Total-cross-section measurements for electron scattering by NH_3, SiH_4, and H_2S in the intermediate-energy range

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Total cross sections for electron scattering have been measured in the 75–4000-eV energy range for NH_3, SiH_4, and H_2S. For these gases, as well as for CH_4 and H_2O, cross sections have been fitted with a Born-like formula containing two parameters for each gas. The high-energy parameter of the fit to the cross sections has been related to the bond length of molecules. Partitioning of total cross sections into inelastic and elastic cross sections for these gases is discussed on the basis of available experimental data.

I. INTRODUCTION

The first measurements of total cross sections (TCS's) for electron-atom and electron-molecule scattering date back to the beginning of this century [1,2]. Even at the early stage of these investigations, attempts were performed to derive some systematical behavior of measured cross sections. Brüche [3] and Ramsauer and Kollath [4,5] pointed out qualitative similarities in the energy dependences of total cross sections for pairs of isoelectronic molecules like CO-N_2 and CO_2-N_2O. Similar analogies have also been noticed for positron scattering [6].

Recently, several studies [7–10] have shown that between 50 and 500 eV, the energy dependence of total cross sections is close to $1/\sqrt{E}$. The absolute values of cross sections have been correlated to the number of electrons [7] or to the target's polarizability [8,9]. These correlations hold fairly well for targets constituting certain groups, such as hydrocarbons [7] or noble gases [8]. General formulas [9] proposed to describe a variety of targets were until now only approximate. Further progress toward a semiempirical description of total cross sections is presently hindered by the lack of a sufficient set of reliable data for a large number of molecules. The comparison of cross sections of molecules within chemical families of similar structure could be particularly useful [11].

In this paper we present the cross-section data for the family of hydride molecules of the first and second row of the periodic table. NH_3, SiH_4, and H_2S have been mea-

sured in the 75–4000-eV range. The cross sections from our laboratory for the lighter analogs of the last two gases (CH_4 and H_2O) have been published previously [12,13] and will be discussed together with the latest measurements.

II. TARGETS

Apart from noble gases, the hydride molecules are the most compact targets—their diameters derived from van der Waals coefficients [14] are of the order of 3 Å (see Table I). All these molecules are strongly bonded, with typical binding energies around 100 kcal/mol. For the first-row hydrides, the length of the bond between the central atom and the H atom is about 1 Å; the length of the bond for SiH_4 and H_2S is about 1.4 Å. CH_4 and SiH_4 molecules possess tetrahedral symmetry and can be regarded as spherical. Consequently they are nonpolar. NH_3 has a trigonal pyramidal geometry while H_2O and H_2S have an angular shape; all three possess a strong permanent dipole moment.

These gases, being among the simplest, are widely spread in the interstellar space [15]. CH_4 and NH_3 constitute the main components of the Jovian [16] and Saturnian [17] atmospheres. Recently their presence has also been reported for Uranus [18] and Neptune [19].

Hydride molecules were subject to numerous electron-scattering experiments. TCS's for the first-row hydrides [20,21] and H_2S [22] in the low-energy region have recently been measured by Szmytkowski et al. The normalized data of Sueoka and co-workers for the first-row

TABLE I. Some features of the examined molecules (from Ref. [62]).

Molecule	Bond length (Å)	Bond angle (deg)	Bond strength (kcal/mol)	Molecule diameter (Å)	Dipole moment (D)	Polarizability (Å³)
CH_4	1.091	109.5	104.8	3.23	0	2.59
NH_3	1.008	107.3	107.4	2.94	1.47	2.26
H_2O	0.958	104.5	119.0	2.89	1.85	1.45
SiH_4	1.480	109.5	90.3	3.55	0	5.44
H_2S	1.345	93.3	91.1	3.24	0.97	3.78

hydrides [23–25] and SiH_4 [26] extend up to 400 eV. The absolute data of Dababneh et al. [27] for CH_4 extend up to 700 eV. No measurements have been performed at higher energies.

Due to the simple geometry and small total atomic numbers, hydride molecules are also a convenient test for theoretical models. A number of calculations has been performed in the low-energy region (see Ref. [28] for a recent review). CH_4 [29,30] and SiH_4 [31] exhibit pronounced Ramsauer minima below 1 eV. The minimum becomes more shallow for NH_3 [21], H_2O [20], and H_2S [23]. For CH_4, NH_3, H_2O, and H_2S a single maximum of TCS is observed, located at about 7–10 eV [13,20–22]. The location of the maximum shifts to about 3 eV for SiH_4 [26]. The scattering in the region of maxima is dominated by resonance phenomena [32].

III. APPARATUS AND METHOD

The experimental setup is essentially the same one used for our measurements in noble gases [32,33] and H_2O [12]. A transmission technique is used in a Ramsauer-type configuration. A two-part scattering chamber of 140.2-mm length allows reaching an angular resolution of 0.3 msr. The only modification with respect to previous measurements [34] regards the vacuum system, which is now based on turbomolecular pumps. This change allowed us to extend the energy range down to 75 eV, to get an overlap with the low-energy data, and up to 4000 eV, to determine the high-energy dependence of the cross sections.

The total cross section σ has been evaluated using the formula

$$\frac{I_{ci}}{I_{ci}+I_{si}} = \frac{I_{cj}}{I_{cj}+I_{sj}}\exp[-\sigma l(N_i-N_j)] \ , \qquad (1)$$

where l is the gas chamber length, N is the gas density, I_c and I_s are the collector and the scattering chamber currents, and the indices i and j label the values corresponding to two different pressures.

The systematic error (quadrical sum) has been evaluated as before [34] to 2.5%. This is due primarily to the pressure readout (1%) and to the nonlinearity in the current measurement (1.5%). As the temperature of the pressure meter was tracing the scattering-chamber temperature, the thermal transpiration error was negligible. We evaluate that the systematic error (apart from the angular-resolution error) is constant at the energies used in our measurements. The extended discussion can be found in Ref. [34].

The data presented here are the mean values of several (normally 6–8) runs. In each run, 6–8 pairs of currents have been measured for different pressures. A reduced number of measurements has been performed for SiH_4, due to its aggressive interaction with the pumps' oil. In all cases measurements were continued until the statistical error was reduced to a few percent.

Statistical errors reflect certain experimental difficulties peculiar of different gases. For example, in the case of H_2S the reducing interaction with the oxide coated cathode caused a rapid fall of the emission current. We solved this difficulty by keeping a partial pressure $(10^{-5}$ Torr) of oxygen in the cathode region. Due to the differential pumping, the oxygen partial pressure inside the scattering chamber amounted to 10^{-6} of the pressure of the gas under investigation. CH_4 molecules are dissociated by electron impact and therefore insulating non-stoichiometric compounds of C and H can form on electrodes. This was detected as an impaired current stability. As a consequence of such difficulties, the statistical errors were typically within 3% in the case of H_2S, 2.5% for CH_4 and SiH_4, and 1.5% for NH_3. The statistical error in our measurements tends to diminish with rising energy.

The angular-resolution error [35], lowering the measured cross sections could influence our data only in the high energy limit. A consistent set of small-angle differential cross sections, which would allow one to establish the angular resolution error of our measurements, is not available in the literature. Only fragmentary experimental data at 500 eV (Ref. [36]) and 35 keV [37] exist for NH_3. Theoretical calculations [38] in the Born ap-

TABLE II. Total cross sections for electron scattering (in 10^{-20} m^2). Numbers in parentheses correspond to the total (statistical plus systematic plus angular-resolution) experimental errors (in %).

| Energy (eV)	NH_3	SiH_4	H_2S
75	$10.0(^{+3.0}_{-2.9})$	$17.5(^{+3.9}_{-3.9})$	$15.1(^{+3.2}_{-3.1})$
80	$9.63(^{+3.2}_{-3.1})$	$16.7(^{+3.8}_{-3.8})$	$14.6(^{+3.3}_{-3.2})$
90	$9.07(^{+3.3}_{-3.2})$	$15.7(^{+4.0}_{-4.0})$	$13.9(^{+3.3}_{-3.3})$
100	$8.54(^{+4.4}_{-4.3})$	$14.7(^{+3.8}_{-3.8})$	$13.2(^{+3.7}_{-3.7})$
110	$7.87(^{+3.5}_{-3.4})$	$14.3(^{+2.9}_{-2.9})$	$12.1(^{+3.9}_{-3.8})$
125	$7.37(^{+3.2}_{-3.1})$	$13.8(^{+5.1}_{-5.1})$	$11.4(^{+3.7}_{-3.6})$
150	$6.86(^{+4.5}_{-4.4})$	$12.3(^{+5.2}_{-5.1})$	$10.2(^{+4.9}_{-4.8})$
175	$6.18(^{+3.9}_{-3.8})$	$11.4(^{+3.8}_{-3.7})$	$9.37(^{+3.9}_{-3.8})$
200	$5.64(^{+4.2}_{-4.0})$	$10.7(^{+3.6}_{-3.6})$	$8.82(^{+4.6}_{-4.4})$
225	$5.11(^{+3.0}_{-2.8})$	$9.90(^{+3.5}_{-3.5})$	$7.98(^{+4.6}_{-4.5})$
250	$4.81(^{+3.0}_{-2.8})$	$9.19(^{+4.5}_{-4.5})$	$7.60(^{+4.7}_{-4.5})$
300	$4.25(^{+3.9}_{-2.7})$	$7.92(^{+5.1}_{-5.0})$	$6.70(^{+5.4}_{-5.2})$
350	$3.86(^{+3.1}_{-3.1})$	$7.18(^{+3.2}_{-3.1})$	$6.24(^{+4.2}_{-4.0})$
400	$3.47(^{+3.2}_{-2.0})$	$6.55(^{+3.0}_{-3.0})$	$5.63(^{+4.5}_{-4.3})$
450	$3.15(^{+3.2}_{-2.8})$	$5.87(^{+3.1}_{-2.9})$	$5.31(^{+4.6}_{-4.3})$
500	$2.94(^{+2.3}_{-2.8})$	$5.52(^{+2.9}_{-2.9})$	$4.85(^{+3.8}_{-3.5})$
600	$2.51(^{+3.4}_{-2.8})$	$4.67(^{+3.1}_{-3.1})$	$4.15(^{+3.7}_{-3.7})$
700	$2.20(^{+3.5}_{-3.3})$	$4.14(^{+3.5}_{-3.3})$	$3.79(^{+3.9}_{-3.9})$
800	$1.99(^{+3.5}_{-2.7})$	$3.67(^{+4.1}_{-4.1})$	$3.33(^{+3.7}_{-3.7})$
900	$1.78(^{+3.6}_{-2.7})$	$3.30(^{+3.9}_{-3.9})$	$3.04(^{+3.8}_{-3.8})$
1000	$1.61(^{+3.7}_{-2.7})$	$3.01(^{+4.4}_{-4.4})$	$2.81(^{+3.8}_{-3.8})$
1100	$1.47(^{+4.0}_{-2.9})$	$2.79(^{+3.8}_{-3.5})$	$2.63(^{+4.1}_{-4.1})$
1250	$1.31(^{+4.1}_{-2.8})$	$2.55(^{+4.2}_{-4.2})$	$2.30(^{+4.1}_{-4.1})$
1500	$1.10(^{+4.4}_{-2.9})$	$2.17(^{+5.5}_{-5.5})$	$2.00(^{+4.9}_{-4.0})$
1750	$0.939(^{+4.6}_{-2.6})$	$1.85(^{+5.4}_{-5.4})$	$1.70(^{+4.7}_{-3.6})$
2000	$0.854(^{+5.4}_{-3.4})$	$1.63(^{+3.6}_{-3.6})$	$1.53(^{+4.3}_{-3.3})$
2250	$0.757(^{+5.7}_{-3.4})$	$1.45(^{+4.4}_{-4.4})$	$1.37(^{+4.7}_{-3.3})$
2500	$0.680(^{+5.3}_{-2.8})$	$1.32(^{+4.7}_{-4.1})$	$1.25(^{+4.3}_{-2.7})$
2750	$0.622(^{+5.9}_{-3.2})$	$1.22(^{+3.9}_{-3.9})$	$1.14(^{+4.8}_{-3.0})$
3000	$0.554(^{+6.0}_{-3.0})$	$1.09(^{+3.3}_{-3.3})$	$1.06(^{+4.7}_{-3.0})$
3250	$0.505(^{+6.1}_{-2.9})$	$1.01(^{+4.0}_{-4.0})$	$0.999(^{+4.8}_{-2.8})$
3500	$0.466(^{+6.4}_{-2.9})$	$0.937(^{+3.6}_{-3.6})$	$0.935(^{+5.1}_{-2.9})$
4000	$0.413(^{+7.0}_{-3.0})$	$0.836(^{+4.2}_{-3.2})$	$0.831(^{+6.0}_{-3.5})$
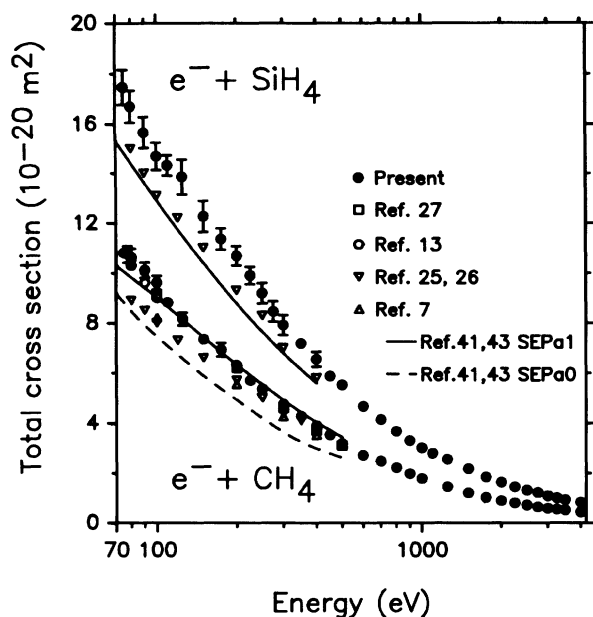
FIG. 1. Absolute total cross sections for electron-CH_4 and -SiH_4 scattering. Present measurements are compared with the results of previous measurements of Sueoka and Mori (Refs. [25] and [26]), Dababneh et al. (Ref. [27]), and Floeder et al. (Ref. [7]), Szmytkowski (from Ref. [13]) and with two theoretical models of Jain (deformed-orbital SEPa1 and nondeformed-orbital SEPa0 of the absorption potential (Refs. [41] and [43]). The error bars correspond to the overall experimental uncertainties; if not shown, the error bar is within the symbol's size.
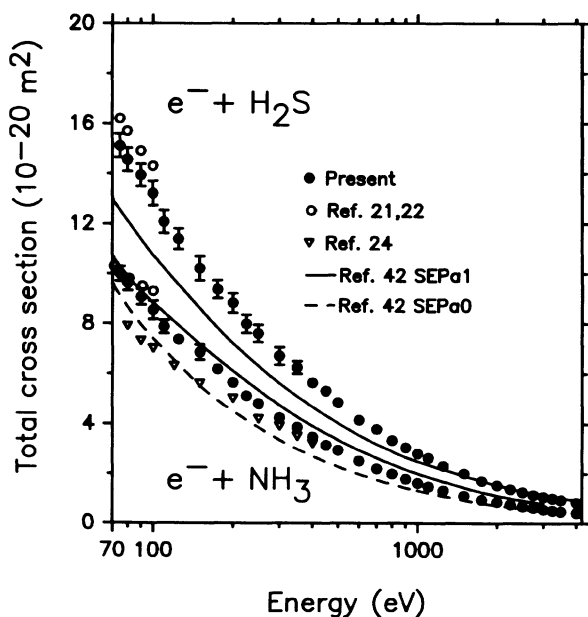
FIG. 2. Absolute total cross sections for electron-NH_3 and -H_2S scattering. Present measurements are compared with the results of previous measurements of Sueoka, Mori, and Katayama (Ref. [24]), Szmytkowski and co-workers (Refs. [21] and [22]), and with theoretical models of Jain for two different forms of the absorption potential (Refs. [42] and [44]). Error bars are as in Fig. 1.

proximation have been performed at intermediate energies for H_2O, NH_3, and CH_4. Recent experimental differential cross sections for H_2O [39] and CH_4 [40] extend only up to 1000 eV. According to the Born approximation, the angular-resolution correction changes like $1/E$ and it is higher for polar molecules [38]. Basing on this observation and using available data we roughly estimate that our error at 4000 eV is as low as 1% for SiH_4, 2.5% for H_2S, and up to 4% for NH_3. A $1/E$ energy dependence of the error has been assumed.

The total error of the present measurements has been computed as a linear sum of systematic, statistical, and angular-resolution errors. The total error values associated with each experimental point are given in Table II and shown in Figs. 1 and 2.

IV. RESULTS

The present results for NH_3, SiH_4, and H_2S are summarized in Table II and in Figs. 1 and 2. Figure 1 also reports our previous measurements on CH_4 [Ref. 13]. For all hydrides studied, the total cross sections are descending functions of energy.

At any given energy in the measured range, the total cross sections descend for the sequence CH_4-NH_3-H_2O. The differences between TCS's for different gases decrease with rising energy, amounting at 3000 eV to 7% between CH_4 and NH_3, the 11% between NH_3 and H_2O [12]. The same behavior is found for the SiH_4-H_2S sequence. The TCS's for these two gases are almost equal at 4000 eV.

As opposed to the small variations of the TCS's along the same row of the Periodic Table, the cross sections change significantly for heavier analogs. In the while energy range, the total cross section for H_2S is about twice that of H_2O. For the SiH_4-CH_4 pair this difference is slightly smaller, about 80%.

Our data for CH_4 are in good agreement with the intermediate energy measurements of Dababneh et al. [27]. No comparison is possible for other gases.

For all gases we observed the same kind of differences with the data of Suoeka et al. [23–26]. Their results are systematically lower than the present ones. This difference is approximately the same for all gases considered and it varies from about 20% at 100 eV to 10% at 400 eV. It can be stressed that in their measurements Sueoka et al. adopted an effective scattering length 6% larger than the geometrical one. This difference partially accounts for the observed discrepancy.

In the low-energy limit our results agree within experimental errors with measurements of Szmytkowski et al. [20–22]. For CH_4 (Ref. [13]) the Gdańsk measurements are at 75–100 eV about 5% lower than the present ones, and for NH_3 [21] and H_2S [22] they are higher by 1–7 %.

In the intermediate-energy range, the only systematical calculations have been performed by Jain with the optical model. Jain examined two forms of the absorption part of the scattering potential: calculated from deformed or from nondeformed molecular orbitals. For CH_4 [41] Jain's calculations only extend up to 500 eV. Our results

agree well with the deformed-orbital model, which at 100 eV gives values only 8% higher, and at 500 eV 8% lower than our measurements.

For NH_3 the present results lie between two data sets from different theoretical models [42] (see Fig. 2). The theoretical results agree with the present data within 3% at 80 eV if deformed orbitals are used to calculate the scattering potential. This model, however, gives, at 3000 eV, a TCS which is 50% higher than the experimental data. On the other hand, the nondeformed-orbital model gives TCS values only 10% lower than the present data in the whole energy range.

For H_2O similar differences are observed between our data and those of Jain (see Ref. [42]). From these comparisons one could conclude that at energies higher than 1 keV electronic-charge adiabatic effects become important.

For the second-row hydrides the optical model of Jain gives results in somewhat worse agreement with the present data than the calculations for lighter analogs. The results of Jain for SiH_4 [43] in the deformed-orbital approach lie below our experimental points in the whole 75–400-eV range of comparison (see Fig. 1). As the calculations in the nondeformed-orbital model are even lower, they are not shown in Fig. 1. A similar discrepancy holds for H_2S [44] in the 75–400-eV energy range (see Fig. 2). On the other hand, at higher energies the present data are in a very good agreement with the theoretical model. Jain's results for H_2S are only 6% lower than the present ones at 2000 eV and only 10% higher at 4000 eV.

V. SEMIEMPIRICAL FIT OF TOTAL CROSS SECTIONS

Our recent measurements for noble gases [33] indicated that in the 100–4000-eV range, the cross-section energy dependence for heavier noble gases is less rapid than $1/E$. We have approximated those total cross sections with a formula, containing the $1/\sqrt{E}$ term as dominant. On the other hand, a rough comparison indicates that the fall of the cross sections with energy is more rapid for the examined molecules than for noble gases.

For methane and argon, analogies between total cross sections in the low-energy range are frequently pointed out [27,45]. However, the electronic structure of Ar corresponds to SiH_4 rather than to CH_4. We find that at 100 eV the argon cross section [34] is quite close to that of methane, while at high energies it is almost identical to that of silane. In other words, the Ar TCS decreases more slowly than the CH_4 and SiH_4 cross sections. We find that in the high-energy region (above 1 keV) the cross sections for molecules become close to a $1/E$ function.

Figure 3 shows a plot of the inverse of the total cross sections versus energy for the five studied gases. At energies higher than 200 eV a straight-line dependence is evident for all gases. The total cross section can therefore be described by a two-parameter formula

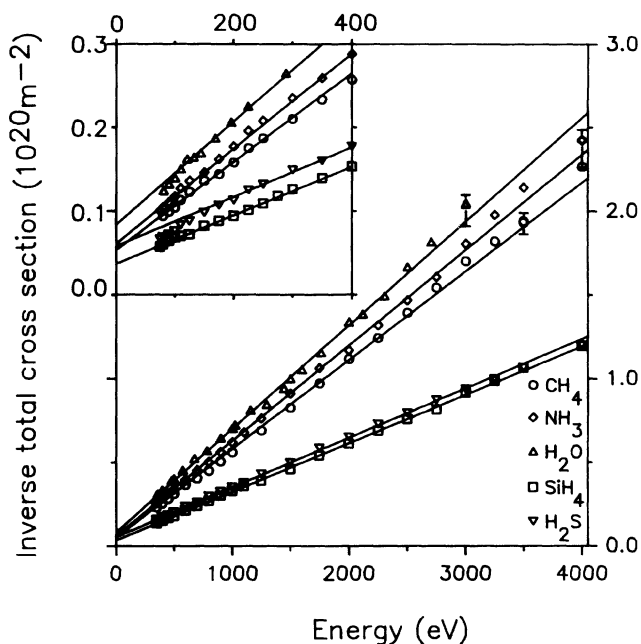$$\sigma(E) = \frac{\sigma_0 B}{B + \sigma_0 E} \cdot \qquad (2)$$

FIG. 3. Energy dependence of the total cross sections for intermediate-energy electron-hydride scattering. The inverse of the total cross section is plotted vs energy. Experimental points: present data and our previous results from Refs. [12] and [13]. Solid lines: fit by Eq. (2) with the coefficients given in Table III. Error bars for selected points correspond to the systematical experimental uncertainty.

This formula has been fitted to the experimental points with a least-squares method. The data below 100 eV in H_2O and below 150 eV in H_2S have not been used in the fitting procedure. The parameters σ_0 and B (E given in keV, σ in 10^{-20} m^2) of the fit are given in Table III.

Note that Eq. (2), which we used to fit the total-cross-section measurements, gives the same energy dependence as the Born approximation for the total elastic cross section [46]

$$\sigma_{el} = \frac{4\pi U_0^2 a^4}{1 + 4ak^2}$$

for scattering on a Yukawa potential

$$U(r) = -\frac{U_0}{r} e^{-r/a},$$

TABLE III. Coefficients obtained by fitting Eq. (2) to our total-cross-section (TCS) measurements.

| Molecule | Fit parameters | | TCS at 1500 eV | (Bond length)^2 |
	σ_0(Å^2)	B (Å^2 keV)	(Å^2)	(Å^2)
CH_4	18.8	1.89	1.209	1.190
NH_3	16.5	1.75	1.097	1.016
H_2O	12.1	1.62	0.999	0.918
SiH_4	27.0	3.45	2.173	2.190
H_2S	17.2	3.38	1.999	1.810

where $k^2 = 2mE/h^2$ and a is the range of the potential.

Simplified theories for the total (elastic plus inelastic) cross section (see Ref. [46]) do not predict the functional dependence of Eq. (2). However, we are led to emphasize that for all examined gases Eq. (2) gives a very good fit to our experimental points. According to Eq. (2), the TCS tends to a constant value σ_0 in the limit of zero energy. At the high-energy limit the TCS falls as B/E.

As can be seen from Table III, both parameters σ_0 and B changes systematically if we consider hydrides in the same row of the Periodic Table. Both parameters decrease going from the IV to the VI group. These regularities reflect several features of the targets: going from CH_4 to NH_3 and to H_2O and from SiH_4 to H_2S, the geometrical dimensions, the dipole polarizability, and the chemical activity (evaluated as the reciprocal of the bond strength) of these molecules decreases. A systematical knowledge of the molecular TCS for different targets would be needed to assess functional relations between σ_0 and B parameters and the molecular structure. Anyhow, some observations can be made.

The parameter B clusters around different values for the two Periodic Table rows: around 1.7 for CH_4, NH_3, and H_2O and around 3.4 for SiH_4 and H_2S. Additionally, a relationship can be noticed between the values of the parameter B and the bond length of the molecule. At high energies, where the TCS is determined mainly by the parameter B, cross sections for different gases are roughly proportional to the square of the corresponding bond length. Such a proportionality is indicated in Table III for the arbitrarily chosen energy of 1500 eV.

Small deviations from the fit are observed at energies below 200 eV for H_2S and H_2O (see inset in Fig. 3). For these molecules, the measured cross sections are systematically slightly higher than the values given by the fit [Eq. (2)]. This could probably be attributed to the strong permanent dipole moment and/or specific geometry of these molecules. From calculations of Jain [42], it follows that for H_2O the scattering on the permanent dipole moment amounts to 20% of the total cross section at 100 eV. Some deviation of the fit from the experimental points in the high-energy limit should probably be attributed to the systematical (mainly angular-resolution) errors of the present measurements (relevant systematical error bars are shown in Fig. 3).

VI. PARTITIONING OF TOTAL CROSS SECTIONS

Absolute measurements of the total cross sections, performed with the accuracy of a few percent, can serve as a reference for partial-cross-section data, which frequently have a normalized character. On the other hand, combining cross sections for specific processes with the total values allows for the analysis of partitioning in electron and positron scattering. A nearly complete analysis of the partitioning is possible for CH_4 and H_2O on the basis of the experimental results; fragmentary data exist for NH_3 and SiH_4. Only theoretical results have been found for H_2S and therefore they are not presented here.

In Fig. 4 the partial cross sections from different experiments (or theories where the experimental data are not available) are presented as a percentage of the total cross section (present results).

Elastic differential-cross-section measurements have recently been performed in the intermediate energy range for CH_4 (Ref. [39]) and H_2O [40]. These measurements extend only up to 100 eV for SiH_4 [47]. Total elastic cross sections have been obtained [39,40] by integration of differential cross sections; the main error in these data results from the uncertainty in determining absolute values of differential cross sections. For NH_3 [48] and SiH_4 [43] the theoretical elastic-scattering data of Jain have been used.
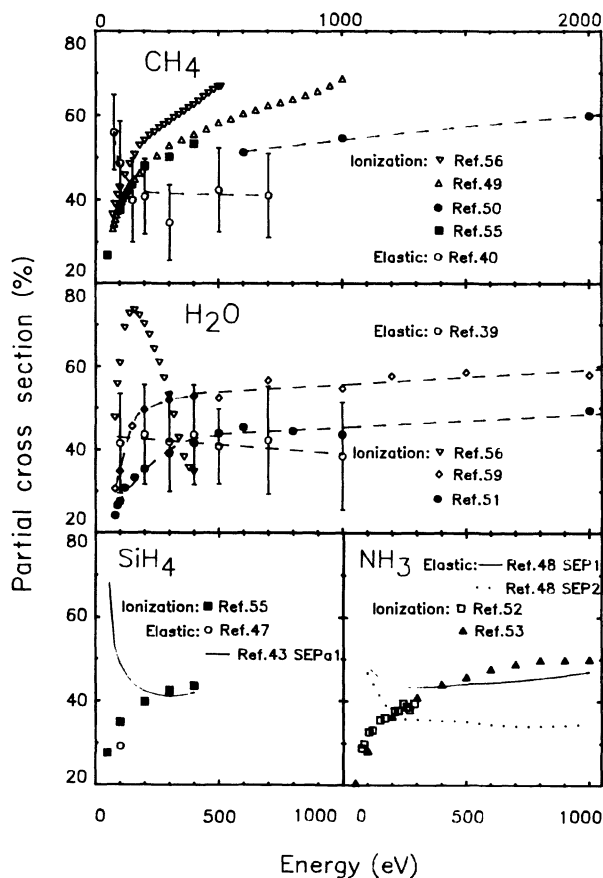

FIG. 4. Partitioning of the total cross section for electron-hydride scattering. CH_4: experimental ionization cross sections of Rapp and Englander-Golden (Ref. [49]), Shram et al. (Ref. [50]), Chatham et al. (Ref. [55]), and Orient and Srivastava (Ref. [56]); experimental elastic cross sections of Sakae et al. (Ref. [40]); broken lines are plotted as eye guides. H_2O: same as for CH_4, except for the experimental ionization of Shutten et al. (Ref. [51]) and Bolorizadeh and Rudd (Ref. [59]); experimental elastic cross sections of Katase et al. (Ref. [39]). SiH_4: experimental ionization of Chatham et al. (Ref. [55]); theoretical elastic cross sections of Jain (Ref. [43], model using deformed-orbital absorption potentials); elastic experimental of Tanaka et al. (Ref. [47]). NH_3: ionization experimental of Bederski, Wójcik, and Adamczyk (Ref. [53]) and Crowe and McConkey (Ref. [52]), both normalized to the theoretical values of Ref. [54]; elastic theoretical of Jain (Ref. [48] SEP1, a model using an energy-independent polarization potential; SEP2, an energy-dependent polarization potential).

Absolute-ionization cross sections have been measured for CH_4 by Rapp and Englander-Golden [49] up to 1000 eV, by Schram et al. [50] up to 12 keV for CH_4, and by Schutten et al. [51] up to 20 keV for H_2O. NH_3 ionization cross sections were measured by Crowe and McConkey [52] and by Bederski, Wójcik, and Adamczyk [53]. Both measurements are normalized to the theoretical values of Khare and Meath [54]. For SiH_4 the available data [55] for ionization extend only to 400 eV. The recent ionization cross sections of Orient and Srivastava [56,57] for CH_4, H_2O, and NH_3 are in some disagreement with other data. As a matter of fact, the subsequent measurements from this group (for noble gases [58]) have been obtained with an improved apparatus. We found the data of Schram et al. [50] and of Shutten et al. [51] and the recent measurements of Bolorizadeh and Rudd [59] to be the most reliable, as only these values sum up with the elastic part to the upper limit set by our total cross sections.

Apart from existing discrepancies, some general conclusions on partitioning can be drawn. The percentage contribution from ionization for all molecules rises sharply from the threshold up to 100 eV, with a corresponding decrease of the elastic channel. At energies higher than 100 eV, this rise becomes more gradual. At 1000 eV the ionization cross section amounts to about 50% of the TCS for all compared gases. For CH_4 [50] it reaches 70% of the TCS at 4000 eV. On the other hand, the elastic part for CH_4 [40] and H_2O [39] above 100 eV is almost constant (at about 40%). Similarly, for SiH_4 [43] and NH_3 [48], the elastic cross section falls to about 40% of the total above 200 eV. The contribution from electronic excitation in CH_4 [60] amounts to about 5% of the total cross sections at 200 eV. From the analysis of partitioning it follows that this contribution is negligible for all gases considered, at energies higher than 500 eV.

For H_2S a comparison can only be made with the theoretical data of Khare and Meath [54]. However, the adoption of these data would suggest that at 100 eV ionization contributes only 15% of the TCS and only 22% at 1000 eV. This is much less than for the other molecules in this study. A comparison of the absolute values of ionization cross sections for NH_3 and H_2S also suggests that the model of Khare and Meath underestimates ionization for H_2S. From the calculations of Jain [61] it follows that the elastic cross section for $e^- + H_2S$ scattering contributes a constant part of the total cross section, almost independently of energy in the 100–500-eV range. The static form of the polarization potential leads to a larger elastic cross section (55% of the TCS), while the energy-dependent form yields a lower value (about 45% of the TCS).

New theoretical investigations as well as absolute measurements of partial cross section would be required for all examined molecules.

Hydride molecules proved to be a convenient test in the search for systematical relations for electron-scattering cross sections. Extension of measurements toward very low energies for some of these targets (i.e., SiH_4) would allow the formulation of general dependences, such as the dispersion relation. Measurements, as well as theoretical calculations, for other simple molecules (GeH_4, PH_3, SeH_2) would be of interest.

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