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MEASURED, CALCULATED AND PREDICTED STARK WIDTHS ALONG A BERYLLIUM ISOELECTRONIC SEQUENCE IN THE 3s-3p TRANSITION

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SUMMARY: On the basis of the observed satisfactory agreement between recent experimental and calculated Stark width values with our earlier predicted ones along the beryllium isoelectronic sequence (BeI, BII, CIII, NIV, OV, FVI, NeVII, ...) new Stark width values have been predicted for high ionized emitters (NaVIII, MgIX, AlX, SiXI and PXII,) in the 3s-3p transition, interesting for astrophysical investigations.

1. INTRODUCTION

In order to find quick and convenient method for Stark width prediction, a simple formula (Eq. (1) in Chapter 4), based on the Stark width regularities along various isoelectronic sequences, was recommended by Purić *et al.* (1988a, 1988b). This enables estimation of Stark width values for four and more time ionized emitters which is welcome in the cases when theoretical calculations can not give convenient results in consequence of the unknown atomic data necessary in calculations. In meantime, since 1988, many new experimental results in Stark broadening are produced for spectral lines that belong up to six times ionized emitters (Lesage and Fuhr, 1999) giving possibility to test validity of our formula (1) (Djeniže 2000ab; Djeniže *et al.* 1998; 1999). Besides, using the semiclassical perturbation method Dimitrijević and Sahal-Bréchot (1998) have calculated Stark width values for a large number of multiply charged (up to XIII) emitters along Periodic System of elements (Dimitrijević 1996 and references therein). The recent work published by Ralchenko *et al.* (2001) gives new Stark width values for emitters from beryllium isoelectronic sequence based on the quantum mechanical calculations up to NeVII. Namely, the knowledge the Stark width data of high ionized emitters is important in astrophysics.

The aim of this work is a comparison of the recent experimental and theoretical Stark FWHM (full-width at half intensity maximum, W) data with our earlier predicted W values among beryllium isoelectronic sequence (BeI, BII, CIII, NIV, OV, FVI, NeVII) in case of the 3s-3p transition. The observed agreement between mentioned values and our predicted values, at higher electron temperatures, allows us to extend our predictions of W up to XI times ionized emitter (PXII) in beryllium isoelectronic sequence. Thus, we have predicted Stark FWHM values for: NaVIII, MgIX, AlX, SiXI and PXII at electron temperatures up to 900 000 K.

2. MEASUREMENTS

The recent experimental works, devoted to the Stark width measurements in the 3s-3p transition along beryllium like emitters (BII, CIII, NIV, OV, NeVII) have been presented by Milosavljević and

Djeniže (1998), Wrubel *et al.* (1998) and Blagojević *et al.* (1999; 2000). In the works by Blagojević *et al.* and Milosavljević and Djeniže the linear pulsed arc discharge was used as a plasma source with electron temperatures up to 80 000 K. Wrubel *et al.* have used the linear z-pinch as a plasma source with electron temperatures up to 240 000 K.

3. CALCULATIONS

For comparison with experimental values the recent theoretical results (Ralchenko *et al.* 2001) have been used. The authors used the impact approximation with the convergent close-coupling (RGBF) method and give calculated W values for BII, CIII, NIV and OV ions. Earlier published theoretical results based on the semiclassical theory (Griem 1974) and modified semiempirical theory (Dimitrijević and Konjević 1980) have been taken into account in our previously published works (Purić *et al.* 1988a, 1988b; Djeniže *et al.* 1998, 1999; Djeniže 2000ab).

4. ESTIMATIONS

The simplest way to estimate values of Stark FWHM is to use the established regularities of W along the isoelectronic (IES) sequence for the given type of quantum transition. It was found (Purić *et al.* 1988a, 1988b) that simple analytical relationship exists between W and corresponding upper-level ionization potential (I) of a particular spectral line, for certain types of transitions. The found relationship, normalized to a N = 10^{23} m^{-3} electron density, is of the form:

$$W(rad/s) = az^2T^{-1/2}I^{-b}. \qquad (1)$$

The upper-level ionization potential I (in eV) and net core charge z (z = 1, 2, 3, 4, ... for neutral, singly, doubly, triply, ... ionized atoms, respectively) specify the emitting ion, while the electron temperature T (in K) characterizes the plasma. The coefficients a and b are independent of I and T.

In the case of the beryllium sequence the found explicit form of the Eq. (1) is:

$$W(rad/s) = 1.15 \times 10^{14} z^2 T^{-1/2} I^{-1.12} \qquad (2)$$

(see Fig. 9 in Purić *et al.* 1988a) for the 3s-3p transition at 10^{23} m^{-3} electron density.

5. RESULTS AND DISCUSSION

In order to make easy comparison between the measured, calculated and estimated Stark width values, in Figs 1-4 the dependence of full width at half maximum (FWHM) values at the electron temperatures at 10^{24} m^{-3} electron density is illustrated. Theoretical predictions (solid lines) present only electron contribution to the Stark width. Estimated Stark width values (IES) are presented by dashed lines.

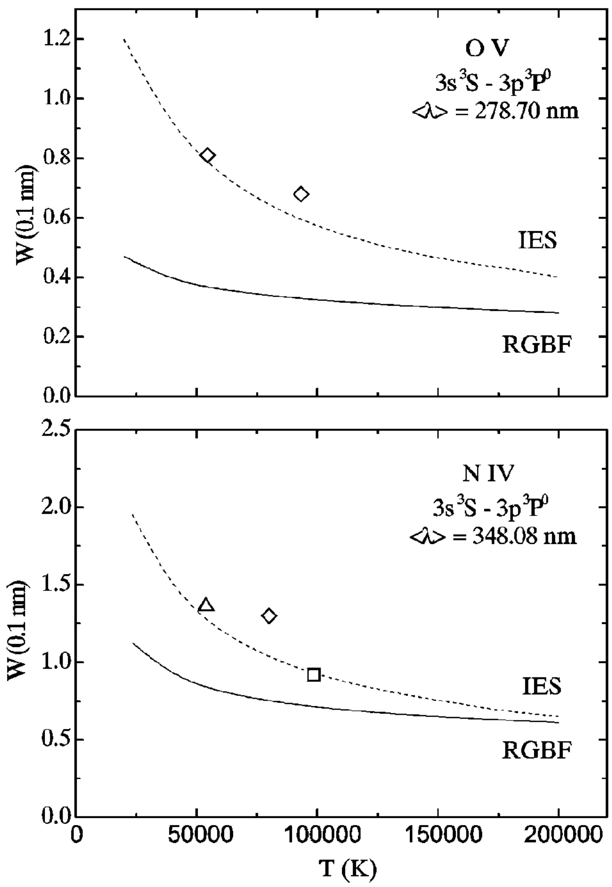

Fig. 1. *Stark FWHM (W) vs. electron temperature at 10^{24} m^{-3} electron density in 3s-3p (triplet) transition. Experiments: △, Milosavljević and Djeniže (1998); □, Wrubel et al. (1998); ◇, Blagojević et al. (1999); ○, Blagojević et al. (2000). Theory: RGBF, Ralchenko et al. (2001). Estimation: IES, Eq. (2).*

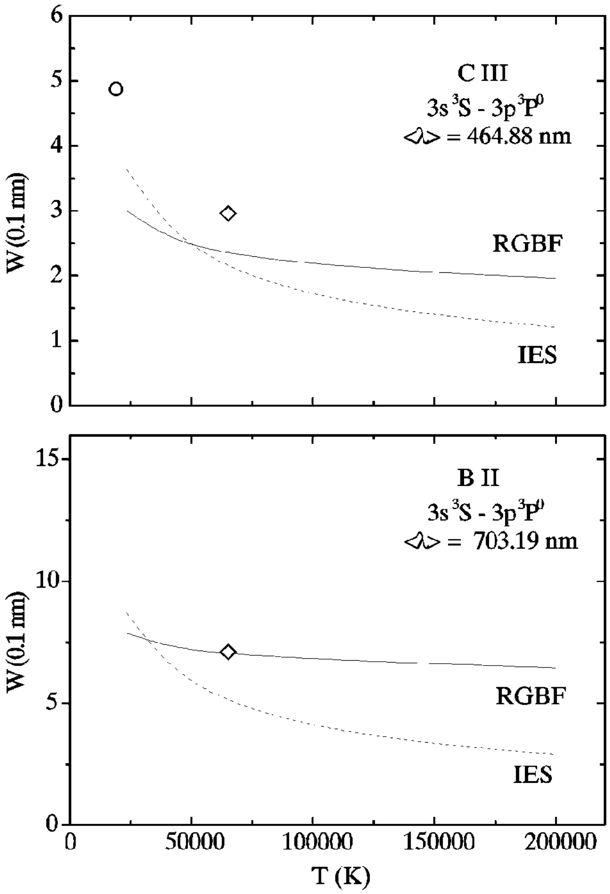

Fig. 2. *Stark FWHM (W) vs. electron temperature at 10^{24} m^{-3} electron density in 3s-3p (triplet) transition. The symbols are same as in Fig. 1.*

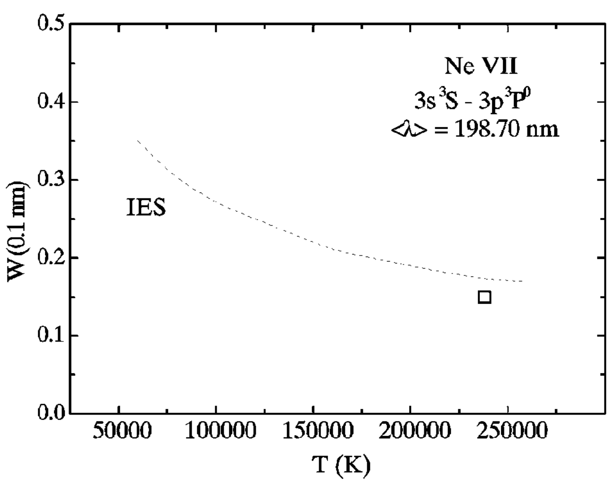

Fig. 3. *Stark FWHM (W) vs. electron temperature at 10^{24} m^{-3} electron density in 3s-3p (triplet) transition. The symbols are same as in Fig.1.*

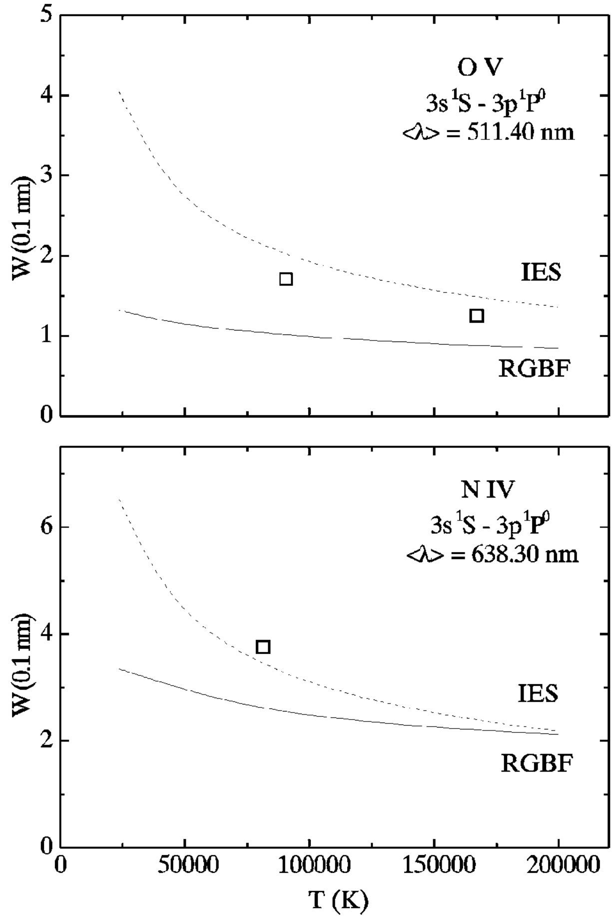

Fig. 4. *Stark FWHM (W) vs. electron temperature at 10^{24} m^{-3} electron density in 3s-3p (singlet) transition. The symbols are same as in Fig. 1.*

Table 1. Predicted Stark FWHM (W_p) values at T_1 = 300 000 K, T_2 = 600 000 K and T_3 = 900 000 K electron temperature and 10^{23} m^{-3} electron density for various emitters in $3s^1S$- $3p^1P^0$ transition along the beryllium isoelectronic sequence on the basis of Eq. (2). $< \lambda >$ is the mean wavelength in the multiplet.

Emitter	$< \lambda >$ (nm)	W_p (pm)		
		T_1	T_2	T_3
Na VIII	318.23	4.0	2.8	2.3
Mg IX	281.42	3.0	2.1	1.7
Al X	252.96	2.5	1.8	1.4
Si XI	229.50	2.0	1.4	1.2
P XII	206.16	1.5	1.1	0.9

On the basis of Figs.1-4 one can conclude that:

1. recent theoretical RGBF values, except BII line, lie below all recent experimental W values,

2. experimental W values agree well (within ±10%) with our IES predictions, except BII value,
3. In the case of the NIV and OV spectra, at high electron temperatures, RGBF and IES values show similar behaviour.

On the other hand, it should be pointed out that recent theoretical RGBF values lie about 60% below values calculated on the basis of the semiclassical theory (Griem 1974) and about 20% below values evaluated on the basis of semiempirical approximation (Dimitrijević and Konjević 1980) and approximation made by Hey and Breger (1980, 1982). Answer to this facts is explained in Ralchenko *et al.* (2001).

Because the new experimental W values , obtained along beryllium sequence, agree very good with our IES predictions Eq.(2) can be recommended for extending the prediction of Stark FWHM values up to PXII .Our predicted W values (within ± 35 % estimated accuracy) are presented in Table 1. The necessary atomic data were taken from Bashkin and Stoner (1975) and Wiese *et al.* (1966,1969). To the knowledge of the authors no theoretical or experimental W values exist for Na VIII, Mg IX, Al X, Si XI and P XII in the 3s-3p transition.

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МЕРЕНЕ, РАЧУНАТЕ И ПРЕДВИЂЕНЕ ШТАРКОВЕ ШИРИНЕ ДУЖ ИЗОЕЛЕКТРОНСКОГ НИЗА БЕРИЛИЈУМА ИЗ ПРЕЛАЗА 3s-3p

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Оригинални научни рад

На основу сагледаних задовољавајућих слагања најновијих експерименталних и рачунатих Штаркових ширина са нашим, раније предвиђеним, вредностима дуж изоелектронског низа берилијума (BeI, BII, CIII, NIV, OV, FVI, NeVII, ...) предвиђене су Штаркове ширине високојонизованих емитера (NaVIII, MgIX, AlX, SiXI, PXII), из прелаза 3s-3p, које су интересантне за разна астрофизичарска истраживања.