DIELECTRONIC RECOMBINATION OF HIGHLY STRIPPED ARGON IONS: THEORETICAL CALCULATIONS AND DIRECT OBSERVATIONS IN AN EBIS SOURCE

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The dielectronic recombination is one of the most important atomic processes in highly ionised plasmas. It corresponds to the simultaneous capture of a free electron and excitation of an ion, i.e.

$$X^{+m+1} + e^- \rightarrow (X^{+m})^{**} \text{ (doubly excited) } \rightarrow (X^{+m})^* + h\nu.$$

It is a collisionally resonant process which occurs only at the energy of the corresponding autoionisation electron. We present here a preliminary theoretical analysis of the results of an experiment using a novel technique in which it is possible to observe the interaction of a given ion with an electron at a given energy and so to measure the differential dielectronic cross section corresponding to each resonant level of this ion.

This technique uses an electron-beam ion EBIS source (Briand et al, 1984) in which a very intense and very narrow electron beam is used to ionise a neutral gas that has been injected into the system. After being prepared the ions are trapped for a very long time (up to 10 s) inside the source. The electron-beam energy is then scanned incrementally in order to study the various dielectronic resonances of the ions by the observation of x rays which are emitted through a small hole drilled into the cathode. Each measurement at energy E of the electron beam corresponds a narrow electron-energy distribution G(E) of 16 eV. The x rays are detected after the plasma has reached a stationary equilibrium following each increment of the electron-beam energy. The relative abundance of the ions is given by the ionisation balance equation

$$\text{Ne } N(X^{+m})\, S = \text{Ne } N(X^{+m+1})\, (\alpha_r + \alpha_d) \qquad (1)$$

where $N(X^{+m})$ and $N(X^{+m+1})$ are the density of the ion ground states. S and α_r were calculated respectively using the Lotz ionisation cross sections (Lotz, 1967) and the hydrogenic photoionisation formulae given by Burgess (1969). Both cross sections were integrated over the energy distribution G(E). In this work, α_d, the dielectronic recombination coefficients were calculated using the usual nomenclature: SUPERSTRUCTURE AUTOLSJ (Bely-Dubau et al, 1982). In this preliminary work, the charge exchange was neglected in formula (1).

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We then calculated the x-ray yield below 3 keV -i.e. the 1s-2p excitation threshold, where only dielectronic recombination can occur as a resonant process- and above 3 keV where only direct excitation behaves as a continuous process.

In both cases, the intensity I is given by:

$$I = Ne\, N(X^{+m}) < \sigma v > \qquad (2)$$

where $< \sigma v >$ is the excitation rate and the G(E) distribution was used.

For the dielectronic contribution we used the same calculations as the ones used for α_d and for the direct excitation contribution we used the calculations of Sampson et al (1978, 1979), for He-like and Li-like systems, and for Be-like and B-like systems we estimated them the former ones.

The theoretical results using an electron-beam resolution of 16 eV are given in Fig. 1 and can be compared to the experimental results shown in Fig. 2.

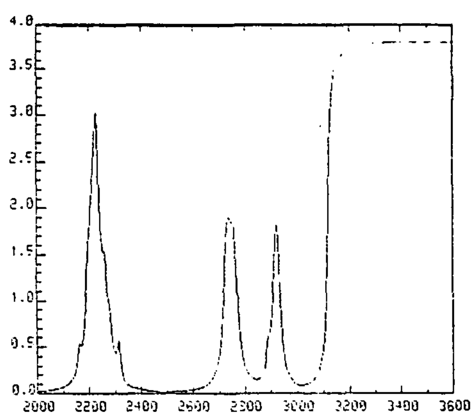

Fig. 1. Argon synthetic spectrum.

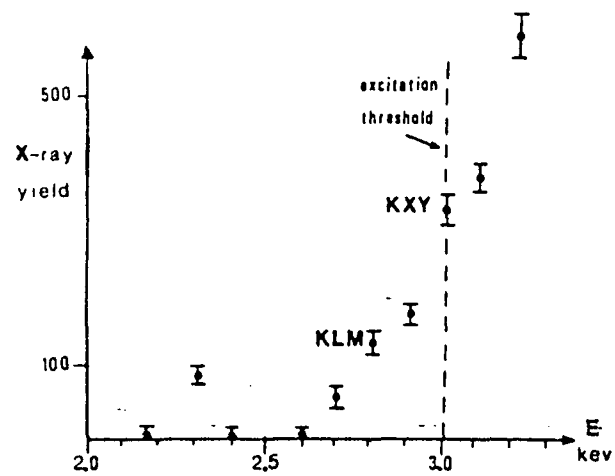

Fig. 2. Experimental x-ray yield (absolute counting rate). The horizontal error bar represents the uncertainty in the absolute energy of of the electrons.

The most proeminent experimental feature is at 2.3 keV, which corresponds to the dielectronic recombination of Ar^{14+}, whereas from the theoretical model used in Fig. 1. the most proeminent feature corresponds to the dielectronic recombination on Ar^{15+} at 2.25 keV. This shift between the two features could be explained by too high abundance value of He-like ion compared to Li-, Be-, B-like abundances. Furthermore the excitation increase above 3 keV is steeper in the experimental results than in the theoretical model. We intend to introduce in the calculations, dielectronic recombination for larger quantum number which will fill the gap around 2.8 keV-3 keV. This will increase the x-ray field and the theoretical results will be closer to the experimental ones in this energy range. This kind of theoretical analysis, whose feasibility has been tested in this work, will be used for ion source diagnostics as well as a test for the atomic data.

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