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ON THE LS COUPLING ALONG THE BORON SEQUENCE

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1. INTRODUCTION

LS or Russell-Saunders coupling is dominant for many transitions in the spectra of light elements. The spin-orbit interaction in atomic Hamiltonian becomes more important in comparison to the electrostatic separation between levels of the same principal quantum number n but different orbital angular moments. Electrostatic separation increases as Z while the spin-orbit interaction grows as $Z^4 \cdot \alpha^2$ where α is fine structure constant, Z is nuclear charge, so the LS-coupling scheme becomes inappropriate at some point. Systematic failure of the LS-coupling approximation is expected from lower to higher elements of an isoelectronic sequence for nl-nl′ transitions. The aim of this paper is to test the validity of experimental data for the LS-coupling approximation in NIII and OIV ions (3s-3p and 3p-3d transitions) with the theory and experimental data in Glenzer *et al.* (1994).

2. THEORY

Detailed model of LS coupling for boron like ions is given in Glenzer *et al.* (1994). Theoretical values calculated from multiconfiguration Dirac-Fock (MCDF) wave function of moderate accuracy are compared with our measured intensity ratios. For the case of pure LS coupling the relative line strength within multiplet for a transition between levels J_1 and J_2 is proportional to the factor (Cowan, 1981; Appendix I)

$$D^2_{\text{line}} = (2J_1 + 1)(2J_2 + 1) \begin{Bmatrix} L_1 & S_1 & J_1 \\ J_2 & 1 & L_2 \end{Bmatrix}. \tag{1}$$

Values of the 6j symbol are given in Appendix D of (Cowan, 1981). The intensity ratio of two multiplet components is represented by Glenzer *et al.* (1994)

$$\frac{I}{I'} = \left(\frac{\lambda'}{\lambda}\right)^4 \left(\frac{D_{\text{line}}}{D'_{\text{line}}}\right)^2 e^{\frac{E'-E}{kT}} \tag{2}$$

where I,λ and I′,λ are the total intensities and wavelengths of the two components, and E and E′ are the energies of the upper levels of the two components, respectively.

3. EXPERIMENT

The light source was a low pressure pulsed arc with quartz discharge tube 10 mm internal diameter. The distance between aluminium electrodes was 161 mm and 3 mm diameter holes were located at the center of both electrodes to allow end-on plasma observations. The central part around the pulsed arc axis was imaged 1 : 1 onto the entrance slit of the 1 m monochromator by means of the concave 1 [m] focal length, focusing mirror. A 30 mm diaphragm placed in front of the focusing mirror ensures that light comes from the narrow cone about the arc axis. The entire description of measuring apparatus is given in Blagojević *et al.* (1994). The greatest care was taken to find the optimum conditions with the least line self absorption. It was found that the percentage of oxygen in the mixture was of crucial importance for the elimination of self-absorption. The ratios N_2 : He = 2 : 98 and O_2 : He = 1.4 : 98.6 were determined after a number of experiments in which N_2 and O_2 were diluted gradually until strong line intensities NIII and OIV are found proportional to the concentration of N_2 and OIV in the gas mixtures respectively. During the spectral line recording continuous flow of nitrogen-helium and oxygen-helium mixtures were maintained at a pressure of about 400 Pa.

4. PLASMA DIAGNOSTICS

For the electron-density measurements we use the width of HeII P_α 468.6 nm line. The full width at half maximum $\Delta\lambda_{FWHM}$ of this line is related to the electron density N_e using the following relationship (Pittman and Fleurier, 1982; Fleurier and Gall, 1984; Pittman and Fleurier, 1986)

$$N_e = 2.04 \cdot 10^{16} (\Delta\lambda_{\mathrm{FWHM}})^{1.21} \ [\mathrm{cm}^{-3}] \tag{3}$$

where $\Delta\lambda$ is in 0.1 [nm] units. This equation is based on the fitting of the experimental data, and in fact closely agrees with calculations by Griem and Shen (1961). Our main concern in electron-density measurements is a possible presence of self-absorption of the 468.6 nm line which may distort the line profile. This would result in erroneous reading of the line half width which, after the use of Eq.(3), introduces an error in electron-density measurements. There are several experimental methods which can be used for self-absorption check (Konjević and Wiese, 1976) but unfortunately, none of them is convenient for the HeII 468.6 nm line or for our long, pulsed plasma source. Recently, in order to determine the optical thickness of the investigated line Kobilarov *et al.* (1989) have introduced in the discharge an additional movable electrode. By positioning the movable electrode at two different positions and by recording the line profiles from two plasma lengths it is possible to determine $k_\lambda l$ where k_λ is the spectral line absorption coefficient and l is the plasma length along the direction of observation. If $k_\lambda l$ is not large ($k_\lambda l < 1$ (Wiese, 1965)) it is possible to recover the line profile (Fig.2 of Kobilarov *et al.* (1989) for the optically thin case. The same method is used here for the HeII 468.6 nm line self absorption testing. For this purpose an additional aluminum electrode (10 mm thick) is located inside the discharge tube and the profiles of 468.6 nm line are recorded with two plasma lengths.

5. EXPERIMENTAL RESULTS AND DISCUSSION

The experimental results for intensity ratios R_m from 3s-3p multiplet ($I_{1/2-3/2}/I_{1/2-1/2}$) and 3p-3d multiplet [$(I_{3/2-5/2}+I_{3/2-3/2})/I_{1/2-3/2}$] of N III and O IV ions are given in Table 1 together with electron concentration.

Table 1

Transition array	N III 3s-(^1S)3p	N III 3p-(^1S)3d	O IV 3s-(^1S)3p	O IV 3p-(^1S)3d
Ne [10^{17} cm^{-3}]	R_m	R_m	R_m	R_m
1.38	2.08	1.99		
1.71	1.78	1.80		
2.06		2.11		
2.52	1.73			
2.64	1.69			
5.07			1.92	1.80
6.45			1.85	
5.38			1.89	
4.97			1.96	
1.04		1.88		
1.11	1.70	1.68		
0.86	1.98			

There is only one intensity ratio R for O IV 3p-3d multiplet because the intensity I is too low for all other electron concentrations. Table 2 contains the comparison between our experimental ratios R with those from Glenzer *et al.* (1994) and theoretical ratios R calculated in Glenzer *et al.* (1994) from eqs. (1) and (2). Our results for $< R >$ are systematically smaller then those from Glenzer *et al.* (1994) (see Table 2). Further investigations are in progress.

Table 2

Transition array	$< R_m >$(our data)	$< R_m >$(Glenzer *et al.*)	R_{LS}(Glenzer *et al.*)
C II 3s-(^1S)3p		2.05±0.03	2.00
C II 3s-(^1S)3p		1.97±0.04	1.99
N III 3s-(^1S)3p	1.8±0.2	1.99±0.09	2.01
N III 3p-(^1S)3d	1.8±0.2	1.97±0.12	1.99
O IV 3s-(^1S)3p	1.9±0.2	2.00±0.09	2.01
O IV 3p-(^1S)3d	1.8±0.2	1.96±0.10	1.98
F V 3s-(^1S)3p		1.97±0.22	2.02
F V 3p-(^1S)3d		2.11±0.31	1.98
Ne VI 3p-(^1S)3d		2.14±0.15	1.96

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