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Cite as: AIP Conference Proceedings **1058**, 257 (2008); <https://doi.org/10.1063/1.3026457>

Published Online: 27 October 2008

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Level Energies, Oscillator Strengths and Lifetimes for Transitions in Pb IV

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Abstract. Oscillator strengths for several lines of astrophysical interest arising from some configurations and some levels radiative lifetimes of Pb IV have been calculated. These values were obtained in intermediate coupling (IC) and using *ab initio* relativistic Hartree-Fock calculations. We use for the IC calculations the standard method of least square fitting of experimental energy levels by means of computer codes from Cowan. Transition Probabilities and oscillator strengths obtained, although in general agreement with the rare experimental data, do present some noticeable discrepancies that are studied in the text.

Keywords: Oscillator strengths, radiative lifetimes.

PACS: 31.15. A-, 31.15.ag.

THEORETICAL CALCULATIONS AND RESULTS

Data on atomic properties are relevant not only to spectroscopy, these values are also of interest in a variety of other fields in physics and technology. The presence of Pb IV in stellar spectra has been reported in a few different type of stars. As an example the Pb IV resonance lines has been detected in Far Ultraviolet Spectroscopic Explorer (FUSE) spectra of hot subdwarf B (sdB) stars [1, 2].

In this work we present oscillator strengths for spectral lines arising from $5d^{10}$ ns ($n= 7, 8$), $5d^{10}6p$ and $5d^{10}6d$ configurations and some radiative lifetimes of Pb IV. We have obtained theoretical values of oscillator strengths in intermediate coupling (IC) using *ab initio* relativistic Hartree-Fock (HFR) calculations.

For the IC calculations we used the standard method of least-square fitting of experimental energy levels by means of computer codes from Cowan [3]. In this way, we obtained the LS composition of each level and the degree of configuration mixing. For the HFR calculations the Cowan computer code provide us the radial parts for determination of transition probabilities and initial estimated of the parameters for the IC fittings. The radial integrals for calculations of transition probabilities were obtained from the HFR wave-functions.

The system considered is complex, since at high Z both relativistic and correlation effects are important. Although least-squares fitting of experimental energy level partially account correlations effects, both effects have been considered in this work.

A most detailed description of this method can be seen in others works of these authors [4-7].

TABLE 1. Oscillator Strengths of spectral lines arising from $5d^{10}6d$ and $5d^{10}ns$ configuration and radiative lifetimes of Pb IV.

Transition Upper	Levels Lower	Wavelength λ (Å) ^a	f-values		Lifetimes (ns)	
			This work	Others	This work	Others
6d $^2D_{3/2}$	6p $^2P_{1/2}$	922.5	1.42	0.92 ^b	0.16	0.28±0.03 ^d 0.281±0.025 ^e 0.234±0.010 ^e
				0.87 ^b		
				1.19 ^c		
	6p $^2P_{3/2}$	1144.9	0.114	0.86 ^c		
				0.088 ^b		
				0.092 ^b		
6d $^2D_{5/2}$	6p $^2P_{3/2}$	1116.1	1.06	0.12 ^c	0.26	0.36±0.02 ^e 0.34±0.02 ^e
				0.093 ^c		
	5d ⁹ 6s6p [4°] _{3/2}	8749.8	0.00046			
7s $^2S_{1/2}$	6p $^2P_{1/2}$	917.9	0.25	0.17 ^b	0.25	0.35±0.5 ^d
				0.16 ^c		
	6p $^2P_{3/2}$	1137.9	0.20	0.23 ^b		
				0.22 ^c		
8s $^2S_{1/2}$	6p $^2P_{1/2}$	576.4	0.032	0.027 ^c	0.41	0.47±0.04 ^e
	6p $^2P_{3/2}$	656.1	0.028	0.029 ^c		
	5d ⁹ 6s6p [4°] _{3/2}	1346.9	0.00019			
	5d ⁹ 6s6p [10°] _{1/2}	1802.2	0.00030			
	5d ⁹ 6s6p [9°] _{3/2}	1795.9	0.00014			
	5d ⁹ 6s6p [12°] _{3/2}	2015.6	0.00046			
	5d ⁹ 6s6p [13°] _{1/2}	2075.8	0.016			
	5d ⁹ 6s6p [15°] _{3/2}	2464.1	0.054			
	5d ⁹ 6s6p [16°] _{1/2}	2509.6	0.28	0.26 ^c		
	5d ⁹ 6s6p [17°] _{1/2}	2546.8	0.078			
	5d ⁹ 6s6p [19°] _{3/2}	2874.2	0.044			
	5d ⁹ 6s6p [22°] _{3/2}	3146.4	0.22	0.35 ^c		
	5d ⁹ 6s6p [25°] _{1/2}	5370.1	0.0030			

^aMoore 1958 ^bMigdalek & Garmulewicz 2000 ^cSafronova 2004 ^dAnsbacher et al 1988

^ePimmington et al 1991

Several of the values calculated in this work are the first presented in the bibliography. Levels no designed by Moore [8] have been assigned in this work.

In table 1 we present oscillator strengths of spectral lines arising from $5d^{10}6d$ and $5d^{10}ns$ configurations and some radiative lifetimes. In Table 2 we present as example the results obtained for two lifetimes corresponding to resonance lines of Pb IV of high astrophysical interest.

TABLE 2. Radiative lifetimes of resonant lines of Pb IV.

Transition		Wavelength (nm) ^a	Lifetimes (ns)	
Upper	Lower		This work	Others
6p $^2P_{1/2}$	6s $^2S_{1/2}$	131.3	0.95	1.11±0.10 ^d
6p $^2P_{3/2}$	6s $^2S_{1/2}$	102.9	0.48	0.52±0.04 ^d

^aMoore 1958 ^dAnsbacher et al

There is a good agreement between our results and the experimental values found in the bibliography [9-12].

ACKNOWLEDGMENTS

This work has been supported by the project CCG07-UPM/ESP-1632 of the TECHNICAL UNIVERSITY OF MADRID (UPM). Support to the lines of UPM investigation groups included in the IV PRICIT of the CAM (Comunidad Autónoma de Madrid), SPAIN.

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