A COLLISIONAL RADIATIVE MODEL OF THE ARGON ION SYSTEM TESTED FOR A LARGE RANGE OF ELECTRON DENSITIES

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Introduction. We reported earlier on a comparison between a Collisional Radiative Model (C.R.M.) for the argon ion system and density measurements of the 4s and 4p group of that system from the plasma column of a hollow cathode arc (H.C.A.) [1,2]. The literature data, available at that time, had been digested in this model; we refer to [2] for a complete description. We only mention that the 3d group had been divided into three subgroups, owing to their different nature (metastable and strongly radiative levels) and that the measurements covered an electron density range n_e from $1\cdot10^{18} m^{-3}$ to $2.5\cdot10^{19} m^{-3}$. It appeared that there was a factor 3 discrepancy between the model and the experimental data for the 4p group. Measurements with a new type of H.C.A. with n_e-values from $2.5\cdot10^{18}$ - $2.5\cdot10^{20}$ m^{-3} showed an increasing discrepancy with the existent model with increasing density, so that it was evident that this model was not adequate to give a good explanation of the experimental behaviour of excited groups over the whole density range. We therefore decided to modify the C.R.M. and to include processes to and from the doubly ionized ground levels. Recent data of Jolly [3] were a helpful guide in this new approach.

Experimental set up. The spectroscopic measurements have been carried out by determination of the radiation of the doublet 4p group from a 10 mm radius plasma column of a steady state H.C.A. with a 0.5 m Jarell-Ash monochromator. The discharge has a pressure of 1 mtorr, a confining axial magnetic field of 0.05 - 0.5 T and a current of 20 - 200 A. The electron temperature and -density measurements have been performed with a Thomson scattering device having a pulsed -50 J, 1.5 ms-ruby laser as a radiation source.

Results. For about 40 different plasma conditions with n_e-values from $2.5\cdot10^{18}$ - $2.5\cdot10^{20} m^{-3}$ and electron temperatures T_e from 2.5 - 4.8 eV, we measured 4p group densities from $4.7\cdot10^{11}$ - $6\cdot10^{13}$ m^{-3}. The conclusion is that there is - apart from experimental scatter - a reasonable agreement between the original model and the experimental data for $n_e < 2.10^{19} m^{-3}$ with a difference of a factor 2.5 - 3 between them. This factor was also found in Refs. [1,2]. For higher n_e-values, however, the discrepancies increase up to a factor 400, showing that this model is inadequate to describe the main physical processes in the argon ion system for this density range.

The modified model. The main changes we propose in the model in this *preliminary* stage are that
1) we diminish the excitation rate from the 3p ion ground levels to all excited groups by a factor 3 in order to obtain a better agreement at low electron densities. This adaption can be justified by the fact that in the low density case, a Corona model exists in which almost the total excitation activity comes directly from the ground levels and no other processes can cause the difference between model and experiment. Also Jolly [3] pointed out that Zapesochnyi's values [4] may be too high;
2) we introduce ionization from all ion groups to the doubly ionized ground levels and recombination from these levels back to the ion system. These latter processes appeared to be of minor significance but the ionization processes appeared to be very important in diminishing the discrepancy between model and experiment for high n_e-values.
With respect to the ionization processes, we used an ionization rate of $1\cdot10^{-13} m^3 s^{-1}$ at T_e = 3 eV for the 4p doublet group, according to recent data of Jolly [3]. This rate represents a very large cross section. For other groups comparable values have been used. This stepwise ionization - or possibly excitation to highly situated groups - play an important deexciting role for the 4p group at high n_e-values. Many other (de)excitation processes between excited groups as e.g. between the

4p and 3d,4s with comparable or even larger rates do only travel the excited particles from one to another group and are not real loss processes for these groups. Processes to singly and doubly ionized ground levels can be considered as such. The latter are far more important than the first.

3) We may drop the condition that $n_e = n_i$ (ion density) and allow that $n_i < n_e$ according to the relation $n_e = n_i + 2n_i^{++}$. This assumption leads to further improvement between model and experiment. Calculations on the balance equation for the singly ionized particles suggest that it is necessary to allow that $n_i < n_e$ for a number of conditions in order to realize that the ionization to the doubly ionized system $n_i <\sigma v_e>_{II-III}$ is smaller than or equal to that from the neutral to the singly ionized system $n_a <\sigma v_e>_{I-II}$. This is necessary to maintain steady state in the case that diffusion of argon ions is negligible or is in the radial outward direction. The condition looses its significance if radial inward diffusion should exist. However, measurements of the intensity of the λ = 328.6 nm argon III line suggest for a simple Corona model for the present 4p level with a rather high transition probability value $A = 4 \cdot 10^8 s^{-1}$ and a relatively low value of the excitation cross-section of $10^{-24} m^2$, that the n_i^{++} densities are much smaller than n_i and conseuqently $n_i \approx n_e$. We conclude that a definite judgement on this point is not possible at this moment. We present in Fig. 1 :

1) the comparison between the original model and the measurements; 2) the comparison with the model, modified according to point 1) and 2); 3) the same, modified according to point 1-3). In both modifications, there is the expected agreement with the experiment for the low n_e-values. There are still discrepancies up to a factor 25 for high n_e-values in the first modification and a factor 6 for $n_e \approx 5 \cdot 10^{19} m^{-3}$ in the second modification. It is in both cases suggested that still other depopulating processes are important. (In fig. 2 we show the ratio n_i/n_e as a function of n_e for all conditions to realize $n_i <\sigma v_e>_{II-III} \leq n_a <\sigma v_e>_{I-II}$. The smoothed curve was used for further model calculations.)

Conclusions. It is evident that for n_e-values $> 5 \cdot 10^{19} m^{-3}$, ionization to the doubly ionized system seems at least to be a partial explanation of the observed phenomena, provided that the rather large values of Jolly are used. Further improvements can be reached if $n_i < n_e$ but the evidence of this assumption is doubtful at the moment. The measurements of Jolly with a 6 mm bore laser tube suggest that in his case $n_e \approx n_i$ to explain the large densities of excited groups.

References.

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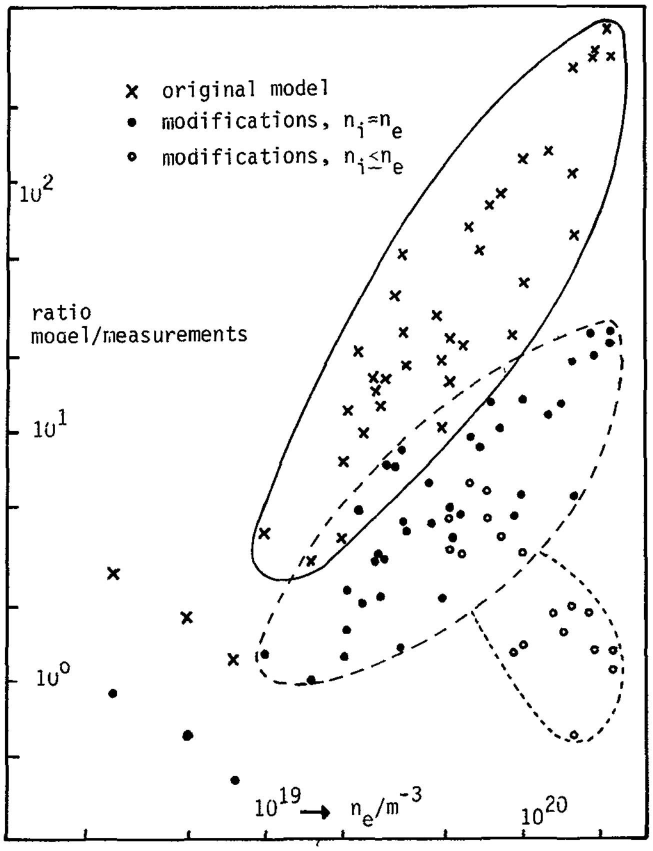

Fig. 1 Discrepancies between model and experiment

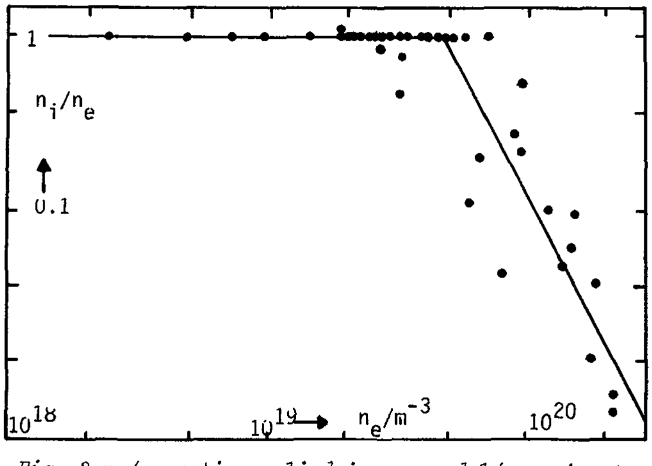

Fig. 2 n_i/n_e ratio applied in one model/experiment comparison.