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Stark broadening of spectral lines of multicharged ions of astrophysical interest

XVIII. Si XI and Si XIII spectral lines*

M.S. Dimitrijević[1] and S. Sahal-Bréchot[2]

[1] Astronomical Observatory, Volgina 7, 11050 Belgrade, Yugoslavia
[2] Laboratoire "Astrophysique, Atomes et Molécules", Département Atomes et Molécules en Astrophysique, Unité associée au CNRS 812, Observatoire de Paris-Meudon, 92190 Meudon, France

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Abstract. Using a semiclassical perturbation approach, we have calculated electron−, proton−, and He III−impact line widths and shifts for 4 Si XI multiplets for perturber densities 10^{18}− 10^{23} cm^{-3} and temperatures $T = 500\,000 - 4\,000\,000$ K, and for 61 Si XIII multiplets for perturber densities 10^{16}− 10^{23} cm^{-3} and temperatures $T = 500\,000 - 6\,000\,000$ K. For lower perturber densities, obtained results are linear with perturber density.

Key words: lines: profile — atomic data — plasmas

1. Introduction

Silicon is present in stellar atmospheres and important for the consideration of physical processes in stellar plasmas. Data on its spectral lines, as well as on spectral lines from its various ionization stages are consequently of particular astrophysical interest. Stark broadening parameters of Si XI and Si XIII spectral lines are important not only for astrophysics, as e.g. for the consideration of radiative transfer through subphotospheric layers, but also for the fusion plasmas and laser produced plasmas research. The development of soft X-ray lasers, where Stark broadening data are needed to calculate gain values, model radiation trapping and to consider photoresonant pumping schemes (see e.g. Griem & Moreno 1990; Fill & Schöning 1994), provided an additional interest for such results.

This paper is the eighteenth of a series devoted to the investigation of Stark broadening parameters of spectral lines of multicharged ions (see Dimitrijević & Sahal-Bréchot 1995 and references therein, as well as Dimitrijević & Sahal-Bréchot 1996a,b, 1997a,b). As a continuation of our programme (see e.g. Dimitrijević 1996) to obtain as large as possible set of reliable Stark broadening data needed for the consideration and modeling of astrophysical and laboratory plasmas as well as laser produced and fusion plasmas, and plasmas in various plasma devices in technology, we have calculated within the semiclassical-perturbation formalism (Sahal-Bréchot 1969a,b), electron-, proton-, and He III-impact line widths and shifts for 4 Si XI and 61 Si XIII multiplets. These data, together with Stark broadening data for Si IV (Dimitrijević et al. 1991b,c) and Si XII (Dimitrijević & Sahal-Bréchot 1993, 1994) will complete availlable results of large-scale Stark broadening calculations for multicharged silicon ion lines.

2. Results and discussion

The semiclassical perturbation formalism applied here as well as the corresponding computer code (Sahal-Bréchot 1969a,b), have been updated and improved several times (Sahal-Bréchot 1974; Fleurier et al. 1977; Dimitrijević & Sahal-Bréchot 1984; Dimitrijević et al. 1991a; Dimitrijević & Sahal-Bréchot 1996b). The semiclassical perturbation method used here, has been reviewed e.g. in Dimitrijević & Sahal-Bréchot (1996c) and Dimitrijević (1996). Atomic energy levels of Si XI and Si XIII needed for calculations, have been taken from Martin & Zalubas (1983). Oscillator strengths have been calculated within the Coulomb approximation (Bates & Damgaard 1949, and the tables of Oertel & Shomo 1968). For higher levels, the method of Van Regemorter et al. (1979) has been used.

Our results for electron−, proton−, and He III−impact line widths and shifts for 4 Si XI and 61 Si XIII multiplets are shown in Table 1 (accessible only in electronic form), for perturber densities $10^{18} - 10^{23}$ cm^{-3} and

Send offprint requests to: M.S. Dimitrijević
* Table 1 is only available in electronic form: The material published electronically can be accessed: by ftp at cdsarc.u-strasbg.fr or 130.79.128.5 or on WWW at: http//cdsweb.u-strasbg.fr/Abstract.html

$10^{16} - 10^{23}$ cm^{-3} respectively. The temperature range is $T = 500\,000 - 4\,000\,000$ K for Si XI and $500\,000 - 6\,000\,000$ K for Si XIII. For Si XIII, the complete set of data is given for the perturber density of 10^{19} cm^{-3}. For lower densities, only data needed for better interpolation are given. Stark broadening parameters for densities lover than tabulated, or for transitions not tabulated for perturber densities lower than 10^{19} cm^{-3} for Si XIII, are linear with perturber density. We present in the Table 1 as well, 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 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 $0.1 < NV \leq 0.5$ are denoted by an asterisk. When the impact approximation is not valid, the ion broadening contribution may be estimated by using quasistatic approach (Sahal-Bréchot 1991 or Griem 1974). In the region between where neither of these two approximations is valid, a unified type theory should be used. For example in Barnard et al. (1974), a simple analytical formulas for such a case are given. The accuracy of the results obtained decreases when broadening by ion interactions becomes important.

Presented results may be of interest for the modelling and research of subphotospheric layers and the considerations of radiation transfer in stellar, fusion and laser produced plasmas, as well as for the investigation and modeling of soft X-ray lasers. They may be of significance as well for further development and rafinement of the Stark broadening theory for multicharged ion lineshapes, as well as for the investigation of regularities and systematic trends of Stark broadening parameters along isoelectronic sequences. The corresponding reliable experimental data will be certainly of particular interest.

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