Revised analysis of the fifth spectrum of rhenium (Re V)

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ABSTRACT

The spectrum of rhenium was observed in the (500–2100) Å wavelength region. A 6.65 m normal incidence VUV spectrograph has been used to record the spectrum. The $(5d^3 + 5d^26s)$–$5d^26p$ transition array of four times ionized rhenium, Re V, has been investigated. The configurations $5d^3$, $5d^26s$ and $5d^26p$ had been previously studied, and all but one levels of these configurations (19, 15 and 45 levels, respectively) had been established. The previous analysis was based on 382 classified spectral lines. In the current analysis we have rejected 74 previously identified spectral lines and added 90 newly classified lines. New list of identified lines contains 398 entries. Comparing with the previous analysis, the current study is based on new spectrograms and significantly more accurate wavelength measurements. We have detected a large (up to 35 mÅ) systematic shift in wavelength measurements used in the previous analysis. In the current study, the standard deviations (by regions) of the undisturbed isolated lines from their Ritz positions are three to five times smaller and the largest deviation of strong isolated lines from their Ritz positions is about seven times smaller than in the previous work. We have confirmed identification of all but three previously found levels. One level has been rejected and two levels have been determined at new positions. One previously unidentified $5d^26s$ level has been added. Based on the new wavelength measurements, we have corrected positions of all previously known $5d^3$, $5d^26s$ and $5d^26p$ energy levels (except for the ground level, rejected and newly determined levels) by up to 8.31 cm^{-1}. From all 80 theoretically possible levels of the configurations $5d^3$, $5d^26s$ and $5d^26p$, only the level $5d^26s$ $(^1S)^2S_{1/2}$ is still not determined. The orthogonal operators technique was used to calculate the level structure and transition probabilities. The energy parameters have been determined by the least squares fit to the observed levels. Calculated transition probabilities, energy values, as well as *LS*-compositions obtained from the fitted parameters are presented.

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Contents

1. Introduction and experiment

Reliable experimental and theoretical data on the Re V spectrum are necessary to study Re IV and Re III, which are among the most complicated 5d spectra. The data should include energy level structure, transition probabilities and identified spectral lines. The first analysis of the Re V spectrum was published in 1996 [1]. According to the publication, the analysis has resulted in establishing all levels of the configurations $5d^3$ and $5d^26p$ (19 and 45 levels, respectively) and 15 of 16 theoretically possible levels of the configuration $5d^26s$. In the study, energy level values have been derived from 381 spectral lines identified in the region of (584–2073) Å.

In order to succeed in the analyses of the Re IV and Re III spectra, we had to estimate parameters of the configurations to be studied as accurately as possible and to obtain the rhenium linelist with the best possible quality. Reliable experimental data on neighboring spectra are the key factors in estimation of energy parameters, as well as in the linelist adjustment. As was shown in the recently published analyses of the Pt IV–Pt VIII spectra [2–6], simultaneous study of neighboring spectra of the same element (spectra in the iso-nuclear sequence) allows improvement of wavelength measurements by using internal (Ritz) standards obtained in the process of the analyses. Realizing importance of the Re V data, we have checked accuracy, completeness and reliability of the published data. First, we have noticed that there are no transition probabilities given in the paper [1] and therefore classified spectral lines cannot be quickly verified by comparison of transition probabilities and intensities of the lines. Second, there are no estimations of uncertainties of wavelength measurements and obtained energy level values provided in the paper. Only the following statement is given in Ref. [1]: "Many lines were asymmetric and the interpolations lacked enough standards which reduced considerably the accuracy of the calculated wavelengths". From the "Diff" column of Table 1 published in Ref. [1], we have obtained the following information regarding deviations of the experimental wavelengths of the identified lines from their Ritz values (multiply identified lines were excluded from the consideration). There are three wavelength regions that clearly show rather large systematic deviations: (686–696) Å, (709–727) Å and (732–741) Å. The first region (11 spectral lines) shows the random part of deviations of 0.004 Å and the systematic part of 0.010 Å. Deviations in the second region (21 spectral lines) have the random and systematic components of 0.006 Å and −0.012 Å, respectively. In the third region (12 spectral lines) the corresponding values are 0.004 and −0.015 Å. For the deviations in the region of (1500–2073) Å (41 spectral lines), one can see a very large random component of 0.033 Å and a moderate systematic component of −0.005 Å. In the region of (1217–1931) Å, Table 1 of Ref. [1] has more than 40 moderate and strong lines deviating by (30–68) mÅ from the calculated (Ritz) positions. For

example, strong lines at 1391.926 Å, 1434.344 Å, 1527.161 Å, 1594.210 Å, 1606.955 Å, 1615.773 Å have deviation of (55–68) mÅ. No explanation or remarks are given in the paper regarding these lines: whether they are masked or blended.

The paper [1] says that out of 381 classified lines, five lines are doubly classified. In fact, Table 1 of Ref. [1] has 382 spectral lines, seven of which are doubly classified, including one line presented as two lines: at 839.400 Å (51) and 839.401 Å (40) (line intensities are given in parentheses). Taking into account the statement in the paper that "the accuracy of measurements for the symmetric lines and with enough standard lines is 0.005 Å", we doubt that the author was able to measure two lines with a separation of 0.001 Å without using special techniques (such as observing lines in the second order of the grating diffraction). Since there were no such special efforts mentioned in the paper, we should consider the line as doubly classified. In that study, the spectrograms were measured on a semi-automatic comparator; line intensities were estimated on a logarithmic scale.

The isoelectronic comparison of the published data in the Lu I sequence (from Ta III to Hg X) shows that the $5d^26s$ levels at 115409.0 cm^{-1} ($J = 1/2$) and 78134.0 cm^{-1} ($J = 1/2$) in Re V [1] are deviating abnormally from the calculated position by more than 370 cm^{-1} and 80 cm^{-1}, respectively. The mean deviations of fits of even levels in the neighboring Os V, Os VI, Ir VII and Pt VIII spectra are 14.6 cm^{-1}, 10.7 cm^{-1}, 13.0 cm^{-1} and 13.8 cm^{-1} [7–9,6], respectively. The largest deviation of the experimental $5d^3$ and $5d^26s$ levels from the calculated positions in the iso-electronic neighbors Os VI, Ir VII and Pt VIII [8,9,6] is about 28 cm^{-1}; and the largest irregularity (deviation from a trend) of the levels along the sequence is about 5 cm^{-1}. Therefore, the above-mentioned level deviations in Re V are highly suspicious. We have also noticed a misprint in the paper [1]. In the text, it was stated that the standard deviation of the experimental even level values from the calculated ones is 6 cm^{-1}. The correct standard deviation of 60 cm^{-1} is given in Table IV of Ref. [1].

From the above listed findings on the published analysis [1], we conclude that (a) the linelist used in the study may have significant local systematic deviations (LSD) of the measured wavelengths from the actual values; (b) the obtained energy level system may not be optimized; (c) the published Re V analysis may not be completely correct.

The purpose of the present work is to revise the published analysis of the Re V spectrum aiming to correct errors, obtain more accurate experimental data (line intensities, line wavelengths, level energies), describe the level structure by means of the orthogonal operators technique and provide probabilities for the $(5d^3 + 5d^26s)$–$5d^26p$ transitions.

The new spectrograms for the current analysis have been photographed in the wavelength region of (500–2100) Å at the Institute of Spectroscopy, Troitsk, Moscow, Russian Federation. Rhenium spectra of different ionization were obtained on a 6.65 m

normal incidence spectrograph with a plate factor of 1.25 Å/mm. The sources used were vacuum triggered and sliding sparks with operating voltage of (4.0–4.5) kV. The sparks were fed from a low-inductance 10 μF capacitor. The photographic plates were measured on an automatic comparator controlled by the system for automatic processing of photo-spectrograms [10]. Impurity lines of O, C, N, Al, and Si [11] present in the spectrograms were used as standards in the initial wavelength interpolation procedure. The initial uncertainty of wavelength measurements was about 0.007 Å and 0.010 Å for the wavelengths shorter and longer than about 1000 Å, respectively, although it was increased to about 0.020 Å locally for some sub-regions due to the lack of standards, imperfection of the plate holder and deformation of photo-emulsion, most notably at the ends of the photographic plates. By using additional internally derived Ritz standards, we have improved the accuracy of our wavelength measurements. Such standards have been obtained in the course of simultaneous analyses of the Re V, Re IV and Re III spectra (to be published). The entire rhenium linelist used in the previous analysis [1] was also at our disposal. In the region below 693 Å it has more weak lines than our linelist. In the current analysis we have used some rhenium lines from that list.

Comparing our linelist with the one used in the previous analysis [1], we have found that previously used wavelength measurements have a significant systematic shift diminishing gradually from about 35 mÅ to zero as wavelength goes from 709 to 840 Å. As an example, one may compare some strong lines previously measured at 709.072, 711.924, 714.441, 715.142, 732.441 and 733.012 Å (see Ref. [1]) with the newly measured positions at 709.1080, 711.9551, 714.4695, 715.1727, 732.4679 and 733.0416 Å (see Table 1 below).

The analysis presented here was based on theoretical calculations utilizing the orthogonal operators approach [12–15] and performed using the program suite IDEN [16,17].

2. Level optimization and reliability check

The IDEN computer program [16,17] includes an iterative level optimization procedure (LOP) [18] for optimization of the energy level system comprising specified identified levels and spectral lines. For each established level, the code provides two types of uncertainties of the level with respect to the levels directly connected to it by identified transitions. The first type of uncertainty is entirely based on the specified estimated uncertainties of the experimental wavelengths. It is a square root of the weighted mean variance (WMV) of the energy level given by Eq. (7) of Ref. [18]. It is referred to as rwmv$_1$. The second type of uncertainty is calculated by re-estimating uncertainties of the involved experimental wavelengths accounting for the deviations of these wavelengths from the calculated (Ritz) values. It is a square root of the WMV of the energy level given by Eq. (8) of Ref. [18]. It is referred to as rwmv$_2$. These two uncertainties are suitable for the verification of the reliability and accuracy of the obtained level. We exclude from the optimization all levels determined by a single transition. If a spectral line is considered to be masked, blended or its identification is doubtful, the line is not included in the LOP. If the uncertainties of wavelengths of the spectral lines used in the LOP are estimated correctly and all disturbed lines are removed from the optimization, we expect the values given by Eq. (8) of Ref. [18] (rwmv$_2$) to be close to or smaller than those given by Eq. (7) of Ref. [18] (rwmv$_1$). We verify this relation for each level and use it as a quality check of the LOP results and the entire analysis. All uncertainties given in this paper are at the level of one standard deviation.

3. Analysis

The ion Re^{4+} studied here belongs to the Lu I isoelectronic sequence. The ground-state configuration of Re V is 5d^3 and the lowest two excited configurations of different parities are 5d^{2}6s and 5d^{2}6p. All three configurations are known in the Ta III [19], W IV [20], Os VI [8], Ir VII [9], Pt VIII [6] spectra. In the Au IX [21] and Hg X [22] spectra, only two configurations have been determined: 5d^3 and 5d^{2}6p. Parametric approximation of such amount of experimental data in one isoelectronic sequence by utilizing orthogonal operators [12–15] allowed us to predict parameters of the three configurations in Re V very accurately.

To avoid line misidentifications in the very dense rhenium spectra recorded, we were simultaneously making analyses of the Re V, Re IV and Re III spectra using the same sets of spectrograms containing spectra photographed under different source conditions. Such approach was helpful as arrays of spectral lines belonging to different Re ions were overlapping, and it was difficult to distinguish lines belonging to ions of close ionization stages. Spectral line identification, determination of levels and optimization of level energies were made by using the program suite IDEN [16–18]. The final level uncertainties and uncertainties of the Ritz wavelengths presented here were calculated by the program LOPT [23].

In the region of (597–2053) Å, we have identified 398 spectral lines belonging to the (5d^3 + 5d^{2}6s)–5d^{2}6p transition array of Re V. Three spectral lines are doubly classified. We have removed 74 previously published Re V spectral lines as incorrectly identified. There were several reasons for that: (a) a level related to a transition has been removed or its position has been changed; (b) another line has been chosen for a transition; (c) the line is weak and too far from the expected position; (d) based on the calculated transition probability, the line should not be observed. We have identified 90 new Re V spectral lines. Comparing with the previous analysis [1], the current study is based on significantly more accurate wavelength measurements. Our list of identified Re V lines shows standard deviations of isolated lines from the calculated (Ritz) positions of less than 0.005 Å, 0.003 Å, 0.005 Å and 0.007 Å for the regions of (597–628) Å, (628–1031) Å, (1045–1563) Å and (1569–2053) Å, respectively. The percentages of the numbers of classified lines in those regions are the following: 2%, 60%, 32% and 6%. Thus, comparing with the previous analysis, in the current study, the standard deviations (by regions) of the undisturbed isolated lines from their Ritz positions are three to five times smaller and the largest deviation of strong isolated lines from their Ritz positions is about seven times smaller: 9 mÅ vs. 68 mÅ.

Some weak lines from the old linelist were used in the current analysis, as they did not appear on our spectrograms. In the region of (597.0–628.1) Å, all lines presented here are from the old linelist used in Ref. [1]. In the region of (628.3–692.3) Å we have added some lines from the old linelist. They are marked as "old" in the table of classified lines.

As was stated above, the previously identified 5d^{2}6s levels at 115409.0 cm^{-1} (J = 1/2) and 78134.0 cm^{-1} (J = 1/2) are deviating abnormally from the calculated position by more than 370 and 80 cm^{-1}, and therefore have to be examined. In the previous analysis, the level 5d^{2}6s (^{3}P)^{4}P$_{1/2}$ at 78134.0 cm^{-1} was determined by five lines. We have determined this level at a new position (78208.65 cm^{-1}) by using six spectral lines. In Table A we compare these two choices by giving calculated probabilities (gA) of the corresponding transitions and newly observed intensities (*Int*) of the lines. We have to note that the line at 1521.6351 Å (147) is stronger than expected. It is explained by the fact that the line has a contribution from an identified transition in Re IV. As can be seen, the new choice has better gA vs. *Int* agreement. For the old level position, deviations of the old experimental wavenumbers

Table A

Comparison of the old and new determinations of the level $5d^2 6s$ $(^3P)^4P_{1/2}$.

λ_{old} (Å) (Ref. [1])	1125.625	1149.079	1210.321	1212.778	-	-	1589.941
Int_{old}	115	5	400	335	-	-	90
gA (10^7 s^{-1})	26	131	497	30	48	27	131
Int_{new}	-	289	459	32	25	147	217
λ_{new} (Å)	-	1150.1144	1211.5432	1213.9989	1411.6021	1521.6351	1591.9980

from the corresponding Ritz values are the following (cm^{-1}): 0.8, 1.0, 1.8, 0.9, 1.1 (see Table 1 of Ref. [1]). These deviations have a systematic part of 1.12 cm^{-1} and a random part of 0.35 cm^{-1}. Obviously, the level had not been set correctly. It had to be shifted. For our new level position, the standard deviation of the six new experimental lines determining the level is 0.26 cm^{-1} with no systematic component (see the table of classified lines below). In addition, the lines at 1210.321 Å, 1212.778 Å, 1589.941 Å used in the previous analysis are identified as Re III lines.

We could not confirm the previously established level $5d^2 6s$ $(^1S)^2S_{1/2}$ at 115409.0 cm^{-1}. It is too far from the calculated position and the identified lines do not match predicted intensities. The strongest transitions to the level have the following gA values (10^7 s^{-1}): 728, 184, 22. For comparison, two identified transitions from the same upper levels as for the first two of the three above-mentioned transitions have the following gA values (10^7 s^{-1}): 2268, 1860. Lines observed in the current study for these two transitions are at 698.7671 Å (408) and 760.7633 Å (474), where intensities are given in parentheses. Thus, line intensities for the three strongest transitions to the level $5d^2 6s$ $(^1S)^2S_{1/2}$ should be about 150, 40, 5. In the previous analysis, the lines at 1247.3758 Å (1337), 1473.0047 Å (350) and 1792.7958 Å (1260) had been chosen for those three transitions. These lines are much stronger than expected. Besides, the first line belongs to C III and the second line is attributed to Re III.

The previously identified second highest odd level $5d^2 6p$ $(^1S)^2P_{1/2}$ at 183296.0 cm^{-1} was based on three lines at 761.9805 Å (821), 1191.1209 Å (115), 1473.0047 Å (350) (lines are from the new list). The strongest of these three lines has also been identified as a transition from the level $5d^2 6p$ $(^3F)^4F_{3/2}$ at 131239.2 cm^{-1}. Our calculations show that gA values (10^7 s^{-1}) for the three transitions from the level $5d^2 6p$ $(^1S)^2P_{1/2}$ are 1860, 86, 184. The gA value (10^7 s^{-1}) of the mentioned transition from the level at 131239.2 cm^{-1}, which is the second lowest level in the $5d^2 6p$ configuration, is 2515. If the level at 183296.0 cm^{-1} is correct, intensity of the line at 761.9805 Å should have contribution from the transition from this level of less than 50%. Since this line is not saturated, we should expect the following line intensities for the three transitions: 400, 20, 40. Therefore, the lines at 1191.1209 Å (115) and 1473.0047 Å (350) are too strong for the assigned in Ref. [1] transitions. Also, we have identified these two lines with transitions in Re III. Based on the given facts, we consider the published level $5d^2 6p$ $(^1S)^2P_{1/2}$ at 183296.0 cm^{-1} as doubtful and have re-established it at 183498.82 cm^{-1}, 202.82 cm^{-1} higher than in the previous work. It is based on a single line at 760.7633 Å (476), which is the only strong unidentified line in the vicinity and has a perfectly matching intensity. In analyses of Os VI, Ir VII and Pt VIII spectra this level is also based on one strong/moderate intensity line, although in Pt VIII and Os VI it is supported by one and two additional weak lines, respectively.

We have established the level $5d^2 6s$ $(^3P)^4P_{5/2}$ at 82122.71 cm^{-1}. It was missing in the previous analysis [1]. The level is based on 13 newly identified lines. It is one of the most accurately determined levels (see rwmv$_1$, rwmv$_2$ and Unc values in Table 2).

The list of identified spectral lines is presented in Table 1. Transition probabilities (gA) have been calculated from the final fitted parameters of the investigated configurations. Intensities

of the spectral lines (Int) have been obtained by measuring the plate darkening. The optical density was converted to spectral intensity and the spectral background approximated by a spline curve was subtracted. For isolated, unperturbed and unsaturated lines originating from the same upper level or from close upper levels, agreement between gA and Int is good. Taking into account the Boltzmann factor, describing the decrease of population for levels with increasing energy, agreement between the presented gA and Int is good throughout the entire list. In each case when the intensity of an identified spectral line is notably higher than expected, the expected value is given in Table 1. Uncertainties of the Ritz wavelengths, Unc λ_{calc}, differences between the measured and Ritz wavelengths and wavenumbers, $\Delta(\lambda)$ and $\Delta(\nu)$, as well as the numbers of observed transitions used to determine the odd and even level involved in the particular transition, N_{odd} and N_{even}, are included in the table. Due to strong mixing of the $5d^2 6p$ levels, their labels in the LS-coupling scheme are omitted in Table 1. For each transition, we include a label of the linelist part (pa–pi) used to specify the wavelength uncertainty (see Table B), the symbol "∗" for transitions that were not used in the LOP, the symbol "old" for the lines taken from the old linelist used in the previous analysis, expected line intensity (where appropriate, derived from the gA and Int comparison), and comments for masked and blended lines, and for lines that are also identified as belonging to another ion or impurity. Transitions attributed to lines that are masked, much stronger than expected, have suspiciously large deviations $\Delta(\lambda)$, or have small gA values, for which chances of wrong identification increase, were excluded from the LOP. If a known line of another ion or impurity blends the line, we specify the blending spectrum in parentheses following the "bl" symbol. If the line is also identified with a transition in another ion but does not appear as a blend in the spectrogram, we do not give the "bl" symbol, although blending is possible due to a near coincidence of wavelengths. In addition, if the line is also identified with another Re ion (e.g., Re IV) and, when using the same linelist, the expected intensity of that identification (e.g., 100) is lower than the observed line intensity, we give "Re IV (100)".

It should be noted that we used three sets of plates. They may have been obtained under somewhat different experimental conditions. Parts pc–pe and pf–pi (see Table B) correspond to two plates from the same set (same exposure). The parts pa and pb correspond to plates from different sets (exposures). Part pa contains lines from the old linelist. This information is needed for correct comparison of the presented gA and Int values accounting for the Boltzmann factor, $e^{-E/kT}$. Different exposures may have different kT values.

In Tables 2 and 3 we present experimental and calculated energy values of the even parity levels in the $5d^3$ and $5d^2 6s$ configurations and the odd parity levels in the $5d^2 6p$ configuration of Re V, respectively. The uncertainties of the levels, Unc, are given with respect to the "base" even level $5d^2 6s$ $(^3F)^2F_{5/2}$ at 77994.60 cm^{-1} (see below in the text). Uncertainty of excitation energy for any level can be estimated by combining in quadrature the given uncertainty with the uncertainty of the ground level, 0.30 cm^{-1}.

Based on the new wavelength measurements and the use of the accurate level optimization procedure, we have corrected positions of all previously established $5d^3$, $5d^2 6s$ and $5d^2 6p$ energy levels,

Table B
Description of linelist parts.

Linelist part	Final estimated uncertainty, mÅ	Resulting rms, mÅ	Number of lines used in LOP	Wavelength range, Å
pa	6.0	4.8	6	597.0– 628.1
pb	4.0	2.6	191	628.3–1031.0
pc	5.0	3.2	33	1031.2–1229.9
pd	7.0	4.8	25	1230.0–1295.0
pe	6.0	4.9	43	1295.1–1554.2
pf	9.0	4.1	1	1559.0–1564.9
pg	7.0	6.7	10	1565.0–1634.9
ph	6.0	4.8	10	1635.0–1934.9
pi	9.0	–	–	1935.0–2074.0

except for the ground level, rejected and newly established levels. Odd levels have been shifted by the values ranging from -1.13 to -8.31 cm^{-1}; even levels have been corrected by the values ranging from 1.76 to -7.6 cm^{-1} (see, for instance, old levels at 149058.0 and 160589.0 cm^{-1}). From the 19, 16 and 45 theoretically possible levels of the configurations $5d^3$, $5d^26s$ and $5d^26p$, respectively, only the level $5d^26s$ (^{1}S)^{2}S$_{1/2}$ remains not established.

We have divided the list of experimental lines into nine parts, pa–pi (see Table 1, last column), and assigned to them initial estimated uncertainties. The assigned uncertainties were based on the available standards, distribution of the standards around the wavelength interpolation curve, and the expected increased uncertainty near ends of the plates. After correction of local systematic deviations (LSD, see Refs. [18] and [19]) in the linelist and after the final LOP run, for each part, we have calculated the root-mean-square (rms) deviation of wavelengths of the experimental lines used in the LOP from their calculated (Ritz) positions. They are presented in Table B, where for each linelist part the number of lines used in the LOP is also given. In the part pi we have only one identified spectral line at 2052.8941 Å. It was not used in the LOP; it has an uncertainty of 0.009 Å and a deviation of -0.0094 Å. The final estimated uncertainties of wavelength measurements, which were used in the final LOP run, for the rwmv$_1$ and rwmv$_2$ calculations, and in the program LOPT [23], are also included in Table B. These are square root values of combinations of squares of the statistical and systematic uncertainties, where the latter were estimated from standard deviations of wavelengths of reference lines from their positions derived from the calibration curves. We have found that the optimized level values given by the IDEN's LOP and those given by the program LOPT are in very good agreement: they differ by a small fraction of calculated level uncertainties.

Comparison of the values of rwmv$_1$ and rwmv$_2$ in Tables 2 and 3 shows consistency (see "reliability check" above and Ref. [18] for details). For the even system having 34 established levels, rwmv$_1$ $\geq$ rwmv$_2$ for all but one level. The remaining level at 85741.64 cm^{-1} ($J = 3/2$) has very close rwmv$_1$ and rwmv$_2$ values: 0.10 cm^{-1} and 0.11 cm^{-1}, respectively. In the odd system, 42 of 45 levels have rwmv$_1$ $\geq$ rwmv$_2$. Two levels at 171185.93 cm^{-1} ($J = 1/2$) and 144946.32 cm^{-1} ($J = 1/2$) have rwmv$_2$ larger than rwmv$_1$, but within 8%. The level at 156212.54 cm^{-1} ($J = 3/2$) has the rwmv$_2$ value 45% larger than rwmv$_1$ value, but within the level uncertainty of 0.030 cm^{-1}. This level is determined by 10 transitions, with 5 being used in the LOP. One of these lines at 1278.4683 Å (618) is about three times stronger than expected and deviates by 0.0109 Å from the Ritz position. This somewhat large deviation has affected the rwmv$_2$ value of the level. Probably the line has a contribution from another, yet unclassified transition in Re IV or Re III. The uncertainty of the wavelength measurement of the line is 0.007 Å (part pd), therefore the line deviation is acceptable. We consider the line as identified correctly. Thus, the level has passed the reliability check and is considered to be correct

with acceptable deviations of identified spectral lines from the calculated positions.

As can be seen from the comparison of the values of N, N_{opt}, rwmv$_1$, and rwmv$_2$ (see Tables 2 and 3), the most accurately determined level is $5d^26s$ (^{3}F)^{2}F$_{5/2}$ at 77994.60 cm^{-1}. It is one of the levels with the smallest rwmv$_1$ (0.08 cm^{-1}), with rwmv$_1$ $>$ rwmv$_2$ (0.08 cm^{-1} $>$ 0.06 cm^{-1}), and with the largest number of higher accuracy $5d^26s$–$5d^26p$ transitions used in the LOP (N_{opt} = 13). This level has been chosen to be the "base" in the current presentation of the analysis.

4. Calculations

The theoretical description and least squares fitting (LSF) of the configurations are given in the frame of the orthogonal operators approach. Tables 4 and 5 present the parameters obtained (or kept fixed) in the calculations for the even and odd systems. The parameter values were obtained in the final LSF. The *ab initio* values of the parameters were calculated using the Hartree–Fock method with relativistic correction (HFR) implemented in the code developed by Cowan [24]. For the orthogonal electrostatic parameters, the a*b initio* (HFR) values were calculated (see Ref. [8]) from the Slater parameters given by the Cowan code. The obtained (or predetermined for fixed parameters) scaling factors (LSF/HFR) are also given in Tables 4 and 5. The values of the fixed parameters $A_c \ldots A_0$ and $Z^2_{pp'} \ldots Z^3_{dd'}$ were estimated from the MCDF [25] calculations and the values obtained in the given and neighboring ions.

In both the even and odd parity systems, three configurations were included in the calculations: $(5d^3 + 5d^26s + 5d6s^2)$ and $(5d^26p + 5d6s6p + 6s^26p)$. Interaction between the configurations was added explicitly. The interaction integrals, parameters of unknown configurations and some parameters of the studied configurations were kept fixed at the predetermined values.

As can be seen from Tables 4 and 5, the scaling factors for the strong electrostatic core operators O_2, O_2' and spin–orbit interaction parameter ζ_d for the $5d^3$, $5d^26s$ and $5d^26p$ configurations are close to each other. These factors, as well as the value of the scaling factor for the electrostatic operator C_{ds}, are in agreement with those obtained in Os VI, Ir VII, Pt VIII spectra [8,9,6]. The parameters of the 2-particle magnetic interaction (spin–orbit effect) of the ds-type (A_{mso}) and 3-particle electrostatic T_{dds} interaction in the $5d^26s$ configuration are well defined with small uncertainty. These high order parameters are very important as they improve the fit of the $5d^26s$ configuration considerably. These values are in agreement with those obtained in the neighboring ions in the sequence. For Re V, Os VI, Ir VII and Pt VIII spectra, the parameter A_{mso} has the following values (cm^{-1}, uncertainties are given in parentheses): 43.9(3.3), 43.5(2.3), 49.9(3.6) and 50.1(3.9). The values of the parameter T_{dds} in the sequence are as follows (cm^{-1}): $-19.6(4.5)$, $-22.3(4.4)$, $-27.3(5.0)$ and $-38.3(6.5)$. The trends of the parameters in the $5d^26s$ configuration are in agreement with

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those obtained in the $5d^8 6s$ and $5d^7 6s$ [12,26] configurations. The mean deviations of the fits for the even and odd systems in Re V are 13.1 cm^{-1} and 101 cm^{-1}, respectively, in agreement with the values in Os VI [8] (10.7 and 107 cm^{-1}), in Ir VII [9] (13 and 108 cm^{-1}), and in Pt VIII [6] (13.8 and 116 cm^{-1}).

Acknowledgments

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Explanation of Tables

Table 1.	**Classified lines in the $(5d^3 + 5d^26s) - 5d^26p$ transition array of Re V**	
	gA	Weighted transition probability (10^7 s^{-1}; g is the statistical weight of the upper level)
	Int	Intensity of the experimental spectral line (arbitrary units)
	λ	Wavelength of the experimental spectral line (Å) in vacuum (or in air, if the symbol "a" is present behind the value)
	ν	Wavenumber of the experimental spectral line (cm^{-1})
	λ_{calc}	Calculated (Ritz) wavelength (Å) in vacuum
	Unc λ_{calc}	Uncertainty of the calculated (Ritz) wavelength (Å)
	$\Delta(\nu)$	Difference between the experimental and Ritz wavenumbers (cm^{-1})
	$\Delta(\lambda)$	Difference between the experimental and Ritz wavelengths (Å)
	N_{odd}	Number of observed transitions used to determine the odd level involved in the transition
	N_{even}	Number of observed transitions used to determine the even level involved in the transition
	Even level	Experimental energy value (cm^{-1}), configuration, LS-term an J-value of the even level involved in the transition
	Odd level	Experimental energy value (cm^{-1}) and J-value (in parentheses) of the odd level involved in the transition
	Remark	Remarks for the identified transitions:
		old The line is from the linelist used in the previous analysis
		m The Re V line is masked by some other line
		200 Expected intensity value is 200
		bl The line is blended by a close line
		* The transition has been excluded from the LOP
		pa–pi Parts of the linelist with assigned wavelength uncertainties (see text, Table B)
		Re IV (without "bl") The line is also identified as Re IV line. The line does not appear as a blend in the spectrogram, but blending is possible due to a near coincidence of wavelengths
		Re IV (400) The line is also identified as Re IV line with expected intensity 400
Table 2.	**Experimental and calculated energy levels (cm^{-1}) in the $5d^3$ and $5d^26s$ configurations of Re V**	
	E_{obs}	Observed (experimental) energy value (cm^{-1})
	E_{calc}	Calculated from the least squares fitting (LSF) energy value (cm^{-1})
	Δ	Difference between the observed and calculated energy values, $E_{obs} - E_{calc}$ (cm^{-1})
	N	Number of transitions used to identify the energy level
	N_{opt}	Number of transitions to the level used in the LOP and WMV calculations for the level (see text)
	rwmv$_1$	Square root of the weighted mean variance given by Eq. (7) of Ref. [18] (cm^{-1})
	rwmv$_2$	Square root of the weighted mean variance given by Eq. (8) of Ref. [18] (cm^{-1}) except for the levels determined by a single line (see text)
	Unc	Uncertainty of the level (cm^{-1}) with respect to the "base" even level with $J = 5/2$ at 77994.60 cm^{-1} (see text)
	Composition	LS-composition of the level. The number preceding the symbol "|" and the term name has the following meaning: 1 stands for $5d^3$ and 2 stands for $5d^26s$.
Table 3.	**Experimental and calculated energy levels (cm^{-1}) in the $5d^26p$ configuration of Re V**	
	E_{obs}	Observed (experimental) energy value (cm^{-1})
	E_{calc}	Calculated from the least squares fitting (LSF) energy value (cm^{-1})
	Δ	Difference between the observed and calculated energy values, $E_{obs} - E_{calc}$ (cm^{-1})
	N	Number of transitions used to identify the energy level
	N_{opt}	Number of transitions from the level used in the LOP and WMV calculations for the level (see text)
	rwmv$_1$	Square root of the weighted mean variance given by Eq. (7) of Ref. [18] (cm^{-1})
	rwmv$_2$	Square root of the weighted mean variance given by Eq. (8) of Ref. [18] (cm^{-1}) except for the levels determined by a single line (see text)
	Unc	Uncertainty of the level (cm^{-1}) with respect to the "base" even level with $J = 5/2$ at 77994.60 cm^{-1} (see text)
	Composition	LS-composition of the level.
Table 4.	**Fitted and calculated parameter values (cm^{-1}) in the $5d^3$, $5d^26s$ and $5d6s^2$ configurations of Re V**	
	Parameter	Parameter name
	Fitted value	Parameter value (cm^{-1}) obtained in the final least squares fitting (LSF)
		Uncertainty of the fit (cm^{-1}) is given in parentheses
	HFR	*Ab initio* value (cm^{-1}) of the parameter. It was calculated using the Hartree–Fock method with relativistic correction (HFR) implemented in the code developed by Cowan [24]
	Fitted/HFR	Obtained (or predetermined for fixed parameters) scaling factors
Table 5.	**Fitted and calculated parameter values (cm^{-1}) in the $5d^26p$, $5d6s6p$ and $6s^26p$ configurations of Re V**	
	Parameter	Parameter name
	Fitted value	Parameter value (cm^{-1}) obtained in the final least squares fitting (LSF)
		Uncertainty of the fit (cm^{-1}) is given in parentheses
	HFR	*Ab initio* value (cm^{-1}) of the parameter. It was calculated using the Hartree–Fock method with relativistic correction (HFR) implemented in the code developed by Cowan [24]
	Fitted/HFR	Obtained (or predetermined for fixed parameters) scaling factors

Table 1
Classified lines in the (5d³ + 5d²6s)–5d²6p transition array of Re V.

gA (10⁷ s⁻¹)	Int	λ (Å)	ν (cm⁻¹)	λcalc (Å)	Unc λcalc (Å)	Δ(ν) (cm⁻¹)	Δ(λ) (Å)	N_odd	N_even	Even level (cm⁻¹)		Odd level (cm⁻¹)	Remark
68	80	597.5911	167338.50	597.6030	0.0014	3.33	−0.0119	10	14	5d³ ⁴F₃/₂	0.00	167335.17(3/2)	pa *
90	11	612.8916	163160.99	612.8914	0.0012	−0.07	0.0002	15	17	5d³ ⁴F₅/₂	4852.98	168014.04(5/2)	pa *
175	23	614.2167	162808.99	614.2154	0.0023	−0.36	0.0013	3	13	5d³ ²P₃/₂	32766.42	195575.77(3/2)	pa
61	7	614.3801	162765.69	614.3777	0.0012	−0.63	0.0024	8	18	5d³ ⁴F₇/₂	8972.90	171739.22(7/2)	pa
33	5	615.4588	162480.41	615.4521	0.0015	−1.78	0.0067	10	17	5d³ ⁴F₅/₂	4852.98	167335.17(3/2)	pa *
70	20	622.1002	160745.81	622.0903	0.0014	−2.56	0.0099	7	14	5d³ ⁴F₃/₂	0.00	160748.37(3/2)	pa *
45	12	623.8089	160305.50	623.8155	0.0014	1.69	−0.0066	7	17	5d³ ⁴F₅/₂	4852.98	165156.79(3/2)	pa
131	30	625.6808	159825.91	625.6830	0.0013	0.55	−0.0022	8	13	5d³ ⁴F₉/₂	11913.86	171739.22(7/2)	pa
12	6	626.1012	159718.59	626.1011	0.0011	−0.02	0.0001	9	18	5d³ ⁴F₇/₂	8972.90	168691.51(9/2)	pa *
8	5	626.6732	159572.80	626.6767	0.0012	0.89	−0.0035	14	17	5d³ ⁴F₅/₂	4852.98	164424.89(7/2)	pa *
174	10	628.0117	159232.70	628.0192	0.0013	1.91	−0.0075	9	16	5d³ ²G₇/₂	19012.90	178243.69(5/2)	pa
111	27	628.0756	159216.50	628.0806	0.0012	1.26	−0.0050	10	17	5d³ ⁴F₅/₂	4852.98	164068.22(5/2)	pa
210	110	628.7633	159042.36	628.7682	0.0011	1.22	−0.0049	15	18	5d³ ⁴F₇/₂	8972.90	168014.04(5/2)	pb
88	13	640.1442	156214.80	640.1535	0.0013	2.26	−0.0093	10	14	5d³ ⁴F₃/₂	0.00	156212.54(3/2)	pb * old
39	5	641.4492	155896.99	641.4558	0.0015	1.60	−0.0066	7	17	5d³ ⁴F₅/₂	4852.98	160748.37(3/2)	pb * old
262	28	643.2828	155452.63	643.2854	0.0011	0.64	−0.0026	14	18	5d³ ⁴F₇/₂	8972.90	164424.89(7/2)	pb
217	20	644.7690	155094.31	644.7648	0.0012	−1.01	0.0042	10	18	5d³ ⁴F₇/₂	8972.90	164068.22(5/2)	pb *
104	10	644.9774	155044.19	644.9853	0.0014	1.91	−0.0079	9	12	5d³ ²D2₃/₂	23201.41	178243.69(5/2)	pb * old
53	10	645.4403	154933.00	645.4424	0.0015	0.51	−0.0021	10	13	5d³ ⁴P₃/₂	12402.68	167335.17(3/2)	pb * old
302	26	646.3543	154713.91	646.3610	0.0012	1.60	−0.0067	15	16	5d³ ²G₇/₂	19012.90	173725.21(5/2)	pb * old
215	20	647.7955	154369.71	647.8017	0.0011	1.49	−0.0062	9	18	5d³ ⁴F₇/₂	8972.90	163341.12(9/2)	pb * old
374	31	648.7047	154153.35	648.7029	0.0012	−0.42	0.0018	8	14	5d³ ²H₉/₂	19966.76	174120.53(7/2)	pb
28	10	650.0514	153833.99	650.0579	0.0012	1.54	−0.0065	16	14	5d³ ⁴F₃/₂	0.00	153832.45(5/2)	pb * old
170	22	652.7381	153200.80	652.7480	0.0012	2.33	−0.0099	8	16	5d³ ⁴P₅/₂	20922.06	174120.53(7/2)	pb * old
154	21	654.4276	152805.29	654.4367	0.0012	2.14	−0.0091	15	16	5d³ ⁴P₅/₂	20922.06	173725.21(5/2)	pb * old
316	32	655.3153	152598.30	655.3255	0.0023	2.39	−0.0102	3	14	5d³ ²H₉/₂	19966.76	172562.67(11/2)	pb * old
670	176	655.6877	152511.63	655.6903	0.0012	0.60	−0.0026	14	13	5d³ ⁴F₉/₂	11913.86	164424.89(7/2)	pb
143	19	656.6054	152298.47	656.6019	0.0013	−0.81	0.0035	11	17	5d³ ⁴F₅/₂	4852.98	157152.26(5/2)	pb
302	31	658.8874	151771.00	658.8811	0.0014	−1.46	0.0063	8	14	5d³ ²H₉/₂	19966.76	171739.22(7/2)	pb
167	24	659.3427	151666.20	659.3456	0.0012	0.66	−0.0029	10	13	5d³ ⁴P₃/₂	12402.68	164068.22(5/2)	pb * old
631	93	660.3838	151427.09	660.3831	0.0012	−0.17	0.0007	9	13	5d³ ⁴F₉/₂	11913.86	163341.12(9/2)	pb
175	29	660.6805	151359.09	660.6785	0.0014	−0.47	0.0020	10	17	5d³ ⁴F₅/₂	4852.98	156212.54(3/2)	pb * old
75	28	663.0007	150829.40	662.9920	0.0015	−1.97	0.0087	7	9	5d³ ⁴P₁/₂	14325.42	165156.79(3/2)	pb *
144	35	664.3477	150523.59	664.3468	0.0012	−0.21	0.0009	5	12	5d³ ²D2₃/₂	23201.41	173725.21(5/2)	pb
53	25	668.0901	149680.41	668.0981	0.0013	1.80	−0.0080	9	16	5d³ ²G₇/₂	19012.90	168691.51(9/2)	pb * old
107	15	668.8833	149502.91	668.8743	0.0014	−2.00	0.0090	9	18	5d³ ²D2₅/₂	28738.78	178243.69(5/2)	pb * old
180	35	670.9181	149049.49	670.9158	0.0017	−0.50	0.0023	6	14	5d³ ⁴F₃/₂	0.00	149049.99(1/2)	pb old
69	20	671.1310	149002.21	671.1358	0.0013	1.07	−0.0048	15	16	5d³ ²G₇/₂	19012.90	168014.04(5/2)	pb * old
39	13	671.2337	148979.41	671.2335	0.0013	−0.06	0.0002	16	17	5d³ ⁴F₅/₂	4852.98	153832.45(5/2)	pb * old
146	12	672.3778	148725.91	672.3830	0.0013	1.16	−0.0052	9	14	5d³ ²H₉/₂	19966.76	168691.51(9/2)	pb * old
292	51	673.6660	148441.51	673.6654	0.0013	−0.15	0.0006	12	17	5d³ ⁴F₅/₂	4852.98	153294.64(7/2)	pb
420	78	674.8565	148179.65	674.8578	0.0012	0.29	−0.0013	11	18	5d³ ⁴F₇/₂	8972.90	157152.26(5/2)	pb
184	58	675.0155	148144.75	675.0191	0.0014	0.80	−0.0036	11	14	5d³ ⁴F₃/₂	0.00	148143.95(3/2)	pb
561	124	675.7462	147984.55	675.7464	0.0021	0.03	−0.0002	5	12	5d³ ²D2₃/₂	23201.41	171185.93(1/2)	pb
80	27	677.8880	147516.99	677.8846	0.0013	−0.74	0.0034	11	18	5d³ ⁴F₇/₂	8972.90	156490.63(9/2)	pb * old
69	27	677.8880	147516.99	677.8876	0.0030	−0.09	0.0004	5	7	5d³ ²P₁/₂	23668.85	171185.93(1/2)	pb * old
139	18	679.8409	147093.24	679.8467	0.0013	1.26	−0.0058	15	16	5d³ ⁴P₅/₂	20922.06	168014.04(5/2)	pb *
429	205	682.0146	146624.43	682.0129	0.0012	−0.37	0.0017	13	18	5d³ ⁴F₇/₂	8972.90	155597.70(7/2)	pb
433	141	682.4620	146528.31	682.4587	0.0013	−0.70	0.0033	12	13	5d³ ⁴F₉/₂	11913.86	158442.87(7/2)	pb
174	20	682.9981	146413.29	682.9989	0.0016	0.18	−0.0008	10	16	5d³ ⁴P₅/₂	20922.06	167335.17(3/2)	pb *
893	618	686.2718	145714.86	686.2695	0.0017	−0.49	0.0023	5	13	5d³ ⁴F₉/₂	11913.86	157629.21(11/2)	pb
4115	1303	687.3405	145488.30	687.3523	0.0030	2.50	−0.0118	3	6	5d³ ²H₁₁/₂	27076.87	172562.67(11/2)	pb * 900, bl(C II)
81	58	687.7099	145410.15	687.7012	0.0013	−1.84	0.0087	14	16	5d³ ²G₇/₂	19012.90	164424.89(7/2)	pb * 30
69	25	688.1782	145311.20	688.1792	0.0014	0.20	−0.0010	7	14	5d³ ⁴F₃/₂	0.00	145311.00(3/2)	pb old
133	26	689.3937	145055.00	689.3922	0.0014	−0.32	0.0015	10	16	5d³ ²G₇/₂	19012.90	164068.22(5/2)	pb * old
581	154	689.7176	144986.88	689.7197	0.0012	0.45	−0.0021	15	18	5d³ ²D2₅/₂	28738.78	173725.21(5/2)	pb
382	273	689.9102	144946.40	689.9106	0.0014	0.08	−0.0004	8	14	5d³ ⁴F₃/₂	0.00	144946.32(1/2)	pb
82	59	690.3260	144859.10	690.3239	0.0012	−0.45	0.0021	16	18	5d³ ⁴F₇/₂	8972.90	153832.45(5/2)	pb
204	70	690.5483	144812.46	690.5475	0.0014	−0.17	0.0008	15	12	5d³ ²D2₃/₂	23201.41	168014.04(5/2)	pb
840	395	691.6718	144577.24	691.6741	0.0014	0.47	−0.0023	11	13	5d³ ⁴F₉/₂	11913.86	156490.63(9/2)	pb
16	5	692.2327	144460.09	692.2421	0.0013	1.96	−0.0094	14	14	5d³ ²H₉/₂	19966.76	164424.89(7/2)	pb * old
1054	139	692.3867	144427.96	692.3908	0.0018	0.84	−0.0041	6	13	5d³ ²P₃/₂	32766.42	177193.54(3/2)	pb
700	356	692.8939	144322.24	692.8963	0.0012	0.50	−0.0024	12	18	5d³ ⁴F₇/₂	8972.90	153294.64(7/2)	pb
1374	375	694.0488	144082.09	694.0498	0.0014	0.21	−0.0010	9	17	5d³ ²F₅/₂	34161.81	178243.69(5/2)	pb
167	96	694.7973	143926.87	694.7942	0.0014	−0.64	0.0031	11	14	5d³ ⁴F₃/₂	0.00	143927.51(3/2)	pb
1703	463	695.6293	143754.73	695.6280	0.0015	−0.26	0.0013	8	10	5d³ ²G₉/₂	30365.54	174120.53(7/2)	pb
1102	534	695.9744	143683.45	695.9725	0.0013	−0.39	0.0019	13	13	5d³ ⁴F₉/₂	11913.86	155597.70(7/2)	pb
85	91	696.2881	143618.71	696.2894	0.0014	0.28	−0.0013	9	20	5d³ ²F₇/₂	34625.26	178243.69(5/2)	pb *
356	45	696.7502	143523.46	696.7482	0.0030	−0.42	0.0020	3	9	5d³ ²D1₃/₂	52051.89	195575.77(3/2)	pb
776	295	696.8497	143502.97	696.8503	0.0012	0.14	−0.0006	14	16	5d³ ⁴P₅/₂	20922.06	164424.89(7/2)	pb

Table 1 (*continued*)

gA (10⁷ s⁻¹)	Int	λ (Å)	v (cm⁻¹)	λcalc (Å)	Unc λcalc (Å)	Δ(v) (cm⁻¹)	Δ(λ) (Å)	N_{odd}	N_{even}	Even level (cm⁻¹)		Odd level (cm⁻¹)	Remark
191	159	696.9812	143475.89	696.9832	0.0013	0.41	−0.0020	11	14	5d³ ⁴F₃/₂	0.00	143475.48(5/2)	pb
323	102	697.4749	143374.34	697.4748	0.0013	−0.02	0.0001	9	14	5d³ ²H₉/₂	19966.76	163341.12(9/2)	pb
950	700	697.8808	143290.95	697.8807	0.0015	−0.02	0.0001	11	17	5d³ ⁴F₅/₂	4852.98	148143.95(3/2)	pb
1620	758	698.5876	143145.97	698.5867	0.0013	−0.19	0.0009	10	16	5d³ ⁴P₅/₂	20922.06	164068.22(5/2)	pb
2268	408	698.7671	143109.20	698.7696	0.0030	0.50	−0.0025	3	10	5d³ ²D1₅/₂	52467.07	195575.77(3/2)	pb
271	141	698.9079	143080.37	698.9094	0.0014	0.30	−0.0015	9	16	5d³ ²G₇/₂	19012.90	162092.97(5/2)	pb
375	92	699.1468	143031.48	699.1456	0.0017	−0.25	0.0012	6	17	5d³ ²F₅/₂	34161.81	177193.54(3/2)	pb
236	77	699.3007	143000.00	699.2986	0.0015	−0.44	0.0021	8	18	5d³ ²D₅/₂	28738.78	171739.22(7/2)	pb
59	46	699.7684	142904.42	699.7683	0.0014	−0.02	0.0001	10	18	5d³ ⁴F₇/₂	8972.90	151877.34(9/2)	pb
264	46	705.8900	141665.13	705.8921	0.0021	0.41	−0.0021	5	9	5d³ ⁴P₁/₂	14325.42	155990.14(3/2)	pb
1565	679	706.1431	141614.36	706.1416	0.0018	−0.28	0.0015	9	6	5d³ ²H₁₁/₂	27076.87	168691.51(9/2)	pb
303	184	707.0669	141429.33	707.0647	0.0012	−0.44	0.0022	16	13	5d³ ⁴P₃/₂	12402.68	153832.45(5/2)	pb
317	200	707.3103	141380.66	707.3098	0.0013	−0.12	0.0005	12	13	5d³ ⁴F₉/₂	11913.86	153294.64(7/2)	pb
7080	1126	707.3437	141373.99	707.3452	0.0017	0.31	−0.0015	8	10	5d³ ²G₉/₂	30365.54	171739.22(7/2)	pb
1388	918	709.1080	141022.24	709.1064	0.0017	−0.33	0.0016	6	14	5d³ ⁴F₃/₂	0.00	141022.57(1/2)	pb
201	56	709.4278	140958.67	709.4272	0.0014	−0.12	0.0006	15	13	5d³ ²P₃/₂	32766.42	173725.21(5/2)	pb
1634	897	711.9551	140458.30	711.9565	0.0015	0.28	−0.0014	7	17	5d³ ⁴F₅/₂	4852.98	145311.00(3/2)	pb
2850	874	714.4695	139963.99	714.4721	0.0015	0.51	−0.0026	10	13	5d³ ⁴F₉/₂	11913.86	151877.34(9/2)	pb
202	109	715.0544	139849.50	715.0530	0.0015	−0.28	0.0014	11	17	5d³ ⁴F₅/₂	4852.98	144702.76(7/2)	pb
2115	634	715.1727	139826.37	715.1730	0.0016	0.06	−0.0003	7	16	5d³ ⁴P₅/₂	20922.06	160748.37(3/2)	pb
307	36	716.5202	139563.41	716.5202	0.0011	0.01	0.0000	15	17	5d³ ²F₅/₂	34161.81	173725.21(5/2)	pb
1841	604	716.8667	139495.95	716.8702	0.0013	0.68	−0.0035	8	20	5d³ ²F₇/₂	34625.26	174120.53(7/2)	pb
321	8	718.0035	139275.09	718.0026	0.0013	−0.17	0.0009	15	18	5d³ ²D25/2	28738.78	168014.04(5/2)	pb
378	292	718.7805	139124.53	718.7817	0.0013	0.23	−0.0012	12	18	5d³ ⁴F₇/₂	8972.90	148097.20(7/2)	pb
989	506	718.9045	139100.53	718.9075	0.0012	0.58	−0.0030	15	20	5d³ ²F₇/₂	34625.26	173725.21(5/2)	pb
1085	769	719.0393	139074.46	719.0389	0.0015	−0.07	0.0004	11	17	5d³ ⁴F₅/₂	4852.98	143927.51(3/2)	pb
319	142	719.9823	138892.30	719.9861	0.0015	0.74	−0.0038	9	12	5d³ ²D2₃/₂	23201.41	162092.97(5/2)	pb
5148	927	720.5799	138777.12	720.5818	0.0013	0.37	−0.0019	12	18	5d³ ⁴F₇/₂	8972.90	147749.65(5/2)	pb
1842	937	721.3833	138622.56	721.3836	0.0014	0.06	−0.0003	11	17	5d³ ⁴F₅/₂	4852.98	143475.48(5/2)	pb
7699	916	722.1418	138476.96	722.1462	0.0015	0.85	−0.0044	12	14	5d³ ²H₉/₂	19966.76	158442.87(7/2)	pb
409	195	722.4462	138418.61	722.4415	0.0024	−0.90	0.0047	5	13	5d³ ²P₃/₂	32766.42	171185.93(1/2)	pb
4224	848	722.9328	138325.44	722.9300	0.0016	−0.53	0.0028	9	10	5d³ ²G₉/₂	30365.54	168691.51(9/2)	pb
4933	844	723.9051	138139.65	723.9066	0.0014	0.29	−0.0015	11	16	5d³ ²G₇/₂	19012.90	157152.26(5/2)	pb
189	80	726.4110	137663.11	726.4145	0.0019	0.66	−0.0035	5	14	5d³ ²H₉/₂	19966.76	157629.21(11/2)	pb
253	249	727.0686	137538.60	727.0690	0.0015	0.06	−0.0004	9	14	5d³ ⁴F₃/₂	0.00	137538.54(5/2)	pb
433	70	727.1635	137520.65	727.1627	0.0014	−0.16	0.0008	12	16	5d³ ⁴P₅/₂	20922.06	158442.87(7/2)	pb
259	26	727.3928	137477.30	727.3906	0.0015	−0.43	0.0022	11	16	5d³ ²G₇/₂	19012.90	156490.63(9/2)	pb
511	260	727.9152	137378.64	727.9118	0.0016	−0.64	0.0034	6	12	5d³ ²D2₃/₂	23201.41	160580.69(1/2)	pb
235	29	729.3203	137113.97	729.3203	0.0015	0.01	0.0000	8	20	5d³ ²F₇/₂	34625.26	171739.22(7/2)	pb
91	22	729.5044	137079.37	729.5035	0.0020	−0.15	0.0009	7	7	5d³ ²P₁/₂	23668.85	160748.37(3/2)	pb
894	438	730.3961	136912.01	730.3970	0.0019	0.17	−0.0009	7	7	5d³ ²P₁/₂	23668.85	160580.69(1/2)	pb
132	34	731.8060	136648.24	731.8110	0.0019	0.93	−0.0050	6	13	5d³ ⁴P₃/₂	12402.68	149049.99(1/2)	pb
4129	875	732.4679	136524.75	732.4726	0.0015	0.88	−0.0047	11	14	5d³ ²H₉/₂	19966.76	156490.63(9/2)	pb
2176	743	733.0416	136417.91	733.0410	0.0016	−0.10	0.0006	7	18	5d³ ²D2₅/₂	28738.78	165156.79(3/2)	pb
11612	1134	733.8657	136264.71	733.8682	0.0018	0.46	−0.0025	9	6	5d³ ²H₁₁/₂	27076.87	163341.12(9/2)	pb
5270	1051	734.3059	136183.03	734.3042	0.0014	−0.31	0.0017	12	13	5d³ ⁴F₉/₂	11913.86	148097.20(7/2)	pb
1117	834	736.7000	135740.46	736.6956	0.0014	−0.81	0.0044	11	13	5d³ ⁴P₃/₂	12402.68	148143.95(3/2)	pb
3659	1040	736.7591	135729.58	736.7576	0.0013	−0.28	0.0015	11	18	5d³ ⁴F₇/₂	8972.90	144702.76(7/2)	pb
314	41	736.9936	135686.39	736.9951	0.0013	0.28	−0.0015	14	18	5d³ ²D2₅/₂	28738.78	164424.89(7/2)	pb
1434	709	737.2960	135630.74	737.2949	0.0014	−0.20	0.0011	13	14	5d³ ²H₉/₂	19966.76	155597.70(7/2)	pb
432	63	738.9350	135329.90	738.9375	0.0014	0.46	−0.0025	10	18	5d³ ²D2₅/₂	28738.78	164068.22(5/2)	pb
457	68	739.3842	135247.68	739.3846	0.0016	0.06	−0.0004	15	13	5d³ ²P₃/₂	32766.42	168014.04(5/2)	pb
449	271	740.3686	135067.86	740.3674	0.0022	−0.22	0.0012	5	16	5d³ ⁴P₅/₂	20922.06	155990.14(3/2)	pb
713	590	741.7335	134819.31	741.7322	0.0014	−0.24	0.0013	16	16	5d³ ²G₇/₂	19012.90	153832.45(5/2)	pb
684	602	742.2545	134724.68	742.2551	0.0020	0.11	−0.0006	9	9	5d³ ⁴P₁/₂	14325.42	149049.99(1/2)	pb
73	28	742.5207	134676.38	742.5248	0.0014	0.74	−0.0041	13	16	5d³ ⁴P₅/₂	20922.06	155597.70(7/2)	pb
108	5	743.1205	134567.68	743.1146	0.0020	−1.07	0.0059	10	13	5d³ ²P₃/₂	32766.42	167335.17(3/2)	pb *
3823	1005	744.7024	134281.83	744.7029	0.0014	0.09	−0.0005	12	16	5d³ ²G₇/₂	19012.90	153294.64(7/2)	pb
1021	689	744.8390	134257.20	744.8366	0.0014	−0.44	0.0024	9	18	5d³ ⁴F₇/₂	8972.90	143230.54(9/2)	pb
1399	579	745.1508	134201.02	745.1512	0.0024	0.06	−0.0004	3	13	5d³ ²P₃/₂	32766.42	166967.38(1/2)	pb
674	322	745.9018	134065.91	745.8998	0.0013	−0.34	0.0020	9	20	5d³ ²F₇/₂	34625.26	168691.51(9/2)	pb
1470	628	745.9374	134059.51	745.9383	0.0016	0.16	−0.0009	14	10	5d³ ²G₉/₂	30365.54	164424.89(7/2)	pb
598	350	747.2838	133817.97	747.2806	0.0016	−0.56	0.0032	11	9	5d³ ⁴P₁/₂	14325.42	148143.95(3/2)	pb
3608	731	749.6871	133388.98	749.6882	0.0014	0.20	−0.0011	15	20	5d³ ²F₇/₂	34625.26	168014.04(5/2)	pb
1562	685	749.8823	133354.26	749.8827	0.0014	0.07	−0.0004	9	18	5d³ ²D2₅/₂	28738.78	162092.97(5/2)	pb
3400	834	750.9040	133172.82	750.9009	0.0017	−0.54	0.0031	10	17	5d³ ²F₅/₂	34161.81	167335.17(3/2)	pb
2857	926	751.8128	133011.84	751.8168	0.0016	0.71	−0.0040	10	12	5d³ ²D2₃/₂	23201.41	156212.54(3/2)	pb
1030	376	752.0170	132975.72	752.0177	0.0016	0.14	−0.0007	9	10	5d³ ²G₉/₂	30365.54	163341.12(9/2)	pb
1114	782	752.3976	132908.45	752.3984	0.0015	0.13	−0.0008	7	13	5d³ ⁴P₃/₂	12402.68	145311.00(3/2)	pb
222	78	752.6476	132864.31	752.6468	0.0016	−0.13	0.0008	10	16	5d³ ²G₇/₂	19012.90	151877.34(9/2)	pb
444	762	753.0739	132789.09	753.0750	0.0014	0.19	−0.0011	11	13	5d³ ⁴F₉/₂	11913.86	144702.76(7/2)	pb

Table 1 (*continued*)

gA (10⁷ s⁻¹)	Int	λ (Å)	ν (cm⁻¹)	λcalc (Å)	Unc λcalc (Å)	Δ(ν) (cm⁻¹)	Δ(λ) (Å)	N_{odd}	N_{even}	Even level (cm⁻¹)	Odd level (cm⁻¹)	Remark
2036	1000	753.6599	132685.84	753.6616	0.0016	0.28	−0.0017	9	17	5d³ ⁴F₅/₂ 4852.98	137538.54(5/2)	pb
809	814	754.4680	132543.73	754.4685	0.0014	0.09	−0.0005	8	13	5d³ ⁴P₃/₂ 12402.68	144946.32(1/2)	pb
581	146	755.3408	132390.57	755.3420	0.0018	0.20	−0.0012	7	13	5d³ ²P₃/₂ 32766.42	165156.79(3/2)	pb
1279	647	755.7327	132321.92	755.7363	0.0020	0.63	−0.0036	5	7	5d³ ²P₁/₂ 23668.85	155990.14(3/2)	pb
143	31	757.5150	132010.59	757.5207	0.0017	1.00	−0.0057	7	18	5d³ ²D2₅/₂ 28738.78	160748.37(3/2)	pb
72	22	758.0925	131910.02	758.0893	0.0016	−0.56	0.0032	10	14	5d³ ²H₉/₂ 19966.76	151877.34(9/2)	pb
237	162	760.3136	131524.68	760.3127	0.0015	−0.15	0.0009	11	13	5d³ ⁴P₃/₂ 12402.68	143927.51(3/2)	pb
1860	476	760.7633	131446.93	760.7633	0.0040	0.00	0.0000	1	9	5d³ ²D1₃/₂ 52051.89	183498.82(1/2)	pb
2383	817	761.5173	131316.78	761.5179	0.0015	0.10	−0.0006	9	13	5d³ ⁴F₉/₂ 11913.86	143230.54(9/2)	pb
2515	821	761.9805	131236.95	761.9828	0.0016	0.39	−0.0023	9	14	5d³ ⁴F₃/₂ 0.00	131236.56(3/2)	pb
237	298	762.9376	131072.32	762.9348	0.0014	−0.48	0.0028	11	13	5d³ ⁴P₃/₂ 12402.68	143475.48(5/2)	pb
886	836	763.0474	131053.46	763.0455	0.0016	−0.33	0.0019	10	17	5d³ ⁴F₅/₂ 4852.98	135906.77(7/2)	pb
301	144	763.3829	130995.86	763.3880	0.0016	0.88	−0.0051	7	17	5d³ ²F₅/₂ 34161.81	165156.79(3/2)	pb
285	170	763.4410	130985.89	763.4428	0.0017	0.31	−0.0018	7	9	5d³ ⁴P₁/₂ 14325.42	145311.00(3/2)	pb
834	560	765.5119	130631.54	765.5149	0.0014	0.50	−0.0030	16	12	5d³ ²D2₃/₂ 23201.41	153832.45(5/2)	pb
53	34	765.5778	130620.30	765.5743	0.0016	−0.60	0.0035	8	9	5d³ ⁴P₁/₂ 14325.42	144946.32(1/2)	pb
235	214	765.9765	130552.31	765.9763	0.0023	−0.03	0.0002	5	6	5d³ ²H₁₁/₂ 27076.87	157629.21(11/2)	pb
1828	838	770.4142	129800.31	770.4182	0.0013	0.68	−0.0040	14	20	5d³ ²F₇/₂ 34625.26	164424.89(7/2)	pb
418	108	770.9890	129703.54	770.9857	0.0015	−0.55	0.0033	12	18	5d³ ²D2₅/₂ 28738.78	158442.87(7/2)	pb
621	679	771.5932	129601.97	771.5925	0.0016	−0.12	0.0007	11	9	5d³ ⁴P₁/₂ 14325.42	143927.51(3/2)	pb
221	46	772.5400	129443.14	772.5410	0.0014	0.18	−0.0010	11	20	5d³ ²F₇/₂ 34625.26	164068.22(5/2)	pb
1284	720	772.7125	129414.24	772.7153	0.0020	0.48	−0.0028	11	6	5d³ ²H₁₁/₂ 27076.87	156490.63(9/2)	pb
844	504	773.2361	129326.61	773.2364	0.0017	0.06	−0.0003	9	13	5d³ ²P₃/₂ 32766.42	162092.97(5/2)	pb
346	139	774.6894	129083.99	774.6876	0.0015	−0.31	0.0018	12	16	5d³ ²G₇/₂ 19012.90	148097.20(7/2)	pb
645	584	776.7793	128736.70	776.7790	0.0015	−0.05	0.0003	12	16	5d³ ²G₇/₂ 19012.90	147749.65(5/2)	pb
44	21	777.4812	128620.47	777.4847	0.0019	0.58	−0.0035	6	13	5d³ ⁴P₃/₂ 12402.68	141022.57(1/2)	pb *
412	123	778.7346	128413.45	778.7344	0.0014	−0.03	0.0002	11	18	5d³ ²D2₅/₂ 28738.78	157152.26(5/2)	pb
738	575	780.4523	128130.83	780.4547	0.0015	0.39	−0.0024	14	14	5d³ ²H₉/₂ 19966.76	148097.20(7/2)	pb
132	22	780.7852	128076.20	780.7783	0.0019	−1.13	0.0069	12	10	5d³ ²G₉/₂ 30365.54	158442.87(7/2)	pb *
30	2	782.3761	127815.77	782.3853	0.0019	1.50	−0.0092	6	13	5d³ ²P₃/₂ 32766.42	160580.69(1/2)	pb *
304	77	784.4802	127472.94	784.4752	0.0016	−0.82	0.0050	10	18	5d³ ²D2₅/₂ 28738.78	156212.54(3/2)	pb
326	180	784.5088	127468.30	784.5124	0.0014	0.59	−0.0036	9	20	5d³ ²F₇/₂ 34625.26	162092.97(5/2)	pb
56	37	785.7686	127263.93	785.7701	0.0022	0.26	−0.0015	5	10	5d³ ²G₉/₂ 30365.54	157629.21(11/2)	pb
296	395	785.8501	127250.73	785.8462	0.0024	−0.63	0.0039	5	18	5d³ ²D2₅/₂ 28738.78	155990.14(3/2)	pb
613	460	786.0283	127221.88	786.0282	0.0016	−0.01	0.0001	11	16	5d³ ⁴P₅/₂ 20922.06	148143.95(3/2)	pb
581	329	786.3183	127174.96	786.3172	0.0015	−0.18	0.0011	12	16	5d³ ⁴P₅/₂ 20922.06	148097.20(7/2)	pb
171	356	787.8166	126933.10	787.8118	0.0015	−0.77	0.0048	10	18	5d³ ⁴F₇/₂ 8972.90	135906.77(7/2)	pb
838	626	788.2793	126858.59	788.2773	0.0014	−0.33	0.0020	13	18	5d³ ²D2₅/₂ 28738.78	155597.70(7/2)	pb
336	228	788.4714	126827.68	788.4720	0.0014	0.09	−0.0006	12	16	5d³ ⁴P₅/₂ 20922.06	147749.65(5/2)	pb
179	89	789.2837	126697.16	789.2838	0.0020	0.01	−0.0001	6	9	5d³ ⁴P₁/₂ 14325.42	141022.57(1/2)	pb
549	988	792.1783	126234.21	792.1759	0.0018	−0.38	0.0024	7	14	5d³ ⁴F₃/₂ 0.00	126234.59(5/2)	pb
773	180	792.4434	126191.98	792.4445	0.0022	0.18	−0.0011	9	9	5d³ ²D1₃/₂ 52051.89	178243.69(5/2)	pb
1481	467	795.0607	125776.56	795.0603	0.0022	−0.06	0.0004	9	10	5d³ ²D1₅/₂ 52467.07	178243.69(5/2)	pb
70	20	795.6136	125689.15	795.6091	0.0015	−0.71	0.0045	11	16	5d³ ²G₇/₂ 19012.90	144702.76(7/2)	pb
377	256	798.5196	125231.74	798.5169	0.0018	−0.42	0.0027	13	10	5d³ ²G₉/₂ 30365.54	155597.70(7/2)	pb
515	514	799.0939	125141.74	799.0945	0.0024	0.09	−0.0006	6	9	5d³ ²D1₃/₂ 52051.89	177193.54(3/2)	pb 150
954	829	799.1272	125136.52	799.1315	0.0016	0.66	−0.0043	9	13	5d³ ⁴P₃/₂ 12402.68	137538.54(5/2)	pb
106	28	799.4006	125093.73	799.4010	0.0014	0.06	−0.0004	16	18	5d³ ²D2₅/₂ 28738.78	153832.45(5/2)	pb
1400	552	801.7559	124726.24	801.7545	0.0024	−0.23	0.0014	6	10	5d³ ²D1₅/₂ 52467.07	177193.54(3/2)	pb
64	28	802.9034	124547.98	802.9018	0.0015	−0.26	0.0016	12	12	5d³ ²D2₃/₂ 23201.41	147749.65(5/2)	pb
67	18	803.9508	124385.72	803.9500	0.0018	−0.12	0.0008	11	13	5d³ ²P₃/₂ 32766.42	157152.26(5/2)	pb *
271	400	806.4976	123992.93	806.4978	0.0016	0.02	−0.0002	10	13	5d³ ⁴F₉/₂ 11913.86	135906.77(7/2)	pb
76	30	807.6401	123817.53	807.6395	0.0015	−0.08	0.0006	12	20	5d³ ²F₇/₂ 34625.26	158442.87(7/2)	pb *
1042	728	807.8773	123781.17	807.8803	0.0015	0.47	−0.0030	11	16	5d³ ⁴P₅/₂ 20922.06	144702.76(7/2)	pb
61	118	811.2742	123262.89	811.2683	0.0016	−0.89	0.0059	9	14	5d³ ²H₉/₂ 19966.76	143230.54(9/2)	pb
39	19	812.9675	123006.15	812.9721	0.0016	0.70	−0.0046	11	16	5d³ ⁴P₅/₂ 20922.06	143927.51(3/2)	pb
564	319	813.0704	122990.58	813.0712	0.0013	0.13	−0.0008	11	17	5d³ ²F₅/₂ 34161.81	157152.26(5/2)	pb
169	34	816.1446	122527.31	816.1466	0.0014	0.31	−0.0020	11	20	5d³ ²F₇/₂ 34625.26	157152.26(5/2)	pb
48	3	819.3287	122051.14	819.3314	0.0017	0.41	−0.0027	10	17	5d³ ²F₅/₂ 34161.81	156212.54(3/2)	pb *
125	4	820.5861	121864.12	820.5776	0.0016	−1.25	0.0085	11	20	5d³ ²F₇/₂ 34625.26	156490.63(9/2)	pb *
599	159	821.8736	121673.21	821.8728	0.0023	−0.11	0.0008	15	9	5d³ ²D1₃/₂ 52051.89	173725.21(5/2)	pb
1423	443	822.0058	121653.64	822.0071	0.0023	0.18	−0.0013	8	10	5d³ ²D1₅/₂ 52467.07	174120.53(7/2)	pb
66	15	822.9633	121512.10	822.9653	0.0021	0.30	−0.0020	10	10	5d³ ²G₉/₂ 30365.54	151877.34(9/2)	pb *
412	133	823.4826	121435.47	823.4798	0.0014	−0.42	0.0028	13	17	5d³ ²F₅/₂ 34161.81	155597.70(7/2)	pb
93	25	824.5596	121276.86	824.5555	0.0022	−0.61	0.0041	8	7	5d³ ²P₁/₂ 23668.85	144946.32(1/2)	pb
136	17	824.6842	121258.54	824.6869	0.0023	0.40	−0.0027	15	10	5d³ ²D1₅/₂ 52467.07	173725.21(5/2)	pb *
421	386	825.9974	121065.76	825.9956	0.0018	−0.27	0.0018	16	13	5d³ ²P₃/₂ 32766.42	153832.45(5/2)	pb
276	190	826.6410	120971.50	826.6345	0.0014	−0.94	0.0065	13	20	5d³ ²F₇/₂ 34625.26	155597.70(7/2)	pb
93	55	831.4341	120274.11	831.4344	0.0017	0.04	−0.0003	11	12	5d³ ²D2₃/₂ 23201.41	143475.48(5/2)	pb
167	139	831.5398	120258.83	831.5409	0.0022	0.17	−0.0011	11	7	5d³ ²P₁/₂ 23668.85	143927.51(3/2)	pb
98	41	835.6210	119671.48	835.6269	0.0013	0.84	−0.0059	16	17	5d³ ²F₅/₂ 34161.81	153832.45(5/2)	pb

Table 1 (*continued*)

gA (10^7 s^{-1})	Int	λ (Å)	ν (cm^{-1})	λcalc (Å)	Unc λcalc (Å)	Δ(ν) (cm^{-1})	Δ(λ) (Å)	N$_{odd}$	N$_{even}$	Even level (cm^{-1})		Odd level (cm^{-1})	Remark
223	145	838.8790	119206.70	838.8756	0.0013	−0.49	0.0034	16	20	5d^3 ^{2}F$_{7/2}$	34625.26	153832.45(5/2)	pb
452	447	839.3971	119133.13	839.3992	0.0013	0.30	−0.0021	12	17	5d^3 ^{2}F$_{5/2}$	34161.81	153294.64(7/2)	pb
181	447	839.3971	119133.13	839.3906	0.0040	−0.91	0.0065	5	9	5d^3 ^{2}D1$_{3/2}$	52051.89	171185.93(1/2)	pb * 100
179	169	841.5126	118833.63	841.5109	0.0017	−0.25	0.0017	9	13	5d^3 ^{4}P$_{3/2}$	12402.68	131236.56(3/2)	pb
17	70	852.7922	117261.86	852.7935	0.0018	0.17	−0.0013	7	18	5d^3 ^{4}F$_{7/2}$	8972.90	126234.59(5/2)	pb
146	101	852.8655	117251.78	852.8633	0.0017	−0.30	0.0022	10	20	5d^3 ^{2}F$_{7/2}$	34625.26	151877.34(9/2)	pb
64	40	855.3481	116911.47	855.3505	0.0020	0.33	−0.0024	9	9	5d^3 ^{4}P$_{1/2}$	14325.42	131236.56(3/2)	pb
54	34	855.4724	116894.48	855.4769	0.0017	0.61	−0.0045	10	16	5d^3 ^{2}G$_{7/2}$	19012.90	135906.77(7/2)	pb
104	56	857.5195	116615.42	857.5117	0.0017	−1.06	0.0078	9	16	5d^3 ^{4}P$_{5/2}$	20922.06	137538.54(5/2)	pb
209	238	860.9313	116153.29	860.9284	0.0024	−0.38	0.0029	9	6	5d^3 ^{2}H$_{11/2}$	27076.87	143230.54(9/2)	pb
132	27	862.3538	115961.69	862.3504	0.0030	−0.46	0.0034	15	9	5d^3 ^{2}D1$_{3/2}$	52051.89	168014.04(5/2)	pb *
94	122	862.5126	115940.34	862.5150	0.0018	0.33	−0.0024	10	14	5d^3 ^{2}H$_{9/2}$	19966.76	135906.77(7/2)	pb
291	45	865.4502	115546.80	865.4490	0.0030	−0.17	0.0012	15	10	5d^3 ^{2}D1$_{5/2}$	52467.07	168014.04(5/2)	pb
148	47	867.4278	115283.37	867.4284	0.0030	0.09	−0.0006	10	9	5d^3 ^{2}D1$_{3/2}$	52051.89	167335.17(3/2)	pb
89	50	868.1361	115189.31	868.1405	0.0016	0.58	−0.0044	11	18	5d^3 ^{2}D2$_{5/2}$	28738.78	143927.51(3/2)	pb
114	10	870.1972	114916.48	870.2047	0.0040	0.99	−0.0075	3	9	5d^3 ^{2}D1$_{3/2}$	52051.89	166967.38(1/2)	pb *
149	10	870.5675	114867.60	870.5637	0.0030	−0.50	0.0038	10	10	5d^3 ^{2}D1$_{5/2}$	52467.07	167335.17(3/2)	pb *
40	23	871.5603	114736.75	871.5607	0.0016	0.05	−0.0004	11	18	5d^3 ^{2}D2$_{5/2}$	28738.78	143475.48(5/2)	pb
125	40	877.3351	113981.53	877.3304	0.0017	−0.61	0.0047	11	17	5d^3 ^{2}F$_{5/2}$	34161.81	148143.95(3/2)	pb
54	25	877.6955	113934.73	877.6904	0.0015	−0.66	0.0051	12	17	5d^3 ^{2}F$_{5/2}$	34161.81	148097.20(7/2)	pb
62	85	878.4873	113832.04	878.4883	0.0019	0.13	−0.0010	7	13	5d^3 ^{4}P$_{3/2}$	12402.68	126234.59(5/2)	pb
175	250	880.3728	113588.24	880.3759	0.0014	0.40	−0.0031	12	17	5d^3 ^{2}F$_{5/2}$	34161.81	147749.65(5/2)	pb
129	43	881.2769	113471.71	881.2751	0.0015	−0.23	0.0018	12	20	5d^3 ^{2}F$_{7/2}$	34625.26	148097.20(7/2)	pb
46	36	883.9844	113124.17	883.9827	0.0014	−0.22	0.0017	12	20	5d^3 ^{2}F$_{7/2}$	34625.26	147749.65(5/2)	pb Re IV
80	200	886.0127	112865.20	886.0142	0.0021	0.20	−0.0015	9	10	5d^3 ^{2}G$_{9/2}$	30365.54	143230.54(9/2)	pb
46	30	891.4242	112180.04	891.4254	0.0021	0.14	−0.0012	8	13	5d^3 ^{2}P$_{3/2}$	32766.42	144946.32(1/2)	pb
56	36	904.6393	110541.30	904.6421	0.0015	0.35	−0.0028	11	17	5d^3 ^{2}F$_{5/2}$	34161.81	144702.76(7/2)	pb
78	51	908.4536	110077.17	908.4508	0.0015	−0.33	0.0028	11	20	5d^3 ^{2}F$_{7/2}$	34625.26	144702.76(7/2)	pb
58	460	919.1155	108800.25	919.1197	0.0019	0.49	−0.0042	9	18	5d^3 ^{2}D2$_{5/2}$	28738.78	137538.54(5/2)	pb * 50, m(Re IV)
41	47	920.7665	108605.17	920.7655	0.0016	−0.11	0.0010	9	20	5d^3 ^{2}F$_{7/2}$	34625.26	143230.54(9/2)	pb
22	714	925.6236	108035.28	925.6247	0.0021	0.13	−0.0011	9	12	5d^3 ^{2}D2$_{3/2}$	23201.41	131236.56(3/2)	pb * 50, m(Re IV)
12	16	929.6461	107567.82	929.6470	0.0030	0.11	−0.0009	9	7	5d^3 ^{2}P$_{1/2}$	23668.85	131236.56(3/2)	pb *
79	86	943.6096	105976.03	943.6117	0.0030	0.23	−0.0021	12	10	5d^3 ^{2}D1$_{5/2}$	52467.07	158442.87(7/2)	pb * 50
23	31	967.3394	103376.33	967.3357	0.0017	−0.40	0.0037	9	17	5d^3 ^{2}F$_{5/2}$	34161.81	137538.54(5/2)	pb
32	140	970.5640	103032.88	970.5612	0.0023	−0.30	0.0028	7	12	5d^3 ^{2}D2$_{3/2}$	23201.41	126234.59(5/2)	pb
31	19	987.3420	101282.03	987.3470	0.0017	0.52	−0.0050	10	20	5d^3 ^{2}F$_{7/2}$	34625.26	135906.77(7/2)	pb
16	21	1030.1355	97074.61	1030.1340	0.0019	−0.14	0.0015	9	17	5d^3 ^{2}F$_{5/2}$	34161.81	131236.56(3/2)	pb
36	42	1045.1868	95676.68	1045.1846	0.0040	−0.20	0.0022	11	10	5d^3 ^{2}D1$_{5/2}$	52467.07	148143.95(3/2)	pc *
37	25	1045.6955	95630.13	1045.6956	0.0040	0.00	−0.0001	12	10	5d^3 ^{2}D1$_{5/2}$	52467.07	148097.20(7/2)	pc *
13	24	1078.6780	92706.07	1078.6773	0.0031	−0.07	0.0007	10	9	5d^{2}6s (^{3}F)^{4}F$_{3/2}$	63506.40	156212.54(3/2)	pc *
46	11	1080.6729	92534.94	1080.6625	0.0023	−0.89	0.0104	15	15	5d^{2}6s (^{3}F)^{4}F$_{7/2}$	71889.06	164424.89(7/2)	pc *
32	24	1081.3343	92478.34	1081.3250	0.0030	−0.80	0.0093	15	13	5d^{2}6s (^{3}P)^{4}P$_{3/2}$	81246.07	173725.21(5/2)	pc *
25	64	1086.0938	92073.08	1086.0973	0.0023	0.30	−0.0035	7	17	5d^3 ^{2}F$_{5/2}$	34161.81	126234.59(5/2)	pc
121	43	1091.6754	91602.32	1091.6732	0.0024	−0.18	0.0022	15	13	5d^{2}6s (^{3}P)^{4}P$_{5/2}$	82122.71	173725.21(5/2)	pc
209	213	1108.5987	90203.97	1108.5993	0.0030	0.06	−0.0006	9	15	5d^{2}6s (^{3}F)^{4}F$_{7/2}$	71889.06	162092.97(5/2)	pc
166	246	1110.8131	90024.15	1110.8162	0.0031	0.26	−0.0031	10	12	5d^{2}6s (^{3}F)^{4}F$_{5/2}$	66188.65	156212.54(3/2)	pc
182	294	1140.9848	87643.59	1140.9820	0.0020	−0.21	0.0028	16	12	5d^{2}6s (^{3}F)^{4}F$_{5/2}$	66188.65	153832.45(5/2)	pc
276	261	1142.0332	87563.13	1142.0302	0.0030	−0.23	0.0030	15	13	5d^{2}6s (^{3}P)^{2}F$_{7/2}$	86161.85	173725.21(5/2)	pc 130
271	155	1147.8813	87117.02	1147.8763	0.0030	−0.38	0.0050	14	10	5d^{2}6s (^{3}F)^{4}F$_{9/2}$	77307.49	164424.89(7/2)	pc
67	71	1148.0289	87105.82	1148.0266	0.0022	−0.17	0.0023	12	12	5d^{2}6s (^{3}F)^{4}F$_{5/2}$	66188.65	153294.64(7/2)	pc Re III
131	289	1150.1144	86947.87	1150.1108	0.0030	−0.27	0.0036	7	6	5d^{2}6s (^{3}P)^{4}P$_{1/2}$	78208.65	165156.79(3/2)	pc 200
97	55	1152.5018	86767.76	1152.4991	0.0030	−0.21	0.0027	15	13	5d^{2}6s (^{3}P)^{4}P$_{3/2}$	81246.07	168014.04(5/2)	pc *
317	395	1155.3722	86552.20	1155.3506	0.0030	−1.61	0.0216	12	15	5d^{2}6s (^{3}F)^{4}F$_{7/2}$	71889.06	158442.87(7/2)	pc *
169	167	1157.0041	86430.12	1157.0018	0.0020	−0.17	0.0023	14	16	5d^{2}6s (^{3}F)^{2}F$_{5/2}$	77994.60	164424.89(7/2)	pc
160	112	1161.5831	86089.41	1161.5873	0.0040	0.31	−0.0042	10	13	5d^{2}6s (^{3}P)^{4}P$_{3/2}$	81246.07	167335.17(3/2)	pc
176	149	1161.7981	86073.48	1161.7963	0.0030	−0.14	0.0018	10	16	5d^{2}6s (^{3}F)^{2}F$_{5/2}$	77994.60	164068.22(5/2)	pc
685	561	1162.3386	86033.45	1162.3362	0.0030	−0.18	0.0024	9	10	5d^{2}6s (^{3}F)^{4}F$_{9/2}$	77307.49	163341.12(9/2)	pc
337	860	1168.9970	85543.42	1168.9947	0.0040	−0.17	0.0023	6	9	5d^{2}6s (^{3}F)^{4}F$_{3/2}$	63506.40	149049.99(1/2)	pc
96	69	1172.8410	85263.05	1172.8389	0.0024	−0.15	0.0021	11	15	5d^{2}6s (^{3}F)^{4}F$_{7/2}$	71889.06	157152.26(5/2)	pc
50	40	1173.6914	85201.27	1173.6939	0.0050	0.18	−0.0025	6	7	5d^{2}6s (^{1}D)^{2}D5$_{5/2}$	91992.45	177193.54(3/2)	pc *
277	537	1182.0119	84601.52	1182.0112	0.0030	−0.05	0.0007	15	15	5d^{2}6s (^{3}F)^{4}F$_{7/2}$	71889.06	156490.63(9/2)	pc
958	1178	1182.9314	84535.76	1182.9275	0.0040	−0.27	0.0039	9	9	5d^{2}6s (^{1}G)^{2}G$_{7/2}$	93707.66	178243.69(5/2)	pc Re IV(250)
227	425	1187.0441	84242.87	1187.0388	0.0024	−0.38	0.0053	12	9	5d^{2}6s (^{3}F)^{4}F$_{3/2}$	63506.40	147749.65(5/2)	pc
818	1030	1207.4072	82822.10	1207.4066	0.0031	−0.05	0.0006	10	13	5d^{2}6s (^{3}P)^{4}P$_{3/2}$	81246.07	164068.22(5/2)	pc
497	459	1211.5432	82539.36	1211.5379	0.0041	−0.36	0.0053	7	6	5d^{2}6s (^{3}P)^{4}P$_{1/2}$	78208.65	160748.37(3/2)	pc
176	100	1211.6856	82529.66	1211.6855	0.0030	0.00	0.0001	9	13	5d^{2}6s (^{3}F)^{2}F$_{7/2}$	86161.85	168691.51(9/2)	pc
30	32	1213.9989	82372.40	1214.0042	0.0030	0.36	−0.0053	6	6	5d^{2}6s (^{3}P)^{4}P$_{1/2}$	78208.65	160580.69(1/2)	pc
838	1102	1215.0328	82302.31	1215.0346	0.0030	0.13	−0.0018	14	13	5d^{2}6s (^{3}P)^{4}P$_{5/2}$	82122.71	164424.89(7/2)	pc Re III
389	1549	1215.6607	82259.80	1215.4745	0.0040	−12.60	0.1862	15	10	5d^{2}6s (^{1}D)^{2}D3$_{3/2}$	85741.64	168014.04(5/2)	pc * 100, m(H I)
198	57	1217.6118	82127.98	1217.6104	0.0030	−0.10	0.0014	8	7	5d^{2}6s (^{1}D)^{2}D5$_{5/2}$	91992.45	174120.53(7/2)	pc
730	381	1217.7842	82116.36	1217.7886	0.0030	0.30	−0.0044	8	8	5d^{2}6s (^{1}G)^{2}G$_{9/2}$	92004.47	174120.53(7/2)	pc

Table 1 (*continued*)

gA (10⁷ s⁻¹)	Int	λ (Å)	ν (cm⁻¹)	λcalc (Å)	Unc λcalc (Å)	Δ(ν) (cm⁻¹)	Δ(λ) (Å)	N$_{odd}$	N$_{even}$	Even level (cm⁻¹)	Odd level (cm⁻¹)	Remark
196	163	1220.3234	81945.49	1220.3231	0.0030	−0.02	0.0003	10	13	$5d^26s\,(^3P)^4P_{5/2}$ 82122.71	164068.22(5/2)	pc
114	188	1220.3593	81943.08	1220.3547	0.0023	−0.31	0.0046	16	15	$5d^26s\,(^3F)^4F_{7/2}$ 71889.06	153832.45(5/2)	pc
892	1130	1220.8785	81908.23	1220.8737	0.0024	−0.32	0.0048	12	12	$5d^26s\,(^3F)^4F_{5/2}$ 66188.65	148097.20(7/2)	pc
244	250	1221.7157	81852.10	1221.7145	0.0030	−0.09	0.0012	15	13	$5d^26s\,(^3F)^2F_{7/2}$ 86161.85	168014.04(5/2)	pc 2xO III
579	985	1222.4250	81804.61	1222.4252	0.0030	0.01	−0.0002	7	9	$5d^26s\,(^3F)^4F_{3/2}$ 63506.40	145311.00(3/2)	pc
357	132	1223.4961	81732.99	1223.4996	0.0030	0.23	−0.0035	15	7	$5d^26s\,(^1D)^2D_{5/2}$ 91992.45	173725.21(5/2)	pc
330	584	1226.0762	81561.00	1226.0762	0.0022	0.00	0.0000	12	12	$5d^26s\,(^3F)^4F_{5/2}$ 66188.65	147749.65(5/2)	pc
39	49	1227.8940	81440.26	1227.8992	0.0030	0.34	−0.0052	8	9	$5d^26s\,(^3F)^4F_{3/2}$ 63506.40	144946.32(1/2)	pc
472	1194	1228.4313	81404.63	1228.4170	0.0030	−0.95	0.0143	12	15	$5d^26s\,(^3F)^4F_{7/2}$ 71889.06	153294.64(7/2)	pc * 900, Re III
179	66	1231.1373	81225.71	1231.1369	0.0060	−0.03	0.0004	3	10	$5d^26s\,(^1D)^2D_{3/2}$ 85741.64	166967.38(1/2)	pd
249	100	1232.5047	81135.59	1232.5080	0.0030	0.21	−0.0033	12	10	$5d^26s\,(^3F)^4F_{9/2}$ 77307.49	158442.87(7/2)	pd
104	32	1236.9085	80846.72	1236.9058	0.0030	−0.18	0.0027	9	13	$5d^26s\,(^3P)^4P_{3/2}$ 81246.07	162092.97(5/2)	pd
2665	1133	1241.3385	80558.20	1241.3385	0.0070	0.00	0.0000	3	8	$5d^26s\,(^1G)^2G_{9/2}$ 92004.47	172562.67(11/2)	pd
58	29	1243.0389	80448.01	1243.0349	0.0030	−0.26	0.0040	12	16	$5d^26s\,(^3F)^2F_{5/2}$ 77994.60	158442.87(7/2)	pd *
577	1053	1243.5902	80412.34	1243.5820	0.0040	−0.53	0.0082	8	9	$5d^26s\,(^1G)^2G_{7/2}$ 93707.66	174120.53(7/2)	pd 400
2596	1351	1244.9963	80321.52	1244.9932	0.0050	−0.20	0.0031	5	10	$5d^26s\,(^3F)^4F_{9/2}$ 77307.49	157629.21(11/2)	pd
91	19	1249.7372	80016.82	1249.7258	0.0040	−0.73	0.0114	15	9	$5d^26s\,(^1G)^2G_{7/2}$ 93707.66	173725.21(5/2)	pd *
1501	1087	1250.1761	79988.73	1250.1831	0.0030	0.45	−0.0070	10	15	$5d^26s\,(^3F)^4F_{7/2}$ 71889.06	151877.34(9/2)	pd
359	458	1250.4815	79969.20	1250.4833	0.0030	0.12	−0.0018	11	9	$5d^26s\,(^3F)^4F_{3/2}$ 63506.40	143475.48(5/2)	pd
179	458	1250.4815	79969.20	1250.4648	0.0030	−1.06	0.0167	9	13	$5d^26s\,(^3P)^4P_{5/2}$ 82122.71	162092.97(5/2)	pd * 150
1380	644	1253.9724	79746.57	1253.9693	0.0041	−0.20	0.0031	8	7	$5d^26s\,(^1D)^2D_{5/2}$ 91992.45	171739.22(7/2)	pd
166	64	1257.8215	79502.54	1257.8253	0.0040	0.24	−0.0038	7	13	$5d^26s\,(^3P)^4P_{3/2}$ 81246.07	160748.37(3/2)	pd
484	374	1259.2083	79414.98	1259.2055	0.0040	−0.17	0.0028	7	10	$5d^26s\,(^1D)^2D_{3/2}$ 85741.64	165156.79(3/2)	pd
222	94	1260.4791	79334.91	1260.4838	0.0040	0.29	−0.0047	6	13	$5d^26s\,(^3P)^4P_{3/2}$ 81246.07	160580.69(1/2)	pd
396	300	1262.8923	79183.32	1262.8952	0.0030	0.18	−0.0029	11	10	$5d^26s\,(^3F)^4F_{9/2}$ 77307.49	156490.63(9/2)	pd
176	119	1263.3020	79157.64	1263.3016	0.0030	−0.02	0.0004	11	16	$5d^26s\,(^3F)^2F_{5/2}$ 77994.60	157152.26(5/2)	pd
79	23	1263.8636	79122.46	1263.8654	0.0030	0.11	−0.0018	7	12	$5d^26s\,(^3F)^4F_{5/2}$ 66188.65	145311.00(3/2)	pd
152	45	1267.3022	78907.78	1267.3047	0.0050	0.16	−0.0025	9	5	$5d^26s\,(^3P)^2P_{3/2}$ 99336.07	178243.69(5/2)	pd
126	67	1268.0774	78859.54	1268.0819	0.0061	0.28	−0.0045	5	3	$5d^26s\,(^3P)^2P_{1/2}$ 92326.67	171185.93(1/2)	pd
199	273	1273.6481	78514.62	1273.6563	0.0030	0.51	−0.0082	11	12	$5d^26s\,(^3F)^4F_{5/2}$ 66188.65	144702.76(7/2)	pd
25	32	1277.2883	78290.86	1277.2990	0.0030	0.65	−0.0107	13	10	$5d^26s\,(^3F)^4F_{9/2}$ 77307.49	155597.70(7/2)	pd *
253	185	1277.7457	78262.83	1277.7423	0.0030	−0.21	0.0034	14	13	$5d^26s\,(^3F)^2F_{7/2}$ 86161.85	164424.89(7/2)	pd
203	618	1278.4683	78218.60	1278.4792	0.0041	0.66	−0.0109	10	16	$5d^26s\,(^3F)^2F_{5/2}$ 77994.60	156212.54(3/2)	pd 200
246	155	1281.5241	78032.09	1281.5327	0.0040	0.53	−0.0086	8	9	$5d^26s\,(^1G)^2G_{7/2}$ 93707.66	171739.22(7/2)	pd
641	171	1284.3998	77857.38	1284.3984	0.0050	−0.09	0.0014	5	5	$5d^26s\,(^3P)^2P_{3/2}$ 99336.07	177193.54(3/2)	pd
542	992	1288.6097	77603.02	1288.6084	0.0030	−0.08	0.0013	13	16	$5d^26s\,(^3F)^2F_{5/2}$ 77994.60	155597.70(7/2)	pd
56	39	1290.0612	77515.70	1290.0536	0.0040	−0.47	0.0076	6	9	$5d^26s\,(^3F)^4F_{3/2}$ 63506.40	141022.57(1/2)	pd
190	358	1293.8826	77286.77	1293.8814	0.0031	−0.06	0.0012	11	12	$5d^26s\,(^3F)^4F_{5/2}$ 66188.65	143475.48(5/2)	pd
1025	826	1295.6797	77179.57	1295.6847	0.0030	0.30	−0.0050	9	13	$5d^26s\,(^3F)^2F_{7/2}$ 86161.85	163341.12(9/2)	pe Re III
681	338	1303.9981	76687.23	1304.0012	0.0040	0.19	−0.0031	9	8	$5d^26s\,(^1G)^2G_{9/2}$ 92004.47	168691.51(9/2)	pe
516	898	1310.2665	76320.35	1310.2698	0.0030	0.19	−0.0033	12	13	$5d^26s\,(^3P)^4P_{5/2}$ 82122.71	158442.87(7/2)	pe Re III
114	76	1312.2005	76207.87	1312.1958	0.0030	−0.27	0.0047	12	15	$5d^26s\,(^3F)^4F_{7/2}$ 71889.06	148097.20(7/2)	pe
288	42	1315.4158	76021.59	1315.4159	0.0040	0.00	−0.0001	15	7	$5d^26s\,(^1D)^2D_{5/2}$ 91992.45	168014.04(5/2)	pe
324	221	1316.9889	75930.78	1316.9830	0.0040	−0.34	0.0059	9	13	$5d^26s\,(^3F)^2F_{7/2}$ 86161.85	162092.97(5/2)	pe
100	35	1318.2003	75861.01	1318.2076	0.0030	0.42	−0.0073	12	15	$5d^26s\,(^3F)^4F_{7/2}$ 71889.06	147749.65(5/2)	pe
182	218	1318.6024	75837.87	1318.6029	0.0030	0.02	−0.0005	16	16	$5d^26s\,(^3F)^2F_{5/2}$ 77994.60	153832.45(5/2)	pe
254	359	1328.0147	75300.37	1328.0206	0.0030	0.33	−0.0059	12	16	$5d^26s\,(^3F)^2F_{5/2}$ 77994.60	153294.64(7/2)	pe
469	204	1333.1852	75008.33	1333.1822	0.0060	−0.17	0.0030	3	10	$5d^26s\,(^3P)^2P_{1/2}$ 92326.67	167335.17(3/2)	pe
881	255	1333.6191	74983.93	1333.6204	0.0040	0.08	−0.0013	9	9	$5d^26s\,(^1G)^2G_{7/2}$ 93707.66	168691.51(9/2)	pe
62	20	1333.9390	74965.95	1333.9298	0.0040	−0.52	0.0092	10	13	$5d^26s\,(^3P)^4P_{3/2}$ 81246.07	156212.54(3/2)	pe *
69	43	1336.2084	74838.63	1336.2007	0.0040	−0.42	0.0077	6	10	$5d^26s\,(^1D)^2D_{3/2}$ 85741.64	160580.69(1/2)	pe *
63	25	1341.0141	74570.43	1341.0245	0.0040	0.58	−0.0104	10	10	$5d^26s\,(^3F)^4F_{9/2}$ 77307.49	151877.34(9/2)	pe *
274	39	1344.2830	74389.10	1344.2823	0.0050	−0.04	0.0007	15	5	$5d^26s\,(^3P)^2P_{3/2}$ 99336.07	173725.21(5/2)	pe
71	91	1349.7221	74089.33	1349.7129	0.0041	−0.50	0.0092	10	13	$5d^26s\,(^3P)^4P_{5/2}$ 82122.71	156212.54(3/2)	pe
79	61	1360.9985	73475.47	1361.0073	0.0030	0.48	−0.0088	13	13	$5d^26s\,(^3P)^4P_{5/2}$ 82122.71	155597.70(7/2)	pe Re IV
89	125	1373.3648	72813.87	1373.3679	0.0030	0.17	−0.0031	11	15	$5d^26s\,(^3F)^4F_{7/2}$ 71889.06	144702.76(7/2)	pe
286	370	1383.4921	72280.86	1383.4891	0.0040	−0.16	0.0030	12	13	$5d^26s\,(^3F)^2F_{7/2}$ 86161.85	158442.87(7/2)	pe Re III(150)
183	104	1394.5131	71709.62	1394.5108	0.0030	−0.12	0.0023	16	13	$5d^26s\,(^3P)^4P_{5/2}$ 82122.71	153832.45(5/2)	pe Re IV
57	31	1396.9158	71586.28	1396.9129	0.0030	−0.14	0.0029	11	15	$5d^26s\,(^3F)^4F_{7/2}$ 71889.06	143475.48(5/2)	pe
282	156	1400.3508	71410.68	1400.3518	0.0040	0.06	−0.0010	11	10	$5d^26s\,(^1D)^2D_{3/2}$ 85741.64	157152.26(5/2)	pe
83	47	1401.5452	71349.82	1401.5439	0.0030	−0.07	0.0013	9	12	$5d^26s\,(^3F)^4F_{5/2}$ 66188.65	137538.54(5/2)	pe
269	705	1401.7102	71341.42	1401.7090	0.0030	−0.06	0.0012	9	15	$5d^26s\,(^3F)^4F_{7/2}$ 71889.06	143230.54(9/2)	pe
119	133	1401.8087	71336.41	1401.8039	0.0040	−0.24	0.0048	9	8	$5d^26s\,(^1G)^2G_{9/2}$ 92004.47	163341.12(9/2)	pe
46	17	1405.0409	71172.31	1405.0483	0.0030	0.38	−0.0074	12	13	$5d^26s\,(^3P)^4P_{5/2}$ 82122.71	153294.64(7/2)	pe *
48	25	1411.6021	70841.49	1411.6052	0.0070	0.15	−0.0031	6	6	$5d^26s\,(^3P)^4P_{1/2}$ 78208.65	149049.99(1/2)	pe *
138	63	1412.6244	70790.23	1412.6347	0.0040	0.52	−0.0103	12	10	$5d^26s\,(^3F)^4F_{9/2}$ 77307.49	148097.20(7/2)	pe
72	33	1421.8986	70328.50	1421.8930	0.0040	−0.28	0.0056	12	13	$5d^26s\,(^3F)^2F_{7/2}$ 86161.85	156490.63(9/2)	pe
95	1007	1425.5087	70150.40	1425.5300	0.0040	1.05	−0.0213	11	16	$5d^26s\,(^3F)^2F_{5/2}$ 77994.60	148143.95(3/2)	pe * 300, m(Re III)
203	509	1426.4753	70102.86	1426.4807	0.0030	0.26	−0.0054	12	16	$5d^26s\,(^3F)^2F_{5/2}$ 77994.60	148097.20(7/2)	pe
391	1741	1434.3430	69718.33	1434.3473	0.0030	0.21	−0.0043	10	12	$5d^26s\,(^3F)^4F_{5/2}$ 66188.65	135906.77(7/2)	pe
240	62	1436.0897	69633.53	1436.0911	0.0040	0.07	−0.0014	9	9	$5d^26s\,(^1G)^2G_{7/2}$ 93707.66	163341.12(9/2)	pe

Table 1 (*continued*)

gA (10⁷ s⁻¹)	Int	λ (Å)	υ (cm⁻¹)	λcalc (Å)	Unc λcalc (Å)	$\Delta(\upsilon)$ (cm⁻¹)	$\Delta(\lambda)$ (Å)	N_{odd}	N_{even}	Even level (cm⁻¹)	Odd level (cm⁻¹)	Remark
98	20	1456.0845	68677.33	1456.0712	0.0070	−0.64	0.0133	15	5	$5d^26s\,(^3P)^2P_{3/2}$ 99336.07	168014.04(5/2)	pe *
135	701	1476.4406	67730.46	1476.4473	0.0040	0.30	−0.0067	9	9	$5d^26s\,(^3F)^4F_{3/2}$ 63506.40	131236.56(3/2)	pe
56	49	1477.7379	67671.00	1477.7467	0.0030	0.40	−0.0088	16	13	$5d^26s\,(^3F)^2F_{7/2}$ 86161.85	153832.45(5/2)	pe
512	1100	1483.7833	67395.29	1483.7837	0.0040	0.02	−0.0004	11	10	$5d^26s\,(^3F)^4F_{9/2}$ 77307.49	144702.76(7/2)	pe
41	140	1485.5262	67316.21	1485.5223	0.0040	−0.19	0.0039	7	16	$5d^26s\,(^3F)^2F_{5/2}$ 77994.60	145311.00(3/2)	pe
167	384	1489.5858	67132.76	1489.5851	0.0030	−0.03	0.0007	12	13	$5d^26s\,(^3F)^2F_{7/2}$ 86161.85	153294.64(7/2)	pe
162	621	1494.8113	66898.08	1494.8157	0.0040	0.20	−0.0044	11	13	$5d^26s\,(^3P)^4P_{3/2}$ 81246.07	148143.95(3/2)	pe
100	184	1503.6794	66503.54	1503.6786	0.0030	−0.04	0.0008	12	13	$5d^26s\,(^3P)^4P_{3/2}$ 81246.07	147749.65(5/2)	pe
67	31	1514.6605	66021.40	1514.6639	0.0050	0.16	−0.0034	11	13	$5d^26s\,(^3P)^4P_{5/2}$ 82122.71	148143.95(3/2)	pe *
19	20	1516.6893	65933.08	1516.6933	0.0040	0.17	−0.0040	11	16	$5d^26s\,(^3F)^2F_{5/2}$ 77994.60	143927.51(3/2)	pe *
568	1334	1516.9248	65922.85	1516.9201	0.0040	−0.20	0.0047	9	10	$5d^26s\,(^3F)^4F_{9/2}$ 77307.49	143230.54(9/2)	pe
27	147	1521.6351	65718.78	1521.6332	0.0040	−0.08	0.0019	11	6	$5d^26s\,(^3P)^4P_{1/2}$ 78208.65	143927.51(3/2)	pe Re IV
98	120	1521.7121	65715.45	1521.7112	0.0040	−0.04	0.0009	10	13	$5d^26s\,(^3F)^2F_{7/2}$ 86161.85	151877.34(9/2)	pe
353	651	1523.2377	65649.64	1523.2414	0.0040	0.16	−0.0037	9	15	$5d^26s\,(^3F)^4F_{7/2}$ 71889.06	137538.54(5/2)	pe
185	412	1523.7538	65627.40	1523.7645	0.0030	0.46	−0.0107	12	13	$5d^26s\,(^3P)^4P_{5/2}$ 82122.71	147749.65(5/2)	pe 300, Re III
89	378	1527.1689	65480.64	1527.1633	0.0030	−0.24	0.0056	11	16	$5d^26s\,(^3F)^2F_{5/2}$ 77994.60	143475.48(5/2)	pe
182	78	1534.6888	65159.79	1534.6883	0.0040	−0.02	0.0005	11	7	$5d^26s\,(^1D)^2D_{5/2}$ 91992.45	157152.26(5/2)	pe
247	1182	1537.3308	65047.81	1537.3284	0.0031	−0.10	0.0024	9	12	$5d^26s\,(^3F)^4F_{5/2}$ 66188.65	131236.56(3/2)	pe
387	2365	1550.7806	64483.65	1550.7204	0.0060	−2.51	0.0602	11	8	$5d^26s\,(^1G)^2G_{9/2}$ 92004.47	156490.63(9/2)	pe * 300, m(C IV)
330	1445	1562.0718	64017.54	1562.0677	0.0040	−0.17	0.0041	10	15	$5d^26s\,(^3F)^4F_{7/2}$ 71889.06	135906.77(7/2)	pf Re III(350)
175	899	1562.5777	63996.82	1562.5565	0.0100	−0.87	0.0212	5	7	$5d^26s\,(^1D)^2D_{5/2}$ 91992.45	155990.14(3/2)	pf * 300, m(Re III)
74	74	1569.8636	63699.80	1569.8527	0.0040	−0.45	0.0109	8	13	$5d^26s\,(^3P)^4P_{3/2}$ 81246.07	144946.32(1/2)	pg
176	122	1572.4910	63593.37	1572.4945	0.0050	0.14	−0.0035	13	8	$5d^26s\,(^1G)^2G_{9/2}$ 92004.47	155597.70(7/2)	pg
9	21	1579.5806	63307.94	1579.5704	0.0080	−0.41	0.0102	6	10	$5d^26s\,(^1D)^2D_{3/2}$ 85741.64	149049.99(1/2)	pg *
131	217	1591.9980	62814.15	1592.0040	0.0061	0.23	−0.0060	6	6	$5d^26s\,(^3P)^4P_{1/2}$ 78208.65	141022.57(1/2)	pg
310	256	1592.7915	62782.86	1592.7886	0.0060	−0.11	0.0029	11	9	$5d^26s\,(^1G)^2G_{7/2}$ 93707.66	156490.63(9/2)	pg *
343	975	1594.1819	62728.10	1594.1798	0.0040	−0.09	0.0021	7	9	$5d^26s\,(^3F)^4F_{3/2}$ 63506.40	126234.59(5/2)	pg
79	326	1595.3673	62681.49	1595.3686	0.0040	0.05	−0.0013	11	13	$5d^26s\,(^3P)^4P_{3/2}$ 81246.07	143927.51(3/2)	pg
58	311	1602.5023	62402.41	1602.5046	0.0050	0.10	−0.0023	11	10	$5d^26s\,(^1D)^2D_{3/2}$ 85741.64	148143.95(3/2)	pg
49	135	1606.9595	62229.32	1606.9572	0.0040	−0.09	0.0023	11	13	$5d^26s\,(^3P)^4P_{3/2}$ 81246.07	143475.48(5/2)	pg
34	54	1612.7095	62007.45	1612.6949	0.0040	−0.56	0.0146	12	10	$5d^26s\,(^1D)^2D_{3/2}$ 85741.64	147749.65(5/2)	pg
169	717	1615.7624	61890.29	1615.7688	0.0060	0.25	−0.0064	13	9	$5d^26s\,(^1G)^2G_{7/2}$ 93707.66	155597.70(7/2)	pg * 100
176	706	1618.0013	61804.65	1617.9972	0.0040	−0.15	0.0041	11	13	$5d^26s\,(^3P)^4P_{5/2}$ 82122.71	143927.51(3/2)	pg
94	48	1631.5890	61289.95	1631.5830	0.0050	−0.22	0.0060	12	8	$5d^26s\,(^1G)^2G_{9/2}$ 92004.47	153294.64(7/2)	pg
162	573	1665.3904	60045.98	1665.3916	0.0040	0.04	−0.0012	7	12	$5d^26s\,(^3F)^4F_{5/2}$ 66188.65	126234.59(5/2)	ph Re IV(250)
111	1142	1670.1886	59873.48	1670.2055	0.0070	0.61	−0.0169	10	8	$5d^26s\,(^1G)^2G_{9/2}$ 92004.47	151877.34(9/2)	ph * 200, m(Re III,2xO III)
77	74	1678.2182	59587.01	1678.2189	0.0050	0.03	−0.0007	12	9	$5d^26s\,(^1G)^2G_{7/2}$ 93707.66	153294.64(7/2)	ph
111	626	1679.4302	59544.01	1679.4323	0.0040	0.07	−0.0021	9	16	$5d^26s\,(^3F)^2F_{5/2}$ 77994.60	137538.54(5/2)	ph
32	97	1689.0501	59204.88	1689.0557	0.0040	0.20	−0.0056	8	10	$5d^26s\,(^1D)^2D_{3/2}$ 85741.64	144946.32(1/2)	ph
149	393	1708.2114	58540.76	1708.2071	0.0040	−0.15	0.0043	11	13	$5d^26s\,(^3F)^2F_{7/2}$ 86161.85	144702.76(7/2)	ph
113	868	1726.7530	57912.16	1726.7529	0.0040	−0.01	0.0001	10	16	$5d^26s\,(^3F)^2F_{5/2}$ 77994.60	135906.77(7/2)	ph
64	264	1732.0787	57734.10	1732.0862	0.0040	0.26	−0.0075	11	10	$5d^26s\,(^1D)^2D_{3/2}$ 85741.64	143475.48(5/2)	ph
221	336	1752.2650	57068.99	1752.2742	0.0040	0.30	−0.0092	9	13	$5d^26s\,(^3F)^2F_{7/2}$ 86161.85	143230.54(9/2)	ph
63	49	1834.9812	54496.47	1834.9846	0.0100	0.09	−0.0034	16	5	$5d^26s\,(^3P)^2P_{3/2}$ 99336.07	153832.45(5/2)	ph *
23	34	1859.2919	53783.92	1859.2869	0.0040	−0.14	0.0050	10	13	$5d^26s\,(^3P)^4P_{5/2}$ 82122.71	135906.77(7/2)	ph
18	52	1878.2209	53241.87	1878.2181	0.0040	−0.09	0.0028	9	16	$5d^26s\,(^3F)^2F_{5/2}$ 77994.60	131236.56(3/2)	ph
10	16	2052.8941	48696.12	2052.9035	0.0190	0.22	−0.0094	6	3	$5d^26s\,(^3P)^2P_{1/2}$ 92326.67	141022.57(1/2)	pi *

Table 2

Experimental and calculated energy levels (cm^{-1}) in the 5d^3 and 5d^{2}6s configurations of Re V.

E_{obs}	E_{calc}	Δ	N	N_{opt}	rwmv$_1$	rwmv$_2$	Unc	Composition					
$J = 1/2$													
-	115780.37	-						92% 2|(^{1}S)^{2}S	+	5% 2|(^{3}P)^{2}P	+	4% 2|(^{3}P)^{4}P	
92326.67	92340.30	−13.63	3	2	0.27	0.22	0.40	91% 2|(^{3}P)^{2}P	+	3% 2|(^{3}P)^{4}P	+	3% 2|(^{1}S)^{2}S	
78208.65	78215.98	−7.33	6	5	0.14	0.13	0.21	93% 2|(^{3}P)^{4}P	+	5% 2|(^{1}S)^{2}S	+	2% 2|(^{3}P)^{2}P	
23668.85	23683.64	−14.79	7	5	0.30	0.21	0.40	65% 1|^{2}P	+	33% 1|^{4}P	+	2% 2|(^{3}P)^{2}P	
14325.42	14322.45	2.97	9	8	0.24	0.14	0.30	67% 1|^{4}P	+	33% 1|^{2}P	+	1% 2|(^{3}P)^{2}P	
$J = 3/2$													
99336.07	99324.56	11.51	5	3	0.22	0.07	0.30	81% 2|(^{3}P)^{2}P	+	15% 2|(^{1}D)^{2}D	+	2% 1|^{2}P	
85741.64	85760.77	−19.13	10	8	0.10	0.11	0.15	66% 2|(^{1}D)^{2}D	+	16% 2|(^{3}P)^{2}P	+	11% 2|(^{3}P)^{4}P	
81246.07	81236.29	9.78	13	10	0.10	0.07	0.15	87% 2|(^{3}P)^{4}P	+	11% 2|(^{1}D)^{2}D	+	1% 2|(^{3}F)^{4}F	
63506.40	63491.24	15.16	9	8	0.12	0.10	0.16	93% 2|(^{3}F)^{4}F	+	7% 2|(^{1}D)^{2}D			
52051.89	52056.41	−4.52	9	5	0.28	0.09	0.30	67% 1|^{2}D1	+	32% 1|^{2}D2			
32766.42	32764.34	2.08	13	10	0.22	0.13	0.30	53% 1|^{2}P	+	19% 1|^{2}D2	+	14% 1|^{2}D1	
23201.41	23202.84	−1.43	12	10	0.21	0.14	0.24	33% 1|^{2}D2	+	43% 1|^{4}P	+	10% 1|^{2}D1	
12402.68	12395.47	7.21	13	10	0.21	0.16	0.30	46% 1|^{4}P	+	36% 1|^{2}P	+	7% 1|^{2}D2	
0.00	8.71	−8.71	14	10	0.25	0.14	0.30	85% 1|^{4}F	+	8% 1|^{2}D2	+	5% 1|^{2}D1	
$J = 5/2$													
91992.45	91975.13	17.32	7	5	0.15	0.07	0.20	56% 2|(^{1}D)^{2}D	+	37% 2|(^{3}P)^{4}P	+	5% 2|(^{3}F)^{2}F	
82122.71	82137.75	−15.04	13	10	0.09	0.09	0.13	51% 2|(^{3}P)^{4}P	+	33% 2|(^{3}F)^{2}F	+	15% 2|(^{1}D)^{2}D	
77994.60	78001.86	−7.26	16	13	0.08	0.06	0.00	51% 2|(^{3}F)^{2}F	+	20% 2|(^{1}D)^{2}D	+	16% 2|(^{3}F)^{4}F	
66188.65	66185.61	3.04	12	12	0.09	0.06	0.13	83% 2|(^{3}F)^{4}F	+	8% 2|(^{3}F)^{2}F	+	7% 2|(^{1}D)^{2}D	
52467.07	52464.65	2.42	10	5	0.28	0.12	0.30	78% 1|^{2}D1	+	9% 1|^{2}F	+	8% 1|^{2}D2	
34161.81	34161.66	0.15	17	16	0.14	0.12	0.18	86% 1|^{2}F	+	6% 1|^{2}D1	+	5% 1|^{2}D2	
28738.78	28735.79	2.99	18	16	0.17	0.12	0.21	81% 1|^{2}D2	+	8% 1|^{2}D1	+	6% 1|^{4}P	
20922.06	20925.30	−3.24	16	12	0.20	0.16	0.30	90% 1|^{4}P	+	6% 1|^{2}D1	+	2% 1|^{2}D2	
4852.98	4846.00	6.98	17	11	0.25	0.15	0.30	95% 1|^{4}F	+	3% 1|^{2}D2	+	1% 1|^{2}D1	
$J = 7/2$													
93707.66	93721.61	−13.95	9	6	0.13	0.11	0.19	66% 2|(^{1}G)^{2}G	+	31% 2|(^{3}F)2F	+	3% 2|(^{3}F)^{4}F	
86161.85	86146.72	15.13	13	13	0.08	0.07	0.14	64% 2|(^{3}F)^{2}F	+	33% 2|(^{1}G)^{2}G	+	1% 2|(^{3}F)^{4}F	
71889.06	71888.59	0.47	15	12	0.10	0.07	0.13	96% 2|(^{3}F)^{4}F	+	4% 2|(^{3}F)^{2}F			
34625.26	34623.98	1.28	20	17	0.14	0.11	0.18	94% 1|^{2}F	+	4% 1|^{2}G	+	1% 2|(^{3}F)^{2}F	
19012.90	19013.64	−0.74	16	11	0.22	0.15	0.30	85% 1|^{2}G	+	12% 1|^{4}F	+	3% 1|^{2}F	
8972.90	8967.20	5.70	18	14	0.21	0.14	0.23	88% 1|^{4}F	+	10% 1|^{2}G	+	2% 1|^{2}F	
$J = 9/2$													
92004.47	91999.82	4.65	8	6	0.13	0.10	0.19	92% 1|(^{1}G)^{2}G	+	7% 2|(^{3}F)^{4}F			
77307.49	77315.04	−7.55	10	8	0.12	0.11	0.17	93% 2|(^{3}F)^{4}F	+	7% 2|(^{1}G)^{2}G			
30365.54	30366.79	−1.25	10	8	0.24	0.11	0.30	56% 1|^{2}G	+	36% 1|^{2}H	+	8% 1|^{4}F	
19966.76	19969.12	−2.36	14	11	0.22	0.21	0.30	57% 1|^{2}H	+	28% 1|^{4}F	+	16% 1|^{2}G	
11913.86	11919.17	−5.31	13	13	0.22	0.11	0.24	64% 1|^{4}F	+	28% 1|^{2}G	+	8% 1|^{2}H	
$J = 11/2$													
27076.87	27074.49	2.38	6	5	0.30	0.19	0.30	100% 1|^{2}H					

Table 3

Experimental and calculated energy levels (cm^{-1}) in the $5d^2 6p$ configuration of Re V.

E_{obs}	E_{calc}	Δ	N	N_{opt}	rwmv_1	rwmv_2	Unc	Composition				
$J = 1/2$												
183498.82	183833.30	−334.48	1	1	0.69	0.69	0.80	63% $(^1\text{S})^2\text{P}$	+	23% $(^3\text{P})^2\text{P}$	+	11% $(^1\text{D})^2\text{P}$
171185.93	170871.97	313.96	5	3	0.35	0.37	0.40	54% $(^3\text{P})^2\text{P}$	+	23% $(^1\text{S})^2\text{P}$	+	13% $(^3\text{P})^4\text{D}$
166967.38	167095.12	−127.74	3	2	0.39	0.05	0.40	41% $(^1\text{D})^2\text{P}$	+	22% $(^3\text{P})^4\text{P}$	+	17% $(^3\text{P})^2\text{S}$
160580.69	160620.97	−40.28	6	5	0.20	0.20	0.30	42% $(^3\text{P})^4\text{P}$	+	30% $(^1\text{D})^2\text{P}$	+	16% $(^3\text{P})^2\text{S}$
149049.99	149034.93	15.06	6	4	0.28	0.27	0.30	64% $(^3\text{F})^4\text{D}$	+	19% $(^3\text{P})^4\text{D}$	+	10% $(^1\text{D})^2\text{P}$
144946.32	144724.82	221.50	8	8	0.13	0.14	0.19	40% $(^3\text{P})^2\text{S}$	+	28% $(^3\text{P})^4\text{P}$	+	22% $(^3\text{P})^4\text{D}$
141022.57	140796.13	226.44	6	4	0.21	0.20	0.30	45% $(^3\text{P})^4\text{D}$	+	20% $(^3\text{P})^2\text{S}$	+	11% $(^3\text{F})^4\text{D}$
$J = 3/2$												
195575.77	195504.52	71.25	3	3	0.55	0.34	0.60	89% $(^1\text{S})^2\text{P}$	+	3% $(^3\text{P})^2\text{D}$	+	2% $(^3\text{P})^4\text{P}$
177193.54	177397.61	−204.07	6	5	0.27	0.16	0.30	53% $(^3\text{P})^2\text{P}$	+	15% $(^1\text{D})^2\text{D}$	+	12% $(^3\text{P})^2\text{D}$
167335.17	167405.82	−70.65	10	4	0.22	0.16	0.30	58% $(^3\text{P})^2\text{D}$	+	13% $(^3\text{P})^2\text{P}$	+	9% $(^3\text{F})^2\text{D}$
165156.79	165119.21	37.58	7	6	0.23	0.21	0.30	31% $(^1\text{D})^2\text{D}$	+	25% $(^1\text{D})^2\text{P}$	+	18% $(^3\text{P})^2\text{P}$
160748.37	160720.63	27.74	7	5	0.23	0.23	0.30	58% $(^3\text{P})^4\text{P}$	+	13% $(^3\text{P})^4\text{S}$	+	7% $(^1\text{D})^2\text{P}$
156212.54	156232.13	−19.59	10	5	0.20	0.29	0.30	33% $(^3\text{F})^4\text{D}$	+	18% $(^3\text{P})^4\text{S}$	+	15% $(^3\text{F})^2\text{D}$
155990.14	156068.75	−78.61	5	4	0.36	0.30	0.40	24% $(^3\text{P})^4\text{S}$	+	23% $(^3\text{P})^4\text{D}$	+	20% $(^3\text{F})^4\text{D}$
148143.95	148374.48	−230.53	11	8	0.16	0.14	0.20	36% $(^3\text{P})^4\text{D}$	+	24% $(^3\text{P})^4\text{S}$	+	10% $(^1\text{D})^2\text{P}$
145311.00	145307.71	3.29	7	7	0.17	0.07	0.19	36% $(^3\text{F})^4\text{F}$	+	26% $(^3\text{F})^4\text{D}$	+	18% $(^3\text{F})^2\text{D}$
143927.51	143904.87	22.64	11	10	0.13	0.09	0.17	30% $(^3\text{P})^4\text{D}$	+	18% $(^1\text{D})^2\text{P}$	+	17% $(^1\text{D})^2\text{D}$
131236.56	131256.31	−19.75	9	7	0.11	0.08	0.13	51% $(^3\text{F})^4\text{F}$	+	31% $(^3\text{F})^2\text{D}$	+	9% $(^3\text{F})^4\text{D}$
$J = 5/2$												
178243.69	178087.26	156.43	9	6	0.22	0.17	0.30	65% $(^1\text{G})^2\text{F}$	+	12% $(^3\text{F})^2\text{D}$	+	8% $(^3\text{P})^2\text{D}$
173725.21	173603.22	121.99	15	10	0.16	0.08	0.20	31% $(^3\text{P})^4\text{P}$	+	25% $(^1\text{G})^2\text{F}$	+	23% $(^3\text{P})^2\text{D}$
168014.04	168119.62	−105.58	15	8	0.19	0.10	0.23	29% $(^1\text{D})^2\text{D}$	+	27% $(^3\text{P})^2\text{D}$	+	15% $(^3\text{F})^2\text{D}$
164068.22	164066.72	1.50	10	7	0.18	0.09	0.20	38% $(^3\text{P})^4\text{P}$	+	30% $(^1\text{D})^2\text{D}$	+	19% $(^3\text{P})^4\text{D}$
162092.97	162139.67	−46.70	9	8	0.19	0.13	0.22	31% $(^3\text{F})^2\text{D}$	+	26% $(^3\text{P})^4\text{D}$	+	19% $(^3\text{F})^4\text{D}$
157152.26	157035.74	116.52	11	10	0.14	0.06	0.17	41% $(^3\text{F})^4\text{D}$	+	19% $(^3\text{P})^4\text{D}$	+	18% $(^3\text{F})^2\text{F}$
153832.45	153905.30	−72.85	16	13	0.12	0.10	0.16	31% $(^3\text{F})^2\text{F}$	+	17% $(^3\text{F})^4\text{D}$	+	11% $(^3\text{P})^2\text{D}$
147749.65	147689.95	59.70	12	12	0.11	0.11	0.17	26% $(^3\text{F})^4\text{D}$	+	18% $(^3\text{P})^4\text{D}$	+	17% $(^3\text{F})^2\text{F}$
143475.48	143461.17	14.31	11	11	0.11	0.07	0.14	28% $(^3\text{F})^4\text{F}$	+	22% $(^3\text{F})^4\text{G}$	+	14% $(^1\text{D})^2\text{D}$
137538.54	137532.93	5.61	9	8	0.13	0.13	0.15	42% $(^3\text{F})^4\text{F}$	+	20% $(^3\text{F})^2\text{D}$	+	18% $(^3\text{F})^4\text{D}$
126234.59	126340.37	−105.78	7	7	0.13	0.07	0.17	64% $(^3\text{F})^4\text{G}$	+	18% $(^3\text{F})^2\text{F}$	+	12% $(^1\text{D})^2\text{F}$
$J = 7/2$												
174120.53	174205.16	−84.63	8	7	0.18	0.14	0.23	54% $(^1\text{G})^2\text{F}$	+	19% $(^1\text{G})^2\text{G}$	+	7% $(^3\text{P})^4\text{D}$
171739.22	171655.04	84.18	8	8	0.24	0.21	0.30	40% $(^1\text{D})^2\text{F}$	+	36% $(^3\text{P})^4\text{D}$	+	6% $(^3\text{F})^2\text{G}$
164424.89	164350.82	74.07	14	10	0.16	0.11	0.19	36% $(^3\text{P})^4\text{D}$	+	17% $(^3\text{F})^2\text{F}$	+	14% $(^3\text{F})^4\text{D}$
158442.87	158476.86	−33.99	12	7	0.18	0.14	0.21	30% $(^3\text{F})^4\text{D}$	+	19% $(^1\text{G})^2\text{G}$	+	18% $(^3\text{F})^2\text{G}$
155597.70	155648.31	−50.61	13	11	0.15	0.14	0.20	27% $(^1\text{D})^2\text{F}$	+	21% $(^1\text{G})^2\text{F}$	+	16% $(^3\text{F})^2\text{F}$
153294.64	153297.71	−3.07	12	10	0.12	0.07	0.16	39% $(^3\text{F})^4\text{F}$	+	30% $(^1\text{G})^2\text{G}$	+	20% $(^3\text{F})^2\text{G}$
148097.20	148065.04	32.16	12	11	0.13	0.12	0.19	30% $(^3\text{F})^4\text{D}$	+	20% $(^3\text{F})^4\text{F}$	+	19% $(^3\text{F})^2\text{F}$
144702.76	144654.26	48.50	11	11	0.12	0.09	0.16	38% $(^3\text{F})^4\text{F}$	+	29% $(^3\text{F})^4\text{D}$	+	11% $(^3\text{F})^2\text{F}$
135906.77	135895.42	11.35	10	10	0.10	0.09	0.13	75% $(^3\text{F})^4\text{G}$	+	10% $(^3\text{F})^2\text{F}$	+	8% $(^3\text{F})^4\text{F}$
$J = 9/2$												
168691.51	168765.53	−74.02	9	6	0.18	0.09	0.22	47% $(^1\text{G})^2\text{G}$	+	40% $(^1\text{G})^2\text{H}$	+	9% $(^3\text{F})^4\text{F}$
163341.12	163301.90	39.22	9	8	0.15	0.08	0.20	66% $(^3\text{F})^2\text{G}$	+	18% $(^3\text{F})^4\text{F}$	+	16% $(^1\text{G})^2\text{G}$
156490.63	156499.96	−9.33	11	7	0.18	0.15	0.22	42% $(^1\text{G})^2\text{H}$	+	41% $(^3\text{F})^4\text{F}$	+	13% $(^1\text{G})^2\text{G}$
151877.34	151894.24	−16.90	10	7	0.18	0.13	0.21	57% $(^3\text{F})^4\text{G}$	+	14% $(^1\text{G})^2\text{G}$	+	11% $(^3\text{F})^4\text{F}$
143230.54	143165.01	65.53	9	9	0.12	0.11	0.18	42% $(^3\text{F})^4\text{G}$	+	21% $(^3\text{F})^4\text{F}$	+	17% $(^3\text{F})^2\text{G}$
$J = 11/2$												
172562.67	172531.74	30.93	3	1	0.45	0.45	0.50	93% $(^1\text{G})^2\text{H}$	+	7% $(^3\text{F})^4\text{G}$		
157629.21	157681.29	−52.08	5	5	0.28	0.17	0.30	93% $(^3\text{F})^4\text{G}$	+	7% $(^1\text{G})^2\text{H}$		

Table 4

Fitted and calculated parameter values (cm^{-1}) in the 5d^3, 5d^{2}6s and 5d6s^2 configurations of Re V.

Parameter	Fitted value	HFR	Fitted/HFR
5d^3			
E_{av}	24106.6 (3.0)	27309.5	0.8827
O_2	6111.5 (5.2)	7396.8	0.8262
O'_2	4070.9 (4.3)	5019.6	0.8110
E_α	74.5 (3.5)		
E_β	61.7 (3.8)		
ζ_d	3593.4 (3.7)	3776.4	0.9515
T_1	−0.07 (0.16)		
T_2	0.05 (0.16)		
T_3	0.0		
T_4	0.0		
A_c	20.1 (3.6)		
A_3	3.9 (2.4)		
A_4	−0.9 (2.8)		
A_5	5.6 (2.7)		
A_6	14.2 (2.3)		
A_1	−1.7		
A_2	2.0		
A_0	−1.6		
5d^{2}6s			
E_{av}	83101.0 (3.6)	89020.8	0.9560[a]
O_2	6266.7 (9.9)	7580.4	0.8267
O'_2	4180.9 (5.6)	5130.3	0.8149
E_α	73.2 (4.9)		
E_β	65.0		
ζ_d	3815.2 (3.5)	3980.4	0.9585
A_c	20.1		
A_3	3.9		
A_4	−0.9		
A_5	5.6		
A_6	14.2		
A_1	−1.7		
A_2	2.0		
A_0	−1.6		
C_{ds}	3085.9 (4.7)	3847.7	0.8020
T_{dds}	−19.6 (4.5)		
A_{mso}	43.9 (3.3)		
A_{ss}	0.0		
5d6s^2			
E_{av}	153043.0	166853.1	0.9240[a]
ζ_d	4028.0	4187.4	0.9619
R^2(dd, ds)12[b]	−22395.0	−26981.4	0.83
R^2(dd, ss)13	20263.0	24413.6	0.83
R^2(dd, ds)23	−22356.0	−26934.5	0.83
Mean deviation[c]= 13.1 cm^{-1}			

[a] The energy differences with respect to the ground configuration were used: $(E_{av}(conf) - E_{av}(5d^3))_{LSF}/(E_{av}(conf) - E_{av}(5d^3))_{HFR}$, where "conf" is either 5d^{2}6s or 5d6s^2.

[b] Trailing digits *xy* in the *R*-integral labels denote interaction between configurations *x* and *y*, where 1 stands for 5d^3, 2 stands for 5d^{2}6s and 3 stands for 5d6s^2.

[c] Mean deviation = $[(\Sigma(E_{obs} - E_{calc})^2)/(n - m)]^{1/2}$, where *n* is the number of known levels, *m* is the number of free parameters.

Table 5
Fitted and calculated parameter values (cm^{-1}) in the $5d^26p$, $5d6s6p$ and $6s^26p$ configurations of Re V.

Parameter	Fitted value	HFR	Fitted/HFR
$5d^26p$			
E_{av}	157971.5 (15.1)	161983.3	0.9940[a]
O_2	6319.9 (30.4)	7631.3	0.8282
O'_2	4216.5 (35.1)	5160.7	0.8170
E_α	75.3 (31.3)		
E_β	50.0 (27.8)		
ζ_d	3910.4 (17.4)	4032.8	0.9697
A_c	21.6		
A_3	2.4		
A_4	4.2		
A_5	4.3		
A_6	11.7		
A_1	−1.8		
A_2	2.0		
A_0	−1.6		
$C_1(dp)$	2787.4 (25.6)	3305.1	0.8434
$C_2(dp)$	2412.6 (29.5)	3170.2	0.7610
$C_3(dp)$	1335.7 (27.5)	1643.2	0.8129
$S_1(dp)$	208.2 (21.3)		
$S_2(dp)$	−79.4 (32.3)		
T_{16}	−25.0		
T_{25}	5.0		
T_{26}	−35.0		
T_{27}	5.0		
T_{28}	55.0		
T_{29}	−35.0		
T_{30}	10.0		
ζ_p	10607.8 (35.4)	9440.9	1.1236
SS_{02}	0.0		
SS_{20}	0.0		
$S_d.L_p$	−120.0		
$S_p.L_d$	−17.0		
$Z^2_{pp'}$	−50.0		
$Z^2_{dd'}$	60.0		
$Z^1_{pp'}$	155.0		
$Z^1_{dd'}$	−15.0		
$Z^3_{pp'}$	70.0		
$Z^3_{dd'}$	5.0		
$5d6s6p$			
E_{av}	227859.0	234123.9	0.9852[a]
ζ_d	4108.0	4236.7	0.9696
C_{ds}	3067.0	3823.6	0.8021
A_{mso}	52.0		
A_{ss}	0.0		
$C_1(dp)$	2920.0	3461.0	0.8437
$C_2(dp)$	2454.0	3222.1	0.7616
$C_3(dp)$	1341.0	1650.8	0.8123
$S_1(dp)$	210.0		
$S_2(dp)$	−80.0		
ζ_p	11703.0	10415.7	1.1236
$S_d.L_p$	−120.0		
$S_p.L_d$	−17.0		
$Z^2_{pp'}$	−50.0		
$Z^2_{dd'}$	60.0		
$Z^1_{pp'}$	155.0		
$Z^1_{dd'}$	−15.0		
$Z^3_{pp'}$	70.0		
$Z^3_{dd'}$	5.0		
C_{sp}	11951.0	14398.8	0.83
$A_{mso}(sp)$	−783.0		
$6s^26p$			
E_{av}	315304.0	322883.4	0.9852[a]
ζ_p	12876.0	11459.5	1.1236
$R^2(dd, ds)12$[b]	−22255.2	−26813.5	0.83
$R^2(dp, sp)12$	−20390.9	−24567.4	0.83
$R^1(dp, ps)12$	−18293.0	−22039.7	0.83
$R^2(dd, ss)13$	20133.9	24257.7	0.83
$R^2(dp, sp)23$	−20681.0	−24916.9	0.83
$R^1(dp, ps)23$	−18448.3	−22226.9	0.83

Mean deviation[c] $= 101$ cm^{-1}

[a] The energy differences with respect to the ground configuration were used: $(E_{av}(conf) - E_{av}(5d^3))_{LSF}/(E_{av}(conf) - E_{av}(5d^3))_{HFR}$, where "conf" is either $5d^26p$, $5d6s6p$ or $6s^26p$.

[b] Trailing digits xy in the R-integral labels denote interaction between configurations x and y, where 1 stands for $5d^26p$, 2 stands for $5d6s6p$ and 3 stands for $6s^26p$.

[c] Mean deviation $= [(\Sigma(E_{obs} - E_{calc})^2)/(n - m)]^{1/2}$, where n is the number of known levels, m is the number of free parameters.