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Core Effects on Transition Energies for $3d^k$ Configurations in Tungsten Ions

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Abstract: All energy levels of the $3d^k$, $k = 1,2,\ldots, 8, 9$, configurations for tungsten ions, computed using the GRASP2K fully relativistic code based on the variational multiconfiguration Dirac–Hartree–Fock method, are reported. Included in the calculations are valence correlation where all $3s, 3p, 3d$ orbitals are considered to be valence orbitals, as well as core–valence and core–core effects from the $2s, 2p$ subshells. Results are compared with other recent theory and with levels obtained from the wavelengths of lines observed in the experimental spectra. It is shown that the core correlation effects considerably reduce the disagreement with levels linked directly to observed wavelengths, but may differ significantly from the NIST levels, where an unknown shift of the levels could not be determined from experimental wavelengths. For low values of k, levels were in good agreement with relativistic many-body perturbation levels, but for $2 < k < 8$, the present results were in better agreement with observation.

Keywords: core correlation effects; energy levels; multiconfiguration Dirac-Hartree-Fock; tungsten ions

1. Introduction

Because of their importance for the ITER project [1], spectra of tungsten ions have recently received much attention over a wide range of wavelengths. Of special interest are the NIST EBIT experiments reported by Ralchenko et al. [2], who studied tungsten ions with the ground states $3d$, $3d^2$, ..., $3d^8$, and $3d^9$. Detailed collisional-radiative modelling was undertaken to identify the measured spectral lines. For the modelling they relied on energy levels, radiative transition probabilities, and electron-impact collisional cross-sections obtained using the relativistic Flexible Atomic Code (FAC) [3]. They found that many of the strong lines arose from magnetic dipole (M1) transitions. These lines were located in a narrow range of wavelengths, mostly well isolated with line ratios that could infer plasma properties, and were sensitive to electron densities. All these features make the M1 lines useful for plasma diagnostics. The measured observed wavelengths for M1 transitions and the FAC energy levels were analyzed by Kramida [4] for spectra for these ions, and form the basis for the energy levels included in the Atomic Spectra Database (ASD) [5].

At the same time, highly charged ions are of special interest for theory in that both correlation and relativistic effects are interrelated, and additional quantum electrodynamic (QED) corrections are needed for accurate results. Quinet [6] reports an extensive summary of a large variety of theoretical energy levels and forbidden transitions for all levels of $3d^k$ ground configurations, and compared their energy levels with the NIST energies. Included among the various methods were results that he obtained using the GRASP code developed by Norrington [7]. Most of the correlation included in the calculation was valence correlation restricted to the $n = 3$ complex. More recently, Guo et al. [8] computed energy levels, wavelengths, and transition probabilities for the same configurations for a number of ions, including tungsten. The theoretical basis for their work was the relativistic many-body perturbation theory (RMBPT) as described in [9], but small corrections for finite nuclear size, nuclear recoil, vacuum polarization, and self-energy correction were also included using standard procedures such as those in GRASP2K [10]. All basis orbitals were determined from the same central field, and all three types of correlation—valence–valence (VV), core–valence (CV), and core–core (CC)—where the core consists of the the full $1s, 2s, 2p$ core were included . Statistically, their energy levels were in much better agreement with NIST values than those of Quinet [6].

The purpose of the present work was to evaluate the accuracy of energy levels obtained from variational multconfiguration Dirac–Hartree–Fock methods as implemented in the GRASP2K code [10]. Included are all three correlation types as in the RMBPT calculation—except for the $1s^2$ core, that will be assumed to be inactive.

2. Multiconfiguration Dirac–Hartree–Fock (MCDHF) and Configuration Interaction Methods

In the MCDHF method [11,12], as implemented in the GRASP2K program package [10], the wave function $\Psi(\gamma PJM_J)$ for a state labeled γPJM_J, where J and M_J are the angular quantum numbers and P is the parity, is expanded in antisymmetrized and coupled configuration state functions (CSFs)

$$\Psi(\gamma PJM_J) = \sum_{j=1}^{M} c_j \Phi(\gamma_j PJM_J). \tag{1}$$

The labels $\{\gamma_j\}$ denote other appropriate information about the CSFs, such as orbital occupancy and coupling of the subshells. The CSFs are built from products of one-electron orbitals, having the general form

$$\psi_{n\kappa,m}(\mathbf{r}) = \frac{1}{r}\begin{pmatrix} P_{n\kappa}(r)\chi_{\kappa,m}(\theta,\varphi) \\ \imath Q_{n\kappa}(r)\chi_{-\kappa,m}(\theta,\varphi) \end{pmatrix}, \tag{2}$$

where $\chi_{\pm\kappa,m}(\theta,\varphi)$ are two-component spin–orbit functions. The radial functions $\{P_{n\kappa}(r), Q_{n\kappa}(r)\}$ are represented numerically on a grid.

Wave functions for a number of targeted states are determined simultaneously in the extended optimal level (EOL) scheme. Given initial estimates of the radial functions, the energies E and expansion coefficients $\mathbf{c} = (c_1, \ldots, c_M)^t$ for the targeted states are obtained as solutions to the configuration interaction (CI) problem

$$\mathbf{Hc} = E\mathbf{c}, \tag{3}$$

where $\mathbf{H}$ is the CI matrix of dimension $M \times M$ with elements

$$H_{ij} = \langle \Phi(\gamma_i PJM_J)|H|\Phi(\gamma_j PJM_J)\rangle. \tag{4}$$

Radial functions are solutions of systems of differential equations that define a stationary state of an energy functional for a wave function expansion.

Two types of expansions may be used. In the past, both usually were the same, but for large calculations, there are advantages to relaxing this restraint. The first is the expansion that determines the radial functions using the RMCDHF program of the GRASP2K package. For occupied orbitals, optimized radial functions can be obtained by applying the variational principal of an energy expression. However, when correlation orbitals are to be determined, the most effective orbitals are those that are in the same region of space as the occupied orbitals for a given type of correlation, as has been shown in partitioned configuration interaction (PCFI) studies [13]. In this work, we consider two regions: the $3s, 3p, 3d$ region for valence–valence (VV) correlation and the $2s, 2p$ region for core–valence (CV) and core–core (CC) correlations.

The second is an expansion for the relativistic configuration interaction (RCI) program that determines the wavefunction and its associated energy for a given Hamiltonian and based on a given orbital basis. In the present work, the Hamiltonian for RCI was the Dirac–Coulomb Hamiltonian (DC) plus the transverse photon interaction (DCB), the vacuum polarization effects as accounted for by the Uehling potential, and electron self-energies as calculated with the screened hydrogenic formula [12,14], namely the DCBQ Hamiltonian. The RCI program is relatively simple to parallelize efficiently [15,16] using message passing. As a result, much larger expansions are possible for RCI calculations than RMCDHF ones that build the orbital basis. Present calculations were done with forty-eight (48) processors for the larger cases.

The computational procedure was essentially the same for all ions. The first step was to perform Dirac–Hartree–Fock (DHF) calculations (in the EOL approximation) for all states associated with the $3s^2 3p^6 3d^k$ configuration. This calculation determined the $1s, 2s, 2p$ orbitals for all subsequent calculations. Then, sequentially, orbital sets of increasing size, with maximum principal quantum numbers $n = 3, 4, 5$, were determined from expansions that defined valence–valence correlation expansions. The latter were obtained from single- and double-excitations from the valence shells to those of the orbital set. Since the $3d$ shell is unfilled, excitations such as $3s^2 \rightarrow 3d^2$ are allowed and increase the generalized occupation number for the $3d$ orbitals but decrease those of $3s$. Variational methods determined the new orbitals introduced at each stage using the Dirac–Coulomb Hamiltonian. The $n = 6$ orbitals were targeted for core correlation effects. They were obtained from calculations that included CV correlation from the $n = 2$ shell where one orbital from the active core (either $2s$ or $2p$) and one $3s, 3p$, or $3d$ orbital were excited, as well as CC, where two $n = 2$ orbitals were excited. At the same time, excitations from $3s, 3p$ subshells were limited to single excitations for $3s$ or $3p$, thereby contracting the $n = 6$ orbitals to overlap more strongly with the $n = 2$ orbitals and reducing the size of the expansions. For the configurations $3d^k$, $k = 3, 4, 5, 6, 7$, the expansions were still exceedingly large and additional restrictions on interactions were imposed that define the energy functional. First, what might be considered a zero-order approximation was obtained that consisted of the CSFs of the $n = 5$ VV expansion that accounted for 99.9 percent of the normalized expansion. All other terms of the $n = 6$ expansions were treated as first-order corrections. In deriving the energy expression that determines the radial factors of the $n = 6$ orbitals, it was assumed that the interaction between CSFs of the first-order corrections could be neglected. This procedure optimizes the interaction of the $n = 6$ orbitals with the zero-order wave function, and has the effect of contracting the core–valence orbitals.

Each of these four orbital sets were then used in relativistic configuration interaction (RCI) calculations that included VV, CV, and CC correlation effects (excluding the $1s$ shell) for the three Hamiltonians—DC, DCB, and DCBQ. Again, for the cases where $k = 3, 4, 5, 6, 7$, the RCI calculations were performed under the assumption that interactions between CSF of the first-order correction could be ignored.

Table 1 summarizes the size of various expansions for the different $3d^k$ configurations, whereas Table 2 shows how the mean radii of the $n = 6$ orbitals are contracted relative to the valence correlation orbitals. Note that the size increases rapidly as the number of electrons (or holes) increases from one to five, as well as the number of J values and levels. The number of CSFs defining 99.9% of the wave

function composition is relatively small. Increasing this percentage to 99.99% would include some higher order corrections. As for mean radii, it should be noted the the $3d$ orbitals (in non-relativistic notation) have a mean radius closer to the core than either $3s$ or $3p$. Listed in Table 2 are typical values for the $3d^5$ configuration. The mean radii are also depicted graphically in Figure 1. Correlation increases the generalized orbital occupation number of the $3d$ orbitals, but decreases those of all other occupied orbitals. The $n = 4$ and $n = 5$ orbitals have mean radii similar to those of the valence orbitals, whereas the $n = 6$ orbitals that are used to represent CC and CV correlation have mean radii either similar to $n = 2$ orbitals or between $n = 2$ and $n = 3$, as in CV correlation.

Table 1. Table showing the size (M) of the $n = 6$ relativistic configuration interaction (RCI) expansions and the size of the zero-order space (m) for the different tungsten ions.

J	M	m	J	M	m
$3d$			$3d^9$		
3/2	103 104	-	3/2	152 230	-
5/2	130 021	-	5/2	193 718	-
$3d^2$			$3d^8$		
0	109 376	-	0	138 241	-
1	306 873	-	1	388 664	-
2	453 546	-	2	576 194	-
3	526 871	-	3	672 708	-
4	529 065	-	4	679 881	-
$3d^3$			$3d^7$		
1/2	508 854	514	1/2	584 675	734
3/2	934 941	1 056	3/2	1 075 476	1 564
5/2	1 217 067	1 062	5/2	1 402 693	1 563
7/2	1 328 694	668	7/2	1 535 467	1 020
9/2	1 281 840	737	9/2	1 486 446	1 055
11/2	2216460	277	11/2	1 300 160	353
$3d^4$			$3d^6$		
0	433 540	925	0	462 613	1 113
1	1 228 917	1 070	1	1 311 786	1 244
2	1 840 515	1 688	2	1 965 798	2 071
3	2 187 525	1 375	3	2 338 660	1 738
4	2 261 243	1 624	4	2 420 366	1 921
5	2 095 354	632	5	2 246 438	761
6	1 771 535	572	6	1 902 774	659
$3d^5$					
1/2	1 022 700	1 119			
3/2	1 888 910	1 688			
5/2	2 480 422	2 352			
7/2	2 741 429	1 857			
9/2	2 687 207	1 306			
11/2	2 387 571	910			
13/2	1 943 915	329			

Table 2. Mean radii in a.u. of orbitals for the $3d^5$ configuration and their generalized occupation number w.

nl	$\langle nl\|r\|nl\rangle$	w
1s	1.83433D-02	2.00000
2s	7.64525D-02	1.99992
2$p_$	6.33222D-02	1.99986
2p	7.10859D-02	3.99969
3s	1.91692D-01	1.99940
3$p_$	1.81324D-01	1.99853
3p	1.93743D-01	3.99577
3$d_$	1.67488D-01	2.00137
3d	1.71346D-01	3.00266
4s	2.04509D-01	1.24D-04
4$p_$	1.89988D-01	1.45D-04
4p	2.01490D-01	2.94D-04
4$d_$	1.71036D-01	1.73D-04
4d	1.70979D-01	2.82D-04
4$f_$	1.94058D-01	5.94D-04
4f	1.97398D-01	8.24D-04
5s	2.03090D-01	1.93D-05
5$p_$	1.95387D-01	2.23D-05
5p	1.97508D-01	4.08D-05
5$d_$	2.12303D-01	2.88D-05
5d	2.17420D-01	4.47D-05
5$f_$	1.86560D-01	1.30D-05
5f	1.85984D-01	2.01D-05
5$g_$	1.97882D-01	3.38D-05
5g	2.00859D-01	5.11D-05
6s	1.31230D-01	6.77D-06
6$p_$	1.19574D-01	8.04D-06
6p	1.20726D-01	1.40D-05
6$d_$	1.18546D-01	1.71D-05
6d	1.24725D-01	2.58D-05
6$f_$	8.84520D-02	7.35D-06
6f	9.29611D-02	1.10D-05
6$g_$	7.72823D-02	2.26D-06
6g	7.88248D-02	3.31D-06
6$h_$	1.62256D-01	2.42D-06
6h	8.04121D-02	7.65D-07

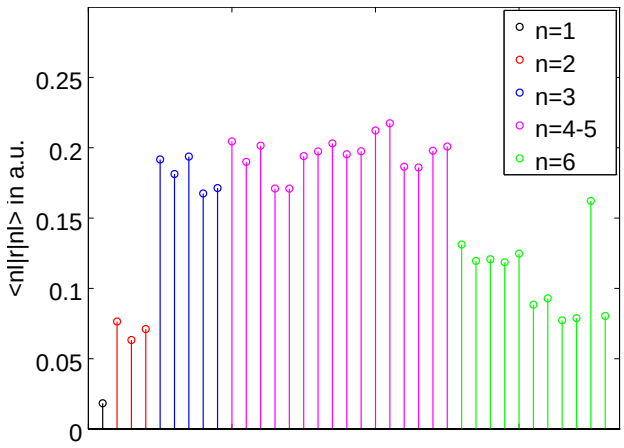

Figure 1. Plot of the mean radii of orbitals of the $3d^5$ configuration in the order listed in Table 2.

3. Results and Their Comparison

Table 3 reports some of the results for all levels of the $3d^k$ configurations of tungsten ions from RCI calculations for the DCBQ Hamiltonian. The classification of energy levels are presented in the LSJ- and jj-couplings. A set of three quantum numbers L, S, and seniority v allows a one-to-one classification of $3d^k$ ($k = 3,4,5,6,7$) energy levels in LSJ-coupling. These quantum numbers are presented in Table 3 as $^{(2S+1)}L^v$. The $n = 5$ results include only VV correlation, whereas $n = 6$ include all three correlation effects. The next column is the energy levels as reported by NIST [5]. Included here are the different types of results. Energies with no square brackets are directly related to observed wavelengths—often these are in the lower portion of the spectrum. Then, there are levels that may be linked to an observed wavelength but the shift of the energy levels relative to the ground state is not known from experiment. These levels include a $+x$ or $+y$ in the table. Thus, the difference between two levels with the same $+x$ is known accurately, but not the levels themselves. Taking these factors into account, it is clear that the inclusion of core effects has reduced the discrepancy with NIST values by about a factor of 1/2. In the next column, the values found by Quinet [6] are generally like the VV results. From a general theoretical point of view, the the RMBPT results of Guo et al. [8] should be the most accurate. In the case of $3d^2$, RMBPT results have also been reported by Safronova and Safronova [17], and are reported in the last column. These results are not as accurate as those of Guo et al. In these tables, all energies are reported in the units of 1000 cm^{-1}.

Table 3. Energy level results for $3d$, $3d^2$, …, $3d^8$, $3d^9$ ground configuration of tungsten ions. Shown is a unique label in LSJ- and jj-notation, the J value, the present n = 5 result for valence–valence (VV) correlation, and n = 6 result for all three types of correlation, the Atomic Spectra Database (ASD) value [5], the Quinet value [6], the Guo et al. RMBPT$_g$ value [8], and the Safronova & Safronova RMBPT$_s$ value [17]. All energy levels are reported in 1000 cm^{-1}.

Label			J	Present Work		ASD	GRASP	RMBPT$_g$	RMBPT$_s$
LSJ-	jj-Couplings			$n = 5$	$n = 6$				
W^{55+} (K-like)									
$3d\ ^2D$	$3d_-$	(3/2,0)	3/2	0.00	0.00	0.00	0.00	0.00	
$3d\ ^2D$	$3d_+$	(0,5/2)	5/2	625.23	626.17	626.49	624.7	626.56	
W^{54+} (Ca-like)									
$3d^2\ ^3F$	$3d_-^2$	(2,0)	2	0.00	0.00	0.00	0.00	0.00	0.00
$3d^2\ ^3P$	$3d_-^2$	(0,0)	0	186.42	186.23	[188]	186.9	184.86	187.11
$3d^2\ ^3F$	$3d_-3d_+$	(3/2,5/2)	3	584.05	584.75	585.48	583.5	585.80	582.85
$3d^2\ ^3P$	$3d_-3d_+$	(3/2,5/2)	2	667.45	667.96	668.49	667.6	668.00	666.21
$3d^2\ ^3P$	$3d_-3d_+$	(3/2,5/2)	1	706.35	706.75	709.46+x	707.1	706.78	705.41
$3d^2\ ^1G$	$3d_-3d_+$	(3/2,5/2)	4	695.68	696.10	[697]	697.1	696.74	693.81
$3d^2\ ^3F$	$3d_+^2$	(0,4)	4	1234.31	1235.57	[1234]	1234.1	1237.00	1231.64
$3d^2\ ^3P$	$3d_+^2$	(0,2)	2	1298.91	1300.18	[1299]	1298.6	1300.28	1296.73
$3d^2\ ^1S$	$3d_+^2$	(0,0)	0	1492.04	1493.71	[1493]	1491.0	1491.18	1491.54
W^{53+} (Sc-like)									
$3d^3\ ^4F^3$	$3d_-^3$	(3/2,0)	3/2	0.00	0.00	0.00	0.00	0.00	
$3d^3\ ^4F^3$	$3d_-^2 3d_+$	(2,5/2)	5/2	528.39	529.07	530.03	528.2	530.51	
$3d^3\ ^4P^3$	$3d_-^2 3d_+$	(2,5/2)	3/2	579.43	579.99	580.86	579.9	580.86	
$3d^3\ ^2G^3$	$3d_-^2 3d_+$	(2,5/2)	7/2	610.41	610.86	[610]	611.7	611.86	
$3d^3\ ^4P^3$	$3d_-^2 3d_+$	(2,5/2)	1/2	622.72	623.22	623.95	623.6	623.53	
$3d^3\ ^2H^3$	$3d_-^2 3d_+$	(2,5/2)	9/2	609.94	610.32	[610]+x	612.0	611.62	
$3d^3\ ^2D^1$	$3d_-^2 3d_+$	(0,5/2)	5/2	811.84	812.07	812.22	814.2	811.77	
$3d^3\ ^4F^3$	$3d_-3d_+^2$	(3/2,4)	7/2	1127.31	1128.60	[1126]	1127.1	1130.58	
$3d^3\ ^4F^3$	$3d_-3d_+^2$	(3/2,4)	9/2	1164.81	1165.99	[1164]	1165.7	1168.15	

Table 3. *Cont.*

Label			J	Present Work		ASD	GRASP	RMBPT$_g$	RMBPT$_s$
LSJ-	*jj*-Couplings			$n=5$	$n=6$				
$3d^3\ ^4P^3$	$3d_-3d_+^2$	(3/2,2)	3/2	1206.41	1207.73	[1206]	1206.2	1208.34	
$3d^3\ ^2P^3$	$3d_-3d_+^2$	(3/2,2)	1/2	1230.34	1231.58	[1230]	1230.5	1232.08	
$3d^3\ ^2D^3$	$3d_-3d_+^2$	(3/2,4)	5/2	1243.67	1244.61	[1244]	1245.0	1245.39	
$3d^3\ ^2H^3$	$3d_-3d_+^2$	(3/2,4)	11/2	1242.38	1243.30	1243.51+x	1245.2	1245.42	
$3d^3\ ^2F^3$	$3d_-3d_+^2$	(3/2,2)	5/2	1314.58	1315.54	[1315]	1316.4	1315.84	
$3d^3\ ^2F^3$	$3d_-3d_+^2$	(3/2,2)	7/2	1318.68	1319.55	[1320]	1321.5	1320.10	
$3d^3\ ^2D^1$	$3d_-3d_+^2$	(3/2,0)	3/2	1479.96	1481.26	[1482]	1481.3	1479.89	
$3d^3\ ^2G^3$	$3d_+^3$	(0,9/2)	9/2	1762.93	1764.86		1762.9	1767.02	
$3d^3\ ^2P^3$	$3d_+^3$	(0,3/2)	3/2	1876.44	1878.32		1877.0	1878.54	
$3d^3\ ^2D^1$	$3d_+^3$	(0,5/2)	5/2	1958.00	1960.12		1957.9	1959.56	
W^{52+} (Ti-like)									
$3d^4\ ^3P^2$	$3d_-^4$	(0,0)	0	0.00	0.00	0.00	0.00	0.00	
$3d^4\ ^5D^4$	$3d_-^3 3d_+$	(3/2,5/2)	1	515.87	516.51	517.63	516.0	518.08	
$3d^4\ ^3H^4$	$3d_-^3 3d_+$	(3/2,5/2)	4	613.24	613.54	[613]+y	615.6	614.79	
$3d^4\ ^5D^4$	$3d_-^3 3d_+$	(3/2,5/2)	2	637.98	638.39	[638]+x	639.9	639.34	
$3d^4\ ^3F^2$	$3d_-^3 3d_+$	(3/2,5/2)	3	665.84	666.09	665.5621+x	668.6	667.04	
$3d^4\ ^5D^4$	$3d_-^2 3d_+^2$	(2,2)	0	1101.86	1103.18	[1100]	1101.6	1104.66	
$3d^4\ ^5D^4$	$3d_-^2 3d_+^2$	(2,4)	2	1106.82	1107.98	1109.69	1107.6	1110.02	
$3d^4\ ^3H^4$	$3d_-^2 3d_+^2$	(2,4)	4	1125.54	1126.59	1127.27+y	1127.3	1129.11	
$3d^4\ ^5D^4$	$3d_-^2 3d_+^2$	(2,4)	3	1142.02	1143.02	[1141]	1144.0	1145.19	
$3d^4\ ^3H^4$	$3d_-^2 3d_+^2$	(2,4)	5	1172.24	1173.06	1173.35+y	1175.7	1175.60	
$3d^4\ ^3D^4$	$3d_-^2 3d_+^2$	(2,2)	1	1213.52	1214.54	[1213]	1215.4	1215.64	
$3d^4\ ^1I^4$	$3d_-^2 3d_+^2$	(2,4)	6	1195.60	1196.31	[1195]	1200.00	1199.02	
$3d^4\ ^3F^4$	$3d_-^2 3d_+^2$	(2,2)	3	1239.13	1239.92	[1240]	1242.5	1240.99	
$3d^4\ ^3G^4$	$3d_-^2 3d_+^2$	(2,2)	4	1242.41	1243.17	[1243]	1245.7	1244.47	
$3d^4\ ^3F^4$	$3d_-^2 3d_+^2$	(2,2)	2	1257.75	1258.62	[1258]	1260.6	1259.43	
$3d^4\ ^3F^2$	$3d_-^2 3d_+^2$	(2,0)	2	1359.28	1360.44	[1361]	1361.1	1360.35	
$3d^4\ ^3F^2$	$3d_-^2 3d_+^2$	(0,4)	4	1403.66	1404.22	1403.95+x	1408.6	1405.11	
$3d^4\ ^1D^2$	$3d_-^2 3d_+^2$	(0,2)	2	1505.68	1506.35	[1509]	1510.3	1505.82	
$3d^4\ ^3P^4$	$3d_-^2 3d_+^2$	(0,0)	0	1633.13	1634.15	[1637]	1636.5	1632.74	
$3d^4\ ^5D^4$	$3d_-3d_+^3$	(3/2,9/2)	4	1714.26	1715.10		1715.3	1718.50	
$3d^4\ ^3F^4$	$3d_-3d_+^3$	(3/2,9/2)	3	1725.24	1727.04		1725.9	1729.15	
$3d^4\ ^3D^4$	$3d_-3d_+^3$	(3/2,3/2)	1	1766.70	1768.58		1767.1	1769.70	
$3d^4\ ^3G^4$	$3d_-3d_+^3$	(3/2,9/2)	5	1773.76	1775.28		1776.4	1777.84	
$3d^4\ ^3H^4$	$3d_-3d_+^3$	(3/2,9/2)	6	1778.76	1780.21		1782.4	1783.28	
$3d^4\ ^3F^4$	$3d_-3d_+^3$	(3/2,3/2)	2	1841.18	1842.98		1842.9	1843.90	
$3d^4\ ^3D^4$	$3d_-3d_+^3$	(3/2,3/2)	3	1857.70	1859.24		1860.2	1860.18	
$3d^4\ ^1S^4$	$3d_-3d_+^3$	(3/2,3/2)	0	1922.88	1924.06		1925.8	1923.37	
$3d^4\ ^3P^2$	$3d_-3d_+^3$	(3/2,5/2)	1	1983.87	1985.44		1987.2	1985.44	
$3d^4\ ^3F^2$	$3d_-3d_+^3$	(3/2,5/2)	3	1979.96	1981.50		1983.6	1981.91	
$3d^4\ ^1G^2$	$3d_-3d_+^3$	(3/2,5/2)	4	1985.00	1986.57		1988.7	1987.02	
$3d^4\ ^1D^4$	$3d_-3d_+^3$	(3/2,5/2)	2	2018.63	2020.04		2022.8	2019.68	
$3d^4\ ^3F^2$	$3d_+^4$	(0,4)	4	2376.23	2378.86		2376.1	2380.51	
$3d^4\ ^1D^2$	$3d_+^4$	(0,2)	2	2460.51	2463.08		2461.4	2463.56	
$3d^4\ ^3P^2$	$3d_+^4$	(0,0)	0	2662.74	2665.52		2663.5	2663.60	
W^{51+} (V-like)									
$3d^5\ ^4P^3$	$3d_-^4 3d_+$	(0,5/2)	5/2	0.00	0.00	0.00	0.00	0.00	
$3d^5\ ^6S^5$	$3d_-^3 3d_+^2$	(3/2,4)	5/2	469.71	470.75	71.63	469.1	472.03	

Table 3. *Cont.*

Label			J	Present Work		ASD	GRASP	RMBPT$_g$	RMBPT$_s$
LSJ-	*jj*-Couplings			$n=5$	$n=6$				
$3d^5\ ^4G^5$	$3d_-^3 3d_+^2$	(3/2,4)	7/2	564.98	565.80	66.25	566.2	566.41	
$3d^5\ ^4D^5$	$3d_-^3 3d_+^2$	(3/2,2)	3/2	579.61	580.50	80.89	579.8	580.44	
$3d^5\ ^2H^3$	$3d_-^3 3d_+^2$	(3/2,4)	11/2	576.03	576.78	[577]+x	578.5	577.80	
$3d^5\ ^2G^5$	$3d_-^3 3d_+^2$	(3/2,4)	9/2	620.92	621.61	[623]	623.7	622.20	
$3d^5\ ^4D^5$	$3d_-^3 3d_+^2$	(3/2,2)	5/2	650.71	651.45	[652]	652.8	651.27	
$3d^5\ ^4P^3$	$3d_-^3 3d_+^2$	(3/2,2)	1/2	679.60	680.38	[681]	680.8	679.83	
$3d^5\ ^2F^5$	$3d_-^3 3d_+^2$	(3/2,2)	7/2	687.73	688.28	88.18	690.9	687.90	
$3d^5\ ^2D^1$	$3d_-^3 3d_+^2$	(3/2,0)	3/2	823.99	824.95	[827]	825.5	823.60	
$3d^5\ ^6S^5$	$3d_-^2 3d_+^3$	(2,9/2)	5/2	1025.98	1027.97	[1015]	1024.9	1029.11	
$3d^5\ ^4D^5$	$3d_-^2 3d_+^3$	(2,9/2)	7/2	1096.84	1098.61	[1097]	1097.9	1099.59	
$3d^5\ ^4G^5$	$3d_-^2 3d_+^3$	(2,9/2)	11/2	1100.79	1102.51	1103.43	1103.0	1104.04	
$3d^5\ ^4G^5$	$3d_-^2 3d_+^3$	(2,9/2)	9/2	1116.98	1118.70	[1118]	1118.8	1119.70	
$3d^5\ ^4D^5$	$3d_-^2 3d_+^3$	(2,3/2)	1/2	1155.66	1157.40		1156.6	1157.55	
$3d^5\ ^4P^3$	$3d_-^2 3d_+^3$	(2,5/2)	3/2	1164.73	1166.79		1163.6	1166.64	
$3d^5\ ^2I^5$	$3d_-^2 3d_+^3$	(2,9/2)	13/2	1142.15	1143.78	[1143]	1145.6	1145.272	
$3d^5\ ^2F^5$	$3d_-^2 3d_+^3$	(2,3/2)	5/2	1174.89	1176.61		1176.3	1176.63	
$3d^5\ ^2H^3$	$3d_-^2 3d_+^3$	(2,5/2)	9/2	1217.34	1219.21		1218.4	1219.39	
$3d^5\ ^2G^5$	$3d_-^2 3d_+^3$	(2,3/2)	7/2	1237.88	1239.44		1240.9	1239.13	
$3d^5\ ^4F^3$	$3d_-^2 3d_+^3$	(2,5/2)	5/2	1254.59	1256.46		1255.8	1256.02	
$3d^5\ ^2D^5$	$3d_-^2 3d_+^3$	(2,3/2)	3/2	1259.49	1260.94		1262.1	1259.77	
$3d^5\ ^4P^3$	$3d_-^2 3d_+^3$	(2,5/2)	1/2	1308.19	1309.93		1309.8	1308.63	
$3d^5\ ^2G^3$	$3d_-^2 3d_+^3$	(2,5/2)	7/2	1307.82	1309.62		1309.9	1308.84	
$3d^5\ ^2G^3$	$3d_-^2 3d_+^3$	(0,9/2)	9/2	1379.66	1381.18		1383.8	1380.57	
$3d^5\ ^2P^3$	$3d_-^2 3d_+^3$	(0,3/2)	3/2	1504.94	1506.22		1510.4	1504.14	
$3d^5\ ^2D^1$	$3d_-^2 3d_+^3$	(0,5/2)	5/2	1533.17	1534.71		1537.4	1532.74	
$3d^5\ ^4P^3$	$3d_- 3d_+^4$	(3/2,4)	5/2	1660.92	1663.98		1658.7	1664.07	
$3d^5\ ^4F^3$	$3d_- 3d_+^4$	(3/2,4)	7/2	1733.68	1736.62		1733.1	1736.60	
$3d^5\ ^4D^5$	$3d_- 3d_+^4$	(3/2,2)	3/2	1759.25	1762.30		1758.1	1761.85	
$3d^5\ ^2H^3$	$3d_- 3d_+^4$	(3/2,4)	11/2	1746.45	1749.34		1747.2	1749.91	
$3d^5\ ^2G^5$	$3d_- 3d_+^4$	(3/2,4)	9/2	1806.21	1808.95		1807.7	1808.86	
$3d^5\ ^2D^3$	$3d_- 3d_+^4$	(3/2,2)	5/2	1843.82	1846.49		1844.6	1845.21	
$3d^5\ ^2G^3$	$3d_- 3d_+^4$	(3/2,2)	7/2	1871.70	1874.38		1874.1	1873.74	
$3d^5\ ^2P^3$	$3d_- 3d_+^4$	(3/2,2)	1/2	1933.91	1936.39		1937.0	1934.46	
$3d^5\ ^2D^1$	$3d_- 3d_+^4$	(3/2,0)	3/2	2063.04	2065.78		2065.5	2062.96	
$3d^5\ ^2D^1$	$3d_+^5$	(0,5/2)	5/2	2362.48	2366.70		2359.4	2365.33	
W^{50+} (Cr-like)									
$3d^6\ ^5D^4$	$3d_-^4 3d_+^2$	(0,4)	4	0.00	0.00	0.00	0.00	0.00	
$3d^6\ ^3D^4$	$3d_-^4 3d_+^2$	(0,2)	2	62.74	62.71	62.38	62.6	61.56	
$3d^6\ ^3P^2$	$3d_-^4 3d_+^2$	(0,0)	0	207.31	207.66	[208]+x	205.9	205.74	
$3d^6\ ^5D^4$	$3d_-^3 3d_+^3$	(3/2,9/2)	3	506.28	507.09	508.03	505.2	507.80	
$3d^6\ ^5D^4$	$3d_-^3 3d_+^3$	(3/2,9/2)	4	518.36	519.02	519.78	518.0	519.83	
$3d^6\ ^5D^4$	$3d_-^3 3d_+^3$	(3/2,3/2)	1	545.62	546.54	[545]	543.8	546.53	
$3d^6\ ^3G^4$	$3d_-^3 3d_+^3$	(3/2,9/2)	5	582.70	583.09	583.67	584.2	583.74	
$3d^6\ ^3H^4$	$3d_-^3 3d_+^3$	(3/2,9/2)	6	582.40	582.70	[583]	584.3	583.61	
$3d^6\ ^3F^4$	$3d_-^3 3d_+^3$	(3/2,3/2)	2	637.99	638.51	[639]	638.1	637.59	
$3d^6\ ^3D^4$	$3d_-^3 3d_+^3$	(3/2,3/2)	3	649.76	650.29	650.91	650.6	649.82	
$3d^6\ ^3P^4$	$3d_-^3 3d_+^3$	(3/2,3/2)	0	725.01	725.35	[729]	727.9	723.98	
$3d^6\ ^3P^2$	$3d_-^3 3d_+^3$	(3/2,5/2)	1	767.07	767.54	768.98+x	769.3	766.38	

Table 3. *Cont.*

Label			J	Present Work		ASD	GRASP	RMBPT$_g$	RMBPT$_s$
LSJ-	*jj*-Couplings			$n=5$	$n=6$				
$3d^6\ ^3D^4$	$3d_-^3 3d_+^3$	(3/2,5/2)	2	766.25	766.84	766.95	767.6	765.69	
$3d^6\ ^1G^2$	$3d_-^3 3d_+^3$	(3/2,5/2)	4	760.65	761.12	761.21	762.5	760.28	
$3d^6\ ^3F^2$	$3d_-^3 3d_+^3$	(3/2,5/2)	3	782.18	782.54	782.53	785.0	781.26	
$3d^6\ ^5D^4$	$3d_-^2 3d_+^4$	(2,4)	2	1058.57	1060.19		1055.6	1060.64	
$3d^6\ ^5D^4$	$3d_-^2 3d_+^4$	(2,2)	0	1083.07	1084.88		1079.6	1085.16	
$3d^6\ ^3H^4$	$3d_-^2 3d_+^4$	(2,4)	4	1108.16	1109.55		1106.9	1110.13	
$3d^6\ ^5D^4$	$3d_-^2 3d_+^4$	(2,4)	3	1135.23	1136.57		1134.6	1136.84	
$3d^6\ ^3H^4$	$3d_-^2 3d_+^4$	(2,4)	5	1142.11	1143.32		1142.4	1144.11	
$3d^6\ ^1I^4$	$3d_-^2 3d_+^4$	(2,4)	6	1169.18	1170.23		1170.5	1171.16	
$3d^6\ ^3F^4$	$3d_-^2 3d_+^4$	(2,2)	3	1196.79	1198.08		1197.0	1198.01	
$3d^6\ ^3D^4$	$3d_-^2 3d_+^4$	(2,2)	1	1217.26	1218.50		1217.8	1217.79	
$3d^6\ ^1G^4$	$3d_-^2 3d_+^4$	(2,2)	4	1232.82	1233.95		1234.1	1233.73	
$3d^6\ ^3F^4$	$3d_-^2 3d_+^4$	(2,2)	2	1243.66	1244.79		1244.0	1243.75	
$3d^6\ ^3F^2$	$3d_-^2 3d_+^4$	(2,0)	2	1336.95	1338.38		1336.9	1336.97	
$3d^6\ ^3F^2$	$3d_-^2 3d_+^4$	(0,4)	4	1374.79	1375.77		1376.9	1375.03	
$3d^6\ ^1D^2$	$3d_-^2 3d_+^4$	(0,2)	2	1518.97	1519.86		1523.2	1517.58	
$3d^6\ ^1S^0$	$3d_-^2 3d_+^4$	(0,0)	0	1660.58	1661.58		1664.9	1658.28	
$3d^6\ ^3P^2$	$3d_- 3d_+^5$	(3/2,5/2)	1	1663.26	1665.83		1657.7	1665.57	
$3d^6\ ^1G^2$	$3d_- 3d_+^5$	(3/2,5/2)	4	1764.33	1766.52		1762.0	1766.29	
$3d^6\ ^3P^2$	$3d_- 3d_+^5$	(3/2,5/2)	2	1813.76	1815.87		1811.7	1814.75	
$3d^6\ ^3F^2$	$3d_- 3d_+^5$	(3/2,5/2)	3	1831.23	1833.30		1830.3	1832.64	
$3d^6\ ^3P^2$	$3d_+^6$	(0,0)	0	2321.86	2325.36		2314.1	2323.82	
W^{49+} (Mn-like)									
$3d^7\ ^4F^3$	$3d_-^4 3d_+^3$	(0,9/2)	9/2	0.00	0.00	0.00	0.00	0.00	
$3d^7\ ^2P^3$	$3d_-^4 3d_+^3$	(0,3/2)	3/2	101.71	101.64	[103]+x	102.1	100.13	
$3d^7\ ^2D^1$	$3d_-^4 3d_+^3$	(0,5/2)	5/2	158.95	159.10	158.75	158.7	157.62	
$3d^7\ ^4F^3$	$3d_-^3 3d_+^4$	(3/2,4)	7/2	527.98	528.88	529.66	526.1	529.08	
$3d^7\ ^4F^3$	$3d_-^3 3d_+^4$	(3/2,4)	9/2	583.50	584.16	584.59	583.1	584.18	
$3d^7\ ^4P^3$	$3d_-^3 3d_+^4$	(3/2,2)	3/2	607.96	608.87	[608]	606.6	608.30	
$3d^7\ ^4P^3$	$3d_-^3 3d_+^4$	(3/2,4)	5/2	624.97	625.72	628.02+x	624.9	625.41	
$3d^7\ ^4P^3$	$3d_-^3 3d_+^4$	(3/2,2)	1/2	635.89	636.62	638.62+x	635.1	635.45	
$3d^7\ ^2H^3$	$3d_-^3 3d_+^4$	(3/2,4)	11/2	650.16	650.58	650.70	651.8	650.55	
$3d^7\ ^2F^3$	$3d_-^3 3d_+^4$	(3/2,2)	7/2	705.20	705.71	705.92	706.4	704.86	
$3d^7\ ^2F^3$	$3d_-^3 3d_+^4$	(3/2,2)	5/2	742.86	743.30	[747]	745.4	742.07	
$3d^7\ ^2D^1$	$3d_-^3 3d_+^4$	(3/2,0)	3/2	888.41	889.03	[893]	890.8	886.67	
$3d^7\ ^4F^3$	$3d_-^2 3d_+^5$	(2,5/2)	5/2	1115.46	1117.19		1112.0	1116.93	
$3d^7\ ^4P^3$	$3d_-^2 3d_+^5$	(2,5/2)	3/2	1147.62	1149.25		1145.1	1148.65	
$3d^7\ ^2P^3$	$3d_-^2 3d_+^5$	(2,5/2)	1/2	1192.13	1193.65		1189.9	1192.53	
$3d^7\ ^2H^3$	$3d_-^2 3d_+^5$	(2,5/2)	9/2	1185.68	1187.07		1184.9	1186.89	
$3d^7\ ^2F^3$	$3d_-^2 3d_+^5$	(2,5/2)	7/2	1210.79	1212.16		1210.3	1211.44	
$3d^7\ ^2D^1$	$3d_-^2 3d_+^5$	(0,5/2)	5/2	1410.07	1411.30		1411.0	1409.49	
$3d^7\ ^2D^1$	$3d_- 3d_+^6$	(3/2,0)	3/2	1751.87	1754.44		1746.4	1753.15	
W^{48+} (Fe-like)									
$3d^8\ ^3F$	$3d_-^4 3d_+^4$	(0,4)	4	0.00	0.00	0.00	0.00	0.00	
$3d^8\ ^1D$	$3d_-^4 3d_+^4$	(0,2)	2	72.15	72.12	[73.4]+x	72.8	71.26	
$3d^8\ ^3P$	$3d_-^4 3d_+^4$	(0,0)	0	229.94	230.10	[233]	230.7	228.17	
$3d^8\ ^3F$	$3d_-^3 3d_+^5$	(3/2,5/2)	3	525.18	526.07	526.65	523.2	526.13	
$3d^8\ ^3P$	$3d_-^3 3d_+^5$	(3/2,5/2)	2	600.38	601.15	603.12+x	599.7	600.69	

Table 3. *Cont.*

Label			J	Present Work		ASD	GRASP	RMBPT$_g$	RMBPT$_s$
LSJ-	*jj*-Couplings			$n=5$	$n=6$				
$3d^8\ ^3P$	$3d_-^3 3d_+^5$	(3/2,5/2)	1	642.01	642.71	644.76+x	642.7	642.14	
$3d^8\ ^1G$	$3d_-^3 3d_+^5$	(3/2,5/2)	4	643.89	644.43	644.70	645.0	644.03	
$3d^8\ ^3F$	$3d_-^2 3d_+^6$	(2,2)	2	1106.91	1108.59	[1106]	1103.6	1108.17	
$3d^8\ ^1S$	$3d_-^2 3d_+^6$	(0,0)	0	1304.16	1305.75	[1306]	1301.7	1304.07	
W^{47+} (Co-like)									
$3d^9\ ^2D$	$3d_-^4 3d_+^5$	(0,5/2)	5/2	0.00	0.00	0.00	0.00	0.00	
$3d^9\ ^2D$	$3d_-^3 3d_+^6$	(3/2,0)	3/2	537.21	538.04	538.59	535.6	538.05	

The uncertainties of NIST energy levels not based on observed wavelengths are estimated as being less than 5000 cm^{-1}, or 5.00 in our table. In order to better understand the importance of various effects in Table 4, we report the NIST energy levels that are based on observation and differences of various theories for only those levels where NIST values are accurate, although there may be an unknown shift.

Table 4. Difference from NIST energy levels derived from observation. Shown is the *LS* label, the J value, the present $n=5$ result for VV correlation, and $n=6$ result for all three types of correlation, the ASD value [5], the Quinet value [6], the Guo et al. RMBPT$_g$ value [8], and the Safranova & Safronova RMBPT$_s$ value [17]. All energy levels are reported in 1000 cm^{-1}.

Label	J	Present Work		ASD	GRASP	RMBPT$_g$	RMBPT$_s$
		$n=5$	$n=6$				
W^{55+} (K-like)							
$3d\ ^2D$	3/2	0.00	0.00	0.00	0.00	0.00	
$3d\ ^2D$	5/2	1.25	0.32	626.49	2.49	−0.07	
W^{54+} (Ca-like)							
$3d^2\ ^3F$	2	0.00	0.00	0.00	0.00	0.00	0.00
$3d^2\ ^3F$	3	1.43	0.73	585.48	1.98	−0.32	2.63
$3d^2\ ^3P$	2	1.04	0.53	668.49	0.89	0.49	2.28
$3d^2\ ^3P$	1	3.11	2.71	709.46+x	2.36	2.68	4.05
W^{53+} (Sc-like)							
$3d^3\ ^4F^3$	3/2	0.00	0.00	0.00	0.00	0.00	
$3d^3\ ^4F^3$	5/2	1.64	0.96	530.03	1.83	−0.48	
$3d^3\ ^4P^3$	3/2	1.43	0.87	580.86	0.96	0.0	
$3d^3\ ^4P^3$	1/2	1.23	0.73	623.95	0.35	0.42	
$3d^3\ ^2D^1$	5/2	0.38	0.15	812.22	−1.98	0.45	
$3d^3\ ^2H^3$	11/2	1.13	0.21	1234.51+x	−1.69	0.45	
W^{52+} (Ti-like)							
$3d^4\ ^3P^2$	0	0.00	0.00	0.00	0.00	0.00	
$3d^4\ ^5D^4$	1	1.76	1.12	517.63	1.63	−0.45	
$3d^4\ ^3F^2$	3	−0.28	−0.53	665.5621+x	−3.04	−1.48	
$3d^4\ ^5D^4$	2	2.87	1.71	1109.69	2.09	−0.33	
$3d^4\ ^3H^4$	4	1.73	0.68	1127.27+y	−0.03	−1.84	
$3d^4\ ^3H^4$	5	1.11	0.29	1173.35+y	−2.35	−22.25	
$3d^4\ ^3F^2$	4	0.29	−0.27	1403.95+x	−4.65	−1.16	

Table 4. *Cont.*

Label	J	Present Work $n=5$	Present Work $n=6$	ASD	GRASP	RMBPT$_g$	RMBPT$_s$
W^{51+} (V-like)							
$3d^5\ ^4P^3$	5/2	0.00	0.00	0.00	0.00	0.00	
$3d^5\ ^6S^5$	5/2	1.92	0.88	471.63	2.53	−0.40	
$3d^5\ ^4G^5$	7/2	1.27	0.45	566.25	0.05	−0.16	
$3d^5\ ^4D^5$	3/2	1.28	0.39	580.89	1.09	0.45	
$3d^5\ ^2F^5$	7/2	0.45	−0.10	688.18	−2.72	0.28	
$3d^5\ ^4G^5$	11/2	2.64	0.92	1103.43	0.43	−0.61	
W^{50+} (Cr-like)							
$3d^6\ ^5D^4$	4	0.00	0.00	0.00	0.00	0.00	
$3d^6\ ^3D^4$	2	−0.36	−0.29	62.38	−0.22	0.82	
$3d^6\ ^5D^4$	3	1.75	1.04	508.03	2.83	0.23	
$3d^6\ ^5D^4$	4	1.41	0.74	519.78	1.78	0.05	
$3d^6\ ^3G^4$	5	0.97	0.44	583.67	−0.53	−0.07	
$3d^6\ ^3D^4$	3	1.15	0.56	650.91	0.31	1.09	
$3d^6\ ^3P^2$	1	1.91	1.44	768.98+x	−0.32	2.60	
$3d^6\ ^3D^4$	2	0.70	0.11	766.95	−0.65	1.26	
$3d^6\ ^1G^2$	4	0.56	−0.04	761.21	−1.29	0.93	
$3d^6\ ^3F^2$	3	0.35	−0.08	782.53	−2.47	1.27	
W^{49+} (Mn-like)							
$3d^7\ ^4F^3$	9/2	0.00	0.00	0.00	0.00	0.00	
$3d^7\ ^2D^1$	5/2	−0.20	−0.35	158.75	0.05	1.13	
$3d^7\ ^4F^3$	7/2	1.68	0.78	529.66	3.56	0.58	
$3d^7\ ^4F^3$	9/2	1.09	0.43	584.59	1.49	0.41	
$3d^7\ ^4P^3$	5/2	3.05	2.30	628.02+x	3.12	2.61	
$3d^7\ ^4P^3$	1/2	2.73	2.00	638.62+x	3.52	3.17	
$3d^7\ ^2H^3$	11/2	0.54	0.12	650.70	−1.10	0.15	
$3d^7\ ^2F^3$	7/2	0.72	0.21	705.92	−0.48	1.06	
W^{48+} (Fe-like)							
$3d^8\ ^3F$	4	0.00			0.00	0.00	0.00
$3d^8\ ^3F$	3	1.47	0.58	526.65	3.45	0.52	
$3d^8\ ^3P$	2	2.74	1.97	603.12+x	3.42	2.43	
$3d^8\ ^3P$	1	2.73	2.05	644.76+x	2.06	2.62	
W^{47+} (Co-like)							
$3d^9\ ^2D$	5/2	0.00	0.00	0.00	0.00	0.00	
$3d^9\ ^2D$	3/2	1.38	0.55	538.59	2.99	0.54	

Table 4 shows clearly that the uncertainties of the present $n = 6$ results are smaller by about a factor of a half when no shifts are indicated in the NIST value. For these levels, the $n = 6$ results statistically differ less than the Quinet values that are similar to the less accurate $n = 5$ values. The most accurate results for $3d$ and $3d^9$ are the RMCDHF$_g$ results, although for $3d^9$, the $n = 6$ are almost of the same accuracy. RMBPT$_g$ is the more accurate for $3d^2$, with $n = 6$ almost the same. For $3d^8$, the two lower levels, RMBPT$_g$ is the more accurate, whereas $n = 6$ is the more accurate for the two upper levels. A similar pattern seems to hold for other spectra. An interesting case is $3d^7\ ^4P\ J = 5/2$ and 1/2, where both levels have an unknown shift. An exact theoretical value and an exact NIST value (except for the shift) would have the same difference for the two levels. In the present case, the

$n = 6$ differences are more similar than the RMCDHF$_g$ differences. In fact, from this table, we can conclude that any NIST value for which the theoretical difference from NIST for both methods is more than 1.00 has a noticeable error. Thus, for example, the $^3P_1$ level of $3d^8$ with an energy level of 644.70 Kcm^{-1} suggests that the NIST values is not accurate to two decimal places.

The errors in different theoretical results are shown in Figure 2. Note the similarity in accuracy of the present $n = 6$ results and values reported by Guo et al. [8].

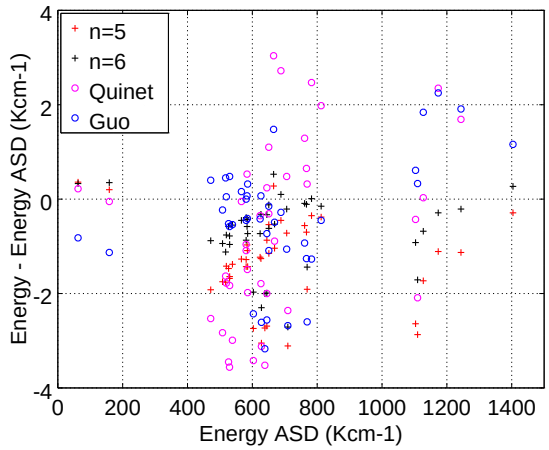

Figure 2. Plot comparing the accuracy of different theoretical methods.

The accuracy of theoretical energy levels are best evaluated by comparing theoretical wavelengths with wavelengths of observed lines in the spectrum. In Table 5, all wavelengths for M1 transitions between the $3d^k$ levels for the present $n = 5, 6$ results are compared with experimental results and other theory, when available. This table clearly shows the improvement in accuracy of $n = 6$ calculations over $n = 5$, as well as the GRASP results reported by Quinet [6], and in many cases the very close agreement with Guo et al. [8]. Two exceptions are the $3d^7\ ^4F^3 - 3d^7\ ^2F^3$ ($J = 9/2$ to $J = 7/2$) transition, for which the observed wavelength is 14.166(3) nm, the present $n = 6$ is 14.170 nm, and the Guo et al. value is 14.187 nm. Similarly, the $3d^8\ ^3F - 3d^8\ ^1G$ ($J = 4$ to $J = 4$) transition has an observed wavelength of 15.511(3) nm, whereas the present value is 15.518 nm and the Guo et al. value is 15.463 nm.

Table 5. Wavelengths from theory for observed M1 transitions compared with observed wavelengths (in nm). Included are some long wavelengths for transitions between close-lying levels.

Label and J for Lower		Label and J for Upper		Present Work $n = 5$	Present Work $n = 6$	Expt (Ref. [2])	GRASP	RMBPT$_g$	RCI$_g$
W^{55+} (K-like)									
$3d\ ^2D$	3/2	$3d\ ^2D$	5/2	15.994	15.970	15.962(3)	16.008	15.960	16.035
W^{54+} (Ca-like)									
$3d^2\ ^3F$	2	$3d^2\ ^3F$	3	17.122	17.101	17.080(3)	17.138	17.071	17.218
$3d^2\ ^3F$	2	$3d^2\ ^3P$	2	14.982	14.971	14.959(3)	14.980	14.970	14.924
$3d^2\ ^3F$	2	$3d^2\ ^3P$	1	14.157	14.149				
$3d^2\ ^3F$	2	$3d^2\ ^3P$	2	7.699	7.691				
$3d^2\ ^3P$	0	$3d^2\ ^3P$	1	19.233	19.211	19.177(3)	19.222	19.160	19.422
$3d^2\ ^3F$	3	$3d^2\ ^3P$	2	119.908	120.168				
$3d^2\ ^3F$	3	$3d^2\ ^1G$	4	89.580	89.805				
$3d^2\ ^3F$	3	$3d^2\ ^3F$	4	15.378	15.365				
$3d^2\ ^3F$	3	$3d^2\ ^3P$	2	13.989	13.977				

Table 5. *Cont.*

Label and J for Lower		Label and J for Upper		Present Work $n = 5$	Present Work $n = 6$	Expt (Ref. [2])	GRASP	RMBPT$_g$	RCI$_g$
$3d^2\ ^3P$	2	$3d^2\ ^3P$	1	257.054	257.793				
$3d^2\ ^3P$	2	$3d^2\ ^3P$	2	15.836	15.817				
$3d^2\ ^3P$	1	$3d^2\ ^3P$	2	16.876	16.851				
$3d^2\ ^3P$	1	$3d^2\ ^1S$	0	12.728	12.707				
$3d^2\ ^1G$	4	$3d^2\ ^3F$	4	18.566	18.537				
W^{53+} (Sc-like)									
$3d^3\ ^4F^3$	3/2	$3d^3\ ^4F^3$	5/2	18.925	18.901	18.867(3)	18.933	18.850	19.120
$3d^3\ ^4F^3$	3/2	$3d^3\ ^4P^3$	3/2	17.258	17.242	17.216(3)	17.243	17.216	17.315
$3d^3\ ^4F^3$	3/2	$3d^3\ ^4P^3$	1/2	16.059	16.046	16.027(3)	16.035	16.038	16.038
$3d^3\ ^4F^3$	3/2	$3d^3\ ^2D^1$	5/2	12.318	12.314	12.312(3)	12.282	12.319	12.225
$3d^3\ ^4F^3$	3/2	$3d^3\ ^4P^3$	3/2	8.289	8.280				
$3d^3\ ^4F^3$	3/2	$3d^3\ ^2P^3$	1/2	8.128	8.120				
$3d^3\ ^4F^3$	3/2	$3d^3\ ^2D^3$	5/2	8.041	8.035				
$3d^3\ ^4F^3$	3/2	$3d^3\ ^2F^3$	5/2	7.607	7.601				
$3d^3\ ^4F^3$	3/2	$3d^3\ ^2D^1$	3/2	6.757	6.751				
$3d^3\ ^4F^3$	3/2	$3d^3\ ^2P^3$	3/2	5.329	5.324				
$3d^3\ ^4F^3$	3/2	$3d^3\ ^2D^1$	5/2	5.107	5.102				
$3d^3\ ^4F^3$	5/2	$3d^3\ ^4P^3$	3/2	195.953	196.390				
$3d^3\ ^4F^3$	5/2	$3d^3\ ^2G^3$	7/2	121.923	122.264				
$3d^3\ ^4F^3$	5/2	$3d^3\ ^2D^1$	5/2	35.279	35.336				
$3d^3\ ^4F^3$	5/2	$3d^3\ ^4F^3$	7/2	16.697	16.680				
$3d^3\ ^4F^3$	5/2	$3d^3\ ^4P^3$	3/2	14.749	14.735				
$3d^3\ ^4F^3$	5/2	$3d^3\ ^2D^3$	5/2	13.981	13.975				
$3d^3\ ^4F^3$	5/2	$3d^3\ ^2F^3$	5/2	12.720	12.715				
$3d^3\ ^4F^3$	5/2	$3d^3\ ^2F^3$	7/2	12.654	12.651				
$3d^3\ ^4F^3$	5/2	$3d^3\ ^2D^1$	3/2	10.509	10.502				
$3d^3\ ^4F^3$	5/2	$3d^3\ ^2P^3$	3/2	7.418	7.412				
$3d^3\ ^4F^3$	5/2	$3d^3\ ^2D^1$	5/2	6.995	6.988				
$3d^3\ ^4P^3$	3/2	$3d^3\ ^4P^3$	1/2	230.965	231.304				
$3d^3\ ^4P^3$	3/2	$3d^3\ ^2D^1$	5/2	43.026	43.089				
$3d^3\ ^4P^3$	3/2	$3d^3\ ^4P^3$	3/2	15.949	15.930				
$3d^3\ ^4P^3$	3/2	$3d^3\ ^2P^3$	1/2	15.364	15.347				
$3d^3\ ^4P^3$	3/2	$3d^3\ ^2D^3$	5/2	15.055	15.046				
$3d^3\ ^4P^3$	3/2	$3d^3\ ^2F^3$	5/2	13.603	13.595				
$3d^3\ ^4P^3$	3/2	$3d^3\ ^2D^1$	3/2	11.105	11.095				
$3d^3\ ^4P^3$	3/2	$3d^3\ ^2P^3$	3/2	7.710	7.702				
$3d^3\ ^4P^3$	3/2	$3d^3\ ^2D^1$	5/2	7.254	7.246				
$3d^3\ ^2H^3$	9/2	$3d^3\ ^2G^3$	7/2	21322.871	18591.162				
$3d^3\ ^2H^3$	9/2	$3d^3\ ^4F^3$	7/2	19.329	19.295				
$3d^3\ ^2H^3$	9/2	$3d^3\ ^4F^3$	9/2	18.022	17.996				
$3d^3\ ^2H^3$	9/2	$3d^3\ ^2H^3$	11/2	15.812	15.798	15.785(3)	15.792	15.778	15.876
$3d^3\ ^2H^3$	9/2	$3d^3\ ^2F^3$	7/2	14.110	14.100				
$3d^3\ ^2H^3$	9/2	$3d^3\ ^2G^3$	9/2	8.673	8.661				
$3d^3\ ^2G^3$	7/2	$3d^3\ ^2D^1$	5/2	49.645	49.700				
$3d^3\ ^2G^3$	7/2	$3d^3\ ^4F^3$	7/2	19.346	19.315				
$3d^3\ ^2G^3$	7/2	$3d^3\ ^4F^3$	9/2	18.037	18.014				
$3d^3\ ^2G^3$	7/2	$3d^3\ ^2D^3$	5/2	15.791	15.779				
$3d^3\ ^2G^3$	7/2	$3d^3\ ^2F^3$	5/2	14.201	14.191				

Table 5. *Cont.*

Label and J for Lower		Label and J for Upper		Present Work $n = 5$	Present Work $n = 6$	Expt (Ref. [2])	GRASP	RMBPT$_g$	RCI$_g$
$3d^3\ ^2G^3$	7/2	$3d^3\ ^2F^3$	7/2	14.119	14.110				
$3d^3\ ^2G^3$	7/2	$3d^3\ ^2G^3$	9/2	8.677	8.665				
$3d^3\ ^2G^3$	7/2	$3d^3\ ^2D^1$	5/2	7.421	7.411				
$3d^3\ ^4P^3$	1/2	$3d^3\ ^4P^3$	3/2	17.132	17.108				
$3d^3\ ^4P^3$	1/2	$3d^3\ ^2P^3$	1/2	16.459	16.438				
$3d^3\ ^4P^3$	1/2	$3d^3\ ^2D^1$	3/2	11.665	11.654				
$3d^3\ ^4P^3$	1/2	$3d^3\ ^2P^3$	3/2	7.976	7.968				
$3d^3\ ^2D^1$	5/2	$3d^3\ ^4F^3$	7/2	31.700	31.592				
$3d^3\ ^2D^1$	5/2	$3d^3\ ^4P^3$	3/2	25.344	25.274				
$3d^3\ ^2D^1$	5/2	$3d^3\ ^2D^3$	5/2	23.157	23.119				
$3d^3\ ^2D^1$	5/2	$3d^3\ ^2F^3$	5/2	19.891	19.862				
$3d^3\ ^2D^1$	5/2	$3d^3\ ^2F^3$	7/2	19.730	19.705				
$3d^3\ ^2D^1$	5/2	$3d^3\ ^2D^1$	3/2	14.968	14.943				
$3d^3\ ^2D^1$	5/2	$3d^3\ ^2P^3$	3/2	9.393	9.379				
$3d^3\ ^2D^1$	5/2	$3d^3\ ^2D^1$	5/2	8.725	8.710				
$3d^3\ ^4F^3$	7/2	$3d^3\ ^4F^3$	9/2	266.613	267.448				
$3d^3\ ^4F^3$	7/2	$3d^3\ ^2D^3$	5/2	85.937	86.197				
$3d^3\ ^4F^3$	7/2	$3d^3\ ^2F^3$	5/2	53.397	53.492				
$3d^3\ ^4F^3$	7/2	$3d^3\ ^2F^3$	7/2	52.253	52.370				
$3d^3\ ^4F^3$	7/2	$3d^3\ ^2G^3$	9/2	15.733	15.717				
$3d^3\ ^4F^3$	7/2	$3d^3\ ^2D^1$	5/2	12.038	12.026				
$3d^3\ ^4F^3$	9/2	$3d^3\ ^2H^3$	11/2	128.917	129.345				
$3d^3\ ^4F^3$	9/2	$3d^3\ ^2F^3$	7/2	64.991	65.122				
$3d^3\ ^4F^3$	9/2	$3d^3\ ^2G^3$	9/2	16.719	16.698				
$3d^3\ ^4P^3$	3/2	$3d^3\ ^2P^3$	1/2	418.463	419.226				
$3d^3\ ^4P^3$	3/2	$3d^3\ ^2D^3$	5/2	268.399	271.110				
$3d^3\ ^4P^3$	3/2	$3d^3\ ^2F^3$	5/2	92.445	92.751				
$3d^3\ ^4P^3$	3/2	$3d^3\ ^2D^1$	3/2	36.557	36.559				
$3d^3\ ^4P^3$	3/2	$3d^3\ ^2P^3$	3/2	14.925	14.912				
$3d^3\ ^4P^3$	3/2	$3d^3\ ^2D^1$	5/2	13.305	13.291				
$3d^3\ ^2P^3$	1/2	$3d^3\ ^2D^1$	3/2	40.056	40.051				
$3d^3\ ^2P^3$	1/2	$3d^3\ ^2P^3$	3/2	15.477	15.462				
$3d^3\ ^2H^3$	11/2	$3d^3\ ^2G^3$	9/2	19.211	19.173				
$3d^3\ ^2D^3$	5/2	$3d^3\ ^2F^3$	5/2	141.016	140.984				
$3d^3\ ^2D^3$	5/2	$3d^3\ ^2F^3$	7/2	133.312	133.450				
$3d^3\ ^2D^3$	5/2	$3d^3\ ^2D^1$	3/2	42.321	42.257				
$3d^3\ ^2D^3$	5/2	$3d^3\ ^2P^3$	3/2	15.804	15.780				
$3d^3\ ^2D^3$	5/2	$3d^3\ ^2D^1$	5/2	13.999	13.976				
$3d^3\ ^2F^3$	5/2	$3d^3\ ^2F^3$	7/2	2440.155	2497.085				
$3d^3\ ^2F^3$	5/2	$3d^3\ ^2D^1$	3/2	60.469	60.343				
$3d^3\ ^2F^3$	5/2	$3d^3\ ^2P^3$	3/2	17.798	17.769				
$3d^3\ ^2F^3$	5/2	$3d^3\ ^2D^1$	5/2	15.542	15.514				
$3d^3\ ^2F^3$	7/2	$3d^3\ ^2G^3$	9/2	22.510	22.456				
$3d^3\ ^2F^3$	7/2	$3d^3\ ^2D^1$	5/2	15.642	15.611				
$3d^3\ ^2D^1$	3/2	$3d^3\ ^2P^3$	3/2	25.222	25.185				
$3d^3\ ^2D^1$	3/2	$3d^3\ ^2D^1$	5/2	20.919	20.883				
$3d^3\ ^2P^3$	3/2	$3d^3\ ^2D^1$	5/2	122.606	122.246				

Table 5. *Cont.*

Label and J for Lower		Label and J for Upper		Present Work $n = 5$	Present Work $n = 6$	Expt (Ref. [2])	GRASP	RMBPT$_g$	RCI$_g$
W^{52+} (Ti-like)									
$3d^4\ ^3P^2$	0	$3d^4\ ^5D^4$	1	19.385	19.361	19.319(3)	19.379	19.302	19.605
$3d^4\ ^3P^2$	0	$3d^4\ ^3D^4$	1	8.241	8.234				
$3d^4\ ^3P^2$	0	$3d^4\ ^3D^4$	1	5.660	5.654				
$3d^4\ ^3P^2$	0	$3d^4\ ^3P^2$	1	5.041	5.037				
$3d^4\ ^5D^4$	1	$3d^4\ ^5D^4$	2	81.888	82.053				
$3d^4\ ^5D^4$	1	$3d^4\ ^5D^4$	0	17.065	17.045				
$3d^4\ ^5D^4$	1	$3d^4\ ^5D^4$	2	16.922	16.907	16.890(3)	16.903	16.894	16.958
$3d^4\ ^5D^4$	1	$3d^4\ ^3D^4$	1	14.334	14.326				
$3d^4\ ^5D^4$	1	$3d^4\ ^3F^4$	2	13.479	13.475				
$3d^4\ ^5D^4$	1	$3d^4\ ^3F^2$	2	11.857	11.849				
$3d^4\ ^5D^4$	1	$3d^4\ ^1D^2$	2	10.103	10.103				
$3d^4\ ^5D^4$	1	$3d^4\ ^3P^4$	0	8.950	8.947				
$3d^4\ ^5D^4$	1	$3d^4\ ^3D^4$	1	7.995	7.987				
$3d^4\ ^5D^4$	1	$3d^4\ ^3F^4$	2	7.545	7.539				
$3d^4\ ^5D^4$	1	$3d^4\ ^1S^4$	0	7.107	7.105				
$3d^4\ ^5D^4$	1	$3d^4\ ^3P^2$	1	6.812	6.808				
$3d^4\ ^5D^4$	1	$3d^4\ ^1D^4$	2	6.654	6.651				
$3d^4\ ^5D^4$	1	$3d^4\ ^1D^2$	2	5.142	5.137				
$3d^4\ ^5D^4$	1	$3d^4\ ^3P^2$	0	4.658	4.653				
$3d^4\ ^3H^4$	4	$3d^4\ ^3F^2$	3	190.114	190.262				
$3d^4\ ^3H^4$	4	$3d^4\ ^3H^4$	4	19.520	19.491	19.445(3)	19.543	19.443	19.696
$3d^4\ ^3H^4$	4	$3d^4\ ^5D^4$	3	18.912	18.886				
$3d^4\ ^3H^4$	4	$3d^4\ ^3H^4$	5	17.889	17.872	17.846(3)	17.855	17.831	18.065
$3d^4\ ^3H^4$	4	$3d^4\ ^3F^4$	3	15.977	15.965				
$3d^4\ ^3H^4$	4	$3d^4\ ^3G^4$	4	15.894	15.882				
$3d^4\ ^3H^4$	4	$3d^4\ ^3F^2$	4	12.652	12.647				
$3d^4\ ^3H^4$	4	$3d^4\ ^5D^4$	4	9.083	9.071				
$3d^4\ ^3H^4$	4	$3d^4\ ^3F^4$	3	8.993	8.981				
$3d^4\ ^3H^4$	4	$3d^4\ ^3G^4$	5	8.617	8.608				
$3d^4\ ^3H^4$	4	$3d^4\ ^3D^4$	3	8.036	8.028				
$3d^4\ ^3H^4$	4	$3d^4\ ^3F^2$	3	7.317	7.310				
$3d^4\ ^3H^4$	4	$3d^4\ ^1G^2$	4	7.290	7.283				
$3d^4\ ^3H^4$	4	$3d^4\ ^3F^2$	4	5.672	5.665				
$3d^4\ ^5D^4$	2	$3d^4\ ^3F^2$	3	358.990	360.907				
$3d^4\ ^5D^4$	2	$3d^4\ ^5D^4$	2	21.329	21.295				
$3d^4\ ^5D^4$	2	$3d^4\ ^5D^4$	3	19.840	19.816				
$3d^4\ ^5D^4$	2	$3d^4\ ^3D^4$	1	17.375	17.356				
$3d^4\ ^5D^4$	2	$3d^4\ ^3F^4$	3	16.635	16.624				
$3d^4\ ^5D^4$	2	$3d^4\ ^3F^4$	2	16.135	16.123				
$3d^4\ ^5D^4$	2	$3d^4\ ^3F^2$	2	13.864	13.849				
$3d^4\ ^5D^4$	2	$3d^4\ ^1D^2$	2	11.525	11.521				
$3d^4\ ^5D^4$	2	$3d^4\ ^3F^4$	3	9.197	9.186				
$3d^4\ ^5D^4$	2	$3d^4\ ^3D^4$	1	8.860	8.848				
$3d^4\ ^5D^4$	2	$3d^4\ ^3F^4$	2	8.311	8.302				
$3d^4\ ^5D^4$	2	$3d^4\ ^3D^4$	3	8.199	8.191				
$3d^4\ ^5D^4$	2	$3d^4\ ^3F^2$	3	7.452	7.445				
$3d^4\ ^5D^4$	2	$3d^4\ ^3P^2$	1	7.430	7.424				
$3d^4\ ^5D^4$	2	$3d^4\ ^1D^4$	2	7.243	7.238				

Table 5. *Cont.*

Label and J for Lower		Label and J for Upper		Present Work $n = 5$	Present Work $n = 6$	Expt (Ref. [2])	GRASP	RMBPT$_g$	RCI$_g$
$3d^4\ ^5D^4$	2	$3d^4\ ^1D^2$	2	5.487	5.480				
$3d^4\ ^3F^2$	3	$3d^4\ ^5D^4$	2	22.677	22.630				
$3d^4\ ^3F^2$	3	$3d^4\ ^3H^4$	4	21.753	21.716				
$3d^4\ ^3F^2$	3	$3d^4\ ^5D^4$	3	21.001	20.968				
$3d^4\ ^3F^2$	3	$3d^4\ ^3F^4$	3	17.443	17.427				
$3d^4\ ^3F^2$	3	$3d^4\ ^3G^4$	4	17.344	17.329				
$3d^4\ ^3F^2$	3	$3d^4\ ^3F^4$	2	16.895	16.877				
$3d^4\ ^3F^2$	3	$3d^4\ ^3F^2$	2	14.421	14.402				
$3d^4\ ^3F^2$	3	$3d^4\ ^3F^2$	4	13.554	13.548	13.543(3)	13.513	13.549	13.495
$3d^4\ ^3F^2$	3	$3d^4\ ^1D^2$	2	11.907	11.901				
$3d^4\ ^3F^2$	3	$3d^4\ ^5D^4$	4	9.538	9.525				
$3d^4\ ^3F^2$	3	$3d^4\ ^3F^4$	3	9.439	9.426				
$3d^4\ ^3F^2$	3	$3d^4\ ^3F^4$	2	8.508	8.497				
$3d^4\ ^3F^2$	3	$3d^4\ ^3D^4$	3	8.390	8.381				
$3d^4\ ^3F^2$	3	$3d^4\ ^3F^2$	3	7.610	7.602				
$3d^4\ ^3F^2$	3	$3d^4\ ^1G^2$	4	7.581	7.573				
$3d^4\ ^3F^2$	3	$3d^4\ ^1D^4$	2	7.392	7.386				
$3d^4\ ^3F^2$	3	$3d^4\ ^3F^2$	4	5.847	5.839				
$3d^4\ ^3F^2$	3	$3d^4\ ^1D^2$	2	5.572	5.565				
$3d^4\ ^5D^4$	0	$3d^4\ ^3D^4$	1	89.555	89.798				
$3d^4\ ^5D^4$	0	$3d^4\ ^3D^4$	1	15.041	15.028				
$3d^4\ ^5D^4$	0	$3d^4\ ^3P^2$	1	11.338	11.334				
$3d^4\ ^5D^4$	2	$3d^4\ ^5D^4$	3	284.116	285.346				
$3d^4\ ^5D^4$	2	$3d^4\ ^3D^4$	1	93.723	93.840				
$3d^4\ ^5D^4$	2	$3d^4\ ^3F^4$	3	75.583	75.791				
$3d^4\ ^5D^4$	2	$3d^4\ ^3F^4$	2	66.257	66.382				
$3d^4\ ^5D^4$	2	$3d^4\ ^3F^2$	2	39.611	39.610				
$3d^4\ ^5D^4$	2	$3d^4\ ^1D^2$	2	25.072	25.102				
$3d^4\ ^5D^4$	2	$3d^4\ ^3F^4$	3	16.170	16.153				
$3d^4\ ^5D^4$	2	$3d^4\ ^3D^4$	1	15.154	15.138				
$3d^4\ ^5D^4$	2	$3d^4\ ^3F^4$	2	13.617	13.605				
$3d^4\ ^5D^4$	2	$3d^4\ ^3D^4$	3	13.318	13.311				
$3d^4\ ^5D^4$	2	$3d^4\ ^3F^2$	3	11.453	11.448				
$3d^4\ ^5D^4$	2	$3d^4\ ^3P^2$	1	11.402	11.396				
$3d^4\ ^5D^4$	2	$3d^4\ ^1D^4$	2	10.967	10.964				
$3d^4\ ^5D^4$	2	$3d^4\ ^1D^2$	2	7.387	7.380				
$3d^4\ ^3H^4$	4	$3d^4\ ^5D^4$	3	606.876	608.761				
$3d^4\ ^3H^4$	4	$3d^4\ ^3H^4$	5	214.114	215.206				
$3d^4\ ^3H^4$	4	$3d^4\ ^3F^4$	3	88.039	88.243				
$3d^4\ ^3H^4$	4	$3d^4\ ^3G^4$	4	85.561	85.781				
$3d^4\ ^3H^4$	4	$3d^4\ ^3F^2$	4	35.956	36.020				
$3d^4\ ^3H^4$	4	$3d^4\ ^5D^4$	4	16.986	16.966				
$3d^4\ ^3H^4$	4	$3d^4\ ^3F^4$	3	16.675	16.654				
$3d^4\ ^3H^4$	4	$3d^4\ ^3G^4$	5	15.427	15.416				
$3d^4\ ^3H^4$	4	$3d^4\ ^3D^4$	3	13.658	13.649				
$3d^4\ ^3H^4$	4	$3d^4\ ^3F^2$	3	11.704	11.697				
$3d^4\ ^3H^4$	4	$3d^4\ ^1G^2$	4	11.635	11.628				
$3d^4\ ^3H^4$	4	$3d^4\ ^3F^2$	4	7.996	7.986				
$3d^4\ ^5D^4$	3	$3d^4\ ^3F^4$	3	102.978	103.203				

Table 5. *Cont.*

Label and J for Lower		Label and J for Upper		Present Work $n = 5$	Present Work $n = 6$	Expt (Ref. [2])	GRASP	RMBPT$_g$	RCI$_g$
$3d^4\ ^5D^4$	3	$3d^4\ ^3G^4$	4	99.604	99.852				
$3d^4\ ^5D^4$	3	$3d^4\ ^3F^4$	2	86.407	86.507				
$3d^4\ ^5D^4$	3	$3d^4\ ^3F^2$	2	46.028	45.995				
$3d^4\ ^5D^4$	3	$3d^4\ ^3F^2$	4	38.221	38.285				
$3d^4\ ^5D^4$	3	$3d^4\ ^1D^2$	2	27.498	27.524				
$3d^4\ ^5D^4$	3	$3d^4\ ^5D^4$	4	17.475	17.453				
$3d^4\ ^5D^4$	3	$3d^4\ ^3F^4$	3	17.146	17.123				
$3d^4\ ^5D^4$	3	$3d^4\ ^3F^4$	2	14.303	14.287				
$3d^4\ ^5D^4$	3	$3d^4\ ^3D^4$	3	13.973	13.962				
$3d^4\ ^5D^4$	3	$3d^4\ ^3F^2$	3	11.934	11.926				
$3d^4\ ^5D^4$	3	$3d^4\ ^1G^2$	4	11.863	11.855				
$3d^4\ ^5D^4$	3	$3d^4\ ^1D^4$	2	11.408	11.402				
$3d^4\ ^5D^4$	3	$3d^4\ ^3F^2$	4	8.102	8.092				
$3d^4\ ^5D^4$	3	$3d^4\ ^1D^2$	2	7.584	7.575				
$3d^4\ ^3H^4$	5	$3d^4\ ^1I^4$	6	428.184	430.120				
$3d^4\ ^3H^4$	5	$3d^4\ ^3G^4$	4	142.509	142.637				
$3d^4\ ^3H^4$	5	$3d^4\ ^3F^2$	4	43.213	43.261				
$3d^4\ ^3H^4$	5	$3d^4\ ^5D^4$	4	18.450	18.418				
$3d^4\ ^3H^4$	5	$3d^4\ ^3G^4$	5	16.625	16.605				
$3d^4\ ^3H^4$	5	$3d^4\ ^3H^4$	6	16.488	16.470				
$3d^4\ ^3H^4$	5	$3d^4\ ^1G^2$	4	12.304	12.292				
$3d^4\ ^3H^4$	5	$3d^4\ ^3F^2$	4	8.306	8.293				
$3d^4\ ^1I^4$	6	$3d^4\ ^3G^4$	5	17.296	17.272				
$3d^4\ ^1I^4$	6	$3d^4\ ^3H^4$	6	17.148	17.126				
$3d^4\ ^3D^4$	1	$3d^4\ ^3F^4$	2	226.092	226.868				
$3d^4\ ^3D^4$	1	$3d^4\ ^3F^2$	2	68.606	68.541				
$3d^4\ ^3D^4$	1	$3d^4\ ^1D^2$	2	34.228	34.269				
$3d^4\ ^3D^4$	1	$3d^4\ ^3P^4$	0	23.832	23.832				
$3d^4\ ^3D^4$	1	$3d^4\ ^3D^4$	1	18.077	18.049				
$3d^4\ ^3D^4$	1	$3d^4\ ^3F^4$	2	15.932	15.912				
$3d^4\ ^3D^4$	1	$3d^4\ ^1S^4$	0	14.097	14.094				
$3d^4\ ^3D^4$	1	$3d^4\ ^3P^2$	1	12.981	12.972				
$3d^4\ ^3D^4$	1	$3d^4\ ^1D^4$	2	12.421	12.415				
$3d^4\ ^3D^4$	1	$3d^4\ ^1D^2$	2	8.019	8.009				
$3d^4\ ^3D^4$	1	$3d^4\ ^3P^2$	0	6.900	6.892				
$3d^4\ ^3F^4$	3	$3d^4\ ^3G^4$	4	3040.724	3074.775				
$3d^4\ ^3F^4$	3	$3d^4\ ^3F^4$	2	536.990	534.715				
$3d^4\ ^3F^4$	3	$3d^4\ ^3F^2$	2	83.228	82.973				
$3d^4\ ^3F^4$	3	$3d^4\ ^3F^2$	4	60.779	60.864				
$3d^4\ ^3F^4$	3	$3d^4\ ^1D^2$	2	37.516	37.533				
$3d^4\ ^3F^4$	3	$3d^4\ ^5D^4$	4	21.047	21.005				
$3d^4\ ^3F^4$	3	$3d^4\ ^3F^4$	3	20.571	20.529				
$3d^4\ ^3F^4$	3	$3d^4\ ^3F^4$	2	16.610	16.582				
$3d^4\ ^3F^4$	3	$3d^4\ ^3D^4$	3	16.166	16.147				
$3d^4\ ^3F^4$	3	$3d^4\ ^3F^2$	3	13.498	13.485				
$3d^4\ ^3F^4$	3	$3d^4\ ^1G^2$	4	13.407	13.393				
$3d^4\ ^3F^4$	3	$3d^4\ ^1D^4$	2	12.829	12.819				
$3d^4\ ^3F^4$	3	$3d^4\ ^3F^2$	4	8.794	8.780				
$3d^4\ ^3F^4$	3	$3d^4\ ^1D^2$	2	8.187	8.176				

Table 5. *Cont.*

Label and J for Lower		Label and J for Upper		Present Work $n = 5$	Present Work $n = 6$	Expt (Ref. [2])	GRASP	RMBPT$_g$	RCI$_g$
$3d^4\ ^3G^4$	4	$3d^4\ ^3F^2$	4	62.019	62.093				
$3d^4\ ^3G^4$	4	$3d^4\ ^5D^4$	4	21.194	21.149				
$3d^4\ ^3G^4$	4	$3d^4\ ^3F^4$	3	20.711	20.667				
$3d^4\ ^3G^4$	4	$3d^4\ ^3G^4$	5	18.820	18.793				
$3d^4\ ^3G^4$	4	$3d^4\ ^3D^4$	3	16.253	16.232				
$3d^4\ ^3G^4$	4	$3d^4\ ^3F^2$	3	13.559	13.544				
$3d^4\ ^3G^4$	4	$3d^4\ ^1G^2$	4	13.466	13.452				
$3d^4\ ^3G^4$	4	$3d^4\ ^3F^2$	4	8.820	8.805				
$3d^4\ ^3F^4$	2	$3d^4\ ^3F^2$	2	98.494	98.213				
$3d^4\ ^3F^4$	2	$3d^4\ ^1D^2$	2	40.334	40.367				
$3d^4\ ^3F^4$	2	$3d^4\ ^3F^4$	3	21.391	21.348				
$3d^4\ ^3F^4$	2	$3d^4\ ^3D^4$	1	19.648	19.609				
$3d^4\ ^3F^4$	2	$3d^4\ ^3F^4$	2	17.140	17.113				
$3d^4\ ^3F^4$	2	$3d^4\ ^3D^4$	3	16.668	16.649				
$3d^4\ ^3F^4$	2	$3d^4\ ^3F^2$	3	13.846	13.834				
$3d^4\ ^3F^4$	2	$3d^4\ ^3P^2$	1	13.772	13.759				
$3d^4\ ^3F^4$	2	$3d^4\ ^1D^4$	2	13.143	13.133				
$3d^4\ ^3F^4$	2	$3d^4\ ^1D^2$	2	8.314	8.302				
$3d^4\ ^3F^2$	2	$3d^4\ ^1D^2$	2	68.306	68.536				
$3d^4\ ^3F^2$	2	$3d^4\ ^3F^4$	3	27.325	27.278				
$3d^4\ ^3F^2$	2	$3d^4\ ^3D^4$	1	24.544	24.501				
$3d^4\ ^3F^2$	2	$3d^4\ ^3F^4$	2	20.751	20.724				
$3d^4\ ^3F^2$	2	$3d^4\ ^3D^4$	3	20.063	20.048				
$3d^4\ ^3F^2$	2	$3d^4\ ^3F^2$	3	16.111	16.102				
$3d^4\ ^3F^2$	2	$3d^4\ ^3P^2$	1	16.011	16.000				
$3d^4\ ^3F^2$	2	$3d^4\ ^1D^4$	2	15.166	15.161				
$3d^4\ ^3F^2$	2	$3d^4\ ^1D^2$	2	9.081	9.069				
$3d^4\ ^3F^2$	4	$3d^4\ ^5D^4$	4	32.196	32.074				
$3d^4\ ^3F^2$	4	$3d^4\ ^3F^4$	3	31.096	30.977				
$3d^4\ ^3F^2$	4	$3d^4\ ^3G^4$	5	27.020	26.950				
$3d^4\ ^3F^2$	4	$3d^4\ ^3D^4$	3	22.024	21.977				
$3d^4\ ^3F^2$	4	$3d^4\ ^3F^2$	3	17.352	17.323				
$3d^4\ ^3F^2$	4	$3d^4\ ^1G^2$	4	17.201	17.172				
$3d^4\ ^3F^2$	4	$3d^4\ ^3F^2$	4	10.282	10.260				
$3d^4\ ^1D^2$	2	$3d^4\ ^3F^4$	3	45.544	45.312				
$3d^4\ ^1D^2$	2	$3d^4\ ^3D^4$	1	38.310	38.133				
$3d^4\ ^1D^2$	2	$3d^4\ ^3F^4$	2	29.806	29.706				
$3d^4\ ^1D^2$	2	$3d^4\ ^3D^4$	3	28.407	28.337				
$3d^4\ ^1D^2$	2	$3d^4\ ^3F^2$	3	21.085	21.046				
$3d^4\ ^1D^2$	2	$3d^4\ ^3P^2$	1	20.912	20.873				
$3d^4\ ^1D^2$	2	$3d^4\ ^1D^4$	2	19.495	19.467				
$3d^4\ ^1D^2$	2	$3d^4\ ^1D^2$	2	10.473	10.452				
$3d^4\ ^3P^4$	0	$3d^4\ ^3D^4$	1	74.865	74.385				
$3d^4\ ^3P^4$	0	$3d^4\ ^3P^2$	1	28.511	28.466				
$3d^4\ ^5D^4$	4	$3d^4\ ^3F^4$	3	910.088	905.530				
$3d^4\ ^5D^4$	4	$3d^4\ ^3G^4$	5	168.067	168.682				
$3d^4\ ^5D^4$	4	$3d^4\ ^3D^4$	3	69.712	69.810				
$3d^4\ ^5D^4$	4	$3d^4\ ^3F^2$	3	37.636	37.665				
$3d^4\ ^5D^4$	4	$3d^4\ ^1G^2$	4	36.935	36.959				

Table 5. *Cont.*

Label and J for Lower		Label and J for Upper		Present Work $n = 5$	Present Work $n = 6$	Expt (Ref. [2])	GRASP	RMBPT$_g$	RCI$_g$
$3d^4\ ^5D^4$	4	$3d^4\ ^3F^2$	4	15.106	15.086				
$3d^4\ ^3F^4$	3	$3d^4\ ^3F^4$	2	86.253	86.253				
$3d^4\ ^3F^4$	3	$3d^4\ ^3D^4$	3	75.495	75.642				
$3d^4\ ^3F^4$	3	$3d^4\ ^3F^2$	3	39.260	39.300				
$3d^4\ ^3F^4$	3	$3d^4\ ^1G^2$	4	38.498	38.532				
$3d^4\ ^3F^4$	3	$3d^4\ ^1D^4$	2	34.085	34.130				
$3d^4\ ^3F^4$	3	$3d^4\ ^3F^2$	4	15.361	15.342				
$3d^4\ ^3F^4$	3	$3d^4\ ^1D^2$	2	13.600	13.586				
$3d^4\ ^3D^4$	1	$3d^4\ ^3F^4$	2	134.268	134.420				
$3d^4\ ^3D^4$	1	$3d^4\ ^1S^4$	0	64.031	64.317				
$3d^4\ ^3D^4$	1	$3d^4\ ^3P^2$	1	46.049	46.113				
$3d^4\ ^3D^4$	1	$3d^4\ ^1D^4$	2	39.694	39.769				
$3d^4\ ^3D^4$	1	$3d^4\ ^1D^2$	2	14.413	14.399				
$3d^4\ ^3D^4$	1	$3d^4\ ^3P^2$	0	11.160	11.149				
$3d^4\ ^3G^4$	5	$3d^4\ ^3H^4$	6	1997.212	2027.160				
$3d^4\ ^3G^4$	5	$3d^4\ ^1G^2$	4	47.338	47.329				
$3d^4\ ^3G^4$	5	$3d^4\ ^3F^2$	4	16.598	16.568				
$3d^4\ ^3F^4$	2	$3d^4\ ^3D^4$	3	605.307	614.828				
$3d^4\ ^3F^4$	2	$3d^4\ ^3F^2$	3	72.059	72.193				
$3d^4\ ^3F^4$	2	$3d^4\ ^3P^2$	1	70.085	70.193				
$3d^4\ ^3F^4$	2	$3d^4\ ^1D^4$	2	56.355	56.479				
$3d^4\ ^3F^4$	2	$3d^4\ ^1D^2$	2	16.146	16.126				
$3d^4\ ^3D^4$	3	$3d^4\ ^3F^2$	3	81.796	81.797				
$3d^4\ ^3D^4$	3	$3d^4\ ^1G^2$	4	78.556	78.539				
$3d^4\ ^3D^4$	3	$3d^4\ ^1D^4$	2	62.140	62.192				
$3d^4\ ^3D^4$	3	$3d^4\ ^3F^2$	4	19.285	19.245				
$3d^4\ ^3D^4$	3	$3d^4\ ^1D^2$	2	16.589	16.561				
$3d^4\ ^1S^4$	0	$3d^4\ ^3P^2$	1	163.968	162.926				
$3d^4\ ^3F^2$	3	$3d^4\ ^1G^2$	4	1982.892	1971.659				
$3d^4\ ^3F^2$	3	$3d^4\ ^1D^4$	2	258.586	259.474				
$3d^4\ ^3F^2$	3	$3d^4\ ^3F^2$	4	25.235	25.166				
$3d^4\ ^3F^2$	3	$3d^4\ ^1D^2$	2	20.809	20.765				
$3d^4\ ^3P^2$	1	$3d^4\ ^1D^4$	2	287.662	289.068				
$3d^4\ ^3P^2$	1	$3d^4\ ^1D^2$	2	20.980	20.936				
$3d^4\ ^3P^2$	1	$3d^4\ ^3P^2$	0	14.730	14.704				
$3d^4\ ^1G^2$	4	$3d^4\ ^3F^2$	4	25.560	25.491				
$3d^4\ ^1D^4$	2	$3d^4\ ^1D^2$	2	22.630	22.571				
W^{51+} (V-like)									
$3d^5\ ^4P^3$	5/2	$3d^5\ ^6S^5$	5/2	21.290	21.243	21.203(3)	21.317	21.185	21.492
$3d^5\ ^4P^3$	5/2	$3d^5\ ^4G^5$	7/2	17.700	17.674	17.660(3)	17.660	17.655	17.826
$3d^5\ ^4P^3$	5/2	$3d^5\ ^4D^5$	3/2	17.253	17.227	17.215(3)	17.247	17.228	17.249
$3d^5\ ^4P^3$	5/2	$3d^5\ ^4D^5$	5/2	15.368	15.350				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^2F^5$	7/2	14.541	14.529	14.531(3)	14.475	14.537	14.513
$3d^5\ ^4P^3$	5/2	$3d^5\ ^2D^1$	3/2	12.136	12.122				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^6S^5$	5/2	9.747	9.728				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^4D^5$	7/2	9.117	9.102				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^4P^3$	3/2	8.586	8.571				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^2F^5$	5/2	8.511	8.499				

Table 5. *Cont.*

Label and J for Lower		Label and J for Upper		Present Work $n = 5$	Present Work $n = 6$	Expt (Ref. [2])	GRASP	RMBPT$_g$	RCI$_g$
$3d^5\ ^4P^3$	5/2	$3d^5\ ^2G^5$	7/2	8.078	8.068				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^4F^3$	5/2	7.971	7.959				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^2D^5$	3/2	7.940	7.931				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^2G^3$	7/2	7.646	7.636				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^2P^3$	3/2	6.645	6.639				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^2D^1$	5/2	6.522	6.516				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^4P^3$	5/2	6.021	6.010				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^4F^3$	7/2	5.768	5.758				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^4D^5$	3/2	5.684	5.674				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^2D^3$	5/2	5.424	5.416				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^2G^3$	7/2	5.343	5.335				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^2D^1$	3/2	4.847	4.841				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^2D^1$	5/2	4.233	4.225				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^4G^5$	7/2	104.969	105.214				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^4D^5$	3/2	90.995	91.119				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^4D^5$	5/2	55.250	55.341				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^2F^5$	7/2	45.868	45.971				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^2D^1$	3/2	28.226	28.233				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^6S^5$	5/2	17.977	17.946				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^4D^5$	7/2	15.946	15.927				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^4P^3$	3/2	14.388	14.367				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^2F^5$	5/2	14.181	14.167				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^2G^5$	7/2	13.018	13.009				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^4F^3$	5/2	12.741	12.727				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^2D^5$	3/2	12.662	12.655				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^2G^3$	7/2	11.932	11.921				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^2P^3$	3/2	9.660	9.657				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^2D^1$	5/2	9.403	9.399				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^4P^3$	5/2	8.395	8.381				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^4F^3$	7/2	7.912	7.900				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^4D^5$	3/2	7.755	7.743				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^2D^3$	5/2	7.277	7.269				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^2G^3$	7/2	7.133	7.124				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^2D^1$	3/2	6.276	6.269				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^2D^1$	5/2	5.283	5.274				
$3d^5\ ^4G^5$	7/2	$3d^5\ ^2G^5$	9/2	178.750	179.156				
$3d^5\ ^4G^5$	7/2	$3d^5\ ^4D^5$	5/2	116.648	116.752				
$3d^5\ ^4G^5$	7/2	$3d^5\ ^2F^5$	7/2	81.465	81.645				
$3d^5\ ^4G^5$	7/2	$3d^5\ ^6S^5$	5/2	21.692	21.637				
$3d^5\ ^4G^5$	7/2	$3d^5\ ^4D^5$	7/2	18.802	18.768				
$3d^5\ ^4G^5$	7/2	$3d^5\ ^4G^5$	9/2	18.116	18.086				
$3d^5\ ^4G^5$	7/2	$3d^5\ ^2F^5$	5/2	16.396	16.372				
$3d^5\ ^4G^5$	7/2	$3d^5\ ^2H^3$	9/2	15.329	15.304				
$3d^5\ ^4G^5$	7/2	$3d^5\ ^2G^5$	7/2	14.861	14.845				
$3d^5\ ^4G^5$	7/2	$3d^5\ ^4F^3$	5/2	14.501	14.479				
$3d^5\ ^4G^5$	7/2	$3d^5\ ^2G^3$	7/2	13.462	13.444				
$3d^5\ ^4G^5$	7/2	$3d^5\ ^2G^3$	9/2	12.275	12.264				
$3d^5\ ^4G^5$	7/2	$3d^5\ ^2D^1$	5/2	10.329	10.321				
$3d^5\ ^4G^5$	7/2	$3d^5\ ^4P^3$	5/2	9.125	9.106				

Table 5. *Cont.*

Label and J for Lower		Label and J for Upper		Present Work $n = 5$	Present Work $n = 6$	Expt (Ref. [2])	GRASP	RMBPT$_g$	RCI$_g$
$3d^5\ ^4G^5$	7/2	$3d^5\ ^4F^3$	7/2	8.557	8.541				
$3d^5\ ^4G^5$	7/2	$3d^5\ ^2G^5$	9/2	8.057	8.044				
$3d^5\ ^4G^5$	7/2	$3d^5\ ^2D^3$	5/2	7.820	7.808				
$3d^5\ ^4G^5$	7/2	$3d^5\ ^2G^3$	7/2	7.653	7.642				
$3d^5\ ^4G^5$	7/2	$3d^5\ ^2D^1$	5/2	5.563	5.553				
$3d^5\ ^2H^3$	11/2	$3d^5\ ^2G^5$	9/2	222.726	223.030				
$3d^5\ ^2H^3$	11/2	$3d^5\ ^4G^5$	11/2	19.056	19.021	18.996(3)	19.064	19.002	19.185
$3d^5\ ^2H^3$	11/2	$3d^5\ ^4G^5$	9/2	18.486	18.453				
$3d^5\ ^2H^3$	11/2	$3d^5\ ^2I^5$	13/2	17.664	17.637				
$3d^5\ ^2H^3$	11/2	$3d^5\ ^2H^3$	9/2	15.593	15.566				
$3d^5\ ^2H^3$	11/2	$3d^5\ ^2G^3$	9/2	12.443	12.432				
$3d^5\ ^2H^3$	11/2	$3d^5\ ^2H^3$	11/2	8.544	8.528				
$3d^5\ ^2H^3$	11/2	$3d^5\ ^2G^5$	9/2	8.129	8.116				
$3d^5\ ^4D^5$	3/2	$3d^5\ ^4D^5$	5/2	140.653	140.944				
$3d^5\ ^4D^5$	3/2	$3d^5\ ^4P^3$	1/2	100.009	100.120				
$3d^5\ ^4D^5$	3/2	$3d^5\ ^2D^1$	3/2	40.920	40.907				
$3d^5\ ^4D^5$	3/2	$3d^5\ ^6S^5$	5/2	22.403	22.348				
$3d^5\ ^4D^5$	3/2	$3d^5\ ^4D^5$	1/2	17.360	17.334				
$3d^5\ ^4D^5$	3/2	$3d^5\ ^4P^3$	3/2	17.091	17.056				
$3d^5\ ^4D^5$	3/2	$3d^5\ ^2F^5$	5/2	16.799	16.775				
$3d^5\ ^4D^5$	3/2	$3d^5\ ^4F^3$	5/2	14.815	14.794				
$3d^5\ ^4D^5$	3/2	$3d^5\ ^2D^5$	3/2	14.708	14.696				
$3d^5\ ^4D^5$	3/2	$3d^5\ ^4P^3$	1/2	13.725	13.709				
$3d^5\ ^4D^5$	3/2	$3d^5\ ^2P^3$	3/2	10.807	10.802				
$3d^5\ ^4D^5$	3/2	$3d^5\ ^2D^1$	5/2	10.487	10.480				
$3d^5\ ^4D^5$	3/2	$3d^5\ ^4P^3$	5/2	9.248	9.230				
$3d^5\ ^4D^5$	3/2	$3d^5\ ^4D^5$	3/2	8.477	8.462				
$3d^5\ ^4D^5$	3/2	$3d^5\ ^2D^3$	5/2	7.910	7.899				
$3d^5\ ^4D^5$	3/2	$3d^5\ ^2P^3$	1/2	7.384	7.375				
$3d^5\ ^4D^5$	3/2	$3d^5\ ^2D^1$	3/2	6.741	6.733				
$3d^5\ ^4D^5$	3/2	$3d^5\ ^2D^1$	5/2	5.609	5.598				
$3d^5\ ^2G^5$	9/2	$3d^5\ ^2F^5$	7/2	149.683	150.005				
$3d^5\ ^2G^5$	9/2	$3d^5\ ^4D^5$	7/2	21.012	20.964				
$3d^5\ ^2G^5$	9/2	$3d^5\ ^4G^5$	11/2	20.839	20.795				
$3d^5\ ^2G^5$	9/2	$3d^5\ ^4G^5$	9/2	20.159	20.117				
$3d^5\ ^2G^5$	9/2	$3d^5\ ^2H^3$	9/2	16.767	16.734				
$3d^5\ ^2G^5$	9/2	$3d^5\ ^2G^5$	7/2	16.209	16.186				
$3d^5\ ^2G^5$	9/2	$3d^5\ ^2G^3$	7/2	14.558	14.535				
$3d^5\ ^2G^5$	9/2	$3d^5\ ^2G^3$	9/2	13.180	13.165				
$3d^5\ ^2G^5$	9/2	$3d^5\ ^4F^3$	7/2	8.987	8.969				
$3d^5\ ^2G^5$	9/2	$3d^5\ ^2H^3$	11/2	8.885	8.867				
$3d^5\ ^2G^5$	9/2	$3d^5\ ^2G^5$	9/2	8.437	8.422				
$3d^5\ ^2G^5$	9/2	$3d^5\ ^2G^3$	7/2	7.995	7.982				
$3d^5\ ^4D^5$	5/2	$3d^5\ ^2F^5$	7/2	270.094	271.516				
$3d^5\ ^4D^5$	5/2	$3d^5\ ^2D^1$	3/2	57.709	57.636				
$3d^5\ ^4D^5$	5/2	$3d^5\ ^6S^5$	5/2	26.647	26.559				
$3d^5\ ^4D^5$	5/2	$3d^5\ ^4D^5$	7/2	22.415	22.363				
$3d^5\ ^4D^5$	5/2	$3d^5\ ^4P^3$	3/2	19.454	19.404				
$3d^5\ ^4D^5$	5/2	$3d^5\ ^2F^5$	5/2	19.077	19.042				

Table 5. *Cont.*

Label and J for Lower		Label and J for Upper		Present Work $n = 5$	Present Work $n = 6$	Expt (Ref. [2])	GRASP	RMBPT$_g$	RCI$_g$
$3d^5\ ^4D^5$	5/2	$3d^5\ ^2G^5$	7/2	17.031	17.007				
$3d^5\ ^4D^5$	5/2	$3d^5\ ^4F^3$	5/2	16.560	16.529				
$3d^5\ ^4D^5$	5/2	$3d^5\ ^2D^5$	3/2	16.426	16.407				
$3d^5\ ^4D^5$	5/2	$3d^5\ ^2G^3$	7/2	15.218	15.194				
$3d^5\ ^4D^5$	5/2	$3d^5\ ^2P^3$	3/2	11.706	11.699				
$3d^5\ ^4D^5$	5/2	$3d^5\ ^2D^1$	5/2	11.332	11.322				
$3d^5\ ^4D^5$	5/2	$3d^5\ ^4P^3$	5/2	9.899	9.876				
$3d^5\ ^4D^5$	5/2	$3d^5\ ^4F^3$	7/2	9.234	9.215				
$3d^5\ ^4D^5$	5/2	$3d^5\ ^4D^5$	3/2	9.021	9.002				
$3d^5\ ^4D^5$	5/2	$3d^5\ ^2D^3$	5/2	8.381	8.368				
$3d^5\ ^4D^5$	5/2	$3d^5\ ^2G^3$	7/2	8.190	8.177				
$3d^5\ ^4D^5$	5/2	$3d^5\ ^2D^1$	3/2	7.080	7.070				
$3d^5\ ^4D^5$	5/2	$3d^5\ ^2D^1$	5/2	5.842	5.830				
$3d^5\ ^4P^3$	1/2	$3d^5\ ^2D^1$	3/2	69.257	69.169				
$3d^5\ ^4P^3$	1/2	$3d^5\ ^4D^5$	1/2	21.006	20.963				
$3d^5\ ^4P^3$	1/2	$3d^5\ ^4P^3$	3/2	20.613	20.559				
$3d^5\ ^4P^3$	1/2	$3d^5\ ^2D^5$	3/2	17.245	17.225				
$3d^5\ ^4P^3$	1/2	$3d^5\ ^4P^3$	1/2	15.909	15.884				
$3d^5\ ^4P^3$	1/2	$3d^5\ ^2P^3$	3/2	12.116	12.109				
$3d^5\ ^4P^3$	1/2	$3d^5\ ^4D^5$	3/2	9.262	9.243				
$3d^5\ ^4P^3$	1/2	$3d^5\ ^2P^3$	1/2	7.973	7.962				
$3d^5\ ^4P^3$	1/2	$3d^5\ ^2D^1$	3/2	7.228	7.218				
$3d^5\ ^2F^5$	7/2	$3d^5\ ^6S^5$	5/2	29.564	29.438				
$3d^5\ ^2F^5$	7/2	$3d^5\ ^4D^5$	7/2	24.443	24.370				
$3d^5\ ^2F^5$	7/2	$3d^5\ ^4G^5$	9/2	23.296	23.233				
$3d^5\ ^2F^5$	7/2	$3d^5\ ^2F^5$	5/2	20.527	20.478				
$3d^5\ ^2F^5$	7/2	$3d^5\ ^2H^3$	9/2	18.882	18.835				
$3d^5\ ^2F^5$	7/2	$3d^5\ ^2G^5$	7/2	18.177	18.143				
$3d^5\ ^2F^5$	7/2	$3d^5\ ^4F^3$	5/2	17.641	17.600				
$3d^5\ ^2F^5$	7/2	$3d^5\ ^2G^3$	7/2	16.127	16.094				
$3d^5\ ^2F^5$	7/2	$3d^5\ ^2G^3$	9/2	14.452	14.432				
$3d^5\ ^2F^5$	7/2	$3d^5\ ^2D^1$	5/2	11.828	11.814				
$3d^5\ ^2F^5$	7/2	$3d^5\ ^4P^3$	5/2	10.275	10.249				
$3d^5\ ^2F^5$	7/2	$3d^5\ ^4F^3$	7/2	9.561	9.539				
$3d^5\ ^2F^5$	7/2	$3d^5\ ^2G^5$	9/2	8.941	8.923				
$3d^5\ ^2F^5$	7/2	$3d^5\ ^2D^3$	5/2	8.650	8.634				
$3d^5\ ^2F^5$	7/2	$3d^5\ ^2G^3$	7/2	8.446	8.431				
$3d^5\ ^2F^5$	7/2	$3d^5\ ^2D^1$	5/2	5.971	5.958				
$3d^5\ ^2D^1$	3/2	$3d^5\ ^6S^5$	5/2	49.507	49.256				
$3d^5\ ^2D^1$	3/2	$3d^5\ ^4D^5$	1/2	30.151	30.080				
$3d^5\ ^2D^1$	3/2	$3d^5\ ^4P^3$	3/2	29.348	29.253				
$3d^5\ ^2D^1$	3/2	$3d^5\ ^2F^5$	5/2	28.498	28.437				
$3d^5\ ^2D^1$	3/2	$3d^5\ ^4F^3$	5/2	23.224	23.175				
$3d^5\ ^2D^1$	3/2	$3d^5\ ^2D^5$	3/2	22.962	22.936				
$3d^5\ ^2D^1$	3/2	$3d^5\ ^4P^3$	1/2	20.653	20.619				
$3d^5\ ^2D^1$	3/2	$3d^5\ ^2P^3$	3/2	14.685	14.678				
$3d^5\ ^2D^1$	3/2	$3d^5\ ^2D^1$	5/2	14.101	14.089				
$3d^5\ ^2D^1$	3/2	$3d^5\ ^4P^3$	5/2	11.948	11.919				
$3d^5\ ^2D^1$	3/2	$3d^5\ ^4D^5$	3/2	10.692	10.668				

Table 5. *Cont.*

Label and J for Lower		Label and J for Upper		Present Work $n = 5$	Present Work $n = 6$	Expt (Ref. [2])	GRASP	RMBPT$_g$	RCI$_g$
$3d^5\ ^2D^1$	3/2	$3d^5\ ^2D^3$	5/2	9.806	9.789				
$3d^5\ ^2D^1$	3/2	$3d^5\ ^2P^3$	1/2	9.010	8.997				
$3d^5\ ^2D^1$	3/2	$3d^5\ ^2D^1$	3/2	8.071	8.059				
$3d^5\ ^2D^1$	3/2	$3d^5\ ^2D^1$	5/2	6.500	6.486				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^4D^5$	7/2	141.121	141.559				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^4P^3$	3/2	72.074	72.035				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^2F^5$	5/2	67.156	67.278				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^2G^5$	7/2	47.192	47.288				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^4F^3$	5/2	43.743	43.766				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^2D^5$	3/2	42.824	42.924				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^2G^3$	7/2	35.481	35.505				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^2P^3$	3/2	20.879	20.910				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^2D^1$	5/2	19.717	19.734				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^4P^3$	5/2	15.749	15.723				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^4F^3$	7/2	14.130	14.111				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^4D^5$	3/2	13.638	13.618				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^2D^3$	5/2	12.227	12.217				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^2G^3$	7/2	11.824	11.815				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^2D^1$	3/2	9.643	9.636				
$3d^5\ ^6S^5$	5/2	$3d^5\ ^2D^1$	5/2	7.482	7.470				
$3d^5\ ^4D^5$	7/2	$3d^5\ ^4G^5$	9/2	496.548	497.861				
$3d^5\ ^4D^5$	7/2	$3d^5\ ^2F^5$	5/2	128.131	128.214				
$3d^5\ ^4D^5$	7/2	$3d^5\ ^2H^3$	9/2	82.993	82.924				
$3d^5\ ^4D^5$	7/2	$3d^5\ ^2G^5$	7/2	70.903	71.009				
$3d^5\ ^4D^5$	7/2	$3d^5\ ^4F^3$	5/2	63.393	63.353				
$3d^5\ ^4D^5$	7/2	$3d^5\ ^2G^3$	7/2	47.397	47.392				
$3d^5\ ^4D^5$	7/2	$3d^5\ ^2G^3$	9/2	35.359	35.390				
$3d^5\ ^4D^5$	7/2	$3d^5\ ^2D^1$	5/2	22.919	22.931				
$3d^5\ ^4D^5$	7/2	$3d^5\ ^4P^3$	5/2	17.728	17.688				
$3d^5\ ^4D^5$	7/2	$3d^5\ ^4F^3$	7/2	15.703	15.674				
$3d^5\ ^4D^5$	7/2	$3d^5\ ^2G^5$	9/2	14.097	14.078				
$3d^5\ ^4D^5$	7/2	$3d^5\ ^2D^3$	5/2	13.387	13.371				
$3d^5\ ^4D^5$	7/2	$3d^5\ ^2G^3$	7/2	12.906	12.891				
$3d^5\ ^4D^5$	7/2	$3d^5\ ^2D^1$	5/2	7.901	7.886				
$3d^5\ ^4G^5$	11/2	$3d^5\ ^4G^5$	9/2	617.468	617.572				
$3d^5\ ^4G^5$	11/2	$3d^5\ ^2I^5$	13/2	241.792	242.297				
$3d^5\ ^4G^5$	11/2	$3d^5\ ^2H^3$	9/2	85.801	85.691				
$3d^5\ ^4G^5$	11/2	$3d^5\ ^2G^3$	9/2	35.859	35.885				
$3d^5\ ^4G^5$	11/2	$3d^5\ ^2H^3$	11/2	15.488	15.460				
$3d^5\ ^4G^5$	11/2	$3d^5\ ^2G^5$	9/2	14.176	14.155				
$3d^5\ ^4G^5$	9/2	$3d^5\ ^2H^3$	9/2	99.648	99.496				
$3d^5\ ^4G^5$	9/2	$3d^5\ ^2G^5$	7/2	82.713	82.822				
$3d^5\ ^4G^5$	9/2	$3d^5\ ^2G^3$	7/2	52.399	52.378				
$3d^5\ ^4G^5$	9/2	$3d^5\ ^2G^3$	9/2	38.069	38.098				
$3d^5\ ^4G^5$	9/2	$3d^5\ ^4F^3$	7/2	16.215	16.183				
$3d^5\ ^4G^5$	9/2	$3d^5\ ^2H^3$	11/2	15.887	15.857				
$3d^5\ ^4G^5$	9/2	$3d^5\ ^2G^5$	9/2	14.509	14.487				
$3d^5\ ^4G^5$	9/2	$3d^5\ ^2G^3$	7/2	13.250	13.233				
$3d^5\ ^2I^5$	13/2	$3d^5\ ^2H^3$	11/2	16.548	16.513				

Table 5. *Cont.*

Label and J for Lower		Label and J for Upper		Present Work $n = 5$	Present Work $n = 6$	Expt (Ref. [2])	GRASP	RMBPT$_g$	RCI$_g$
$3d^5\ ^4D^5$	1/2	$3d^5\ ^4P^3$	3/2	1102.758	1064.996				
$3d^5\ ^4D^5$	1/2	$3d^5\ ^2D^5$	3/2	96.307	96.583				
$3d^5\ ^4D^5$	1/2	$3d^5\ ^4P^3$	1/2	65.560	65.562				
$3d^5\ ^4D^5$	1/2	$3d^5\ ^2P^3$	3/2	28.630	28.668				
$3d^5\ ^4D^5$	1/2	$3d^5\ ^4D^5$	3/2	16.568	16.532				
$3d^5\ ^4D^5$	1/2	$3d^5\ ^2P^3$	1/2	12.849	12.837				
$3d^5\ ^4D^5$	1/2	$3d^5\ ^2D^1$	3/2	11.021	11.009				
$3d^5\ ^4P^3$	3/2	$3d^5\ ^2F^5$	5/2	984.197	1018.757				
$3d^5\ ^4P^3$	3/2	$3d^5\ ^4F^3$	5/2	111.284	111.525				
$3d^5\ ^4P^3$	3/2	$3d^5\ ^2D^5$	3/2	105.523	106.216				
$3d^5\ ^4P^3$	3/2	$3d^5\ ^4P^3$	1/2	69.704	69.863				
$3d^5\ ^4P^3$	3/2	$3d^5\ ^2P^3$	3/2	29.393	29.461				
$3d^5\ ^4P^3$	3/2	$3d^5\ ^2D^1$	5/2	27.141	27.180				
$3d^5\ ^4P^3$	3/2	$3d^5\ ^4P^3$	5/2	20.153	20.113				
$3d^5\ ^4P^3$	3/2	$3d^5\ ^4D^5$	3/2	16.820	16.793				
$3d^5\ ^4P^3$	3/2	$3d^5\ ^2D^3$	5/2	14.726	14.712				
$3d^5\ ^4P^3$	3/2	$3d^5\ ^2P^3$	1/2	13.001	12.994				
$3d^5\ ^4P^3$	3/2	$3d^5\ ^2D^1$	3/2	11.132	11.124				
$3d^5\ ^4P^3$	3/2	$3d^5\ ^2D^1$	5/2	8.349	8.334				
$3d^5\ ^2F^5$	5/2	$3d^5\ ^2G^5$	7/2	158.747	159.155				
$3d^5\ ^2F^5$	5/2	$3d^5\ ^4F^3$	5/2	125.471	125.234				
$3d^5\ ^2F^5$	5/2	$3d^5\ ^2D^5$	3/2	118.195	118.578				
$3d^5\ ^2F^5$	5/2	$3d^5\ ^2G^3$	7/2	75.224	75.182				
$3d^5\ ^2F^5$	5/2	$3d^5\ ^2P^3$	3/2	30.298	30.339				
$3d^5\ ^2F^5$	5/2	$3d^5\ ^2D^1$	5/2	27.911	27.925				
$3d^5\ ^2F^5$	5/2	$3d^5\ ^4P^3$	5/2	20.575	20.518				
$3d^5\ ^2F^5$	5/2	$3d^5\ ^4F^3$	7/2	17.896	17.857				
$3d^5\ ^2F^5$	5/2	$3d^5\ ^4D^5$	3/2	17.113	17.074				
$3d^5\ ^2F^5$	5/2	$3d^5\ ^2D^3$	5/2	14.949	14.928				
$3d^5\ ^2F^5$	5/2	$3d^5\ ^2G^3$	7/2	14.351	14.331				
$3d^5\ ^2F^5$	5/2	$3d^5\ ^2D^1$	3/2	11.259	11.246				
$3d^5\ ^2F^5$	5/2	$3d^5\ ^2D^1$	5/2	8.420	8.403				
$3d^5\ ^2H^3$	9/2	$3d^5\ ^2G^5$	7/2	486.710	494.218				
$3d^5\ ^2H^3$	9/2	$3d^5\ ^2G^3$	7/2	110.511	110.603				
$3d^5\ ^2H^3$	9/2	$3d^5\ ^2G^3$	9/2	61.605	61.739				
$3d^5\ ^2H^3$	9/2	$3d^5\ ^4F^3$	7/2	19.367	19.327				
$3d^5\ ^2H^3$	9/2	$3d^5\ ^2H^3$	11/2	18.900	18.863				
$3d^5\ ^2H^3$	9/2	$3d^5\ ^2G^5$	9/2	16.982	16.957				
$3d^5\ ^2H^3$	9/2	$3d^5\ ^2G^3$	7/2	15.282	15.263				
$3d^5\ ^2G^5$	7/2	$3d^5\ ^4F^3$	5/2	598.575	587.600				
$3d^5\ ^2G^5$	7/2	$3d^5\ ^2G^3$	7/2	142.974	142.492				
$3d^5\ ^2G^5$	7/2	$3d^5\ ^2G^3$	9/2	70.533	70.553				
$3d^5\ ^2G^5$	7/2	$3d^5\ ^2D^1$	5/2	33.865	33.867				
$3d^5\ ^2G^5$	7/2	$3d^5\ ^4P^3$	5/2	23.638	23.555				
$3d^5\ ^2G^5$	7/2	$3d^5\ ^4F^3$	7/2	20.170	20.113				
$3d^5\ ^2G^5$	7/2	$3d^5\ ^2G^5$	9/2	17.595	17.559				
$3d^5\ ^2G^5$	7/2	$3d^5\ ^2D^3$	5/2	16.503	16.473				
$3d^5\ ^2G^5$	7/2	$3d^5\ ^2G^3$	7/2	15.777	15.750				
$3d^5\ ^2G^5$	7/2	$3d^5\ ^2D^1$	5/2	8.892	8.871				

Table 5. *Cont.*

Label and J for Lower		Label and J for Upper		Present Work $n = 5$	Present Work $n = 6$	Expt (Ref. [2])	GRASP	RMBPT$_g$	RCI$_g$
$3d^5\ ^4F^3$	5/2	$3d^5\ ^2D^5$	3/2	2038.287	2231.127				
$3d^5\ ^4F^3$	5/2	$3d^5\ ^2G^3$	7/2	187.841	188.108				
$3d^5\ ^4F^3$	5/2	$3d^5\ ^2P^3$	3/2	39.944	40.038				
$3d^5\ ^4F^3$	5/2	$3d^5\ ^2D^1$	5/2	35.896	35.939				
$3d^5\ ^4F^3$	5/2	$3d^5\ ^4P^3$	5/2	24.610	24.539				
$3d^5\ ^4F^3$	5/2	$3d^5\ ^4F^3$	7/2	20.873	20.826				
$3d^5\ ^4F^3$	5/2	$3d^5\ ^4D^5$	3/2	19.815	19.769				
$3d^5\ ^4F^3$	5/2	$3d^5\ ^2D^3$	5/2	16.971	16.948				
$3d^5\ ^4F^3$	5/2	$3d^5\ ^2G^3$	7/2	16.205	16.183				
$3d^5\ ^4F^3$	5/2	$3d^5\ ^2D^1$	3/2	12.369	12.356				
$3d^5\ ^4F^3$	5/2	$3d^5\ ^2D^1$	5/2	9.026	9.007				
$3d^5\ ^2D^5$	3/2	$3d^5\ ^4P^3$	1/2	205.353	204.123				
$3d^5\ ^2D^5$	3/2	$3d^5\ ^2P^3$	3/2	40.742	40.770				
$3d^5\ ^2D^5$	3/2	$3d^5\ ^2D^1$	5/2	36.540	36.527				
$3d^5\ ^2D^5$	3/2	$3d^5\ ^4P^3$	5/2	24.911	24.812				
$3d^5\ ^2D^5$	3/2	$3d^5\ ^4D^5$	3/2	20.010	19.946				
$3d^5\ ^2D^5$	3/2	$3d^5\ ^2D^3$	5/2	17.114	17.078				
$3d^5\ ^2D^5$	3/2	$3d^5\ ^2P^3$	1/2	14.828	14.805				
$3d^5\ ^2D^5$	3/2	$3d^5\ ^2D^1$	3/2	12.445	12.425				
$3d^5\ ^2D^5$	3/2	$3d^5\ ^2D^1$	5/2	9.066	9.044				
$3d^5\ ^2G^3$	7/2	$3d^5\ ^2G^3$	9/2	139.208	139.747				
$3d^5\ ^2G^3$	7/2	$3d^5\ ^2D^1$	5/2	44.377	44.427				
$3d^5\ ^2G^3$	7/2	$3d^5\ ^4P^3$	5/2	28.321	28.220				
$3d^5\ ^2G^3$	7/2	$3d^5\ ^4F^3$	7/2	23.482	23.419				
$3d^5\ ^2G^3$	7/2	$3d^5\ ^2G^5$	9/2	20.065	20.027				
$3d^5\ ^2G^3$	7/2	$3d^5\ ^2D^3$	5/2	18.657	18.626				
$3d^5\ ^2G^3$	7/2	$3d^5\ ^2G^3$	7/2	17.735	17.707				
$3d^5\ ^2G^3$	7/2	$3d^5\ ^2D^1$	5/2	9.482	9.460				
$3d^5\ ^4P^3$	1/2	$3d^5\ ^2P^3$	3/2	50.826	50.945				
$3d^5\ ^4P^3$	1/2	$3d^5\ ^4D^5$	3/2	22.170	22.106				
$3d^5\ ^4P^3$	1/2	$3d^5\ ^2P^3$	1/2	15.982	15.963				
$3d^5\ ^4P^3$	1/2	$3d^5\ ^2D^1$	3/2	13.248	13.230				
$3d^5\ ^2G^3$	9/2	$3d^5\ ^4F^3$	7/2	28.247	28.134				
$3d^5\ ^2G^3$	9/2	$3d^5\ ^2H^3$	11/2	27.264	27.162				
$3d^5\ ^2G^3$	9/2	$3d^5\ ^2G^5$	9/2	23.444	23.377				
$3d^5\ ^2G^3$	9/2	$3d^5\ ^2G^3$	7/2	20.324	20.276				
$3d^5\ ^2P^3$	3/2	$3d^5\ ^2D^1$	5/2	354.267	351.029				
$3d^5\ ^2P^3$	3/2	$3d^5\ ^4P^3$	5/2	64.110	63.389				
$3d^5\ ^2P^3$	3/2	$3d^5\ ^4D^5$	3/2	39.323	39.051				
$3d^5\ ^2P^3$	3/2	$3d^5\ ^2D^3$	5/2	29.510	29.388				
$3d^5\ ^2P^3$	3/2	$3d^5\ ^2P^3$	1/2	23.312	23.247				
$3d^5\ ^2P^3$	3/2	$3d^5\ ^2D^1$	3/2	17.918	17.871				
$3d^5\ ^2P^3$	3/2	$3d^5\ ^2D^1$	5/2	11.661	11.621				
$3d^5\ ^2D^1$	5/2	$3d^5\ ^4P^3$	5/2	78.275	77.359				
$3d^5\ ^2D^1$	5/2	$3d^5\ ^4F^3$	7/2	49.873	49.527				
$3d^5\ ^2D^1$	5/2	$3d^5\ ^4D^5$	3/2	44.232	43.939				
$3d^5\ ^2D^1$	5/2	$3d^5\ ^2D^3$	5/2	32.191	32.073				
$3d^5\ ^2D^1$	5/2	$3d^5\ ^2G^3$	7/2	29.540	29.440				
$3d^5\ ^2D^1$	5/2	$3d^5\ ^2D^1$	3/2	18.873	18.830				

Table 5. *Cont.*

Label and J for Lower		Label and J for Upper		Present Work $n = 5$	Present Work $n = 6$	Expt (Ref. [2])	GRASP	RMBPT$_g$	RCI$_g$
$3d^5\ ^2D^1$	5/2	$3d^5\ ^2D^1$	5/2	12.058	12.019				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^4F^3$	7/2	137.450	137.658				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^4D^5$	3/2	101.706	101.709				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^2D^3$	5/2	54.677	54.789				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^2G^3$	7/2	47.445	47.528				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^2D^1$	3/2	24.869	24.888				
$3d^5\ ^4P^3$	5/2	$3d^5\ ^2D^1$	5/2	14.254	14.230				
$3d^5\ ^4F^3$	7/2	$3d^5\ ^2G^5$	9/2	137.868	138.255				
$3d^5\ ^4F^3$	7/2	$3d^5\ ^2D^3$	5/2	90.796	91.013				
$3d^5\ ^4F^3$	7/2	$3d^5\ ^2G^3$	7/2	72.454	72.591				
$3d^5\ ^4F^3$	7/2	$3d^5\ ^2D^1$	5/2	15.903	15.871				
$3d^5\ ^2H^3$	11/2	$3d^5\ ^2G^5$	9/2	167.319	167.768				
$3d^5\ ^4D^5$	3/2	$3d^5\ ^2D^3$	5/2	118.248	118.767				
$3d^5\ ^4D^5$	3/2	$3d^5\ ^2P^3$	1/2	57.255	57.442				
$3d^5\ ^4D^5$	3/2	$3d^5\ ^2D^1$	3/2	32.917	32.951				
$3d^5\ ^4D^5$	3/2	$3d^5\ ^2D^1$	5/2	16.577	16.545				
$3d^5\ ^2G^5$	9/2	$3d^5\ ^2G^3$	7/2	152.705	152.840				
$3d^5\ ^2D^3$	5/2	$3d^5\ ^2G^3$	7/2	358.662	358.634				
$3d^5\ ^2D^3$	5/2	$3d^5\ ^2D^1$	3/2	45.616	45.602				
$3d^5\ ^2D^3$	5/2	$3d^5\ ^2D^1$	5/2	19.280	19.223				
$3d^5\ ^2G^3$	7/2	$3d^5\ ^2D^1$	5/2	20.376	20.312				
$3d^5\ ^2P^3$	1/2	$3d^5\ ^2D^1$	3/2	77.440	77.283				
$3d^5\ ^2D^1$	3/2	$3d^5\ ^2D^1$	5/2	33.396	33.231				
W^{50+} (Cr-like)									
$3d^6\ ^5D^4$	4	$3d^6\ ^5D^4$	3	19.752	19.720	19.684(3)	19.796	19.693	19.835
$3d^6\ ^5D^4$	4	$3d^6\ ^5D^4$	4	19.291	19.267	19.239(3)	19.303	19.237	19.425
$3d^6\ ^5D^4$	4	$3d^6\ ^3G^4$	5	17.162	17.150	17.133(3)	17.118	17.131	17.259
$3d^6\ ^5D^4$	4	$3d^6\ ^3D^4$	3	15.390	15.378	15.363(3)	15.370	15.289	15.316
$3d^6\ ^5D^4$	4	$3d^6\ ^1G^2$	4	13.147	13.139	13.137(3)	13.114	13.153	13.050
$3d^6\ ^5D^4$	4	$3d^6\ ^3F^2$	3	12.785	12.779	12.779(3)	12.739	12.800	12.642
$3d^6\ ^5D^4$	4	$3d^6\ ^3H^4$	4	9.024	9.013				
$3d^6\ ^5D^4$	4	$3d^6\ ^5D^4$	3	8.809	8.798				
$3d^6\ ^5D^4$	4	$3d^6\ ^3H^4$	5	8.756	8.746				
$3d^6\ ^5D^4$	4	$3d^6\ ^3F^4$	3	8.356	8.347				
$3d^6\ ^5D^4$	4	$3d^6\ ^1G^4$	4	8.111	8.104				
$3d^6\ ^5D^4$	4	$3d^6\ ^3F^2$	4	7.274	7.269				
$3d^6\ ^5D^4$	4	$3d^6\ ^1G^2$	4	5.668	5.661				
$3d^6\ ^5D^4$	4	$3d^6\ ^3F^2$	3	5.461	5.455				
$3d^6\ ^3D^4$	2	$3d^6\ ^5D^4$	3	22.546	22.503				
$3d^6\ ^3D^4$	2	$3d^6\ ^5D^4$	1	20.709	20.668				
$3d^6\ ^3D^4$	2	$3d^6\ ^3F^4$	2	17.384	17.367				
$3d^6\ ^3D^4$	2	$3d^6\ ^3D^4$	3	17.035	17.019				
$3d^6\ ^3D^4$	2	$3d^6\ ^3D^4$	2	14.214	14.202	14.193(3)	14.184	14.202	14.170
$3d^6\ ^3D^4$	2	$3d^6\ ^3P^2$	1	14.198	14.188				
$3d^6\ ^3D^4$	2	$3d^6\ ^3F^2$	3	13.900	13.892	13.886(3)	13.843	13.895	13.848
$3d^6\ ^3D^4$	2	$3d^6\ ^5D^4$	2	10.042	10.025				
$3d^6\ ^3D^4$	2	$3d^6\ ^5D^4$	3	9.324	9.312				
$3d^6\ ^3D^4$	2	$3d^6\ ^3F^4$	3	8.818	8.808				

Table 5. *Cont.*

Label and J for Lower		Label and J for Upper		Present Work $n = 5$	Present Work $n = 6$	Expt (Ref. [2])	GRASP	RMBPT$_g$	RCI$_g$
$3d^6\ ^3D^4$	2	$3d^6\ ^3D^4$	1	8.662	8.652				
$3d^6\ ^3D^4$	2	$3d^6\ ^3F^4$	2	8.468	8.460				
$3d^6\ ^3D^4$	2	$3d^6\ ^3F^2$	2	7.848	7.839				
$3d^6\ ^3D^4$	2	$3d^6\ ^1D^2$	2	6.867	6.863				
$3d^6\ ^3D^4$	2	$3d^6\ ^3P^2$	1	6.248	6.238				
$3d^6\ ^3D^4$	2	$3d^6\ ^3P^2$	2	5.711	5.704				
$3d^6\ ^3D^4$	2	$3d^6\ ^3F^2$	3	5.655	5.648				
$3d^6\ ^3P^2$	0	$3d^6\ ^5D^4$	1	29.559	29.509				
$3d^6\ ^3P^2$	0	$3d^6\ ^3P^2$	1	17.865	17.861	17.826(3)	17.750	17.837	17.921
$3d^6\ ^3P^2$	0	$3d^6\ ^3D^4$	1	9.901	9.893				
$3d^6\ ^3P^2$	0	$3d^6\ ^3P^2$	1	6.868	6.858				
$3d^6\ ^5D^4$	3	$3d^6\ ^5D^4$	4	827.797	838.107				
$3d^6\ ^5D^4$	3	$3d^6\ ^3F^4$	2	75.926	76.090				
$3d^6\ ^5D^4$	3	$3d^6\ ^3D^4$	3	69.700	69.830				
$3d^6\ ^5D^4$	3	$3d^6\ ^1G^2$	4	39.314	39.365				
$3d^6\ ^5D^4$	3	$3d^6\ ^3D^4$	2	38.467	38.499				
$3d^6\ ^5D^4$	3	$3d^6\ ^3F^2$	3	36.246	36.304				
$3d^6\ ^5D^4$	3	$3d^6\ ^5D^4$	2	18.107	18.080				
$3d^6\ ^5D^4$	3	$3d^6\ ^3H^4$	4	16.615	16.599				
$3d^6\ ^5D^4$	3	$3d^6\ ^5D^4$	3	15.900	15.886				
$3d^6\ ^5D^4$	3	$3d^6\ ^3F^4$	3	14.482	14.472				
$3d^6\ ^5D^4$	3	$3d^6\ ^1G^4$	4	13.764	13.758				
$3d^6\ ^5D^4$	3	$3d^6\ ^3F^4$	2	13.562	13.556				
$3d^6\ ^5D^4$	3	$3d^6\ ^3F^2$	2	12.038	12.029				
$3d^6\ ^5D^4$	3	$3d^6\ ^3F^2$	4	11.514	11.512				
$3d^6\ ^5D^4$	3	$3d^6\ ^1D^2$	2	9.875	9.874				
$3d^6\ ^5D^4$	3	$3d^6\ ^1G^2$	4	7.949	7.940				
$3d^6\ ^5D^4$	3	$3d^6\ ^3P^2$	2	7.648	7.641				
$3d^6\ ^5D^4$	3	$3d^6\ ^3F^2$	3	7.547	7.540				
$3d^6\ ^5D^4$	4	$3d^6\ ^3G^4$	5	155.438	156.080				
$3d^6\ ^5D^4$	4	$3d^6\ ^3D^4$	3	76.108	76.177				
$3d^6\ ^5D^4$	4	$3d^6\ ^1G^2$	4	41.274	41.305				
$3d^6\ ^5D^4$	4	$3d^6\ ^3F^2$	3	37.905	37.948				
$3d^6\ ^5D^4$	4	$3d^6\ ^3H^4$	4	16.955	16.934				
$3d^6\ ^5D^4$	4	$3d^6\ ^5D^4$	3	16.211	16.193				
$3d^6\ ^5D^4$	4	$3d^6\ ^3H^4$	5	16.032	16.018				
$3d^6\ ^5D^4$	4	$3d^6\ ^3F^4$	3	14.740	14.726				
$3d^6\ ^5D^4$	4	$3d^6\ ^1G^4$	4	13.997	13.987				
$3d^6\ ^5D^4$	4	$3d^6\ ^3F^2$	4	11.676	11.672				
$3d^6\ ^5D^4$	4	$3d^6\ ^1G^2$	4	8.026	8.016				
$3d^6\ ^5D^4$	4	$3d^6\ ^3F^2$	3	7.617	7.609				
$3d^6\ ^5D^4$	1	$3d^6\ ^3F^4$	2	108.263	108.730				
$3d^6\ ^5D^4$	1	$3d^6\ ^3P^4$	0	55.744	55.924				
$3d^6\ ^5D^4$	1	$3d^6\ ^3D^4$	2	45.325	45.393				
$3d^6\ ^5D^4$	1	$3d^6\ ^3P^2$	1	45.157	45.248				
$3d^6\ ^5D^4$	1	$3d^6\ ^5D^4$	2	19.495	19.468				
$3d^6\ ^5D^4$	1	$3d^6\ ^5D^4$	0	18.606	18.576				
$3d^6\ ^5D^4$	1	$3d^6\ ^3D^4$	1	14.889	14.882				
$3d^6\ ^5D^4$	1	$3d^6\ ^3F^4$	2	14.326	14.322				

Table 5. *Cont.*

Label and J for Lower		Label and J for Upper		Present Work $n = 5$	Present Work $n = 6$	Expt (Ref. [2])	GRASP	RMBPT$_g$	RCI$_g$
$3d^6\ ^5D^4$	1	$3d^6\ ^3F^2$	2	12.637	12.629				
$3d^6\ ^5D^4$	1	$3d^6\ ^1D^2$	2	10.274	10.274				
$3d^6\ ^5D^4$	1	$3d^6\ ^1S^0$	0	8.969	8.968				
$3d^6\ ^5D^4$	1	$3d^6\ ^3P^2$	1	8.947	8.934				
$3d^6\ ^5D^4$	1	$3d^6\ ^3P^2$	2	7.886	7.878				
$3d^6\ ^5D^4$	1	$3d^6\ ^3P^2$	0	5.630	5.622				
$3d^6\ ^3H^4$	6	$3d^6\ ^3G^4$	5	33171.897	25414.252				
$3d^6\ ^3H^4$	6	$3d^6\ ^3H^4$	5	17.866	17.837				
$3d^6\ ^3H^4$	6	$3d^6\ ^1I^4$	6	17.042	17.020				
$3d^6\ ^3G^4$	5	$3d^6\ ^1G^2$	4	56.196	56.170				
$3d^6\ ^3G^4$	5	$3d^6\ ^3H^4$	4	19.031	18.995				
$3d^6\ ^3G^4$	5	$3d^6\ ^3H^4$	5	17.876	17.850				
$3d^6\ ^3G^4$	5	$3d^6\ ^1I^4$	6	17.051	17.032				
$3d^6\ ^3G^4$	5	$3d^6\ ^1G^4$	4	15.382	15.364				
$3d^6\ ^3G^4$	5	$3d^6\ ^3F^2$	4	12.625	12.615				
$3d^6\ ^3G^4$	5	$3d^6\ ^1G^2$	4	8.463	8.450				
$3d^6\ ^3F^4$	2	$3d^6\ ^3D^4$	3	850.017	848.731				
$3d^6\ ^3F^4$	2	$3d^6\ ^3D^4$	2	77.967	77.927				
$3d^6\ ^3F^4$	2	$3d^6\ ^3P^2$	1	77.469	77.499				
$3d^6\ ^3F^4$	2	$3d^6\ ^3F^2$	3	69.354	69.431				
$3d^6\ ^3F^4$	2	$3d^6\ ^5D^4$	2	23.777	23.715				
$3d^6\ ^3F^4$	2	$3d^6\ ^5D^4$	3	20.111	20.078				
$3d^6\ ^3F^4$	2	$3d^6\ ^3F^4$	3	17.895	17.871				
$3d^6\ ^3F^4$	2	$3d^6\ ^3D^4$	1	17.263	17.242				
$3d^6\ ^3F^4$	2	$3d^6\ ^3F^4$	2	16.511	16.494				
$3d^6\ ^3F^4$	2	$3d^6\ ^3F^2$	2	14.307	14.288				
$3d^6\ ^3F^4$	2	$3d^6\ ^1D^2$	2	11.351	11.346				
$3d^6\ ^3F^4$	2	$3d^6\ ^3P^2$	1	9.754	9.734				
$3d^6\ ^3F^4$	2	$3d^6\ ^3P^2$	2	8.505	8.494				
$3d^6\ ^3F^4$	2	$3d^6\ ^3F^2$	3	8.381	8.370				
$3d^6\ ^3D^4$	3	$3d^6\ ^1G^2$	4	90.179	90.232				
$3d^6\ ^3D^4$	3	$3d^6\ ^3D^4$	2	85.841	85.805				
$3d^6\ ^3D^4$	3	$3d^6\ ^3F^2$	3	75.516	75.617				
$3d^6\ ^3D^4$	3	$3d^6\ ^5D^4$	2	24.461	24.396				
$3d^6\ ^3D^4$	3	$3d^6\ ^3H^4$	4	21.815	21.774				
$3d^6\ ^3D^4$	3	$3d^6\ ^5D^4$	3	20.598	20.565				
$3d^6\ ^3D^4$	3	$3d^6\ ^3F^4$	3	18.280	18.255				
$3d^6\ ^3D^4$	3	$3d^6\ ^1G^4$	4	17.151	17.133				
$3d^6\ ^3D^4$	3	$3d^6\ ^3F^4$	2	16.838	16.821				
$3d^6\ ^3D^4$	3	$3d^6\ ^3F^2$	2	14.552	14.533				
$3d^6\ ^3D^4$	3	$3d^6\ ^3F^2$	4	13.792	13.784				
$3d^6\ ^3D^4$	3	$3d^6\ ^1D^2$	2	11.505	11.500				
$3d^6\ ^3D^4$	3	$3d^6\ ^1G^2$	4	8.972	8.959				
$3d^6\ ^3D^4$	3	$3d^6\ ^3P^2$	2	8.591	8.579				
$3d^6\ ^3D^4$	3	$3d^6\ ^3F^2$	3	8.464	8.453				
$3d^6\ ^3P^4$	0	$3d^6\ ^3P^2$	1	237.757	237.023				
$3d^6\ ^3P^4$	0	$3d^6\ ^3D^4$	1	20.315	20.278				
$3d^6\ ^3P^4$	0	$3d^6\ ^3P^2$	1	10.658	10.633				
$3d^6\ ^1G^2$	4	$3d^6\ ^3F^2$	3	464.412	466.858				

Table 5. *Cont.*

Label and J for Lower		Label and J for Upper		Present Work $n = 5$	Present Work $n = 6$	Expt (Ref. [2])	GRASP	RMBPT$_g$	RCI$_g$
$3d^6\ ^1G^2$	4	$3d^6\ ^3H^4$	4	28.776	28.700				
$3d^6\ ^1G^2$	4	$3d^6\ ^5D^4$	3	26.696	26.635				
$3d^6\ ^1G^2$	4	$3d^6\ ^3H^4$	5	26.215	26.164				
$3d^6\ ^1G^2$	4	$3d^6\ ^3F^4$	3	22.928	22.886				
$3d^6\ ^1G^2$	4	$3d^6\ ^1G^4$	4	21.178	21.149				
$3d^6\ ^1G^2$	4	$3d^6\ ^3F^2$	4	16.283	16.269				
$3d^6\ ^1G^2$	4	$3d^6\ ^1G^2$	4	9.963	9.946				
$3d^6\ ^1G^2$	4	$3d^6\ ^3F^2$	3	9.341	9.327				
$3d^6\ ^3D^4$	2	$3d^6\ ^3P^2$	1	12130.770	14130.082				
$3d^6\ ^3D^4$	2	$3d^6\ ^3F^2$	3	627.813	636.845				
$3d^6\ ^3D^4$	2	$3d^6\ ^5D^4$	2	34.209	34.088				
$3d^6\ ^3D^4$	2	$3d^6\ ^5D^4$	3	27.101	27.047				
$3d^6\ ^3D^4$	2	$3d^6\ ^3F^4$	3	23.226	23.189				
$3d^6\ ^3D^4$	2	$3d^6\ ^3D^4$	1	22.172	22.140				
$3d^6\ ^3D^4$	2	$3d^6\ ^3F^4$	2	20.946	20.922				
$3d^6\ ^3D^4$	2	$3d^6\ ^3F^2$	2	17.522	17.497				
$3d^6\ ^3D^4$	2	$3d^6\ ^1D^2$	2	13.285	13.280				
$3d^6\ ^3D^4$	2	$3d^6\ ^3P^2$	1	11.148	11.124				
$3d^6\ ^3D^4$	2	$3d^6\ ^3P^2$	2	9.546	9.533				
$3d^6\ ^3D^4$	2	$3d^6\ ^3F^2$	3	9.390	9.377				
$3d^6\ ^3P^2$	1	$3d^6\ ^5D^4$	2	34.306	34.171				
$3d^6\ ^3P^2$	1	$3d^6\ ^5D^4$	0	31.646	31.512				
$3d^6\ ^3P^2$	1	$3d^6\ ^3D^4$	1	22.213	22.175				
$3d^6\ ^3P^2$	1	$3d^6\ ^3F^4$	2	20.982	20.954				
$3d^6\ ^3P^2$	1	$3d^6\ ^3F^2$	2	17.548	17.518				
$3d^6\ ^3P^2$	1	$3d^6\ ^1D^2$	2	13.300	13.292				
$3d^6\ ^3P^2$	1	$3d^6\ ^1S^0$	0	11.192	11.185				
$3d^6\ ^3P^2$	1	$3d^6\ ^3P^2$	1	11.158	11.132				
$3d^6\ ^3P^2$	1	$3d^6\ ^3P^2$	2	9.554	9.539				
$3d^6\ ^3P^2$	1	$3d^6\ ^3P^2$	0	6.432	6.419				
$3d^6\ ^3F^2$	3	$3d^6\ ^5D^4$	2	36.181	36.016				
$3d^6\ ^3F^2$	3	$3d^6\ ^3H^4$	4	30.677	30.580				
$3d^6\ ^3F^2$	3	$3d^6\ ^5D^4$	3	28.324	28.246				
$3d^6\ ^3F^2$	3	$3d^6\ ^3F^4$	3	24.119	24.065				
$3d^6\ ^3F^2$	3	$3d^6\ ^1G^4$	4	22.190	22.153				
$3d^6\ ^3F^2$	3	$3d^6\ ^3F^4$	2	21.669	21.633				
$3d^6\ ^3F^2$	3	$3d^6\ ^3F^2$	2	18.025	17.991				
$3d^6\ ^3F^2$	3	$3d^6\ ^3F^2$	4	16.875	16.857				
$3d^6\ ^3F^2$	3	$3d^6\ ^1D^2$	2	13.572	13.563				
$3d^6\ ^3F^2$	3	$3d^6\ ^1G^2$	4	10.182	10.163				
$3d^6\ ^3F^2$	3	$3d^6\ ^3P^2$	2	9.694	9.677				
$3d^6\ ^3F^2$	3	$3d^6\ ^3F^2$	3	9.532	9.517				
$3d^6\ ^5D^4$	2	$3d^6\ ^5D^4$	3	130.436	130.930				
$3d^6\ ^5D^4$	2	$3d^6\ ^3F^4$	3	72.345	72.524				
$3d^6\ ^5D^4$	2	$3d^6\ ^3D^4$	1	63.013	63.168				
$3d^6\ ^5D^4$	2	$3d^6\ ^3F^4$	2	54.026	54.171				
$3d^6\ ^5D^4$	2	$3d^6\ ^3F^2$	2	35.921	35.947				
$3d^6\ ^5D^4$	2	$3d^6\ ^1D^2$	2	21.720	21.755				
$3d^6\ ^5D^4$	2	$3d^6\ ^3P^2$	1	16.537	16.511				

Table 5. *Cont.*

Label and J for Lower		Label and J for Upper		Present Work $n = 5$	Present Work $n = 6$	Expt (Ref. [2])	GRASP	RMBPT$_g$	RCI$_g$
$3d^6\ ^5D^4$	2	$3d^6\ ^3P^2$	2	13.242	13.233				
$3d^6\ ^5D^4$	2	$3d^6\ ^3F^2$	3	12.942	12.935				
$3d^6\ ^5D^4$	0	$3d^6\ ^3D^4$	1	74.520	74.840				
$3d^6\ ^5D^4$	0	$3d^6\ ^3P^2$	1	17.236	17.213				
$3d^6\ ^3H^4$	4	$3d^6\ ^5D^4$	3	369.368	370.105				
$3d^6\ ^3H^4$	4	$3d^6\ ^3H^4$	5	294.589	296.075				
$3d^6\ ^3H^4$	4	$3d^6\ ^3F^4$	3	112.825	112.959				
$3d^6\ ^3H^4$	4	$3d^6\ ^1G^4$	4	80.216	80.382				
$3d^6\ ^3H^4$	4	$3d^6\ ^3F^2$	4	37.506	37.563				
$3d^6\ ^3H^4$	4	$3d^6\ ^1G^2$	4	15.240	15.221				
$3d^6\ ^3H^4$	4	$3d^6\ ^3F^2$	3	13.830	13.817				
$3d^6\ ^5D^4$	3	$3d^6\ ^3F^4$	3	162.444	162.579				
$3d^6\ ^5D^4$	3	$3d^6\ ^1G^4$	4	102.469	102.683				
$3d^6\ ^5D^4$	3	$3d^6\ ^3F^4$	2	92.227	92.402				
$3d^6\ ^5D^4$	3	$3d^6\ ^3F^2$	2	49.574	49.552				
$3d^6\ ^5D^4$	3	$3d^6\ ^3F^2$	4	41.744	41.805				
$3d^6\ ^5D^4$	3	$3d^6\ ^1D^2$	2	26.059	26.090				
$3d^6\ ^5D^4$	3	$3d^6\ ^1G^2$	4	15.896	15.874				
$3d^6\ ^5D^4$	3	$3d^6\ ^3P^2$	2	14.738	14.721				
$3d^6\ ^5D^4$	3	$3d^6\ ^3F^2$	3	14.368	14.353				
$3d^6\ ^3H^4$	5	$3d^6\ ^1I^4$	6	369.318	371.637				
$3d^6\ ^3H^4$	5	$3d^6\ ^1G^4$	4	110.232	110.337				
$3d^6\ ^3H^4$	5	$3d^6\ ^3F^2$	4	42.977	43.021				
$3d^6\ ^3H^4$	5	$3d^6\ ^1G^2$	4	16.071	16.046				
$3d^6\ ^3F^4$	3	$3d^6\ ^1G^4$	4	277.541	278.717				
$3d^6\ ^3F^4$	3	$3d^6\ ^3F^4$	2	213.361	214.066				
$3d^6\ ^3F^4$	3	$3d^6\ ^3F^2$	2	71.346	71.275				
$3d^6\ ^3F^4$	3	$3d^6\ ^3F^2$	4	56.181	56.276				
$3d^6\ ^3F^4$	3	$3d^6\ ^1D^2$	2	31.039	31.076				
$3d^6\ ^3F^4$	3	$3d^6\ ^1G^2$	4	17.620	17.592				
$3d^6\ ^3F^4$	3	$3d^6\ ^3P^2$	2	16.208	16.187				
$3d^6\ ^3F^4$	3	$3d^6\ ^3F^2$	3	15.762	15.743				
$3d^6\ ^3D^4$	1	$3d^6\ ^3F^4$	2	378.830	380.349				
$3d^6\ ^3D^4$	1	$3d^6\ ^3F^2$	2	83.550	83.418				
$3d^6\ ^3D^4$	1	$3d^6\ ^1D^2$	2	33.145	33.182				
$3d^6\ ^3D^4$	1	$3d^6\ ^1S^0$	0	22.557	22.569				
$3d^6\ ^3D^4$	1	$3d^6\ ^3P^2$	1	22.422	22.355				
$3d^6\ ^3D^4$	1	$3d^6\ ^3P^2$	2	16.764	16.740				
$3d^6\ ^3D^4$	1	$3d^6\ ^3P^2$	0	9.053	9.035				
$3d^6\ ^1G^4$	4	$3d^6\ ^3F^2$	4	70.440	70.514				
$3d^6\ ^1G^4$	4	$3d^6\ ^1G^2$	4	18.815	18.777				
$3d^6\ ^1G^4$	4	$3d^6\ ^3F^2$	3	16.711	16.685				
$3d^6\ ^3F^4$	2	$3d^6\ ^3F^2$	2	107.190	106.853				
$3d^6\ ^3F^4$	2	$3d^6\ ^1D^2$	2	36.323	36.354				
$3d^6\ ^3F^4$	2	$3d^6\ ^3P^2$	1	23.832	23.751				
$3d^6\ ^3F^4$	2	$3d^6\ ^3P^2$	2	17.541	17.511				
$3d^6\ ^3F^4$	2	$3d^6\ ^3F^2$	3	17.019	16.992				
$3d^6\ ^3F^2$	2	$3d^6\ ^1D^2$	2	54.939	55.101				
$3d^6\ ^3F^2$	2	$3d^6\ ^3P^2$	1	30.646	30.539				

Table 5. *Cont.*

Label and J for Lower		Label and J for Upper		Present Work $n = 5$	Present Work $n = 6$	Expt (Ref. [2])	GRASP	RMBPT$_g$	RCI$_g$
$3d^6\ ^3F^2$	2	$3d^6\ ^3P^2$	2	20.973	20.943				
$3d^6\ ^3F^2$	2	$3d^6\ ^3F^2$	3	20.232	20.205				
$3d^6\ ^3F^2$	4	$3d^6\ ^1G^2$	4	25.671	25.592				
$3d^6\ ^3F^2$	4	$3d^6\ ^3F^2$	3	21.909	21.857				
$3d^6\ ^1D^2$	2	$3d^6\ ^3P^2$	1	69.307	68.508				
$3d^6\ ^1D^2$	2	$3d^6\ ^3P^2$	2	33.922	33.783				
$3d^6\ ^1D^2$	2	$3d^6\ ^3F^2$	3	32.025	31.905				
$3d^6\ ^1S^0$	0	$3d^6\ ^3P^2$	1	3732.652	2353.561				
$3d^6\ ^3P^2$	1	$3d^6\ ^3P^2$	2	66.443	66.648				
$3d^6\ ^3P^2$	1	$3d^6\ ^3P^2$	0	15.184	15.162				
$3d^6\ ^1G^2$	4	$3d^6\ ^3F^2$	3	149.470	149.753				
$3d^6\ ^3P^2$	2	$3d^6\ ^3F^2$	3	572.500	573.976				
W^{49+} (Mn-like)									
$3d^7\ ^4F^3$	9/2	$3d^7\ ^4F^3$	7/2	18.940	18.908	18.880(3)	19.006	18.901	18.943
$3d^7\ ^4F^3$	9/2	$3d^7\ ^4F^3$	9/2	17.138	17.119	17.106(3)	17.149	17.118	17.132
$3d^7\ ^4F^3$	9/2	$3d^7\ ^2H^3$	11/2	15.381	15.371	15.368(3)	15.343	15.372	15.380
$3d^7\ ^4F^3$	9/2	$3d^7\ ^2F^3$	7/2	14.180	14.170	14.166(3)	14.156	14.187	14.063
$3d^7\ ^4F^3$	9/2	$3d^7\ ^2H^3$	9/2	8.434	8.424				
$3d^7\ ^4F^3$	9/2	$3d^7\ ^2F^3$	7/2	8.259	8.250				
$3d^7\ ^2P^3$	3/2	$3d^7\ ^2D^1$	5/2	174.708	174.056				
$3d^7\ ^2P^3$	3/2	$3d^7\ ^4P^3$	3/2	19.753	19.715				
$3d^7\ ^2P^3$	3/2	$3d^7\ ^4P^3$	5/2	19.111	19.081	19.047(3)	19.130	19.037	19.271
$3d^7\ ^2P^3$	3/2	$3d^7\ ^4P^3$	1/2	18.720	18.692	18.670(3)	18.764	18.680	18.733
$3d^7\ ^2P^3$	3/2	$3d^7\ ^2F^3$	5/2	15.597	15.585				
$3d^7\ ^2P^3$	3/2	$3d^7\ ^2D^1$	3/2	12.711	12.700				
$3d^7\ ^2P^3$	3/2	$3d^7\ ^4F^3$	5/2	9.864	9.847				
$3d^7\ ^2P^3$	3/2	$3d^7\ ^4P^3$	3/2	9.561	9.546				
$3d^7\ ^2P^3$	3/2	$3d^7\ ^2P^3$	1/2	9.171	9.157				
$3d^7\ ^2P^3$	3/2	$3d^7\ ^2D^1$	5/2	7.643	7.636				
$3d^7\ ^2P^3$	3/2	$3d^7\ ^2D^1$	3/2	6.060	6.050				
$3d^7\ ^2D^1$	5/2	$3d^7\ ^4F^3$	7/2	27.098	27.043				
$3d^7\ ^2D^1$	5/2	$3d^7\ ^4P^3$	3/2	22.271	22.233				
$3d^7\ ^2D^1$	5/2	$3d^7\ ^4P^3$	5/2	21.458	21.430				
$3d^7\ ^2D^1$	5/2	$3d^7\ ^2F^3$	7/2	18.307	18.294	18.276(3)	18.258	18.274	18.425
$3d^7\ ^2D^1$	5/2	$3d^7\ ^2F^3$	5/2	17.126	17.117				
$3d^7\ ^2D^1$	5/2	$3d^7\ ^2D^1$	3/2	13.709	13.700				
$3d^7\ ^2D^1$	5/2	$3d^7\ ^4F^3$	5/2	10.455	10.437				
$3d^7\ ^2D^1$	5/2	$3d^7\ ^4P^3$	3/2	10.115	10.099				
$3d^7\ ^2D^1$	5/2	$3d^7\ ^2F^3$	7/2	9.507	9.496				
$3d^7\ ^2D^1$	5/2	$3d^7\ ^2D^1$	5/2	7.993	7.986				
$3d^7\ ^2D^1$	5/2	$3d^7\ ^2D^1$	3/2	6.278	6.268				
$3d^7\ ^4F^3$	7/2	$3d^7\ ^4F^3$	9/2	180.107	180.908				
$3d^7\ ^4F^3$	7/2	$3d^7\ ^4P^3$	5/2	103.103	103.259				
$3d^7\ ^4F^3$	7/2	$3d^7\ ^2F^3$	7/2	56.428	56.550				
$3d^7\ ^4F^3$	7/2	$3d^7\ ^2F^3$	5/2	46.537	46.637				
$3d^7\ ^4F^3$	7/2	$3d^7\ ^4F^3$	5/2	17.022	16.998				
$3d^7\ ^4F^3$	7/2	$3d^7\ ^2H^3$	9/2	15.204	15.193				
$3d^7\ ^4F^3$	7/2	$3d^7\ ^2F^3$	7/2	14.645	14.635				

Table 5. *Cont.*

Label and J for Lower		Label and J for Upper		Present Work $n = 5$	Present Work $n = 6$	Expt (Ref. [2])	GRASP	RMBPT$_g$	RCI$_g$
$3d^7\ ^4F^3$	7/2	$3d^7\ ^2D^1$	5/2	11.337	11.332				
$3d^7\ ^4F^3$	9/2	$3d^7\ ^2H^3$	11/2	150.021	150.559				
$3d^7\ ^4F^3$	9/2	$3d^7\ ^2F^3$	7/2	82.173	82.265				
$3d^7\ ^4F^3$	9/2	$3d^7\ ^2H^3$	9/2	16.606	16.586				
$3d^7\ ^4F^3$	9/2	$3d^7\ ^2F^3$	7/2	15.942	15.923				
$3d^7\ ^4P^3$	3/2	$3d^7\ ^4P^3$	5/2	587.816	593.270				
$3d^7\ ^4P^3$	3/2	$3d^7\ ^4P^3$	1/2	357.969	360.283				
$3d^7\ ^4P^3$	3/2	$3d^7\ ^2F^3$	5/2	74.127	74.387				
$3d^7\ ^4P^3$	3/2	$3d^7\ ^2D^1$	3/2	35.657	35.693				
$3d^7\ ^4P^3$	3/2	$3d^7\ ^4F^3$	5/2	19.704	19.673				
$3d^7\ ^4P^3$	3/2	$3d^7\ ^4P^3$	3/2	18.530	18.506				
$3d^7\ ^4P^3$	3/2	$3d^7\ ^2P^3$	1/2	17.118	17.100				
$3d^7\ ^4P^3$	3/2	$3d^7\ ^2D^1$	5/2	12.467	12.462				
$3d^7\ ^4P^3$	3/2	$3d^7\ ^2D^1$	3/2	8.742	8.729				
$3d^7\ ^4P^3$	5/2	$3d^7\ ^2F^3$	7/2	124.648	125.014				
$3d^7\ ^4P^3$	5/2	$3d^7\ ^2F^3$	5/2	84.823	85.051				
$3d^7\ ^4P^3$	5/2	$3d^7\ ^2D^1$	3/2	37.960	37.978				
$3d^7\ ^4P^3$	5/2	$3d^7\ ^4F^3$	5/2	20.388	20.347				
$3d^7\ ^4P^3$	5/2	$3d^7\ ^4P^3$	3/2	19.133	19.101				
$3d^7\ ^4P^3$	5/2	$3d^7\ ^2F^3$	7/2	17.070	17.052				
$3d^7\ ^4P^3$	5/2	$3d^7\ ^2D^1$	5/2	12.737	12.729				
$3d^7\ ^4P^3$	5/2	$3d^7\ ^2D^1$	3/2	8.874	8.860				
$3d^7\ ^4P^3$	1/2	$3d^7\ ^2D^1$	3/2	39.602	39.618				
$3d^7\ ^4P^3$	1/2	$3d^7\ ^4P^3$	3/2	19.542	19.508				
$3d^7\ ^4P^3$	1/2	$3d^7\ ^2P^3$	1/2	17.978	17.952				
$3d^7\ ^4P^3$	1/2	$3d^7\ ^2D^1$	3/2	8.961	8.946				
$3d^7\ ^2H^3$	11/2	$3d^7\ ^2H^3$	9/2	18.673	18.639				
$3d^7\ ^2F^3$	7/2	$3d^7\ ^2F^3$	5/2	265.490	266.061				
$3d^7\ ^2F^3$	7/2	$3d^7\ ^4F^3$	5/2	24.375	24.303				
$3d^7\ ^2F^3$	7/2	$3d^7\ ^2H^3$	9/2	20.812	20.774				
$3d^7\ ^2F^3$	7/2	$3d^7\ ^2F^3$	7/2	19.779	19.745				
$3d^7\ ^2F^3$	7/2	$3d^7\ ^2D^1$	5/2	14.187	14.173				
$3d^7\ ^2F^3$	5/2	$3d^7\ ^2D^1$	3/2	68.707	68.619				
$3d^7\ ^2F^3$	5/2	$3d^7\ ^4F^3$	5/2	26.839	26.746				
$3d^7\ ^2F^3$	5/2	$3d^7\ ^4P^3$	3/2	24.706	24.634				
$3d^7\ ^2F^3$	5/2	$3d^7\ ^2F^3$	7/2	21.371	21.328				
$3d^7\ ^2F^3$	5/2	$3d^7\ ^2D^1$	5/2	14.988	14.970				
$3d^7\ ^2F^3$	5/2	$3d^7\ ^2D^1$	3/2	9.911	9.890				
$3d^7\ ^2D^1$	3/2	$3d^7\ ^4F^3$	5/2	44.043	43.830				
$3d^7\ ^2D^1$	3/2	$3d^7\ ^4P^3$	3/2	38.579	38.430				
$3d^7\ ^2D^1$	3/2	$3d^7\ ^2P^3$	1/2	32.925	32.828				
$3d^7\ ^2D^1$	3/2	$3d^7\ ^2D^1$	5/2	19.169	19.147				
$3d^7\ ^2D^1$	3/2	$3d^7\ ^2D^1$	3/2	11.581	11.555				
$3d^7\ ^4F^3$	5/2	$3d^7\ ^4P^3$	3/2	310.962	311.919				
$3d^7\ ^4F^3$	5/2	$3d^7\ ^2F^3$	7/2	104.893	105.290				
$3d^7\ ^4F^3$	5/2	$3d^7\ ^2D^1$	5/2	33.943	34.000				
$3d^7\ ^4F^3$	5/2	$3d^7\ ^2D^1$	3/2	15.713	15.692				
$3d^7\ ^4P^3$	3/2	$3d^7\ ^2P^3$	1/2	224.661	225.205				
$3d^7\ ^4P^3$	3/2	$3d^7\ ^2D^1$	5/2	38.102	38.159				

Table 5. *Cont.*

Label and J for Lower		Label and J for Upper		Present Work $n=5$	Present Work $n=6$	Expt (Ref. [2])	GRASP	RMBPT$_g$	RCI$_g$
$3d^7\ ^4P^3$	3/2	$3d^7\ ^2D^1$	3/2	16.549	16.524				
$3d^7\ ^2P^3$	1/2	$3d^7\ ^2D^1$	3/2	17.865	17.832				
$3d^7\ ^2H^3$	9/2	$3d^7\ ^2F^3$	7/2	398.243	398.611				
$3d^7\ ^2F^3$	7/2	$3d^7\ ^2D^1$	5/2	50.182	50.215				
$3d^7\ ^2D^1$	5/2	$3d^7\ ^2D^1$	3/2	29.257	29.143				
W^{48+} (Fe-like)									
$3d^8\ ^3F$	4	$3d^8\ ^3F$	3	19.041	19.009	18.988(3)	19.114	19.007	19.027
$3d^8\ ^3F$	4	$3d^8\ ^1G$	4	15.531	15.518	15.511(3)	15.503	15.463	15.525
$3d^8\ ^1D$	2	$3d^8\ ^3F$	3	22.073	22.029				
$3d^8\ ^1D$	2	$3d^8\ ^3P$	2	18.931	18.902	18.878(3)	18.978	18.888	18.966
$3d^8\ ^1D$	2	$3d^8\ ^3P$	1	17.548	17.525	17.502(3)	17.548	17.517	17.489
$3d^8\ ^1D$	2	$3d^8\ ^3F$	2	9.664	9.648				
$3d^8\ ^3P$	0	$3d^8\ ^3P$	1	24.268	24.236				
$3d^8\ ^3F$	3	$3d^8\ ^3P$	2	132.993	133.189				
$3d^8\ ^3F$	3	$3d^8\ ^1G$	4	84.240	84.489				
$3d^8\ ^3F$	3	$3d^8\ ^3F$	2	17.190	17.167				
$3d^8\ ^3P$	2	$3d^8\ ^3P$	1	240.207	240.600				
$3d^8\ ^3P$	2	$3d^8\ ^3F$	2	19.742	19.707				
$3d^8\ ^3P$	1	$3d^8\ ^3F$	2	21.510	21.465				
$3d^8\ ^3P$	1	$3d^8\ ^1S$	0	15.102	15.082				
W^{47+} (Co-like)									
$3d^9\ ^2D$	5/2	$3d^9\ ^2D$	3/2	18.615	18.586	18.567(3)	18.671	18.586	18.580

4. Conclusions

The present study has shown that the inclusion of core correlation effects improves the accuracy of theoretical transition wavelengths for M1 transitions in $3d^k$ configurations of tungsten ions. Omitted in our work were correlation effects arising from the $1s^2$ core. Further studies are needed to determine whether the discrepancy with observation arises from the limited orbital set for core correlation or from the inactive $1s^2$ shell in our present work.

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