

ABSOLUTE TOTAL ELECTRON SCATTERING CROSS SECTION OF CO, CO₂ AND OCS IN THE LOW ENERGY REGION

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Received 1 December 1977

Revised manuscript received 24 February 1978

Absolute total cross sections for electron scattering from CO, CO₂ and OCS molecules at low energies have been measured. An increase of the cross sections due to the formation of negative ion resonance states was observed.

1. Introduction

The knowledge of accurate values of cross sections in investigations of electron scattering from molecules is particularly important from the experimental and theoretical points of view. Most of the presently available total cross sections for low energy electron-molecule scattering have been obtained in the 1920's and 30's by means of the magnetic Ramsauer technique.

This paper reports the results of measurements obtained with an apparatus of high energy resolution, in which electrons transmitted through the collision chamber move along a straight line. We present the total cross sections for CO, CO₂, and as far as we know, for the first time for the OCS molecule. The measurements were carried out in the energy range in which electron scattering is dominated by resonance processes via the first shape resonance states in molecules.

2. Experimental

The total electron scattering cross section was found from the measurements of the attenuation of the current intensity of electrons passing through the gas under study [1]. In the present work we used a 127° electrostatic electron energy spectrometer in a transmission mode. A monochromator produced and directed a collimated, monoenergetic beam of electrons

into the collision chamber filled with the gas. The unscattered electrons leaving the collision chamber passed through the energy analyzer and were collected by a Faraday cup.

The energy resolution of the spectrometer in transmission was better than 0.05 eV and the angular resolution was about 0.6°. The diameter of the collision chamber was equal to 15 mm. A typical electron current in the spectrometer was about 10⁻¹¹ A. The external magnetic field was compensated. More details of the constructed spectrometer will be published in a forthcoming paper.

The electron energy scale was determined within ±0.06 eV against the oscillatory resonance structure in the transmission current in N₂. In a separate experiment [2] the positions of the dips in this structure were found against the ²S helium resonance and the following values for the first three dips were obtained: 1.97, 2.22, 2.46 ± 0.04 eV.

The absolute values of the total cross sections were found in the following way. From the measured pressure dependences of the transmission current intensities (exponential dependence was observed) in CO, CO₂, OCS and Ar the relative cross sections of the investigated gases with respect to Ar were obtained. The relative total cross sections were then normalized to Golden and Bandel's results [3] in Ar in the 2–20 eV energy range. The gas pressure was measured with the (calibrated) ionization gauge in a vacuum cham-

ber in which the spectrometer was placed. The pressure in the collision chamber did not exceed 2×10^{-2} torr and it was about 10^3 times higher than that in the vacuum chamber. The described method was also applied for measurements of the total cross sections of noble gases below 40 eV giving results similar (within the limits of experimental errors) to the results of other authors.

The presented results for CO, CO₂ and OCS are the average of several runs. The applied procedure allowed us to obtain total cross sections with a standard deviation usually not exceeding 10% and it was equal to 9% for CO and to 10% for CO₂ over the whole energy ranges investigated.

The gases which we used were made by Matheson Gas Products Company and had the following purities: CO – 99.5%, CO₂ – 99.9% and OCS – 97.5%.

3. Results and discussion

3.1. CO

The total cross section of CO is presented in fig. 1. It has a peak value of $35 \times 10^{-16} \text{ cm}^2$ at an energy of 1.93 eV. In the vicinity of the peak there is a weak oscillatory structure. This structure as well as the pronounced increase of the cross section close to 2 eV are caused by the formation of the $^2\Pi \text{ CO}^-$ resonance state [4]. The positions of the peaks in the structure are as follows: 1.73, 1.93, 2.13 eV.

In fig. 1 we compare our results to the early experi-

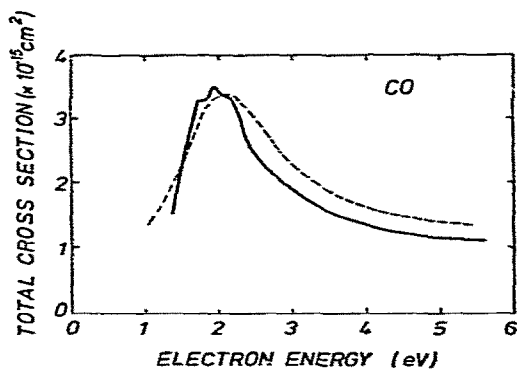


Fig. 1. Total cross section for CO. — present work, --- Brüche [5].

mental data of Brüche [5] carried out in the 30's. The general agreement is good, although now we have observed a resonance structure and obtained a cross section peak of smaller width. This is probably caused by a much better energy resolution in our experiment than in others attempted so far [5,6] in the investigations of CO. Recently Chandra [7] calculated the total cross section for CO applying the frame-transformation theory. The theoretical cross section exhibits a much narrower resonance peak than the experimental one. It seems to us that taking into account the vibrational motion of the nuclei could give cross sections in better agreement with experiment and the autoemission width of the resonance state should increase. A larger value of the autoemission width than that obtained by Chandra is suggested by the larger width of the peak in the experimental cross section and the estimates made by the authors [8].

3.2. CO₂

Fig. 2 presents the measured cross section for electron scattering from CO₂ in the 1.5–8 eV energy range. The general energy dependence of the cross section as well as the peak value of $15 \times 10^{-16} \text{ cm}^2$ at an energy of 3.76 eV are in agreement with the results of the only (to our knowledge) work done in this energy region for CO₂ by Brüche [5] (see fig. 2). However we observed a much narrower peak, similar to the one observed for CO. Separate high sensitivity transmission measurements have shown the presence of an oscillatory structure similar to that seen for the first time by

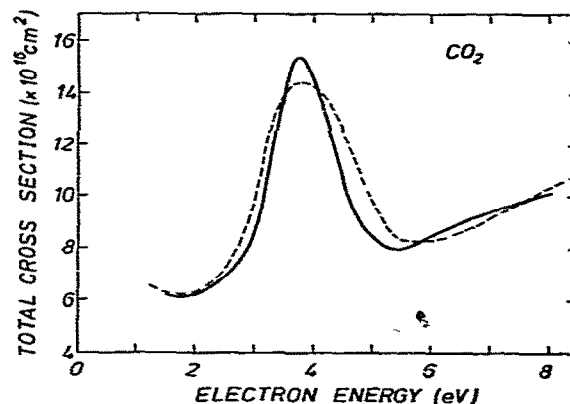


Fig. 2. Total cross section for CO₂. — present work, --- ref. [5].

Table 1
Energy positions in eV of the peaks in the cross sections for CO₂

This work exp-total	Sanche and Schulz [10] exp-total	Čadež et al. [11] exp-elastic	This work calc-elastic
	3.14	3.11	3.15
3.28	3.28	3.27	3.29
3.40	3.41	3.41	3.42
3.53	3.54	3.53	3.55
3.66	3.67	3.68	3.68
3.80	3.80	3.80	3.80
3.92	3.93	3.93	3.93
4.05	4.06	4.05	4.06
	4.18	4.18	4.18
	4.31	4.31	4.31
	4.42	4.42	4.44
	4.54	4.54	4.58

Boness and Hasted [9]. The relative changes of the cross section are smaller than 1%. The peak positions in the oscillatory structure, due to the contribution of the $^2\Pi$ CO₂⁻ resonance state, are given in table 1 together with the results of Sanche and Schulz [10].

The results of Čadež et al. [11] from the elastic scattering measurements as well as the authors' results from the calculations of elastic processes by the method described earlier [12] are presented for comparison.

Recently Morrison et al. [13,14] have calculated the total cross sections for CO₂ in the 0.7–10 eV energy region. Their results are in very good agreement with the experiment below 1 eV but deviate considerably in the peak value near the 3.8 eV resonance. Further refinement of the theory, with the inclusion of vibrational channels (as was suggested [13]) should decrease the differences between theory and experiment particularly in the resonance region.

3.3. OCS

Results of the total cross section for OCS in the 0.4–4.8 eV energy range are shown in fig. 3. There is a remarkable maximum in the cross section at 1.23 ± 0.1 eV which can be related to the formation of the $^2\Pi$ OCS⁻ shape resonance state. The peak value has been estimated to be $17 \times 10^{-15} \text{ cm}^2$ with the standard error of 20%. Below 0.5 eV the cross section seems to increase, probably as the result of the dominance of the interaction of slow electrons with permanent dipole

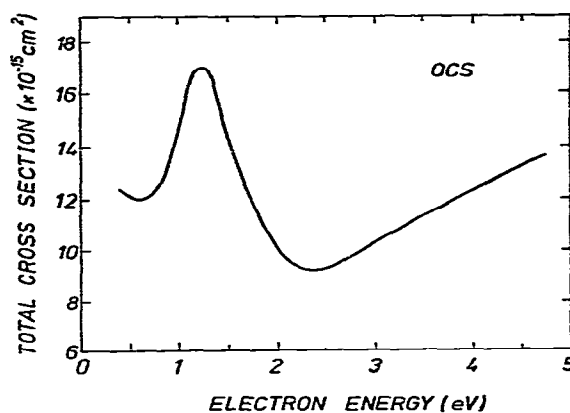


Fig. 3. Total cross section for OCS.

moment of the OCS molecule ($D = 0.715$ debye).

The investigations of the dissociative attachment S^- /OCS process [15–17], and the threshold electron impact excitation spectra [18] indicated the existence of a resonance state in this energy range. In the transmission experiment in OCS an oscillatory structure (similar to those in CO and CO₂) was not observed. The absence of such a structure suggests a short lifetime for the $^2\Pi$ OCS⁻ state. From the estimate based on the dissociative attachment cross section [16] and from the measured cross section in this work it follows (using an expression from ref. [19]) that the mean auto-emission width should be about 0.5 eV.

Acknowledgement

This work was partly supported by the Institute of Physics of Warsaw University.

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