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Stark broadening of spectral lines of multicharged ions of astrophysical interest. XIV. Be III and B III*

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Abstract. — Using a semiclassical approach, we have calculated electron-, proton-, and ionized helium-impact line widths and shifts for 12 Be III and 27 B III multiplets. The obtained results have been compared with available experimental and theoretical data.

Key words: lines: profiles-atomic and molecular data

1. Introduction

Line profiles study of light element ions in different ionization stages is of astrophysical interest, since such lines are present in stellar atmospheres. For studies as e.g. numerical modelling of stellar plasma or abundance determinations, data on Be III and B III lines may be of interest. The Be III Stark broadening parameters are additionally interesting, since the surface content (abundance) of Be, involves problems correlated with nucleogenesis, mixing between the atmospheres and the interior, and stellar structure and evolution (Boesgaard 1988). Line profiles of Be and B in various ionization stages, are of interest for opacity calculations as well (Seaton 1988). Moreover, Stark broadening of Be III and B III lines are of interest for the investigation and diagnostic of laboratory and laser-produced plasma, as well as for the research of regularities and systematic trends. For example Fraenkel et al. (1968) investigated high energy satellites in the vacuum UV Be III spectrum, while Malvezi et al. (1975) reported electron densities up to 10^{21} cm^{-3} in a laser produced Be plasma. Rosznayi (1977) studied theoretically, Stark broadening of Be III lines for a high density plasma with $kT = 21$ eV, and atom density $10^{19} - 10^{22}$ cm^{-3}. In this study, the inelastic contribution has been approximated by a formula for electron - impact ionization, and elastic contribution has been calculated first for $1s^2-2p$ transition, and subsequently has been generalized. In Dimitrijević & Konjević (1981) and Dimitrijević (1988ab) Stark widths of Be III and B III lines have been calculated within the semiempirical method (Griem 1968), the modified semiempirical method (Dimitrijević & Konjević 1980), the simplified semiclassical method (Griem 1974, Eq. (526)) and its modification (Dimitrijević & Konjević 1980). Moreover, Stark widths and shifts for B III 2s − 2p, 2s − 3p, 2p − 3s, 2p − 3d, 3s − 3p and 3p − 3d have been calculated by Seaton (1988) within the quantum mechanical strong coupling method. Stark broadening parameters of B III have been investigated experimentaly as well in two contributions. In Djeniže et al. (1992), the results concerning B III $4f^2F^\circ - 5g^2G$ 4497.6 Å line, measured in a pulsed linear arc plasma, have been reported. Srećković et al. (1993) measured in a linear, low - pressure pulsed arc operating in O_2, the Stark widths of two lines within the B III $2s^2S - 2p^2P^\circ$ multiplet.

The Be III and B III Stark broadening data are of interest and for studies of regularities and systematic trends within isoelectronic sequences. In previous articles Stark broadening data for Be II (Dimitrijević & Sahal-Bréchot 1992a), C IV (Dimitrijević et al. 1991), N V (Dimitrijević & Sahal-Bréchot 1992b), O VI (Dimitrijević & Sahal-Bréchot 1992c), F VII (Dimitrijević & Sahal-Bréchot 1993), Ne VIII and Na IX (Dimitrijević & Sahal-Bréchot 1994a) and Al XI and Si XII (Dimitrijević & Sahal-Bréchot 1994b) all belonging to the lithium isoelectronic sequence have been calculated. Consequently, the results for B III will complete this set of data. Moreover,

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*Table 1 is only available in electronic form at the CDS via anonymous ftp 130.79.128.5

Stark broadening data for Li II (Dimitrijević & Sahal-Bréchot 1996a) and C V (Dimitrijević & Sahal-Bréchot 1996b), belonging to the helium isoelectronic sequence as Be III, have been published also. Results of the investigations of regularities and systematic trends are of interest for acquisition of new data by interpolation and for critical evaluation of existing experimental and theoretical data.

This paper is the fourteenth of a series devoted to the calculation of Stark broadening parameters of spectral lines of multicharged ions (see Dimitrijević & Sahal-Bréchot 1995 and references therein and Dimitrijević & Sahal-Bréchot 1996b). By using the semiclassical-perturbation formalism (Sahal-Bréchot 1969ab), we have calculated electron-, proton-, and ionized helium-impact line widths and shifts for 12 Be III and 27 B III multiplets, in order to continue our research of multiply charged ion line Stark broadening parameters. A summary of the formalism is given in Dimitrijević et al. (1991) and Dimitrijević & Sahal-Bréchot (1996a).

2. Results and discussion

Energy levels for Be III and B III lines have been taken from Bashkin & Stoner (1975). Oscillator strengths have been calculated by using the method of Bates & Damgaard (1949) and the tables of Oertel & Shomo (1968). For higher levels, the method described by Van Regemorter et al. (1979) has been used. In addition to electron-impact full halfwidths and shifts, Stark-broadening parameters due to proton-, and ionized helium - impacts have been calculated.

Our results for 12 Be III and 27 B III multiplets are shown in Table 1 (accessible only in electronic form), for perturber densities $10^{17} - 10^{21}\mathrm{cm}^{-3}$ and temperatures $T = 10.000 - 300.000$ K. We also specify a parameter c (Dimitrijević & Sahal-Bréchot 1984), which gives an estimate for the maximum perturber density for which the line may be treated as isolated when it is divided by the corresponding electron-impact full width at half maximum. For each value given in Table 1, the collision volume (V) multiplied by the perturber density (N) is much less than one and the impact approximation is valid (Sahal-Bréchot 1969a,b). Values for $NV > 0.5$ are not given and values for $0.1 < N \leq 0.5$ are denoted by an asterisk. When the impact approximation is not valid, the ion broadening contribution may be estimated by using quasistatic estimations (Sahal-Bréchot 1991; Griem 1974). The accuracy of the results obtained decreases when broadening by ion interactions becomes important.

The unique experimental result convenient for comparison, are the Stark widths of two lines within the B III $2s^2S - 2p^2P^\circ$ multiplet, measured by Srećković et al. (1993) in a linear, low - pressure pulsed arc operating in O_2. They found a large disagreement between their Stark widths and results (Dimitrijević & Konjević 1981), obtained within the modified semiempirical approach (Dimitrijević & Konjević 1980). For B III 2065.77 Å line, they found that the ratio of measured to theoretical Stark width is 7.8 and for 2067.23 Å line 6.7 for the temperature of 48000 K at an electron density of 2.55 $10^{17}\mathrm{cm}^{-3}$. Corresponding ratios with our results with ionized oxygen-impact broadening included, are 3.9 and 3.5 respectively, which is better but not satisfying.

We may compare available theoretical results for B III $2s^2S - 2p^2P^\circ$ multiplet for the temperature of 160000 K at an electron density of 1 $10^{17}\mathrm{cm}^{-3}$. Our full width at half maximum $W = 0.0103$ Å, and the agreement is closest with calculations of Dimitrijević & Konjević (1981) by using the symplified semiclassical approach of Griem (1974, Eq. (526)), which obtained $W = 0.00892$ Å. Within the modified semiempirical approach (Dimitrijević & Konjević 1980), same authors obtained $W = 0.00449$ Å, which is two times smaller. Within the close coupling quantum mechanical approach Seaton (1988) obtained $W = 0.00602$ Å, which is also in disagreement with experiment and our calculations. In order to clarify the situation, particularly since B III $2s^2S - 2p^2P^\circ$ multiplet is important for the consideration of Stark broadening parameters within the lithium isoelectronic sequence, we recomend a new experimental determination of Stark broadening parameters particularly for this multiplet.[1]

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[1] The very recent experimental results for this resonance multiplet (Glenzer S. & Kunze H.-J., 1996, Phys. Rev. A 53, 1225) agree with our semi-classical results within 10 percent.

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