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# Stark broadening of spectral lines of multicharged ions of astrophysical interest

## XIX. Na X spectral lines⋆

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**Abstract.** Using a semiclassical perturbation approach, we have calculated electron−, proton−, and He III−impact line widths and shifts for 57 Na X multiplets for perturber densities $10^{17}-10^{24}$ cm$^{-3}$ and temperatures $T = 200\,000 - 5\,000\,000$ K. For lower perturber densities, the Stark broadening parameters are proportional to the perturber density.

**Key words:** lines: profile-atomic data

### 1. Introduction

Data on the sodium spectral lines, as well as on spectral lines from its various ionization stages 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. An additional interest for such results provides 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 nineteenth of a series devoted to the research 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, 1997, 1998a-c). In accordance with our project (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, laboratory, laser-produced, fusion plasmas, and plasmas in various devices, we have calculated within the semiclassical-perturbation formalism (Sahal–Bréchot 1969a,b), electron-, proton-, and He III-impact line widths and shifts for 57 Na X multiplets.

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⋆ 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

### 2. Results and discussion

Calculations have been performed within the frame of the semiclassical perturbation formalism, which, 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. 1991; Dimitrijević & Sahal–Bréchot 1996b). Short reviews of the semiclassical perturbation method used here, have been published several times as e.g. in Dimitrijević & Sahal–Bréchot (1996c) and Dimitrijević (1996). The atomic energy levels of Na X needed for calculations, have been taken from Martin & Zalubas (1981). The 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 II−impact line widths and shifts for 57 Na X multiplets are shown in Table 1 (accessible only in electronic form), for perturber densities $10^{17} - 10^{24}$ cm$^{-3}$ and temperatures $T = 200\,000 - 5\,000\,000$ K. The complete set of data is given for the perturber density of $10^{19}$ cm$^{-3}$, while for lower densities, only data needed for better interpolation are given. Stark broadening parameters for densities lower

than tabulated, or for transitions not tabulated for perturber densities lower than $10^{19}$ cm$^{-3}$, are proportional to the perturber density. We present in 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 the 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 formula for such a case is given. The accuracy of the results obtained decreases when broadening by ion interactions becomes important.

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