Observation and interpretation of the 5p54f35d core-excited configuration in triply ionized neodymium Nd 3 + (Nd IV)

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Abstract

Ultraviolet laboratory observation of the emission spectrum of the triply ionized neodymium Nd IV excited in a vacuum spark source was extended to shorter wavelength region down to 350 Å . The present analysis, based on the identification of 313 spectral lines, led to the determination of 125 previously unknown energy levels, all but two belonging to the core-excited configuration $5p^5 4f^3 5d$ in the Nd^{3+} ion. Theoretical calculations of even parity configurations were performed by using the parametric Slater-Racah method including configuration interactions. Energy parameter values were fitted by least-squares with a root-mean-square (rms) deviation of 184 cm^{-1} for an average energy $E_{av}(5p^5 4f^3 5d)$ = 221 076 cm^{-1}. In this work, we quantitatively confirm the effect of reduction of the $5p^6 4f^3$- $5p^6 4f^2 5d$ transition probabilities by the configuration interaction between $5p^6 4f^2 5d$ and core-excited $5p^5 4f^3 5d$ configurations, which is similar to the one observed in Nd V for the $5p^6 4f^2$- $5p^6 4f5d$ transitions.

Keywords: atomic spectra, transitions, energy levels, lanthanide ions

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1. Introduction

Structures and spectroscopic properties of lanthanide ions are of interest in many aspects relevant for laboratory and astrophysical plasmas. The earliest compilation of their energy levels was published by Martin *et al* in 1978 [1]. More recent bibliography on their spectroscopic data can be found in the database maintained by NIST [2]. One may recall that the lanthanides are incorporated into crystals, fibers or glass ceramics as trivalent ions for various applications involving their optical properties (See for example ref [3]). In astrophysics singly and doubly charged ions of lanthanides have been detected in Hubble Space Telescope observations of the atmospheres of chemically peculiar stars (See for example ref [4]). More recently, detection of neutron star mergers by simultaneous emission of gravitational waves and electromagnetic emission, with the predictions on formation of heavy elements in the ejected matter, strengthens the interest for radiative properties of ions up to triply charged [5].

Among all the lanthanides, neodymium has always attracted special attention, if only for the well known laser line at 1064 nm emitted by Nd^{3+} ions embedded in crystals. About a decade ago, analyses of the free ion Nd^{3+}(Nd IV) was carried out based on high resolution emission spectra of vacuum spark sources [6, 7].

The ground-state configuration of the Nd^{3+}ion (Nd IV) is built on three valence electrons $4f^3$. The spectrum belongs to the lanthanum (La I) isoelectronic sequence. In an earlier work [7], a number of 1426 identified lines in the wavelength range of 1160 - 2800 Å led to the complete determination of all 41 levels of $5p^6 4f^3$ and 191 levels of the lowest excited configurations $5p^6 4f^2 5d$, $4f^2 6s$ and $4f^2 6p$. The same set of spectrograms also contained emission lines from the Nd^{4+} ion (Nd V). The subsequent analysis of the Nd V spectrum [8] reported the complete determination of the ground-state configuration $5p^6 4f^2$ (except for $^1S_0$), and the lowest excited configurations $5p^6 4f5d$, 4f6s and 4f6p, altogether with the identification of 250 spectral lines in the range of (700-2240

Å).

In the parametric calculations performed for interpretation of the Nd IV [7] and Nd V [8] spectra, configuration interactions with core-excited configurations, respectively $5p^5 4f^3 5d$ in Nd IV and $5p^5 4f^2 5d$ in Nd V, were taken into account and showed to have influence on the intensities of observed 4f - 5d resonance transitions by reducing them. However, the corresponding interaction parameters could only be fixed to appropriate estimated values in the least-squares fits of energy levels in both ions, in absence of any experimental levels of these higher configurations. Later on, based on the same set of existing experimental level energies [7], transition probabilities for allowed and forbidden lines in Nd IV were investigated by Enzoga Yoca and Quinet [9], who performed similar parametric calculations with a larger basis of configurations and including explicitly more configuration interactions. Comparing their gA values of electric dipole lines with the values from the previous work [7], the authors estimated a good agreement of within %25 . They also mentioned the influence of core-excited configurations leading to a reduction of transition probabilities of resonance lines by a factor of about 2. This was consistent with the fact that lifetimes derived from both parametric calculations [7, 9] for some $5p^6 4f^2 5d$ levels were about two times longer compared to those calculated by Dzuba et al [10] without taking into account core-excited configurations (Cf Table 4 [9]). Such effect on the 4f - 5d resonance line intensities was furthermore studied in the case of Tm IV [11] where the $5p^5 4f^{11}$ and $5p^5 4f^{12} 5d$ configurations were introduced into their respective parities in the parametric calculations. However, again, no available experimental energy levels of the Tm^{3+} ion could be used to fit the corresponding configuration interaction parameters.

The first laboratory observation of core-excited configurations was reported by Reader and Wyart [12] for Ce^{3+} (Ce IV). In the parametric interpretation, 68 and 21 experimentally determined levels belonging respectively to the $5p^5 4f5d$ and $5p^5 4f6s$ configurations were introduced. The authors established that the interaction of these configurations with the $5p^6 nd$ series resulted in a large fine structure splitting of the 6d ^2D term. They also pointed out a reduction of transition probabilities of the 4f - 5d resonance lines by a factor of nearly 2 because of interaction between $5p^6 5d$ and $5p^5 4f5d$. Recently, by extending the experimental observation of ionized neodymium to shorter wavelengths down to 370 Å , the core-excited configuration $5p^5 4f^2 5d$ in the Nd^{4+} ion (Nd V) was observed and interpreted [13]. Consequently the effect of reduction of transition probabilities of the $5p^6 4f^2$ - $5p^6 4f5d$ transition array by the $5p^6 4f5d$ - $5p^5 4f^2 5d$ configuration interaction was made clear and quantitative in Nd V [13].

The main objective of the present work was to study similar effects in triply ionized neodymium Nd^{3+} (Nd IV), by extending the previous analyses [6, 7] to the short wavelength range of 400-600 Å , aiming to determine energy levels of the core-excited $5p^5 4f^3 5d$ configuration by their transitions to the $5p^6 4f^3$ ground-state configuration and to quantitatively confirm the strong reduction of the $5p^6 4f^3$ - $5p^6 4f^2 5d$ transition probabilities by the $5p^6 4f^2 5d$ - $5p^5 4f^3 5d$ configuration interaction. Figure 1 displays a diagram of transitions between configurations of Nd IV that were involved in the present work. Note that mixing may occur between the two overlapping core-excited configurations $5p^5 4f^3 5d$ and $5p^5 4f^3 6s$.

2. Experiment and line list

The spectrograms used in previous publications on neodymium ion spectra [6, 7, 8, 13] contain emission lines from Nd^{3+} and Nd^{4+} at the same time. They are therefore used again in the present work. Experimental details can be found in previous publications [6, 7, 8, 13]. Here we only recall the main features. At the early stage of the work, we had at our disposal two sets of recordings using two sliding spark sources: one in the wavelength range of 390-2700 Å from the National Bureau of Standards (NBS) with photographic plates (PP) (10.7m normal incidence spectrograph with 1200 lines mm^{-1} concave grating, plate factor 0.78 Å mm^{-1} in the first order); the second in the range of 700-1000 Å from the 10.7 m vacuum ultraviolet normal incidence spectrograph of the Meudon Observatory (3600 lines mm $^{-1}$ holographic concave grating, plate factor of 0.26 Å

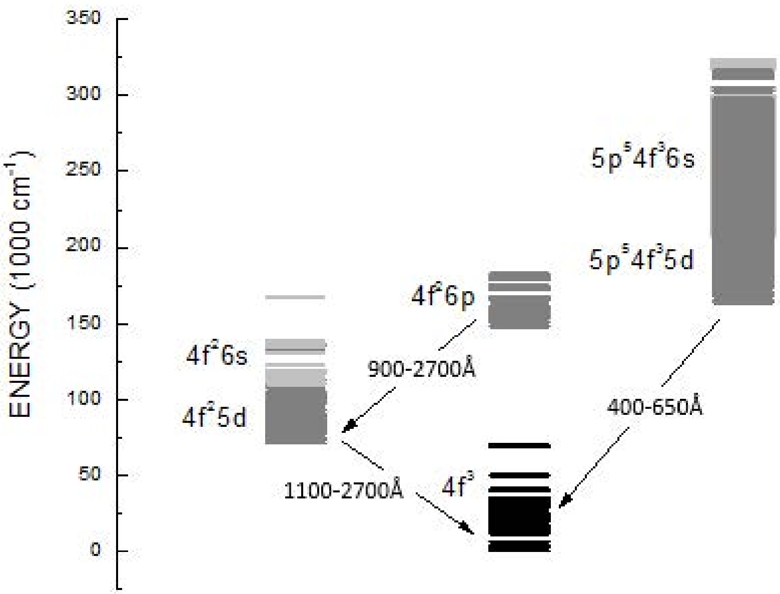

Figure 1: Transition diagram of Nd^{3+}. The longer wavelength region was investigated previously [7]. The shorter one is studied in the present work.

mm^{-1}), either on photographic plates or on phosphor storage image plates (IP). The latter (Fuji BAS-TR 2040) were digitized by a specific scanner FUJI9000 at a sample step of 10 microns and had a linear response over five orders of magnitude in intensity measurements. As for the photographic spectra, they were digitized by a high-resolution optical scanner iQsmart1 simultaneously with an optical ruler for the correction of a possible non-linearity in displacements, as explained in the recent article on Yb V [14]. In the measurement software, an experimental intensity with arbitrary units could be estimated for each line from the area of a triangle fitting the line profile.

The transition arrays connecting core-excited configurations to the ground-state configurations in Nd V and Nd IV were predicted to occur at wavelengths shorter than 500 Å and 600 Å respectively, overlapping each other. We extended the wavelength measurements on the spectrum from NBS PP down to 393 Å and calibrated it with internal reference lines emitted by low Z impurities like C, N, O ions [15]. However, internal references became scarce for wavelengths shorter than 450 Å . More spectra were thus recorded in Meudon, either with the same sliding spark source as used in [6, 7] in the range of 440-650 Å or with a three-electrode triggered spark source for the range of 350-555 Å , with a similar setting as described in the W VIII study [16]. Alternatively to the pure neodymium anode, an anode in a Nd/Fe/B alloy was mounted, producing ionized iron lines, of which the newly compiled Fe V Ritz wavelengths [17] were used for calibration. The uncertainty on measured wavelengths could be estimated to be around ± 0.005 Å for isolated lines. Some blends were unavoidable, given the density of lines reaching 10 lines per Angström.

3. Analysis and determination of energy levels

The present analysis was supported by theoretical calculations applying the Slater-Racah method [18] performed with Cowan's code package (RCN/RCN2/RCG/RCE) [19] in its WINDOWS version [20]. A first *ab initio* step was given by a relativistic Hartree-Fock (HFR) calculation using the RCN code, followed by the calculation of energy parameters P_{HFR}, i.e. electrostatic and spin-orbit radial integrals, including CI integrals, by the RCN2 code. These ab initio values of P_{HFR} were then scaled for obtaining the input data of the diagonalization code RCG. Generally, the initial scaling factor (SF) defined as $SF=P_{fit}/P_{HFR}$ could be estimated from neighboring spectra by regularities. In the present case, the Hamiltonian was diagonalized for the odd parity with the same basis as in the previous work on Nd IV [7]: one core-excited configuration $5p^5 4f^4$ and five closed 5p sub-shell $5p^6 4f^3$, $5p^6 4f^2 6p$, $5p^6 4f(5d+6s)^2$. For the even parity, the basis included two closed 5p sub-shell configurations $5p^6 4f^2 5d$ and $5p^6 4f^2 6s$ and was extended by adjoining one more open shell configuration, $5p^5 4f^3 6s$, to $5p^5 4f^3 5d$. The initial SF values for most of the parameters were their final values from the previous parametric study [7], fitted against experimentally known level energies. For parameters involving the inner $5p^5$ subshell, results on Ce IV [12] provided improved initial SF values. The ab initio HFR average energies of different configurations E_{av} were corrected by estimates from the experimental spectrum, in particular from the positions of the strongest emission arrays.

The search of energy levels was guided by these preliminary estimations. Then we applied the Ritz combination principle and, at the same time, we ensured the consistency between observed spectral lines intensities and theoretical transition probabilities gA. As soon as some experimental level energies became known, we iteratively ran the RCE code where the radial integrals were considered as adjustable parameters P_{fit} in a least-squares fit minimizing the differences between calculated and experimental energies. The procedure was followed until convergence. The last least-squares fit provided the final parameter values for deriving the level compositions, Landé factors and transition probabilities in the RCG code.

The analysis was helped by using the IDEN code [21, 22] which allowed for a great amount of theoretical and experimental data to be visualized simultaneously. On the display screen in IDEN, chains of transitions involving a common level appeared as more or less well defined alignments.

4. Results and discussion

In the present work, the search of levels of the core-excited $5p^54f^35d$ configuration was based on their transitions to the ground-state configuration $5p^64f^3$. Overall a number of 313 spectral lines between 397 and 635 Å were identified and 125 previously unknown excited energy levels were determined. All but two levels belong to the $5p^54f^35d$ configuration. The remaining two levels have main components belonging to the $5p^54f^36s$ configuration. Due to configuration mixings and intermediate coupling, there are two cases where a $5p^54f^35d$ level has many small components among which the leading term is a $5p^54f^36s$ term. The level compositions are very sensitive to small changes in energy parameters. Therefore only the energy value and the quantum number J characterize an energy level unambiguously.

The final classified lines for $5p^6 4f^3$-$5p^5 4f^3 5d$ (or 6s) transitions of Nd IV are reported in Table 1, together with the gA values and the corresponding cancellation factors (CF) as defined by equation (14.107), p 432 in [19], derived from the parametric calculations (See Table 3). In Table 1, each transition is identified by its lower and upper levels (See Table 2). Since more lines were seen in the NBS spectrum in the overlapping region (448 - 636 Å) of NBS photographic plates and Meudon image plates, the listed lines with their intensities in Table 1 are from IP between 397-448 Å and from PP between 448 - 636 Å .

The classified lines, as outputs of IDEN code, provided the input for the LOPT code [23], which carried out an iterative optimization process of the energy values by minimizing the differences between the observed wave numbers of spectral lines and those calculated by the Ritz principle from the experimental level energies. All the level energies of the ground-state configuration $5p^6 4f^3$ were fixed to their values found in [7]. In Table 2, we present the optimized values of 125 level energies of the $5p^5 4f^3 5d$ (or $5p^5 4f^3 6s$) configuration with their uncertainties, their quantum numbers J and the number of transitions to the levels of the opposite parity involved in their determination. The procedure of optimization of level energies in LOPT [23] included implicitly the optimization of Ritz wavelengths. These are compared with measured wavelengths in Table 1, along with their uncertainties as estimated in LOPT .

Two strong transition arrays appeared around 415 and 480 Å for the $5p^6 4f^3$ - $5p^5 4f^3 5d$ transitions. Similar to the Nd V case [13], this structure reflects the structure of the $5p^6$ ^1S - $5p^5 5d$ ^1P and $5p^6$ ^1S - $5p^5 5d$ ^3P or ^3D transitions in the presence of the three $4f^3$ spectator electrons. The ^1P term lies above the other terms of the $5p^5 5d$ configuration because of the large value of the Slater exchange integral $G^1(5p, 5d)$ and generates the transition array from the upper part of the $5p^5 4f^3 5d$ configuration, which is localized around the shortest wavelength of 415Å . A small amount of mixtures between the levels $^1P_1$ - $^3P_1$ and $^1P_1$ - $^3D_1$ generate transitions from the lower part of $5p^5 4f^3 5d$, which are localized around 480 Å . In IDEN, alignments with several (three to six) transitions around 480 Å were observed for energies between 180 000 and 235 000 cm^{-1}, the lower part of the configuration, whereas lines around 415 Å often show alignments with only two strong transitions from the higher part of the configuration.

For the odd-parity configurations including the ground-state configuration $5p^6 4f^3$, the parametric calculations led to the same final parameter values as in [7]. The corresponding results on level compositions were used for the present calculations of transition probabilities.

For the even parity, the diagonalization of Hamiltonian matrix of the four configurations involved a maximum size of 453x453, corresponding to J = 7/2. Table 3 reports the set of energy parameters from the final iteration of the least-squares fit in the RCE code, including the 125 levels identified in this work and the 121 levels of $5p^6 4f^2 5d$ and $5p^6 4f^2 6s$ determined previously in [7]. In Table 3, the fitted parameter values, as well as their uncertainties from the fit, are displayed. HFR values of the parameters and the corresponding $SF=P_{fit}/P_{HFR}$ are listed for comparison. For the average energy E_{av} of a configuration, the difference between fitted and HFR values is given in the column SF. A number of 92 parameters was involved, which included Slater parameters R^k for the first-order configuration interactions (CI) and effective parameters for the second order perturbations from far configurations, such as α, β, γ and the "Slater forbidden" parameters $F^1(fd)$, $G^2(fd)$, $G^4(fd)$ for non-equivalent electrons [19].

Among the 92 parameters, only 5 parameters were left as completely free: the average energies E_{av} of the three configurations $5p^6 4f^2 5d$, $5p^6 4f^2 6s$ and $5p^5 4f^3 5d$, the spin-orbit parameter of the sub-shell 5p, and finally the exchange Slater integral $G^1(5p, 5d)$ which is crucial to fit the gap between the transition arrays at 415 Å and 480 Å . To estimate E_{av} of $5p^5 4f^3 5d$, we paid attention to the lower part of the configuration, where many transitions connect the levels to the $5p^6 4f^3$ ground-state configuration. Its final value of 221 076 cm^{-1} was not far from the adopted value of 221 000 cm^{-1} in [7] (In Table 4 of [7], this number was misprinted in col. 9 instead of col. 10). One may notice that the fitted values of E_{av} are quite different from their HFR values (30 000 cm^{-1}). This is often the case in lanthanide ions. As discussed in [10], these differences are likely due to an underestimation of the core-polarization by external electrons in the HFR calculations. All the effective parameters except β and γ were fixed to their final fitted values from the previous Nd IV study [7]. It was also the case for the exchange parameter G^3 (fs). Constraints were applied to other parameters as indicated in Table 3 by linking their ratios according to the values appropriately chosen from other lanthanide ions. All the CI parameters were linked by the same ratio to their HFR values (SF) and varied as one single parameter. The SF's final value of 0.72 is larger than the value of 0.634 determined in [7], but close to the value of 0.719 found in Nd V [13]. The present value is more reliable since the fit included experimental level energies of $5p^54f^35d$ previously unknown. As for the parameters related to the basically unknown $5p^54f^36s$ configuration (only three experimental levels), their values were fixed by adopting the initial scaling factors from the $5p^54f^35d$ configuration except for G^3 (fs), which SF was adopted from the $5p^64f^26s$ configuration. Overall the number of equivalent free parameters was 19. The root mean square deviation of the fit was 184 cm^{-1}.

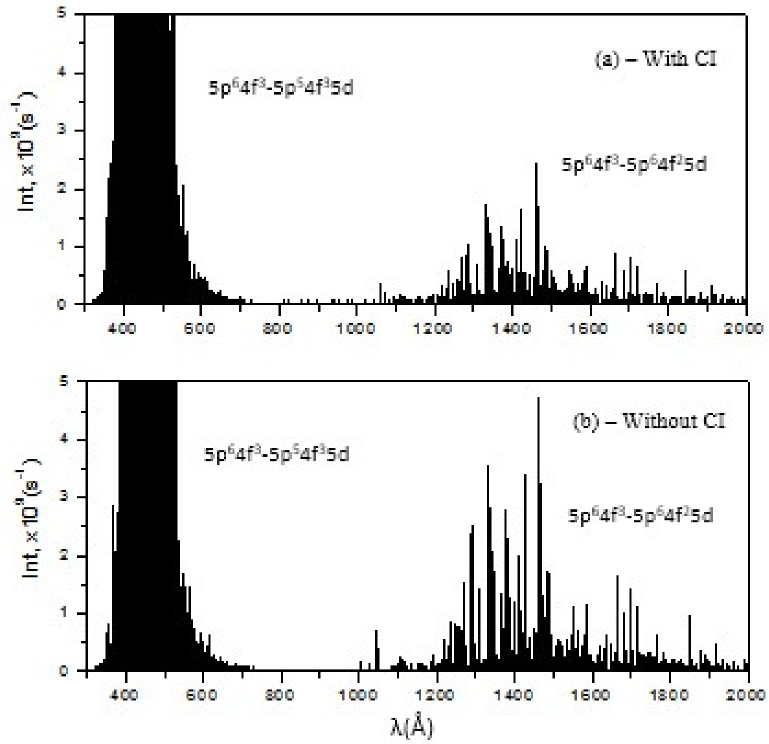

Figure 2: Reduction of the $5p^64f^3$-$5p^64f^25d$ transition probabilities by the $5p^64f^25d$-$5p^54f^35d$ configuration interaction (with and without including configuration interaction with $5p^54f^35d$). (a) With CI ; (b) Without CI.

The parameters of Table 3 were used for a final diagonalization by RCG that resulted in the calculated energies (E_{calc}), the Landé factors (g_L) and the level compositions by the first LS components reported in Table 2. The resulting gA and CF values are listed in Table 1. Although there are many $|CF|$ less than or equal to 0.01, which means severe cancellation effects [24], they do not affect the reliability of the present determination of energy levels. Figure 2 (a) and (b) display the values of gA of the transition array $5p^64f^3$ - $5p^64f^25d$ calculated respectively with and without the $5p^54f^35d$ - $5p^64f^25d$ configuration interaction

(CI) and they illustrate the reduction of transition probabilities by a factor of about two for the $5p^64f^3$ - $5p^64f^25d$ resonance transition array. This reduction was predictable from the previous Nd IV parametric studies [7, 9] with an estimated E_{av} for the then unknown configuration $5p^54f^35d$. However, the newly fitted parameter values, including the CI parameters, derived from the precise knowledge of energy levels in the $5p^54f^35d$ configuration, show a noticeable influence on the calculated gA values of resonance lines. Figure 3 displays a comparison between the gA values as derived from the present parametric study and the values from previous studies [7, 9] for all the observed resonance lines [7]. The present gA values show a smooth reduction of 11% in average compared with the values from [7] using the same configuration basis, whereas their ratios to values calculated with a larger basis [9] have an average close to 1, in spite of more scattered differences. This comparison confirm the reliability of the present gA values.

5. Conclusion

We have extended the analysis of the Nd IV spectrum by classification of 313 spectral lines in the wavelength region of 397-636 Å leading to the determination of 125 previously unknown energy levels belonging all but two to the core-excited configurations $5p^54f^35d$. The parametric interpretation of the even configurations including these new experimental levels allowed a more exact description of the $5p^64f^25d$ -$5p^54f^35d$ configuration interaction and its reduction effect upon the transition probabilities of the transition array $5p^64f^3$-$5p^64f^25d$. At the end of the present work, the lowest part of the $5p^54f^35d$ configuration, mostly consisting of sextuplet states, stays unknown. Indeed, due to the insufficient breakdown of LS coupling in these levels, their transitions to the ground configuration $5p^64f^3$, comprising only doublets and quartets, have too small probabilities to be identified in the experimental line list.

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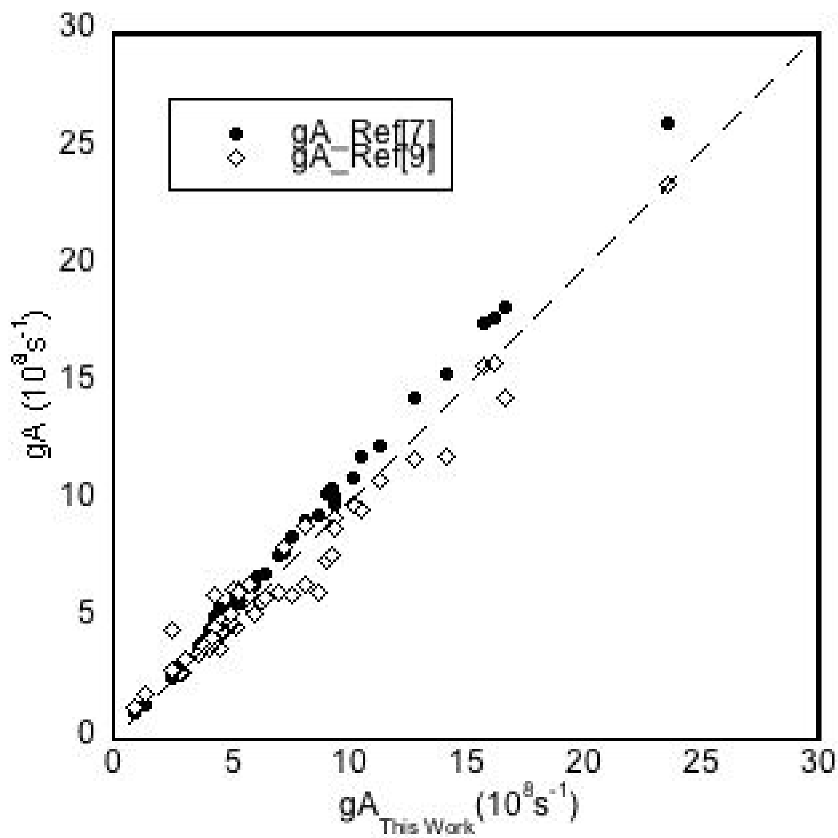

Figure 3: Comparison between gA from the present work and gA from the previous studies [7, 9] for the $5p^64f^3$-$5p^64f^25d$ transitions. In the previous parametric studies, with a larger configuration basis in [9] than in [7], the parameters for the unknown interacting configuration $5p^54f^35d$ were fixed to estimated values. In the present work, they have values fitted with experimentally determined energy levels.

Table 1: Observed lines identified as the 5p^{6}4f^3 -5p^{5}4f^{3}5d transitions in Nd IV. Experimental intensities in arbitrary units ; calculated transition probabilities gA, g being the statistical weight of the upper level, with a 10-configuration basis. CF is the cancellation factor defined by equation (14.107), p432 in [19]. λ_{Ritz} is derived from the level energies as $\lambda_{Ritz}(\AA) = (E_{up} - E_{low})^{-1}$; $\delta\lambda_{Ritz}$ is its uncertainty as estimated in LOPT [23]. $\Delta\lambda = \lambda_{exp} - \lambda_{Ritz}$. All energies and wave numbers are in cm^{-1}. The comments after the wavelengths are explained in footnotes at the end of the table. The energy levels are labelled by their first LS component (Cf Table 2 for upper levels and [7] for lower levels).

λ_{exp}(Å)	Int_{exp}	$gA(s^{-1})$	CF	λ_{Ritz}(Å)	$\delta\lambda_{Ritz}$(Å)	$\Delta\lambda$(Å)	Lower level label	E_{low}	Upper level label	E_{up}
397.257	14	1.50E+10	0.34	397.262	0.003	-0.005	p6f3 4G 5.5	22047.39	p5f3d 4D4Fe 4.5	273770.7
400.786	7	2.60E+10	0.23	400.776	0.003	0.010	p6f3 4F 4.5	14994.87	p5f3d 4G4Fc 4.5	264511.1
401.363	34	3.04E+10	0.09	401.364	0.003	-0.001	p6f3 2K 7.5	22043.77	p5f3d 2L2Le 7.5	271194.2
404.099	28	1.75E+11	0.75	404.104	0.002	-0.005	p6f3 2L 7.5	31036.00	p5f3d 2H2I1$_b$ 6.5	278497.2
405.377	24	6.99E+10	-0.48	405.371	0.002	0.006	p6f3 2I 6.5	31582.85	p5f3d 2H2I1$_b$ 5.5	278270.7
406.563	38	1.58E+11	-0.91	406.557	0.004	0.006	p6f3 2I 6.5	31582.85	p5f3s 2L4L 7.5	277550.8
406.960	38	6.88E+10	-0.54	406.951	0.003	0.009	p6f3 2I 6.5	31582.85	p5f3d 2H2H1 5.5	277312.8
407.570	25	8.65E+09	-0.11	407.562	0.003	0.007	p6f3 2H2 5.5	16161.53	p5f3d 2K2Ke 6.5	261522.8
408.179	34	2.28E+11	-0.45	408.185	0.004	-0.006	p6f3 2L 8.5	32563.57	p5f3s 2L4L 7.5	277550.8
408.932	14	2.05E+11	-0.49	408.949	0.002	-0.017	p6f3 2H1 4.5	33741.15	p5f3d 2H2I1$_b$ 5.5	278270.7
409.311	19	3.69E+10	-0.45	409.318	0.003	-0.007	p6f3 2H2 5.5	16161.53	p5f3d 2G4H2 4.5	260470.3
409.775	26	3.38E+11	-0.82	409.775	0.005	0.001	p6f3 2F2 2.5	39568.42	p5f3d 2F2D1 1.5	283605.0
410.022bl	18	2.46E+10	-0.25	410.0188	0.0023	0.003	p6f3 4I 6.5	3907.43	p5f3s 4I4Kb 6.5	247798.7
410.144bl	39	7.28E+11	-0.75	410.144	0.005	-0.001	p6f3 2G1 4.5	49172.45	p5f3d 2G2G2 4.5	292989.0
410.358	35	2.81E+11	-0.70	410.365	0.004	-0.006	p6f3 2H1 4.5	33741.15	p5f3d 2H2H1 4.5	277426.8
410.552	25	2.94E+11	0.80	410.557	0.003	-0.005	p6f3 2H1 4.5	33741.15	p5f3d 2H2H1 5.5	277312.8
410.589	26	2.55E+10	0.11	410.589	0.004	0.000	p6f3 2D2 1.5	34275.21	p5f3d 2D2D2 2.5	277827.9
410.687	34	4.41E+11	-0.67	410.687	0.005	0.000	p6f3 2H1 5.5	35136.61	p5f3d 2H2G1 4.5	278631.0
410.791	34	7.76E+10	0.14	410.801	0.004	-0.011	p6f3 4D 2.5	29190.91	p5f3d 4D4Df 3.5	272617.7
410.832	25	1.17E+11	0.38	410.832	0.005	0.000	p6f3 2F2 3.5	41012.70	p5f3d 2F2G1 4.5	284421.0
410.918	46	8.98E+11	-0.85	410.913	0.002	0.005	p6f3 2H1 5.5	35136.61	p5f3d 2H2I1$_b$ 6.5	278497.2
410.990	28	4.56E+11	-0.81	410.990	0.005	0.000	p6f3 2F2 3.5	41012.70	p5f3d 2F2D1 2.5	284327.7
411.174	32	4.31E+11	-0.87	411.166	0.004	0.007	p6f3 2K 6.5	20005.22	p5f3d 2K2If 5.5	263215.7
411.306bl	40	5.00E+11	-0.85	411.296	0.002	0.011	p6f3 2H1 5.5	35136.61	p5f3d 2H2I1$_b$ 5.5	278270.7
411.486	32	3.69E+10	0.20	411.493	0.003	-0.007	p6f3 2G2 4.5	21493.39	p5f3d 4G4Fc 4.5	264511.1
411.526	45	2.91E+10	0.24	411.532	0.004	-0.006	p6f3 4G 3.5	19540.80	p5f3d 4G4Ff 3.5	262535.2
411.681	62	1.55E+11	0.89	411.683	0.003	-0.002	p6f3 2K 6.5	20005.22	p5f3d 4G4Ge 5.5	262910.4
411.828	35	9.51E+10	0.44	411.836	0.003	-0.007	p6f3 2G2 3.5	17655.11	p5f3d 2G4H2 4.5	260470.3
411.996	67	7.21E+11	-0.88	411.998	0.004	-0.002	p6f3 2I 5.5	30179.93	p5f3d 2I2Kd 6.5	272899.7
412.178	34	3.02E+11	0.71	412.177	0.004	0.000	p6f3 2D2 2.5	35213.92	p5f3d 2D2D2 2.6	277827.9
412.266	51	1.99E+11	-0.67	412.260	0.004	0.006	p6f3 4G 4.5	19969.79	p5f3d 4G4Ff 3.6	262535.2
412.430	89	5.52E+11	0.86	412.433	0.003	-0.002	p6f3 4G 5.5	22047.39	p5f3d 4G4Fc 4.5	264511.1
412.519	53	6.15E+11	0.92	412.515	0.004	0.004	p6f3 4D 3.5	31355.04	p5f3d 4D4Fe 4.6	273770.7
412.657blV	60	7.07E+11	-0.86	412.660	0.004	-0.003	p6f3 2I 6.5	31582.85	p5f3d 2I2Ie 6.5	273912.9
412.734blV	45	4.77E+10	0.26	412.728	0.004	0.006	p6f3 2H1 5.5	35136.61	p5f3d 2H2H1 4.5	277426.8
412.874	65	5.64E+11	-0.81	412.869	0.003	0.005	p6f3 2I 5.5	30179.93	p5f3d 2I2Hf 4.5	272387.5
412.919	71	4.28E+11	-0.54	412.923	0.003	-0.004	p6f3 2H1 5.5	35136.61	p5f3d 2H2H1 5.5	277312.8
412.967	51	4.81E+11	0.91	412.967	0.005	0.000	p6f3 2D2 1.5	34275.21	p5f3d 2D2F2 2.5	276425.4
413.059	63	6.88E+11	-0.87	413.060	0.003	-0.001	p6f3 2I 6.5	31582.85	p5f3d 2I2Hf 5.5	273678.6
413.151	84	3.55E+11	-0.71	413.148	0.004	0.003	p6f3 4G 3.5	19540.80	p5f3d 4G4Ge 3.5	261585.0
413.264	38	1.44E+10	0.32	413.2662	0.0018	-0.002	p6f3 4I 4.5	0.00	p5f3d 2I4Gb 4.5	241974.8
413.366	69	2.81E+11	0.78	413.364	0.004	0.002	p6f3 4D 2.5	29190.91	p5f3d 4D4Fe 3.5	271108.5
413.458	43	5.36E+10	-0.71	413.456	0.004	0.002	p6f3 2L 7.5	31036.00	p5f3d 2I2Kd 6.5	272899.7
413.557	36	7.17E+10	-0.54	413.5475	0.0023	0.009	p6f3 4I 7.5	5988.51	p5f3s 4I4Kb 6.5	247798.7
413.640	57	5.86E+11	0.79	413.640	0.005	0.000	p6f3 4I 7.5	5988.51	p5f3d 4I4Hc 6.5	247744.4

Table 1: *(continued)*

λ_{exp}(Å)	Int_{exp}	$gA(s^{-1})$	CF	λ_{Ritz}(Å)	$\delta\lambda_{Ritz}$(Å)	$\Delta\lambda$(Å)	Lower level label	E_{low}	Upper level label	E_{up}
413.770blV	39	7.38E+09	0.06	413.773	0.004	-0.003	p6f3 4I 5.5	1897.11	p5f3d 2I4Hb 6.5	243575.6
413.878	65	1.49E+11	-0.60	413.881	0.004	-0.003	p6f3 4G 4.5	19969.79	p5f3d 4G4Ge 3.5	261585.0
413.925	61	5.06E+11	-0.58	413.924	0.004	0.001	p6f3 2L 7.5	31036.00	p5f3d 2L2Le 8.5	272626.1
414.052	57	6.30E+11	-0.87	414.049	0.003	0.004	p6f3 2K 6.5	20005.22	p5f3d 2K2Ke 6.5	261522.8
414.125	87	1.13E+12	0.92	414.115	0.004	0.011	p6f3 2L 7.5	31036.00	p5f3d 2L2Me 8.5	272514.9
414.225	41	2.50E+10	-0.26	414.221	0.003	0.004	p6f3 2G2 4.5	21493.39	p5f3d 4G4Ge 5.5	262910.4
414.324	83	1.23E+12	-0.90	414.326	0.004	-0.003	p6f3 2I 6.5	31582.85	p5f3d 2I2Kd 7.5	272938.4
414.496	56	5.49E+11	0.87	414.486	0.004	0.010	p6f3 4D 3.5	31355.04	p5f3d 4D4Df 3.5	272617.7
414.565	100	4.55E+11	-0.84	414.565	0.005	0.000	p6f3 2I 5.5	30179.93	p5f3d 2I2Ie 5.5	271396.5
414.641	63	2.03E+10	-0.28	414.648	0.004	-0.007	p6f3 4G 5.5	22047.39	p5f3d 2K2If 5.5	263215.7
414.835	81	9.89E+11	-0.88	414.835	0.005	0.000	p6f3 4G 5.5	22047.39	p5f3d 4G4Hd 6.5	263107.0
414.992	112	1.79E+12	-0.90	414.992	0.005	0.000	p6f3 2L 8.5	32563.57	p5f3d 2L2Md$_b$ 9.5	273532.0
415.074	50	4.57E+10	0.21	415.059	0.003	0.014	p6f3 4G 3.5	19540.80	p5f3d 2G4H2 4.5	260470.3
415.113	110	1.42E+11	0.58	415.112	0.003	0.002	p6f3 4I 5.5	1897.11	p5f3d 2L2Ka 6.5	242796.2
415.172	97	7.25E+11	-0.84	415.174	0.003	-0.001	p6f3 4G 5.5	22047.39	p5f3d 4G4Ge 5.5	262910.4
415.276	65	1.40E+12	-0.95	415.276	0.005	0.000	p6f3 2K 6.5	20005.22	p5f3d 2K2Ld 7.5	260809.0
415.339	77	2.06E+11	0.63	415.337	0.004	0.002	p6f3 2H2 4.5	12800.29	p5f3d 2F4I1 5.5	253568.5
415.435	83	4.86E+11	-0.83	415.429	0.003	0.005	p6f3 4F 3.5	13719.82	p5f3d 4F4Gd 4.5	254434.6
415.561	117	4.11E+11	0.91	415.563	0.003	-0.002	p6f3 4I 5.5	1897.11	p5f3d 4I4If 5.5	242534.5
415.750	43	3.15E+11	-0.91	415.750	0.005	-0.001	p6f3 2D1 2.5	24333.10	p5f3d 2D2F1 3.5	264862.0
415.836	34	1.18E+11	0.35	415.842	0.004	-0.006	p6f3 4I 6.5	3907.43	p5f3d 2I2Kc$_b$ 7.5	244383.4
416.020	43	9.69E+10	0.71	416.017	0.004	0.003	p6f3 2L 8.5	32563.57	p5f3d 2I2Kd 7.5	272938.4
416.088	89	1.50E+12	-0.88	416.088	0.005	0.000	p6f3 2K 7.5	22043.77	p5f3d 2K2Ld 8.5	262377.5
416.393	101	9.73E+11	-0.91	416.392	0.004	0.001	p6f3 2L 7.5	31036.00	p5f3d 2L2Le 7.5	271194.2
416.557	69	1.17E+12	-0.88	416.558	0.004	-0.001	p6f3 2L 8.5	32563.57	p5f3d 2L2Le 8.5	272626.1
416.656	79	1.44E+12	-0.89	416.656	0.005	0.001	p6f3 2K 7.5	22043.77	p5f3d 2K2Ke 7.5	262050.0
416.741bl	51	5.17E+11	-0.61	416.751	0.004	-0.010	p6f3 2L 8.5	32563.57	p5f3d 2L2Me 8.5	272514.9
417.093	31	1.66E+10	-0.07	417.095	0.004	-0.002	p6f3 4D 3.5	31355.04	p5f3d 4D4Fe 3.5	271108.5
417.165	66	7.42E+11	-0.82	417.160	0.003	0.005	p6f3 4I 7.5	5988.51	p5f3d 4I4Kd 8.5	245704.8
417.246	80	1.97E+11	0.69	417.244	0.004	0.002	p6f3 4I 6.5	3907.43	p5f3d 2I4Hb 6.5	243575.6
417.641	74	4.28E+10	-0.41	417.642	0.003	0.000	p6f3 4F 4.5	14994.87	p5f3d 4F4Gd 4.5	254434.6
417.759	57	5.13E+10	0.62	417.7874	0.0019	-0.028	p6f3 4I 4.5	0.00	p5f3d(s) 4G4Ha 4.5	239356.2
417.849	87	5.09E+11	0.82	417.858	0.004	-0.009	p6f3 4I 5.5	1897.11	p5f3d 4I4Ka 6.5	241212.6
418.188	62	1.86E+09	-0.03	418.192	0.004	-0.004	p6f3 4I 6.5	3907.43	p5f3d 2I2Kc 7.5	243032.1
418.608	64	4.59E+10	0.53	418.605	0.003	0.004	p6f3 4I 6.5	3907.43	p5f3d 2L2Ka 6.5	242796.2
418.805	65	6.15E+10	0.50	418.802	0.004	0.003	p6f3 2H1 5.5	35136.61	p5f3d 2I2Ie 6.6	273912.9
418.925bl	82	7.96E+09	-0.42	418.920	0.003	0.004	p6f3 4I 4.5	0.00	p5f3d 2G2H2 5.5	238709.0
419.024	34	1.97E+10	0.38	419.030	0.003	-0.006	p6f3 2H1 4.5	33741.15	p5f3d 2I2Hf 4.5	272387.5
419.156bl	59	1.67E+10	0.07	419.158	0.004	-0.002	p6f3 4F 4.5	14994.87	p5f3d 2F4I1 5.6	253568.5
419.214	27	5.97E+10	0.27	419.213	0.004	0.001	p6f3 2H1 5.5	35136.61	p5f3d 2I2Hf 5.5	273678.6
419.478	94	4.44E+11	0.91	419.472	0.004	0.006	p6f3 4I 7.5	5988.51	p5f3d 2I2Kc$_b$ 7.5	244383.4
419.682	21	1.13E+10	0.34	419.687	0.003	-0.005	p6f3 2H2 5.5	16161.53	p5f3d 4F4Gd 4.5	254434.6
419.919	44	3.85E+10	-0.59	419.9153	0.0024	0.004	p6f3 4I 5.5	1897.11	p5f3d 2I2Ke 6.5	240040.4
421.124	20	6.57E+09	0.36	421.1252	0.0020	-0.001	p6f3 4I 5.5	1897.11	p5f3d(s) 4G4Ha 4.5	239356.2
421.179	13	1.23E+10	-0.34	421.1754	0.0019	0.004	p6f3 4I 5.5	1897.11	p5f3d 2L4L 6.5	239327.9
421.407	19	7.45E+09	-0.04	421.398	0.004	0.009	p6f3 4I 6.5	3907.43	p5f3d 4I4Ka 6.5	241212.6
421.496	31	1.26E+10	0.04	421.495	0.003	0.001	p6f3 2H1 5.5	35136.61	p5f3d 2I2Hf 4.5	272387.5
421.867	23	7.23E+10	-0.79	421.863	0.004	0.004	p6f3 4I 7.5	5988.51	p5f3d 2I2Kc 7.5	243032.1
422.275	22	3.65E+10	0.60	422.276	0.003	-0.001	p6f3 4I 5.5	1897.11	p5f3d 2G2H2 5.5	238709.0
422.361	25	6.69E+10	-0.78	422.363	0.003	-0.002	p6f3 4I 6.5	3907.43	p5f3d 2G4I2$_b$ 7.5	240670.5
423.199	95	2.07E+11	0.81	423.2075	0.0025	-0.009	p6f3 4I 7.5	5988.51	p5f3d 2L4Ka 8.5	242279.2
423.783	48	5.67E+09	-0.18	423.7891	0.0021	-0.006	p6f3 4I 4.5	0.00	p5f3d 2K4Hb 5.5	235966.4
423.951	23	3.50E+10	0.67	423.9611	0.0022	-0.011	p6f3 4I 6.5	3907.43	p5f3d 2G4I2 7.5	239778.1
424.760	10	2.25E+10	0.46	424.7719	0.0019	-0.011	p6f3 4I 6.5	3907.43	p5f3d 2L4L 6.5	239327.9
427.448	25	1.35E+10	0.47	427.4429	0.0021	0.005	p6f3 4I 6.5	3907.43	p5f3d 2I4K 6.5	237856.8
427.733	45	5.78E+09	0.29	427.735	0.002	-0.002	p6f3 4I 7.5	5988.51	p5f3d 2G4I2 7.5	239778.1
427.941bl	32	8.52E+09	-0.27	427.940	0.003	0.001	p6f3 4I 7.5	5988.51	p5f3d 2K2Mc 8.5	239666.0
428.710	39	1.51E+10	0.54	428.7075	0.0025	0.003	p6f3 4I 5.5	1897.11	p5f3d 2I4K 5.5	235156.4
430.221	11	8.79E+09	0.46	430.215	0.003	0.006	p6f3 4I 7.5	5988.51	p5f3d 4G4Hb 6.5	238430.3
430.916	13	2.10E+09	-0.25	430.9249	0.0022	-0.009	p6f3 4I 6.5	3907.43	p5f3d 2K4Hb 5.5	235966.4

Table 1: *(continued)*

λ_{exp}(Å)	Int_{exp}	$gA(s^{-1})$	CF	λ_{Ritz}(Å)	$\delta\lambda_{Ritz}$(Å)	$\Delta\lambda$(Å)	Lower level label	E_{low}	Upper level label	E_{up}
430.965	24	1.88E+07	0.00	430.9632	0.0022	0.002	p6f3 4I 4.5	0.00	p5f3d 2G4G1 5.5	232038.4
431.594	39	1.52E+10	0.43	431.609	0.003	-0.015	p6f3 4I 7.5	5988.51	p5f3d 2K4Ka 8.5	237679.7
433.820	29	5.79E+09	-0.33	433.822	0.003	-0.003	p6f3 4I 5.5	1897.11	p5f3d 4G4Hc 6.5	232406.2
434.919	12	3.87E+09	-0.39	434.928	0.003	-0.008	p6f3 4I 6.5	3907.43	p5f3d 4G4Hc$_b$ 6.5	233830.6
438.348	11	2.16E+09	-0.17	438.3447	0.0023	0.004	p6f3 4I 6.5	3907.43	p5f3d 2G4G1 5.5	232038.4
438.820	31	2.62E+09	0.16	438.8158	0.0022	0.004	p6f3 4I 6.5	3907.43	p5f3d 2G2K2 7.5	231793.5
438.913	33	3.04E+09	0.32	438.900	0.003	0.012	p6f3 4I 7.5	5988.51	p5f3d 4G4Hc$_b$ 6.5	233830.6
438.988	38	7.06E+09	-0.25	438.994	0.003	-0.006	p6f3 2K 6.5	20005.22	p5f3s 4I4Kb 6.5	247798.7
439.554	32	1.11E+09	-0.08	439.5597	0.0019	-0.006	p6f3 4I 5.5	1897.11	p5f3d 2K4Hb 6.5	229397.5
440.129blV	20	2.08E+09	-0.09	440.115	0.003	0.014	p6f3 4I 6.5	3907.43	p5f3d 2L4M 7.5	231120.8
440.584	26	2.66E+08	-0.01	440.5676	0.0021	0.016	p6f3 4F 4.5	14994.87	p5f3d 2I4Gb 4.5	241974.8
440.861	47	3.73E+08	0.06	440.8472	0.0025	0.014	p6f3 4I 7.5	5988.51	p5f3d 2G2K2 6.5	232824.5
441.311	29	4.62E+09	-0.06	441.3131	0.0023	-0.002	p6f3 2H2 5.5	16161.53	p5f3d 4D4Ga 5.5	242758.0
441.679blV	42	1.38E+10	-0.57	441.682	0.003	-0.002	p6f3 4I 7.5	5988.51	p5f3d 4G4Ka 8.5	232396.0
441.714blV	46	1.90E+10	-0.17	441.723	0.003	-0.009	p6f3 2H1 5.5	35136.61	p5f3d 2K2Ke 6.5	261522.8
442.772	16	2.80E+09	-0.16	442.758	0.003	0.014	p6f3 4I 7.5	5988.51	p5f3d 2K2Ma 8.5	231845.6
442.878blV	21	3.34E+09	0.11	442.8600	0.0022	0.018	p6f3 4I 7.5	5988.51	p5f3d 2G2K2 7.5	231793.5
442.961	26	1.12E+10	-0.28	442.965	0.003	-0.005	p6f3 4G 5.5	22047.39	p5f3s 4I4Kb 6.5	247798.7
444.192	4	4.68E+09	-0.29	444.183	0.003	0.008	p6f3 4I 7.5	5988.51	p5f3d 2L4M 7.5	231120.8
445.718	22	1.14E+09	0.03	445.7096	0.0022	0.008	p6f3 4F 4.5	14994.87	p5f3d(s) 4G4Ha 4.5	239356.2
446.797	13	8.39E+08	0.10	446.7932	0.0017	0.004	p6f3 4I 6.5	3907.43	p5f3d 2L2Ha 5.5	227724.6
447.311	28	3.33E+09	-0.10	447.3171	0.0019	-0.006	p6f3 4I 6.5	3907.43	p5f3d 2L4H 6.5	227462.5
448.076	45	3.05E+09	0.06	448.0918	0.0021	-0.016	p6f3 4I 6.5	3907.43	p5f3d 4I2Ia 6.5	227076.0
448.943p	47	3.80E+08	0.03	448.9282	0.0024	0.015	p6f3 2K 6.5	20005.22	p5f3d 4D4Ga 5.5	242758.0
449.340	68	6.66E+09	-0.07	449.342	0.003	-0.003	p6f3 2H2 5.5	16161.53	p5f3d 2G2H2 5.5	238709.0
450.400	65	3.02E+09	0.15	450.4138	0.0017	-0.014	p6f3 4I 6.5	3907.43	p5f3d 2H2I1 6.5	225925.5
452.406blV	61	3.13E+09	-0.08	452.405	0.004	0.001	p6f3 2G2 4.5	21493.39	p5f3d 4I4If 5.5	242534.5
452.991blV	30	2.20E+09	-0.02	452.996	0.003	-0.005	p6f3 2K 7.5	22043.77	p5f3d 2L2Ka 6.5	242796.2
453.176blV	84	2.91E+09	0.15	453.175	0.003	0.001	p6f3 2K 6.5	20005.22	p5f3d 2G4I2$_b$ 7.5	240670.5
453.747	42	3.16E+09	0.15	453.760	0.003	-0.013	p6f3 4I 6.5	3907.43	p5f3d 2H4K1 7.5	224288.2
453.829	37	3.25E+08	0.00	453.831	0.003	-0.003	p6f3 4I 6.5	3907.43	p5f3d(s) 4F6G 6.5	224253.6
454.212	19	3.94E+09	0.15	454.2265	0.0017	-0.015	p6f3 4I 6.5	3907.43	p5f3d 2H2I1 5.5	224061.9
454.925	54	7.62E+09	0.10	454.9272	0.0023	-0.002	p6f3 4G 3.5	19540.80	p5f3d(s) 4G4Ha 4.5	239356.2
455.029	26	4.76E+09	-0.16	455.015	0.003	0.014	p6f3 2K 6.5	20005.22	p5f3d 2G4I2 7.5	239778.1
455.954blV	18	1.88E+09	-0.06	455.9492	0.0022	0.005	p6f3 2K 6.5	20005.22	p5f3d 2L4L 6.5	239327.9
456.123	73	2.50E+09	0.03	456.1251	0.0025	-0.003	p6f3 2H2 4.5	12800.29	p5f3d 2G4G1 5.5	232038.4
457.126	32	4.16E+08	0.01	457.130	0.003	-0.004	p6f3 4I 6.5	3907.43	p5f3d 2D4H2 5.5	222663.7
457.822	105	6.14E+09	0.19	457.823	0.003	-0.001	p6f3 2K 6.5	20005.22	p5f3d 4G4Hb 6.5	238430.3
458.099blV	29	6.25E+09	0.18	458.086	0.003	0.014	p6f3 4I 7.5	5988.51	p5f3d 2H4K1 7.5	224288.2
458.162	51	1.02E+05	0.00	458.158	0.003	0.003	p6f3 4I 7.5	5988.51	p5f3d(s) 4F6G 6.5	224253.6
459.033	12	3.99E+09	-0.05	459.0281	0.0024	0.004	p6f3 2K 6.5	20005.22	p5f3d 2I4K 6.5	237856.8
459.410	109	1.59E+10	-0.12	459.413	0.003	-0.003	p6f3 2H2 5.5	16161.53	p5f3d 4G4Hc$_b$ 6.5	233830.6
459.507	135	2.28E+10	-0.07	459.512	0.003	-0.005	p6f3 2K 7.5	22043.77	p5f3d 2K2Mc 8.5	239666.0
463.749	28	2.58E+09	0.01	463.745	0.003	0.005	p6f3 2K 7.5	22043.77	p5f3d 2K4Ka 8.5	237679.7
464.724	32	5.80E+09	0.11	464.713	0.003	0.012	p6f3 4G 4.5	19969.79	p5f3d 2I4K 5.5	235156.4
465.239	21	9.63E+09	0.05	465.236	0.003	0.003	p6f3 4I 7.5	5988.51	p5f3d 4I4Ka 8.5	220933.1
465.830	13	1.29E+10	-0.06	465.834	0.004	-0.004	p6f3 2L 7.5	31036.00	p5f3d 4I4Kd 8.5	245704.8
466.256	27	4.09E+09	0.09	466.259	0.003	-0.003	p6f3 2G2 4.5	21493.39	p5f3d 2K4Hb 5.5	235966.4
466.976blV	27	1.03E+09	-0.01	466.980	0.004	-0.004	p6f3 2H2 4.5	12800.29	p5f3d 4F4Gc 4.5	226942.2
468.851	39	1.41E+09	0.01	468.848	0.003	0.003	p6f3 2K 7.5	22043.77	p5f3d 2L4Na 8.5	235332.7
470.071blV	25	1.50E+08	0.00	470.0800	0.0019	-0.009	p6f3 4F 4.5	14994.87	p5f3d 2L2Ha 5.5	227724.6
470.810	49	1.58E+09	0.06	470.808	0.003	0.002	p6f3 2K 6.5	20005.22	p5f3d 4G4Hc 6.5	232406.2
471.439	30	5.37E+09	-0.12	471.436	0.003	0.003	p6f3 4I 6.5	3907.43	p5f3d 2K4L 6.5	216025.3
471.819	39	1.19E+09	-0.02	471.815	0.004	0.003	p6f3 4F 4.5	14994.87	p5f3d 4F4Gc 4.5	226942.2
472.133	61	1.01E+10	0.15	472.1550	0.0024	-0.022	p6f3 2I 5.5	30179.93	p5f3d 2I4Gb 4.5	241974.8
472.747a	46	7.87E+09	-0.17	472.729	0.004	0.018	p6f3 4I 5.5	1897.11	p5f3d 4I4Kb 6.5	213434.6
473.256	14	4.73E+08	0.01	473.2586	0.0021	-0.002	p6f3 2H2 5.5	16161.53	p5f3d 2L4H 6.5	227462.5
473.387blV	37	6.94E+09	-0.06	473.388	0.003	-0.001	p6f3 2L 7.5	31036.00	p5f3d 2L4Ka 8.5	242279.2
473.548	25	4.46E+08	0.01	473.541	0.003	0.007	p6f3 2I 6.5	31582.85	p5f3d 4D4Ga 5.5	242758.0
474.111blV	34	5.88E+09	-0.09	474.1258	0.0024	-0.015	p6f3 2H2 5.5	16161.53	p5f3d 4I2Ia 6.5	227076.0

Table 1: *(continued)*

λ_{exp}(Å)	Int_{exp}	$gA(s^{-1})$	CF	λ_{Ritz}(Å)	$\delta\lambda_{Ritz}$(Å)	$\Delta\lambda$(Å)	Lower level label	E_{low}	Upper level label	E_{up}
475.147	15	4.68E+08	0.00	475.147	0.003	-0.001	p6f3 2K 7.5	22043.77	p5f3d 2G2K1 7.5	232504.8
475.378	30	2.15E+09	-0.02	475.378	0.003	0.000	p6f3 4G 5.5	22047.39	p5f3d 4G4Hc 6.5	232406.2
476.628	75	1.18E+10	-0.17	476.640	0.004	-0.012	p6f3 2K 7.5	22043.77	p5f3d 2K2Ma 8.5	231845.6
476.845	50	9.14E+09	0.19	476.836	0.003	0.009	p6f3 2L 8.5	32563.57	p5f3d 2L4Ka 8.5	242279.2
477.248	23	1.41E+09	0.05	477.265	0.004	-0.017	p6f3 4I 6.5	3907.43	p5f3d 4I4Kb 6.5	213434.6
477.569	19	1.71E+08	0.01	477.5725	0.0022	-0.003	p6f3 2K 6.5	20005.22	p5f3d 2K4Hb 6.5	229397.5
478.299	80	1.33E+09	0.02	478.3155	0.0018	-0.017	p6f3 4F 4.5	14994.87	p5f3d 2H2I1 5.5	224061.9
478.449	67	6.36E+09	-0.11	478.459	0.003	-0.010	p6f3 2L 7.5	31036.00	p5f3d 2I2Ke 6.5	240040.4
478.813	7	6.44E+08	0.00	478.810	0.004	0.003	p6f3 2K 7.5	22043.77	p5f3d 2L2Md 8.5	230894.7
479.321	31	9.77E+07	0.00	479.317	0.003	0.003	p6f3 2L 7.5	31036.00	p5f3d 2K2Mc 8.5	239666.0
480.104	90	1.86E+10	0.30	480.0955	0.0025	0.008	p6f3 2L 7.5	31036.00	p5f3d 2L4L 6.5	239327.9
480.236	10	3.78E+09	0.05	480.2298	0.0024	0.006	p6f3 2H1 4.5	33741.15	p5f3d 2I4Gb 4.5	241974.8
480.522	50	3.67E+09	-0.05	480.522	0.003	0.000	p6f3 2L 8.5	32563.57	p5f3d 2G4I2$_b$ 7.5	240670.5
481.435blV	67	1.08E+10	-0.30	481.4187	0.0020	0.016	p6f3 2K 6.5	20005.22	p5f3d 2L2Ha 5.5	227724.6
481.509blV	37	8.66E+09	0.14	481.517	0.003	-0.008	p6f3 2I 5.5	30179.93	p5f3d 2I4K 6.5	237856.8
481.628	50	1.75E+09	0.02	481.646	0.003	-0.018	p6f3 2H1 5.5	35136.61	p5f3d 4D4Ga 5.5	242758.0
482.274	72	1.16E+10	0.23	482.2677	0.0022	0.006	p6f3 2K 7.5	22043.77	p5f3d 2K4Hb 6.5	229397.5
482.588	36	4.14E+09	0.05	482.592	0.003	-0.003	p6f3 2L 8.5	32563.57	p5f3d 2G4I2 7.5	239778.1
483.190	62	3.32E+10	-0.61	483.190	0.005	0.000	p6f3 2L 8.5	32563.57	p5f3d 2L4Na 9.5	239521.7
483.474blV	35	1.59E+09	-0.03	483.4697	0.0025	0.004	p6f3 2H1 5.5	35136.61	p5f3d 2I4Gb 4.5	241974.8
484.188	53	1.84E+10	-0.14	484.188	0.005	0.000	p6f3 2L 8.5	32563.57	p5f3d 2K2Kd 7.5	239094.8
484.244blV	57	1.17E+10	0.14	484.237	0.003	0.007	p6f3 2K 7.5	22043.77	p5f3d 2L2Lf 8.5	228554.3
484.793	43	6.84E+09	-0.12	484.792	0.003	0.000	p6f3 2I 6.5	31582.85	p5f3d 2I4K 6.5	237856.8
486.187	14	1.11E+09	-0.04	486.1987	0.0020	-0.012	p6f3 4G 5.5	22047.39	p5f3d 2L2Ha 5.5	227724.6
486.677	56	8.15E+09	-0.05	486.695	0.004	-0.018	p6f3 2L 7.5	31036.00	p5f3d 2L4Mb 8.5	236503.5
486.818	18	2.77E+09	0.12	486.8191	0.0022	-0.001	p6f3 4G 5.5	22047.39	p5f3d 2L4H 6.5	227462.5
487.536	87	1.41E+10	-0.14	487.529	0.003	0.008	p6f3 2L 8.5	32563.57	p5f3d 2K4Ka 8.5	237679.7
487.739	28	2.29E+09	-0.16	487.728	0.003	0.011	p6f3 2K 7.5	22043.77	p5f3d 4I2Ia 6.5	227076.0
487.849	30	3.18E+09	-0.09	487.861	0.003	-0.012	p6f3 2I 5.5	30179.93	p5f3d 2I4K 5.5	235156.4
487.934	44	9.98E+09	-0.15	487.938	0.003	-0.004	p6f3 2K 6.5	20005.22	p5f3d 2H2L1 7.5	224949.2
488.040	17	3.91E+09	-0.03	488.034	0.003	0.006	p6f3 2H1 5.5	35136.61	p5f3d 2I2Ke 6.5	240040.4
489.480p	134	3.07E+10	-0.22	489.484	0.003	-0.005	p6f3 2L 7.5	31036.00	p5f3d 2L4Na 8.5	235332.7
489.685	29	1.09E+09	0.05	489.669	0.003	0.016	p6f3 2H1 5.5	35136.61	p5f3d(s) 4G4Ha 4.5	239356.2
489.730	20	2.50E+09	-0.04	489.737	0.003	-0.007	p6f3 2H1 5.5	35136.61	p5f3d 2L4L 6.5	239327.9
489.996	12	6.53E+08	0.02	489.975	0.0019	0.021	p6f3 4G 4.5	19969.79	p5f3d 2H2I1 5.5	224061.9
490.068	17	5.50E+09	0.31	490.0600	0.0019	0.008	p6f3 2K 6.5	20005.22	p5f3d 2H2I1 5.5	224061.9
490.358	59	9.49E+09	0.06	490.340	0.004	0.018	p6f3 2L 8.5	32563.57	p5f3d 2L4Mb 8.5	236503.5
490.484	65	1.39E+10	0.21	490.4804	0.0020	0.003	p6f3 2K 7.5	22043.77	p5f3d 2H2I1 6.5	225925.5
491.895bl	24	4.37E+09	0.06	491.899	0.003	-0.004	p6f3 2H1 5.5	35136.61	p5f3d 4G4Hb 6.5	238430.3
492.830blV	67	3.77E+09	-0.10	492.840	0.003	-0.010	p6f3 2K 7.5	22043.77	p5f3d 2H2L1 7.5	224949.2
493.053	68	9.52E+09	-0.39	493.052	0.005	0.000	p6f3 4I 7.5	5988.51	p5f3d 4I4La 7.5	208806.7
493.173	16	5.57E+09	-0.12	493.172	0.003	0.001	p6f3 2L 8.5	32563.57	p5f3d 2L4Na 8.5	235332.7
493.471	42	1.50E+10	-0.27	493.475	0.003	-0.004	p6f3 2I 5.5	30179.93	p5f3d 2G2K2 6.5	232824.5
494.450as	88	1.90E+10	0.39	494.451	0.003	-0.001	p6f3 2K 7.5	22043.77	p5f3d 2H4K1 7.5	224288.2
494.544	28	4.97E+09	0.13	494.545	0.003	-0.001	p6f3 4G 5.5	22047.39	p5f3d(s) 4F6G 6.5	224253.6
494.973as	63	4.02E+10	-0.20	494.973	0.005	0.000	p6f3 2L 8.5	32563.57	p5f3d 2L2Md 9.5	234594.7
495.561	14	2.49E+09	0.19	495.568	0.003	-0.007	p6f3 2L 7.5	31036.00	p5f3d 2G2K2 6.5	232824.5
496.355blV	36	1.03E+09	0.02	496.355	0.004	0.001	p6f3 2L 7.5	31036.00	p5f3d 2G2K1 7.5	232504.8
497.095	87	9.75E+09	0.35	497.091	0.004	0.003	p6f3 2G2 4.5	21493.39	p5f3d 2D4H2 5.5	222663.7
497.947	36	1.72E+09	-0.05	497.934	0.003	0.013	p6f3 2H1 5.5	35136.61	p5f3d 2K4Hb 5.5	235966.4
498.098blV	26	7.05E+09	-0.23	498.113	0.003	-0.015	p6f3 2L 7.5	31036.00	p5f3d 2G2K2 7.5	231793.5
498.862	25	1.91E+09	0.14	498.864	0.003	-0.002	p6f3 2I 6.5	31582.85	p5f3d 2G4G1 5.5	232038.4
499.384	73	1.54E+10	0.48	499.384	0.005	0.000	p6f3 4I 7.5	5988.51	p5f3d 2L4L 8.5	206235.2
499.471	35	6.43E+09	-0.18	499.474	0.003	-0.002	p6f3 2I 6.5	31582.85	p5f3d 2G2K2 7.5	231793.5
499.771	73	2.76E+10	-0.37	499.788	0.003	-0.018	p6f3 2L 7.5	31036.00	p5f3d 2L4M 7.5	231120.8
500.348D	84	1.66E+10	0.43	500.358	0.004	-0.009	p6f3 4I 7.5	5988.51	p5f3d 4G4Kb 8.5	205845.6
500.348D	84	1.92E+10	-0.08	500.353	0.004	-0.005	p6f3 2L 7.5	31036.00	p5f3d 2L2Md 8.5	230894.7
500.421blV	43	1.07E+10	0.18	500.419	0.004	0.002	p6f3 2L 8.5	32563.57	p5f3d 4G4Ka 8.5	232396.0
500.557	23	1.94E+07	0.00	500.5576	0.0023	-0.001	p6f3 4I 5.5	1897.11	p5f3d 4G4Ka 6.5	201674.3
500.693	12	3.13E+09	0.10	500.690	0.004	0.002	p6f3 4I 5.5	1897.11	p5f3d 4F4Gd 5.5	201621.4

Table 1: *(continued)*

λ_{exp}(Å)	Int_{exp}	$gA(s^{-1})$	CF	λ_{Ritz}(Å)	$\delta\lambda_{Ritz}$(Å)	$\Delta\lambda$(Å)	Lower level label	E_{low}	Upper level label	E_{up}
501.213	67	8.36E+09	0.14	501.213	0.005	0.000	p6f3 2K 7.5	22043.77	p5f3d 4I4Ka$_b$ 8.5	221559.6
501.968	8	1.10E+09	0.03	501.9638	0.0024	0.005	p6f3 2I 5.5	30179.93	p5f3d 2K4Hb 6.5	229397.5
502.801	36	1.16E+10	0.20	502.792	0.003	0.009	p6f3 2K 7.5	22043.77	p5f3d 4I4Ka 8.5	220933.1
504.350	7	8.85E+08	-0.06	504.347	0.002	0.003	p6f3 4I 5.5	1897.11	p5f3d 4G6Gb 6.5	200173.3
505.521	17	2.30E+09	0.11	505.5237	0.0025	-0.003	p6f3 2I 6.5	31582.85	p5f3d 2K4Hb 6.5	229397.5
505.649	29	9.05E+09	-0.33	505.6459	0.0024	0.003	p6f3 4I 6.5	3907.43	p5f3d 4G4Ka 6.5	201674.3
505.779	39	5.14E+09	0.20	505.781	0.004	-0.002	p6f3 4I 6.5	3907.43	p5f3d 4F4Gd 5.5	201621.4
506.149	33	1.22E+10	0.38	506.141	0.004	0.007	p6f3 4I 6.5	3907.43	p5f3d 4F6Hb 7.5	201480.7
509.091	11	5.22E+08	0.02	509.0963	0.0024	-0.005	p6f3 2L 7.5	31036.00	p5f3d 2L4H 6.5	227462.5
509.504	29	1.46E+08	0.00	509.5129	0.0020	-0.009	p6f3 4I 6.5	3907.43	p5f3d 4G6Gb 6.5	200173.3
510.150bl	12	8.74E+09	-0.40	510.152	0.004	-0.002	p6f3 2K 6.5	20005.22	p5f3d 2K4L 6.5	216025.3
510.222	21	1.49E+10	0.12	510.228	0.004	-0.006	p6f3 2L 8.5	32563.57	p5f3d 2L2Lf 8.5	228554.3
510.478	33	6.51E+08	-0.05	510.490	0.003	-0.012	p6f3 4I 4.5	0.00	p5f3d 2H2H2 5.5	195890.1
510.531	59	2.98E+09	-0.14	510.5176	0.0025	0.013	p6f3 2I 6.5	31582.85	p5f3d 2L4H 6.5	227462.5
510.877	10	2.69E+09	-0.06	510.867	0.002	0.010	p6f3 2I 5.5	30179.93	p5f3d 2H2I1 6.5	225925.5
511.019	13	1.62E+09	-0.18	511.0233	0.0024	-0.005	p6f3 4I 7.5	5988.51	p5f3d 4G4Ka 6.5	201674.3
511.522	8	7.51E+08	0.02	511.529	0.004	-0.007	p6f3 4I 7.5	5988.51	p5f3d 4F6Hb 7.5	201480.7
513.327	42	5.27E+09	0.20	513.325	0.003	0.002	p6f3 4I 5.5	1897.11	p5f3d 4G6G 6.5	196705.6
514.553	52	3.86E+09	-0.18	514.5550	0.0022	-0.003	p6f3 2I 6.5	31582.85	p5f3d 2H2I1 6.5	225925.5
514.976	26	9.28E+09	0.17	514.9734	0.0021	0.002	p6f3 4I 7.5	5988.51	p5f3d 4G6Gb 6.5	200173.3
515.505	35	1.61E+09	0.04	515.5079	0.0023	-0.003	p6f3 2H1 4.5	33741.15	p5f3d 2L2Ha 5.5	227724.6
517.166	23	1.04E+09	-0.01	517.153	0.003	0.013	p6f3 2I 6.5	31582.85	p5f3d 2H2L1 7.5	224949.2
519.247	19	1.66E+09	-0.06	519.2432	0.0023	0.004	p6f3 2H1 5.5	35136.61	p5f3d 2L2Ha 5.5	227724.6
519.375	59	4.59E+09	0.11	519.3680	0.0019	0.007	p6f3 4I 4.5	0.00	p5f3d 4I6Lb$_b$ 5.5	192541.7
519.577	39	1.40E+09	-0.04	519.5770	0.0022	0.000	p6f3 4I 4.5	0.00	p5f3d 4I4Gd 5.5	192464.3
520.894	15	2.00E+09	-0.10	520.888	0.003	0.006	p6f3 4I 5.5	1897.11	p5f3d 2H4H2 5.5	193876.8
521.012	9	6.19E+08	0.01	520.998	0.003	0.014	p6f3 2H1 5.5	35136.61	p5f3d 4I2Ia 6.5	227076.0
521.667	54	2.81E+09	0.12	521.675	0.003	-0.008	p6f3 4I 4.5	0.00	p5f3d 4I6Lb 5.5	191690.1
522.309	25	2.81E+08	0.05	522.324	0.003	-0.015	p6f3 4I 5.5	1897.11	p5f3d 2K4La 6.5	193349.2
524.343	3	6.86E+08	0.01	524.337	0.003	0.006	p6f3 4I 7.5	5988.51	p5f3d 4G6G 6.5	196705.6
524.519	5	2.37E+08	0.00	524.5363	0.0020	-0.017	p6f3 4I 5.5	1897.11	p5f3d 4I6Lb$_b$ 5.5	192541.7
525.028	22	2.57E+08	-0.01	525.014	0.004	0.014	p6f3 4I 4.5	0.00	p5f3d 4G6Gb 5.5	190471.1
526.341	53	2.20E+08	-0.03	526.328	0.003	0.013	p6f3 4I 4.5	0.00	p5f3d 4F6F 5.5	189995.5
526.408	25	1.26E+09	-0.05	526.401	0.003	0.007	p6f3 4I 6.5	3907.43	p5f3d 2H4H2 5.5	193876.8
526.591	5	2.32E+09	-0.04	526.601	0.003	-0.010	p6f3 2L 7.5	31036.00	p5f3d 4I4Ka 8.5	220933.1
527.869bl	37	2.92E+08	0.01	527.867	0.003	0.002	p6f3 4I 6.5	3907.43	p5f3d 2K4La 6.5	193349.2
528.762	39	1.25E+09	0.07	528.762	0.005	0.000	p6f3 4I 6.5	3907.43	p5f3d 2H4L2 7.5	193028.4
528.838	17	6.98E+07	0.00	528.8238	0.0025	0.014	p6f3 4I 4.5	0.00	p5f3d 2H4G2 3.5	189098.9
530.113	12	1.40E+08	-0.01	530.1264	0.0020	-0.013	p6f3 4I 6.5	3907.43	p5f3d 4I6Lb$_b$ 5.5	192541.7
530.282	16	8.25E+08	0.02	530.296	0.004	-0.013	p6f3 4I 5.5	1897.11	p5f3d 4G6Gb 5.5	190471.1
532.053	21	8.41E+09	0.07	532.053	0.005	0.000	p6f3 2L 8.5	32563.57	p5f3d 2L4Ma 9.5	220514.9
532.551	12	8.61E+07	0.01	532.531	0.003	0.020	p6f3 4I 6.5	3907.43	p5f3d 4I6Lb 5.5	191690.1
534.531	12	2.38E+09	0.17	534.531	0.005	0.000	p6f3 2L 8.5	32563.57	p5f3d 4I2M 9.5	219643.5
535.721	30	1.65E+09	0.03	535.717	0.003	0.004	p6f3 4I 5.5	1897.11	p5f3d 4F6I 5.5	188563.0
538.158	52	9.57E+08	0.01	538.151	0.004	0.007	p6f3 4I 6.5	3907.43	p5f3d 4F6I 7.5	189729.0
539.278	60	1.02E+09	-0.01	539.278	0.005	0.000	p6f3 4I 7.5	5988.51	p5f3d 4I4Lc 8.5	191421.6
541.507	45	4.01E+07	0.00	541.500	0.002	0.007	p6f3 4I 6.5	3907.43	p5f3d 4G6Hb 5.5	188579.7
544.068	5	2.38E+08	0.00	544.064	0.004	0.004	p6f3 2K 7.5	22043.77	p5f3d 4G4Kb 8.5	205845.6
544.698blV	6	7.14E+07	0.00	544.698	0.003	-0.001	p6f3 4I 4.5	0.00	p5f3d 4I2H 4.5	183587.9
546.191	28	2.39E+08	0.00	546.180	0.004	0.010	p6f3 2H2 4.5	12800.29	p5f3d 2H2H2 5.5	195890.1
548.723	15	4.54E+07	0.00	548.725	0.003	-0.002	p6f3 4I 5.5	1897.11	p5f3d 4I6Ga$_b$ 6.5	184137.8
549.839	34	1.84E+07	0.00	549.851	0.003	-0.012	p6f3 4I 5.5	1897.11	p5f3d 4F6Ha 6.5	183764.4
550.399	28	4.45E+08	0.01	550.386	0.003	0.013	p6f3 4I 5.5	1897.11	p5f3d 4I2H 4.5	183587.9
551.679	14	1.91E+08	0.00	551.676	0.003	0.002	p6f3 4I 5.5	1897.11	p5f3d 4I4Hf 6.5	183162.8
553.425	29	4.98E+07	0.00	553.4169	0.0024	0.008	p6f3 4I 5.5	1897.11	p5f3d 4I6Ga 6.5	182592.7
555.996	49	1.46E+08	0.00	555.997	0.003	-0.002	p6f3 4I 6.5	3907.43	p5f3d 4F6Ha 6.5	183764.4
556.712	19	2.61E+08	-0.05	556.709	0.003	0.002	p6f3 4G 5.5	22047.39	p5f3d 4G4Ka 6.5	201674.3
559.623	29	3.02E+06	-0.00	559.6432	0.0024	-0.021	p6f3 4I 6.5	3907.43	p5f3d 4I6Ga 6.5	182592.7
561.322	104	7.48E+08	-0.01	561.327	0.003	-0.004	p6f3 4I 7.5	5988.51	p5f3d 4I6Ga$_b$ 6.5	184137.8
561.401	58	1.09E+09	0.04	561.4006	0.0024	0.001	p6f3 4G 5.5	22047.39	p5f3d 4G6Gb 6.5	200173.3

Table 1: *(continued)*

λ_{exp}(Å)	Int_{exp}	$gA(s^{-1})$	CF	λ_{Ritz}(Å)	$\delta\lambda_{Ritz}$(Å)	$\Delta\lambda$(Å)	Lower level label	E_{low}	Upper level label	E_{up}
563.234	32	4.40E+07	0.00	563.2317	0.0023	0.002	p6f3 4F 4.5	14994.87	p5f3d 4I6Lb$_b$ 5.5	192541.7
564.414	72	1.18E+09	-0.01	564.416	0.004	-0.002	p6f3 4I 7.5	5988.51	p5f3d 4I4Hf 6.5	183162.8
566.255	40	3.05E+08	0.00	566.238	0.003	0.017	p6f3 4I 7.5	5988.51	p5f3d 4I6Ga 6.5	182592.7
571.416	96	1.39E+08	-0.01	571.427	0.004	-0.011	p6f3 4F 4.5	14994.87	p5f3d 4F6F 5.5	189995.5
572.540	36	4.58E+08	-0.03	572.547	0.003	-0.007	p6f3 4G 5.5	22047.39	p5f3d 4G6G 6.5	196705.6
574.881	43	1.85E+08	-0.01	574.8822	0.0023	-0.001	p6f3 2H2 5.5	16161.53	p5f3d 4F6F 4.5	190110.2
576.139	29	7.15E+07	-0.01	576.143	0.004	-0.004	p6f3 4F 4.5	14994.87	p5f3d 4F6I 5.5	188563.0
576.898	21	4.62E+07	-0.01	576.888	0.003	0.010	p6f3 2K 6.5	20005.22	p5f3d 2K4La 6.5	193349.2
579.990	37	1.10E+08	-0.01	579.985	0.003	0.005	p6f3 2H2 5.5	16161.53	p5f3d 4G6Hb 5.5	188579.7
581.962	39	3.93E+08	-0.02	581.973	0.003	-0.010	p6f3 4G 5.5	22047.39	p5f3d 2H4H2 5.5	193876.8
582.332	43	4.69E+06	-0.00	582.342	0.003	-0.010	p6f3 4G 4.5	19969.79	p5f3d 4I6Lb 5.5	191690.1
583.005	19	7.46E+07	0.00	583.005	0.003	0.001	p6f3 2G2 3.5	17655.11	p5f3d 4I4Gd 4.5	189180.3
583.451	37	9.82E+07	-0.03	583.459	0.003	-0.008	p6f3 4G 2.5	17707.17	p5f3d 2H4G2 3.5	189098.9
587.769	53	9.96E+07	0.00	587.7498	0.0024	0.019	p6f3 4G 4.5	19969.79	p5f3d 4F6F 4.5	190110.2
588.260	34	4.54E+06	0.00	588.258	0.003	0.002	p6f3 2I 5.5	30179.93	p5f3d 4G6Gb 6.5	200173.3
590.984	21	1.06E+08	0.00	590.980	0.003	0.004	p6f3 4G 4.5	19969.79	p5f3d 4I4Gd 4.5	189180.3
595.006	83	4.80E+08	0.02	595.0156	0.0025	-0.009	p6f3 4G 5.5	22047.39	p5f3d 4F6F 4.5	190110.2
595.328	20	1.19E+08	0.02	595.322	0.003	0.006	p6f3 2H2 5.5	16161.53	p5f3d 4I6Ga$_b$ 6.5	184137.8
596.344D	22	9.55E+07	0.00	596.349	0.003	-0.006	p6f3 2G2 4.5	21493.39	p5f3d 4I4Gd 4.5	189180.3
596.344D	22	1.41E+08	0.02	596.355	0.005	-0.012	p6f3 2K 7.5	22043.77	p5f3d 4F6I 7.5	189729.0
596.635	45	9.19E+07	0.00	596.639	0.003	-0.004	p6f3 2G2 4.5	21493.39	p5f3d 2H4G2 3.5	189098.9
596.660	35	3.37E+07	0.00	596.648	0.003	0.012	p6f3 2H2 5.5	16161.53	p5f3d 4F6Ha 6.5	183764.4
598.325	73	3.14E+08	0.02	598.326	0.003	-0.002	p6f3 4G 5.5	22047.39	p5f3d 4I4Gd 4.5	189180.3
598.482	92	9.26E+07	0.01	598.493	0.003	-0.011	p6f3 2G2 4.5	21493.39	p5f3d 4G6Hb 5.5	188579.7
600.845	21	5.15E+07	-0.01	600.849	0.003	-0.004	p6f3 2H2 5.5	16161.53	p5f3d 4I6Ga 6.5	182592.7
602.643	23	4.13E+06	0.00	602.654	0.003	-0.010	p6f3 2G2 3.5	17655.11	p5f3d 4I2H 4.5	183587.9
629.894	34	1.67E+08	-0.07	629.901	0.003	-0.007	p6f3 4D 3.5	31355.04	p5f3d 4F6F 4.5	190110.2
635.317	26	4.24E+07	0.00	635.303	0.003	0.014	p6f3 2H1 5.5	35136.61	p5f3d 4I6Lb$_b$ 5.5	192541.7

p: line resolved on the plate but perturbed by a close line

bl: line partially resolved in a blended emission peak with components of similar intensities; blV means blend by Nd V.

as: asymmetrical line, when the components of the blend have different intensities

D: doubly classified

Lower level label: read $5p^6 4f^3\ ^4G$ J=5.5 for p6f3 4G 5.5 and so on.

Upper level label: read $5p^5 4f^3 5d$ or $5p^5 4f^3 6s$ for p5f3d or for p5f3s and $(^4D)^4Fe$ J=4.5 for 4D4Fe 4.5 and so on. p5f3d(s) means a mixed 5d level with a 6s leading component (Cf Table2).

Table 2: Even-parity energy levels of the $5p^54f^35d$ configuration of Nd^{3+}. For each level are given : J, the total angular momentum; E_{exp}, the experimental energy value and its uncertainty (in cm^{-1}); N, the number of transitions involved in its determination; E_{calc} , the calculated energy value from the parametric fit and $\Delta E = E_{exp} - E_{calc}$ (in cm^{-1}); g_L, the calculated Landé factor, the leading LS component of the wavefunction and its percentage as derived from Cowan codes [19]. Two levels of identical first component are distinguished by a subscript "b" for the higher energy level. Levels marked with a " * " belong to the $5p^54f^36s$ configuration. Two levels of $5p^54f^35d$ marked by (s) have a first LS component belonging to the $5p^54f^36s$ configuration.

J	E_{exp} (cm^{-1})	Unc.(cm^{-1})	N	E_{calc} (cm^{-1})	ΔE(cm^{-1})	g_L	1^{st} LS comp.	Perc.
6.5	182592.7	2.2	4	182292	301	1.107	(4I) 6Ga	13%
6.5	183162.8	1.3	2	183382	-219	1.112	(4I) 4Hf	8%.
4.5	183587.9	2.0	3	183626	-38	1.048	(4I) 2H	15%.
6.5	183764.4	2.0	3	183594	171	1.209	(4F) 6Ha	14%
6.5	184137.8	1.2	3	183948	190	1.164	(4I) $6Ga_b$	9%
5.5	188563.0	1.4	2	188514	49	1.049	(4F) 6I	11%
5.5	188579.7	1.7	3	189026	-447	1.136	(4G) 6Hb	9%
3.5	189098.9	1.8	3	189028	71	1.153	(2H) 4G2	5%.
4.5	189180.3	0.9	4	188956	224	1.120	(4I) 4Gd	8%.
7.5	189729.0	2.4	2	189674	55	1.114	(4F) 6I	14%
5.5	189995.5	3.0	2	190098	-103	1.311	(4F) 6F	17%
4.5	190110.2	1.7	4	190325	-215	1.202	(4F) 6F	6%
5.5	190471.1	4.0	2	190307	164	1.130	(4G) 6Gb	7%
8.5	191421.6	1.7	1	191683	-261	1.135	(4I) 4Lc	13%
5.5	191690.1	3.0	3	191573	117	1.047	(4I) 6Lb	6%.
5.5	192464.3	1.9	1	192118	347	1.101	(4I) 4Gd	7%
5.5	192541.7	1.9	5	192557	-15	1.034	(4I) $6Lb_b$	7%
7.5	193028.4	1.8	1	192962	67	1.101	(2H) 4L2	14%
6.5	193349.2	2.3	3	193118	231	1.087	(2K) 4La	5%
6.5	193876.8	1.9	3	193564	313	1.158	(2H) 4H2	5%
5.5	195890.1	3.0	2	196173	-283	1.104	(2H) 2H2	4%
6.5	196705.6	1.5	3	197207	-501	1.177	(4G) 6G	12%
6.5	200173.3	1.0	5	200154	20	1.150	(4G) 6Gb	6%
7.5	201480.7	2.4	2	202075	-594	1.118	(4F) 6Hb	11%
5.5	201621.4	1.5	2	201782	-160	1.125	(4F) 4Gd	4%
6.5	201674.3	1.1	4	201813	-138	1.066	(4G) 4Ka	8%
8.5	205845.6	2.0	2	205655	191	1.095	(4G) 4Kb	11%
8.5	206235.2	2.0	1	206309	-74	1.061	(2L) 4L	13%.
7.5	208806.7	2.1	1	208523	284	1.033	(4I) 4La	14%
6.5	213434.6	6.0	2	213540	-105	1.014	(4I) 4Kb	4%
6.5	216025.3	1.6	2	216180	-155	1.012	(2K) 4L	7%
9.5	219643.5	1.7	1	219834	-190	1.099	(4I) 2M	18%.
9.5	220514.9	1.8	1	220460	55	1.047	(2L) 4Ma	28%.
8.5	220933.1	2.2	3	220327	607	1.081	(4I) 4Ka	7%
8.5	221559.6	2.0	1	221375	185	1.069	(4I) $4Ka_b$	5%

Table 2: *(continued)*

J	E_{exp} (cm^{-1})	Unc.(cm^{-1})	N	E_{calc} (cm^{-1})	$\Delta E(cm^{-1})$	g_L	1^{st} LS comp.	Perc.
5.5	222663.7	1.9	2	222599	65	1.091	(2D) 4H2	4%
5.5	224061.9	4.0	4	223892	170	1.067	(2H) 2I1	5%
6.5	224253.6	1.5	3	224447	-193	1.107	(4F) 6G (s)	7%
7.5	224288.2	3.0	3	224654	-366	1.071	(2H) 4K1	8%
7.5	224949.2	3.0	3	225273	-324	1.021	(2H) 2L1	9%
6.5	225925.5	2.0	4	226088	-163	1.079	(2H) 2I1	7%
4.5	226942.2	2.0	2	226950	-8	1.094	(4F) 4Gc	4%
6.5	227076.0	3.0	4	226737	339	1.077	(4I) 2Ia	4%
6.5	227462.5	1.7	5	227497	-34	1.076	(2L) 4H	12%
5.5	227724.6	1.8	6	227666	59	1.053	(2L) 2Ha	7%
8.5	228554.3	2.3	2	228538	16	1.033	(2L) 2Lf	10%
6.5	229397.5	1.3	5	229205	193	1.073	(2K) 4Hb	6%
8.5	230894.7	2.0	2	230591	304	1.011	(2L) 2Md	13%
7.5	231120.8	4.0	3	231318	-197	1.028	(2L) 4M	9%
7.5	231793.5	3.0	4	231963	-170	1.065	(2G) 2K2	10%
8.5	231845.6	5.0	2	231927	-81	1.035	(2K) 2Ma	18%
5.5	232038.4	1.3	4	231803	235	1.062	(2G) 4G1	4%
8.5	232396.0	1.7	2	232128	268	1.087	(4G) 4Ka	11%
6.5	232406.2	1.5	3	232524	-118	1.112	(4G) 4Hc	9%
7.5	232504.8	1.5	2	232683	-179	1.108	(2G) 2K1	7%
6.5	232824.5	2.4	3	232805	19	1.046	(2G) 2K2	5%
6.5	233830.6	3.0	3	233781	49	1.135	(4G) 4Hc_b	9%
9.5	234594.7	2.0	1	234688	-93	1.031	(2L) 2Md	19%
5.5	235156.4	3.0	3	235158	-2	1.012	(2I) 4K	7%
8.5	235332.7	1.5	3	235217	116	0.990	(2L) 4Na	23%
5.5	235966.4	3.0	4	235894	73	1.056	(2K) 4Hb	6%
8.5	236503.5	5.0	2	236503	1	0.997	(2L) 4Mb	11%
8.5	237679.7	3.0	3	237623	57	1.056	(2K) 4Ka	13%
6.5	237856.8	1.7	4	238372	-515	0.996	(2I) 4K	8%
6.5	238430.3	1.7	3	237961	470	1.070	(4G) 4Hb	6%
5.5	238709.0	1.8	3	238446	263	1.073	(2G) 2H2	6%
7.5	239094.8	2.1	1	239129	-34	1.074	(2K) 2Kd	6%
6.5	239327.9	1.9	5	238891	437	1.037	(2L) 4L	7%
4.5	239356.2	3.0	5	239748	-392	1.047	(4G) 4Ha (s)	5%
9.5	239521.7	2.1	1	240122	-600	1.025	(2L) 4Na	33%
8.5	239666.0	1.7	3	239400	266	1.054	(2K) 2Mc	14%
7.5	239778.1	3.0	4	239794	-16	1.114	(2G) 4I2	7%
6.5	240040.4	2.3	3	239965	75	1.040	(2I) 2Ke	5%
7.5	240670.5	1.5	3	240786	-115	1.080	(2G) 4$I2_b$	11%
6.5	241212.6	4.0	2	241149	64	0.991	(4I) 4Ka	11%

Table 2: *(continued)*

J	E_{exp} (cm^{-1})	Unc.(cm^{-1})	N	E_{calc} (cm^{-1})	$\Delta E(cm^{-1})$	g_L	1^{st} LS comp.	Perc.
4.5	241974.8	3.0	5	241922	53	1.022	(2I) 4Gb	3%
8.5	242279.2	2.3	3	242248	31	1.061	(2L) 4Ka	11%
5.5	242534.5	1.9	2	242538	-4	0.998	(4I) 4If	8%
5.5	242758.0	3.0	4	242725	33	1.103	(4D) 4Ga	4%
6.5	242796.2	1.9	3	243008	-212	1.010	(2L) 2Ka	6%
7.5	243032.1	2.5	2	243079	-47	1.091	(2I) 2Kc	9%
6.5	243575.6	2.3	2	243489	86	1.071	(2I) 4Hb	3%
7.5	244383.4	3.0	2	244288	95	1.095	(2I) 2Kc_b	7%
8.5	245704.8	2.4	2	245777	-72	1.073	(4I) 4Kd	17%
6.5	247744.4	2.9	1	247529	216	1.138	(4I) 4Hc	12%
6.5	247798.7	2.2	4	247880	-81	1.079	(4I) 4Kb *	9%
5.5	253568.5	2.2	2	253419	149	1.044	(2F) 4I1	6%
4.5	254434.6	2.1	3	254806	-371	1.130	(4F) 4Gd	13%
4.5	260470.3	4.0	3	260153	318	1.051	(2G) 4H2	5%
7.5	260809.0	3.0	1	260684	125	0.946	(2K) 2Ld	26%
6.5	261522.8	3.0	3	261161	362	0.998	(2K) 2Ke	16%
3.5	261585.0	2.4	2	261182	403	1.018	(4G) 4Ge	8%
7.5	262050.0	3.0	1	262001	49	1.060	(2K) 2Ke	29%
8.5	262377.5	2.9	1	262762	-384	1.050	(2K) 2Ld	37%
3.5	262535.2	3.0	2	262780	-245	1.114	(4G) 4Ff	11%
5.5	262910.4	1.9	3	263251	-341	1.176	(4G) 4Ge	14%
6.5	263107.0	3.0	1	262892	215	1.190	(4G) 4Hd	26%
5.5	263215.7	4.0	2	263730	-515	1.025	(2K) 2If	18%
4.5	264511.1	3.0	3	264464	47	1.225	(4G) 4Fc	16%
3.5	264862.0	3.0	1	265132	-270	1.081	(2D) 2F1	13%
3.5	271108.5	2.3	2	271172	-64	1.160	(4D) 4Fe	6%
7.5	271194.2	2.1	2	270940	255	1.015	(2L) 2Le	16%
5.5	271396.5	2.9	1	271013	383	1.049	(2I) 2Ie	11%
4.5	272387.5	2.2	3	272741	-354	1.000	(2I) 2Hf	26%
8.5	272514.9	5.0	2	272680	-165	0.991	(2L) 2Me	22%
3.5	272617.7	5.0	2	272664	-46	1.293	(4D) 4Df	11%
8.5	272626.1	2.1	2	272536	90	1.017	(2L) 2Le	20%
6.5	272899.7	2.2	2	273050	-150	0.984	(2I) 2Kd	15%
7.5	272938.4	2.4	2	272761	178	1.062	(2I) 2Kd	34%
9.5	273532.0	3.0	1	273873	-341	1.048	(2L) 2Md_b	36%
5.5	273678.6	2.1	2	274160	-481	1.061	(2I) 2Hf	21%
4.5	273770.7	3.0	2	273831	-60	1.261	(4D) 4Fe	20%
6.5	273912.9	2.4	2	273961	-48	1.090	(2I) 2Ie	16%
2.5	276425.4	2.9	1	276146	279	0.991	(2D) 2F2	18%
5.5	277312.8	3.0	3	277076	237	1.059	(2H) 2H1	12%

Table 2: *(continued)*

J	E_{exp} (cm^{-1})	Unc.(cm^{-1})	N	E_{calc} (cm^{-1})	$\Delta E(cm^{-1})$	g_L	1^{st} LS comp.	Perc.
4.5	277426.8	3.0	2	277150	277	0.988	(2H) 2H1	8%
7.5	277550.8	3.0	2	277201	350	1.033	(2L) 4L *	14%
2.5	277827.9	2.1	2	277542	286	1.061	(2D) 2D2	10%
5.5	278270.7	5.0	3	278374	-104	1.027	(2H) 2I1_b	8%
6.5	278497.2	3.0	2	278382	115	1.054	(2H) 2I1_b	22%
4.5	278631.0	3.0	1	278635	-4	1.050	(2H) 2G1	12%
1.5	283605.0	3.0	1	283321	284	0.968	(2F) 2D1	17%
2.5	284327.7	3.0	1	284464	-137	1.184	(2F) 2D1	19%
4.5	284421.0	3.0	1	284453	-32	1.113	(2F) 2G1	20%
4.5	292989.0	3.0	1	293011	-22	1.098	(2G) 2G2	14%

Read (^{4}I) ^{6}Ga for (4I) 6Ga and so on.

Table 3: Fitted parameters and Hartree-Fock integrals (in cm^{-1}) of even-parity configurations of Nd^{3+}. Unc. (in cm^{-1}) are the uncertainties of the parameters from the fit. Constraints on parameters are denoted by 'f' (fixed) or 'r' (linked ratios). The scaling factor SF = P_{fit}/P_{HFR}, except for the average energy E_{av} where P_{fit} - P_{HFR} is given. For the unknown $5p^54f^36s$ configuration, the column "Adop." gives the parameter values adopting the initial SF from $5p^54f^35d$, except for G^3(fs), which SF is adopted from $5p^64f^26s$.

	$5p^64f^25d$				$5p^64f^26s$				$5p^54f^35d$				$5p^54f^36s$		
Param. P	P_{fit}	Unc.	P_{HFR}	SF	P_{fit}	Unc.	P_{HFR}	SF	P_{fit}	Unc.	P_{HFR}	SF	Adop.	P_{HFR}	SF
E_{av}	90146	106	55887	34259	123058	52	90977	32081	221076	22	196424	24652	252021	226039	25982
F^2(ff) r1	84092	183	109950	0.765	83412	181	110707	0.753	80394	175	104121	0.772	80848	104997	0.770
F^4(ff) r2	60125	624	69359	0.867	60575	629	69878	0.867	54372	565	65415	0.831	55450	66012	0.840
F^6(ff) r3	40495	485	50007	0.810	40795	488	50392	0.810	37453	448	47084	0.795	38022	47527	0.800
α	20	f			20	f			22	f			22		
β r4	-556	-96			-556	-96			-553	-96			-557		
γ r5	1291	115			1291	115			1887	168			1817		
ζ_f r6	987	12	1052	0.938	993	12	1059	0.938	901	11	972	0.926	908	979	0.927
ζ_{5p}									17360	88	17350	1.001	17803	17803	1.000
ζ_{5d} r7	1129	26	1146	0.985					1028	24	1047	0.982			
F^2(fp)									34443	570	51787	0.665	36682	52403	0.700
F^1(fd)	758	f							758	f					
F^2(fd) r8	23442	204	30830	0.760					22110	192	30248	0.731			
F^3(fd)	149	f							149	f					
F^4(fd) r9	16745	435	15288	1.095					17247	449	15161	1.138			
F^2(pd)									40350	f	49630	0.813			
G^2(fp)									22829	f	27437	0.832	22939	27570	0.832
G^4(fp)									15873	f	21226	0.748	16018	21415	0.748
G^1(fd) r10	11626	112	13343	0.871					11152	108	14201	0.785			
G^2(fd)	2012	f							2012	f					
G^3(fd) r11	10759	351	11355	0.948					11632	379	11677	0.996			
G^4(fd)	1757	f							1757	f					
G^5(fd) r12	6868	337	8788	0.782					7334	360	8956	0.819			
G^1(pd) r13									38791	64	58080	0.668			
G^3(pd) r13									28455	48	36257	0.785			
G^3(fs)					2732	f	3365	0.812					2847	3506	0.812
G^1(ps)													6336	6336	1.000

CI param.	P_{fit}	Unc.	P_{HFR}	SF
$5p^64f^25d$-$5p^64f^26s$				
R^2(fd.fs) r14	702	21	974	0.72
R^3(fd.sf) r14	2136	62	2962	0.72
$5p^64f^25d$-$5p^54f^35d$				
R^2(fp.ff) r14	-13651	-402	-18934	0.72
R^4(fp.ff) r14	-7281	-214	-10099	0.72
R^2(pp.fp) r14	-27124	-799	-37622	0.72
R^2(pd.fd) r14	-19289	-568	-26754	0.72
R^4(pd.fd) r14	-12210	-360	-16936	0.72
R^1(pd.df) r14	-17931	-528	-24870	0.72
R^3(pd.df) r14	-12494	-368	-17330	0.72
$5p^64f^25d$-$5p^54f^36s$				
R^2(pd.fs) r14	3799	112	5275	0.72
R^1(pd.sf) r14	1687	50	2342	0.72
$5p^64f^26s$-$5p^54f^35d$				
R^2(ps.fd) r14	4670	138	6481	0.72
R^3(ps.df) r14	-1000	-29	-1384	0.72
$5p^64f^26s$-$5p^54f^36s$				
R^2(fp.ff) r14	-13546	-399	-18809	0.72
R^4(fp.ff) r14	-7218	-213	-10022	0.72
R^2(pp.fp) r14	-27204	-801	-37774	0.72
$5p^54f^35d$-$5p^54f^36s$				
R^2(fd.fs) r14	109	3	152	0.72
R^3(fd.sf) r14	1900	56	2639	0.72
R^2(pd.ps) r14	-9178	-270	-12744	0.72
R^1(pd.sp) r14	-3414	-101	-4739	0.72