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

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# Bibliography of Electron and Photon Cross Sections With Atoms and Molecules Published in the 20th Century

## —— Nitrogen Molecule ——*

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A bibliography 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 nitrogen molecule ($N_2$). About 2240 papers were compiled. A comprehensive author index is included. The bibliography covers the period 1906 through 2000 for $N_2$. Finally, author's comments for $N_2$ electron collision cross section are given.

Keywords : $N_2$ molecule, collision cross section, 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 nitrogen molecule, $N_2$. The review papers on this subject are also included. Some nitrogen molecule cluster papers are included. Some conference reports, company or agency reports and PhD thesis are included. Nitrogen 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 nitrogen 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. Famous authors C. Ramsauer, J. S. Townsend and L. B. Loeb's papers were published in 1921 independently. But oldest paper in this list is given by H. E. Hurst (1906). So for this nitrogen molecule bibliography, published papers from 1906 to 1999 are compiled in alphabetical order of the first author's surname of the paper. References published in 2000 and plus some old papers found very recently after compilation are added as "Addenda of References for Nitrogen Molecule". In total, about 2240 papers are compiled in the nitrogen 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 $N_2$ are divided into four parts :



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.

Some Comments on Electron Collision Cross Sections for $N_2$


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# References for $N_2$ (1990 - 1999)

## (Nitrogen)

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


E M. Abdolsalami, F. Abdolsalami and L. Perez : J. Phys. B30, 713-728 (1997) ·
Study of rigid-rotor exact exchange electron - $N_2$ scattering using the first-order non-degenarate adiabatic theory.
[T, $N_2$; 0.0027 - 13.6 eV]

I N. Abramzon, R. B. Siegel and K. Becker : J. Phys. B32, L247-L254 (1999a) ·
Absolute cross section for the formation of $N_2^+(X^2\Sigma_u^+)$ ions produces by electron impact on $N_2$. [E, $N_2$; th. - 200 eV]

I N. Abramzon, R. B. Siegel and K. Becker : Int. J. Mass Spectrom. Ion Process. 188, 147-153 (1999b)
Cross section for the production of $N_2^+(X^2\Sigma_u^+)$ ions by electron impact on $N_2$. [E, $N_2$; th. - 200 eV]

EX J. M. Ajello and M. Ciocca : J. Geophys. Res. 101, 18953-18960 (1996) ·
Fast nitrogen atoms from dissociative excitation of $N_2$ by electron impact.
[E, $N_2$]

EX J. M. Ajello, G. K. James and M. Ciocca : J. Phys. B31, 2437-2448 (1998) ·
High resolution EUV emission spectroscopy of the $N_2$ $c'^1\Sigma_u^+$ $v'=3$ and 4 levels by electron impact. [E, $N_2$; 100 eV]

D N. L. Aleksandrov and A. M. Konchakov : Sov. Tech. Phys. Lett. 16, 206-207 (1990) ·
O Dissociation of oxygen molecules in a microwave discharge in air.
[T, $N_2$ + $O_2$]

S N. L. Aleksandrov and I. V. Kochetov : Sov. J. Plasma Phys. 18, 828-833 (1992)
Electron transport coefficients in a weakly ionized plasma with vibrationally excited molecules. [T, $N_2$, $CO_2$, CO]

S N. L. Aleksandrov and I. V. Kochetov : J. Phys. D26, 387-392 (1993a)
Electron transport parameters in a weakly ionized gas with vibrationally excited molecules. [T, $N_2$, $CO_2$, CO]

A N. L. Aleksandrov and A. P. Napartovich : Phys. Usp. 36, 107-128 (1993b)
Phenomena in gases and plasmas with negative ions.
[review, $N_2$, CO, $O_2$, $SF_6$, $N_2O$, $CCl_4$, $NH_3$]

S N. L. Aleksandrov, N. A. Dyatko and I. V. Kochetov : Plasma Phys. Rep. 21, 763-767 (1995) ·
Rate of inelastic electron processes in a weakly ionized plasma in a nonstationally electric field. [T, $N_2$, $CO_2$, Ar; B. Eq.]

S N. L. Aleksandrov, N. A. Dyatko and I. V. Kochetov : Plasma Phys. Rep. 22, 82-86 (1996) ·
Longitudinal diffusion of electrons in a weakly ionized plasma in the presence of an alternating electricfield. [T, $N_2$, Ar; B. Eq.]

I A. W. Ali : in Nonequilibrium Processes in Partially Ionized Gases, Ed. by M. Capitelli and J. M. Bardsley, Plenum 651-658 (1990)
Ionization and deionization of electron beam disturbed air.
[compilation, $N_2$ + $O_2$]

EX J. S. Allen, S. Chung and C. C. Lin : Phys. Rev. A41, 1324-1334 (1990) ·
Electron-impact excitation of the $x^1\Sigma_g^-$, $y^1\Pi_g$ and $o_3{}^1\Pi_u$ Rydberg electronic states of the nitrogen molecule.
[E, $N_2$; emission, th. - 500 eV]

O U. Asaf, J. Meyer, R. Reininger and I. T. Steinberger : J. Chem. Phys. 96, 7885-7889 (1992) Z
High Rydberg states of methyl iodide perturved by nitrogen : A mutual cancellation of shift terms. [E, $N_2$ + $CH_3I$]

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Pressure shifts and electron scattering lengths in atomic and molecular gases. [E and T, $N_2$, $H_2$, $CH_4$, $C_2H_6$, $C_3H_8$, $CO_2$, He - Xe]

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Ionization of the $N_2$ $3\sigma_g$ orbital by electron impact studied by asymmetric (e, 2e) experiments. [E, $N_2$; 300 eV]

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Density dependence of electron mobility in dense gases.
[T, $N_2$, $H_2$, $O_2$, $CO_2$, He - Xe; multiple-scattering approach]

O P. Baltzer, L. Karlsson and B. Wannberg : Phys. Rev. A46, 315-317 (1992a)
Rotational line profiles in the He I -excited photoelectron spectra of the $N_2$ molecule. [E, $N_2$]

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Inner-valence states of $N_2^+$ studied by UV photoelectron spectroscopy and configuration-interaction calculations. [T, $h\nu$, $N_2$]

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Experimental determination of ground-state correlation effects in molecular nitrogen. [E, $N_2$; 25 - 28 keV]

EX R. S. Barbieri and R. A. Bonham : Phys. Rev. A45, 7929-7941 (1992)
Momentum-transfer dependence of the Lyman-Birge-Hopfield and the K-shell preionization lines in the nitrogen molecule by means of high-energy electron-impact spectroscopy. [E, $N_2$; 25 - 28 keV]

I R. S. Barbieri, J. C. Nogueira and M. A. E. Ferreira : 19th ICPEAC, Whistler 49-49 (1995)
Differential cross section for electron-impact ionization of molecular nitrogen : A theoretical calculation. [T, $N_2$; DDCS at $10^3$ eV]

E G. Basavaraju, S. M. Bharathi, K. G. Bhushan, S. Maji and S. H. Patil : Phys. Scr. 60, 28-31 (1999)・
A unified description of elastic, high energy electron-molecule scattering. [T, $N_2$, CO, $O_2$, $H_2O$, $CO_2$, $CH_4$, $C_2H_4$, $C_2H_6$; 3 keV for $N_2$]

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Threshold behaviour and resonances in the photoionization of atoms and molecules. [E, $h\nu$, $N_2$, CO, Ne - Xe, Li]

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Studies of photoionization and photodissociation of $N_2$ in the 15 - 30 eV region using intense synchrotron radiation. [E, $h\nu$, $N_2$]

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Low-energy electron scattering by $N_2$, $P_2$, $As_2$ and $Sb_2$.
[T, $N_2$, etc.; 10 - 30 eV]

EX C. E. Bielschowsky, M. A. C. Nascimento and E. Hollauer : Phys. Rev. A42, 5223-5227 (1990a)
Correlation and relaxation effects on the electron-impact excitation of the Lyman-Birge-Hopfield band of $N_2$. [T, $N_2$]

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Ab initio and configuration interaction calculations of optical oscillator strengths for $N_2$ molecules. [T, $N_2$]

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Generalized multistructural calculation of the optical and generalized oscillator strengths for inner-shell excitations in $N_2$. [T, $N_2$]

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Non-local descriptions of electron swarms in space-time.
[E and T, $N_2$]

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Higher-order transport processes in electron swarms. [E and T, $N_2$; MCS]

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Optical studies of pre-breakdown electron avalanches. [E, $N_2$]

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Mechanism for ionization of nitrogen molecules in self-sustained discharges. [E, $N_2$; afterglow]

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Electric field strengths, ion energy distributions, and ion density decay for low-pressure, moderate-current nitrogen discharge. [E, $N_2$]

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The role of neutral metastable $N_2(A)$ molecules in the breakdown probability and glow discharge in nitrogen. [E, $N_2$]

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Elastic electron scattering and rovibrational excitation of $N_2$ at low incident energies. [E, $N_2$; DCS, 1.5 - 5 eV]

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The Fano factor for electrons in gas mixtures.
[T, $N_2$, He - Xe, $H_2$, $O_2$, $CO_2$, $CH_4$, $C_2H_2$]

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Electron-ion coincidence experiments : absolute detector efficiencies and neutral dissociation cross sections.
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Differential cross sections for electron-impact excitation of the electronic states of $N_2$. [E, $N_2$; DCS, 15 - 50 eV]

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Non-equilibrium vibrational distributions and transport coefficients of $N_2(v)$ - N mixtures. [T, $N_2(v)$ + N]

E S. J. Buckman, M. J. Brunger, M. J. Brennan, D. J. Alle, R. J. Gulley and S. J. Newman :
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Low energy electron-molecules collision cross sections.
[E, $N_2$; 1.5 - 3 eV]

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R A critical comparison of electron scattering cross sections measured by
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[compilation, $N_2$, He - Ar, $H_2$, CO, $O_2$, $CO_2$, $CH_4$]

E P. G. Burke : in AIP Conf. Proc. 295, 18th ICPEAC, Aarhus, AIP Press 26-47
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EX P. D. Burrow : in AIP Conf. Proc. 360, 19th ICPEAC, Whistler 257-266 (1995)・
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EX Need for cross sections in plasma chemistry.
I [review, $N_2$, $H_2$, $O_2$, CO, HCl, $Cl_2$, $F_2$, HF, $CO_2$, etc.]

O M. Capitelli, D. Giordano, C. Gorse and S. Longo : Chem. Phys. Lett. 263, 635-639
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Effects of non-Boltzmann vibrational distributions on electron-molecule
and bimolecular reaction rates. [T, $N_2(v) + O \rightarrow NO$; mostly $N_2(v)$]

O V. Carrevetta, Y. Luo and H. Agren : Chem. Phys. 174, 141-153 (1993)・
Accurate photoionization cross sections of diatomic molecules by multi-
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Energy-diffusion calculation of the electron-swarm distribution function.
[T, $N_2$, $O_2$]

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Absolute optical oscillator strengths for discrete and continuum
photoabsorption of molecular nitrogen (11 - 200 eV). [E, $h\nu$, $N_2$]

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Application of the stabilization method to the $N_2^-(1^2\Pi_g)$ and $Mg^-(1^2P)$
temporary anion states. [T, $N_2$, Mg]

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The relationship of the virtual orbitals of self-consistent-field theory
to temporary negative ions in electron scattering from molecules.
[T, $N_2$, $H_2$, $C_2H_4$, $C_3H_4$, $C_4H_6$]

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Total cross section measurements for electron scattering on $N_2$ in the
energy range 250 - 1400 eV. [E, $N_2$]

EX Z. Chen and A. Z. Msezane : Int. Sympo. on Electron- and Photon-Molecule Collisions and Swarms, Berkeley H-26 (1995)
Calculation of the generalized oscillator strength for the dipole allowed transitions in e - $N_2$ scattering. [T, $N_2$]

EX Z. Chen and A. Z. Msezane : J. Phys. B29, 1525-1530 (1996)
Calculation of excitation cross sections for the lowest five dipole-allowed transtions in e - $N_2$ scattering. [T, $N_2$; DCS, 200 - 1000 eV]

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Formula for the calculation of integral cross sections in a Fourier expansion method. [T, $N_2$, Xe; GOS → integral c.s. for $b^1\Pi_u$ state of $N_2$]

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Qualitative analysis of the relation between drift velocities of electrons in gas mixtures and pure gases forming these mixtures in gas-discharge plasma. [T, $N_2$, He, Ar, Kr, $H_2$, $O_2$, CO, $CO_2$, $CF_4$]

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Energy distribution of low-energy secondary electrons from $N_2$, $O_2$ and $H_2O$ by electron impact. [E, $N_2$, $O_2$, $H_2O$; 100 eV]

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Angular distributions of $N^+$ from $N_2^{2+}$ produced by electron impact on $N_2$. [E, $N_2$; 60 eV]

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Angular distribution of $N^+$ from $N_2^{2+}$ produced by electron impact on $N_2$. [E, $N_2$]

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Energy distributions of $N^+$ from $N_2^{2+}$ produced by electron impact on $N_2$ near the double-ionization threshold. [E, $N_2$]

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Influence of cross section data bases on electron transport coefficients in gases. [T, $N_2$]

S G. Colonna, C. Gorse, M. Capitelli, R. Winkler and J. Wilhelm : Chem. Phys. Lett. 213, 5-9 (1993)
The influence of electron-electron collision on electron energy distirbution functions in $N_2$ post discharge. [T, $N_2$]

O C. Cornaggia, J. Lavancier, D. Normand, J. Morellec and H. X. Liu : Phys. Rev. A42, 5464-5472 (1990)
Intensity dependence of the multielectron dissociative ionization of $N_2$ at 305 and 610 nm. [E, $h\nu$, $N_2$]

O C. Cornaggia, J. Lavancier, D. Normand, J. Molellec, P. Agostini, J. P. Chambaret and A. Antonetti : Phys. Rev. A44, 4499-4505 (1991)
Multielectron dissociative ionization of diatomic molecules in an intense femtosecond laser field. [E, hν, $N_2$, CO, $O_2$]

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Role of the molecular electronic configuration in the Coulomb fragmentation of $N_2$, $C_2H_2$ and $C_2H_4$ in and intense laser field.
[E, hν, $N_2$, $C_2H_2$, $C_2H_4$]

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Electron-impact dissociation of nitrogen. [E, $N_2$; 18.5 - 148.5 eV]

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Measurement and interpretation of the second light-scattering virial coefficients of linear and quasi-linear molecules.
[E and T, $N_2$, CO, $CO_2$, $C_2H_6$, $CH_3Cl$]

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Beam, swarm and theoretical studies of low-energy electron scattering : Some exemplers. [review, $N_2$, $H_2$, Ne - Kr, Hg]

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Electron-correlated calculations of the nuclear-shielding polarizability and magnetizability polarizability of $H_2$, $N_2$, HF and CO.
[T, $N_2$, $H_2$, HF, CO]

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Effective cross sections of the excitation of certain bands of $N_2$ and $N_2^+$ by electrons. [E, $N_2$; 4 keV]

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Measurements of attachment coefficients in the presence of ionization.
[E, $N_2$ + $O_2$, $N_2$ + $O_2$ + $H_2O$, HCl, $CO_2$, $CCl_4$]

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Threshold photoelectrons coincidence spectroscopy of doubly-charged ions of nitrogen, carbon monoxide, nitric oxide and oxygen.
[E, $N_2$, CO, NO, $O_2$]

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Observation of the $y^1\Pi_g - c'_4{}^1\Sigma_u^+$ and $k^1\Pi_g - c^1{}_4{}^1\Sigma_u^+$ system of $N_2$. [E, $N_2$]

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Study of a beam-driven discharge in $H_2$ - $N_2$ mixtures at room and cryogenic temperatures. [E, $N_2$ + $H_2$]

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(Nitrogen)

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

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(Nitrogen)

E : Elastic collision,
V : Vibrational excitation,
D : Dissociation,
A : Attachment,
S : Swarm,
O : The others,
R : Rotational excitation,
EX : Electronic excitation,
I : Ionization,
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# Author Index for $N_2$ References

## Author Index for $N_2$ References. Addenda (1)

Some Comments on Electron Collision Cross Sections for $N_2$

Electron collision cross section set of elastic, rotational excitation, vibrational excitation, electronic excitation, dissociation and ionization collision for nitrogen molecule are reported by many authors. An example is given by A.V.Phelps (1985a) and (1985b). Another one is given by Y.Itikawa (1986).

Recently, we have pointed out at International Symposium on Electron-Molecule Collisions and Swarms, Tokyo that we cannot measure the exact values of electron collision cross sections for all molecules at present (M.Hayashi (1999)). For $N_2$, target molecules of beam and swarm experiments are mixture of $N_2(g)$, $N_2(r)$ and small amount of $N_2(v)$ molecules. The concentration of $N_2(v)$ increses with high temperature. Electron collision cross section sets for $N_2(g)$, $N_2(r)$ and $N_2(v)$ are different each other. Nitrogen is the homo-nuclear diatomic molecule. Then differences of cross section sets for $N_2(g)$, $N_2(r)$ and $N_2(v)$ are not so large, compaired with triatomic or polyatomic molecules, and concentration of $N_2(v)$ is little. So we can assume that all cross section sets of $N_2(g)$, $N_2(r)$ and $N_2(v)$ are equal approximately. We can use these cross section sets of $N_2$ for many applications. But if we want more exact cross section sets for $N_2$, we have to determine these cross section sets separately and independently.

Theoreticians calculate the cross section set for M(g), not for M(r) and M(v) for most molecules. Theoretical values for M(r) and M(v) are urgently required for many molecules.

The experiments of $N_2 + h\nu$ are also carried out in the mixtures of $N_2(g)$, $N_2(r)$ and $N_2(v)$ molecules. Then obtained results have the temperature dependence. But temperature effects are also not so large for $N_2$, compaired with triatomic or polyatomic molecules.

Author would like to present our conference report at the end of this report.

M.Hayashi and Y.Nakamura : International Symposium on Electron-Molecule Collisions and Swarms, EMS-99, Tokyo 175-176 (1999)

The review paper,

Y.Itikawa, et al. : J.Phys.Chem.Ref.Data 15, 985-1010 (1986)
is a useful and convenient report for $N_2$ molecule. This report is not shown here.

# 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 :

$$M = M(g) + M(r_J) + M(v_1) + M_N$$

where $M(g)$, $M(r_J)$, $M(v_1)$ 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 $M(v_1)$, and the concentration of $M(r_J)$ and $M(v_1)$ 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 $M(v_1)$. 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 $M(v_1)$ 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 $M(v_1)$, 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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|---|---|---|---|---|---|---|---|
| A + e, | A + hν | | | M + e, | | M + hν, | |
| He 2 | 2170 * | | 2 | $H_2$, $D_2$ | 1870 | 5 | $CH_4$ 780 |
| Ne 10 | 1140 * | | | $N_2$ | 2240 | | |
| Ar 18 | 1960 | | | $O_2$ | 1700 | | $CF_4$ 390 |
| Kr 36 | 900 | | | CO | 1190 | | $CCl_4$ 210 |
| Xe 54 | 1040 | | | NO | 880 | | $CCl_2F_2$ 250 |
| | | | | | | | $CH_3Cl$ 90 |
| Li 3 | 450 | | | $F_2$ | 190 | | $SiH_4$ 230 |
| Na 11 | 800 | | | $Cl_2$ | 360 | | $SiF_4$ 140 |
| K 19 | 370 | | | $Br_2$ | 140 | | $GeH_4$ 50 |
| Rb 37 | 220 | | | $I_2$ | 240 | | |
| Cs 55 | 370 | | | | | 6 | $C_2H_4$ 370 |
| | | | | HF | 260 | | $CH_3OH$ 240 |
| O 8 | 390 | | | HCl | 320 | | |
| | | | | HBr | 190 | | |
| F 9 | 90 | | | HI | 130 | 7 | $SF_6$ 920 |
| Cl 17 | 130 | | | | | | |
| | | | 3 | $CO_2$ | 1240 | | |
| | | | | | | 8 | $C_2H_6$ 260 |
| Cu 29 | 180 | | | $H_2O$ | 850 | | $C_2F_6$ 150 |
| Cd 48 | 210 | | | $O_3$ | 480 | | $Si_2H_6$ 70 |
| Ba 56 | 320 | | | $N_2O$ | 450 | | |
| | | | | $NO_2$ | 300 | 9 | $C_3H_6$ 120 |
| Hg 80 | 600 | | | $H_2S$ | 270 | | $C_2H_5OH$ 60 |
| | | | | $SO_2$ | 260 | | |
| | | | | $CS_2$ | 260 | | |
| | | | | OCS | 240 | 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 | | | | $NH_3$ | 400 | | $C_6H_6$ 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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