TECHNISCHE UNIVERSITÄT KAISERSLAUTERN
TU Kaiserslautern · Postfach 3049 · D-67653 Kaiserslautern

Fachbereich Physik
AG Prof. Dr. H. Hotop
Dipl.Phys. Tim H. Hoffmann
Tel.: (+49) (0631) 205-2817
Fax: (+49) (0631) 205-3906
E-Mail: thoffman@rhrk.uni-kl.de

Electron Induced Processing at the Molecular Level (EIPAM)
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Host: Prof. D. Field, Department of Physics and Astronomy, University of Aarhus, Denmark
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Resonance structure in total cross sections for electron scattering from selected molecules

Introduction

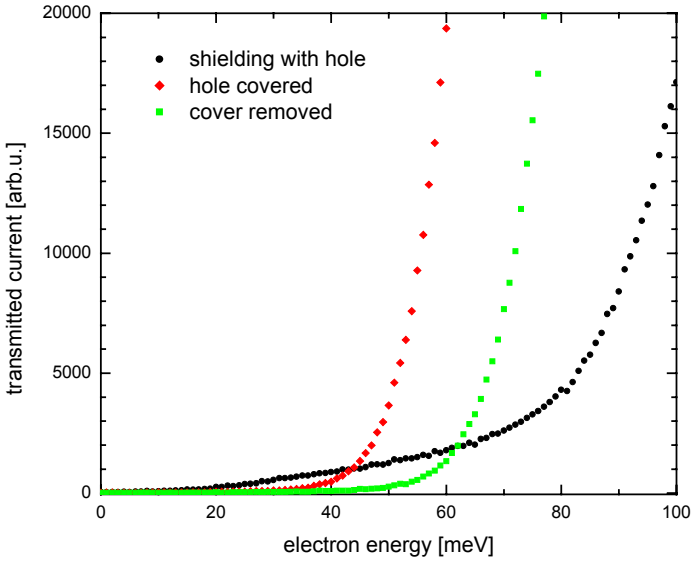
The group of Prof. D. Field uses photoionisation of Ar atoms by synchrotron radiation of the ASTRID storage ring to create nearly monoenergetic electrons, which are then accelerated by a zoom lens. Electrons transmitted through a cell containing the gas under study are detected with a channel electron multiplier. Total scattering cross sections are then determined using the Beer-Lambert-law. In addition, backward scattering cross sections can be measured when an appropriately chosen axial magnetic field is applied [1]. Strong resonances were observed in electron-CS_2 collisions at energies below 150 meV in total [2] and angle-differential [3] cross section measurements. No structure has been found in the cross section for electron scattering from CO_2 at low energies [4], which is enhanced due to a virtual state.

To complement the CS_2 and CO_2 measurements, examination of electron scattering from OCS was one goal of this work. In dissociative electron attachment (DEA) to small OCS clusters sharp vibrational Feshbach resonances (VFRs) have been observed [5], so that vibrational structure in the scattering cross section for the monomer may be expected. Another goal was to gain further insight into the narrow window-type resonance structure around 70 meV in electron scattering from CF_3Cl [6]. Significant discrepancies exist in the total cross section for electron scattering from SO_2 [7,8], which especially in view of the atmospheric and astronomic interest in this molecule demands clarification. Since DEA to small SO_2 clusters shows VFRs [9], vibrational structure could also occur in scattering from single molecules.

Work carried out

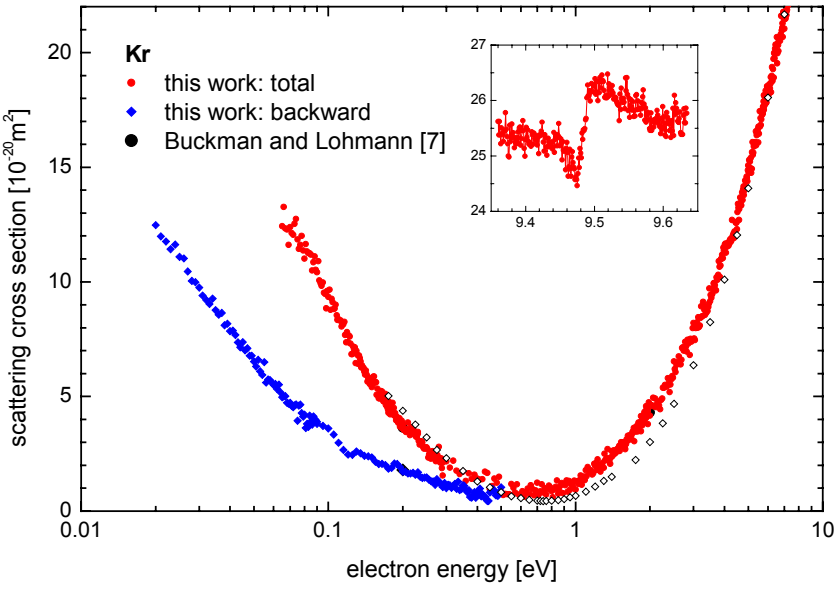
During my first stay in Aarhus, I mainly got acquainted with the scattering apparatus and participated in some measurements on electron transmission by thin films of fluorobenzene adsorbed on a cooled metal surface. The apparatus had been completely redesigned in 2004 and 2005 for this purpose, replacing one vacuum chamber with matched magnetic shielding by two chambers without shielding plus two concentric mu-metal cylinders surrounding the electron optics. The electron optics stayed, but the second aperture of the scattering cell and the detection optics can be removed and a sample holder (made of tantalum) put in place. Transmitted current can be measured by connecting a femtoamperemeter. Samples are prepared in the lower chamber by blowing fluorobenzene on the liquid-nitrogen-cooled tantalum rod, thus causing the gas to condense. The sample holder can be cleaned by sputtering and a mass spectrometer allows for an analysis of the sample composition. Sample preparation involves moving the target holder in several positions, inducing the risk of mechanical problems. Directly after my arrival the sampler holder got stuck and a leak occured in the reservoir for liquid nitrogen cooling, so the lower chamber had to be opened and the tubing re-welded. Since sputtering does not work while cooling the sample, a resistive heating is fixed to the sample holder; this heating wire was also replaced.

Gas phase measurements were carried out during my second visit to Aarhus, with two weeks of beam time on schedule. Pressures were determined using a rotating ball gauge (Leybold Viscovac VM 212).The energy scale was fixed by measuring the position of the third peak in the N_2^- $^2\Pi_g$ shape resonance at 2.440(15) eV [10]. It turned out difficult to reach electron energies below 150 meV. One problem stemmed from the inevitable movement of the sample holder for thin film transmission measurements, causing scratches in the graphite coating of the collision cell. This was already recognized during my first stay, so it was fixed by coating the interior of the cell with a new graphite layer before starting the gas phase work. A second problem resulted from the changed magnetic shielding. The connection for measuring the current in thin film transmission experiments necessitates a hole in the mumetal cylinder for magnetically shielding the electron optics; this orifice is located directly below the scattering chamber, leading to lateral penetration of magnetic fields. Measurements with a fluxgate magnetometer indicate also that the cylinder is not long enough to fully shield the scattering region, which further leads to magnetic field penetration. The effect of these magnetic fields is easily observed by measuring the transmitted current without gas in the scattering chamber, as shown in the diagram below. One of the first measurements is drawn as black circles with an onset around 80 meV (the slope below onset may be caused by some Kr in the photoionisation region). Covering the hole for the femtoamperemeter by a mumetal sheet (shown in the left photo, the upper hole is for measuring the photon flux with a photodiode) leads to a curve shown in the diagram as red diamonds, with an onset around 50 meV. After finishing the cross section measurements, the covering sheet was removed (see right photo with uncovered lower hole; here the shielding cylinder had been disconnected from the electron optics, and the coil for applying a magnetic field can partially be seen). The onset shifted again to higher energies as can be seen from the curve drawn as green squares, although not as high as before.

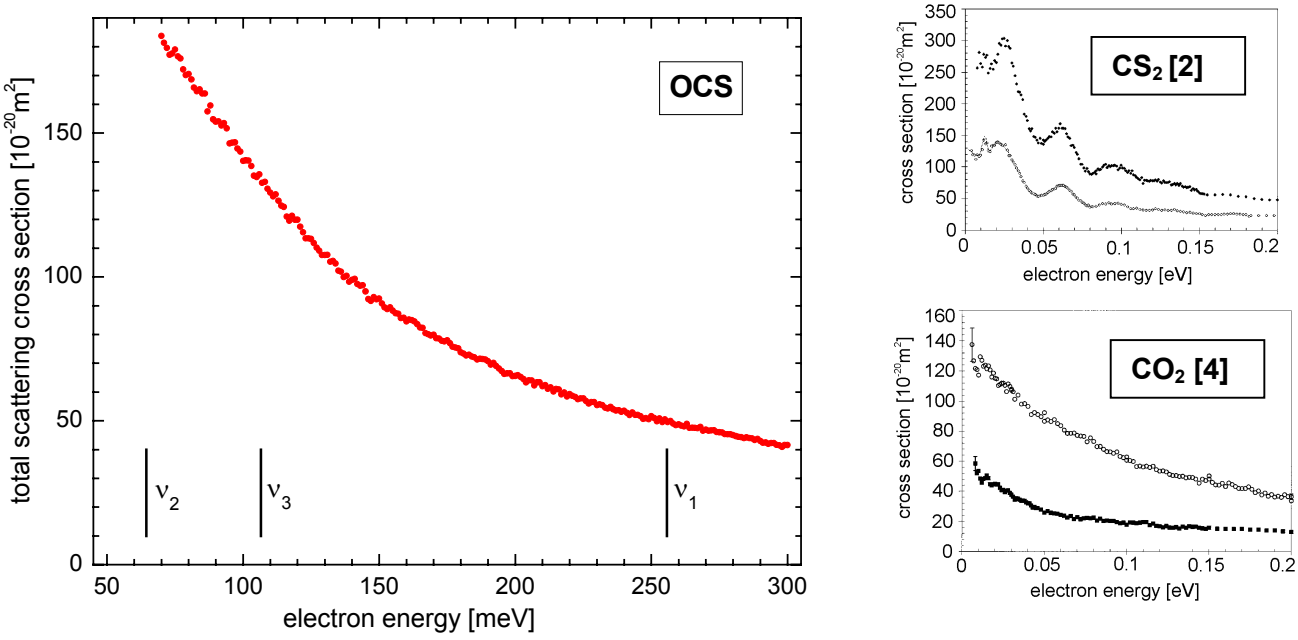


Results obtained

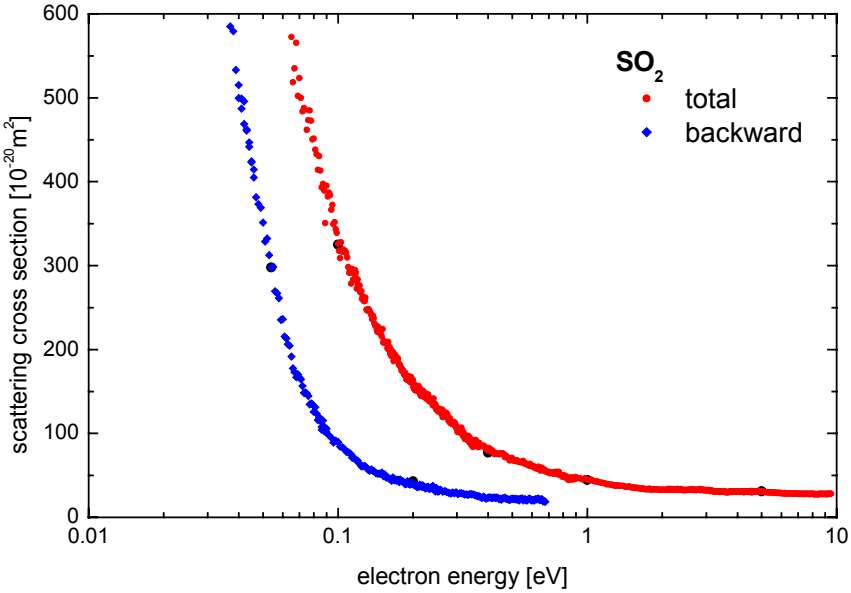
As a test for the apparatus and in connection with angle-differential work at Kaiserslautern, we measured the total cross section for electron scattering by Kr in the range 0.07 eV to 9.7 eV. Below the threshold for the first excited state around 10 eV, electron scattering from krypton is purely elastic. The Ramsauer-Townsend-minimum [11,12] as well as the lowest Feshbach resonance [13] can clearly be seen in the measured cross section. The backward cross section from 0.02 eV to 0.5 eV was measured by applying a magnetic field; the necessary high pressure (around 10^{-3} mbar) together with magnetic guiding lead to spurious counts by photoionisation of Kr. This effect was characterized and the cross section corrected.



The total cross section for electron scattering from OCS has been measured from 70 meV to 300 meV, a region where vibrational structure may occur. Repeated measurements at high OCS pressures with corresponding high attenuation (for good resonance visibility) gave no evidence for the presence of resonance structure. Over the range from 100 meV to 200 meV, the total cross section for OCS is observed to be higher than those for CS_2 [2] and CO_2 [4]; this is probably caused by the enhancement of the cross section by dipolar scattering (μ(OCS)=0.72 D). Due to the problems with low-energy electrons, no reasonable cross section could be measured below 70 meV, so the window structure in the cross section for electron scattering from CF_3Cl could not be reinvestigated.



The total and backward scattering cross section for SO_2 were also measured. Because of the high dipole moment (μ=1.63 D) of SO_2, strongly forward peaked rotational inelastic scattering prevails in low-energy electron collisions, with limited angular discrimination leading to an underestimation of the cross section. No sharp structures were observed.



Conclusions

Measured total cross sections for electron scattering from carbonyl sulfide show no evidence of vibrational structure. Total scattering cross sections for sulfur dioxide and krypton have been measured in the energy range from 0.070 eV to 9.5 eV, as well as backward scattering cross sections up to 0.5 eV. The results for SO_2 and Kr will be further analysed and presented at the EIPAM meeting in Malta, 16-20 September 2006.

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