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Bibliography of Electron and Photon Cross Sections
with Atoms and Molecules
Published in the 20th Century
– Water vapour –

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Bibliography of Electron and Photon Cross Sections

with Atoms and Molecules

Published in the 20th Century

—— Water vapour ——*

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Bibliographies of original and review reports of experiments or theories of electron and photon cross sections and also electron swarm data are presented for atomic or molecular species with specified targets. These works covered 17 atoms and 51 molecules. The present bibliography is only for water vapour (H_2O, D_2O and HDO). About 1200 papers were compiled. A comprehensive author index is included. The bibliography covers the period 1915 through 2000 for H_2O. Finally, author's comments for electron collision cross sections and photodissociation processes of H_2O are given.

Keywords : H_2O molecule, collision cross sections, electron, elastic scattering, rotational, vibrational and electronic excitations, dissociation, ionization photon, photoabsorption, photodissociation, photoexcitation, photoionization, electron swarm, drift velocity, diffusion coefficient, ionization coefficient, excitation and ionization energies, transition probabilities, lifetimes of excited states

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Introduction

History

This bibliography is the result of a continuing literature survey which was begun around 1970 and originally encompassed only electron collision cross section and electron swarm data. The organization responsible for continuing this survey is Nagoya Institute of Technology, Nagoya. From 1994, the work continued to Gaseous Electronics Insititute, Nagoya. In 1997, the collection of photon cross section references was begun. The search for references in both cases was retrospective and included all papers reporting measurements, theoretical calculations or reviews and data compilations of such cross sections and electron swarm data.

Scope

This bibliography contains references to original research papers which report experiments or theoretical calculations of cross sections for electron and photon collisions with water vapour H_2O. The review papers on this subject are also included. Some water vapour molecule cluster papers are included. Some conference reports, company or agency reports and PhD thesis are included. Water vapour ion papers and positron collision papers are not included in principle.

Papers reporting the following data are included.

For electron collision cross section :

1) elastic scattering
2) rotational excitation
3) vibrational excitation
4) electronic excitation
5) dissociation
6) ionization
7) attachment
8) grand total scattering (sum of elastic and inelastic cross sections)
9) metastable ni-trogen molecules
10) electron swarm parameters (drift velocity, diffusion coefficient)
11) excitation and ionization coefficients

For photon collision cross section :

1) photoabsorption
2) photoexcitation and fluorescence
3) photodissociation
4) photoionization

For some related data :

1) excitation and ionization energies
2) transition probabilities
3) lifetimes of excited states
4) others

The energy range for electron cross section data is usually 0 - 10 keV, but some higher electron energy papers are included. The wavelength range for photon cross section data is from microwave to X-ray. Most papers are concerned with infrared, visible and ultraviolet ray region.

The bibliography includes the papers published in the 20th century, from 1901 to 2000. Oldest paper in this list is given by J.S.Townsend (1915). So for this water vapour bibliography, published papers from 1915 to 1999 are compiled by alphabetical order of the first author's surname of the paper. And the references published in 2000 and plus some old papers found very recently after compilation are added as " Addenda of References for H_2O (1) and (2) ". In total, about 1200 papers are compiled in the water vapour molecule bibliography.

Organization

This report consists of four parts : introduction, the bibliography and its addenda, author index, and some comments on electron collision cross sections.

Bibliography

In this section the complete citation for all references are given. At first following classifications are shown :

E : Elastic collision
R : Rotational excitation
V : Vibrational excitation
EX : electronic EXcitation
D : Dissociation
I : Ionization
A : Attachment
ME : MEtastable argon
S : electron Swarm
O : Others (photon cross sections and the others)

All authors' initials and surname, journal name, volume, inclusive pages and year of publication are given as well as the title, and some additional information in the square bracket [ ]. E and T in the square bracket mean experiment and theory.

Bibliography for H_2O are divided into two parts :

Part 1. 1915 - 1999 p. 1 - 78
Part 2. Addenda of References (1) and (2) published in 2000, plus some old papers p. 79 - 104

Author Index

In this section all authors are listed alphabetically by surname. After each author's name is a list of page numbers indicating which references he or she authored or coauthored.

Part 1. 1915 - 1999 p. 1 - 13
Part 2. Addenda (1) p. 14 - 17

Some Comments on Electron Collision Cross Sections and Photodissociation Processes for H_2O

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References for H_2O, HDO and D_2O

and radical OH and OD (1900 - 1999)

(Water vapour, Deuterated water, Heavy water)

E	: Elastic collision,	R	: Rotational excitation,
V	: Vibrational excitation,	EX	: Electronic excitation,
D	: Dissociation,	I	: Ionization,
A	: Attachment,	QT	: Grand total cross section,
S	: Swarm,	α	: Ionization coefficient,
O	: The others,	[ ]	: Additional informations,
			E : Exp., T : Theory.

The oldest paper in this list is given by J.S.Townsend (1915).

O E.H.Abramson, J.Zhang and D.G.Imre : J.Chem.Phys.93, 947-950 (1990)
A linear $^1B_2$ state of the water molecule. [T, H_2O]

O H.Agren, V.Carravetta, H.J.Aa.Jensen, P.Jφrgensen and J.Olsen : Phys.Rev.A47, 3810-3823 (1993)
Multiconfiguration linear-response approaches to the calculation of absolute photoionization cross sections : HF, H_2O, and Ne.
[T, hν, H_2O, HF, Ne]

O R.Akamatsu and K.O-ohta : J.Phys.Soc.Jpn.44, 589-597 (1978)
Semiclassical approach to the abnormal rotation of $OH(A^2\Sigma^+)$ resulting from H_2O photodissociation. [T, hν, H_2O]

O M.I.Al-Jobury and T.W.Turner : J.Chem.Soc.4434-4441 (1964)
Molecular photoelectron spectroscopy. Part II. A summary of ionization potentials. [E, hν, H_2O, D_2O, O_2, CO, NO, H_2S, CS_2, SO_2, NO_2, N_2O, CO_2, NH_3, CH_4 - C_5H_{12}, etc.]

E S.Altshuler : Phys.Rev.107, 114-117 (1957)
Theory of low-energy electron scattering by polar molecules.
[T, H_2O, NH_3; 0.36 - 1 eV]

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Geometries, harmonic frequencies and infrared and Raman intensities for H_2O, NH_3 and CH_4. [T, H_2O, NH_3, CH_4]

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Laser photodissociation of H_2O at 157 nm : Rotational energy distribution in product $OH(X^2\Pi)$. [E, hν, H_2O]

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Creation of population invesions in the Λ doublets of OH by the photodissociation of H_2O at 157 nm : A possible mechanism for the astronomical maser. [E, hν, H_2O]

O P.Andresen and E.W.Rothe : J.Chem.Phys.78,989-990 (1983b)
Polarized LIF spectroscopy of OH formed by the photodissociation of H_2O by polarized 157 nm light. [E, hν, H_2O]

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Nuclear and electron dynamics in the photodissociation of water.
[E, hν, H_2O]

O P.Andresen and E.W.Rothe : J.Chem.Phys.82,3634-3640 (1985a)
Analysis of chemical dynamics via Λ doubling : Directed lobes in product molecules and transition states. [T, H_2O, HO, NO, etc.]

O P.Andresen, V.Beushausen, D.Hausler, H.W.Lulf and E.W.Rothe : J.Chem.Phys.83, 1429-1430 (1985b)
Strong propensity rules in the photodissociation of a single rotational quantum state of vibrationally excited H_2O. [E, hν, $H_2O(v)$]

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Classification of pump mechanisms for astronomical OH masers and a maser model for the H_2O photodissociation pump mechanism. [T, hν, H_2O]

O P.Andresen and R.Schinke : in Molecular Photodissociation Dynamics. M.N.R.Ashfold and J.E.Baggott (Ed), Royal Society of Chemistry, 61- (1987)

EX V.Ya.Antonchenko, N.V.Gloskovskaya, V.V.Ilyin and K.Heinzinger : Ukr.J.Phys. (41,198-204) (1996)
Calculation of properties of a water molecule and its dissociation products in the frame of the polarization model. [T, H_2O]

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The formation of protons by impact of low energy electrons on water molecules. [E, H_2O, D_2O; 18 - 40 eV]

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Absorption measurements of water-vapor concentration, temperature, and line-shape parameters using a tunable InGaAsP diode laser.
[E, hν, H_2O]

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Diode-laser absorption technique for simultaneous measurements of multiple gasdynamic parameters in high-speed flows containing water vapor. [E, hν, H_2O]

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Molecular predissociation dynamics revealed through multiphoton ionisation spectroscopy. I. The C $^1B_1$ states of H_2O and D_2O.
[E, hν, H_2O, D_2O]

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The 4s ← $1b_1$ and 3d ← $1b_1$ Rydberg states of H_2O and D_2O : Spectroscopy and predissociation dynamics. [E, hν, H_2O, D_2O]

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Characterisation of the $E^1B_1(3da_1 \leftarrow 1b_1)$ Rydberg state of water by resonance-enhanced multiphoton ionisation (MPI) spectroscopy. [E, D_2O]

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V The electron energy loss rates by polar molecules. [T]

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Absorption de la vapeur d'eau dans l'ultraviolet extreme. [E, hν, H_2O]

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Sur le spetre d'absorption de la vapeur d'eau et d'eau lourde dans l'ultraviolet extreme. [E, hν, H_2O]

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Spectrographie dans l'ultraviolet extreme absorption de NO, N_2O, H_2O, et D_2O (gazeux). [, H_2O, D_2O, NO, N_2O]

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Sur l'excitation de l'eau par impact electronique entre 3 et 6 eV.
[E, H_2O; 3 - 6 eV]

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Resonant negative ion states of H_2O as observed by measurement of the OH ($A^2\Sigma \rightarrow X^2\Pi$) emission following near-threshold electron impact.
[E, H_2O]

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On the behaviour of electrons amongst the molecules NH_3, H_2O and HCl.
[E, H_2O, NH_3, HCl]

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Interpretation of photoelectron spectra, especially those of benzene and water. [E, hν, H_2O, C_6H_6, O_2]

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Investigation of the B $^2B_2$ state of H_2O^+ using valence-bond techniques.
[T, H_2O]

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Dynamics of OH Λ-doublet production through photodissociation of water in its first absorption band. I. Formal theory. [T, hν, H_2O]

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Molecular photoelectron spectroscopy at 132.3 eV. The second-row hydrides. [E, H_2O, NH_3, CH_4; HF, Ne]

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Spectra of simple molecules. The infra-red spectra of triatomic molecules. [review, H_2O, CO_2, N_2O, SO_2, HCN]

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A unified description of elastic, high energy electron-molecule scattering. [T, H_2O, CH_4, C_2H_4, C_2H_6, CO, N_2, O_2, CO_2; 1 keV for H_2O]

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Self- and air-broadened linewidth of the 183 GHz absorption in water vapor. [E, $h\nu$, H_2O; 299 - 251 K]

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Temperature dependence of water-vapor absorption in the wing of the 183 GHz line. [E, $h\nu$, H_2O, $H_2O + N_2$; 295 - 375 K]

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Absorption by H_2O and $H_2O - N_2$ mixtures at 153 GHz.
[E and T, $h\nu$, H_2O, $H_2O + N_2$]

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Das Rotationsschwingungsspektrum des Wasserdampfes. II.
[E, $h\nu$, H_2O; I. R.Mecke (1933), III. K.Freudenberg (1933)]

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An investigation of the valence orbitals of water by high momentum resolution electron momentum spectroscopy. [E, H_2O]

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Electron momentum spectroscopy of the valence orbitals of H_2O and D_2O : Quantitative comparisons using Hartree-Fock limit and correlated wavefunctions. [E and T, H_2O, D_2O]

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A new method for incorporating momentum resolution effects and defining the momentum scale in electron momentum spectroscopy.
[E, H_2O, D_2O, Ar; see Addenda, A.O.Bawagan (1987)]

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Measurement by cyclotron resonance of molecular cross sections for elastic collisions with 295°K electrons.
[E, H_2O, CO_2, N_2, N_2O, SO_2, NH_3, CF_3H, etc.]

E V. I. Bazhanov : J. Struct. Chem. 31, 540-544 (1990)
Calculation of intensity of high-energy electron scattering by molecules of water and carbon tetrachloride. [T, H_2O, CCl_4]

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Cross section for collision of electrons with H_2O molecules in a thermally ionized gas behind a shock wave at T = 2500 - 3500 °K.
[E, H_2O]

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Water vapor absorption of electromagnetic radiation in the centimeter wave-length range. [E, $h\nu$, H_2O]

EX K. Becker, B. Stumpf and G. Schulz : Chem. Phys. 53, 31-38 (1980a)
Polarisation of the OH ($A^2\Sigma^+$, v' = 0 → $X^2\Pi_i$, v'' = 0) fluorescence produced electron impact on water vapour.
[E, H_2O; OH emission, 11.9 - 500 eV]

EX K. Becker, B. Stumpf and G. Schulz : Chem. Phys. Lett. 73, 102-105 (1980b) ·
Crossed-beam investigations of the OH($A^2\Sigma^+$ → $X^2\Pi_i$) emission spectrum after dissociative excitation of water by electron impact.
[E, H_2O; OH emission, 9.3 - 100 eV]

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Polarised emission from highly rotational excited OH($A^2\Sigma^+$) radicals produced by dissociative electron-impact excitation of H_2O.
[E, H_2O]

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Excitation and polarization analysis of the OD fragment radiation produced by dissociative electron impact on D_2O. [E, D_2O; th. - 1000 eV]

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Dissociative excitation of water by electron impact.
[E, H_2O; emission c. s. from OH, O and H, th. - 1000 eV]

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A modified plane wave model for calculating UV photoionization cross-sections. [T, $h\nu$, H_2O, N_2, CO, HF, $(CN)_2$, etc.]

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Energy and angular dependence of H^-(D^-) ions produced by dissociative electron attachment to H_2O(D_2O). [E, H_2O, D_2O]

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The spectra of H_2O and D_2O in the vacuum ultraviolet.
[E, $h\nu$, H_2O, D_2O]

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Isotope effect in resonant vibrational excitation of H_2O(D_2O), NH_3(ND_3), CH_4(CD_4). [E, H_2O, D_2O, NH_3, ND_3, CH_4, CD_4]

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New bands in the vibration-rotation spectrum of water vapor.
[E, hν, H_2O]

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Absorption spectra of water vapor and carbon dioxide in the region of 2.7 microns. [E, hν, H_2O, CO_2]

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Absorption spectrum of water vapor between 4.5 and 13 microns.
[E, hν, H_2O]

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Flame-emission spectrum of water vapor in the 1.9-micron region.
[E, hν, H_2O]

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Rotation-vibration spectra of deuterated water vapor.
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Calculation of line widths in H_2O - N_2 collisions. [T, hν, H_2O]

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Calculation of line widths in H_2O - H_2O and H_2O - O_2 collisions.
[T, hν, H_2O]

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Photodissoziationen von H_2, N_2, O_2, NO, CO, H_2O, CO_2 und NH_3 in extremen Vakuum-UV. [E, hν, H_2O, NO, etc.; <1000 A]

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Photodissoziation zu elektronisch angeregten Bruchstucken von H_2, H_2O und NH_3 im extremen Vakuum-UV. II. [E, hν, H_2O, H_2, NH_3]

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Theoretical study of the generalized oscillator strength for the A^1B_1-X^1A_1 transition in the water molecule. [T, H_2O]

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A multiterm Boltzmann analysis of drift velocity, diffusion, gain and megnetic-field effects in argon-methane-water-vapour mixtures.
[T, H_2O + Ar + CH_4, cross section set for H_2O]

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Hybrid approach to electron scattering from polar molecules.
[T, rigid-rotor molecule]

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Simple one-center calculation of breathing force constants and equilibrium internuclear distances for NH_3, H_2O, and HF. [T, H_2O, NH_3, HF]

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Investigation of the $^1A_1$ excited states of water. [T, H_2O]

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An investigation of the $^1B_1$ excited states of water. [T, H_2O]

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Vibrational contributions to molecular dipole polarizabilities.
[compilation, H_2O, HF - HI, DCl, CO, NO, CO_2, CS_2, N_2O, O_3, OCS, SO_2, BCl_3, BF_3, H_2CO, NF_3, NH_3, PF_3, PH_3, CCl_4, CF_4, CH_4, CHF_3, SiH_4, GeH_4, SF_6, C_6H_6, C_6F_6, etc.]

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Determination of partial photoionization cross sections by photoelectron spectroscopy. [E, hν, H_2O, Ar, H_2, O_2, N_2]

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Simple models for the calculation of photoionization and electron impact ionization cross sections of polyatomic molecules.
[T, H_2O, NH_3, C_3H_6, C_6H_6, $C_{10}H_{22}$, etc.]

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A flowing afterglow study of water vapour. [E, H_2O]

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Dissociative excitation processes in H_2O. [E, H_2O; 8th ICPEAC 357 (1973)]

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Electron impact resonances of the water molecules observed in the $A^2\Sigma^+ \rightarrow X^2\Pi_i$ radiation of OH and OD. [E, H_2O, D_2O]

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Intermolecular association and infra-red absorption of water.
[E, hν, H_2O]

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Spectre de photoelectrons et calcul des facteurs de Franck-Condon pour H_2O, D_2O, HDO. [E, H_2O, D_2O, HDO]

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Attachment of thermal electrons to oxygen in the presence of varions compounds as a third body.
[E, O_2; third body H_2O, C_2H_4, CO_2, H_2S, NH_3, CH_3OH, etc.]

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Some Comments on Electron Collision Cross Sections and Photodissociation Processes for H_2O

The pioneer work on electron collision cross section set for H_2O is given by J. J. Lowke in 1969. I have compiled the same set for H_2O including new data two times. An example was shown in M. Hayashi (1989). This cross section set is shown in Figure 1. The other cross section sets for H_2O were presented by many authors, N. Gee (1983), M. Yousfi (1987), K. F. Ness (1988), S. F. Biagi (1989), T. J. Dolan (1993), M. Yousfi (1994, 1996) and so on.

Now I do not like these cross section sets. Reasonable and correct cross section set have to calculate the temperature dependence of electron drift velocities at high E/N by B. Eq. and MCS method. We have solved this problem in the case of CO_2 and reported at the 51th GEC Conference, Maui, as shown in this report.

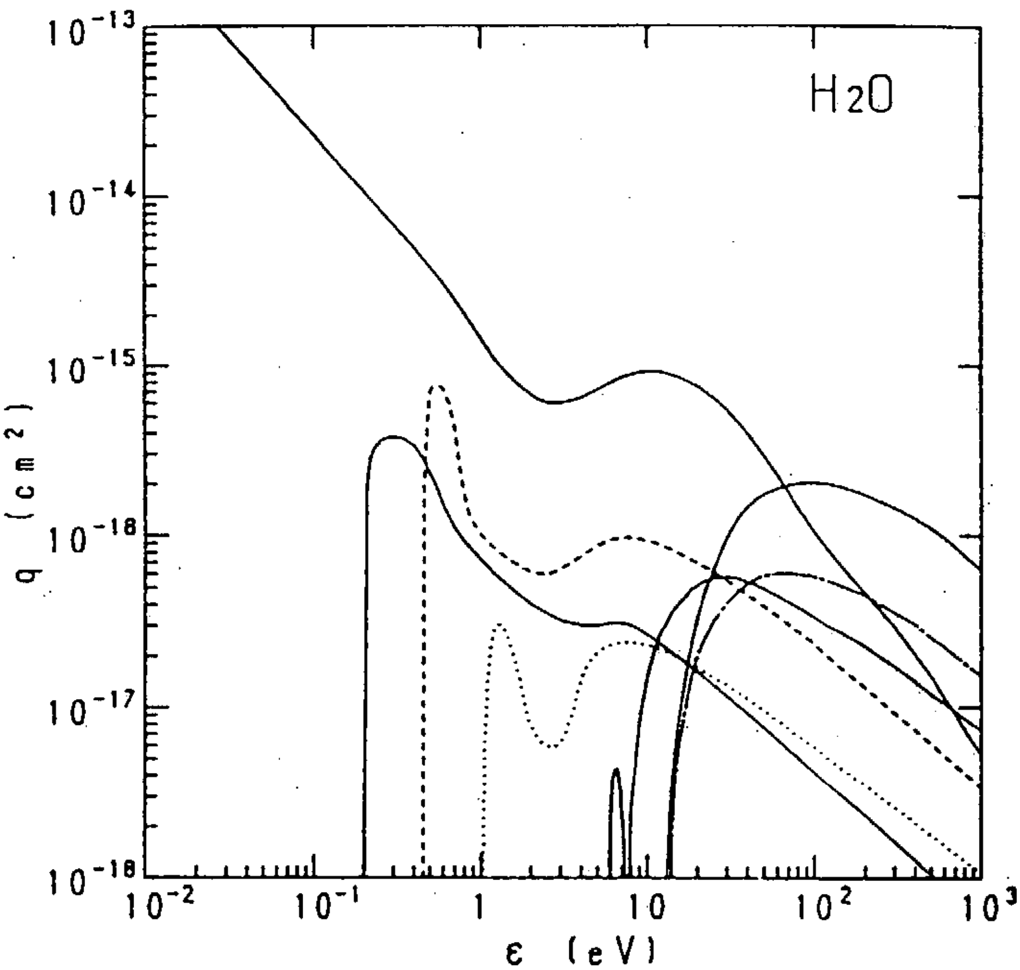

Figure 1. Electron collision cross section set for H_2O, assuming all H_2O molecules are in H_2O(g) state (M. Hayashi, 1990). In all H_2O + e experiments, H_2O molecules are mixture of H_2O(g), H_2O(r) and H_2O(v). So this cross section set is not applicable for exact calculations, and can use only for approximate applications.

In the case of H_2O, the concentration of $H_2O(v)$ is small at 300 K. At high temperature, the effect of $H_2O(v)$ is important and interesting.

All molecules have the component M(g), M(r), M(v) and M_n (n = 2), depend on the pressure and temperature condition of the experiment. Most interesting experimental results occur in the triatomic molecules. The change from linear mode combination of three atoms to bend mode combination of three atoms, or vice versa, occur very easy in the triatomic molecules by vibrational excitation.

Almost theoretical results of electron collision cross sections for molecules are for M(g). Theoretical studies involving the M(r) and M(v) are urgently required for many molecules.

I would like to present our recent two conference reports at the end of this report.

M. Hayashi and Y. Nakamura : 51th GEC, Maui 265-266 (1998)
M. Hayashi and Y. Nakamura : EMS-99, Tokyo 175-176 (1999)

The photodissociation of H_2O in the first absorption band has been studied in great detail by P. Andresen, R. Schinke, V. Engel, R. L Vander Wal, V. Staemmler, F. F. Crim, D. Hausler, and so on, both experimentally and theoretically.

Photodissociation processes consist essentially of two steps. The first step is the absorption of a photon leading to the excited state. The second step is the subsequent dissociation of this complex to the products. This has been tested for several different initial vibrational and rotational states,

$$H_2O\ [X^1A_1(000)J_{k_a k_c}] \xrightarrow{\text{IR laser}} H_2O\ [X^1A_1(v_1, v_2, v_3)J_{k_a' k_c'}] \xrightarrow{\text{excimer laser}} OH\ (n, j) + H$$

The experimental procedure require three lasers.

1. H_2O is vibrationally excited to a well defined rotational state with a tunable IR laser. This IR excitation is used to prepare single rotational and vibrational states of H_2O in the electronic ground state.

2. The prepared H_2O is photodissociated using 193 nm ArF excimer laser.

3. A third probe laser is used to determine the vibrational state distribution of the OH product by laser induced fluorescence.

Details are not discussed here. Please find the selected papers from this bibliography. Photodissociation dynamics of H_2O at 121.6 nm (Lyman-α wavelength) have been studied by some authors. The results are also interesting but complicated a little bit.

The author would like to expect that the similar studies on electron collision cross section experiments of single rotational and vibrational states of H_2O in the electronic ground state.

JTP7.07

Temperature Dependence of Electron Drift Velocity and Electron Collision Cross Section Sets for Ground State and Vibrationally Excited State of the CO_2 Molecule

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The drift velocity of electrons in carbon dioxide have been calculated at gas temperatures ranging from 193 to 573 K and at E/N values up to 100 Td assuming that the gas was a mixture of the ground state molecules and the vibrationally excited molecules and its mix ratio depended on the temperature. The calculated drift velocities agreed well with the measurement of Elford (1980).

Generally, target molecule M in beam and swarm experiments consists of the mixture of different states:

$$M = M(g) + M(r_j) + M(v_i) + M_N ,$$

where M(g), $M(r_j)$, $M(v_i)$ and M_N represent the ground state molecules, the rotationally excited molecules, the vibrationally excited molecules and the van der Waals clusters consisting of N molecules (N≥2), respectively. It is known that the concentration of $M(v_i)$ increases with temperature. For example, the concentration of $CO_2(v_i)$ in CO_2 has been calculated to be 8.4 % at 313 K and 26.5 % at 673 K, respectively [1,2]. This is due to the low threshold energy (0.083 eV) of the lowest vibrational excited level (010) mode. The concentrations of rotationally excited molecules are much larger than of the vibrationally excited molecules. The concentration of the clusters are important at low temperature and high pressure conditions.

Most of theoretical calculations of electron collision cross sections have been performed for pure M(g) target, not for the M(v) molecules.

A number of different electron collision cross sections for molecules have been determined with beam and swarm experiments. So far, in most of the experiments it is implicitly assumed that the target molecules are all in the ground state, or electron collision cross section set of M(g), M(r) and M(v) are almost the same. Strictly speaking, this assumption is not correct, and in particular, cannot be applied to the molecules which have temperature dependence in electron collision cross sections.

Take the CO_2 molecule. The ground state $CO_2(g)$ is linear, but $CO_2(010)$ is bent and this has a dipole moment. Electron collision cross section set of $CO_2(g)$ and $CO_2(v)$ are expected to be different each other. In fact, Buckman [3], Ferch [1] and Strakeljahn [4] have determined the grand total cross section Q_T for $CO_2(g)$ and $CO_2(v)$ and found that $Q_T(v)$ of CO_2 are larger than $Q_T(g)$ at the electron energies lower than about 10 eV.

It seems to be quite difficult to determine directly the electron collision cross section sets of $CO_2(g)$ and $CO_2(v)$ from the beam and swarm experiments. However, if the cross section sets of $CO_2(g)$ and $CO_2(v)$ are available, we can calculate the electron swarm parameters of a known concentration of $CO_2(g)$ and $CO_2(v)$ very easily. Momentum transfer cross sections q_m for $CO_2(g)$ and $CO_2(v)$, which have been based on the compilation of Hayashi [5] and recent experiments of Nakamura [6] and Strakeljahn [4], are shown in Fig. 1. Tentatively, we have assumed that all other inelastic cross sections of $CO_2(g)$ and $CO_2(v)$ are practically the same [7,8]. At a given temperature, the concentrations of $CO_2(g)$ and $CO_2(v)$ are known, then we have calculated the values of electron drift velocity W in CO_2. The results are shown in Fig. 2. The calculated W values at three temperatures are in general agreement with the experimental data of Elford [9].

Haddad [10] have discussed the importance of the populations of vibrationally excited CO_2 molecules already. They also have mentioned the contributions due to CO_2 molecules in rotational states and have concluded that such states are not likely to play a significant role compared with vibrationally excited molecules. But they could not reproduce their experimental data for W at high E/N from the analysis.

A similar analysis on $H_2(g)$, $H_2(r\ )$ and $H_2(v)$

also have to be started. The H_2 molecule have the famous long-standing controversy in the vibrational excitation cross section [11]. In the present paper, we propose to investigate and to measure the cross sections for molecules not only in the ground state but also in the excited states which should have different cross sections from those in the ground state. Although the difference among the cross section sets for $H_2(g)$, $H_2(r)$ and $H_2(v)$ may be small compared with the CO_2 molecule since the H_2 molecule is diatomic. Theoretical studies involving the excited species are urgently required.

The term "*temperature dependence* of cross section" may not be appropriate. The molecules, $CO_2(g)$, $CO_2(r)$ and $CO_2(v)$, have the definite and individual cross section sets, and their concentrations change with temperature. The temperature dependence is caused through different concentration of the excited components at different temperatures. Attachment cross section of the excited molecules is quite different from the ground state molecules for many attaching gases.

We wish to thank Professor H. Tawara for valuable comments.

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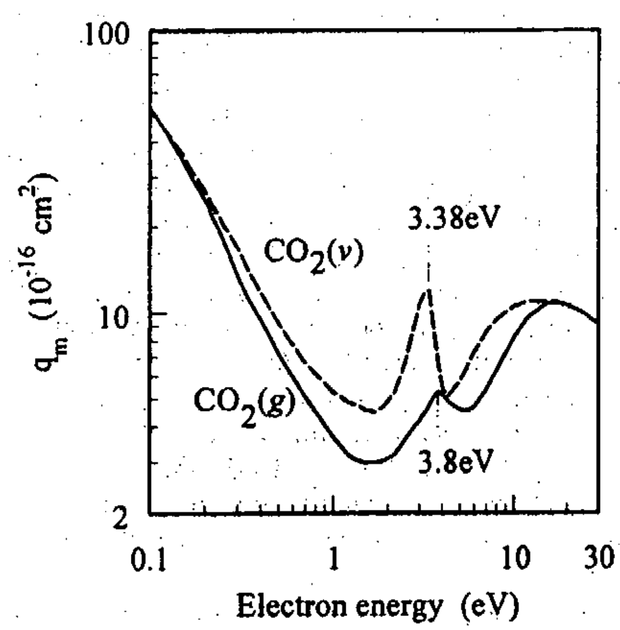

Fig. 1. The assumed elastic momentum transfer cross sections for the ground state (solid curve) and vibrationally excited CO_2 molecules (broken curve).

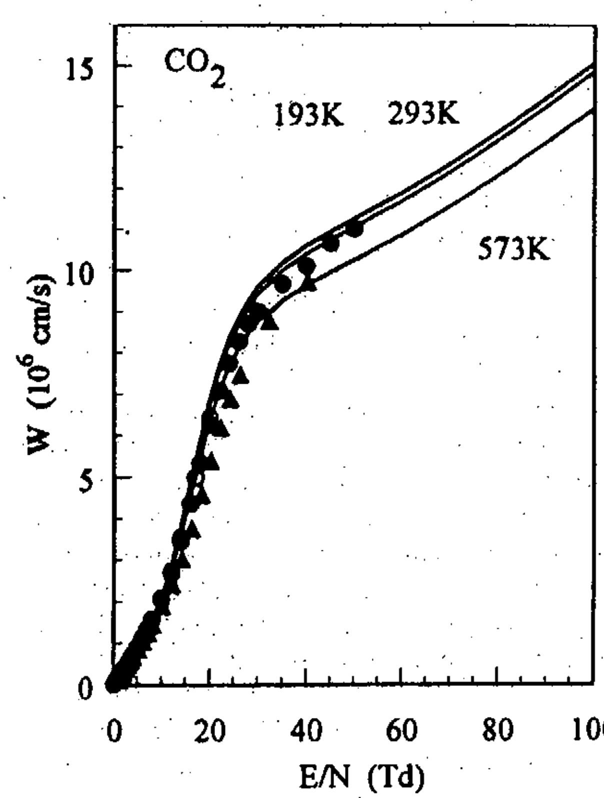

Fig. 2. Calculated electron drift velocities in CO_2 at different temperatures. Open and closed circles and closed triangles show the measurements of Elford [9] at 193, 293 and 573 K, respectively.

May We Measure the Exact Values of Electron Collision Cross Sections for Molecules by Beam and Swarm Experiments ?

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We cannot measure the exact values of DCS for molecules intrinsically. Of course, we can measure the approximate values of DCS for molecules, but can measure the exact values of DCS for atoms. The reason is very simple.

Target molecule M in both beam and swarm experiments consists of the mixture of different states :

$$M = M(g) + M(r_J) + M(v_i) + M_N$$

where $M(g)$, $M(r_J)$, $M(v_i)$ and M_N represent the completely ground state molecules, the rotationally excited molecules, the vibrationally excited molecules and the van der Waals clusters consisting of N molecules ($N \geqq 2$), respectively. Usually beam and swarm experiments are carried out at about 300 K. The concentration of $M(g)$ is small compared to $M(r_J)$ (except H_2 molecules) at 300 K. Then the molecule M is always mixture of $M(r_J)$ and $M(v_i)$, and the concentration of $M(r_J)$ and $M(v_i)$ changes with temperature. And electron collision cross section sets from elastic to inelastic collision processes for $M(r)$ and $M(v)$ are different each other. The target molecules M in the beam and swarm experiments are always mixtures of different molecules $M(r_J)$ and $M(v_i)$. In the case of H_2, the target gas consists of $M(g)$ and $M(r_J)$, especially $M(g)$ and $M(r_1)$ at 78 K.

Most clear change of cross sections of $M(r_J)$ and $M(v_i)$ will occur for triatomic molecules. CO_2, N_2O and so on. Triatomic molecules can change from linear to bend, or vice versa easily. The authors [1] have presented the different elastic momentum transfer cross sections q_{mr} and q_{mv} for $CO_2(r)$ and $CO_2(v)$, where they assumed that all other inelastic cross sections of $CO_2(r)$ and $CO_2(v)$ are practically the same. Then they have calculated the electron drift velocity W as a function of gas temperature T. When T increas, concentrations of $CO_2(v)$ increases, then W decreases with T at the same E/N, the electric field over the gas number density, around 50 Td.

We have a comment to the interesting and important paper of W. Johnstone, et al. [2]. They have measured the temperature dependence of elastic DCS for CO_2 at 4.0 eV. Unfortunitly, q_{mv} for $CO_2(v)$ at 4 eV is almost equal to q_{mr} for $CO_2(r)$ [1]. Then we propose the same experiments at about 3.4 eV for CO_2, because the temperature dependence of DCS seems to be very large there.

Winstead and McKoy [3] calculated the elastic DCS for $N_2O(g)$ at low electron energies and compare the experimental DCS data for $N_2O(r)$ + $N_2O(v)$ mixture at 300 K. We can see large discrepancy between them at lower than about 10 eV. We urge Winstead and Mckoy to calculate the DCS for $N_2O(v)$ and also $N_2O(r)$ for comparison. We can see the same discrepancy of DCS for CO_2 [4] [5] at low electron energies..

H_2 molecules have the famous long standing controversy in the vibrational excitation cross section [6]. A possible way to solve the problem may be as follows. At first, theoreticians calculate the q_{mg}, q_{mr}, q_{mv}, q_{rg}, q_{rr}, q_{rv}, q_{vg}, q_{vr}, and q_{vv} for $H_2(g)$, $H_2(r_1)$ and $H_2(v_1)$, as a function of electron energies. Using these data, we calculate the electron swarm parameters. From beam experiments, we cannot determine the values of q_{mg}, q_{mr}, q_{rg}, q_{rr} for $H_2(g)$ and $H_2(r_1)$ at the same time. It is clear that the threshold energies of q_r and q_v for $H_2(g)$ and $H_2(r_1)$ are different. Bhattacharyya, et al. [7] have shown that elastic integral cross sections q_{tr} are larger than q_{tg} for 20 to 200 eV for $H_2(g)$ and $H_2(r_1)$. We want the elastic DCS values for $H_2(g)$ and $H_2(r_1)$ at low electron energies lower than 10 eV. Swarm experiments also carried out in the mixtures of $H_2(g)$ and $H_2(r_1)$, except for para-$H_2(g)$ at 78 K (concentration of $H_2(g)$ is 99.3 %). We compare the experimental and calculated swarm parameters at given conditions.

Usually, theoreticians calculate the DCS for $M(g)$, not for $M(r_j)$ and $M(v_i)$, for most molecules. Theoretical studies involving the rotationally and vibrationally excited species are urgently required for many molecules. There is a interesting paper given by A. Jain [8].

If we have the cross section sets for excited inert gas clusters, we can calculate the electron swarm parameters of inert gases at high pressure and low temperature conditions. The concentration of the clusters for atoms and molecules are important at low temperature and high pressure conditions.

Most interesting temperature dependence occur for attachment cross sections q_a [9]-[13]. The values of non-dissociative q_{an} and dissociative q_{ad} are quite different for $M(r)$ and $M(v)$, and $M(r)$ and $M(v)$ have the definit and individual cross sections, independ on the temperature. Apparent temperature dependence of attachment cross section is caused through different concentration of the excited components $M(r)$ and $M(v)$ at different temperatures.

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Atoms (17)				Molecules (51)							
A + e, A + hν					M + e, M + hν,						
He	2	2170	*	2	H_2, D_2	2000		5	CH_4	780	
Ne	10	1140	*		N_2	2240	○				
Ar	18	1960	○		O_2	1700			CF_4	390	
Kr	36	1000			CO	1190			CCl_4	210	
Xe	54	1180	○		NO	880			CCl_2F_2	250	
									CH_3Cl	90	
Li	3	450			F_2	190	○				
Na	11	800			Cl_2	360	○		SiH_4	230	
					Br_2	140	○		SiF_4	140	
K	19	370			I_2	240	○		GeH_4	50	
Rb	37	220									
Cs	55	370			HF	260		6	C_2H_4	370	
					HCl	320			CH_3OH	350	
O	8	390			HBr	200					
					HI	130		7	SF_6	920	○
F	9	90									
Cl	17	130		3	CO_2	1240	○				
					H_2O	1200	○	8	C_2H_6	260	
Cu	29	180							C_2F_6	150	
Cd	48	210			O_3	480			Si_2H_6	70	
Ba	56	340			N_2O	450					
					NO_2	350		9	C_3H_6	120	
Hg	80	600			H_2S	270			C_2H_5OH	60	
					SO_2	290					
					CS_2	260					
					OCS	280		11	C_3H_8	190	
not final, but									C_3F_8	100	
finished mostly				4	C_2H_2	390					
								12	C_4F_8	100	
include electron					NH_3	500			C_6H_6	240	
swarm papers					NF_3	110			C_6F_6	100	
					BF_3	110					
include					BCl_3	90		60	C_{60}	300	
review papers					PH_3	80					
					H_2CO	180			$M_r + M_v$	850	

* He(Ne) + e only. Not include He(Ne) + hν papers.
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