

# Elastic Differential Cross Sections for Electron Collisions with Polyatomic Molecules

M. Hoshino<sup>1</sup>, H. Kato<sup>1</sup>, C. Makochekanwa<sup>1,2</sup>, S.J. Buckman<sup>2</sup>, M. J. Brunger<sup>3</sup>,  
H. Cho<sup>4</sup>, M. Kimura<sup>5</sup>, D. Kato<sup>6</sup>, I. Murakami<sup>6</sup>, T. Kato<sup>6</sup>, and H. Tanaka<sup>1</sup>

<sup>1</sup>Department of Physics, Sophia University, Tokyo 102-8554, Japan

<sup>2</sup>Center for Antimatter-Matter Studies, Australian National University,  
Canberra ACT 0200, Australia

<sup>3</sup>Center for Antimatter-Matter Studies, Flinders University, Adelaide SA 5001, Australia

<sup>4</sup>Department of Physics, Chungnam National University, Daejeon 305-764, Korea

<sup>5</sup>Graduate School of Sciences, Kyushu University, Fukuoka 812-8581, Japan

<sup>6</sup>National Institute of Fusion Science, Toki 509-5292, Japan

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## Abstract

Experimental data for electron-polyatomic molecule collisions are reviewed in connection with fusion and processing plasmas, as well as with the associated environmental issues. The electron scattering experiments for differential cross section (DCS) measurements for various processes, such as elastic scattering, have been performed across a broad range of energies (1-100 eV), mainly, at Sophia University since 1978, and some done under the collaborations with the Australian National University, Flinders University, and the Chungnam National University. As a benchmark cross section, elastic DCS are essential for the absolute scale conversion of inelastic DCS, as well as for testing computational methods. The need for cross-section data for a wide variety of molecular

species is also discussed, because there is an urgent need to develop an international program to provide the scientific and technological communities with authoritative cross sections for electron-molecule interactions. Note that the detailed comparison with other data available is not given here. Rather, other available data can be found in the references we cite. This course of action was adopted to keep this report to a sensible length, so that only our numerical data is provided here.

### **Keywords**

electron-molecule collision, differential cross section, polyatomic molecule, elastic scattering, excitation process, resonant electron scattering

## **1 Introduction**

The interaction of electrons with atoms and molecules is an essential process in many areas of modern science and technology, recently referred to as “nano-technology”, and is pivotal for a greater understanding of aeronomy, astrophysics, gas and laser discharges, plasma processing, fusion plasmas, medical radiation studies and cellular biology. An example of its application is to the technology of plasma processing, which includes chemical vapor deposition (CVD) and plasma etching (Tanaka and Inokuti 1999, Makabe and Petrovic 2006). Similarly a detailed understanding of electron molecule collisions is fundamental in environmental processes, i.e., the chemistry of dissociated fluorocarbons, in order to develop their use as replacements for the environmentally damaging chloro- and bromo-halocarbons, which are also notable as global warming gases (Samukawa and Mukai 1999). The current techniques of plasma diagnosis and modeling potentially elucidate plasma characteristics from the point of view of atomic, molecular, and optical physics, i.e., from much more fundamentally scientific bases rather than the empiricism and intuition relied on so far. For discharges utilized in industrial plasma processes, the most significant electron collisions occur in the electron energy range less than 100 eV. The generic primary processes are elastic and inelastic electron scattering, electron impact ionization, electron-impact dissociation, and attachment. However, the many possible excitation processes arising from the many degrees of freedom available within molecules make the study of electron-molecule collisions extremely complex. Comprehensive sets of electron-molecule collision cross section data are, therefore, only limited to the simplest of diatomics (e.g. H<sub>2</sub>, N<sub>2</sub>, O<sub>2</sub>) (Brunger and Buckman 2002) and a few polyatomics (e.g. CH<sub>4</sub>, CF<sub>4</sub>, SiH<sub>4</sub> and SF<sub>6</sub>) (Brunger et al 2003). Electron collision data, however, have provided the most stringent test of the theoretical methods.

As pointed out above, electron collisions with atoms and molecules are of general importance in the initiation of discharges and plasmas. In particular, a newer trend in etching technology is to use lower pressures, so that reactive species readily reach the base surface after a minimal number of collisions with gaseous molecules on the way. Therefore, the control of electron collision processes

becomes even more important.

Our research program is based on three major objectives, achieved experimentally by studies of electron-molecule collision mechanisms under: (1) Elastic Scattering, (2) Excitation Processes (vibrational and electronic), and (3) Resonant Electron Scattering. Three broad classes of polyatomic molecular targets have been studied (see Table 1): Hydrocarbons, Fluorocarbons, and Linear Tri-atomic Molecules. A *systematic* measurement of Absolute Differential Cross Sections (DCSs) for electron scattering by these molecules has been performed within an impact energy range from 1.5 to 100 eV and scattering angles between 10° and normally around 130°, but for a few molecules even up to 180°.

In this report, illustrative examples of elastic DCSs will be reviewed, not particularly because of any special relevance to applications, but because it is possible in these cases to compare recent experimental results obtained by different groups and with available theoretical data. Elastic DCSs are important since they usually contribute the largest portion to the total cross sections (TCSs), especially in the low impact-energy region below a few tens of eV. TCSs are determined with uncertainties not more than 5 % for most cases, and therefore, precise measurements of elastic DCSs are the basis for better estimation of other cross sections which are otherwise normally difficult to measure.

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## **2 Definition of Cross Sections**

In what follows we shall concentrate first on a single collision between an electron and an atom or molecule. We first classify collisions into two kinds, namely, elastic and inelastic. In an elastic collision, the internal energy of an atom or molecule is unchanged. However a part ( $\Delta E$ ) of the electron energy  $E_0$  is transferred to the atom or a molecule as given by  $\Delta E / E_0 \approx m/M \approx 10^{-4}$ , where  $m$  is the electron mass and  $M$  is the mass of the atom or molecule. In an inelastic collision, there is a change in the internal energy, which leads to one or more of rotational, vibrational, or electronic excitation, dissociation, ionization, or attachment of an electron to a molecule. For an

atom, electronic excitation and ionization are the only possibilities. The energy transfer to rotational, vibrational, and electronic degrees of freedom is roughly in order of the ratios  $(m/M)^{1/2} : (m/M)^{1/4} : 1 \approx 10^{-3} : 10^{-1} : 10$ .

The probability of an inelastic collision is expressed in terms of the cross section defined as follows. Suppose that  $I_0$  electrons per unit area of energy  $E_0$  per unit area are incident on a gas consisting of  $N$  atoms or molecules per unit volume. The number of electrons scattered into the solid angular element  $d\Omega$  in the direction  $\Omega(\theta, \phi)$ , measured from the polar axis taken along the direction of electron incidence, can be written as:

$$I_{0n}(\Omega) = N I_0 d\sigma_{0n}(E_0, \Omega)/d\Omega \quad (1)$$

The subscript  $0n$  indicates a transition from the ground state  $0$  to an excited or ionized state  $n$ . One calls the quantity  $d\sigma_{0n}(E_0, \Omega)/d\Omega$  the differential cross section for the excitation  $0 \rightarrow n$ .

Theoretically, the differential cross section is expressed in terms of the scattering amplitude  $f_{0n}(E_0, \Omega)$ , which is determined from the asymptotic behavior of the electron wave function, in the form:

$$d\sigma_{0n}(E_0, \Omega)/d\Omega = (k_n/k_0) |f_{0n}(E_0, \Omega)|^2, \quad (2)$$

where  $k_0$  is the magnitude of the electron momentum before the collision, and  $k_n$  the same after the collision.

The integral of the differential cross section over all scattering angles, viz. ,:

$$q_{0n}(E_0) = \int \int d\sigma_{0n}(E_0, \Omega)/d\Omega \sin \theta d\theta d\phi \quad (3)$$

is called the (integral) cross section for the excitation  $0 \rightarrow n$ .

The elastic-scattering cross section  $q_0(E_0)$  is defined similarly, by replacing the final state  $n$  by the ground state  $0$  in Eqs. (1) - (3). To discuss effects of elastic scattering on electron transport phenomena, it is more important to use the momentum-transfer cross section defined by:

$$q_0^M(E_0) = \int \int d\sigma_0(E_0, \Omega)/d\Omega (1 - \cos \theta) \sin \theta d\theta d\phi. \quad (4)$$

The sum of the cross sections given by Eq. (3) over all possible kinds of excitation (including

the elastic-scattering cross section), viz.,

$$Q(E_0) = q_0(E_0) + \sum_n q_{0n}(E_0) \quad (5)$$

is called the total cross section.

If the distribution of particle speeds  $v$  is given by  $F(v)$ , then the reaction rate constant for a process with cross section  $q_n$  is calculated as:

$$\kappa_n = \int q_n F(v) v dv \quad (6)$$

### 3 Experimental Techniques for Precision Measurement of Elastic DCS

#### 3.1 Instrumentation:

A typical electron spectrometer [eg. Tanaka *et al* 1988 as shown in Figure1] consists of an electron gun with a hemispherical monochromator, a molecular beam, and a rotatable detector ( $\theta$  :  $10^\circ$  to around  $130^\circ$ ) with a hemispherical analyzer, all contained in a vacuum chamber. A beam of molecules is produced by effusing the target through a nozzle with an internal diameter of, for example 0.3 mm, and a long length to ensure a high aspect ratio. The spectrometer and the nozzle can be heated to a temperature of about  $50^\circ\text{C}$  to reduce the possibility of contamination during the measurements. The molecular beam is crossed with a monoenergetic beam of electrons of fixed incident energy. At a particular scattering angle, scattered electrons are detected. A number of lenses in the spectrometer are used for imaging and energy control of the electron beam, whose characteristics are carefully modeled by electron trajectory calculations. The ideal molecular beam has a small size and a uniform high density. As far as this molecular beam remains within the view cone angle of the electron analyzer, the detection probability for scattered electrons should be uniform and measured scattering intensities are directly proportional to the scattering cross sections.

In some systems, both the monochromator and analyzer are enclosed in differentially pumped boxes in order to reduce the effect of background gases and to minimize any stray electron background. The magnetic field in the chamber has to be kept as low as a few milli-gauss. Overall energy resolution varies typically from around 20 to 80 meV (FWHM). The angular scale is accurate to about  $\pm 1.5^\circ$ , as determined by noting the symmetry of elastic scattering about the true zero-degree point.

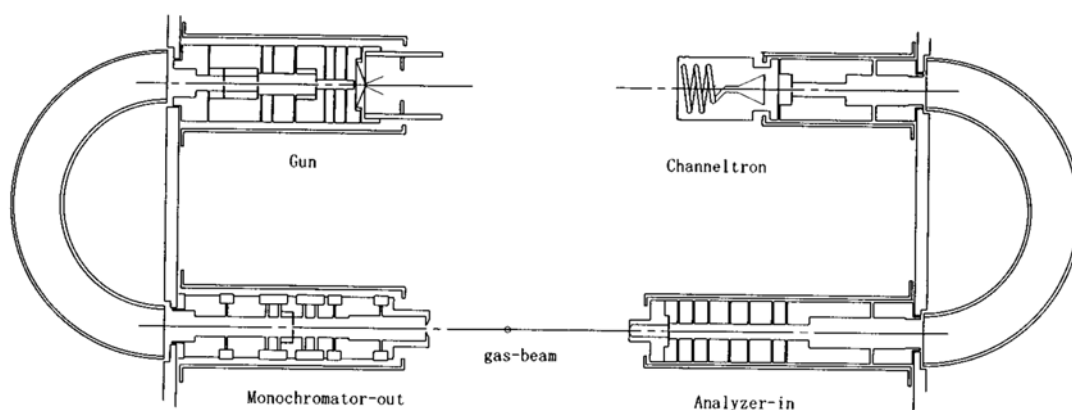


Figure 1. Schematic diagram of electron spectrometer at Sophia University

However, this conventional spectrometer is only capable of differential scattering measurements over an angular range typically ranging from  $10^\circ$  to around  $130^\circ$ . This is because of the mechanical restriction imposed by the size of some of the elements in the electron spectrometer. To overcome this limitation, an electron spectrometer with a magnetic-angle changing device has been developed to measure electron scattering cross sections at backward angles up to  $180^\circ$  (Read and Channing 1996). This technique involves the production of a magnetic field, localized in the vicinity of the interaction region, to change the trajectories of the incident and scattered electrons, such that one can effectively rotate the scattering geometry. The use of two concentric coils, producing opposed but coaxial magnetic fields, ensures that the electron beam passes through the common centres of the coils and thus crosses with the target molecular beam. The arrangement of the coils and their currents is such as to cancel the dipole and the octupole moments of the magnetic field outside the solenoids and so have a minimal effect on the effective operation of the electrostatic spectrometer. This technique has been used in measuring some of the elastic differential cross sections presented later, with detailed descriptions being found in earlier publications (Cho et al 2000, 2003).

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### 3.2 Normalization and Energy Calibration:

Relative measurements of the angular distribution are placed on an absolute scale by use of the relative flow technique (Srivastava *et al* 1975). This technique relies on measurements of the ratio of scattered electron intensities for the gas of interest relative to that for a standard gas. To establish the correct flow conditions, in particular that the mean-free-paths for the two gases are identical in the capillary needle, the driving pressures for the two gases must be set very carefully. In other words, the densities of the two gases are set to be identical by adjusting the pressure behind the nozzle so as to maintain approximately equal gas Knudsen numbers. The ratio of the driving pressures is determined from values of the molecular diameters of the standard gas and the target molecules. The conditions that need to be fulfilled to properly conduct a relative flow experiment have been discussed in detail by Gibson *et al* (1999), and references therein.

Providing the above conditions are satisfied, the ratio of the two cross sections  $\sigma_x$  and  $\sigma_h$  ( $x$  for the target gas of interest,  $h$  for the helium standard) can be determined from the following equation:

$$\frac{\sigma_x}{\sigma_h} = \frac{I_x P_h}{I_h P_x},$$

where  $I_x$  and  $I_h$  are the scattered electron intensities, and  $P_x$  and  $P_h$  are the corresponding driving pressures for the two gases respectively.

For most elastic differential cross section measurements presented here, the following helium cross sections were used: Boesten and Tanaka (1992), or Nesbet (1979) for energies below 20 eV, and Brunger *et al* (1992) at higher energies. Boesten and Tanaka (1992) have accumulated a large data base and calculated rational function fits for a representative set of elastic, non-resonant  $e + \text{He}$  differential cross sections (DCS) comprising (1) the variational DCS of Nesbet (1979), (2) the eikonal DCS of Byron and Joachain (1977), and the experimental data of Wagenaar *et al* (1986), Register *et al* (1980), Bromberg (1974), and Jansen *et al* (1976), with the priorities in the order given. The fits, expressed as functions of the scattering angle with the impact energy as the parameter, form smooth functions at sufficiently closely spaced intervals to allow for easy first- or second-order interpolation over angles  $\theta$  from  $0^\circ$  to  $180^\circ$  and energies  $E_0$  from 0.1 to 1000 eV. Maximum deviation from the data set is 10.4% for experiments and 20% for theory at low angles smaller or equal to  $10^\circ$ , where theory deviates from the experiments.

The absolute electron energy scale is calibrated by observing either the position of the second quasi-vibrational resonance peak of the  $\text{N}_2^- \ ^2\Pi_g$  resonance, at the energy of 2.198 eV for a scattering angle of  $60^\circ$  (Rohr 1977), or the position of the  $\text{He}^- \ 1s2s^2\ ^2S$  resonance at 19.367 eV (Brunt *et al* 1977).

### 3.3 Extrapolation procedures for DCS to derive Integral cross sections

The new technique, discussed above in section 3.1, for measuring DCS over a wide angular range has been implemented by several groups and some of the data which has resulted is presented in later sections. This technique helps to remove much of the uncertainty involved in the derivation of integral cross sections as it is only necessary to extrapolate the measured data in the forward angular region. However, in general, extrapolation procedures are necessary as most DCS measurements are over a finite angular range and do not cover the full range from  $0^{\circ}$  to  $180^{\circ}$ . A number of techniques are used including, in many cases, the simple ‘by eye’ procedure, although this remains a rather subjective process. A somewhat more physically sound process which has been developed in recent years is to use a form of molecular phase shift analysis. In this technique, the measured DCS is fitted by an expression for the cross section which is expanded in terms of the scattering phase shifts. The phase shifts (usually less than 10 are needed) are free parameters and other molecular properties such as the dipole polarizability and dipole moment are required. Details of this technique can be found in the papers of Boesten and Tanaka (1991) and Panajotovic *et al.* (2003).

### 3.4 Error estimation:

Typical experimental errors for elastic scattering cross sections are estimated to be between 10 and 20%. They arise from a combination, in quadrature, of the statistical uncertainties on the scattered electron count rates together with those arising from measurements of parameters such as the electron current, gas pressure and the determination of relative flow rates and the uncertainties on the helium cross section. Each of these contributions varies typically from 2% to 5%.

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#### 4 Benchmark Cross Sections for Elastic DCS

In Table 1 below we summarize the broad classes of polyatomic molecules, and specific molecules within those classes, that we will consider in this report.

Table 1: List of molecules tabled in this report

A. Fusion Plasma-Related Gases

CH<sub>4</sub>, C<sub>2</sub>H<sub>6</sub>, C<sub>3</sub>H<sub>8</sub>, C<sub>2</sub>H<sub>4</sub>, C<sub>3</sub>H<sub>6</sub>, *isomers*-C<sub>3</sub>H<sub>4</sub>

B. Processing Plasma-Related Gases

CF<sub>4</sub>, C<sub>2</sub>F<sub>6</sub>, C<sub>3</sub>F<sub>8</sub>, C<sub>3</sub>F<sub>6</sub>, *cyclo*-C<sub>4</sub>F<sub>8</sub>, C<sub>2</sub>F<sub>4</sub>, C<sub>6</sub>F<sub>6</sub>,

CH<sub>3</sub>F, CH<sub>2</sub>F<sub>2</sub>, CHF<sub>3</sub>

NF<sub>3</sub>, SF<sub>6</sub>

SiH<sub>4</sub>, Si<sub>2</sub>H<sub>6</sub>, GeH<sub>4</sub>

C. Environmental Issues -Related Gases

CF<sub>3</sub>Cl, CF<sub>3</sub>Br, CF<sub>3</sub>I

H<sub>2</sub>O, CO<sub>2</sub>, N<sub>2</sub>O

We now consider each of these sequentially and present the available data.

#### A. Fusion Plasma-Related Gases

##### CH<sub>4</sub>

Absolute cross sections for elastic scattering of electrons from CH<sub>4</sub> have been determined in the energy range of 1.5–100 eV and over the scattering angles of 15–130°. The DCS were analyzed using a molecular phase-shift approach, in order to extrapolate them to lower and higher angles, i.e.,  $\theta < 10^\circ$  and  $\theta > 130^\circ$ , to facilitate derivation of the integral cross sections.

All these data are recommended in Table 2.

#### Reference:

L. Boesten, H. Tanaka, *J. Phys. B: At. Mol. Opt. Phys.* 24 821 (1991).

Table 2. Differential cross sections for elastic electron scattering (in units of  $10^{-16}$  cm<sup>2</sup>/sr) and integral elastic (ICS) and elastic momentum transfer cross sections (MTCS), respectively (in units of  $10^{-16}$  cm<sup>2</sup>), from CH<sub>4</sub>. The estimated uncertainty in the DCS data is 15%, whilst the uncertainty on the ICS and MTCS is 25%.

Angle (deg)	Energy (eV)							
	1.5	2.0	3.0	4.0	5.0	6.0	7.5	8.0
10	-	-	-	-	-	5.101	7.360	8.127
15	-	0.250	0.562	1.753	2.810	4.909	6.862	7.517
20	0.151	0.194	0.419	1.604	2.532	4.390	6.000	6.432
25	0.102	0.152	0.368	1.158	2.247	3.765	4.942	5.407
30	0.064	0.136	0.347	1.014	1.734	3.009	4.078	4.431
35	0.070	0.147	0.364	0.948	1.383	2.546	3.396	3.622
40	0.089	0.195	0.480	0.895	1.262	2.139	2.859	3.016
45	0.126	0.266	0.635	0.992	1.232	1.889	2.315	2.466
50	0.181	0.367	0.722	1.102	1.283	1.661	1.879	2.076
55	-	0.465	0.953	1.217	1.416	-	1.706	1.765
60	0.312	0.555	1.092	1.357	1.540	1.653	1.609	1.643
65	-	0.645	-	-	-	-	1.591	1.517
70	0.412	0.718	1.306	1.595	1.588	1.725	1.574	1.409
75	-	0.758	-	-	-	-	1.484	1.382
80	0.471	0.771	1.246	1.673	1.737	1.733	1.528	1.403
85	-	0.748	-	-	-	-	1.387	1.271
90	0.505	0.722	1.082	1.313	1.530	1.421	1.255	1.153
95	-	0.677	-	-	-	1.190	1.050	0.879
100	0.458	0.625	0.804	1.016	1.001	0.945	0.816	0.773
105	-	0.528	0.640	0.738	0.734	0.680	0.612	0.568
110	0.363	0.451	0.492	0.543	0.444	0.419	0.435	0.387
115	-	0.380	0.332	0.323	0.282	0.257	0.262	0.273
120	0.272	0.302	0.206	0.183	0.153	0.189	0.209	0.227
125	-	0.239	0.126	0.160	0.192	0.249	0.245	0.303
130	0.175	0.167	0.115	0.179	0.281	0.356	0.414	0.474
ICS	3.61	5.61	9.25	14.41	18.04	22.97	26.49	26.30
MTCS	3.49	5.40	8.43	13.71	17.55	21.79	25.07	23.76

(continued)

Angle (deg)	Energy (eV)							
	9.0	10	12	15	20	30	50	100
10	8.991	7.237	9.287	8.143	8.612	9.858	11.046	6.316
15	8.225	6.485	8.308	-	-	-	-	-
20	6.861	5.646	6.764	6.659	6.905	5.596	4.024	1.623
25	5.853	4.885	5.789	-	-	-	-	-
30	4.713	4.107	4.784	4.555	3.956	2.600	1.274	0.439
35	3.786	3.361	3.937	-	-	-	-	-
40	3.045	2.741	3.122	2.866	2.213	1.153	0.492	0.205
45	2.609	2.206	2.395	-	-	-	-	0.166
50	2.126	2.142	2.021	1.803	1.206	0.606	0.290	0.130
55	1.771	-	-	-	-	-	-	0.097
60	1.566	1.570	1.364	1.176	0.768	0.415	0.217	0.062
65	1.430	-	-	-	-	-	0.170	0.046
70	1.308	1.254	1.034	0.879	0.586	0.317	0.139	0.039
75	1.273	1.201	-	-	-	-	0.114	0.031
80	1.210	1.089	0.862	0.704	0.462	0.246	0.082	0.030
85	1.094	0.986	-	-	-	-	0.069	0.027
90	0.972	0.852	0.656	0.525	0.351	0.183	0.053	0.027
95	0.843	0.736	-	-	-	-	0.048	0.028
100	0.658	0.588	0.472	0.389	0.263	0.130	0.046	0.033
105	0.516	0.441	-	-	-	-	0.048	0.037
110	0.348	0.336	0.313	0.306	0.231	0.131	0.062	0.039
115	0.272	0.271	-	-	-	-	0.072	0.043
120	0.228	0.268	0.294	0.329	0.274	0.162	0.086	0.043
125	0.293	0.347	-	-	-	-	0.103	0.043
130	0.456	0.502	0.475	0.465	0.355	0.215	0.116	0.049
ICS	25.55	23.02	20.74	18.27	14.41	9.49	6.57	3.20
MTCS	21.77	20.21	14.63	11.78	6.95	3.87	2.22	1.08

## C<sub>2</sub>H<sub>6</sub>

Absolute cross sections for elastic scattering of electrons from C<sub>2</sub>H<sub>6</sub> have been determined in the energy range of 2–100 eV and over the scattering angles of 10–130°. These DCS were analyzed using a molecular phase-shift approach in order to extrapolate them to lower and higher angles, i.e.,  $\theta < 10^\circ$  and  $\theta > 130^\circ$ , to facilitate derivation of the integral cross sections.

All these data are recommended in Table 3.

### Reference:

H. Tanaka, L. Boesten, D. Matsunaga and T. Kubo, *J. Phys. B: At. Mol. Opt. Phys.* **21** 1255 (1988).

Table 3. Differential cross sections for elastic electron scattering (in units of  $10^{-16}$  cm<sup>2</sup>/sr) and integral elastic (ICS) and elastic momentum transfer cross sections (MTCS), respectively (in units of  $10^{-16}$  cm<sup>2</sup>), from C<sub>2</sub>H<sub>6</sub>. The estimated uncertainty in the DCS data is 15%–22%, whilst the uncertainty on the integral and momentum transfer cross sections is 25%.

Angle (deg)	Energy (eV)							
	2.0	3.0	4.0	5.0	6.0	7.5	8.5	10
10	-	-	-	-	-	-	-	-
15	-	-	-	-	-	12.900	12.020	13.360
20	1.235	1.543	2.809	5.217	6.223	9.555	10.490	12.770
30	0.795	1.166	1.878	3.249	4.048	5.732	6.163	6.686
40	0.487	0.871	1.335	2.270	2.460	3.260	3.507	3.575
50	0.493	1.060	1.485	2.129	1.921	2.359	2.361	1.964
60	0.678	1.450	1.734	2.083	1.950	2.011	2.103	1.416
70	0.929	1.696	1.956	1.950	1.792	1.831	1.787	1.252
80	1.173	1.728	1.828	1.738	1.417	1.321	1.212	0.963
90	1.242	1.652	1.422	1.453	1.113	0.924	0.834	0.699
100	1.240	1.340	1.015	1.181	0.924	0.893	0.941	0.645
110	1.048	0.947	0.794	1.063	1.055	1.132	1.452	0.871
120	0.754	0.666	0.672	1.087	1.488	1.660	1.726	1.119
130	0.655	0.585	0.788	1.309	1.636	1.852	1.835	1.240
ICS	10.82	14.71	19.13	24.34	26.76	31.68	30.11	28.75
MTCS	9.74	12.10	15.78	19.82	22.20	23.48	20.10	16.25

(continued)

Angle (deg)	Energy (eV)			
	15	20	40	100
10	-	-	25.120	17.870
15	15.460	15.900	-	-
20	11.020	11.350	7.910	2.158
30	5.668	4.936	2.001	0.652
40	2.898	2.108	0.806	0.337
50	1.730	1.259	0.638	0.220
60	1.291	0.995	0.370	0.144
70	1.026	0.731	0.236	0.079
80	0.801	0.482	0.199	0.051
90	0.591	0.380	0.169	0.061
100	0.577	0.358	0.147	0.067
110	0.650	0.404	0.142	0.079
120	0.740	0.448	0.172	0.088
130	0.909	0.480	0.193	0.090
ICS	25.26	21.82	14.10	6.60
MTCS	10.88	6.99	3.76	1.41

### C<sub>3</sub>H<sub>8</sub>

Absolute cross sections for elastic scattering of electrons from C<sub>3</sub>H<sub>8</sub> have been determined in the energy range of 2–100 eV and over the scattering angles of 5–130°. The DCS were, again, analyzed using a molecular phase-shift approach in order to extrapolate them to lower and higher angles, to facilitate derivation of the integral cross sections.

All these data are recommended in Table 4.

#### **Reference:**

L. Boesten, M. A. Dillon, H. Tanaka, M. Kimura and H. Sato, *J. Phys. B: At. Mol. Opt. Phys.* **27** 1845 (1994).

Table 4. Differential cross sections for elastic electron scattering (in units of  $10^{-16}$  cm<sup>2</sup>/sr) and integral elastic (ICS) and elastic momentum transfer cross sections (MTCS), respectively (in units of  $10^{-16}$  cm<sup>2</sup>), from C<sub>3</sub>H<sub>8</sub>. The estimated uncertainty in the DCS data is 15%–20%, whilst the uncertainty on the integral and momentum transfer cross sections is 30%.

Angle (deg)	Energy (eV)							
	2.0	3.0	4.0	5.0	6.0	7.5	8.5	10
20	-	2.466	3.240	5.628	7.195	14.159	13.466	13.471
25	2.277	-	-	-	-	-	-	-
30	1.668	1.543	2.359	3.638	5.002	7.713	7.544	7.177
40	0.933	1.074	1.809	2.298	2.840	3.891	3.595	3.340
50	0.752	1.252	1.983	2.306	2.358	2.713	2.441	2.237
60	0.999	1.657	2.371	2.503	2.416	2.662	2.211	1.994
70	1.450	1.992	2.463	2.525	2.225	2.261	1.916	1.684
80	1.623	1.859	2.274	1.968	1.710	1.813	1.470	1.352
90	1.568	1.264	1.417	1.638	1.480	1.443	1.235	1.155
100	1.430	1.117	1.144	1.292	1.257	1.526	1.384	1.199
110	1.271	0.922	1.025	1.344	1.639	1.689	1.510	1.289
120	1.044	0.804	0.888	1.495	1.639	1.911	1.627	1.340
130	0.837	0.784	0.981	1.600	1.737	1.967	1.689	1.486
ICS	17.04	19.82	26.97	34.09	39.95	44.46	41.54	38.36
MTCS	14.41	17.65	21.97	25.40	27.68	29.98	25.98	23.13

(continued)

Angle (deg)	Energy (eV)			
	15	20	40	100
5	-	-	-	34.452
10	23.396	25.685	30.073	19.275
20	13.438	10.063	7.500	1.992
25	-	-	-	-
30	6.036	4.754	1.769	0.800
40	2.823	2.212	1.000	0.383
50	1.955	1.638	0.725	0.222

60	1.619	1.388	0.490	0.1693
70	1.295	0.974	0.291	0.0829
80	1.006	0.762	0.232	0.0525
90	0.822	0.547	0.208	0.0616
100	0.789	0.557	0.188	0.0798
110	0.781	0.587	0.192	0.0848
120	0.840	0.666	0.219	0.0915
130	1.056	0.731	0.266	0.0972
ICS	30.86	24.32	15.92	8.21
MTCS	16.73	13.73	6.34	2.88

## C<sub>2</sub>H<sub>4</sub>

Absolute cross sections for elastic scattering of electrons from C<sub>2</sub>H<sub>4</sub> have been determined in the energy range of 1.5–100 eV and over the scattering angles of 15–130°. As before, the DCS were analyzed using a molecular phase-shift approach in order to extrapolate the DCS to lower and higher angles, to facilitate derivation of the integral cross sections.

All these data are recommended in Table 5.

### Reference:

R. Panajotovic, M. Kitajima, H. Tanaka, M. Jelisavcic, J. Lower, L. Campbell, M. J. Brunger and S. J. Buckman, *J. Phys. B: At. Mol. Opt. Phys.* **36** 1615 (2003).

Table 5. Differential cross sections for elastic electron scattering (in units of 10<sup>-16</sup> cm<sup>2</sup>/sr) and integral elastic (ICS) and elastic momentum transfer cross sections (MTCS), respectively (in units of 10<sup>-16</sup> cm<sup>2</sup>), from C<sub>2</sub>H<sub>4</sub>. The estimated uncertainty in the DCS data is 15%, whilst the uncertainty on the integral and momentum transfer cross sections is 20%–25%.

Angle (deg)	Energy (eV)							
	1.5	1.8	2.0	2.2	2.5	3.1	4.1	4.6
15	-	-	-	-	-	1.79	2.59	3.26
20	0.581	1.26	1.66	1.34	1.11	1.77	2.44	2.95
30	0.705	1.42	1.62	1.40	1.32	1.82	2.01	2.31
40	0.667	1.30	1.55	1.45	1.65	1.94	1.94	2.28

45	-	-	-	-	-	2.12	-	2.36
50	0.787	1.29	1.72	1.56	1.78	2.24	2.09	2.39
55	-	-	-	-	-	2.18	-	2.34
60	1.04	1.28	1.79	1.55	1.81	2.09	2.18	2.23
70	1.60	1.68	1.82	1.57	1.90	1.87	1.97	1.96
80	1.92	1.99	1.88	1.86	1.72	1.81	1.75	1.56
90	2.04	1.95	1.94	1.68	1.59	1.55	1.38	1.35
100	1.90	1.83	1.82	1.57	1.49	1.33	1.15	1.15
110	1.73	1.41	1.69	1.42	1.46	1.20	1.17	1.19
120	1.39	1.36	1.52	1.37	1.31	1.09	1.04	1.24
130	1.12	1.25	1.51	1.47	1.36	1.11	1.06	1.30
ICS	16.3	18.4	21.3	19.4	18.6	19.5	18.2	20.1
MTCS	16.8	17.9	20.8	19.3	17.6	17.3	14.6	16.3

(continued)

Angle (deg)	Energy (eV)							
	5.1	8.1	10.1	15	20	30	60	100
15	6.05	9.95	12.16	-	-	-	-	-
20	4.54	8.39	9.47	9.98	9.47	7.40	3.20	2.02
30	2.90	4.87	5.63	5.40	4.22	2.90	0.95	0.662
40	2.36	3.09	3.26	2.45	1.95	1.20	0.525	0.31
45	-	-	-	-	-	-	-	-
50	2.28	2.23	2.04	1.32	1.05	0.773	0.274	0.197
55	-	-	-	-	-	-	-	-
60	2.27	1.70	1.48	0.914	0.713	0.531	0.197	0.153
70	2.05	1.29	1.09	0.707	0.597	0.351	0.158	0.099
80	1.51	1.01	0.849	0.567	0.438	0.277	0.118	0.074
90	1.21	0.898	0.677	0.544	0.426	0.256	0.108	0.069
100	1.11	0.986	0.898	0.648	0.454	0.264	0.113	0.070
110	1.14	1.17	1.02	0.769	0.477	0.311	0.114	0.079
120	1.18	1.42	1.08	0.908	0.559	0.332	0.131	0.086
130	1.35	1.35	1.04	0.913	0.563	0.392	0.178	0.103
ICS	22.9	25.6	24.5	22.8	18.5	12.3	6.14	3.73
MTCS	18.5	19.6	15.8	13.8	9.8 0	5.3 0	2.5 0	1.50



## C<sub>3</sub>H<sub>6</sub> (propene and cyclopropane)

Absolute cross sections for elastic scattering of electrons from C<sub>3</sub>H<sub>6</sub> have been determined in the energy range of 1.5–100 eV and over the scattering angles of 15–130°. The DCS were analyzed using a molecular phase-shift approach in order to extrapolate them to lower and higher angles, i.e.,  $\theta < 20^\circ$  and  $\theta > 130^\circ$ , to facilitate derivation of the integral cross sections.

The propene data are recommended in Table 6, while the cyclopropane data are recommended in Table 7.

### Reference:

C. Makochekanwa, H. Kato, M. Hoshino, H. Tanaka, H. Kubo, M. H. F. Bettega, A. R. Lopes, M. A. P. Lima and L. G. Ferreira, *J. Chem. Phys.* **124** 024323 (2006).

Table 6. Differential cross sections ( $10^{-16}$  cm<sup>2</sup>/sr) for elastic scattering from propene (C<sub>3</sub>H<sub>6</sub>). Their absolute uncertainties are 15%. The experimental integral cross section (ICS) and momentum-transfer cross section (MTCS) have units of  $10^{-16}$  cm<sup>2</sup> and are estimated to have experimental uncertainties of between 20% and 25%.

Angle (deg)	Energy (eV)							
	1.5	1.8	2.0	2.3	2.6	3.0	5.0	8.0
15	-	-	-	-	-	2.806	20.354	9.643
20	10.691	2.093	3.001	2.939	2.628	2.577	10.916	10.192
30	2.279	1.505	2.416	2.61	2.685	2.307	3.979	6.888
40	1.507	1.338	1.953	2.434	2.626	2.393	2.949	4.202
50	1.261	1.349	1.823	2.501	2.688	2.456	2.968	2.537
60	1.605	1.676	1.914	2.619	2.722	2.539	2.803	2.267
70	1.925	2.151	2.126	2.365	2.497	2.307	2.350	1.799
80	2.729	2.496	2.293	2.038	2.122	1.854	1.969	—
90	2.730	2.385	2.047	1.972	1.858	1.620	1.627	1.458
100	2.536	2.074	1.791	1.526	1.712	1.363	1.442	1.539
110	2.231	1.773	1.414	1.520	1.504	1.192	1.570	1.512
120	2.005	1.460	1.299	1.464	1.447	1.095	1.601	1.413
130	1.649	1.355	1.354	1.544	1.483	1.101	1.356	1.472
ICS	20.9	22.8	28.8	25.7	26.8	20.9	25.6	28.6
MTCS	21.5	21.8	25.8	22.4	24.4	18.9	20.4	19.9

(continued)

Angle (deg)	Energy (eV)				
	10	20	30	60	100
15	19.854	19.754	18.77	9.366	4.33
20	13.958	12.637	9.885	3.622	2.054
30	8.342	4.756	2.921	1.476	0.843
40	3.654	2.037	1.481	0.699	0.377
50	2.476	1.389	1.098	0.422	0.225
60	1.888	1.049	0.697	0.302	0.193
70	1.211	0.686	0.330	0.181	0.088
80	-	-	-	-	-
90	1.244	0.604	0.274	0.181	0.083
100	1.218	0.558	0.247	0.157	0.098
110	1.405	0.511	0.277	0.169	0.097
120	1.103	0.599	0.438	0.185	0.098
130	1.298	0.723	0.452	0.235	0.101
ICS	33.5	25.1	19.8	11.6	6.1
MTCS	19.1	13.7	8.9	8.1	4.3

Table 7. Differential cross sections ( $10^{-16}$  cm<sup>2</sup>/sr) for elastic scattering from cyclopropane (c-C<sub>3</sub>H<sub>6</sub>). Their absolute uncertainties are 15%. The experimental integral cross section (ICS) and momentum-transfer cross section (MTCS) have units of  $10^{-16}$  cm<sup>2</sup> and are estimated to have experimental uncertainties of between 20% and 25%

Angle (deg)	Energy (eV)							
	1.5	2.0	3.0	4.0	5.0	7.0	10	12
15	-	-	-	-	-	-	-	15.74
20	1.92	2.233	3.132	4.859	8.545	9.555	11.57	11.73
30	1.206	1.214	1.513	2.331	4.287	4.874	5.81	5.784
40	0.729	0.944	1.243	1.784	2.538	2.854	2.806	2.581
50	0.727	0.927	1.124	1.746	2.221	2.348	1.949	1.661
60	0.878	1.068	1.148	1.681	2.145	2.131	1.722	1.587
70	1.084	1.220	1.195	1.495	1.723	1.688	1.398	1.411
80	1.353	1.394	1.234	1.094	0.978	0.993	0.973	1.051
90	1.479	1.487	1.121	0.827	0.732	0.851	0.924	0.934

100	1.601	1.481	1.036	0.863	1.145	1.283	1.386	1.22
110	1.645	1.258	1.032	1.096	1.837	2.099	1.964	1.52
120	1.621	1.201	1.216	1.312	2.279	2.374	2.085	1.634
130	1.622	1.203	1.361	1.465	2.645	2.145	1.682	1.334
ICS	17.7	17.2	17.8	19.5	28.9	30.8	30.0	28.0
MTCS	19.1	17.6	17.1	18.5	26.4	24.7	21.3	17.7

(continued)

Angle (deg)	Energy (eV)					
	15	20	25	30	60	100
15	16.853	18.37	20.086	22.44	15.34	9.10
20	12.453	12.98	12.407	12.27	6.46	3.068
30	5.898	4.963	4.026	3.50	1.22	0.774
40	2.355	1.908	1.645	1.444	0.673	0.358
50	1.530	1.354	1.277	1.061	0.368	0.252
60	1.451	1.243	0.971	0.736	0.258	0.189
70	1.275	0.924	0.644	0.442	0.223	0.103
80	0.944	0.644	0.457	0.357	0.1469	0.063
90	0.858	0.581	0.458	0.391	0.094	0.056
100	0.95	0.663	0.518	0.484	0.0846	0.074
110	1.09	0.718	0.53	0.522	0.106	0.076
120	1.13	0.812	0.61	0.644	0.142	0.094
130	1.035	0.851	0.674	0.863	0.18	0.115
ICS	27.2	25.5	23.8	22.6	11.8	6.4
MTCS	15.4	11.5	10.6	9.8	8.6	4.7

### **C<sub>3</sub>H<sub>4</sub> (allene and propyne)**

Absolute cross sections for elastic scattering of electrons from C<sub>3</sub>H<sub>4</sub> have been determined in the energy range of 1.5–100 eV and over the scattering angles of 15–130°.

The allene data are recommended in Table 8, with the propyne data being recommended in Table 9.

#### **Reference:**

Y. Nakano, M. Hoshino, M. Kitajima, H. Tanaka and M. Kimura, *Phys. Rev. A* **66** 032714 (2002).

Table 8. Differential cross sections ( $10^{-16}$  cm<sup>2</sup>/sr) for elastic scattering from allene. Their absolute uncertainties are 15%.

Angle (deg)	Energy (eV)							
	2.0	3.0	4.0	5.0	7.0	10	12	15
15	-	-	-	-	-	15.809	16.973	16.998
20	4.97	2.685	2.786	3.609	6.844	11.646	13.088	12.808
30	3.096	2.432	2.959	2.729	4.396	6.046	6.651	6.230
40	2.333	2.506	2.943	2.603	3.507	4.062	3.772	3.089
50	2.063	2.275	2.939	2.462	2.743	2.574	2.686	2.068
60	1.868	2.213	2.694	2.211	2.186	1.711	1.602	1.332
70	1.714	2.101	2.302	1.947	1.761	1.182	1.159	0.848
80	1.651	1.796	1.966	1.808	1.459	1.166	0.985	0.771
90	1.372	1.517	1.551	1.428	1.310	1.079	0.971	0.769
100	1.197	1.136	1.306	1.267	1.131	0.998	0.865	0.669
110	1.029	1.070	1.096	0.996	1.080	1.014	0.802	0.656
120	1.070	0.858	0.970	0.973	1.055	0.980	0.747	0.710
130	1.120	0.911	0.961	1.077	1.120	1.154	1.063	0.883

(continued)

Angle (deg)	Energy (eV)			
	20	30	60	100
15	16.956	18.769	9.835	6.581
20	11.514	11.156	4.336	3.176
30	4.755	3.943	1.351	0.858
40	2.592	1.941	0.603	0.309
50	1.722	0.886	0.294	0.220
60	0.937	0.458	0.208	0.187
70	0.585	0.369	0.159	0.117
80	0.613	0.358	0.142	0.0796
90	0.613	0.369	0.126	0.0823
100	0.558	0.274	0.102	0.0791
110	0.541	0.281	0.131	0.0866
120	0.547	0.357	0.162	0.0801
130	0.746	0.479	0.199	0.0751

Table 9. Differential cross sections ( $10^{-16}$  cm<sup>2</sup>/sr) for elastic scattering from propyne. Their absolute uncertainties are 15%.

Angle (deg)	Energy (eV)							
	1.5	2.0	3.0	3.2	4.0	5.0	7.0	10
15	-	-	-	-	-	-	-	15.403
20	2.93	3.253	5.01	7.102	4.702	5.158	9.546	11.036
30	1.771	1.537	3.772	4.847	3.696	4.424	6.463	6.941
40	1.441	1.189	2.722	3.559	2.931	3.319	4.527	4.173
50	1.543	1.275	2.486	3.066	2.486	2.768	3.166	2.819
60	1.798	1.526	2.449	3.173	2.211	2.380	2.300	2.133
70	1.836	1.490	2.155	2.691	1.893	2.096	1.926	1.611
80	2.365	1.407	1.877	2.191	1.621	1.901	1.943	1.490
90	1.920	1.256	1.622	1.557	1.505	1.786	1.783	1.256
100	1.492	1.183	1.377	1.501	1.218	1.528	1.550	1.184
110	1.225	0.942	1.468	1.566	1.302	1.378	1.233	0.949
120	1.010	0.841	1.501	1.870	1.330	1.306	1.127	1.074
130	0.918	0.847	1.832	2.072	1.354	1.286	1.149	1.286

(continued)

Angle (deg)	Energy (eV)					
	12	15	20	25	60	100
15	13.371	17.924	19.579	19.194	14.385	9.227
20	9.009	13.895	13.822	12.666	6.783	4.718
30	5.502	6.414	5.681	4.418	1.936	1.258
40	3.082	3.486	2.623	2.141	1.013	0.644
50	2.065	2.348	1.612	1.252	0.503	0.341
60	1.378	1.565	1.131	0.823	0.314	0.239
70	0.921	1.209	0.832	0.607	0.233	0.142
80	0.800	0.965	0.752	0.569	0.182	0.119
90	0.813	0.909	0.660	0.448	0.147	0.104
100	0.736	0.842	0.617	0.410	0.135	0.096
110	0.686	0.875	0.617	0.358	0.140	0.089
120	0.760	0.907	0.605	0.360	0.165	0.0936
130	0.988	1.078	0.725	0.529	0.212	0.0903

## B. Processing Plasma-Related Gases

### CF<sub>4</sub>

Absolute cross sections for elastic scattering of electrons from CF<sub>4</sub> have been determined in the energy range of 1.5–100 eV and over the scattering angles of 15–130°. The DCS were again analyzed using a molecular phase-shift approach in order to extrapolate them to lower and higher angles, to facilitate derivation of the integral cross sections.

All these data are recommended in Table 10.

#### Reference:

L. Boesten, H. Tanaka, A. Kobayashi, M. A. Dillon and M. Kimura, *J. Phys. B: At. Mol. Opt. Phys.* **25** 1607 (1992).

Table 10. Differential cross sections for elastic electron scattering (in units of 10<sup>-16</sup> cm<sup>2</sup>/sr) and integral elastic (ICS) and elastic momentum transfer cross sections (MTCS), respectively (in units of 10<sup>-16</sup> cm<sup>2</sup>) from CF<sub>4</sub>. The estimated uncertainty in the DCS data is 15%–20%, whilst the uncertainty on the integral and momentum transfer cross sections is 25%.

Angle (deg)	Energy (eV)							
	1.5	2.0	3.0	5.0	6.0	7.0	8.0	9.0
15	-	0.1189	0.3408	0.9647	1.5526	2.5565	3.7041	4.7153
20	0.1156	0.2107	0.5437	1.1780	1.6739	2.4716	3.5055	4.0973
30	0.2929	0.5174	0.9571	1.7782	2.0409	2.3776	2.9866	3.5126
40	0.4775	0.7532	1.2560	2.1309	2.3629	2.4221	2.4890	2.6564
50	0.8106	1.1179	1.5905	2.3340	2.4184	2.0523	1.7570	1.7135
60	0.9146	1.3994	1.6028	2.0814	1.9375	1.7795	1.1971	1.1146
70	1.0264	1.2575	1.5126	1.4717	1.4875	1.1095	0.7749	0.7199
80	0.9225	1.0442	1.1786	1.0226	0.9028	0.6573	0.5520	0.6045
90	0.8779	0.8065	0.8906	0.6066	0.5430	0.4349	0.4953	0.6814
100	0.8154	0.7264	0.5381	0.4080	0.3774	0.4683	0.5924	0.7671
110	0.6146	0.4861	0.4399	0.3552	0.4347	0.5385	0.6781	0.7541
120	0.4576	0.4031	0.3167	0.3363	0.4473	0.5927	0.6703	0.7307
130	0.3618	0.2978	0.2637	0.3782	0.4503	0.5735	0.6118	0.6584
ICS	7.738	8.555	10.46	12.72	13.4	13.36	13.91	15.4

MTCS 6.963 7.136 7.645 8.243 8.62 8.781 9.124 10.24

(continued)

Angle (deg)	Energy (eV)						
	10	15	20	35	50	60	100
15	4.4007	5.4326	6.7566	14.1044	13.3217	12.1904	9.9255
20	4.7677	4.8219	5.1461	7.8265	6.9383	5.8892	3.4611
30	4.1163	3.4725	3.1666	2.6912	1.4085	1.0154	1.0555
40	2.8836	2.4642	1.7198	0.8776	0.7378	0.7464	0.7534
50	1.6848	1.3828	0.9118	0.8609	0.8566	0.7594	0.3187
60	0.9990	0.9010	0.7949	0.9268	0.6723	0.4286	0.2172
70	0.7302	0.8689	1.0042	0.8090	0.3603	0.2190	0.2153
80	0.7817	1.0580	1.0952	0.4353	0.1696	0.1289	0.1571
90	0.7996	1.0762	0.9876	0.2011	0.1364	0.1275	0.0995
100	0.7938	0.9311	0.6900	0.1760	0.1331	0.1237	0.0948
110	0.7272	0.6981	0.5303	0.2550	0.2002	0.1851	0.1223
120	0.6215	0.5948	0.5540	0.4546	0.4086	0.3220	0.1917
130	0.6514	0.6907	0.8226	0.6906	0.6573	0.4328	0.2619
ICS	16.63	16.92	17.63	16.72	14.24	13.06	9.844
MTCS	11.38	13.49	14.11	8.757	6.722	5.836	3.848

## C<sub>2</sub>F<sub>6</sub>

Absolute cross sections for elastic scattering of electrons from C<sub>2</sub>F<sub>6</sub> have been determined in the energy range of 2–100 eV and over the scattering angles of 10–130°. These DCS were also analyzed using a molecular phase-shift approach in order to extrapolate them to lower and higher angles, to facilitate derivation of the integral cross sections.

All these data are recommended in Table 11.

### Reference:

T. Takagi, L. Boesten, H. Tanaka and M. A. Dillon, *J. Phys. B: At. Mol. Opt. Phys.* **27** 5389 (1994).

Table 11. Differential cross sections for elastic electron scattering (in units of  $10^{-16}$  cm<sup>2</sup>/sr) and integral elastic (ICS) and elastic momentum transfer cross sections (MTCS), respectively (in units of  $10^{-16}$  cm<sup>2</sup>), from C<sub>2</sub>F<sub>6</sub>. The estimated uncertainty in the DCS data is 15%–20%, whilst the uncertainty on the integral and momentum transfer cross sections is 25%.

Angle (deg)	Energy (eV)							
	2.0	3.0	4.0	5.0	7.0	8.0	10	15
10	-	-	-	-	-	-	-	-
15	-	-	-	-	5.304	7.05	8.261	11.28
20	0.4578	1.042	2.113	3.963	5.536	6.882	7.803	8.700
25	-	-	-	-	-	-	-	-
30	0.9265	1.758	2.562	4.269	5.332	5.772	5.676	5.326
40	1.368	2.496	2.805	4.089	4.127	4.094	3.322	2.269
50	1.837	2.772	2.660	3.365	2.797	2.370	1.487	1.146
60	1.952	2.439	2.160	2.191	1.549	1.228	0.9494	1.230
70	1.960	2.018	1.650	1.471	0.9424	0.876	1.033	1.633
80	1.838	1.591	1.109	1.190	0.839	0.9448	1.243	1.813
90	1.394	1.168	0.9805	1.058	1.060	1.107	1.328	1.551
100	1.132	0.8898	0.8343	0.9543	1.047	1.125	1.187	1.365
110	1.066	0.8162	0.7842	0.8861	0.9339	0.9334	1.034	1.114
120	0.8144	0.6880	0.6748	0.8246	0.7572	0.8326	1.010	1.124
130	0.7224	0.7152	0.5981	0.6253	0.7671	0.9042	0.8516	1.209
ICS	15.53	17.61	19.11	21.19	22.66	24.26	24.88	28.04
MTCS	12.98	13.18	14.11	14.56	16.43	17.85	18.81	22.73

(continued)

Angle (deg)	Energy (eV)			
	20	30	60	100
10	-	23.54	41.13	37.91
15	15.45	-	19.31	11.26
20	10.09	14.07	6.473	2.772
25	-	-	2.092	1.859
30	4.126	3.220	1.373	1.607
40	1.174	1.154	1.428	0.8559
50	1.015	1.694	0.9475	0.3984



60	1.477	1.681	0.5767	0.3622
70	1.598	1.239	0.4094	0.3113
80	1.405	0.8628	0.2396	0.1880
90	1.172	0.7576	0.2132	0.1566
100	0.9623	0.5131	0.2386	0.1387
110	0.7965	0.5407	0.2924	0.1694
120	0.9013	0.7836	0.4476	0.2530
130	1.227	1.148	0.5915	0.3439
ICS	28.09	25.33	21.51	16.12
MTCS	22.45	18.93	10.62	5.86

### C<sub>3</sub>F<sub>8</sub>

Absolute cross sections for elastic scattering of electrons from C<sub>3</sub>F<sub>8</sub> have been determined in the energy range of 1.5–100 eV and over the scattering angles of 15–130°. The DCS were analyzed using a molecular phase-shift approach in order to extrapolate them to lower and higher angles, to facilitate derivation of the integral cross sections.

All these data are recommended in Table 12.

#### **Reference:**

H. Tanaka, Y. Tachibana, M. Kitajima, O. Sueoka, H. Takaki, A. Hamada and M. Kimura, *Phys. Rev. A* **59** 2006 (1999).

Table 12. Differential cross sections for elastic electron scattering (in units of 10<sup>-16</sup> cm<sup>2</sup>/sr) and integral elastic (ICS) and elastic momentum transfer cross sections (MTCS), respectively (in units of 10<sup>-16</sup> cm<sup>2</sup>), from C<sub>3</sub>F<sub>8</sub>. The estimated uncertainty in the DCS data is 15%–20%, whilst the uncertainty on the integral and momentum transfer cross sections is 30%.

Angle (deg)	Energy (eV)								
	1.5	2.0	3.0	4.0	5.0	6.5	7.0	8.0	9.0
15	-	-	-	-	-	-	-	-	-
20	1.224	1.185	3.270	5.757	7.099	9.769	10.830	12.417	14.415
30	0.883	1.624	4.100	6.171	6.284	9.395	9.306	9.099	9.232
40	1.309	2.258	4.143	6.085	5.510	5.981	5.916	4.958	4.154

50	1.792	2.632	3.811	4.941	4.940	3.409	3.048	2.313	1.595
60	2.033	2.718	3.250	3.739	2.946	1.900	1.642	1.280	1.253
70	2.232	2.418	2.618	2.436	1.889	1.356	1.303	1.429	1.612
80	2.290	2.034	1.811	1.773	1.474	1.375	1.516	1.603	1.669
90	2.038	1.752	1.323	1.315	1.391	1.435	1.613	1.777	1.650
100	1.640	1.369	1.075	1.179	1.178	1.315	1.465	1.457	1.535
110	1.355	1.078	0.890	1.010	1.038	1.138	1.340	1.328	1.422
120	1.176	0.939	0.767	0.870	0.942	1.053	1.122	1.295	1.382
130	1.115	0.916	0.734	0.872	0.908	1.081	1.199	1.334	1.580
ICS	19.800	20.817	27.401	35.317	37.503	42.877	44.365	44.513	44.942
MTCS	18.244	17.524	21.909	26.542	32.918	35.031	33.888	38.513	41.088

(continued)

Angle (deg)	Energy (eV)							
	10	12	15	20	25	30	60	100
15	16.748	15.202	14.168	22.021	26.080	28.094	17.724	7.253
20	14.339	12.969	12.032	13.724	14.267	13.322	4.860	3.174
30	9.051	7.671	5.932	3.473	2.665	2.098	2.683	2.436
40	3.662	3.083	1.866	1.161	1.565	1.551	2.007	1.251
50	1.608	1.417	1.217	1.689	2.010	1.844	1.276	0.596
60	1.289	1.481	1.628	1.978	2.132	1.776	0.751	0.525
70	1.549	1.767	2.046	1.945	1.908	1.328	0.571	0.442
80	1.751	1.906	2.204	1.684	1.225	0.825	0.397	0.263
90	1.716	1.959	2.168	1.418	0.813	0.640	0.334	0.207
100	1.624	1.791	1.972	1.166	0.762	0.570	0.354	0.222
110	1.586	1.609	1.591	1.150	0.852	0.656	0.472	0.299
120	1.508	1.537	1.382	1.315	1.221	0.813	0.530	0.449
130	1.623	1.590	1.569	1.929	1.645	1.283	0.942	0.632
ICS	44.335	42.379	39.150	37.631	36.324	32.869	18.784	13.001
MTCS	40.784	38.193	35.610	31.745	26.921	23.625	16.713	10.376

### cyclo-C<sub>4</sub>F<sub>8</sub>

Absolute cross sections for elastic scattering of electrons from cyclo-C<sub>4</sub>F<sub>8</sub> have been determined in the energy range of 1.5–100 eV and over the scattering angles of 10–130°. The DCS were also analyzed using a molecular phase-shift approach in order to extrapolate them to lower and higher angles, to facilitate derivation of the integral cross sections.

All these data are recommended in Table 13.

#### **Reference:**

M. Jelisavcic, R. Panajotovic, M. Kitajima, M. Hoshino, H. Tanaka and S. J. Buckman, *J. Chem. Phys.* **121** 5272 (2004).

Table 13. Differential cross sections in units of 10<sup>-16</sup> cm<sup>2</sup>/sr, for elastic electron scattering from cyclo-C<sub>4</sub>F<sub>8</sub>. The ANU results are designated (A) and the Sophia results (S). For the ANU results the figures in parentheses represent the absolute error, expressed as a percentage, while for the Sophia data the estimated uncertainty is 15%. The figures at the base of each column are the integral elastic and elastic momentum transfer cross sections, for which the estimated uncertainties are 20%–25%.

Angle (deg)	Energy (eV)						
	1.5 (A)	1.5 (S)	2.0 (A)	2.0 (S)	2.6 (S)	3.0 (S)	4.0 (S)
10	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-
20	0.604(46)	1.534	1.266(39)	1.413	1.424	1.802	3.050
30	1.816(24)	1.623	0.823(17)	2.020	2.712	2.977	3.704
40	2.083(24)	2.455	2.511(17)	3.077	3.594	3.516	4.011
50	2.669(11)	2.705	3.682(9)	3.638	4.061	3.951	3.293
60	2.528(9)	2.838	2.668(7)	3.149	3.378	2.889	2.137
70	2.288(7)	2.398	2.021(7)	2.694	1.963	1.522	0.960
80	1.575(7)	2.009	1.238(7)	1.574	1.194	0.821	0.525
90	1.105(7)	1.338	0.662(7)	0.909	0.556	0.414	0.691
100	0.700(7)	0.914	0.365(7)	0.559	0.332	0.397	0.949
110	0.510(7)	0.642	0.295(7)	0.410	0.378	0.684	1.248
120	0.477(7)	0.593	0.389(7)	0.466	0.613	0.941	1.580
130	0.571(7)	0.693	0.605(6)	0.708	0.905	1.213	1.769
ICS	16.9	18.8	16.8	18.5	18.1	18.7	21.4

MTCS	12.5	14.0	10.8	12.1	11.0	12.9	16.6
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(continued)

Angle (deg)	Energy (eV)						
	5.0 (A)	5.0 (S)	6.0 (A)	7.0 (A)	8.0 (S)	10 (A)	10 (S)
10	-	-	-	-	-	-	-
15	-	-	8.451(36)	-	-	-	-
20	5.870(8)	5.703	8.305(8)	11.574(8)	12.021	15.486(13)	15.035
30	4.769(7)	4.480	6.891(7)	8.000(7)	9.142	8.782(12)	9.273
40	3.893(7)	3.947	4.669(7)	4.783(7)	4.826	3.465(12)	4.004
50	2.342(8)	2.454	2.679(7)	2.273(7)	2.068	1.330(8)	1.344
60	1.025(8)	1.212	1.146(7)	0.983(7)	0.995	1.360(6)	1.428
70	0.600(7)	0.701	0.829(6)	0.844(7)	1.344	1.840(6)	1.980
80	0.676(7)	0.803	0.920(6)	1.032(6)	1.511	1.885(7)	1.989
90	0.906(8)	0.936	1.020(6)	1.048(7)	1.542	1.558(6)	1.796
100	1.032(8)	1.111	0.966(7)	0.913(8)	1.218	1.316(7)	1.799
110	1.027(8)	1.301	0.883(7)	0.810(7)	1.267	1.295(7)	1.630
120	1.030(7)	1.182	0.879(8)	0.808(7)	1.262	1.363(8)	1.711
130	1.110(6)	1.311	0.948(6)	0.919(7)	1.430	1.540(7)	2.108
ICS	22.5	21.3	22.8	24.9	30.5	34.9	35.6
MTCS	14.2	16.2	11.9	13.3	18.5	21.5	22.3

(continued)

Angle (deg)	Energy (eV)						
	15 (A)	15 (S)	20 (A)	20 (S)	30 (S)	60 (S)	100 (S)
10	37.581(35)	-	47.398(7)	-	-	-	-
15	-	-	-	-	-	-	-
20	15.553(8)	15.908	15.956(7)	17.773	14.627	5.112	3.822
30	5.632(8)	6.280	2.880(7)	3.890	1.554	3.479	3.045
40	1.299(8)	1.568	0.990(7)	1.160	2.500	2.142	1.557
50	1.166(8)	1.279	1.812(6)	2.448	2.530	1.403	0.769
60	1.834(6)	2.045	2.016(8)	2.776	1.890	0.842	0.538
70	1.961(7)	2.663	1.725(7)	2.390	1.543	0.616	0.489
80	1.848(6)	2.290	1.452(7)	1.929	1.073	0.423	0.275
90	1.687(6)	2.112	1.167(7)	1.595	0.827	0.363	0.200

100	1.401(6)	1.865	1.020(6)	1.376	0.921	0.352	0.244
110	1.266(6)	1.758	1.088(7)	1.381	0.872	0.472	0.300
120	1.309(6)	1.600	1.302(7)	1.599	1.270	0.666	0.373
130	1.621(7)	2.022	1.780(7)	2.117	1.700	0.935	0.674
ICS	34.2	35.2	32.9	37.8	31.3	16.1	11.0
MTCS	19.0	21.6	17.2	20.4	15.6	6.21	3.68

## C<sub>2</sub>F<sub>4</sub>

Absolute cross sections for elastic scattering of electrons from C<sub>2</sub>F<sub>4</sub> have been determined in the energy range of 1.5–100 eV and over the scattering angles of 20–130°. The DCS were analyzed using a molecular phase-shift approach in order to extrapolate them to lower and higher angles, to facilitate derivation of the integral cross sections.

All these data are recommended in Table 14.

### Reference:

R. Panajotovic, M. Jelisavcic, R. Kajita, T. Tanaka, M. Kitajima, H. Cho, H. Tanaka and S. J. Buckman, *J. Chem. Phys.* **121** 4559 (2004).

Table 14. Differential cross sections for elastic electron scattering (in units of 10<sup>-16</sup> cm<sup>2</sup>/sr) and integral elastic (ICS) and elastic momentum transfer cross sections (MTCS), respectively (in units of 10<sup>-16</sup> cm<sup>2</sup>), from C<sub>2</sub>F<sub>4</sub>. The estimated uncertainty in the DCS data is 15%, whilst the uncertainty on the integral and momentum transfer cross sections is 20%–25%.

Angle (deg)	Energy (eV)							
	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0
20	0.596	0.539	0.781	0.842	1.487	2.455	2.388	3.149
30	0.399	0.356	0.627	0.950	1.587	2.477	2.301	2.698
40	0.250	0.287	0.701	0.969	1.621	2.263	1.965	2.058
50	0.247	0.346	0.802	1.091	1.555	1.880	1.521	1.572
60	0.330	0.392	0.756	0.954	1.211	1.323	1.083	1.048
70	0.352	0.417	0.719	0.755	0.911	0.928	0.873	0.966
80	0.393	0.435	0.589	0.537	0.652	0.725	0.700	0.867
90	0.412	0.367	0.563	0.480	0.579	0.672	0.683	0.882

100	0.433	0.343	0.501	0.409	0.529	0.580	0.607	0.809
110	0.410	0.320	0.440	0.385	0.479	0.528	0.594	0.788
120	0.413	0.306	0.402	0.348	0.427	0.531	0.661	0.845
130	0.366	0.286	0.410	0.349	0.511	0.621	0.803	0.955
ICS	4.55	4.34	7.13	7.73	10.1	13.1	10.5	14.4
MTCS	4.13	3.7	5.84	5.9	7.38	8.37	7.62	11.6

(continued)

Angle (deg)	Energy (eV)						
	9.0	10	15	20	30	60	100
20	3.427	4.594	7.896	8.781	9.537	6.75	2.800
30	2.981	3.312	4.233	3.866	2.970	1.440	1.290
40	2.168	2.428	2.373	1.815	1.298	0.940	0.645
50	1.600	1.605	1.365	1.173	1.064	0.642	0.332
60	1.166	1.222	1.085	1.101	0.911	0.437	0.229
70	1.049	1.022	0.981	0.934	0.753	0.245	0.185
80	0.922	0.979	0.830	0.861	0.543	0.202	0.157
90	1.014	0.896	0.808	0.660	0.387	0.177	0.114
100	0.913	0.869	0.711	0.54	0.332	0.172	0.106
110	0.840	0.852	0.711	0.578	0.446	0.221	0.140
120	0.935	0.896	0.771	0.795	0.558	0.328	0.205
130	1.104	1.053	0.983	1.034	0.773	0.441	0.288
ICS	16.8	19.4	18.7	20.8	16.9	12.2	5.43
MTCS	12.5	15.8	12.7	16.1	9.64	4.66	2.72

### C<sub>3</sub>F<sub>6</sub>

Absolute cross sections for elastic scattering of electrons from C<sub>3</sub>F<sub>6</sub> have been determined in the energy range of 1.5–100 eV and over the scattering angles of 15–130°. As before the DCS were analyzed using a molecular phase-shift approach in order to extrapolate them to lower and higher angles, to facilitate derivation of the integral cross sections.

All these data are recommended in Table 15.

**Reference:**

H. Cho, R. J. Gulley, K. Sunohara, M. Kitajima, L. J. Uhlmann, H. Tanaka and S. J. Buckman, *J. Phys. B: At. Mol. Opt. Phys.* **34** 1019 (2001).

Table 15. Differential cross sections for elastic electron scattering (in units of  $10^{-16}$  cm<sup>2</sup>/sr) and integral elastic (ICS) and elastic momentum transfer cross sections (MTCS), respectively (in units of  $10^{-16}$  cm<sup>2</sup>), from C<sub>3</sub>F<sub>6</sub>. The estimated uncertainty in the DCS data is 15%, whilst the uncertainty on the integral and momentum transfer cross sections is 20%–25%.

angle (deg)	Energy (eV)							
	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0
15	4.204	4.777	3.995	4.880	5.137	7.582	8.857	9.234
20	3.725	3.909	3.513	4.496	4.560	6.428	7.000	7.548
30	2.328	2.647	2.755	4.259	4.304	4.606	5.152	4.966
40	1.509	2.091	2.583	4.164	4.108	3.702	3.259	3.246
50	1.404	1.932	2.694	3.539	3.255	2.603	1.825	1.773
60	1.348	1.988	2.449	2.533	2.088	1.827	1.367	1.178
70	1.344	1.720	1.870	1.862	1.645	1.189	1.049	1.088
80	1.249	1.429	1.498	1.418	1.337	0.961	0.984	1.103
90	0.938	1.329	1.275	1.274	1.080	1.019	0.955	1.096
100	0.894	1.006	1.078	1.151	0.913	1.051	0.952	1.114
110	0.882	0.914	0.943	1.068	0.935	0.931	1.019	1.151
120	0.781	0.812	0.947	1.005	0.941	0.923	1.075	1.204
130	0.682	0.728	0.951	1.061	0.955	1.047	1.149	1.173
ICS	20.0	20.9	22.9	23.9	25.4	26.2	27.1	26.1
MTCS	18.4	19.6	20.2	21.5	22.4	24.4	25.2	24.9

(continued)

angle (deg)	Energy (eV)						
	9.0	10	15	20	30	60	100
15	12.060	13.570	17.965	20.224	25.496	15.944	9.357
20	9.358	10.923	13.295	12.190	12.480	5.249	3.750
30	6.080	6.483	5.788	4.181	2.704	2.068	2.095
40	3.305	3.288	2.542	1.832	1.662	1.462	1.171
50	1.704	1.830	1.588	1.602	1.556	0.986	0.476

60	1.454	1.460	1.551	1.581	1.578	0.589	0.387
70	1.305	1.634	1.561	1.472	1.202	0.393	0.319
80	1.469	1.644	1.462	1.376	0.722	0.311	0.185
90	1.367	1.481	1.284	1.093	0.516	0.271	0.142
100	1.280	1.452	1.153	0.830	0.560	0.237	0.157
110	1.267	1.351	1.042	0.966	0.666	0.321	0.214
120	1.300	1.313	1.120	1.214	0.848	0.543	0.305
130	1.290	1.560	1.588	1.558	1.175	0.704	0.394
ICS	29.1	29.7	28.3	28.9	28.3	14.1	10.4
MTCS	23.7	22.9	20.9	18.7	15.4	6.9	3.5

## C<sub>6</sub>F<sub>6</sub>

Absolute cross sections for elastic scattering of electrons from C<sub>6</sub>F<sub>6</sub> have been determined in the energy range of 1.5–100 eV and over the scattering angles of 20–130°. As before the DCS were analyzed using a molecular phase-shift approach in order to extrapolate them to lower and higher angles, to facilitate derivation of the integral cross sections.

All these data are recommended in Table 16.

### Reference:

H. Cho, R. J. Gulley, K. Sunohara, M. Kitajima, L. J. Uhlmann, H. Tanaka and S. J. Buckman, *J. Phys. B: At. Mol. Opt. Phys.* **34** 1019 (2001).

Table 16. Differential cross sections for elastic electron scattering (in units of 10<sup>-16</sup> cm<sup>2</sup>/sr) and integral elastic (ICS) and elastic momentum transfer cross sections (MTCS), respectively (in units of 10<sup>-16</sup> cm<sup>2</sup>), from hexafluorobenzene. The estimated uncertainty in the DCS data is 15%, whilst the uncertainty on the integral and momentum transfer cross sections is 25%.

Angle (deg)	Energy (eV)							
	1.5	3.0	5.0	8.0	10	15	20	30
20	9.534	5.695	6.330	17.310	17.990	27.230	23.960	13.140
30	5.130	3.103	3.731	5.023	8.583	8.649	6.193	2.601
40	2.706	1.917	2.382	2.208	3.201	2.941	2.553	1.290
50	1.612	1.412	1.498	1.024	1.915	1.480	1.585	1.230
60	1.123	1.174	1.047	0.851	1.713	1.422	1.932	1.502



70	0.840	0.904	0.760	1.059	1.346	1.993	2.217	1.185
80	0.690	0.736	0.727	0.927	1.391	2.276	1.984	0.655
90	0.588	0.685	0.733	0.931	1.554	1.828	1.288	0.525
100	0.472	0.608	0.856	1.125	1.708	1.519	1.104	0.602
110	0.515	0.643	0.908	1.378	1.820	1.628	1.570	0.695
120	0.602	0.694	0.967	1.463	1.824	2.308	2.108	0.841
130	0.762	1.129	1.185	1.646	1.938	2.371	2.128	1.286
ICS	21.75	18.60	21.51	30.98	41.09	51.62	48.01	32.65
MTCS	11.49	14.25	16.54	18.50	24.40	29.93	26.35	16.86

(continued)

Angle (deg)	Energy (eV)	
	60	100
20	6.583	2.594
30	2.374	1.918
40	2.065	1.095
50	1.416	0.418
60	0.658	0.464
70	0.386	0.379
80	0.428	0.218
90	0.425	0.179
100	0.367	0.189
110	0.364	0.217
120	0.493	0.319
130	0.779	0.402
ICS	24.26	9.04
MTCS	11.58	5.63

### **CH<sub>3</sub>F**

Absolute cross sections for elastic scattering of electrons from CH<sub>3</sub>F have been determined in the energy range of 1.5–100 eV and over the scattering angles of 15–130°.

All these data are recommended in Table 17.

**Reference:**

Márcio T., N. Varella, C. Winstead, V. Mckoy, M. Kitajima and H. Tanaka, *Phys. Rev. A* **65** 022702 (2002).

Table 17. Differential cross sections ( $10^{-16}$  cm<sup>2</sup>/sr) for elastic scattering from CH<sub>3</sub>F. Their absolute uncertainties are 15%.

Angle (deg)	Energy (eV)							
	1.5	2.0	3.0	4.0	5.0	6.5	7.0	8.0
15	-	-	-	-	-	-	-	-
20	14.1540	9.8276	7.4441	6.0525	7.0843	7.7898	8.0992	7.8911
30	7.1874	5.6562	4.0018	3.4945	4.1983	4.4785	4.6517	5.0518
40	3.8364	3.1210	2.1882	2.1424	2.3673	2.9357	2.8488	3.0756
50	2.2522	2.1132	1.3786	1.5485	1.6474	1.8061	1.7177	1.8000
60	1.6898	1.4086	1.1454	1.2539	1.4041	1.2465	1.3696	1.2924
70	1.0707	1.0683	1.1635	1.2975	1.2625	1.1107	1.1556	1.0046
80	0.9570	1.0478	1.1553	1.3416	1.3097	1.2281	1.1426	1.0010
90	0.8825	0.8323	1.1215	1.2426	1.4064	1.4072	1.2777	1.1234
100	0.7660	0.8923	1.0984	1.2070	1.3022	1.3379	1.2877	1.2020
110	0.7705	0.8579	1.0003	1.0502	1.2825	1.2004	1.3155	1.2724
120	0.7196	0.7659	0.9292	0.8941	1.1856	1.1851	1.2422	1.1599
130	0.6702	0.6979	0.7637	0.9579	1.0813	1.1207	1.2399	1.2863

(continued)

Angle (deg)	Energy (eV)						
	9.0	10	15	20	30	60	100
15	-	9.9915	9.7406	10.363	10.201	7.2117	2.5456
20	3.3488	8.2624	8.5840	7.6735	7.9241	4.0624	1.0977
30	5.0519	5.1938	4.7734	4.1405	3.1670	0.9253	0.2859
40	2.9920	1.3046	2.5443	2.1341	1.3697	0.4905	0.2521
50	1.8140	1.8203	1.5009	1.1827	0.6134	0.3519	0.2197
60	1.1114	1.0767	0.9337	0.7440	0.4983	0.2501	0.1489
70	0.8962	0.8114	0.6601	0.6409	0.4755	0.1414	0.0878
80	0.8893	0.7719	0.6260	0.5804	0.3436	0.1150	0.0629
90	0.8997	0.9428	0.6139	0.5165	0.2329	0.0744	0.0505

100	1.0631	1.0123	0.6384	0.3976	0.1874	0.0663	0.0552
110	1.1124	1.0556	0.6392	0.4287	0.2004	0.0799	0.0731
120	1.2329	1.0469	0.6743	0.4397	0.2955	0.1354	0.1071
130	1.1841	1.1701	0.7566	0.5727	0.3968	0.1906	0.1114

## CH<sub>2</sub>F<sub>2</sub>

Absolute cross sections for elastic scattering of electrons from CH<sub>2</sub>F<sub>2</sub> have been determined in the energy range of 1.5–100 eV and over the scattering angles of 15–130°.

All these data are recommended in Table 18.

### Reference:

Márcio T., N. Varela, C. Winstead, V. Mckoy, M. Kitajima and H. Tanaka, *Phys. Rev. A* **65** 022702 (2002).

Table 18. Differential cross sections ( $10^{-16}$  cm<sup>2</sup>/sr) for elastic scattering from CH<sub>2</sub>F<sub>2</sub>. Their absolute uncertainties are 15%.

Angle (deg)	Energy (eV)							
	1.5	2.0	3.0	4.0	5.0	6.5	7.0	8.0
15	-	-	-	-	-	-	-	-
20	21.3310	16.2830	11.5580	9.0750	9.7206	8.8760	8.4820	8.3492
30	8.5640	6.8560	5.6684	4.8670	4.4180	4.4710	4.9131	5.1217
40	4.6070	4.1600	3.6126	2.8320	3.0815	2.8070	3.5260	3.1706
50	2.8370	2.5047	2.2076	1.9440	2.0835	2.0618	2.1745	2.0621
60	1.9590	1.7140	1.8537	1.4480	1.4515	1.3635	1.3946	1.4373
70	1.6460	1.2980	1.3511	1.0850	0.9725	0.8670	0.8886	0.9045
80	1.2560	1.0820	0.9557	0.8350	0.7247	0.6164	0.6223	0.5381
90	1.1860	1.0637	0.9048	0.7271	0.6829	0.6441	0.6435	0.6352
100	0.9826	0.9339	0.7467	0.6775	0.6159	0.6132	0.6592	0.7877
110	0.9461	0.9448	0.7187	0.7262	0.6490	0.7416	0.8139	0.9840
120	0.9439	0.8562	0.7729	0.7282	0.8211	0.9898	0.9314	0.9863
130	0.9639	0.8741	0.8330	0.8820	0.9830	1.0857	1.0451	1.2380

(continued)

Angle (deg)	Energy (eV)						
	9.0	10	15	20	30	60	100
15	-	13.0880	11.872	-	12.2110	8.3641	3.0323
20	8.1393	10.0440	9.2324	9.0980	7.5670	4.4855	1.6570
30	4.9203	5.0470	4.5488	4.6290	2.8768	1.3501	0.6164
40	2.9339	2.8850	2.3204	2.0610	1.3866	0.6615	0.4509
50	1.9643	1.9130	1.4704	1.2640	0.6873	0.4951	0.3159
60	1.3768	1.2522	0.9873	1.0000	0.6541	0.2972	0.1993
70	0.7684	0.7654	0.6998	0.8349	0.6490	0.2028	0.1134
80	0.6600	0.7691	0.7558	0.7447	0.4273	0.1476	0.0678
90	0.7528	0.7563	0.7162	0.6768	0.2597	0.1084	0.0596
100	0.8472	0.8092	0.8178	0.5402	0.1939	0.1058	0.0841
110	1.0161	1.0320	0.7121	0.5804	0.2545	0.1141	0.0946
120	1.0991	1.1034	0.8297	0.6617	0.3280	0.2147	0.1267
130	1.2089	1.0930	0.8445	0.7382	0.5917	0.3238	0.1866

### CHF<sub>3</sub>

Absolute cross sections for elastic scattering of electrons from CHF<sub>3</sub> have been determined in the energy range of 1.5–100 eV and over the scattering angles of 15–130°.

All these data are recommended in Table 19.

#### **Reference:**

Márcio T., N. Varella, C. Winstead, V. Mckoy, M. Kitajima and H. Tanaka, *Phys. Rev. A* **65** 022702 (2002).

Table 19. Differential cross sections ( $10^{-16}$  cm<sup>2</sup>/sr) for elastic scattering from CHF<sub>3</sub>. Their absolute uncertainties are 15%.

Angle (deg)	Energy (eV)							
	1.5	2.0	3.0	4.0	5.0	6.5	7.0	8.0
15	-	-	-	-	-	-	-	-
20	9.6869	7.5023	5.4249	6.7053	6.7146	6.4416	6.4840	6.5110

25	6.9478	5.7449	-	-	-	-	-	-
30	6.0904	4.8100	3.8389	4.1436	4.0816	4.6603	4.4950	4.1289
35	4.4904	3.8554	-	-	-	-	-	-
40	4.0253	3.2733	3.1524	3.1566	3.1587	3.3108	3.1550	3.1992
45	3.3327	2.7083	-	-	-	-	-	-
50	3.2382	2.4114	2.2942	2.4882	2.5785	2.4440	2.1730	2.7750
55	2.7542	-	-	-	-	-	-	-
60	2.4263	2.1154	2.0532	2.0347	2.0618	1.7840	1.5492	1.3405
65	2.1290	-	-	-	-	-	-	-
70	1.9364	1.8134	1.5601	1.6556	1.4514	1.2392	1.0041	0.9010
80	1.6762	1.5821	1.3502	1.3835	1.1383	0.8841	0.6806	0.6028
90	1.6596	1.4240	1.1844	1.0640	0.8284	0.5768	0.5668	0.5356
100	1.2772	1.2108	1.0814	0.8631	0.6731	0.4882	0.4707	0.5301
110	1.1922	1.0968	0.9240	0.7209	0.5561	0.5272	0.5313	0.5243
120	1.0928	1.0080	0.8603	0.6441	0.5409	0.5442	0.6051	0.6241
130	1.0524	0.9638	0.7440	0.6087	0.6297	0.7722	0.7365	0.7556

(continued)

Angle (deg)	Energy (eV)						
	9.0	10	15	20	30	60	100
15	-	-	8.4548	9.5002	12.1410	11.9050	6.6705
20	6.5873	7.3083	6.2872	7.2141	8.6783	6.8642	3.7217
25	-	-	-	-	-	-	-
30	4.7737	4.7163	4.2750	3.8040	3.4654	1.5453	0.9134
35	-	-	-	-	-	-	-
40	3.2033	3.2311	2.6826	2.0897	1.1538	0.7087	0.6237
45	-	-	-	-	-	-	-
50	2.2542	2.1301	1.6188	1.1224	0.7951	0.7031	0.3117
55	-	-	-	-	-	-	-
60	1.4336	1.3653	1.0298	0.7820	0.7492	0.4744	0.1915
65	-	-	-	-	-	-	-
70	0.8992	0.8555	0.7528	0.8545	0.7682	0.2643	0.1724
80	0.6296	0.6595	0.8004	0.8357	0.5775	0.1533	0.1286
90	0.6331	0.6376	0.7544	0.7317	0.3213	0.1304	0.0864
100	0.5809	0.6808	0.7628	0.5666	0.2219	0.1255	0.0849

110	0.6149	0.7013	0.7915	0.5301	0.2873	0.1596	0.1053
120	0.6619	0.7507	0.7513	0.5853	0.4531	0.2845	0.1615
130	0.8209	0.8503	0.8633	0.7619	0.6315	0.3845	0.2268

### **NF<sub>3</sub>**

Absolute cross sections for elastic scattering of electrons from NF<sub>3</sub> have been determined in the energy range of 1.5–100 eV and over the scattering angles of 15–130°. The DCS were analyzed using a phase-shift approach in order to extrapolate them to lower and higher angles, to facilitate derivation of the integral cross sections.

All these data are recommended in Table 20.

### **Reference:**

L. Boesten, Y. Tachibana, Y. Nakano, T. Shinohara, H. Tanaka and M. A. Dillon, *J. Phys. B: At. Mol. Opt. Phys.* **29** 5475 (1996).

Table 20. Differential cross sections for elastic electron scattering (in units of 10<sup>-16</sup> cm<sup>2</sup>/sr) and integral elastic (ICS) and elastic momentum transfer cross sections (MTCS), respectively (in units of 10<sup>-16</sup> cm<sup>2</sup>), from NF<sub>3</sub>. The estimated uncertainty in the DCS data is 15%, whilst the uncertainty on the integral and momentum transfer cross sections is 20%–25%.

angle (deg)	Energy (eV)							
	1.5	2.0	3.0	4.0	5.0	7.0	7.5	8
15	—	—	—	—	—	—	—	—
20	0.933	1.430	2.199	2.960	2.729	2.671	2.896	2.908
30	0.667	1.216	2.436	2.949	2.807	2.932	3.036	3.132
40	0.656	1.078	2.331	2.822	2.577	2.868	2.731	2.699
50	0.729	1.197	2.052	2.511	2.119	2.123	2.224	2.115
60	0.787	1.152	1.768	1.818	1.552	1.655	1.517	1.460
70	0.962	1.074	1.329	1.297	1.261	1.137	1.108	1.209
80	0.981	1.100	1.114	1.099	0.947	0.808	0.851	0.868
90	1.097	1.011	0.920	0.794	0.714	0.727	0.719	0.766
100	1.053	0.884	0.685	0.640	0.641	0.663	0.704	0.702
110	0.998	0.843	0.598	0.542	0.622	0.666	0.704	0.707
120	0.992	0.778	0.584	0.539	0.637	0.652	0.661	0.639

130	0.920	0.723	0.576	0.604	0.765	0.655	0.645	0.623
ICS	11.90	12.98	17.24	18.41	18.11	17.35	17.47	17.89
MTCS	12.46	12.39	14.24	14.92	14.92	14.24	14.17	12.82

(Continued)

angle (deg)	Energy (eV)							
	10	15	20	25	30	50	60	100
15	3.323	4.641	6.890	9.051	10.710	12.330	11.200	9.000
20	3.168	3.946	5.006	6.490	6.946	6.715	5.955	3.201
30	3.037	3.077	2.777	2.863	2.657	1.838	1.243	0.851
40	2.680	2.107	1.680	1.358	1.004	0.666	0.671	0.623
50	1.934	1.271	0.934	0.742	0.616	0.621	0.537	0.340
60	1.390	0.826	0.750	0.688	0.639	0.601	0.328	0.195
70	0.954	0.715	0.799	0.747	0.671	0.340	0.232	0.156
80	0.737	0.725	0.798	0.665	0.509	0.196	0.155	0.116
90	0.702	0.786	0.715	0.510	0.320	0.116	0.109	0.067
100	0.694	0.738	0.569	0.322	0.191	0.093	0.093	0.073
110	0.673	0.610	0.462	0.295	0.200	0.146	0.152	0.108
120	0.626	0.555	0.561	0.440	0.376	0.314	0.265	0.169
130	0.605	0.598	0.746	0.725	0.623	0.483	0.378	0.273
ICS	16.91	14.60	14.48	14.05	13.33	12.32	11.03	9.72
MTCS	13.53	10.41	9.87	8.54	7.63	6.62	5.81	5.42

## SF<sub>6</sub>

The interaction of low-energy electrons with SF<sub>6</sub> has been the subject of numerous experimental and theoretical studies, due to its involvement in plasma discharge processes and as the most commonly used insulating gas in the electrical industry. SF<sub>6</sub> is a non-polar molecule and has a high polarizability of 44 au. Absolute elastic differential cross sections have been measured at 11 different energies ranging from 2.7 eV to 75 eV including at several resonant energies. The magnetic angle-changing device was employed in conjunction with a spectrometer to measure the cross sections to backward angles at low impact energies. At higher impact energies, there is a heating problem caused by the high electric current flowing through the coils, required to deflect the high-energy electron beam. All these data are recommended in Table 21.

**Reference:**

H. Cho, R. J. Gulley, K. W. Trantham, L. J. Uhlmann, C. J. Dedman and S. J. Buckman, *J. Phys. B: At. Mol. Opt. Phys.* **33** 3531 (2000).

Table 21. Differential cross sections (in units of  $10^{-16} \text{ cm}^2 \text{ sr}^{-1}$ ) for elastic electron scattering from SF<sub>6</sub>. The experimental uncertainties on each measured point are indicated in the table as a percentage.

Angle (deg)	Energy (eV)				
	2.7	5.0	7.0	8.5	10
15	-	-	5.896(8)	8.500(11)	11.168(7)
20	1.949(13)	3.939(11)	7.899(7)	8.823(9)	8.892(7)
25	1.990(8)	4.225(7)	6.843(7)	7.720(7)	7.558(8)
30	2.336(7)	4.001(8)	5.899(7)	6.404(7)	6.236(7)
35	2.467(7)	3.827(8)	4.893(7)	5.201(8)	4.811(7)
40	2.516(8)	3.597(7)	3.988(7)	3.893(7)	3.507(7)
45	2.506(8)	3.143(8)	2.995(7)	2.811(7)	2.517(7)
50	2.401(8)	2.819(9)	2.201(7)	2.066(7)	1.708(8)
55	2.184(8)	2.329(7)	1.550(7)	1.442(7)	1.189(7)
60	2.049(7)	1.894(7)	1.107(7)	1.089(7)	1.028(7)
65	1.787(7)	1.422(8)	0.873(7)	0.953(7)	0.982(7)
70	1.539(7)	1.150(7)	0.802(7)	0.941(7)	1.091(8)
75	1.405(7)	0.907(9)	0.842(7)	1.073(7)	1.263(7)
80	1.199(7)	0.825(8)	1.002(7)	1.263(7)	1.456(9)
85	1.077(8)	0.795(7)	1.153(7)	1.317(8)	1.531(8)
90	0.969(8)	0.884(8)	1.288(7)	1.391(8)	1.516(9)
95	0.906(8)	0.960(9)	1.388(7)	1.385(7)	1.413(12)
100	0.935(8)	1.124(8)	1.420(7)	1.345(7)	1.244(8)
105	0.981(8)	1.229(7)	1.397(7)	1.217(7)	1.067(8)
110	1.037(7)	1.268(9)	1.296(7)	1.069(8)	0.952(7)
115	1.057(7)	1.254(8)	1.165(8)	0.945(7)	0.831(7)
120	1.099(8)	1.231(9)	1.048(7)	0.816(7)	0.771(8)
125	1.236(7)	1.150(11)	0.909(7)	0.745(7)	0.779(7)
130	1.311(7)	1.016(9)	0.810(7)	0.830(12)	0.846(8)
135	1.351(7)	0.956(8)	0.977(7)	0.956(7)	0.916(7)
140	1.372(7)	0.908(8)	0.999(7)	0.995(7)	0.999(8)



145	1.402(8)	0.792(8)	1.006(7)	1.072(8)	1.113(7)
150	1.415(7)	0.744(9)	1.110(7)	1.233(7)	1.173(7)
155	1.390(7)	0.703(8)	1.235(7)	1.305(8)	1.247(7)
160	1.485(7)	0.641(7)	1.288(7)	1.467(8)	1.306(7)
165	1.486(7)	0.606(7)	1.395(8)	1.571(9)	1.357(7)
170	1.485(7)	0.576(8)	1.467(7)	1.618(8)	1.369(7)
175	1.499(7)	0.572(7)	1.512(7)	1.706(7)	1.440(7)
180	1.500(7)	0.535(9)	1.542(7)	1.775(7)	1.473(8)

(Continued)

Angle (deg)	Energy (eV)					
	12	15	20	30	50	75
10	13.788(17)	-	23.711(8)	55.574(8)	49.457(7)	45.477(8)
15	15.218(8)	12.994(7)	15.656(7)	23.329(7)	24.678(7)	15.422(8)
20	12.415(7)	11.128(7)	10.983(9)	13.255(7)	9.672(8)	4.414(9)
25	9.312(7)	8.699(7)	7.988(7)	6.916(7)	3.510(8)	1.369(13)
30	6.651(7)	6.652(7)	5.246(8)	3.307(7)	1.606(8)	1.230(8)
35	4.511(7)	4.649(7)	3.228(10)	1.573(7)	1.295(8)	1.379(10)
40	2.911(8)	3.046(7)	1.867(7)	0.988(7)	1.376(8)	1.326(10)
45	1.724(7)	1.837(7)	1.002(9)	0.993(7)	1.378(7)	0.965(8)
50	1.104(7)	1.126(7)	0.703(9)	1.266(7)	1.159(10)	0.670(8)
55	0.748(7)	0.839(7)	0.740(9)	1.369(7)	1.038(8)	0.478(8)
60	0.677(8)	0.869(7)	0.984(9)	1.430(7)	0.758(10)	0.340(8)
65	0.737(8)	1.053(7)	1.331(11)	-	0.533(11)	0.298(8)
70	0.858(8)	1.246(7)	1.433(10)	1.052(8)	0.342(9)	0.274(10)
75	0.994(8)	1.393(7)	1.500(8)	-	0.236(9)	0.262(10)
80	1.088(8)	1.403(7)	1.343(7)	0.655(8)	0.180(12)	0.248(12)
85	1.103(8)	1.308(7)	1.128(8)	-	0.199(9)	0.231(9)
90	1.168(7)	1.218(7)	1.011(8)	0.402(7)	0.234(9)	0.214(11)
95	1.193(8)	1.069(7)	0.823(9)	-	0.283(8)	0.218(14)
100	1.132(8)	0.974(8)	0.690(7)	0.473(7)	0.316(9)	0.194(8)
105	1.095(7)	0.864(7)	0.596(8)	-	0.320(10)	0.182(9)
110	1.117(7)	0.791(7)	0.611(8)	0.643(8)	0.348(10)	0.210(10)
115	1.210(8)	0.778(7)	0.602(8)	-	0.389(11)	0.262(13)
120	1.376(8)	0.765(7)	0.669(8)	0.873(7)	0.420(10)	0.356(10)
125	1.450(7)	0.811(7)	0.811(9)	-	0.469(11)	0.472(11)

130	1.544(7)	0.867(7)	0.933(7)	1.098(7)	0.583(12)	0.632(13)
135	1.566(7)	0.971(7)	-	-	-	-
140	1.616(7)	1.118(7)	-	-	-	-
145	1.651(7)	1.257(7)	-	-	-	-
150	1.686(7)	1.353(7)	-	-	-	-
155	1.711(7)	1.495(8)	-	-	-	-
160	1.758(7)	1.652(7)	-	-	-	-
165	1.752(8)	1.774(7)	-	-	-	-
170	1.829(8)	1.915(7)	-	-	-	-
175	1.862(7)	1.940(7)	-	-	-	-
180	1.843(7)	1.973(7)	-	-	-	-

### SiH<sub>4</sub>

Absolute cross sections for elastic scattering of electrons from SiH<sub>4</sub> have been determined in the energy range of 1.8–100 eV and over the scattering angles of 10–130°. The DCS were then analyzed using a molecular phase-shift approach in order to extrapolate them to lower and higher angles, to facilitate derivation of the integral cross sections.

All these data are recommended in Table 22.

### **Reference:**

H. Tanaka, L. Boesten, H. Sato, M. Kimura, M. A. Dillon and D. Spence, *J. Phys. B: At. Mol. Opt. Phys.* **23** 577 (1990).

Table 22. Differential cross sections for elastic electron scattering (in units of 10<sup>-16</sup> cm<sup>2</sup>/sr) and integral elastic (ICS) and elastic momentum transfer cross sections (MTCS), respectively (in units of 10<sup>-16</sup> cm<sup>2</sup>), from SiH<sub>4</sub>. The absolute uncertainties on the DCS are 15%, while the uncertainties on the ICS and MTCS are in the range of 20 to 30%.

Angle (deg)	Energy (eV)							
	1.8	2.15	2.65	3.0	4.0	5.0	7.5	10
10	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-
20	3.352	4.243	5.166	7.407	11.221	13.490	18.709	19.985
30	2.861	4.233	5.858	6.459	11.032	12.450	17.061	15.271

40	1.870	3.058	4.818	5.587	7.980	9.524	10.870	7.998
50	1.073	2.056	3.365	3.702	5.580	6.696	6.403	4.227
60	1.080	1.575	2.477	2.723	3.423	3.994	3.467	2.091
70	1.340	1.853	2.331	2.309	2.144	2.283	1.855	0.990
80	2.017	2.370	2.466	2.360	1.828	1.655	1.344	0.936
90	3.064	3.058	2.686	2.670	1.525	1.524	1.490	1.334
100	3.019	2.990	2.844	2.605	1.563	1.578	1.801	1.400
110	2.359	2.581	2.458	2.325	1.517	1.432	1.966	1.370
120	1.771	2.163	2.036	1.831	1.333	1.432	1.709	1.150
130	1.458	1.806	1.861	1.729	1.475	1.552	1.521	0.892
ICS	27.5	31.6	34.8	36.5	40.1	44.4	49.9	39.4
MTCS	29.0	30.1	29.1	28.1	24.5	25.6	24.4	15.8

(continued)

Angle (deg)	Energy (eV)			
	15	20	40	100
10	23.473	23.48	35.644	10.11
15	21.948	19.857	17.68	4.165
20	18.028	15.426	9.891	1.684
30	10.248	7.035	2.447	0.509
40	4.657	2.708	0.734	0.277
50	1.917	0.891	0.364	0.127
60	0.699	0.423	0.255	0.0915
70	0.478	0.426	0.227	0.101
80	0.612	0.540	0.229	0.0923
90	0.750	0.519	0.276	0.0599
100	0.768	0.415	0.241	0.0268
110	0.612	0.326	0.196	0.00941
120	0.400	0.209	0.131	0.0192
130	0.244	0.147	0.0943	0.0461
ICS	28.7	20.7	14.0	4.3
MTCS	11.2	8.7	2.9	1.2

## Si<sub>2</sub>H<sub>6</sub>

Absolute cross sections for elastic scattering of electrons from Si<sub>2</sub>H<sub>6</sub> have been determined in the energy range of 2–100 eV and over the scattering angles of 10–130°. These DCS were analyzed using a molecular phase-shift approach in order to extrapolate them to lower and higher angles, to facilitate derivation of the integral cross sections.

All these data are recommended in Table 23.

### Reference:

M. A. Dillon, L. Boesten, H. Tanaka, M. Kimura and H.Sato, *J. Phys. B: At. Mol. Opt. Phys.* **27** 1209 (1994).

Table 23. Differential cross sections for elastic electron scattering (in units of 10<sup>-16</sup> cm<sup>2</sup>/sr) and integral elastic (ICS) and elastic momentum transfer cross sections (MTCS), respectively (in units of 10<sup>-16</sup> cm<sup>2</sup>), from Si<sub>2</sub>H<sub>6</sub>. The estimated uncertainty in the DCS data is 15%–20%, whilst the uncertainty on the integral and momentum transfer cross sections is 30%.

Angle (deg)	Energy (eV)							
	2.0	3.0	4.0	5.0	7.5	10	15	20
10	-	-	-	-	-	40.54	68.49	80.82
20	18.165	15.02	18.05	21.42	29.46	32.41	36.03	32.96
30	7.681	12.31	15.83	17.52	16.23	15.29	13.66	9.716
40	5.845	9.025	10.70	10.16	7.56	6.445	4.257	3.477
50	3.482	5.444	5.181	4.705	3.404	2.774	2.409	2.138
60	2.913	3.213	3.337	2.885	2.389	2.065	1.758	1.215
70	2.911	3.271	3.016	2.689	2.528	2.025	1.224	0.741
80	2.639	3.131	3.107	3.115	3.174	1.859	0.982	0.701
90	2.685	3.331	2.775	2.890	2.715	1.713	1.035	0.751
100	2.489	3.498	2.802	2.638	2.373	1.518	1.102	0.661
110	2.462	3.486	3.142	2.762	2.175	1.339	0.958	0.410
115	-	-	-	-	-	-	-	-
120	2.399	4.344	3.311	2.543	1.860	1.333	0.656	0.277
125	-	-	-	-	-	-	-	-
130	2.378	4.459	3.459	2.536	1.609	1.418	0.410	0.238
ICS	49.3	82.8	83.2	83.1	68.8	61.4	54.6	50.0

MTCS	38.0	62.6	53.1	44.4	35.4	30.3	16.5	10.7
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(continued)

Angle (deg)	Energy (eV)	
	40	100
10	63.36	26.00
20	10.33	2.218
30	1.955	0.8952
40	0.9451	0.4386
50	0.380	0.1936
60	0.313	0.1420
70	0.267	0.1626
80	0.245	0.1583
90	0.245	0.08568
100	0.247	0.03399
110	0.218	0.01414
115	-	0.0135
120	0.141	0.01846
125	-	0.04159
130	0.141	0.068
ICS	23.7	9.6
MTCS	4.7	1.7

### GeH<sub>4</sub>

Absolute cross sections for elastic scattering of electrons from GeH<sub>4</sub> have been determined in the energy range of 1–100 eV and over the scattering angles of 10–130°. The DCS were analyzed using a phase-shift approach in order to extrapolate them to lower and higher angles, to facilitate derivation of the integral cross sections.

All these data are recommended in Table 24.

### **Reference:**

M. A. Dillon, L. Boesten, H. Tanaka, M. Kimura and H. Sato, *J. Phys. B: At. Mol. Opt. Phys.* **26** 3147 (1993).

Table 24. Differential cross sections for elastic electron scattering (in units of  $10^{-16}$  cm<sup>2</sup>/sr) and integral elastic (ICS) and elastic momentum transfer cross sections (MTCS), respectively (in units of  $10^{-16}$  cm<sup>2</sup>), from GeH<sub>4</sub>. The absolute uncertainties on the DCS are 15%–20%, while the uncertainties on the ICS and MTCS are in the range of 20 to 30%

Angle (deg)	Energy (eV)							
	1.0	2.0	2.5	3.0	5.0	7.5	10	15
10	-	-	-	-	-	-	28.21	32.22
20	1.835	3.655	4.47	6.991	15.81	17.49	19.24	20.11
30	0.9723	2.470	2.732	5.271	11.660	12.560	12.830	10.230
40	0.4523	1.629	2.088	4.056	8.195	8.734	7.117	4.206
45	-	-	-	-	-	-	-	-
50	0.2067	1.249	1.650	2.664	4.624	4.644	3.856	1.639
55	-	-	-	-	-	-	-	-
60	0.3381	1.419	1.735	2.180	2.801	2.619	1.804	0.815
65	-	-	-	-	-	-	-	-
70	0.6484	1.863	2.052	2.175	2.110	1.705	1.050	0.724
75	-	-	-	-	-	-	-	-
80	0.9420	2.475	2.636	2.369	1.989	1.379	1.077	0.630
85	-	-	-	-	-	-	-	-
90	0.9632	2.612	2.573	2.820	1.773	1.439	1.129	0.597
95	-	-	-	-	-	-	-	-
100	0.9854	2.507	2.338	2.314	1.894	1.547	1.079	0.491
105	-	-	-	-	-	-	-	-
110	0.6952	1.835	1.859	1.835	1.716	1.519	1.019	0.376
115	-	-	-	-	-	-	-	-
120	0.4742	1.359	1.487	1.442	1.341	1.369	0.848	0.311
125	-	-	-	-	-	-	-	-
130	0.3256	1.222	1.422	1.431	1.387	1.176	0.679	0.244
ICS	8.40	26.45	28.76	34.07	45.48	43.40	39.42	30.14
MTCS	7.11	26.03	27.31	27.67	26.87	21.72	18.54	11.48

(continued)

Angle (deg)	Energy (eV)		
	20	60	100
10	20.04	16.95	—
20	19.20	3.536	2.063
30	7.094	0.416	0.376
40	2.227	0.253	0.281
45	—	0.239	0.230
50	0.680	0.263	0.192
55	0.235	0.235	0.191
60	0.463	0.205	0.168
65	—	0.183	0.163
70	0.461	0.142	0.121
75	—	0.113	0.0736
80	0.416	0.0871	0.0449
85	—	0.0603	0.0234
90	0.293	0.0505	0.0216
95	—	0.0354	0.0297
100	0.19	0.0267	0.0625
105	—	0.0325	0.0956
110	0.139	0.0368	0.113
115	—	0.0479	0.144
120	0.125	0.0528	0.116
125	—	0.0509	0.106
130	0.14	0.0438	0.0965
ICS	23.63	7.47	6.36
MTCS	6.52	1.44	1.60

## C. Environmental Issues-Related Gases

### CF<sub>3</sub>Cl, CF<sub>3</sub>Br, and CF<sub>3</sub>I

Absolute differential cross sections for elastic scattering of electrons from CF<sub>3</sub>Cl, CF<sub>3</sub>Br, and CF<sub>3</sub>I have been determined in the energy range of 0.7–100 eV and over the scattering angular range of 15–130°. CF<sub>3</sub>X (X = Cl, Br, I) are fluoromethane molecules in which one fluorine atom is replaced with a halogen atom. This series of molecules has both fundamental importance and applications ranging from the depletion of the ozone layer to plasmas. CF<sub>3</sub>Cl is more heavily studied than any other halofluorocarbon. In a molecule with a permanent dipole moment, the long-range electron-dipole interaction dominates the scattering at low energies and small scattering angles. The permanent dipole moments of CF<sub>3</sub>Cl, CF<sub>3</sub>Br, and CF<sub>3</sub>I which we will now discuss below, are 0.5 D, 0.65 D, and 1.05 D, respectively, i.e. about the same magnitude with each other, and small compared with other polar molecules in the series. Therefore, we can expect that they might share similar qualitatively behavior in their cross sections.

The data for CF<sub>3</sub>Cl is presented in Table 25, while those for CF<sub>3</sub>Br and CF<sub>3</sub>I are given as follows in Tables 26 and 27, respectively.

#### References:

- K. Sunohara, M. Kitajima, H. Tanaka, M. Kimura and H. Cho, *J. Phys. B: At. Mol. Opt. Phys.* **36** 1843 (2003).
- M. Kitajima, M. Okamoto, K. Sunohara, H. Tanaka, H. Cho, S. Samukawa, S. Eden and N. J. Mason, *J. Phys. B: At. Mol. Opt. Phys.* **35** 3257 (2002).

Table 25. Differential cross sections (in units of  $10^{-16}$  cm<sup>2</sup> sr<sup>-1</sup>) for elastic electron scattering from CF<sub>3</sub>Cl. Experimental errors are estimated to be in the range 15–20%.

Angle (deg)	Energy (eV)				
	1.5	2.0	3.0	5.0	8.0
15	2.77	3.27	2.18	6.38	10.85
20	2.09	3.00	2.15	5.77	9.92
30	1.77	2.73	2.45	4.94	8.98
40	1.60	2.58	2.72	4.30	6.82



50	1.71	2.66	2.54	3.68	3.65
60	1.80	2.57	2.37	2.82	2.14
70	1.88	2.36	2.06	2.00	1.51
80	1.82	2.11	1.52	1.48	1.31
90	1.63	1.88	1.16	1.21	1.46
100	1.41	1.50	0.92	1.03	1.35
110	1.15	1.33	0.78	0.93	1.10
120	0.92	1.23	0.75	0.88	0.82
130	0.71	1.30	0.77	0.89	0.87

(continued)

Angle (deg)	Energy (eV)				
	10	20	30	60	100
15	19.86	15.48	19.46	17.68	8.88
20	16.17	11.42	11.16	6.62	2.83
30	8.11	5.03	3.20	1.53	1.56
40	4.34	1.95	1.42	1.38	0.87
50	2.10	1.27	1.37	0.75	0.37
60	1.17	1.22	1.13	0.36	0.26
70	1.08	1.09	0.69	0.26	0.25
80	1.44	0.83	0.53	0.24	0.20
90	1.36	0.75	0.61	0.28	0.19
100	1.21	0.91	0.61	0.29	0.17
110	0.87	0.92	0.64	0.28	0.14

120	0.78	0.84	0.63	0.34	0.15
130	1.10	0.80	0.65	0.38	0.23

### **CF<sub>3</sub>Br**

Table 26. Differential cross sections (in units of  $10^{-16} \text{ cm}^2 \text{ sr}^{-1}$ ) for elastic electron scattering from CF<sub>3</sub>Br. Experimental errors are estimated to be in the range 15–20%.

Angle (deg)	Energy (eV)						
	0.7	1.1	1.5	2.0	3.0	4.0	5.0
15	7.00	3.72	2.88	2.16	2.93	6.29	10.83
20	6.78	3.36	2.31	2.00	2.47	4.96	9.25
30	4.71	2.50	2.11	1.96	2.78	4.27	7.51
40	3.37	2.18	2.29	2.32	3.17	4.00	5.52
50	2.70	2.15	2.21	2.59	3.39	4.16	4.36
60	2.50	2.21	2.35	2.78	3.20	3.67	3.18
70	2.39	2.14	2.20	2.30	2.58	2.82	2.22
80	2.38	2.10	1.85	1.83	1.95	2.08	1.86
90	2.34	2.02	1.62	1.41	1.31	1.49	1.65
100	2.17	1.87	1.53	1.13	0.98	1.08	1.35
110	2.04	1.82	1.32	0.95	0.73	0.98	1.20
120	2.11	1.71	1.19	0.85	0.59	0.82	0.99
130	2.07	1.77	1.27	0.87	0.67	0.77	0.98

(continued)

Angle (deg)	Energy (eV)						
	6.0	8.0	10	20	30	60	100
15	13.43	17.24	18.81	26.60	23.50	20.56	3.33
20	11.05	14.42	15.81	18.34	13.75	7.87	2.86
30	8.87	9.31	11.12	6.89	3.43	1.77	1.38
40	6.40	5.80	5.53	2.47	1.42	1.03	0.56
50	4.42	3.06	2.40	1.43	1.14	0.65	0.37
60	2.85	1.75	1.36	1.28	0.88	0.44	0.31
70	2.00	1.47	1.43	1.09	0.65	0.34	0.27
80	1.64	1.47	1.70	0.80	0.50	0.27	0.19
90	1.56	1.56	1.57	0.69	0.38	0.16	0.11
100	1.42	1.30	1.23	0.78	0.35	0.15	0.09
110	1.18	0.99	0.90	0.77	0.37	0.18	0.17
120	0.97	0.84	0.89	0.79	0.47	0.26	0.22
130	0.91	0.99	1.16	0.85	0.60	0.37	0.28

### CF<sub>3</sub>I

Table 27. Differential cross sections (in units of  $10^{-16} \text{ cm}^2 \text{ sr}^{-1}$ ) for elastic electron scattering from CF<sub>3</sub>Br. Experimental errors are estimated to be in the range 10–15%.

Angle (deg)	Energy (eV)							
	1.5	3.0	4.0	6.0	8.0	10	20	60
20	2.22	3.35	6.79	15.73	19.25	23.04	20.77	4.06
30	1.21	2.27	6.16	11.24	12.03	12.44	6.62	1.10
40	0.82	3.16	4.96	7.01	6.40	5.62	1.98	0.66

50	1.00	3.49	3.88	4.33	3.03	2.39	1.16	0.51
60	1.02	3.52	3.18	2.65	1.67	1.36	1.15	0.31
70	1.09	3.20	3.10	1.92	1.36	1.50	1.08	0.18
80	0.97	2.61	2.28	1.70	1.39	1.30	0.89	0.14
90	0.82	1.91	1.94	1.70	1.46	1.24	0.68	0.12
100	0.70	1.41	1.63	1.52	1.23	1.00	0.53	0.16
110	0.55	0.90	1.14	1.21	0.94	0.82	0.54	0.27
120	0.46	0.68	0.89	0.92	0.85	0.90	0.65	0.43
130	0.40	0.84	1.03	1.16	1.15	1.29	0.72	0.51

## CO<sub>2</sub>

Absolute cross sections for elastic scattering of electrons from CO<sub>2</sub> have been determined in the energy range of 1.5–100 eV and over the scattering angles of 15–130°. The DCS were analyzed using a phase-shift approach in order to extrapolate them to lower and higher angles, to facilitate derivation of the integral cross sections.

All these data are recommended in Table 28.

### Reference:

H. Tanaka, T. Ishikawa, T. Masai, T. Sagara, L. Boesten, M. Takekawa, Y. Itikawa and M. Kimura, *Phys. Rev. A* **57** 1798 (1998).

Table 28. Differential cross sections for elastic electron scattering (in units of 10<sup>-16</sup> cm<sup>2</sup>/sr) and integral elastic (ICS) and elastic momentum transfer cross sections (MTCS), respectively (in units of 10<sup>-16</sup> cm<sup>2</sup>), from CO<sub>2</sub>. The absolute uncertainties on the DCS are 10–15%, while the uncertainties on the ICS and MTCS are in the range of 20 to 30%

Angle (deg)	Energy (eV)								
	1.5	2.0	3.0	3.8	4.0	5.0	6.0	6.5	7.0
15	—	—	—	—	—	—	—	—	—
20	0.958	0.7505	0.716	1.3536	1.3537	0.5824	0.6823	0.8599	0.8828
30	0.762	0.5472	0.4868	0.8831	1.0269	0.7486	0.773	0.8236	0.8313
40	0.541	0.3896	0.3069	0.6294	0.777	0.8076	0.8244	0.9132	0.9039
50	0.405	0.2455	0.3118	0.5897	0.6857	0.8994	0.8383	0.9286	0.9391

60	0.3289	0.2368	0.3386	0.5715	0.6472	0.8079	0.8373	0.895	0.8025
70	0.2957	0.2489	0.3779	0.5367	0.5834	0.7272	0.7644	0.6978	0.7558
80	0.27	0.2765	0.3876	0.5539	0.5595	0.6026	0.6422	0.6616	0.6258
90	0.2405	0.2845	0.3937	0.5739	0.5037	0.4794	0.5258	0.53	0.5273
100	0.308	0.3021	0.395	0.5096	0.4431	0.391	0.4518	0.4252	0.4333
110	0.304	0.3276	0.438	0.5187	0.4217	0.2647	0.3476	0.339	0.3766
120	0.3567	0.3776	0.483	0.528	0.4258	0.2523	0.3136	0.3201	0.3798
130	0.365	0.3992	0.5173	0.5475	0.4803	0.2853	0.3798	0.352	0.3724
ICS	5.04	4.62	5.77	8.25	8.16	6.85	7.59	7.8	7.87
MTCS	4.48	4.53	5.96	7.69	7.22	5.66	6.69	6.56	6.56

(Continued)

Angle (deg)	Energy (eV)							
	8.0	9.0	10	15	20	30	60	100
15	5.089	7.183	11.52	10.843	7.7149	—	—	—
20	1.1594	1.4958	2.2977	3.843	5.6871	8.731	5.671	3.7543
30	1.002	1.1588	1.5342	2.718	3.2623	3.154	1.786	0.995
40	0.964	1.087	1.2136	1.7789	1.8542	1.4363	0.6597	0.3969
50	0.8542	0.9487	0.9926	1.1756	1.2248	0.743	0.3412	0.2026
60	0.7214	0.8375	0.743	0.7997	0.7475	0.4678	0.1683	0.1502
70	0.6755	0.6622	0.626	0.5777	0.4324	0.306	0.1109	0.1124
80	0.6761	0.5799	0.5468	0.4471	0.3516	0.1896	0.0936	0.084
90	0.5343	0.5394	0.4856	0.3596	0.3041	0.1882	0.0911	0.0697
100	0.4596	0.4811	0.4478	0.3673	0.3071	0.2391	0.0812	0.0754
110	0.4263	0.4381	0.4319	0.4046	0.3887	0.2536	0.1175	0.088
120	0.4058	0.4816	0.5304	0.5445	0.5493	0.3195	0.1805	0.1076
130	0.5183	0.6006	0.7077	0.7832	0.6738	0.4441	0.2748	0.1373
ICS	8.99	10.06	11.4	13.79	14.59	15.01	11.04	8.1
MTCS	8.07	9.24	9.94	11.19	10.17	7.51	4.15	2.65

## N<sub>2</sub>O

Absolute cross sections for elastic scattering of electrons from N<sub>2</sub>O have been determined in the energy range of 1.5–100 eV and over the scattering angles of 15–130°. The DCS were analyzed using a phase-shift approach in order to extrapolate them to lower and higher angles, to facilitate derivation of the integral cross sections.

All these data are recommended in Table 29.

### Reference:

M. Kitajima, Y. Sakamoto, R. J. Gulley, M. Hoshino, J. C. Gibson, H. Tanaka and S. J. Buckman, *J. Phys. B: At. Mol. Opt. Phys.* **33** 1687 (2000).

Table 29. Differential cross sections in units of 10<sup>-16</sup> cm<sup>2</sup>/sr, for elastic electron scattering from N<sub>2</sub>O. The ANU results are designated (A) and the Sophia results (S). For the ANU results the figures in parentheses represent the absolute error, expressed as a percentage, while for the Sophia data the estimated uncertainty is 15%. The figures at the base of each column are the ICS, for which the estimated uncertainty is 25%.

Angle (deg)	Energy (eV)							
	1.5 (S)	2.0 (S)	2.0 (A)	2.2 (S)	2.3 (A)	2.4 (S)	2.5 (S)	3.0 (S)
15	—	—	—	—	—	—	—	—
20	1.35	2.35	—	2.38	—	2.58	2.42	1.63
25	—	—	—	—	1.911(14)	—	—	—
30	0.96	1.82	1.620(9)	2.02	1.753(10)	2.47	2.09	1.78
35	—	—	—	—	1.678(10)	—	—	—
40	0.67	1.35	1.149(10)	1.49	1.562(10)	1.97	1.87	1.68
45	—	—	—	—	1.475(10)	—	—	—
50	0.46	0.96	0.702(9)	1.18	1.385(9)	1.54	1.51	1.68
55	—	—	—	—	1.224(7)	—	—	—
60	0.32	0.71	0.624(9)	0.88	1.099(7)	1.19	1.19	1.48
65	—	—	—	—	0.922(7)	—	—	—
70	0.30	0.52	0.479(9)	0.66	0.783(7)	0.93	0.86	1.10
75	—	—	—	—	0.678(7)	—	—	—
80	0.30	0.45	0.399(8)	0.52	0.580(7)	0.67	0.64	0.82
85	—	—	—	—	0.531(7)	—	—	—
90	0.35	0.45	0.406(9)	0.47	0.503(8)	0.51	0.50	0.62

95	—	—	—	—	0.491(7)	—	—	—
100	0.46	0.52	0.478(8)	0.49	0.496(7)	0.47	0.45	0.41
105	—	—	—	—	0.514(7)	—	—	—
110	0.56	0.59	0.602(9)	0.59	0.542(7)	0.50	0.50	0.33
115	—	—	—	—	0.601(7)	—	—	—
120	0.66	0.78	0.692(10)	0.75	0.699(8)	0.60	0.57	0.28
125	—	—	—	—	0.826(7)	—	—	—
130	0.76	1.02	0.825(8)	0.96	0.980(7)	0.77	0.79	0.30
ICS	—	12.57	10.14	12.21	12.84	12.90	—	9.98

(Continued)

angle (deg)	Energy (eV)							
	3.0 (A)	3.5 (S)	4.0 (S)	4.0 (A)	5.0 (S)	5.0 (A)	6.0 (S)	6.0 (A)
15	—	—	—	—	—	0.722(16)	—	0.877(21)
20	—	0.98	0.68	0.640(10)	0.57	0.640(8)	0.60	0.610(8)
25	—	—	—	0.783(11)	—	0.652(8)	—	0.661(9)
30	—	1.10	0.84	0.826(8)	0.62	0.763(7)	0.68	0.769(8)
35	1.747(7)	—	—	0.895(9)	—	0.853(7)	—	0.859(8)
40	1.761(7)	1.22	1.01	0.990(11)	0.80	0.941(9)	0.86	0.935(8)
45	1.711(7)	—	—	1.027(10)	—	1.011(8)	—	1.000(8)
50	1.663(7)	1.37	1.15	1.038(11)	0.95	1.015(7)	1.02	0.997(7)
55	1.542(7)	—	—	1.065(10)	—	1.029(8)	—	0.995(8)
60	1.454(7)	1.22	1.10	0.958(8)	1.04	1.041(7)	1.08	0.962(7)
65	1.315(7)	—	—	0.925(10)	—	1.003(7)	—	0.950(7)
70	1.177(7)	1.08	1.06	0.838(11)	0.94	0.939(8)	0.94	0.869(7)
75	1.041(7)	—	—	0.776(10)	—	0.894(8)	—	0.840(8)
80	0.906(7)	0.89	0.83	0.714(10)	0.83	0.810(7)	0.77	0.781(7)
85	0.786(7)	—	—	0.662(8)	—	0.754(8)	—	0.710(7)
90	0.676(7)	0.71	0.70	0.561(11)	0.68	0.666(7)	0.69	0.624(7)
95	0.587(7)	—	—	0.501(9)	—	0.601(7)	—	0.553(7)
100	0.486(7)	0.50	0.58	0.447(10)	0.52	0.502(8)	0.55	0.485(7)
105	0.410(7)	—	—	0.373(7)	—	0.446(7)	—	0.419(8)
110	0.349(7)	0.39	0.40	0.314(14)	0.40	0.370(8)	0.40	0.368(11)
115	0.307(7)	—	—	0.266(8)	—	0.324(8)	—	0.317(10)
120	0.280(7)	0.28	0.30	0.245(8)	0.31	0.284(8)	0.30	0.295(10)

125	0.276(7)	—	—	0.243(8)	—	0.260(8)	—	0.279(11)
130	0.311(8)	0.23	0.25	0.215(9)	0.27	0.249(7)	0.30	0.263(9)
ICS	11.47	—	8.34	7.39	7.60	7.96	7.73	8.10

(Continued)

angle (deg)	Energy (eV)							
	7.0 (S)	7.0 (A)	7.5 (A)	8.0 (S)	8.0 (A)	9.0 (S)	9.0 (A)	10 (S)
15	—	0.995(16)	2.224(8)	—	1.912(15)	—	3.053(12)	—
20	0.94	0.912(7)	1.270(7)	1.62	1.570(7)	2.34	2.382(7)	2.69
25	0.85	0.881(7)	1.063(7)	1.26	1.336(7)	—	1.860(7)	2.21
30	0.80	0.875(7)	0.977(7)	1.12	1.153(7)	1.53	1.544(7)	1.84
35	0.79	0.916(7)	0.922(7)	0.99	1.067(7)	—	1.341(7)	1.57
40	0.86	0.945(7)	0.908(7)	0.99	1.043(7)	1.17	1.206(7)	1.34
45	0.93	0.976(7)	0.912(7)	0.99	1.020(7)	—	1.119(8)	1.19
50	0.99	0.984(7)	0.920(7)	0.95	0.990(7)	1.04	1.028(7)	1.09
55	0.95	0.988(7)	0.908(7)	0.87	0.962(7)	—	0.956(7)	1.01
60	0.90	0.930(7)	0.861(7)	0.89	0.919(7)	0.86	0.893(7)	0.94
65	0.90	0.887(7)	0.786(8)	0.83	0.864(7)	—	0.811(9)	0.86
70	0.85	0.849(8)	0.738(7)	0.80	0.806(7)	0.77	0.754(7)	0.78
75	0.83	0.777(7)	0.681(7)	0.74	0.748(7)	—	0.680(7)	0.74
80	0.74	0.719(7)	0.626(7)	0.70	0.665(7)	0.64	0.610(7)	0.64
85	0.70	0.659(7)	0.568(7)	0.59	0.605(7)	—	0.550(7)	0.58
90	0.61	0.591(7)	0.508(7)	0.53	0.541(7)	0.51	0.490(7)	0.51
95	0.56	0.518(7)	0.453(7)	0.46	0.482(7)	—	0.432(7)	0.44
100	0.48	0.454(7)	0.405(7)	0.45	0.424(7)	0.41	0.384(7)	0.40
105	0.39	0.396(7)	0.350(8)	0.39	0.374(7)	—	0.358(7)	0.36
110	0.36	0.346(7)	0.329(7)	0.36	0.355(7)	0.34	0.356(7)	0.35
115	0.33	0.313(7)	0.305(8)	0.35	0.352(7)	—	0.377(7)	0.40
120	0.31	0.302(7)	0.322(7)	0.37	0.386(7)	0.43	0.446(7)	0.44
125	0.35	0.324(7)	0.357(8)	0.40	0.462(7)	—	0.552(7)	0.56
130	0.35	0.369(8)	0.419(7)	0.48	0.653(7)	0.61	0.693(7)	0.69
ICS	—	8.34	8.82	9.25	10.35	—	11.11	10.39



(Continued)

angle (deg)	Energy (eV)							
	10 (A)	15 (S)	15 (A)	20 (S)	20 (A)	30 (S)	60 (S)	100 (S)
15	4.133(8)	—	6.454(10)	—	8.201(8)	—	—	—
20	3.107(8)	4.38	4.850(7)	6.67	5.661(8)	5.98	4.31	3.23
25	2.566(8)	—	—	—	—	—	—	—
30	2.142(8)	2.72	2.869(10)	3.48	2.821(8)	2.60	1.38	0.94
35	1.717(8)	—	—	—	—	—	—	—
40	1.517(9)	1.79	1.814(7)	1.88	1.649(8)	1.27	0.63	0.35
45	1.312(8)	—	—	—	—	—	—	—
50	1.235(11)	1.29	1.299(8)	1.24	1.099(8)	0.75	0.32	0.19
55	1.122(8)	—	—	—	—	—	—	—
60	1.042(11)	0.97	0.987(8)	0.84	0.747(8)	0.45	0.18	0.12
65	0.955(12)	—	—	—	—	—	—	—
70	0.878(16)	0.78	0.772(8)	0.61	0.528(8)	0.30	0.11	0.10
75	0.797(12)	—	—	—	—	—	—	—
80	0.699(11)	0.59	0.595(8)	0.40	0.345(8)	0.15	0.10	0.09
85	0.626(8)	—	—	—	—	—	—	—
90	0.523(11)	0.40	0.396(10)	0.27	0.236(8)	0.16	0.09	0.08
95	0.494(10)	—	0.336(8)	—	—	—	—	—
100	0.457(12)	0.30	0.293(9)	0.26	0.246(8)	0.23	0.08	0.09
105	0.415(10)	—	0.278(13)	—	—	—	—	—
110	0.442(13)	0.35	0.339(15)	0.35	0.340(8)	0.27	0.12	0.11
115	0.463(13)	—	—	—	—	—	—	—
120	0.525(10)	0.48	0.467(18)	0.52	0.498(9)	0.33	0.19	0.12
125	0.689(15)	—	—	—	—	—	—	—
130	0.830(14)	0.72	0.671(9)	0.7	0.696(9)	0.43	0.28	0.14
ICS	14.36	—	14.30	—	13.77	—	4.27	2.95

## H<sub>2</sub>O

Water vapour has attracted significant research interest in recent years as a target for low energy electron collision studies. This results from the broad application of collision cross section data in fields as diverse as planetary science, the interstellar medium and radiation chemistry and biology. Indeed, cross sections for water are amongst some of the essential parameters in modeling the effects of ionizing radiation on humans and other species. The magnetic angle-changing device is again employed in conjunction with the spectrometer to measure the cross sections to the backward angles. The absolute differential cross sections (DCS) for elastic scattering from H<sub>2</sub>O at nine incident energies between 4 and 50 eV, and at scattering angles between 10 and 180° are presented in Table 30.

### Reference:

H. Cho, Y. S. Park, H. Tanaka and S. J. Buckman, *J. Phys. B: At. Mol. Opt. Phys.* **37** 625 (2004).

Table 30. Differential cross sections (in units of 10<sup>-16</sup> cm<sup>2</sup> sr<sup>-1</sup>) for elastic electron scattering from H<sub>2</sub>O. The experimental uncertainties on each measured point are indicated in the table in brackets as an absolute value.

Angle (deg)	Energy (eV)				
	4	6	8	10	15
10	-	-	-	10.01 (1.011)	10.99 (1.429)
20	5.223 (0.501)	4.209 (0.463)	5.012 (0.534)	4.555 (0.451)	5.120 (0.563)
30	2.973 (0.377)	2.241 (0.217)	2.472 (0.225)	2.511 (0.226)	3.038 (0.283)
40	1.735 (0.154)	1.513 (0.133)	1.455 (0.147)	1.726 (0.147)	1.803 (0.153)
50	1.107 (0.149)	1.146 (0.124)	1.207 (0.155)	1.327 (0.104)	1.198 (0.115)
60	0.981 (0.088)	0.897 (0.097)	0.954 (0.124)	1.033 (0.099)	0.783 (0.091)
70	0.680 (0.061)	0.887 (0.087)	0.883 (0.106)	0.769 (0.081)	0.591 (0.055)
80	0.520 (0.067)	0.704 (0.063)	0.779 (0.092)	0.652 (0.061)	0.450 (0.038)
90	0.451 (0.044)	0.562 (0.072)	0.570 (0.063)	0.515 (0.062)	0.333 (0.030)
100	0.367 (0.035)	0.423 (0.046)	0.424 (0.044)	0.398 (0.052)	0.343 (0.045)
110	0.255 (0.028)	0.344 (0.067)	0.397 (0.043)	0.340 (0.036)	0.338 (0.047)
120	0.211 (0.026)	0.310 (0.033)	0.408 (0.036)	0.369 (0.054)	0.385 (0.045)
130	0.272 (0.026)	0.374 (0.037)	0.461 (0.043)	0.474 (0.056)	0.526 (0.052)
140	0.283 (0.041)	0.418 (0.035)	0.630 (0.093)	0.601 (0.056)	0.779 (0.067)
150	0.339 (0.043)	0.440 (0.041)	0.945 (0.113)	0.924 (0.085)	0.902 (0.097)

160	0.384 (0.032)	0.601 (0.064)	0.992 (0.107)	1.104 (0.097)	1.312 (0.144)
170	0.502 (0.066)	0.751 (0.076)	1.050 (0.102)	1.382 (0.096)	1.465 (0.180)
180	0.577 (0.057)	0.835 (0.084)	1.314 (0.146)	1.576 (0.197)	1.737 (0.191)

(Continued)

Angle (deg)	Energy (eV)			
	20	30	40	50
10	9.913 (1.169)	11.04 (1.170)	11.05 (0.961)	11.03 (1.211)
20	4.500 (0.414)	4.978 (0.641)	5.911 (0.579)	4.538 (0.404)
30	2.794 (0.299)	2.533 (0.279)	2.030 (0.219)	1.991 (0.169)
40	1.546 (0.136)	1.220 (0.115)	0.832 (0.099)	0.854 (0.097)
50	1.117 (0.110)	0.891 (0.064)	0.371 (0.034)	0.352 (0.037)
60	0.628 (0.069)	0.512 (0.051)	0.227 (0.018)	0.189 (0.016)
70	0.388 (0.042)	0.281 (0.032)	0.162 (0.015)	0.107 (0.013)
80	0.315 (0.033)	0.194 (0.026)	0.101 (0.010)	0.070 (0.008)
90	0.291 (0.043)	0.178 (0.016)	0.084 (0.011)	0.057 (0.007)
100	0.253 (0.028)	0.156 (0.014)	0.076 (0.010)	0.061 (0.006)
110	0.273 (0.032)	0.157 (0.015)	0.083 (0.011)	0.058 (0.007)
120	0.349 (0.033)	0.180 (0.019)	0.129 (0.014)	0.085 (0.011)
130	0.425 (0.046)	0.269 (0.038)	0.195 (0.023)	0.132 (0.014)
140	0.552 (0.061)	0.344 (0.046)	0.288 (0.032)	0.166 (0.024)
150	0.736 (0.068)	0.431 (0.052)	0.379 (0.041)	0.204 (0.021)
160	0.889 (0.094)	0.492 (0.059)	0.442 (0.053)	0.264 (0.025)
170	1.020 (0.090)	0.547 (0.059)	0.504 (0.072)	0.303 (0.030)
180	1.093 (0.124)	0.620 (0.056)	0.585 (0.077)	0.345 (0.031)

## **5 Concluding Remarks**

In this report elastic differential cross sections for electron collisions with polyatomic molecules have been reviewed with particular emphasis on the methodology for the precise measurement of absolute values. A selection of the latest results, from a range extending over the past three decades, have been presented and briefly discussed. In particular, we have chosen data for specific interest in the fields of fusion plasmas, processing plasmas and environmental modeling.

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