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Energy Levels and Radiative Lifetimes for Four Times Ionized Xenon (Xe V)

Selda ESER*[1]

Abstract

By employing the general-purpose relativistic atomic structure package (GRASP) based on fully relativistic multiconfiguration Dirac-Fock (MCDF) method, energies and radiative lifetimes of levels have been reported for four times ionized xenon (Xe V). In calculations, the Breit interactions for relativistic effects, quantum electrodynamical (QED) contributions have been included as a perturbation, as well as electron correlation effects (VV, CV and CC). We have compared the results obtained in this work with experimental and theoretical values in available literature for Xe V. We have obtained good agreement with previous works.

Keywords: Energy levels, correlation effects, relativistic effects, radiative lifetimes

1. INTRODUCTION

There is quite a lot of interest in rare gases because of their applications in collision physics, fusion diagnostics, photo-elect[2]ron spectroscopy, astrophysics, and laser physics [1]. Especially for the understanding of the mechanisms involved in the multi-ionic xenon laser action, obtained spectroscopic data from xenon ions are needed in these areas [2]. Four times ionized xenon (Z=54), which belongs to the Sn I isoelectronic sequence, has $5s^25p^2$ electron ground configuration. The ground level of this ion is $5p^2\ ^3P_0$, and this level is followed by $^3P_1$, $^3P_2$, $^1D_2$ and $^1S_0$ in the same configuration. Saloman compiled the energy levels and observed spectral lines of the xenon atom, in all stages of ionization [3]. Reyna Almandos et al. presented an overview of studies concerning the spectral analysis of several ions for noble gases [4]. Calculated lifetimes for 12 new energy levels belonging to the $5s^25p6d$ and $5s^25p7s$ configurations and weighted oscillator strengths and transition probabilities for 81 new classified lines were presented by Raineri et al. [2]. Dzuba and Flambaum calculated the energy levels and Landé g factors for neutral xenon and all its positive ions from Xe II to Xe VIII [5]. The energies, lifetimes and transition probabilities were calculated with the pseudorelativistic Hartree-Fock (HFR) approach for Xe V by Biémont et al. [6]. Sobral et al. reported laser gain analyses for several lines by using level parameters (lifetimes and radiative transition rates) obtained from HFR method [7]. Tauheed et al. analyzed some energy levels and $5s^25p^2$-($5s5p^3$+$5s^25p5d$+$5s^25p6s$) transitions of four-times ionized xenon [8]. Using MCHF method Pinnington and co-workers calculated energy levels, lifetimes and some transition parameters for Xe V [9]. Larsson et al. obtained the

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wavelengths and energy levels of Xe V and Xe VI by collision-based spectroscopy [10]. For zirconium and xenon and their some ion lines in the ultraviolet (UV) spectra, oscillator strengths were reported by Rauch et al [11]. The spectrum of four times ionized xenon, were observed in the 500-6800 Å range and 84 new lines were identified as transitions between levels of $5s5p^3$, $5s^25p5d$, $5s^25p6s$, $5s^25p^2$, and $5s^25p6p$ configurations by Gallardo et al [12, 13].

The aim of this work is to calculate the level energies and lifetimes in four times ionized xenon, using the general-purpose relativistic atomic structure package (GRASP) [14] based on a fully relativistic multiconfiguration Dirac-Fock (MCDF) method [15]. This code includes Breit interactions (magnetic interaction between the electrons and retardation effects of the electron-electron interaction) for relativistic effects and quantum electrodynamical (QED) contributions (self-energy and vacuum polarization) beside the electron correlation effects (valence-valence (VV), core-valence (CV) and core-core (CC)). These contributions are important in investigations include electronic structure and spectroscopic properties of many electron systems. We have performed a series of calculations according to configuration sets including excitations from valence and core (valence, core-valence and core-core correlation) for considering correlation effects. We have reported the configuration sets, which have been here taken into account, in Table 1 below.

Table 1
Configuration sets taken in calculations for Xe V

VV	$5s^25p^2$, $5s^25p5d$, $5s^25p6s$, $5s^25p4f$, $5s^25p6p$
CV	VV+($5s5p^3$, $5s5p7s^2$, $5s5p6d^2$, $5s5p7p^2$, $5s^25p7s$, $5s^25p6d$, $5s^25p7p$)
CC	$5s^25p^2$, $5p^4$, $5s^25p4f$, $5p^25d^2$, $5s^25p6p$, $5s^25p7p$, $5s5p^3$, $5s^25p5d$, $5s^25p6s$, $5s5p7s^2$, $5s5p6d^2$, $5s^25p6d$, $5s5p7p^2$, $5s^25p7s$

The spectral analysis of rare -gas atoms have been carried out in our groups for many years. More detailed information is available on the ref. [16].

2. CALCULATION PROCEDURE

The calculations were performed by using the general-purpose relativistic atomic structure package, GRASP code [14], which is based on a multiconfiguration Dirac-Fock (MCDF) method, although we used MCHF code in our previous studies. The both method includes correlation effects. But fully relativistic MCDF method is based on the Dirac-Coulomb Hamiltonian and MCHF method is based on the non-relativistic Hamiltonian. So, obtained results are better in MCDF method than the MCHF method. MCDF code considers the Thomas-Fermi and Coulomb potential for calculate wavefunctions according to JJ and LS couplings. In the MCDF method [15], an atomic state can be expanded as a linear combination of configuration state functions and is optimized usually on the basis of the many-electron Dirac-Coulomb Hamiltonian

$$\Psi_a(PJM) = \sum_{r=1}^{n_c} C_r(\alpha)\left|\gamma_r(PJM)\right\rangle \tag{1}$$

where n_c is the number of CSFs included in the evaluation of atomic state functions and C_r is the mixing coefficient, optimized usually on the basis of the many-electron Dirac-Coulomb Hamiltonian. The CSFs are the sum of products of single-electron Dirac spinors,

$$\phi(r,\theta,\varphi,\sigma) = \frac{1}{r}\begin{pmatrix} P(r)\chi_{\kappa m}(\theta,\varphi,\sigma) \\ iQ(r)\chi_{-\kappa m}(\theta,\varphi,\sigma) \end{pmatrix} \tag{2}$$

where κ is a quantum number and $\chi_{\kappa m}$ is the spinor spherical harmonic in the LSJ coupling scheme. The *P(r)* and *Q(r)* are large and small radial components of one-electron wavefunctions represented on a logarithmic grid. The energy functional is based on the Dirac-Coulomb Hamiltonian,[3]

$$H_{DC} = \sum_{j=1}^{N}[C\boldsymbol{\alpha}_j\cdot\boldsymbol{p}_j) + (\beta_j - 1)c^2 + V(r_j)] + \sum_{j<k}^{N}\frac{1}{r_{jk}} \tag{3}$$

where $V\left(r_j\right)$ is the electron-nucleon interaction. Once initial and final state functions have been calculated, the radiative matrix element for radiative properties computation can be obtained from

$$O_{if} = \langle \psi(i) | \boldsymbol{O}_q^{\pi(k)} | \psi(f) \rangle \quad (4)$$

where $\boldsymbol{O}_q^{\pi(k)}$ is a spherical operator of rank k and parity π, and $\pi(k)$ is $\pi = (-1)^k$, for an electric multipole transition or $\pi = (-1)^{k+1}$, for a magnetic multipole transition. The largest transition probability is for electric dipole (E1) radiation, dominated by the least factor $1/_{\alpha^2}$ over other types of transitions (E2, M1, M2, etc.).

The lifetime, $\tau_{\gamma' J'}$, of upper level $\gamma' J'$ is

$$\tau_{\gamma' J'} = \frac{1}{\sum_{\pi k, \gamma J} A^{\pi k}(\gamma' J', \gamma J)}. \quad (5)$$

In calculations we have used the option *extended average level* (EAL) averaging of the expression energy. It is extended to configuration states with not only different total angular momentum but also with different parity. Also, Breit corrections (magnetic interaction between the electrons and retardation effects of the electron-electron interaction), and QED (self-energy and vacuum polarization), and various correlation contributions have been considered. Due to the Coulomb interaction between the electrons, the electron correlation effects are also important, in particular, for fine structure and transitions. Therefore, the configurations including excitations from valence and core have been taken into account in calculations. QED contributions are self-energy and vacuum polarization, which are also included in the computations of the transition energy. The finite-nucleus effect is taken into account by assuming an extended Fermi distribution for the nucleus. Both the Breit and QED contributions are treated as perturbation and are not included directly in the SCF procedure. The mixing coefficients are calculated by diagonalizing the modified Hamiltonian.

The used package program had been written by the other authors and we have compiled this code in our computations.

3. RESULTS

In this work, we have determined the excitation energies and radiative lifetimes for Xe V by employing the MCDF method [15]. Breit interactions for relativistic effects and QED contributions have been included in this method. Due to the Coulomb interaction between the electrons, the electron correlation effects are also important. Therefore, we have considered the various correlation effects and configuration sets including electron excitations from the valence 5p to other high sub-shell (VV) and electron excitation(s) from 5s subshell to other high subshells (CV and CC). We have taken into account three configuration sets, which have been given in Table 1 in details, represented by VV, CV and CC. When the excitation is made from the core, the number of configuration state functions (CSF) is increased. We have obtained 43, 215 and 331 energy levels for VV, CV and CC computation, respectively. In Table 2, only 65 energy levels and their radiative lifetimes have been sorted, for Xe V. In generally, VV and CV calculation results are close to each other. But the results have improved when calculations have been made with the CC configuration set. We think that these levels can be improved by considering more the configurations excited from the core. For this reason, the effects of Breit effects and QED contributions have been examined for the levels obtained from CC calculations. Breit and QED contributions have been shown to have an effect in reducing to MCDF energies in generally. We have compared our energy level results both theoretical values and experimental values [2-6, 9-13, 16] in Table 2. When the differences (%) in percent between our results and other results are investigated, the differences are generally in range of 0.01- 15.75. In addition, the obtained results from this work have been compared with other previous works in Fig. 1. Linear correlation coefficient R^2 is 0.9995 for MCDF results. It is seen that both differences in percent and Fig.1, there is good agreement between our results and others. The excellent agreement between obtained data in this work and the other works is a strong evidence for reliability of MCDF calculations. Also, the radiative lifetimes have good agreement with comparison values in generally. The results obtained from this work using MCDF method can be useful for describing the spectra of four times ionized xenon.

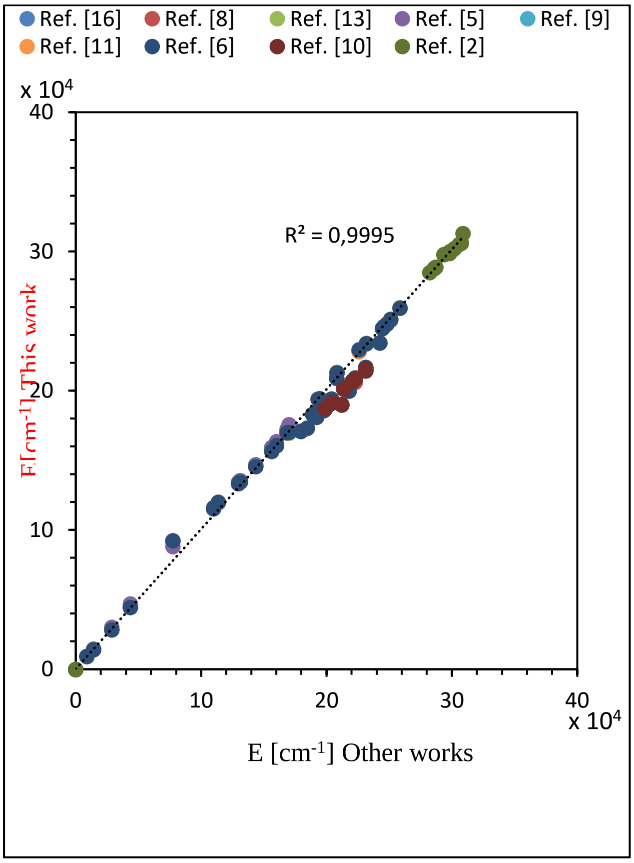

Figure 1 A comparison of energy levels obtained from MCDF calculation with other works.

Table 2
Excitation energies, E [cm^{-1}], and radiative lifetimes, τ [ns], for Xe V. $E^T = E^0 + E^1 + E^2$ (E^T: Total energies, E^0: MCDF energies, E^1: Breit contributions, E^2: QED contributions).

Level	Term	E^0			E_{CC}^1	E_{CC}^2	E_{CC}^T	E_{OW}	τ	$τ_{OW}$
		VV	CV	CC						
$5s^25p^2$	$^3P_0$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-
$5s^25p^2$	$^3P_1$	8727.2	8614.4	9028.4	-169.0	7.49	8866.5	9291.8[a] 9286.3[b] 9300.8[c] 8969.0[d] 9320.0[e] 9290.0[f] 9289[g]	-	-
$5s^25p^2$	$^3P_2$	14203.5	14041.4	14387.3	-211.0	8.76	14184.9	14126.7[a] 14102.5[b] 14150.2[c] 14643.0[d] 14150.0[e] 14142.0[f] 14146[g]	-	-
$5s^25p^2$	$^1D_2$	29416.2	29100.7	29130.6	-355.0	13.9	28789.4	28411.2[a] 28398.6[b] 28387.8[c] 30169.0[d] 28440.0[e] 28402.0[f] 28401[g]	-	-
$5s^25p^2$	$^1S_0$	50556.3	50103.3	44104.9	-372.0	8.8	43741.6	44470.4[a] 44470.7[b] 44476.1[c] 47061.0[d] 44580.0[e] 44471.0[f] 44471[g]	-	-
$5s5p^3$	$^5S^\circ_2$	-	75851.0	77955.5	-181.0	-110.0	77664.8	92182.8[a] 92158.7[b] 92202.7[c] 88033.0[d] 92210.0[e] 92194.0[f] 92194[g]	89.023	34.7[e] 19.3[e] 37.16[g] 39.19[g] 45.55[g] 54.31[g]
$5s5p^3$	$^3D^\circ_1$	-	108629.4	110186.0	-181.0	-94.7	109909.9	115286.3[a] 115298.5[b] 115276.0[c] 115554.0[d] 115300.0[e] 115441.0[f] 115434[g]	3.293	1.87[e] 0.97[e] 1.81[g] 1.97[g] 2.00[g] 2.57[g]
$5s5p^3$	$^3D^\circ_2$	-	109006.8	110569.8	-197.0	-94.6	110278.6	116097.0[a] 116172.7[b] 116021.0[c] 116202.0[d] 116140.0[e] 116138.0[f] 116130[g]	4.473	4.53[e] 1.47[e] 3.01[g] 2.99[g] 3.23[g] 3.91[g]
$5s5p^3$	$^3D^\circ_3$	-	112670.4	114238.6	-282.0	-91.9	113864.7	119919.0[a] 119902.5[b] 119931.7[c] 120152.0[d] 119940.0[e] 119913.0[f] 119906[g]	8.091	6.56[e] 1.82[e] 3.49[g] 3.80[g] 3.77[g] 5.02[g]

Table 2 Continue

$5s5p^3$	$^3P^\circ_0$	-	128907.0	130281.9	-270.0	-93.0	129919.0	133408.1[a] 133417.1[b] 133406.5[c] 134320.0[d] 133488.0[f] 133481[g]	0.717	1.38[g] 1.03[g] 1.46[g] 1.31[g]
$5s5p^3$	$^3P^\circ_1$	-	130086.7	131486.7	-307.0	-90.7	131088.8	134575.2[a] 134616.9[b] 134536.5[c] 135493.0[d] 134507.0[f] 134506[g]	0.726	0.94[g] 0.81[g] 1.02[g] 1.01[g]
$5s5p^3$	$^3P^\circ_2$	-	130215.4	131696.6	-330.0	-79.4	131286.8	134702.7[a] 134654.7[b] 134737.0[c] 135579.0[d] 134710.0[e] 134496.0[f] 134525[g]	1.331	1.55[e] 0.65[e] 1.29[g] 1.28[g] 1.41[g] 1.69[g]
$5s5p^3$	$^1D^\circ_2$	-	196070.2	144204.9	-454.0	-40.4	143710.3	145807.0[a] 145633.8[b] 145976.2[c] 147030.0[d] 145820.0[e] 145525.0[f] 145577[g]	0.033	1.83[e] 0.86[e] 2.03[g] 1.71[g] 2.10[g] 2.28[g]
$5s5p^3$	$^3S^\circ_1$	-	182893.2	179014.4	-378.0	-34.5	178601.7	155518.1[a] 155498.4[b] 155545.3[c] 160672.0[d] 155545.0[e] 155393.0[f] 155402[g]	0.037	0.115[e] 0.049[e] 0.080[g] 0.078[g] 0.092[g]
$5s^25p(^2P^\circ)5d$	$^3F^\circ_2$	152500.1	154600.1	156947.7	-456.0	1.5	156493.0	156506.8[a] 156550.7[b] 156462.7[c] 159419.0[d] 156540.0[e] 156303.0[f] 156525[g]	1.823	1.28[e] 0.68[e] 0.78[h] 1.12[g] 1.04[g] 1.16[g] 1.21[g]
$5s^25p(^2P^\circ)5d$	$^3F^\circ_3$	159084.5	158297.9	160783.7	-511.0	8.3	160280.8	160630.4[a] 160642.4[b] 160663.5[c] 163534.0[d] 160660.0[e] 160677.0[f] 160679[g]	1.202	1.14±0.1[e] 0.69[e] 0.71[h] 0.95[g] 0.96[g] 1.03[g]
$5s^25p(^2P^\circ)5d$	$^3F^\circ_4$	168248.5	166921.4	169311.4	-671.0	14.5	168655.3	169799.4[a] 171311.0[b] 169759.2[c] 172418.0[d] 170055.0[f] 170013[g]	0.000	-
$5s5p^3$	$^1P^\circ_1$	-	169041.8	170435.7	-226.0	-88.4	170120.8	169672.6[a] 169918.3[b] 169435.1[c] 175704.0[d] 170261.0[f] 170155[g]	0.063	0.07[h] 0.082[g] 0.089[g] 0.104[g] 0.099[g]
$5s^25p(^2P^\circ)5d$	$^3P^\circ_2$	174693.5	176915.5	180078.1	-420.0	-13.9	179643.7	170987.6[a] 170941.6[b] 171018.9[c] 171010.0[e] 170919.0[f] 170938[g]	0.039	0.080[e] 0.043[e] 0.04[h] 0.066[g] 0.065[g] 0.072[g] 0.073[g]

Table 2 Continue

$5s^25p(^2P^\circ)5d$	$^3P^\circ_0$	181390.5	186326.4	189568.2	-582.0	2.1	188988.4	183025.2[a] 182986.5[b] 183059.3[c] 182962.0[f] 182980[g]	0.033	0.04[h] 0.062[g] 0.059[g] 0.066[g] 0.064[g]
$5s^25p(^2P^\circ)5d$	$^3P^\circ_1$	182059.8	176150.1	191829.8	-583.0	0.2	191247.1	184147.6[a] 184148.9[b] 184139.3[c] 184255.0[e] 184100.0[f] 184111[g]	0.032	0.087[e] 0.042[e] 0.04[h] 0. 057[g] 0.063[g]
$5s^25p(^2P^\circ)5d$	$^3D^\circ_1$	170959.0	-	185109.7	-437.0	-51.0	184621.3	173071.7[a] 172879.3[b] 173220.1[c] 173063.0[f] 173086[g]	0.036	0.06[h] 0.050[g] 0.053[g] 0.060[g]
$5s^25p(^2P^\circ)5d$	$^3D^\circ_2$	182807.2	189325.4	192640.4	-575.0	-7.9	192057.2	181004.3[a] 180967.9[b] 181050.6[c] 181000.0[e] 181097.0[f] 181084[g]	0.030	0.072[e] 0.034[e] 0.05[h] 0.045[g] 0.051[g] 0.054[g] 0.057[g]
$5s^25p(^2P^\circ)5d$	$^3D^\circ_3$	181680.4	188146.4	191716.9	-587.0	-1.0	191129.1	182167.2[a] 182385.9[b] 181959.0[c] 182165.0[e] 182145.0[f] 182142[g]	3.066	0.071[e] 0.035[e] 0.04[h] 0.048[g] 0.050[g] 0.055[g]
$5s^25p(^2P^\circ)5d$	$^1D^\circ_2$	163261.1	142494.1	198633.1	-500.0	-43.7	198089.3	185795.0[a] 185821.4[b] 185803.9[c] 185800.0[e] 185780.0[f] 185766[g]	2.588	0.083[e] 0.046[e] 0.05[h] 0.059[g] 0.063[g] 0.068[g] 0.070[g]
$5s^25p(^2P^\circ)4f$	$^3G_3$	194244.0	196911.5	199563.8	-452.0	6.2	199117.8	186746.7[a] 186745[b] 186752.3[c] 187089.0[i] 186635.0[f] 186647[g]	2.812	9.9[h]
$5s^25p(^2P^\circ)4f$	$^3G_4$	198414.1	201086.8	203730.0	-524.0	7.0	203213.4	190644.7[a] 190643.0[b] 190712.6[c] 190955.0[i] 190745.0[f] 190719[g]	3.275	-
$5s^25p(^2P^\circ)4f$	$^3G_5$	209909.8	212488.5	215048.1	-722.0	14.5	214340.3	202281.8[a] 203796.0[b] 202517.7[c] 201913.0[i] 202341.0[f] 202311[g]	3.410	-
$5s^25p(^2P^\circ)4f$	$^3F_3$	197438.4	200120.8	212911.5	-660.0	14.1	212265.8	189663.8[a] 189662.0[b] 189876.0[c] 190154.0[i] 189859.0[f] 189841[g]	2.791	9.7[h]
$5s^25p(^2P^\circ)4f$	$^3F_4$	209262.9	211901.6	214490.9	-699.0	14.4	213805.9	201545.2[a] 201554.0[b] 201559.1[c] 201176.0[i] 201629.0[f] 201628[g]	2.975	12.0[h]

Table 2 Continue

$5s^25p(^2P^\circ)4f$	$^3F_2$	199724.8	202448.3	205104.0	-483.0	7.6	204628.3	191603.5[a] 191604.0[b] 191268.2[c] 191545.0[i] 191400.0[f] 191436[g]	2.680	8.8[h]
$5s^25p(^2P^\circ)6s$	$^3P^\circ_0$	193572.3	191186.1	193847.7	-470.0	22.4	193399.7	194033.1[a] 194060.1[b] 194065.0[c] 194105.0[f] 193957[g]	0.620	0.170[g] 0.179[g] 0.158[g]
$5s^25p(^2P^\circ)6s$	$^3P^\circ_1$	193840.3	192410.0	195099.5	-487.0	16.3	194628.8	194232.9[a] 194208.2[b] 194182.5[c] 194190.0[f] 194349	0.152	0.103[g] 0.106[g] 0.101[g]
$5s^25p(^2P^\circ)6s$	$^3P^\circ_2$	208907.7	206010.9	208816.5	-686.0	32.9	208163.9	209068.9[a] 209067.7[b] 209045.5[c] 209100.0[e] 209078.0[f] 209120[g]	0.164	0.163[e] 0.123[e] 0.124[g] 0.121[g] 0.122[g] 0.114[g]
$5s^25p(^2P^\circ)5d$	$^1F^\circ_3$	204496.4	200732.4	204739.8	-662.0	12.2	204090.1	194138.0[a] 194091.8[b] 194190.1[c] 194170.0[e] 194159.0[f] 194156[g]	0.030	0.068[e] 0.033[e] 0.04[h] 0.047[g] 0.046[g] 0.051[g] 0.050[g]
$5s^25p(^2P^\circ)5d$	$^1P^\circ_1$	201407.9	215665.3	218760.4	-607.0	-5.6	218148.1	199959.0[a] 199893.4[b] 200018.4[c] 199730.0[f] 199765[g]	0.036	0.07[h] 0.064[g] 0.075[g] 0.076[g] 0.081[g]
$5s^25p(^2P^\circ)4f$	$^3D_3$	214383.3	217097.4	219662.4	-683.0	13.4	218993.3	205758.8[a] 205762.0[b] 205913.2[c] 205185.0[i] 205942.0[f] 246023[g]	2.645	9.2[h]
$5s^25p(^2P^\circ)4f$	$^3D_2$	216327.2	219045.8	221604.4	-648.0	13.7	220969.6	207366.7[a] 207204.4[c] 206391.0[i] 207261.0[f] 207283[g]	2.498	8.6[h]
$5s^25p(^2P^\circ)4f$	$^3D_1$	218362.7	221018.2	223594.2	-651.0	14.2	222957.5	209310.7[a] 206145.0[b] 209139.1[c] 208139.0[i] 209194.0[f] 209213[g]	2.254	8.3[h]
$5s^25p(^2P^\circ)6s$	$^1P^\circ_1$	214446.1	206113.9	209163.7	-647.0	11.9	208528.4	213040.2[a] 213045.9[b] 213058.2[c] 213135.0[e] 213053.0[f] 213000[g]	0.051	0.097[e] 0.062[e] 0.052[g] 0.057[g] 0.053[g] 0.055[g]
$5s^25p(^2P^\circ)4f$	$^1G_4$	226507.9	229549.8	232078.3	-658.0	13.3	231433.4	214317.7[a] 214323.0[b] 214683.1[c] 214505.0[i] 214380.0[f] 214336[g]	11.831	38.3[h]

Table 2 Continue

$5s^25p(^2P^\circ)4f$	$^1D_2$	227951.6	232327.5	231960.6	-596.0	9.8	231374.3	216745.6[a] 216483.3[c] 215850.0[i] 216701.0[f] 216737[g]	1.047	8.2[h]
$5s^25p(^2P^\circ)6p$	$^3D_1$	226803.1	223517.1	226572.4	-457.0	5.2	226120.6	228064.9[a] 228484.3[c] 228416.0[f] 229428[g]	0.536	-
$5s^25p(^2P^\circ)6p$	$^3D_3$	247274.5	243652.5	246739.3	-722.0	15.0	246032.1	246208.0[a] 246101.9[c] 245966.0[f] 246023[g]	0.445	-
$5s^25p(^2P^\circ)6p$	$^3P_0$	232900.3	229532.7	232308.3	-430.0	4.9	231883.3	233999.3[a] 233755.0[c] 233744.0[f] 233773[g]	0.591	-
$5s^25p(^2P^\circ)6p$	$^3P_1$	233369.5	240312.2	243234.0	-665.0	13.4	242582.4	234455.6[a] 234452.7[c] 234336[f] 234337[g]	0.549	-
$5s^25p(^2P^\circ)6p$	$^3P_2$	245975.3	242575.9	245374.3	-651.0	12.3	244735.1	244821.3[a] 244805.1[c] 244637[f] 244676[g]	0.563	-
$5s^25p(^2P^\circ)6p$	$^3S_1$	249437.6	245749.5	248823.4	-704.0	14.3	248133.8	247810.4[a] 247814.9[c] 247929[f] 247857[g]	0.516	-
$5s^25p(^2P^\circ)6p$	$^1D_2$	252906.1	249435.5	251903.2	-655.0	-0.0	251248.1	250557.2[a] 251227.1[c] 251379[f] 251293[g]	0.546	-
$5s^25p(^2P^\circ)6p$	$^1S_0$	261612.8	256768.9	259320.7	-683.0	9.2	258647.3	259642.3[a] 259642.3[c] 259444[f] 259452[g]	0.628	-
$5s^25p(^2P^\circ)6d$	$^3F^\circ_2$	-	280367.9	282984.7	-514.0	5.4	282476.3	284871[j]	0.364	0.48[j] 0.41[j*]
$5s^25p(^2P^\circ)6d$	$^3P^\circ_2$	-	283811.1	286205.6	-526.0	5.0	285684.8	287391[j] 287420[f]	0.177	0.29[j] 0.23[j*]
$5s^25p(^2P^\circ)6d$	$^3F^\circ_3$	-	283951.0	286516.5	-543.0	6.0	285979.6	287696[j] 288003[f]	0.230	0.53[j] 0.27[j*]
$5s^25p(^2P^\circ)6d$	$^3D^\circ_1$	-	285489.0	287838.8	-501.0	5.3	287343.5	288830[j] 288586[f]	0.118	0.28[j] 0.16[j*]
$5s^25p(^2P^\circ)7s$	$^3P^\circ_0$	-	291068.3	294086.3	-519.0	9.8	293577.5	297673[j]	0.137	0.16[j] 0.19[j*]
$5s^25p(^2P^\circ)7s$	$^3P^\circ_1$	-	291649.6	294668.6	-518.0	9.9	294160.1	298053[j] 298054[f]	0.117	0.15[j] 0.18[j*]
$5s^25p(^2P^\circ)6d$	$^3F^\circ_4$	-	296411.1	299093.3	-764.0	14.3	298343.4	298739[j] 298717[f]	0.542	0.65[j] 0.55[j*]
$5s^25p(^2P^\circ)6d$	$^1D^\circ_2$	-	296386.4	298794.1	-733.0	13.3	298074.9	299596[j] 299417[f]	0.184	0.34[j] 0.21[j*]
$5s^25p(^2P^\circ)6d$	$^3D^\circ_3$	-	297797.4	300183.8	-735.0	13.6	299462.1	300327[j] 300484[f]	0.160	0.28[j] 0.21[j*]
$5s^25p(^2P^\circ)6d$	$^3P^\circ_1$	-	299854.5	302231.6	-723.0	13.6	301522.5	301555[j] 301796[f]	0.161	0.31[j] 0.21[j*]
$5s^25p(^2P^\circ)6d$	$^3P^\circ_0$	-	300325.5	302744.4	-724.0	13.8	302034.3	301998[j] 301794[f]	0.187	0.38[j] 0.25[j*]
$5s^25p(^2P^\circ)6d$	$^1P^\circ_1$	-	305939.1	308411.4	-717.0	13.5	307707.8	306065[j] 306081[f]	0.152	0.35[j] 0.21[j*]
$5s^25p(^2P^\circ)7s$	$^3P^\circ_2$	-	306634.2	309629.5	-744.0	18.4	308904.1	312956[j] 312959[f]	0.161	0.18[j] 0.23[j*]
$5s^25p(^2P^\circ)7s$	$^1P^\circ_1$	-	308382.8	311354.8	-733.0	17.6	310.639	313883[j] 313880[f]	0.086	0.14[j] 0.15[j*]

[a]: Ref. [17], [b]: Ref. [8], [c]: Ref. [13], [d]: Ref. [5], [e]: Ref. [9], [f]: Ref. [11], [g]: Ref. [6], [h]: Ref. [4], [i]: Ref. [10], [j, j*]: Ref. [2]

4. CONCLUSION

The main purpose of this paper is to obtain energy levels and radiative lifetimes for four times ionized xenon (Xe V). I have compared my results in available literature. In this work, the values reported for energy levels and radiative lifetimes can be useful to investigations for these parameters. We hope that these results will be useful for theoretical and experimental works on Xe V spectra in the future.

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The Declaration of Ethics Committee Approval

This study does not require ethics committee permission or any special permission.

The Declaration of Research and Publication Ethics

During the writing process of our study, the information of which is given above, international scientific, ethical and citation rules have been followed, no falsification has been made on the data collected, and Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered. I undertake that I have full responsibility and that this study has not been evaluated in any academic environment other than Sakarya University Journal of Science.

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