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ON THE STARK WIDTH REGULARITIES IN THE SINGLY IONIZED ARGON SPECTRUM

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SUMMARY: The existence of the Stark width dependence on the upper-level ionization potential of the quantum transition have been presented for the four types of transitions (4s' - 4p', 4p' - 4d', 4p - 5s, 3d - 4p') in the singly ionized argon spectrum (Ar II). On the basis of established regularities the Stark width values for 6 spectral lines, not measured or calculated before, have been predicted. Critical analysis of the existing experimental Stark width data are, also, given.

1. INTRODUCTION

The great number of papers, devoted to the experimental investigation of the Stark HWHM (half-width at half intensity maximum, w) of the singly ionized argon spectral lines testify their actuality in the plasma diagnostics (Lesage and Fuhr 1998, and references therein). Namely, extensive studies of the star atmospheres (and other cosmic sources) on the basis of the shape and position of spectral lines emitted by atomic or ionic emitters, have enhanced the effort to develop a fast and reliable method to find the Stark widths of spectral lines. If the Stark broadening is the principal pressure broadening mechanism in plasmas (with 1022 - 1027 m-3 electron density), on the basis of Stark HWHM values it is possible to obtain the other basic plasma parameters e.g. electron temperature (T) and density (N), essential in the modeling of the stellar atmospheres (Dimitrijević 1989; Lesage 1994).

The simplest way to quick and reliable estimation of the values of w is to use an established regularities for a given type of quantum transition in a particular ionic spectrum.

The main objective of this study is to establish regularities of Stark HWHM values using existing experimental results and, on that basis, to predict the w values for spectral lines of the singly ionized argon atoms, that have not been measured or calculated before, in the wide range of the electron temperatures. Trends of the Stark HWHM values within four types of transitions (4s'-4p', 4p'-4d', 4p-5s, 3d-4p') have been established in singly ionized argon spectrum. On that basis Stark HWHM values for 6 spectral lines, not measured or calculated before, to the knowledge of the authors (Lesage and Fuhr 1998) have been predicted. In the view of established regularities critical analysis of the existing experimental w data are given.

2. REGULARITIES

The simplest way to estimate values of Stark HWHM is to use established regularities of w along the same type of quantum transition in the ionic spectra (Djeniže *et al.* 1989, and references therein). Namely, on the basis of the existing experimental results of a Stark HWHM of the spectral lines that belong to 4p-4d transition in the ArII spectrum it was found that simple analytical relationship exist between w and corresponding upper-level ionization potential (I) of a particular spectral line for the same type of transitions. Thus, relationship, normalized to a $N = 1 \times 10^{23}$ m^{-3} electron density, is of a form:

$$w = aT^{-1/2} I^{-b} \quad \text{(rad/s)}. \qquad (1)$$

Table 1. Coefficients a and b in the Eq. (1), obtained for various transitions in singly ionized argon spectrum for T in (K) and I in (eV).

Transition	Coefficients	
	a	b
4s' – 4p'	1.50 10^{22}	10.29
4p' – 4d'	2.10 10^{14}	0.72
4p – 5s	6.93 10^{13}	0.0
3d – 4p'	2.65 10^{16}	3.82

Table 2. Predicted Stark FWHM ($2w$) values at T = 20 000 K electron temperature and $N = 1 \times 10^{23}$ m^{-3} electron density with their estimated accuracy's.

Transition	Multip.	λ (nm)	$2w$ (nm)	Acc (%)
4p' – 4d'	$^2F^0$–^2D (107)	342.96	0.0867	20
		343.26	0.0878	20
	$^2P^0$–^2D (116)	363.98	0.0927	20
4p – 5s	$^4P^0$–^2P (43)	365.09	0.0693	20
	$^2D^0$–^4P (63)	425.56	0.0942	20
	$^2P^0$–^4P (76)	547.76	0.1561	20

The upper-level ionization potential I (in eV) specifies the emitting ion, while the electron temperature T (in K) characterizes the assembly. The coefficients a and b are independent of I and T. The successful application of Eq. (1) (including the all existing experimental w data) in the cases of the 4s-4p, 4p-4d and 3d-4p transitions of the ArII spectrum is presented by Djeniže *et al.* (1999, received in march 1998). In the meantime, new experimental Stark HWHM data are published (Aparicio *et al.* 1998) for the lines that belong to higher multiplets, giving possibility for inclusion theire in the investigation of the Stark HWHM regularities. Inclusion of all existing experimental Stark HWHM data in the Eq. (1), in the cases of the investigated transitions, leads to the coefficients a and b which are presented in Tab. 1. The found Stark HWHM trends along various type of the transition are graphically presented in the Figs. 1-4. The error bar 20%, in these figures, shows the magnitude of the scatter of the experimental data of reduced Stark HWHM ($wT^{1/2}$) values. Stark width values, predicted on the basis of Eq. (1), at T = 20000 K electron temperature and $N = 1 \times 10^{23}$ m^{-3} electron density, are presented in Tab. 2. Namely, at these plasma parameters existence of the singly ionized atoms is expected. The necessary atomic data are taken from Wiese *et al.* (1969).

3. RESULTS

3.1. 4s' - 4p' transition

Eighteen spectral lines from three multiplets in 4s' - 4p' transition have been investigated in seven experiments; Chapell *et al.* (1968), Labat *et al.* (1974), Konjević *et al.* (1970), Djeniže *et al.* (1989), Dzierżega and Musiol (1994), Pellerin *et al.* (1997) and Aparacio *et al.* (1998). Characteristics electron temperatures in these references were: 13 800, 16 500, 16 500, 26 000, 12 400*, 22 200* and 22 400* K, respectively. Asterix denote averaged values. Measured stark HWHM values satisfy our Eq. (1) (see Fig. 1).

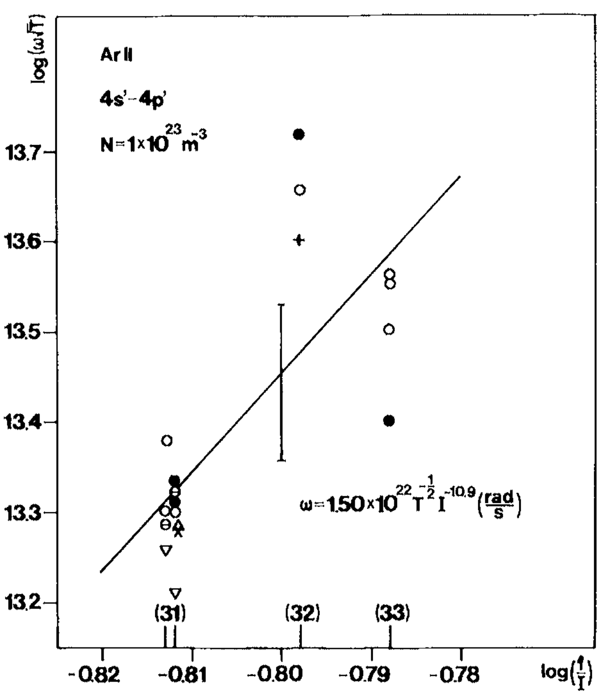

Fig. 1. *Reduced Stark HWHM versus inverse value of the upper-level ionization potential. 4s' - 4p' transition, θ, Chapell et al. (1968), △, Konjević et al. (1970); X, Labat et al. (1974); +, Djeniže et al. (1989); ∇, Dzierżega and Musiol (1994); •, Pellerin et al. (1997); o, Aparacio et al. (1998).*

3.2. 4p' - 4d' transition

Eighteen spectral lines from seven multiplets in 4p' - 4d' transition have been investigated in six experiments; Mazing and Vrubljoskaia (1962) (30 000 K), Lhuissier (1987) (15 000K), Djeniže *et al.* (1989), Dzierżega and Musiol (1994), Pelerin *et al.* (1997) and Aparacio *et al.* (1998). Measured stark HWHM values satisfy our Eq. (1) (see Fig.2). Predicted Stark width data for three spectral lines, not measured or calculated before, are presented in Tab. 2.

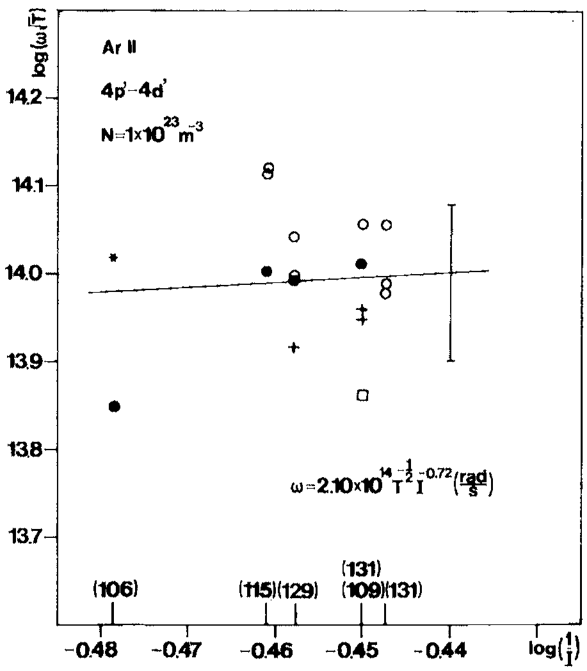

Fig. 2. *Reduced Stark HWHM versus inverse value of the upper-level ionization potential. 4p' -4d' transition. The symbols are the same as in Fig.1. In addition: *, Mazing and Vrubljoskaia (1962); □, Lhuissier (1987).*

3.3. 4p - 5s transition

Twentytwo spectral lines from seven multiplets in 4p - 5s transition have been investigated in only three experiments (Lhuissier 1987; Pellerin *et al.* 1997; Aparacio *et al.* 1998). Measured Stark HWHM values satisfy our Eq.(1) (see Fig.3). Predicted Stark width data for three spectral lines from three multiplets, not measured or calculated before, are presented in Tab.2.

3.4. 3d - 4p' transition

Fourteen spectral lines from four multiplets in 3d - 4p' transition have been investigated in five experiments (Konjević *et al.* 1970; Lhuissier 1987; Dzierżega and Musiol 1994; Pellerin *et al.* 1997; Aparicio *et al.* 1998). Measured Stark HWHM values satisfy our Eq. (1) (see Fig.4).

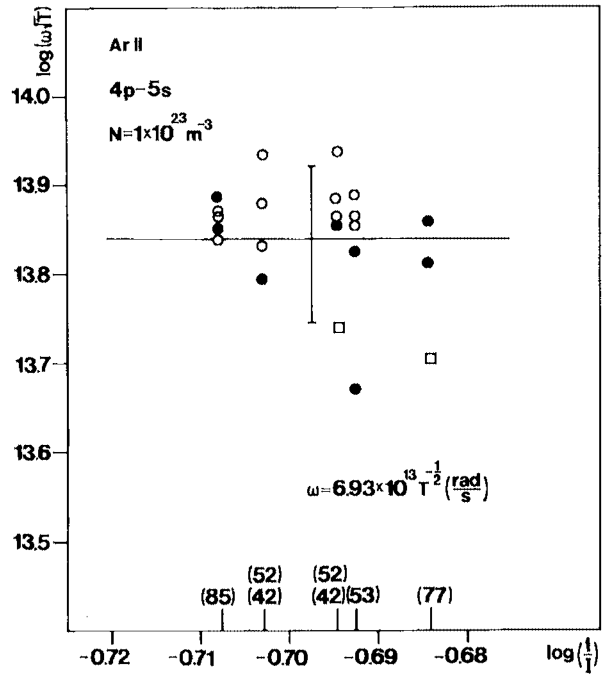

Fig. 3. *Reduced Stark HWHM versus inverse value of the upper-level ionization potential. 4p - 5s transition. The symbols are the same as in Fig.1. In addition: □, Lhuissier (1987).*

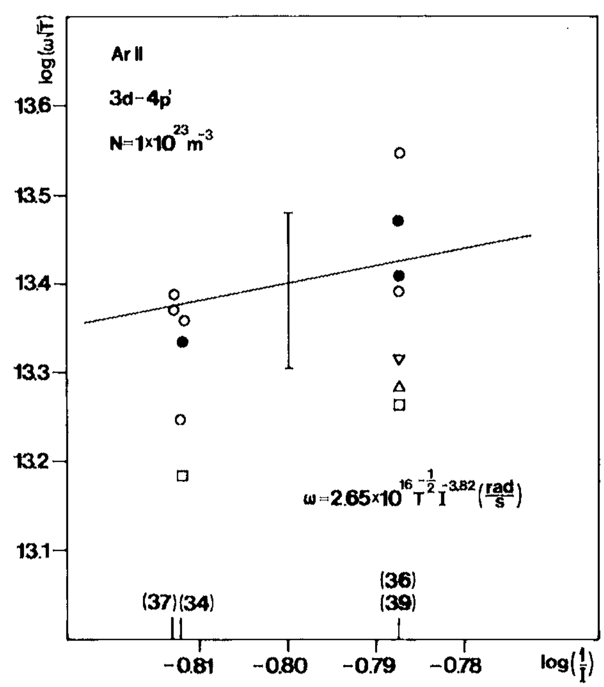

Fig. 4. *Reduced Stark HWHM versus inverse value of the upper-level ionization potential. 3d - 4p' transition. The symbols are the same as in Fig.1. In addition: □, Lhuissier (1987).*

4. DISCUSSION

On the basis of the established regularities of the Stark HWHM values on the upper-level ionization potential, it is evident that the recent experimental data from Pellerin *et al.* (1997) and Aparacio *et al.* (1998) lies above other experimental results, especially in the case of the lines belonging to the 3d-4p' transition (Fig.4). On the other hand, the reduced stark HWHM (wT1/2) values show tolerable mutually scatter. It is within 20% in comparison to the values calculated on the basis of the established trends. Only exception makes values from Lhuissier (1987). These lies systematically under the other experimental values. It should be pointed out that the investigated spectral lines origin from the upper levels (i) whose energies lies in the narrow energy interval (ΔE_i) (0.37 eV; 0.21 eV, 0.28 eV and 0.37 eV for the 4s' - 4p', 4p'-4d', 4p-5s and 3d-4p' transitions, respectively). In the cases of the 4p'-4d' ($\Delta E_i = 0.21$ eV) and 4p-5s ($\Delta E_i = 0.28$ eV) transitions the Stark HWHM dependence on the upper-level ionization potential (I) is weak. These facts confirm the statement published by Wiese and Konjević (1982). They pointed out that all Stark widths for lines within a transition array should be nearly equal because of similar positions of their upper energy levels.

5. CONCLUSIONS

On the basis of existing experimental data, trends of Stark HWHM values for spectral lines from singly ionized argon spectrum have been established in 4 types of transition. They confirm the correct from of the dependence of w on the upper-level ionization potential. Using these regularities Stark with values have been predicted for 6 spectral lines that have not been measured or calculated. The evident scatter among results of particular experiments in the case of the 3d-4p' transition can be explained on the basis of various uncertainties of the electron density and temperature measurements in these experiments. It should be pointed out that these experiments were performed with various diagnostics methods. In any case, new measurements of the Stark HWHM values for spectral lines, that belong to this transition, would be helpful.

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РЕГУЛАРНОСТИ ШТАРКОВИХ ШИРИНА У СПЕКТРУ ЈЕДНОСТРУКО ЈОНИЗОВАНОГ АРГОНА

С. Ђениже

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Указано је на постојање зависности Штаркове ширине од потенцијала јонизације горњег енергијског нивоа квантног прелаза за четири типа прелаза (4s' - 4p', 4p' - 4d', 4p - 5s, 3d- 4p') у спектру једноструко јонизованог аргона. На основу утврђених регуларности предвиђене су Штаркове ширине за 6 спектралних линија, које до сада нису мерене нити рачунате. Дат је и критички осврт на постојеће експерименталне вредности Штаркових ширина.