Publ. Astron. Obs. Belgrade No. 67 (2000), 55 – 58

TRANSITION PROBABILITIES IN THE 4s′ – 4p′ AND 4p′ – 4d′ TRANSITIONS IN Ar III SPECTRUM

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Abstract. Using the relative line intensity ratios method between three strongest Ar III spectral lines in $4s' - 4p'(^3D^0 - ^3F)$ transition with $\Delta J = -1$, their existing transition probability values (A) have been controlled. These A values, within ±10% accuracy, have been confirmed in the case of the 333.61 nm ($\Delta J = 3 - 4$) and 334.47 nm ($\Delta J = 2 - 3$) spectral lines. Conversely, by transition with 335.85 nm ($\Delta J = 1 - 2$) a necessity for correcting the A value appeared. This correction is about +47% and transform the earlier A value ($1.6\ 10^8 s^{-1}$) up to $2.35\ 10^8 s^{-1}$ within ±15% accuracy.Besides, the A values, not known before, are determined for the 248.89 nm and 250.44 nm Ar III spectral lines belonging to the $4p' - 4d'$ transition.

1. INTRODUCTION

Transition probability of spontaneous emission (A) plays an important role in plasma and laser investigation and, also, in astrophysics. Namely, various kinetic processes appearing in plasma modeling need reliable knowledge of A values (Griem 1964, 1974, 1997). However, the existing A values (Wiese et al. 1966, 1969; Lide 1994), for number of emitters, are given with high uncertainties. These values are calculated on the basis of the Coulomb approximation (Allen 1973) or by using the Self-Consistent Field (SCF) method (Hartree 1956). In the case of ionized emitters (doubly or triply ionized, as example) the expected uncertainties are 50% or larger (Wiese et al. 1969). On the other hand, known experimental techniques involve various difficulties (Wiese et al. 1966, Rompe & Stenbeeck 1967) which limit accuracy of the measured A values.

In this work the transition probabilities of spontaneous emission of five transitions in Ar III spectrum have been obtained using the relative line intensity ratios method. Three among them (333.61, 334.47 and 335.85 nm) are strongest in the Ar III spectrum and they are frequently applied in different sort of investigations. As a source of radiation plasma of optically thin linear pulsed arc has been used. The total line intensities (I) were calculated from line profiles measured with high accuracy using the step-by-step technique. Three researched transitions belong to the $^3D^0 - ^3F$ multiplet with upper energy levels (E) within narrow energy interval, therefore correction to the electron temperature (T) of the measured line intensity ratio is not necessary. This fact allows us to establish a simple relation between measured line intensity ratios and ratios of the products of the spontaneous emission probabilities and the corresponding statistical weights (g) of the upper levels of the lines. This relation is expressed as:

$$(I_1/I_2)_{exp} = g_1 A_1 / g_2 A_2 \qquad (1)$$

and gives us possibility to check the existing A values.

2. EXPERIMENT AND RESULTS

The modified version of the linear low pressure pulsed arc (Djeniže et al. 1991, 1998, 2000ab) has been used as a plasma source. A pulsed discharge was driven in a quartz discharge tube of 5 mm inner diameter and effective plasma length of 7.2 cm (Fig. 1 in Djeniže et al. (1991,1998)). The tube has end-on quartz windows. The working gas was argon-helium mixture (72% Ar +28%He) at 130 Pa filling pressure in constant flux flowing regime. Spectroscopic observation of isolated spectral lines were made end-on along the axis of the discharge tube. The line profiles were recorded using a step-by-step technique with a photomultiplier and a grating spectrograph system. The system was calibrated by using the standard lamp (EOA-101). The spectrograph exit slit (10 μm) with the calibrated photomultiplier was micrometrically traversed along the spectral plane in small wavelength steps (0.0073 nm). The averaged photomultiplier signal (five shots at each position) was digitized using an oscilloscope, interfaced to a computer. A sample spectrum is shown in Fig.1.

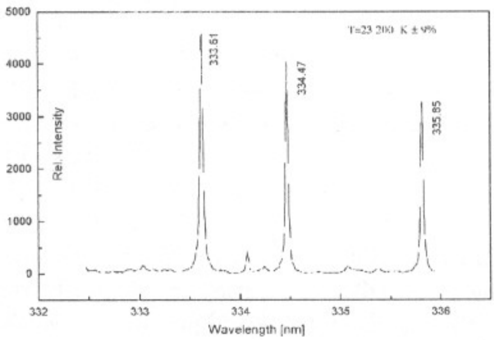

Fig.1. Recorded Ar III spectrum with researched spectral lines.

Plasma reproducibility was monitored by the Ar III and Ar IV lines radiation and, also, by the discharge current (it was found to be within ± 4%). Recorded line profiles can be fitted to the Voigt function as a superposition of the Gauss (instrumental and Doppler broadening) and Lorentz (Stark broadening) functions. The standard deconvolution procedure (Davies & Vaughan 1963) was computerized using the least square algorithm. Total line intensity (I) represents the area under the line profile. On the basis of the recorded Ar III spectrum (as can be see in Fig.1) there follows that these lines are well isolated from the other Ar I, Ar II, Ar III and Ar IV lines and, practically lie on the continuum which is equal to zero. These facts are important by determination in the total line intensity and these conveniences lead to the increase of their reliability.

The plasma parameters were determined using standard diagnostic methods (Rompe & Steenbeck 1967). Thus, the electron temperature was determined from the Boltzman-slope on seven Ar III lines with a corresponding upper-level energy interval of 8.32 eV with an estimated error of ± 9%, assuming the existence of LTE, according to criterion from Griem (1974). All necessary atomic data were taken from Wiese et al. (1969) and Striganov & Sventickii (1966).The electron density decay was measured using a well known single laser interferometry technique for the 632.8 nm He-Ne laser wavelength with an estimated error of ±7%. The electron density and temperature decays are presented in Fig. 4 in Djeniže et al. (2000b) (T_{max} = 23 200 K, $N_{max} = 1.9\ 10^{23}\ m^{-3}$).

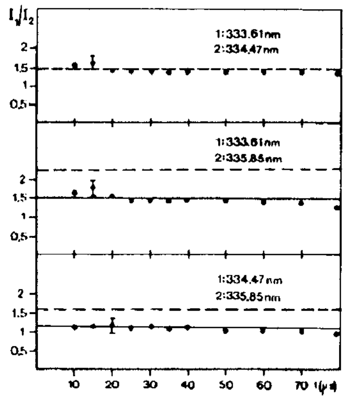

Fig. 2. Relative line intensity ratios (I_1/I_2) during the plasma decay. •, our experimental values within 12% accuracy. - - -, theoretical ratios by using the existing transition probability values from Wiese (1969) and Lide (1994) within estimated uncertainties of 50%. Solid lines represent theoretical intensity ratios after the correction of the transition probabilities. All three lines belong to the same multiplet.

In order to make direct estimation of the influence of the self-absorption on the line intensity, method of the relative line intensity ratios has been applied. Ratios $(I_1/I_2)_{exp}$ were monitored in a wide range of the decaying plasma up to 80th μs after beginning of the discharge when the line intensity maximum dropped down to 10% of its maximal value. Experimental points are presented in Fig.2. These experimental ratios are constant within ±6%, during the plasma decay. From this fact it follows that for employed experimental conditions (spatial distribution, discharge characteristics, gas pressure etc.) our plasma can be treated as optically thin. On the other hand, Stark width values of these lines measured by Djeniže et. al. (2000 a) in the same plasma conditions agree well with existing experimental and theoretical Stark width values testifying, also, to the absence of the self-absorption. This suggests that the comparison between measured and calculated relative line intensity ratios can be employed as a method for estimation of the transition probabilities relatively to the selected referent A values.

Therefore, we suppose that there is at least one pair of lines, belonging to the same multiplet, for which measured and calculated relative line intensity ratios are in agreement during the whole plasma decay period. If such agreement really exists one can accept these lines with corresponding transition probabilities as the referent A values. Among the lines that we have investigated, see Fig.2., described behavior is found for the 333.61 nm and 334.47 nm transitions, while existing A value of the 335.85 nm transition has to be corrected in accordance with the experimental I_1/I_3 and I_2/I_3 values. The corrected value is presented in Table 1.

On the basis of the known transition probabilities it is possible to determine unknown A values by using the relative line intensity ratio dependence on the electron temperature (Griem 1964, 1974, 1997):

$$I_1/I_2 = (g_1 A_1 \lambda_2 / g_2 A_2 \lambda_1) exp(\Delta E_{21}/kT) \quad (2)$$

This relation allows the mutual comparison between the relative intensities of the spectral lines that origin from the much different parent energy levels. Using Eq. (2) A values for the 248.89 nm and 250.44 nm transitions have been obtained relatively to the 333.61 nm and 334.47 nm transitions.

Table 1. Atomic data for the five researched Ar III spectral lines. E and g denote the upper level energy and the corresponded statistical weights. A_w is the existing transition probability (Wiese et al. 1969) and A_{exp} is the new value obtained by us.

Transit.	Multipl.	λ(nm)	E(eV)	g	$A_w(10^8 s^{-1})$	$A_{exp}(10^8 s^{-1})$
$4s' - 4p'$	$^3D^0 - ^3F$	333.61	28.10	9	2.0	2.00±10%
		334.47	28.08	7	1.8	1.80±10%
		335.85	28.06	5	1.6	2.35±15%
$4p' - 4d'$	$^3P^0 - ^3P^0$	248.89	33.66	5	—	1.30±20%
	$^3P - ^3P^0$	250.44	33.68	3	—	0.45±20%

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