Electron scattering on triatomic molecules - the need for data

Sendai, 24.01.2006

Electron scattering cross sections

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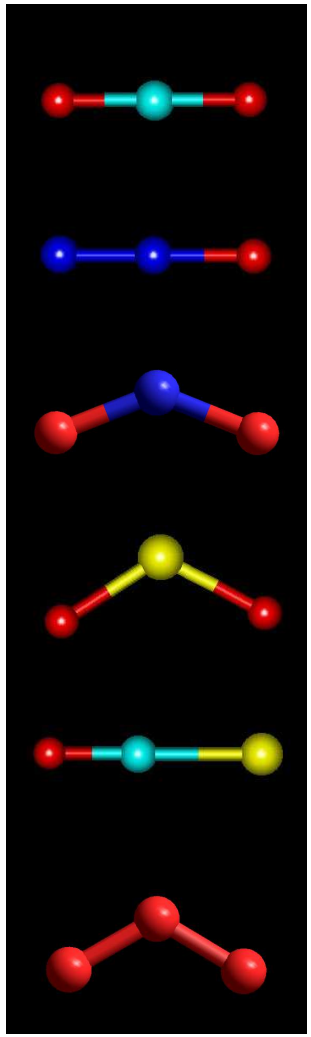
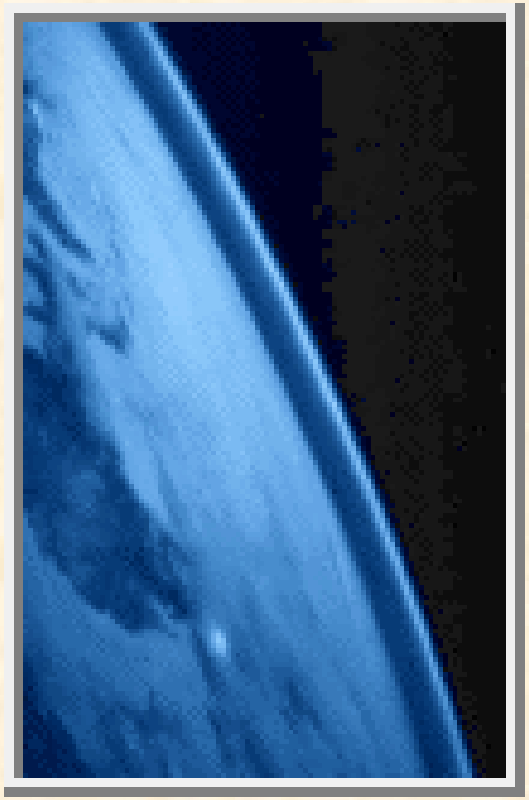
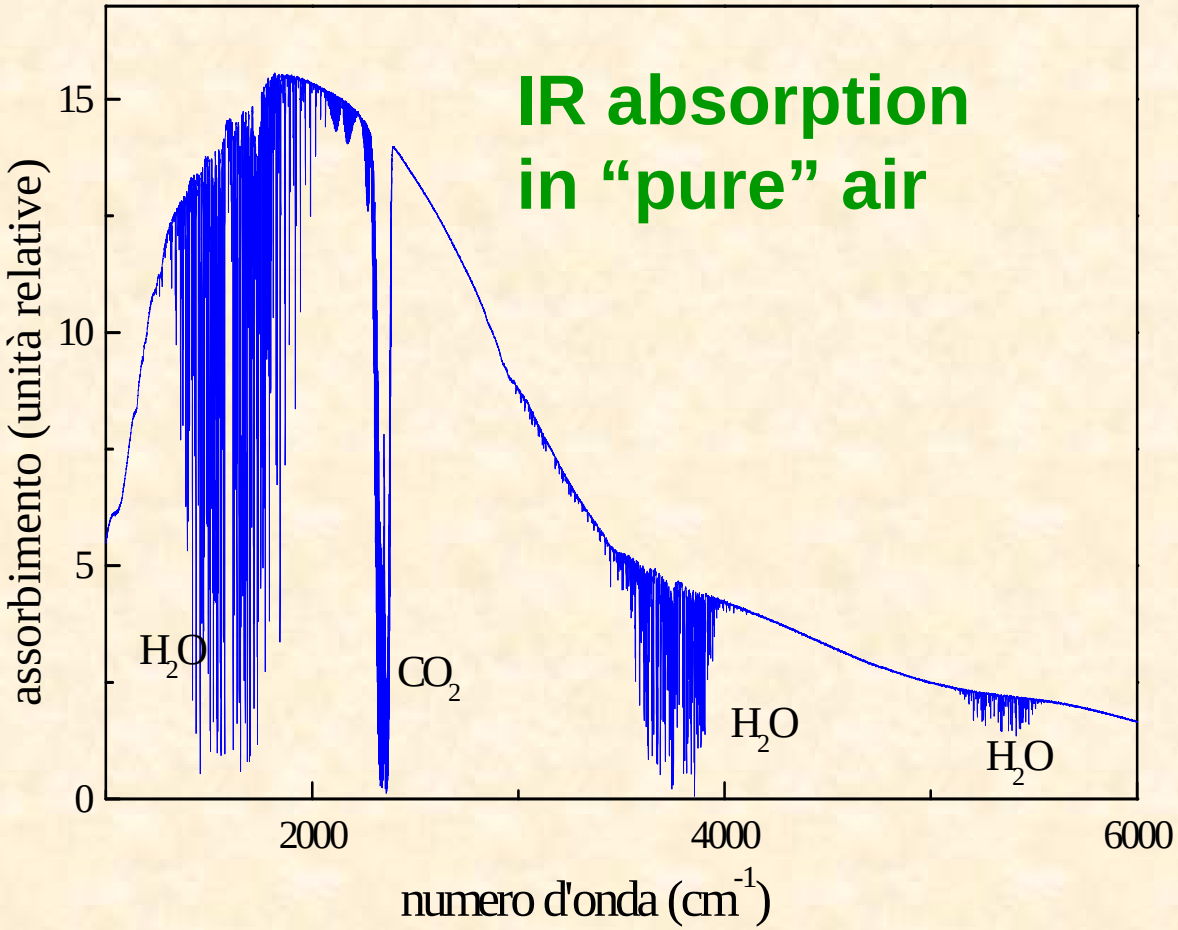
“Triatomic” molecules

Molecule	No electrons	No. valence	Bond length	Bond angle	Dipole
CO_2	22	14	1.16 Å	180°	0
N_2O	22	14	1.13/1.19 Å	180°	0.167 D
NO_2	23	15	1.19 Å	134°	0.316 D
SO_2	32	32	1.43 Å	119°	1.63 D
OCS	30	30	1.16/1.59 Å	180°	0.712 D
O_3	**24**	**18**	**1.27Å**	**117°**	**0.53 D**



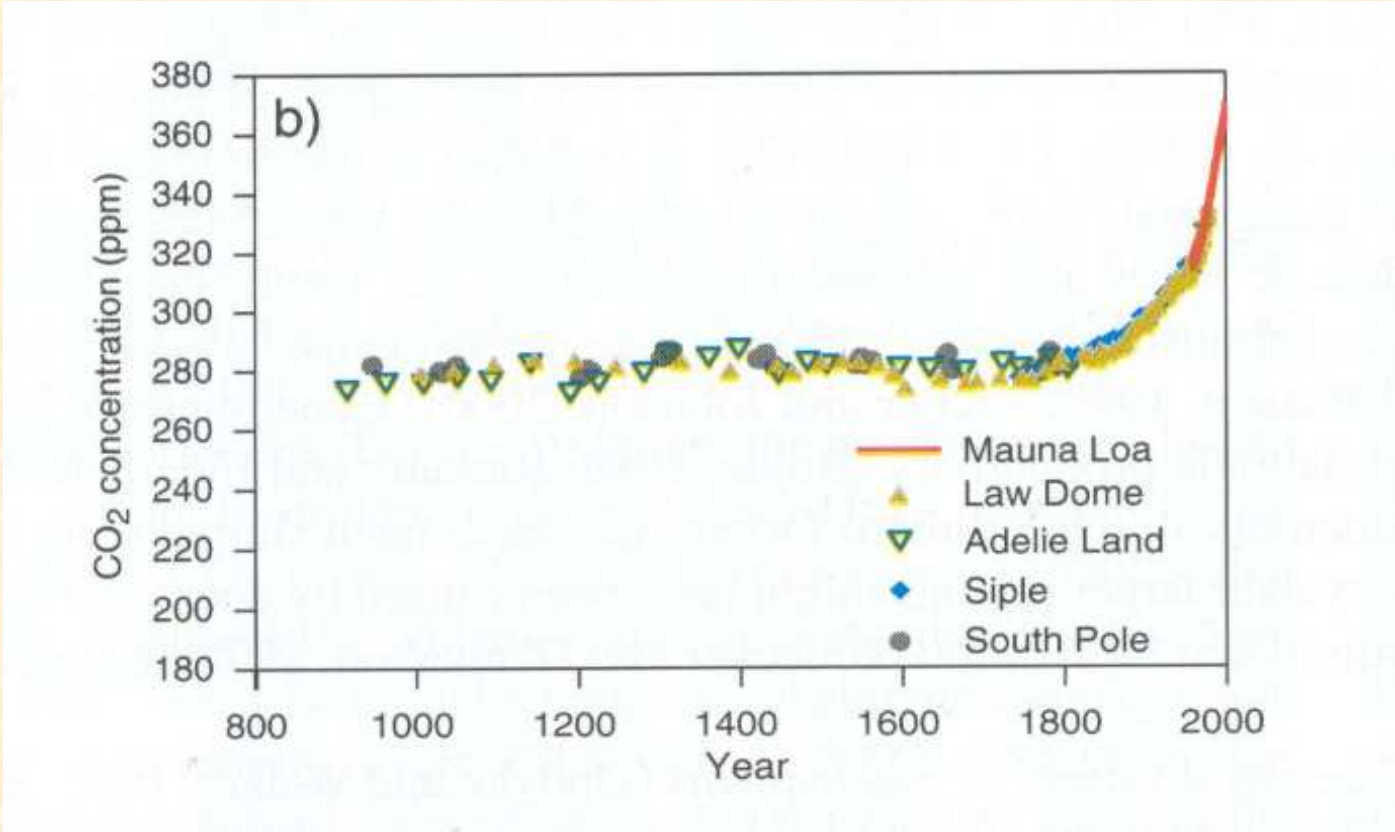
“Blanket effect” = water vapour + carbon dioxide





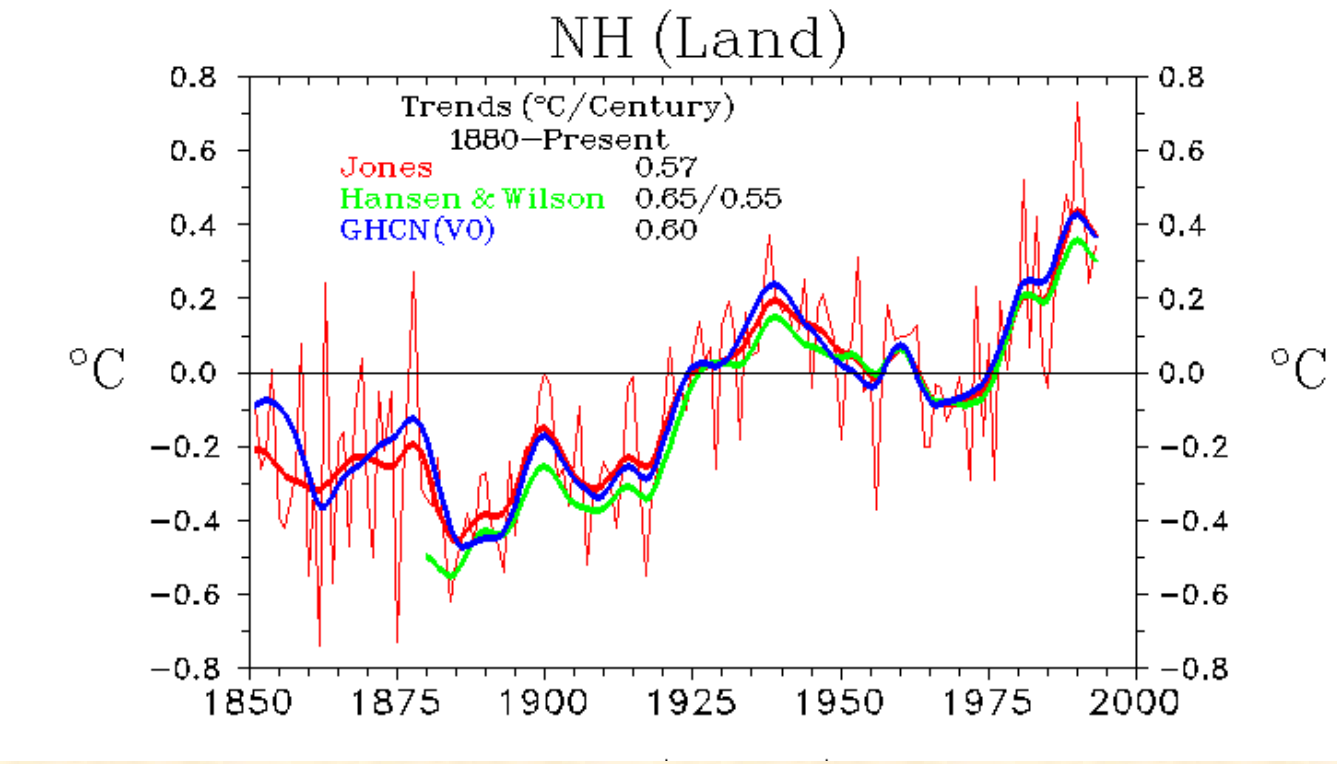
H_2O: -18℃ →+15°C **CO_2: +15℃ →+???**

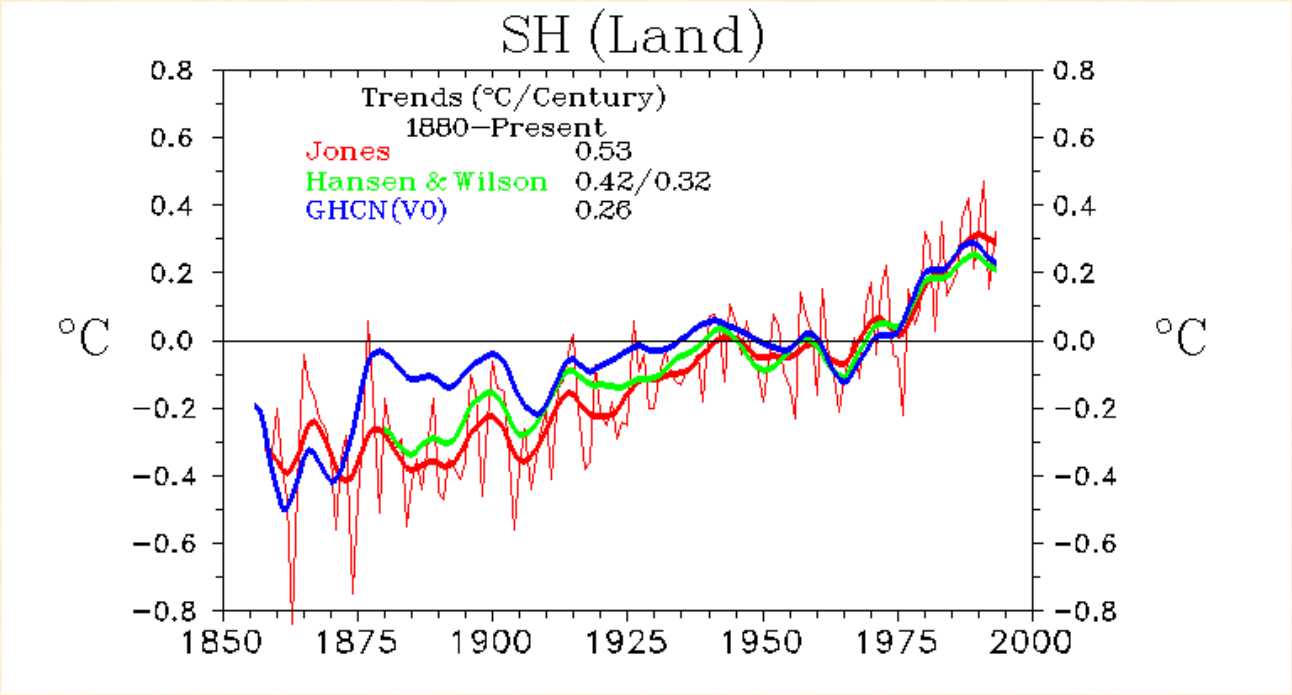
CO_2 contents in atmosphere



from 1850 to 2005 **>25% rise**

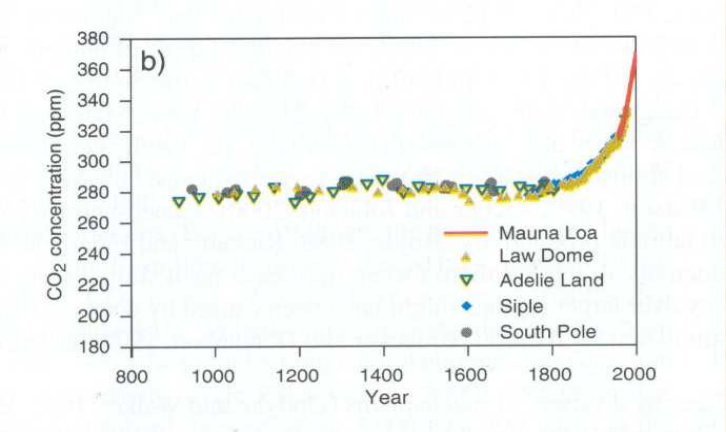
“Greenhouse” effect





Kyoto Protocool!

Greenhouse and anti-greenhouse gases



$\tau_{CO2} = 150$ y

N_2O $\tau = 210$ y (rise cropping, bio-mass burning)

SO_2 τ = few weeks but albedo rising (cooling) effect and antropogenic production = 10x natural

NO_2 automobile traffic (poisonous) pollutant

OCS tundra de-freezing processes

Semiconductor industry

JOURNAL OF APPLIED PHYSICS 97, 113502 (2005)

Vibrational spectroscopy study of Ar^+-ion irradiated Si-rich oxide films grown by plasma-enhanced chemical vapor deposition

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SiO_x thin films with different stoichiometry degree were obtained by plasma-enhanced chemical vapor deposition on crystalline silicon substrates from SiH_4 and N_2O gas mixtures. Two twin sets

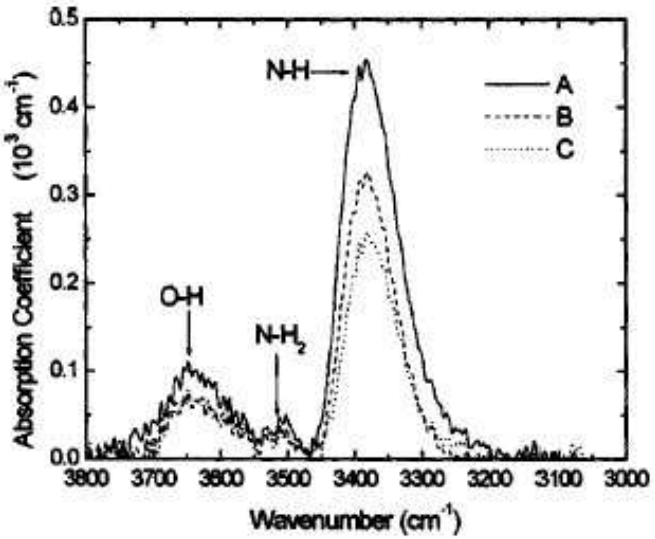


FIG. 2. Absorption peaks of as-deposited samples A, B, and C related to the O–H (3650 cm^{-1}), NH_2 (3500 cm^{-1}), and N–H (3380 cm^{-1}) vibrations.

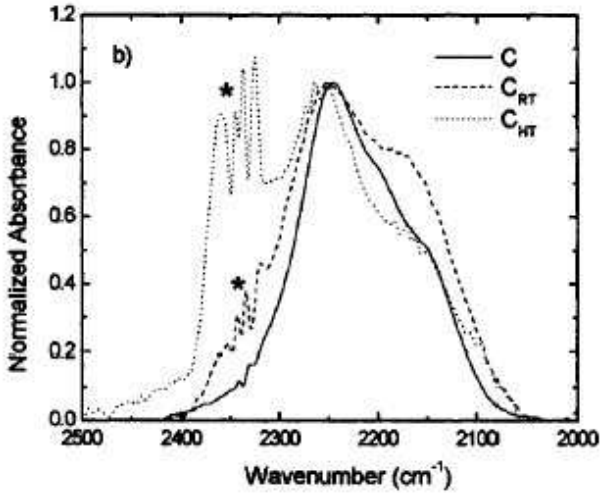


FIG. 4. (a) Si–H-related absorption spectrum of untreated and ion-irradiated C sample. The features at about 2350 cm^{-1}, labeled by the star (*), are due to the presence of residual CO_2 into the sample chamber. (b) The same spectrum normalized to the absorption peak at 2250 cm^{-1}.

“Electron” scattering

Paul Lenard (1895)

4. *Ueber die Absorption der Kathodenstrahlen; von P. Lenard.*

Seit in den Metallen zum ersten male feste Körper gefunden wurden, welche für Kathodenstrahlen durchlässig sind, gelang es, die Durchlässigkeit auch anderer Stoffe zu prüfen. Es zeigte sich, dass nicht etwa die Metalle allein, sondern dass so gut wie alle feste Körper durchstrahlt werden, aber alle nur in ganz dünnen, zarten Schichten; kein einziger fester Körper fand sich, der gegen Kathodenstrahlen sich verhielte wie etwa Glas gegen Licht. Viel durchlässiger als die festen Körper waren dagegen die gasförmigen. Hier maassen die durchstrahlbaren Strecken schon nach Centimetern; sie gaben so ein leicht zu erhaltendes relatives Maass ab für die Durchlässigkeit. So gemessen zeigte sich die Durchlässigkeit in Zusammenhang mit der Dichte der gasförmigen Medien insofern, als jedesmal ein dünneres Gas durchlässiger war als ein dichteres. Es schien mir nun, dass dieser Zusammenhang

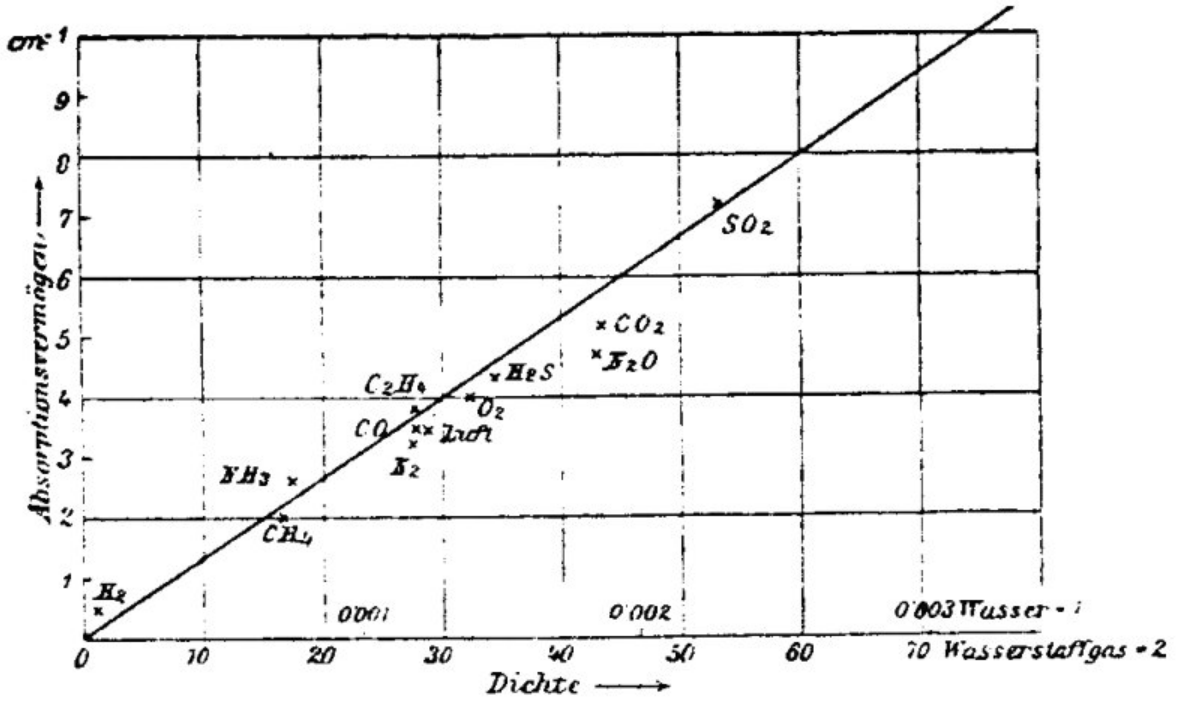


Fig. 1.

Ann.d.Phys.u.Chem. N.F. 56 (1895)

Total (absolute) cross sections: $I = I_0 \exp(-\sigma n l)$

Partial cross sections:

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

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

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

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

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

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

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

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

Hayashi 1992

Electron Collision Cross Sections

Makoto Hayashi

ここでは電子が気相の原子・分子と衝突するときに起こる種々の衝突断面積の一組の値をまとめることにする．この電子衝突の過程の内容としては，弾性衝突，回転励起，振動励起，電子励起，解離衝突，電離衝突および電子付着がある．これらの素過程は，このハンドブックのⅠ編2章に，また総合報告[1]，およびそれらの引用文献の中に論じられている．

1992年5月現在，筆者が電子衝突断面積の一組の値を決定した原子・分子は，表3・1のとおりである．何回か改訂を行ったものもある．原則として筆者が決定した値を，結論だけ図3・1に示す．衝突する電子のエネルギー範囲は0～10^3eVで，弾性衝突断面積の値として，全弾性衝突断面積の値は示さず，運動量移行断面積の値を用いた．表3・1の原子・分子のうち，Cd，NO，CCl_2F_2，CCl_4は，新しいデータを含めて改訂したいので，図は省略した．また，K，Cl_2，CS_2，NO_2，NF_3，SiF_4，C_2H_5OH，C_3F_8などの断面積の値を決めたいが，データが不足している．図に示された値は，現段階での最も良いと思う値であって，今後より正確な値が報告されるごとに，改訂を行わなければならない．　（林　眞）

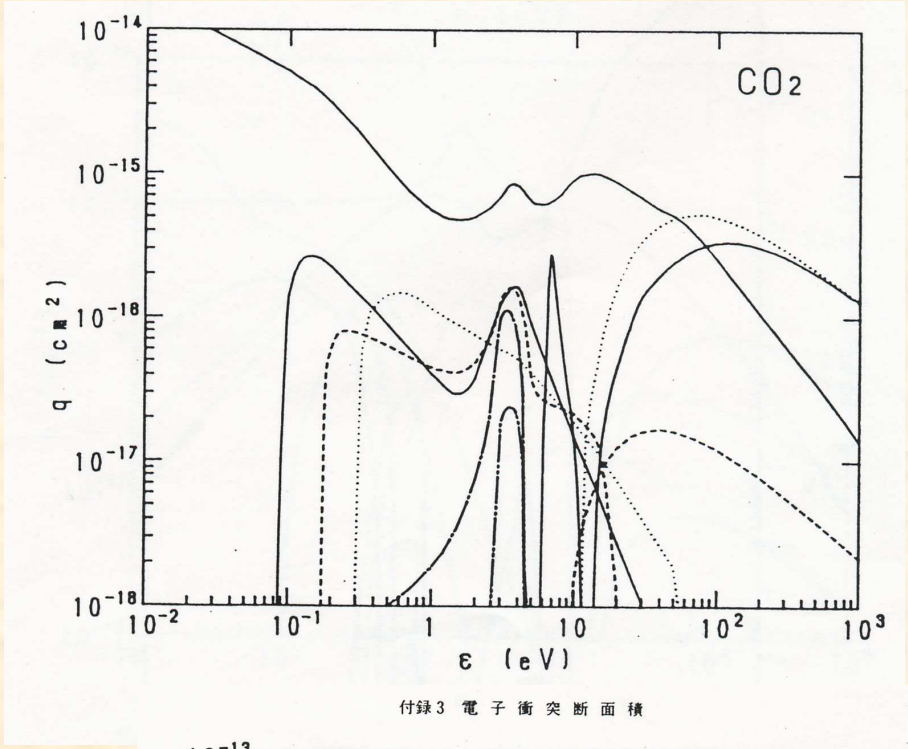
参考文献

1) 林　眞：応用物理，58，2-20（1989）

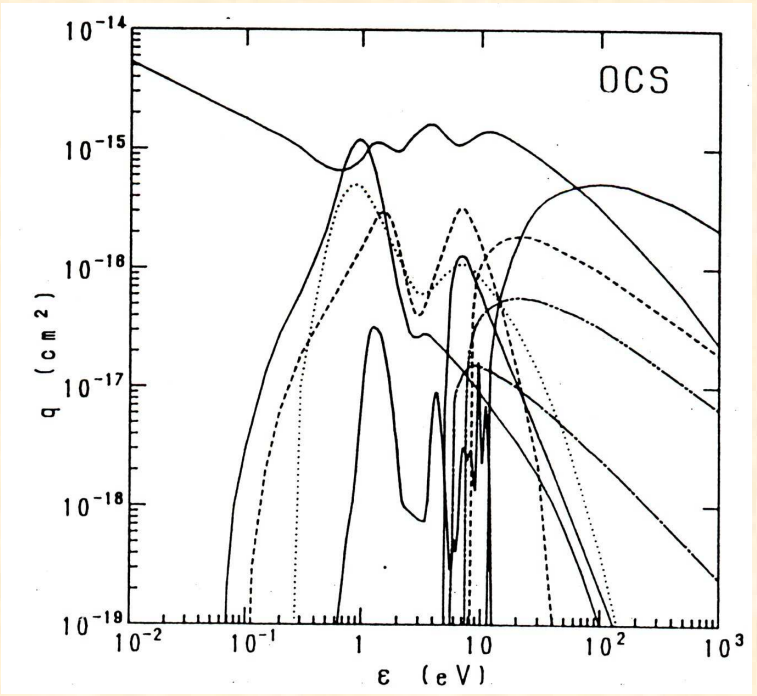
表3・1　1992年5月現在，筆者が一組の電子衝突断面積の値を決定した原子・分子

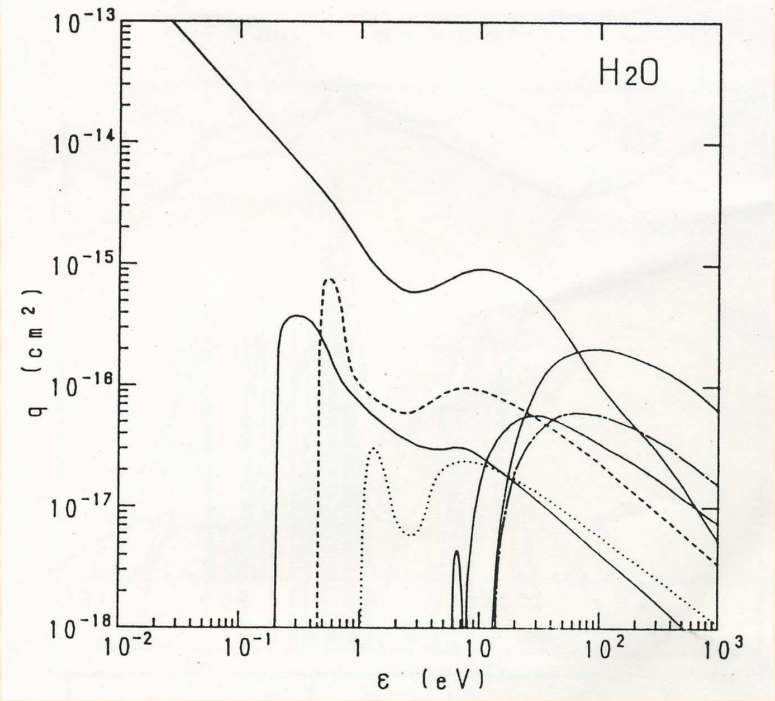
He	He(2³S)	Ne	Ar	Kr	Xe
H	O	Na	Cu	Cd	Hg
H_2	N_2	O_2	F_2		
CO	NO	HCl			
H_2O	CO_2	OCS	SO_2	N_2O	
C_2H_2	BF_3	NH_3			
CH_4	SiH_4	GeH_4	CF_4	CCl_2F_2	CCl_4
C_2H_4	CH_3OH				
SF_6					
C_2H_6	Si_2H_6	C_2F_6			
C_3H_8					

Hayashi 1992



付録3 電子衝突断面積





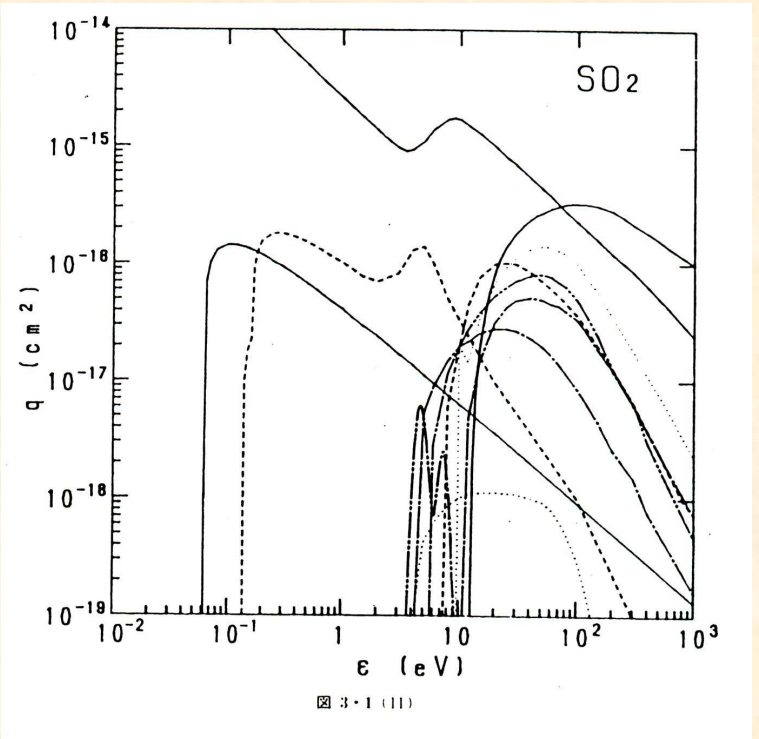
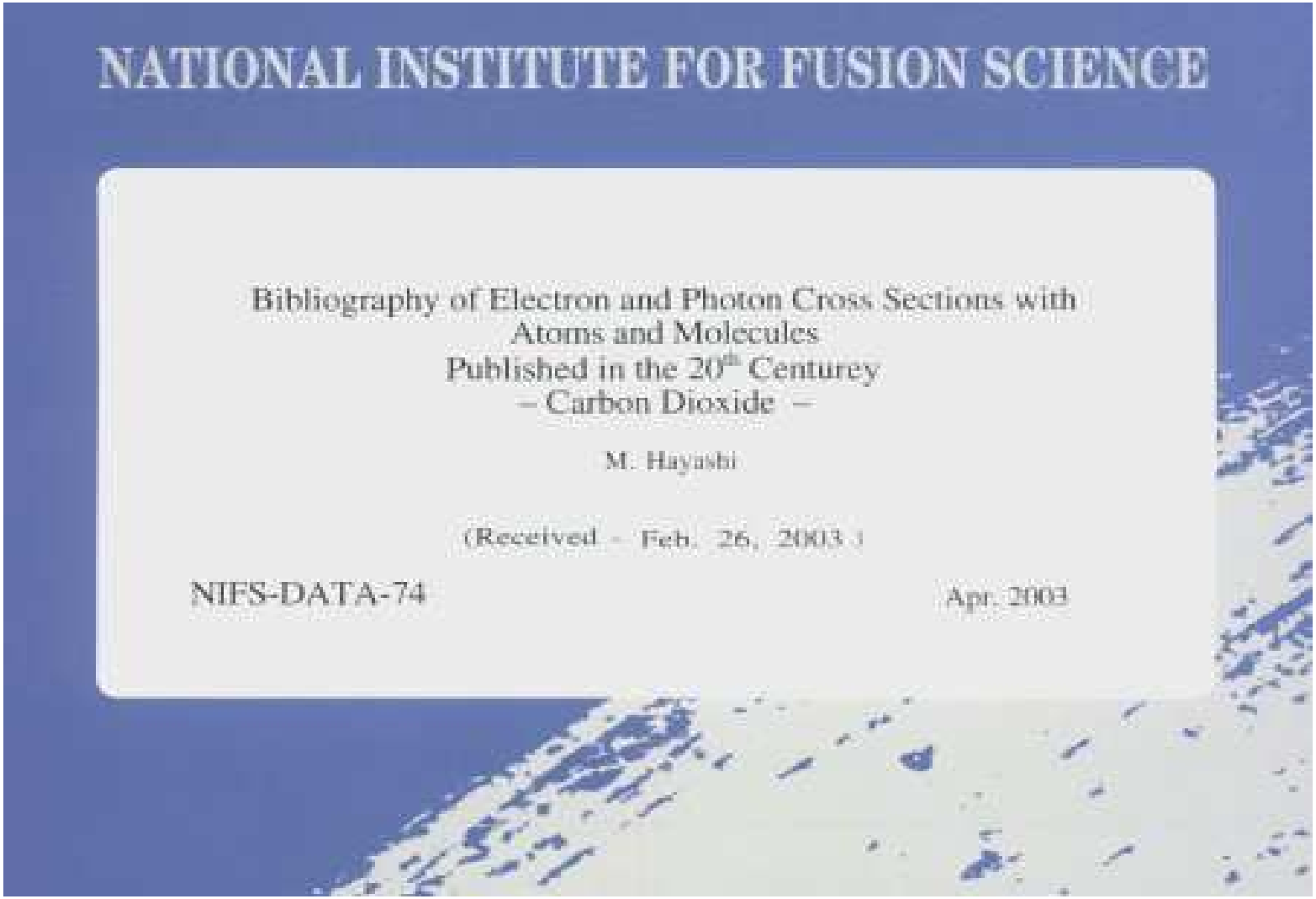


図 3・1 (11)

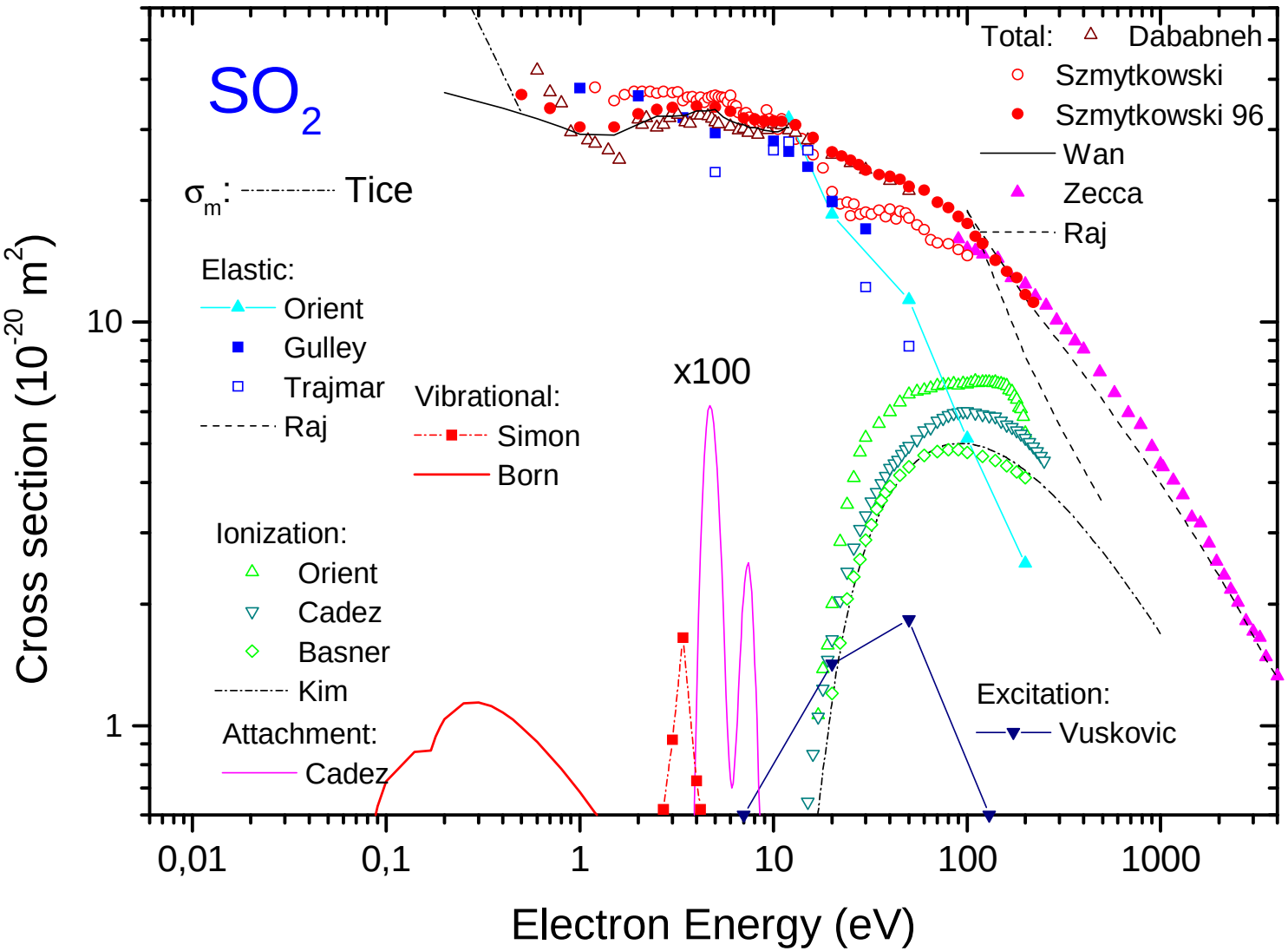
Hayashi 2003



“About 1,240 papers were compiled.
The bibliography covers the period 1901 through 2000 for CO_2.”

1	1.	Introduction
1		1·1. General remarks
2		1·2. Review papers
2		1·3. Updating references
4		1·4. Aims of the paper
4		1·5. Organization of the paper
12	2.	Tetrahedral hydrides
12		2·1. Methane (CH_4)
22		2·2. Silane (SiH_4)
29		2·3. Germane (GeH_4)
34	3.	Hydrides
34		3·1. Ammonia (NH_3)
41		3·2. Water vapour (H_2O)
51		3·3. Phosphine (PH_3)
52		3·4. Hydrogen sulfide (H_2S)
58		3·5. Hydrogen chloride (HCl)
66		3·6. Other hydrogen halides (HF, HBr)
69	4.	Triatomic molecules
69		4·1. Carbon dioxide (CO_2)
79		4·2. Nitrous oxide (N_2O)
87		4·3. Nitrogen dioxide (NO_2)
91		4·4. Ozone (O_3)
97		4·5. Carbonyl sulfide (OCS)
104		4·6. Sulphur dioxide (SO_2)
112		4·7. Chlorine dioxide (ClO_2)
114		4·8. Carbon disulphide (CS_2)

Cross sections for SO_2



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

4 **Cross sections for photoabsorption, photoionization, and neutral dissociation of molecules** (K. KAMETA, N. KOUCHI, Y. HATANO)

5 **Cross sections for ion production by electron collisions with molecules**

5.1 **Ionization** (B.G. LINDSAY, M.A. MANGAN) 5-1

5.2 **Electron attachment** (Y. ITIKAWA) 5-78

6 **Cross sections for scattering- and excitation-processes in electron-molecule collisions**

6.1 **Total scattering cross sections** (G.P. KARWASZ, R.S. BRUSA, A. ZECCA) . . . 6-1

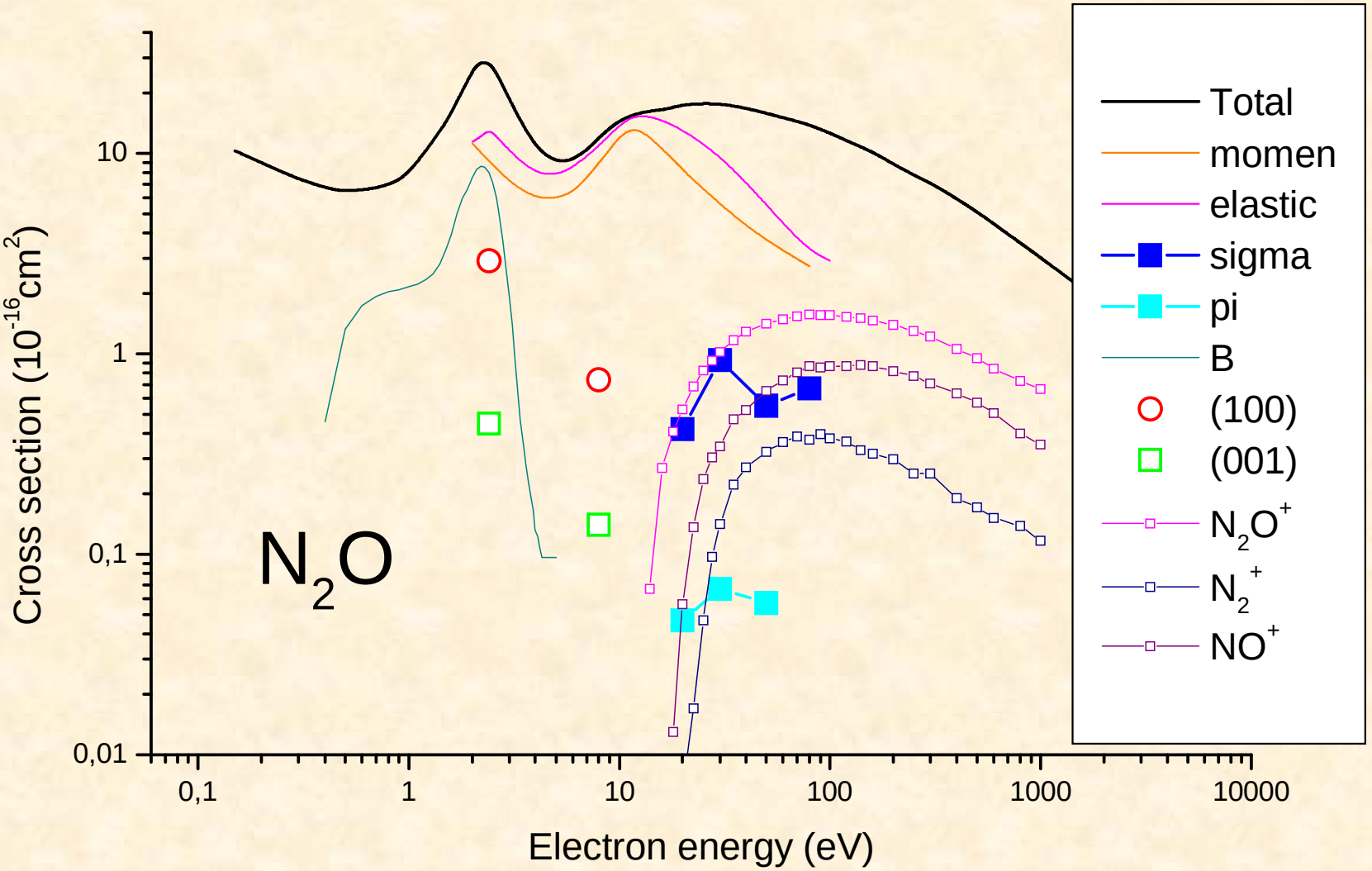
6.2 **Integral elastic cross sections** (S.J. BUCKMAN, M. BRUNGER, M.T. ELFORD) . 6-52

6.3 **Elastic momentum transfer cross sections** (M.T. ELFORD, S.J. BUCKMAN, M. BRUNGER) 6-85

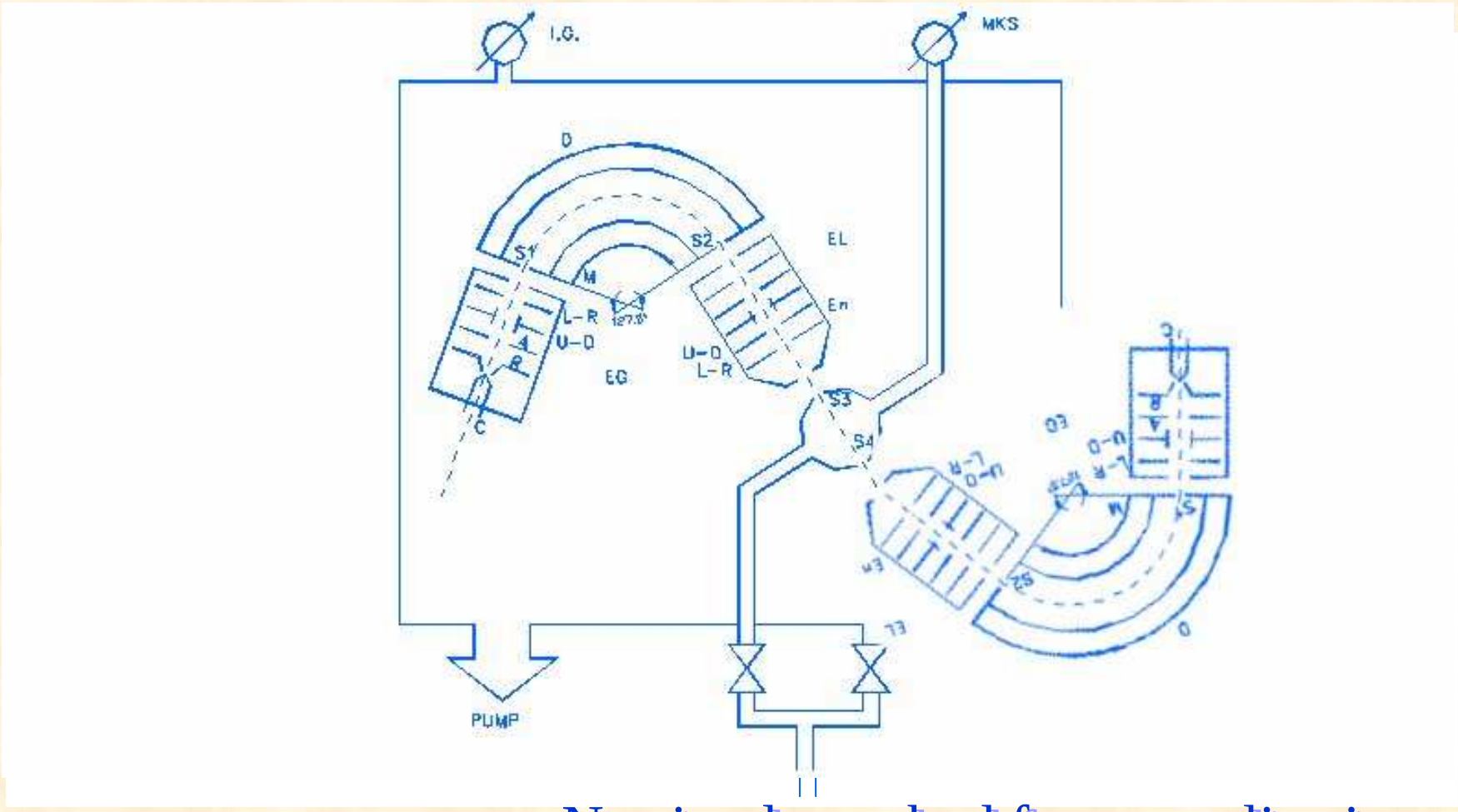
6.4 **Excitation cross sections** (M. BRUNGER, S.J. BUCKMAN, M.T. ELFORD) 6-118

Edited by Y. Itikawa

Recommended (preferred)

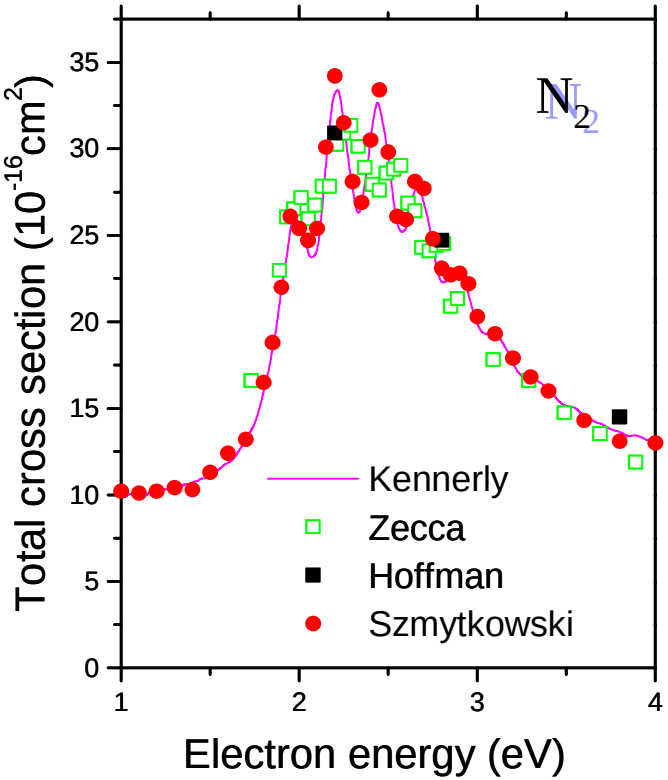


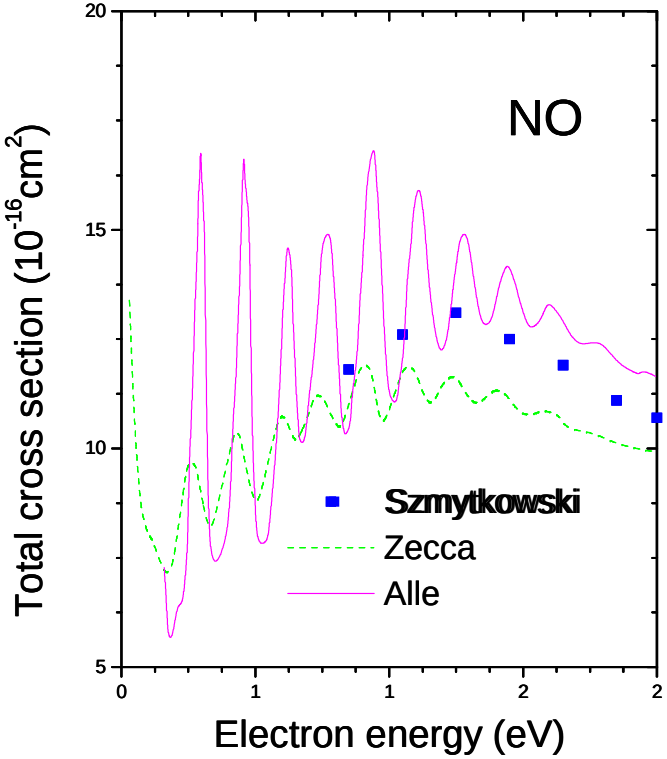
Total vs. partial cross section measurements



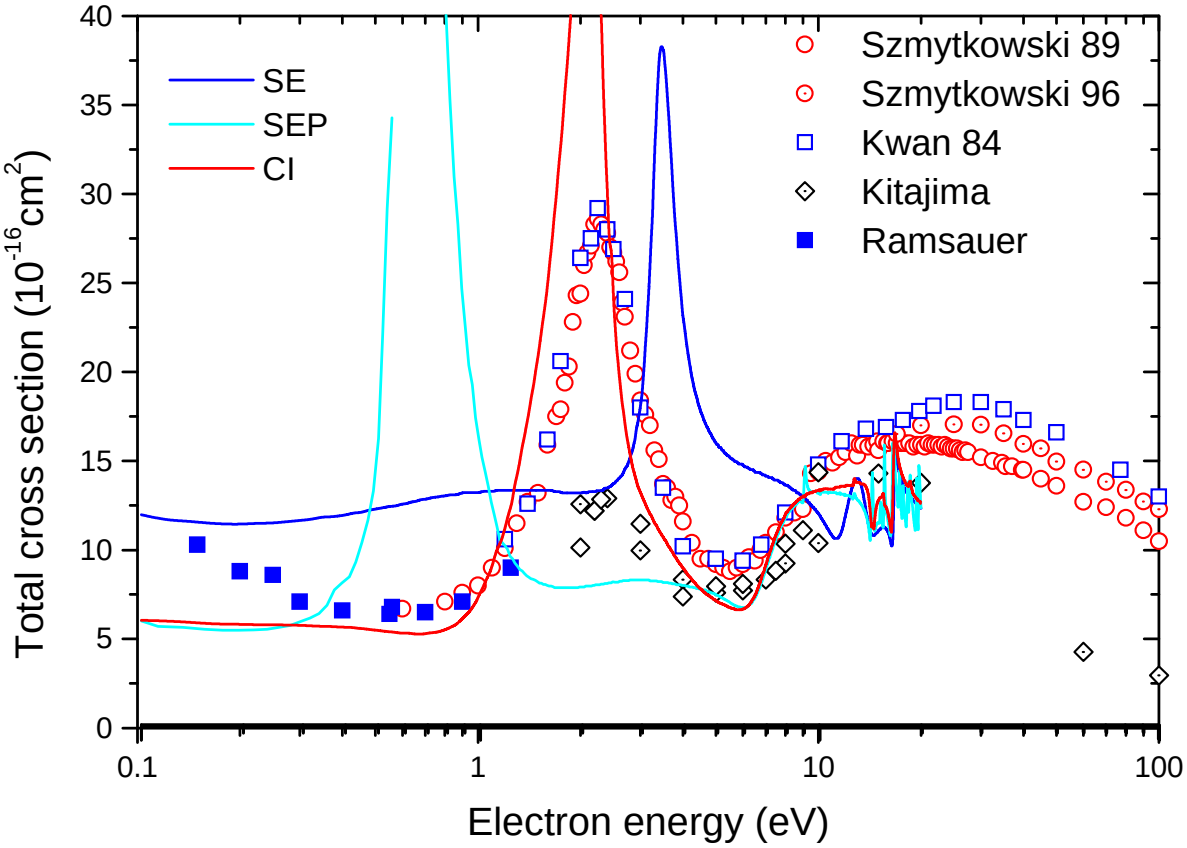
No simple method for normalization

Molecules: inelastic processes!



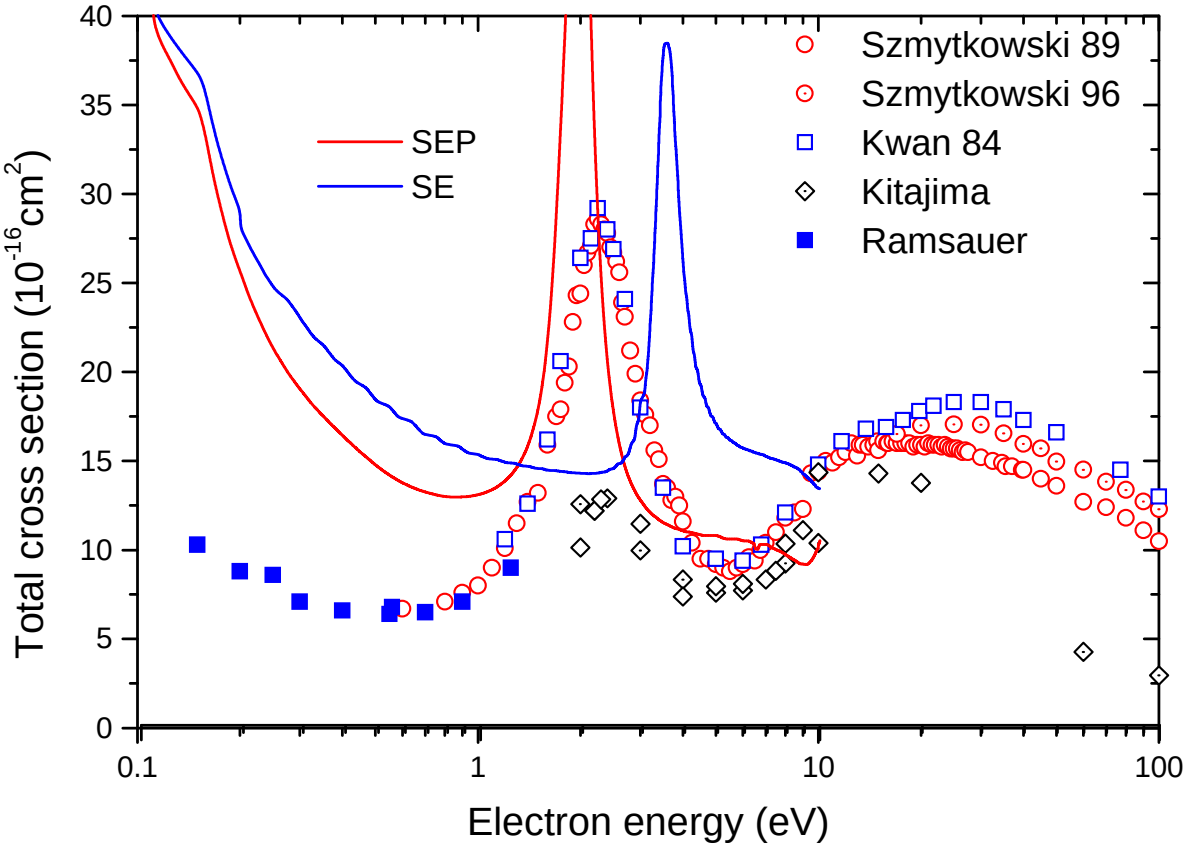


Experiment ↔ Theory (N_2O)



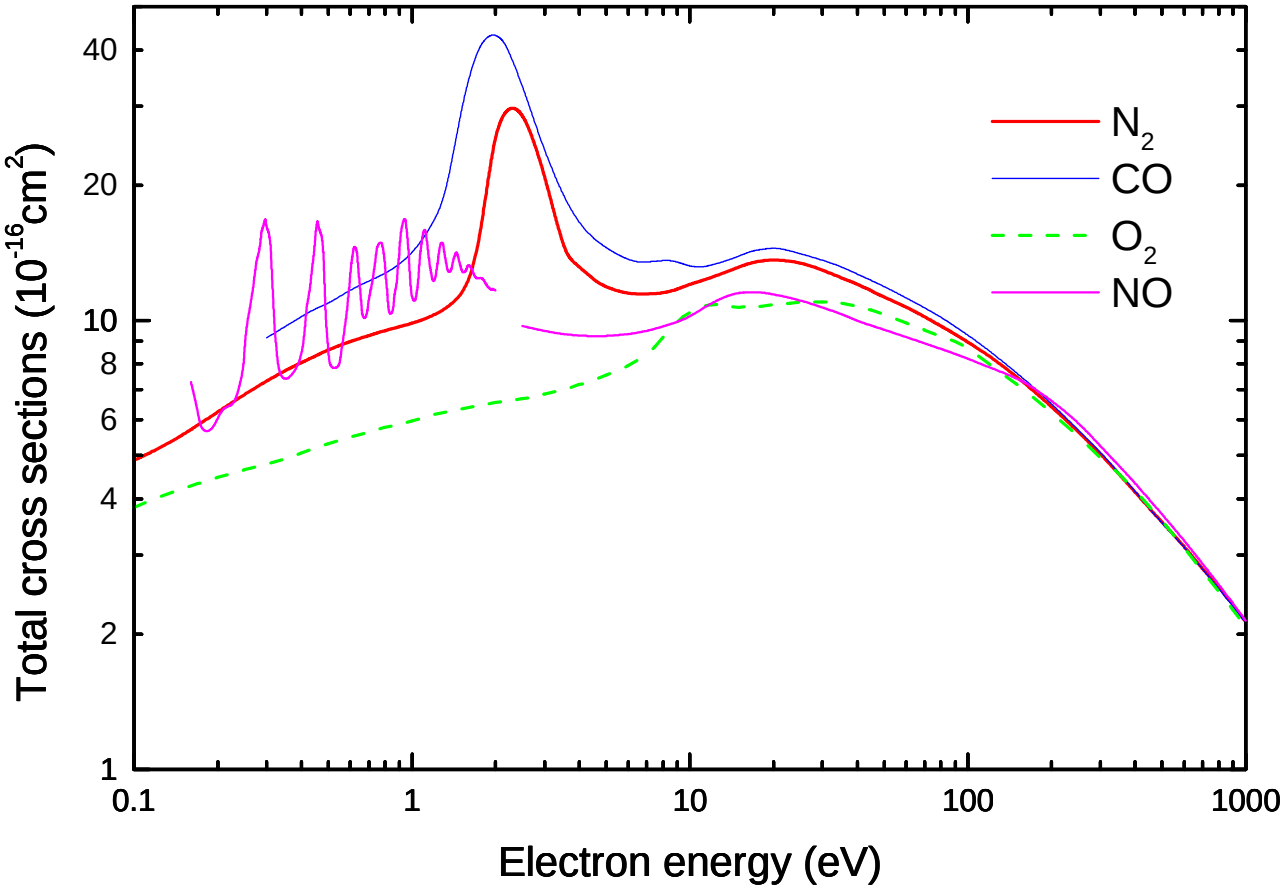
Sarpal et al. 1996

Experiment ↔ Theory (N_2O)

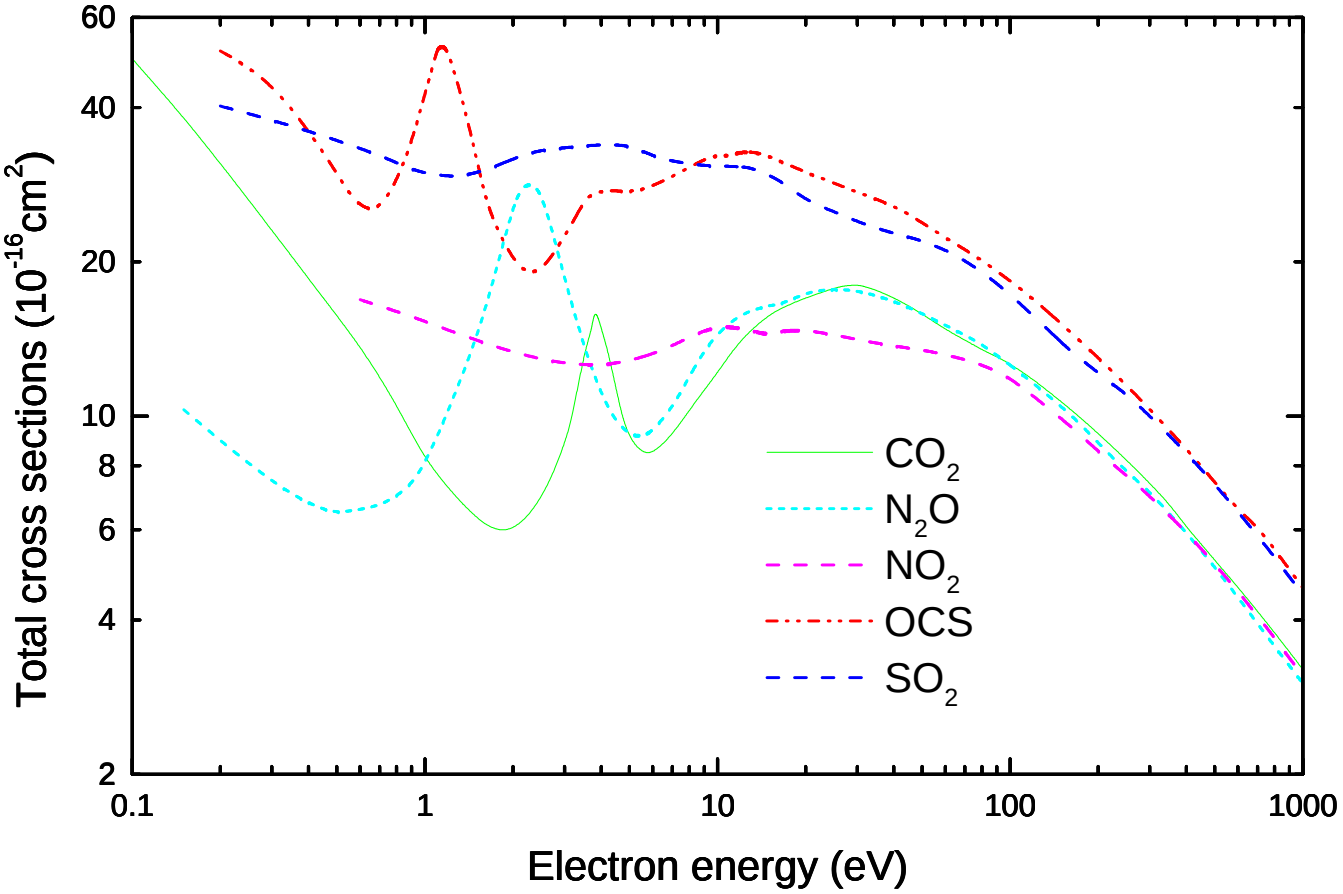


Morgan et al. 1997

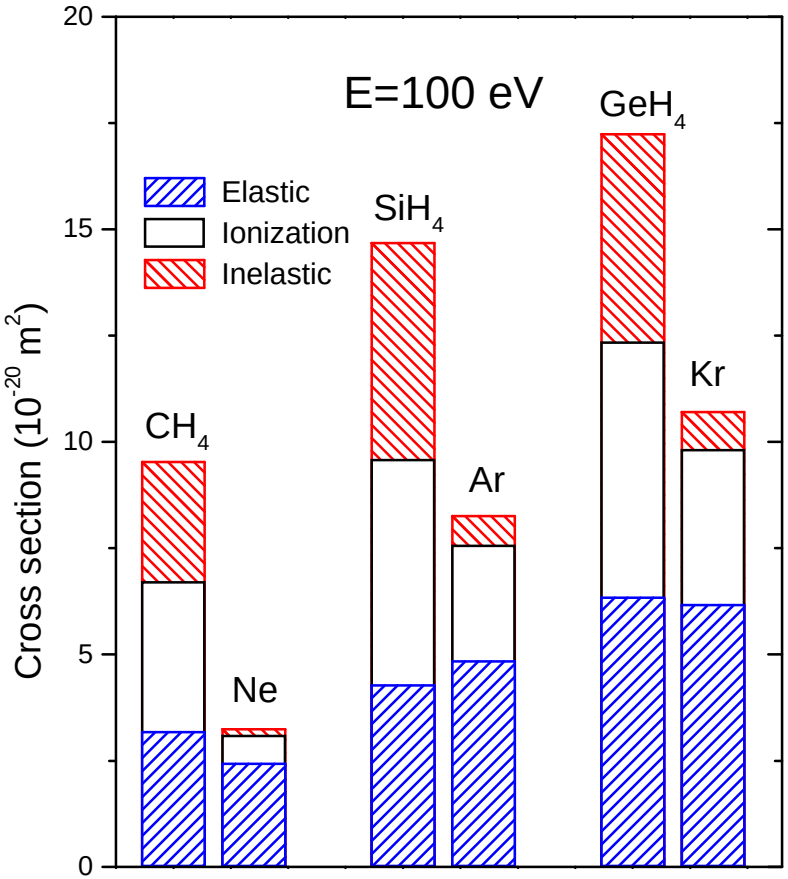
Total cross sections – analogies

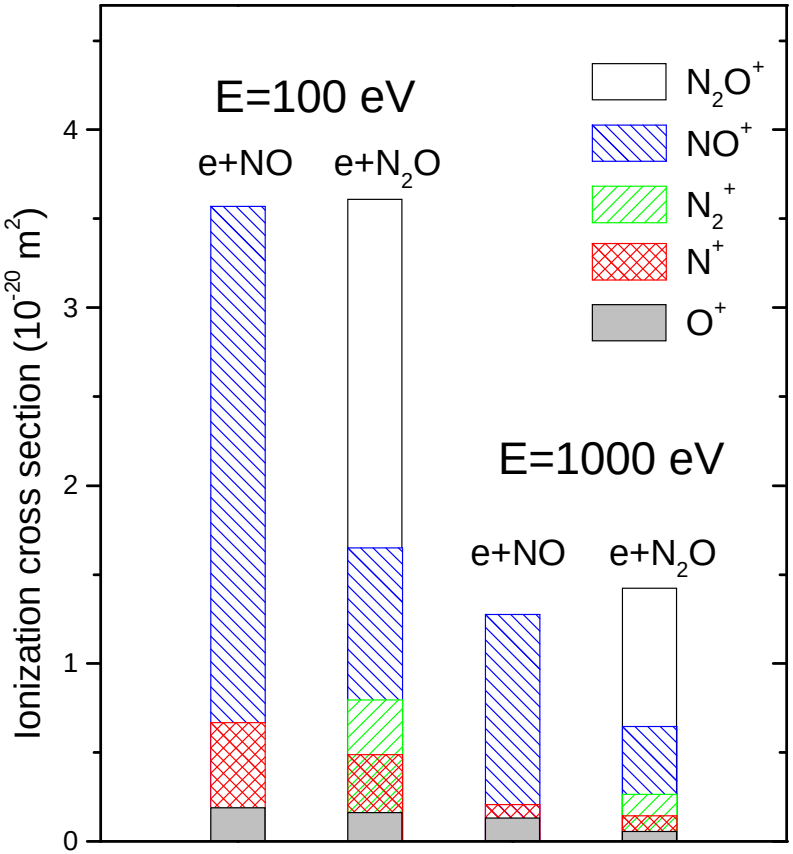


Total cross sections - analogies

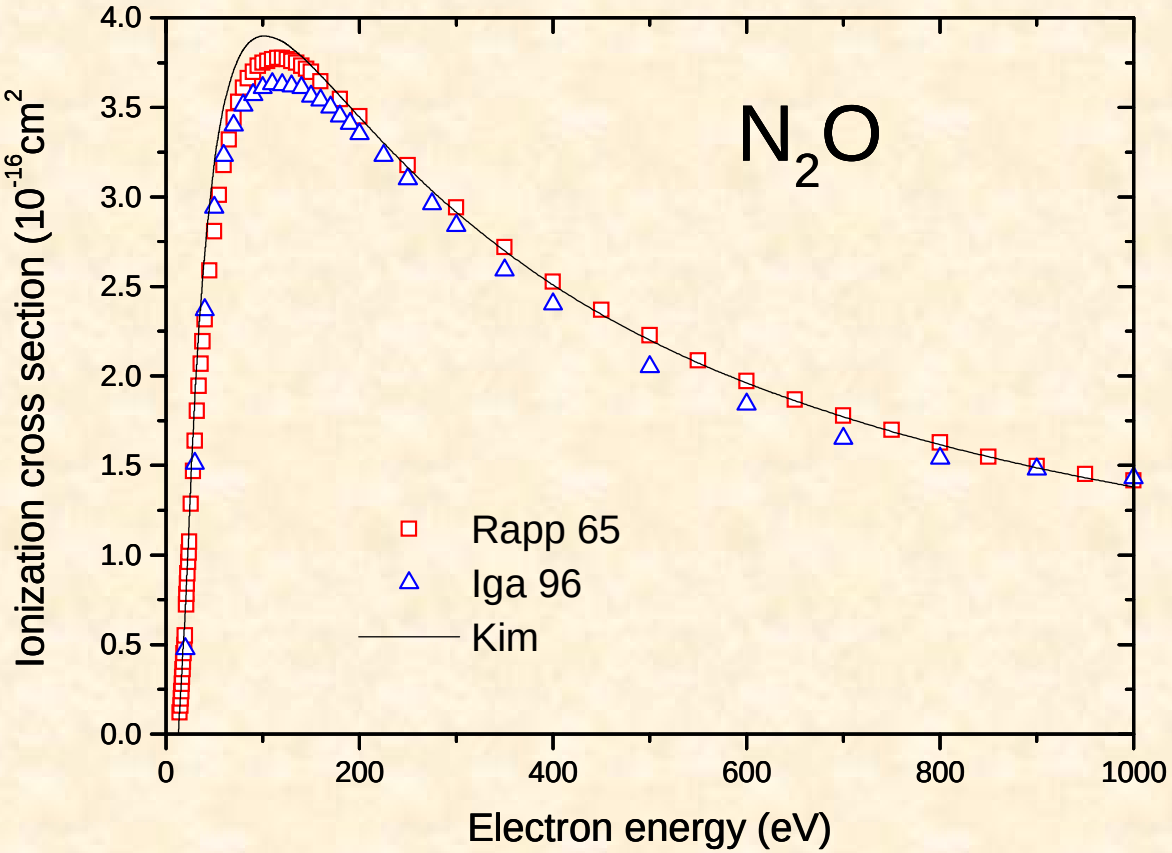


„semiempirical” analogies – partitioning





Ionization – experiment and models



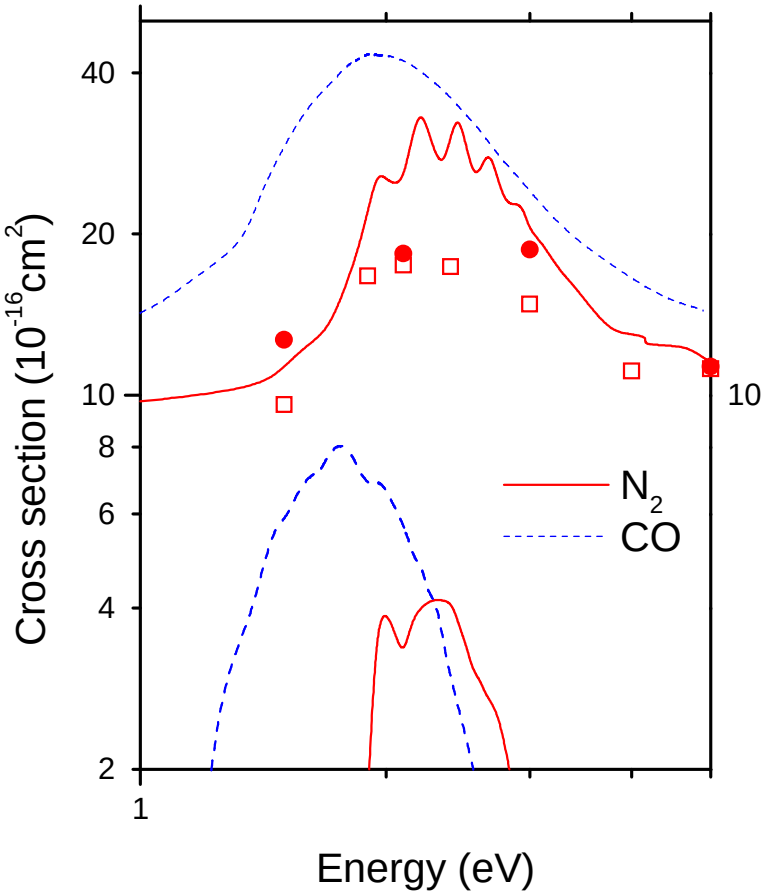
U=<**p**^{2}>/2m – electron momentum in subshell
W- ejected electron
B- binding energy
R – Rydberg energy
$S=4\pi a_0^2 N(R/B)^2$
t=T/B,...

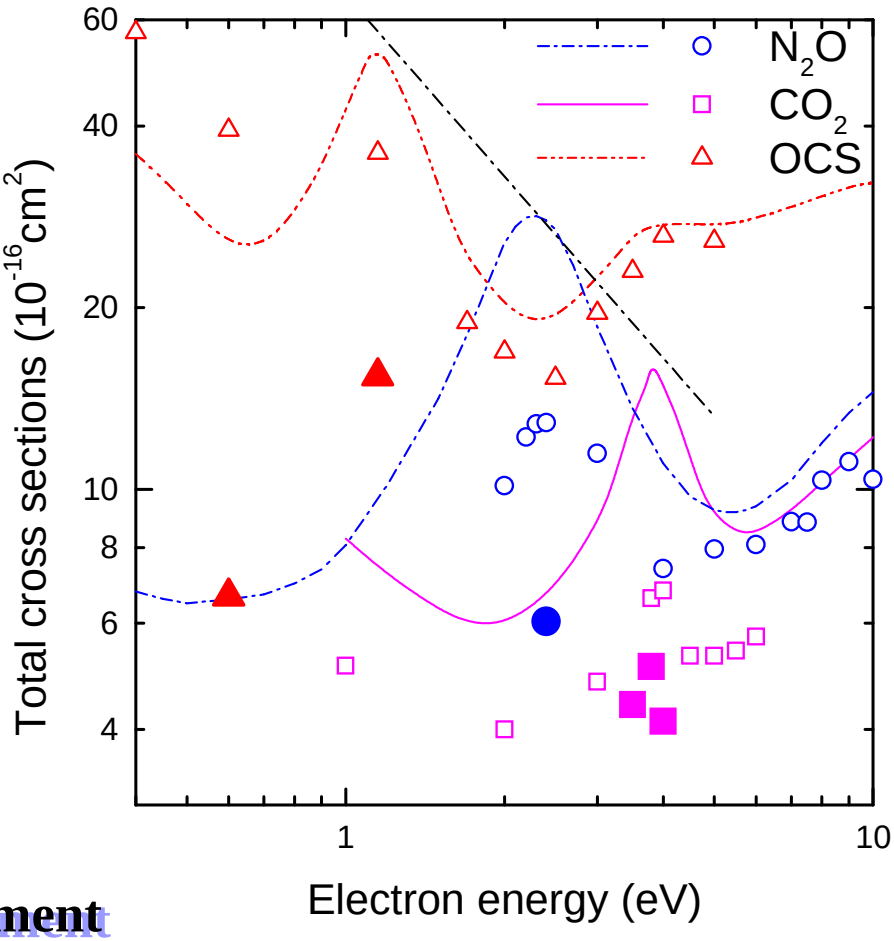
$$\sigma(t)=S/(t+u+1)[D(t)\ln t + (2-N_i/N)((t-1)t-\ln t/t+1)]$$

.... and Deutsch – Märk model

Kim, Rudd 1994

Partitioning - resonances





Vibrational:

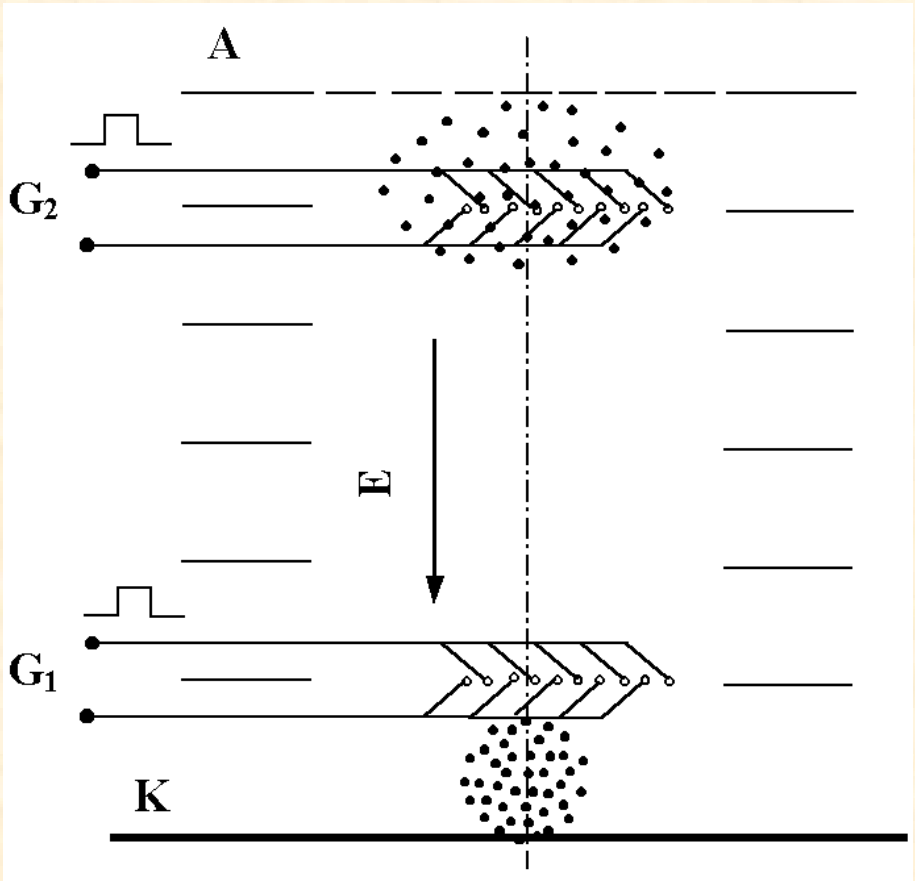
CO	1/6	
N_2	1/6	
N_2O	1/3	?
CO_2	1/3	

Attachment

CO_2	(4.4 eV)	0.1%
N_2O	(2.2 eV)	0.3%
NO_2	(1.8 eV)	0.8% ?
OCS	(1.3 eV)	0.5%

Swarm experiments

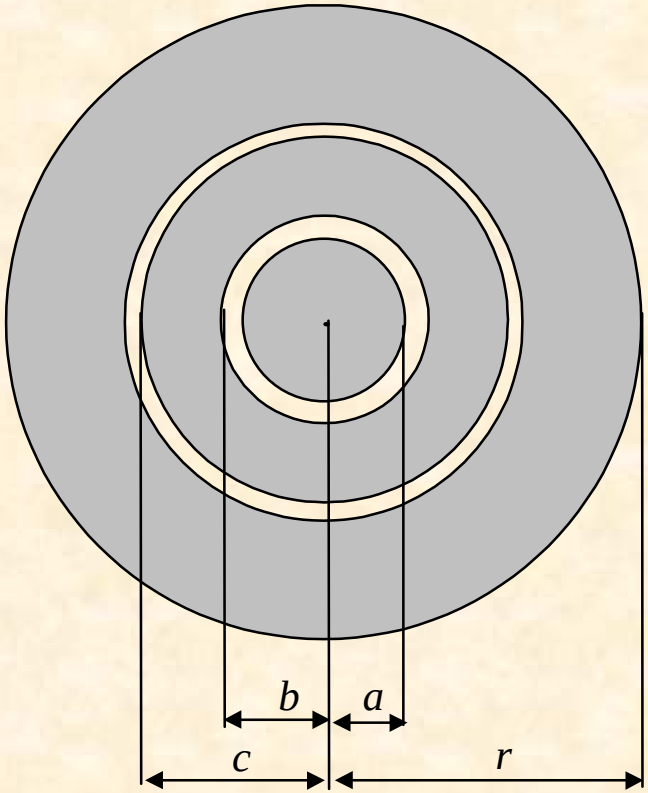
$$\frac{\partial}{\partial t} n_e(\mathbf{r},t) = -w\frac{\partial}{\partial z} n_e(\mathbf{r},t) + D_T\left[\frac{\partial^2}{\partial x^2} n_e(\mathbf{r},t) + \frac{\partial^2}{\partial y^2} n_e(\mathbf{r},t)\right] + D_L \frac{\partial^2}{\partial z^2} n_e(\mathbf{r},t)$$



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

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

Swarm experiments



$$R = \frac{i_{bc} + I_{bc}}{i_{bd} + I_{bd}}$$

$$R_s = F_S\,(D_T/\mu, D_L/\mu)$$

Lowke (1973):

$$n(\rho, z) = \sum_{k=-\infty}^{+\infty} r_k^{-3}(z - 2kh)(\beta r_k + 1)\exp(\lambda_L z - \beta r_k)$$

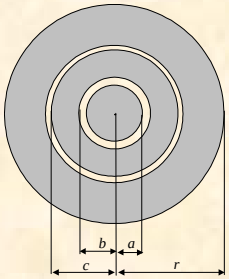
with $r_k = \left[(z-2kh)^2 + (D_L / D_T)\rho^2\right]^{1/2}$

$$\beta = \lambda_L \left[1 + \left(\frac{2\alpha'}{\lambda_L}\right)\right]^{1/2}$$

where $\lambda_L = \dfrac{W}{2D_L}$ and $\alpha' = \eta - \alpha$

"effective ionization"

Diffusion coefficients - measurements



$$R = \frac{i_{bc} + I_{bc}}{i_{bd} + I_{bd}}$$

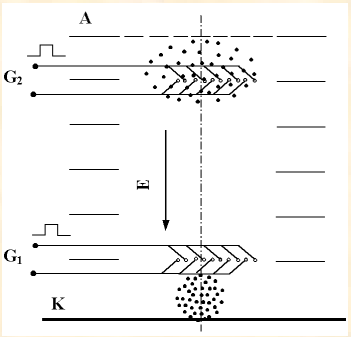
$$i = -2\pi D \sum_{k=-\infty}^{+\infty} \left[r_k^{-3} \exp(\lambda_L h - \beta r_k) \left[(\beta r_k + 1)(2k-1)^2 h^2 - (1 - \lambda_L h(2k-1)) r_k^2 \right] \right]_{\rho_1}^{\rho_2}$$

Huxley and Crompton, 1974

$$R = 1 - \frac{h}{d} \exp(-\lambda_T (d - h)); \qquad d^2 = h^2 + b^2, \qquad \lambda_L = \frac{W}{2D_L}$$

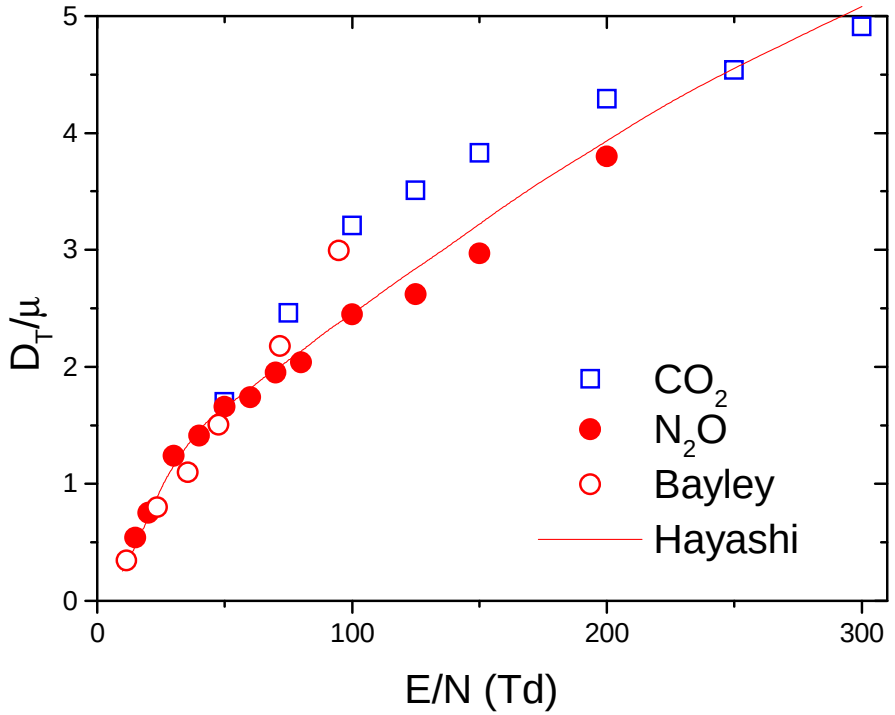
Lowke, 1973

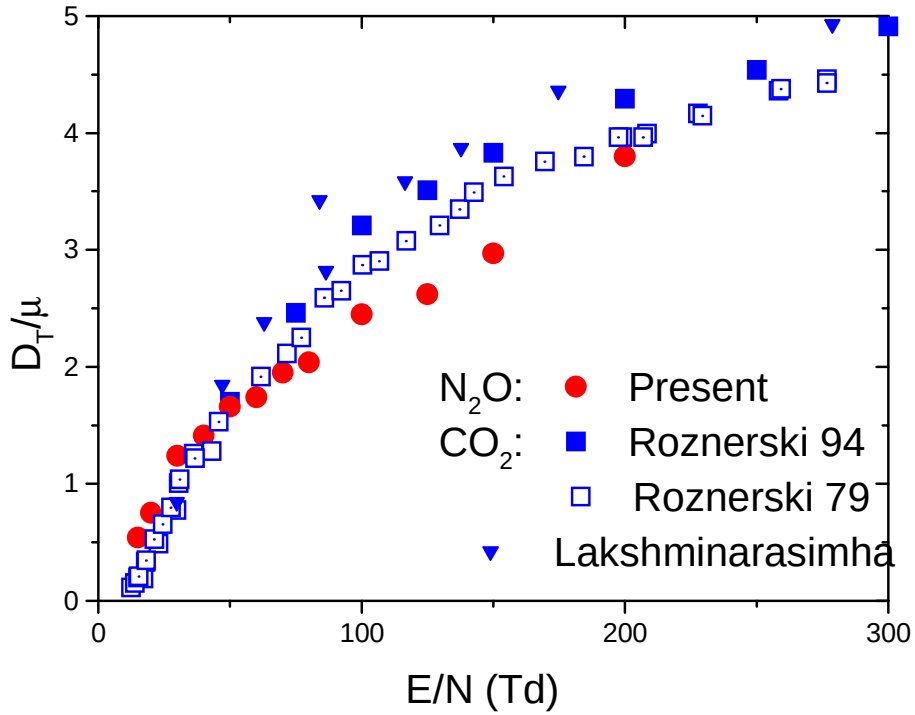
$$R = 1 - \left[1 + \left(\frac{1}{2} + \frac{D_L}{D_T} \right) \left(\frac{b}{d} \right)^2 \right] \left(\frac{h}{d} \right) \exp(-\lambda_T (1 - \frac{\alpha}{\lambda_L})(d - h))$$



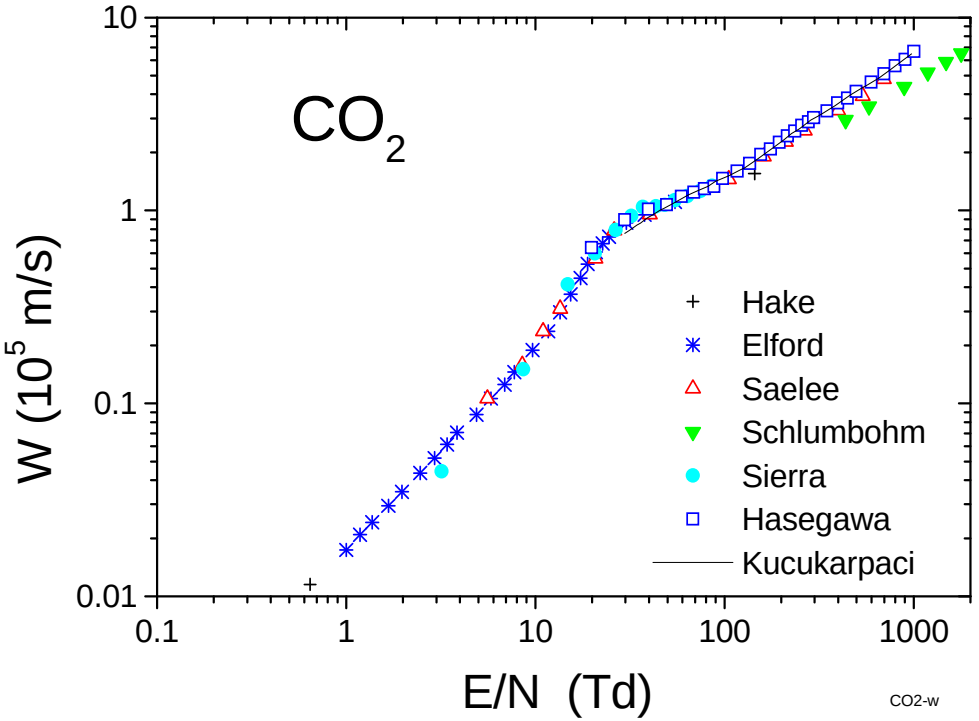
= interactive procedure for D_L/μ, D_T/μ, α, η

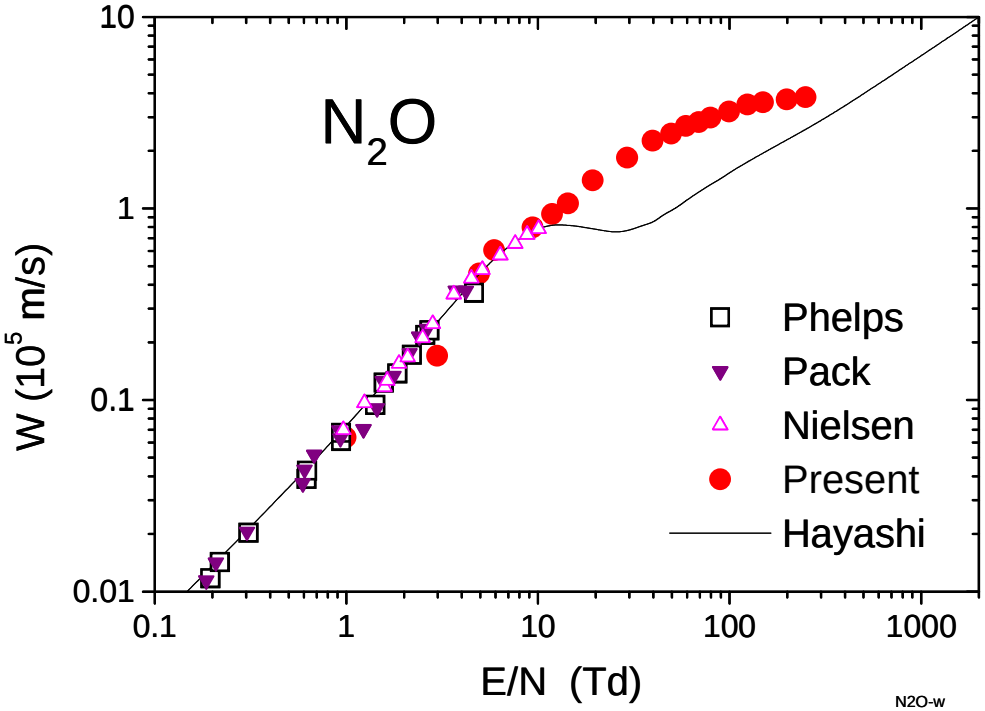
Transverse diffusion CO_2-N_2O (resonance region)



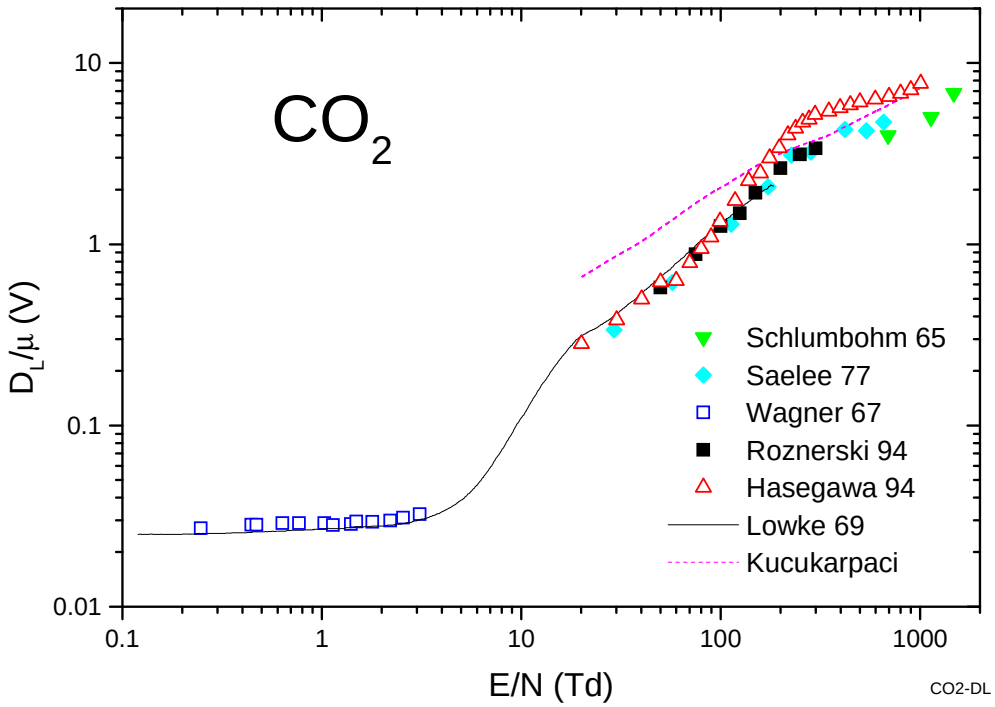


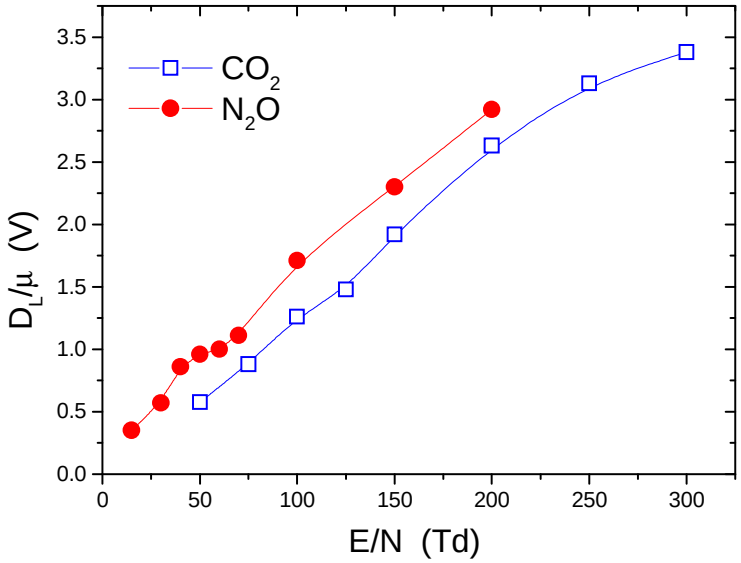
Drift velocity CO_2 and N_2O





D_L/μ in CO_2-N_2O (resonance region)

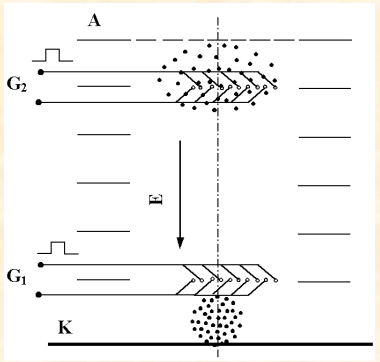




Diffusion coefficients – Boltzmann analysis

Eq. Boltzmann

$$\frac{\partial f}{\partial t} + \boldsymbol{v}\nabla_{\boldsymbol{r}} f + \frac{e\boldsymbol{E}}{m}\nabla_{\boldsymbol{v}} f = \left(\frac{\partial f}{\partial t}\right)_{col}$$



Two-term approximation

$$f(\boldsymbol{r},\boldsymbol{v},t) = f_0(\boldsymbol{r},v,t) + f_1(\boldsymbol{r},v)\hat{\boldsymbol{v}}$$

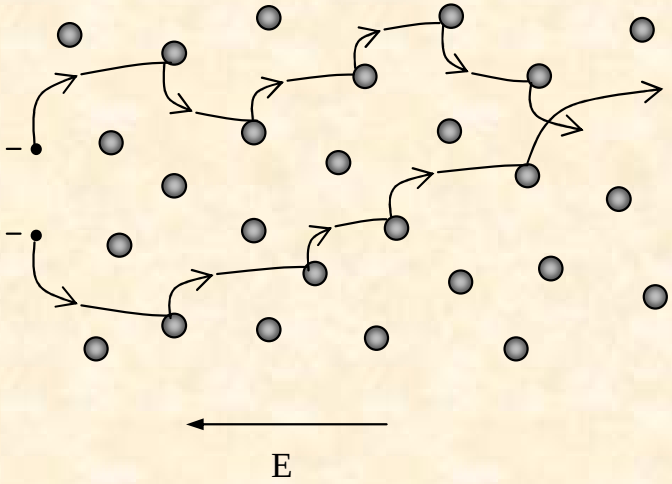
$$\frac{(eE)^2}{3}\frac{d}{d\in}\left(\frac{\in}{N\sigma_m(\in)}\frac{df_0}{d\in}\right) + \frac{2m}{M}\frac{d}{d\in}\left(\in^2 N\sigma_m(\in)\times\left(f_0 + kT\frac{df_0}{d\in}\right)\right) +$$

$$+\sum_j\left((\in+\in_j) f(\in+\in_j) N\sigma_j(\in+\in_j) - \in f(\in) N\sigma_j(\in)\right) +$$

$$+\sum_j\left((\in+\in_j) f(\in+\in_j) N\sigma_{-j}(\in-\in_j) - \in f(\in) N\sigma_{-j}(\in)\right) = 0$$

ELENDIF, W.L. Morgan, B.M. Penetrante, Comp.Phys.Comm. 58 (1990) 127

Diffusion coefficients – Monte Carlo

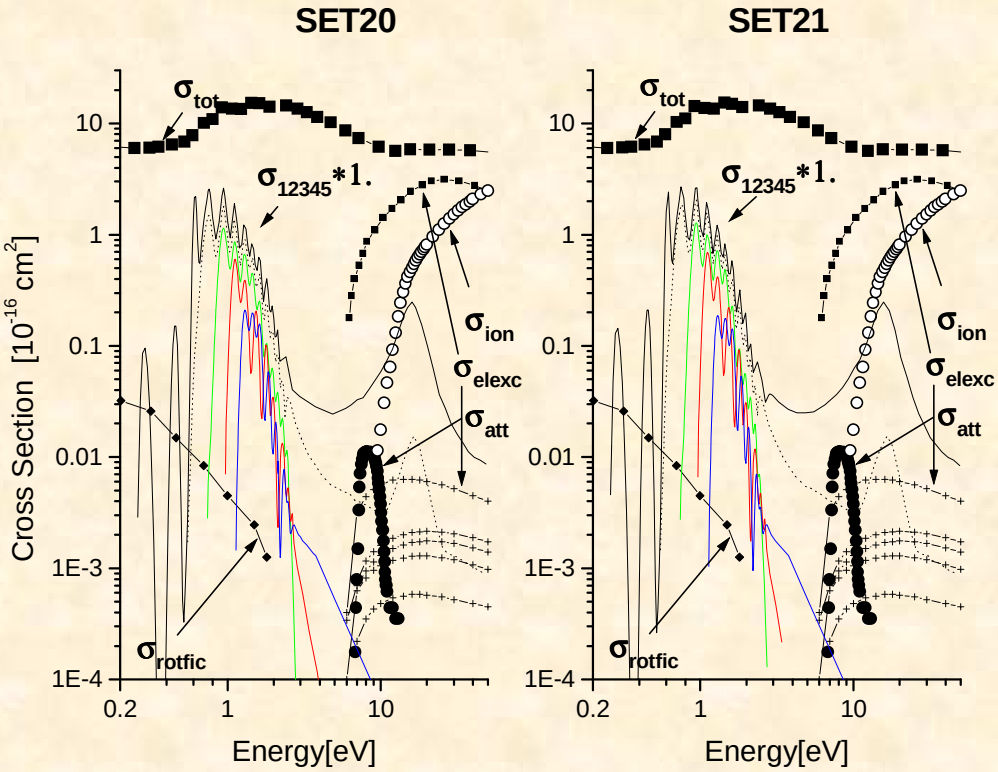


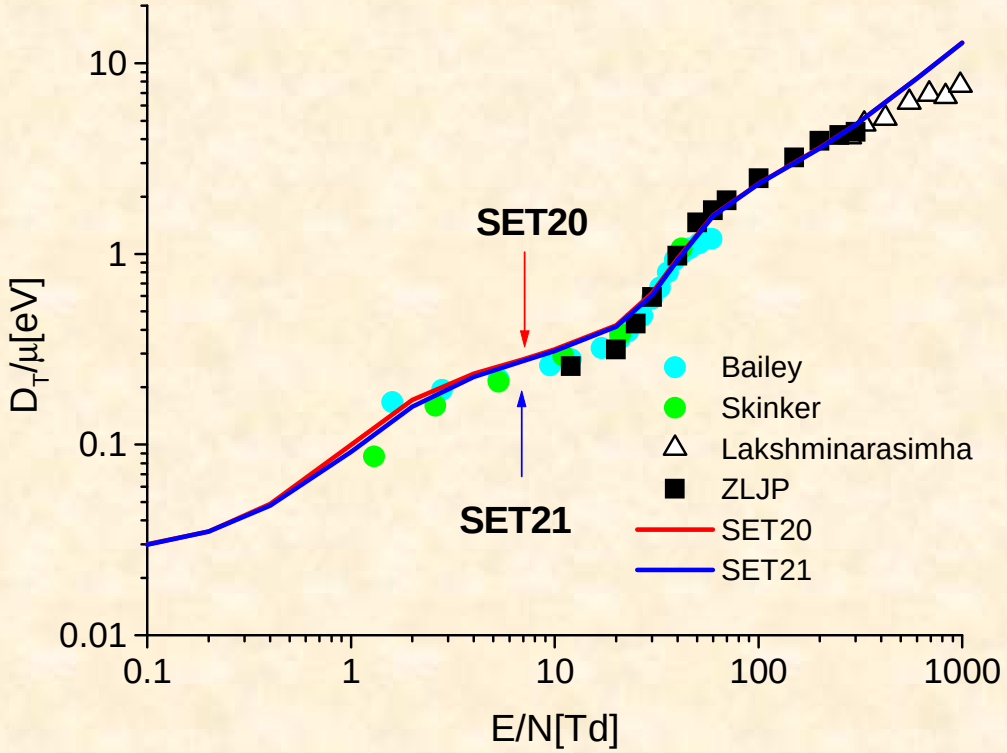
MagBoltz

S. Biagi, Nucl. Instr. and Meth. A421 (1999) 234

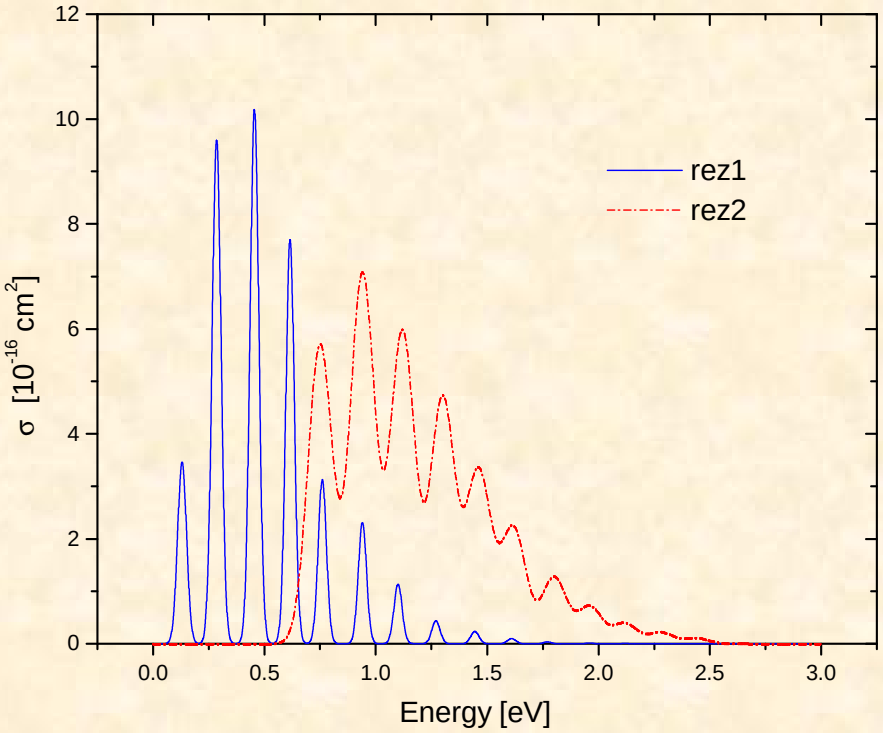
V.D. Stojanović and Z. Lj Petrović, J. Phys. D *31* (1998) 834

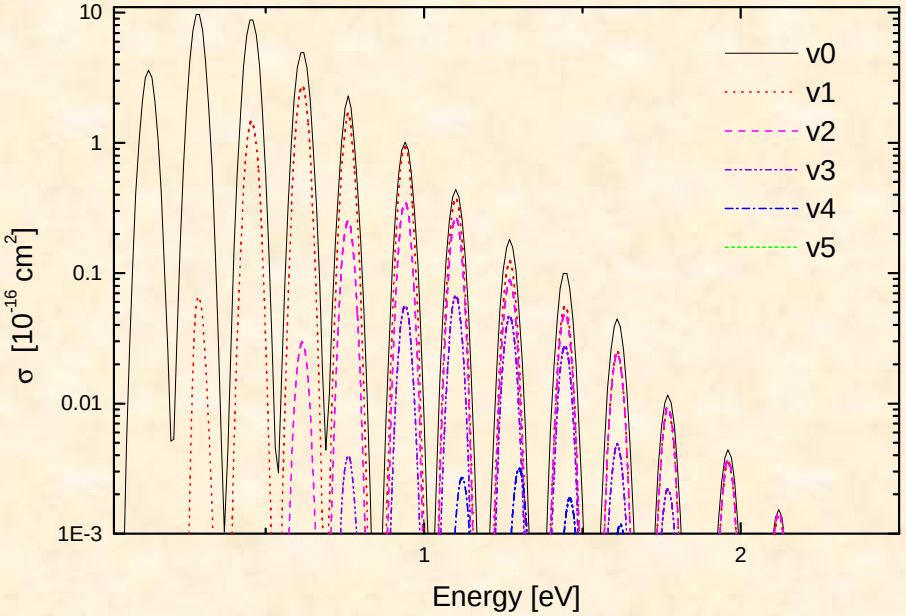
Beam ↔ Swarm (NO)

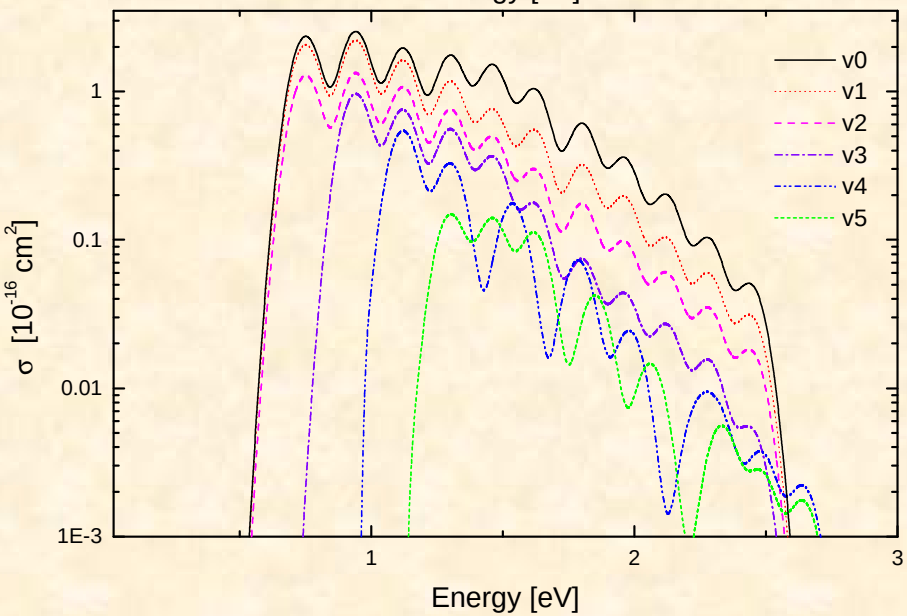




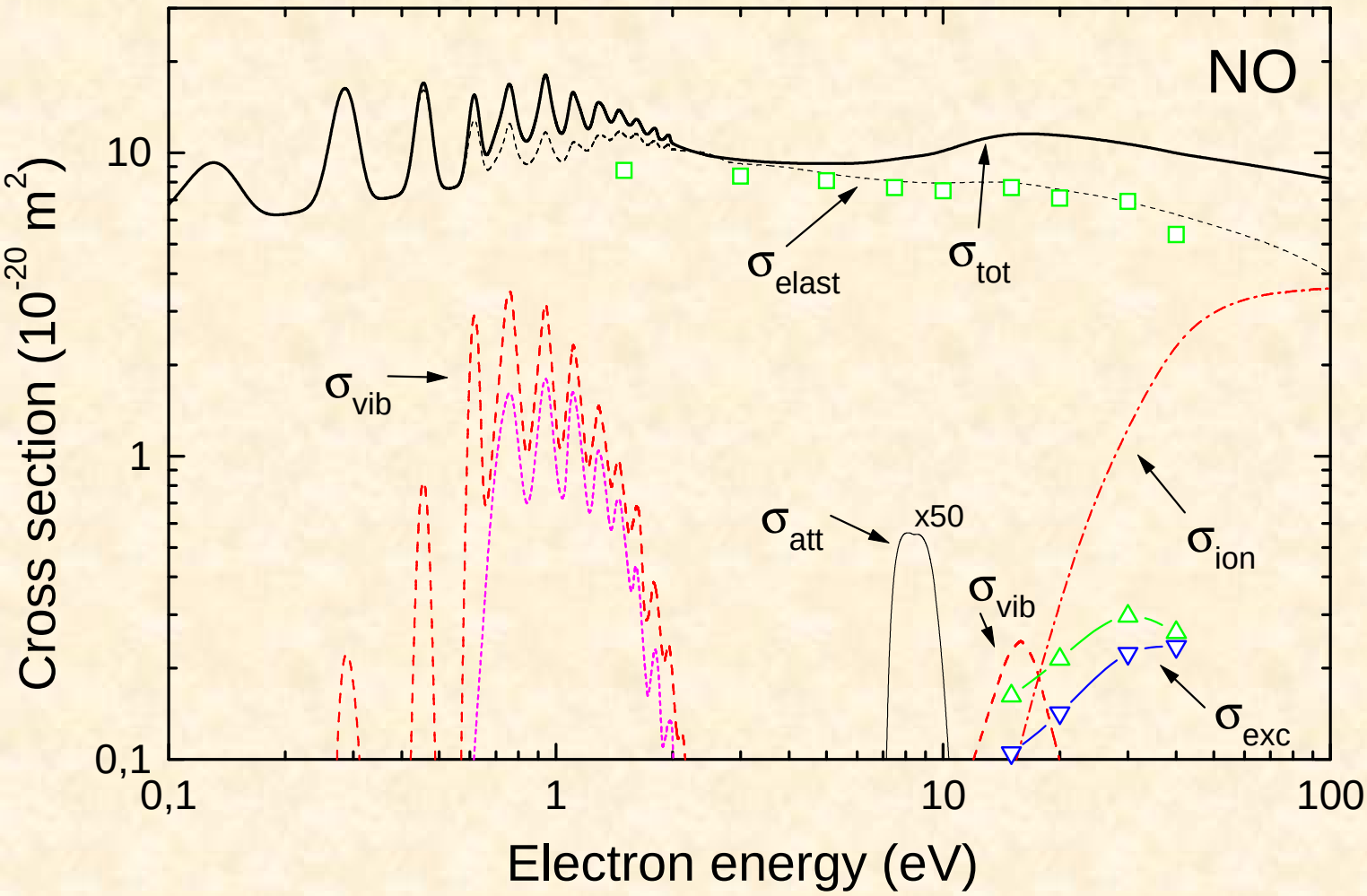
NO –resonances



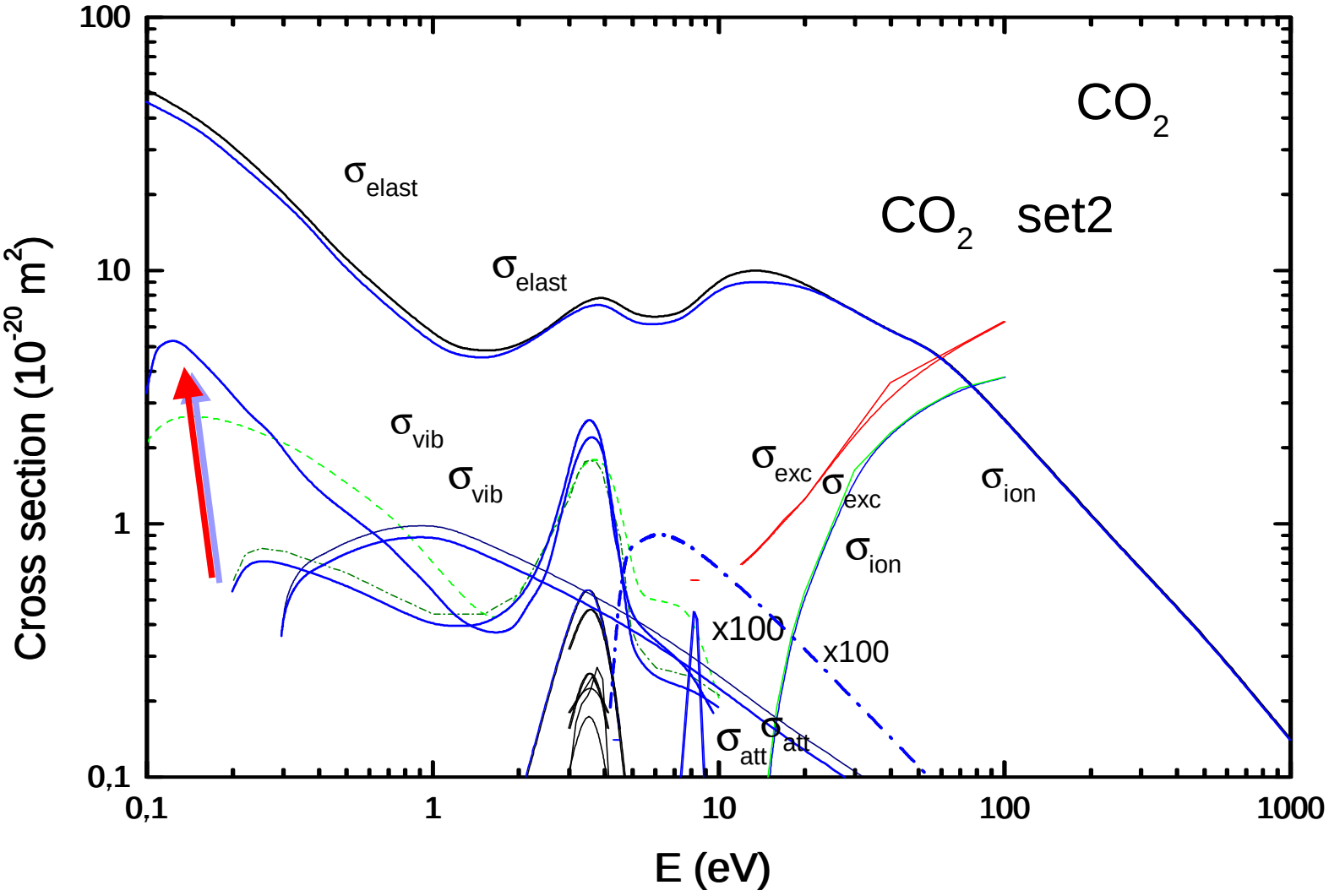




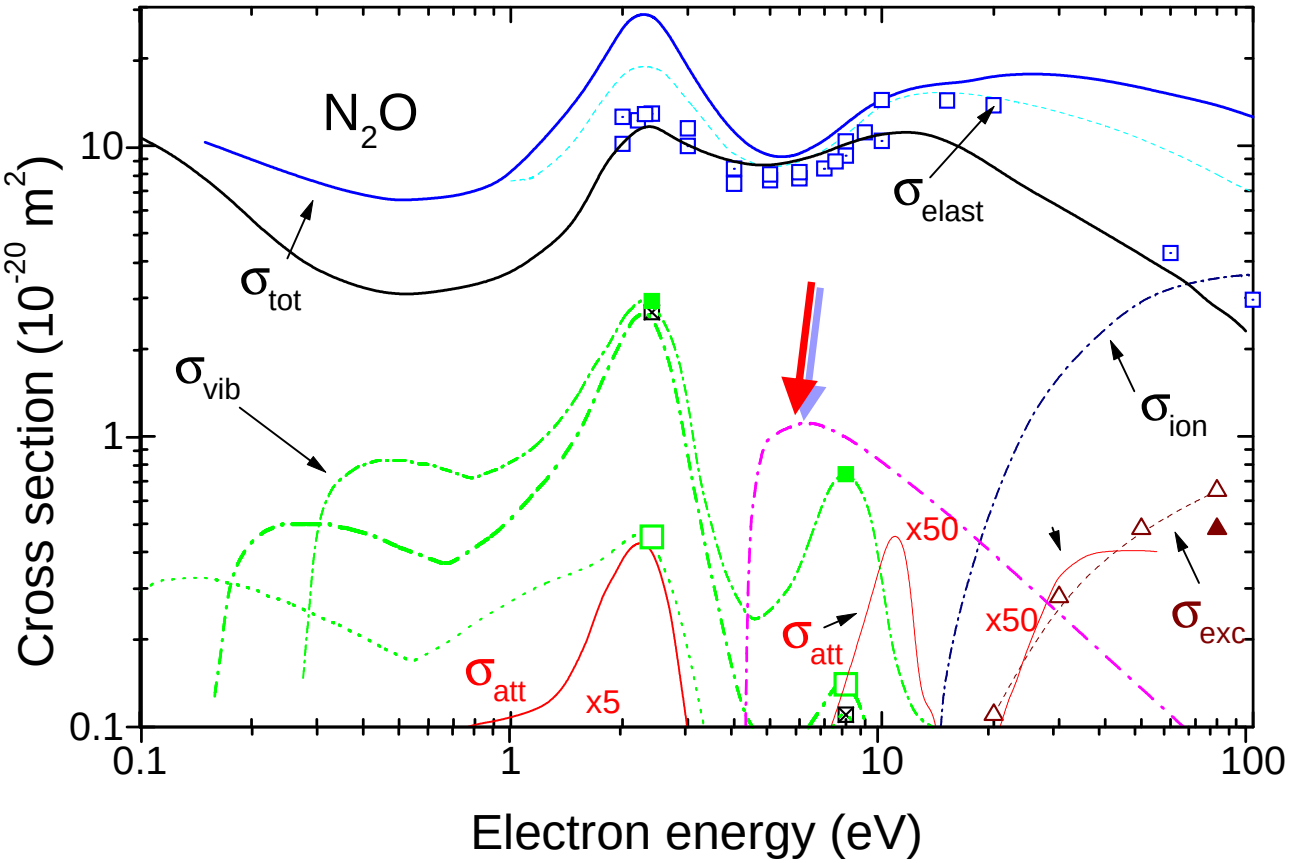
NO –resonances



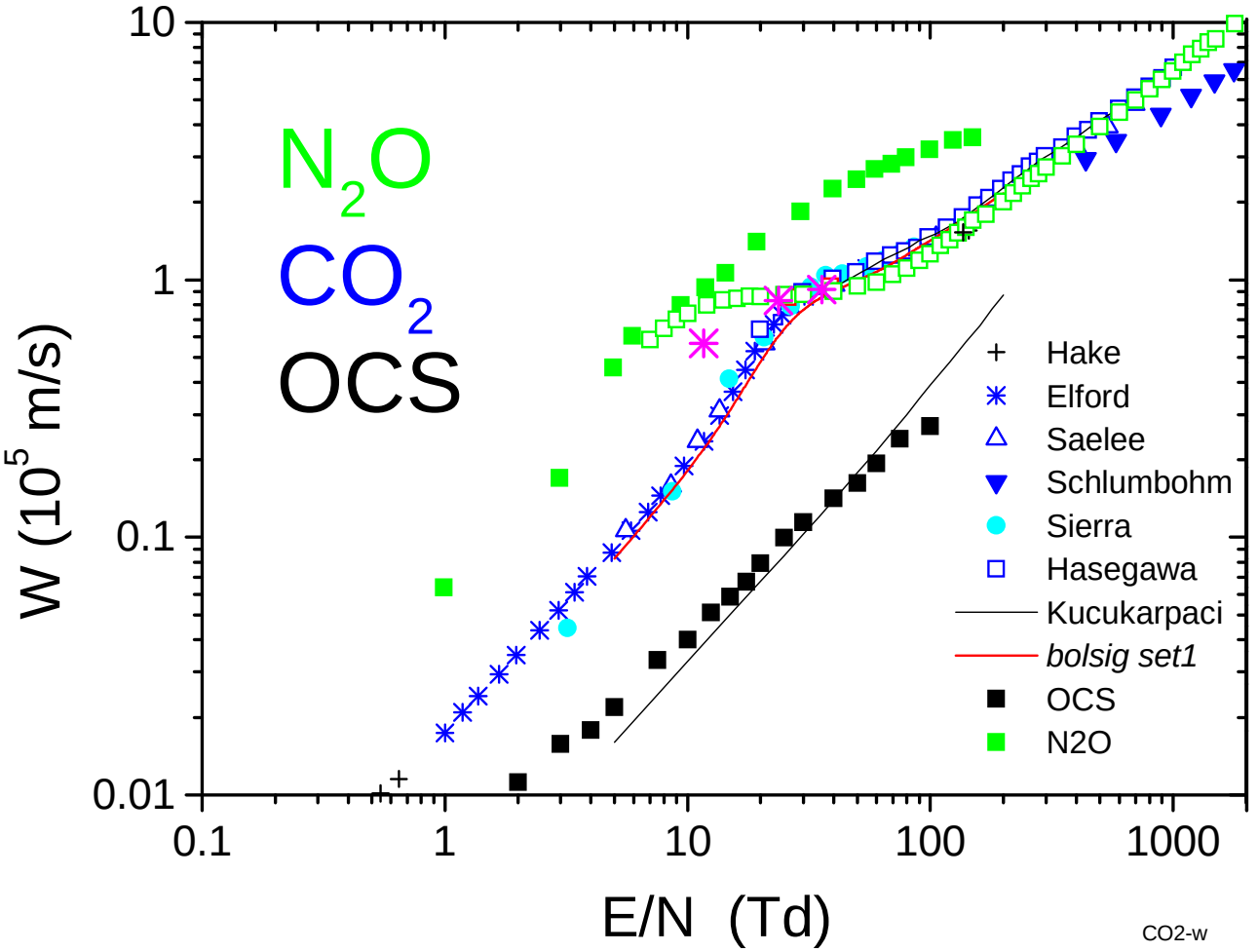
Swarm-derived cross sections for CO_2



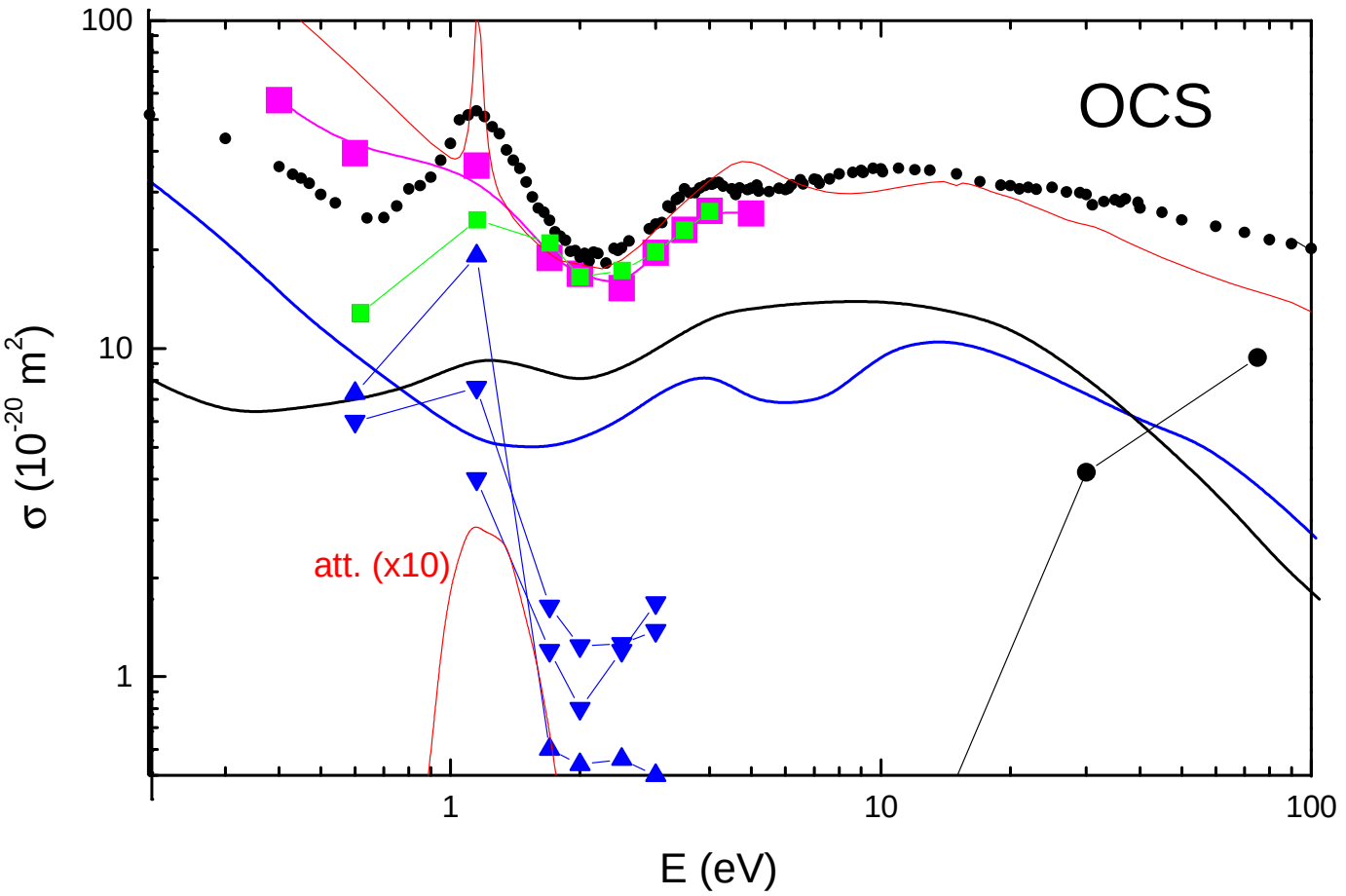
Cross sections for N_2O



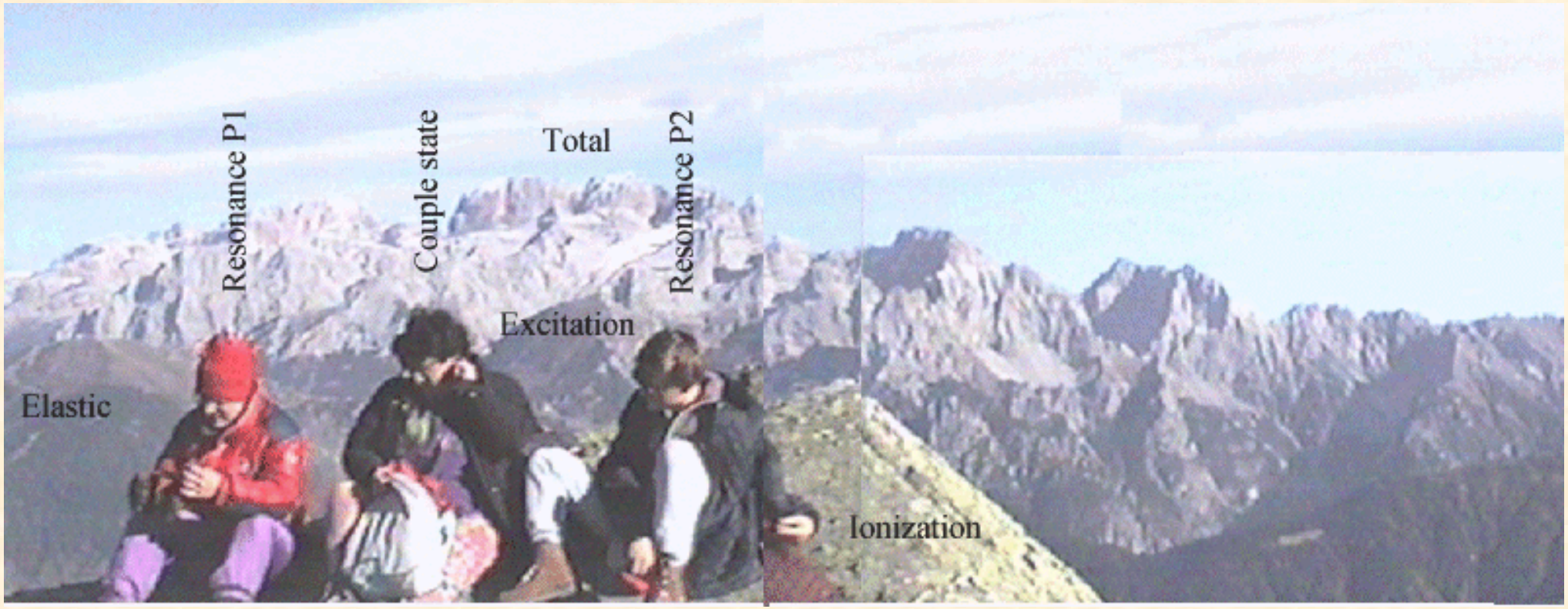
w for OCS


10
1
0.1
0.01
W (10^5 m/s)
0.1
1
10
100
1000
E/N (Td)
N2O
CO2
OCS
Hake
Elford
Saelee
Schlumbohm
Sierra
Hasegawa
Kucukarpaci
bolsig set1
OCS
N2O
CO2-w

Cross sections for **OCS**

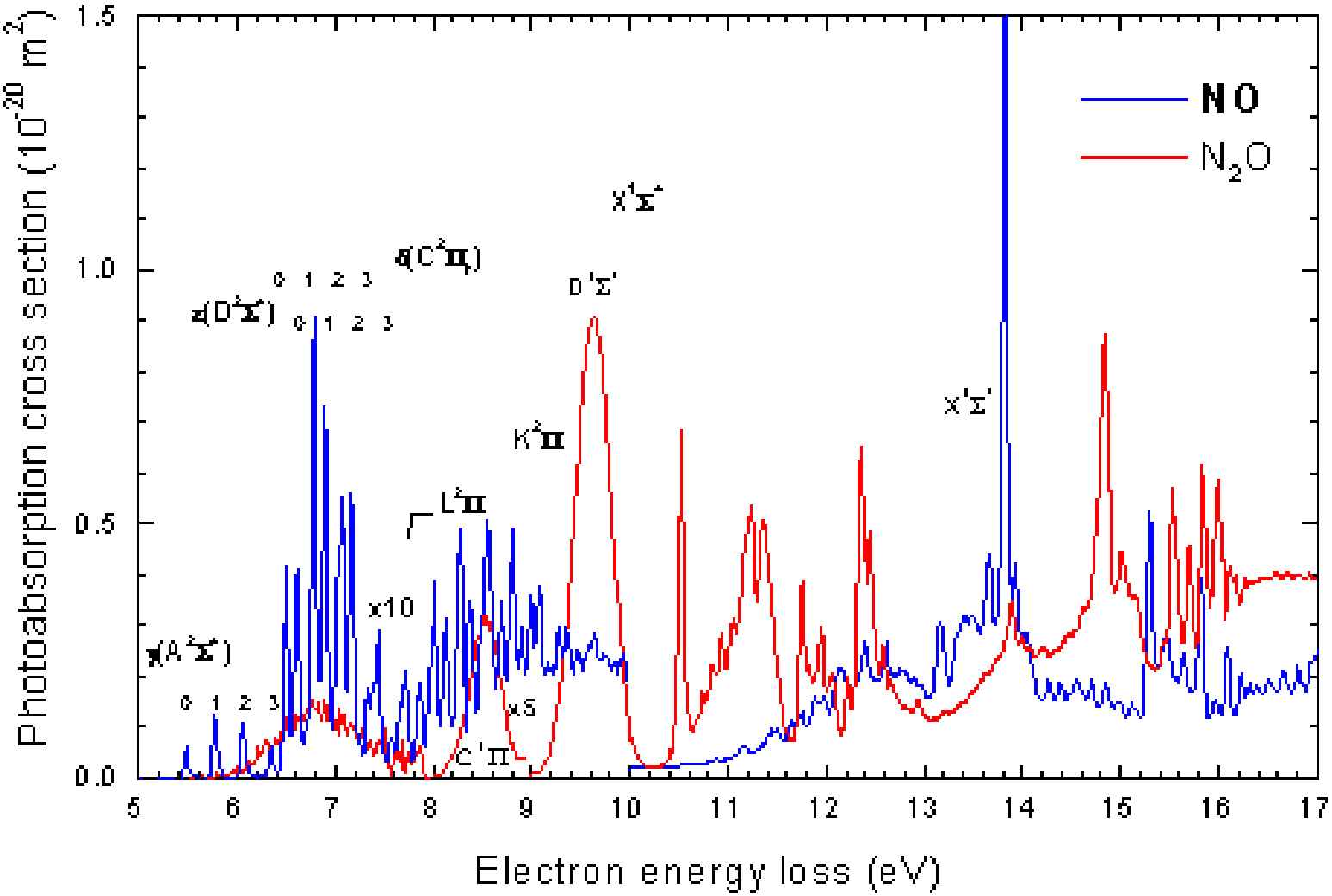


Still no (chemical) details!



Trento, 1996

Electronic excitation – NO and N_2O



“Photo-absorption” = forward electron scattering

„Simple system”: N_2 afteglow

ON THE IMPOSSIBILITY OF N(^{4}S) ATOM RECOMBINATION TO EXPLAIN THE APPEARANCE OF THE PINK-AFTERGLOW IN A N_2 FLOWING DISCHARGE

J. Loureiro[1], P. A. Sá[1,2] and V. Guerra[1]

In a flowing nitrogen discharge two different types of flowing afterglow may occur. One existing in the far remote zones of the post-discharge with origin in the homogeneous three-body recombination of N(^{4}S) atoms, which leads to a strong emission of first positive system bands $N_2(B\ ^3\Pi_g, v' \rightarrow A\ ^3\Sigma_u^+, v'')$, that is the classical yellow Lewis-Rayleigh afterglow (LRA). The other occurring upstream to the LRA, at a short distance from the end of the discharge, characterized by the emission of the first negative system bands corresponding to transitions between the ionic states $N_2^+(B\ ^2\Sigma_u^+, v' \rightarrow X\ ^2\Sigma_g^+, v'')$ with a pink colouring, which is the so-called pink afterglow (PA). This latter is hence representative of a re-ionization zone in the

The vibrationally excited $N_2(X\ ^1\Sigma_g^+, v)$ molecules and the ground-state atoms N(^{4}S) are the sole flowing long-lived carriers that may come from the discharge to the post-discharge zone [9,10]. As a consequence of this, the ground-ionic state $N_2^+(X\ ^2\Sigma_g^+)$ needs to be created in the post-discharge too. Re-ionization in the afterglow may occur as a result of Penning ionization reactions due to collisions between metastable species $N_2(A\ ^3\Sigma_u^+)$ and $N_2(a'\ ^1\Sigma_u^-)$ [11,12]

$$N_2(A) + N_2(a') \rightarrow N_2(X) + N_2^+(X) + e \qquad (2)$$

$$N_2(a') + N_2(a') \rightarrow N_2(X) + N_2^+(X) + e\ , \qquad (3)$$

Dissociative attachment (1)

CS_2

PHYSICAL REVIEW A **64** 012707

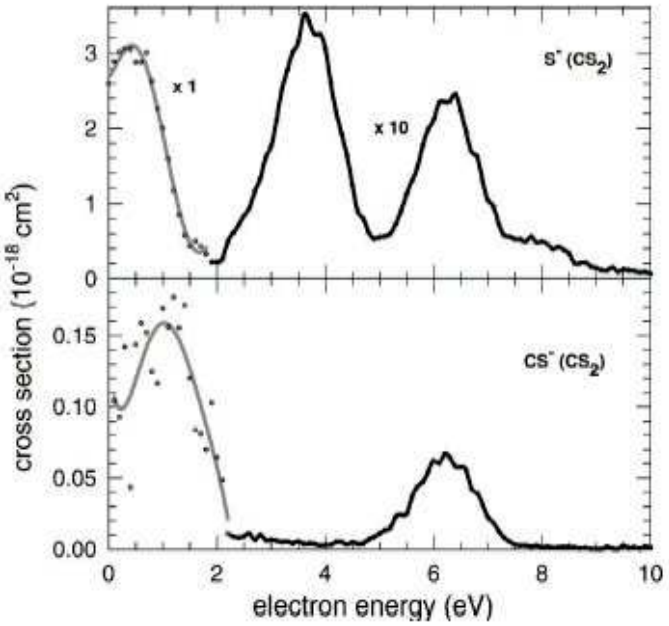


FIG. 2. The S^- and CS^- fragment ion cross sections as a function of incident electron energy. The open symbols indicate the DEA cross section from the excited $^1B_2$ neutral state. The solid symbols represent the ground-state cross sections. In the S^- excitation the DEA signal from the ground state is multiplied by a factor of 10.

SO_2

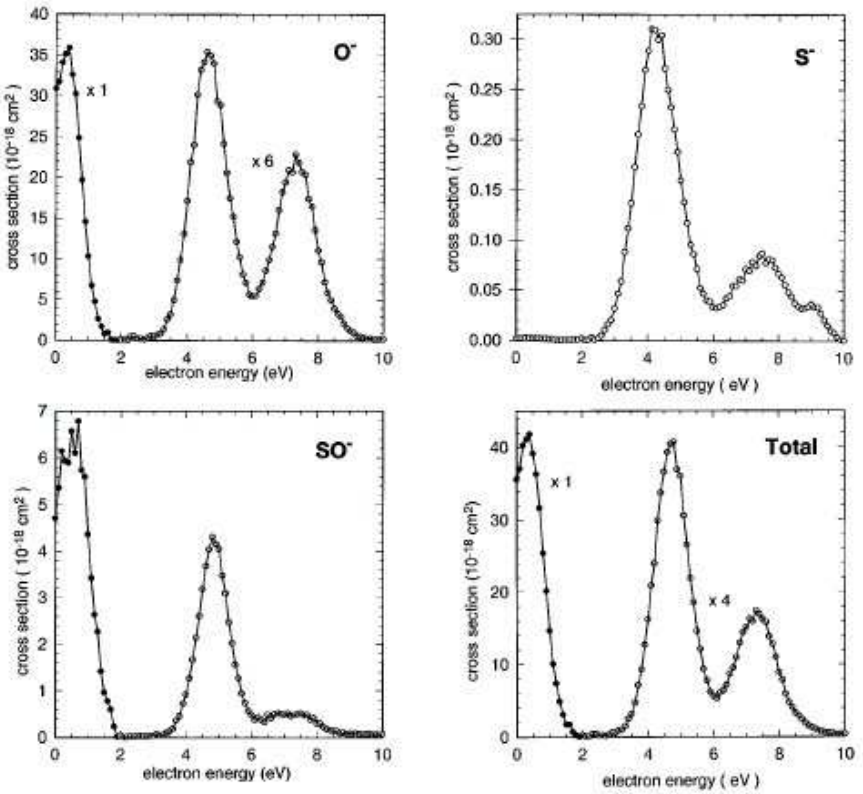


FIG. 6. Partial and total dissociative-attachment cross sections from ground and excited states of SO_2. The filled circles represent the cross sections from the excited ($\tilde{B}\,^1B_1$) state and the open circles from the ground ($\tilde{X}\,^1A_1$) state, respectively. The values for the ground state have been multiplied by a factor of 6 in the case of O^- cross sections and a factor of 4 in the case of total cross sections as marked in the respective figures: (a) O^-, (b) SO^-, (c) S^-, and (d) total.

These are absolute cross sections!

.... and not so small (1%)!

Krishnakumar et al. PRA 57 (1997) 1945

Dissociative attachment: NO_2, O_3

RANGWALA, KRISHNAKUMAR, AND KUMAR

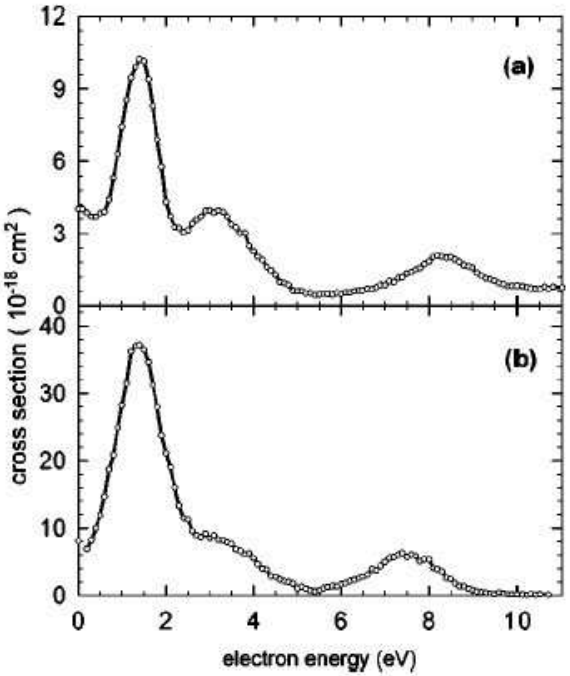


FIG. 1. O^- cross section as a function of incident electron energy from (a) NO_2 and (b) O_3.

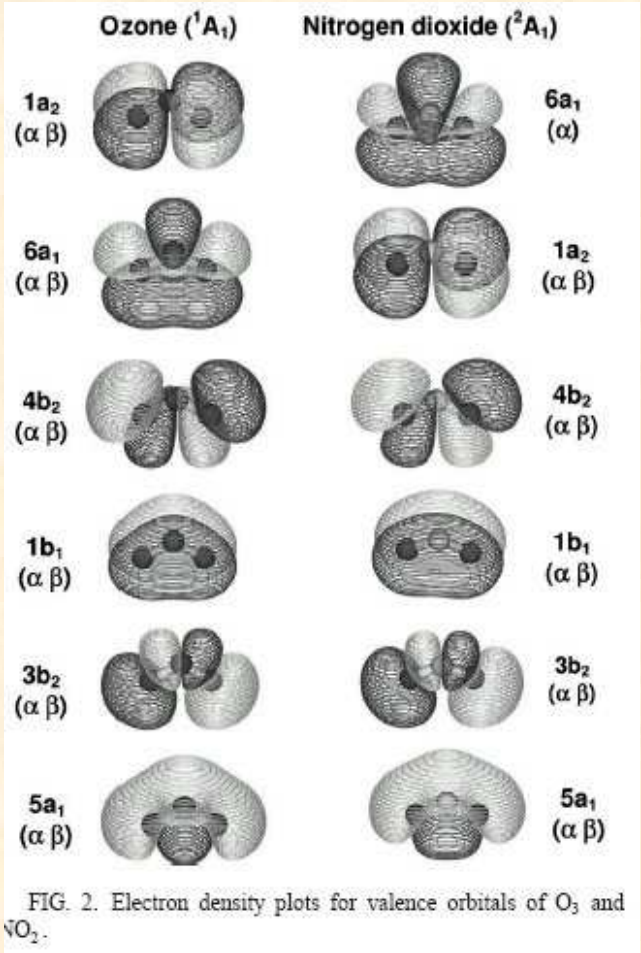


FIG. 2. Electron density plots for valence orbitals of O_3 and NO_2.

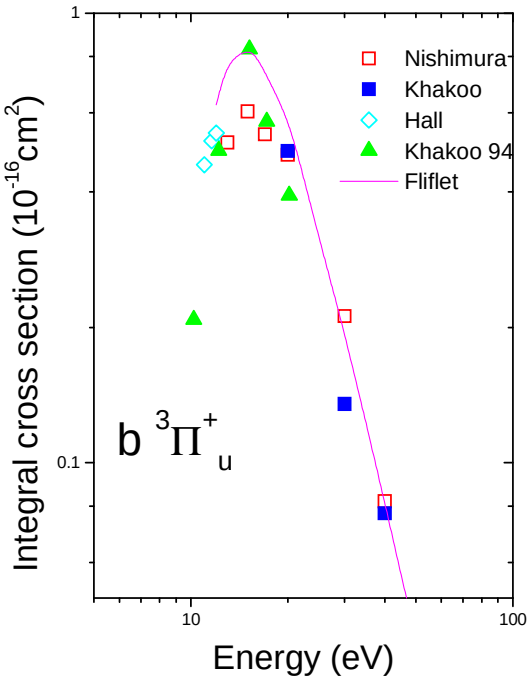
O_3: 3 times more!

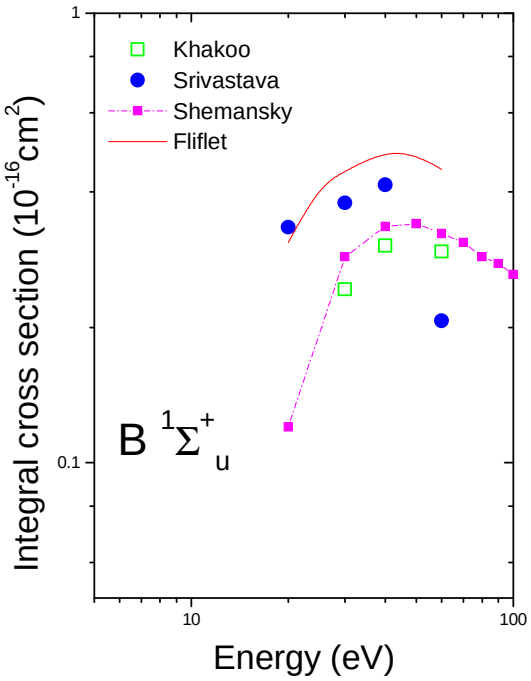
DE: 3.11 eV (NO_2), 1.04 eV (O_3)

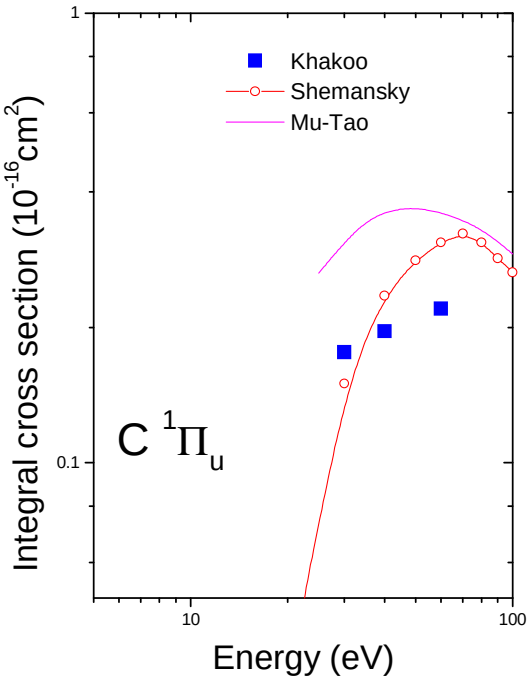
i.e. also Quantum Chemistry

Rangwala et al. PRA 68 (2003) 052710

Optically allowed (radiative) vs. forbidden (dissociation)

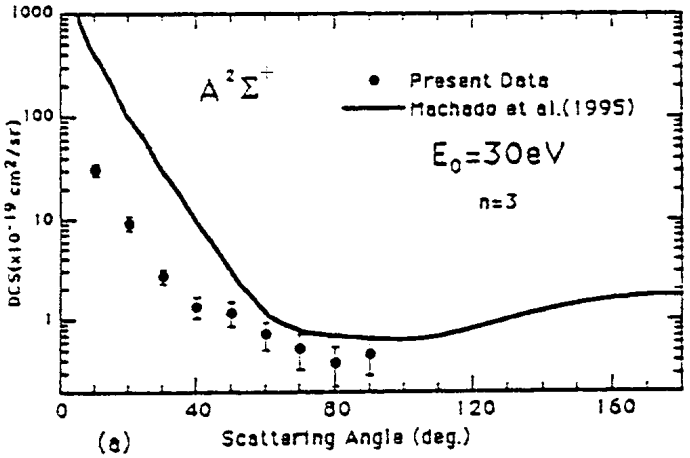


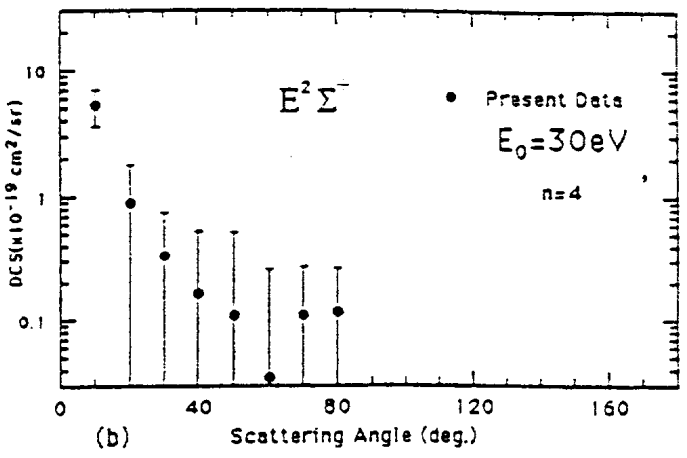


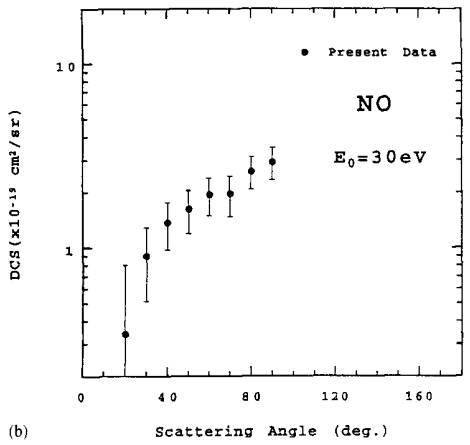


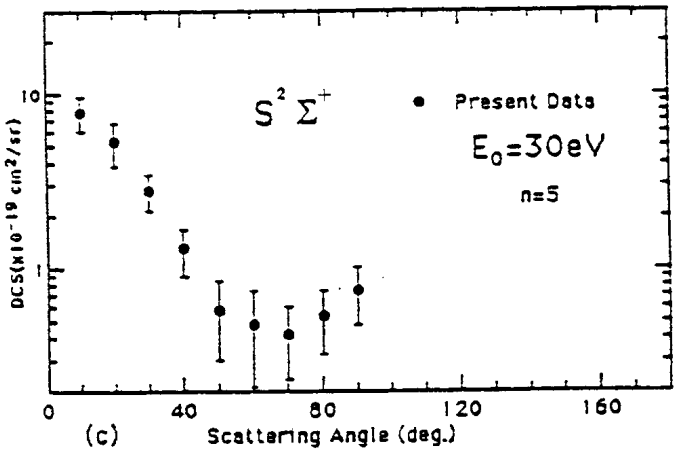
Hydrogen (H_2)

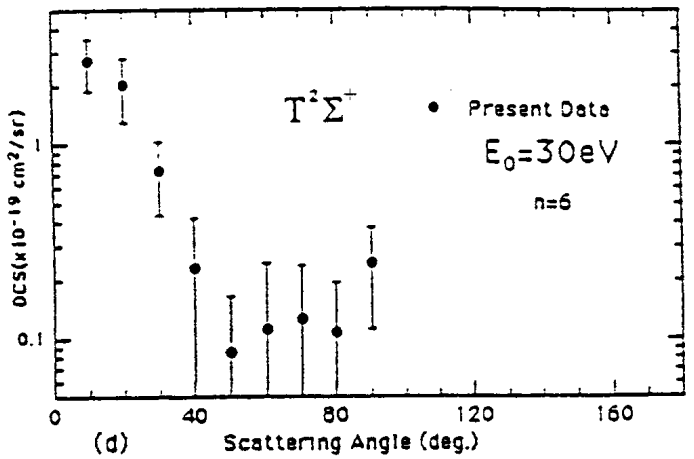
Optically allowed (radiative) vs. forbidden (dissociation)

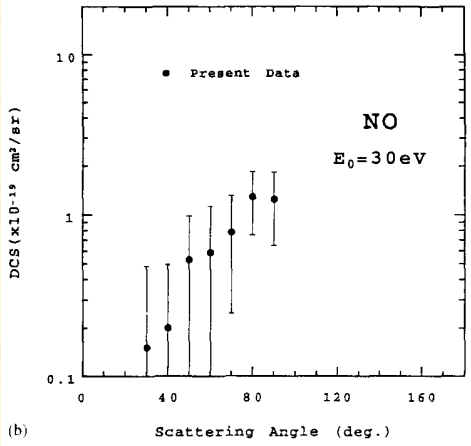












Nitric oxide (NO)

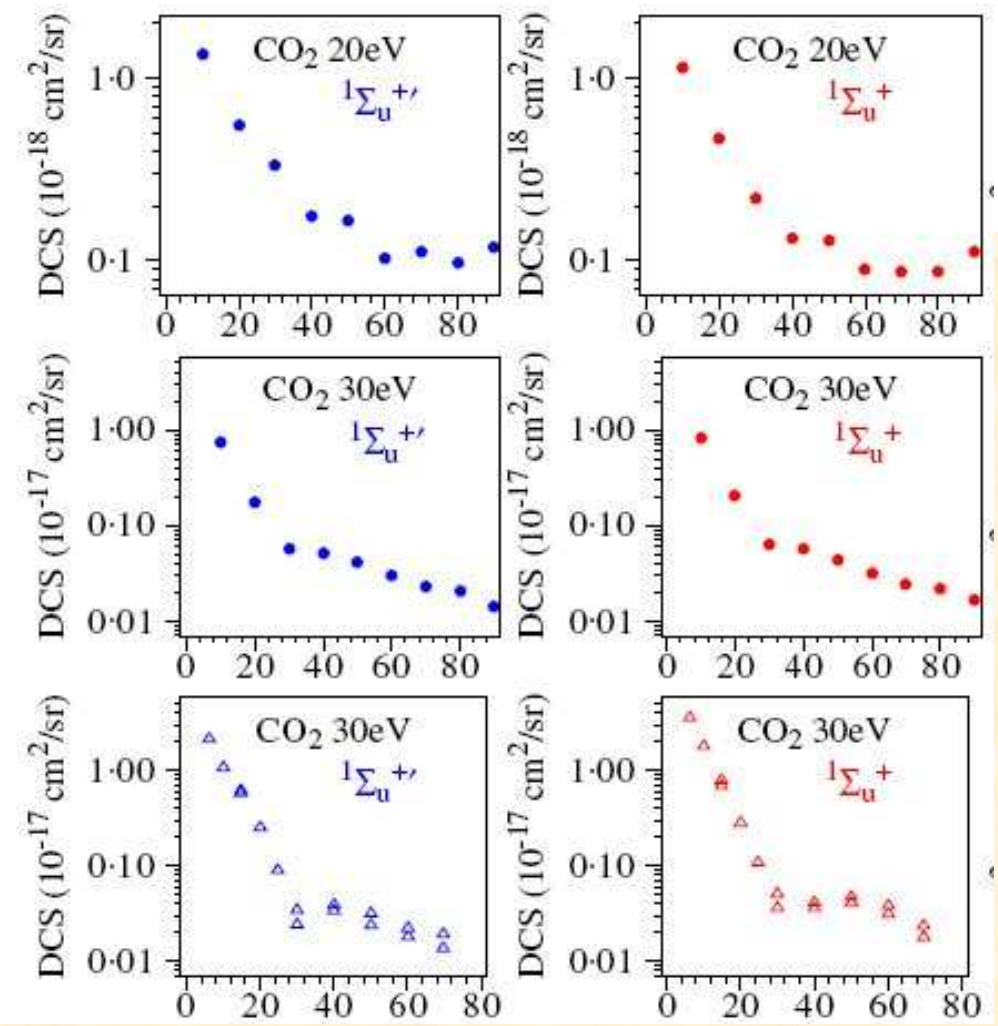
Triatomic?

6.4.5.5	Nitric oxide (NO)	6-164
6.4.5.5.1	$v' = 0 \rightarrow 1$	6-164
6.4.5.5.2	$v' = 0 \rightarrow 2$	6-165
6.4.5.5.3	$X^2\Pi \rightarrow A^2\Sigma^+$	6-165
6.4.5.5.4	$X^2\Pi \rightarrow C^2\Pi_i$	6-166
6.4.5.5.5	$X^2\Pi \rightarrow F^2\Delta$	6-166
6.4.5.5.6	$X^2\Pi \rightarrow B^2\Pi_r$	6-167
6.4.5.5.7	$X^2\Pi \rightarrow b^4\Sigma^-$	6-167
6.4.5.5.8	$X^2\Pi \rightarrow B'^2\Delta$	6-169
6.4.5.5.9	$X^2\Pi \rightarrow D^2\Sigma^+$	6-169
6.4.5.5.10	$X^2\Pi \rightarrow a^4\Pi$	6-170
6.4.5.5.11	$X^2\Pi \rightarrow L'^2\Phi$	6-171
6.4.5.5.12	$X^2\Pi \rightarrow L^2\Pi$	6-171
6.4.5.5.13	$X^2\Pi \rightarrow K^2\Pi$	6-172
6.4.5.5.14	$X^2\Pi \rightarrow E^2\Sigma^+$	6-173
6.4.5.5.15	$X^2\Pi \rightarrow Q^2\Pi$	6-173
6.4.5.5.16	$X^2\Pi \rightarrow S^2\Sigma^+$	6-174
6.4.5.5.17	$X^2\Pi \rightarrow M^2\Sigma^+$	6-175
6.4.5.5.18	$X^2\Pi \rightarrow H'^2\Pi$	6-175
6.4.5.5.19	$X^2\Pi \rightarrow H^2\Sigma^+$	6-176
6.4.5.5.20	$X^2\Pi \rightarrow N^2\Delta$	6-176
6.4.5.5.21	$X^2\Pi \rightarrow O'^2\Pi + O^2\Sigma^+$	6-177
6.4.5.5.22	$X^2\Pi \rightarrow W^2\Pi + Y^2\Sigma^+$	6-178
6.4.5.5.23	$X^2\Pi \rightarrow T^2\Sigma + U^2\Delta + 5f$	6-178
6.4.5.5.24	$X^2\Pi \rightarrow Z^2\Sigma^+ + 6d\delta + 6f$	6-179

Electronic excitation (CO_2)

Absolute differential cross sections for electron impact excitation of the 10.8–11.5 eV energy-loss states of CO_2

M A Green[1], P J O Teubner[1], L Campbell[1], M J Brunger[1], M Hoshino[2],



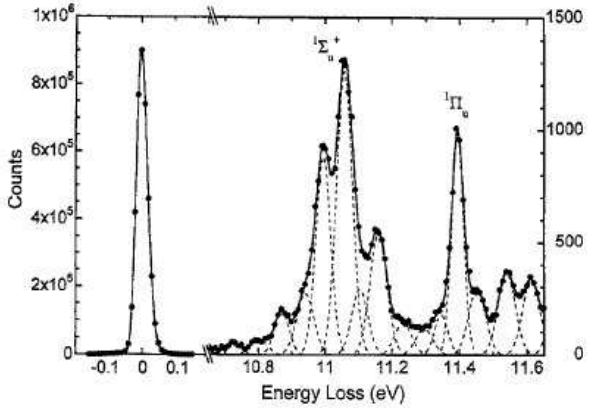
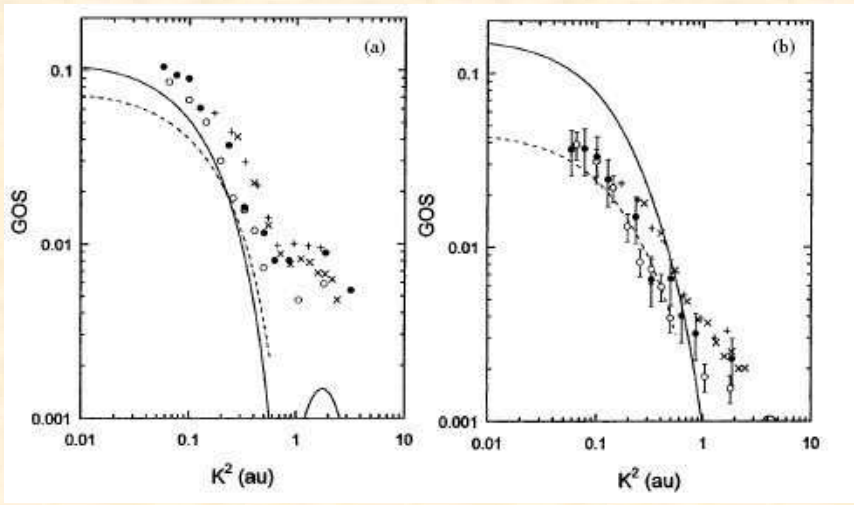


Figure 2. Representative example from the result of our spectral deconvolution procedure. In this case the energy-loss spectrum was measured at $E_0 = 100$ eV and $\theta_e = 20°$.

GOS:

$f = W/2\,(K_1/K_2)\,(\Delta K)^2\,\sigma$



No integral CS

Electronic excitation (2)

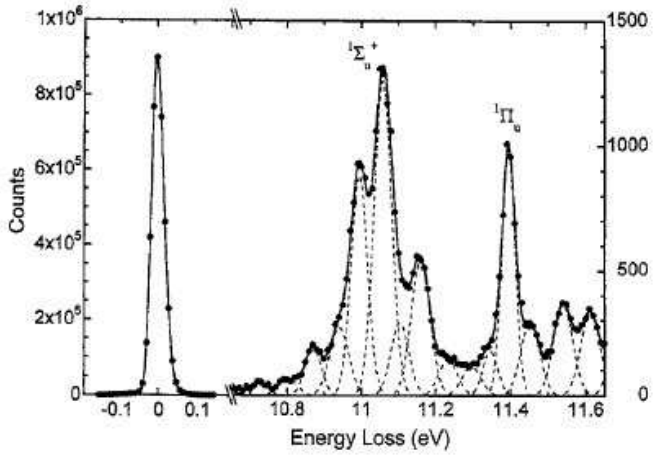


Figure 2. Representative example from the result of our spectral deconvolution procedure. In this case the energy-loss spectrum was measured at $E_0 = 100$ eV and $\theta_e = 20°$.

Predissociation path:

$^1\Pi_u \rightarrow O(^1S)+CO(X\,^1\Sigma^+)$

„Hydrocarbon combustion by pulsed DC discharge"

involving excited atoms of oxygen $O(^1D)$ which are produced by direct electron impact from molecular oxygen,

$$O_2+e \rightarrow O+O(^1D)+e,$$

and, in the process of recombination of molecular ions of oxygen,

$$O_2^+ + e \rightarrow O+O(^1D).$$

In the case of partially processed rich and stoichiometric mixtures,

$$CO_2+e \rightarrow CO+O(^1D)+e,$$

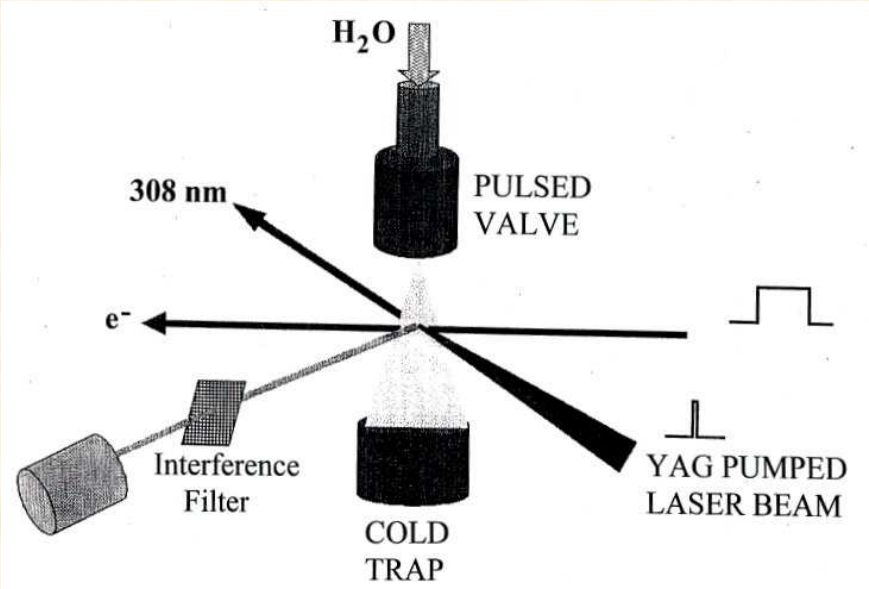
may become the main channel of generation of $O(^1D)$; in so doing, the formation of radicals from water cannot be ignored in the case of either lean or rich mixtures.

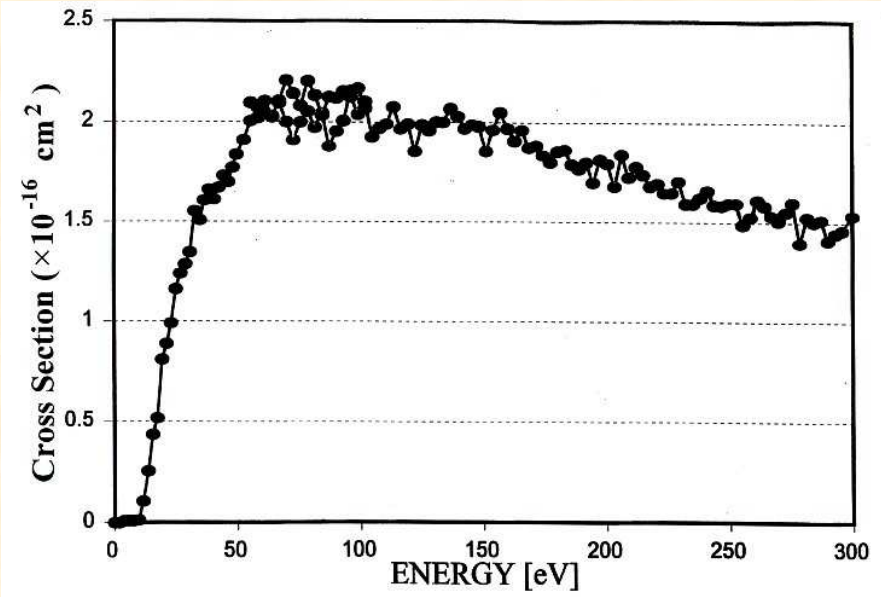
Therefore, under our experimental conditions, the excitation, dissociation, and ionization of saturated hydrocarbons by electron impact do not affect the oxidation rate. The process of oxidation is governed by the processes of production of excited molecules and atoms from oxygen, water, carbon dioxide, and, possibly, stable intermediate substances.

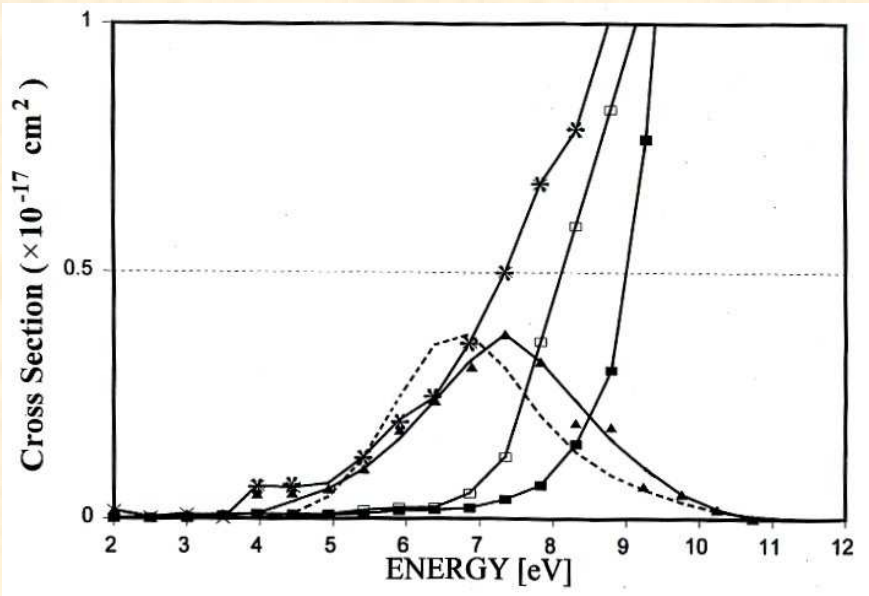
NO cross sections!

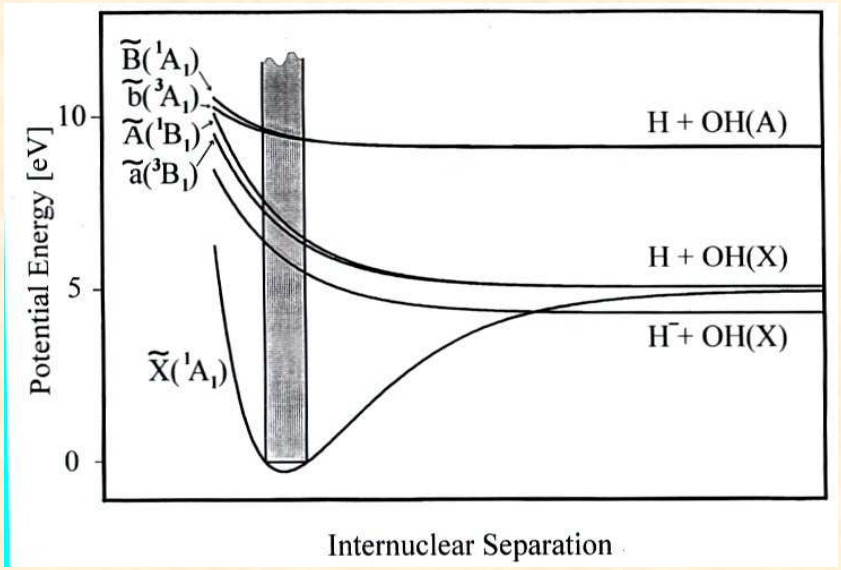
Dissociation into neutrals (H_2O)

„Laser induced fluorescence”





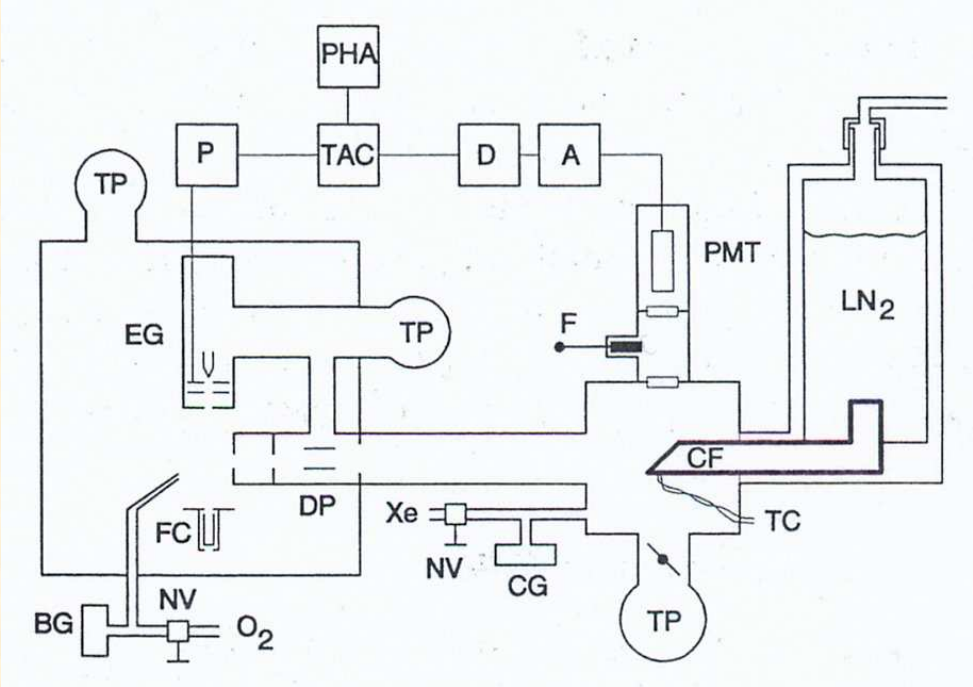




Herb and McConkey

Dissociation into neutrals (N_2O)

XeO^* excimer decay



$N_2O \rightarrow O(^1S_0)$

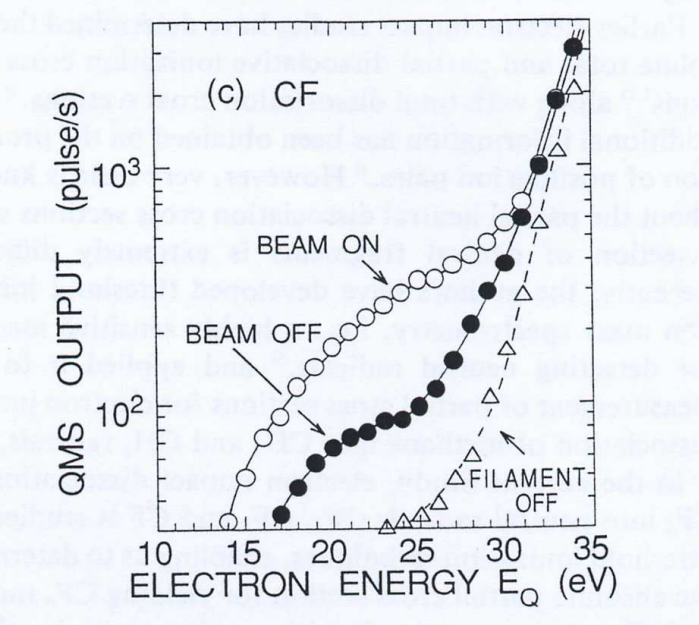
LeClair and McConkey JCP 99 (1993) 4566

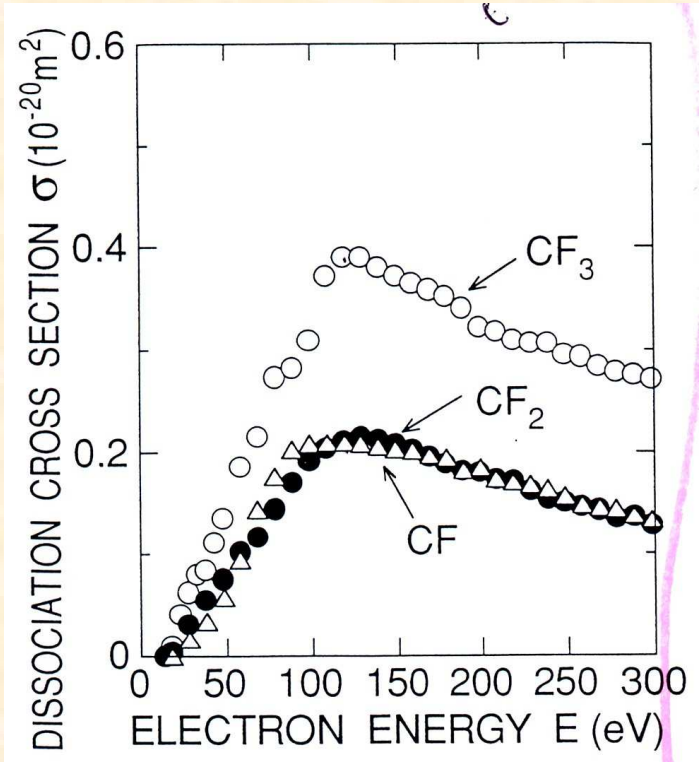
TABLE I. Absolute cross sections for the production of $O(^1S)$ following electron impact on $O(^3P)$, $O_2(X\,^3\Sigma_g^-)$, and $N_2O(X\,^1\Sigma^+)$ in units of 10^{-18} cm^2. The atomic oxygen data are taken from Ref. 57.

E (eV)	O	O_2	N_2O
4.4	0.54	···	···
4.8	1.30	···	···
5	1.60	···	···
6	2.57	···	···
7	3.02	···	···
8	3.22	···	···
9	3.28	···	···
10	3.27	···	···
12	3.15	···	5.12
14	2.97	···	9.52
16	2.79	0.35	13.8
20	2.44	0.92	18.1
24	···	1.26	20.5
28	···	1.47	21.7
32	···	1.61	22.2
36	···	1.73	22.4
40	1.37	1.82	22.4
45	1.21	1.92	22.5
50	1.07	1.97	22.4
60	···	2.04	22.2
70	0.69	2.07	21.7
80	···	2.08	21.1
90	···	2.06	20.6
100	0.38	2.04	20.1
120	···	1.98	18.9
140	···	1.90	18.0
160	···	1.82	17.1
180	···	1.75	16.3
200	0.08	1.67	15.6
250	···	1.53	13.9
300	···	1.39	12.8
350	···	1.26	11.8
400	···	1.16	11.0
450	···	1.08	10.3
500	···	1.02	9.60
600	···	0.92	8.63
700	···	0.82	7.91
800	···	0.75	7.39
900	···	0.69	6.88
1000	···	0.65	6.49

Dissociation into neutrals (CF_4)

„Two electron beams”





Nakano and Sugai, Jpn. J. Appl. Phys. 31 (1992) 2919

Dissociation into neutrals (CF_4, CH_3F…)

„Volatile organotellurides”

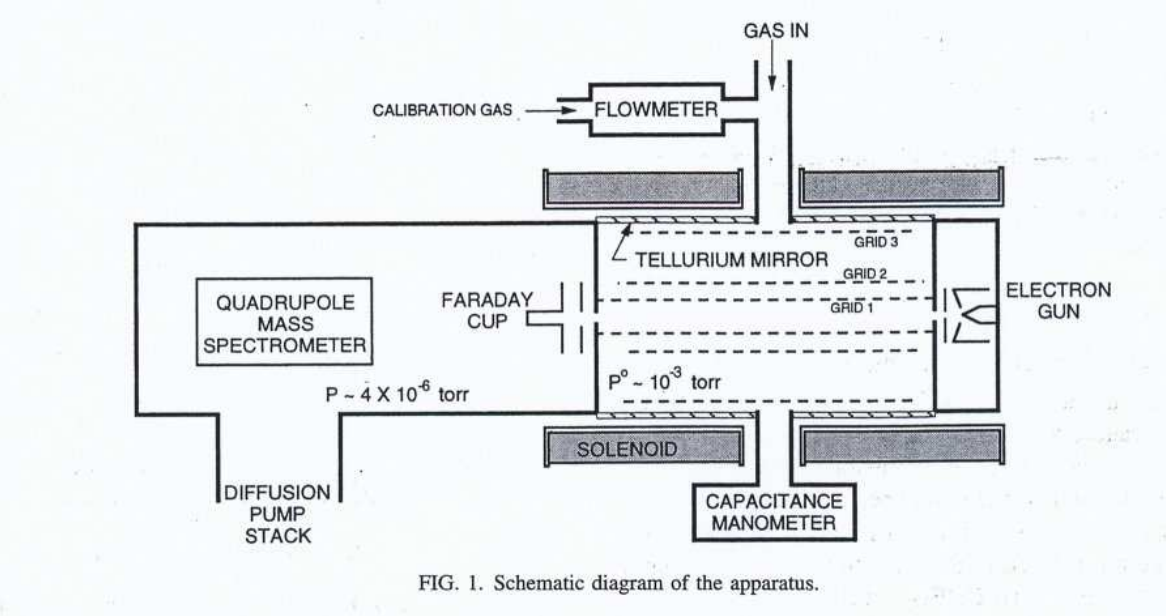


FIG. 1. Schematic diagram of the apparatus.

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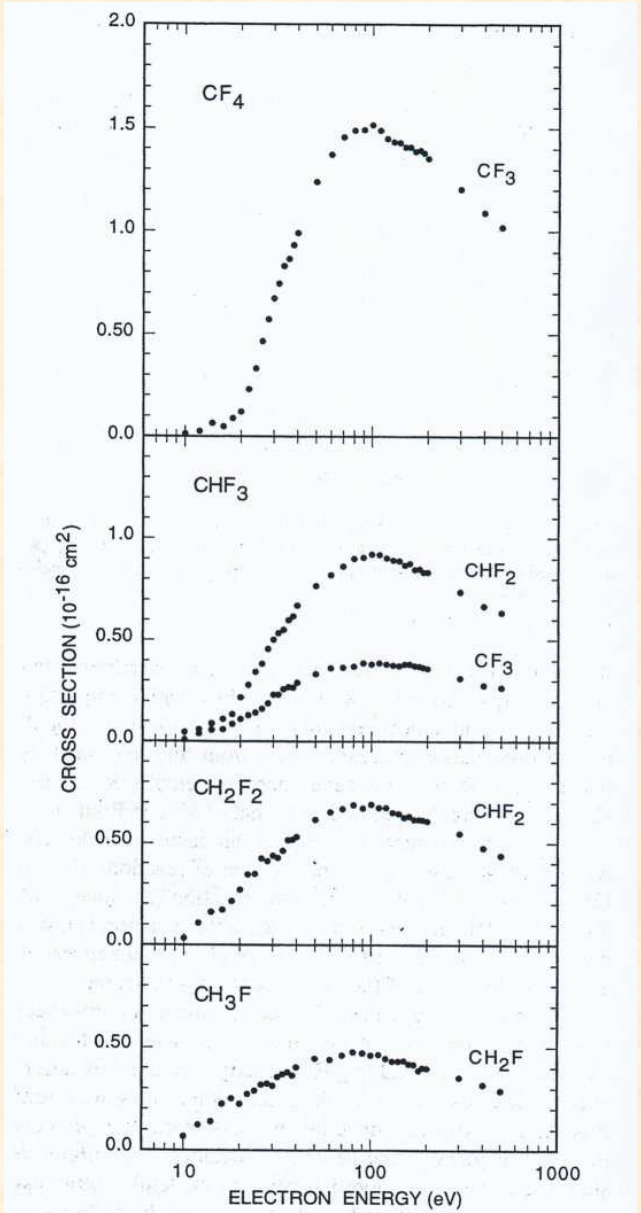
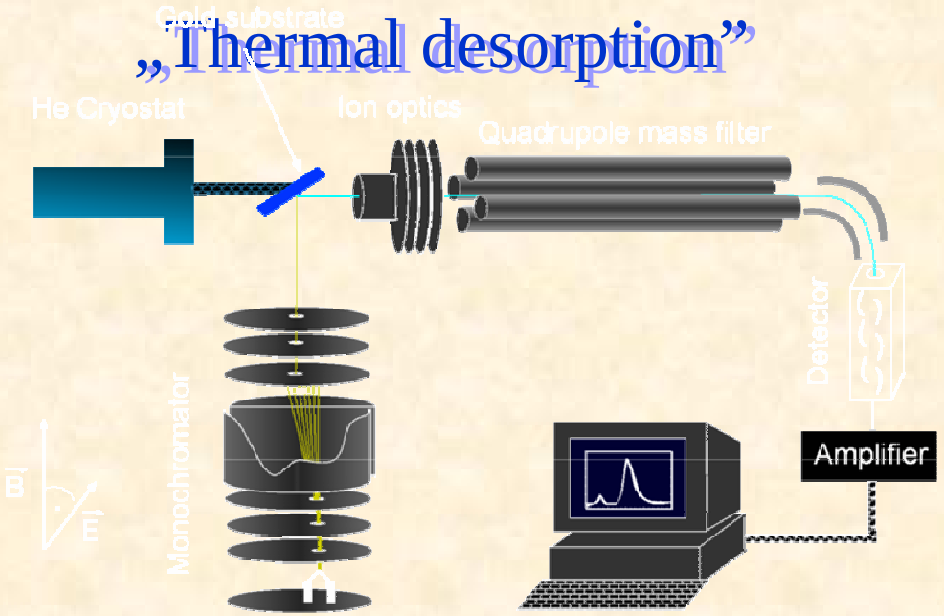
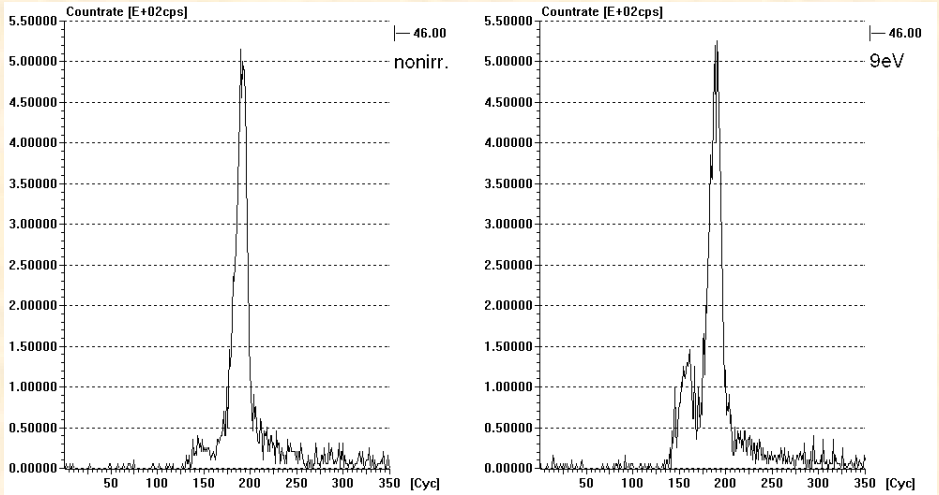


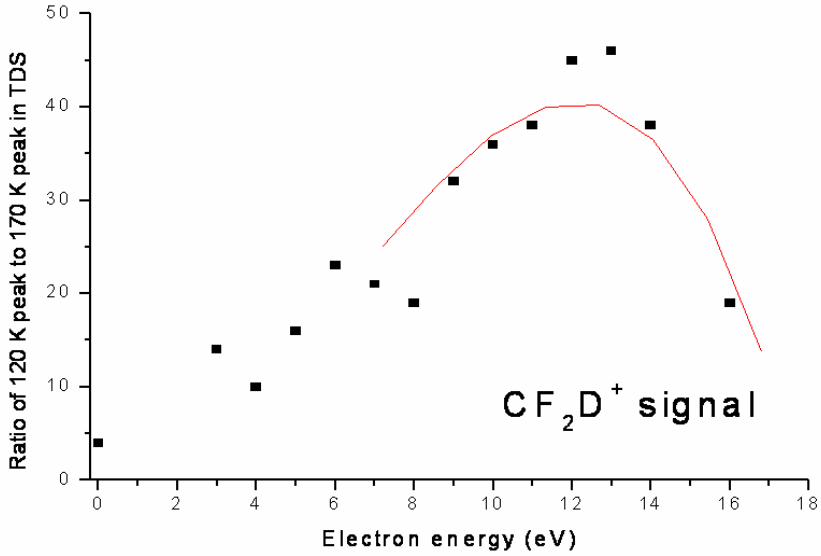
FIG. 5. Cross sections for the production of fluoromethyl radicals by neutral dissociation (n.d.) and dissociative ionization (d.i.) from electron impact on fluoromethanes.

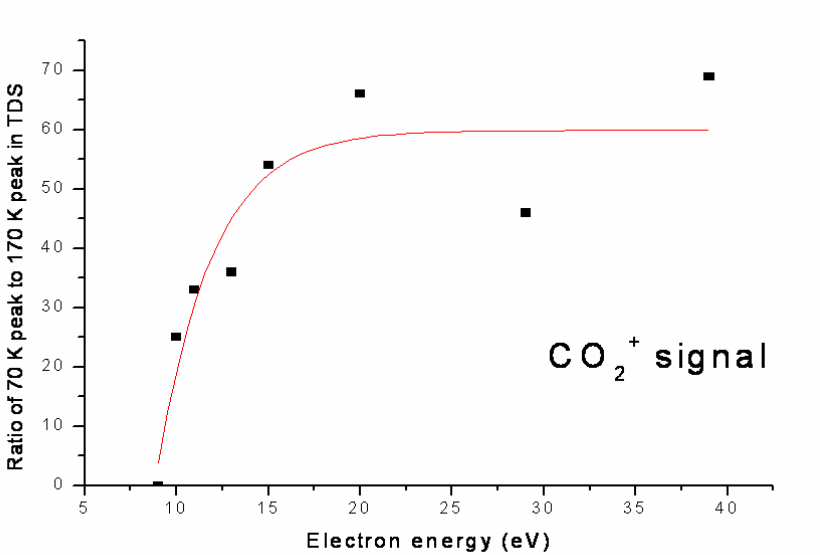
Dissociation into neutrals (CF_3COOH)

„Thermal desorption"









Illenberger and collaborators

Cross sections in (triatomic) gases - the need for data

Conclusions (1): elastic cross sections

- Beam cross sections require a *cross check*
  (spread in data > declared errors)
- Electron diffusion measurements are not straightforwards
  (difficilty in deriving diffusion coefficients)
- Boltzmann models fail for polar molecules and high E/N
- Monte Carlo codes need *well chosen* cross sections data
- Theory: input from experiments
  on inelasting contribution ***in resonances***

Cross sections in (triatomic) gases - the need for data

Conclusions (2): inelastic processes

- Ionization – only recently satisfactory agreement and semiempirical models
- Dissociative (non-dissociative?) electron attachment: new labs
- Electronic excitation: extend the angular range, give integral values
- Dissociation channels: develop new techniques

Cross sections in triatomic gases - the need for data

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