ASTRONOMY & ASTROPHYSICS
SUPPLEMENT SERIES

Astron. Astrophys. Suppl. Ser. **128,** 359-360 (1998)

Stark broadening of spectral lines of multicharged ions of astrophysical interest

XVII. Ca IX and Ca X 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 No. 812, Observatoire de Paris–Meudon, 92190 Meudon, France

Received July 2; accepted July 10, 1997

Abstract. Using a semiclassical approach, we have calculated electron−, proton−, and He III−impact line widths and shifts for 4 Ca IX multiplets for perturber densities $10^{18} - 10^{22}$ cm^{-3} and 48 Ca X multiplets for perturber densities $10^{17} - 10^{22}$ cm^{-3}. In both cases the temperature range is $T = 200000 - 5000000$ K. For lower perturber densities, obtained results are linear with perturber density.

Key words: lines: profile-atomic data — plasmas

1. Introduction

Stark widths and shifts of Ca IX and Ca X lines are obviously of interest for the laboratory plasmas, fusion plasmas and laser produced plasmas research as well as for testing and developing of the Stark-broadening theory for multicharged ion lines. Due to the abundance of calcium, such data are of interest for the consideration of solar and stellar plasma, particularly for subphotospheric layers, as well as for radiative transfer considerations. They are also of importance for the investigations of regularities and systematic trends particularly along isoelectronic sequences.

This paper is the seventeenth 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, 1997). As the continuation of our work with the objective to provide to astrophysicists and plasma physicists Stark broadening parameters needed for research on astrophysical and laboratory plasmas, we have calculated within the semiclassical-perturbation formalism (Sahal-Bréchot 1969a,b), electron-, proton-, and He III-impact line widths and shifts for 4 Ca IX and 48 Ca X multiplets.

2. Results and discussion

The semiclassical perturbation formalism and the relevant computer code (Sahal-Bréchot 1969a,b) used here, have been modernized, updated and optimized several times (Sahal-Bréchot 1974; Fleurier et al. 1977; Dimitrijević & Sahal-Bréchot 1984; Dimitrijević et al. 1991; Dimitrijević & Sahal-Bréchot 1996b). The used formalism has been reviewed e.g. in Dimitrijević & Sahal-Bréchot (1996c) and Dimitrijević (1996). The atomic energy levels of Ca IX and Ca X needed for calculations have been taken from Bashkin & Stoner (1975). 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 III−impact line widths and shifts for 4 Ca IX multiplets for perturber densities $10^{18} - 10^{22}$ cm^{-3} and 48 Ca X multiplets for perturber densities $10^{17} - 10^{22}$ cm^{-3}, for the electron temperatures $T = 200000-5000000$ K, are shown in Table 1 (accessible only in electronic form). The complete set of data is given for the perturber density of 10^{19} cm^{-3} for Ca IX and 10^{17} cm^{-3} for Ca X. For lower tabulated perturber densities, only data for higher transitions, needed for better interpolation are given. Stark broadening parameters for densities lower than tabulated, are linear with perturber density. We also specify a parameter c (Dimitrijević & Sahal-Bréchot 1984), which gives an estimate for the maximum perturber density for which the

---

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

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), simple analytical formulas for such a case are given. The accuracy of the results obtained decreases when broadening by ion interactions becomes important.

We hope the presented results will be useful for the modelling and research of subphotospheric layers and that considerations of radiation transfer, as well as for laboratory plasma investigations. Besides the theoretical data, reliable experimental data will be of significance for further development and refinement 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.

Acknowledgements. This work is a part of the project "Astrometrical, Astrodynamical and Astrophysical Investigations", supported by Ministry of Science and Technology of Serbia.

References

Barnard A.J., Cooper J., Smith E.W., 1974, J. Quant. Spectrosc. Radiat. Transfer 14, 1025

Bashkin S., Stoner J.O. Jr., 1975, Atomic Energy Levels and Grotrian Diagrams, Vol. 1, North Holland, Amsterdam

Bates D.R., Damgaard A., 1949, Trans. Roy. Soc. London, Ser. A 242, 101

Dimitrijević M.S., 1996, Zh. Prikl. Spektrosk. 63, 810

Dimitrijević M.S., Sahal-Bréchot S., 1984, J. Quant. Spectrosc. Radiat. Transfer 31, 301

Dimitrijević M.S., Sahal-Bréchot S., Bommier V., 1991, A&AS 89, 581

Dimitrijević M.S., Sahal-Bréchot S., 1995, A&AS 109, 551

Dimitrijević M.S., Sahal−Bréchot S., 1996a, A&AS 115, 351

Dimitrijević M.S., Sahal-Bréchot S., 1996b, A&AS 119, 369

Dimitrijević M.S., Sahal-Bréchot S., 1996c, Phys. Scripta 54, 50

Dimitrijević M.S., Sahal-Bréchot S., 1997, A&AS 122, 533

Fleurier C., Sahal-Bréchot S., Chapelle J., 1977, J. Quant. Spectrosc. Radiat. Transfer 17, 595

Griem H.R., 1974, Spectral Line Broadening by Plasmas. Academic Press, New York

Oertel G.K., Shomo L.P., 1968, ApJS 16, 175

Sahal-Bréchot S., 1969a, A&A 1, 91

Sahal-Bréchot S., 1969b, A&A 2, 322

Sahal-Bréchot S., 1974, A&A 35, 321

Sahal-Bréchot S., 1991, A&A 245, 322

Van Regemorter H., Hoang Binh Dy, Prud'homme M., 1979, J. Phys. B 12, 1073