Publ. Astron. Obs. Belgrade No. 65 (1999), 55 – 58

ON THE STARK BROADENING OF NEUTRAL ZINC SPECTRAL LINES

MILAN S. DIMITRIJEVIĆ[1] and SYLVIE SAHAL-BRÉCHOT[2]
[1]*Astronomical Observatory, Volgina 7, 11160 Belgrade-74, Yugoslavia*
E-mail mdimitrijevic@aob.aob.bg.ac.yu

[2]*Observatoire de Paris, 92195 Meudon Cedex, France*
E-mail sahal@obspm.fr

Abstract. Using the semiclassical perturbation approach, we have calculated electron–, proton– and He II–impact line widths and shifts for 32 Zn I multiplets for perturber densities 10^{13}– 10^{19} cm^{-3} and temperatures T = 2,500 – 50,000 K. Obtained results have been compared with the existing theoretical and experimental data.

1. INTRODUCTION

The Zn I spectral lines have been observed in stellar (see *e.g.* Sneden *et al.* 1991) and solar (see *e.g.* Biémont and Godefroid 1980, Grevesse 1984) spectra, so that corresponding Stark broadening parameters are of interest for a number of astrophysical problems, as well as for laboratory plasma diagnostics.

Within the semiclassical-perturbation formalism (Sahal–Bréchot 1969ab, see also Dimitrijević and Sahal– Bréchot 1995, Dimitrijević and Sahal - Bréchot 1984), we have calculated electron-, proton-, and ionized helium-impact line widths and shifts for 32 Zn I multiplets, as the continuation of our project to create a large Stark broadening data set for astrophysical and laboratory plasma research purposes.

In this contribution, the comparison of our results with existing experimental (Kusch and Oberschelp 1987, Fishman *et al.* 1979, Rathore *et al.* 1985) and theoretical (Dimitrijević and Konjević 1983, Lakićević 1983), and Rathore *et al.* 1985) data is presented.

2. RESULTS AND DISCUSSION

A review of the used semiclassical perturbation formalism is given e. g. in Dimitrijević and Sahal-Bréchot 1984. Atomic energy levels needed for calculations are taken from Sugar and Musgrove (1995).

Our results for 32 neutral zinc spectral lines as a function of the perturber density and temperature will be published in Dimitrijević and Sahal-Bréchot (1999).

Table 1
Comparison between experimental and theoretical Stark full widths at half maximum for Zn I triplets. Experimental data: a-Kusch and Oberschelp (1967); b-Fishman, Semin and Desyatnik (1979); c-Rathore *et al.* (1985). Theoretical data: W1 - present results; W2 - Dimitrijević and Konjević (1983).

Transition	λ (Å)	T(K)	$N/10^{+17}$ (cm^{-3}	Wm (Å)	Wm/W1	Wm/W2	Ref.
4p-5s	4810.53	11000	1.0	1.65	3.56	3.25	a
		11000	4.5	0.92	0.43	0.40	b
		13700	1.0	1.00	2.24	2.02	c
		14800	1.0	0.90	1.99	1.79	c
		16300	1.0	0.52	1.13	1.01	c
		18100	1.0	0.40	0.86	0.76	c
	4722.16	11000	1.0	1.57	3.39	3.09	a
		11000	4.5	1.20	0.58	0.52	b
		13700	1.0	1.00	2.24	2.02	c
		14800	1.0	0.64	1.42	1.27	c
		16300	1.0	0.42	0.92	0.82	c
		18100	1.0	0.36	0.77	0.69	c
	4680.14	11000	1.0	0.84	1.81	1.66	a
		11000	4.5	1.29	0.62	0.56	b
4p-6s	3072.06	11000	1.0	0.70	0.76	0.65	a
	3035.78	11000	1.0	0.61	0.66	0.57	a
	3018.36	11000	1.0	0.56	0.61	0.52	a
4p-4d	3345.02	11000	1.0	1.74	2.87	2.66	a
	3302.58	11000	1.0	1.40	2.31	2.14	a
	3282.33	11000	1.0	0.91	1.50	1.39	a
4p-5d	2800.9	11000	1.0	1.96	0.53	0.39	a
	2770.9	11000	1.0	2.49	0.67	0.50	a
	2756.45	11000	1.0	1.27	0.34	0.25	a

There are three experimental studies with data of Stark widths and shifts of neutral zinc lines (Kusch and Oberschelp 1987, Fishman *et al.* 1979, Rathore *et al.* 1985). Theoretical data suitable for comparison with our results are published in Dimitrijević and Konjević (1983), Lakićević (1983), and Rathore *et al.* (1985).

In Tables 1 and 2, experimental (Kusch and Oberschelp 1987, Fishman *et al.* 1979, Rathore *et al.* 1985) Stark widths (Table 1) and shifts (Table 2) are compared with present resuts and with semiclassical Stark broadening parameters from Dimitrijević and Konjević (1983). In experiments of Kusch and Oberschelp (1987) and Fishman *et al.* (1979), ion perturbers are protons, while in the experiment of Rathore *et al.* (1985) the carrier gas was neon. In order to make an adequate comparison, Stark broadening of neutral zinc by impacts with neon ions is calculated and included in W1 and d1 (present calculation of Stark widths - W1 and shifts - d1) values in Tables 1 and 2. For $4p^3P^o$ - $5d^3D$ multiplet, the impact approximation is not valid for proton perturbers and the quasistatic ion broadening contribution is calculated according to Griem (1974). One can see in Table 1 that the agreement of all experiments with both calculations is very poor. The ratio of experimental widths of Kusch and Oberschelp (1967) and the theoretical ones vary from 0.25 up to 3.56. The experimental widths of Fishman *et al.* (1979) are two times larger than theoretically obtained within both approaches. The temperature trend of the experimental widths of Rathore *et al.* (1985) is in such disagreement with both theoretical approaches that the ratio of measured and calculated Stark widths vary *e.g.* for 4722.16 Å line from 2.24 for $T =$ 13,700 K up to 0.77 for $T =$ 18100 K for present results, and from 2.02 up to 0.69 for theoretical values of Dimitrijević and Konjević (1983). For the shift, the ratio of experimental values of Rathore *et al.* (1985) and the results of present calculations vary from 1.24 up to 0.46 for the same spectral line.

Table 2

Comparison between experimental and theoretical Stark shifts for Zn I triplets. Experimental data: b-Fishman, Semin and Desyatnik (1979); c-Rathore *et al.* (1985). Theoretical data: d1 - present results; d2 - Dimitrijević and Konjević (1983).

Transition	λ (Å)	T(K)	N/10^{+17} (cm^{-3}	dm (Å)	dm/d1	dm/d2	Ref.
4p-5s	4810.53	13700	1.0	0.44	1.24	1.58	c
		14800	1.0	0.35	0.97	1.24	c
		16300	1.0	0.25	0.66	0.87	c
		18100	1.0	0.21	0.55	0.72	c
	4722.16	11000	4.5	0.78	0.49	0.69	b
		13700	1.0	0.44	1.24	1.58	c
		14800	1.0	0.35	0.97	1.24	c
		16300	1.0	0.256	0.67	0.89	c
		18100	1.0	0.175	0.46	0.60	c

Experimental results of Fishman *et al.* (1979) and Rathore *et al.* (1985) are not selected for critical compilations of reliable Stark broadening experimental data (Konjević and Roberts 1976, Konjević *et al.* 1984, Konjević and Wiese 1990) and results of Kusch and Oberschelp (1967) are selected but with the atribution of the lowest accuracy (Konjević and Roberts 1976). In the analysis of the Kusch and Oberschelp (1967) experiment, Konjević and Roberts (1976) have found large variations of Stark widths within multiplets, and supposed that this may be caused by improper treatment of self-absorption. Moreover, Dimitrijević and Konjević (1983) have shown on the basis of the analysis of Stark width systematic trends within spectral series, that experimental results of Kusch and Oberschelp (1967) are in disagreement with such trends.

Lakićević (1983) estimated on the basis of regularities and systematic trends, Stark width and shift for Zn I $4s^2\ ^1S$ -$4p^1P^o$ transition for an electron temperature (T) of 20,000 K and an electron density of $10^{17}cm^{-3}$. He obtained the value of 0.066Å for full width at half maximum, and 0.035Å for the shift. We obtain the value of 0.039Å for the width and 0.029Å for the shift. On the basis of regularities and systematic trends as well, Stark widths and shifts for Zn I $4p^3P^o$ - $5s^3S$ transition for electron temperatures of 10,000 and 20,000 K and an electron density of $10^{17}cm^{-3}$, have been estimated by Rathore *et al.* (1985). They obtained the value of 0.60Å for full width at half maximum, and 0.36Å for the shift, for T = 10,000 K, and our results are 0.371Å for the width and 0.295Å for the shift. For T = 20,000 K, they obtained 0.61Å for the width and 0.30Å for the shift, and we 0.408Å for the width and 0.336Å for the shift. Particularly for the shift, this is in both cases an encouraging agreement of simple estimates, with our semiclassical perturbation results.

Semiclassical perturbation method used here and the semiclassical method described in Griem (1974) and used in Dimitrijević and Konjević (1983) have been compared with critically selected experimental data for 13 He I multiplets (Dimitrijević and Sahal-Bréchot 1985) and it was found that the agreement between experimental data and both semiclassical methods is within the limits of 20 percent, which is the predicted accuracy of the semiclassical method (Griem 1974). Differences between our results and results for Zn I from Dimitrijević and Konjević (1983) are larger and increase with temperature, particularly for the shift. One must take into account, that more recent and more complete energy levels have been used in our calculations.

The obtained Stark broadening data are of interest for a number of problems in astrophysics and plasma physics as *e.g.* abundance determinations, stellar spectra analysis and laboratory plasma diagnostics. Reliable experimental determinations of neutral zinc Stark broadening parameters will be of interest for checking and development of Stark broadening theory.

References

Biémont, E. and Godefroid, M.: 1980, *Astron. Astrophys.* **84**, 361.
Dimitrijević, M. S. and Konjević, N.: 1983, *J. Quant. Spectrosc. Radiat. Transfer* **30**, 45.
Dimitrijević, M.S. and Sahal-Bréchot, S.: 1984, *JQSRT* **31**, 301.
Dimitrijević, M.S. and Sahal-Bréchot, S.: 1999, *Astron. Astrophys. Suppl. Series* submitted.
Dimitrijević, M. S. and Sahal–Bréchot, S.: 1985, *Phys. Rev. A* **31**, 316.
Dimitrijević, M.S. and Sahal–Bréchot, S.: 1995, *Phys. Scripta* **52**, 42.
Fishman, I.S., Semin, P.S. and Desyatnik, G.A.: 1979, *Opt. Spectrosc.* **47**, 245.
Grevesse, N.: 1984, *Phys. Scripta* **T8**, 49.
Griem, H.R.: 1974, Spectral Line Broadening by Plasmas, Academic Press, New York.
Konjević, N., Dimitrijević, M.S., Wiese, W.L.: 1984, *J. Phys. Chem. Ref. Data* **13**, 619.
Konjević, N., Roberts, J.R.: 1976, *J. Phys. Chem. Ref. Data* **5**, 209.
Konjević, N., Wiese, W.L.: 1990, *J. Phys. Chem. Ref. Data* **19**, 1307.
Kusch, H.J. and Oberschelp, E.: 1967, *Z. Astrophys.* **67**, 77.
Lakićević, I.S., 1983: *Astron. Astrophys.* **127**, 37.
Rathore, B.A., Purić, J. and Ćuk, M., Lakićević, I.S.: 1985, *Sing. J. Phys.* **2**, 105.
Sahal-Bréchot, S.: 1969a, *Astron. Astrophys.* **1**, 91.
Sahal-Bréchot, S.: 1969b, *Astron. Astrophys.* **2**, 322.
Sneden, C., Gratton, R.G. and Crocker, D.A.: 1991, *Astron. Astrophys.* **246**, 354.
Sugar, J. and Musgrove, A.: 1995, *J. Phys. Chem. Ref. Data* **24**, 1803.