Publ. Obs. Astron. Belgrade No. 53 (1996), 101 – 104

ON THE STARK WIDTH REGULARITIES ALONG A SODIUM LIKE ISOELECTRONIC SEQUENCE

S. DJENIŽE and J. LABAT
Faculty of Physics, University of Belgrade
P.O.B. 368, 11001 Belgrade, Serbia, Yugoslavia

Abstract. Recent values of the spectral lines Stark widths (calculated and measured since 1988) for multiply ionized atoms of the third period of the Periodic system, have been compared to the values previously predicted by us. These were found from the established regularities of the Stark widths along Na-like isoelectronic sequence for 4s-4p type of transition. The new data fit favourably to the established trend along the mentioned sequence, alowing thus to predict further the Stark width values for even higher ionization states (such as KIX-TiXII), that have not been calculated or measured before, but are of a considerable astrophysical interest.

1. INTRODUCTION

Extensive studies of the star atmospheres (effective temperature $\approx 10^5 - 10^6$ K) on the basis of the shape and position of spectral lines emitted by atomic or ionic emitters, have enhanced an effort to develop a fast and reliable method to find the Stark widths of spectral lines. Namely, Stark broadening is a principal broadening mechanism in a plasmas of $10^{22} - 10^{27}$ m^{-3} electron density. On the basis of Stark HWHM (half-width at half intensity maximum, w) values it is possible to obatin the other basic plasma parameters e.g. electron temperature (T) and density (N). The simplest way to estimate the values of w is to use an established regularities of w along the isoelectronic sequences for a given type of quantum transition (Purić et al 1988, and references therein). For the case of elements from the third period of the Periodic system, that have large abundance in the atmospheres of hot stars, the simple trend has been established from experimental and theoretical w data for spectral lines from ionic spectra, including as a highest ionized states ClIV and ArIV, obatined for various plasmas with the electron temperature not exceeding 60 000 K (Purić et al 1988). In the meantime, since 1988, the results of new experiments have been published and theoretical calculations have been performed, on the basis of semiclassical perturbation formalism, for ionized states : MgII (Dimitrijević & Sahal Bréchot 1995b) PV (Dimitrijević & Sahal Bréchot 1995a) and SVI (Dimitrijević & Sahal-Bréchot 1993).

The main objective of this study is to compare the recent experimental and theoretical Stark HWHM results with the values that follow from previously established regularities and, on that basis, to predict the w values for highly ionized atoms (up to 11 times) for temperatures of the order of 10^5 K.

2. REGULARITIES

On the basis of the existing experimental and theoretical results of a stark HWHM of the spectral lines from a Na-like (NaI, MgII, AlIII, SiIV, PV, SVI, ClVII, ArVIII) isoelectronic sequence it was found (Purić et al 1988) that simple analytical relationship exists between w and correspondent upper-level ionization potential (I) of a particular spectral line for the same type of the transition. The found relationship, normalized to a $N = 1 \times 10^{23}$ m^{-3} electron density, is of a form :

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

The upper-level ionization potential I (in eV) and the net core charge $z(z = 1, 2, 3, \ldots$ for neutral, singly, doubly,... ionized atoms) specify the emitting ions, while the electron temperature T (in K) characterizes the assembly. The coeficients a and b are independent of I, z and T. For the Na-like (4s-4p transition) isoelectronic sequence the dependence is expressed as :

$$\mathrm{w}_{\text{Na-like}} = 1.91 \times 10^{14}z^2T^{-1/2}I^{-1.59}(\mathrm{rad/s}) \qquad (2)$$

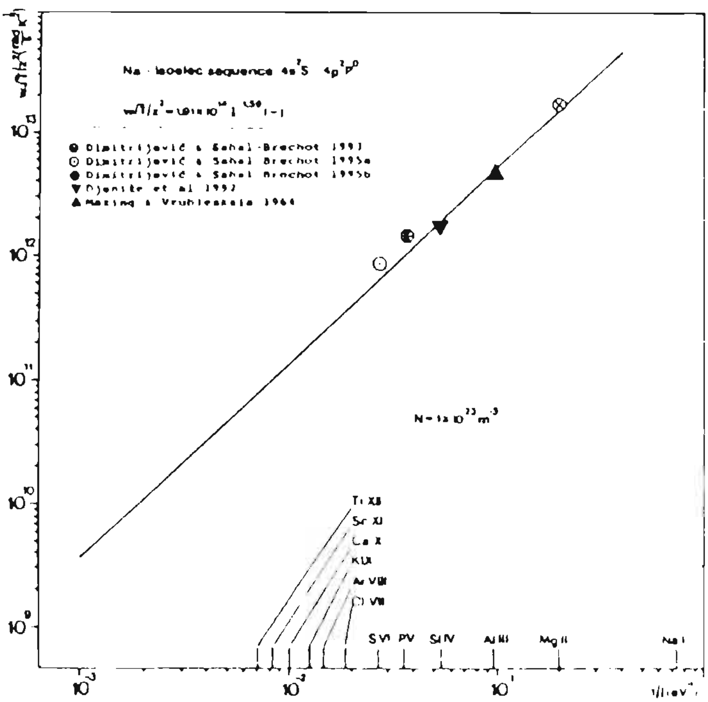

Fig. 1.

On the basis of Eq.(2) it was possible to predict w values for the spectral lines from the high ionized states, like ClVII and ArVIII, not measured or calculeted before. These predictions were summarized in Purić et al (1988).

In the meantime measurements of w have been repeated for the lines already measured, such as emitters SiIV (Djeniže et al 1992). Experimental values for AlIII, althoug published quite a long time ago (Mazing & Vrubleskaia 1964) will also be included, for the first time, into considerations of regularities.

In Figure 1 we present graphically (in log-log scale) reduced Stark widths ($wT^{1/2}z^{-2}$) vs inverse value of the upper-level ionization potential for Na-like isoelectornic sequence. The full line represent the predicted values on the basis of early established regularities (Eq.2), while the new experimental and calculated values are given by various symbols.

3. DISCUSSION

For sodium-like isoelectronic sequence the agreement of recent experimental values with predicted on the basis of Eq.(2) is excellent (AlIII, SiIV), while theoretical Stark HWHM values are in average for 20% larger (MgII, PV, SVI) (see Fig.1). This, together with previous arguments proves that Eq.(2) is reliable for description of regularities of Stark HWHM along the sodium-like isoelectronic sequence for $4s^2S$-$4p^2P^0$ transition.

4. PREDICTIONS

On the basis of confirmed regularities of Stark HWHM values along the sodium-like isoelectronic sequence, up to the five times ionized sulfur atoms, follows a possibility of further predictions. By extrapolation we have now predicted Stark HWHM values for sodium-like isoelectronic sequence for 4s-4p transitions from KIX to TiXII. Wavelengths of mentioned transitions lie in the range 120-170 nm, that is very convenient for spectroscopic observations by orbital telescopes in the far UV spectrum. The selected emitters belong to the class of very interesting radiation sources in astrophysical and laboratory plasmas of high temperature.

Predicted values of Stark HWHM for spectral lines of highly ionized emitters are presented in Tab.1, along with the electron temperatures at which these emitters are expected at the electron density of $N = 1 \times 10^{23}$ m^{-3}. Relevant atomic parameters are taken from Bashkin & Stoner (1978).

Emitter	Transition	λ (nm)	T(10^6K)	2w(10^{-1}nm)
KIX	$4s^2S$- $4p^2P^0$	165	0.5	$0.0057 \pm 25\%$
CaX		146	0.5	$0.0041 \pm 25\%$
ScXI		131	0.5	$0.0030 \pm 25\%$
TiXII		119	0.5	$0.0022 \pm 25\%$

To the knowledge of the authors, calculations of Stark HWHM for investigated spectral lines have not been performed (Fuhr & Lesage 1993).

Acknowledgements

This research as a part of the project "Plasma Spectroscopy" was supported by Ministry of Science and Technology of the Republic of Serbia.

References

Bashkin S., Stoner J.O. : 1978, *"Atomic Energy Levels and Grotrian Diagrams"* **Vol. 2**, North Holland, Amsterdam.
Dimitrijević M.S., Sahal-Bréchot S. : 1993, *A&A S.S.* **100**, 91.
Dimitrijević M.S., Sahal-Bréchot S. : 1995a, Proceed. the 1^{st} YU CSLS, Publ. Obs. Astron. Belgrade, **50**, 51.
Dimitrijević M.S., Sahal-Bréchot S. : 1995b, *Bull. Astron. Belgrade*, **151**, 101.
Djeniže S., Srećković A., Labat J., Purić J., Platiša M. : 1992, *J. Phys.* B **25**, 785.
Fuhr J.R., Lesage A. : 1993, Bibliography on Atomic Line Shapes and Shifts (July 1978 through March 1992) NIST Special Publication 366, Supp. 4 U.S.D.C., National Institute of Standards and Technology.
Mazing M.A., Vrubleskaia N.A. : 1964, Optics and Spectroscopy (in Russian) **XVI**, 11.
Purić J., Djeniže S., Labat J., Platiša M., Srećković A., Ćuk M. : 1988, *Z. Phys.* D **10**, 431.