A numerical collisional radiative model for the argon neutral system

A NUMERICAL COLLISIONAL RADIATIVE MODEL FOR THE ARGON NEUTRAL SYSTEM

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INTRODUCTION. In this paper we shall describe a numerical model developed for the argon neutral system. The major question for non-hydrogenlike systems is which electron-collision cross-sections between excited states have to be used, since theoretical or measured values are in general not available. Another sever problem, specific to the numerical approach, is how many states or groups have to be taken into account to get a reliable model. Up till now, the specific results of several C.R. models for the argon neutral system were unsatisfactory and disagree with each other.

Katsonis [1] describes an extended model, based on Drawin excitation and ionization formulae for hydrogen. Van der Mullen etal. [2] report on a model with only a few number of groups with an excitation between excited groups also based on Drawin's formulae. The ground state excitation to 4s and 4p however is taken from experimental data. Pots [3] presents a model with more groups as van der Mullen, also with Drawin's formulae.

In Fig. 1 we present the $r^1(4p)$ coefficient as a function of the electron density n_e for the models discussed to illustrate the great differences with respect to each other. For all these models we see a $r^1(4p)$ course in which the typical saturation behaviour observed in experiments, namely a constant $r^1(4p)$ value, cannot be found.

PRESENT MODEL. The main change in the model described here with respect to the previous ones is that we employ the semi empirical excitation and ionization formulae of Vriens and Smeets [4] proposed for hydrogen and alkalis excited states. For the argon I system these excitation rates appear to be a factor 5-15 larger than those of Drawin. These differences cause in our model the argon neutral system to be collisionally dominated for smaller n_e-values than in the previous models. The typical saturation (ESP) sets in at the correct n_e-values, in agreement with experimental data.

In the model presented here we include 49 lumped states containing groups uptill the 15S, 15p, 14d and 13f groups. The exatation cross-sections between the 3p ground state and the 4s and 4p groups have been deduced from experimental data [5-7]. Transition probability values have been derived from NBS-tables [8] and from Katsonis [1].

The s, p and d group have been given the correct statistical weights of 12,36 and 60 respectively. The statistical weight of the f group has been increased artificially to the value $(12p^2 - 108)$ in order to account for the total statistical weight of $12p^2$ for each p.q.n. p. The application of the correct total statistical weight appeared to be essential for a good result.

The coupling between the excited groups is between s and p, p and d, and d and f; ns is coupled with (n+1)s, np and (n+1)p, and so on.

RESULTS. In Fig. 1 we present the value of the $r^1(4p)$ coefficient as a function of n_e for T_e = 3eV, $n_o = 10^{19} m^{-3}$, T_a = 1eV and R = 10 mm, an optically thin plasma. The Fig. also shows the satisfactory agreement with 2 measured values. The two indicated measured points are averaged values of 15-20 individual measurements of the 696.5 nm, 4p → 4s line with n_e-T_e values, measured with Thomson scattering and T_a-values measured with Fabry-Perot interferometry.

In Fig. 2 we show densities of excited groups as a function of the effective p.q.n. $p = \sqrt{Ry/E_{pi}}$, for N = 49 groups included; Ry is the Rydberg constant and E_{pi} is the ionization energy of state p. The Fig. clearly shows the weakness of numerical models caused by the truncation of the model at a certain group even if a great number of groups have been included. Especially the densities of high lying groups show significant deviations caused by that fact. The slope of the straight part of the density-curve depends on the number N of involved groups.

In Fig. 3 the slope of this part as a function of this number N is indicated. It shows that a sufficiently large number of groups involved leads to a definite value of the slope of this straight part. It means that the density of the lower groups, roughly up to N/2 doesnot change any more. Moreover, the value of 5.2 is in satisfactory agreement with measurements and the analytical model, of van der Mullen etal. [9]. We conclude that though the truncation of the excitation flow at a certain group N to higher groups causes significant deviations in the densities of groups between N/2 and N, the densities of groups < N/2 are reliable with respect to other models and experimental data if $N \geq 40$. In Fig. 4 we present a n_e-p phase diagram for T_e = 3eV.

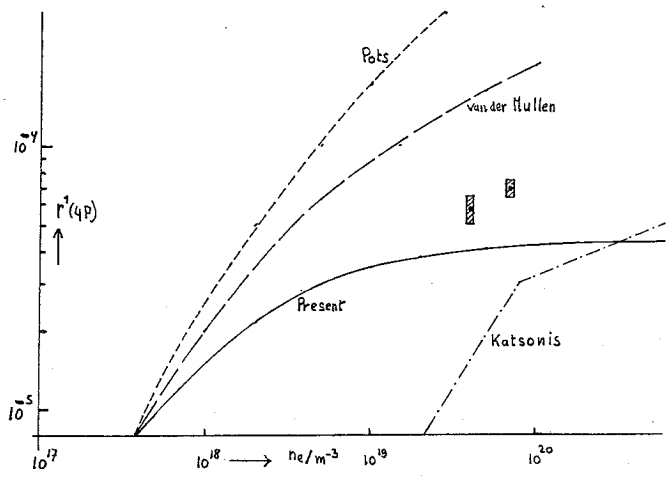

Figure 1: The $r^1(4p)$ coefficient for T_e = 3eV, T_a = 1eV, $n_o = 10^{19}$ m^{-3}, R_p = 10 mm compared with measurement and other models.

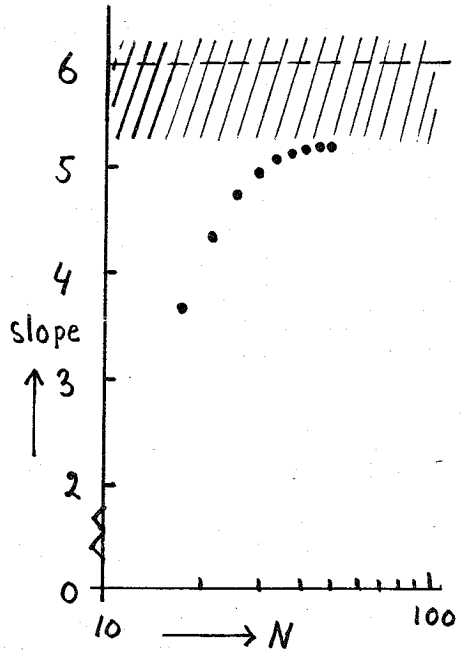

Figure 3: The slope of density curves as a function of N, the number of groups included.

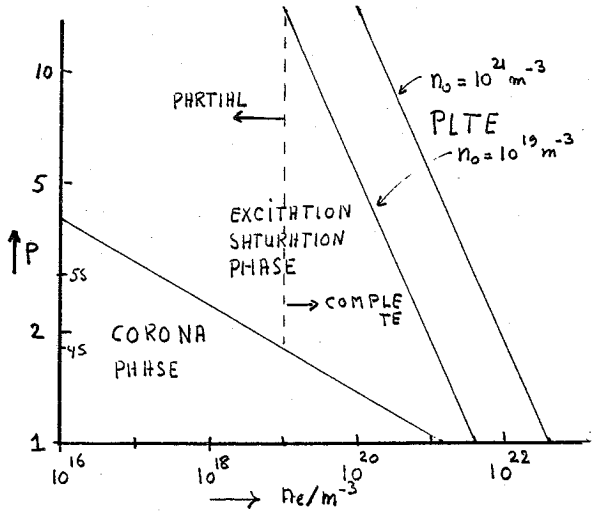

Figure 4: A phase diagram for T_e = 3eV, T_a = 1eV and R_p = 10 mm

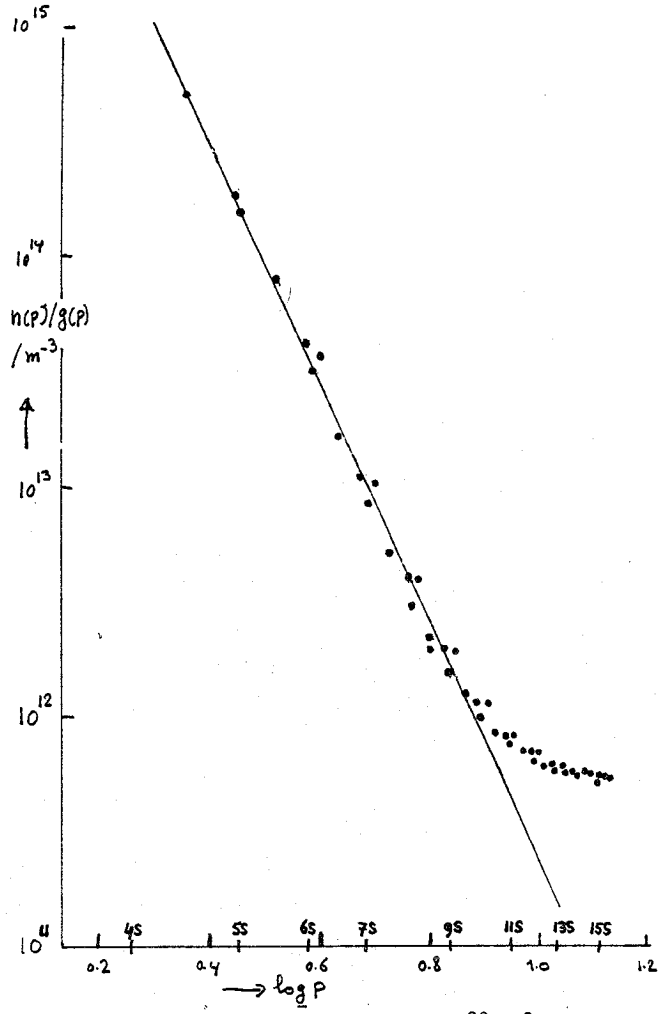

Figure 2: A density curve for $n_e = n_i = 10^{20}$ m^{-3}, T_e = 3eV, $n_o = 10^{21} m^{-3}$, T_a = 1eV, R_p = 10 mm and N = 49; slope 5.2, stat. weight: $12p^2$

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