Elastic Cross Sections for Electron Collisions with Molecules Relevant to Plasma Processing

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Absolute electron-impact cross sections for molecular targets, including their radicals, are important in developing plasma reactors and testing various plasma processing gases. Low-energy electron collision data for these gases are sparse and only the limited cross section data are available. In this report, elastic cross sections for electron-polyatomic molecule collisions are compiled and reviewed for 17 molecules relevant to plasma processing. Elastic cross sections are essential for the absolute scale conversion of inelastic cross sections, as well as for testing computational methods. Data are collected and reviewed for elastic differential, integral, and momentum transfer cross sections and, for each molecule, the recommended values of the cross section are presented. The literature has been surveyed through early 2010. © *2010 American Institute of Physics*. [doi:10.1063/1.3475647]

Key words: differential cross sections; electron collisions; integrated elastic scattering cross sections; momentum transfer cross sections.

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1. Introduction

Gaseous electronics—the term which is loosely applied to describe low temperature discharge physics—is a broad and diverse area of research and development which encompasses both established and emerging technologies. These include semiconductor production, lighting, propulsion, environmental remediation, and material processing to name just a few. One of the major areas of application of gaseous electronics is in the plasma modification and processing of semiconductor and other electronic materials. This industry worldwide had a turnover in excess of US 210 billion dollars in 2009.[1] Such plasma processing discharges are used to either etch surfaces in a controlled fashion or to deposit materials, or layers of materials, which provide the required electronic response. Plasma discharges are complex environments in which a multitude of atomic and molecular processes occur. Many, if not most, of these processes are initiated by electron impact and an understanding of these precursor reactions is critical to a broader understanding of the dynamics of the discharge. Absolute electron scattering cross sections for molecular targets, including their daughter radicals, are important in developing models of plasma reactors and testing the efficacy of various plasma processing gases. Low-energy electron collision data for these gases are generally quite sparse and, in many cases, only a limited range of cross section data is available. This is particularly the case for many of the important reactions (e.g., dissociation, dissociative attachment), which lead directly to the production of those reactive species in the plasma which are responsible for the surface modification or deposition. As an important aspect of the operation and development of plasma processing reactors is the ability to model the atomic and molecular processes that take place, we must inevitably draw upon scattering theory, in many cases, to provide the important collision data. In this context, accurate absolute scattering data which also maps out the energy and/or angular dependence of scattering processes can be extremely important in benchmarking theory which in turn can be applied to the calculation of some of the more complex and experimentally inaccessible processes. In this paper we present recommended cross sections for one of the key processes that can be used to benchmark theory—elastic electron scattering for 17 molecules that are commonly used and are important in plasma processing applications. We have reviewed data from the literature up to early 2010 and the recommended values are presented for the total elastic, elastic momentum transfer,

TABLE 1. Recommended differential cross sections for elastic electron scattering (in units of 10^{-16} cm^2/sr) from CF_2. Recommended integral elastic cross sections (in units of 10^{-16} cm^2) are given at the foot of each column. The uncertainty on the integral cross sections is estimated to be ~45%

Angle	Energy(eV)																
(deg)	2.0	3.0	4.0	5.0	6.0	8.0	10	12	14	15	16	18	20	25	30	40	50
20	—	—	—	2.04 ±0.81	—	—	—	—	—	—	—	—	—	—	4.27 ±1.73	4.87 ±1.46	3.70 ±1.01
30	—	—	—	—	—	—	1.79 ±0.48	3.19 ±0.88	2.08 ±0.92	—	2.59 ±0.76	—	—	—	—	—	—
40	—	1.35 ±0.45	1.26 ±0.41	1.19 ±0.39	1.56 ±0.41	1.47 ±0.41	1.66 ±0.44	1.86 ±0.5	2.00 ±0.59	1.79 ±0.99	1.72 ±0.46	1.07 ±0.29	0.73 ±0.24	0.75 ±0.26	0.66 ±0.22	0.60 ±0.18	0.34 ±0.09
45	—	—	—	—	—	—	—	—	—	0.93 ±0.34	—	—	—	—	—	—	—
60	0.28 ±0.27	0.93 ±0.31	1.12 ±0.37	0.98 ±0.32	1.03 ±0.22	0.58 ±0.17	0.84 ±0.33	0.67 ±0.29	—	—	0.74 ±0.33	0.77 ±0.3	0.34 ±0.11	0.39 ±0.15	0.35 ±0.13	0.38 ±0.11	0.22 ±0.06
75	0.14 ±0.17	0.77 ±0.25	0.80 ±0.26	0.63 ±0.21	0.75 ±0.16	0.40 ±0.15	0.53 ±0.2	0.66 ±0.24	—	—	0.68 ±0.26	0.29 ±0.11	0.30 ±0.1	0.20 ±0.08	0.23 ±0.09	0.28 ±0.08	0.13 ±0.03
90	—	0.62 ±0.2	0.46 ±0.15	0.42 ±0.14	0.42 ±0.08	0.22 ±0.08	0.46 ±0.14	0.49 ±0.15	0.53 ±0.19	0.44 ±0.13	0.54 ±0.16	0.29 ±0.09	0.22 ±0.07	0.16 ±0.06	0.11 ±0.04	0.12 ±0.04	0.06 ±0.02
105	—	0.54 ±0.18	0.58 ±0.19	0.51 ±0.17	0.43 ±0.09	0.29 ±0.12	0.40 ±0.13	0.46 ±0.15	0.57 ±0.27	0.63 ±0.32	0.58 ±0.19	0.31 ±0.1	0.19 ±0.06	0.15 ±0.07	0.08 ±0.04	0.08 ±0.03	0.06 ±0.02
120	—	—	0.88 ±0.29	0.33 ±0.11	0.36 ±0.11	0.35 ±0.16	0.34 ±0.11	0.31 ±0.11	0.38 ±0.16	0.44 ±0.22	0.52 ±0.18	0.21 ±0.07	0.24 ±0.08	0.20 ±0.1	0.20 ±0.09	0.15 ±0.05	0.11 ±0.03
135	—	—	—	—	—	—	0.45 ±0.15	0.51 ±0.16	0.46 ±0.21	—	0.68 ±0.23	0.36 ±0.12	0.48 ±0.16	0.54 ±0.21	0.38 ±0.14	0.38 ±0.12	0.46 ±0.14
ICS	—	10.20	10.60	10.33	9.69	8.70	6.64	9.45	12.66	10.91	12.84	9.85	11.40	14.00	11.80	10.30	8.30

and elastic differential cross sections. The energy range of interest is up to and including 100 eV, with several exceptions.

2. Elastic Scattering Cross Sections

2.1. CF_2

There have been several theoretical[2–6] studies into elastic cross sections for electrons scattering from CF_2. These include the R-matrix,[2,3] iterative Schwinger variational method,[4] and Schwinger multichannel (SMC) method.[5,6] Experimental studies are limited to a series of measurements from the Flinders University group.[5,6] Those data are found to be in quite good agreement with the results from the SMC computations, and form the basis of the recommended cross sections that are listed in Table 1 and plotted in Figs. 1 and 2.

2.2. CF_4

There are three experiments on measurements of differential elastic electron scattering cross sections (DCS) of CF_4. Sakae *et al.*[7] measured the DCS for incident electron energies between 75 and 700 eV and for scattering angles between 5° and 135°. The experimental DCS were extrapolated to 0° and 180° scattering angles by fitting the square of the Legendre polynomials to the measured values, and the integral cross section (ICS) and momentum transfer cross section (MTCS) were obtained. Mann and Linder[8] measured the DCS in the energy range 0.3–20 eV for scattering angles from 10° to 105°. The data have been evaluated using a modified effective range theory (MERT) analysis and the ICS and MTCS are estimated for the energies between 0.001 and 0.5 eV. Boesten *et al.*[9] measured the DCS 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

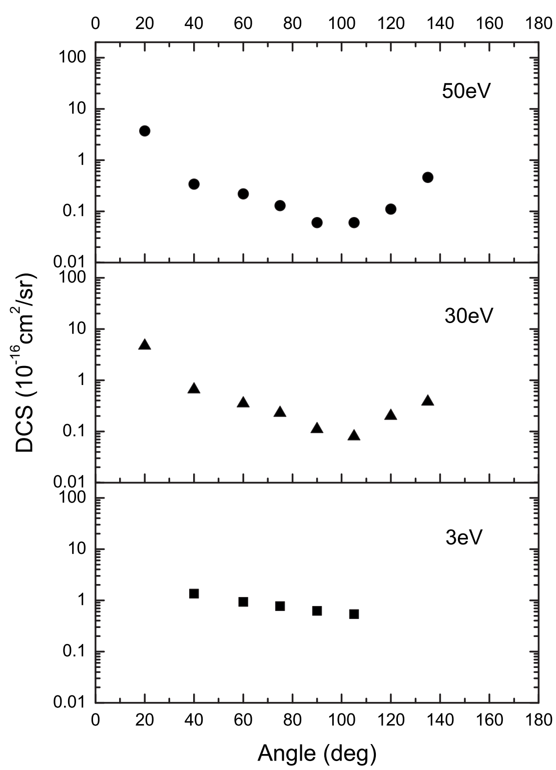

FIG. 1. Representative elastic differential cross sections for electron scattering from CF_2 (in units of 10^{-16} cm^2/sr).

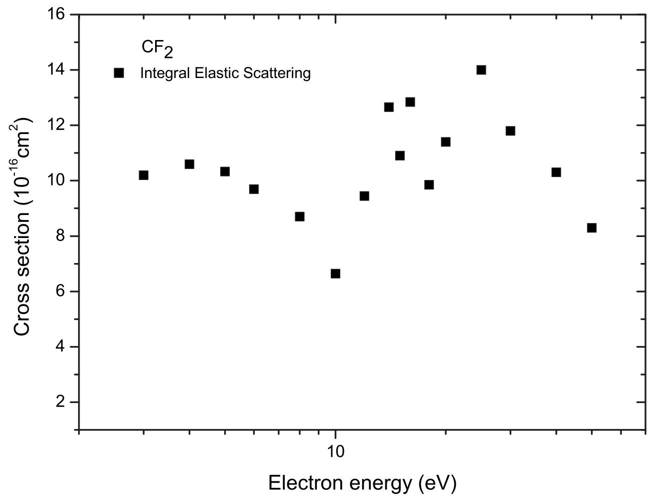

FIG. 2. Recommended integral elastic cross sections for electron scattering from CF_2 (in units of 10^{-16} cm^2).

phase-shift approach in order to extrapolate them to lower and higher angles, to facilitate derivation of the ICS and MTCS. In the energy region of interest of this article (100 eV and below), Boesten *et al.* covered most of the region. In addition Boesten *et al.* overlapped with Sakae *et al.* and Mann and Linder at the low and high energy ends, respectively, and in these overlapped regions they agree very well with each other within the estimated uncertainties. Therefore, we recommend and tabulate the DCS of Boesten *et al.* in Table 2 with the plots in Fig. 3. The estimated uncertainty is 15%–20%. For ICS and MTCS, these three reports give somewhat different results in the overlapping energy regions. Christophorou *et al.*[10] combined and fitted all three results including the MERT evaluation of Mann and Linder and suggested the ICS and MTCS. We present their values in Tables 3 and 4 with the plots in Fig. 4. The uncertainties in the ICS/MTCS results from Boesten *et al.* Sakae *et al.* and Mann and Linder are claimed to be, respectively, 25%, 10%, and 20%. The uncertainty in the least-squares fitted results by Christophorou *et al.* is not reported.

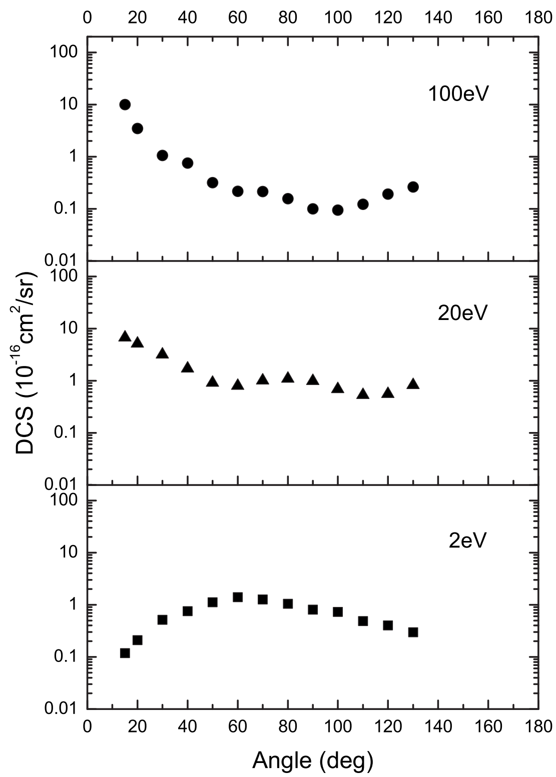

FIG. 3. Representative elastic differential cross sections for electron scattering from CF_4 (in units of 10^{-16} cm^2/sr).

2.3. C_2F_4

Absolute cross sections for elastic scattering of electrons from C_2F_4 have been determined in the energy range of 1.5–100 eV and over the scattering angles of 20°–130° by Panajotovic *et al.*,[11] and that is the only report for the absolute elastic scattering cross sections. This is a joint work

TABLE 2. Differential cross sections for elastic electron scattering (in units of 10^{-16} cm^2/sr) from CF_4. The estimated uncertainty is 15%–20%

Angle (deg)	Energy(eV)														
	1.5	2.0	3.0	5.0	6.0	7.0	8.0	9.0	10	15	20	35	50	60	100
15	—	0.1189	0.3408	0.9647	1.5526	2.5565	3.7041	4.7153	4.4007	5.4326	6.7566	14.1044	13.3217	12.1904	9.9255
20	0.1156	0.2107	0.5437	1.1780	1.6739	2.4716	3.5055	4.0973	4.7677	4.8219	5.1461	7.8265	6.9383	5.8892	3.4611
30	0.2929	0.5174	0.9571	1.7782	2.0409	2.3776	2.9866	3.5126	4.1163	3.4725	3.1666	2.6912	1.4085	1.0154	1.0555
40	0.4775	0.7532	1.2560	2.1309	2.3629	2.4221	2.4890	2.6564	2.8836	2.4642	1.7198	0.8776	0.7378	0.7464	0.7534
50	0.8106	1.1179	1.5905	2.3340	2.4184	2.0523	1.7570	1.7135	1.6848	1.3828	0.9118	0.8609	0.8566	0.7594	0.3187
60	0.9146	1.3994	1.6028	2.0814	1.9375	1.7795	1.1971	1.1146	0.9990	0.9010	0.7949	0.9268	0.6723	0.4286	0.2172
70	1.0264	1.2575	1.5126	1.4717	1.4875	1.1095	0.7749	0.7199	0.7302	0.8689	1.0042	0.8090	0.3603	0.2190	0.2153
80	0.9225	1.0442	1.1786	1.0226	0.9028	0.6573	0.5520	0.6045	0.7817	1.0580	1.0952	0.4353	0.1696	0.1289	0.1571
90	0.8779	0.8065	0.8906	0.6066	0.5430	0.4349	0.4953	0.6814	0.7996	1.0762	0.9876	0.2011	0.1364	0.1275	0.0995
100	0.8154	0.7264	0.5381	0.4080	0.3774	0.4683	0.5924	0.7671	0.7938	0.9311	0.6900	0.1760	0.1331	0.1237	0.0948
110	0.6146	0.4861	0.4399	0.3552	0.4347	0.5385	0.6781	0.7541	0.7272	0.6981	0.5303	0.2550	0.2002	0.1851	0.1223
120	0.4576	0.4031	0.3167	0.3363	0.4473	0.5927	0.6703	0.7307	0.6215	0.5948	0.5540	0.4546	0.4086	0.3220	0.1917
130	0.3618	0.2978	0.2637	0.3782	0.4503	0.5735	0.6118	0.6584	0.6514	0.6907	0.8226	0.6906	0.6573	0.4328	0.2619

TABLE 3. Integral elastic cross sections (in units of 10^{-16} cm^2) from CF_4

Electron energy (eV)	Cross section (10^{-16} cm^2)	Electron energy (eV)	Cross section (10^{-16} cm^2)	Electron energy (eV)	Cross section (10^{-16} cm^2)
0.0030	12.7	0.10	1.09	6.0	12.4
0.0035	12.2	0.15	0.62	7.0	12.6
0.0040	11.9	0.20	0.56	8.0	13.2
0.0045	11.5	0.25	0.68	9.0	14.2
0.0050	11.2	0.30	0.89	10.0	15.1
0.0060	10.6	0.35	1.18	12.5	15.5
0.0070	10.1	0.40	1.53	15.0	15.7
0.0080	9.68	0.45	1.91	17.5	15.9
0.0090	9.27	0.50	2.29	20.0	16.1
0.010	8.88	0.60	2.96	25.0	15.9
0.015	7.39	0.70	3.52	30.0	15.6
0.020	6.35	0.80	4.02	35.0	15.2
0.025	5.42	0.90	4.46	40.0	14.9
0.030	4.68	1.0	4.48	45.0	14.6
0.035	4.11	1.5	6.87	50.0	14.4
0.040	3.62	2.0	8.48	60.0	13.7
0.045	3.21	2.5	9.68	70.0	13.1
0.050	2.85	3.0	10.5	80.0	12.4
0.060	2.29	3.5	11.1	90.0	11.9
0.070	1.87	4.0	11.6	100.0	11.4
0.080	1.54	4.5	11.9		
0.090	1.29	5.0	12.1		

between the groups at Sophia University (SU) and the Australian National University (ANU). They independently measured the DCS at selected electron energies, some of which overlap. At the energies (5, 10, 15, and 20 eV) where both SU and ANU data sets are available and they agree with each other within uncertainties, we least-squares-fitted both data sets for each energy to obtain recommended DCS. However, if there are discrepancies between the two, for certain ener-

TABLE 4. Elastic momentum transfer cross sections (in units of 10^{-16} cm^2) from CF_4

Electron energy (eV)	Cross section (10^{-16} cm^2)	Electron energy (eV)	Cross section (10^{-16} cm^2)	Electron energy (eV)	Cross section (10^{-16} cm^2)
0.0010	13.0	0.060	1.10	3.5	7.72
0.0015	12.3	0.070	0.78	4.0	7.89
0.0020	11.8	0.080	0.55	4.5	8.04
0.0025	11.3	0.090	0.39	5.0	8.21
0.0030	10.9	0.10	0.26	6	8.55
0.0035	10.6	0.15	0.13	7	8.68
0.0040	10.2	0.20	0.27	8	8.96
0.0045	9.93	0.25	0.48	9	10.1
0.0050	9.65	0.30	0.76	10	11.2
0.0060	9.14	0.35	1.05	15	13.4
0.0070	8.67	0.40	1.39	20	14.1
0.0080	8.25	0.45	1.76	25	12.5
0.0090	7.85	0.50	2.13	30	10.4
0.010	7.52	0.60	2.82	35	8.80
0.015	6.15	0.70	3.45	40	7.80
0.020	5.06	0.80	4.01	45	7.24
0.025	4.16	0.90	4.48	50	6.66
0.030	3.44	1.0	4.92	60	5.80
0.035	2.82	1.5	6.26	70	5.28
0.040	2.29	2.0	6.92	80	4.77
0.045	1.90	2.5	7.30	90	4.37
0.050	1.54	3.0	7.53	100	4.03

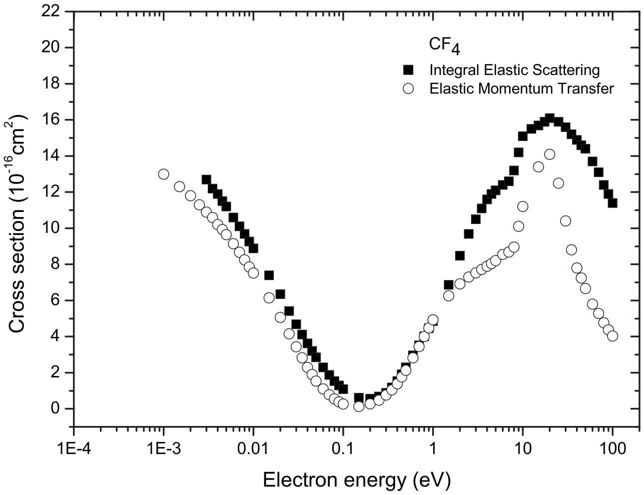

FIG. 4. Recommended integral elastic cross sections and momentum transfer cross sections for electron scattering from CF_4 (in units of 10^{-16} cm^2).

gies, we do not recommend any DCS at those energies. At the energies where only one, either SU or ANU, data set is available, we present it as our recommended DCS. The DCSs 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. Again, at the energies where both SU and ANU ICS/MTCS data sets are available, we have averaged them at each energy to obtain the recommended ICS/MTCS. At the energies where only one data set is available, we present it as our recommended ICS/MTCS. The estimated uncertainty in the original DCS data is claimed to be 15%, while the uncertainty on the integral and momentum transfer cross sections is 20%–25%. We do not provide uncertainties for DCS/ICS/MTCS which are derived from the least-squares fitting or averaging process for this article, although we expect that they would

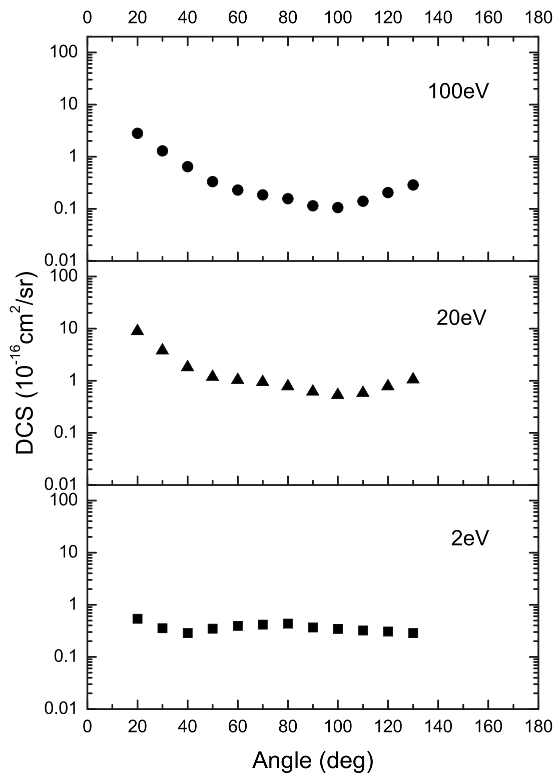

FIG. 5. Representative elastic differential cross sections for electron scattering from C_2F_4 (in units of 10^{-16} cm^2/sr).

be significiantly less than ±50%. All the cross sections are presented in Table 5 and plotted in Figs. 5 and 6.

2.4. C_2F_6

There are two experimental measurements of the elastic DCS for C_2F_6. Takagi *et al.*[12] measured the DCS in the energy range of 2–100 eV and over the scattering angles of

TABLE 5. Differential cross sections for elastic electron scattering (in units of 10^{-16} cm^2/sr) and ICS and elastic MTCS, respectively (both in units of 10^{-16} cm^2) from C_2F_4

Angle (deg)	Energy(eV)												
	2.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	15	20	30	60	100
20	0.539	0.842		2.455	2.388	3.149	3.427	4.842	8.133	8.94	9.537	6.75	2.8
30	0.356	0.95	1.794	2.477	2.301	2.698	2.981	3.386	4.502	3.804	2.97	1.44	1.29
40	0.287	0.969	1.759	2.263	1.965	2.058	2.168	2.483	2.344	1.803	1.298	0.94	0.645
50	0.346	1.091	1.537	1.88	1.521	1.572	1.6	1.626	1.404	1.179	1.064	0.642	0.332
60	0.392	0.954	1.174	1.323	1.083	1.048	1.166	1.199	1.073	1.037	0.911	0.437	0.229
70	0.417	0.755	0.86	0.928	0.873	0.966	1.049	1.034	0.943	0.94	0.753	0.245	0.185
80	0.435	0.537	0.657	0.725	0.7	0.867	0.922	0.954	0.845	0.782	0.543	0.202	0.157
90	0.367	0.48	0.543	0.672	0.683	0.882	1.014	0.885	0.746	0.618	0.387	0.177	0.114
100	0.343	0.409	0.477	0.58	0.607	0.809	0.913	0.83	0.675	0.533	0.332	0.172	0.106
110	0.32	0.385	0.434	0.528	0.594	0.788	0.84	0.819	0.672	0.584	0.446	0.221	0.14
120	0.306	0.348	0.418	0.531	0.661	0.845	0.935	0.884	0.768	0.777	0.558	0.328	0.205
130	0.286	0.349	0.467	0.621	0.803	0.955	1.104	1.035	0.975	1.058	0.773	0.441	0.288
ICS	4.34	7.73	10.5	13.1	10.5	14.4	16.8	19.6	18.9	21.5	16.9	12.2	5.43
MTCS	3.7	5.9	7.08	8.37	7.62	11.6	12.5	15.5	11.9	16	9.64	4.66	2.72

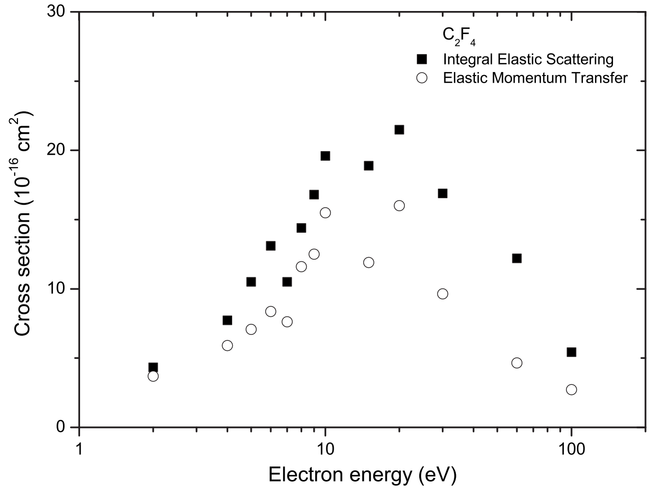

FIG. 6. Recommended integral elastic cross sections and momentum transfer cross sections for electron scattering from C_2F_4 (in units of 10^{-16} cm^2).

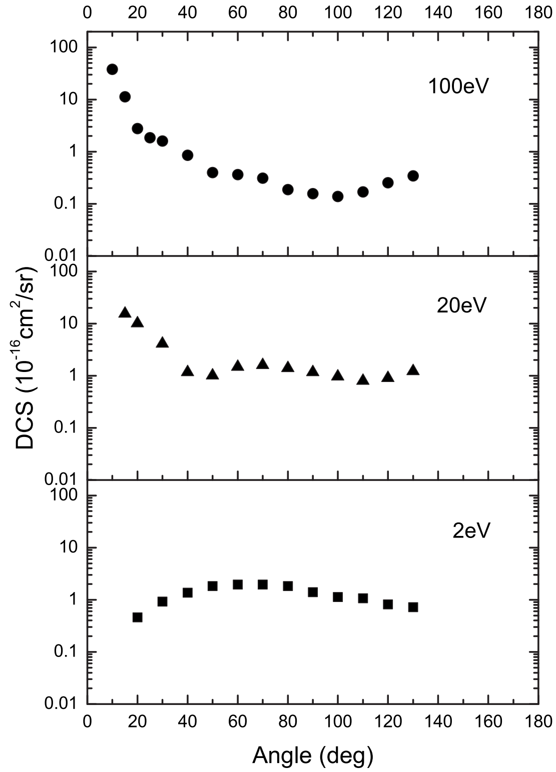

FIG. 7. Representative elastic differential cross sections for electron scattering from C_2F_6 (in units of 10^{-16} cm^2/sr).

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 ICS and MTCS. Iga *et al.*[13] reported the DCS for a range of energies between 30 and 500 eV and for scattering angles of 10°–135°. A manual extrapolation procedure was adopted to estimate DCS at low and high scattering angles in order to derive ICS and MTCS. In the energy region of 100 eV and below, the measurements of Takagi *et al.* covers most of the region, while that of Iga *et al.* was done mostly at high energies overlapping with Takagi *et al.* only at three energies; 30, 60, and 100 eV. At these overlapping energies, the agreement is good within the estimated uncertainties, with a few exceptions, especially at the scattering angle of 30°. Therefore, we recommend and tabulate the DCS of Takagi *et al.* in Table 6 and they are plotted in Fig. 7. The estimated uncertainty is 15%–20%. For ICS and MTCS, Christophorou and Olthoff[14] used the unpublished results of Merz and Linder, who estimated ICS/MTCS in the very low energy region using the MERT technique. Christophorou and Olthoff suggested ICS and MTCS values from both Takagi *et al.* and Merz and Linder at medium and low energies, respectively. We present the results from Christophorou and Olthoff in Tables 7 and 8 with the plots in Fig. 8. The uncertainties in the ICS/MTCS results from Takagi *et al.* are claimed to be

TABLE 6. Differential cross sections for elastic electron scattering (in units of 10^{-16} cm^2/sr) from C_2F_6. The estimated uncertainty is 15%–20%

Angle	Energy(eV)											
(deg)	2.0	3.0	4.0	5.0	7.0	8.0	10	15	20	30	60	100
10	—	—	—	—	—	—	—	—	—	23.54	41.13	37.91
15	—	—	—	—	5.304	7.05	8.261	11.28	15.45	—	19.31	11.26
20	0.4578	1.042	2.113	3.963	5.536	6.882	7.803	8.700	10.09	14.07	6.473	2.772
25	—	—	—	—	—	—	—	—	—	—	2.092	1.859
30	0.9265	1.758	2.562	4.269	5.332	5.772	5.676	5.326	4.126	3.220	1.373	1.607
40	1.368	2.496	2.805	4.089	4.127	4.094	3.322	2.269	1.174	1.154	1.428	0.8559
50	1.837	2.772	2.660	3.365	2.797	2.370	1.487	1.146	1.015	1.694	0.9475	0.3984
60	1.952	2.439	2.160	2.191	1.549	1.228	0.9494	1.230	1.477	1.681	0.5767	0.3622
70	1.960	2.018	1.650	1.471	0.9424	0.876	1.033	1.633	1.598	1.239	0.4094	0.3113
80	1.838	1.591	1.109	1.190	0.839	0.9448	1.243	1.813	1.405	0.8628	0.2396	0.1880
90	1.394	1.168	0.9805	1.058	1.060	1.107	1.328	1.551	1.172	0.7576	0.2132	0.1566
100	1.132	0.8898	0.8343	0.9543	1.047	1.125	1.187	1.365	0.9623	0.5131	0.2386	0.1387
110	1.066	0.8162	0.7842	0.8861	0.9339	0.9334	1.034	1.114	0.7965	0.5407	0.2924	0.1694
120	0.8144	0.6880	0.6748	0.8246	0.7572	0.8326	1.010	1.124	0.9013	0.7836	0.4476	0.2530
130	0.7224	0.7152	0.5981	0.6253	0.7671	0.9042	0.8516	1.209	1.227	1.148	0.5915	0.3439

TABLE 7. Integral elastic cross sections (in units of 10^{-16} cm^2) from C_2F_6

Electron energy (eV)	Cross section (10^{-16} cm^2)	Electron energy (eV)	Cross section (10^{-16} cm^2)	Electron energy (eV)	Cross section (10^{-16} cm^2)
0.01	12.2	0.5	4.91	9	24.2
0.02	7.86	0.6	5.71	10	24.9
0.03	5.68	0.7	7.54	15	27.9
0.04	4.41	0.8	9.39	20	28.0
0.05	3.61	0.9	10.6	25	27.3
0.06	3.07	1.0	11.3	30	26.3
0.07	2.70	1.5	13.2	40	24.4
0.08	2.43	2.0	14.5	50	22.5
0.09	2.23	2.5	15.4	60	20.9
0.10	2.07	3.0	16.3	70	19.6
0.15	1.69	4.0	18.3	80	18.4
0.20	1.66	5.0	20.1	90	17.3
0.25	1.91	6.0	21.4	100	16.4
0.30	2.39	7.0	22.5		
0.40	3.70	8.0	23.5		

25%, but no uncertainty information is available for the results from Merz and Linder. The uncertainty in the least-squares fitted results by Christophorou and Olthoff is also not reported.

2.5. C_3F_6

Absolute cross sections for elastic scattering of electrons from C_3F_6 have been determined in the energy range of 1.5–100 eV over the scattering angles of 15°–130° by the Sophia University group,[15] but only a part of these data was published in Ref. 16 and later, the full set of data was reported in Ref. 17. These are the only two reports on the elastic cross sections of C_3F_6. 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. The estimated uncertainty in the DCS data is 15%, while the uncertainty on the integral and the momentum transfer cross sections is 20%–25%. All these data are listed in Table 9 and plotted in Figs. 9 and 10.

2.6. C_3F_8

Tanaka *et al.*[18] measured the elastic scattering cross sections for C_3F_8 in the energy range of 1.5–100 eV and over the scattering angles of 15°–130°, and that is the only available, published result. The DCSs were analyzed using a molecular phase-shift approach in order to extrapolate them to lower and higher angles, to facilitate derivation of the ICS and MTCS. All these data are recommended in Table 10 and are plotted in Figs. 11 and 12. The estimated uncertainty in the DCS data is 15%–20%, while the uncertainty on the integral and the momentum transfer cross sections is 30%.

TABLE 8. Elastic momentum transfer cross sections (in units of 10^{-16} cm^2) from C_2F_6

Electron energy (eV)	Cross section (10^{-16} cm^2)	Electron energy (eV)	Cross section (10^{-16} cm^2)	Electron energy (eV)	Cross section (10^{-16} cm^2)
0.01	9.47	0.5	4.82	9	18.4
0.02	5.08	0.6	5.71	10	18.8
0.03	3.06	0.7	6.55	15	22.7
0.04	1.99	0.8	7.39	20	22.5
0.05	1.38	0.9	8.20	25	20.8
0.06	1.01	1.0	8.96	30	18.9
0.07	0.78	1.5	11.8	40	15.5
0.08	0.63	2.0	13.0	50	12.8
0.09	0.53	2.5	13.1	60	10.6
0.10	0.46	3.0	13.2	70	8.96
0.15	0.32	4.0	14.1	80	7.67
0.20	0.47	5.0	14.6	90	6.66
0.25	0.93	6.0	15.2	100	5.86
0.30	1.66	7.0	16.4		
0.40	3.45	8.0	17.9		

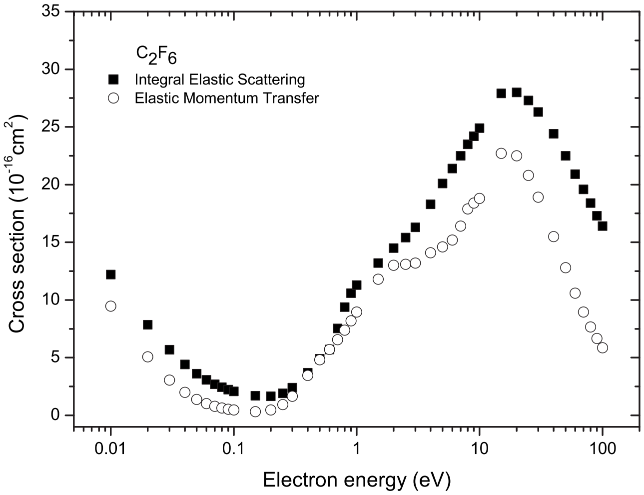

FIG. 8. Recommended integral elastic cross sections and momentum transfer cross sections for electron scattering from C_2F_6 (in units of 10^{-16} cm^2).

2.7. Cyclo-C_4F_8

Absolute cross sections for elastic scattering of electrons from cyclo-C_4F_8 have been determined in the energy range of 1.5–100 eV and over the scattering angles of 10°–130° by Jelisavcic *et al.*,[19] and that is the only published report. This is again a joint work between the Sophia University (SU) and the Australian National University (ANU). They independently measured the DCS at selected electron energies, some of which overlapped. At the energies (1.5, 5, and 10 eV) where both SU and ANU data sets are available and they agree with each other within uncertainties, we again least-square-fitted both data sets for each energy to obtain recommended DCS. As before, if there are discrepancies between the two for certain energies, then we do not recommend any DCS at those energies. At the energies where only one, either SU or ANU, data set is available, we present it as

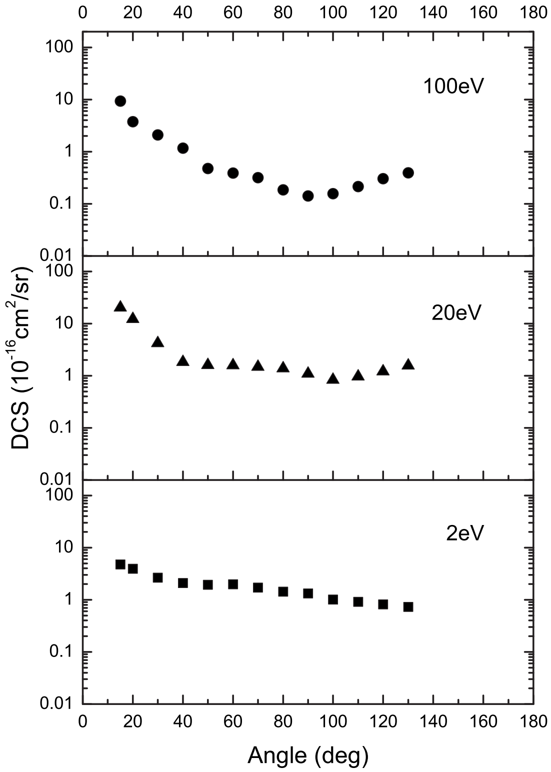

FIG. 9. Representative elastic differential cross sections for electron scattering from C_3F_6 (in units of 10^{-16} cm^2/sr).

our recommended DCS. The DCSs 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. Again, at the energies where both SU and ANU ICS/MTCS data sets are available, we averaged them at each energy to obtain the recommended ICS/MTCS. At the energies where only one data set is available, we present it as our recommended ICS/MTCS. The estimated

TABLE 9. Differential cross sections for elastic electron scattering (in units of 10^{-16} cm^2/sr) and ICS and elastic MTCS, respectively (both in units of 10^{-16} cm^2) from C_3F_6

Angle (deg)	Energy(eV) 1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10	15	20	30	60	100
15	4.204	4.777	3.995	4.88	5.137	7.582	8.857	9.234	12.06	13.57	17.965	20.224	25.496	15.944	9.357
20	3.725	3.909	3.513	4.496	4.56	6.428	7.000	7.548	9.358	10.923	13.295	12.19	12.48	5.249	3.75
30	2.328	2.647	2.755	4.259	4.304	4.606	5.152	4.966	6.080	6.483	5.788	4.181	2.704	2.068	2.095
40	1.509	2.091	2.583	4.164	4.108	3.702	3.259	3.246	3.305	3.288	2.542	1.832	1.662	1.462	1.171
50	1.404	1.932	2.694	3.539	3.255	2.603	1.825	1.773	1.704	1.83	1.588	1.602	1.556	0.986	0.476
60	1.348	1.988	2.449	2.533	2.088	1.827	1.367	1.178	1.454	1.46	1.551	1.581	1.578	0.589	0.387
70	1.344	1.720	1.870	1.862	1.645	1.189	1.049	1.088	1.305	1.634	1.561	1.472	1.202	0.393	0.319
80	1.249	1.429	1.498	1.418	1.337	0.961	0.984	1.103	1.469	1.644	1.462	1.376	0.722	0.311	0.185
90	0.938	1.329	1.275	1.274	1.08	1.019	0.955	1.096	1.367	1.481	1.284	1.093	0.516	0.271	0.142
100	0.894	1.006	1.078	1.151	0.913	1.051	0.952	1.114	1.28	1.452	1.153	0.83	0.56	0.237	0.157
110	0.882	0.914	0.943	1.068	0.935	0.931	1.019	1.151	1.267	1.351	1.042	0.966	0.666	0.321	0.214
120	0.781	0.812	0.947	1.005	0.941	0.923	1.075	1.204	1.3 00	1.313	1.120	1.214	0.848	0.543	0.305
130	0.682	0.728	0.951	1.061	0.955	1.047	1.149	1.173	1.290	1.560	1.588	1.558	1.175	0.704	0.394
ICS	20	20.9	22.9	23.9	25.4	26.2	27.1	26.1	29.1	29.7	28.3	28.9	28.3	14.1	10.4
MTCS	18.4	19.6	20.2	21.5	22.4	24.4	25.2	24.9	23.7	22.9	20.9	18.7	15.4	6.9	3.5

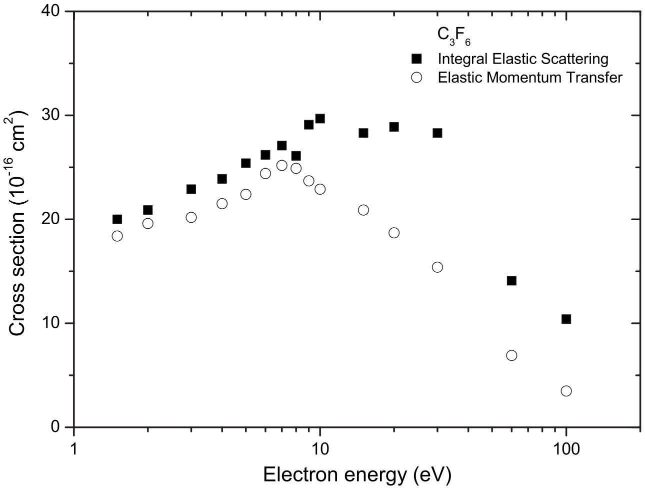

FIG. 10. Recommended integral elastic cross sections and momentum transfer cross sections for electron scattering from C_3F_6 (in units of 10^{-16} cm^2).

uncertainty in the original DCS data was claimed to be 15%, while the uncertainty on the integral and momentum transfer cross sections is 20%–25%. We do not provide uncertainties for DCS/ICS/MTCS which have been derived from the least-squares fit or averaging process for this article, but in all casses we expect them to be significantly less than 50%. All the cross sections are presented in Table 11 and plotted in Figs. 13 and 14.

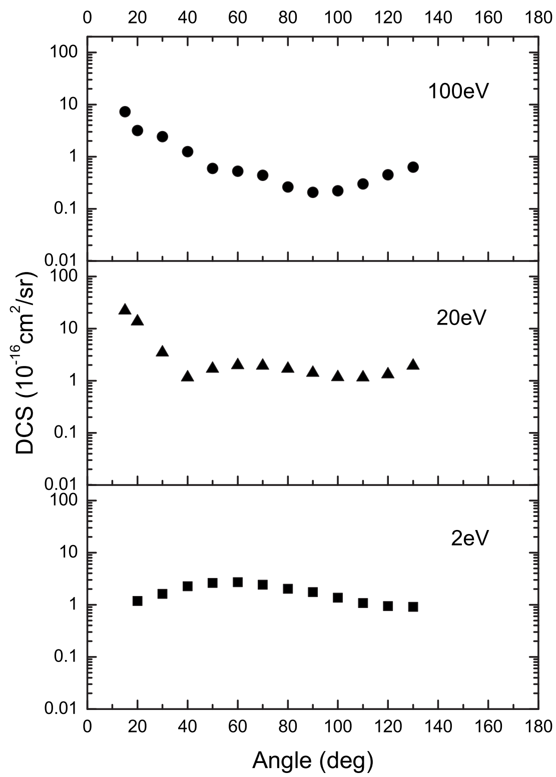

FIG. 11. Representative elastic differential cross sections for electron scattering from C_3F_8 (in units of 10^{-16} cm^2/sr).

2.8. C_6F_6

Cho *et al.*[20] measured the elastic differential scattering cross sections for C_6F_6 in the energy range of 1.5–100 eV and over the scattering angles of 20°–130°, and that is the only available published result. The DCSs were analyzed using a molecular phase-shift approach in order to extrapolate them to lower and higher angles, to derive the ICS and MTCS. All these cross sections are recommended in Table 12 and they are plotted in Figs. 15 and 16. The estimated uncertainty in the DCS data is 15%, while the uncertainty on the integral and momentum transfer cross sections is 25%.

TABLE 10. Differential cross sections for elastic electron scattering (in units of 10^{-16} cm^2/sr) and integral elastic and elastic momentum transfer cross sections, respectively (in units of 10^{-16} cm^2), from C_3F_8. The estimated uncertainty in the DCS data is 15%–20% and 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	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	1.224	1.185	3.270	5.757	7.099	9.769	10.830	12.417	14.415	14.339	12.969	12.032	13.724	14.267	13.322	4.860	3.174
30	0.883	1.624	4.100	6.171	6.284	9.395	9.306	9.099	9.232	9.051	7.671	5.932	3.473	2.665	2.098	2.683	2.436
40	1.309	2.258	4.143	6.085	5.510	5.981	5.916	4.958	4.154	3.662	3.083	1.866	1.161	1.565	1.551	2.007	1.251
50	1.792	2.632	3.811	4.941	4.940	3.409	3.048	2.313	1.595	1.608	1.417	1.217	1.689	2.010	1.844	1.276	0.596
60	2.033	2.718	3.250	3.739	2.946	1.900	1.642	1.280	1.253	1.289	1.481	1.628	1.978	2.132	1.776	0.751	0.525
70	2.232	2.418	2.618	2.436	1.889	1.356	1.303	1.429	1.612	1.549	1.767	2.046	1.945	1.908	1.328	0.571	0.442
80	2.290	2.034	1.811	1.773	1.474	1.375	1.516	1.603	1.669	1.751	1.906	2.204	1.684	1.225	0.825	0.397	0.263
90	2.038	1.752	1.323	1.315	1.391	1.435	1.613	1.777	1.650	1.716	1.959	2.168	1.418	0.813	0.640	0.334	0.207
100	1.640	1.369	1.075	1.179	1.178	1.315	1.465	1.457	1.535	1.624	1.791	1.972	1.166	0.762	0.570	0.354	0.222
110	1.355	1.078	0.890	1.010	1.038	1.138	1.340	1.328	1.422	1.586	1.609	1.591	1.150	0.852	0.656	0.472	0.299
120	1.176	0.939	0.767	0.870	0.942	1.053	1.122	1.295	1.382	1.508	1.537	1.382	1.315	1.221	0.813	0.530	0.449
130	1.115	0.916	0.734	0.872	0.908	1.081	1.199	1.334	1.580	1.623	1.590	1.569	1.929	1.645	1.283	0.942	0.632
ICS	19.800	20.817	27.401	35.317	37.503	42.877	44.365	44.513	44.942	44.335	42.379	39.150	37.631	36.324	32.869	18.784	13.001
MTCS	18.244	17.524	21.909	26.542	32.918	35.031	33.888	38.513	41.088	40.784	38.193	35.610	31.745	26.921	23.625	16.713	10.376

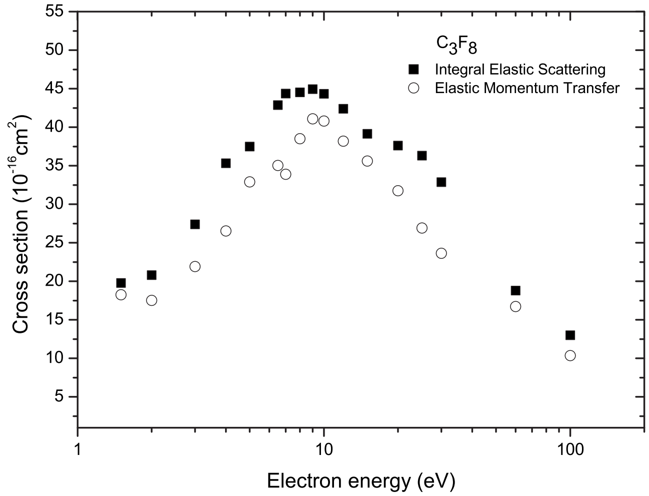

FIG. 12. Recommended integral elastic cross sections and momentum transfer cross section for electron scattering from C_3F_8 (in units of 10^{-16} cm^2).

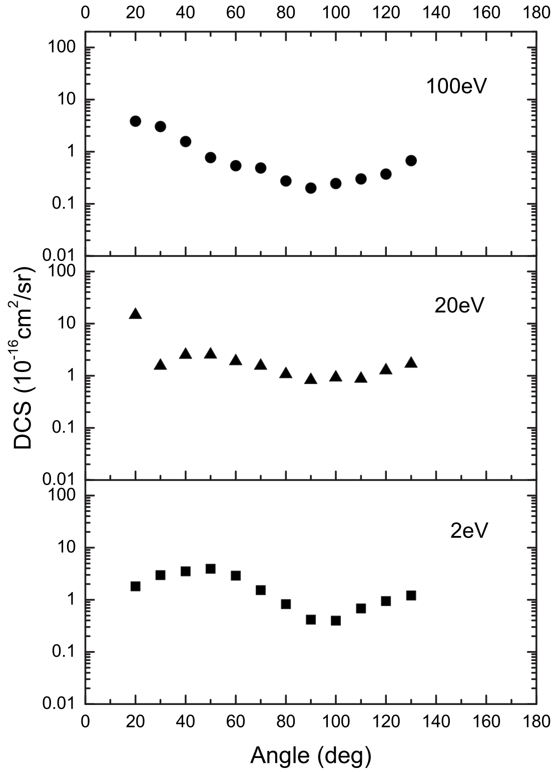

FIG. 13. Representative elastic differential cross sections for electron scattering from C_4F_8 (in units of 10^{-16} cm^2/sr).

2.9. CHF_3

Compared to some of the other species in this article, studies into elastic electron scattering from CHF_3 are much more prevalent. In this regard we note the comprehensive data compilations from Christophorou *et al.*[21] and Christophorou and Olthoff,[22] and the theoretical elastic scattering computations from Natalense *et al.*,[23,24] Dimiz *et al.*,[25] Morgan *et al.*,[26] Varella *et al.*,[27] and Iga *et al.*[28] The work of Morgan *et al.* also contained an electron-swarm analysis of the Schwinger multichannel computation results, while significant experimental results, from 1.5–30 eV, are contained in Varella *et al.*[27] and, from 20–500 eV, in Iga *et al.*[28] We also note additional experimental results from Meier *et al.*[29] and Tanaka *et al.*[30] In general, we find very good agreement between the data of Varella *et al.*[27] and Tanaka *et al.*,[30] when they are compared with the DCSs from Iga *et al.*[28] at each common energy. As a consequence, our recommended data in Table 13 and Fig. 17 are taken as a compilation from Refs. 27, 28, and 30. ICSs from Iga *et al.*[28] are also listed at the foot of Table 13 and Fig. 18.

TABLE 11. Differential cross sections for elastic electron scattering (in units of 10^{-16} cm^2/sr) and ICS and elastic MTCS, respectively (both in units of 10^{-16} cm^2) from cyclo-C_4F_8

Angle (deg)	Energy(eV)											
	1.5	2.6	3.0	4.0	5.0	6.0	7.0	8.0	10	30	60	100
10												
15						8.451						
20		1.424	1.802	3.05	5.787	8.305	11.574	12.021	15.26	14.627	5.112	3.822
30	1.72	2.712	2.977	3.704	4.624	6.891	8.000	9.142	9.028	1.554	3.479	3.045
40	2.269	3.594	3.516	4.011	3.921	4.669	4.783	4.826	3.732	2.5	2.142	1.557
50	2.687	4.061	3.951	3.293	2.396	2.679	2.273	2.068	1.342	2.53	1.403	0.769
60	2.682	3.378	2.889	2.137	1.119	1.146	0.983	0.995	1.385	1.89	0.842	0.538
70	2.344	1.963	1.522	0.96	0.653	0.829	0.844	1.344	1.921	1.543	0.616	0.489
80	1.792	1.194	0.821	0.525	0.735	0.92	1.032	1.511	1.928	1.073	0.423	0.275
90	1.222	0.556	0.414	0.691	0.926	1.02	1.048	1.542	1.682	0.827	0.363	0.200
100	0.807	0.332	0.397	0.949	1.068	0.966	0.913	1.218	1.556	0.921	0.352	0.244
110	0.576	0.378	0.684	1.248	1.165	0.883	0.81	1.267	1.463	0.872	0.472	0.300
120	0.535	0.613	0.941	1.580	1.106	0.879	0.808	1.262	1.537	1.270	0.666	0.373
130	0.632	0.905	1.213	1.769	1.211	0.948	0.919	1.430		1.700	0.935	0.674
ICS	17.9	18.1	18.7	21.4	21.9	22.8	24.9	30.5	35.3	31.3	16.1	11.0
MTCS	13.3	11	12.9	16.6	15.2	11.9	13.3	18.5	21.9	15.6	6.21	3.68

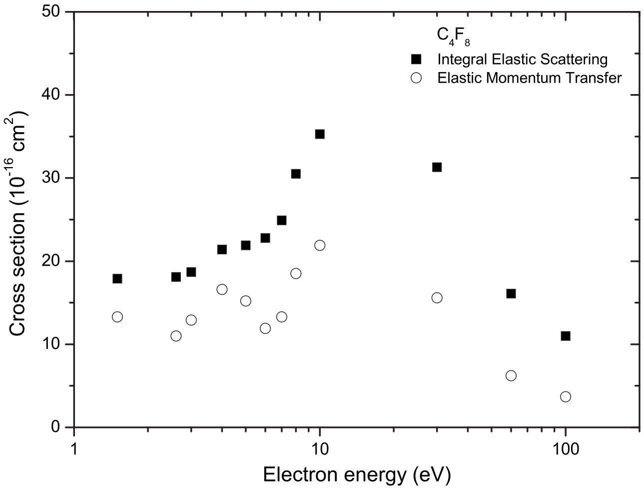

FIG. 14. Recommended integral elastic cross sections and momentum transfer cross sections for electron scattering from C_4F_8 (in units of 10^{-16} cm^2).

2.10. CH_2F_2

The original study into elastic electron scattering from CH_2F_2 came from Sophia University.[30] This was followed by a model potential calculation from Nishimura[31] and a Schwinger multichannel calculation, using nonconserving pseudopotentials, from Natalense *et al.*[23] A comprehensive experimental and theoretical study was most recently undertaken by Varella *et al.*[27] Here very good agreement is found between the data from the Sophia University and the result from the Schwinger multichannel method with a Born–Closure procedure. As a consequence this latter study[27] forms the basis of the recommended cross sections which are listed in Table 14 and plotted in Fig. 19. Note that here no estimates of ICS were given by Tanaka *et al.*,[30] so that here none can therefore be incorporated into Table 14.

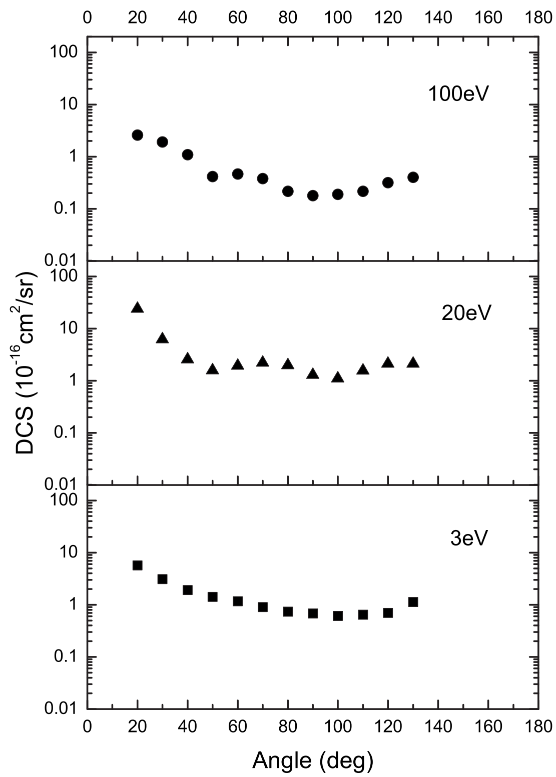

FIG. 15. Representative elastic differential cross sections for electron scattering from C_6F_6 (in units of 10^{-16} cm^2/sr).

2.11. CH_3F

The original investigation into elastic electron scattering from CH_3F came from Meier *et al.*[29] However, as that was only a relative measurement at 1 keV, we need not consider it further. A preliminary study that concentrated on fluorination effects, but included elastic CH_3F DCS at 1.5, 30, and 100 eV, was published by Tanaka *et al.*[30] That measurement

TABLE 12. Differential cross sections for elastic electron scattering (in units of 10^{-16} cm^2/sr) and integral elastic and elastic momentum transfer cross sections, respectively (in units of 10^{-16} cm^2), from hexafluorobenzene. The estimated uncertainty in the DCS data is 15% and 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	60	100
20	9.534	5.695	6.330	17.310	17.990	27.230	23.960	13.140	6.583	2.594
30	5.130	3.103	3.731	5.023	8.583	8.649	6.193	2.601	2.374	1.918
40	2.706	1.917	2.382	2.208	3.201	2.941	2.553	1.290	2.065	1.095
50	1.612	1.412	1.498	1.024	1.915	1.480	1.585	1.230	1.416	0.418
60	1.123	1.174	1.047	0.851	1.713	1.422	1.932	1.502	0.658	0.464
70	0.840	0.904	0.760	1.059	1.346	1.993	2.217	1.185	0.386	0.379
80	0.690	0.736	0.727	0.927	1.391	2.276	1.984	0.655	0.428	0.218
90	0.588	0.685	0.733	0.931	1.554	1.828	1.288	0.525	0.425	0.179
100	0.472	0.608	0.856	1.125	1.708	1.519	1.104	0.602	0.367	0.189
110	0.515	0.643	0.908	1.378	1.820	1.628	1.570	0.695	0.364	0.217
120	0.602	0.694	0.967	1.463	1.824	2.308	2.108	0.841	0.493	0.319
130	0.762	1.129	1.185	1.646	1.938	2.371	2.128	1.286	0.779	0.402
ICS	21.75	18.60	21.51	30.98	41.09	51.62	48.01	32.65	24.26	9.04
MTCS	11.49	14.25	16.54	18.50	24.40	29.93	26.35	16.86	11.58	5.63

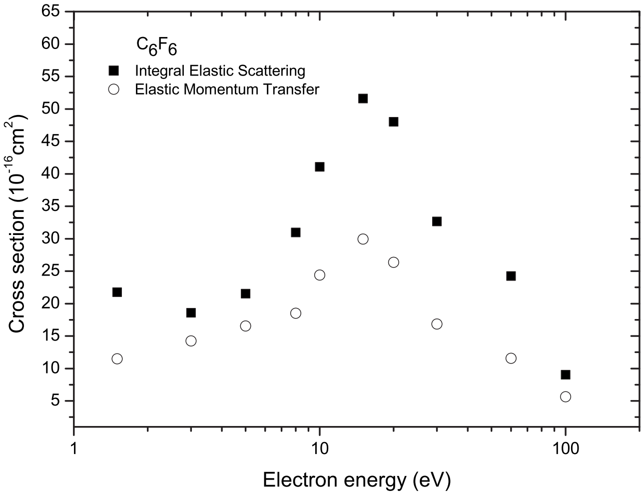

FIG. 16. Recommended integral elastic cross sections and momentum transfer cross sections for electron scattering from C_6F_6 (in units of 10^{-16} cm^2).

stimulated theoretical studies by Natalense *et al.*,[23,24] using a Schwinger multichannel method with norm-conserving pseudopotentials. The most complete, at this time, experimental and theoretical investigations into this scattering system came from Varella *et al.*[27] and Kato *et al.*[32] In the former case the incident electron energy range was 1.5–30 eV, while in the latter it was 60–200 eV. It is the measured DCS from Refs. 27 and 32 that form the basis of our recommended cross section set in Table 15 which are also plotted in Fig. 20. Also listed in Table. 15 are the ICS from Kato *et al.*[32] and they are plotted in Fig. 21.

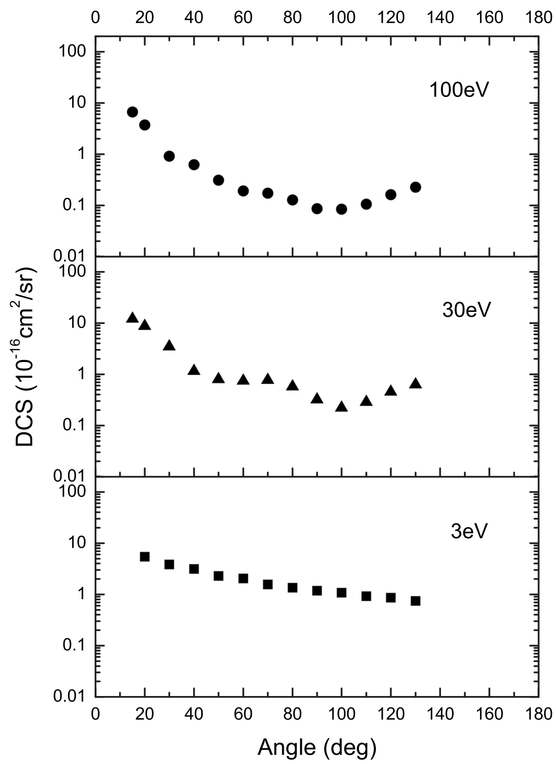

FIG. 17. Representative elastic differential cross sections for electron scattering from CHF_3 (in units of 10^{-16} cm^2/sr).

2.12. CF_3I

There are three elastic cross section sets reported for this species. Kitajima *et al.*[33] measured the elastic DCS from CF_3I in the energy range of 1.5–60 eV and for the scattering

TABLE 13. Differential cross sections (in units of 10^{-16} cm^2/sr) for elastic scattering from CHF_3. Their absolute uncertainties are ~15%–20%. Integral cross sections (in units of 10^{-16} cm^2) are given at the foot of this table, with errors of ~30%

Angle	Energy(eV)														
(deg)	1.5	2.0	3.0	4.0	5.0	6.5	7.0	8.0	9.0	10	15	20	30	60	100	200
15	—	—	—	—	—	—	—	—	—	—	8.4548	9.5002	12.1410	11.9050	6.6705	2.840
20	9.6869	7.5023	5.4249	6.7053	6.7146	6.4416	6.4840	6.5110	6.5873	7.3083	6.2872	7.2141	8.6783	6.8642	3.7217	1.520
25	6.9478	5.7449	—	—	—	—	—	—	—	—	—	—	—	—	—	1.230
30	6.0904	4.8100	3.8389	4.1436	4.0816	4.6603	4.4950	4.1289	4.7737	4.7163	4.2750	3.8040	3.4654	1.5453	0.9134	0.834
35	4.4904	3.8554	—	—	—	—	—	—	—	—	—	—	—	—	—	0.508
40	4.0253	3.2733	3.1524	3.1566	3.1587	3.3108	3.1550	3.1992	3.2033	3.2311	2.6826	2.0897	1.1538	0.7087	0.6237	0.381
45	3.3327	2.7083	—	—	—	—	—	—	—	—	—	—	—	—	—	0.331
50	3.2382	2.4114	2.2942	2.4882	2.5785	2.4440	2.1730	2.7750	2.2542	2.1301	1.6188	1.1224	0.7951	0.7031	0.3117	0.273
55	2.7542	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.203
60	2.4263	2.1154	2.0532	2.0347	2.0618	1.7840	1.5492	1.3405	1.4336	1.3653	1.0298	0.7820	0.7492	0.4744	0.1915	0.142
65	2.1290	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.103
70	1.9364	1.8134	1.5601	1.6556	1.4514	1.2392	1.0041	0.9010	0.8992	0.8555	0.7528	0.8545	0.7682	0.2643	0.1724	0.096
80	1.6762	1.5821	1.3502	1.3835	1.1383	0.8841	0.6806	0.6028	0.6296	0.6595	0.8004	0.8357	0.5775	0.1533	0.1286	0.095
90	1.6596	1.4240	1.1844	1.0640	0.8284	0.5768	0.5668	0.5356	0.6331	0.6376	0.7544	0.7317	0.3213	0.1304	0.0864	0.080
100	1.2772	1.2108	1.0814	0.8631	0.6731	0.4882	0.4707	0.5301	0.5809	0.6808	0.7628	0.5666	0.2219	0.1255	0.0849	0.090
110	1.1922	1.0968	0.9240	0.7209	0.5561	0.5272	0.5313	0.5243	0.6149	0.7013	0.7915	0.5301	0.2873	0.1596	0.1053	0.086
120	1.0928	1.0080	0.8603	0.6441	0.5409	0.5442	0.6051	0.6241	0.6619	0.7507	0.7513	0.5853	0.4531	0.2845	0.1615	0.090
130	1.0524	0.9638	0.7440	0.6087	0.6297	0.7722	0.7365	0.7556	0.8209	0.8503	0.8633	0.7619	0.6315	0.3845	0.2268	0.099
ICS	—	—	—	—	—	—	—	—	—	—	—	20.0	19.2	—	10.6	6.93

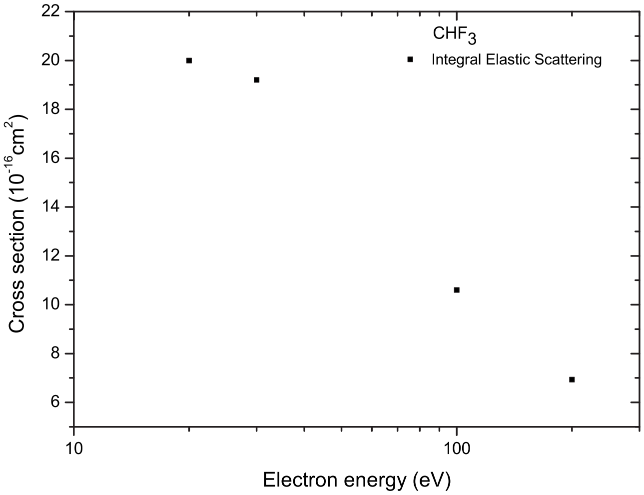

FIG. 18. Recommended integral elastic cross sections for electron scattering from CHF_3 (in units of 10^{-16} cm^2).

angles of 20°–130°, and Francis-Staite *et al.*[34] made DCS measurements at ten incident electron energies in the range 10–50 eV with a scattered electron angular range of 20°–135°, from which they derived ICS. Cho *et al.*[35] presented DCS for scattering angles from 10° or 20° up to 180° at the incident electron energies of 5, 10, 20, 30, and 50 eV. Cho *et al.* also estimated ICS and MTCS from their experimental DCS set and from the previous DCS result of Kitajima *et al.*[33] In the energy and angular ranges where these results overlapped, their overall behavior is similar to each other, with a significant exception at 10 eV, and also for some angular ranges at other energies. Since it is difficult to recommend a specific data set due to these discrepancies, we plotted all three results with error bars on a single plot for each energy and deleted data points which are not overlapped with any other data point within the limits of uncertainties. We least-squares-fitted the remaining data points at each energy to obtain the suggested DCS. For the energies where only one data set is available at each energy, we decided not to recommend, but simply *present* available DCS sets, considering the recent interests in this molecule. We decided not to recommend or suggest ICS/MTCS, either. The estimated uncertainties in the original cross sections provided by each

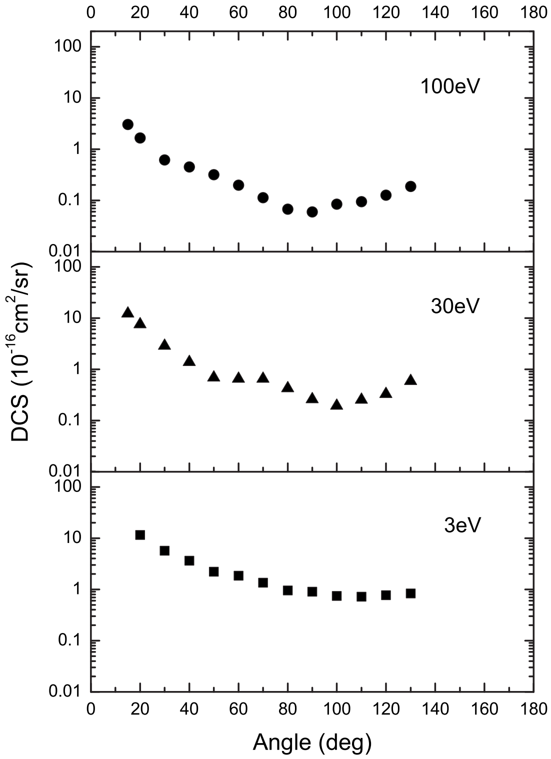

FIG. 19. Representative elastic differential cross sections for electron scattering from CH_2F_2 (in units of 10^{-16} cm^2/sr).

TABLE 14. Differential cross sections (in units of 10^{-16} cm^2/sr) for elastic scattering from CH_2F_2. 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	9.0	10	15	20	30	60	100
15	—	—	—	—	—	—	—	—	—	13.0880	11.872	—	12.2110	8.3641	3.0323
20	21.3310	16.2830	11.5580	9.0750	9.7206	8.8760	8.4820	8.3492	8.1393	10.0440	9.2324	9.0980	7.5670	4.4855	1.6570
30	8.5640	6.8560	5.6684	4.8670	4.4180	4.4710	4.9131	5.1217	4.9203	5.0470	4.5488	4.6290	2.8768	1.3501	0.6164
40	4.6070	4.1600	3.6126	2.8320	3.0815	2.8070	3.5260	3.1706	2.9339	2.8850	2.3204	2.0610	1.3866	0.6615	0.4509
50	2.8370	2.5047	2.2076	1.9440	2.0835	2.0618	2.1745	2.0621	1.9643	1.9130	1.4704	1.2640	0.6873	0.4951	0.3159
60	1.9590	1.7140	1.8537	1.4480	1.4515	1.3635	1.3946	1.4373	1.3768	1.2522	0.9873	1.0000	0.6541	0.2972	0.1993
70	1.6460	1.2980	1.3511	1.0850	0.9725	0.8670	0.8886	0.9045	0.7684	0.7654	0.6998	0.8349	0.6490	0.2028	0.1134
80	1.2560	1.0820	0.9557	0.8350	0.7247	0.6164	0.6223	0.5381	0.6600	0.7691	0.7558	0.7447	0.4273	0.1476	0.0678
90	1.1860	1.0637	0.9048	0.7271	0.6829	0.6441	0.6435	0.6352	0.7528	0.7563	0.7162	0.6768	0.2597	0.1084	0.0596
100	0.9826	0.9339	0.7467	0.6775	0.6159	0.6132	0.6592	0.7877	0.8472	0.8092	0.8178	0.5402	0.1939	0.1058	0.0841
110	0.9461	0.9448	0.7187	0.7262	0.6490	0.7416	0.8139	0.9840	1.0161	1.0320	0.7121	0.5804	0.2545	0.1141	0.0946
120	0.9439	0.8562	0.7729	0.7282	0.8211	0.9898	0.9314	0.9863	1.0991	1.1034	0.8297	0.6617	0.3280	0.2147	0.1267
130	0.9639	0.8741	0.8330	0.8820	0.9830	1.0857	1.0451	1.2380	1.2089	1.0930	0.8445	0.7382	0.5917	0.3238	0.1866

TABLE 15. Differential cross sections (in units of 10^{-16} cm^2/sr) for elastic scattering from CH_3F. Their absolute uncertainties are ~15%–20%. Integral cross sections (in units of 10^{-16} cm^2) are given at the foot of this table, with errors of ~30%

Angle (deg)	Energy(eV) 1.5	2.0	3.0	4.0	5.0	6.5	7.0	8.0	9.0	10	15	20	30	60	100	200
15	—	—	—	—	—	—	—	—	—	9.9915	9.7406	10.363	10.201	7.2117	2.5456	3.5112
20	14.1540	9.8276	7.4441	6.0525	7.0843	7.7898	8.0992	7.8911	3.3488	8.2624	8.5840	7.6735	7.9241	4.0624	1.0977	1.5024
30	7.1874	5.6562	4.0018	3.4945	4.1983	4.4785	4.6517	5.0518	5.0519	5.1938	4.7734	4.1405	3.1670	0.9253	0.2859	0.5534
40	3.8364	3.1210	2.1882	2.1424	2.3673	2.9357	2.8488	3.0756	2.9920	1.3046	2.5443	2.1341	1.3697	0.4905	0.2521	0.2706
50	2.2522	2.1132	1.3786	1.5485	1.6474	1.8061	1.7177	1.8000	1.8140	1.8203	1.5009	1.1827	0.6134	0.3519	0.2197	0.1630
60	1.6898	1.4086	1.1454	1.2539	1.4041	1.2465	1.3696	1.2924	1.1114	1.0767	0.9337	0.7440	0.4983	0.2501	0.1489	0.0831
70	1.0707	1.0683	1.1635	1.2975	1.2625	1.1107	1.1556	1.0046	0.8962	0.8114	0.6601	0.6409	0.4755	0.1414	0.0878	0.0631
80	0.9570	1.0478	1.1553	1.3416	1.3097	1.2281	1.1426	1.0010	0.8893	0.7719	0.6260	0.5804	0.3436	0.1150	0.0629	0.0544
90	0.8825	0.8323	1.1215	1.2426	1.4064	1.4072	1.2777	1.1234	0.8997	0.9428	0.6139	0.5165	0.2329	0.0744	0.0505	0.0498
100	0.7660	0.8923	1.0984	1.2070	1.3022	1.3379	1.2877	1.2020	1.0631	1.0123	0.6384	0.3976	0.1874	0.0663	0.0552	0.0445
110	0.7705	0.8579	1.0003	1.0502	1.2825	1.2004	1.3155	1.2724	1.1124	1.0556	0.6392	0.4287	0.2004	0.0799	0.0731	0.0412
120	0.7196	0.7659	0.9292	0.8941	1.1856	1.1851	1.2422	1.1599	1.2329	1.0469	0.6743	0.4397	0.2955	0.1354	0.1071	0.0443
130	0.6702	0.6979	0.7637	0.9579	1.0813	1.1207	1.2399	1.2863	1.1841	1.1701	0.7566	0.5727	0.3968	0.1906	0.1114	0.0442
ICS	—	—	—	—	—	—	—	—	—	—	—	—	—	6.123	2.929	3.253

group are the following: 15%–20% in DCS for Kitajima *et al.*,[33] 30% in DCS and 40% in ICS/MTCS for Francis-Staite *et al.*,[34] and 8%–15% in DCS and 25%–30% in ICS/MTCS for Cho *et al.*[35] We do not provide uncertainties for DCS/ICS/MTCS which are least-squares-fitted or averaged for this article. All the cross sections are presented in Table. 16 and plotted in Fig. 22.

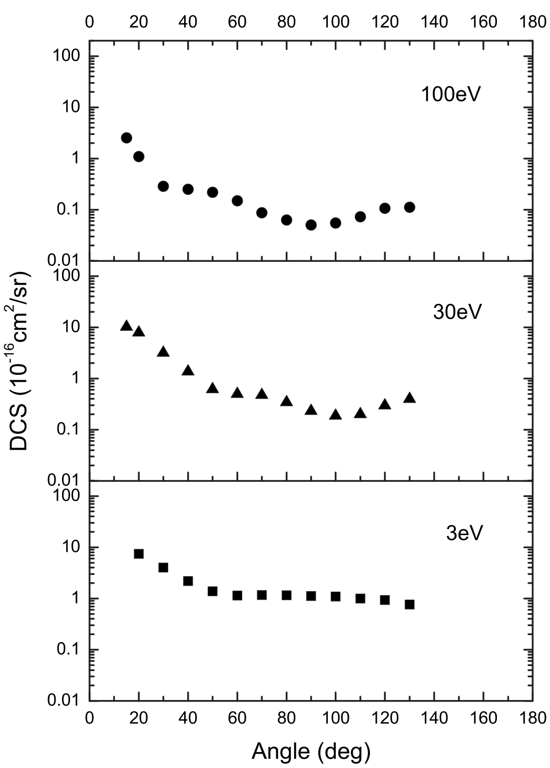

FIG. 20. Representative elastic differential cross sections for electron scattering from CH_3F (in units of 10^{-16} cm^2/sr).

2.13. NF_3

There is a real sparsity of available data for electron scattering from NF_3. The first theoretical study on low-energy electron collision processes in NF_3 was from Rescigno,[36] which included Kohn variation calculations of elastic DCS and ICS for electrons with energies in the range 0–10 eV. Shortly thereafter, the only comprehensive experimental study, which reported elastic DCS, ICS, and MTCS for energies between 1.5 and 100 eV, was published by Boesten *et al.*[37] Subsequently, a Schwinger multichannel theoretical approach[38] reported corresponding cross sections for electron energies in the range 0–60 eV. Generally quite good agreement was found between the results from that calculation and the data of Boesten *et al.*,[37] so our recommended data in Table 17 and Figs. 23 and 24 is consequently taken from the measurements of Boesten *et al.*

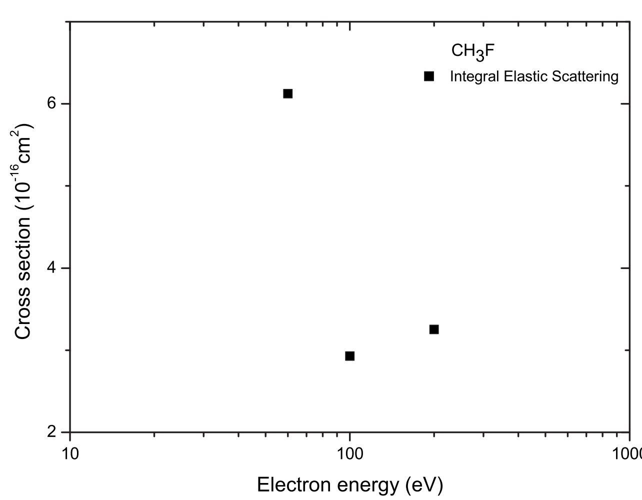

FIG. 21. Recommended integral elastic cross sections for electron scattering from CH_3F (in units of 10^{-16} cm^2).

TABLE 16. Differential cross sections for elastic electron scattering (in units of 10^{-16} cm^2/sr) from CF_3I

Angle	Energy(eV)											
(deg)	1.5	3.0	5.0	8.0	10	15	20	25	30	40	50	60
10							28.06		26.36		10.69	
20	2.22	3.35	11.38	19.25	20.54		19.45		11.02		4.83	4.06
30	1.21	2.27	8.79	12.03	11.97	14.67	7.70	32.5	4.21	2.84	2.38	1.10
40	0.82	3.16	6.45	6.40	5.71	7.51	2.38	2.54	1.94	3.33	1.19	0.66
45						3.89	1.51	2.47			0.86	
50	1.00	3.49	4.19	3.03	2.58		1.23		1.34		0.65	0.51
60	1.02	3.52	3.16	1.67	1.57	1.39	1.23	1.7	1.04	0.67	0.45	0.31
70	1.09	3.2	2.25	1.36	1.43		1.11		0.74		0.35	0.18
75						1.84	0.98	0.49	0.60	0.72	0.30	
80	0.97	2.61	1.91	1.39	1.39		0.85		0.49		0.25	0.14
90	0.82	1.91	1.67	1.46	1.21	1.68	0.66	0.7	0.39	0.26	0.19	0.12
100	0.7	1.41	1.43	1.23	0.97		0.62		0.39		0.21	0.16
105						1.19	0.62	0.47	0.42	0.46	0.26	
110	0.55	0.9	1.15	0.94	0.85		0.62		0.46		0.32	0.27
120	0.46	0.68	0.95	0.85	0.95	1.01	0.65	0.74	0.55	0.68	0.44	0.43
130	0.40	0.84	1.07	1.15	1.27		0.75		0.72		0.50	0.51
135						1.67		1.34	0.84	0.73		
140			1.62		1.76		0.95		0.99		0.52	
150			2.61		2.34		1.13		1.31		0.59	
160			3.48		2.88		1.22		1.58		0.71	
170			3.78		3.27		1.47		1.78		0.70	
180			4.23		3.71		1.65		2.03		0.78	

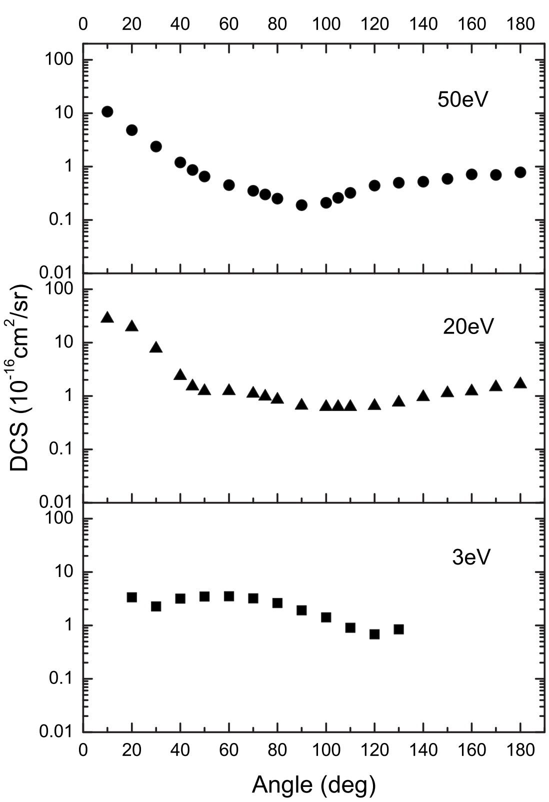

FIG. 22. Representative elastic differential cross sections for electron scattering from CF_3I (in units of 10^{-16} cm^2/sr).

2.14. SF_6

Unlike most of the other molecules in this report, there have been numerous measurements of elastic cross sections of this molecule for the last several decades[7,39–44] and these were reviewed by Christophorou and Olthoff.[45] In the work of Cho *et al.*[40,41] a magnetic angle-changing device was employed in conjunction with an electron spectrometer to measure the cross sections to backward angles at low impact energies. While these results show somewhat scattered distributions, Rohr,[42] Sakae *et al.*[7] and Cho *et al.*[40,41] show remarkably good agreement at those electron energies for which they overlap. We would also like to note that there is a quite recent measurement by Bhushan *et al.*[46] for the energy region from 50 to 500 eV, which is pretty much overlapped with that of Sakae *et al.*, and both measurements agree with each other within the uncertainties in the energy region of the current interest. Rohr reported elastic DCS at 0.5, 2.7, and 7 eV, while Sakae *et al.* measured DCS for electron energies from 75 to 700 eV. Cho *et al.* measured at 11 energies between 2.7 and 75 eV. Also, ICS/MTCS from these three groups are very smoothly connected at the boundary of the energy ranges where their results meet each other. This consistency justifies choosing the elastic DCS/ICS/MTCS from these three groups as recommended data—Rohr[42] for 0.5 eV, Cho *et al.*[40] for 2.7–75 eV, and Sakae *et al.*[7] for 100 eV. Christophorou and Olthoff[46] fitted ICS/MTCS from these three groups and presented recommended data. We simply give their fitting results as our recommended values for ICS/MTCS. All these DCS/ICS/MTCS

TABLE 17. Differential cross sections for elastic electron scattering (in units of 10^{-16} cm^2/sr) and ICS and elastic MTCS, respectively (in units of 10^{-16} cm^2), from NF_3. The estimated uncertainty in the DCS data is ~15%–20%, while the uncertainty on the integral and momentum transfer cross sections is ~20%–30%

Angle	Energy(eV)															
(deg)	1.5	2.0	3.0	4.0	5.0	7.0	7.5	8	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	0.933	1.430	2.199	2.960	2.729	2.671	2.896	2.908	3.168	3.946	5.006	6.490	6.946	6.715	5.955	3.201
30	0.667	1.216	2.436	2.949	2.807	2.932	3.036	3.132	3.037	3.077	2.777	2.863	2.657	1.838	1.243	0.851
40	0.656	1.078	2.331	2.822	2.577	2.868	2.731	2.699	2.680	2.107	1.680	1.358	1.004	0.666	0.671	0.623
50	0.729	1.197	2.052	2.511	2.119	2.123	2.224	2.115	1.934	1.271	0.934	0.742	0.616	0.621	0.537	0.340
60	0.787	1.152	1.768	1.818	1.552	1.655	1.517	1.460	1.390	0.826	0.750	0.688	0.639	0.601	0.328	0.195
70	0.962	1.074	1.329	1.297	1.261	1.137	1.108	1.209	0.954	0.715	0.799	0.747	0.671	0.340	0.232	0.156
80	0.981	1.100	1.114	1.099	0.947	0.808	0.851	0.868	0.737	0.725	0.798	0.665	0.509	0.196	0.155	0.116
90	1.097	1.011	0.920	0.794	0.714	0.727	0.719	0.766	0.702	0.786	0.715	0.510	0.320	0.116	0.109	0.067
100	1.053	0.884	0.685	0.640	0.641	0.663	0.704	0.702	0.694	0.738	0.569	0.322	0.191	0.093	0.093	0.073
110	0.998	0.843	0.598	0.542	0.622	0.666	0.704	0.707	0.673	0.610	0.462	0.295	0.200	0.146	0.152	0.108
120	0.992	0.778	0.584	0.539	0.637	0.652	0.661	0.639	0.626	0.555	0.561	0.440	0.376	0.314	0.265	0.169
130	0.920	0.723	0.576	0.604	0.765	0.655	0.645	0.623	0.605	0.598	0.746	0.725	0.623	0.483	0.378	0.273
ICS	11.90	12.98	17.24	18.41	18.11	17.35	17.47	17.89	16.91	14.60	14.48	14.05	13.33	12.32	11.03	9.72
MTCS	12.46	12.39	14.24	14.92	14.92	14.24	14.17	12.82	13.53	10.41	9.87	8.54	7.63	6.62	5.81	5.42

data are presented in Tables 18 and 19 and plotted in Figs. 25 and 26. Numbers in parentheses in Table 18 between 2.7 and 75 eV are the uncertainties given by Cho *et al.*[40] Rohr[42] and Sakae *et al.*[7] claimed the uncertainties of 10% and 20%, respectively, for their DCS.

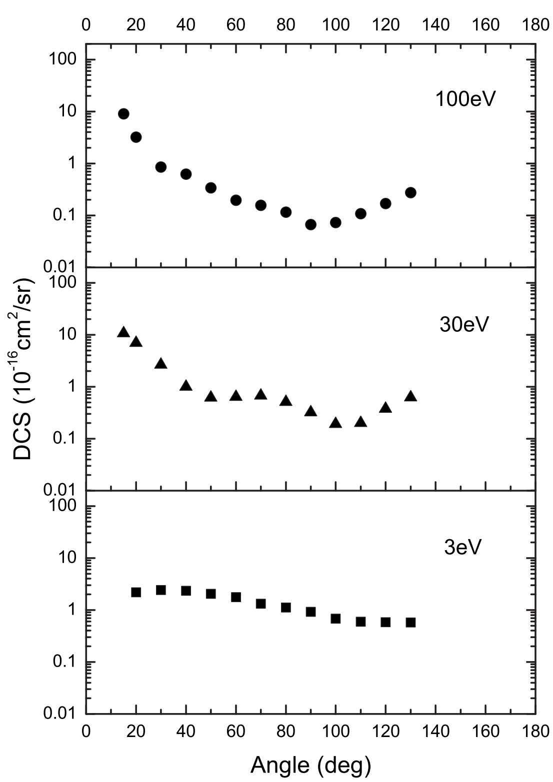

FIG. 23. Representative elastic differential cross sections for electron scattering from NF_3 (in units of 10^{-16} cm^2/sr).

2.15. SiH_4

Since the discovery of the hydrogenerated amorphous silicon used in solar cells, various chemical systems have been investigated to deposit a-Si-based materials by plasma-enhanced chemical vapor deposition (PECVD). However, there is a sparsity of available data for electron scattering from SiH_4. A set of cross sections, including the elastic MTCS for SiH_4, was derived from a swarm experiment by Shimada *et al.*[47] The first theoretical study on total (elastic +absorption), MTCS, and DCS for e-SiH_4 in the energy range 30–400 eV was reported by Jain[48] using a parameter-free and energy-dependent spherical-complex-optical poten-

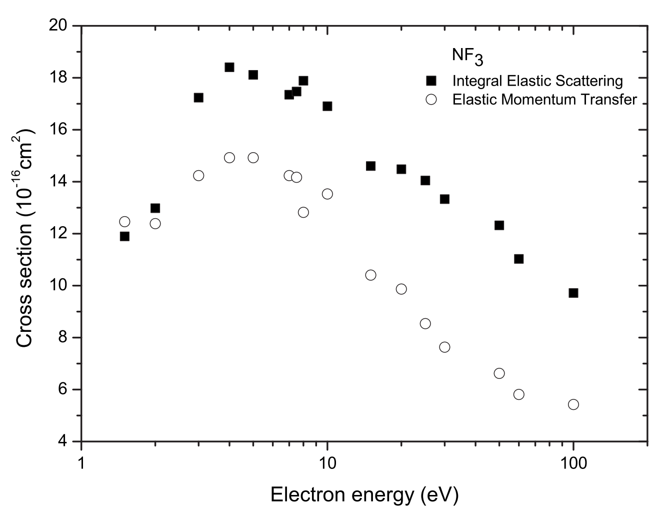

FIG. 24. Recommended integral elastic cross sections and momentum transfer cross sections for electron scattering from NF_3 (in units of 10^{-16} cm^2).

TABLE 18. Differential cross sections for elastic electron scattering (in units of 10^{-16} cm^2/sr) from SF_6

Angle (deg)	Energy(eV) 0.5	2.7	5.0	7.0	9.0	10	12	15	20	30	50	75	100
5													125.449
10	5.790						13.788(17)		23.711(8)	55.574(8)	49.457(7)	45.477(8)	43.519
15				5.896(8)	8.500(11)	11.168(7)	15.218(8)	12.994(7)	15.656(7)	23.329(7)	24.678(7)	15.422(8)	12.423
20	2.895	1.949(13)	3.939(11)	7.899(7)	8.823(9)	8.892(7)	12.415(7)	11.128(7)	10.983(9)	13.255(7)	9.672(8)	4.414(9)	2.510
25		1.990(8)	4.225(7)	6.843(7)	7.720(7)	7.558(8)	9.312(7)	8.699(7)	7.988(7)	6.916(7)	3.510(8)	1.369(13)	1.499
30	2.272	2.336(7)	4.001(8)	5.899(7)	6.404(7)	6.236(7)	6.651(7)	6.652(7)	5.246(8)	3.307(7)	1.606(8)	1.230(8)	1.575
35		2.467(7)	3.827(8)	4.893(7)	5.201(8)	4.811(7)	4.511(7)	4.649(7)	3.228(10)	1.573(7)	1.295(8)	1.379(10)	1.427
40	1.748	2.516(8)	3.597(7)	3.988(7)	3.893(7)	3.507(7)	2.911(8)	3.046(7)	1.867(7)	0.988(7)	1.376(8)	1.326(10)	0.915
45		2.506(8)	3.143(8)	2.995(7)	2.811(7)	2.517(7)	1.724(7)	1.837(7)	1.002(9)	0.993(7)	1.378(7)	0.965(8)	0.546
50	1.358	2.401(8)	2.819(9)	2.201(7)	2.066(7)	1.708(8)	1.104(7)	1.126(7)	0.703(9)	1.266(7)	1.159(10)	0.670(8)	0.326
55		2.184(8)	2.329(7)	1.550(7)	1.442(7)	1.189(7)	0.748(7)	0.839(7)	0.740(9)	1.369(7)	1.038(8)	0.478(8)	0.255
60	1.025	2.049(7)	1.894(7)	1.107(7)	1.089(7)	1.028(7)	0.677(8)	0.869(7)	0.984(9)	1.430(7)	0.758(10)	0.340(8)	0.249
65		1.787(7)	1.422(8)	0.873(7)	0.953(7)	0.982(7)	0.737(8)	1.053(7)	1.331(11)		0.533(11)	0.298(8)	0.274
70	0.969	1.539(7)	1.150(7)	0.802(7)	0.941(7)	1.091(8)	0.858(8)	1.246(7)	1.433(10)	1.052(8)	0.342(9)	0.274(10)	0.310
75		1.405(7)	0.907(9)	0.842(7)	1.073(7)	1.263(7)	0.994(8)	1.393(7)	1.500(8)		0.236(9)	0.262(10)	0.281
80	0.879	1.199(7)	0.825(8)	1.002(7)	1.263(7)	1.456(9)	1.088(8)	1.403(7)	1.343(7)	0.655(8)	0.180(12)	0.248(12)	0.220
85		1.077(8)	0.795(7)	1.153(7)	1.317(8)	1.531(8)	1.103(8)	1.308(7)	1.128(8)		0.199(9)	0.231(9)	0.176
90	0.768	0.969(8)	0.884(8)	1.288(7)	1.391(8)	1.516(9)	1.168(7)	1.218(7)	1.011(8)	0.402(7)	0.234(9)	0.214(11)	0.131
95		0.906(8)	0.960(9)	1.388(7)	1.385(7)	1.413(12)	1.193(8)	1.069(7)	0.823(9)		0.283(8)	0.218(14)	0.119
100	0.713	0.935(8)	1.124(8)	1.420(7)	1.345(7)	1.244(8)	1.132(8)	0.974(8)	0.690(7)	0.473(7)	0.316(9)	0.194(8)	0.141
105		0.981(8)	1.229(7)	1.397(7)	1.217(7)	1.067(8)	1.095(7)	0.864(7)	0.596(8)		0.320(10)	0.182(9)	0.172
110	0.725	1.037(7)	1.268(9)	1.296(7)	1.069(8)	0.952(7)	1.117(7)	0.791(7)	0.611(8)	0.643(8)	0.348(10)	0.210(10)	0.204
115		1.057(7)	1.254(8)	1.165(8)	0.945(7)	0.831(7)	1.210(8)	0.778(7)	0.602(8)		0.389(11)	0.262(13)	0.249
120	0.690	1.099(8)	1.231(9)	1.048(7)	0.816(7)	0.771(8)	1.376(8)	0.765(7)	0.669(8)	0.873(7)	0.420(10)	0.356(10)	0.295
125		1.236(7)	1.150(11)	0.909(7)	0.745(7)	0.779(7)	1.450(7)	0.811(7)	0.811(9)		0.469(11)	0.472(11)	0.416
130		1.311(7)	1.016(9)	0.810(7)	0.830(12)	0.846(8)	1.544(7)	0.867(7)	0.933(7)	1.098(7)	0.583(12)	0.632(13)	0.495
135		1.351(7)	0.956(8)	0.977(7)	0.956(7)	0.916(7)	1.566(7)	0.971(7)					
140		1.372(7)	0.908(8)	0.999(7)	0.995(7)	0.999(8)	1.616(7)	1.118(7)					
145		1.402(8)	0.792(8)	1.006(7)	1.072(8)	1.113(7)	1.651(7)	1.257(7)					
150		1.415(7)	0.744(9)	1.110(7)	1.233(7)	1.173(7)	1.686(7)	1.353(7)					
155		1.390(7)	0.703(8)	1.235(7)	1.305(8)	1.247(7)	1.711(7)	1.495(8)					
160		1.485(7)	0.641(7)	1.288(7)	1.467(8)	1.306(7)	1.758(7)	1.652(7)					
165		1.486(7)	0.606(7)	1.395(8)	1.571(9)	1.357(7)	1.752(8)	1.774(7)					
170		1.485(7)	0.576(8)	1.467(7)	1.618(8)	1.369(7)	1.829(8)	1.915(7)					
175		1.499(7)	0.572(7)	1.512(7)	1.706(7)	1.440(7)	1.862(7)	1.940(7)					
180		1.500(7)	0.535(9)	1.542(7)	1.775(7)	1.473(8)	1.843(7)	1.973(7)					

tial. Thereafter, the elastic DCS, ICS, and MTCS for energies between 1.8 and 100 eV and a scattering angle range of 20°–130° was published by Tanaka *et al.*[49] Subsequently, a Schwinger multichannel theoretical approach[50] reported corresponding cross sections for electron energies in the range 1–30 eV. Recently, the DCS and ICS were calculated in the energy range of 20–2000 eV by Mozejko *et al.*[51] using an independent atom model. Generally quite good agreement was found between the results from these calculations and the data of Tanaka *et al.*,[49] so our recommended data in Table 20 below is consequently taken from the measurements of Tanaka *et al.* Figures for DCS, ICS and MTCS are given in Figs. 27 and 28.

2.16. Si_2H_6

Similar to SiH_4, this species is also relevant to PECVD of a-Si-based materials. Again there is little available data for electron scattering from Si_2H_6. A set of cross sections, including the elastic MTCS for Si_2H_6, was also derived from a swarm experiment by Shimada *et al.*[47] A recent theoretical study on total elastic, total ionization, and total cross sections for e-Si_2H_6 in the energy range of threshold to 2000 eV was made by Vinodkumar *et al.*,[52] using a parameter-free, and energy-dependent spherical-complex-optical potential. Shortly thereafter, the only comprehensive experimental study, which reported elastic DCS, ICS, and MTCS for energies between 1.5 and 100 eV and scattering angles of 10°–130° was published by Dillon *et al.*[53] Subsequently, a Schwinger multichannel theoretical approach[54,55] reported corresponding cross sections for electron energies in the range 5–30 eV. Generally quite good agreement was found between the results from these calculations and the data of Dillon *et al.*,[53] so our recommended data in Table 21 below

TABLE 19. ICS and elastic MTCS, respectively (in units of 10^{-16} cm^2) from SF_6

Electron Energy eV	ICS 10^{-16} cm^2	MTCS 10^{-16} cm^2	Electron Energy eV	ICS 10^{-16} cm^2	MTCS 10^{-16} cm^2
0.3	45.6		10	24.8	15.1
0.35	33.0		11	26.1	16.7
0.4	26.2		12	26.6	17.6
0.45	21.8		13	26.5	17.1
0.5	18.7		14	26.1	15.8
0.6	14.8		15	25.6	14.9
0.7	12.5		16	25.2	14.5
0.8	11.1		17	24.9	14.7
0.9	10.2		18	24.8	15.0
1	9.72		19	24.8	15.4
1.2	9.73		20	24.7	15.7
1.5	10.9		22	24.7	15.7
2	14.8		25	24.7	15.0
2.5	17.8		30	24.4	13.2
2.75		16.0	35	24.0	11.5
3	19.3	15.4	40	23.5	10.3
3.5	19.9	14.5	45	22.8	9.37
4	20.1	14.0	50	22.2	8.65
4.5	20.6	13.9	60	21.3	7.69
5	21.3	14.1	70	20.5	7.06
6	23.6	15.1	75	20.2	6.74
7	24.2	15.5	80	19.8	6.46
8	24.6	14.8	90	19.1	6.03
9	24.5	14.4	100	18.4	5.7

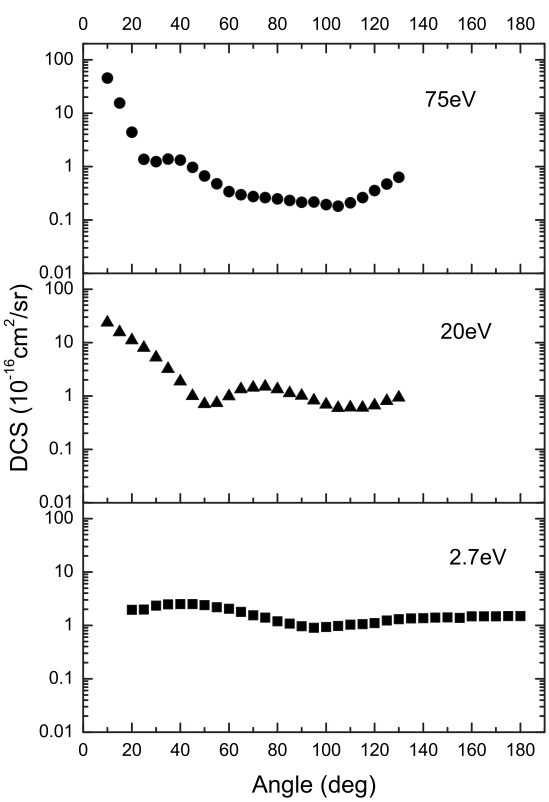

FIG. 25. Representative elastic differential cross sections for electron scattering from SF_6 (in units of 10^{-16} cm^2/sr).

is consequently taken from the measurements of Dillon *et al.* Figures for the DCS, ICS and MTCS are given in Figs. 29 and 30.

2.17. GeH_4

A set of cross sections, including the elastic MTCS for GeH_4, was derived from a swarm experiment by Soejima and Nakamura.[56] A recent theoretical study, on total elastic, total ionization, and total cross sections for e-GeH_4 in the energy

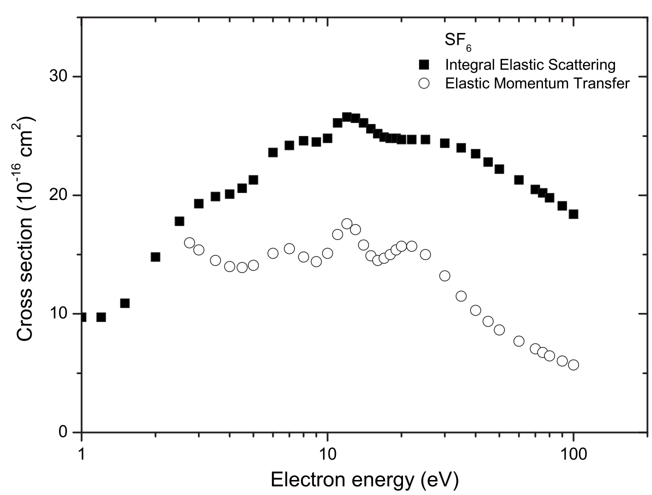

FIG. 26. Recommended integral elastic cross sections and momentum transfer cross sections for electron scattering from SF_6 (in units of 10^{-16} cm^2).

TABLE 20. Differential cross sections for elastic electron scattering (in units of 10^{-16} cm^2/sr), ICS and elastic MTCS, respectively (in units of 10^{-16} cm^2), from SiH_4. The estimated uncertainties on the DCS data is 15%–20%, while the uncertainties on the ICS and MTCS are in the range of 20%–30%

Angle	Energy(eV)											
(deg)	1.8	2.15	2.65	3.0	4.0	5.0	7.5	10	15	20	40	100
10	—	—	—	—	—	—	—	—	23.473	23.48	35.644	10.11
15	—	—	—	—	—	—	—	—	21.948	19.857	17.68	4.165
20	3.352	4.243	5.166	7.407	11.221	13.490	18.709	19.985	18.028	15.426	9.891	1.684
30	2.861	4.233	5.858	6.459	11.032	12.450	17.061	15.271	10.248	7.035	2.447	0.509
40	1.870	3.058	4.818	5.587	7.980	9.524	10.870	7.998	4.657	2.708	0.734	0.277
50	1.073	2.056	3.365	3.702	5.580	6.696	6.403	4.227	1.917	0.891	0.364	0.127
60	1.080	1.575	2.477	2.723	3.423	3.994	3.467	2.091	0.699	0.423	0.255	0.0915
70	1.340	1.853	2.331	2.309	2.144	2.283	1.855	0.990	0.478	0.426	0.227	0.101
80	2.017	2.370	2.466	2.360	1.828	1.655	1.344	0.936	0.612	0.540	0.229	0.0923
90	3.064	3.058	2.686	2.670	1.525	1.524	1.490	1.334	0.750	0.519	0.276	0.0599
100	3.019	2.990	2.844	2.605	1.563	1.578	1.801	1.400	0.768	0.415	0.241	0.0268
110	2.359	2.581	2.458	2.325	1.517	1.432	1.966	1.370	0.612	0.326	0.196	0.00941
120	1.771	2.163	2.036	1.831	1.333	1.432	1.709	1.150	0.400	0.209	0.131	0.0192
130	1.458	1.806	1.861	1.729	1.475	1.552	1.521	0.892	0.244	0.147	0.0943	0.0461
ICS	27.5	31.6	34.8	36.5	40.1	44.4	49.9	39.4	28.7	20.7	14.0	4.30
MTCS	29.0	30.1	29.1	28.1	24.5	25.6	24.4	15.8	11.2	8.70	2.90	1.20

range of the ionization threshold to 2000 eV was carried out by Vinodkumar *et al.*,[57] using a parameter-free and energy-dependent spherical-complex-optical potential. Thereafter, the only comprehensive experimental study, which reported elastic DCS, ICS, and MTCS for energies between 1.5 and 100 eV and scattering angles of 10°–130°, was published by Dillon *et al.*[58] Subsequently, a Schwinger multichannel theoretical approach[54] reported corresponding cross sections for electron energies in the range 5–30 eV. Recently, two other calculations have also been reported. One was a calculation of elastic DCS, ISC, and MTCS in the energy range from 0.2 to 100 eV using the Schwinger iterative variational method in the fixed-nuclei, static-exchange plus correlation-polarization approximation.[59] The other was for elastic DCS and ICS from 20–2000 eV, using an independent atom model with static-polarization model potential.[52] Generally quite good agreement was found between the results from those calculations and the data of Dillon *et al.*,[58] so our recommended data in Table 22 is consequently taken from the measurements of Dillon *et al.* Figures for the DCS, ICS and MTCS are given in Figs. 31 and 32.

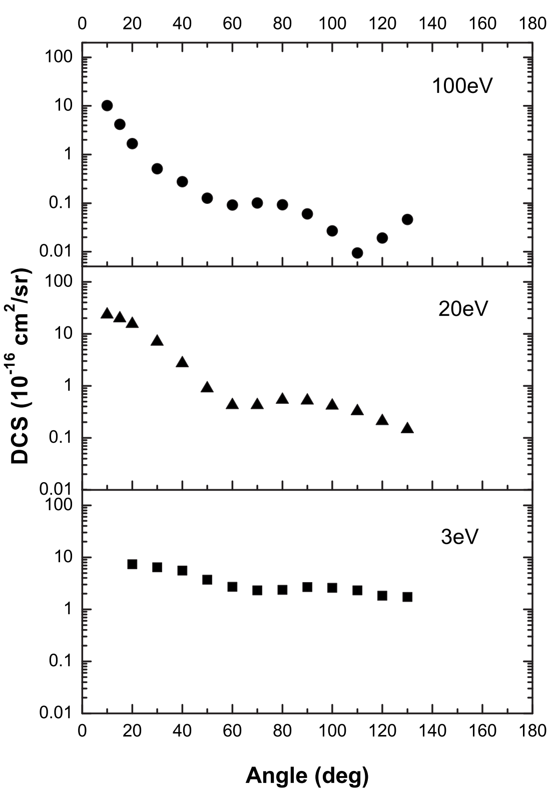

FIG. 27. Representative elastic differential cross sections for electron scattering from SiH_4 (in units of 10^{-16} cm^2/sr).

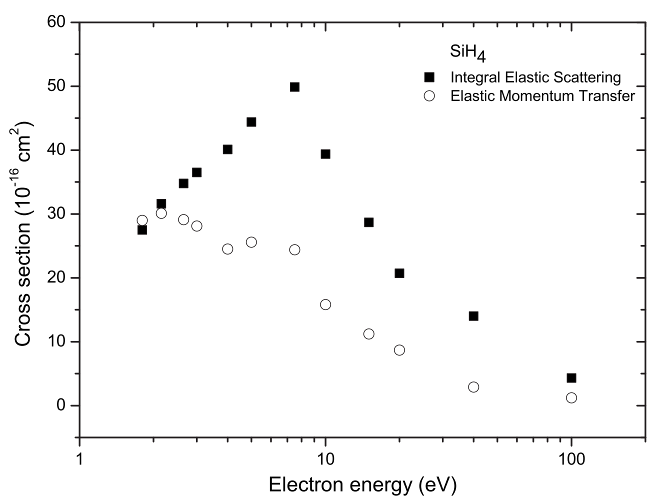

FIG. 28. Recommended integral elastic cross sections and momentum transfer cross sections for electron scattering from SiH_4 (in units of 10^{-16} cm^2).

TABLE 21. Differential cross sections for elastic electron scattering (in units of 10^{-16} cm^2/sr) and ICS and elastic MTCS, respectively (in units of 10^{-16} cm^2), from Si_2H_6. The estimated uncertainties on the DCS data is 15%–20%, while the uncertainties on the ICS and MTCS are in the range of 20%–30%

Angle (deg)	Energy(eV)									
	2.0	3.0	4.0	5.0	7.5	10	15	20	40	100
10	—	—	—	—	—	40.54	68.49	80.82	63.36	26.00
20	18.165	15.02	18.05	21.42	29.46	32.41	36.03	32.96	10.33	2.218
30	7.681	12.31	15.83	17.52	16.23	15.29	13.66	9.716	1.955	0.8952
40	5.845	9.025	10.70	10.16	7.56	6.445	4.257	3.477	0.9451	0.4386
50	3.482	5.444	5.181	4.705	3.404	2.774	2.409	2.138	0.380	0.1936
60	2.913	3.213	3.337	2.885	2.389	2.065	1.758	1.215	0.313	0.1420
70	2.911	3.271	3.016	2.689	2.528	2.025	1.224	0.741	0.267	0.1626
80	2.639	3.131	3.107	3.115	3.174	1.859	0.982	0.701	0.245	0.1583
90	2.685	3.331	2.775	2.890	2.715	1.713	1.035	0.751	0.245	0.08568
100	2.489	3.498	2.802	2.638	2.373	1.518	1.102	0.661	0.247	0.03399
110	2.462	3.486	3.142	2.762	2.175	1.339	0.958	0.410	0.218	0.01414
115	—	—	—	—	—	—	—	—	—	0.0135
120	2.399	4.344	3.311	2.543	1.860	1.333	0.656	0.277	0.141	0.01846
125	—	—	—	—	—	—	—	—	—	0.04159
130	2.378	4.459	3.459	2.536	1.609	1.418	0.410	0.238	0.141	0.068
ICS	49.3	82.8	83.2	83.1	68.8	61.4	54.6	50.0	23.7	9.60
MTCS	38.0	62.6	53.1	44.4	35.4	30.3	16.5	10.7	4.70	1.70

3. Summary

Elastic differential, integral, and momentum transfer cross sections for electron-polyatomic molecule collisions are compiled and reviewed for 17 molecules relevant to plasma processing. For each molecule, the recommended values of the cross sections with the representative figures are presented. For many of the molecules presented here, there is only one measurement, or at best a few measurements, available. Therefore, further studies are still required in many cases to make the cross section data more comprehensive and, hopefully, more accurate in order to confirm the limited data that are presently available.

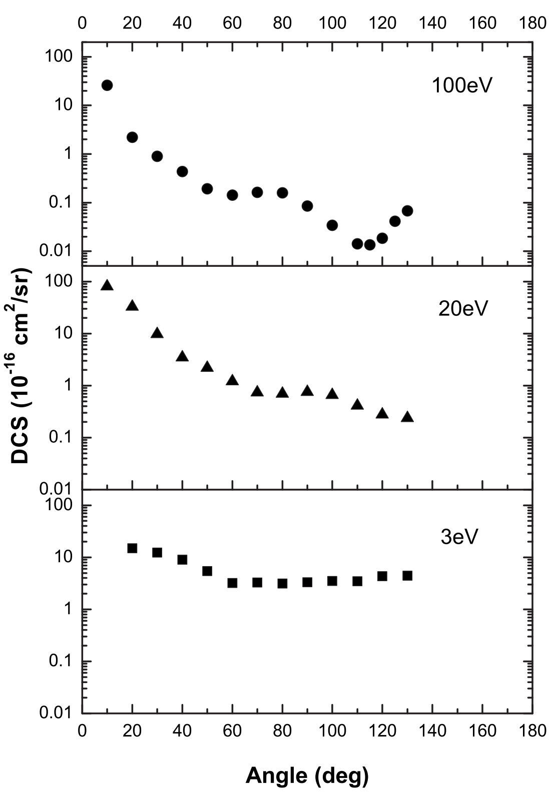

FIG. 29. Representative elastic differential cross sections for electron scattering from Si_2H_6 (in units of 10^{-16} cm^2/sr).

4. Acknowledgments

This work is accomplished as a collaboration through APAN (Asia-Pacific Atomic Data Network: a network for dissemination of collisional data relevant to plasmas,

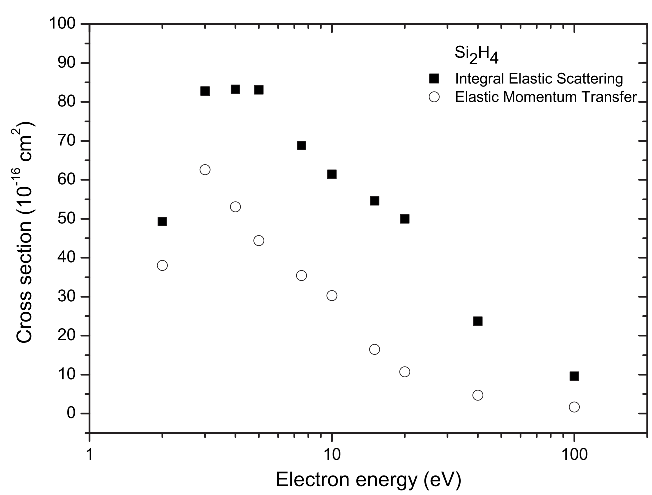

FIG. 30. Recommended integral elastic cross sections and momentum transfer cross sections for electron scattering from Si_2H_6 (in units of 10^{-16} cm^2).

TABLE 22. Differential cross sections for elastic electron scattering (in units of 10^{-16} cm^2/sr) and ICS and elastic MTCS, respectively (in units of 10^{-16} cm^2), from GeH_4. The estimated uncertainties on the DCS data is 15%–20%, while the uncertainties on the ICS and MTCS are in the range of 20%–30%

Angle	Energy(eV)										
(deg)	1.0	2.0	2.5	3.0	5.0	7.5	10	15	20	60	100
10	—	—	—	—	—	—	28.21	32.22	20.04	16.95	—
20	1.835	3.655	4.47	6.991	15.81	17.49	19.24	20.11	19.20	3.536	2.063
30	0.9723	2.470	2.732	5.271	11.660	12.560	12.830	10.230	7.094	0.416	0.376
40	0.4523	1.629	2.088	4.056	8.195	8.734	7.117	4.206	2.227	0.253	0.281
45	—	—	—	—	—	—	—	—	—	0.239	0.230
50	0.2067	1.249	1.650	2.664	4.624	4.644	3.856	1.639	0.680	0.263	0.192
55	—	—	—	—	—	—	—	—	0.235	0.235	0.191
60	0.3381	1.419	1.735	2.180	2.801	2.619	1.804	0.815	0.463	0.205	0.168
65	—	—	—	—	—	—	—	—	—	0.183	0.163
70	0.6484	1.863	2.052	2.175	2.110	1.705	1.050	0.724	0.461	0.142	0.121
75	—	—	—	—	—	—	—	—	—	0.113	0.0736
80	0.9420	2.475	2.636	2.369	1.989	1.379	1.077	0.630	0.416	0.0871	0.0449
85	—	—	—	—	—	—	—	—	—	0.0603	0.0234
90	0.9632	2.612	2.573	2.820	1.773	1.439	1.129	0.597	0.293	0.0505	0.0216
95	—	—	—	—	—	—	—	—	—	0.0354	0.0297
100	0.9854	2.507	2.338	2.314	1.894	1.547	1.079	0.491	0.19	0.0267	0.0625
105	—	—	—	—	—	—	—	—	—	0.0325	0.0956
110	0.6952	1.835	1.859	1.835	1.716	1.519	1.019	0.376	0.139	0.0368	0.113
115	—	—	—	—	—	—	—	—	—	0.0479	0.144
120	0.4742	1.359	1.487	1.442	1.341	1.369	0.848	0.311	0.125	0.0528	0.116
125	—	—	—	—	—	—	—	—	—	0.0509	0.106
130	0.3256	1.222	1.422	1.431	1.387	1.176	0.679	0.244	0.14	0.0438	0.0965
ICS	8.40	26.45	28.76	34.07	45.48	43.40	39.42	30.14	23.63	7.47	6.36
MTCS	7.11	26.03	27.31	27.67	26.87	21.72	18.54	11.48	6.52	1.44	1.60

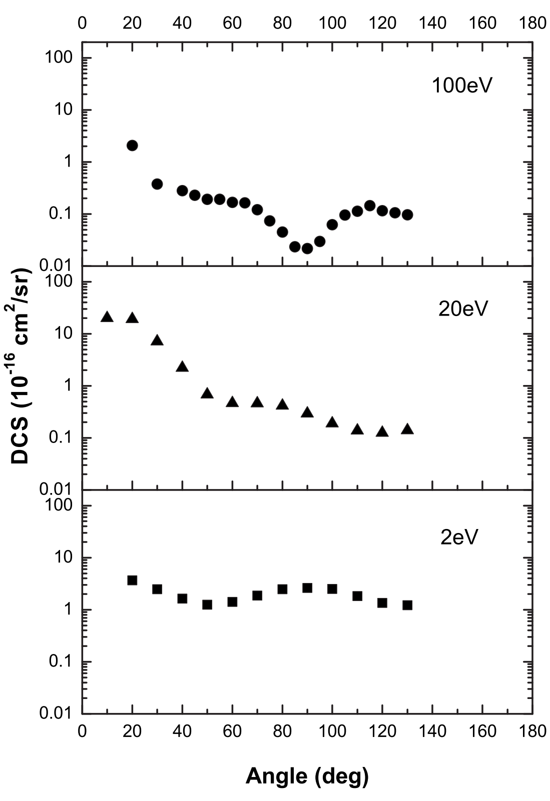

FIG. 31. Representative elastic differential cross sections for electron scattering from GeH_4 (in units of 10^{-16} cm^2/sr).

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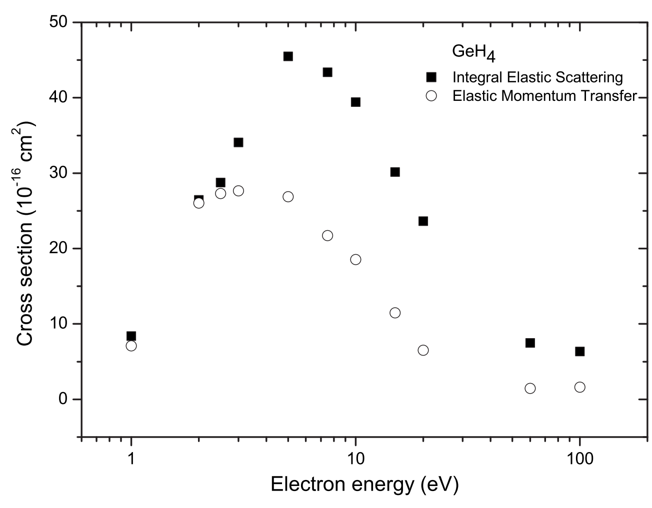

FIG. 32. Recommended integral elastic cross sections and momentum transfer cross sections for electron scattering from GeH_4 (in units of 10^{-16} cm^2).

5. References

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