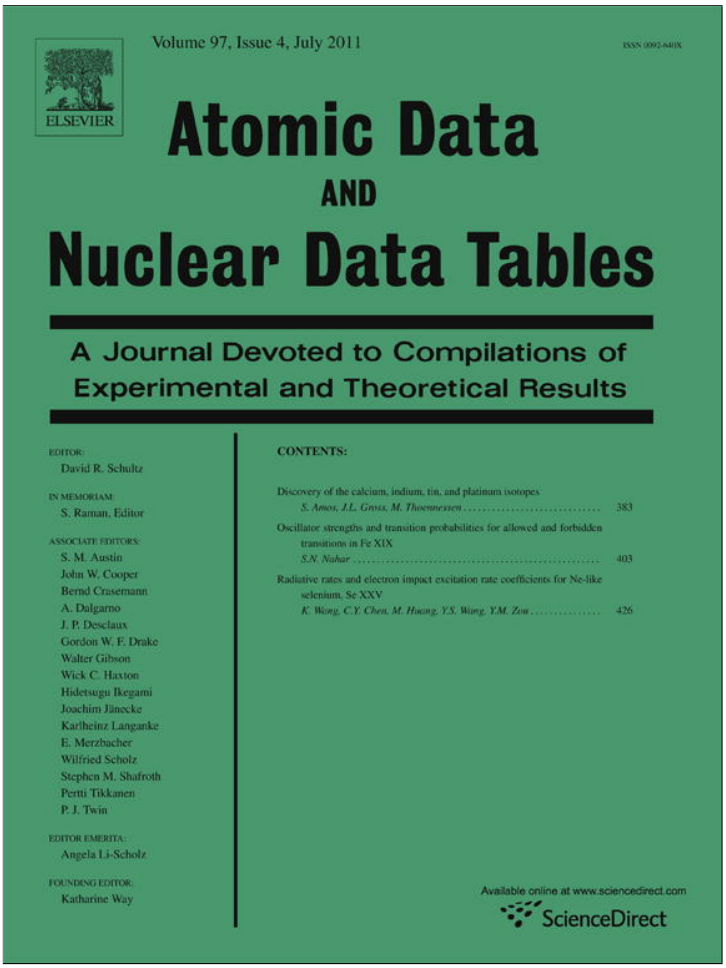

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Oscillator strengths and transition probabilities for allowed and forbidden transitions in Fe XIX

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ABSTRACT

An extensive set of oscillator strengths, line strengths, and radiative decay rates for the allowed and forbidden transitions in Fe XIX is presented. They correspond to 1626 fine structure levels of total angular momenta $0 \leq J \leq 8$ of even and odd parities with $2 \leq n \leq 10$, $0 \leq l \leq 9$, $0 \leq L \leq 10$, and $(2S + 1) = 1$, 3, 5. In contrast, the compiled table of the National Institute for Standards and Technology (NIST) lists only 63 observed levels. A total of 289,291 electric dipole allowed transitions are presented. They were obtained in the close coupling approximation using the relativistic Breit–Pauli *R*-matrix method. The wavefunction expansion included 15 levels of the configurations $2s^22p^3$, $2s2p^4$, and $2p^5$ of the Fe XX core. The calculated fine structure levels are assigned with spectroscopic identifications using quantum defect analysis. Comparison with the observed energies shows very good agreement, the largest difference being less than 4%. The transitions also compare well with the compiled data by NIST and recent calculations. The forbidden transitions of the electric quadrupole and octupole, and magnetic dipole and quadrupole, type are presented for the 379 levels of the configurations $2s^22p^4$, $2s2p^5$, $2p^6$, $2s^22p^33s$, $2s^22p^33p$, $2s^22p^33d$, $2s^22p^34s$, $2s^22p^34p$, $2s^22p^34d$, $2s^22p^34f$, $2s2p^43s$, $2s2p^43p$, $2s2p^43d$, $2s2p^44s$, $2s2p^44p$, and $2s^22p^23s^2$ of Fe XIX. They correspond to a total of 66,619 transitions. These results have been obtained from relativistic Breit–Pauli atomic structure calculations using the program SUPERSTRUCTURE. The forbidden transition probabilities show very good agreement with those compiled by NIST.

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Contents

1. Introduction

The highly charged oxygen-like iron ion, Fe XIX, is important to study because it is a constituent of astrophysical plasmas, especially in high temperature regions. For example, an emission line of Fe XIX has been studied relevant to the postflare loop oscillation in the solar limb using SOHO [1], and Desai et al. [2] found a peak in the X-ray to far-UV emissions of Fe XVIII and Fe XIX from Capella observed by the Chandra observatory. With observatories like Chandra, SOHO, HST, FUSE, EXOSAT, ROSAT, and XMM-Newton, large numbers of high precision spectra are being obtained. Study of these spectra requires highly accurate theoretical atomic data for radiative and collisional processes. However, for Fe XIX, the compiled table of the National Institute of Standards and Technology (NIST) [3] contains only 63 fine structure levels and 92 transitions. This report presents extensive results for Fe XIX fine structure transitions obtained from relativistic calculations in the Breit–Pauli approximation as part of the Iron Project (IP) [4].

Most of the earlier works considering Fe XIX were carried out through atomic structure calculations, but using different codes. Results obtained by Cheng et al. [5], Loulergue et al. [6], and Fawcett [7] are included in the NIST compilation, but only a limited number of transitions is given. Shirai et al. [8] also provided a compilation of the earlier works and some additional transitions, and the lifetime for one level of Fe XIX was measured by Buchet et al. [9]. The recent calculations for oscillator strengths using the relativistic Dirac–Fock approximation were carried out by Jonauskas et al. [10] for a relatively large set and Kotochigova et al. [11] for a limited number of transitions. The first *R*-matrix results for a large set of energy levels, photoionization cross sections, and oscillator strengths were obtained by Butler and Zeippen [12] as part of the Opacity Project (OP) [13]. The results correspond to the non-relativistic *LS* coupling approximation. Although the work was not published, the data is available from the OP database, TOPbase [14]. Photoionization cross sections and recombination rates of the ground state fine structure levels $2s^22p^4(^4P_{2,0,1})$ of Fe XIX in the relativistic Breit–Pauli *R*-matrix (BPRM) method were obtained by Zhang and Pradhan [15] who found significant differences with the results of Donnelly et al. [16]. Zhang and Pradhan [15] also provided the transition probabilities for $2s^22p^4(^4P_{2,0,1}) - 2s2p^5(^{3,1}P^o)$ allowed transitions. Though the NIST compilation [3] provides a total of 92 transitions, many more lines of low and high excitation of most ionization stages of iron are found in observations from space based UV and X-ray observatories. Hence, the present consideration of a large number of transitions should meet most of the practical needs for the atomic transitions in Fe XIX.

2. Theory

In this report, the electric dipole (E1) allowed transitions are obtained in the close coupling approximation using the Breit–Pauli *R*-matrix (BPRM) method developed as part of the IP [4,17–20]. The forbidden electric quadrupole (E2) and octupole (E3), and magnetic dipole (M1) and quadrupole (M2), transitions are obtained from configuration interaction atomic structure calculations using the computer code SUPERSTRUCTURE (SS) [21–24].

In the BPRM method, the atomic system is described as an N-electron target (core) interacting with a $(N+1)'$th electron. The wavefunction expansion, Ψ_E, of the $(N+1)$ electron system with total orbital angular momentum L, spin multiplicity $(2S+1)$, and total angular momentum symmetry $J\pi$, is written as

$$\Psi_E(e+ion) = A\sum_i \chi_i(ion)\theta_i + \sum_j c_j\Phi_j(e+ion), \tag{1}$$

where χ_i is the target ion wavefunction in a specific state $S_iL_i\pi_i$ or level $J_i\pi_i$, and θ_i is the wavefunction of the interacting $(N+1)$th electron in a channel labeled as $S_iL_i(J_i)\pi_i\, k_i^2\ell_i(SL\pi$ or $J\pi)$ where k_i^2 is the incident kinetic energy. The Φ_j's are correlation wavefunctions of the $(N+1)$ electron system that (a) compensate for the orthogonality conditions between the continuum and the bound orbitals, and (b) represent additional short-range correlation.

The relativistic Hamiltonian for the $(N+1)$ electron system in the Breit–Pauli approximation is given by (see e.g., [23])

$$\begin{aligned} H_{N+1}^{\rm BP} = {} & \sum_{i=1}^{N+1}\left\{-\nabla_i^2 - \frac{2Z}{r_i} + \sum_{j>i}^{N+1}\frac{2}{r_{ij}}\right\} + H_{N+1}^{\rm mass} + H_{N+1}^{\rm Dar} + H_{N+1}^{\rm so} \\ & + \frac{1}{2}\sum_{i\neq j}^{N}[g_{ij}(so+so') + g_{ij}(ss') \\ & + g_{ij}(css') + g_{ij}(d) + g_{ij}(oo')] \end{aligned} \tag{2}$$

where $H_{N+1}^{\rm mass}$ is the mass correction, $H_{N+1}^{\rm Dar}$ is the Darwin term, and $H_{N+1}^{\rm so}$ is the spin–orbit interaction term. The two-body interaction terms are given with the notation c for contraction, d for Darwin, o for orbit, s for spin, and a prime indicates 'other'. All terms improve the energies except the spin–orbit interaction term which splits the energies into fine structure components. The BPRM

Hamiltonian includes the first three one-body corrections and part of two-body interactions terms. However, the atomic structure calculations for the forbidden transitions include the contribution of the full Breit interaction term consisting of the fine structure terms, that is spin-other-orbit (so') and spin-other-spin (ss') terms and ignores the last three two-body interaction terms. In the BPRM method, the set of quantum numbers $SL\pi$ are recoupled to obtain $(e + ion)$ states with total $J\pi$, following the diagonalization of the $(N + 1)$-electron Hamiltonian,

$$H^{BP}_{N+1}\Psi = E\Psi. \tag{3}$$

Substitution of the wavefunction expansion results in a set of coupled equations that are solved using the R-matrix approach. The bound states solutions Ψ_B correspond to negative total energies $(E < 0)$ at discrete eigenvalues of the $(e + ion)$ Hamiltonian.

The generalized line strength for an E1 transition is given by

$$S(if) = \left| \langle \Psi_f | \sum_{j=1}^{N+1} r_j | \Psi_i \rangle \right|^2 \tag{4}$$

where Ψ_i and Ψ_f are the initial and final bound wavefunctions, respectively. The line strengths are energy independent quantities. The oscillator strength (f_{ij}) and radiative decay rate or Einstein's A-coefficient for an E1 transition are given by

$$f_{ij} = \frac{E_{ji}}{3g_i} S(ij), \qquad A_{ji}\ (\text{a.u.}) = \frac{1}{2}\alpha^3 \frac{g_i}{g_j} E_{ji}^2 f_{ij}. \tag{5}$$

E_{ji} is the energy difference between the initial and final states, α is the fine structure constant, and g_i, g_j are the statistical weight factors of the initial and final states, respectively.

The radiative decay rates for various types of forbidden transitions are obtained from the general line strength,

$$S^{\mathrm{X}\lambda}(ij) = \left| \left\langle \Psi_j \middle\| O^{\mathrm{X}\lambda} \middle\| \Psi_i \right\rangle \right|^2, \qquad S(ji) = S(ij) \tag{6}$$

where $O^{\mathrm{X}\lambda}$ represents the operator for various types of transitions, X represents the electric or magnetic type and λ represents various multipoles, such as 1 for dipole, 2 for quadrupole, 3 for octupole [24]. The radiative decay rates for various higher-order radiation are obtained from the line strength, $S^{\mathrm{X}\lambda}(ij)$. The A-coefficients for electric quadrupole and magnetic dipole transitions are

$$g_j A^{\mathrm{E2}}_{ji} = 2.6733 \times 10^3 \mathrm{s}^{-1}\ (E_j - E_i)^5 S^{\mathrm{E2}}(i,j) \tag{7}$$

$$g_j A^{\mathrm{M1}}_{ji} = 3.5644 \times 10^4 \mathrm{s}^{-1}\ (E_j - E_i)^3 S^{\mathrm{M1}}(i,j), \tag{8}$$

and for electric octupole and magnetic quadrupole transitions are

$$g_j A^{\mathrm{E3}}_{ji} = 1.2050 \times 10^{-3} \mathrm{s}^{-1}\ (E_j - E_i)^7 S^{\mathrm{E3}}(i,j) \tag{9}$$

$$g_j A^{\mathrm{M2}}_{ji} = 2.3727 \times 10^{-2} \mathrm{s}^{-1}\ (E_j - E_i)^5 S^{\mathrm{M2}}(i,j). \tag{10}$$

The lifetime of a level can be obtained from the A-value as,

$$\tau_k(s) = \frac{1}{\sum_i A_{ki}(s^{-1})}, \tag{11}$$

where the sum is the total radiative transition probability for the level k, and $A_{ji}(s^{-1}) = A_{ji}(\text{a.u.})/\tau_0$, $\tau_0 = 2.4191 \times 10^{-17}$ s is the atomic unit (a.u.) of time.

3. Calculations

3.1. BPRM calculations for E1 transitions

The initial step for BPRM calculations is to construct an accurate representation of the eigenstates of the target or core ion, χ, in the first term of Eq. (1). They were constructed from the orbital wavefunctions of the Fe XX core obtained using the atomic structure program SS [21] which uses the Thomas–Fermi–Amaldi approximation. A set of 15 configurations, listed in Table A, was optimized for the core eigenstates. Table A also lists the values of Thomas–Fermi scaling parameters for individual orbitals λ_{nl} employed in the atomic structure calculations. It was found that optimization of the wavefunction was more sensitive to inclusion of proper configurations than to changes in the λ_{nl} values. The present wavefunction for Fe XIX included the first 15 fine structure levels of Fe XX as given in Table A. The calculated energies for Fe XX are compared with the measured values given in the NIST [3] compilation. The comparison shows good agreement, the largest discrepancy between the calculated and NIST data being 2.5%. The bound-channel term of the wavefunction, the second term in Eq. (1), included 107 possible $(N + 1)$-configurations with filled 1s orbital, and minimum and maximum occupancies, given within parentheses, of other orbitals as 2s (0–2), 2p (2–6), 3s (0–2), 3p (0–2), 3d (0–2), 4s (0–1), 4p (0–1), and 4d (0–1).

Table A
Fine structure levels and relative energies (E_t) of the target (core) ion Fe XX in the wavefunction expansion of Fe XIX. The atomic structure calculations for Fe XX employs the set of spectroscopic configurations: $2s^22p^3$, $2s2p^4$, $2p^5$, $2s^22p^23s$, $2s^22p^23p$, $2s^22p^23d$, $2s^22p^24s$, $2s^22p^24p$, $2s^22p^24d$, $2s2p^33s$, $2s2p^33p$, $2s2p^33d$, $2s2p^34s$, $2s2p^34p$, and $2s2p^34d$, and the Thomas–Fermi scaling parameters for the orbitals: $\lambda_{nl} = 1.35(1s)$, $1.25(2s)$, $1.12(2p)$, $1.07(3s)$, $1.05(3p)$, $1.0(3d)$, $1.0(4s)$, $1.0(4p)$, and $1.0(4d)$. The present SS energies are compared with the observed energies from the NIST compilation [3].

	Level	J_t	E_t (Ry) NIST	E_t (Ry) SS
1	$2s^22p^3(^4S^o)$	1.5	0.	0.0
2	$2s^22p^3(^2D^o)$	1.5	1.294	1.2632
3	$2s^22p^3(^2D^o)$	2.5	1.674	1.6050
4	$2s^22p^3(^2P^o)$	0.5	2.409	2.3718
5	$2s^22p^3(^2P^o)$	1.5	3.00	2.9465
6	$2s2p^4(^4P)$	2.5	6.914	6.8594
7	$2s2p^4(^4P)$	1.5	7.525	7.4799
8	$2s2p^4(^4P)$	0.5	7.724	7.6796
9	$2s2p^4(^2D)$	1.5	9.641	9.5006
10	$2s2p^4(^2D)$	2.5	9.803	9.6445
11	$2s2p^4(^2S)$	0.5	11.027	10.892
12	$2s2p^4(^2P)$	1.5	11.548	11.322
13	$2s2p^4(^2P)$	0.5	12.418	12.211
14	$2p^5(^2P^o)$	1.5	18.058	17.811
15	$2p^5(^2P^o)$	0.5	19.071	18.792

The suite of BPRM codes [19,20] was used for the computations of energies and oscillator strengths. The relevant radial integrals are computed in the code STG1. The algebraic and angular coefficients of the (e, ion) Hamiltonian are computed in STG2. The intermediate coupling calculations are enabled by recoupling the LS symmetries in a pair-coupling representation in stage RECUPD. The $(e+core)$ Hamiltonian matrix is diagonalized for each resulting $J\pi$ in STGH. The Fe XIX fine structure levels were obtained by scanning through the poles in the $(e+ion)$ Hamiltonian with a fine mesh of effective quantum number ν, with $\Delta\nu = 0.001$ to 0.00025 using the code STGB.

The energy eigenvalues were then identified through a theoretical spectroscopy procedure as described in Ref. [25] using the code PRCBPID. The procedure analyzes quantum defects, possible matching of components of the relevant LS terms, and channel percentage contributions corresponding to the integrated wavefunctions in the outer region. Although these criteria are built into the identification code PRCBPID, it can assign only possible identifications that are then sorted out manually using the procedure described below for final identification.

PRCBPID assigns each level with one or more LS terms based on the highest percentage of the contributing channels. These channels provide information about the configuration, LS term, and

Table B
Partial set of fine structure energy levels of Fe XIX in $J\pi$ order. i_e is the general energy index and I_J is the energy index of the level in its symmetry. *jjpiiii* is the numerical code of the level, where values are $jj = J$, $pi = \pi$ (0 for even and 1 for odd), and *iii* is I_J.

1626 = number of levels, $n \leq 10$, $l \leq 9$						
i_e	$J\pi$	I_J	E (Ry)	Config	$^{2S+1}L^{\pi}$	*jjpiiii*
1	0.0 e	1	−1.07214E+02	2s2 2p4	^{3}Pe	000001
2	0.0 e	2	−1.04937E+02	2s2 2p4	^{1}Se	000002
3	0.0 e	3	−8.84519E+01	2p6	^{1}Se	000003
4	0.0 e	4	−4.38691E+01	2s22p3 4So 3p	^{3}P e	000004
5	0.0 e	5	−4.25150E+01	2s22p3 2Do 3p	^{3}P e	000005
6	0.0 e	6	−4.14035E+01	2s22p3 2Po 3p	^{3}P e	000006
7	0.0 e	7	−3.99212E+01	2s22p3 2Po 3p	^{1}S e	000007
8	0.0 e	8	−3.81537E+01	2s2p4 4Pe 3s	^{3}P e	000008
9	0.0 e	9	−3.51869E+01	2s2p4 2Se 3s	^{1}S e	000009
10	0.0 e	10	−3.46015E+01	2s2p4 4Pe 3d	^{5}D e	000010
11	0.0 e	11	−3.39672E+01	2s2p4 2Pe 3s	^{3}P e	000011
12	0.0 e	12	−3.38166E+01	2s2p4 4Pe 3d	^{3}P e	000012
13	0.0 e	13	−3.16487E+01	2s2p4 2De 3d	^{3}P e	000013
14	0.0 e	14	−3.10743E+01	2s2p4 2De 3d	^{1}S e	000014
15	0.0 e	15	−2.97844E+01	2s2p4 2Pe 3d	^{3}P e	000015
16	0.0 e	16	−2.52969E+01	2p5 2Po 3p	^{3}P e	000016
17	0.0 e	17	−2.39710E+01	2s22p3 4So 4p	^{3}P e	000017
18	0.0 e	18	−2.37946E+01	2p5 2Po 3p	^{1}S e	000018
19	0.0 e	19	−2.27598E+01	2s22p3 2Do 4p	^{3}P e	000019
20	0.0 e	20	−2.16601E+01	2s22p3 2Po 4p	^{3}P e	000020
21	0.0 e	21	−2.09721E+01	2s22p3 2Do 4f	^{3}P e	000021
22	0.0 e	22	−2.07593E+01	2s22p3 2Po 4p	^{1}S e	000022
23	0.0 e	23	−1.72058E+01	2s2p4 4Pe 4s	^{3}P e	000023
24	0.0 e	24	−1.60853E+01	2s2p4 4Pe 4d	^{5}D e	000024
25	0.0 e	25	−1.56928E+01	2s2p4 4Pe 4d	^{3}P e	000025
26	0.0 e	26	−1.51235E+01	2s22p3 4So 5p	^{3}P e	000026
27	0.0 e	27	−1.39972E+01	2s22p3 2Do 5p	^{3}P e	000027
28	0.0 e	28	−1.38949E+01	2s2p4 2Se 4s	^{1}S e	000028
29	0.0 e	29	−1.34752E+01	2s2p4 2Pe 4s	^{3}P e	000029
30	0.0 e	30	−1.31613E+01	2s22p3 2Do 5f	^{3}P e	000030
31	0.0 e	31	−1.28694E+01	2s2p4 2De 4d	^{3}P e	000031
32	0.0 e	32	−1.28171E+01	2s22p3 2Po 5p	^{3}P e	000032

J value of the core and the valence electron. The levels $(S_iL_iJ_i)n\ell$ yield quantum defects relative to the parent target level $S_iL_iJ_i$ that they belong to. Quantum defects are matched for the series of Rydberg states. The identification of the low-lying levels are reconfirmed by comparing with those of available levels, especially those found in the NIST database. In other cases, Hund's rule is followed for levels from the same configurations such that the level with higher angular orbital momentum L and/or higher spin multiplicity will lie lower than those with lower L and lower spin. The final designation is assigned as $C_t(S_tL_t\pi_t)J_tnlJ(SL)\pi$, where C_t, $S_tL_t\pi_t$, and J_t are the configuration, LS term, parity, and total angular momentum of the target, n and l are the principal and orbital quantum numbers of the outer or the valence electron, and J and $SL\pi$ are the total angular momentum, LS term, and parity of the $(N + 1)$-electron system. This procedure establishes a unique correspondence between the fine structure levels and their LS terms such that the exact number of fine structure levels are accounted for each LS term. Thus, using this procedure, the bound–bound transitions from the BPRM code have been processed for energies and transition wavelengths using code PBPRAD (see Tables 1 and 2 as described below).

3.2. Atomic structure calculations for the forbidden transitions

The calculations for forbidden transitions in Fe XIX include sixteen configurations with orbitals ranging up to $4f$. These configurations are listed in Table 3. All sixteen of them are treated as spectroscopic in the atomic structure calculations using the SS [24] code. The λ_{nl} parameters for the orbitals are 1.35(1s), 1.25(2s), 1.12(2p), 1.07(3s), 1.05(3p), 1.1(3d), 1.1(4s), 1.0(4p), 1.0(4d), and 1.0(4f). These configurations yield 183 LS terms and the corresponding 379 fine structure levels. All transitions among the 379 fine structure levels are considered for the forbidden transitions of the electric dipole, quadrupole, and octupole, and magnetic dipole and quadrupole, types. E1 transitions are not reported since it is a smaller set and BPRM transitions are expected to be more accurate. The transitions have been processed by replacing the calculated energies with the limited number of observed energies using the code PRCSS.

4. Results and discussions

The oscillator strengths, line strengths, and radiative decay rates for E1 (same spin dipole allowed and intercombination) and forbidden electric quadrupole and octupole, and magnetic dipole and quadrupole, fine structure transitions in oxygen-like Fe XIX have been calculated. The large set of atomic data for various transitions should comprise a reasonably complete set for this ion. The results for the energy levels, oscillator strengths for allowed E1 transitions, and radiative decay rates for forbidden E2, E3, M1, and M2 transitions are discussed separately below.

4.1. Level energies and spectroscopic designations in the BPRM approximation

A total of 1626 fine structure levels have been obtained for Fe XIX. They correspond to total angular momenta $0 \leq J \leq 8$ for even and odd parities with $n \leq 10$, $0 \leq l \leq 9$, total orbital angular momenta $0 \leq L \leq 10$, and spin multiplicities 1, 3, and 5. The calculations included only the first 15 levels, out of complete spectroscopic set of 415 target levels. No bound states are expected to form with core excitations beyond these 15 levels since the next excited core level lies about 47 Rydbergs (Ry) higher. The complete set of energy levels of Fe XIX is available as supplemental material.

The energies are presented in two formats for various practical reasons: (i) in "$J\pi$" order format where levels of the symmetry are listed in ascending order of energies, and (ii) in "LSJ" component format where fine structure levels are grouped as components of a LS term. A partial set in $J\pi$ order, useful for modeling code applications, is given Table B. This set contains mainly calculated energies. However, the calculated energies for the observed levels have been replaced by the measured values to compute more accurate transition wavelengths. Table 1 provides energies in LSJ format, useful for spectroscopic diagnostics, where the completeness of the set of energy levels belonging to the relevant LS term can be checked and any missing level can be detected. All energies in this table correspond to calculated values. In this table, the effective quantum number ν of an equivalent electron level is set to zero because the value may have some uncertainty. However, it can be estimated by using the formula $\nu = z/\sqrt{E}$, where z is the effective charge.

The BPRM method computes the energy eigenvalues, but does not identify them. As discussed in Section 2, these energies have been identified through a spectroscopic procedure [25]. This theoretical spectroscopy requires a considerable amount of time. In contrast, in the atomic structure calculations the levels are identified automatically based on the highest mixing coefficient. The percentage weight of this mixing of levels in the BPRM method is different, where it is related to a channel contribution in the outer region of the R-matrix boundary. The number of contributing channels is typically much larger than that in an atomic structure calculation. Analysis of the quantum defects and matching of algebraic summation of angular momenta of various contributing channels are crucial to determine the level designation. Due to mixing of states and similarities in quantum defects, the present identification criteria may assign more than one spectroscopic

Table C
Comparison of calculated energies, E(BPRM), for Fe XIX with observed values (NIST). I_J is the calculated level index for its position. An asterisk indicates an incomplete set of observed energy levels.

Level		J: I_J	E (Ry, NIST)	E (Ry, BPRM)
2s2 2p4	^{3}P^e	2.0 : 1	107.90000	107.24300
2s2 2p4	^{3}P^e	1.0 : 1	107.08500	106.43000
2s2 2p4	^{3}P^e	0.0 : 1	107.21400	106.56300
2s2 2p4	^{1}D^e	2.0 : 2	106.36100	105.66900
2s2 2p4	^{1}S^e	0.0 : 2	104.93700	104.21700
2s2p5	^{3}P^o	2.0 : 1	99.49000	98.77570
2s2p5	^{3}P^o	1.0 : 1	98.92640	98.20250
2s2p5	^{3}P^o	0.0 : 1	98.51380	97.78800
2s2p5	^{1}P^o	1.0 : 2	96.34880	95.59100
2p6	^{1}S^e	0.0 : 3	88.45190	87.65300
2s22p3 4So3s	^{3}S^o	1.0 : 3	47.02740	46.32100
2s22p3 2Do3s	^{3}D^o	3.0 : 1	45.76980	45.00950
2s22p3 2Do3s	^{3}D^o	2.0 : 3	46.05230	45.34050
2s22p3 2Do3s	^{3}D^o	1.0 : 4	46.04320	45.32430
2s22p3 2Do3s	^{1}D^o	2.0 : 4	45.62400	44.83330
2s22p3 2Po3s	^{3}P^o	2.0 : 5	44.38470	43.65750
2s22p3 2Po3s	^{3}P^o	1.0 : 5	44.81300	44.19400
2s22p3 2Po3s	^{3}P^o	0.0 : 2	44.95880	44.26550
2s22p3 2Po3s	^{1}P^o	1.0 : 6	44.24800	43.51780
2s22p3 4So3d	^{3}D^o	3.0*: 3	41.84220	41.10710
2s22p3 2Do3d 3/2	^{3}P^o	2.0*: 8	40.73960	40.48040
2s22p3 2Do3d 5/2	^{3}D^o	3.0*: 7	40.50270	39.23750
2s22p3 2Do3d 5/2	^{3}D^o	2.0*: 9	40.42070	39.90600
2s22p3 2Do3d 5/2	^{1}F^o	3.0 : 6	40.01970	39.71650
2s22p3 2Po3d 1/2	^{3}F^o	3.0*: 8	40.01060	39.05150
2s22p3 2Po3d 1/2	^{3}F^o	2.0*:11	39.84660	39.53240
2s22p3 2Po3d 3/2	^{3}D^o	3.0 : 9	38.96260	38.34430
2s22p3 2Po3d 3/2	^{3}D^o	2.0 :13	39.06290	38.91690
2s22p3 2Po3d 3/2	^{3}D^o	1.0 :13	38.94440	38.75480
2s22p3 2Po3d 3/2	^{1}P^o	1.0 :15	38.58900	37.61080
2s22p3 4So4d	^{3}D^o	3.0 :21	23.62600	23.18590
2s22p3 4So4d	^{3}D^o	2.0 :34	23.68070	23.31060
2s22p3 4So4d	^{3}D^o	1.0 :34	23.66250	23.63240
2s22p3 2Do4d3/2	^{3}F^o	3.0*:23	22.61450	22.32150
2s22p3 2Do4d3/2	^{3}D^o	2.0*:40	22.47780	21.93750

term to a level belonging to a set with the same configuration, parity, and spin multiplicity. In that case, application of Hund's rule rearranges them in a manner such that all levels are designated uniquely, that is, there is no repetition of identity. However, due to the differences in approaches, the present identifications of some levels may differ from those in other atomic structure calculations, although both can be valid theoretical results.

In Table C the present energies for Fe XIX are compared with the available measured values as compiled by NIST [3]. The level index, I_J, in the table, is the position of the calculated level in the given $J\pi$ symmetry. The index establishes the correspondence between the calculated and the observed levels. As noted above, sixty three levels with proper spectroscopic identification are listed in the NIST table. Each of these levels has been identified in the present set of energy levels. Comparison between the present BPRM energies and the measured values shows that most of the calculated levels are well within a few percent of the measured energies, and the largest discrepancy is 3.85% for the level $2s^22p^3(^2P^o_{3/2})4d(^1F^o_3)$. Two high levels of Fe XIX from the present calculations show differences in identification with those in the NIST compilation; the present $2s^22p^3(^2P^o)6d(^1F^o_3)$ level is identified as $2s^22p^3(^2D^o)6d(^1F^o_3)$ and the $2s^22p^3(^4S^o)6d(^3D^o_1)$ level as $2s^22p^3(^2P^o)6d(^3D^o_1)$ in the NIST compilation.

4.2. E1 transitions in the BPRM approximation

A total of 289,291 E1 transitions among the 1626 fine structure levels of Fe XIX have been calculated. A sample set of oscillator strengths, line strengths, and radiative decay rates for E1 transitions is presented in Table D. The complete set is available as supplemental material. In Table D, the top line specifies the nuclear charge ($Z = 26$) and number of electrons in the ion ($N_{elc} = 8$). This line is followed by sets of oscillator strengths belonging to various pairs of symmetries $J_i\pi_i - J_k\pi_k$. The symmetries are expressed in the form of the statistical weight factors, $g = 2J + 1$, and parity π (0 for even and 1 for odd parity). N_i and N_k are the number of bound levels of symmetries i and k, and NN is the number of transitions. A transition can be identified by the level indices I_i and I_k given in the table listing the energies, Table B. The transition wavelength (λ) in Å is obtained using the relation E (Å) $= 911.2671/E_{ik}$ (Ry). The energies E_i and E_k in Rydbergs of the levels involved in the transition are also given. The sign of an oscillator strength indicates the position of levels such that a negative value means that i is the lower level, while a positive value means k is the lower level. In this table the calculated energies have been replaced by the observed energies wherever available for improvement of the transition wavelength. Since the agreement of the calculated energies is within 1% to less than 4% with the observed values, accuracy improvement could be attained up to about 10% depending on the values of the energy levels.

For comparisons with experimental results and diagnostic applications, a set of transitions employing only the observed set of levels has been processed with complete spectroscopic notation. They have been grouped as fine structure components of LS multiplets and are given in Table 2.

The present A-values for fine structure transitions in Fe XIX are compared with those from other calculations in Table E. A-values for E1 transitions have also been obtained in the present work from atomic structure calculations using the SS code. This set is much smaller than that from the BPRM code and is not presented because the *ab initio* BPRM values include much larger correlation effects and are expected to be more consistent and accurate. However, some SS values have been used for comparison in Table E. In addition, the NIST compilation lists A-values obtained by Cheng et al. [5], Loulergue et al. [6], Fawcett [7], and Shirai et al. [8]. Cheng et al. employed the Dirac–Fock approximation which included the Breit interaction and Lamb shift. Fawcett employed the configuration interaction Hartree–Fock relativistic approximation in the semi-empirical method implemented in Cowan's code. Results from all three atomic structure calculations agree with each other for a number of transitions and the present BPRM A-values agree very well with most of the earlier calculations.

Although NIST assigns an accuracy notation for the A-values, the notation does not reflect the agreement. The present transitions are also in good agreement with those by Jonauskas et al. [10] in general. Kotochigova et al. [11] used the Dirac–Fock-Sturm method to present oscillator strengths for the $1s^22s^22p^4 - 1s^22s2p^43p$ transitions, but did not provide any spectroscopic identification for comparison. Their closely lying transition energies do not correspond to any observed values for any identifications. There are cases where the BPRM values show larger discrepancies than those of the earlier values. For example, the A-value for the transition $2s^22p^4(^1D_2) - 2s^22p^3(^2P^o)3s(^3P^o_2)$ given by Shirai et al. [8] is $6.8e+11$ s^{-1} with a NIST rating of E. While Jonauskas et al. [10] agrees better with a value of $6.49e+11$ s^{-1}, the present BPRM value is $5.05e+11$ s^{-1}, and the SS value is $5.22e+11$ s^{-1}. Another case with a difference is the transition $2s^22p^4(^1D_2) - 2s^22p^3(^2P^o)3d(^3F^o_3)$ for which Shirai et al. give an A-value of $1.0e+13$, Jonauskas et al. [10] a very low value of $2.06e+12$, and the present BPRM result of $8.10e+12$ s^{-1}. However, if one replaces the mixed level $2s^22p^3(^2P^o)3d(^3F^o_3)$ by another mixed level $2s^22p^3(^2P^o)3d(^1F^o_3)$, where $(^3F^o_3)$ has changed to $(^1F^o_3)$, then the value obtained by Jonauskas et al., 8.03e+12, is in very good agreement with the BPRM value. This type of difference can be expected for transitions among mixed levels. Some differences can also arise from differences in the number of configurations included and approximations being made in the calculations.

Table D
Sample set of *f*-, *S*- and *A*-values for allowed E1 transitions in Fe XIX.

26		8					
I_i	I_k	λ (Å)	E_i (Ry)	E_k (Ry)	f	S	A_{ki} (s^{-1})
1 0 3 1 59 150 8850 = gi Pi gk Pk Ni Nk NN							
1	1	109.96	−1.0721E+02	−9.8926E+01	−7.633E−02	2.763E−02	1.404E+10
1	2	83.87	−1.0721E+02	−9.6349E+01	−3.779E−03	1.043E−03	1.195E+09
1	3	15.14	−1.0721E+02	−4.7027E+01	−4.901E−02	2.443E−03	4.753E+11
1	4	14.90	−1.0721E+02	−4.6043E+01	−1.889E−02	9.264E−04	1.892E+11
1	5	14.60	−1.0721E+02	−4.4813E+01	−6.658E−02	3.201E−03	6.942E+11
1	6	14.47	−1.0721E+02	−4.4248E+01	−4.944E−03	2.355E−04	5.248E+10
1	7	13.93	−1.0721E+02	−4.1792E+01	−4.562E−03	2.092E−04	5.229E+10
1	8	13.79	−1.0721E+02	−4.1121E+01	−3.378E−01	1.533E−02	3.952E+12
1	9	13.61	−1.0721E+02	−4.0273E+01	−2.856E−01	1.280E−02	3.426E+12
1	10	13.52	−1.0721E+02	−3.9826E+01	−1.396E−01	6.217E−03	1.698E+12
1	11	13.48	−1.0721E+02	−3.9629E+01	−9.655E−02	4.286E−03	1.181E+12
1	12	13.44	−1.0721E+02	−3.9414E+01	−6.450E−05	2.854E−06	7.939E+08
1	13	13.35	−1.0721E+02	−3.8944E+01	−1.360E+00	5.977E−02	1.697E+13
1	14	13.26	−1.0721E+02	−3.8508E+01	−8.329E−02	3.637E−03	1.053E+12
1	15	13.28	−1.0721E+02	−3.8589E+01	−9.158E−03	4.004E−04	1.154E+11
1	16	13.01	−1.0721E+02	−3.7182E+01	−1.901E−04	8.142E−06	2.496E+09
1	17	12.93	−1.0721E+02	−3.6734E+01	−4.342E−03	1.848E−04	5.775E+10
1	18	12.92	−1.0721E+02	−3.6688E+01	−9.067E−03	3.857E−04	1.207E+11
1	19	12.84	−1.0721E+02	−3.6231E+01	−3.704E−02	1.565E−03	4.997E+11
1	20	12.81	−1.0721E+02	−3.6061E+01	−2.328E−01	9.817E−03	3.156E+12
1	21	12.58	−1.0721E+02	−3.4755E+01	−2.717E−03	1.125E−04	3.819E+10
1	22	12.49	−1.0721E+02	−3.4251E+01	−5.814E−03	2.390E−04	8.287E+10
1	23	12.45	−1.0721E+02	−3.4042E+01	−2.466E−02	1.011E−03	3.536E+11
1	24	12.32	−1.0721E+02	−3.3273E+01	−4.592E−03	1.863E−04	6.722E+10
1	25	12.27	−1.0721E+02	−3.2961E+01	−6.386E−02	2.580E−03	9.427E+11
1	26	12.20	−1.0721E+02	−3.2547E+01	−3.007E−03	1.208E−04	4.489E+10
1	27	12.14	−1.0721E+02	−3.2172E+01	−9.895E−03	3.956E−04	1.492E+11
1	28	12.07	−1.0721E+02	−3.1721E+01	−1.617E−02	6.426E−04	2.467E+11
1	29	11.98	−1.0721E+02	−3.1148E+01	−8.835E−04	3.484E−05	1.369E+10
1	30	11.50	−1.0721E+02	−2.7963E+01	−3.788E−04	1.434E−05	6.370E+09
1	31	11.36	−1.0721E+02	−2.7026E+01	−9.053E−05	3.387E−06	1.559E+09
1	32	11.09	−1.0721E+02	−2.5045E+01	−8.616E−03	3.146E−04	1.558E+11
1	33	10.93	−1.0721E+02	−2.3848E+01	−4.531E−03	1.631E−04	8.432E+10
–	–	–	–	–	–	–	–

Table E
Comparison of the present *A*-values for E1 transitions in Fe XIX with those from various references; a [8], b [7], c [5], d [6], e [10], f [9], g [26], h [27], and i [28].

λ (Å)	A (s^{-1}) (NIST)	A (s^{-1}) (Present) BPRM, SS	$C_i - C_j$	$SL\pi_i - SL\pi_j$	$g_i - g_j$
108.355	$3.9e+10^a$: C, $3.57e+10^e$	3.35e+10,3.54+10	$2s^22p^4 - 2s2p^5$	$^3P - {}^3P^o$	5–5
109.952	$1.6e+10^c$: C	1.40e+10,1.46+10	$2s^22p^4 - 2s^2p^5$	$^3P - {}^3P^o$	1–3
111.695	$1.26e+10^c$: C	1.09e+10,1.15+10	$2s^22p^4 - 2s2p^5$	$^3P - {}^3P^o$	3–3
119.983	$1.04e+10^a$: C	9.02e+9,8.54+9	$2s^22p^4 - 2s2p^5$	$^3P - {}^3P^o$	3–5
101.55	$3.17+10^c$: E, $2.91e+10^e$	2.77e+10	2s22p4 − 2s2p5	3P − 3P	5–3
78.888	$1.3e+10^c$: E	1.12+10, 1.14+10	2s22p4 − 2s2p5	3P − 1P	5–3
83.87	$1.6e+09^c$: E	1.19E+09,1.26+9	2s22p4 − 2s2p5	3P − 1P	1–3
84.874	$9.3e+08^c$: E	8.75e+08,8.32+8,	$2s^22p^4 - 2s^2p^5$	$^3P - {}^1P^o$	3–3
132.63	$2.2e+09^a$:E	1.96e+9,2.01+9	$2s^22p^4 - 2s2p^5$	$^1D - {}^3P^o$	5–5
91.012	$1.49e+11^c$:C	1.32e+11,1.38e+11	$2s^22p^4 - 2s^2p^5$	$^1D - {}^1P^o$	5–3
151.607	$7.9e+08^c$:E	5.86e+8,6,65+8s	$2s^22p^4 - 2s2p^5$	$^1S - {}^3P^o$	1–3
14.966	$2.5e+12^a$:C	2.24e+12,2.09e+12	2s22p4 − 2s22p3(4S)3s	3P − 3S	5–3
14.929	$2.5e+11^b$:D	2.45e+11,2.77e+11	2s22p4 − 2s22p3(2D)3s	3P − 3D	3–5
14.668	$1.1e+12^b$:C	1.06e+12,1.12+12	$2s^22p^4 - 2s^22p^3(^2P^o)3s$	$^3P - {}^3P^o$	3–1
14.735	$9.8e+11^b$:D, $9.53e+11^e$	9.29e+11,8.52 +11	2s22p4 − 2s22p3(2D)3s	3P- 3D	5–5
14.929	$1.2e+12^b$:D	1.16e+12,1.04e+12	2s22p4 − 2s22p3(2D)3s	3P − 3D	3–3
14.633	$1.4e+11^b$: E, $1.27e+11^e$	1.18E+11	2s22p4 − 2s22p3(2D)3s	3P − 1D	5–5
14.995	$2.2e+12^b$:D	2.05e+12,2.0e+12	2s22p4 − 2s22p3(2D)3s	1D − 1D	5–5
14.534	$6.8e+11^b$:D	6.36e+11,6.05+11	2s22p4 − 2s22p3(2P)3s	3P − 3P	3–5
14.603	$7.5e+11^b$:D	6.94e+11,6,53+11	2s22p4 − 2s22p3(2P)3s	3P − 3P	1–3
14.668	$1.1e+12^b$:C	1.07e+12,9.74+11	$2s^22p^4 - 2s^22p^3(^2D^o)3s$	$^3P - {}^3D^o$	5–7
14.70	$6.8e+11^a$: E, $6.49e+11^e$	5.05e+11,5.22+11	$2s^22p^4 - 2s^22p^3(^2P^o)3s$	$^1D - {}^3P^o$	5–5
14.806	$5.6e+11^b$: E	5.05e+11,4.88+11	2s22p4 − 2s22p3(2P)3s	1D − 3P	5–3
14.671	$1.1e+12^b$:D, 1.11e+12e	9.36e+11,1.03+12	$2s^22p^4 - 2s^22p^3(^2P^o)3s$	$^1D - {}^1P^o$	5–3
13.424	$4.8e+12^a$: E	4.02e+12	$2s^22p^4 - 2s^22p^3(^2P^o_{5/2})3d$	$^3P - {}^3F^o$	5–7
13.52	$2.0e+13^b$: D	1.90e+13	$2s^22p^4 - 2s^22p^3(^2D^o_{5/2})3d$	$^3P - {}^3D^o$	5–7
13.735	$1.0e+13^a$:D, $2.06e+12^e$	8.10e+12	$2s^22p^4 - 2s^22p^3(^2P^o_{5/2})3d$	$^1D - {}^3F^o$	5–7
86.999	$1.2e+10^c$: E	1.09e+10,1.05e+10	$2s2p^5 - 2p^6$	$^3P^o - {}^1S$	3–1
115.396	$1.61e+11^c$: C	1.35e+11,1.51e+11	$2s2p^5 - 2p^6$	$^1P^o - {}^1S$	3–1

Table F
Comparison of the present *A*-values for forbidden transitions in Fe XIX with those in references a [5], b [6], and c [10]. The alphabetic letter is the NIST accuracy rating.

λ (Å)	A (s^{-1}) (Others)	A (s^{-1}) SS (present)	$C_i - C_j$	$SL\pi_i - SL\pi_j$	$g_i - g_j$
424.26	1.50e + 05[a]:C, 1.39e + 05[c]	1.41e+5	$2s^22p^4 - 2s^22p^4$: M1	$^3P - {}^1S$	3–1
592.234	6.00[a]: E, 6.18[c]	6.0	$2s^22p^4 - 2s^22p^4$: E2	^3P- ^1D	5–5
592.234	1.73e + 04[a]:C, 1.69e + 04[c]	1.67e+4	$2s^22p^4 - 2s^22p^4$: M1	$^3P - {}^1D$	5–5
639.84	4.9e + 01[a]:E, 4.83e + 01[c]	4.92e+1	$2s^22p^4 - 2s^22p^4$: E2	$^1D - {}^1S$	5–1
1118.06	0.611[a]: E, 0.614[c]	0.635	$2s^22p^4 - 2s^22p^4$: E2	$^3P - {}^3P$	5–3
1118.06	1.45e + 04[a]:C, 1.42e + 04[c]	1.46e+4	$2s^22p^4 - 2s^22p^4$: M1	$^3P - {}^3P$	5–3
1259.27	6.70e + 02[a]:D, 6.99e + 02[c]	6.51e+2	$2s^22p^4 - 2s^22p^4$: M1	$^3P - {}^1D$	3–5
1328.90	0.491[a]:E, 0.509[c]	0.502	$2s^22p^4 - 2s^22p^4$: E2	^3P -^3P	5–1
2207.8	4.820e + 03[b]:C	4.96e+03	$2s2p^5 - 2s2p^5$: M1	$^3P^o - {}^3P^o$	3–1
7045	4.0e + 01[a]: C	41.0	$2s^22p^4 - 2s^22p^4$: M1	$^3P - {}^3P$	1–3
353.532	9.4e + 03[b]: D	8.79e+03	$2s2p^5 - 2s2p^5$: M1	$^3P^o - {}^1P^o$	3–3
420.911	7.7e + 03[b]:D, 8.06e + 03[c]	7.31e+03	$2s2p^5 - 2s2p^5$: M1	$^3P^o - {}^1P^o$	1–3

Table G
Sample set of lifetimes of excited Fe XIX levels obtained from E1 transitions.

	Level				*J*	*Ij*	*E* (Ry)	Lifetime (s)	#transitions
1	2s2 2p4			1Se	0.0	2	−1.0494E+02	Infinity	0
2	2p6			1Se	0.0	3	−8.8452E+01	6.851E−12	2
3	2s22p3	4So	3p	3 P e	0.0	4	−4.3869E+01	1.100E−10	6
4	2s22p3	2Do	3p	3 P e	0.0	5	−4.2515E+01	1.344E−11	6
5	2s22p3	2Po	3p	3 P e	0.0	6	−4.1403E+01	1.272E−11	7
6	2s22p3	2Po	3p	1 S e	0.0	7	−3.9921E+01	5.344E−12	9
7	2s2p4	4Pe	3s	3 P e	0.0	8	−3.8154E+01	4.198E−13	15
8	2s2p4	2Se	3s	1 S e	0.0	9	−3.5187E+01	7.854E−13	20
9	2s2p4	4Pe	3d	5 D e	0.0	10	−3.4602E+01	6.125E−12	21
10	2s2p4	2Pe	3s	3 P e	0.0	11	−3.3967E+01	1.058E−12	23
11	2s2p4	4Pe	3d	3 P e	0.0	12	−3.3817E+01	2.657E−13	23
12	2s2p4	2De	3d	3 P e	0.0	13	−3.1649E+01	5.905E−14	28
13	2s2p4	2De	3d	1 S e	0.0	14	−3.1074E+01	4.748E−14	29
14	2s2p4	2Pe	3d	3 P e	0.0	15	−2.9784E+01	1.303E−13	29
15	2p5	2Po	3p	3 P e	0.0	16	−2.5297E+01	4.377E−13	31
16	2s22p3	4So	4p	3 P e	0.0	17	−2.3971E+01	1.928E−12	32
17	2p5	2Po	3p	1 S e	0.0	18	−2.3795E+01	2.243E−13	33
18	2s22p3	2Do	4p	3 P e	0.0	19	−2.2760E+01	2.013E−12	37
19	2s22p3	2Po	4p	3 P e	0.0	20	−2.1660E+01	1.865E−12	41
20	2s22p3	2Do	4f	3 P e	0.0	21	−2.0972E+01	5.014E−13	45
21	2s22p3	2Po	4p	1 S e	0.0	22	−2.0759E+01	2.084E−12	46

4.3. Energies and forbidden E2, E3, M1, and M2 transitions from the SS code

The *A*-values for a total of 66,619 forbidden transitions in Fe XIX have been calculated for the 379 fine structure levels with *nl* ranging up to 4*f*. Forbidden transitions are observed mainly in the low-lying levels and are important diagnostics for the plasma ambient conditions. As mentioned earlier, the *A*-values have been obtained from atomic structure calculations using the later [24] version of the SS code.

A sample set of the fine structure levels and the corresponding sixteen configurations in Fe XIX are listed in Table 3. The levels are tabulated in ascending energy order. The calculated energies agree with the measured values given in the NIST compilation to within less than 1% for most levels, the maximum difference being 2.6% for the level $2s^22p^4(^3P_0)$. Table 3 includes mainly calculated energies and the rest of the energies have been replaced by the observed energies for more accurate transition wavelengths. The forbidden transitions have been reprocessed with these energies for improved accuracy.

Sample subsets of the radiative decay rates for the forbidden transitions are given in Table 4. The parity remains unchanged for the E2 and M1 transitions, which are presented together. On the other hand, parity changes for E3 and M2 transitions which are grouped together in the Table. The complete sets of energies and the transitions have been processed from the SS code output to standard spectroscopic notation and are available as supplemental material.

The present *A*-coefficients for forbidden transitions for Fe XIX are compared with previous works in Table F. The comparison shows that the present rates for both the E2 and M1 transitions agree almost exactly with those found by Cheng et al. [5] and Fawcett [7] given in the NIST compilation, and with the recent calculations by Jonauskas et al. [10].

4.4. Lifetimes

Lifetimes of all 1625 excited levels of Fe XIX considered here have been calculated. These include only contributions of the allowed E1 transitions. A sample set is presented in Table G. The last column in the table lists the number of E1 transitions from the level to lower levels that contributed to the lifetimes. This file and an additional file containing details of the contributing levels and their contributions are available as supplemental material. Forbidden transitions typically have negligible contributions to lifetimes compared to those from allowed transitions.

The lifetime for the $2s2p^5(^3P^o_2)$ level of Fe XIX was measured by Buchet et al. [9] using the beam-foil technique. The measured value 23.5±2.0 ps agrees very well with some earlier theoretical calculations. The present value 22.48 ps is also within the range of the experimental value. For this level, the summed *A*-value from E1 transitions is 4.448E+10 s^{-1} in contrast to a negligible contribution of 7.333E+01 s^{-1} by the forbidden transitions.

However, there are levels that are accessible only through forbidden transitions, such as, the two levels $2p^4(^3P_{0,1})$ of the ground configuration. For these cases the lifetimes are obtained

Table H
Sample set of summed *A*-values for forbidden transitions (*Af*) and allowed transitions (*Aa*) contributing to lifetimes of excited Fe XIX levels (sslvl), as given in Table 3, obtained from SS calculations.

lifetime: level 3Pe 0/2
[E = 6.857E−01 Ry = 7.5250166E+ 04 cm^{-1}, sslvl = 2, cf = 1]
Summed *A*-values-forbidden & allowed: Af = 5.020E−01, Aa = 0.000E+00 s^{-1}
TotalSum-Aji (1 transitions) to level E (= 7.5250166E+ 04/cm):
5.020E−01 s^{-1}
Lifetime (= 1/Aji): 1.992E+00 s

lifetime: level 3Pe 2/2 [E = 8.151E−01 Ry = 8.9441395E+04 cm^{-1},
sslvl = 3, cf = 1]
Summed A-values-forbidden & allowed: Af = 1.464E+04,Aa = 0.000E+00 s^{-1}
TotalSum-Aji (3 transitions) to level E (= 8.9441395E+04/cm):
1.464E+04s^{-1}

Lifetime (= 1/Aji): 6.830E−05 s
lifetime: level 1De 4/2 [E = 1.539E+00 Ry = 1.6885280E+ 05 cm^{-1},
sslvl = 4, cf = 1]
Summed A-values-forbidden & allowed:Af = 1.736E+04, Aa = 0.000E+00 s^{-1}
TotalSum-Aji (5 transitions) to level E (= 1.6885280E+05/cm):
1.736E+04 s^{-1}

Lifetime (= 1/Aji): 5.761E−05 s
lifetime: level 1Se 0/2 [E = 2.963E+00 Ry = 3.2514068E+ 05 cm^{-1},
sslvl = 5, cf = 1]
Summed A-values-forbidden& allowed: Af = 1.411E+05, Aa = 0.000E+00 s^{-1}
TotalSum-Aji (3 transitions) to level E (= 3.2514068E+05/cm):
1.411E+ 05 s^{-1}
Lifetime (= 1/Aji): 7.089E−06 s

from the summed *A*-values of the forbidden transitions. Table H presents a sample set of the lifetimes of all Fe XIX excited levels obtained in the SS calculations. For each level, the table also shows the individual summed *A*-values for all the forbidden transitions and allowed transitions contributing to the lifetime. The sum of *A*-values (*Af*) for forbidden transitions can be added to that of the allowed transitions from the BPRM calculations for more accurate lifetime values. The full set of lifetimes from the SS calculation are available as supplemental material. It should be noted that there are also cases, especially for large *J* values, where both the allowed and forbidden transitions contribute significantly.

5. Conclusions

For Fe XIX, same spin and intercombination electric E1 transitions have been presented from application of the *ab initio* relativistic BPRM method. The set of transitions provided, containing 289,291 transitions in total, exceeds all the existing ones. The energies and transition probabilities agree very well in general with the currently available results. Among the present lifetimes good agreement with the single available measurement is also found.

The set of forbidden transitions includes radiative decay rates for E2, E3, M1, and M2 transitions, for a total of 66,619 transitions. Comparison with the available results indicates that the level of accuracy of the present transition parameters is similar to that of the other published results.

The present complete set of *A*-values is expected to be accurate and complete enough for most diagnostic and plasma modeling applications concerning X-ray, extreme ultraviolet, ultraviolet, optical, and infrared wavelengths.

All data are available electronically as supplemental material and at the NORAD-Atomic-Data website: www.astronomy.ohio-state.edu/~nahar/nahar_radiativeatomicdata/index.html.

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Appendix. Supplementary data

Supplementary material related to this article can be found online at doi:10.1016/j.adt.2011.03.003.

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Explanation of Tables

Table 1. Fine structure levels of Fe XIX.

Table 1 presents 1626 energy levels of Fe XIX. The levels are grouped as fine structure components of *LS* terms. The top line of each set provides the total number of fine structure levels (Nlv) for the all possible $^{(2S+1)}L^{\pi}$ terms with the given configuration. For the set of levels, the spin multiplicity $(2S+1)$ and parity π are fixed, but L varies. All possible J-values associated with the given LS term are specified within parenthesis next to each L. This line is followed by a set of the energy levels of the same configurations. The total number Nlv (c) of calculated J-levels found for the set is specified at the end of the set. If $Nlv = Nlv$(c), the calculated energy set for the given terms is complete.

The levels are designated as $C_t(S_tL_t\pi_t)J_tnlJ(SL)\pi$.

C_t	target configuration
$S_tL_t\pi_t$	$SL\pi$ symmetry of the target
J_t	total angular momentum of the target state
nl	configuration of the valence electron
J	total angular momentum of the level
E (Ry)	level energy in Rydberg
ν	effective quantum number (it is set to zero for equivalent electron levels)
$SL\pi$	symmetry of the level

Table 2. Transitions for observed levels of Fe XIX.

Table 2 presents E1 transition probabilities for observed levels of Fe XIX. The calculated transition energies have been replaced by the observed energies. The transitions are grouped as fine structure components of *LS* multiplets.

$C_{i,k}$	configurations of transitional levels
T_i	*LS* term designation of the level
g_i	statistical weight factor $(2J+1)$ of the level
I	position of the level in its $SL\pi$ symmetry
E_{ik}	transition energy
f, S, A	oscillator strength, line strength, radiative decay rate

Table 3. Levels for forbidden transitions.

The table gives a partial set of fine structure energy levels of Fe XIX for which forbidden (E2, E3, M1, M2) transitions are presented. The indices (cf) correspond to the configurations $2s^22p^4$ (1), $2s2p^5$ (2), $2p^6$ (3), $2s^22p^33s$ (4), $2s^22p^33p$ (5), $2s^22p^33d$(6), $2s^22p^34s$ (7), $2s^22p^34p$ (8), $2s^22p^34d$ (9), $2s^22p^34f$(10), $2s2p^43s$ (11), $2s2p^43p$ (12), $2s2p^43d$ (13), $2s2p^44s$ (14), $2s2p^44p$ (15), and $2s^22p^23s^2$ (16).

i_e	Level index
$SLp(cf)$	*LS* term of the level and configuration number cf given in the caption
$2J$	J is total angular momentum
E (Ry)	Relative energy in Rydberg of the level

Table 4. Forbidden transitions in Fe XIX

The table gives a partial set of radiative decay rates for forbidden E2, M1, E3, and M2 transitions in Fe XIX. C_i is the configuration number; $2s^22p^4$ (1), $2s2p^5$ (2), $2p^6$ (3), $2s^22p^33s$(4), $2s^22p^33p$ (5), $2s^22p^33d$ (6), $2s^22p^34s$ (7), $2s^22p^34p$ (8), $2s^22p^34d$ (9), $2s^22p^34f$ (10), $2s2p^43s$ (11), $2s2p^43p$ (12), $2s2p^43d$ (13), $2s2p^44s$ (14), $2s2p^44p$ (15), and $2s^22p^23s^2$ (16).

N_{tr}	total number of transitions
i, j	energy indices of the levels as given in Table 3
T_i	*LS* term designation of the level
C_i	configuration number of the transitional level
g_i	statistical weight factor $(2J+1)$ of the level
λ	transition energy. Note that for extremely low energy, $\lambda = 99{,}999$ Å
E_i, E_f	energies of the levels
$AE2$	radiative decay rate for E2 transition
$AE3$	radiative decay rate for E3 transition
$AM1$	radiative decay rate for M1 transition
$AM2$	radiative decay rate for M2 transition

Table 1
Fine structure levels of Fe XIX. See explanation of tables.

$C_t(S_tL_t\pi_t)$		J_t	nl	J	E (Ry)	ν	$SL\pi$
Eqv electron/unidentified levels, parity: e							
2s22p4				2	−1.07243E+02	0.00	3P e
2s22p4				0	−1.06563E+02	0.00	3P e
2s22p4				1	−1.06430E+02	0.00	3P e
$Nl\nu(c) = 3$: set complete							
Eqv electron/unidentified levels, parity: e							
2s22p4				2	−1.05669E+02	0.00	1D e
$Nl\nu(c) = 1$: set complete							
Eqv electron/unidentified levels, parity: e							
2s22p4				0	−1.04217E+02	0.00	1S e
$Nl\nu(c) = 1$: set complete							
Eqv electron/unidentified levels, parity: o							
2s2p5				2	−9.87757E+01	0.00	3P o
2s2p5				1	−9.82025E+01	0.00	3P o
2s2p5				0	−9.77880E+01	0.00	3P o
$Nl\nu(c) = 3$: set complete							
Eqv electron/unidentified levels, parity: o							
2s2p5				1	−9.55910E+01	0.00	1P o
$Nl\nu(c) = 1$: set complete							
Eqv electron/unidentified levels, parity: e							
2p6				0	−8.76530E+01	0.00	1S e
$Nl\nu(c) = 1$: set complete							
$Nl\nu = 1$, ^{5}L^o: S (2)							
2s22p3	(4So)	3/2	3s	2	−4.67874E+01	2.78	5S o
$Nl\nu(c) = 1$: set complete							
$Nl\nu = 1$, ^{3}L^o: S (1)							
2s22p3	(4So)	3/2	3s	1	−4.63210E+01	2.79	3S o
$Nl\nu(c) = 1$: set complete							
$Nl\nu = 3$, ^{3}L^o: D (3 2 1)							
2s22p3	(2Do)	3/2	3s	2	−4.53405E+01	2.78	3D o
2s22p3	(2Do)	3/2	3s	1	−4.53243E+01	2.78	3D o
2s22p3	(2Do)	3/2	3s	3	−4.50095E+01	2.78	3D o
$Nl\nu(c) = 3$: set complete							
$Nl\nu = 1$, ^{1}L^o: D (2)							
2s22p3	(2Do)	5/2	3s	2	−4.48333E+01	2.79	1D o
$Nl\nu(c) = 1$: set complete							
$Nl\nu = 3$, ^{5}L^e: P (3 2 1)							
2s22p3	(4So)	3/2	3p	1	−4.46481E+01	2.84	5P e
2s22p3	(4So)	3/2	3p	2	−4.46091E+01	2.85	5P e
2s22p3	(4So)	3/2	3p	3	−4.44247E+01	2.85	5P e
$Nl\nu(c) = 3$: set complete							
$Nl\nu = 3$, ^{3}L^o: P (2 1 0)							
2s22p3	(2Po)	1/2	3s	0	−4.42655E+01	2.78	3P o
2s22p3	(2Po)	1/2	3s	1	−4.41940E+01	2.78	3P o
2s22p3	(2Po)	3/2	3s	2	−4.36575E+01	2.78	3P o
$Nl\nu(c) = 3$: set complete							
$Nl\nu = 3$, ^{3}L^e: P (2 1 0)							
2s22p3	(4So)	3/2	3p	1	−4.41474E+01	2.81	3P e
2s22p3	(4So)	3/2	3p	2	−4.39568E+01	2.87	3P e
2s22p3	(4So)	3/2	3p	0	−4.38691E+01	2.87	3P e
$Nl\nu(c) = 3$: set complete							
$Nl\nu = 1$, ^{1}L^o: P (1)							
2s22p3	(2Po)	3/2	3s	1	−4.35178E+01	2.79	1P o
$Nl\nu(c) = 1$: set complete							
$Nl\nu = 9$, ^{3}L^e: P (2 1 0) D (3 2 1) F (4 3 2)							
2s22p3	(2Do)	3/2	3p	1	−4.34211E+01	2.84	3PD e
2s22p3	(2Do)	5/2	3p	2	−4.32081E+01	2.84	3PDF e
2s22p3	(2Do)	3/2	3p	2	−4.30388E+01	2.86	3PDF e
2s22p3	(2Do)	3/2	3p	3	−4.29991E+01	2.86	3DF e
2s22p3	(2Do)	3/2	3p	1	−4.28879E+01	2.86	3PD e
2s22p3	(2Do)	5/2	3p	3	−4.28669E+01	2.85	3DF e
2s22p3	(2Do)	5/2	3p	4	−4.26229E+01	2.86	3F e
2s22p3	(2Do)	3/2	3p	0	−4.25150E+01	2.84	3P e
2s22p3	(2Do)	3/2	3p	2	−4.17793E+01	2.90	3PDF e
$Nl\nu(c) = 9$: set complete							
$Nl\nu = 3$, ^{1}L^e: P (1) D (2) F (3)							
2s22p3	(2Do)	5/2	3p	3	−4.26713E+01	2.86	1F e
2s22p3	(2Do)	3/2	3p	1	−4.22973E+01	2.88	1P e
2s22p3	(2Do)	5/2	3p	2	−4.10717E+01	2.91	1D e
$Nl\nu(c) = 3$: set complete							

(*continued on next page*)

Table 1 (*continued*)

$C_t(S_tL_t\pi_t)$		J_t	nl	J	E (Ry)	v	$SL\pi$
$Nlv = 7$, ^{3}L^e: S (1) P (2 1 0) D (3 2 1)							
2s22p3	(2Po)	1/2	3p	2	−4.21616E+01	2.93	3PD e
2s22p3	(2Po)	1/2	3p	1	−4.20630E+01	2.85	3SPD e
2s22p3	(2Po)	1/2	3p	2	−4.18688E+01	2.94	3PD e
2s22p3	(2Po)	1/2	3p	1	−4.17912E+01	2.90	3SPD e
2s22p3	(2Po)	1/2	3p	0	−4.14035E+01	2.87	3P e
2s22p3	(2Po)	3/2	3p	1	−4.13684E+01	2.85	3SPD e
2s22p3	(2Po)	3/2	3p	3	−4.13457E+01	2.86	3D e
$Nlv(c) = 7$: set complete							
$Nlv = 5$, ^{5}L^o: D (4 3 2 1 0)							
2s22p3	(4So)	3/2	3d	0	−4.17991E+01	2.94	5D o
2s22p3	(4So)	3/2	3d	2	−4.17937E+01	2.94	5D o
2s22p3	(4So)	3/2	3d	3	−4.17897E+01	2.94	5D o
2s22p3	(4So)	3/2	3d	4	−4.17489E+01	2.94	5D o
2s22p3	(4So)	3/2	3d	1	−4.11215E+01	2.96	5D o
$Nlv(c) = 5$: set complete							
$Nlv = 3$, ^{3}L^o: D (3 2 1)							
2s22p3	(4So)	3/2	3d	1	−4.17922E+01	2.94	3D o
2s22p3	(4So)	3/2	3d	2	−4.13489E+01	2.96	3D o
2s22p3	(4So)	3/2	3d	3	−4.11071E+01	2.96	3D o
$Nlv(c) = 3$: set complete							
$Nlv = 3$, ^{1}L^e: S (0) P (1) D (2)							
2s22p3	(2Po)	3/2	3p	1	−4.11313E+01	2.86	1P e
2s22p3	(2Po)	1/2	3p	2	−4.08453E+01	2.89	1D e
2s22p3	(2Po)	3/2	3p	0	−3.99212E+01	2.90	1S e
$Nlv(c) = 3$: set complete							
$Nlv = 13$, ^{3}L^o: S (1) P (2 1 0) D (3 2 1) F (4 3 2) G (5 4 3)							
2s22p3	(2Do)	3/2	3d	2	−4.04804E+01	2.94	3PDF o
2s22p3	(2Do)	5/2	3d	3	−4.03598E+01	2.93	3DFG o
2s22p3	(2Do)	3/2	3d	0	−4.03493E+01	2.95	3P o
2s22p3	(2Do)	3/2	3d	3	−4.03107E+01	2.95	3DFG o
2s22p3	(2Do)	3/2	3d	4	−4.02927E+01	2.95	3FG o
2s22p3	(2Do)	3/2	3d	1	−4.02732E+01	2.95	3SPD o
2s22p3	(2Do)	5/2	3d	4	−4.00609E+01	2.94	3FG o
2s22p3	(2Do)	5/2	3d	5	−3.99450E+01	2.95	3G o
2s22p3	(2Do)	3/2	3d	2	−3.99060E+01	2.96	3PDF o
2s22p3	(2Do)	3/2	3d	1	−3.98262E+01	2.96	3SPD o
2s22p3	(2Do)	5/2	3d	2	−3.95324E+01	2.96	3PDF o
2s22p3	(2Do)	5/2	3d	1	−3.94143E+01	2.97	3SPD o
2s22p3	(2Do)	5/2	3d	3	−3.92375E+01	2.97	3DFG o
$Nlv(c) = 13$: set complete							
$Nlv = 5$, ^{1}L^o: S (0) P (1) D (2) F (3) G (4)							
2s22p3	(2Do)	5/2	3d	4	−3.99493E+01	2.95	1G o
2s22p3	(2Do)	5/2	3d	3	−3.97165E+01	2.96	1F o
2s22p3	(2Do)	5/2	3d	0	−3.96710E+01	2.96	1S o
2s22p3	(2Do)	5/2	3d	2	−3.96457E+01	2.96	1D o
2s22p3	(2Do)	5/2	3d	1	−3.96291E+01	2.96	1P o
$Nlv(c) = 5$: set complete							
$Nlv = 3$, ^{5}L^e: P (3 2 1)							
2s2p4	(4Pe)	5/2	3s	3	−3.97111E+01	2.78	5P e
2s2p4	(4Pe)	5/2	3s	2	−3.92721E+01	2.80	5P e
2s2p4	(4Pe)	1/2	3s	1	−3.89591E+01	2.78	5P e
$Nlv(c) = 3$: set complete							
$Nlv = 9$, ^{3}L^o: P (2 1 0) D (3 2 1) F (4 3 2)							
2s22p3	(2Po)	1/2	3d	2	−3.91180E+01	2.95	3PDF o
2s22p3	(2Po)	1/2	3d	3	−3.90515E+01	2.95	3DF o
2s22p3	(2Po)	1/2	3d	2	−3.89169E+01	2.96	3PDF o
2s22p3	(2Po)	1/2	3d	1	−3.87548E+01	2.96	3PD o
2s22p3	(2Po)	3/2	3d	4	−3.86862E+01	2.95	3F o
2s22p3	(2Po)	3/2	3d	0	−3.86573E+01	2.95	3P o
2s22p3	(2Po)	3/2	3d	2	−3.85458E+01	2.95	3PDF o
2s22p3	(2Po)	1/2	3d	1	−3.85082E+01	2.95	3PD o
2s22p3	(2Po)	3/2	3d	3	−3.83443E+01	2.96	3DF o
$Nlv(c) = 9$: set complete							
$Nlv = 3$, ^{3}L^e: P (2 1 0)							
2s2p4	(4Pe)	3/2	3s	2	−3.87988E+01	2.79	3P e
2s2p4	(4Pe)	3/2	3s	1	−3.83331E+01	2.81	3P e
2s2p4	(4Pe)	1/2	3s	0	−3.81537E+01	2.81	3P e
$Nlv(c) = 3$: set complete							
$Nlv = 3$, ^{1}L^o: P (1) D (2) F (3)							
2s22p3	(2Po)	1/2	3d	3	−3.81837E+01	2.96	1F o
2s22p3	(2Po)	3/2	3d	2	−3.81472E+01	2.96	1D o

(*continued on next page*)

Table 1 (*continued*)

$C_t(S_tL_t\pi_t)$		J_t	nl	J	E (Ry)	ν	$SL\pi$
2s22p3	(2Po)	3/2	3d	1	−3.76108E+01	2.98	1P o
$Nlv(c) = 3$: set complete							
$Nlv = 9$, ^{5}L^o: S (2) P (3 2 1) D (4 3 2 1 0)							
2s2p4	(4Pe)	5/2	3p	3	−3.75689E+01	2.85	5PD o
2s2p4	(4Pe)	5/2	3p	2	−3.75653E+01	2.85	5SPD o
2s2p4	(4Pe)	5/2	3p	4	−3.72664E+01	2.86	5D o
2s2p4	(4Pe)	3/2	3p	1	−3.71816E+01	2.84	5PD o
2s2p4	(4Pe)	5/2	3p	3	−3.71534E+01	2.86	5PD o
2s2p4	(4Pe)	3/2	3p	2	−3.68628E+01	2.85	5SPD o
2s2p4	(4Pe)	3/2	3p	1	−3.67339E+01	2.86	5PD o
2s2p4	(4Pe)	5/2	3p	0	−3.67054E+01	2.88	5D o
2s2p4	(4Pe)	5/2	3p	2	−3.64083E+01	2.89	5SPD o
$Nlv(c) = 9$: set complete							
$Nlv = 3$, ^{3}L^e: D (3 2 1)							
2s2p4	(2De)	3/2	3s	1	−3.68848E+01	2.79	3D e
2s2p4	(2De)	3/2	3s	2	−3.68473E+01	2.79	3D e
2s2p4	(2De)	5/2	3s	3	−3.67426E+01	2.79	3D e
$Nlv(c) = 3$: set complete							
$Nlv = 7$, ^{3}L^o: S (1) P (2 1 0) D (3 2 1)							
2s2p4	(4Pe)	5/2	3p	1	−3.66884E+01	2.88	3SPD o
2s2p4	(4Pe)	3/2	3p	3	−3.66512E+01	2.86	3D o
2s2p4	(4Pe)	5/2	3p	2	−3.66141E+01	2.88	3PD o
2s2p4	(4Pe)	3/2	3p	0	−3.62560E+01	2.87	3P o
2s2p4	(4Pe)	3/2	3p	1	−3.62310E+01	2.87	3SPD o
2s2p4	(4Pe)	3/2	3p	2	−3.62076E+01	2.88	3PD o
2s2p4	(4Pe)	1/2	3p	1	−3.60609E+01	2.87	3SPD o
$Nlv(c) = 7$: set complete							
$Nlv = 1$, ^{1}L^e: D (2)							
2s2p4	(2De)	5/2	3s	2	−3.63011E+01	2.80	1D e
$Nlv(c) = 1$: set complete							
$Nlv = 1$, ^{3}L^e: S (1)							
2s2p4	(2Se)	1/2	3s	1	−3.54824E+01	2.79	3S e
$Nlv(c) = 1$: set complete							
$Nlv = 1$, ^{1}L^e: S (0)							
2s2p4	(2Se)	1/2	3s	0	−3.51869E+01	2.80	1S e
$Nlv(c) = 1$: set complete							
$Nlv = 3$, ^{3}L^e: P (2 1 0)							
2s2p4	(2Pe)	3/2	3s	2	−3.50021E+01	2.79	3P e
2s2p4	(2Pe)	3/2	3s	1	−3.48885E+01	2.80	3P e
2s2p4	(2Pe)	1/2	3s	0	−3.39672E+01	2.80	3P e
$Nlv(c) = 3$: set complete							
$Nlv = 13$, ^{5}L^e: P (3 2 1) D (4 3 2 1 0) F (5 4 3 2 1)							
2s2p4	(4Pe)	5/2	3d	3	−3.49409E+01	2.94	5PDF e
2s2p4	(4Pe)	5/2	3d	4	−3.49359E+01	2.94	5DF e
2s2p4	(4Pe)	5/2	3d	2	−3.48826E+01	2.94	5PDF e
2s2p4	(4Pe)	5/2	3d	1	−3.47762E+01	2.95	5PDF e
2s2p4	(4Pe)	5/2	3d	5	−3.47030E+01	2.95	5F e
2s2p4	(4Pe)	3/2	3d	0	−3.46015E+01	2.93	5D e
2s2p4	(4Pe)	5/2	3d	4	−3.44326E+01	2.96	5DF e
2s2p4	(4Pe)	5/2	3d	1	−3.43207E+01	2.96	5PDF e
2s2p4	(4Pe)	5/2	3d	3	−3.42214E+01	2.96	5PDF e
2s2p4	(4Pe)	5/2	3d	2	−3.41663E+01	2.97	5PDF e
2s2p4	(4Pe)	1/2	3d	2	−3.40190E+01	2.94	5PDF e
2s2p4	(4Pe)	1/2	3d	1	−3.39957E+01	2.94	5PDF e
2s2p4	(4Pe)	1/2	3d	3	−3.39177E+01	2.95	5PDF e
$Nlv(c) = 13$: set complete							
$Nlv = 9$, ^{3}L^o: P (2 1 0) D (3 2 1) F (4 3 2)							
2s2p4	(2De)	5/2	3p	2	−3.47903E+01	2.85	3PDF o
2s2p4	(2De)	3/2	3p	1	−3.47545E+01	2.86	3PD o
2s2p4	(2De)	3/2	3p	3	−3.46392E+01	2.86	3DF o
2s2p4	(2De)	3/2	3p	4	−3.44413E+01	2.87	3F o
2s2p4	(2De)	5/2	3p	2	−3.43428E+01	2.87	3PDF o
2s2p4	(2De)	3/2	3p	1	−3.42507E+01	2.87	3PD o
2s2p4	(2De)	5/2	3p	3	−3.41442E+01	2.87	3DF o
2s2p4	(2De)	5/2	3p	2	−3.41175E+01	2.95	3PDF o
2s2p4	(2De)	5/2	3p	0	−3.40385E+01	2.88	3P o
$Nlv(c) = 9$: set complete							
$Nlv = 3$, ^{1}L^o: P (1) D (2) F (3)							
2s2p4	(2De)	5/2	3p	3	−3.44302E+01	2.86	1F o
2s2p4	(2De)	3/2	3p	1	−3.40419E+01	2.94	1P o
2s2p4	(2De)	5/2	3p	2	−3.40054E+01	2.88	1D o
$Nlv(c) = 3$: set complete							

(*continued on next page*)

Table 1 (*continued*)

$C_t(S_tL_t\pi_t)$		J_t	nl	J	E (Ry)	ν	$SL\pi$
$Nlv = 1$, ^{1}L^e: P (1)							
2s2p4	(2Pe)	1/2	3s	1	−3.40876E+01	2.79	1P e
$Nlv(c) = 1$: set complete							
$Nlv = 9$, ^{3}L^e: P (2 1 0) D (3 2 1) F (4 3 2)							
2s2p4	(4Pe)	3/2	3d	4	−3.40083E+01	2.95	3F e
2s2p4	(4Pe)	3/2	3d	3	−3.38237E+01	2.96	3DF e
2s2p4	(4Pe)	5/2	3d	0	−3.38166E+01	2.98	3P e
2s2p4	(4Pe)	5/2	3d	1	−3.37752E+01	2.98	3PD e
2s2p4	(4Pe)	5/2	3d	2	−3.37440E+01	2.98	3PDF e
2s2p4	(4Pe)	3/2	3d	2	−3.34381E+01	2.97	3PDF e
2s2p4	(4Pe)	3/2	3d	1	−3.33726E+01	2.97	3PD e
2s2p4	(4Pe)	3/2	3d	3	−3.33121E+01	2.98	3DF e
2s2p4	(4Pe)	1/2	3d	2	−3.31371E+01	2.97	3PDF e
$Nlv(c) = 9$: set complete							
$Nlv = 3$, ^{3}L^o: P (2 1 0)							
2s2p4	(2Se)	1/2	3p	0	−3.33594E+01	2.86	3P o
2s2p4	(2Se)	1/2	3p	2	−3.30451E+01	2.91	3P o
2s2p4	(2Se)	1/2	3p	1	−3.29611E+01	2.87	3P o
$Nlv(c) = 3$: set complete							
$Nlv = 1$, ^{1}L^o: P (1)							
2s2p4	(2Se)	1/2	3p	1	−3.32728E+01	2.86	1P o
$Nlv(c) = 1$: set complete							
$Nlv = 7$, ^{3}L^o: S (1) P (2 1 0) D (3 2 1)							
2s2p4	(2Pe)	3/2	3p	2	−3.28749E+01	2.86	3PD o
2s2p4	(2Pe)	3/2	3p	2	−3.26741E+01	2.86	3PD o
2s2p4	(2Pe)	3/2	3p	3	−3.26435E+01	2.93	3D o
2s2p4	(2Pe)	3/2	3p	1	−3.25467E+01	2.87	3SPD o
2s2p4	(2Pe)	3/2	3p	0	−3.23830E+01	2.87	3P o
2s2p4	(2Pe)	1/2	3p	1	−3.21715E+01	2.85	3SPD o
2s2p4	(2Pe)	1/2	3p	1	−3.17207E+01	2.87	3SPD o
$Nlv(c) = 7$: set complete							
$Nlv = 13$, ^{3}L^e: S (1) P (2 1 0) D (3 2 1) F (4 3 2) G (5 4 3)							
2s2p4	(2De)	5/2	3d	3	−3.21342E+01	2.94	3DFG e
2s2p4	(2De)	3/2	3d	4	−3.20594E+01	2.95	3FG e
2s2p4	(2De)	5/2	3d	5	−3.19506E+01	2.95	3G e
2s2p4	(2De)	3/2	3d	2	−3.17958E+01	2.96	3PDF e
2s2p4	(2De)	3/2	3d	1	−3.17157E+01	2.96	3SPD e
2s2p4	(2De)	3/2	3d	3	−3.17067E+01	2.96	3DFG e
2s2p4	(2De)	3/2	3d	4	−3.16633E+01	2.96	3FG e
2s2p4	(2De)	5/2	3d	1	−3.16593E+01	2.96	3SPD e
2s2p4	(2De)	5/2	3d	0	−3.16487E+01	3.06	3P e
2s2p4	(2De)	3/2	3d	2	−3.16005E+01	2.96	3PDF e
2s2p4	(2De)	5/2	3d	3	−3.15226E+01	2.96	3DFG e
2s2p4	(2De)	5/2	3d	2	−3.15154E+01	2.96	3PDF e
2s2p4	(2De)	5/2	3d	1	−3.14801E+01	3.07	3SPD e
$Nlv(c) = 13$: set complete							
$Nlv = 3$, ^{1}L^o: S (0) P (1) D (2)							
2s2p4	(2Pe)	1/2	3p	0	−3.18047E+01	2.86	1S o
2s2p4	(2Pe)	1/2	3p	2	−3.17520E+01	2.95	1D o
2s2p4	(2Pe)	1/2	3p	1	−3.11475E+01	2.89	1P o
$Nlv(c) = 3$: set complete							

Table 2
Transitions for observed levels of Fe XIX. See explanation of tables.

$C_i - C_k$	$T_i - T_k$	$g_i : I - g_k$:K	E_{ik} (Å)	f	S	A (s^{-1})
2s22p4 — 2s2p5	3Pe — 3Po	1: 1 — 3: 1	109.96	7.63E−02	2.76E−02	1.40E+10
2s22p4 — 2s2p5	3Pe — 3Po	3: 1 — 1: 1	106.32	2.97E−02	3.12E−02	5.25E+10
2s22p4 — 2s2p5	3Pe — 3Po	3: 1 — 3: 1	111.69	2.04E−02	2.25E−02	1.09E+10
2s22p4 — 2s2p5	3Pe — 3Po	3: 1 — 5: 1	119.98	3.24E−02	3.84E−02	9.02E+09
2s22p4 — 2s2p5	3Pe — 3Po	5: 1 — 3: 1	101.55	2.57E−02	4.30E−02	2.77E+10
2s22p4 — 2s2p5	3Pe — 3Po	5: 1 — 5: 1	108.36	5.90E−02	1.05E−01	3.35E+10
LS	3Pe — 3Po	9 — 9		8.30E−02	2.68E−01	4.68E+10
2s22p4 — 2s2p5	3Pe — 1Po	1: 1 — 3: 2	83.87	3.78E−03	1.04E−03	1.19E+09
2s22p4 — 2s2p5	3Pe — 1Po	3: 1 — 3: 2	84.88	9.45E−04	7.92E−04	8.75E+08
2s22p4 — 2s2p5	3Pe — 1Po	5: 1 — 3: 2	78.89	6.27E−03	8.14E−03	1.12E+10
2s22p4 — 2s22p34So3s	3Pe — 3So	1: 1 — 3: 3	15.14	4.90E−02	2.44E−03	4.75E+11
2s22p4 — 2s22p34So3s	3Pe — 3So	3: 1 — 3: 3	15.17	1.99E−02	2.98E−03	5.77E+11
2s22p4 — 2s22p34So3s	3Pe — 3So	5: 1 — 3: 3	14.97	4.52E−02	1.11E−02	2.24E+12
LS	3Pe — 3So	9 — 3		3.72E−02	1.65E−02	3.31E+12
2s22p4 — 2s22p32Do3s	3Pe — 3Do	1: 1 — 3: 4	14.90	1.89E−02	9.26E−04	1.89E+11
2s22p4 — 2s22p32Do3s	3Pe — 3Do	3: 1 — 3: 4	14.93	3.88E−02	5.72E−03	1.16E+12
2s22p4 — 2s22p32Do3s	3Pe — 3Do	3: 1 — 5: 3	14.93	1.37E−02	2.01E−03	2.45E+11
2s22p4 — 2s22p32Do3s	3Pe — 3Do	5: 1 — 3: 4	14.73	4.88E−05	1.18E−05	2.50E+09
2s22p4 — 2s22p32Do3s	3Pe — 3Do	5: 1 — 5: 3	14.73	3.03E−02	7.34E−03	9.29E+11
2s22p4 — 2s22p32Do3s	3Pe — 3Do	5: 1 — 7: 1	14.67	4.78E−02	1.16E−02	1.06E+12
LS	3Pe — 3Do	9 — 15		6.30E−02	2.76E−02	1.15E+12
2s22p4 — 2s22p32Po3s	3Pe — 3Po	1: 1 — 3: 5	14.60	6.66E−02	3.20E−03	6.94E+11
2s22p4 — 2s22p32Po3s	3Pe — 3Po	3: 1 — 1: 2	14.67	1.15E−02	1.66E−03	1.07E+12
2s22p4 — 2s22p32Po3s	3Pe — 3Po	3: 1 — 3: 5	14.63	5.72E−03	8.26E−04	1.78E+11
2s22p4 — 2s22p32Po3s	3Pe — 3Po	3: 1 — 5: 5	14.53	3.36E−02	4.82E−03	6.36E+11
2s22p4 — 2s22p32Po3s	3Pe — 3Po	5: 1 — 3: 5	14.44	1.66E−03	3.94E−04	8.83E+10
2s22p4 — 2s22p32Po3s	3Pe — 3Po	5: 1 — 5: 5	14.35	3.67E−03	8.66E−04	1.19E+11
LS	3Pe — 3Po	9 — 9		2.73E−02	1.18E−02	8.61E+11
2s22p4 — 2s22p32Po3s	3Pe — 1Po	1: 1 — 3: 6	14.47	4.94E−03	2.36E−04	5.25E+10
2s22p4 — 2s22p32Po3s	3Pe — 1Po	3: 1 — 3: 6	14.50	7.75E−04	1.11E−04	2.46E+10
2s22p4 — 2s22p32Po3s	3Pe — 1Po	5: 1 — 3: 6	14.32	4.44E−04	1.05E−04	2.41E+10
2s22p4 — 2s22p32Po3d	3Pe — 3Do	1: 1 — 3: 13	13.35	1.36E+00	5.98E−02	1.70E+13
2s22p4 — 2s22p32Po3d	3Pe — 3Do	3: 1 — 3: 13	13.37	5.47E−03	7.22E−04	2.04E+11
2s22p4 — 2s22p32Po3d	3Pe — 3Do	3: 1 — 5: 13	13.40	3.84E−01	5.08E−02	8.56E+12
2s22p4 — 2s22p32Po3d	3Pe — 3Do	5: 1 — 3: 13	13.22	3.15E−03	6.84E−04	2.00E+11
2s22p4 — 2s22p32Po3d	3Pe — 3Do	5: 1 — 5: 13	13.24	2.94E−02	6.40E−03	1.12E+12
2s22p4 — 2s22p32Po3d	3Pe — 3Do	5: 1 — 7: 9	13.22	3.08E−02	6.69E−03	8.39E+11
LS	3Pe — 3Do	9 — 15		3.16E−01	1.25E−01	7.09E+12
2s22p4 — 2s22p32Po3d	3Pe — 1Po	1: 1 — 3: 15	13.28	9.16E−03	4.00E−04	1.15E+11
2s22p4 — 2s22p32Po3d	3Pe — 1Po	3: 1 — 3: 15	13.30	1.69E−02	2.22E−03	6.38E+11
2s22p4 — 2s22p32Po3d	3Pe — 1Po	5: 1 — 3: 15	13.15	3.13E−05	6.77E−06	2.01E+09
2s22p4 — 2s22p34So4d	3Pe — 3Do	1: 1 — 3: 34	10.91	5.10E−04	1.83E−05	9.52E+09
2s22p4 — 2s22p34So4d	3Pe — 3Do	3: 1 — 3: 34	10.92	7.54E−04	8.13E−05	4.21E+10
2s22p4 — 2s22p34So4d	3Pe — 3Do	3: 1 — 5: 34	10.93	7.86E−05	8.49E−06	2.64E+09
2s22p4 — 2s22p34So4d	3Pe — 3Do	5: 1 — 3: 34	10.82	3.38E−04	6.02E−05	3.21E+10
2s22p4 — 2s22p34So4d	3Pe — 3Do	5: 1 — 5: 34	10.82	5.61E−07	9.99E−08	3.20E+07
2s22p4 — 2s22p34So4d	3Pe — 3Do	5: 1 — 7: 21	10.81	1.14E−03	2.02E−04	4.63E+10
LS	3Pe — 3Do	9 — 15		1.16E−03	3.70E−04	3.95E+10
2s22p4 — 2s22p32Do4d	3Pe — 3Do	1: 1 — 3: 40	10.72	3.77E−02	1.33E−03	7.29E+11
2s22p4 — 2s22p32Do4d	3Pe — 3Do	3: 1 — 3: 40	10.74	6.11E−05	6.48E−06	3.53E+09
2s22p4 — 2s22p32Do4d	3Pe — 3Do	3: 1 — 5: 40	10.77	1.53E−02	1.63E−03	5.29E+11
2s22p4 — 2s22p32Do4d	3Pe — 3Do	3: 1 — 5: 41	10.75	1.02E−01	1.09E−02	3.55E+12
2s22p4 — 2s22p32Do4d	3Pe — 3Do	5: 1 — 3: 40	10.63	5.19E−03	9.09E−04	5.11E+11
2s22p4 — 2s22p32Do4d	3Pe — 3Do	5: 1 — 5: 40	10.67	1.42E−02	2.50E−03	8.33E+11
2s22p4 — 2s22p32Do4d	3Pe — 3Do	5: 1 — 5: 41	10.64	1.49E−02	2.61E−03	8.78E+11
2s22p4 — 2s22p32Do4d	3Pe — 3Do	5: 1 — 7: 25	10.66	5.29E−02	9.28E−03	2.22E+12
LS	3Pe — 3Do	9 — 15		9.17E−02	2.92E−02	3.19E+12
2s22p4 — 2s22p32Po4d	3Pe — 3Do	1: 1 — 3: 45	10.62	2.49E−01	8.70E−03	4.91E+12
2s22p4 — 2s22p32Po4d	3Pe — 3Do	3: 1 — 3: 45	10.63	6.76E−03	7.10E−04	3.99E+11
2s22p4 — 2s22p32Po4d	3Pe — 3Do	5: 1 — 3: 45	10.53	1.61E−05	2.80E−06	1.62E+09
LS	3Pe — 3Do	9 — 15		2.99E−02	9.41E−03	1.06E+12
2s22p4 — 2s22p32Po4d	3Pe — 3Po	1: 1 — 3: 46	10.55	4.52E−04	1.57E−05	9.03E+09
2s22p4 — 2s22p32Po4d	3Pe — 3Po	3: 1 — 3: 46	10.56	5.65E−02	5.90E−03	3.38E+12
2s22p4 — 2s22p32Po4d	3Pe — 3Po	5: 1 — 3: 46	10.46	7.26E−04	1.25E−04	7.37E+10
LS	3Pe — 3Po	9 — 9		1.93E−02	6.04E−03	1.15E+12
2s22p4 — 2s22p32Po4d	3Pe — 1Po	1: 1 — 3: 47	10.53	1.66E−02	5.77E−04	3.34E+11
2s22p4 — 2s22p32Po4d	3Pe — 1Po	3: 1 — 3: 47	10.54	4.07E−03	4.24E−04	2.44E+11

(*continued on next page*)

Table 2 (*continued*)

$C_i - C_k$	$T_i - T_k$	$g_i : I - g_k$:K	E_{ik} (Å)	f	S	A (s^{-1})
2s22p4 − 2s22p32Po4d	3Pe − 1Po	5: 1 − 3: 47	10.45	2.28E−08	3.93E−09	2.33E+06
2s22p4 − 2s22p32Po5d	3Pe − 3Do	1: 1 − 3: 75	9.64	9.48E−05	3.01E−06	2.27E+09
2s22p4 − 2s22p32Po5d	3Pe − 3Do	3: 1 − 3: 75	9.65	2.37E−04	2.26E−05	1.70E+10
2s22p4 − 2s22p32Po5d	3Pe − 3Do	5: 1 − 3: 75	9.57	1.75E−03	2.75E−04	2.12E+11
2s22p4 − 2s22p32Po5d	3Pe − 3Do	5: 1 − 7: 61	9.52	1.32E−03	2.07E−04	6.92E+10
LS	3Pe − 3Do	9 − 15		1.80E−03	5.08E−04	7.89E+10
2s22p4 − 2s22p32Po5d	3Pe − 3Po	1: 1 − 3: 78	9.59	9.85E−04	3.11E−05	2.38E+10
2s22p4 − 2s22p32Po5d	3Pe − 3Po	3: 1 − 3: 78	9.61	2.34E−02	2.22E−03	1.69E+12
2s22p4 − 2s22p32Po5d	3Pe − 3Po	5: 1 − 3: 78	9.52	3.75E−04	5.87E−05	4.59E+10
LS	3Pe − 3Po	9 − 9		8.12E−03	2.31E−03	5.87E+11
2s22p4 − 2s22p32Po5d	3Pe − 1Po	1: 1 − 3: 79	9.58	1.29E−02	4.06E−04	3.12E+11
2s22p4 − 2s22p32Po5d	3Pe − 1Po	3: 1 − 3: 79	9.60	2.95E−04	2.80E−05	2.14E+10
2s22p4 − 2s22p32Po5d	3Pe − 1Po	5: 1 − 3: 79	9.51	6.78E−06	1.06E−06	8.33E+08
2s22p4 − 2s2p5	1Se − 3Po	1: 2 − 3: 1	151.61	6.06E−03	3.03E−03	5.86E+08
2s22p4 − 2s2p5	1Se − 1Po	1: 2 − 3: 2	106.11	4.84E−02	1.69E−02	9.56E+09
2s22p4 − 2s22p34So3s	1Se − 3So	1: 2 − 3: 3	15.74	1.82E−05	9.44E−07	1.64E+08
2s22p4 − 2s22p32Do3s	1Se − 3Do	1: 2 − 3: 4	15.47	2.02E−03	1.03E−04	1.87E+10
2s22p4 − 2s22p32Po3s	1Se − 3Po	1: 2 − 3: 5	15.16	5.21E−03	2.60E−04	5.04E+10
2s22p4 − 2s22p32Po3s	1Se − 1Po	1: 2 − 3: 6	15.02	1.33E−01	6.56E−03	1.31E+12
2s22p4 − 2s22p32Po3d	1Se − 3Do	1: 2 − 3: 13	13.81	1.03E−03	4.68E−05	1.20E+10
2s22p4 − 2s22p32Po3d	1Se − 1Po	1: 2 − 3: 15	13.73	2.14E+00	9.66E−02	2.52E+13
2s22p4 − 2s22p34So4d	1Se − 3Do	1: 2 − 3: 34	11.21	3.98E−05	1.47E−06	7.05E+08
2s22p4 − 2s22p32Do4d	1Se − 3Do	1: 2 − 3: 40	11.02	7.63E−03	2.77E−04	1.40E+11
2s22p4 − 2s22p32Po4d	1Se − 3Do	1: 2 − 3: 45	10.91	1.86E−02	6.66E−04	3.47E+11
2s22p4 − 2s22p32Po4d	1Se − 3Po	1: 2 − 3: 46	10.83	1.67E−02	5.97E−04	3.17E+11
2s22p4 − 2s22p32Po4d	1Se − 1Po	1: 2 − 3: 47	10.81	4.73E−01	1.68E−02	8.99E+12
2s22p4 − 2s22p32Po5d	1Se − 3Do	1: 2 − 3: 75	9.88	2.83E−04	9.21E−06	6.45E+09
2s22p4 − 2s22p32Po5d	1Se − 3Po	1: 2 − 3: 78	9.83	8.81E−03	2.85E−04	2.03E+11
2s22p4 − 2s22p32Po5d	1Se − 1Po	1: 2 − 3: 79	9.82	1.25E−01	4.04E−03	2.88E+12
2s2p5 − 2p6	3Po − 1Se	3: 1 − 1: 3	87.00	4.03E−03	3.46E−03	1.07E+10
2s2p5 − 2p6	1Po − 1Se	3: 2 − 1: 3	115.40	9.01E−02	1.03E−01	1.35E+11
2p6 − 2s22p34So3s	1Se − 3So	1: 3 − 3: 3	22.00	2.63E−12	1.90E−13	1.21E+01
2p6 − 2s22p32Do3s	1Se − 3Do	1: 3 − 3: 4	21.49	8.00E−08	5.66E−09	3.85E+05
2p6 − 2s22p32Po3s	1Se − 3Po	1: 3 − 3: 5	20.88	2.15E−08	1.48E−09	1.10E+05
2p6 − 2s22p32Po3s	1Se − 1Po	1: 3 − 3: 6	20.62	9.85E−07	6.69E−08	5.16E+06
2p6 − 2s22p32Po3d	1Se − 3Do	1: 3 − 3: 13	18.41	1.48E−07	8.95E−09	9.69E+05
2p6 − 2s22p32Po3d	1Se − 1Po	1: 3 − 3: 15	18.28	2.67E−05	1.61E−06	1.78E+08
2p6 − 2s22p34So4d	1Se − 3Do	1: 3 − 3: 34	14.07	7.05E−03	3.27E−04	7.93E+10
2p6 − 2s22p32Do4d	1Se − 3Do	1: 3 − 3: 40	13.76	6.16E−03	2.79E−04	7.24E+10
2p6 − 2s22p32Po4d	1Se − 3Do	1: 3 − 3: 45	13.59	4.91E−04	2.20E−05	5.91E+09
2p6 − 2s22p32Po4d	1Se − 3Po	1: 3 − 3: 46	13.47	2.63E−04	1.17E−05	3.23E+09
2p6 − 2s22p32Po4d	1Se − 1Po	1: 3 − 3: 47	13.44	5.33E−04	2.36E−05	6.56E+09
2p6 − 2s22p32Po5d	1Se − 3Do	1: 3 − 3: 75	12.03	2.57E−05	1.02E−06	3.96E+08
2p6 − 2s22p32Po5d	1Se − 3Po	1: 3 − 3: 78	11.95	1.49E−05	5.88E−07	2.32E+08
2p6 − 2s22p32Po5d	1Se − 1Po	1: 3 − 3: 79	11.94	1.63E−03	6.39E−05	2.54E+10
2s22p4 − 2s22p32Do3s	3Pe − 1Do	3: 1 − 5: 4	14.83	1.49E−02	2.18E−03	2.71E+11
2s22p4 − 2s22p32Do3s	3Pe − 1Do	5: 1 − 5: 4	14.63	3.78E−03	9.10E−04	1.18E+11
2s22p4 − 2s22p32Do3d	3Pe − 3Po	3: 1 − 5: 8	13.74	2.14E−02	2.90E−03	4.54E+11
2s22p4 − 2s22p32Do3d	3Pe − 3Po	5: 1 − 5: 8	13.57	3.31E−02	7.39E−03	1.20E+12
LS	3Pe − 3Po	9 − 9		2.55E−02	1.03E−02	9.19E+11
2s22p4 − 2s22p32Do3d	3Pe − 3Do	3: 1 − 5: 9	13.67	4.51E−01	6.09E−02	9.66E+12
2s22p4 − 2s22p32Do3d	3Pe − 3Do	5: 1 − 5: 9	13.50	1.05E−01	2.33E−02	3.84E+12
2s22p4 − 2s22p32Do3d	3Pe − 3Do	5: 1 − 7: 7	13.52	1.54E−01	3.44E−02	4.02E+12
LS	3Pe − 3Do	9 − 15		2.94E−01	1.19E−01	6.36E+12
2s22p4 − 2s22p32Po3d	3Pe − 3Fo	3: 1 − 5: 11	13.55	3.24E−02	4.33E−03	7.06E+11
2s22p4 − 2s22p32Po3d	3Pe − 3Fo	5: 1 − 5: 11	13.39	3.07E−02	6.77E−03	1.14E+12
2s22p4 − 2s22p32Po3d	3Pe − 3Fo	5: 1 − 7: 8	13.42	1.00E−02	2.22E−03	2.66E+11
LS	3Pe − 3Fo	9 − 21		3.34E−02	1.33E−02	5.28E+11
2s22p4 − 2s22p32Do4d	3Pe − 1Do	3: 1 − 5: 42	10.72	4.08E−03	4.32E−04	1.42E+11
2s22p4 − 2s22p32Do4d	3Pe − 1Do	5: 1 − 5: 42	10.62	8.70E−02	1.52E−02	5.14E+12
2s22p4 − 2s22p32Po4d	3Pe − 3Fo	3: 1 − 5: 43	10.64	1.51E−02	1.59E−03	5.34E+11
2s22p4 − 2s22p32Po4d	3Pe − 3Fo	5: 1 − 5: 43	10.54	2.87E−04	4.98E−05	1.73E+10
2s22p4 − 2s22p32Po4d	3Pe − 3Fo	5: 1 − 7: 28	10.55	4.22E−03	7.33E−04	1.81E+11
LS	3Pe − 3Fo	9 − 21		7.54E−03	2.37E−03	1.91E+11
2s22p4 − 2s22p32Do5d	3Pe − 3Do	3: 1 − 5: 68	9.77	7.80E−03	7.53E−04	3.27E+11
2s22p4 − 2s22p32Do5d	3Pe − 3Do	5: 1 − 5: 68	9.68	6.48E−03	1.03E−03	4.61E+11
2s22p4 − 2s22p32Do5d	3Pe − 3Do	5: 1 − 7: 48	9.68	5.61E−05	8.94E−06	2.85E+09

(*continued on next page*)

Table 2 (*continued*)

$C_i - C_k$	$T_i - T_k$	$g_i : I - g_k$:K	E_{ik} (Å)	f	S	A (s^{-1})
LS	3Pe − 3Do	9 − 15		6.23E−03	1.79E−03	2.65E+11
2s22p4 − 2s22p32Do5d	3Pe − 1Do	3: 1 − 5: 69	9.74	3.63E−02	3.49E−03	1.53E+12
2s22p4 − 2s22p32Do5d	3Pe − 1Do	5: 1 − 5: 69	9.65	1.11E−02	1.77E−03	7.97E+11
2s22p4 − 2s22p34So6d	3Pe − 5Do	3: 1 − 5: 93	9.44	1.72E−08	1.60E−09	7.72E+05
2s22p4 − 2s22p34So6d	3Pe − 5Do	5: 1 − 5: 93	9.36	3.62E−07	5.57E−08	2.75E+07
2s22p4 − 2s2p5	1De − 3Po	5: 2 − 3: 1	122.57	2.25E−05	4.54E−05	1.67E+07
2s22p4 − 2s2p5	1De − 3Po	5: 2 − 5: 1	132.63	5.17E−03	1.13E−02	1.96E+09
2s22p4 − 2s2p5	1De − 1Po	5: 2 − 3: 2	91.02	9.82E−02	1.47E−01	1.32E+11
2s22p4 − 2s22p34So3s	1De − 3So	5: 2 − 3: 3	15.36	5.25E−04	1.33E−04	2.48E+10
2s22p4 − 2s22p32Do3s	1De − 3Do	5: 2 − 3: 4	15.11	2.75E−03	6.83E−04	1.34E+11
2s22p4 − 2s22p32Do3s	1De − 3Do	5: 2 − 5: 3	15.11	3.89E−03	9.68E−04	1.14E+11
2s22p4 − 2s22p32Do3s	1De − 3Do	5: 2 − 7: 1	15.04	5.09E−03	1.26E−03	1.07E+11
2s22p4 − 2s22p32Po3s	1De − 3Po	5: 2 − 3: 5	14.81	9.95E−03	2.43E−03	5.05E+11
2s22p4 − 2s22p32Po3s	1De − 3Po	5: 2 − 5: 5	14.70	2.01E−02	4.88E−03	6.22E+11
2s22p4 − 2s22p32Po3s	1De − 1Po	5: 2 − 3: 6	14.67	1.81E−02	4.38E−03	9.36E+11
2s22p4 − 2s22p32Po3d	1De − 3Do	5: 2 − 3: 13	13.52	1.08E−02	2.40E−03	6.55E+11
2s22p4 − 2s22p32Po3d	1De − 3Do	5: 2 − 5: 13	13.54	1.50E−01	3.35E−02	5.47E+12
2s22p4 − 2s22p32Po3d	1De − 3Do	5: 2 − 7: 9	13.52	2.44E−03	5.43E−04	6.36E+10
2s22p4 − 2s22p32Po3d	1De − 1Po	5: 2 − 3: 15	13.45	1.91E−02	4.22E−03	1.17E+12
2s22p4 − 2s22p34So4d	1De − 3Do	5: 2 − 3: 34	11.02	4.96E−05	9.00E−06	4.54E+09
2s22p4 − 2s22p34So4d	1De − 3Do	5: 2 − 5: 34	11.02	1.94E−04	3.52E−05	1.07E+10
2s22p4 − 2s22p34So4d	1De − 3Do	5: 2 − 7: 21	11.01	5.95E−04	1.08E−04	2.34E+10
2s22p4 − 2s22p32Do4d	1De − 3Do	5: 2 − 3: 40	10.83	2.86E−03	5.10E−04	2.71E+11
2s22p4 − 2s22p32Do4d	1De − 3Do	5: 2 − 5: 40	10.86	8.48E−04	1.52E−04	4.79E+10
2s22p4 − 2s22p32Do4d	1De − 3Do	5: 2 − 5: 41	10.84	7.68E−03	1.37E−03	4.36E+11
2s22p4 − 2s22p32Do4d	1De − 3Do	5: 2 − 7: 25	10.85	4.08E−03	7.29E−04	1.65E+11
2s22p4 − 2s22p32Po4d	1De − 3Do	5: 2 − 3: 45	10.72	1.04E−03	1.84E−04	1.01E+11
2s22p4 − 2s22p32Po4d	1De − 3Po	5: 2 − 3: 46	10.65	4.00E−03	7.01E−04	3.92E+11
2s22p4 − 2s22p32Po4d	1De − 1Po	5: 2 − 3: 47	10.63	2.46E−03	4.31E−04	2.42E+11
2s22p4 − 2s22p32Po5d	1De − 3Do	5: 2 − 3: 75	9.73	2.10E−03	3.36E−04	2.47E+11
2s22p4 − 2s22p32Po5d	1De − 3Do	5: 2 − 7: 61	9.68	1.65E−02	2.62E−03	8.37E+11
2s22p4 − 2s22p32Po5d	1De − 3Po	5: 2 − 3: 78	9.68	1.05E−03	1.68E−04	1.25E+11
2s22p4 − 2s22p32Po5d	1De − 1Po	5: 2 − 3: 79	9.67	1.29E−05	2.05E−06	1.53E+09
2s22p4 − 2s22p32Do3s	1De − 1Do	5: 2 − 5: 4	15.00	6.92E−02	1.71E−02	2.05E+12
2s22p4 − 2s22p32Do3d	1De − 3Po	5: 2 − 5: 8	13.89	4.74E−04	1.08E−04	1.64E+10
2s22p4 − 2s22p32Do3d	1De − 3Do	5: 2 − 5: 9	13.82	8.11E−03	1.84E−03	2.83E+11
2s22p4 − 2s22p32Do3d	1De − 3Do	5: 2 − 7: 7	13.84	3.26E−01	7.42E−02	8.10E+12
2s22p4 − 2s22p32Po3d	1De − 3Fo	5: 2 − 5: 11	13.70	1.32E−01	2.99E−02	4.70E+12
2s22p4 − 2s22p32Po3d	1De − 3Fo	5: 2 − 7: 8	13.73	7.94E−02	1.79E−02	2.00E+12
2s22p4 − 2s22p32Do4d	1De − 1Do	5: 2 − 5: 42	10.81	1.81E−04	3.23E−05	1.03E+10
2s22p4 − 2s22p32Po4d	1De − 3Fo	5: 2 − 5: 43	10.73	8.36E−02	1.48E−02	4.85E+12
2s22p4 − 2s22p32Po4d	1De − 3Fo	5: 2 − 7: 28	10.74	3.63E−02	6.41E−03	1.50E+12
2s22p4 − 2s22p32Do5d	1De − 3Do	5: 2 − 5: 68	9.84	5.95E−04	9.64E−05	4.10E+10
2s22p4 − 2s22p32Do5d	1De − 3Do	5: 2 − 7: 48	9.84	3.29E−03	5.34E−04	1.62E+11
2s22p4 − 2s22p32Do5d	1De − 1Do	5: 2 − 5: 69	9.81	1.92E−03	3.10E−04	1.33E+11
2s22p4 − 2s22p34So6d	1De − 5Do	5: 2 − 5: 93	9.51	1.49E−05	2.33E−06	1.10E+09
2s22p4 − 2s22p34So3d	3Pe − 3Do	5: 1 − 7: 3	13.79	2.39E−01	5.43E−02	5.99E+12
2s22p4 − 2s22p32Do3d	3Pe − 1Fo	5: 1 − 7: 6	13.42	7.17E−01	1.58E−01	1.90E+13
2s22p4 − 2s22p32Do4d	3Pe − 3Fo	5: 1 − 7: 23	10.68	5.48E−04	9.63E−05	2.29E+10
2s22p4 − 2s22p32Do4d	3Pe − 1Fo	5: 1 − 7: 26	10.62	8.03E−02	1.40E−02	3.39E+12
2s22p4 − 2s22p32Po4d	3Pe − 1Fo	5: 1 − 7: 29	10.47	5.31E−03	9.15E−04	2.31E+11
2s22p4 − 2s22p34So5d	3Pe − 3Do	5: 1 − 7: 38	9.81	1.62E−08	2.62E−09	8.04E+05
2s22p4 − 2s22p32Do5d	3Pe − 1Fo	5: 1 − 7: 52	9.62	2.43E−02	3.85E−03	1.25E+12
2s22p4 − 2s22p32Do5d	3Pe − 3Fo	5: 1 − 7: 57	9.60	1.19E−04	1.89E−05	6.18E+09
2s22p4 − 2s22p32Po5d	3Pe − 3Fo	5: 1 − 7: 62	9.52	1.14E−07	1.79E−08	5.98E+06
2s22p4 − 2s22p32Po5d	3Pe − 1Fo	5: 1 − 7: 63	9.52	2.04E−04	3.20E−05	1.07E+10
2s22p4 − 2s22p34So6d	3Pe − 3Do	5: 1 − 7: 72	9.34	3.64E−05	5.59E−06	1.99E+09
2s22p4 − 2s22p32Po6d	3Pe − 1Fo	5: 1 − 7: 90	9.07	8.87E−07	1.32E−07	5.14E+07

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Table 2 (*continued*)

$C_i - C_k$	$T_i - T_k$	$g_i : I - g_k$:K	E_{ik} (Å)	f	S	A (s^{-1})
2s22p4 − 2s22p34So3d	1De − 3Do	5: 2 − 7: 3	14.12	3.15E−03	7.31E−04	7.51E+10
2s22p4 − 2s22p32Do3d	1De − 1Fo	5: 2 − 7: 6	13.74	1.26E−02	2.85E−03	3.19E+11
2s22p4 − 2s22p32Do4d	1De − 3Fo	5: 2 − 7: 23	10.88	2.24E−03	4.01E−04	9.01E+10
2s22p4 − 2s22p32Do4d	1De − 1Fo	5: 2 − 7: 26	10.81	3.77E−04	6.70E−05	1.53E+10
2s22p4 − 2s22p32Po4d	1De − 1Fo	5: 2 − 7: 29	10.66	2.83E−02	4.96E−03	1.19E+12
2s22p4 − 2s22p34So5d	1De − 3Do	5: 2 − 7: 38	9.98	5.69E−05	9.35E−06	2.72E+09
2s22p4 − 2s22p32Do5d	1De − 1Fo	5: 2 − 7: 52	9.78	1.61E−04	2.59E−05	8.00E+09
2s22p4 − 2s22p32Do5d	1De − 3Fo	5: 2 − 7: 57	9.76	4.18E−03	6.72E−04	2.09E+11
2s22p4 − 2s22p32Po5d	1De − 3Fo	5: 2 − 7: 62	9.68	4.71E−06	7.51E−07	2.40E+08
2s22p4 − 2s22p32Po5d	1De − 1Fo	5: 2 − 7: 63	9.68	3.11E−02	4.95E−03	1.58E+12
2s22p4 − 2s22p34So6d	1De − 3Do	5: 2 − 7: 72	9.49	6.00E−06	9.37E−07	3.18E+08

Table 3
Levels for forbidden transitions. See explanation of tables.

i_e	*SLp* (*cf*)	2*J*	*E* (Ry)
1	3Pe(1)	4	0.00000E+00
2	3Pe(1)	0	6.85730E−01
3	3Pe(1)	2	8.15050E−01
4	1De(1)	4	1.53870E+00
5	1Se(1)	0	2.96290E+00
6	3Po(2)	4	8.41000E+00
7	3Po(2)	2	8.97360E+00
8	3Po(2)	0	9.38620E+00
9	1Po(2)	2	1.15510E+01
10	1Se(3)	0	1.94480E+01
11	5So(4)	4	6.07327E+01
12	3So(4)	2	6.08730E+01
13	3Do(4)	4	6.18480E+01
14	3Do(4)	2	6.18570E+01
15	3Do(4)	6	6.21300E+01
16	1Do(4)	4	6.22760E+01
17	5Pe(5)	2	6.28417E+01
18	5Pe(5)	4	6.28804E+01
19	5Pe(5)	6	6.30517E+01
20	3De(5)	2	6.33572E+01
21	3Po(4)	0	6.29410E+01
22	3Po(4)	2	6.30870E+01
23	3Pe(5)	4	6.35297E+01
24	3Pe(5)	0	6.36047E+01
25	3Po(4)	4	6.35150E+01
26	3Pe(5)	2	6.40520E+01
27	1Po(4)	2	6.36520E+01
28	3Fe(5)	4	6.42583E+01
29	3De(5)	4	6.44187E+01
30	3Fe(5)	6	6.44565E+01
31	1Pe(5)	2	6.45575E+01
32	1Fe(5)	6	6.45718E+01
33	3De(5)	6	6.47467E+01
34	3Fe(5)	8	6.47888E+01
35	3Pe(5)	0	6.50097E+01
36	3Pe(5)	2	6.52057E+01
37	3Pe(5)	4	6.53355E+01
38	1Pe(5)	2	6.55259E+01
39	1De(5)	4	6.56276E+01
40	5Do(6)	0	6.56732E+01
41	5Do(6)	2	6.56798E+01
42	5Do(6)	4	6.56811E+01
43	5Do(6)	6	6.56870E+01
44	5Do(6)	8	6.57252E+01
45	3Se(5)	2	6.57984E+01
46	3De(5)	4	6.57999E+01
47	3Pe(5)	2	6.61488E+01
48	3Do(6)	4	6.61617E+01
49	3De(5)	6	6.61740E+01
50	3Pe(5)	0	6.61922E+01
51	3Do(6)	2	6.63713E+01
52	3Do(6)	6	6.60580E+01
53	3De(5)	2	6.64209E+01
54	3Pe(5)	4	6.64716E+01
55	1De(5)	4	6.67001E+01
56	3Fo(6)	4	6.80530E+01
57	3Go(6)	6	6.70906E+01
58	1So(6)	0	6.70970E+01
59	3Fo(6)	6	6.78890E+01
60	1Go(6)	8	6.71790E+01
61	3Do(6)	2	6.72042E+01
62	3Fo(6)	8	6.73482E+01
63	3Go(6)	8	6.74697E+01
64	3Go(6)	10	6.74698E+01
65	3Do(6)	4	6.74790E+01
66	1Po(6)	2	6.76349E+01
67	1Se(5)	0	6.76533E+01
68	5Pe(11)	6	6.77160E+01
69	3Do(6)	6	6.73970E+01
70	3Po(6)	0	6.77707E+01
71	1Do(6)	4	6.77977E+01
72	3Po(6)	2	6.78054E+01
73	3Po(6)	4	6.71600E+01
74	3So(6)	2	6.79845E+01

(*continued on next page*)

Table 3 (*continued*)

i_e	*SLp* (*cf*)	2*J*	*E* (Ry)
75	5Pe(11)	4	6.81452E+01
76	3Fo(6)	6	6.82489E+01
77	5Pe(11)	2	6.84400E+01
78	1Do(6)	4	6.84528E+01
79	3Do(6)	6	6.89370E+01
80	3Pe(11)	4	6.86279E+01
81	3Po(6)	4	6.86596E+01
82	3Po(6)	2	6.88131E+01
83	3Fo(6)	8	6.88395E+01
84	3Po(6)	0	6.88634E+01
85	3Do(6)	4	6.88370E+01
86	3Do(6)	2	6.89560E+01
87	3Pe(11)	2	6.90836E+01
88	1Fo(6)	6	6.78800E+01
89	3Pe(11)	0	6.92568E+01
90	3Fo(6)	4	6.93730E+01
91	1Fo(6)	6	6.93827E+01
92	5Po(12)	6	6.97875E+01
93	5Po(12)	4	6.97979E+01
94	1Po(6)	2	6.93110E+01
95	5Do(12)	8	7.00875E+01
96	5Po(12)	2	7.01577E+01
97	5Do(12)	6	7.02128E+01
98	5Do(12)	4	7.04856E+01
99	3De(11)	2	7.05616E+01
100	3De(11)	4	7.05982E+01
101	5Do(12)	2	7.06126E+01
102	5Do(12)	0	7.06314E+01
103	3So(12)	2	7.06775E+01
104	3Do(12)	6	7.06818E+01
105	3De(11)	6	7.06895E+01
106	3Do(12)	4	7.07639E+01
107	5So(12)	4	7.09256E+01
108	3Do(12)	2	7.11089E+01
109	3Po(12)	0	7.11200E+01
110	1De(11)	4	7.11469E+01
111	3Fo(12)	4	7.11584E+01
112	3Po(12)	2	7.13026E+01
113	3Se(11)	2	7.19185E+01
114	1Se(11)	0	7.22755E+01
115	5De(13)	6	7.24167E+01
116	5De(13)	8	7.24210E+01
117	5De(13)	4	7.24733E+01
118	3Pe(11)	4	7.25251E+01
119	5De(13)	2	7.25757E+01
120	3Do(12)	4	7.25850E+01
121	1Pe(11)	2	7.26307E+01
122	5Fe(13)	10	7.26475E+01
123	3Fo(12)	6	7.27264E+01
124	5De(13)	0	7.27449E+01
125	3Do(12)	2	7.27491E+01
126	3Fo(12)	8	7.29147E+01
127	5Fe(13)	8	7.29165E+01
128	1Fo(12)	6	7.29388E+01
129	5Pe(13)	2	7.30154E+01

Table 4
Forbidden transitions in Fe XIX. See explanation of tables.

$i-j$	$T_i\ C_i - T_j\ C_j$	$g_i - g_j$	λ (Å)	E_i (Ry)	E_j (Ry)	AE2	AM1
E2 and M1, $N_{tr} = 48219$							
1 − 3	3Pe 1 − 3Pe 1	5 − 3	1118	0.00E+00	8.15E−01	6.35E−01	1.46E+04
2 − 3	3Pe 1 − 3Pe 1	1 − 3	7046	6.86E−01	8.15E−01	0.00E+00	4.10E+01
1 − 4	3Pe 1 − 1De 1	5 − 5	592.23	0.00E+00	1.54E+00	6.00E+00	1.67E+04
2 − 4	3Pe 1 − 1De 1	1 − 5	1068	6.86E−01	1.54E+00	7.28E−02	0.00E+00
3 − 4	3Pe 1 − 1De 1	3 − 5	1259	8.15E−01	1.54E+00	2.27E−02	6.51E+02
1 − 5	3Pe 1 − 1Se 1	5 − 1	307.56	0.00E+00	2.96E+00	8.32E+00	0.00E+00
3 − 5	3Pe 1 − 1Se 1	3 − 1	424.27	8.15E−01	2.96E+00	0.00E+00	1.41E+05
4 − 5	1De 1 − 1Se 1	5 − 1	639.84	1.54E+00	2.96E+00	4.92E+01	0.00E+00
6 − 7	3Po 2 − 3Po 2	5 − 3	1616	8.41E+00	8.97E+00	1.09E−01	5.15E+03
6 − 8	3Po 2 − 3Po 2	5 − 1	933.48	8.41E+00	9.39E+00	2.32E+00	0.00E+00
7 − 8	3Po 2 − 3Po 2	3 − 1	2208	8.97E+00	9.39E+00	0.00E+00	4.86E+03
6 − 9	3Po 2 − 1Po 2	5 − 3	290.12	8.41E+00	1.16E+01	1.75E+01	2.78E+04
7 − 9	3Po 2 − 1Po 2	3 − 3	353.56	8.97E+00	1.16E+01	1.97E+01	8.79E+03
8 − 9	3Po 2 − 1Po 2	1 − 3	420.95	9.39E+00	1.16E+01	0.00E+00	7.31E+03
1 − 10	3Pe 1 − 1Se 3	5 − 1	46.86	0.00E+00	1.94E+01	7.85E+04	0.00E+00
3 − 10	3Pe 1 − 1Se 3	3 − 1	48.91	8.15E−01	1.94E+01	0.00E+00	2.49E+04
4 − 10	1De 1 − 1Se 3	5 − 1	50.88	1.54E+00	1.94E+01	5.50E+05	0.00E+00
6 − 11	3Po 2 − 5So 4	5 − 5	17.42	8.41E+00	6.07E+01	3.11E+05	1.06E+03
7 − 11	3Po 2 − 5So 4	3 − 5	17.61	8.97E+00	6.07E+01	1.15E+05	1.57E+02
8 − 11	3Po 2 − 5So 4	1 − 5	17.75	9.39E+00	6.07E+01	1.18E+04	0.00E+00
9 − 11	1Po 2 − 5So 4	3 − 5	18.53	1.16E+01	6.07E+01	1.03E+04	2.87E+00
6 − 12	3Po 2 − 3So 4	5 − 3	17.37	8.41E+00	6.09E+01	3.98E+05	6.62E+02
7 − 12	3Po 2 − 3So 4	3 − 3	17.56	8.97E+00	6.09E+01	1.50E+05	5.45E+01
8 − 12	3Po 2 − 3So 4	1 − 3	17.70	9.39E+00	6.09E+01	0.00E+00	2.49E+01
9 − 12	1Po 2 − 3So 4	3 − 3	18.48	1.16E+01	6.09E+01	2.08E+05	4.51E+01
11 − 12	5So 4 − 3So 4	5 − 3	6493	6.07E+01	6.09E+01	6.56E−08	4.69E−01
6 − 13	3Po 2 − 3Do 4	5 − 5	17.05	8.41E+00	6.18E+01	6.84E+06	6.52E+01
7 − 13	3Po 2 − 3Do 4	3 − 5	17.23	8.97E+00	6.18E+01	4.84E+02	3.31E+02
8 − 13	3Po 2 − 3Do 4	1 − 5	17.37	9.39E+00	6.18E+01	1.13E+06	0.00E+00
9 − 13	1Po 2 − 3Do 4	3 − 5	18.12	1.16E+01	6.18E+01	7.84E+05	3.28E+02
11 − 13	5So 4 − 3Do 4	5 − 5	817.03	6.07E+01	6.18E+01	1.45E−01	5.21E+03
12 − 13	3So 4 − 3Do 4	3 − 5	934.63	6.09E+01	6.18E+01	1.93E−03	1.34E+03
6 − 14	3Po 2 − 3Do 4	5 − 3	17.05	8.41E+00	6.19E+01	3.94E+06	2.66E+01
7 − 14	3Po 2 − 3Do 4	3 − 3	17.23	8.97E+00	6.19E+01	5.28E+06	1.95E+02
8 − 14	3Po 2 − 3Do 4	1 − 3	17.37	9.39E+00	6.19E+01	0.00E+00	3.16E+01
9 − 14	1Po 2 − 3Do 4	3 − 3	18.11	1.16E+01	6.19E+01	4.70E+04	2.90E+02
11 − 14	5So 4 − 3Do 4	5 − 3	810.49	6.07E+01	6.19E+01	8.27E−02	1.09E+03
12 − 14	3So 4 − 3Do 4	3 − 3	926.09	6.09E+01	6.19E+01	2.33E−01	7.60E+03
13 − 14	3Do 4 − 3Do 4	5 − 3	101264	6.18E+01	6.19E+01	1.43E−11	2.52E−02
6 − 15	3Po 2 − 3Do 4	5 − 7	16.96	8.41E+00	6.21E+01	7.21E+06	1.90E+02
7 − 15	3Po 2 − 3Do 4	3 − 7	17.14	8.97E+00	6.21E+01	3.10E+06	0.00E+00
9 − 15	1Po 2 − 3Do 4	3 − 7	18.02	1.16E+01	6.21E+01	9.95E+04	0.00E+00
11 − 15	5So 4 − 3Do 4	5 − 7	652.14	6.07E+01	6.21E+01	5.78E−01	4.61E+02
12 − 15	3So 4 − 3Do 4	3 − 7	724.95	6.09E+01	6.21E+01	8.18E−04	0.00E+00
13 − 15	3Do 4 − 3Do 4	5 − 7	3231	6.18E+01	6.21E+01	4.12E−04	3.63E+02
14 − 15	3Do 4 − 3Do 4	3 − 7	3337	6.19E+01	6.21E+01	9.21E−05	0.00E+00
6 − 16	3Po 2 − 1Do 4	5 − 5	16.92	8.41E+00	6.23E+01	1.13E+06	1.26E+02
7 − 16	3Po 2 − 1Do 4	3 − 5	17.10	8.97E+00	6.23E+01	1.26E+06	4.64E+01
8 − 16	3Po 2 − 1Do 4	1 − 5	17.23	9.39E+00	6.23E+01	9.72E+05	0.00E+00
9 − 16	1Po 2 − 1Do 4	3 − 5	17.96	1.16E+01	6.23E+01	5.02E+06	3.16E+01
11 − 16	5So 4 − 1Do 4	5 − 5	590.45	6.07E+01	6.23E+01	2.15E−01	1.29E+03
12 − 16	3So 4 − 1Do 4	3 − 5	649.51	6.09E+01	6.23E+01	1.27E+00	3.28E+02
13 − 16	3Do 4 − 1Do 4	5 − 5	2129	6.18E+01	6.23E+01	7.21E−04	6.49E+00
14 − 16	3Do 4 − 1Do 4	3 − 5	2174	6.19E+01	6.23E+01	2.42E−03	3.40E+02
15 − 16	3Do 4 − 1Do 4	7 − 5	6241	6.21E+01	6.23E+01	5.09E−06	2.13E+01
1 − 17	3Pe 1 − 5Pe 5	5 − 3	14.50	0.00E+00	6.28E+01	2.30E+08	1.78E+05
2 − 17	3Pe 1 − 5Pe 5	1 − 3	14.66	6.86E−01	6.28E+01	0.00E+00	9.36E+04
3 − 17	3Pe 1 − 5Pe 5	3 − 3	14.69	8.15E−01	6.28E+01	1.25E+07	1.45E+05
4 − 17	1De 1 − 5Pe 5	5 − 3	14.86	1.54E+00	6.28E+01	1.02E+06	2.41E+03
5 − 17	1Se 1 − 5Pe 5	1 − 3	15.22	2.96E+00	6.28E+01	0.00E+00	6.83E+02
10 − 17	1Se 3 − 5Pe 5	1 − 3	21.00	1.94E+01	6.28E+01	0.00E+00	1.45E+02
1 − 18	3Pe 1 − 5Pe 5	5 − 5	14.49	0.00E+00	6.29E+01	3.49E+08	1.48E+05
2 − 18	3Pe 1 − 5Pe 5	1 − 5	14.65	6.86E−01	6.29E+01	5.18E+07	0.00E+00
3 − 18	3Pe 1 − 5Pe 5	3 − 5	14.68	8.15E−01	6.29E+01	9.38E+07	9.54E+03
4 − 18	1De 1 − 5Pe 5	5 − 5	14.86	1.54E+00	6.29E+01	2.12E+06	2.91E+03
5 − 18	1Se 1 − 5Pe 5	1 − 5	15.21	2.96E+00	6.29E+01	2.60E+05	0.00E+00
10 − 18	1Se 3 − 5Pe 5	1 − 5	20.98	1.94E+01	6.29E+01	2.32E+04	0.00E+00
17 − 18	5Pe 5 − 5Pe 5	3 − 5	23559	6.28E+01	6.29E+01	5.75E−07	1.60E+00
1 − 19	3Pe 1 − 5Pe 5	5 − 7	14.45	0.00E+00	6.31E+01	8.69E+07	4.83E+03
3 − 19	3Pe 1 − 5Pe 5	3 − 7	14.64	8.15E−01	6.31E+01	6.35E+06	0.00E+00
4 − 19	1De 1 − 5Pe 5	5 − 7	14.81	1.54E+00	6.31E+01	1.59E+05	1.19E+03
17 − 19	5Pe 5 − 5Pe 5	3 − 7	4340	6.28E+01	6.31E+01	1.65E−02	0.00E+00
18 − 19	5Pe 5 − 5Pe 5	5 − 7	5321	6.29E+01	6.31E+01	6.13E−03	9.94E+01

(*continued on next page*)

Table 4 (*continued*)

$i-j$	$T_i\ C_i - T_j\ C_j$	$g_i - g_j$	λ (Å)	E_i (Ry)	E_j (Ry)	AE2	AM1
1 − 20	3Pe 1 − 3De 5	5 − 3	14.38	0.00E+00	6.34E+01	2.04E+09	1.50E+05
2 − 20	3Pe 1 − 3De 5	1 − 3	14.54	6.86E−01	6.34E+01	0.00E+00	1.79E+04
3 − 20	3Pe 1 − 3De 5	3 − 3	14.57	8.15E−01	6.34E+01	2.21E+08	1.41E+04
4 − 20	1De 1 − 3De 5	5 − 3	14.74	1.54E+00	6.34E+01	1.47E+06	3.29E+03
5 − 20	1Se 1 − 3De 5	1 − 3	15.09	2.96E+00	6.34E+01	0.00E+00	2.43E+03
10 − 20	1Se 3 − 3De 5	1 − 3	20.75	1.94E+01	6.34E+01	0.00E+00	2.89E+00
17 − 20	5Pe 5 − 3De 5	3 − 3	1767	6.28E+01	6.34E+01	5.79E−02	6.64E+02
18 − 20	5Pe 5 − 3De 5	5 − 3	1911	6.29E+01	6.34E+01	3.17E−01	3.58E+01
19 − 20	5Pe 5 − 3De 5	7 − 3	2982	6.31E+01	6.34E+01	1.36E−02	0.00E+00
6 − 21	3Po 2 − 3Po 4	5 − 1	16.71	8.41E+00	6.29E+01	6.66E+06	0.00E+00
7 − 21	3Po 2 − 3Po 4	3 − 1	16.89	8.97E+00	6.29E+01	0.00E+00	2.43E+01
9 − 21	1Po 2 − 3Po 4	3 − 1	17.73	1.16E+01	6.29E+01	0.00E+00	1.62E+03
11 − 21	5So 4 − 3Po 4	5 − 1	412.65	6.07E+01	6.29E+01	2.49E+00	0.00E+00
12 − 21	3So 4 − 3Po 4	3 − 1	440.65	6.09E+01	6.29E+01	0.00E+00	2.45E+04
13 − 21	3Do 4 − 3Po 4	5 − 1	833.73	6.18E+01	6.29E+01	4.99E+00	0.00E+00
14 − 21	3Do 4 − 3Po 4	3 − 1	840.65	6.19E+01	6.29E+01	0.00E+00	4.39E+03
16 − 21	1Do 4 − 3Po 4	5 − 1	1370	6.23E+01	6.29E+01	1.12E−01	0.00E+00
6 − 22	3Po 2 − 3Po 4	5 − 3	16.67	8.41E+00	6.31E+01	3.23E+06	2.83E+01
7 − 22	3Po 2 − 3Po 4	3 − 3	16.84	8.97E+00	6.31E+01	2.36E+06	1.34E+01
8 − 22	3Po 2 − 3Po 4	1 − 3	16.97	9.39E+00	6.31E+01	0.00E+00	2.42E+02
9 − 22	1Po 2 − 3Po 4	3 − 3	17.68	1.16E+01	6.31E+01	6.14E+05	5.35E+02
11 − 22	5So 4 − 3Po 4	5 − 3	387.06	6.07E+01	6.31E+01	1.76E+00	1.90E+04
12 − 22	3So 4 − 3Po 4	3 − 3	411.59	6.09E+01	6.31E+01	1.06E+00	2.19E+03
13 − 22	3Do 4 − 3Po 4	5 − 3	735.48	6.18E+01	6.31E+01	2.07E+00	3.25E+03
14 − 22	3Do 4 − 3Po 4	3 − 3	740.87	6.19E+01	6.31E+01	3.10E+00	3.33E+03
15 − 22	3Do 4 − 3Po 4	7 − 3	952.21	6.21E+01	6.31E+01	1.33E+00	0.00E+00
16 − 22	1Do 4 − 3Po 4	5 − 3	1123	6.23E+01	6.31E+01	1.35E−01	6.17E+02
21 − 22	3Po 4 − 3Po 4	1 − 3	6241	6.29E+01	6.31E+01	0.00E+00	5.84E+01
1 − 23	3Pe 1 − 3Pe 5	5 − 5	14.34	0.00E+00	6.35E+01	9.62E+08	1.88E+04
2 − 23	3Pe 1 − 3Pe 5	1 − 5	14.50	6.86E−01	6.35E+01	4.98E+08	0.00E+00
3 − 23	3Pe 1 − 3Pe 5	3 − 5	14.53	8.15E−01	6.35E+01	5.41E+08	2.27E+04
4 − 23	1De 1 − 3Pe 5	5 − 5	14.70	1.54E+00	6.35E+01	7.42E+05	3.20E+03
5 − 23	1Se 1 − 3Pe 5	1 − 5	15.05	2.96E+00	6.35E+01	2.49E+06	0.00E+00
10 − 23	1Se 3 − 3Pe 5	1 − 5	20.67	1.94E+01	6.35E+01	2.18E+05	0.00E+00
17 − 23	5Pe 5 − 3Pe 5	3 − 5	1324	6.28E+01	6.35E+01	8.34E−01	5.36E+02
18 − 23	5Pe 5 − 3Pe 5	5 − 5	1403	6.29E+01	6.35E+01	1.64E+00	1.11E+03
19 − 23	5Pe 5 − 3Pe 5	7 − 5	1906	6.31E+01	6.35E+01	1.68E−01	3.37E+02
20 − 23	3De 5 − 3Pe 5	3 − 5	5282	6.34E+01	6.35E+01	4.73E−03	7.09E+01
1 − 24	3Pe 1 − 3Pe 5	5 − 1	14.33	0.00E+00	6.36E+01	2.81E+09	0.00E+00
3 − 24	3Pe 1 − 3Pe 5	3 − 1	14.51	8.15E−01	6.36E+01	0.00E+00	2.26E+05
4 − 24	1De 1 − 3Pe 5	5 − 1	14.68	1.54E+00	6.36E+01	1.66E+08	0.00E+00
17 − 24	5Pe 5 − 3Pe 5	3 − 1	1194	6.28E+01	6.36E+01	0.00E+00	1.47E+03
18 − 24	5Pe 5 − 3Pe 5	5 − 1	1258	6.29E+01	6.36E+01	2.12E+00	0.00E+00
20 − 24	3De 5 − 3Pe 5	3 − 1	3682	6.34E+01	6.36E+01	0.00E+00	7.96E+02
23 − 24	3Pe 5 − 3Pe 5	5 − 1	12157	6.35E+01	6.36E+01	1.79E−04	0.00E+00
6 − 25	3Po 2 − 3Po 4	5 − 5	16.54	8.41E+00	6.35E+01	1.69E+05	4.07E+01
7 − 25	3Po 2 − 3Po 4	3 − 5	16.71	8.97E+00	6.35E+01	2.29E+06	6.55E+01
8 − 25	3Po 2 − 3Po 4	1 − 5	16.84	9.39E+00	6.35E+01	2.33E+06	0.00E+00
9 − 25	1Po 2 − 3Po 4	3 − 5	17.54	1.16E+01	6.35E+01	1.36E+06	6.88E+02
11 − 25	5So 4 − 3Po 4	5 − 5	327.52	6.07E+01	6.35E+01	2.71E−01	2.22E+04
12 − 25	3So 4 − 3Po 4	3 − 5	344.92	6.09E+01	6.35E+01	3.07E−01	2.48E+03
13 − 25	3Do 4 − 3Po 4	5 − 5	546.65	6.18E+01	6.35E+01	6.06E+00	2.74E+04
14 − 25	3Do 4 − 3Po 4	3 − 5	549.62	6.19E+01	6.35E+01	1.13E+00	3.50E+03
15 − 25	3Do 4 − 3Po 4	7 − 5	657.96	6.21E+01	6.35E+01	9.36E+00	9.72E+03
E3 and M2, $N_{tr} = 29671$							
5 − 6	1Se 1 − 3Po 2	1 − 5	167.29	2.96E+00	8.41E+00	0.00E+00	5.33E+00
1 − 8	3Pe 1 − 3Po 2	5 − 1	97.09	0.00E+00	9.39E+00	0.00E+00	9.17E+01
4 − 8	1De 1 − 3Po 2	5 − 1	116.12	1.54E+00	9.39E+00	0.00E+00	3.56E+02
6 − 10	3Po 2 − 1Se 3	5 − 1	82.56	8.41E+00	1.94E+01	0.00E+00	3.56E+03
2 − 11	3Pe 1 − 5So 4	1 − 5	15.18	6.86E−01	6.07E+01	0.00E+00	7.45E+04
5 − 11	1Se 1 − 5So 4	1 − 5	15.77	2.96E+00	6.07E+01	0.00E+00	1.83E+02
10 − 11	1Se 3 − 5So 4	1 − 5	22.07	1.94E+01	6.07E+01	0.00E+00	3.60E+01
2 − 13	3Pe 1 − 3Do 4	1 − 5	14.90	6.86E−01	6.18E+01	0.00E+00	4.86E+04
5 − 13	1Se 1 − 3Do 4	1 − 5	15.48	2.96E+00	6.18E+01	0.00E+00	8.00E+04
10 − 13	1Se 3 − 3Do 4	1 − 5	21.49	1.94E+01	6.18E+01	0.00E+00	1.69E+02
2 − 15	3Pe 1 − 3Do 4	1 − 7	14.83	6.86E−01	6.21E+01	1.22E+05	0.00E+00
3 − 15	3Pe 1 − 3Do 4	3 − 7	14.86	8.15E−01	6.21E+01	2.94E+05	1.04E+05
5 − 15	1Se 1 − 3Do 4	1 − 7	15.40	2.96E+00	6.21E+01	2.39E+04	0.00E+00
10 − 15	1Se 3 − 3Do 4	1 − 7	21.35	1.94E+01	6.21E+01	7.84E−01	0.00E+00
2 − 16	3Pe 1 − 1Do 4	1 − 5	14.80	6.86E−01	6.23E+01	0.00E+00	8.86E+04
5 − 16	1Se 1 − 1Do 4	1 − 5	15.36	2.96E+00	6.23E+01	0.00E+00	1.43E+03
10 − 16	1Se 3 − 1Do 4	1 − 5	21.28	1.94E+01	6.23E+01	0.00E+00	3.87E+01
15 − 17	3Do 4 − 5Pe 5	7 − 3	1280	6.21E+01	6.28E+01	4.52E−09	5.65E−06
8 − 18	3Po 2 − 5Pe 5	1 − 5	17.03	9.39E+00	6.29E+01	0.00E+00	2.10E+01

(*continued on next page*)

Table 4 (*continued*)

$i-j$	$T_i\ C_i - T_j\ C_j$	$g_i - g_j$	λ (Å)	E_i (Ry)	E_j (Ry)	AE2	AM1
7 − 19	3Po 2 − 5Pe 5	3 − 7	16.85	8.97E+00	6.31E+01	5.03E+00	1.30E−01
8 − 19	3Po 2 − 5Pe 5	1 − 7	16.98	9.39E+00	6.31E+01	4.91E−02	0.00E+00
9 − 19	1Po 2 − 5Pe 5	3 − 7	17.69	1.16E+01	6.31E+01	2.18E+00	2.05E+00
12 − 19	3So 4 − 5Pe 5	3 − 7	418.27	6.09E+01	6.31E+01	9.46E−06	1.02E+00
14 − 19	3Do 4 − 5Pe 5	3 − 7	762.79	6.19E+01	6.31E+01	4.60E−07	4.97E−03
15 − 20	3Do 4 − 3De 5	7 − 3	742.56	6.21E+01	6.34E+01	1.47E−06	3.43E−03
1 − 21	3Pe 1 − 3Po 4	5 − 1	14.48	0.00E+00	6.29E+01	0.00E+00	5.02E+04
4 − 21	1De 1 − 3Po 4	5 − 1	14.84	1.54E+00	6.29E+01	0.00E+00	4.32E+05
18 − 21	5Pe 5 − 3Po 4	5 − 1	15036	6.29E+01	6.29E+01	0.00E+00	4.19E−09
19 − 21	5Pe 5 − 3Po 4	7 − 1	8235	6.31E+01	6.29E+01	4.53E−13	0.00E+00
19 − 22	5Pe 5 − 3Po 4	7 − 3	25777	6.31E+01	6.31E+01	7.62E−17	2.27E−10
8 − 23	3Po 2 − 3Pe 5	1 − 5	16.83	9.39E+00	6.35E+01	0.00E+00	4.41E+01
21 − 23	3Po 4 − 3Pe 5	1 − 5	1547	6.29E+01	6.35E+01	0.00E+00	6.45E−05
6 − 24	3Po 2 − 3Pe 5	5 − 1	16.51	8.41E+00	6.36E+01	0.00E+00	1.65E+00
11 − 24	5So 4 − 3Pe 5	5 − 1	317.29	6.07E+01	6.36E+01	0.00E+00	7.85E+00
13 − 24	3Do 4 − 3Pe 5	5 − 1	518.74	6.18E+01	6.36E+01	0.00E+00	8.15E−06
15 − 24	3Do 4 − 3Pe 5	7 − 1	617.94	6.21E+01	6.36E+01	1.71E−05	0.00E+00
16 − 24	1Do 4 − 3Pe 5	5 − 1	685.84	6.23E+01	6.36E+01	0.00E+00	1.62E−02
2 − 25	3Pe 1 − 3Po 4	1 − 5	14.50	6.86E−01	6.35E+01	0.00E+00	1.00E+03
5 − 25	1Se 1 − 3Po 4	1 − 5	15.05	2.96E+00	6.35E+01	0.00E+00	1.44E+05
10 − 25	1Se 3 − 3Po 4	1 − 5	20.68	1.94E+01	6.35E+01	0.00E+00	6.28E+02
24 − 25	3Pe 5 − 3Po 4	1 − 5	10161	6.36E+01	6.35E+01	0.00E+00	3.44E−12
15 − 26	3Do 4 − 3Pe 5	7 − 3	474.14	6.21E+01	6.41E+01	6.04E−04	1.29E−01
19 − 27	5Pe 5 − 1Po 4	7 − 3	1517	6.31E+01	6.37E+01	2.93E−09	2.22E−05
8 − 28	3Po 2 − 3Fe 5	1 − 5	16.61	9.39E+00	6.43E+01	0.00E+00	9.82E+02
21 − 28	3Po 4 − 3Fe 5	1 − 5	691.76	6.29E+01	6.43E+01	0.00E+00	8.29E−03
8 − 29	3Po 2 − 3De 5	1 − 5	16.56	9.39E+00	6.44E+01	0.00E+00	1.47E+03
21 − 29	3Po 4 − 3De 5	1 − 5	616.69	6.29E+01	6.44E+01	0.00E+00	1.51E−04
7 − 30	3Po 2 − 3Fe 5	3 − 7	16.42	8.97E+00	6.45E+01	1.49E+02	4.42E+02
8 − 30	3Po 2 − 3Fe 5	1 − 7	16.55	9.39E+00	6.45E+01	2.22E+01	0.00E+00
9 − 30	1Po 2 − 3Fe 5	3 − 7	17.22	1.16E+01	6.45E+01	7.65E−01	2.24E+02
12 − 30	3So 4 − 3Fe 5	3 − 7	254.30	6.09E+01	6.45E+01	2.05E−03	9.41E−01
14 − 30	3Do 4 − 3Fe 5	3 − 7	350.56	6.19E+01	6.45E+01	2.19E−03	7.76E−01
21 − 30	3Po 4 − 3Fe 5	1 − 7	601.32	6.29E+01	6.45E+01	7.67E−06	0.00E+00
22 − 30	3Po 4 − 3Fe 5	3 − 7	665.42	6.31E+01	6.45E+01	4.35E−06	6.10E−03
27 − 30	1Po 4 − 3Fe 5	3 − 7	1132	6.37E+01	6.45E+01	1.56E−08	1.63E−03
15 − 31	3Do 4 − 1Pe 5	7 − 3	375.39	6.21E+01	6.46E+01	9.70E−04	2.19E+00
7 − 32	3Po 2 − 1Fe 5	3 − 7	16.39	8.97E+00	6.46E+01	8.49E+02	4.32E+02
8 − 32	3Po 2 − 1Fe 5	1 − 7	16.51	9.39E+00	6.46E+01	6.60E+02	0.00E+00
9 − 32	1Po 2 − 1Fe 5	3 − 7	17.19	1.16E+01	6.46E+01	5.65E+02	3.79E+03
12 − 32	3So 4 − 1Fe 5	3 − 7	246.37	6.09E+01	6.46E+01	2.15E−03	1.45E−04
14 − 32	3Do 4 − 1Fe 5	3 − 7	335.67	6.19E+01	6.46E+01	3.07E−03	8.45E−01
21 − 32	3Po 4 − 1Fe 5	1 − 7	558.80	6.29E+01	6.46E+01	7.31E−06	0.00E+00
22 − 32	3Po 4 − 1Fe 5	3 − 7	613.75	6.31E+01	6.46E+01	2.64E−06	9.78E−03
27 − 32	1Po 4 − 1Fe 5	3 − 7	990.76	6.37E+01	6.46E+01	6.02E−08	4.95E−05
7 − 33	3Po 2 − 3De 5	3 − 7	16.34	8.97E+00	6.47E+01	1.05E+03	6.92E+02
8 − 33	3Po 2 − 3De 5	1 − 7	16.46	9.39E+00	6.47E+01	6.94E+02	0.00E+00
9 − 33	1Po 2 − 3De 5	3 − 7	17.13	1.16E+01	6.47E+01	3.86E+02	3.71E+02
12 − 33	3So 4 − 3De 5	3 − 7	235.24	6.09E+01	6.47E+01	1.19E−03	1.55E−01
14 − 33	3Do 4 − 3De 5	3 − 7	315.34	6.19E+01	6.47E+01	4.90E−03	1.74E+00
21 − 33	3Po 4 − 3De 5	1 − 7	504.65	6.29E+01	6.47E+01	4.62E−06	0.00E+00
22 − 33	3Po 4 − 3De 5	3 − 7	549.04	6.31E+01	6.47E+01	7.88E−06	9.84E−03
27 − 33	1Po 4 − 3De 5	3 − 7	832.40	6.37E+01	6.47E+01	1.97E−06	1.68E−03
6 − 34	3Po 2 − 3Fe 5	5 − 9	16.16	8.41E+00	6.48E+01	1.01E+03	6.49E+01
7 − 34	3Po 2 − 3Fe 5	3 − 9	16.33	8.97E+00	6.48E+01	5.17E+02	0.00E+00
9 − 34	1Po 2 − 3Fe 5	3 − 9	17.12	1.16E+01	6.48E+01	1.49E+01	0.00E+00
11 − 34	5So 4 − 3Fe 5	5 − 9	224.66	6.07E+01	6.48E+01	7.53E−04	3.19E−01
12 − 34	3So 4 − 3Fe 5	3 − 9	232.71	6.09E+01	6.48E+01	2.41E−04	0.00E+00
13 − 34	3Do 4 − 3Fe 5	5 − 9	309.87	6.18E+01	6.48E+01	8.68E−03	3.93E+00
14 − 34	3Do 4 − 3Fe 5	3 − 9	310.82	6.19E+01	6.48E+01	1.23E−03	0.00E+00
16 − 34	1Do 4 − 3Fe 5	5 − 9	362.65	6.23E+01	6.48E+01	9.28E−04	4.32E−01
22 − 34	3Po 4 − 3Fe 5	3 − 9	535.47	6.31E+01	6.48E+01	1.29E−06	0.00E+00
25 − 34	3Po 4 − 3Fe 5	5 − 9	715.38	6.35E+01	6.48E+01	5.31E−06	2.19E−02
27 − 34	1Po 4 − 3Fe 5	3 − 9	801.59	6.37E+01	6.48E+01	3.59E−07	0.00E+00
6 − 35	3Po 2 − 3Pe 5	5 − 1	16.10	8.41E+00	6.50E+01	0.00E+00	6.69E−01
11 − 35	5So 4 − 3Pe 5	5 − 1	213.06	6.07E+01	6.50E+01	0.00E+00	1.39E+00
13 − 35	3Do 4 − 3Pe 5	5 − 1	288.22	6.18E+01	6.50E+01	0.00E+00	4.99E−01
15 − 35	3Do 4 − 3Pe 5	7 − 1	316.44	6.21E+01	6.50E+01	2.50E−02	0.00E+00
16 − 35	1Do 4 − 3Pe 5	5 − 1	333.34	6.23E+01	6.50E+01	0.00E+00	4.75E+00
25 − 35	3Po 4 − 3Pe 5	5 − 1	609.66	6.35E+01	6.50E+01	0.00E+00	4.45E−02
15 − 36	3Do 4 − 3Pe 5	7 − 3	296.28	6.21E+01	6.52E+01	1.55E−02	4.25E−01
8 − 37	3Po 2 − 3Pe 5	1 − 5	16.29	9.39E+00	6.53E+01	0.00E+00	3.10E+02
21 − 37	3Po 4 − 3Pe 5	1 − 5	380.57	6.29E+01	6.53E+01	0.00E+00	5.24E−04
15 − 38	3Do 4 − 1Pe 5	7 − 3	268.34	6.21E+01	6.55E+01	3.13E−03	5.75E−01
8 − 39	3Po 2 − 1De 5	1 − 5	16.20	9.39E+00	6.56E+01	0.00E+00	1.09E+01

(*continued on next page*)

Table 4 (*continued*)

$i-j$	$T_i\ C_i - T_j\ C_j$	$g_i - g_j$	λ (Å)	E_i (Ry)	E_j (Ry)	AE2	AM1
21 — 39	3Po 4 — 1De 5	1 — 5	339.19	6.29E+01	6.56E+01	0.00E+00	4.45E−01
1 — 40	3Pe 1 — 5Do 6	5 — 1	13.88	0.00E+00	6.57E+01	0.00E+00	1.20E+06
4 — 40	1De 1 — 5Do 6	5 — 1	14.21	1.54E+00	6.57E+01	0.00E+00	3.21E+02
18 — 40	5Pe 5 — 5Do 6	5 — 1	326.29	6.29E+01	6.57E+01	0.00E+00	4.05E+00
19 — 40	5Pe 5 — 5Do 6	7 — 1	347.60	6.31E+01	6.57E+01	1.09E−02	0.00E+00
23 — 40	3Pe 5 — 5Do 6	5 — 1	425.13	6.35E+01	6.57E+01	0.00E+00	1.05E−01
28 — 40	3Fe 5 — 5Do 6	5 — 1	644.05	6.43E+01	6.57E+01	0.00E+00	3.71E−03
29 — 40	3De 5 — 5Do 6	5 — 1	726.37	6.44E+01	6.57E+01	0.00E+00	3.38E−04
30 — 40	3Fe 5 — 5Do 6	7 — 1	748.93	6.45E+01	6.57E+01	1.93E−06	0.00E+00
32 — 40	1Fe 5 — 5Do 6	7 — 1	827.33	6.46E+01	6.57E+01	7.38E−07	0.00E+00
33 — 40	3De 5 — 5Do 6	7 — 1	983.60	6.47E+01	6.57E+01	2.36E−08	0.00E+00
37 — 40	3Pe 5 — 5Do 6	5 — 1	2697	6.53E+01	6.57E+01	0.00E+00	5.84E−06
39 — 40	1De 5 — 5Do 6	5 — 1	19991	6.56E+01	6.57E+01	0.00E+00	2.43E−10
19 — 41	5Pe 5 — 5Do 6	7 — 3	346.73	6.31E+01	6.57E+01	1.01E−02	5.13E−01
30 — 41	3Fe 5 — 5Do 6	7 — 3	744.87	6.45E+01	6.57E+01	1.03E−06	2.06E−04
32 — 41	1Fe 5 — 5Do 6	7 — 3	822.38	6.46E+01	6.57E+01	4.90E−07	2.67E−04
33 — 41	3De 5 — 5Do 6	7 — 3	976.61	6.47E+01	6.57E+01	2.89E−08	5.04E−06
34 — 41	3Fe 5 — 5Do 6	9 — 3	1022	6.48E+01	6.57E+01	3.01E−09	0.00E+00
2 — 42	3Pe 1 — 5Do 6	1 — 5	14.02	6.86E−01	6.57E+01	0.00E+00	2.17E+06
5 — 42	1Se 1 — 5Do 6	1 — 5	14.53	2.96E+00	6.57E+01	0.00E+00	7.57E+04
10 — 42	1Se 3 — 5Do 6	1 — 5	19.71	1.94E+01	6.57E+01	0.00E+00	4.05E+02
24 — 42	3Pe 5 — 5Do 6	1 — 5	438.86	6.36E+01	6.57E+01	0.00E+00	8.69E−02
34 — 42	3Fe 5 — 5Do 6	9 — 5	1021	6.48E+01	6.57E+01	1.16E−08	2.97E−06
35 — 42	3Pe 5 — 5Do 6	1 — 5	1357	6.50E+01	6.57E+01	0.00E+00	1.44E−06
2 — 43	3Pe 1 — 5Do 6	1 — 7	14.02	6.86E−01	6.57E+01	1.01E+03	0.00E+00
3 — 43	3Pe 1 — 5Do 6	3 — 7	14.05	8.15E−01	6.57E+01	2.95E+03	3.19E+06
5 — 43	1Se 1 — 5Do 6	1 — 7	14.53	2.96E+00	6.57E+01	1.88E+03	0.00E+00
10 — 43	1Se 3 — 5Do 6	1 — 7	19.71	1.94E+01	6.57E+01	1.98E+00	0.00E+00
17 — 43	5Pe 5 — 5Do 6	3 — 7	320.28	6.28E+01	6.57E+01	1.62E−03	1.33E+00
20 — 43	3De 5 — 5Do 6	3 — 7	391.14	6.34E+01	6.57E+01	1.91E−04	6.40E−01
24 — 43	3Pe 5 — 5Do 6	1 — 7	437.63	6.36E+01	6.57E+01	1.84E−05	0.00E+00
26 — 43	3Pe 5 — 5Do 6	3 — 7	557.34	6.41E+01	6.57E+01	4.80E−06	8.39E−05
31 — 43	1Pe 5 — 5Do 6	3 — 7	806.83	6.46E+01	6.57E+01	1.44E−08	2.53E−03
35 — 43	3Pe 5 — 5Do 6	1 — 7	1345	6.50E+01	6.57E+01	1.05E−11	0.00E+00