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STARK BROADENING REGULARITIES WITHIN SUCCESSIVE IONIZATION STAGES OF PHOSPHORUS AND SULFUR

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Stark width dependence of the particular spectral lines on the upper-level ionization potential and net core charge of the emitter within the isonuclear sequence has been studied for the 4s-4p and 4p-4d transitions of the phosphorus and sulfur, respectively. Using the obtained trends, one can successfully predict the Stark widths of the PV and SVI spectral lines that have not yet been measured or calculated.

1. Introduction

Large number of published experimental and theoretical papers dealing with the Stark broadening of spectral lines emitted by higher ionization states of atoms from first and second period of the Periodic table, point to an importance and actuality of these data. On the basis of existing results we have already established regularity of Stark HWHM (half half-width at half intensity maximum) values on the ionization potentials[1-3]. Existence of the regularity of Stark HWHM for lithium-like and sodium-like isoelectronic sequences has been found in Ref. 1 while for isonuclear sequences of C, N, O, F, Ne, Si, Cl and Ar it was pointed in Ref. 2 and Ref. 3.

The aim of this contribution is to point also to the regularity of Stark HWHM (w) values on upper-level ionization potential for 4s-4p and 4p-4d transitions in successive ionization stages (isonuclear sequences) of phophorus and sulfur, respectively. The obtained regularity, for the given type of transition is of the form:

$$w = a\, z^2\, T^{-1/2}\, I^{-b} \quad \text{(rad/s)} \tag{1}$$

where I (eV) is the upper-level ionization potential, T (K) electron temperature, z net core charge ($z = 2, 3, 4$ for: PII, SII; PIII, SIII and PIV, SIV, respectively) and a and b are constants independent of I, T and z).

The Eq. (1) is normalized to $N = 1 \times 10^{23}\ \mathrm{m}^{-3}$ electron density. We assume that the upper-level ionization potential and the net core charge specify the emitting ion, while the electron temperature characterizes an essembly, the emitting ions belong to.

2. *Regularities*

Existing experimental and theoretical data of Stark HWHM were taken: from Ref. 4 and Ref. 5 for PII spectral lines (603.40, 542.59, 529.61, 525.35 and 442.07 nm), from Ref. 6 for PIII (423.04 and 335.59 nm) and for PIV (335.53 and 424.96 nm) spectral lines, from Ref. 7 for SII (416.27, 402.88, 426.78, 389.23, 361.69 and 403.28 nm) spectral lines and from Ref. 8 and Ref. 9 for SIII (285.60, 271.89 and 295.02 nm) spectral lines.

The best fit of the data according to Eq. (1), is of the form:

$$w_{4s-4p} = 2.39 \times 10^{14}\, z^2\, T^{-1/2}\, I^{-1.65}\ \text{(rad/s)} \tag{2}$$

$$w_{4p-4d} = 1.81 \times 10^{14}\, z^2\, T^{-1/2}\, I^{-1.73}\ \text{(ra/d)} \tag{3}$$

for the phosphorus and sulfur with the correlation factors 0.98 and 0.95, respectively.

The energy level values for all emitters were taken from Ref. 10.

Graphic presentation of the reduced Stark HWHM ($w\, T^{1/2}/z^2$) values versus the inverse upper-level ionization potential are given in the Fig. 1 and Fig. 2 in log-log scale for the phosphorus and sulfur, respectively. It should be pointed out that value of reduced Stark HWHM for 394.35 nm PII spectral line is in a way out of the trend due to fact that it belongs to 4s-4p transition with the electron core in an excited state (see Ref. 11).

In Fig. 3 we present simultaneously dependence of reduced Stark HWHM on the inverse value of upper-level ionization potentials for isonuclear sequence of phosphorus and complete sodium-like isoelectronic sequence (see Fig. 2b in Ref. 1) for transitions of 4s-4p type. One concludes that the dependence following from Eq. (1) satisfies also an isonuclear and isoelectronic sequences.

3. *Predictions*

The established trends given by Eq. (2) and Eq. (3) enables to estimate the Stark HWHM values for lines from PV and SVI spectra. By using this equation one can predict Stark HWHM for spectral lines belonging to 4s-4p transitions of PV and 4p-4d of SVI. The predicted Stark HWHM values for PV 317.52 nm and SVI 199.25 nm spectral lines were 0.007 nm and 0.017 nm at 40 000 K electron temperature and $N = 1 \times 10^{23}\ \mathrm{m}^{-3}$ electron density with an estimated errors of $\pm 20\%$ and $\pm 27\%$, respectively.

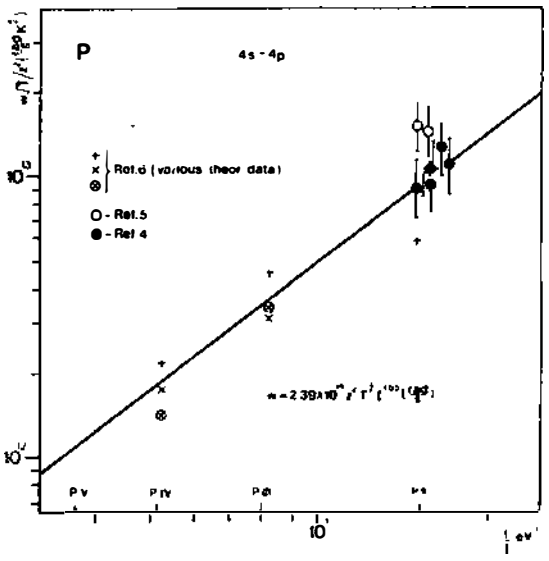

Fig. 1. Reduced Stark HWHM ($w\ T^{1/2}/z^2$) versus the inverse value of the upper-level ionization potential for 4s-4p transition of phosphorus isonuclear sequence at $N = 1 \times 10^{23}\ \mathrm{m}^{-3}$ electron density: ●, Ref. 4; ○, Ref. 5; +, ⊗, ×, Ref. 6; —, The best fit.

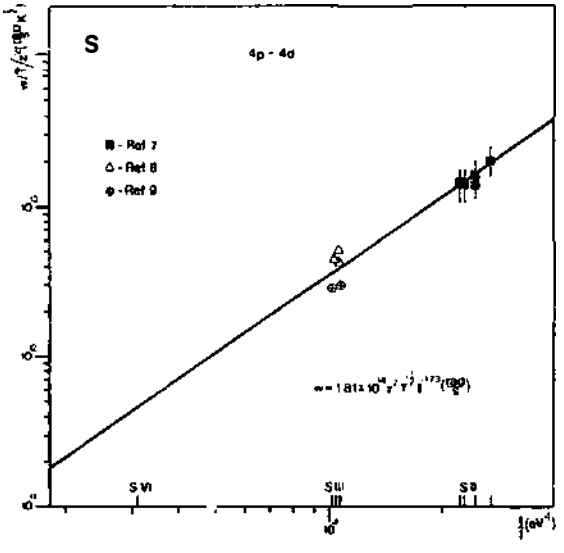

Fig. 2. Reduced Stark HWHM ($w\ T^{1/2}/z^2$) versus the inverse value of the upper-level ionization potential for 4p-4d transition of sulfur isonuclear sequence at $N = 1 \times 10^{23}\ \mathrm{m}^{-3}$ electron density: ■ Ref. 7; △, Ref. 8 and ⊕, Ref. 9. —, The best fit.

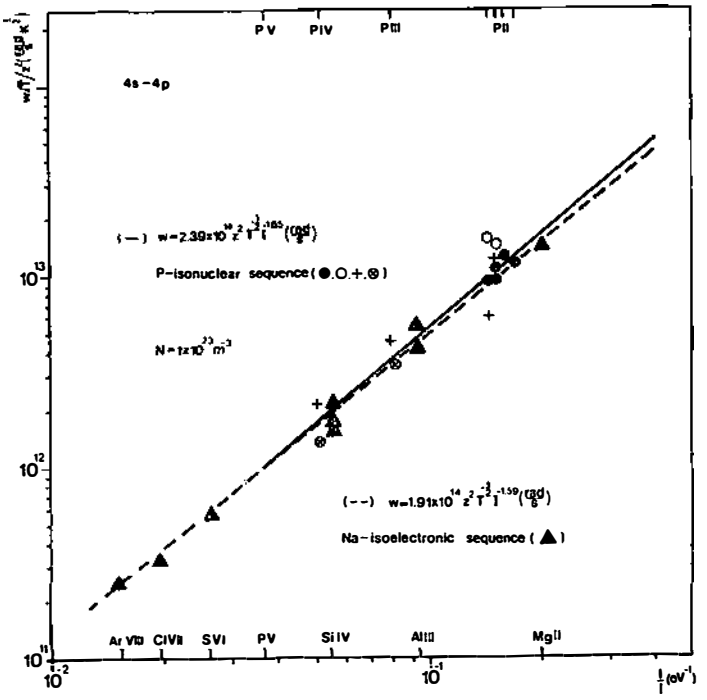

Fig. 3. Reduced Stark HWHM ($w\ T^{1/2}/z^2$) versus the inverse value of the upper-level ionization potential for 4s-4p transition of sodium-like isoelectronic (— — —) and phosphorus isonuclear (—) sequences. ▲, Ref. 1; ●, Ref. 4; ○, Ref. 5; +, ×, ⊗, Ref. 6.

We would like to emphasise that the predicted value for PV spectral line on the basis of Eq. (2) is in a very good agreement with the value previously estimated on the basis of Eq. (4) from Ref. 1. This follows also from Fig. 3 in which the trends of reduced Stark HWHM ($w\ T^{1/2}/z^2$) values of phosphorus isonuclear and sodium-like isoelectronic sequences intercept at the point of PV where one has identical electron configuration ($1s^2\ 2s^2\ 2p^6\ 3s$) similar to the neutral atom of sodium.

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PRAVILNOST ŠTARKOVOG ŠIRENJA U IZONUKLEARNIM GRUPAMA FOSFORA I SUMPORA

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Ukazano je na postojanje zavisnosti Štarkove širine spektralnih linija od jonizacionog potencijala gornjeg energijskog nivoa prelaza i efektivnog naelektrisanja ostatka omotača za izonuklearne sekvence fosfora i sumpora u slučajevima 4s-4p i 4p-4d prelaza, respektivno. Koristeći se utvrđenim zavisnostima predviđene su Štarkove širine spektralnih linija iz spektra PV i SVI koje do sada nisu merene ili računate.