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TRANSITION PROBABILITY RATIOS IN THE Mg I 3p - 4s TRANSITION

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SUMMARY: Using the relative line intensity (I) ratios of the astrophysically important 518.360 nm, 517.268 nm and 516.732 nm neutral magnesium (Mg I) lines in the $3p\ ^3P^o_{0,1,2} - 4s\ ^3S_1$ transition we have obtained the ratios of corresponding transition probability values (Einstein's A values). They represent the first experimental data based on the analysis of the emission spectral lines. The linear, low-pressure, pulsed arc was used as a plasma source operated in the helium with magnesium atoms introduced as impurities from discharge electrodes, providing there is no self-absorption within the investigated range of Mg I spectrum. We have found excellent agreement with theoretical transition probability ratios tabulated by NIST (2003).

Key words. **atomic data**

1. INTRODUCTION

The 516.732 nm, 517.268 nm and 518.360 nm spectral lines of the neutral magnesium (Mg I) in the $3p\ ^3P^o_{0,1,2} - 4s\ ^3S_1$ transition are useful for investigations of various cosmic light sources. They are of interest in the astrophysical plasma diagnostics and modeling (Greenhill et al. 2002, Bower et al. 2001, Allende Prieto et al. 1999, Garcia Lorenco, Mediavilla and Arribas 1999). The transition probability (Einstein's A) values of these lines are of importance in radiation processes used in plasma modeling and diagnostics. However, their ratios (NIST 2003, Kurucz and Bell 1995) show mutual scatter up to a factor 1.42 caused by large difference between the A values corresponding to the 516.732 nm Mg I transition. On the other hand, only one experiment is dedicated to the line intensities investigation in this transition (Penkin and Shabanova 1962) and it is based on anomalous dispersion measurements.

The aim of this work is to present the transition probability ratios of the mentioned Mg I transitions using the relative line intensity ratio (RLIR) method (Griem 1964, Djeniže and Bukvić 2001, Djeniže et al. 2002, 2003a, 2004, Srećković et al. 2001, 2002) in the emission spectra, not applied up to now in the case of the Mg I $3p\ ^3P^o_{0,1,2} - 4s\ ^3S_1$ transition. Our experimental transition probability ratios are compared with tabulated ones (Wiese et al. 1969, NIST 2003, Kurucz and Bell 1995). We have found excellent agreement with values presented by NIST (2003) which were calculated by Weiss (1967) and were recommended in Wiese et al. (1969).

2. EXPERIMENT

A linear, low pressure arc has been used as a plasma source. A pulsed discharge was driven in a pyrex discharge tube of 5 mm inner diameter and plasma length of 14 cm (Fig. 1 in Djeniže et al. 1991). The tube has end-on quartz windows. The magnesium atoms have been introduced through erosion of the magnesium metal bands deposited on the discharge electrodes following the idea described in Djeniže et al. (1990ab, 1991, 1992). The working gas was helium at 552 Pa in flowing regime. Investigated Mg I spectral lines remain isolated in the helium plasma. The plasma length of 14 cm enables detectable intensities of the Mg I lines. Namely, the density of the magnesium atoms is low because they are introduced as impurities in the helium plasma. Due to this fact our plasma behaves as an optically thin source of Mg I lines. A capacitor of 14 μF was charged up to 55 J bank energy. Spectroscopic observation of isolated spectral lines was made end - on along the axis of the discharge tube.

The line profiles were recorded using a step-by-step technique with a photomultiplier (EMI 9789QB) and a grating spectrograph system (Zeiss-PGS with the reciprocal linear dispersion of 0.73 nm/mm in the first order). The spectrograph exit slit (10 μm) with the calibrated photomultiplier was micrometrically moved along the spectral plane in small wavelength steps (7.3 pm). The averaged photomultiplier signal (seven shots in the same spectral range) was digitized using an oscilloscope attached to the computer (Djeniže and Bukvić 2001, Djeniže et al. 2002, 2003ab, 2004). The recorded Mg I spectral line profiles are shown in Fig. 1. The lines are well isolated, with continuum close to zero, which enables high accuracy of the measured line intensities (I) (within ±4%).

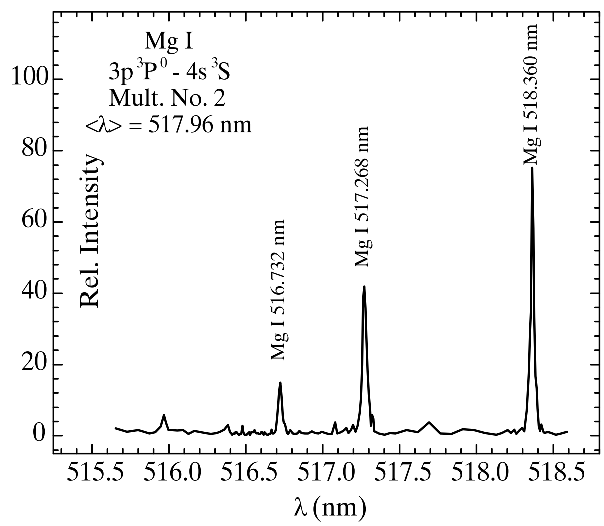

Fig. 1. *Mg I spectral line profiles 40 μs after the beginning of the discharge. The mean wavelength in the multiplet is denoted with* $< \lambda >$.

The plasma parameters were found using well-known diagnostical methods. Electron density (N) decay was obtained by the use of the single wavelength interferometry technique at a 632. 8 nm He - Ne laser wavelength (Ashby et al. 1965). Electron temperature (T) was obtained from the He I 587.6 nm and He II 468.6 nm lines intensity ratio (Griem 1964). The maxima of the plasma parameters were : $T = 54\,000$ K ± 8% and $N = 1.3\ 10^{23}$ m^{-3} ±7%. The absence of the self - absorption in the Mg I line intensities was checked by a method described in Djeniže and Bukvić (2001).

3. TRANSITION PROBABILITY RATIO

When two spectral lines (denoted with 1 and 2) arise from the same upper energy level their relative line intensity ratio is given as (Griem 1964):

$$(I_1/I_2)_m = A_1\lambda_2/A_2\lambda_1 \qquad (1)$$

where A and λ denote transition probability and the wavelength of the transition. I_m denotes measured relative line intensity. Eq. (1) enables determination of the transition probability ratio on the basis of the measured relative line intensities. The characteristics of the investigated Mg I transitions are given in Table 1.

Table 1. Characteristics of the investigated Mg I transitions. J_f and J_i are the inner quantum numbers of the final (f) and initial (i) state of the transition. Atomic data (the energy of the initial levels (E_i) and the wavelengths (λ)) are taken from NIST (2003). Transition probability values (A) are given in 10^8 s^{-1} units. The indices: N (NIST 2003), W (Wiese 1969) and K (Kurucz and Bell 1995) denote tabulated transition probabilities.

Multiplet	λ (nm)	E_i (eV)	A_N	A_W	A_K
$3p\ ^3P^o$ - $4s\ ^3S$					
J_f - J_i					
2 − 1	518.36043	5.108	0.575	0.575	0.547
1 − 1	517.26844	5.108	0.346	0.346	0.329
0 − 1	516.73213	5.108	0.116	0.116	0.078

4. RESULTS AND DISCUSSION

Using the measured relative line intensities (I_m) we have obtained, on the basis of Eq. (1), the transition probability ratio of the Mg I transitions during the entire plasma decay. They are presented in Fig. 2. They show (Fig. 2 abc) mutual scatter within the estimated uncertainties of ±8%. Our averaged transition probability ratios are presented in Table 2 together with values taken from NIST (2003) and Kurucz and Bell (1995). One notices that our experimental transition probability values are in very good agreement (within ±4%) with the values provided by NIST. In the case of the A (518.3 nm) / A (517.2 nm) ratio also the value tabulated by Kurucz and Bell (1995) agrees well. Large differences were found between our and Kurucz and Bell's (1995) values in the cases of the A (518.3 nm) / A (516.7 nm) and A (517.2 nm) / A (516.7 nm) ratios. They are caused by low A value adopted by Kurucz and Bell (1995) for the Mg I 516.7 nm transition. We have found that this A value must be higher by approximately 41%.

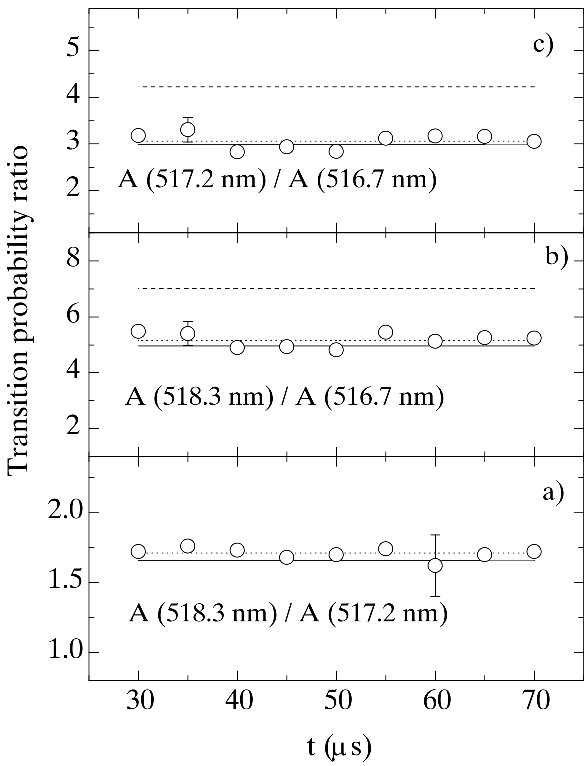

Fig. 2. *Mg I transition probability ratios (a, b, c) during the plasma decay. The solid and dashed lines represent calculated ratios taking A values from NIST (2003) and Kurucz and Bell (1995), respectively (see Table 2). Open circles represent our experimental values obtained from Eq. (1) with an estimated accuracy of ± 8%. Dotted line denotes our averaged experimental values.*

Table 2. Transition probability ratios of the Mg I lines. The symbol Tw (this work) denotes our experimentally obtained results. Data from NIST (2003) and Kurucz and Bell (1995) represent tabulated theoretical values (see Table 1).

Mg I lines (nm)	Transition probability ratios		
	Tw	NIST	Kurucz
518.3/517.2	1.71±8%	1.66	1.66
518.3/516.7	5.16±8%	4.96	7.01
517.2/516.7	3.06±8%	2.98	4.22

5. CONCLUSION

On the basis of the accurately measured intensities of three Mg I spectral lines we have obtained corresponding probability ratios. They are in excellent agreement with values provided by NIST. This implies that the transition probability values of the 518.360 nm, 517.268 nm and 516.732 nm Mg I lines presented by NIST (see Table 2) represent reliable atomic data (within ±5% uncertainties) to be used in the plasma diagnostics and modeling.

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ОДНОСИ ВЕРОВАТНОЋА ПРЕЛАЗА У Mg I 3p - 4s ПРЕЛАЗУ

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На основу релативних интензитета (I) астрофизички интересантних 518.360 nm, 517.268 nm и 516.732 nm спектралних линија атома магнезијума (Mg I) у прелазу $3p\ ^3P^o_{0,1,2} - 4s\ ^3S_1$ одредили смо односе њихових вероватноћа прелаза (Ајнштајнови A коефицијенти). Ови односи представљају прве експерименталне податке добијене на основу емисионих линија. Линеарни импулсни лук, на ниском притиску, коришћен је као извор плазме у хелијуму са атомима магнезијума, као нечистоћама, обезбеђујући одсуство самоапсорпције у интензитетима испитиваних Mg I спектралних линија. Нађено је изванредно слагање са теоријски одређеним односима вероватноћа прелаза табелираних у NIST-у (2003).