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Total cross section measurements for electron scattering on H_2 and N_2 from 4 to 300 eV

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Abstract. Total cross sections have been measured for electron scattering on H_2 and N_2 in the 4–300 eV energy range utilizing a linear attenuation technique. The present results are compared with existing experimental data of other groups in this energy range where good agreement with other experimental data is found.

1. Introduction

It is well known that several areas of physics (astrophysics, plasma physics, laser physics) require the accurate knowledge of total electron scattering cross sections by molecules. Total cross sections are useful for checking the validity of the scattering theory, for checking the consistency of available data, and for normalizing cross sections for specific excitation processes. Among the cross sections which can be measured the total cross section is the most reliable.

Electron scattering by H_2 is one of the most fundamental scattering processes and has been investigated by many workers in this field. Previously Bruche (1927), Ramsauer and Kollath (1930), Golden (1966), Ferch *et al* (1980), Dalba *et al* (1980a) and van Wingerden *et al* (1980) measured total $e^- + H_2$ scattering cross sections. Later Hoffman *et al* (1982), Deuring *et al* (1983) reported total electron scattering cross sections for H_2 over a broad energy range. Recently Jones (1985) reported results for electron scattering on H_2 for incident electron energies from 1 to 50 eV. Theoretically, H_2 has also been extensively studied (Lane 1980). Wilkins and Taylor (1967) calculated the integral elastic scattering cross sections using a Hartree-Fock approach. Hara (1969) computed (fixed-nuclei) integral elastic cross sections for $e^- + H_2$ scattering in the static, static exchange and adiabatic exchange approximations. Henry and Lane (1969) calculated total electron scattering cross sections for H_2 using a close-coupling approximation (including polarization). Later Morrison *et al* (1984) calculated the total cross sections including vibrational and rotational excitations. They used static exchange (with polarization) approximation for the elastic contribution and close coupling calculation with exchange and polarization for the inelastic contribution. It has been found that the agreement between the previous measurements is only marginal at all energies of overlap. The discrepancy among these measurements reaches up to 13% which is larger than the combined experimental errors they claim. This indicated that more accurate data for $e^- + H_2$ scattering cross sections were needed.

N_2 was selected for the present study because of its importance in several fields of fundamental and applied research especially in the study of atmospheric phenomena such as aurora and the airglow. Electron scattering cross sections in molecular nitrogen are particularly important since N_2 is often used as a buffer gas in many types of swarm and discharge plasmas (Trajmar *et al* 1983). Early experiments on electron scattering cross sections for N_2 were carried out by Bruche (1927), Golden (1966), and Blaauw *et al* (1977). Later measurements include the work carried out by Blaauw *et al* (1980), Dalba *et al* (1980b) over a very broad energy range (17.5–1600 eV). Kennerly (1980) reported his result for electron scattering on N_2 in the low and intermediate energy region (0.5–50 eV). More recently Hoffman *et al* (1982), Sueoka and Mori (1984) and Szmytkowski (1988) have reported the $e^- + N_2$ total cross section measurements over a broad energy range (0.5–400 eV).

These previous measurements with a stated experimental accuracy of 5% or less agree with one another to 11% or better over the energy range where overlap in the data exists. Not much work has been done theoretically to compute the electron scattering cross sections for nitrogen. The 'hybrid theory' calculations of Chandra and Temkin (1976) give total cross section results which exhibit the vibrational structure of the temporary negative ion in the resonant state observed by Kennerly (1980).

The present paper is part of a continuing effort which aims to measure total electron scattering cross sections for different target atoms and molecules in a broad energy range.

This article reports absolute total cross section measurements for electron scattering on H_2 and N_2 from 4 to 300 eV.

2. Experimental procedure and error estimation

The apparatus and experimental procedure used in the present measurements are basically the same as those described in the previous articles (Nickel *et al* 1985, Kanik *et al* 1992). It should be pointed out here that the H_2 cross sections were corrected for about 1% due to the thermal transpiration effect and higher values of cross sections were obtained. For the case of N_2 this effect was found to be unimportant and an error associated with it is negligible compared to the other errors. As reported in the previous paper (Kanik *et al* 1992), the combined systematic errors in the data are of order of 2%. Total errors (statistical + systematic) are given in table 1.

3. Results and discussion

The results together with the statistical errors are summarized in table 1 in the electron impact energy range of 4–300 eV. Each entry given in table 1 is the average of at least three independent experimental runs.

Figure 1 compares the present data for H_2 with those of Dalba *et al* (1980a) in the energy range 4.5–100 eV, van Wingerden *et al* (1980) in the energy range 25–300 eV, Hoffman *et al* (1982) in the energy range of 4.9–300 eV, Deuring *et al* (1983) in the energy range of 9–300 eV, and Jones (1985) in the energy range of 4–50 eV.

Our results are about 2 to 9% higher than that of During *et al* in the full 9–300 eV energy range. The agreement between the present data set and those of other workers are found to be, in general, within 5% (usually much less) at all energies of overlap.

The present measurement of $e^- + N_2$ total scattering cross sections is shown in figure 2, together with other measurements. We compare our results with those of

Table 1. Total electron scattering cross sections (Å^2). The numbers in parentheses refer to total errors (%).

Impact energy (eV)	H_2	N_2	Impact energy (eV)	H_2	N_2
4	16.07 (2.6)	13.60 (2.2)	40	4.20 (2.6)	12.05 (3.6)
5	15.36 (2.3)	11.99 (2.4)	50	3.70 (2.1)	11.34 (3.3)
6	14.28 (2.0)	11.46 (2.3)	60	3.34 (2.5)	10.60 (2.0)
8	12.38 (2.0)	11.17 (4.1)	70	3.08 (2.8)	10.12 (2.8)
10	10.73 (2.1)	11.92 (2.1)	80	2.87 (2.0)	9.66 (2.5)
12	9.49 (2.9)	12.10 (2.0)	90	2.69 (2.1)	9.26 (2.2)
14	8.49 (2.5)	12.94 (2.3)	100	2.53 (2.6)	8.92 (2.3)
16	7.72 (2.6)	13.12 (2.2)	125	2.22 (2.0)	8.14 (2.1)
18	7.12 (2.4)	13.38 (2.3)	150	1.99 (2.0)	7.48 (2.4)
20	6.54 (2.7)	13.66 (2.8)	200	1.66 (2.3)	6.43 (2.2)
25	5.59 (2.3)	13.42 (2.9)	250	1.43 (2.3)	5.70 (2.5)
30	4.98 (2.1)	12.82 (3.4)	300	1.27 (3.4)	5.11 (2.6)

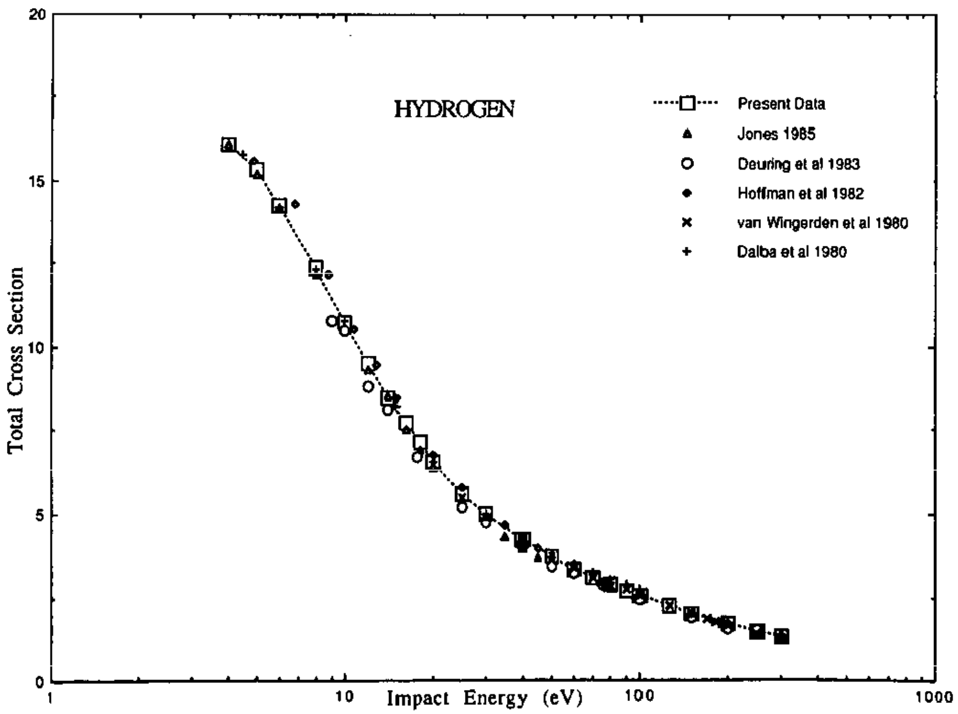

Figure 1. Total electron scattering cross sections for H_2, in units of Å^2. —□—, present data; △, Jones (1985); ○, Deuring *et al* (1983); ◇, Hoffman *et al* (1982); ×, van Wingerden *et al* (1980); +, Dalba *et al* (1980a).

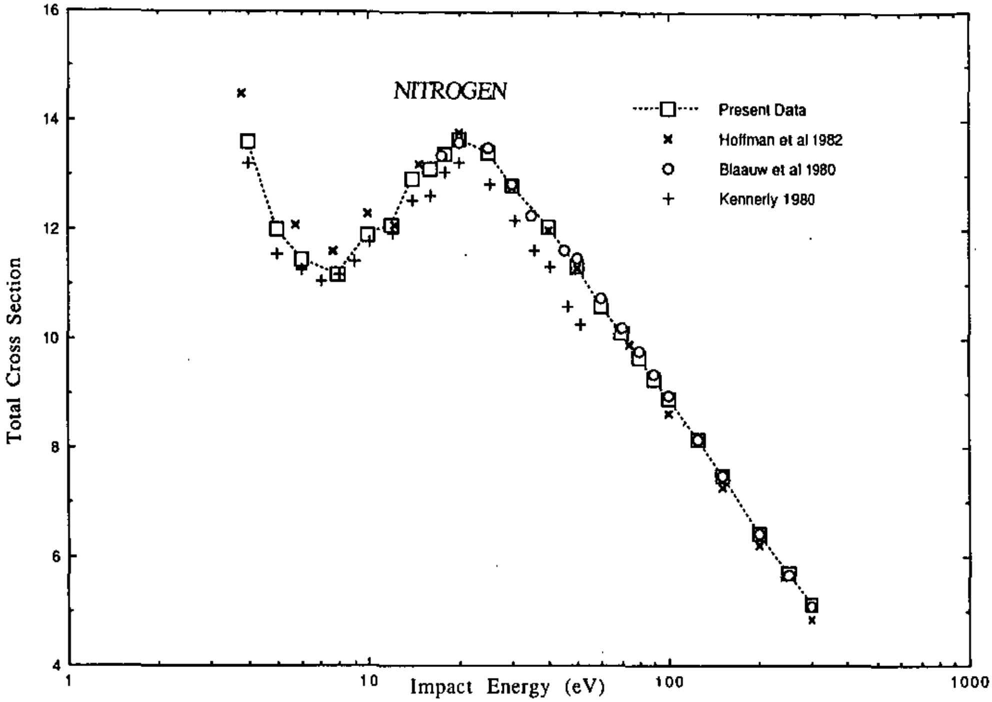

Figure 2. Total electron scattering cross sections for N_2, in units of Å^2. —□—, present data; ×, Hoffman *et al* (1982); ○, Blaauw *et al* (1980); +, Kennerly *et al* (1980).

Kennerly (1980) in the 4–51.3 eV energy range, Blaauw *et al* (1980) in the 17.5–300 eV energy range, and Hoffman *et al* (1982) in the 3.8–300 eV energy range. Our results are 2–10% higher than those of Kennerly at all the energies of overlap. The present results are in overwhelmingly good agreement with those of Blaauw *et al* (1980) where the discrepancy between these two data sets is, in general, less than 1% in the full 17.5–300 eV energy range. In the low energy range the present data are about 3% lower than those of Hoffman *et al.* The discrepancy between these measurements is less than 1% between 20–50 eV and tends to increase up to 5% as the incident energy increases.

4. Conclusion

We have presented the total electron scattering cross sections for H_2 and N_2 in the electron impact energy range of 4–300 eV. Fair to excellent agreement has been found with the results of other workers. Discrepancy between our measurements and those of other workers for the case of H_2 is about 9% at most and is typically within 5%. For the case of N_2 the discrepancy between our data and those of other groups is within 3% (usually much less) except those of Kennerly *et al* (1980) where disagreement reaches up to 9% at 50 eV.

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