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ON THE STARK BROADENING OF Ba I SPECTRAL LINES

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Abstract. Using a semiclassical approach, we have calculated electron-, proton-, and ionized helium- impact line widths and shifts for 14 Ba I multiplets. The results have been compared with existing theoretical estimates.

1. INTRODUCTION

Barium is important for investigation of nuclear reactions in stellar interiors, since it is one of thermonuclear s - processes product in stars and its overabundance is observed in CH subgiants, characterized by enhanced Sr and Ba lines, and in metal deficient barium stars, giants showing overabundance of s-processes elements (Šleivyté & Bartkevičius, 1995). Moreover, barium lines are observed in solar and stellar spectra (e.g. Komarov & Basak 1993, and Anders & Grevesse, 1989).

Barium lines are also of interest for the investigation of laboratory plasmas. Consequently, Aulehla & Herman (1958) have determined neutral barium Stark effect constants by investigating metallic lines broadened by an intermolecular field. Kato et al. (1984) investigated wavelength shifts of Ba I lines emitted by an inductively coupled plasma.

Theoretically, Ba I lines have been investigated by Grechikhin (1969), considering their applicability to plasma diagnostics, and by Davis (1972), for research of a laser - generated barium plasma. Lakićević (1983) estimated line widths and shifts for Ba I $6s^2{}^1S$ - $6p{}^1P^o$ multiplet for T = 20000 K, on the basis of the Stark broadening parameter dependence on the ionization potential from the lower level of the corresponding transition.

In order to continue our research of Stark broadening parameters needed for the investigation of astrophysical and laboratory plasmas and to provide the needed Stark broadening data, we have calculated within the semiclassical-perturbation formalism (Sahal–Bréchot, 1969ab) electron-, proton-, and ionized helium- impact line widths and shifts for 14 Ba I multiplets. A summary of the formalism is given in Dimitrijević & Sahal-Bréchot (1984). We note here that the inelastic collision contribution is included in the ion-impact line widths.

Table 1. This Table shows electron-, and proton- impact broadening parameters for Ba I for a perturber density of 10^{16} cm^{-3} and temperatures from 2,500 up to 50,000 K. Transitions and averaged wavelengths for the multiplet (in Å) are also given. If one divides c value with the linewidth value, we obtain an estimate for the maximum perturber density (in cm^{-3}) for which the line may be treated as isolated and tabulated data may be used. The asterisk identifies cases for which the collision volume multiplied by the perturber density (the condition for validity of the impact approximation) lies between 0.1 and 0.5.

PERTURBER DENSITY= 1xE+16cm-3					
PERTURBERS ARE:		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(Å)	SHIFT(Å)	WIDTH(Å)	SHIFT(Å)
6S - 6P	2500.	0.231E-01	0.402E-02	0.115E-01	0.108E-02
5537.0 Å	5000.	0.228E-01	0.433E-02	0.115E-01	0.123E-02
C= 0.20E+20	10000.	0.246E-01	0.397E-02	0.115E-01	0.139E-02
	20000.	0.301E-01	0.204E-02	0.115E-01	0.157E-02
	30000.	0.353E-01	0.104E-02	0.115E-01	0.168E-02
	50000.	0.432E-01	0.300E-03	0.116E-01	0.183E-02
6S - 7P	2500.	0.516E-01	-0.240E-01	*0.259E-01	-0.586E-02
3072.5 Å	5000.	0.560E-01	-0.281E-01	*0.266E-01	-0.699E-02
C= 0.22E+19	10000.	0.607E-01	-0.313E-01	0.270E-01	-0.813E-02
	20000.	0.658E-01	-0.317E-01	0.273E-01	-0.933E-02
	30000.	0.688E-01	-0.305E-01	0.275E-01	-0.101E-01
	50000.	0.725E-01	-0.276E-01	0.278E-01	-0.111E-01
7S - 7P	2500.	3.74	-1.98	*1.51	-0.482
23164.3 Å	5000.	4.30	-2.33	*1.57	-0.584
C= 0.12E+21	10000.	4.97	-2.72	1.61	-0.685
	20000.	5.60	-3.00	1.65	-0.790
	30000.	5.93	-3.01	1.68	-0.855
	50000.	6.27	-2.86	1.73	-0.940
6P - 7S	2500.	0.317	0.212	0.728E-01	0.536E-01
9833.0 Å	5000.	0.366	0.257	0.801E-01	0.637E-01
C= 0.42E+20	10000.	0.413	0.310	0.884E-01	0.739E-01
	20000.	0.449	0.312	0.979E-01	0.847E-01
	30000.	0.480	0.320	0.104	0.913E-01
	50000.	0.512	0.276	0.113	0.100
6P - 8S	2500.	1.09	0.700		
5268.5 Å	5000.	1.23	0.844		
C= 0.20E+19	10000.	1.34	0.881	*0.283	*0.219
	20000.	1.49	0.810	*0.318	*0.266
	30000.	1.64	0.692	*0.340	*0.294
	50000.	1.84	0.574	*0.371	*0.329

PERTURBER DENSITY= 1xE+16cm-3

PERTURBERS ARE: TRANSITION	T(K)	ELECTRONS WIDTH(Å)	SHIFT(Å)	PROTONS WIDTH(Å)	SHIFT(Å)
6P - 9S	2500.	1.66	-0.974		
4948.7 Å	5000.	1.78	-1.18		
C= 0.12E+19	10000.	1.85	-1.18		
	20000.	1.92	-1.03		
	30000.	2.05	-0.872		
	50000.	2.19	-0.701	*0.530	-0.461
7P - 8S	2500.	20.6	12.6		
22252.3 Å	5000.	23.6	15.3		
C= 0.36E+20	10000.	26.4	16.4		
	20000.	29.8	15.5	*5.91	*4.83
	30000.	32.5	13.8	*6.31	*5.34
	50000.	36.0	11.6	*6.85	*5.97
7P - 9S	2500.	20.9	-12.2		
17480.9 Å	5000.	22.3	-14.5		
C= 0.15E+20	10000.	23.8	-14.9		
	20000.	25.0	-11.8		
	30000.	27.0	-10.00		
	50000.	29.0	-8.18	*6.59	-5.70
6P - 6D	2500.	0.261	0.173	0.893E-01	0.423E-01
8212.5 Å	5000.	0.303	0.206	0.935E-01	0.504E-01
C= 0.16E+20	10000.	0.343	0.241	0.980E-01	0.586E-01
	20000.	0.380	0.242	0.103	0.673E-01
	30000.	0.405	0.235	0.107	0.726E-01
	50000.	0.437	0.198	0.112	0.797E-01
6P - 7D	2500.	1.76	-0.265		
5161.4 Å	5000.	2.15	-0.161		
C= 0.41E+18	10000.	2.43	-0.821E-01		
	20000.	2.67	-0.172E-01		
	30000.	2.74	0.245E-01		
	50000.	2.77	0.465E-01	*0.574	-0.430

The obtained results will be presented elsewhere (Dimitrijević and Sahal-Bréchot, 1996). Here, only a part of the results will be shown as an illustration, as well as the comparison with simple estimates (Lakićević, 1983).

2. RESULTS AND DISCUSSION

Energy levels for Ba I lines have been taken from Moore (1971). 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 He II- impacts have been calculated.

As the illustration, one part of our results is shown in Table 1 for a perturber density of 10^{16} cm^{-3} and temperatures T = 2,500 - 50,000 K. 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, 1969ab). Values for $0.1 < \mathrm{NV} \leq 0.5$ are denoted with an asterisk.

Our results for Stark width are in agreement with the simple Stark width estimates of Lakićević (1983), on the basis of the Stark broadening parameter dependence on the ionization potential from the lower level of the corresponding transition. For Ba I $6s^2\,{}^1S$ - $6p\,{}^1P^o$ Lakićević (1983) obtained FWHM = 0.48 Å at an electron density of $N_e = 10^{17}$ cm^{-3} and electron temperature T=20000 K, and our result is 0.30 Å, which is good accordance.

On the other hand, our results for the shift are in strong desagreement with simple estimates of Lakićević (1983). Reliable experimental data for Ba I Stark broadening parameters will be of interest for the development of theoretical methods for heavy atoms and ions.

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