Physics Letters A 184 (1994) 432–434
North-Holland

PHYSICS LETTERS A

Absolute Kr 4s-electron photoionization cross sections between 30 and 90 eV measured by photon-induced fluorescence spectroscopy (PIFS)

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Received 29 March 1993; revised manuscript received 22 November 1993; accepted for publication 24 November 1993
Communicated by B. Fricke

Absolute Kr 4s-electron photoionization cross sections as a function of the exciting-photon energy between 30 and 90 eV were measured by photon-induced fluorescence spectroscopy (PIFS). The measurements were compared with available experimental data and theoretical calculations.

The photoionization of the subvalence s-shells of rare gases is known to be strongly influenced by electron correlations (see, e.g., refs. [1,2], and references therein). In contrast to the Ar 3s-electron photoionization cross section for which the exciting-photon energy dependence has been intensively investigated during the past five years (see, e.g., ref. [3], and references therein) only a few measurements of the exciting-photon energy dependence of the Kr 4s-electron photoionization cross section have been published [2,4–6].

Very recently, new theoretical calculations have been carried out [6,8] which underline the necessity of accurate measurements of the Kr 4s-electron photoionization cross section in an exciting-photon energy range between threshold and 90 eV. None of the measurements [2,4–6] covers this entire region which is of special interest because it contains the minimum of the Kr 4s-electron photoionization cross section. In the present work these cross sections were determined absolutely by PIFS, extending considerably our preceding measurements [2] which were restricted to the narrow exciting-photon energy region between the 4s-electron ionization threshold and 33.5 eV. A brief description of PIFS and the method of evaluating the Kr 4s-electron photoionization cross sections from the spectroscopic measurements will be given. The results and a comparison with available experimental data and calculations will be presented.

The PIFS method and several of its applications have been previously described in detail [1,9–12]. Thus we mention here only some major differences from the earlier works [2,12] and the important experimental parameters.

Synchrotron radiation from the electron storage ring BESSY, Berlin, was monochromatized by a toroidal-grating primary monochromator (typical bandwidth 0.05 eV at 27.5 eV) and focussed into a target cell at a typical target gas pressure of 0.01 mbar. The primary flux was measured by a Faraday cup. The fluorescence radiation emitted by the excited ions was dispersed by a 1 m-normal incidence monochromator (McPherson 225) and detected by a position-sensitive microchannel plate detector. A typical fluorescence spectrum of Kr at an exciting-photon energy of 33.0 eV is shown in fig. 1

For the determination of the Kr 4s-electron photoionization cross section the exciting-photon energy was varied between 30 and 90 eV in steps of differ-

0375-9601/94/$ 07.00
SSDI 0375-9601(93)E0939-8

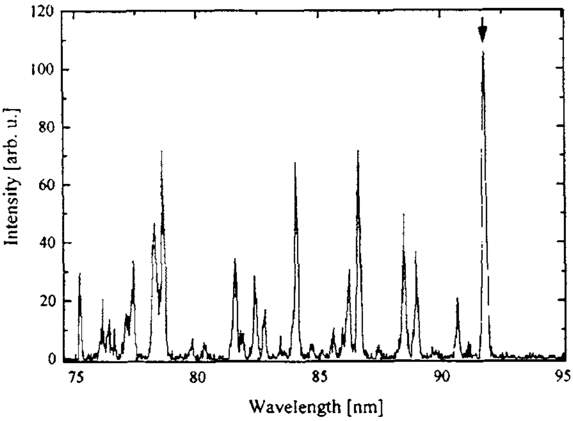

Fig. 1. Typical Kr fluorescence spectrum between 75 and 95 nm at an exciting-photon energy of 33.0 eV. The $4s^14p^6\,^2S_{1/2}\rightarrow 4s^24p^5\,^2P_{3/2}$ transition at 91.74 nm is marked by an arrow. The other lines are satellites.

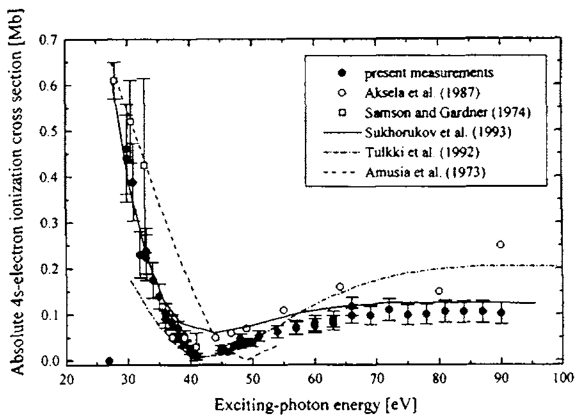

Fig. 2. Absolute KrII 4s-electron photoionization cross section in the exciting-photon energy range between threshold and 90 eV.

ent widths and the fluorescence intensity of the two lines arising from the decay of the Kr 4s-hole at 91.74 and 96.49 nm was recorded as a function of the exciting-photon energy. Then the target gas was changed "in situ" to Ar and the fluorescence intensity from the decay of the Ar 3s-hole at 91.98 and 93.20 nm was recorded at exactly the same exciting-photon energies. Since the relative quantum efficiency of the monochromator–detector combination [13] and the absolute Ar 3s-electron photoionization cross sections as a function of the exciting-photon energy [3] are known the absolute Kr 4s-electron photoionization cross section could be determined by comparing the intensities of the Ar and the Kr lines. Cascade effects have been assumed to be small [2] and were neglected in the present analysis for the Kr data. In this sense the measured cross sections have to be regarded as an upper limit of the true cross sections.

Figure 2 shows the measured Kr 4s-electron photoionization cross section as a function of the exciting-photon energy in the range between 30 and 90 eV together with earlier experimental data [4,5] and calculations [6,8,14]. In the low exciting-photon energy region our measured cross sections agree within the uncertainties with the measurements of Samson and Gardner [4]. At higher exciting-photon energies our measured cross sections are systematically smaller than those of Aksela et al. [5]. In ref. [6] an experimental cross section of 0.1 Mb was obtained at 110 eV exciting-photon energy, which is smaller by approximately a factor of two when compared to ref. [5]. This underlines the accuracy of the present measurements. Additionally very recent measurements using PES [7] agree with the present results, too.

The comparison with the various theoretical calculations reveals that the gross features of the measured cross sections as a function of the exciting-photon energy are best described by ref. [8] where the so-called Coulomb interaction correlational decrease [2] and the configuration interaction of the $4s^14p^6\,^2S_{1/2}$-state with the correlation satellites have been included. In the low exciting-photon energy range these new calculations [8] are in good agreement with the experimental cross sections whereas in the high energy range they are somewhat too high but almost within the uncertainties of the present measurements. In the energy range around the minimum the cross sections are best described by ref. [6]. These calculations, however, agree only for energies around the minimum, whereas in other exciting-photon energy ranges they differ considerably from the present measurements. At large photon energies where the calculations [6] exceed our measurements the discrepancies may probably be attributed to the fact that the configuration interaction between the $4s^14p^6\,^2S_{1/2}$-state and the correlation satellites which would lead to smaller calculated cross sections (cf. ref. [2]) was neglected in the calculations. The reasons for the calculated cross sections of ref. [6] being too small at lower photon energies when compared with the experiment are at present unclear. The very early RPAE calculations [14] seem to be too high in the energy range between 30 and 45 eV and also the exciting-photon energy of the calculated cross section minimum is too high. Both deviations may be related to the neglect of the Coulomb interaction correlational decrease [2] in the calculations [14].

The authors would like to thank Dipl.-Phys. Ralf Henkel for his assistance during the experiments. The continuous help of the staff of BESSY is gratefully acknowledged. This work was funded by the German Federal Minister for Research and Technology under contract nos. 05 5UKAXB and 05 5RGAXB.

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