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PHOTONS SHEDDING LIGHT UPON CHARGE EXCHANGE PROCESSES IN COLLISIONS OF 24 keV $O^{3+}$ WITH ATOMIC HYDROGEN

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Résumé.-Nous avons déterminé les sections efficaces de capture électronique pour la collision 24 keV $O^{3+}$ - H par spectroscopie photonique. Ces mesures ont montré que le 3s $^3P^0$ canal est dominant ce qu'est à l'opposé de calculs complètement quantiques. Ils sont d'accord qualitatif avec mesures récentes de "translational energy" spectroscopie bien que les valeurs absolu des sections efficaces sont plus grands. Pourtant, le total des section efficaces partielles de capture électronique pour toutes les états est d'accord avec mesures totales de capture d'un électron.

Abstract.-The state selective electron capture cross sections for 24 keV $O^{3+}$ colliding on atomic hydrogen, obtained by photon emission spectroscopy show that the 3s $^3P^0$ is the dominant capture channel, which is in contradiction with recent fully quantal calculations. Our measurements are qualitatively in agreement with recent translational energy spectroscopy measurements, although the absolute values of the cross sections are found to be larger. However the sum of all our state selective electron capture cross sections is in agreement with total one electron capture measurements.

Electron capture by $O^{3+}$ in collisions with H is of importance in the colder regions of tokamak plasmas. Furthermore photon emission following electron capture in $O^{3+}$ - H collisions plays an important role in astrophysical studies,1/. Therefore fully quantal calculations have been performed by Heil et al.2/ and Bienstock et al.3/ for 4.6 eV - 85 keV $O^{3+}$ colliding on atomic hydrogen. They predicted that for the charge transfer process

$$O^{3+}(1s^22s^22p)\,^2P^0 + H \rightarrow O^{3+}(1s^22s^22pnl) + H^+ \quad (1)$$

the dominantly populated nl state is $3p\,^3D$ followed by $3p\,^3S$, $3p\,^1P$, $3s\,^1P^0$ and $3s\,^3P^0$. Their calculated total one electron capture cross section ($\sigma_{\text{1 electron}}$) was found to be on the average some 40% larger than the charge
transfer measurements by Phaneuf et al./5/. This discrepancy was described to be due to metastables in the primary ion beam, which would have smaller cross sections for electron capture.

However recent translational energy measurements by Wilson et al./4/ also yielded results at variance with the fully quantal calculations, their results showing clearly that the dominant capture channels are the 3s and not the 3p states. Their relative 3s and 3p sum cross sections (sum of all the 3s L and all the 3p L states respectively) were put on an absolute scale by normalizing to total one electron capture cross section calculated with the multi-channel Landau-Zener (MCLZ) method. The cross sections predicted by this MCLZ calculation are circa a factor of two smaller than the ones experimentally determined by Phaneuf et al./5/. However their MCLZ calculations did show that the 3s channels are the dominant ones, which is in accordance with their experimental findings.

By measuring transitions between specific nl states, photon emission spectroscopy can yield absolute electron capture cross sections for all the different 3s L and 3p L states. These state selective electron capture cross provide a stringent test to theory.

The experimental set up will be described briefly; for a detailed discussion see Dijkkamp et al./6/. The O^+ ion beam was produced by the ECR ion source installed at the KVI /7/. The electrical ion beam intensity obtained at a beam diameter of circa 3 mm was almost 1 μA. In the experimental set up the ions crossed a partly dissociated hydrogen beam produced by a Slevin-type radiofrequency discharge source /8/. The absolute density profiles of the atomic and molecular components of the target beam were determined by observation of electron impact induced atomic (Balmer-β) and molecular radiation. The radiation was observed with a monochromator (LEISS) equipped with an imaging lens system which enabled the measurement of the target density profiles along the beam axis. In this way (for a detailed description Ciric et al./9/) we found an effective dissociation degree of 74%. The photon emission, resulting from decaying O^2+ was observed perpendicular to the ion beam with the above mentioned LEISS spectrometer for visible (300-650 nm) light and a grazing incidence vacuum spectrometer (GRINS) for the vuv (10-85 nm) radiation, equipped with a position sensitive microchannelplate detector, enabling simultaneous detection of emission lines within ranges of about 20 nm. The wavelength dependent sensitivity of the spectrometers was determined absolutely by various electron and ion impact processes with well known cross sections (Kadota et al./10/ and Dijkkamp et al./6/).

Fig.1 shows the 3s, 3p and 3d sum cross sections deduced from our photon emission measurements together with translational energy spectroscopy results for the 3s and 3p states /4/, total charge transfer cross sections /5/ and theoretical cross sections /2,3,4/. It can be seen from this fig.1 that our results also show a larger capture into the 3s than the 3p states just as the translational energy spectroscopy measurements. However on the
absolute scale our values are larger than the ones of Wilson et al./4/. Since the total one electron capture cross section deduced from the photon emission measurements is in agreement with the direct charge transfer measurements /5/, it might be more suitable to normalize the relative results of Wilson et al./4/ on the charge transfer cross sections of Phaneuf et al./5/ than on the result of the MCLZ calculation. In that case our $3s$ and $3p$ sum cross section are in agreement with an extrapolation from the translational energy spectroscopy results. Although the MCLZ calculations correctly predict the dominance of the $3s$ states, they do not reproduce the strong increase in capture into the $3p$ states starting at an impact energy of about 10 keV.

The errors in our results are still fairly large, which is predominantly due to the accuracy of the photon emission cross sections resulting from capture into the $3p$ states. This in turn is mainly a consequence of uncertainties in the values of the transition probabilities and branching ratios for these states. It appeared from our spectra that two electron transitions are of importance, however for these transitions
there are to our knowledge no transition probabilities being published. (e.g. $1s^22s^3p^3\text{D} \rightarrow 1s^22s^2p^2\text{D}^0$). Therefore the systems $0^+\text{H}$ and $0^+\text{H}_2$ are still subject to intensive studies, which will allow us to present accurate cross sections for all the 31 states and to present branching ratios for the two electron transitions.

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