Absolute Elastic Differential Cross Sections by N_2O in the Range from 200 to 1000 eV

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Foram medidas secções de choque diferenciais elásticas para elétrons espalhados por N_2O no intervalo angular entre 10° e 120° e energias incidentes de 200, 300, 400, 500, 800 e 1000 eV. Estas secções de choque foram obtidas através da técnica do fluxo relativo usando a molécula de nitrogênio como padrão secundário. As intensidades dos elétrons espalhados elasticamente foram medidas separadamente em uma geometria de feixes cruzados elétron-molécula.

Absolute elastic differencial cross sections for electron scattering by N_2O in the angle range from 10° to 120° are reported for incident energies of 200, 300, 400, 500, 800 and 1000 eV. These cross sections were made absolute by use of the relative flow technique using molecular nitrogen as the secondary standard. The intensities of the elastically scattered electrons were measured separately in a crossed electron beam-molecule beam geometry. The elastic integral and momentum transfer cross sections are reported as well.

Key words: *electron scattering, cross section, N_2O, elastic scattering.*

Introduction

Nitrous oxide is a very important molecule from both scientific and technological points of view. This gas has been presently utilized in a variety of processes. It has been found to play an important role in plasma modelling, it is used in N_2O laser and it is applied as an anaesthetic in medicine as well[1]. Considerable interest has been renewed in chemistry of N_2O in atmosphere, has been generated, since N_2O acts[2] as a source of NO in the stratosphere. The catalytic destruction of ozone by NO is very efficient. The electron impact dissociation of N_2O can be one of these processes which results in the increase of NO in the stratosphere, considering that there is a temporal increase of atmospheric concentration in N_2O (~0.2% per year)[3].

On the other hand, absolute elastic differential and integral cross sections for electron-molecule scattering play an important role in the development of new theoretical methods. Recently, several ab-initio methods have been proposed for electron-molecule scattering[4-6]. The applicabilities of these methods should be tested by comparison with experimental results. In this case, electron - N_2O scattering constitutes an interesting case: due to the cylindrical symmetry of N_2O, the calculation involved becomes simpler than for non-linear systems. Despite these needs, both experimental and theoretical studies of electrons - N_2O interaction are very limited (see Marinkovic *et al* and the references herein)[7]. Marinkovic *et al.*[7] have measured relative differential cross sections for elastic scattering. They also reported in the 10 - 80 eV range the excitation differential cross section (DCS) from the ground electronic state to the $^1\Pi$ and $2\ ^1\Sigma^+$ excited states of N_2O by electron impact. Szmytkowski *et al*[8] have measured total absolute cross section for electron scattering in N_2O at energies from 40 to 100 eV. Finally, Mason and Newell[2] have reported an electron impact dissociation study of N_2O. However, all the previous experimental efforts were at incident energies below 120 eV. There are no experimental attempts for higher energies.

In the present work, we report the measured Absolute Elastic Differential Cross Section (AEDCS) of electrons scattered by N_2O in the energy range from 200 to 1000 eV and in the angular region from 10° to 120°. Since there is no other experimental or theoretical results in this energy region, comparisons are made with the Independent Atomic Model (IAM) and with the estimated DCS of Hayashi[9]. In the next section we will discuss briefly the experimental aspects of the measurements and finally we will present the results and discussion.

Experimental

The apparatus used in the present measurements was described by Iga *et al*[10] and will be only briefly discussed here.

The scattering chamber is formed by an aluminium cylinder of 60 cm diameter and 30 cm height. The ultimate pressure, of the order of 5×10^{-7} Torr, is provided by a six-inch oil diffusion pump equipped with a liquid nitrogen trap. When the gas is admitted to the system, the background pressure of work is normally about 2×10^{-5} Torr. The gas flows through a capillary array of 1mm in diameter, with individual capillaries of 0,05 μm diameter and 5mm long (aspect ratio=0.01). An electron beam perpendicularly crosses the target beam and the scattered electrons are selected by a Möllenstedt velocity analyser[11]. The energy resolution (FWHM) was around 1.0 eV. With this resolution, the inelastically scattered electrons arising from the electronic transitions are discriminated, but the vibrational and rotational transitions are not resolved. The detector view cone is limited by a set of apertures which allows an angular resolution of 0.2 degrees. In the scattering region the diameter of this view cone is about 2.0 mm. With this system, one expects the entire scattering volume to be visible to the detector[12]. The electron beam has a diameter of the order of 1mm. During the measurements, the primary beam current was around 0.1 μA at small scattering angles (up to 50 degree) and 2 μA at large angles (above 40 degree). It is possible to rotate the electron gun around the scattering center in the angular range from $-120°$ to $+120°$ with an accuracy of 0.1 degree. In addition, there is a set of six Helmholtz coils placed in the x, y, and z direction which reduces the residual magnetic field to around 10 mG in the scattering region.

The relative flow technique[12,13] was used to get the EDCS on an absolute scale. The advantage of this technique is that it avoids having to determine difficult experimental parameters. The ADECS can be obtained from the following expression:

$$\frac{(\dot{N}_e)_1}{(\dot{N}_e)_2} = \frac{\sigma_1(\theta)P_2}{\sigma_2(\theta)P_1} \qquad (1)$$

where P_1 and P_2 are the absolute gas pressures, $(\dot{N}_e)_1$ and $(\dot{N}_e)_2$ are the number of the scattered electrons per second and $\sigma_1(\theta)$ and $\sigma_2(\theta)$ are the differential cross sections for gases 1 and 2. If the EDCS for the electron scattered by a certain specimen (the secondary standard) is known, one can obtain from equation (1) the absolute value of the EDCS for the sample gas under study. In the present study, Nitrogen was chosen as the secondary standard because of the numerous experimental absolute cross sections reported in the literature in the energy range under study.

Some precautions were taken during the measurements. The stability of the electron beam current was monitored by a Faraday Cup. For each energy, the measurements of the scattering intensity was performed for one gas, and the measurements were subsequently repeated for another gas under the same experimental conditions. The pressure was continously checked by a MKS Baratron pressure gauge. Measurements of the scattering intensity as a function of the gas pressure in the reservoir were performed for both gases and the results showed that the intensity is a linear function of the pressure. The background contribution was determined by measuring the scattering intensity of the sample gas introduced into the system through a side inlet. At small scattering angles ($< 50°$) the contributions were less than 5% and never exceed 10% in the entire angular range. They are subtracted from the intensity of the beam scattering of the target gas.

For each incident energy, this procedure was repeated several times over different periods.

The overall uncertainty in the cross sections is obtained from the equation:

$$\Delta = (\Sigma_i d_i^2 + D^2)^{1/2} \qquad (2)$$

where d is the uncertainty of each experimental parameter controlled during the measurements and D is the quoted uncertainty in the absolute cross sections of the secondary standard. We used as the secondary standard the absolute EDCS of N_2 reported by DuBois and Rudd[14] at impact energies up to 800 eV, with the quoted uncertainty of 12%. At 1000 eV, the absolute EDCS of N_2 reported by Jansen et al[15] with a quoted uncertanty of 6% were used.

The various sources which contribute to the experimental uncertainties are: 5% in the ratio of the measured intensities, 1% in the measured pressures for each gas and 1% in the fluctuations of the primary beam current during the measurement. In this way, an overall error of 8% is atributed in the measurement of the EDCS at energy of 1000 eV and 13% for the other energies.

Results and Discussion

The measured EDCS's in the 200 - 1000 eV range are shown in Figures 1 and 2, along with the estimated values of Hayashi[8] and the calculated data from the Independent

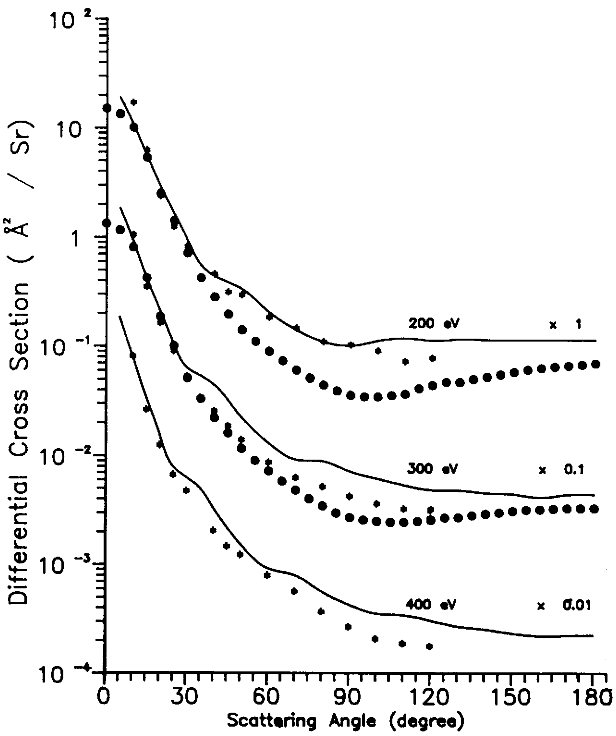

Figure 1. *Absolute elastic differential cross section for electron-N_2O scattering at 200, 300 and 400 eV. ** present results;* ⊙ values estimated by Hayashi (ref. 8) and solid line is calculated data from IAM model.

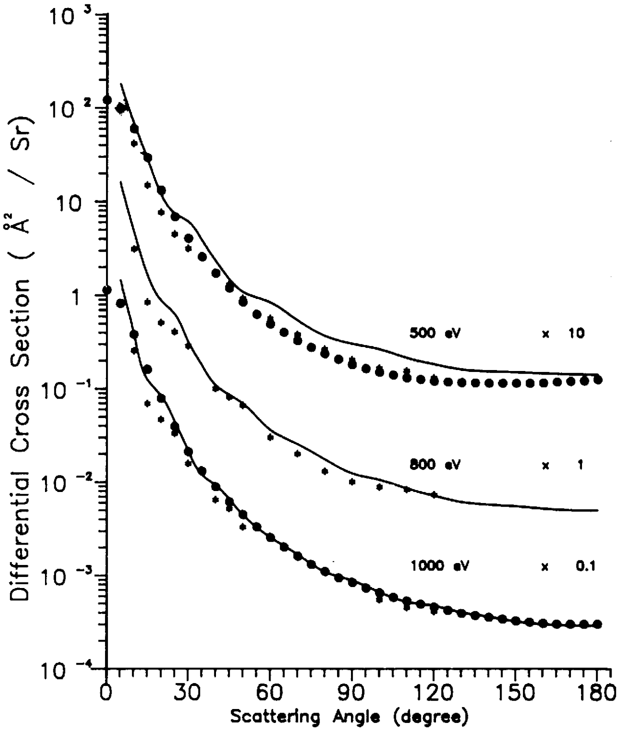

Figure 2. *Same as in figure 1 for 500, 800 and 1000 eV.*

Table 1. *Measured absolute elastic differential cross section of electrons scattered by N_2O (in Å²/sr).*

$\theta\diagdown$E(eV)	200	300	400	500	800	1000
10	17.05	10.50	8.060	4.140	3.100	2.550
15	6.260	3.500	2.640	1.480	0.838	0.690
20	2.380	1.620	1.250	0.759	0.508	0.4650
25	1.240	0.898	0.667	0.447	0.406	0.3300
30	0.820	0.526	0.476	0.313	0.286	0.1570
40	0.457	0.256	0.205	0.171	0.100	0.0644
45	0.313	0.187	0.147	0.129	0.0810	0.0517
50	0.295	0.140	0.123	0.0919	0.0660	0.0330
60	0.185	0.0868	0.0800	0.0562	0.0300	0.0260
70	0.147	0.0627	0.0570	0.0382	0.0200	0.0160
80	0.110	0.0518	0.0370	0.0264	0.0130	0.0110
90	0.103	0.0423	0.0270	0.0203	0.0100	0.0085
100	0.0907	0.0363	0.0210	0.0166	0.0088	0.0055
110	0.0729	0.0326	0.0190	0.0156	0.0083	0.0045
120	0.0783	0.0323	0.0180	0.0130	0.0073	0.0041
IECS	7.32	4.75	3.77	2.05	1.47	1.13
MTCS	1.43	0.655	0.462	0.329	0.198	0.129

Atom Model (IAM) using Yukawa type potentials[16]. Unfortunately, no other theoretical or experimental values could be found in the literature. In general, it can be seen that there is an overall agreement between our measured EDCS with the data calculated by the IAM theory for incident energies above 500 eV. In this energy range, our results also agree well with the estimated data of Hayashi[9]. At 300 eV, there is still agreement between the present measured EDCS's with those estimated by Hayashi[9], while the calculated values from the IAM lie above our data at scattering angles larger than 50°. In contrast, at 200 eV, our measured data agree quite well with the IAM results, whereas the estimated values of Hayashi[9] lie well below ours at large scattering angles. Our IAM calculation does not account for contributions from exchange, polarization and chemical bonding effects. Deviation of the IAM theory from the experimental data at low incident energies is expected. The good agreement observed may indicate some cancelling between the contributions from some of the mentioned effects at 200 eV. Details of the influence of these effects on the EDCS we have to be clarified by more elaborate theoretical studies, where the chemical bonding, exchange and polarization effects are included.

The measured DCS at 200 - 1000 eV range as well as the integrated elastic cross section (IECS) and momentum transfer cross sections (MTCS) are shown in Table 1. To obtain the IECS and MTCS, extrapolations in the small scattering angles were made via Newton's method.

In summary, we report the first absolute EDCS for electrons scattered by N_2O in the incident impact energy range of 200 to 1000 eV. Comparision with experimental data and IAM calculations shows good agreement for energies above 500 eV. At lower energies, some disagreement at 200 eV and 300 eV may indicate some cancelling between the various effects not accounted for in the IAM calculation. We hope this work may stimulate further theoretical studies using more elaborate methods.

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