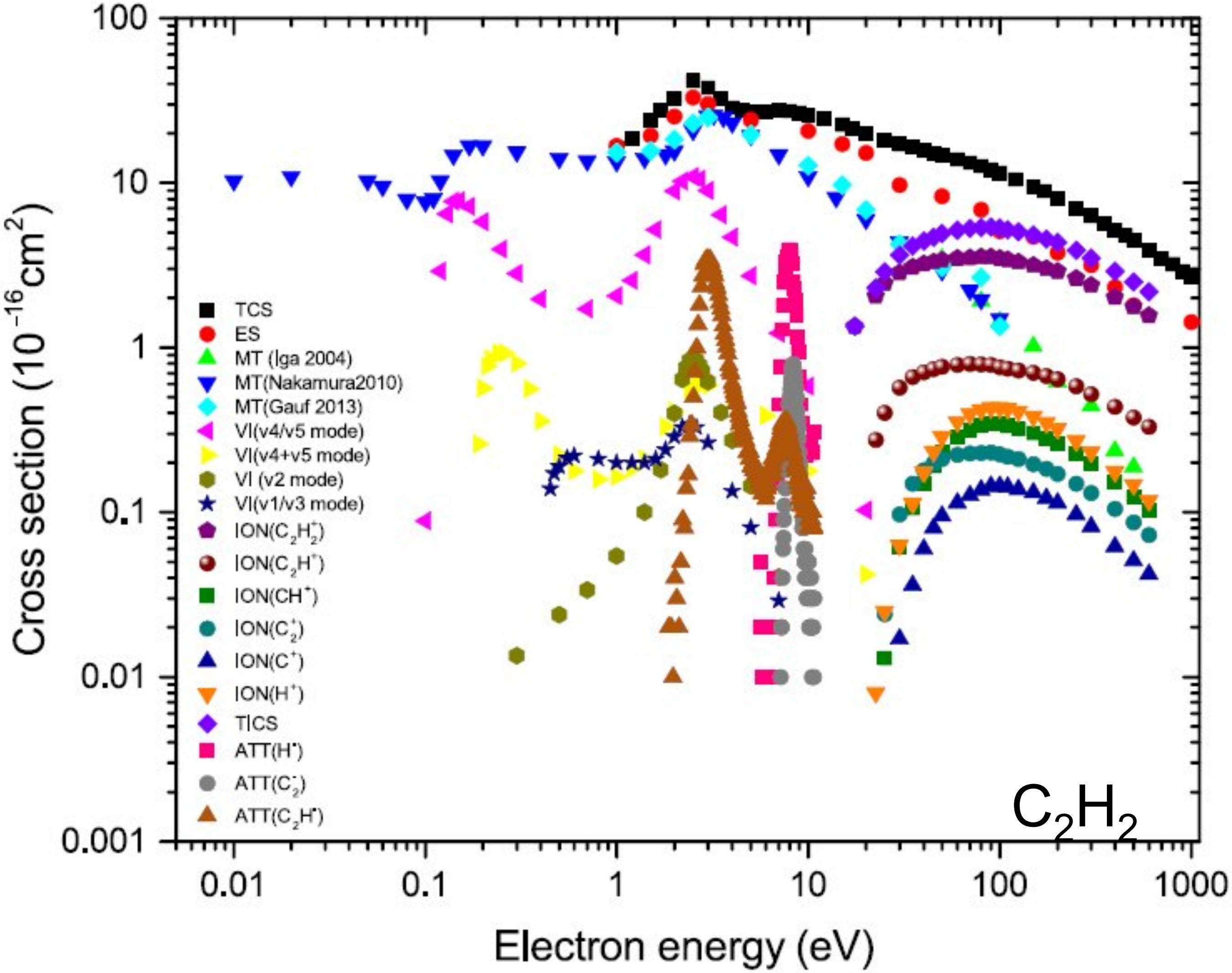
FIG. 16. Partial ionization cross sections for ionization of NO by electron impact: fragment N^+ and O^+ ions and the summed ($N^+ + O^+ + NO^{2+}$ ion signal unresolved in measurements of Lopez *et al.*). Experimental data are from Iga *et al.*,[30] Lindsay *et al.*,[29] and Lopez *et al.*[31]

„Recommended” cross-sections: CH_4



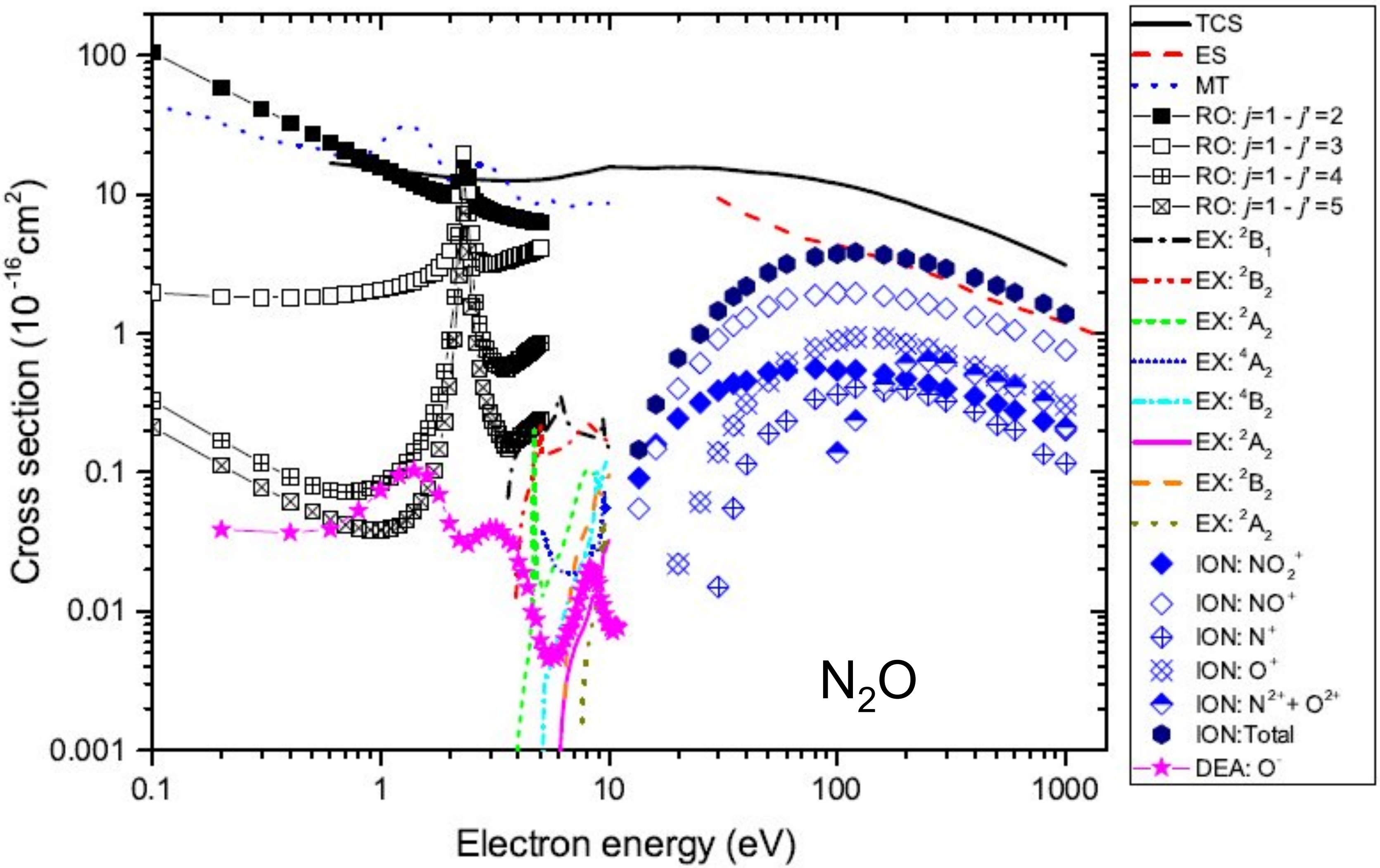
M.-Y. Song, J.-S Yoon, H. Cho, Y. Itikawa, G.P. Karwasz, V. Kokoouline, Y. Nakamura, and J. Tennyson, Cross Sections for Electron Collisions with Methane, J. Phys. Chem. Ref. Data, 44 (2015) 023101.

„Recommended" cross-sections: C_2H_2



M.-Y. Song, J.-S. Yoon, H. Cho, G. Karwasz, V. Kokoouline, Y. Nakamura, J. Tennyson, Cross Sections for Electron Collisions with Acetylene", J. Phys. Chem. Ref. Data 46 (2017); 013106

„Recommended" cross-sections: N_2O



M.-Y. Song et al., JPCRD (2019) in press

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International Atomic Energy Agency

Atomic Molecular Data Services

Provided by the Nuclear Data Section

Thank you for the attention!