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Lifetime measurement of some excited states belonging to the $3p^4nd$ (n=4–6) configuration of ArII

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Abstract. The radiative lifetimes of eight levels belonging to the $3p^4nd$ (n=4–6) configuration of ArII have been measured using high frequency deflection technique together with a delayed coincidence single photon counting arrangement. Lifetimes of some of the levels have been measured for the first time. The results have been compared with other experimental and theoretical values.

Keywords. Oscillator strength; lifetimes; transition moments.

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1. Introduction

There is a constant interest in the study of rare gases in connection with plasma physics, high temperature arcs and laser. The knowledge of lifetime and transition probabilities of singly ionized argon (ArII) is of great value in atomic structure studies and also with regard to the above-mentioned applications. Most of the previous measurements concentrate on the $3p^44p$ states since strong transitions in the ArII spectrum belong to these configuration. There is a shortage of experimental information about the lifetime of $3p^4nd$ (n=4–6) levels of ArII, particularly for the 5d and 6d levels. Lifetimes of some of the 4d levels have been measured previously by different investigators [1–6] using different techniques. The earliest measurements on some of the 4d levels were carried out by Denis and Gaillard [1] and Fink *et al* [2] using beam foil technique. By employing the same technique, Pinnington *et al* [3] measured lifetimes of some 4d levels of ArII. In addition, results of measurements using the delayed coincidence method were reported by Blagoev [4] and Garcia and Campos [5]. Zhechev [6] measured the lifetimes of some 4d levels using the method of Hanle effect. Moreover, for each of the $5d^4F_{7/2}$, $6d^4F_{7/2}$ and $6d^4F_{9/2}$ levels there is only single measurement by Blagoev [4] and for the $4d^4P_{3/2}$ and $6d^4D_{7/2}$ levels

Table 1. Lifetime of $3p^4nd$ (n=4–6) states of ArII (data in ns).

Level	Line (Å)	Experimental values: Present value	Garcia and Campos [5]	Blagoev [4]	Zhechev [6]	Fink [2]	Theoretical values: Rudco and Tang [7]	Garcia and Campos [5]
$4d^4P_{3/2}$	3249.8	3.4 ± 0.2						
$4d^4P_{5/2}$	3868.5	3.6 ± 0.2		3.9 ± 0.4	4.3 ± 0.7	4.4	2.48	
$4d^4D_{3/2}$	3535.3	4.3 ± 0.3	3.3 ± 0.2	4.7 ± 0.6	4.8 ± 0.7	4.2	2.50	3.3
$4d^4D_{5/2}$	3476.7	4.1 ± 0.3	3.2 ± 0.2	4.6 ± 0.6	4.8 ± 0.6		2.51	3.3
$5d^4F_{7/2}$	3637.0	5.8 ± 0.4		6.6 ± 0.6				
$6d^4D_{7/2}$	5281.6	7.2 ± 0.5						
$6d^4F_{7/2}$	5407.3	13.1 ± 0.7		14.4 ± 1.4				
$6d^4F_{9/2}$	5397.5	14.8 ± 0.7		15.7 ± 1.2				

no experimental results have been published to our knowledge until now. There are theoretical data for some 4d levels by Rudco and Tang [7] and Garcia and Campos [5]. However, there are disagreements among the reported lifetime values. This situation points to the need for further experimental investigations. The results obtained in the present work have been compared with values obtained by previous workers.

2. Experimental method

The present work employed the high frequency deflection (HFD) technique together with a delayed coincidence single photon counting arrangement. Details concerning the experimental set-up were reported previously [8,9]. A pulsed beam of high energy electrons (4 keV) was used to excite the atoms to the levels of interest, the DC beam current being 2 mA. The duration of each beam-pulse was about 1.8 ns. To select the spectral lines of interest, a Minuteman 0.5 m monochromator (Model 305) with gratings having 1200 grooves/mm blazed at 3000 Å and 5000 Å was used at a resolution of 0.7 Å. The photons were detected with a cooled Philips XP2020Q photomultiplier tube. The tables of Striganov and Sventitskii [10] and Norlen [11] were used to identify the measured transitions. The coincidence resolving time (FWHM) of the whole system was 2.4 ns. The time delay in the coincidence set-up was adjusted to 0.3 ns per channel. The measurements were carried out at a few gas pressures ranging from 0.4 to 4 mTorr and no significant change of any of the measured lifetimes with pressure was observed within the experimental error. The decay curves were analysed by a least square fit to the experimental data convoluted with the known instrumental response function [12].

3. Results and discussion

Our results for the lifetime measurement of some ArII levels are presented in table 1 which also shows the experimental and theoretical values obtained by other investigators. The lifetime values are the weighted average of three independent

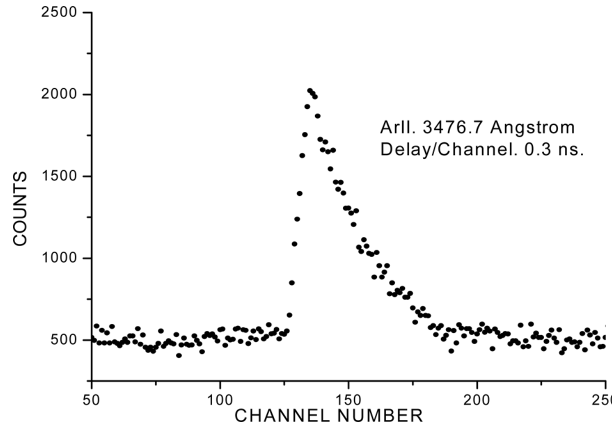

Figure 1. The decay curve of the $4d^4D_{5/2}$ level (gas pressure 5×10^{-4} Torr).

measurements for each level. The errors quoted include the statistical and systematic errors. In order to investigate the effect of cascades in our experiments, an excitation spectrum (intensity vs. wavelength scan) has been recorded between 2000 and 9000 Å by using the monochromator at a resolution of 0.7 Å, keeping the beam energy and current at values mentioned earlier. All these lines recorded in this spectrum were found in the list of classified lines of Striganov and Sventitskii [10] and Norlen [11] for ArII. However, their list contains many more lines than those observed in the present experiment. The spectrum was found to contain no line that appears due to repopulation from a higher level to any of the levels under investigation. It was not possible to examine the other cascading levels that decay by emitting photons having wavelengths less than 2000 Å and higher than 9000 Å in this way because of the limited spectral range of the PMT. But it is seen from the work of Massey [13] that for excitation with electrons having energies well above the threshold, the higher levels are expected to be excited with relatively less probability as compared to the lower ones. On this count also it seems that, in the present case where the excitation energy is 4 keV, the high lying levels do not have any significant cascade feeding to the levels under study. All the decay curves were analysed for single as well as multi-exponential components. In the present work each of the decay curve was found to be best fitted to a single exponential. A typical decay curve for the $4d^4D_{5/2}$ level of ArII, measured at 3476.7 Å, is shown in figure 1.

Comparing the results of these experiments with previous data, it seems that in general, within experimental errors, there is good agreement with the data of Blagoev [4] and Zhechev [6]. The lifetime values obtained by Garcia and Campos [5] through the same delayed coincidence technique are systematically smaller than our values. The beam foil work of Fink *et al* [2] had numerous cascades and blends which made them unable to give separate lifetime values for different fine structure components. They estimated the uncertainty to be 30%. Theoretical works on the lifetimes of nd (n=4–6) levels of ArII are very few. The theoretical work of Rudco and Tang [7] is a modified version of the method used by Statz *et al* [14] who obtained their intermediate coupling wave functions from a fit to the experimental level energies. The radial integrals in the expression for the line strength are solved with the Hartree–Fock method and the Slater approximation. The calculations of Garcia and Campos [5] are based on LS coupling within the Coulomb approximation. However, the theoretical values of both Rudco and Tang [7] and Garcia and Campos [5] are lower than ours. In all these calculations, the possibility of configuration interaction was ignored. But there may be appreciable interaction between certain ArII excited configurations. Therefore, further calculation is necessary for these levels, taking configuration interaction into account, to obtain accurate theoretical values of lifetime.

References

[1] A Denis and M Gaillard, *Phys. Lett.* **A31**, 9 (1970)
[2] U Fink, S Bashkin and W S Bickel, *J. Quant. Spectrosc. Radiat. Transfer* **10**, 1241 (1970)
[3] E H Pinnington, P Weinberg, W Verfuss, H O Lutz and R Hippler, *Phys. Lett.* **A65**, 287 (1978)
[4] K B Blagoev, *J. Phys.* **B16**, 33 (1983)
[5] G Garcia and J Campos, *Phys. Scr.* **33**, 321 (1986)
[6] D Zhechev, *J. Phys.* **B18**, 65 (1985)
[7] R I Rudco and C L Tang, *J. Appl. Phys.* **38**, 4731 (1967)
[8] M B Das and R Bhattacharya, *Z. Phys.* **D14**, 25 (1989)
[9] M B Das and S Karmakar, *Pramana – J. Phys.* **65(6)**, 1061 (2005)
[10] A R Striganov and N S Sventitskii, *Tables of spectral lines of neutral and ionized atoms* (IFI/Plenum, New York, 1968)
[11] G Norlen, *Phys. Scr.* **8**, 249 (1973)
[12] W K Warburton, *Comp. Phys. Commun.* **13**, 371 (1978)
[13] H S W Massey, *Handbuch der Physik* (Springer, Berlin, 1956) vol. 36, p. 335
[14] H Statz, F A Horrigon, S H Koozekanani, C L Tang and G F Koster, *J. Appl. Phys.* **36**, 2278 (1965)