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UCRL-JRNL-217878

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P. Quinet, E. Biémont, P. Palmeri, E. Träbert

December 27, 2005

Atomic Data and Nuclear Data Tables

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MULTICONFIGURATION DIRAC-FOCK WAVELENGTHS AND TRANSITION RATES IN THE X-RAY SPECTRA OF HIGHLY CHARGED Ga-LIKE IONS FROM Yb^{39+} TO U^{61+}

Pascal Quinet[1,2], Émile Biémont[1,2], Patrick Palmeri[1] and Elmar Träbert[3]

[1] *Astrophysique et Spectroscopie, Université de Mons-Hainaut, B-7000 Mons, Belgium*

[2] *IPNAS, Sart Tilman B15, Université de Liège, B-4000 Liège, Belgium*

[3] *Physics and Advanced Technologies, Lawrence Livermore National Laboratory, Livermore, CA 94550-9234, USA*

Abstract

A multiconfiguration Dirac-Fock (MCDF) technique has been used for computing the wavelengths and transition probabilities for lines in the X-ray spectra of the gallium-like ions from Yb LX to U LXII. Results are presented for the $4s^24p$–$4s^24d$ and $4s^24p$–$4s4p^2$ allowed transitions (E1) as well as for the forbidden transitions (M1 and E2) within the ground configuration $4s^24p$. A comparison of the calculated wavelengths with the few experimental results available is also presented.

CONTENTS

INTRODUCTION

Interest in investigating the spectra of gallium-like ions has motivated many experimental and theoretical studies during the past several years.

In 1990, Biémont and Quinet [1,2] reported a detailed theoretical investigation of radiative parameters (wavelengths, oscillator strengths, transition probabilities) for the $4s^24p$-$4s^24d$, $4s^24p$-$4s4p^2$, $4s4p^2$-$4p^3$ and $4s^24d$-$4s^24f$ electric dipole transitions belonging to the Br V - In XIX ions along the sequence using a pseudo-relativistic Hartree-Fock (HFR) model combined with a semi-empirical optimization of radial energy integrals (Slater parameters). This work was motivated by the fact that experimental data corresponding to these ionization stages had been obtained [3-16]. In particular, spectra of the Rb VII-Mo XII ions emitted from sparks and laser-produced plasmas had been investigated [11] while some radiative lifetimes measured with beam-foil spectroscopy had been reported for Br V [12], Kr VI [13-15] and Ag XVII [16].

Recently, at the Livermore electron beam ion trap (EBIT) facility, experimental wavelengths have been obtained for some resonance transitions in the X-ray spectra of highly charged Ga-like ions such as W XLIV [17], Os XLVI [18], Au IL [19], Bi LIII, Th LX and U LXII [18]. These new measurements justify a detailed theoretical analysis of radiative parameters for heavy ions ($Z \geq 70$) along the isoelectronic sequence. The new theoretical results will be useful as a test of experimental observations, and their predictive power will be valuable where experimental data are missing. The lines observed in the aforementioned electron beam ion trap work all connect to the true ground level, $4s^24p$ $J=1/2$. This is typical for a low-density light source in which ions have enough time between collisions to decay to the ground state. In other light sources, for example, laser-produced plasmas or foil-excited ion beams, excitations to levels not reached directly from the ground state are expected to show up as well, and our predictions should be helpful in the analysis of those spectra, too.

The theoretical method

The wavelengths and transition probabilities for the $4s^24p$–$4s^24d$ and $4s^24p$–$4s4p^2$ transitions were obtained using the fully relativistic multiconfiguration Dirac-Fock (MCDF) approach with the latest version of GRASP, the General-purpose Relativistic Atomic Structure Package, developed by Norrington [20] from the MCDF original code of Grant and coworkers [21,22] and improved by Dyall *et al.* [23]. The computations were done with the extended average level (EAL) option, optimizing a weighted trace of the Hamiltonian using level weigths proportional to $2J+1$. All of the odd configurations except $4p4f^2$ and $4f^3$ and all of the even configurations except $4s4f^2$ and $4d4f^2$ within the n=4 complex were included in the calculations. These configurations are $4s^24p$, $4s^24f$, 4s4p4d, 4s4d4f, $4p^3$, $4p^24f$, $4p4d^2$, $4d^24f$ and $4s^24d$, $4s4p^2$, 4s4p4f, $4s4d^2$, $4p^24d$, 4p4d4f, $4d^3$ for the odd and even parities, respectively, and generate a total of 437 relativistic configuration state functions (CSFs). The calculations were completed with the inclusion of the relativistic two-body Breit interaction and of the quantum electrodynamic corrections (QED) due to self-energy and vacuum polarization. For each ion, the nuclear effects were estimated by considering the most abundant isotope.

Energy levels

The energy level values obtained using the MCDF method hereabove described for the $4s^24p$, $4s^24d$ and $4s4p^2$ configurations in Ga-like ions are presented in Table 1. The main components of the computed eigenvectors in both the jj-coupling and the LS-coupling schemes are also given in that table. In the jj-coupling scheme, basis functions are formed by first coupling the spin s of each electron to its own orbital angular momentum l and then coupling together the various resultants $j_{\pm}=l\pm1/2$ to obtain the total angular momentum J. In the notations adopted in the present paper, the subscript - corresponds to the case $j_{-}=l$-1/2 while no subscript is given for $j_{+}=l+1/2$. As expected for such highly ionized atoms, the jj-coupling appears much more adequate than the LS one. Indeed, the average jj purities obtained in our calculations for the $4s^24p$, $4s^24d$ and $4s4p^2$ configurations were found to range from 88% (in Yb XL) to 95% (in U LXII) while the corresponding average LS purities were found to be equal to 74% and 75%, respectively.

Wavelengths and transition probabilities

The MCDF wavelengths and transition probabilities are reported in Table 2 for $4s^24p$-$4s^24d$ and $4s^24p$-$4s4p^2$ electric dipole (E1) transitions in Yb XL to U LXII while magnetic dipole (M1) and electric quadrupole (E2) transitions within the $4s^24p$ ground configuration are presented in Table 3. The spectroscopic designations of the levels are given in the relativistic *jj* coupling, this designation being much more adequate than the *LS* one for the highly ionized atoms considered in the present work, as already mentioned in the previous section.

The calculated wavelengths are compared with the few measured values where they exist. A more detailed comparison along the sequence is illustrated in Fig. 1 for the $4s^24p_-$ J=1/2 – $4s^24d_-$ J'=3/2, $4s^24p_-$ J=1/2 – $4s4p_-4p$ J'=1/2 and $4s^24p_-$ J=1/2 – $4s4p_-4p$ J'=3/2 transitions. In fact, for the ions considered in the present work, wavelengths were measured experimentally only for W XLIV, Os XLVI, Au IL, Bi LIII, Th LX and U LXII. As seen on this figure, the behaviour of the differences $\Delta\lambda$ is very smooth for the first two transitions along the sequence while, for the third one, some irregularities are observed. These irregularities could probably be due to the blends affecting this line for Au IL, Th LX and U LXII, as mentioned in Refs [18,19].

When comparing the MCDF transition probabilities obtained in the Babushkin (length) and the Coulomb (velocity) gauges (Table 2), we can observe a very nice agreement (within 10%) for all the ions considered in the present work. The only exceptions occur for the transition $4s^24p$ J=3/2 – $4s^24d_-$ J'=3/2 in the ions Yb XL, Lu XLI and Hf XLII and for the transition $4s^24p_-$ J=1/2 – $4s4p^2$ J'=3/2 in the ions Os XLVI – U LXII. For the electric quadrupole (E2) transition within the $4s^24p$ ground configuration (Table 3), the agreement between both gauges was found to be excellent, the difference between both gauges being smaller than 1% for all the ions considered.

Acknowledgments. P.Q., P.P. and E.B. are respectively Research Associates and Research Director of the Belgian National Fund for Scientific Research (FNRS). This organization is acknowledged for financial support. E.T. thanks the German Research Association DFG for support. Part of this work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

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EXPLANATION OF TABLES

TABLE 1. MCDF energy levels for the $4s^24p$, $4s^24d$ and $4s4p^2$ configurations in Ga-like ions Yb XL – U LXII.

Level	MCDF energy level value in cm^{-1}
jj-coupling purity	Main contribution in jj-coupling (in %)
	The subscript - corresponds to j_-=l-1/2
	while no subscript is given for j_+=l+1/2
LS-coupling purity	Main contribution in LS-coupling (in %)

TABLE 2. Wavelengths and transition probabilities for lines in Ga-like ions Yb XL – U LXII.

λ (Å)	Wavelength in Ångströms
A_{ki} (s^{-1})	Transition probability in s^{-1}
EXP	Experiment
MCDF(B)	Babushkin (length) gauge
MCDF(C)	Coulomb (velocity) gauge

TABLE 3. Wavelengths and transition probabilities for forbidden lines within the ground configuration of Ga-like ions.

λ (Å)	MCDF wavelength in Ångströms
A_{ki} (s^{-1})	MCDF transition probability in s^{-1}
M1	Magnetic dipole radiation
E2	Electric quadrupole radiation

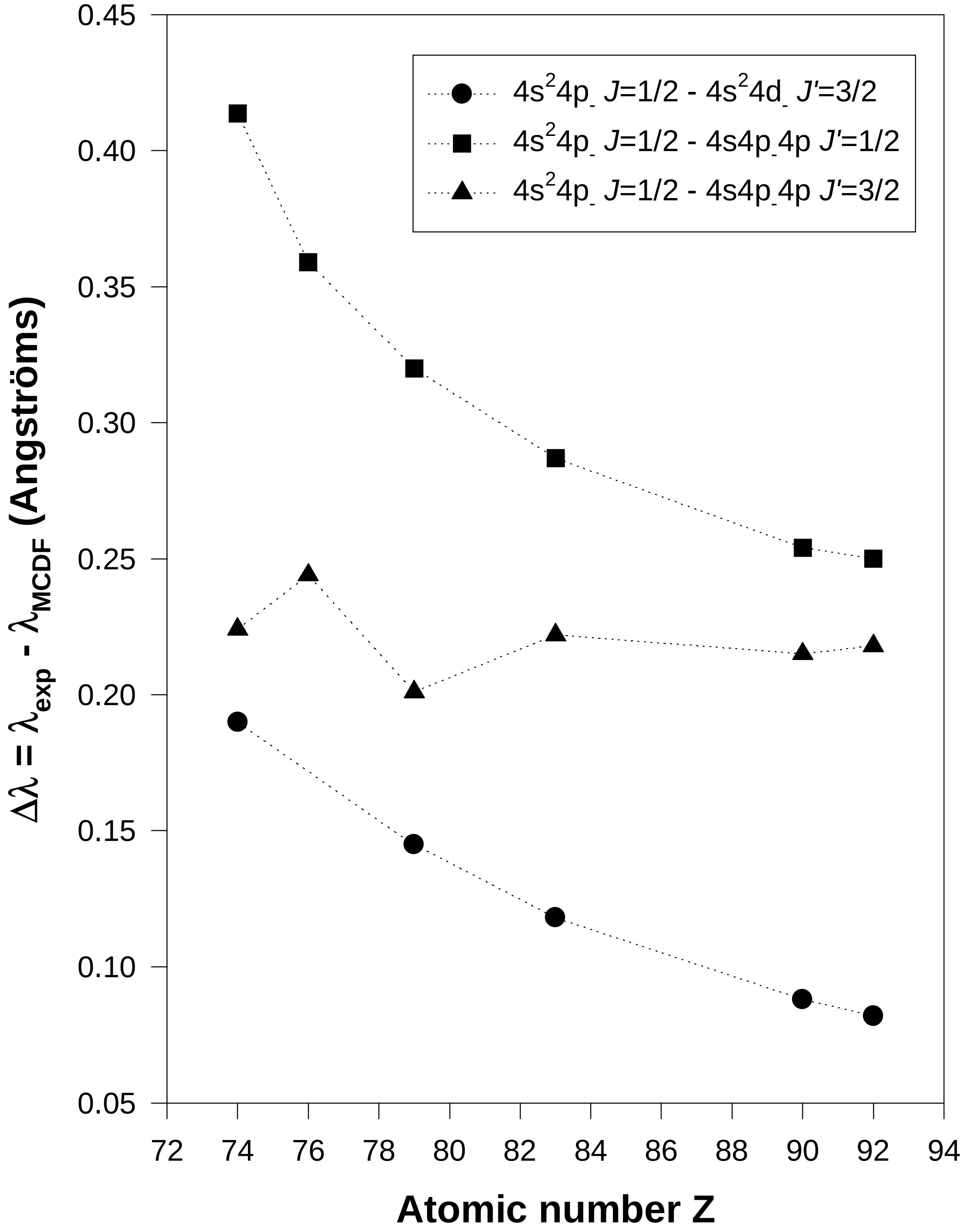

Figure 1: Comparison between experimental and calculated wavelengths for transitions along the gallium isoelectronic sequence.

Table 1. MCDF energy levels for the $4s^24p$, $4s^24d$ and $4s4p^2$ configurations in Ga-like ions Yb XL – U LXII.

Ion	Level (cm^{-1})	jj-coupling purity	LS-coupling purity
Yb XL	0	99% $4s^24p_-$ J=1/2	99% $4s^24p$ $^2P_{1/2}$
	586706	99% $4s^24p$ J=3/2	99% $4s^24p$ $^2P_{3/2}$
	702543	96% $4s4p^2_-$ J=1/2	61% $4s4p^2$ $^4P_{1/2}$
	1190724	90% $4s4p_-4p$ J=3/2	92% $4s4p^2$ $^4P_{3/2}$
	1254381	97% $4s4p_-4p$ J=5/2	55% $4s4p^2$ $^2D_{5/2}$
	1346838	86% $4s4p_-4p$ J=3/2	66% $4s4p^2$ $^2D_{3/2}$
	1373014	95% $4s4p_-4p$ J=1/2	71% $4s4p^2$ $^2P_{1/2}$
	1771920	90% $4s^24d_-$ J=3/2	90% $4s^24d$ $^2D_{3/2}$
	1782255	75% $4s4p^2$ J=5/2	47% $4s4p^2$ $^4P_{5/2}$
	1935978	73% $4s^24d$ J=5/2	73% $4s^24d$ $^2D_{5/2}$
	1958475	98% $4s4p^2$ J=1/2	69% $4s4p^2$ $^2S_{1/2}$
	1992789	93% $4s4p^2$ J=3/2	61% $4s4p^2$ $^2P_{3/2}$
Lu XLI	0	99% $4s^24p_-$ J=1/2	99% $4s^24p$ $^2P_{1/2}$
	633292	99% $4s^24p$ J=3/2	99% $4s^24p$ $^2P_{3/2}$
	722990	97% $4s4p^2_-$ J=1/2	60% $4s4p^2$ $^4P_{1/2}$
	1254730	73% $4s4p_-4p$ J=3/2	92% $4s4p^2$ $^4P_{3/2}$
	1320019	97% $4s4p_-4p$ J=5/2	56% $4s4p^2$ $^2D_{5/2}$
	1414441	69% $4s4p_-4p$ J=3/2	65% $4s4p^2$ $^2D_{3/2}$
	1440188	95% $4s4p_-4p$ J=1/2	71% $4s4p^2$ $^2P_{1/2}$
	1848573	91% $4s^24d_-$ J=3/2	91% $4s^24d$ $^2D_{3/2}$
	1884903	68% $4s4p^2$ J=5/2	38% $4s4p^2$ $^4P_{5/2}$
	2029477	66% $4s^24d$ J=5/2	66% $4s^24d$ $^2D_{5/2}$
	2072108	98% $4s4p^2$ J=1/2	69% $4s4p^2$ $^2S_{1/2}$
	2105802	94% $4s4p^2$ J=3/2	62% $4s4p^2$ $^2P_{3/2}$
Hf XLII	0	99% $4s^24p_-$ J=1/2	99% $4s^24p$ $^2P_{1/2}$
	682765	99% $4s^24p$ J=3/2	99% $4s^24p$ $^2P_{3/2}$
	743635	97% $4s4p^2_-$ J=1/2	59% $4s4p^2$ $^4P_{1/2}$
	1321833	73% $4s4p_-4p$ J=3/2	91% $4s4p^2$ $^4P_{3/2}$
	1388754	97% $4s4p_-4p$ J=5/2	56% $4s4p^2$ $^2D_{5/2}$
	1485135	69% $4s4p_-4p$ J=3/2	65% $4s4p^2$ $^2D_{3/2}$
	1510489	96% $4s4p_-4p$ J=1/2	71% $4s4p^2$ $^2P_{1/2}$
	1927980	92% $4s^24d_-$ J=3/2	92% $4s^24d$ $^2D_{3/2}$
	1990418	59% $4s4p^2$ J=5/2	41% $4s4p^2$ $^2D_{5/2}$
	2129654	57% $4s^24d$ J=5/2	57% $4s^24d$ $^2D_{5/2}$
	2191742	98% $4s4p^2$ J=1/2	69% $4s4p^2$ $^2S_{1/2}$
	2225036	95% $4s4p^2$ J=3/2	62% $4s4p^2$ $^2P_{3/2}$

Table 1. Continued.

Ion	Level (cm^{-1})	jj-coupling purity	LS-coupling purity
Ta XLIII	0	99% $4s^24p_-$ J=1/2	99% $4s^24p$ $^2P_{1/2}$
	735267	99% $4s^24p$ J=3/2	99% $4s^24p$ $^2P_{3/2}$
	764486	97% $4s4p_-^2$ J=1/2	59% $4s4p^2$ $^4P_{1/2}$
	1392182	73% $4s4p_-4p$ J=3/2	91% $4s4p^2$ $^4P_{3/2}$
	1460734	97% $4s4p_-4p$ J=5/2	57% $4s4p^2$ $^2D_{5/2}$
	1559068	69% $4s4p_-4p$ J=3/2	64% $4s4p^2$ $^2D_{3/2}$
	1584065	96% $4s4p_-4p$ J=1/2	70% $4s4p^2$ $^2P_{1/2}$
	2010342	92% $4s^24d_-$ J=3/2	92% $4s^24d$ $^2D_{3/2}$
	2098062	51% $4s^24d$ J=5/2	51% $4s^24d$ $^2D_{5/2}$
	2237704	51% $4s4p^2$ J=5/2	46% $4s4p^2$ $^2D_{5/2}$
	2317668	98% $4s4p^2$ J=1/2	69% $4s4p^2$ $^2S_{1/2}$
	2350728	95% $4s4p^2$ J=3/2	63% $4s4p^2$ $^2P_{3/2}$
W XLIV	0	99% $4s^24p_-$ J=1/2	99% $4s^24p$ $^2P_{1/2}$
	785552	98% $4s4p_-^2$ J=1/2	58% $4s4p^2$ $^4P_{1/2}$
	790945	99% $4s^24p$ J=3/2	99% $4s^24p$ $^2P_{3/2}$
	1465933	73% $4s4p_-4p$ J=3/2	91% $4s4p^2$ $^4P_{3/2}$
	1536118	96% $4s4p_-4p$ J=5/2	57% $4s4p^2$ $^2D_{5/2}$
	1636396	70% $4s4p_-4p$ J=3/2	64% $4s4p^2$ $^2D_{3/2}$
	1661071	97% $4s4p_-4p$ J=1/2	70% $4s4p^2$ $^2P_{1/2}$
	2095846	93% $4s^24d_-$ J=3/2	93% $4s^24d$ $^2D_{3/2}$
	2207272	62% $4s^24d$ J=5/2	62% $4s^24d$ $^2D_{5/2}$
	2354670	62% $4s4p^2$ J=5/2	35% $4s4p^2$ $^2D_{5/2}$
	2450190	98% $4s4p^2$ J=1/2	69% $4s4p^2$ $^2S_{1/2}$
	2483144	96% $4s4p^2$ J=3/2	63% $4s4p^2$ $^2P_{3/2}$
Re XLV	0	99% $4s^24p_-$ J=1/2	99% $4s^24p$ $^2P_{1/2}$
	806842	98% $4s4p_-^2$ J=1/2	57% $4s4p^2$ $^4P_{1/2}$
	849955	99% $4s^24p$ J=3/2	99% $4s^24p$ $^2P_{3/2}$
	1543250	73% $4s4p_-4p$ J=3/2	91% $4s4p^2$ $^4P_{3/2}$
	1615068	98% $4s4p_-4p$ J=5/2	58% $4s4p^2$ $^2D_{5/2}$
	1717281	70% $4s4p_-4p$ J=3/2	63% $4s4p^2$ $^2D_{3/2}$
	1741670	97% $4s4p_-4p$ J=1/2	70% $4s4p^2$ $^2P_{1/2}$
	2184678	93% $4s^24d_-$ J=3/2	93% $4s^24d$ $^2D_{3/2}$
	2317956	72% $4s^24d$ J=5/2	72% $4s^24d$ $^2D_{5/2}$
	2481142	72% $4s4p^2$ J=5/2	38% $4s4p^2$ $^4P_{5/2}$
	2589625	98% $4s4p^2$ J=1/2	69% $4s4p^2$ $^2S_{1/2}$
	2622574	97% $4s4p^2$ J=3/2	63% $4s4p^2$ $^2P_{3/2}$

Table 1. Continued.

Ion	Level (cm^{-1})	jj-coupling purity	LS-coupling purity
Os XLVI	0	99% 4s^{2}4p$_-$ J=1/2	99% 4s^{2}4p ^{2}P$_{1/2}$
	828366	98% 4s4p$^2_-$ J=1/2	57% 4s4p^2 ^{4}P$_{1/2}$
	912457	99% 4s^{2}4p J=3/2	99% 4s^{2}4p ^{2}P$_{3/2}$
	1624302	73% 4s4p$_-$4p J=3/2	91% 4s4p^2 ^{4}P$_{3/2}$
	1697755	98% 4s4p$_-$4p J=5/2	58% 4s4p^2 ^{2}D$_{5/2}$
	1801894	70% 4s4p$_-$4p J=3/2	63% 4s4p^2 ^{2}D$_{3/2}$
	1826032	97% 4s4p$_-$4p J=1/2	70% 4s4p^2 ^{2}P$_{1/2}$
	2277021	93% 4s^{2}4d$_-$ J=3/2	93% 4s^{2}4d ^{2}D$_{3/2}$
	2430516	79% 4s^{2}4d J=5/2	79% 4s^{2}4d ^{2}D$_{5/2}$
	2617237	80% 4s4p^2 J=5/2	44% 4s4p^2 ^{4}P$_{5/2}$
	2736303	98% 4s4p^2 J=1/2	69% 4s4p^2 ^{2}S$_{1/2}$
	2769328	97% 4s4p^2 J=3/2	63% 4s4p^2 ^{2}P$_{3/2}$
Ir XLVII	0	99% 4s^{2}4p$_-$ J=1/2	99% 4s^{2}4p ^{2}P$_{1/2}$
	850135	98% 4s4p$^2_-$ J=1/2	56% 4s4p^2 ^{4}P$_{1/2}$
	978619	99% 4s^{2}4p J=3/2	99% 4s^{2}4p ^{2}P$_{3/2}$
	1709267	74% 4s4p$_-$4p J=3/2	91% 4s4p^2 ^{4}P$_{3/2}$
	1784357	98% 4s4p$_-$4p J=5/2	58% 4s4p^2 ^{2}D$_{5/2}$
	1890412	70% 4s4p$_-$4p J=3/2	62% 4s4p^2 ^{2}D$_{3/2}$
	1914333	97% 4s4p$_-$4p J=1/2	70% 4s4p^2 ^{2}P$_{1/2}$
	2373062	94% 4s^{2}4d$_-$ J=3/2	94% 4s^{2}4d ^{2}D$_{3/2}$
	2545616	85% 4s^{2}4d J=5/2	85% 4s^{2}4d ^{2}D$_{5/2}$
	2762835	85% 4s4p^2 J=5/2	48% 4s4p^2 ^{4}P$_{5/2}$
	2890572	99% 4s4p^2 J=1/2	69% 4s4p^2 ^{2}S$_{1/2}$
	2923736	97% 4s4p^2 J=3/2	62% 4s4p^2 ^{2}P$_{3/2}$
Pt XLVIII	0	99% 4s^{2}4p$_-$ J=1/2	99% 4s^{2}4p ^{2}P$_{1/2}$
	872159	98% 4s4p$^2_-$ J=1/2	56% 4s4p^2 ^{4}P$_{1/2}$
	1048619	99% 4s^{2}4p J=3/2	99% 4s^{2}4p ^{2}P$_{3/2}$
	1798330	74% 4s4p$_-$4p J=3/2	90% 4s4p^2 ^{4}P$_{3/2}$
	1875062	98% 4s4p$_-$4p J=5/2	59% 4s4p^2 ^{2}D$_{5/2}$
	1983020	71% 4s4p$_-$4p J=3/2	62% 4s4p^2 ^{2}D$_{3/2}$
	2006758	98% 4s4p$_-$4p J=1/2	70% 4s4p^2 ^{2}P$_{1/2}$
	2472993	94% 4s^{2}4d$_-$ J=3/2	94% 4s^{2}4d ^{2}D$_{3/2}$
	2663944	88% 4s^{2}4d J=5/2	88% 4s^{2}4d ^{2}D$_{5/2}$
	2917814	89% 4s4p^2 J=5/2	51% 4s4p^2 ^{4}P$_{5/2}$
	3052792	99% 4s4p^2 J=1/2	69% 4s4p^2 ^{2}S$_{1/2}$
	3086149	97% 4s4p^2 J=3/2	62% 4s4p^2 ^{2}P$_{3/2}$

Table 1. Continued.

Ion	Level (cm^{-1})	jj-coupling purity	LS-coupling purity
Au IL	0	99% $4s^24p_-$ J=1/2	99% $4s^24p$ $^2P_{1/2}$
	894450	98% $4s4p_-^2$ J=1/2	55% $4s4p^2$ $^4P_{1/2}$
	1122641	99% $4s^24p$ J=3/2	99% $4s^24p$ $^2P_{3/2}$
	1891687	74% $4s4p_-4p$ J=3/2	90% $4s4p^2$ $^4P_{3/2}$
	1970063	98% $4s4p_-4p$ J=5/2	59% $4s4p^2$ $^2D_{5/2}$
	2079911	71% $4s4p_-4p$ J=3/2	61% $4s4p^2$ $^2D_{3/2}$
	2103501	98% $4s4p_-4p$ J=1/2	70% $4s4p^2$ $^2P_{1/2}$
	2577007	94% $4s^24d_-$ J=3/2	94% $4s^24d$ $^2D_{3/2}$
	2786108	91% $4s^24d$ J=5/2	91% $4s^24d$ $^2D_{5/2}$
	3082158	92% $4s4p^2$ J=5/2	53% $4s4p^2$ $^4P_{5/2}$
	3223343	99% $4s4p^2$ J=1/2	68% $4s4p^2$ $^2S_{1/2}$
	3256935	98% $4s4p^2$ J=3/2	62% $4s4p^2$ $^2P_{3/2}$
Hg L	0	99% $4s^24p_-$ J=1/2	99% $4s^24p$ $^2P_{1/2}$
	917019	99% $4s4p_-^2$ J=1/2	55% $4s4p^2$ $^4P_{1/2}$
	1200876	99% $4s^24p$ J=3/2	99% $4s^24p$ $^2P_{3/2}$
	1989540	74% $4s4p_-4p$ J=3/2	90% $4s4p^2$ $^4P_{3/2}$
	2069565	98% $4s4p_-4p$ J=5/2	56% $4s4p^2$ $^2D_{5/2}$
	2181290	71% $4s4p_-4p$ J=3/2	61% $4s4p^2$ $^2D_{3/2}$
	2204766	98% $4s4p_-4p$ J=1/2	70% $4s4p^2$ $^2P_{1/2}$
	2685310	94% $4s^24d_-$ J=3/2	94% $4s^24d$ $^2D_{3/2}$
	2912617	93% $4s^24d$ J=5/2	93% $4s^24d$ $^2D_{5/2}$
	3255978	94% $4s4p^2$ J=5/2	55% $4s4p^2$ $^4P_{5/2}$
	3402620	99% $4s4p^2$ J=1/2	68% $4s4p^2$ $^2S_{1/2}$
	3436484	98% $4s4p^2$ J=3/2	62% $4s4p^2$ $^2P_{3/2}$
Tl LI	0	99% $4s^24p_-$ J=1/2	99% $4s^24p$ $^2P_{1/2}$
	939879	98% $4s4p_-^2$ J=1/2	54% $4s4p^2$ $^4P_{1/2}$
	1283529	99% $4s^24p$ J=3/2	99% $4s^24p$ $^2P_{3/2}$
	2092104	74% $4s4p_-4p$ J=3/2	90% $4s4p^2$ $^4P_{3/2}$
	2173782	98% $4s4p_-4p$ J=5/2	60% $4s4p^2$ $^2D_{5/2}$
	2287368	71% $4s4p_-4p$ J=3/2	61% $4s4p^2$ $^2D_{3/2}$
	2310763	98% $4s4p_-4p$ J=1/2	68% $4s4p^2$ $^2P_{1/2}$
	2798110	94% $4s^24d_-$ J=3/2	94% $4s^24d$ $^2D_{3/2}$
	3043906	94% $4s^24d$ J=5/2	94% $4s^24d$ $^2D_{5/2}$
	3439485	95% $4s4p^2$ J=5/2	56% $4s4p^2$ $^4P_{5/2}$
	3591039	99% $4s4p^2$ J=1/2	68% $4s4p^2$ $^2S_{1/2}$
	3625203	98% $4s4p^2$ J=3/2	62% $4s4p^2$ $^2P_{3/2}$

Table 1. Continued.

Ion	Level (cm^{-1})	jj-coupling purity	LS-coupling purity
Pb LII	0	99% $4s^24p_-$ J=1/2	99% $4s^24p$ $^2P_{1/2}$
	963042	99% $4s4p_-^2$ J=1/2	54% $4s4p^2$ $^4P_{1/2}$
	1370809	99% $4s^24p$ J=3/2	99% $4s^24p$ $^2P_{3/2}$
	2199601	74% $4s4p_-4p$ J=3/2	90% $4s4p^2$ $^4P_{3/2}$
	2282937	98% $4s4p_-4p$ J=5/2	60% $4s4p^2$ $^2D_{5/2}$
	2398368	71% $4s4p_-4p$ J=3/2	60% $4s4p^2$ $^2D_{3/2}$
	2421715	98% $4s4p_-4p$ J=1/2	69% $4s4p^2$ $^2P_{1/2}$
	2915626	94% $4s^24d_-$ J=3/2	94% $4s^24d$ $^2D_{3/2}$
	3180360	95% $4s^24d$ J=5/2	95% $4s^24d$ $^2D_{5/2}$
	3632971	96% $4s4p^2$ J=5/2	57% $4s4p^2$ $^4P_{5/2}$
	3789034	99% $4s4p^2$ J=1/2	68% $4s4p^2$ $^2S_{1/2}$
	3823523	98% $4s4p^2$ J=3/2	61% $4s4p^2$ $^2P_{3/2}$
Bi LIII	0	99% $4s^24p_-$ J=1/2	99% $4s^24p$ $^2P_{1/2}$
	986522	99% $4s4p_-^2$ J=1/2	53% $4s4p^2$ $^4P_{1/2}$
	1462940	99% $4s^24p$ J=3/2	99% $4s^24p$ $^2P_{3/2}$
	2312266	74% $4s4p_-4p$ J=3/2	90% $4s4p^2$ $^4P_{3/2}$
	2397264	98% $4s4p_-4p$ J=5/2	60% $4s4p^2$ $^2D_{5/2}$
	2514523	72% $4s4p_-4p$ J=3/2	60% $4s4p^2$ $^2D_{3/2}$
	2537856	98% $4s4p_-4p$ J=1/2	69% $4s4p^2$ $^2P_{1/2}$
	3038087	94% $4s^24d_-$ J=3/2	94% $4s^24d$ $^2D_{3/2}$
	3322331	96% $4s^24d$ J=5/2	96% $4s^24d$ $^2D_{5/2}$
	3836794	97% $4s4p^2$ J=5/2	58% $4s4p^2$ $^4P_{5/2}$
	3997061	99% $4s4p^2$ J=1/2	68% $4s4p^2$ $^2S_{1/2}$
	4031893	98% $4s4p^2$ J=3/2	61% $4s4p^2$ $^2P_{3/2}$
Po LIV	0	99% $4s^24p_-$ J=1/2	99% $4s^24p$ $^2P_{1/2}$
	1010332	99% $4s4p_-^2$ J=1/2	53% $4s4p^2$ $^4P_{1/2}$
	1560153	99% $4s^24p$ J=3/2	99% $4s^24p$ $^2P_{3/2}$
	2430345	75% $4s4p_-4p$ J=3/2	89% $4s4p^2$ $^4P_{3/2}$
	2517011	98% $4s4p_-4p$ J=5/2	61% $4s4p^2$ $^2D_{5/2}$
	2636077	72% $4s4p_-4p$ J=3/2	60% $4s4p^2$ $^2D_{3/2}$
	2659431	98% $4s4p_-4p$ J=1/2	69% $4s4p^2$ $^2P_{1/2}$
	3165731	94% $4s^24d_-$ J=3/2	94% $4s^24d$ $^2D_{3/2}$
	3470156	96% $4s^24d$ J=5/2	96% $4s^24d$ $^2D_{5/2}$
	4051359	97% $4s4p^2$ J=5/2	59% $4s4p^2$ $^4P_{5/2}$
	4215598	99% $4s4p^2$ J=1/2	68% $4s4p^2$ $^2S_{1/2}$
	4250789	98% $4s4p^2$ J=3/2	61% $4s4p^2$ $^2P_{3/2}$

Table 1. Continued.

Ion	Level (cm^{-1})	jj-coupling purity	LS-coupling purity
At LV	0	99% $4s^24p_-$ J=1/2	99% $4s^24p$ $^2P_{1/2}$
	1034488	99% $4s4p^2_-$ J=1/2	53% $4s4p^2$ $^4P_{1/2}$
	1662693	99% $4s^24p$ J=3/2	99% $4s^24p$ $^2P_{3/2}$
	2554095	75% $4s4p_-4p$ J=3/2	89% $4s4p^2$ $^4P_{3/2}$
	2642434	98% $4s4p_-4p$ J=5/2	61% $4s4p^2$ $^2D_{5/2}$
	2763287	72% $4s4p_-4p$ J=3/2	59% $4s4p^2$ $^2D_{3/2}$
	2786695	99% $4s4p_-4p$ J=1/2	69% $4s4p^2$ $^2P_{1/2}$
	3298806	94% $4s^24d_-$ J=3/2	94% $4s^24d$ $^2D_{3/2}$
	3624163	97% $4s^24d$ J=5/2	97% $4s^24d$ $^2D_{5/2}$
	4277117	98% $4s4p^2$ J=5/2	59% $4s4p^2$ $^4P_{5/2}$
	4445146	99% $4s4p^2$ J=1/2	68% $4s4p^2$ $^2S_{1/2}$
	4480707	99% $4s4p^2$ J=3/2	61% $4s4p^2$ $^2P_{3/2}$
Rn LVI	0	99% $4s^24p_-$ J=1/2	99% $4s^24p$ $^2P_{1/2}$
	1059005	99% $4s4p^2_-$ J=1/2	52% $4s4p^2$ $^4P_{1/2}$
	1770818	99% $4s^24p$ J=3/2	99% $4s^24p$ $^2P_{3/2}$
	2683788	75% $4s4p_-4p$ J=3/2	89% $4s4p^2$ $^4P_{3/2}$
	2773806	98% $4s4p_-4p$ J=5/2	61% $4s4p^2$ $^2D_{5/2}$
	2896424	72% $4s4p_-4p$ J=3/2	59% $4s4p^2$ $^2D_{3/2}$
	2919920	99% $4s4p_-4p$ J=1/2	69% $4s4p^2$ $^2P_{1/2}$
	3437576	94% $4s^24d_-$ J=3/2	94% $4s^24d$ $^2D_{3/2}$
	3784681	97% $4s^24d$ J=5/2	97% $4s^24d$ $^2D_{5/2}$
	4514557	98% $4s4p^2$ J=5/2	60% $4s4p^2$ $^4P_{5/2}$
	4686233	99% $4s4p^2$ J=1/2	68% $4s4p^2$ $^2S_{1/2}$
	4722173	99% $4s4p^2$ J=3/2	61% $4s4p^2$ $^2P_{3/2}$
Fr LVII	0	99% $4s^24p_-$ J=1/2	99% $4s^24p$ $^2P_{1/2}$
	1083898	99% $4s4p^2_-$ J=1/2	52% $4s4p^2$ $^4P_{1/2}$
	1884795	99% $4s^24p$ J=3/2	99% $4s^24p$ $^2P_{3/2}$
	2819708	75% $4s4p_-4p$ J=3/2	89% $4s4p^2$ $^4P_{3/2}$
	2911410	99% $4s4p_-4p$ J=5/2	61% $4s4p^2$ $^2D_{5/2}$
	3035769	72% $4s4p_-4p$ J=3/2	59% $4s4p^2$ $^2D_{3/2}$
	3059388	99% $4s4p_-4p$ J=1/2	69% $4s4p^2$ $^2P_{1/2}$
	3582312	94% $4s^24d_-$ J=3/2	94% $4s^24d$ $^2D_{3/2}$
	3952041	97% $4s^24d$ J=5/2	97% $4s^24d$ $^2D_{5/2}$
	4764203	98% $4s4p^2$ J=5/2	60% $4s4p^2$ $^4P_{5/2}$
	4939411	99% $4s4p^2$ J=1/2	68% $4s4p^2$ $^2S_{1/2}$
	4975736	99% $4s4p^2$ J=3/2	60% $4s4p^2$ $^2P_{3/2}$

Table 1. Continued.

Ion	Level (cm^{-1})	jj-coupling purity	LS-coupling purity
Ra LVIII	0	99% $4s^24p_-$ J=1/2	99% $4s^24p$ $^2P_{1/2}$
	1109186	99% $4s4p_-^2$ J=1/2	51% $4s4p^2$ $^4P_{1/2}$
	2004909	99% $4s^24p$ J=3/2	99% $4s^24p$ $^2P_{3/2}$
	2962155	75% $4s4p_-4p$ J=3/2	89% $4s4p^2$ $^4P_{3/2}$
	3055547	99% $4s4p_-4p$ J=5/2	62% $4s4p^2$ $^2D_{5/2}$
	3181621	72% $4s4p_-4p$ J=3/2	58% $4s4p^2$ $^2D_{3/2}$
	3205398	99% $4s4p_-4p$ J=1/2	69% $4s4p^2$ $^2P_{1/2}$
	3733302	94% $4s^24d_-$ J=3/2	94% $4s^24d$ $^2D_{3/2}$
	4126583	97% $4s^24d$ J=5/2	97% $4s^24d$ $^2D_{5/2}$
	5026617	99% $4s4p^2$ J=5/2	61% $4s4p^2$ $^4P_{5/2}$
	5205265	99% $4s4p^2$ J=1/2	68% $4s4p^2$ $^2S_{1/2}$
	5241974	99% $4s4p^2$ J=3/2	60% $4s4p^2$ $^2P_{3/2}$
Ac LIX	0	99% $4s^24p_-$ J=1/2	99% $4s^24p$ $^2P_{1/2}$
	1134885	99% $4s4p_-^2$ J=1/2	51% $4s4p^2$ $^4P_{1/2}$
	2131459	99% $4s^24p$ J=3/2	99% $4s^24p$ $^2P_{3/2}$
	3111444	75% $4s4p_-4p$ J=3/2	89% $4s4p^2$ $^4P_{3/2}$
	3206533	99% $4s4p_-4p$ J=5/2	62% $4s4p^2$ $^2D_{5/2}$
	3334294	72% $4s4p_-4p$ J=3/2	58% $4s4p^2$ $^2D_{3/2}$
	3358264	99% $4s4p_-4p$ J=1/2	69% $4s4p^2$ $^2P_{1/2}$
	3890849	94% $4s^24d_-$ J=3/2	94% $4s^24d$ $^2D_{3/2}$
	4308657	98% $4s^24d$ J=5/2	98% $4s^24d$ $^2D_{5/2}$
	5302394	99% $4s4p^2$ J=5/2	61% $4s4p^2$ $^4P_{5/2}$
	5484406	99% $4s4p^2$ J=1/2	68% $4s4p^2$ $^2S_{1/2}$
	5521499	99% $4s4p^2$ J=3/2	60% $4s4p^2$ $^2P_{3/2}$
Th LX	0	99% $4s^24p_-$ J=1/2	99% $4s^24p$ $^2P_{1/2}$
	1161016	99% $4s4p_-^2$ J=1/2	51% $4s4p^2$ $^4P_{1/2}$
	2264758	99% $4s^24p$ J=3/2	99% $4s^24p$ $^2P_{3/2}$
	3267909	75% $4s4p_-4p$ J=3/2	89% $4s4p^2$ $^4P_{3/2}$
	3364700	99% $4s4p_-4p$ J=5/2	62% $4s4p^2$ $^2D_{5/2}$
	3494118	73% $4s4p_-4p$ J=3/2	58% $4s4p^2$ $^2D_{3/2}$
	3518317	99% $4s4p_-4p$ J=1/2	69% $4s4p^2$ $^2P_{1/2}$
	4055270	94% $4s^24d_-$ J=3/2	94% $4s^24d$ $^2D_{3/2}$
	4498628	98% $4s^24d$ J=5/2	98% $4s^24d$ $^2D_{5/2}$
	5592168	99% $4s4p^2$ J=5/2	62% $4s4p^2$ $^4P_{5/2}$
	5777483	99% $4s4p^2$ J=1/2	68% $4s4p^2$ $^2S_{1/2}$
	5814952	99% $4s4p^2$ J=3/2	60% $4s4p^2$ $^2P_{3/2}$

Table 1. Continued.

Ion	Level (cm^{-1})	jj-coupling purity	LS-coupling purity
Pa LXI	0	99% $4s^24p_-$ J=1/2	99% $4s^24p$ $^2P_{1/2}$
	1187599	99% $4s4p_-^2$ J=1/2	51% $4s4p^2$ $^4P_{1/2}$
	2405138	99% $4s^24p$ J=3/2	99% $4s^24p$ $^2P_{3/2}$
	3431900	75% $4s4p_-4p$ J=3/2	88% $4s4p^2$ $^4P_{3/2}$
	3530399	99% $4s4p_-4p$ J=5/2	62% $4s4p^2$ $^2D_{5/2}$
	3661441	73% $4s4p_-4p$ J=3/2	57% $4s4p^2$ $^2D_{3/2}$
	3685907	99% $4s4p_-4p$ J=1/2	69% $4s4p^2$ $^2P_{1/2}$
	4226899	94% $4s^24d_-$ J=3/2	94% $4s^24d$ $^2D_{3/2}$
	4696871	98% $4s^24d$ J=5/2	98% $4s^24d$ $^2D_{5/2}$
	5896609	99% $4s4p^2$ J=5/2	62% $4s4p^2$ $^4P_{5/2}$
	6085174	99% $4s4p^2$ J=1/2	68% $4s4p^2$ $^2S_{1/2}$
	6123009	99% $4s4p^2$ J=3/2	60% $4s4p^2$ $^2P_{3/2}$
U LXII	0	99% $4s^24p_-$ J=1/2	99% $4s^24p$ $^2P_{1/2}$
	1214654	99% $4s4p_-^2$ J=1/2	50% $4s4p^2$ $^4P_{1/2}$
	2552949	99% $4s^24p$ J=3/2	99% $4s^24p$ $^2P_{3/2}$
	3603787	75% $4s4p_-4p$ J=3/2	88% $4s4p^2$ $^4P_{3/2}$
	3704000	99% $4s4p_-4p$ J=5/2	62% $4s4p^2$ $^2D_{5/2}$
	3836631	73% $4s4p_-4p$ J=3/2	57% $4s4p^2$ $^2D_{3/2}$
	3861402	99% $4s4p_-4p$ J=1/2	68% $4s4p^2$ $^2P_{1/2}$
	4406091	94% $4s^24d_-$ J=3/2	94% $4s^24d$ $^2D_{3/2}$
	4903783	98% $4s^24d$ J=5/2	98% $4s^24d$ $^2D_{5/2}$
	6216428	99% $4s4p^2$ J=5/2	62% $4s4p^2$ $^4P_{5/2}$
	6408201	99% $4s4p^2$ J=1/2	68% $4s4p^2$ $^2S_{1/2}$
	6446382	99% $4s4p^2$ J=3/2	59% $4s4p^2$ $^2P_{3/2}$

Table 2. Wavelengths and transition probabilities for lines in Ga-like ions Yb XL – U LXII.

Ion	Lower level	Upper level	λ (Å)		A_{ki} (s^{-1})	
			EXP	MCDF	MCDF(B)	MCDF(C)
Yb XL	$4s^24p_-$ J=1/2	$4s4p^2$ J'=3/2		50.181	1.75E+10	1.92E+10
	$4s^24p_-$ J=1/2	$4s4p^2$ J'=1/2		51.060	5.80E+09	5.51E+09
	$4s^24p_-$ J=1/2	$4s^24d_-$ J'=3/2		56.436	9.19E+11	9.19E+11
	$4s^24p$ J=3/2	$4s4p^2$ J'=3/2		71.120	7.71E+11	7.71E+11
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=1/2		72.832	5.10E+11	5.05E+11
	$4s^24p$ J=3/2	$4s4p^2$ J'=1/2		72.899	3.57E+11	3.53E+11
	$4s^24p$ J=3/2	$4s^24d$ J'=5/2		74.114	5.10E+11	5.10E+11
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=3/2		74.248	2.34E+11	2.32E+11
	$4s^24p$ J=3/2	$4s4p^2$ J'=5/2		83.644	2.52E+08	3.53E+08
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=3/2		83.983	1.61E+09	1.61E+09
	$4s^24p$ J=3/2	$4s^24d_-$ J'=3/2		84.373	1.53E+07	1.83E+06
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=1/2		127.18	2.27E+10	2.27E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=3/2		131.56	1.51E+10	1.51E+10
	$4s^24p_-$ J=1/2	$4s4p^2_-$ J'=1/2		142.34	2.35E+10	2.33E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=5/2		149.77	1.13E+10	1.12E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=3/2		165.56	1.76E+09	1.74E+09
Lu XLI	$4s^24p_-$ J=1/2	$4s4p^2$ J'=3/2		47.488	1.29E+10	1.42E+10
	$4s^24p_-$ J=1/2	$4s4p^2$ J'=1/2		48.260	5.90E+09	5.60E+09
	$4s^24p_-$ J=1/2	$4s^24d_-$ J'=3/2		54.096	1.01E+12	1.01E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=3/2		67.911	8.46E+11	8.46E+11
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=1/2		69.435	5.60E+11	5.54E+11
	$4s^24p$ J=3/2	$4s4p^2$ J'=1/2		69.502	3.93E+11	3.89E+11
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=3/2		70.699	2.62E+11	2.59E+11
	$4s^24p$ J=3/2	$4s^24d$ J'=5/2		71.624	5.35E+11	5.35E+11
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=3/2		79.698	1.87E+09	1.87E+09
	$4s^24p$ J=3/2	$4s4p^2$ J'=5/2		79.897	4.95E+09	5.44E+09
	$4s^24p$ J=3/2	$4s^24d_-$ J'=3/2		82.285	2.13E+08	2.98E+08
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=1/2		123.93	2.40E+10	2.40E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=3/2		128.02	1.63E+10	1.63E+10
	$4s^24p_-$ J=1/2	$4s4p^2_-$ J'=1/2		138.31	2.53E+10	2.50E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=5/2		145.62	1.20E+10	1.19E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=3/2		160.92	1.88E+09	1.86E+09
Hf XLII	$4s^24p_-$ J=1/2	$4s4p^2$ J'=3/2		44.943	9.60E+09	1.06E+10
	$4s^24p_-$ J=1/2	$4s4p^2$ J'=1/2		45.626	6.02E+09	5.72E+09
	$4s^24p_-$ J=1/2	$4s^24d_-$ J'=3/2		51.868	1.10E+12	1.10E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=3/2		64.839	9.29E+11	9.29E+11
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=1/2		66.204	6.16E+11	6.16E+11
	$4s^24p$ J=3/2	$4s4p^2$ J'=1/2		66.270	4.32E+11	4.28E+11
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=3/2		67.334	2.92E+11	2.89E+11
	$4s^24p$ J=3/2	$4s^24d$ J'=5/2		69.114	5.52E+11	5.52E+11
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=3/2		75.653	2.16E+09	2.16E+09
	$4s^24p$ J=3/2	$4s4p^2$ J'=5/2		76.473	1.95E+10	2.15E+10
	$4s^24p$ J=3/2	$4s^24d_-$ J'=3/2		80.307	9.07E+08	1.09E+09
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=1/2		120.81	2.54E+10	2.54E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=3/2		124.63	1.76E+10	1.76E+10
	$4s^24p_-$ J=1/2	$4s4p^2_-$ J'=1/2		134.47	2.71E+10	2.68E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=5/2		141.65	1.27E+10	1.26E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=3/2		156.48	2.01E+09	1.99E+09

Table 2. Continued.

Ion	Lower level	Upper level	λ (Å)		A_{ki} (s^{-1})	
			EXP	MCDF	MCDF(B)	MCDF(C)
Ta XLIII	$4s^24p_-\ J=1/2$	$4s4p^2\ J'=3/2$		42.540	7.23E+09	7.95E+09
	$4s^24p_-\ J=1/2$	$4s4p^2\ J'=1/2$		43.147	6.14E+09	5.83E+09
	$4s^24p_-\ J=1/2$	$4s^24d_-\ J'=3/2$		49.743	1.20E+12	1.20E+12
	$4s^24p\ J=3/2$	$4s4p^2\ J'=3/2$		61.902	1.02E+12	1.02E+12
	$4s^24p_-\ J=1/2$	$4s4p_-4p\ J'=1/2$		63.129	6.78E+11	6.78E+11
	$4s^24p\ J=3/2$	$4s4p^2\ J'=1/2$		63.195	4.76E+11	4.71E+11
	$4s^24p_-\ J=1/2$	$4s4p_-4p\ J'=3/2$		64.141	3.25E+11	3.22E+11
	$4s^24p\ J=3/2$	$4s4p^2\ J'=5/2$		66.559	5.56E+11	5.56E+11
	$4s^24p_-\ J=1/2$	$4s4p_-4p\ J'=3/2$		71.830	2.50E+09	2.50E+09
	$4s^24p\ J=3/2$	$4s^24d\ J'=5/2$		73.379	4.85E+10	4.85E+10
	$4s^24p\ J=3/2$	$4s^24d_-\ J'=3/2$		78.427	1.88E+09	2.07E+09
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=1/2$		117.81	2.68E+10	2.68E+10
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=3/2$		121.39	1.88E+10	1.88E+10
	$4s^24p_-\ J=1/2$	$4s4p_-^2\ J'=1/2$		130.81	2.90E+10	2.87E+10
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=5/2$		137.84	1.34E+10	1.33E+10
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=3/2$		152.23	2.14E+09	2.12E+09
W XLIV	$4s^24p_-\ J=1/2$	$4s4p^2\ J'=3/2$		40.272	5.48E+09	6.03E+09
	$4s^24p_-\ J=1/2$	$4s4p^2\ J'=1/2$		40.813	6.28E+09	5.90E+09
	$4s^24p_-\ J=1/2$	$4s^24d_-\ J'=3/2$	47.9029(24)[a]	47.713	1.31E+12	1.31E+12
	$4s^24p\ J=3/2$	$4s4p^2\ J'=3/2$		59.095	1.12E+12	1.12E+12
	$4s^24p_-\ J=1/2$	$4s4p_-4p\ J'=1/2$	60.6157(42)[a]	60.202	7.47E+11	7.47E+11
	$4s^24p\ J=3/2$	$4s4p^2\ J'=1/2$		60.268	5.25E+11	5.20E+11
	$4s^24p_-\ J=1/2$	$4s4p_-4p\ J'=3/2$	61.3341(21)[a]	61.110	3.62E+11	3.58E+11
	$4s^24p\ J=3/2$	$4s4p^2\ J'=5/2$		63.950	5.48E+11	5.48E+11
	$4s^24p_-\ J=1/2$	$4s4p_-4p\ J'=3/2$		68.216	2.89E+09	2.89E+09
	$4s^24p\ J=3/2$	$4s^24d\ J'=5/2$		70.605	9.23E+10	9.23E+10
	$4s^24p\ J=3/2$	$4s^24d_-\ J'=3/2$		76.634	2.99E+09	3.29E+09
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=1/2$		114.93	2.82E+10	2.82E+10
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=3/2$		118.28	2.01E+10	2.01E+10
	$4s^24p_-\ J=1/2$	$4s4p_-^2\ J'=1/2$		127.30	3.09E+10	3.06E+10
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=5/2$		134.20	1.41E+10	1.40E+10
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=3/2$		148.15	2.28E+09	2.26E+09
Re XLV	$4s^24p_-\ J=1/2$	$4s4p^2\ J'=3/2$		38.130	4.17E+09	4.59E+09
	$4s^24p_-\ J=1/2$	$4s4p^2\ J'=1/2$		38.616	6.42E+09	6.03E+09
	$4s^24p_-\ J=1/2$	$4s^24d_-\ J'=3/2$		45.773	1.43E+12	1.43E+12
	$4s^24p\ J=3/2$	$4s4p^2\ J'=3/2$		56.414	1.23E+12	1.23E+12
	$4s^24p_-\ J=1/2$	$4s4p_-4p\ J'=1/2$		57.416	8.24E+11	8.24E+11
	$4s^24p\ J=3/2$	$4s4p^2\ J'=1/2$		57.482	5.79E+11	5.73E+11
	$4s^24p_-\ J=1/2$	$4s4p_-4p\ J'=3/2$		58.232	4.04E+11	4.00E+11
	$4s^24p\ J=3/2$	$4s4p^2\ J'=5/2$		61.305	5.33E+11	5.33E+11
	$4s^24p_-\ J=1/2$	$4s4p_-4p\ J'=3/2$		64.798	3.33E+09	3.33E+09
	$4s^24p\ J=3/2$	$4s^24d\ J'=5/2$		68.120	1.46E+11	1.46E+11
	$4s^24p\ J=3/2$	$4s^24d_-\ J'=3/2$		74.922	4.18E+09	4.60E+09
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=1/2$		112.14	2.96E+10	2.96E+10
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=3/2$		115.30	2.15E+10	2.15E+10
	$4s^24p_-\ J=1/2$	$4s4p_-^2\ J'=1/2$		123.94	3.29E+10	3.26E+10
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=5/2$		130.70	1.49E+10	1.48E+10
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=3/2$		144.24	2.42E+09	2.37E+09

Table 2. Continued.

Ion	Lower level	Upper level	λ (Å) EXP	λ (Å) MCDF	A_{ki} (s^{-1}) MCDF(B)	A_{ki} (s^{-1}) MCDF(C)
Os XLVI	$4s^24p_-\ J=1/2$	$4s4p^2\ J'=3/2$		36.110	3.18E+09	3.82E+09
	$4s^24p_-\ J=1/2$	$4s4p^2\ J'=1/2$		36.546	6.59E+09	6.19E+09
	$4s^24p_-\ J=1/2$	$4s^24d_-\ J'=3/2$		43.917	1.56E+12	1.56E+12
	$4s^24p\ J=3/2$	$4s4p^2\ J'=3/2$		53.854	1.36E+12	1.36E+12
	$4s^24p_-\ J=1/2$	$4s4p_-4p\ J'=1/2$	55.123(6)[b]	54.764	9.08E+11	9.08E+11
	$4s^24p\ J=3/2$	$4s4p^2\ J'=1/2$		54.829	6.40E+11	6.34E+11
	$4s^24p_-\ J=1/2$	$4s4p_-4p\ J'=3/2$	55.741(5)[b]	55.497	4.50E+11	4.45E+11
	$4s^24p\ J=3/2$	$4s4p^2\ J'=5/2$		58.659	5.19E+11	5.19E+11
	$4s^24p_-\ J=1/2$	$4s4p_-4p\ J'=3/2$		61.565	3.84E+09	3.84E+09
	$4s^24p\ J=3/2$	$4s^24d\ J'=5/2$		65.874	2.02E+11	2.02E+11
	$4s^24p\ J=3/2$	$4s^24d_-\ J'=3/2$		73.283	5.40E+09	5.94E+09
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=1/2$		109.46	3.11E+10	3.11E+10
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=3/2$		112.43	2.29E+10	2.29E+10
	$4s^24p_-\ J=1/2$	$4s4p_-^2\ J'=1/2$		120.72	3.49E+10	3.45E+10
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=5/2$		127.34	1.56E+10	1.54E+10
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=3/2$		140.48	2.56E+09	2.51E+09
Ir XLVII	$4s^24p_-\ J=1/2$	$4s4p^2\ J'=3/2$		34.203	2.42E+09	2.90E+09
	$4s^24p_-\ J=1/2$	$4s4p^2\ J'=1/2$		34.595	6.76E+09	6.29E+09
	$4s^24p_-\ J=1/2$	$4s^24d_-\ J'=3/2$		42.140	1.70E+12	1.70E+12
	$4s^24p\ J=3/2$	$4s4p^2\ J'=3/2$		51.411	1.50E+12	1.50E+12
	$4s^24p_-\ J=1/2$	$4s4p_-4p\ J'=1/2$		52.238	1.00E+12	1.00E+12
	$4s^24p\ J=3/2$	$4s4p^2\ J'=1/2$		52.303	7.06E+11	6.99E+11
	$4s^24p_-\ J=1/2$	$4s4p_-4p\ J'=3/2$		52.899	5.01E+11	5.01E+11
	$4s^24p\ J=3/2$	$4s4p^2\ J'=5/2$		56.047	5.10E+11	5.10E+11
	$4s^24p_-\ J=1/2$	$4s4p_-4p\ J'=3/2$		58.505	4.42E+09	4.42E+09
	$4s^24p\ J=3/2$	$4s^24d\ J'=5/2$		63.816	2.56E+11	2.56E+11
	$4s^24p\ J=3/2$	$4s^24d_-\ J'=3/2$		71.713	6.61E+09	7.27E+09
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=1/2$		106.87	3.26E+10	3.26E+10
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=3/2$		109.67	2.43E+10	2.43E+10
	$4s^24p_-\ J=1/2$	$4s4p_-^2\ J'=1/2$		117.63	3.70E+10	3.66E+10
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=5/2$		124.11	1.64E+10	1.62E+10
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=3/2$		136.86	2.71E+09	2.66E+09
Pt XLVIII	$4s^24p_-\ J=1/2$	$4s4p^2\ J'=3/2$		32.403	1.84E+09	2.21E+09
	$4s^24p_-\ J=1/2$	$4s4p^2\ J'=1/2$		32.757	6.95E+09	6.46E+09
	$4s^24p_-\ J=1/2$	$4s^24d_-\ J'=3/2$		40.437	1.86E+12	1.86E+12
	$4s^24p\ J=3/2$	$4s4p^2\ J'=3/2$		49.079	1.65E+12	1.65E+12
	$4s^24p_-\ J=1/2$	$4s4p_-4p\ J'=1/2$		49.832	1.11E+12	1.11E+12
	$4s^24p\ J=3/2$	$4s4p^2\ J'=1/2$		49.896	7.81E+11	7.73E+11
	$4s^24p_-\ J=1/2$	$4s4p_-4p\ J'=3/2$		50.428	5.57E+11	5.57E+11
	$4s^24p\ J=3/2$	$4s4p^2\ J'=5/2$		53.499	5.08E+11	5.08E+11
	$4s^24p_-\ J=1/2$	$4s4p_-4p\ J'=3/2$		55.607	5.08E+09	5.08E+09
	$4s^24p\ J=3/2$	$4s^24d\ J'=5/2$		61.907	3.06E+11	3.06E+11
	$4s^24p\ J=3/2$	$4s^24d_-\ J'=3/2$		70.206	7.81E+09	8.59E+09
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=1/2$		104.37	3.42E+10	3.42E+10
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=3/2$		107.02	2.58E+10	2.58E+10
	$4s^24p_-\ J=1/2$	$4s4p_-^2\ J'=1/2$		114.66	3.92E+10	3.88E+10
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=5/2$		121.00	1.73E+10	1.71E+10
	$4s^24p\ J=3/2$	$4s4p_-4p\ J'=3/2$		133.38	2.86E+09	2.80E+09

Table 2. Continued.

Ion	Lower level	Upper level	λ (Å)		A_{ki} (s^{-1})	
			EXP	MCDF	MCDF(B)	MCDF(C)
Au IL	$4s^24p_-$ $J=1/2$	$4s4p^2$ $J'=3/2$		30.704	1.38E+09	1.79E+09
	$4s^24p_-$ $J=1/2$	$4s4p^2$ $J'=1/2$		31.024	7.15E+09	6.58E+09
	$4s^24p_-$ $J=1/2$	$4s^24d_-$ $J'=3/2$	38.95(2)[c]	38.805	2.03E+12	2.03E+12
	$4s^24p$ $J=3/2$	$4s4p^2$ $J'=3/2$		46.854	1.82E+12	1.82E+12
	$4s^24p_-$ $J=1/2$	$4s4p_-4p$ $J'=1/2$	47.86(5)[c]	47.540	1.22E+12	1.22E+12
	$4s^24p$ $J=3/2$	$4s4p^2$ $J'=1/2$		47.603	8.63E+11	8.54E+11
	$4s^24p_-$ $J=1/2$	$4s4p_-4p$ $J'=3/2$	48.28(5)[c]	48.079	6.20E+11	6.20E+11
	$4s^24p$ $J=3/2$	$4s4p^2$ $J'=5/2$		51.033	5.14E+11	5.14E+11
	$4s^24p_-$ $J=1/2$	$4s4p_-4p$ $J'=3/2$		52.863	5.83E+09	5.83E+09
	$4s^24p$ $J=3/2$	$4s^24d$ $J'=5/2$		60.115	3.53E+11	3.53E+11
	$4s^24p$ $J=3/2$	$4s^24d_-$ $J'=3/2$		68.758	8.98E+09	9.88E+09
	$4s^24p$ $J=3/2$	$4s4p_-4p$ $J'=1/2$		101.95	3.58E+10	3.58E+10
	$4s^24p$ $J=3/2$	$4s4p_-4p$ $J'=3/2$		104.46	2.73E+10	2.73E+10
	$4s^24p_-$ $J=1/2$	$4s4p_-^2$ $J'=1/2$		111.80	4.14E+10	4.10E+10
	$4s^24p$ $J=3/2$	$4s4p_-4p$ $J'=5/2$		118.00	1.81E+10	1.79E+10
	$4s^24p$ $J=3/2$	$4s4p_-4p$ $J'=3/2$		130.03	3.01E+09	2.95E+09
Hg L	$4s^24p_-$ $J=1/2$	$4s4p^2$ $J'=3/2$		29.100	1.02E+09	1.33E+09
	$4s^24p_-$ $J=1/2$	$4s4p^2$ $J'=1/2$		29.389	7.36E+09	6.77E+09
	$4s^24p_-$ $J=1/2$	$4s^24d_-$ $J'=3/2$		37.240	2.22E+12	2.22E+12
	$4s^24p$ $J=3/2$	$4s4p^2$ $J'=3/2$		44.731	2.01E+12	2.01E+12
	$4s^24p_-$ $J=1/2$	$4s4p_-4p$ $J'=1/2$		45.356	1.35E+12	1.35E+12
	$4s^24p$ $J=3/2$	$4s4p^2$ $J'=1/2$		45.419	9.55E+11	9.45E+11
	$4s^24p_-$ $J=1/2$	$4s4p_-4p$ $J'=3/2$		45.844	6.90E+11	6.90E+11
	$4s^24p$ $J=3/2$	$4s4p^2$ $J'=5/2$		48.659	5.28E+11	5.28E+11
	$4s^24p_-$ $J=1/2$	$4s4p_-4p$ $J'=3/2$		50.263	6.69E+09	6.69E+09
	$4s^24p$ $J=3/2$	$4s^24d$ $J'=5/2$		58.420	3.96E+11	3.96E+11
	$4s^24p$ $J=3/2$	$4s^24d_-$ $J'=3/2$		67.366	1.01E+10	1.11E+10
	$4s^24p$ $J=3/2$	$4s4p_-4p$ $J'=1/2$		99.613	3.74E+10	3.74E+10
	$4s^24p$ $J=3/2$	$4s4p_-4p$ $J'=3/2$		102.00	2.88E+10	2.88E+10
	$4s^24p_-$ $J=1/2$	$4s4p_-^2$ $J'=1/2$		109.05	4.37E+10	4.33E+10
	$4s^24p$ $J=3/2$	$4s4p_-4p$ $J'=5/2$		115.12	1.90E+10	1.88E+10
	$4s^24p$ $J=3/2$	$4s4p_-4p$ $J'=3/2$		126.80	3.17E+09	3.11E+09
Tl LI	$4s^24p_-$ $J=1/2$	$4s4p^2$ $J'=3/2$		27.585	7.47E+08	1.05E+09
	$4s^24p_-$ $J=1/2$	$4s4p^2$ $J'=1/2$		27.847	7.59E+09	6.91E+09
	$4s^24p_-$ $J=1/2$	$4s^24d_-$ $J'=3/2$		35.738	2.43E+12	2.43E+12
	$4s^24p$ $J=3/2$	$4s4p^2$ $J'=3/2$		42.704	2.22E+12	2.22E+12
	$4s^24p_-$ $J=1/2$	$4s4p_-4p$ $J'=1/2$		43.276	1.49E+12	1.49E+12
	$4s^24p$ $J=3/2$	$4s4p^2$ $J'=1/2$		43.337	1.06E+12	1.05E+12
	$4s^24p_-$ $J=1/2$	$4s4p_-4p$ $J'=3/2$		43.718	7.67E+11	7.67E+11
	$4s^24p$ $J=3/2$	$4s4p^2$ $J'=5/2$		46.383	5.48E+11	5.48E+11
	$4s^24p_-$ $J=1/2$	$4s4p_-4p$ $J'=3/2$		47.799	7.67E+09	7.67E+09
	$4s^24p$ $J=3/2$	$4s^24d$ $J'=5/2$		56.806	4.37E+11	4.37E+11
	$4s^24p$ $J=3/2$	$4s^24d_-$ $J'=3/2$		66.025	1.12E+10	1.23E+10
	$4s^24p$ $J=3/2$	$4s4p_-4p$ $J'=1/2$		97.349	3.90E+10	3.90E+10
	$4s^24p$ $J=3/2$	$4s4p_-4p$ $J'=3/2$		99.618	3.04E+10	3.04E+10
	$4s^24p_-$ $J=1/2$	$4s4p_-^2$ $J'=1/2$		106.40	4.60E+10	4.55E+10
	$4s^24p$ $J=3/2$	$4s4p_-4p$ $J'=5/2$		112.33	1.99E+10	1.97E+10
	$4s^24p$ $J=3/2$	$4s4p_-4p$ $J'=3/2$		123.67	3.34E+09	3.27E+09

Table 2. Continued.

Ion	Lower level	Upper level	λ (Å)		A_{ki} (s^{-1})	
			EXP	MCDF	MCDF(B)	MCDF(C)
Pb LII	$4s^2 4p_-$ J=1/2	$4s4p^2$ J'=3/2		26.154	5.31E+08	7.96E+08
	$4s^2 4p_-$ J=1/2	$4s4p^2$ J'=1/2		26.392	7.84E+09	7.13E+09
	$4s^2 4p_-$ J=1/2	$4s^2 4d_-$ J'=3/2		34.298	2.66E+12	2.66E+12
	$4s^2 4p$ J=3/2	$4s4p^2$ J'=3/2		40.771	2.46E+12	2.46E+12
	$4s^2 4p_-$ J=1/2	$4s4p_- 4p$ J'=1/2		41.293	1.65E+12	1.65E+12
	$4s^2 4p$ J=3/2	$4s4p^2$ J'=1/2		41.353	1.17E+12	1.16E+12
	$4s^2 4p_-$ J=1/2	$4s4p_- 4p$ J'=3/2		41.695	8.53E+11	8.53E+11
	$4s^2 4p$ J=3/2	$4s4p^2$ J'=5/2		44.205	5.74E+11	5.74E+11
	$4s^2 4p_-$ J=1/2	$4s4p_- 4p$ J'=3/2		45.463	8.78E+09	8.78E+09
	$4s^2 4p$ J=3/2	$4s^2 4d$ J'=5/2		55.262	4.77E+11	4.77E+11
	$4s^2 4p$ J=3/2	$4s^2 4d_-$ J'=3/2		64.733	1.23E+10	1.35E+10
	$4s^2 4p$ J=3/2	$4s4p_- 4p$ J'=1/2		95.156	4.07E+10	4.07E+10
	$4s^2 4p$ J=3/2	$4s4p_- 4p$ J'=3/2		97.318	3.20E+10	3.20E+10
	$4s^2 4p_-$ J=1/2	$4s4p_-^2$ J'=1/2		103.84	4.84E+10	4.79E+10
	$4s^2 4p$ J=3/2	$4s4p_- 4p$ J'=5/2		109.63	2.08E+10	2.06E+10
	$4s^2 4p$ J=3/2	$4s4p_- 4p$ J'=3/2		120.66	3.51E+09	3.44E+09
Bi LIII	$4s^2 4p_-$ J=1/2	$4s4p^2$ J'=3/2		24.802	3.65E+08	5.84E+08
	$4s^2 4p_-$ J=1/2	$4s4p^2$ J'=1/2		25.018	8.10E+09	7.29E+09
	$4s^2 4p_-$ J=1/2	$4s^2 4d_-$ J'=3/2	33.0330(5)[b]	32.915	2.91E+12	2.91E+12
	$4s^2 4p$ J=3/2	$4s4p^2$ J'=3/2		38.926	2.72E+12	2.72E+12
	$4s^2 4p_-$ J=1/2	$4s4p_- 4p$ J'=1/2	39.690(3)[b]	39.403	1.83E+12	1.83E+12
	$4s^2 4p$ J=3/2	$4s4p^2$ J'=1/2		39.461	1.30E+12	1.29E+12
	$4s^2 4p_-$ J=1/2	$4s4p_- 4p$ J'=3/2	39.991(3)[b]	39.769	9.48E+11	9.48E+11
	$4s^2 4p$ J=3/2	$4s4p^2$ J'=5/2		42.126	6.07E+11	6.07E+11
	$4s^2 4p_-$ J=1/2	$4s4p_- 4p$ J'=3/2		43.248	1.00E+10	1.00E+10
	$4s^2 4p$ J=3/2	$4s^2 4d$ J'=5/2		53.781	5.16E+11	5.16E+11
	$4s^2 4p$ J=3/2	$4s^2 4d_-$ J'=3/2		63.486	1.33E+10	1.46E+10
	$4s^2 4p$ J=3/2	$4s4p_- 4p$ J'=1/2		93.030	4.25E+10	4.25E+10
	$4s^2 4p$ J=3/2	$4s4p_- 4p$ J'=3/2		95.095	3.37E+10	3.37E+10
	$4s^2 4p_-$ J=1/2	$4s4p_-^2$ J'=1/2		101.37	5.09E+10	5.04E+10
	$4s^2 4p$ J=3/2	$4s4p_- 4p$ J'=5/2		107.03	2.18E+10	2.16E+10
	$4s^2 4p$ J=3/2	$4s4p_- 4p$ J'=3/2		117.74	3.68E+09	3.61E+09
Po LIV	$4s^2 4p_-$ J=1/2	$4s4p^2$ J'=3/2		23.525	2.38E+08	4.28E+08
	$4s^2 4p_-$ J=1/2	$4s4p^2$ J'=1/2		23.721	8.38E+09	7.54E+09
	$4s^2 4p_-$ J=1/2	$4s^2 4d_-$ J'=3/2		31.588	3.19E+12	3.19E+12
	$4s^2 4p$ J=3/2	$4s4p^2$ J'=3/2		37.166	3.01E+12	3.01E+12
	$4s^2 4p_-$ J=1/2	$4s4p_- 4p$ J'=1/2		37.602	2.02E+12	2.02E+12
	$4s^2 4p$ J=3/2	$4s4p^2$ J'=1/2		37.658	1.44E+12	1.43E+12
	$4s^2 4p_-$ J=1/2	$4s4p_- 4p$ J'=3/2		37.935	1.05E+12	1.05E+12
	$4s^2 4p$ J=3/2	$4s4p^2$ J'=5/2		40.141	6.47E+11	6.47E+11
	$4s^2 4p_-$ J=1/2	$4s4p_- 4p$ J'=3/2		41.146	1.15E+10	1.15E+10
	$4s^2 4p$ J=3/2	$4s^2 4d$ J'=5/2		52.356	5.55E+11	5.55E+11
	$4s^2 4p$ J=3/2	$4s^2 4d_-$ J'=3/2		62.283	1.43E+10	1.57E+10
	$4s^2 4p$ J=3/2	$4s4p_- 4p$ J'=1/2		90.969	4.43E+10	4.43E+10
	$4s^2 4p$ J=3/2	$4s4p_- 4p$ J'=3/2		92.943	3.55E+10	3.55E+10
	$4s^2 4p_-$ J=1/2	$4s4p_-^2$ J'=1/2		98.977	5.34E+10	5.29E+10
	$4s^2 4p$ J=3/2	$4s4p_- 4p$ J'=5/2		104.51	2.28E+10	2.26E+10
	$4s^2 4p$ J=3/2	$4s4p_- 4p$ J'=3/2		114.92	3.86E+09	3.78E+09

Table 2. Continued.

Ion	Lower level	Upper level	λ (Å) EXP	λ (Å) MCDF	A_{ki} (s^{-1}) MCDF(B)	A_{ki} (s^{-1}) MCDF(C)
At LV	$4s^24p_-$ J=1/2	$4s4p^2$ J'=3/2		22.318	1.43E+08	3.15E+08
	$4s^24p_-$ J=1/2	$4s4p^2$ J'=1/2		22.496	8.68E+09	7.72E+09
	$4s^24p_-$ J=1/2	$4s^24d_-$ J'=3/2		30.314	3.50E+12	3.50E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=3/2		35.486	3.33E+12	3.33E+12
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=1/2		35.885	2.24E+12	2.24E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=1/2		35.940	1.59E+12	1.57E+12
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=3/2		36.189	1.17E+12	1.17E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=5/2		38.249	6.93E+11	6.93E+11
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=3/2		39.153	1.31E+10	1.31E+10
	$4s^24p$ J=3/2	$4s^24d$ J'=5/2		50.982	5.93E+11	5.93E+11
	$4s^24p$ J=3/2	$4s^24d_-$ J'=3/2		61.120	1.53E+10	1.68E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=1/2		88.968	4.61E+10	4.61E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=3/2		90.860	3.73E+10	3.73E+10
	$4s^24p_-$ J=1/2	$4s4p_-^2$ J'=1/2		96.666	5.60E+10	5.54E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=5/2		102.07	2.38E+10	2.36E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=3/2		112.18	4.04E+09	3.96E+09
Rn LVI	$4s^24p_-$ J=1/2	$4s4p^2$ J'=3/2		21.177	7.61E+07	2.13E+08
	$4s^24p_-$ J=1/2	$4s4p^2$ J'=1/2		21.339	8.99E+09	7.91E+09
	$4s^24p_-$ J=1/2	$4s^24d_-$ J'=3/2		29.090	3.84E+12	3.84E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=3/2		33.883	3.69E+12	3.69E+12
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=1/2		34.248	2.48E+12	2.48E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=1/2		34.300	1.76E+12	1.74E+12
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=3/2		34.525	1.30E+12	1.30E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=5/2		36.447	7.46E+11	7.46E+11
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=3/2		37.261	1.50E+10	1.50E+10
	$4s^24p$ J=3/2	$4s^24d$ J'=5/2		49.656	6.33E+11	6.33E+11
	$4s^24p$ J=3/2	$4s^24d_-$ J'=3/2		59.997	1.62E+10	1.78E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=1/2		87.024	4.80E+10	4.80E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=3/2		88.841	3.91E+10	3.91E+10
	$4s^24p_-$ J=1/2	$4s4p_-^2$ J'=1/2		94.428	5.87E+10	5.81E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=5/2		99.702	2.49E+10	2.46E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=3/2		109.53	4.22E+09	4.14E+09
Fr LVII	$4s^24p_-$ J=1/2	$4s4p^2$ J'=3/2		20.098	3.18E+07	1.33E+08
	$4s^24p_-$ J=1/2	$4s4p^2$ J'=1/2		20.245	9.33E+09	8.21E+09
	$4s^24p_-$ J=1/2	$4s^24d_-$ J'=3/2		27.915	4.22E+12	4.22E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=3/2		32.353	4.09E+12	4.09E+12
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=1/2		32.686	2.75E+12	2.75E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=1/2		32.737	1.96E+12	1.96E+12
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=3/2		32.941	1.45E+12	1.45E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=5/2		34.729	8.07E+11	8.07E+11
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=3/2		35.465	1.71E+10	1.71E+10
	$4s^24p$ J=3/2	$4s^24d$ J'=5/2		48.374	6.72E+11	6.72E+11
	$4s^24p$ J=3/2	$4s^24d_-$ J'=3/2		58.910	1.72E+10	1.89E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=1/2		85.136	4.99E+10	4.99E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=3/2		86.883	4.10E+10	4.10E+10
	$4s^24p_-$ J=1/2	$4s4p_-^2$ J'=1/2		92.260	6.15E+10	6.09E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=5/2		94.407	2.60E+10	2.57E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=3/2		106.96	4.41E+09	4.32E+09

Table 2. Continued.

Ion	Lower level	Upper level	λ (Å)		A_{ki} (s^{-1})	
			EXP	MCDF	MCDF(B)	MCDF(C)
Ra LVIII	$4s^24p_-$ J=1/2	$4s4p^2$ J'=3/2		19.077	7.28E+06	8.01E+07
	$4s^24p_-$ J=1/2	$4s4p^2$ J'=1/2		19.211	9.68E+09	8.42E+09
	$4s^24p_-$ J=1/2	$4s^24d_-$ J'=3/2		26.786	4.63E+12	4.63E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=3/2		30.892	4.54E+12	4.54E+12
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=1/2		31.197	3.05E+12	3.05E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=1/2		31.247	2.17E+12	2.17E+12
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=3/2		31.431	1.60E+12	1.60E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=5/2		33.094	8.75E+11	8.75E+11
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=3/2		33.759	1.95E+10	1.95E+10
	$4s^24p$ J=3/2	$4s^24d$ J'=5/2		47.133	7.13E+11	7.13E+11
	$4s^24p$ J=3/2	$4s^24d_-$ J'=3/2		57.857	1.80E+10	1.98E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=1/2		83.299	5.18E+10	5.18E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=3/2		84.983	4.30E+10	4.30E+10
	$4s^24p_-$ J=1/2	$4s4p^2_-$ J'=1/2		90.156	6.44E+10	6.34E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=5/2		95.180	2.71E+10	2.68E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=3/2		104.47	4.61E+09	4.52E+09
Ac LIX	$4s^24p_-$ J=1/2	$4s4p^2$ J'=3/2		18.111	1.93E+04	3.86E+07
	$4s^24p_-$ J=1/2	$4s4p^2$ J'=1/2		18.234	1.01E+10	8.79E+09
	$4s^24p_-$ J=1/2	$4s^24d_-$ J'=3/2		25.701	5.09E+12	5.09E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=3/2		29.498	5.03E+12	5.03E+12
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=1/2		29.777	3.39E+12	3.39E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=1/2		29.825	2.41E+12	2.41E+12
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=3/2		29.991	1.78E+12	1.78E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=5/2		31.536	9.53E+11	9.53E+11
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=3/2		32.139	2.22E+10	2.22E+10
	$4s^24p$ J=3/2	$4s^24d$ J'=5/2		45.931	7.55E+11	7.55E+11
	$4s^24p$ J=3/2	$4s^24d_-$ J'=3/2		56.838	1.89E+10	2.08E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=1/2		81.513	5.39E+10	5.39E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=3/2		83.137	4.50E+10	4.50E+10
	$4s^24p_-$ J=1/2	$4s4p^2_-$ J'=1/2		88.115	6.73E+10	6.66E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=5/2		93.017	2.83E+10	2.80E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=3/2		102.04	4.81E+09	4.71E+09
Th LX	$4s^24p_-$ J=1/2	$4s4p^2$ J'=3/2		17.197	8.37E+06	1.34E+07
	$4s^24p_-$ J=1/2	$4s4p^2$ J'=1/2		17.309	1.05E+10	9.03E+09
	$4s^24p_-$ J=1/2	$4s^24d_-$ J'=3/2	24.747(5)[b]	24.659	5.60E+12	5.60E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=3/2		28.167	5.58E+12	5.58E+12
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=1/2	28.677(3)[b]	28.423	3.76E+12	3.76E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=1/2		28.468	2.68E+12	2.68E+12
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=3/2	28.835(3)[b]	28.620	1.98E+12	1.98E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=5/2		30.053	1.04E+12	1.04E+12
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=3/2		30.601	2.53E+10	2.53E+10
	$4s^24p$ J=3/2	$4s^24d$ J'=5/2		44.765	7.98E+11	7.98E+11
	$4s^24p$ J=3/2	$4s^24d_-$ J'=3/2		55.850	1.97E+10	2.17E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=1/2		79.773	5.59E+10	5.59E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=3/2		81.343	4.71E+10	4.71E+10
	$4s^24p_-$ J=1/2	$4s4p^2_-$ J'=1/2		86.131	7.03E+10	6.96E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=5/2		90.914	2.96E+10	2.93E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=3/2		99.686	5.01E+09	4.91E+09

Table 2. Continued.

Ion	Lower level	Upper level	λ (Å)		A_{ki} (s^{-1})	
			EXP	MCDF	MCDF(B)	MCDF(C)
Pa LXI	$4s^24p_-$ J=1/2	$4s4p^2$ J'=3/2		16.332	3.14E+07	1.41E+06
	$4s^24p_-$ J=1/2	$4s4p^2$ J'=1/2		16.433	1.09E+10	9.26E+09
	$4s^24p_-$ J=1/2	$4s^24d_-$ J'=3/2		23.658	6.17E+12	6.17E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=3/2		26.897	6.19E+12	6.19E+12
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=1/2		27.130	4.17E+12	4.17E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=1/2		27.174	2.97E+12	2.97E+12
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=3/2		27.312	2.19E+12	2.19E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=5/2		28.641	1.14E+12	1.14E+12
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=3/2		29.138	2.88E+10	2.88E+10
	$4s^24p$ J=3/2	$4s^24d$ J'=5/2		43.635	8.43E+11	8.43E+11
	$4s^24p$ J=3/2	$4s^24d_-$ J'=3/2		54.892	2.05E+10	2.25E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=1/2		78.078	5.81E+10	5.81E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=3/2		79.599	4.92E+10	4.92E+10
	$4s^24p_-$ J=1/2	$4s4p^2_-$ J'=1/2		84.204	7.34E+10	7.27E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=5/2		88.868	3.08E+10	3.05E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=3/2		97.394	5.22E+09	5.12E+09
U LXII	$4s^24p_-$ J=1/2	$4s4p^2$ J'=3/2		15.513	6.90E+07	1.66E+06
	$4s^24p_-$ J=1/2	$4s4p^2$ J'=1/2		15.605	1.13E+10	9.49E+09
	$4s^24p_-$ J=1/2	$4s^24d_-$ J'=3/2	22.778(3)[b]	22.696	6.79E+12	6.79E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=3/2		25.684	6.87E+12	6.87E+12
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=1/2	26.147(3)[b]	25.897	4.63E+12	4.63E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=1/2		25.939	3.30E+12	3.30E+12
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=3/2	26.283(3)[b]	26.065	2.43E+12	2.43E+12
	$4s^24p$ J=3/2	$4s4p^2$ J'=5/2		27.296	1.25E+12	1.25E+12
	$4s^24p_-$ J=1/2	$4s4p_-4p$ J'=3/2		27.749	3.28E+10	3.28E+10
	$4s^24p$ J=3/2	$4s^24d$ J'=5/2		42.538	8.90E+11	8.90E+11
	$4s^24p$ J=3/2	$4s^24d_-$ J'=3/2		53.962	2.12E+10	2.33E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=1/2		76.426	6.03E+10	6.03E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=3/2		77.901	5.15E+10	5.15E+10
	$4s^24p_-$ J=1/2	$4s4p^2_-$ J'=1/2		82.328	7.66E+10	7.66E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=5/2		86.877	3.21E+10	3.18E+10
	$4s^24p$ J=3/2	$4s4p_-4p$ J'=3/2		95.162	5.43E+09	5.32E+09

[a] Ref. [17]
[b] Ref. [18]
[c] Ref. [19]

Table 3. Wavelengths and transition probabilities for forbidden lines within the ground configuration of Ga-like ions.

Ion	λ (Å)	A_{ki} (s^{-1})	
		M1	E2
Yb XL	170.44	1.78E+06	6.97E+04
Lu XLI	157.91	2.23E+06	9.39E+04
Hf XLII	146.46	2.80E+06	1.26E+05
Ta XLIII	136.01	3.49E+06	1.68E+05
W XLIV	126.43	4.33E+06	2.24E+05
Re XLV	117.65	5.37E+06	2.96E+05
Os XLVI	109.59	6.63E+06	3.91E+05
Ir XLVII	102.18	8.17E+06	5.14E+05
Pt XLVIII	95.363	1.00E+07	6.73E+05
Au IL	89.076	1.23E+07	8.79E+05
Hg L	83.273	1.50E+07	1.14E+06
Tl LI	77.910	1.83E+07	1.48E+06
Pb LII	72.950	2.22E+07	1.92E+06
Bi LIII	68.356	2.70E+07	2.48E+06
Po LIV	64.096	3.26E+07	3.18E+06
At LV	60.143	3.94E+07	4.09E+06
Rn LVI	56.471	4.74E+07	5.23E+06
Fr LVII	53.056	5.71E+07	6.68E+06
Ra LVIII	49.878	6.85E+07	8.50E+06
Ac LIX	46.916	8.20E+07	1.08E+07
Th LX	44.155	9.81E+07	1.37E+07
Pa LXI	41.578	1.17E+08	1.73E+07
U LXII	39.170	1.39E+08	2.19E+07