A&A 585, A121 (2016)
DOI: 10.1051/0004-6361/201526983

Astronomy & Astrophysics

Radiative rates for forbidden M1 and E2 transitions of astrophysical interest in doubly ionized iron-peak elements

V. Fivet[1], P. Quinet[1,2], and M. A. Bautista[3]

[1] Physique Atomique et Astrophysique, Université de Mons – UMONS, 7000 Mons, Belgium
e-mail: vanessa.fivet@gmail.com
[2] IPNAS, Université de Liège, 4000 Liège, Belgium
[3] Department of Physics, Western Michigan University, Kalamazoo, MI 49008, USA

Received 17 July 2015 / Accepted 11 September 2015

ABSTRACT

Aims. Accurate and reliable atomic data for lowly ionized Fe-peak species (Sc, Ti, V, Cr, Mn, Fe, Co, and Ni) are of paramount importance for analyzing the high-resolution astrophysical spectra currently available. The third spectra of several iron group elements have been observed in different galactic sources, such as Herbig-Haro objects in the Orion Nebula and stars like Eta Carinae. However, forbidden M1 and E2 transitions between low-lying metastable levels of doubly charged iron-peak ions have been investigated very little so far, and radiative rates for those lines remain sparse or nonexistent. We attempt to fill that gap and provide transition probabilities for the most important forbidden lines of all doubly ionized iron-peak elements.

Methods. We carried out a systematic study of the electronic structure of doubly ionized Fe-peak species. The magnetic dipole (M1) and electric quadrupole (E2) transition probabilities were computed using the pseudo-relativistic Hartree-Fock (HFR) code of Cowan and the central Thomas-Fermi-Dirac-Amaldi potential approximation implemented in AUTOSTRUCTURE. This multiplatform approach allowed for consistency checks and intercomparison and has proven very useful in many previous works for estimating the uncertainties affecting the radiative data.

Results. We present transition probabilities for the M1 and E2 forbidden lines depopulating the metastable even levels belonging to the $3d^k$ and $3d^{k-1}4s$ configurations in Sc III ($k = 1$), Ti III ($k = 2$), V III ($k = 3$), Cr III ($k = 4$), Mn III ($k = 5$), Fe III ($k = 6$), Co III ($k = 7$), and Ni III ($k = 8$).

Key words. atomic data – atomic processes

1. Introduction

In relation to their high cosmic abundance, accurate and reliable atomic data for the iron-peak elements are crucial in astrophysics. The advent of high-resolution astrophysical spectroscopy has led to observing these elements in low-ionization stages in various astronomical objects. Emission lines of doubly ionized Fe-peak species have been observed in several nebular environments. Recent *Hubble* Space Telescope/Space Telescope Imaging Spectograph (HST/STIS) observations from the Weigelt blobs of Eta Carinae (η *Car*) have revealed several forbidden lines of Fe III and Ni III (Zethson et al. 2012). Lines of doubly ionized species have also been detected in various galactic sources, such as Herbig-Haro objects in the Orion Nebula (Mesa-Delgado et al. 2009) and extragalactic objects, including active galactic nuclei (Vestergaard & Wilkes 2001). Reliable radiative data are therefore essential for interpreting these observations and obtaining a diagnostic of the physical conditions in the astrophysical plasma. However, our knowledge of doubly charged iron-peak ions is still incomplete, in particular when it comes to forbidden transitions between the low-lying metastable states.

Atomic data calculations for iron-peak elements are very challenging owing to the complexity of these systems due to the open $3d$ subshell. In particular, transition probabilities for magnetic dipole (M1) and electric quadrupole (E2) lines are very difficult to compute due to their extreme sensitivity to configuration interaction and level mixing. Forbidden radiative rates were only available for selected transitions in five ions of the doubly ionized Fe peak. As the simplest atomic structure considered in this work, doubly ionized scandium has been investigated extensively by Ali & Kim (1988) using the multiconfigurational Dirac-Fock (MCDF) method, by Zeippen (1990) with the SUPERSTRUCTURE code, and more recently by Sahoo et al. (2008) and Nandy et al. (2011), both using an all-order, perturbative, relativistic many-body approach, i.e. the relativistic coupled-cluster (RCC) method.

Biémont et al. (1992) published a list of ab initio transition probabilities of M1 and E2 transitions within the $3d^2$ configuration of Ti III using the Relativistic Hatree-Fock (HFR) approach and the SUPERSTRUCTURE code. Raassen & Uylings (1997) also performed fully-relativistic multiconfiguration Dirac-Fock (MCDF) calculations for all the metastable levels of this ion. Irimia (2007) published theoretical lifetimes for the 33 levels belonging to the low-lying metastable terms of V III using the multiconfiguration Hartree-Fock (MCHF) method with Breit-Pauli (BP) corrections to a non-relativistic Hamiltonian. Selected transition probabilities were also presented in this paper. Radiative rates have been computed for the astrophysically important Fe III ion by Quinet (1996) using the HFR approach, by Deb & Hibbert (2009) with the CIV3 code, and more recently by Bautista et al. (2010) using the same theoretical methods as

Table 1. Scaling parameters of the Thomas-Fermi-Dirac-Amaldi potential for all the doubly-ionized iron-peak ions considered in this work.

λ_{nl}	Sc III	Ti III	V III	Cr III	Mn III	Fe III	Co III	Ni III
1s, 2s, 2p, 3s and 3p	1.1012	1.0980	1.0867	1.0729	1.0607	1.0350	1.0604	1.0107
3d	1.0908	1.1062	1.1019	1.0912	1.0814	1.0562	1.0190	1.0300
4s	1.1221	1.1115	1.0818	1.0688	1.0533	1.0629	1.1045	1.0342
4p	1.0995	1.1070	1.1040	1.0933	1.0755	1.0511	1.0651	1.0273
4d	1.0905	1.0603	1.1253	1.1084	1.1828	1.0986	1.1420	1.0948
5s	1.1483	1.2782	1.7940	1.7839	1.7728	1.0517	1.6776	1.0384

those presented in this work. Transition rates have also been published for forbidden lines in the $3d^7$ ground configuration of Co III by Hansen et al. (1984) using a parametric approach.

When computing forbidden radiative rates, it is common to assess the quality of the results by comparing them with a few metastable lifetime measurements performed with a storage ring (see, e.g., Lundin et al. 2007). When experimental data are missing, information on the accuracy of the radiative rates can be obtained by comparing calculations using different independent theoretical approaches. The agreement observed between the sets of results allows us to perform consistency checks and estimate the uncertainties affecting the data. This is the approach adopted in the present work for computing E2 and M1 transition probabilities where we compare the results of two different theoretical methods with each other, together with previous results when available. Since the odd levels can be de-excited by E1 transitions (several orders of magnitude stronger than E2 and M1 transitions) to the even states, odd-odd forbidden transitions are of little or no interest because they are very unlikely to be observed in an experimental and/or astrophysical spectrum. Therefore, we chose to limit our work to the even metastable states.

2. Theoretical models

The first theoretical approach used in this work is the pseudo-relativistic Hartree-Fock (HFR) method implemented in Cowan's chain of computer codes (Cowan 1981). In our calculations, configuration interactions were considered by including the configurations of the type $3d^k$, $3d^{k-1}4s$, $3d^{k-1}5s$, $3d^{k-1}4d$, $3d^{k-2}4s^2$, $3d^{k-2}4p^2$, $3d^{k-2}4d^2$, $3d^{k-2}4s4d$, $3d^{k-2}4s5s$, $3s3p^63d^{k+1}$, $3s3p^63d^k4s$, and $3s3p^63d^{k-1}4s^2$ with $k = 1$ (Sc III), $k = 2$ (Ti III), $k = 3$ (V III), $k = 4$ (Cr III), $k = 5$ (Mn III), $k = 6$ (Fe III), $k = 7$ (Co III), and $k = 8$ (Ni III). This method was then combined with a least-squares optimization routine that minimizes the differences between the calculated and available experimental energy levels belonging to the low-lying even configurations $3d^k$ and $3d^{k-1}4s$. For Sc III, Ti III, V III, Mn III, Co III, and Ni III, the experimental data used in this semi-empirical process were taken from the NIST compilation (Kramida et al. 2013), which is exclusively based on the previous compilation by Sugar & Corliss (1985).

For Cr III and Fe III, we used more recent data from Ekberg (1997) and Ekberg (1993), respectively. We also calculated radiative transition rates for M1 and E2 forbidden transitions using the atomic structure code AUTOSTRUCTURE (Badnell 1988). This code is based on the program SUPERSTRUCTURE originally developed by Eissner et al. (1974). In this approach the wavefunctions are written as a configuration interaction expansion of the type

$$\psi_i = \sum_j c_{ji}\phi_i, \tag{1}$$

where the coefficients c_{ji} are chosen so as to diagonalize $\langle\psi_j|\,H\,|\psi_i\rangle$, where H is the Breit-Pauli Hamiltonian and the basic functions ϕ_j are constructed from one-electron orbitals generated using the Thomas-Fermi-Dirac-Amaldi model potential (Eissner & Nussbaumer 1969).

The Breit-Pauli Hamiltonian for an N-electron system is given by

$$H_{\rm bp} = H_{\rm nr} + H_{\rm 1b} + H_{\rm 2b} \tag{2}$$

where $H_{\rm nr}$ is the usual non-relativistic Hamiltonian, and $H_{\rm 1b}$ and $H_{\rm 2b}$ are the one-body and two-body operators. The one-body relativistic operator

$$H_{\rm 1b} = \sum_{n=1}^{N} f_n(\text{mass}) + f_n(d) + f_n(\text{SO}) \tag{3}$$

represents the spin-orbit interaction $f_n(\text{SO})$, the non-fine structure mass variation $f_n(mass)$, and the one-body Darwin $f_n(d)$ corrections. The two-body corrections

$$H_{\rm 2b} = \sum_{n>m} g_{nm}(\text{SO}) + g_{nm}(\text{SS}) + g_{nm}(\text{CSS}) + g_{nm}(d) + g_{nm}(\text{OO}), \tag{4}$$

usually referred to as the Breit interaction, include, on one hand, the fine-structure terms $g_{nm}(\text{SO})$ (spin-other-orbit and mutual spin-orbit) and $g_{nm}(\text{SS})$ (spin-spin). On the other hand, they inclue the non-fine structure terms: $g_{nm}(\text{CSS})$ (spin-spin contact), $g_{nm}(d)$ (Darwin), and $g_{nm}(\text{OO})$ (orbit-orbit). The scaling parameters $\lambda_{\rm nl}$ for each nl orbital are optimized by minimizing a weighted sum of the energies for all the metastable terms belonging to the $3d^k$ and $3d^{k-1}4s$ configurations. Instead of optimizing each scaling parameter individually, we chose to optimize the core orbitals 1s, 2s, 2p, 3s, and 3p together to simulate the effect of missing open-core configurations in our model. Table 1 gives the values of the $\lambda_{\rm nl}$ for all the ions considered in this work.

The set of configurations used in the AUTOSTRUCTURE model is the same as the one used for the HFR calculations with the addition of $3d^{k-1}4p$ and $3d^{k-2}4s4p$ to ensure a better representation of the 4p orbital. Semi-empirical corrections take the form of term energy corrections (TEC). By considering the relativistic wavefunction,ψ_i^r in a perturbation expansion of the non-relativistic functions ψ_i^{nr}

$$\psi_i^r = \psi_i^{\rm nr} + \sum_{j\neq i}\psi_i^{\rm nr} + \frac{\langle\psi_j^{\rm nr}|\,H_{\rm 1b} + H_{\rm 2b}\,|\psi_i^{\rm nr}\rangle}{E_i^{\rm nr} - E_j^{\rm nr}} \tag{5}$$

where $H_{\rm 1b}$ and $H_{\rm 2b}$ are, respectively, the one- and two-body parts of both fine-structure and non-fine-structure Hamiltonians. A modified non-relativistic Hamiltonian is constructed with improved estimates of the differences $E_i^{\rm nr} - E_j^{\rm nr}$ so as to adjust the centers of gravity of the spectroscopic terms to the available experimental values. Term energy corrections (TEC) have been applied to all the metastable terms considered in this work. Tables A.1 to A.8 compare, respectively, the level energies (in cm^{-1}), which were obtained before applying the TEC, for all the metastable levels of Sc III, Ti III, VIII, Cr III, Mn III, Fe III, Co III, and Ni III along with the corresponding TEC. The average TEC along the sequence are about 10% or less of the calculated energies. For the manganese ion, we were not able to apply TEC to all the metastable terms because this resulted in a switch in the energies and an incorrect representation of the ground state. Therefore, we kept the ab initio term energies for the $3d^5$ c ^{2}D1, $3d^4(^3D)4s$ c ^{4}D, and $3d^4(^1S2)4s$ b ^{2}S.

3. Forbidden M1 and E2 transition probabilities

In this section, we discuss the radiative data calculations for each ion considered in this work. Transition probabilities can be found in Tables A.9 to A.17 for all the forbidden lines depopulating the metastable levels belonging to the $3d^k$ and the $3d^{k-1}4s$ configurations. The lack of space means that only the total A-values (M1+E2) contributing more than 10% to the total de-excitation of each level are presented here. The weakest transition probabilities are available upon request to the authors.

3.1. Scandium (Z = 21)

Only three metastable levels arise from 3d and 4s configurations in Sc III. This gives three spectral lines for which we computed the magnetic dipole (M1) and electric quadrupole (E2) contributions. In Table A.9, our HFR and AUTOSTRUCTURE results are compared to the calculations previously published by Ali & Kim (1988), Zeippen (1990), Sahoo et al. (2008), and Nandy et al. (2011). As seen from this table, the agreement between all sets of data is excellent (within 10%).

3.2. Titanium (Z = 22)

In Table A.10 and Fig. 1, we compare our present HFR transition probabilities for M1 and E2 lines involving the levels of $3d^2$ and 3d4s configurations in Ti III with our AUTOSTRUCTURE results and the previous data published by Biémont et al. (1992) and Raassen & Uylings (1997). Very good agreement (within 5%) is observed between our HFR radiative rates and the MCDF results from Raassen & Uylings (1997). We also note that our present AUTOSTRUCTURE calculations agree within 15% with both our HFR and Raassen & Uylings' results for transitions with A values greater than 10^{-2} s^{-1}, such as $3d^2$ $^3F_3$–$3d^2$ $^1G_4$ (λ = 703.55 nm), $3d^2$ $^3F_4$–$3d^2$ $^1G_4$ (λ = 715.33 nm), $3d^2$ $^3F_2$–$3d^2$ $^1D_2$ (λ = 1180.65 nm), and $3d^2$ $^3F_3$–$3d^2$ $^1D_2$ (λ = 1206.31 nm). Despite a systematic discrepancy between the SUPERSTRUCTURE transition probabilities of Biémont et al. (1992) and all the other sets of results, the overall agreement is still reasonable (within 25%).

3.3. Vanadium (Z = 23)

Computed transition probabilities as obtained in the present work for forbidden lines arising from $3d^3$ and $3d^24s$ configurations in V III are reported in Table A.11 and compared in Fig. 2. We can see that our HFR and AUTOSTRUCTURE data are in excellent agreement (within 5%) for the strongest transitions, while larger discrepancies are observed for some weak lines, in particular for those depopulating the $3d^3$ ^{2}G, ^{2}P, ^{2}D2, and ^{2}H terms. When comparing the lifetimes of the eight levels corresponding to the last terms (see Table A.12), we find an average dispersion of about 30% between our two sets of results. This disagreement is even greater (up to several orders of magnitude) when comparing our new theoretical data with those obtained by Irimia (2007) using a multiconfiguration Hartree-Fock approach that includes Breit-Pauli corrections. Such weak transitions are extremely sensitive and dependent upon the physical model and the configuration expansion considered in the calculations, but in view of the satisfactory agreement between our HFR and AUTOSTRUCTURE results, we can reasonably expect the A values obtained in the present work for those lines to be more reliable than the data published by Irimia (2007).

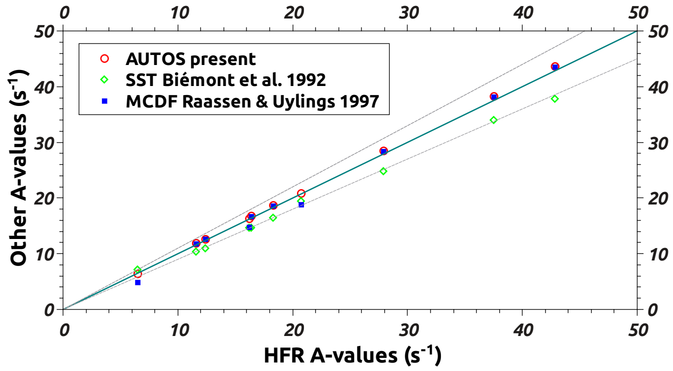

Fig. 1. Comparison between our present HFR and AUTOS calculations with the previous results of Biémont et al. (1992) and Raassen & Uylings (1997) for forbidden transitions in Ti III. The straight line of equality has been drawn, and the two dashed lines represent a 10% deviation from equality.

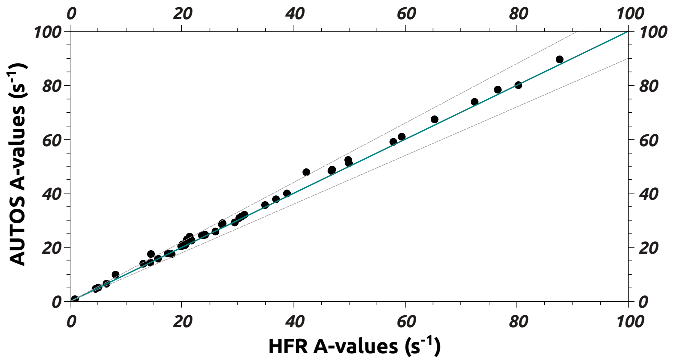

Fig. 2. Comparison between our present HFR and AUTOS calculations for V III. The straight line of equality has been drawn, and the two dashed lines represent a 10% deviation from equality.

3.4. Chromium (Z = 24)

The two lowest configurations of doubly ionized chromium (Cr III) are $3d^4$ and $3d^34s$. Transition probabilities obtained in the present work for forbidden lines involving levels of these last configurations are reported in Table A.13 and compared in Fig. 3. It is clearly seen that both our HFR and AUTOSTRUCTURE models give results in very good agreement (within 15–20%), if we except the E2 transition $3d^4$ $^1G_4$–$3d^34s$ $^1D_2$ located at 201.41 nm. For this transition the A value computed with AUTOSTRUCTURE (A = 1.29×10^2 s^{-1}) is 65% higher than the result obtained with HFR (A = 7.78×10^1 s^{-1}). This discrepancy could be explained by the sensitive mixing of the lower level at 25 137.91 cm^{-1} composed of 64% $3d^4$ a $^1G_4$ and 35% $3d^4$ b $^1G_4$.

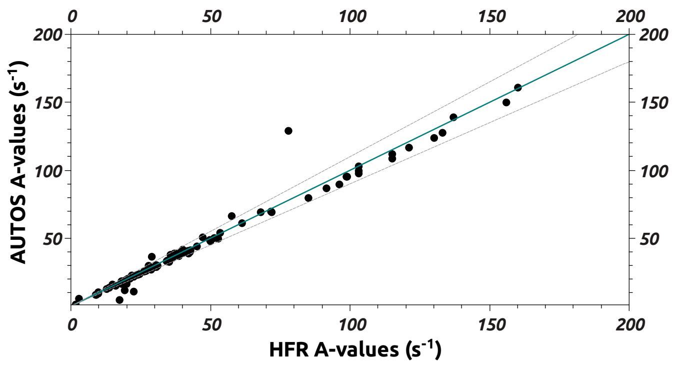

Fig. 3. Comparison between our present HFR and AUTOS calculations in Cr III. The straight line of equality has been drawn, and the two dashed lines represent a 10% deviation from equality.

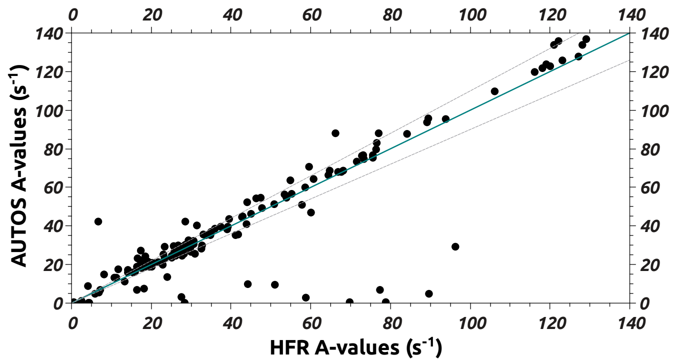

Fig. 4. Comparison between our present HFR and AUTOS calculations in Mn III. The straight line of equality has been drawn, and the two dashed lines represent a 10% deviation from equality.

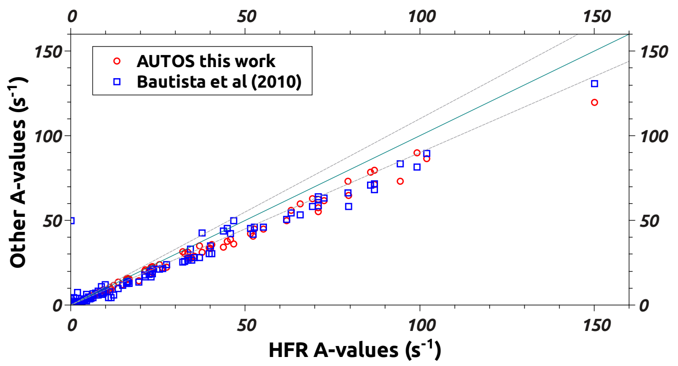

Fig. 5. Comparison between our present HFR and AUTOS calculations in Fe III. The straight line of equality has been drawn, and the two dashed lines represent a 10% deviation from equality.

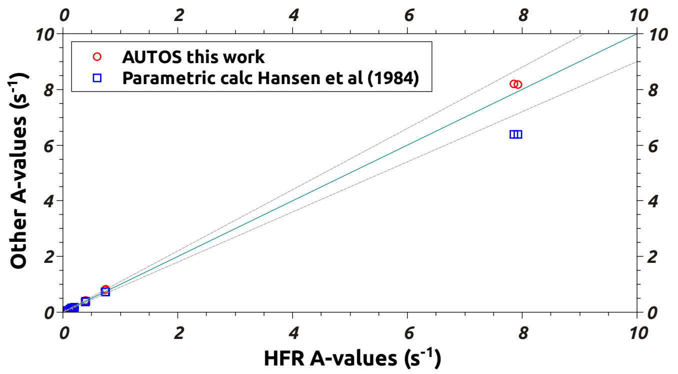

Fig. 6. Comparison between our present HFR and AUTOS calculations in Co III and the results of Hansen et al. (1984). The straight line of equality has been drawn, and the two dashed lines represent a 10% deviation from equality.

3.5. Manganese (Z = 25)

Mn III is characterized by the ground configuration with a half-filled 3d subshell ($3d^5$), which is well known to be rather complicated to deal with theoretically. This complexity affects the calculations of forbidden transition probabilities performed in the present work and reported in Table A.14. Although an overall agreement of 20% is observed when comparing the results obtained with the HFR and AUTOSTRUCTURE approaches for the strongest lines, some rather large discrepancies appear for transitions depopulating highly excited levels. This is illustrated in Fig. 4, which shows a slightly wider scatter in the results than observed in the other ions Sc III, Ti III, V III, and Cr III. This seems to indicate that the A values obtained in this work for forbidden lines in Mn III are probably affected by larger uncertainties in the range of 20–30% for the strongest transitions.

3.6. Iron (Z = 26)

Extensive calculations were carried out recently for Fe III forbidden transitions by Bautista et al. (2010) using similar theoretical approaches to those employed in this work. If their HFR model was the same as the one considered in the present study, their AUTOSTRUCTURE multiconfiguration expansions would include a total of 40 configurations. Figure 5 compares our present HFR and AUTOSTRUCTURE results to the data of Bautista et al. (2010). Although a slight systematic discrepancy is observed with the HFR A values (15 to 20%), the agreement between the two different AUTOSTRUCTURE calculations is really good (often within a few percentage points), indicating that our configuration expansion is sufficient for an accurate calculation of the A- values. The new A values obtained in this work are compared in Table A.15.

3.7. Cobalt (Z = 27)

In Fig. 6, we compare our HFR and AUTOSTRUCTURE results with the calculations published by Hansen et al. (1984) for forbidden lines in Co III. Only A values that correspond to transitions within the $3d^7$ ground configuration are shown in this figure since Hansen et al. (1984) only used a single-configuration model in their computations. Overall good agreement is observed between the three sets of data, but in view of the much larger multiconfiguration bases used in our models and the very good agreement (within 10%) reached between Co III forbidden transition probabilities obtained with these two models, the new data reported in Table A.16 are expected to be more accurate than those of Hansen et al. (1984).

3.8. Nickel (Z = 28)

Transition probabilities for forbidden lines involving the $3d^8$ and $3d^74s$ configurations of Ni III are listed in Table A.17, while a comparison between HFR and AUTOSTRUCTURE results is illustrated in Fig. 7. Even if the AUTOSTRUCTURE A values seem to be systematically smaller than the HFR ones, we observe an overall satisfactory agreement on the order of 20%

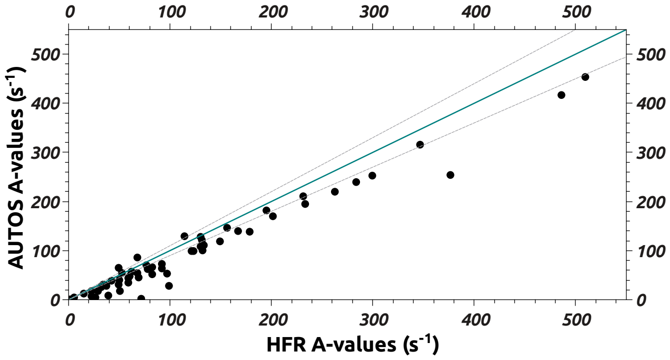

Fig. 7. Comparison between our present HFR and AUTOS calculations in Ni III. The straight line of equality has been drawn, and the two dashed lines represent a 10% deviation from equality.

for the most intense transitions ($A \geq 10^2$ s^{-1}) if we except the E2 line at 127.71 nm ($3d^8$ $^3F_4$–$3d^74s$ $^3P_2$), for which the HFR approach gives a transition probability ($A = 3.76 \times 10^2$ s^{-1}) that is a factor of 1.50 greater than the AUTOSTRUCTURE result ($A = 2.55 \times 10^2$ s^{-1}).

We noticed a slight systematic shift in the A values for several ions considered in this work (Mn III, Fe III, Co III, and Ni III) and found the AUTOSTRUCTURE calculations to be very sensitive to the configuration expansion, to the optimization procedure of the scaling parameters λ_{nl}, and to the TEC applied to the metastable states. To assess the sensitivity of our AUTOSTRUCTURE results to the optimization of the scaling parameters, we performed a second calculation in Ni III where we optimized the λ_{nl} on the terms belonging to the $3d^8$, $3d^74s$ and $3d^74p$ configurations instead of limiting ourselves to the terms of $3d^8$ and $3d^74s$ metastable configurations, While the scaling parameters for the 4s and 4p orbitals only varied by about 10%, we observed a general shift in the A values of about 15% between the two AUTOSTRUCTURE calculations, bringing the disagreement between the HFR and the new AUTOSTRUCTURE calculations to 30% instead of 18%. Therefore, the HFR results are expected to carry a much smaller uncertainty than the AUTOSTRUCTURE A values.

4. Conclusions

Detailed and systematic calculations were carried out for magnetic dipole and electric quadrupole transitions in doubly-ionized iron peak elements from Sc III to Ni III. Using two independent methods based on the pseudo-relativistic Hartree-Fock (HFR) approach and the Thomas-Fermi-Dirac-Amaldi potential approximation implemented in the AUTOSTRUCTURE code allowed us to estimate the uncertainties on the radiative transition probabilities obtained in the present work. For most of the strongest lines, we observed a general agreement of 20% or better between both sets of data. This is consistent with the usual uncertainty expected when considering radiative parameters for forbidden lines. Transition probabilities for some of the weakest lines were found to be affected by larger uncertainties because of their higher sensitivity to level mixing and configuration interaction. These faint lines can also be affected by cancellation effects in the line strength calculation. However, in most cases those lines do not contribute much to the total de-excitation of a level and are, therefore, not listed in the tables reported in this paper.

The overall good agreement obtained in the present work between transition probabilities computed with two different methods indicates that the new results should be reliable. They represent the most comprehensive and consistent study of forbidden lines available to date for doubly-charged ions belonging to the iron group. It is expected that these new data will help astrophysicists with interpreting numerous stellar spectra in which such lines are detected.

Acknowledgements. We acknowledge financial support from the NASA Astronomy and Physics Research and Analysis Program (award NNX10AU60G), the National Science Foundation (award 1313265), and the Belgian F.R.S.-FNRS where P.Q. is a Research Director. V.F. is currently a post-doctoral researcher of the Return Grant program of the Belgian Scientific Policy (BELSPO).

References

Ali, M. A., & Kim, Y. K. 1988, Phys. Rev. A, 38, 3992
Badnell, N. R. 1988, J. Phys. B, 30, 1
Bautista, M. A., Ballance, C., & Quinet, P. 2010, ApJ, 718, L189
Biémont, E., Hansen, J. E., Quinet, P., & Zeippen, C. J. 1992, J. Phys. B, 25, 5029
Cowan, R. D. 1981, The Theory of Atomic Structure and Spectra (Berkeley: Univ. California Press)
Deb, N. C., & Hibbert, A. 2009, J. Phys. B, 42, 065003
Eissner, W., & Nussbaumer, H. 1969, J. Phys. B, 2, 1028
Eissner, W., Jones, M., & Nussbaumer, H. 1974, Comput. Phys. Commun., 8, 270
Ekberg, J. O. 1993, A&A, 101, 1
Ekberg, J. O. 1997, Phys. Scr., 56, 141
Hansen, J. E., Raassen, A. J. J., & Uylings, P. H. M. 1984, ApJ, 277, 435
Irimia, A. 2007, JApA, 28, 157
Kramida, A., Ralchenko, Y., & Reader, J. 2013, http://www.nist.gov/pml/data/asd.cfm
Lundin, P., Gurell, J., Norlin, L.-O., et al. 2007, Phys. Rev. Lett., 99, 213001
Mesa-Delgado, A., Esteban, C., & García-Rojas, J. 2009, MNRAS, 395, 855
Nandy, D. K., Yashpal, S., Sahoo, K., & Li, C. 2011, J. Phys. B, 44, 225701
Quinet, P. 1996, A&AS, 123, 147
Raassen, A. J. J., & Uylings, P. H. M. 1997, A&AS, 116, 573
Sahoo, B. K., Nataraj, H. S., & Das, B. P. 2008, J. Phys. B, 41, 055702
Sugar, J., & Corliss, C. 1985, J. Phys. Chem. Ref. data, 14, 2
Vestergaard, M., & Wilkes, B. J. 2001, ApJS, 134, 1
Zeippen, C. J. 1990, A&A, 229, 248
Zethson, T., Johansson, S., Hartman, H., & Gull, T. R. 2012, A&A, 540, A119

Appendix A: Additional tables

Table A.1. Level energies and term energy corrections (TEC) as used in the final AUTOSTRUCTURE calculation for Sc III.

Configuration	Term	J	Energy (cm^{-1}) exp[a]	Energy (cm^{-1}) AUTOS this work	TEC (cm^{-1})
3d	^{2}D	3/2	0.00	0.00	
		5/2	197.64	207.51	
4s	^{2}S	1/2	25 539.32	25 428.55	–8

References. [a] Kramida et al. (2013).

Table A.2. Level energies and TEC as used in the final AUTOSTRUCTURE calculation for Ti III.

Configuration	Term	J	Energy (cm^{-1}) exp[a]	Energy (cm^{-1}) AUTOS this work	TEC (cm^{-1})
3d^2	^{3}F	2	0.00	0.00	
		3	184.90	219.91	
		4	420.40	500.40	
3d^2	^{1}D	2	8473.50	10 388.06	–2160
3d^2	^{3}P	0	10 538.40	12 385.72	–2118
		1	10 603.60	12 463.52	
		2	10 721.20	12 610.57	
3d^2	^{1}G	4	14 397.60	17 224.37	–3070
3d^2	^{1}S	0	32 475.50	41 310.72	–9081
3d4s	^{3}D	1	38 064.35	37 401.98	418
		2	38 198.95	37 540.25	
		3	38 425.99	37 765.43	
3d4s	^{1}D	2	41 704.27	42 374.51	–916

References. [a] Kramida et al. (2013).

Table A.3. Level energies and TEC as used in the final AUTOSTRUCTURE calculation for V III.

Configuration	Term	J	Energy (cm^{-1}) exp[a]	Energy (cm^{-1}) AUTOS this work	TEC (cm^{-1})
$3d^3$	a ^{4}F	3/2	0.00	0.00	
		5/2	145.50	172.84	
		7/2	341.50	406.80	
		9/2	583.80	695.19	
$3d^3$	a ^{4}P	1/2	11 513.80	13 652.20	–2497
		3/2	11 591.80	13 742.40	
		5/2	11 769.70	13 946.95	
$3d^3$	a ^{2}G	7/2	11 966.30	14 416.19	–2809
		9/2	12 187.00	14 673.74	
$3d^3$	a ^{2}P	3/2	15 550.30	19 114.04	–3844
		1/2	15 579.80	19 129.74	
$3d^3$	a ^{2}D2	3/2	16 330.50	20 100.91	–4152
		5/2	16 374.70	20 146.12	
$3d^3$	a ^{2}H	9/2	16 810.90	20 078.30	–3621
		11/2	16 977.60	20 266.61	
$3d^3$	a ^{2}F	7/2	27 727.80	33 089.20	–5714
		5/2	27 846.80	33 235.15	
$3d^3$	b ^{2}D1	5/2	42 267.40	51 583.88	–9671
		3/2	42 371.20	51 719.41	
$3d^2(^3F)4s$	b ^{4}F	3/2	43 942.49	42 602.54	987
		5/2	44 110.04	42 776.48	
		7/2	44 345.82	43 020.31	
		9/2	44 646.96	43 331.75	
$3d^2(^3F)4s$	b ^{2}F	5/2	49 327.74	49 213.89	–232
		7/2	49 805.29	49 701.01	
$3d^2(^1D)4s$	c ^{2}D	5/2	56 160.42	57 018.51	–1315
		3/2	56 256.75	57 375.49	
$3d^2(^3P)4s$	b ^{4}P	1/2	56 529.30	57 113.98	–942
		3/2	56 669.05	57 121.34	
		5/2	56 922.50	57 648.95	
$3d^2(^3P)4s$	b ^{2}P	1/2	61 578.74	63 473.37	–2243
		3/2	61 777.15	63 680.34	
$3d^2(^1G)4s$	b ^{2}G	9/2	63 303.12	64 977.65	–2011
		7/2	63 315.05	64 979.63	

References. [a] Kramida et al. (2013).

Table A.4. Level energies and TEC as used in the final AUTOSTRUCTURE calculation for Cr III.

Configuration	Term	J	Energy (cm^{-1}) exp[a]	Energy (cm^{-1}) AUTOS this work	TEC (cm^{-1})
$3d^4$	^{5}D	0	0.00	0.00	
		1	61.76	72.10	
		2	182.44	212.23	
		3	356.00	413.38	
		4	575.73	667.53	
$3d^4$	^{3}P2	0	16 770.26	21 192.58	–4915.57
		1	17 167.54	21 662.36	
		2	17 850.13	22 471.78	
$3d^4$	^{3}H	4	17 272.67	20 687.35	–3777.27
		5	17 395.84	20 820.46	
		6	17 529.68	20 965.53	
$3d^4$	^{3}F2	2	18 451.06	22 668.10	–4562.99
		3	18 510.09	22 715.40	
		4	18 582.39	22 781.68	
$3d^4$	^{3}G	3	20 702.45	24 870.64	–4539.61
		4	20 851.87	25 036.46	
		5	20 995.16	25 180.98	
$3d^4$	^{1}G2	4	25 137.91	30 614.62	–5849.22
$3d^4$	^{3}D	3	25 725.24	30 942.41	–5587.49
		2	25 779.72	31 020.76	
		1	25 847.28	31 103.39	
$3d^4$	^{1}I	6	26 014.10	31 029.76	–5375.59
$3d^4$	^{1}S2	0	27 371.30	33 703.73	–6697.38
$3d^4$	^{1}D2	2	32 150.53	39 577.20	–7791.24
$3d^4$	^{1}F	3	37 004.38	44 667.58	–8017.08
$3d^4$	^{3}F 1	4	43 285.81	52 959.22	–10 056.77
		2	43 303.26	53 021.44	
		3	43 321.22	53 023.09	
$3d^4$	^{3}P1	2	43 440.85	53 197.24	–10 169.68
		1	43 915.56	53 778.08	
		0	44 140.06	54 054.51	
$3d^3(^4F)4s$	^{5}F	1	49 491.59	47 953.66	1164.64
		2	49 627.27	48 093.91	
		3	49 828.04	48 301.53	
		4	50 090.28	48 573.13	
		5	50 409.28	48 903.99	
$3d^4$	^{1}G1	4	49 767.47	60 658.94	–11 253.34
$3d^3(^4F)4s$	^{3}F	2	56 650.51	56 473.01	–183.70
		3	56 992.24	56 820.55	
		4	57 422.53	57 260.48	
$3d^3(^4P)4s$	^{5}P	1	63 044.61	63 794.02	–1103.74
		2	63 173.17	63 925.05	
		3	63 420.87	64 170.86	
$3d^4$	^{1}D1	2	65 762.08	79 930.56	–14 372.18

References. [a] Ekberg (1997).

Table A.4. continued.

Configuration	Term	J	Energy (cm^{-1}) exp[a]	Energy (cm^{-1}) AUTOS this work	TEC (cm^{-1})
3d^3(^{2}G)4s	^{3}G	3	65 891.35	67 025.35	–1499.78
		4	66 028.88	67 171.85	
		5	66 224.05	67 374.97	
3d^3(^{4}P)4s	^{3}P	0	69 600.40	71 852.36	–2565.55
		1	69 780.80	72 045.17	
		2	70 291.77	72 414.33	
3d^3(^{2}G)4s	^{1}G	4	69 658.70	71 443.26	–2139.88
3d^3(^{2}P)4s	^{3}P	2	70 189.89	72 689.00	–2714.90
		1	70 344.55	72 680.44	
		0	70 485.87	72 797.09	
3d^3(^{2}D2)4s	^{3}D	1	70 980.15	73 670.82	–3080.44
		3	71 321.98	74 026.92	
		2	71 322.09	73 991.69	
3d^3(^{2}H)4s	^{3}H	4	71 676.22	73 529.26	–2219.33
		5	71 736.45	73 594.55	
		6	71 869.19	73 734.03	
3d^3(^{2}P)4s	^{1}P	1	73 880.42	77 033.83	–3537.93
3d^3(^{2}D2)4s	^{1}D	2	74 787.89	78 006.10	–3721.63
3d^3(^{2}H)4s	^{1}H	5	75 350.49	77 850.82	–2860.30
3d^3(^{2}F)4s	^{3}F	4	84 372.87	88 718.77	–4706.52
		3	84 483.43	88 830.70	
		2	84 571.41	88 919.37	
3d^3(^{2}F)4s	^{1}F	3	87 769.57	92 899.43	–5490.82

Table A.5. Level energies and TEC as used in the final AUTOSTRUCTURE calculation for Mn III.

Configuration	Term	J	Energy (cm^{-1}) exp[a]	Energy (cm^{-1}) AUTOS this work	TEC (cm^{-1})
3d^5	a ^{6}S	5/2	0.00	0.00	
3d^5	a ^{4}G	11/2	26 824.40	31 472.00	–4668
		9/2	26 851.10	31 519.63	
		7/2	26 859.90	31 542.56	
		5/2	26 857.80	31 550.46	
3d^5	a ^{4}P	5/2	29 167.70	35 329.05	–6203
		3/2	29 207.30	35 395.22	
		1/2	29 241.40	35 458.43	
3d^5	a ^{4}D	7/2	32 307.30	38 202.30	–5927
		1/2	32 368.90	38 316.75	
		5/2	32 383.70	38 338.04	
		3/2	32 384.70	38 347.26	
3d^5	a ^{2}I	11/2	39 174.40	45 778.12	–6592
		13/2	39 176.50	45 761.33	
3d^5	a ^{2}D3	5/2	41 238.10	49 473.09	
		3/2	41 569.80	49 849.49	
3d^5	a ^{2}F1	7/2	42 606.50	51 118.38	–8339

References. [(a)] Kramida et al. (2013).

Table A.5. continued.

Configuration	Term	J	Energy (cm^{-1}) exp[a]	Energy (cm^{-1}) AUTOS this work	TEC (cm^{-1})
		5/2	43 105.40	51 705.69	
3d^5	a ^{4}F	9/2	43 573.16	52 018.22	–8479
		7/2	43 602.50	52 095.26	
		5/2	43 668.84	52 219.81	
		3/2	43 674.70	52 226.94	
3d^5	a ^{2}H	9/2	46 515.90	55 354.79	–8973
		11/2	46 670.70	55 574.70	
3d^5	a ^{2}G2	7/2	47 842.00	56 423.52	33 838
		9/2	48 005.20	56 662.09	
3d^5	b ^{2}F2	5/2	51 002.70	60 322.59	–9396
		7/2	51 059.70	60 413.02	
3d^5	a ^{2}S	1/2	55 677.70	66 087.97	10 419
3d^5	b ^{2}D2	3/2	61 580.20	73 621.88	12 064
		5/2	61 603.80	73 660.83	
3d^4(^{5}D)4s	a ^{6}D	1/2	62 456.99	61 319.67	1120
		3/2	62 568.08	61 434.01	
		5/2	62 747.50	61 619.69	
		7/2	62 988.92	61 870.11	
		9/2	63 285.37	62 177.59	
3d^5	b ^{2}G1	7/2	68 892.00	81 837.14	89
		9/2	68 899.20	81 802.79	
3d^4(^{5}D)4s	b ^{4}D	1/2	71 395.27	71 298.74	–4582
		3/2	71 564.21	71 471.25	
		5/2	71 831.98	71 745.70	
		7/2	72 183.33	72 107.28	
3d^5	a ^{2}P	3/2	83 176.00	99 257.61	12 083
		1/2	83 229.00	99 260.35	
3d^4(^{3}P2)4s	b ^{4}P	1/2	84 610.53	88 342.26	–3837
		3/2	85 173.88	88 931.66	
		5/2	86 051.50	89 857.40	
3d^4(^{3}H)4s	a ^{4}H	7/2	84 981.63	87 328.94	–2346
		9/2	85 077.09	87 427.16	
		11/2	85 200.76	87 550.50	
		13/2	85 346.72	87 695.80	
3d^4(^{3}F2)4s	b ^{4}F	3/2	86 486.77	89 842.48	–3347
		5/2	86 520.94	89 868.81	
		7/2	86 578.24	89 915.78	
		9/2	86 654.07	89 985.57	
3d^4(^{3}G)4s	b ^{4}G	5/2	88 880.08	92 197.22	–3322
		7/2	89 052.44	92 370.06	
		9/2	89 204.69	92 516.55	
		11/2	89 307.22	92 601.16	
3d^5	c ^{2}D1	5/2	89 496.30	10 7883.18	
		3/2	89 543.40	10 7937.61	
3d^4(^{3}P2)4s	b ^{2}P	1/2	90 233.50	94 577.75	–8322
		3/2	91 308.30	95 704.86	
3d^4(^{3}H)4s	b ^{2}H	9/2	90 440.50	93 416.51	–2960

Table A.5. continued.

Configuration	Term	J	Energy (cm^{-1}) exp[a]	Energy (cm^{-1}) AUTOS this work	TEC (cm^{-1})
		11/2	90 746.06	93 716.86	
3d^4(^{3}F2)4s	c ^{2}F	5/2	91 906.10	95 885.05	–3970
		7/2	91 948.30	95 904.47	
3d^4(^{3}G)4s	c ^{2}G	7/2	94 397.20	98 347.99	–3938
		9/2	94 707.20	98 627.28	
3d^4(^{3}D)4s	c ^{4}D	7/2	94 697.85	99 265.73	
		5/2	94 771.47	99 351.54	
		3/2	94 850.66	99 438.56	
		1/2	94 906.45	99 496.18	
3d^4(^{1}G2)4s	d ^{2}G	9/2	96 430.40	10 1217.41	–4810
		7/2	96 487.50	10 1254.17	
3d^4(^{1}I)4s	b ^{2}I	13/2	97 239.86	10 1268.32	–4029
		11/2	97 271.76	10 1280.94	
3d^4(^{1}S2)4s	b ^{2}S	1/2	98 960.70	10 4949.13	
3d^4(^{3}D)4s	d ^{2}D	5/2	10 0001.30	10 5131.19	–5162
		3/2	10 0085.20	10 5255.19	
3d^4(^{1}D2)4s	e ^{2}D	5/2	10 4470.80	11 1409.59	–6947
		3/2	10 4517.90	11 1436.58	
3d^4(^{1}F)4s	d ^{2}F	7/2	10 9861.35	11 7115.27	–7280
		5/2	10 9864.40	11 7119.66	

Table A.6. Level energies and TEC as used in the final AUTOSTRUCTURE calculation for Fe III.

Configuration	Term	J	Energy (cm^{-1}) exp[a]	Energy (cm^{-1}) AUTOS this work	TEC (cm^{-1})
3d^6	^{5}D	4	0.00	0.00	
		3	435.80	507.10	
		2	738.55	862.97	
		1	932.06	1091.89	
		0	1027.00	1204.04	
3d^6	^{3}P2	2	19 404.19	23 647.18	–4737
		1	20 687.78	25 059.72	
		0	21 207.76	25 649.67	
3d^6	^{3}H	6	20 051.10	23 394.24	–3802
		5	20 300.32	23 698.76	
		4	20 481.58	23 931.40	
3d^6	^{3}F2	4	21 461.67	25 801.21	–4791
		3	21 699.44	26 073.14	
		2	21 856.76	26 252.78	
3d^6	^{3}G	5	24 558.25	29 192.43	–5133
		4	24 940.95	29 644.65	
		3	25 142.00	29 894.20	
3d^5(^{6}S)4s	^{7}S	3	30 089.42	30 029.61	–366
3d^6	^{1}I	6	30 355.52	35 454.70	–5534
3d^6	^{3}D	2	30 715.68	37 203.58	–6915

References. [a] Ekberg (1993).

Table A.6. continued.

Configuration	Term	J	Energy (cm^{-1}) exp[a]	Energy (cm^{-1}) AUTOS this work	TEC (cm^{-1})
		1	30 725.34	37 219.16	
		3	30 857.32	37 341.52	
3d^6	^{1}G2	4	30 886.01	37 173.51	–6742
3d^6	^{1}S2	0	34 811.74	43 025.47	–8668
3d^6	^{1}D2	2	35 802.99	42 863.72	–7500
3d^5(^{6}S)4s	^{5}S	2	41 000.09	42 950.74	–2376
3d^6	^{1}F	3	42 896.90	51 453.84	–8975
3d^6	^{3}P1	0	49 149.27	60 520.89	–11 839
		1	49 576.82	60 964.56	
		2	50 411.69	61 828.63	
3d^6	^{3}F1	2	50 184.65	61 680.59	–11 882
		4	50 275.84	61 681.47	
		3	50 294.89	61 742.81	
3d^6	^{1}G1	4	57 221.01	69 422.01	–12 637
3d^5(^{4}G)4s	^{5}G	6	63 425.49	68 373.14	–5395
		5	63 466.67	68 421.76	
		4	63 487.08	68 450.62	
		3	63 494.38	68 466.20	
		2	63 494.58	68 473.44	
3d^5(^{4}P)4s	^{5}P	3	66 464.80	73 367.40	–7365
		2	66 523.02	73 432.03	
		1	66 591.78	73 514.33	
3d^5(^{4}D)4s	^{5}D	4	69 695.89	76 285.20	–7040
		0	69 747.69	76 369.37	
		1	69 788.23	76 412.83	
		3	69 836.89	76 453.43	
		2	69 837.89	76 463.09	
3d^5(^{4}G)4s	^{3}G	5	70 694.17	76 977.86	–6742
		3	70 725.22	77 054.02	
		4	70 728.93	77 034.71	
3d^5(^{4}P)4s	^{3}P	2	73 727.79	81 960.38	–8711
		1	73 849.13	82 093.60	
		0	73 936.03	82 194.55	
3d^5(^{4}D)4s	^{3}D	3	76 956.76	84 898.92	–8401
		1	77 075.39	85 060.78	
		2	77 102.41	85 079.33	
3d^6	^{1}D	2	77 044.53	94 090.72	–17 060
3d^5(^{2}I)4s	^{3}I	7	79 840.19	86 694.22	–7300
		6	79 844.83	86 706.95	
		5	79 860.50	86 725.28	

Table A.7. Level energies and TEC as used in the final AUTOSTRUCTURE calculation for Co III.

Configuration	Term	J	Energy (cm^{-1}) exp[a]	Energy (cm^{-1}) AUTOS this work	TEC (cm^{-1})
3d^7	a ^{4}F	9/2	0.00	0.00	
		7/2	841.20	867.15	
		5/2	1451.30	1505.90	
		3/2	1866.80	1944.88	
3d^7	a ^{4}P	5/2	15 201.90	18 089.98	–3731
		3/2	15 428.20	18 335.81	
		1/2	15 811.40	18 769.11	
3d^7	a ^{2}G	9/2	16 977.60	19 029.45	–2893
		7/2	17 766.20	19 858.52	
3d^7	a ^{2}P	3/2	20 194.90	23 185.20	–3771
		1/2	20 918.50	23 891.09	
3d^7	a ^{2}H	11/2	22 720.30	25 432.02	–3552
		9/2	23 434.30	26 164.52	
3d^7	a ^{2}D2	5/2	23 058.80	26 838.05	–4634
		3/2	24 236.80	27 998.98	
3d^7	a ^{2}F	5/2	37 021.00	42 644.52	–6493
		7/2	37 316.50	43 006.16	
3d^6(^{5}D)4s	A ^{6}D	9/2	46 438.30	43 285.79	2380
		7/2	47 003.10	43 802.35	
		5/2	47 415.40	44 186.67	
		3/2	47 698.60	44 453.42	
		1/2	47 864.80	44 610.74	
3d^6(^{5}D)4s	a ^{4}D	7/2	55 729.20	54 471.03	469
		5/2	56 373.80	55 072.23	
		3/2	56 794.80	55 474.52	
		1/2	57 036.80	55 707.77	
3d^6(^{3}P2)4s	b ^{4}P	5/2	70 934.10	71 119.41	–961
		3/2	72 341.90	72 452.62	
		1/2	73 214.50	73 274.20	
3d^6(^{3}H)4s	a ^{4}H	13/2	71 623.10	70 476.03	386
		11/2	71 873.70	70 683.52	
		9/2	72 083.30	70 862.04	
		7/2	72 270.50	71 013.51	
3d^6(^{3}F2)4s	b ^{4}F	9/2	73 286.00	73 283.79	–792
		7/2	73 540.20	73 496.41	
		5/2	73 726.60	73 665.13	
		3/2	73 861.80	73 789.73	
3d^6(^{3}G)4s	a ^{4}G	11/2	76 518.90	76 513.10	–777
		9/2	77 121.10	77 054.53	
		7/2	77 383.10	77 317.16	
		5/2	77 472.30	77 406.28	
3d^6(^{3}P2)4s	b ^{2}P	3/2	76 791.10	78 102.72	–2140
		1/2	78 434.30	79 682.30	
3d^6(^{3}H)4s	b ^{2}H	11/2	77 411.60	77 372.28	–770
		9/2	77 622.90	77 563.20	
3d^6(^{3}F2)4s	b ^{2}F	7/2	78 927.80	80 027.54	–1932

References. [a] Kramida et al. (2013).

Table A.7. continued.

Configuration	Term	J	Energy (cm^{-1}) exp[a]	Energy (cm^{-1}) AUTOS this work	TEC (cm^{-1})
		5/2	79 425.30	80 467.23	
$3d^6(^3G)4s$	b ^2G	9/2	82 363.30	83 470.73	–1933
		7/2	82 920.70	83 997.43	
$3d^6(^3D)4s$	b ^4D	3/2	83 773.40	85 489.81	–2561
		1/2	83 789.30	85 483.39	
		5/2	83 799.60	85 535.53	
		7/2	83 938.90	85 665.80	
$3d^6(^1I)4s$	a ^2I	13/2	85 474.10	85 538.64	–879
		11/2	85 517.30	85 553.50	
$3d^6(^1G2)4s$	c ^2G	9/2	86 283.80	87 559.33	–2110
		7/2	86 327.10	87 584.76	

Table A.8. Level energies and TEC as used in the final AUTOSTRUCTURE calculation for Ni III.

Configuration	Term	J	Energy (cm^{-1}) exp[a]	Energy (cm^{-1}) AUTOS this work	TEC (cm^{-1})
$3d^8$	^3F	4	0.00	0.00	
		3	1360.70	1472.24	
		2	2269.60	2468.98	
$3d^8$	^1D	2	14 031.60	16 842.26	–3666
$3d^8$	^3P	2	16 661.60	20 528.23	–5035
		1	16 977.80	21 006.68	
		0	17 230.70	21 293.86	
$3d^8$	^1G	4	23 108.70	27 445.30	–5340
$3d^8$	^1S	0	52 532.00	65 278.00	–13 764
$3d^7(^4F)4s$	^5F	5	53 703.93	53 005.75	–296
		4	54 657.83	53 960.13	
		3	55 406.29	54 711.95	
		2	55 952.21	55 263.92	
		1	56 308.24	55 625.51	
$3d^7(^4F)4s$	^3F	4	61 338.58	61 734.69	–1404
		3	62 605.58	63 016.75	
		2	63 471.93	63 906.28	
$3d^7(^4P)4s$	^5P	3	71 067.35	74 699.72	–4635
		2	71 384.10	75 018.39	
		1	71 842.42	75 482.14	
$3d^7(^2G)4s$	^3G	5	75 123.65	77 321.56	–3178
		4	75 646.61	77 843.80	
		3	76 237.25	78 411.25	
$3d^7(^4P)4s$	^3P	2	78 303.54	82 010.96	–4545
		1	78 482.43	82 367.83	
		0	78 657.55	82 466.04	
$3d^7(^2P)4s$	^3P	2	79 143.01	83 532.03	–5487
		1	79 749.22	83 850.82	
		0	80 621.10	84 804.55	
$3d^7(^2G)4s$	^1G	4	79 250.11	82 004.38	–3749

References. [a] Kramida et al. (2013).

Table A.8. continued.

Configuration	Term	J	Energy (cm^{-1}) exp[a]	Energy (cm^{-1}) AUTOS this work	TEC (cm^{-1})
3d^7(^{2}H)4s	^{3}H	6	81 686.80	84 968.06	–4274
		5	82 193.80	85 463.96	
		4	82 826.40	86 063.23	
3d^7(^{2}D)4s	^{3}D	3	82 172.60	86 627.94	–5479
		1	82 277.26	88 786.80	
		2	83 033.45	87 434.51	
3d^7(^{2}P)4s	^{1}P	1	84 604.10	86 420.10	–4696
3d^7(^{2}H)4s	^{1}H	5	85 834.20	89 665.91	–4850
3d^7(^{2}D)4s	^{1}D	2	86 645.88	91 555.04	–5963
3d^7(^{2}F)4s	^{3}F	2	97 841.60	10 5278.78	–8437
		3	97 995.81	10 5430.55	
		4	98 237.93	10 5657.60	
3d^7(^{2}F)4s	^{1}F	3	10 1954.90	10 9886.32	–8942

Table A.9. Comparison of transition probabilities for M1 and E2 lines from our calculations (HFR and AUTOS) and previous works in Sc III. A[B] denotes $A \times 10^B$.

Lower level	Upper level	λ (nm)	A(M1+E2) (s^{-1}) Type	HFR	AUTOS	Others
3d $^2D_{3/2}$	3d $^2D_{5/2}$	50 597.04	M1+E2	8.36[–05]	8.33[–05]	8.32[–05][a], 8.32[-05][b], 8.24[–05][c], 8.33[–05][d]
3d $^2D_{3/2}$	4s $^2S_{1/2}$	391.55	M1+E2	7.67	8.71	8.21[a], 7.95[b], 7.86[c], 7.83[d]
3d $^2D_{5/2}$	4s $^2S_{1/2}$	394.61	E2	11.07	12.56	11.9[a], 11.5[b], 11.41[c], 11.40[d]

References. [(a)] Ali & Kim (1988); [(b)] Zeippen (1990); [(c)] Sahoo et al. (2008) and [(d)] Nandy et al. (2011).

Table A.10. Comparison of total (M1+E2) transition probabilities from our calculations (HFR and AUTOS) and previous works in Ti III. A[B] denotes $A \times 10^B$.

Lower level Config.	Term	J	Upper level Config.	Term	J	λ (nm)	A(M1+E2) (s^{-1}) HFR	AUTOS	SST[a]	MCDF[b]
3d^2	^{3}F	3	3d4s	^{3}D	3	261.49	1.24[+01]	1.26[+01]	1.10[+01]	1.26[+01]
3d^2	^{3}F	2	3d4s	^{3}D	2	261.81	1.64[+01]	1.68[+01]	1.47[+01]	1.67[+01]
3d^2	^{3}F	2	3d4s	^{3}D	1	262.74	3.75[+01]	3.83[+01]	3.40[+01]	3.82[+01]
3d^2	^{3}F	3	3d4s	^{3}D	2	263.05	2.79[+01]	2.85[+01]	2.48[+01]	2.84[+01]
3d^2	^{3}F	4	3d4s	^{3}D	3	263.10	4.28[+01]	4.37[+01]	3.78[+01]	4.35[+01]
3d^2	^{3}F	3	3d4s	^{3}D	1	263.99	1.83[+01]	1.87[+01]	1.65[+01]	1.86[+01]
3d^2	^{3}F	4	3d4s	^{3}D	2	264.68	1.16[+01]	1.19[+01]	1.04[+01]	1.18[+01]
3d^2	^{1}D	2	3d4s	^{1}D	2	300.93	2.07[+01]	2.09[+01]	1.94[+01]	1.89[+01]
3d^2	^{1}G	4	3d4s	^{1}D	2	366.21	1.62[+01]	1.64[+01]	1.47[+01]	1.48[+01]
3d^2	^{1}D	2	3d^2	^{1}S	0	416.63	6.51[+00]	6.43[+00]	7.13[+00]	4.95[+00]
3d^2	^{3}F	3	3d^2	^{1}G	4	703.55	4.11[–03]	6.61[–03]	6.84[–03]	4.50[–03]
3d^2	^{3}F	4	3d^2	^{1}G	4	715.33	6.53[–03]	1.05[–02]	1.07[–02]	7.14[–03]
3d^2	^{3}F	2	3d^2	^{3}P	1	943.84	1.34[–02]	1.32[–02]	1.38[–02]	1.39[–02]
3d^2	^{3}F	3	3d^2	^{3}P	2	948.29	7.89[–03]	7.80[–03]	8.14[–03]	8.13[–03]
3d^2	^{3}F	2	3d^2	^{3}P	0	949.45	3.91[–02]	3.85[–02]	3.99[–02]	4.05[–02]
3d^2	^{3}F	3	3d^2	^{3}P	1	960.17	2.46[–02]	2.42[–02]	2.48[–02]	2.55[–02]
3d^2	^{3}F	4	3d^2	^{3}P	2	969.81	2.69[–02]	2.62[–02]	2.66[–02]	2.77[–02]
3d^2	^{3}F	2	3d^2	^{1}D	2	1180.65	5.05[–03]	7.92[–03]	8.27[–03]	5.47[–03]
3d^2	^{3}F	3	3d^2	^{1}D	2	1206.31	9.43[–03]	1.47[–02]	1.51[–02]	1.02[–02]
3d^2	^{3}F	3	3d^2	^{3}F	4	42 730.85	2.60[–04]	2.64[–04]	4.80[–04]	2.65[–04]
3d^2	^{3}F	2	3d^2	^{3}F	3	55 508.75	1.51[–04]	1.62[–04]	2.99[–04]	1.63[–04]

References. [(a)] Biémont et al. (1992); [(b)] Raassen & Uylings (1997).

Table A.11. Comparison of total (M1+E2) transition probabilities from our calculations (HFR and AUTOS) and previous works in V III. A[B] denotes $A \times 10^B$.

λ (nm)	Lower level				Upper level				A(M1+E2) (s^{-1})	
	E (cm^{-1})	Config.	Term	J	E (cm^{-1})	Config.	Term	J	HFR	AUTOS
176.74	341.50	$3d^3$	^4F	7/ 2	56 922.50	$3d^24s$	^4P	5/2	2.60[+01]	2.61[+01]
176.90	0.00	$3d^3$	^4F	3/ 2	56 529.30	$3d^24s$	^4P	1/2	8.77[+01]	8.98[+01]
176.92	145.50	$3d^3$	^4F	5/ 2	56 669.05	$3d^24s$	^4P	3/2	4.68[+01]	4.85[+01]
177.36	145.50	$3d^3$	^4F	5/ 2	56 529.30	$3d^24s$	^4P	1/2	5.78[+01]	5.91[+01]
177.50	583.80	$3d^3$	^4F	9/ 2	56 922.50	$3d^24s$	^4P	5/2	8.03[+01]	8.02[+01]
177.53	341.50	$3d^3$	^4F	7/ 2	56 669.05	$3d^24s$	^4P	3/2	6.53[+01]	6.75[+01]
179.93	583.80	$3d^3$	^4F	9/ 2	56 160.42	$3d^24s$	^2D	5/2	2.09[+01]	2.32[+01]
194.75	11 966.30	$3d^3$	^2G	7/ 2	63 315.05	$3d^24s$	^2G	7/2	4.69[+01]	4.89[+01]
195.63	12 187.00	$3d^3$	^2G	9/ 2	63 303.12	$3d^24s$	^2G	9/2	4.98[+01]	5.25[+01]
215.03	16 810.90	$3d^3$	^2H	9/ 2	63 315.05	$3d^24s$	^2G	7/2	7.66[+01]	7.86[+01]
215.86	16 977.60	$3d^3$	^2H	11/ 2	63 303.12	$3d^24s$	^2G	9/2	7.24[+01]	7.39[+01]
216.46	15 579.80	$3d^3$	^2P	1/ 2	61 777.15	$3d^24s$	^2P	3/2	1.30[+01]	1.40[+01]
217.26	15 550.30	$3d^3$	^2P	3/ 2	61 578.74	$3d^24s$	^2P	1/2	4.23[+01]	4.79[+01]
220.04	16 330.50	$3d^3$	^2D	3/ 2	61 777.15	$3d^24s$	^2P	3/2	2.14[+01]	2.40[+01]
220.25	16 374.70	$3d^3$	^2D	5/ 2	61 777.15	$3d^24s$	^2P	3/2	1.44[+01]	1.77[+01]
220.60	11 591.80	$3d^3$	^4P	3/ 2	56 922.50	$3d^24s$	^4P	5/2	1.81[+01]	1.77[+01]
221.22	16 374.70	$3d^3$	^2D	5/ 2	61 578.74	$3d^24s$	^2P	1/2	8.05[+00]	9.91[+00]
222.72	11 769.70	$3d^3$	^4P	5/ 2	56 669.05	$3d^24s$	^4P	3/2	3.12[+01]	3.23[+01]
223.42	11 769.70	$3d^3$	^4P	5/ 2	56 529.30	$3d^24s$	^4P	1/2	4.99[+01]	5.12[+01]
225.71	341.50	$3d^3$	^4F	7/ 2	44 646.96	$3d^24s$	^4F	9/2	1.74[+01]	1.79[+01]
225.78	11 966.30	$3d^3$	^2G	7/ 2	56 256.75	$3d^24s$	^2D	3/2	3.88[+01]	4.01[+01]
226.24	145.50	$3d^3$	^4F	5/ 2	44 345.82	$3d^24s$	^4F	7/2	2.38[+01]	2.45[+01]
226.71	0.00	$3d^3$	^4F	3/ 2	44 110.04	$3d^24s$	^4F	5/2	2.41[+01]	2.48[+01]
226.95	583.80	$3d^3$	^4F	9/ 2	44 646.96	$3d^24s$	^4F	9/2	5.94[+01]	6.11[+01]
227.25	341.50	$3d^3$	^4F	7/ 2	44 345.82	$3d^24s$	^4F	7/2	3.06[+01]	3.15[+01]
227.41	12 187.00	$3d^3$	^2G	9/ 2	56 160.42	$3d^24s$	^2D	5/2	2.95[+01]	2.93[+01]
227.46	145.50	$3d^3$	^4F	5/ 2	44 110.04	$3d^24s$	^4F	5/2	1.99[+01]	2.05[+01]
227.57	0.00	$3d^3$	^4F	3/ 2	43 942.49	$3d^24s$	^4F	3/2	3.68[+01]	3.79[+01]
228.33	145.50	$3d^3$	^4F	5/ 2	43 942.49	$3d^24s$	^4F	3/2	3.49[+01]	3.59[+01]
228.47	341.50	$3d^3$	^4F	7/ 2	44 110.04	$3d^24s$	^4F	5/2	3.02[+01]	3.11[+01]
228.51	583.80	$3d^3$	^4F	9/ 2	44 345.82	$3d^24s$	^4F	7/2	2.05[+01]	2.11[+01]
246.24	15 550.30	$3d^3$	^2P	3/ 2	56 160.42	$3d^24s$	^2D	5/2	1.43[+01]	1.45[+01]
250.46	16 330.50	$3d^3$	^2D	3/ 2	56 256.75	$3d^24s$	^2D	3/2	2.17[+01]	2.26[+01]
251.35	16 374.70	$3d^3$	^2D	5/ 2	56 160.42	$3d^24s$	^2D	5/2	1.57[+01]	1.59[+01]
265.83	12 187.00	$3d^3$	^2G	9/ 2	49 805.29	$3d^24s$	^2F	7/2	2.71[+01]	2.87[+01]
267.66	11 966.30	$3d^3$	^2G	7/ 2	49 327.74	$3d^24s$	^2F	5/2	2.72[+01]	2.91[+01]
293.69	27 727.80	$3d^3$	^2F	7/ 2	61 777.15	$3d^24s$	^2P	3/2	2.35[+01]	2.46[+01]
296.45	27 846.80	$3d^3$	^2F	5/ 2	61 578.74	$3d^24s$	^2P	1/2	2.73[+01]	2.88[+01]
299.13	16 374.70	$3d^3$	^2D	5/ 2	49 805.29	$3d^24s$	^2F	7/2	6.46[+00]	6.68[+00]
304.62	16 977.60	$3d^3$	^2H	11/ 2	49 805.29	$3d^24s$	^2F	7/2	2.09[+01]	2.22[+01]
307.53	16 810.90	$3d^3$	^2H	9/ 2	49 327.74	$3d^24s$	^2F	5/2	2.01[+01]	2.12[+01]
328.89	11 966.30	$3d^3$	^2G	7/ 2	42 371.20	$3d^3$	^2D	3/2	4.99[+00]	5.31[+00]
332.44	12 187.00	$3d^3$	^2G	9/ 2	42 267.40	$3d^3$	^2D	5/2	4.46[+00]	4.75[+00]
372.84	15 550.30	$3d^3$	^2P	3/ 2	42 371.20	$3d^3$	^2D	3/2	8.66[−01]	1.07[+00]
612.35	0.00	$3d^3$	^4F	3/ 2	16 330.50	$3d^3$	^2D	3/2	2.12[−02]	3.04[−02]
617.86	145.50	$3d^3$	^4F	5/ 2	16 330.50	$3d^3$	^2D	3/2	3.83[−02]	5.65[−02]
623.71	341.50	$3d^3$	^4F	7/ 2	16 374.70	$3d^3$	^2D	5/2	5.62[−02]	7.47[−02]
629.70	11 966.30	$3d^3$	^2G	7/ 2	27 846.80	$3d^3$	^2F	5/2	9.55[−02]	9.91[−02]
634.46	11 966.30	$3d^3$	^2G	7/ 2	27 727.80	$3d^3$	^2F	7/2	2.05[−02]	2.58[−02]
643.07	0.00	$3d^3$	^4F	3/ 2	15 550.30	$3d^3$	^2P	3/2	1.50[−02]	1.97[−02]
643.47	12 187.00	$3d^3$	^2G	9/ 2	27 727.80	$3d^3$	^2F	7/2	8.62[−02]	8.97[−02]
649.15	145.50	$3d^3$	^4F	5/ 2	15 550.30	$3d^3$	^2P	3/2	2.53[−02]	3.32[−02]
844.20	341.50	$3d^3$	^4F	7/ 2	12 187.00	$3d^3$	^2G	9/2	1.20[−02]	1.67[−02]
845.97	145.50	$3d^3$	^4F	5/ 2	11 966.30	$3d^3$	^2G	7/2	1.10[−02]	1.59[−02]
860.23	341.50	$3d^3$	^4F	7/ 2	11 966.30	$3d^3$	^2G	7/2	1.24[−02]	1.80[−02]
861.83	583.80	$3d^3$	^4F	9/ 2	12 187.00	$3d^3$	^2G	9/2	3.12[−02]	4.39[−02]
862.68	0.00	$3d^3$	^4F	3/ 2	11 591.80	$3d^3$	^4P	3/2	5.79[−03]	5.78[−03]
868.52	0.00	$3d^3$	^4F	3/ 2	11 513.80	$3d^3$	^4P	1/2	2.79[−02]	2.75[−02]
873.64	145.50	$3d^3$	^4F	5/ 2	11 591.80	$3d^3$	^4P	3/2	1.65[−02]	1.63[−02]
875.03	341.50	$3d^3$	^4F	7/ 2	11 769.70	$3d^3$	^4P	5/2	1.03[−02]	1.02[−02]

Table A.11. continued.

λ (nm)	Lower level				Upper level				A(M1+E2) (s^{-1})	
	E (cm^{-1})	Config.	Term	J	E (cm^{-1})	Config.	Term	J	HFR	AUTOS
879.64	145.50	$3d^3$	^4F	5/ 2	11 513.80	$3d^3$	^4P	1/2	1.74[–02]	1.71[–02]
880.82	16 374.70	$3d^3$	^2D	5/ 2	27 727.80	$3d^3$	^2F	7/2	1.85[–02]	2.03[–02]
888.87	341.50	$3d^3$	^4F	7/ 2	11 591.80	$3d^3$	^4P	3/2	2.12[–02]	2.08[–02]
893.98	583.80	$3d^3$	^4F	9/ 2	11 769.70	$3d^3$	^4P	5/2	2.88[–02]	2.84[–02]
906.13	16 810.90	$3d^3$	^2H	9/ 2	27 846.80	$3d^3$	^2F	5/2	2.81[–02]	2.82[–02]
930.22	16 977.60	$3d^3$	^2H	11/ 2	27 727.80	$3d^3$	^2F	7/2	2.32[–02]	2.33[–02]
2064.15	11 966.30	$3d^3$	^2G	7/ 2	16 810.90	$3d^3$	^2H	9/2	5.46[–03]	7.86[–03]
2087.42	12 187.00	$3d^3$	^2G	9/ 2	16 977.60	$3d^3$	^2H	11/2	5.39[–03]	7.76[–03]
2162.68	12 187.00	$3d^3$	^2G	9/ 2	16 810.90	$3d^3$	^2H	9/2	1.06[–02]	1.53[–02]
2192.60	11 769.70	$3d^3$	^4P	5/ 2	16 330.50	$3d^3$	^2D	3/2	7.36[–03]	8.90[–03]
2459.42	11 513.80	$3d^3$	^4P	1/ 2	15 579.80	$3d^3$	^2P	1/2	1.56[–02]	2.29[–02]
2526.21	11 591.80	$3d^3$	^4P	3/ 2	15 550.30	$3d^3$	^2P	3/2	8.75[–03]	1.32[–02]
41 271.15	341.50	$3d^3$	^4F	7/ 2	583.80	$3d^3$	^4F	9/2	3.85[–04]	3.84[–04]
51 124.74	145.50	$3d^3$	^4F	5/ 2	341.10	$3d^3$	^4F	7/2	3.26[–04]	3.24[–04]
68 728.52	0.00	$3d^3$	^4F	3/ 2	145.50	$3d^3$	^4F	5/2	1.33[–04]	1.33[–04]

Table A.12. Theoretical lifetimes obtained in this work for VIII using the HFR and AUTOS methods compared to the previous MCHF results of Irimia (2007). A[B] denotes $A \times 10^B$.

Config.	Term	J	Lifetime (ns)		
			HFR	AUTOS	Previous[a]
$3d^3$	a ^{4}F	5/2	7.49[+03]	7.53[+03]	4.20[+03]
		7/2	3.07[+03]	3.08[+03]	2.06[+03]
		9/2	2.60[+03]	2.61[+03]	2.47[+03]
$3d^3$	a ^{4}P	1/2	2.21[+01]	2.24[+01]	2.30[+01]
		3/2	2.30[+01]	2.33[+01]	2.37[+01]
		5/2	2.38[+01]	2.41[+01]	2.52[+01]
$3d^3$	a ^{2}G	7/2	4.13[+01]	2.86[+01]	7.65[+02]
		9/2	2.30[+01]	1.65[+01]	4.94[+03]
$3d^3$	a ^{2}P	3/2	1.71[+01]	1.23[+01]	9.82[+02]
		1/2	6.19[+01]	4.22[+01]	1.19[+04]
$3d^3$	a ^{2}D2	3/2	1.37[+01]	9.85[+00]	4.48[+04]
		5/2	1.40[+01]	1.07[+01]	3.27[+03]
$3d^3$	a ^{2}H	9/2	6.17[+01]	4.28[+01]	1.43[+04]
		11/2	1.82[+02]	1.27[+02]	6.00[+03]
$3d^3$	a ^{2}F	7/2	5.67[+00]	5.06[+00]	8.21[+00]
		5/2	5.83[+00]	5.40[+00]	7.28[+00]
$3d^3$	b ^{2}D1	5/2	1.51[–01]	1.36[–01]	1.70[–01]
		3/2	1.46[–01]	1.32[–01]	1.62[–01]
$3d^2(^3F)4s$	b ^{4}F	3/2	1.24[–02]	1.21[–02]	1.16[–02]
		5/2	1.23[–02]	1.20[–02]	1.14[–02]
		7/2	1.22[–02]	1.18[–02]	1.13[–02]
		9/2	1.20[–02]	1.17[–02]	1.12[–02]
$3d^2(^3F)4s$	b ^{2}F	5/2	1.60[–02]	1.50[–02]	1.76[–02]
		7/2	1.58[–02]	1.49[–02]	1.69[–02]
$3d^2(^1D)4s$	c ^{2}D	5/2	8.91[–03]	8.52[–03]	1.11[–02]
		3/2	9.73[–03]	9.55[–03]	1.12[–02]
$3d^2(^3P)4s$	b ^{4}P	1/2	4.97[–03]	4.85[–03]	4.50[–03]
		3/2	5.29[–03]	5.14[–03]	4.49[–03]
		5/2	5.57[–03]	5.50[–03]	4.50[–03]
$3d^2(^3P)4s$	b ^{2}P	1/2	1.26[–02]	1.13[–02]	1.30[–02]
		3/2	1.26[–02]	1.13[–02]	1.25[–02]
$3d^2(^1G)4s$	b ^{2}G	9/2	7.05[–03]	6.78[–03]	7.26[–03]
		7/2	7.06[–03]	6.82[–03]	7.16[–03]

References. [(a)] Irimia (2007).

Table A.13. Comparison of total (M1+E2) transition probabilities from our calculations (HFR and AUTOS) and previous works in Cr III. A[B] denotes $A \times 10^B$.

λ (nm)	Lower level				Upper level				A(M1+E2) (s^{-1})	
	E (cm^{-1})	Config.	Term	J	E (cm^{-1})	Config.	Term	J	HFR	AUTOS
148.59	17 272.67	$3d^4$	^{3}H	4	84 571.41	$3d^34s$	^{3}F	2	9.60[+01]	9.00[+01]
149.06	17 395.84	$3d^4$	^{3}H	5	84 483.43	$3d^34s$	^{3}F	3	8.50[+01]	8.00[+01]
149.60	17 529.68	$3d^4$	^{3}H	6	84 372.87	$3d^34s$	^{3}F	4	9.14[+01]	8.72[+01]
152.00	18 582.39	$3d^4$	^{3}F	4	84 372.87	$3d^34s$	^{3}F	4	3.56[+01]	3.80[+01]
156.57	20 702.45	$3d^4$	^{3}G	3	84 571.41	$3d^34s$	^{3}F	2	1.30[+02]	1.24[+02]
157.15	20 851.87	$3d^4$	^{3}G	4	84 483.43	$3d^34s$	^{3}F	3	1.03[+02]	9.77[+01]
157.78	20 995.16	$3d^4$	^{3}G	5	84 372.87	$3d^34s$	^{3}F	4	1.15[+02]	1.09[+02]
158.13	182.44	$3d^4$	^{5}D	2	63 420.87	$3d^34s$	^{5}P	3	4.99[+01]	4.81[+01]
158.30	0.00	$3d^4$	^{5}D	0	63 173.17	$3d^34s$	^{5}P	2	3.47[+01]	3.34[+01]
158.45	61.76	$3d^4$	^{5}D	1	63 173.17	$3d^34s$	^{5}P	2	7.19[+01]	6.94[+01]
158.57	356.00	$3d^4$	^{5}D	3	63 420.87	$3d^34s$	^{5}P	3	1.03[+02]	9.98[+01]
158.75	182.44	$3d^4$	^{5}D	2	63 173.17	$3d^34s$	^{5}P	2	4.28[+01]	4.13[+01]
159.08	182.44	$3d^4$	^{5}D	2	63 044.61	$3d^34s$	^{5}P	1	9.89[+01]	9.54[+01]
159.12	575.73	$3d^4$	^{5}D	4	63 420.87	$3d^34s$	^{5}P	3	1.21[+02]	1.17[+02]
159.52	356.00	$3d^4$	^{5}D	3	63 044.61	$3d^34s$	^{5}P	1	1.56[+02]	1.50[+02]
159.66	25 137.91	$3d^4$	^{1}G	4	87 769.57	$3d^34s$	^{1}F	3	5.76[+01]	6.65[+01]
159.75	575.73	$3d^4$	^{5}D	4	63 173.17	$3d^34s$	^{5}P	2	1.33[+02]	1.28[+02]
179.79	32 150.53	$3d^4$	^{1}D	2	87 769.57	$3d^34s$	^{1}F	3	4.72[+01]	5.10[+01]
183.81	17 272.67	$3d^4$	^{3}H	4	71 676.22	$3d^34s$	^{3}H	4	1.03[+02]	9.78[+01]
184.02	17 395.84	$3d^4$	^{3}H	5	71 736.45	$3d^34s$	^{3}H	5	9.86[+01]	9.56[+01]
184.03	17 529.68	$3d^4$	^{3}H	6	71 869.19	$3d^34s$	^{3}H	6	1.15[+02]	1.12[+02]
184.66	17 167.54	$3d^4$	^{3}P	1	71 321.98	$3d^34s$	^{3}D	3	1.88[+01]	1.79[+01]
187.01	17 850.13	$3d^4$	^{3}P	2	71 322.09	$3d^34s$	^{3}D	2	5.27[+01]	4.97[+01]
187.01	17 850.13	$3d^4$	^{3}P	2	71 321.98	$3d^34s$	^{3}D	3	3.86[+01]	3.70[+01]
187.20	16 770.26	$3d^4$	^{3}P	0	70 189.89	$3d^34s$	^{3}P	2	1.92[+01]	1.21[+01]
188.05	17 167.54	$3d^4$	^{3}P	1	70 344.55	$3d^34s$	^{3}P	1	2.86[+01]	2.72[+01]
188.22	17 850.13	$3d^4$	^{3}P	2	70 980.15	$3d^34s$	^{3}D	1	4.20[+01]	3.89[+01]
188.60	17 167.54	$3d^4$	^{3}P	1	70 189.89	$3d^34s$	^{3}P	2	1.99[+01]	1.65[+01]
189.35	18 510.09	$3d^4$	^{3}F	3	71 322.09	$3d^34s$	^{3}D	2	1.83[+01]	1.69[+01]
189.61	18 582.39	$3d^4$	^{3}F	4	71 321.98	$3d^34s$	^{3}D	3	1.79[+01]	1.65[+01]
189.98	17 850.13	$3d^4$	^{3}P	2	70 485.87	$3d^34s$	^{3}P	0	4.25[+01]	3.99[+01]
190.07	17 167.54	$3d^4$	^{3}P	1	69 780.80	$3d^34s$	^{3}P	1	1.59[+01]	1.51[+01]
190.37	18 451.06	$3d^4$	^{3}F	2	70 980.15	$3d^34s$	^{3}D	1	3.51[+01]	3.27[+01]
192.18	18 451.06	$3d^4$	^{3}F	2	70 485.87	$3d^34s$	^{3}P	0	1.37[+02]	1.39[+02]
192.70	18 451.06	$3d^4$	^{3}F	2	70 344.55	$3d^34s$	^{3}P	1	2.17[+01]	2.28[+01]
192.92	18 510.09	$3d^4$	^{3}F	3	70 344.55	$3d^34s$	^{3}P	1	1.03[+02]	1.03[+02]
193.12	18 510.09	$3d^4$	^{3}F	3	70 291.77	$3d^34s$	^{3}P	2	1.74[+01]	4.65[+00]
193.24	17 850.13	$3d^4$	^{3}P	2	69 600.40	$3d^34s$	^{3}P	0	2.78[+01]	3.02[+01]
193.39	18 582.39	$3d^4$	^{3}F	4	70 291.77	$3d^34s$	^{3}P	2	1.14[+02]	1.93[–02]
196.18	20 702.45	$3d^4$	^{3}G	3	71 676.22	$3d^34s$	^{3}H	4	2.39[+01]	2.34[+01]
196.52	20 851.87	$3d^4$	^{3}G	4	71 736.45	$3d^34s$	^{3}H	5	2.10[+01]	2.04[+01]
196.56	20 995.16	$3d^4$	^{3}G	5	71 869.19	$3d^34s$	^{3}H	6	2.67[+01]	2.63[+01]
196.99	37 004.38	$3d^4$	^{1}F	3	87 769.57	$3d^34s$	^{1}F	3	3.93[+01]	3.99[+01]
198.14	20 851.87	$3d^4$	^{3}G	4	71 322.09	$3d^34s$	^{3}D	2	2.03[+01]	2.07[+01]
198.70	20 995.16	$3d^4$	^{3}G	5	71 321.98	$3d^34s$	^{3}D	3	3.00[+01]	2.90[+01]
198.90	20 702.45	$3d^4$	^{3}G	3	70 980.15	$3d^34s$	^{3}D	1	2.62[+01]	2.57[+01]
199.79	356.00	$3d^4$	^{5}D	3	50 409.28	$3d^34s$	^{5}F	5	2.44[+01]	2.39[+01]
200.37	182.44	$3d^4$	^{5}D	2	50 090.28	$3d^34s$	^{5}F	4	3.43[+01]	3.36[+01]
200.67	575.73	$3d^4$	^{5}D	4	50 409.28	$3d^34s$	^{5}F	5	7.15[+01]	7.00[+01]
200.94	61.76	$3d^4$	^{5}D	1	49 828.04	$3d^34s$	^{5}F	3	3.41[+01]	3.34[+01]
201.07	356.00	$3d^4$	^{5}D	3	50 090.28	$3d^34s$	^{5}F	4	2.36[+01]	2.31[+01]
201.41	25 137.91	$3d^4$	^{1}G	4	74 787.89	$3d^34s$	^{1}D	2	7.78[+01]	1.29[+02]
201.50	0.00	$3d^4$	^{5}D	0	49 627.27	$3d^34s$	^{5}F	2	2.62[+01]	2.56[+01]
201.96	575.73	$3d^4$	^{5}D	4	50 090.28	$3d^34s$	^{5}F	4	3.63[+01]	3.56[+01]
202.13	356.00	$3d^4$	^{5}D	3	49 828.04	$3d^34s$	^{5}F	3	4.50[+01]	4.41[+01]
202.25	182.44	$3d^4$	^{5}D	2	49 627.27	$3d^34s$	^{5}F	2	4.19[+01]	4.11[+01]
202.31	61.76	$3d^4$	^{5}D	1	49 491.59	$3d^34s$	^{5}F	1	5.13[+01]	5.02[+01]
202.69	26 014.10	$3d^4$	^{1}I	6	75 350.49	$3d^34s$	^{1}H	5	1.60[+02]	1.61[+02]
202.80	182.44	$3d^4$	^{5}D	2	49 491.59	$3d^34s$	^{5}F	1	3.62[+01]	3.55[+01]
202.96	356.00	$3d^4$	^{5}D	3	49 627.27	$3d^34s$	^{5}F	2	2.25[+01]	2.21[+01]
203.04	575.73	$3d^4$	^{5}D	4	49 828.04	$3d^34s$	^{5}F	3	9.66[+00]	9.47[+00]
205.36	17 529.68	$3d^4$	^{3}H	6	66 224.05	$3d^34s$	^{3}G	5	3.10[+01]	2.98[+01]

Table A.13. continued.

λ (nm)	Lower level				Upper level				A(M1+E2) (s^{-1})	
	E (cm^{-1})	Config.	Term	J	E (cm^{-1})	Config.	Term	J	HFR	AUTOS
205.62	17 395.84	$3d^4$	^3H	5	66 028.88	$3d^34s$	^3G	4	2.97[+01]	2.88[+01]
205.68	17 272.67	$3d^4$	^3H	4	65 891.35	$3d^34s$	^3G	3	3.10[+01]	2.99[+01]
209.90	18 582.39	$3d^4$	^3F	4	66 224.05	$3d^34s$	^3G	5	4.01[+01]	3.97[+01]
210.44	18 510.09	$3d^4$	^3F	3	66 028.88	$3d^34s$	^3G	4	3.06[+01]	3.05[+01]
210.79	18 451.06	$3d^4$	^3F	2	65 891.35	$3d^34s$	^3G	3	3.00[+01]	2.95[+01]
210.90	27 371.30	$3d^4$	^1S	0	74 787.89	$3d^34s$	^1D	2	2.89[+01]	3.66[+01]
219.31	25 725.24	$3d^4$	^3D	3	71 321.98	$3d^34s$	^3D	3	1.96[+01]	1.96[+01]
219.58	25 779.72	$3d^4$	^3D	2	71 322.09	$3d^34s$	^3D	2	1.82[+01]	1.73[+01]
221.10	20 995.16	$3d^4$	^3G	5	66 224.05	$3d^34s$	^3G	5	1.90[+01]	1.86[+01]
221.29	20 702.45	$3d^4$	^3G	3	65 891.35	$3d^34s$	^3G	3	2.10[+01]	2.10[+01]
221.35	20 851.87	$3d^4$	^3G	4	66 028.88	$3d^34s$	^3G	4	1.85[+01]	1.85[+01]
221.57	25 847.28	$3d^4$	^3D	1	70 980.15	$3d^34s$	^3D	1	1.78[+01]	1.72[+01]
224.61	25 137.91	$3d^4$	^1G	4	69 658.70	$3d^34s$	^1G	4	6.79[+01]	6.92[+01]
224.90	25 725.24	$3d^4$	^3D	3	70 189.89	$3d^34s$	^3P	2	3.99[+01]	3.83[–01]
226.99	25 725.24	$3d^4$	^3D	3	69 780.80	$3d^34s$	^3P	1	2.77[+01]	2.85[+01]
227.62	25 847.28	$3d^4$	^3D	1	69 780.80	$3d^34s$	^3P	1	1.47[+01]	1.60[+01]
228.20	25 779.72	$3d^4$	^3D	2	69 600.40	$3d^34s$	^3P	0	5.33[+01]	5.44[+01]
229.12	26 014.10	$3d^4$	^1I	6	69 658.70	$3d^34s$	^1G	4	4.96[+01]	4.89[+01]
239.64	32 150.53	$3d^4$	^1D	2	73 880.42	$3d^34s$	^1P	1	6.12[+01]	6.15[+01]
246.16	25 137.91	$3d^4$	^1G	4	65 762.08	$3d^4$	^1D	2	1.92[+01]	6.18[–01]
250.67	17 529.68	$3d^4$	^3H	6	57 422.53	$3d^34s$	^3F	4	3.75[+01]	3.90[+01]
252.55	17 395.84	$3d^4$	^3H	5	56 992.24	$3d^34s$	^3F	3	3.70[+01]	3.88[+01]
252.70	17 850.13	$3d^4$	^3P	2	57 422.53	$3d^34s$	^3F	4	9.81[+00]	1.06[+01]
253.95	17 272.67	$3d^4$	^3H	4	56 650.51	$3d^34s$	^3F	2	4.00[+01]	4.19[+01]
257.47	18 582.39	$3d^4$	^3F	4	57 422.53	$3d^34s$	^3F	4	8.97[+00]	8.56[+00]
261.78	18 451.06	$3d^4$	^3F	2	56 650.51	$3d^34s$	^3F	2	8.67[+00]	8.67[+00]
263.14	49 767.47	$3d^4$	^1G	4	87 769.57	$3d^34s$	^1F	3	3.06[+01]	2.92[+01]
264.67	37 004.38	$3d^4$	^1F	3	74 787.89	$3d^34s$	^1D	2	2.25[+01]	1.12[+01]
271.18	37 004.38	$3d^4$	^1F	3	73 880.42	$3d^34s$	^1P	1	2.35[+01]	2.35[+01]
274.52	20 995.16	$3d^4$	^3G	5	57 422.53	$3d^34s$	^3F	4	1.81[+01]	1.87[+01]
276.70	20 851.87	$3d^4$	^3G	4	56 992.24	$3d^34s$	^3F	3	1.27[+01]	1.29[+01]
278.18	20 702.45	$3d^4$	^3G	3	56 650.51	$3d^34s$	^3F	2	1.37[+01]	1.38[+01]
297.52	32 150.53	$3d^4$	^1D	2	65 762.08	$3d^4$	^1D	2	2.81[+00]	5.86[+00]
373.86	17 167.54	$3d^4$	^3P	1	43 915.56	$3d^4$	^3P	1	1.97[–01]	1.98[–01]
374.94	16 770.26	$3d^4$	^3P	0	43 440.85	$3d^4$	^3P	2	1.72[–01]	1.75[–01]
380.37	17 850.13	$3d^4$	^3P	2	44 140.06	$3d^4$	^3P	0	7.27[–01]	7.35[–01]
380.61	17 167.54	$3d^4$	^3P	1	43 440.85	$3d^4$	^3P	2	3.97[–01]	4.14[–01]
383.65	17 850.13	$3d^4$	^3P	2	43 915.56	$3d^4$	^3P	1	5.76[–01]	5.87[–01]
384.16	17 272.67	$3d^4$	^3H	4	43 303.26	$3d^4$	^3F	2	1.57[+00]	1.22[+00]
385.72	17 395.84	$3d^4$	^3H	5	43 321.22	$3d^4$	^3F	3	1.16[+00]	1.11[+00]
386.89	0.00	$3d^4$	^5D	0	25 847.28	$3d^4$	^3D	1	3.74[–02]	5.08[–02]
387.81	61.76	$3d^4$	^5D	1	25 847.28	$3d^4$	^3D	1	3.45[–02]	4.64[–02]
388.26	17 529.68	$3d^4$	^3H	6	43 285.81	$3d^4$	^3F	4	1.24[+00]	1.21[+00]
388.83	61.76	$3d^4$	^5D	1	25 779.72	$3d^4$	^3D	2	3.08[–02]	4.19[–02]
390.67	182.44	$3d^4$	^5D	2	25 779.72	$3d^4$	^3D	2	2.65[–02]	3.57[–02]
390.77	17 850.13	$3d^4$	^3P	2	43 440.85	$3d^4$	^3P	2	2.94[–01]	3.09[–01]
391.50	182.44	$3d^4$	^5D	2	25 725.24	$3d^4$	^3D	3	1.54[–02]	2.07[–02]
393.33	356.00	$3d^4$	^5D	3	25 779.72	$3d^4$	^3D	2	1.47[–02]	2.12[–02]
394.18	356.00	$3d^4$	^5D	3	25 725.24	$3d^4$	^3D	3	1.52[–02]	2.06[–02]
397.62	575.73	$3d^4$	^5D	4	25 725.24	$3d^4$	^3D	3	6.23[–02]	8.37[–02]
402.38	18 451.06	$3d^4$	^3F	2	43 303.26	$3d^4$	^3F	2	6.62[–01]	6.23[–01]
403.04	18 510.09	$3d^4$	^3F	3	43 321.22	$3d^4$	^3F	3	3.63[–01]	4.03[–01]
403.34	18 510.09	$3d^4$	^3F	3	43 303.26	$3d^4$	^3F	2	4.59[–01]	4.54[–01]
404.80	18 582.39	$3d^4$	^3F	4	43 285.81	$3d^4$	^3F	4	5.46[–01]	6.15[–01]
406.02	25 137.91	$3d^4$	^1G	4	49 767.47	$3d^4$	^1G	4	2.93[–01]	2.56[–01]

Table A.13. continued.

λ (nm)	Lower level				Upper level				A(M1+E2) (s^{-1})	
	E (cm^{-1})	Config.	Term	J	E (cm^{-1})	Config.	Term	J	HFR	AUTOS
420.99	26 014.10	$3d^4$	^1I	6	49 767.47	$3d^4$	^1G	4	1.56[+00]	1.58[+00]
442.46	20 702.45	$3d^4$	^3G	3	43 303.26	$3d^4$	^3F	2	7.63[–01]	6.64[–01]
445.05	20 851.87	$3d^4$	^3G	4	43 321.22	$3d^4$	^3F	3	4.49[–01]	4.69[–01]
448.62	20 995.16	$3d^4$	^3G	5	43 285.81	$3d^4$	^3F	4	6.49[–01]	7.10[–01]
493.19	575.73	$3d^4$	^5D	4	20 851.87	$3d^4$	^3G	4	2.09[–03]	3.13[–03]
543.79	61.76	$3d^4$	^5D	1	18 451.06	$3d^4$	^3F	2	1.60[–02]	2.26[–02]
544.65	25 779.72	$3d^4$	^3D	2	44 140.06	$3d^4$	^3P	0	5.65[–01]	5.61[–01]
545.62	182.44	$3d^4$	^5D	2	18 510.09	$3d^4$	^3F	3	2.82[–02]	3.90[–02]
547.39	182.44	$3d^4$	^5D	2	18 451.06	$3d^4$	^3F	2	3.09[–02]	4.39[–02]
548.65	356.00	$3d^4$	^5D	3	18 582.39	$3d^4$	^3F	4	2.71[–02]	3.64[–02]
549.74	25 725.24	$3d^4$	^3D	3	43 915.56	$3d^4$	^3P	1	2.44[–01]	2.41[–01]
550.84	356.00	$3d^4$	^5D	3	18 510.09	$3d^4$	^3F	3	7.47[–02]	1.04[–01]
552.64	356.00	$3d^4$	^5D	3	18 451.06	$3d^4$	^3F	2	7.65[–03]	1.07[–02]
553.46	25 847.28	$3d^4$	^3D	1	43 915.56	$3d^4$	^3P	1	2.66[–01]	2.76[–01]
555.35	575.73	$3d^4$	^5D	4	18 582.39	$3d^4$	^3F	4	1.30[–01]	1.78[–01]
564.47	25 725.24	$3d^4$	^3D	3	43 440.85	$3d^4$	^3P	2	2.93[–01]	3.01[–01]
566.22	25 779.72	$3d^4$	^3D	2	43 440.85	$3d^4$	^3P	2	1.79[–01]	1.86[–01]
571.62	356.00	$3d^4$	^5D	3	17 850.13	$3d^4$	^3P	2	1.19[–01]	1.55[–01]
582.49	0.00	$3d^4$	^5D	0	17 167.54	$3d^4$	^3P	1	2.16[–02]	2.79[–02]
588.75	182.44	$3d^4$	^5D	2	17 167.54	$3d^4$	^3P	1	1.76[–01]	2.34[–01]
591.13	356.00	$3d^4$	^5D	3	17 272.67	$3d^4$	^3H	4	3.56[–05]	1.08[–04]
598.50	61.76	$3d^4$	^5D	1	16 770.26	$3d^4$	^3P	0	2.22[–01]	3.07[–01]
598.91	575.73	$3d^4$	^5D	4	17 272.67	$3d^4$	^3H	4	1.85[–04]	5.79[–04]
613.42	20 702.45	$3d^4$	^3G	3	37 004.38	$3d^4$	^1F	3	2.12[–02]	2.73[–02]
619.10	20 851.87	$3d^4$	^3G	4	37 004.38	$3d^4$	^1F	3	3.05[–02]	3.87[–02]
699.28	17 850.13	$3d^4$	^3P	2	32 150.53	$3d^4$	^1D	2	3.43[–02]	4.74[–02]
729.96	18 451.06	$3d^4$	^3F	2	32 150.53	$3d^4$	^1D	2	3.55[–02]	5.11[–02]
733.11	18 510.09	$3d^4$	^3F	3	32 150.53	$3d^4$	^1D	2	7.20[–02]	1.03[–01]
886.59	25 725.24	$3d^4$	^3D	3	37 004.38	$3d^4$	^1F	3	2.55[–02]	3.40[–02]
890.90	25 779.72	$3d^4$	^3D	2	37 004.38	$3d^4$	^1F	3	1.18[–02]	1.56[–02]
980.03	17 167.54	$3d^4$	^3P	1	27 371.30	$3d^4$	^1S	0	2.70[–01]	3.29[–01]
1152.11	17 167.54	$3d^4$	^3P	1	25 847.28	$3d^4$	^3D	1	2.04[–02]	2.86[–02]
1160.33	17 395.84	$3d^4$	^3H	5	26 014.10	$3d^4$	^1I	6	1.84[–02]	2.50[–02]
1178.63	17 529.68	$3d^4$	^3H	6	26 014.10	$3d^4$	^1I	6	2.48[–02]	3.37[–02]
1261.10	17 850.13	$3d^4$	^3P	2	25 779.72	$3d^4$	^3D	2	1.00[–02]	1.35[–02]
1271.42	17 272.67	$3d^4$	^3H	4	25 137.91	$3d^4$	^1G	4	2.84[–02]	3.58[–02]
1291.64	17 395.84	$3d^4$	^3H	5	25 137.91	$3d^4$	^1G	4	4.07[–02]	5.24[–02]
1508.79	18 510.09	$3d^4$	^3F	3	25 137.91	$3d^4$	^1G	4	2.45[–02]	3.02[–02]
1525.43	18 582.39	$3d^4$	^3F	4	25 137.91	$3d^4$	^1G	4	4.73[–02]	6.23[–02]
2778.30	17 395.84	$3d^4$	^3H	5	20 995.16	$3d^4$	^3G	5	6.99[–03]	9.52[–03]
2793.92	17 272.67	$3d^4$	^3H	4	20 851.87	$3d^4$	^3G	4	6.57[–03]	8.31[–03]
2885.60	17 529.68	$3d^4$	^3H	6	20 995.16	$3d^4$	^3G	5	7.46[–03]	1.02[–02]
2915.64	17 272.67	$3d^4$	^3H	4	20 702.45	$3d^4$	^3G	3	7.10[–03]	9.67[–03]
4144.61	18 582.39	$3d^4$	^3F	4	20 995.16	$3d^4$	^3G	5	5.87[–03]	7.65[–03]
4406.30	18 582.39	$3d^4$	^3F	4	20 851.87	$3d^4$	^3G	4	4.77[–03]	6.23[–03]
4441.70	18 451.06	$3d^4$	^3F	2	20 702.45	$3d^4$	^3G	3	5.03[–03]	6.71[–03]
4561.29	18 510.09	$3d^4$	^3F	3	20 702.45	$3d^4$	^3G	3	6.40[–03]	8.50[–03]
45 510.40	356.00	$3d^4$	^5D	3	575.73	$3d^4$	^5D	4	2.87[–04]	2.85[–04]
57 616.96	182.44	$3d^4$	^5D	2	356.00	$3d^4$	^5D	3	2.42[–04]	2.41[–04]
74 716.08	17 395.84	$3d^4$	^3H	5	17 529.68	$3d^4$	^3H	6	5.36[–05]	5.32[–05]
81 188.60	17 272.67	$3d^4$	^3H	4	17 395.84	$3d^4$	^3H	5	4.95[–05]	4.91[–05]
82 863.77	61.76	$3d^4$	^5D	1	182.44	$3d^4$	^5D	2	1.01[–04]	1.00[–04]
16 1917.10	0.00	$3d^4$	^5D	0	61.76	$3d^4$	^5D	1	1.30[–05]	1.30[–05]

Table A.14. Comparison of total (M1+E2) transition probabilities from our calculations (HFR and AUTOS) and previous works in Mn III. A[B] denotes $A \times 10^B$.

λ (nm)	Lower level				Upper level				A(M1+E2) (s^{-1})	
	E (cm^{-1})	Config.	Term	J	E (cm^{-1})	Config.	Term	J	HFR	AUTOS
146.95	26 857.80	$3d^5$	^4G	5/2	94 906.45	$3d^44s$	^4D	1/2	9.38[+01]	9.57[+01]
147.08	26 859.90	$3d^5$	^4G	7/2	94 850.66	$3d^44s$	^4D	3/2	6.75[+01]	6.83[+01]
147.23	26 851.10	$3d^5$	^4G	9/2	94 771.47	$3d^44s$	^4D	5/2	6.81[+01]	6.89[+01]
147.33	26 824.40	$3d^5$	^4G	11/2	94 697.85	$3d^44s$	^4D	7/2	7.55[+01]	7.70[+01]
152.21	29 207.30	$3d^5$	^4P	3/2	94 906.45	$3d^44s$	^4D	1/2	2.81[+01]	2.56[+01]
152.43	29 167.70	$3d^5$	^4P	5/2	94 771.47	$3d^44s$	^4D	5/2	2.60[+01]	2.48[+01]
152.60	29 167.70	$3d^5$	^4P	5/2	94 697.85	$3d^44s$	^4D	7/2	3.95[+01]	4.37[+01]
158.01	0.00	$3d^5$	^6S	5/2	63 285.37	$3d^44s$	^6D	9/2	1.27[+02]	1.28[+02]
158.15	41 238.10	$3d^5$	^2D	5/2	10 4470.80	$3d^44s$	^2D	5/2	5.87[+01]	3.11[+00]
158.25	46 670.70	$3d^5$	^2H	11/2	10 9861.35	$3d^44s$	^2F	7/2	2.99[+01]	2.67[+01]
158.76	0.00	$3d^5$	^6S	5/2	62 988.92	$3d^44s$	^6D	7/2	1.23[+02]	1.26[+02]
158.86	41 569.80	$3d^5$	^2D	3/2	10 4517.90	$3d^44s$	^2D	3/2	5.03[+01]	2.99[–02]
159.37	0.00	$3d^5$	^6S	5/2	62 747.50	$3d^44s$	^6D	5/2	1.20[+02]	1.23[+02]
159.83	0.00	$3d^5$	^6S	5/2	62 568.08	$3d^44s$	^6D	3/2	1.18[+02]	1.22[+02]
159.94	32 383.70	$3d^5$	^4D	5/2	94 906.45	$3d^44s$	^4D	1/2	3.49[+01]	3.71[+01]
159.94	32 384.70	$3d^5$	^4D	3/2	94 906.45	$3d^44s$	^4D	1/2	8.94[+01]	9.60[+01]
160.04	26 824.40	$3d^5$	^4G	11/2	89 307.22	$3d^44s$	^4G	11/2	6.68[+01]	6.83[+01]
160.05	32 368.90	$3d^5$	^4D	1/2	94 850.66	$3d^44s$	^4D	3/2	4.26[+01]	4.47[+01]
160.08	32 383.70	$3d^5$	^4D	5/2	94 850.66	$3d^44s$	^4D	3/2	6.46[+01]	6.88[+01]
160.09	32 307.30	$3d^5$	^4D	7/2	94 771.47	$3d^44s$	^4D	5/2	4.50[+01]	4.63[+01]
160.11	0.00	$3d^5$	^6S	5/2	62 456.99	$3d^44s$	^6D	1/2	1.16[+02]	1.20[+02]
160.11	26 851.10	$3d^5$	^4G	9/2	89 307.22	$3d^44s$	^4G	11/2	2.17[+01]	2.15[+01]
160.28	32 307.30	$3d^5$	^4D	7/2	94 697.85	$3d^44s$	^4D	7/2	6.44[+01]	6.66[+01]
160.29	32 384.70	$3d^5$	^4D	3/2	94 771.47	$3d^44s$	^4D	5/2	3.92[+01]	3.96[+01]
160.38	26 851.10	$3d^5$	^4G	9/2	89 204.69	$3d^44s$	^4G	9/2	5.38[+01]	5.48[+01]
160.40	26 859.90	$3d^5$	^4G	7/2	89 204.69	$3d^44s$	^4G	9/2	3.06[+01]	3.08[+01]
160.48	32 383.70	$3d^5$	^4D	5/2	94 697.85	$3d^44s$	^4D	7/2	2.79[+01]	2.60[+01]
160.79	26 857.80	$3d^5$	^4G	5/2	89 052.44	$3d^44s$	^4G	7/2	2.87[+01]	2.91[+01]
160.79	26 859.90	$3d^5$	^4G	7/2	89 052.44	$3d^44s$	^4G	7/2	5.08[+01]	5.16[+01]
161.23	47 842.00	$3d^5$	^2G	7/2	10 9864.40	$3d^44s$	^2F	5/2	8.96[+01]	5.07[+00]
161.23	26 857.80	$3d^5$	^4G	5/2	88 880.08	$3d^44s$	^4G	5/2	7.32[+01]	7.48[+01]
161.24	26 859.90	$3d^5$	^4G	7/2	88 880.08	$3d^44s$	^4G	5/2	1.58[+01]	1.63[+01]
161.64	42 606.50	$3d^5$	^2F	7/2	10 4470.80	$3d^44s$	^2D	5/2	6.00[+01]	4.72[+01]
161.67	48 005.20	$3d^5$	^2G	9/2	10 9861.35	$3d^44s$	^2F	7/2	7.88[+01]	8.35[–01]
162.83	43 105.40	$3d^5$	^2F	5/2	10 4517.90	$3d^44s$	^2D	3/2	9.62[+01]	2.94[+01]
167.14	26 824.40	$3d^5$	^4G	11/2	86 654.07	$3d^44s$	^4F	9/2	7.15[+01]	7.36[+01]
167.43	26 851.10	$3d^5$	^4G	9/2	86 578.24	$3d^44s$	^4F	7/2	5.52[+01]	5.69[+01]
167.59	26 851.10	$3d^5$	^4G	9/2	86 520.94	$3d^44s$	^4F	5/2	1.84[+01]	1.89[+01]
167.61	26 859.90	$3d^5$	^4G	7/2	86 520.94	$3d^44s$	^4F	5/2	4.77[+01]	4.93[+01]
167.70	26 857.80	$3d^5$	^4G	5/2	86 486.77	$3d^44s$	^4F	3/2	5.85[+01]	6.03[+01]
167.71	26 859.90	$3d^5$	^4G	7/2	86 486.77	$3d^44s$	^4F	3/2	2.04[+01]	2.10[+01]
169.89	51 002.70	$3d^5$	^2F	5/2	10 9864.40	$3d^44s$	^2F	5/2	7.63[+01]	8.00[+01]
170.06	51 059.70	$3d^5$	^2F	7/2	10 9861.35	$3d^44s$	^2F	7/2	7.64[+01]	8.32[+01]
170.17	41 238.10	$3d^5$	^2D	5/2	10 0001.30	$3d^44s$	^2D	5/2	3.27[+01]	3.01[+01]
170.87	26 824.40	$3d^5$	^4G	11/2	85 346.72	$3d^44s$	^4H	13/2	1.19[+02]	1.24[+02]
170.90	41 569.80	$3d^5$	^2D	3/2	10 0085.20	$3d^44s$	^2D	3/2	1.65[+01]	2.34[+01]
171.30	26 824.40	$3d^5$	^4G	11/2	85 200.76	$3d^44s$	^4H	11/2	2.63[+01]	2.74[+01]
171.38	26 851.10	$3d^5$	^4G	9/2	85 200.76	$3d^44s$	^4H	11/2	8.40[+01]	8.80[+01]
171.41	26 859.90	$3d^5$	^4G	7/2	85 200.76	$3d^44s$	^4H	11/2	1.76[+01]	1.86[+01]
171.74	26 851.10	$3d^5$	^4G	9/2	85 077.09	$3d^44s$	^4H	9/2	3.37[+01]	3.55[+01]
171.76	26 857.80	$3d^5$	^4G	5/2	85 077.09	$3d^44s$	^4H	9/2	1.53[+01]	1.62[+01]
171.77	26 859.90	$3d^5$	^4G	7/2	85 077.09	$3d^44s$	^4H	9/2	7.28[+01]	7.65[+01]
172.05	26 857.80	$3d^5$	^4G	5/2	84 981.63	$3d^44s$	^4H	7/2	8.90[+01]	9.38[+01]
172.05	26 859.90	$3d^5$	^4G	7/2	84 981.63	$3d^44s$	^4H	7/2	3.06[+01]	3.22[+01]
172.12	39 174.40	$3d^5$	^2I	11/2	97 271.76	$3d^44s$	^2I	11/2	1.28[+02]	1.34[+02]
172.23	39 176.50	$3d^5$	^2I	13/2	97 239.86	$3d^44s$	^2I	13/2	1.29[+02]	1.37[+02]
173.24	41 238.10	$3d^5$	^2D	5/2	98 960.70	$3d^44s$	^2S	1/2	6.62[+01]	8.82[+01]
173.95	29 167.70	$3d^5$	^4P	5/2	86 654.07	$3d^44s$	^4F	9/2	6.06[+01]	6.45[+01]
174.18	29 167.70	$3d^5$	^4P	5/2	86 578.24	$3d^44s$	^4F	7/2	1.94[+01]	1.90[+01]
174.23	42 606.50	$3d^5$	^2F	7/2	10 0001.30	$3d^44s$	^2D	5/2	3.13[+01]	4.05[+01]
174.24	41 569.80	$3d^5$	^2D	3/2	98 960.70	$3d^44s$	^2S	1/2	7.70[+01]	8.82[+01]

Table A.14. continued.

λ (nm)	Lower level				Upper level				A(M1+E2) (s^{-1})	
	E (cm^{-1})	Config.	Term	J	E (cm^{-1})	Config.	Term	J	HFR	AUTOS
174.30	29 207.30	3d^5	^{4}P	3/2	86 578.24	3d4^{4}s	^{4}F	7/2	3.59[+01]	3.88[+01]
174.48	29 207.30	3d^5	^{4}P	3/2	86 520.94	3d4^{4}s	^{4}F	5/2	2.87[+01]	2.97[+01]
174.48	39 174.40	3d^5	^{2}I	11/2	96 487.50	3d4^{4}s	^{2}G	7/2	4.28[+01]	4.52[+01]
174.58	29 241.40	3d^5	^{4}P	1/2	86 520.94	3d4^{4}s	^{4}F	5/2	1.75[+01]	1.84[+01]
174.66	39 176.50	3d^5	^{2}I	13/2	96 430.40	3d4^{4}s	^{2}G	9/2	1.90[+01]	2.16[+01]
174.69	29 241.40	3d^5	^{4}P	1/2	86 486.77	3d4^{4}s	^{4}F	3/2	3.48[+01]	3.54[+01]
175.44	32 307.30	3d^5	^{4}D	7/2	89 307.22	3d4^{4}s	^{4}G	11/2	5.33[+01]	5.66[+01]
175.50	43 105.40	3d^5	^{2}F	5/2	10 0085.20	3d4^{4}s	^{2}D	3/2	2.84[+01]	4.23[+01]
175.80	29 167.70	3d^5	^{4}P	5/2	86 051.50	3d4^{4}s	^{4}P	5/2	1.33[+01]	1.15[+01]
175.92	29 207.30	3d^5	^{4}P	3/2	86 051.50	3d4^{4}s	^{4}P	5/2	2.82[+01]	2.57[+01]
175.99	32 383.70	3d^5	^{4}D	5/2	89 204.69	3d4^{4}s	^{4}G	9/2	3.74[+01]	3.99[+01]
176.03	29 241.40	3d^5	^{4}P	1/2	86 051.50	3d4^{4}s	^{4}P	5/2	2.50[+01]	2.48[+01]
176.44	47 842.00	3d^5	^{2}G	7/2	10 4517.90	3d4^{4}s	^{2}D	3/2	4.69[+01]	2.14[+02]
176.46	32 383.70	3d^5	^{4}D	5/2	89 052.44	3d4^{4}s	^{4}G	7/2	2.00[+01]	2.09[+01]
176.47	32 384.70	3d^5	^{4}D	3/2	89 052.44	3d4^{4}s	^{4}G	7/2	2.84[+01]	3.04[+01]
176.96	32 368.90	3d^5	^{4}D	1/2	88 880.08	3d4^{4}s	^{4}G	5/2	2.64[+01]	2.83[+01]
177.01	32 384.70	3d^5	^{4}D	3/2	88 880.08	3d4^{4}s	^{4}G	5/2	1.88[+01]	1.99[+01]
177.10	48 005.20	3d^5	^{2}G	9/2	10 4470.80	3d4^{4}s	^{2}D	5/2	3.31[+01]	2.08[+02]
178.55	29 167.70	3d^5	^{4}P	5/2	85 173.88	3d4^{4}s	^{4}P	3/2	4.38[+01]	4.10[+01]
178.68	29 207.30	3d^5	^{4}P	3/2	85 173.88	3d4^{4}s	^{4}P	3/2	2.97[+01]	2.90[+01]
179.03	43 105.40	3d^5	^{2}F	5/2	98 960.70	3d4^{4}s	^{2}S	1/2	2.28[+01]	2.01[+01]
180.08	39 176.50	3d^5	^{2}I	13/2	94 707.20	3d4^{4}s	^{2}G	9/2	1.06[+02]	1.10[+02]
180.37	29 167.70	3d^5	^{4}P	5/2	84 610.53	3d4^{4}s	^{4}P	1/2	7.55[+01]	7.54[+01]
181.08	39 174.40	3d^5	^{2}I	11/2	94 397.20	3d4^{4}s	^{2}G	7/2	7.31[+01]	7.69[+01]
181.18	41 238.10	3d^5	^{2}D	5/2	96 430.40	3d4^{4}s	^{2}G	9/2	2.83[+01]	3.00[+01]
185.79	42 606.50	3d^5	^{2}F	7/2	96 430.40	3d4^{4}s	^{2}G	9/2	4.74[+01]	5.49[+01]
186.07	32 307.30	3d^5	^{4}D	7/2	86 051.50	3d4^{4}s	^{4}P	5/2	2.57[+01]	2.66[+01]
186.33	32 383.70	3d^5	^{4}D	5/2	86 051.50	3d4^{4}s	^{4}P	5/2	2.30[+01]	2.54[+01]
187.33	43 105.40	3d^5	^{2}F	5/2	96 487.50	3d4^{4}s	^{2}G	7/2	5.77[+01]	5.11[+01]
189.16	32 307.30	3d^5	^{4}D	7/2	85 173.88	3d4^{4}s	^{4}P	3/2	2.33[+01]	2.33[+01]
191.41	47 842.00	3d^5	^{2}G	7/2	10 0085.20	3d4^{4}s	^{2}D	3/2	1.90[+01]	4.67[–05]
191.47	32 383.70	3d^5	^{4}D	5/2	84 610.53	3d4^{4}s	^{4}P	1/2	2.01[+01]	1.89[+01]
191.94	42 606.50	3d^5	^{2}F	7/2	94 707.20	3d4^{4}s	^{2}G	9/2	3.30[+01]	3.59[+01]
192.32	48 005.20	3d^5	^{2}G	9/2	10 0001.30	3d4^{4}s	^{2}D	5/2	2.40[+01]	2.08[–02]
193.91	39 176.50	3d^5	^{2}I	13/2	90 746.06	3d4^{4}s	^{2}H	11/2	1.21[+02]	1.34[+02]
195.06	39 174.40	3d^5	^{2}I	11/2	90 440.50	3d4^{4}s	^{2}H	9/2	1.22[+02]	1.36[+02]
197.02	46 515.90	3d^5	^{2}H	9/2	97 271.76	3d4^{4}s	^{2}I	11/2	2.32[+01]	2.94[+01]
197.20	41 238.10	3d^5	^{2}D	5/2	91 948.30	3d4^{4}s	^{2}F	7/2	3.09[+01]	2.57[+01]
197.36	41 238.10	3d^5	^{2}D	5/2	91 906.10	3d4^{4}s	^{2}F	5/2	2.50[+01]	2.37[+01]
197.75	46 670.70	3d^5	^{2}H	11/2	97 239.86	3d4^{4}s	^{2}I	13/2	2.77[+01]	2.93[+01]
198.66	41 569.80	3d^5	^{2}D	3/2	91 906.10	3d4^{4}s	^{2}F	5/2	3.25[+01]	2.83[+01]
200.11	46 515.90	3d^5	^{2}H	9/2	96 487.50	3d4^{4}s	^{2}G	7/2	1.80[+01]	2.08[+01]
200.97	46 670.70	3d^5	^{2}H	11/2	96 430.40	3d4^{4}s	^{2}G	9/2	2.58[+01]	2.61[+01]
201.05	41 569.80	3d^5	^{2}D	3/2	91 308.30	3d4^{4}s	^{2}P	3/2	1.81[+01]	7.76[+00]
202.67	42 606.50	3d^5	^{2}F	7/2	91 948.30	3d4^{4}s	^{2}F	7/2	2.67[+01]	3.00[+01]
203.74	51 002.70	3d^5	^{2}F	5/2	10 0085.20	3d4^{4}s	^{2}D	3/2	5.09[+01]	9.59[+00]
204.10	41 238.10	3d^5	^{2}D	5/2	90 233.50	3d4^{4}s	^{2}P	1/2	7.72[+01]	7.09[+00]
204.33	51 059.70	3d^5	^{2}F	7/2	10 0001.30	3d4^{4}s	^{2}D	5/2	4.42[+01]	9.94[+00]
205.33	42 606.50	3d^5	^{2}F	7/2	91 308.30	3d4^{4}s	^{2}P	3/2	6.96[+01]	7.72[–01]
205.49	41 569.80	3d^5	^{2}D	3/2	90 233.50	3d4^{4}s	^{2}P	1/2	2.40[+01]	1.37[+01]
207.02	41 238.10	3d^5	^{2}D	5/2	89 543.40	3d^5	^{2}D	3/2	2.04[+00]	1.79[–01]
207.46	43 105.40	3d^5	^{2}F	5/2	91 308.30	3d4^{4}s	^{2}P	3/2	2.75[+01]	3.25[+00]
208.85	46 515.90	3d^5	^{2}H	9/2	94 397.20	3d4^{4}s	^{2}G	7/2	2.76[+01]	2.46[+01]
212.19	43 105.40	3d^5	^{2}F	5/2	90 233.50	3d4^{4}s	^{2}P	1/2	2.83[+01]	3.14[–01]
213.05	42 606.50	3d^5	^{2}F	7/2	89 543.40	3d^5	^{2}D	3/2	2.38[+00]	1.31[+00]
213.27	42 606.50	3d^5	^{2}F	7/2	89 496.30	3d^5	^{2}D	5/2	1.41[+01]	1.75[+01]
214.12	48 005.20	3d^5	^{2}G	9/2	94 707.20	3d4^{4}s	^{2}G	9/2	4.17[+01]	3.57[+01]
214.80	47 842.00	3d^5	^{2}G	7/2	94 397.20	3d4^{4}s	^{2}G	7/2	4.10[+01]	3.54[+01]
215.34	43 105.40	3d^5	^{2}F	5/2	89 543.40	3d^5	^{2}D	3/2	1.16[+01]	1.77[+01]
220.31	46 515.90	3d^5	^{2}H	9/2	91 906.10	3d4^{4}s	^{2}F	5/2	3.90[+01]	3.84[+01]
220.46	26 824.40	3d^5	^{4}G	11/2	72 183.33	3d4^{4}s	^{4}D	7/2	5.48[+01]	6.39[+01]
220.86	46 670.70	3d^5	^{2}H	11/2	91 948.30	3d4^{4}s	^{2}F	7/2	3.05[+01]	3.23[+01]

Table A.14. continued.

λ (nm)	Lower level				Upper level				A(M1+E2) (s^{-1})	
	E (cm^{-1})	Config.	Term	J	E (cm^{-1})	Config.	Term	J	HFR	AUTOS
222.32	26 851.10	3d^5	^{4}G	9/2	71 831.98	3d4^{4}s	^{4}D	5/2	4.63[+01]	5.46[+01]
222.36	26 859.90	3d^5	^{4}G	7/2	71 831.98	3d4^{4}s	^{4}D	5/2	1.40[+01]	1.61[+01]
223.68	26 857.80	3d^5	^{4}G	5/2	71 564.21	3d4^{4}s	^{4}D	3/2	1.63[+01]	1.90[+01]
223.69	26 859.90	3d^5	^{4}G	7/2	71 564.21	3d4^{4}s	^{4}D	3/2	4.40[+01]	5.23[+01]
224.53	26 857.80	3d^5	^{4}G	5/2	71 395.27	3d4^{4}s	^{4}D	1/2	5.95[+01]	7.09[+01]
225.19	55 677.70	3d^5	^{2}S	1/2	10 0085.20	3d4^{4}s	^{2}D	3/2	1.63[+01]	7.12[+00]
226.88	46 670.70	3d^5	^{2}H	11/2	90 746.06	3d4^{4}s	^{2}H	11/2	2.93[+01]	3.29[+01]
226.94	47 842.00	3d^5	^{2}G	7/2	91 906.10	3d4^{4}s	^{2}F	5/2	2.51[+01]	2.83[–02]
227.57	48 005.20	3d^5	^{2}G	9/2	91 948.30	3d4^{4}s	^{2}F	7/2	2.33[+01]	6.99[–02]
227.66	46 515.90	3d^5	^{2}H	9/2	90 440.50	3d4^{4}s	^{2}H	9/2	2.56[+01]	2.96[+01]
234.39	29 167.70	3d^5	^{4}P	5/2	71 831.98	3d4^{4}s	^{4}D	5/2	1.07[+01]	1.32[+01]
237.03	29 207.30	3d^5	^{4}P	3/2	71 395.27	3d4^{4}s	^{4}D	1/2	1.71[+01]	2.23[+01]
238.15	41 238.10	3d^5	^{2}D	5/2	83 229.00	3d^5	^{2}P	1/2	6.59[+00]	4.25[+01]
238.45	41 238.10	3d^5	^{2}D	5/2	83 176.00	3d^5	^{2}P	3/2	7.06[+00]	7.05[+00]
240.04	41 569.80	3d^5	^{2}D	3/2	83 229.00	3d^5	^{2}P	1/2	8.03[+00]	1.50[+01]
240.35	41 569.80	3d^5	^{2}D	3/2	83 176.00	3d^5	^{2}P	3/2	4.03[+00]	9.15[+00]
248.46	51 059.70	3d^5	^{2}F	7/2	91 308.30	3d4^{4}s	^{2}P	3/2	1.84[+01]	2.44[+01]
250.78	32 307.30	3d^5	^{4}D	7/2	72 183.33	3d4^{4}s	^{4}D	7/2	1.11[+01]	1.33[+01]
254.90	51 002.70	3d^5	^{2}F	5/2	90 233.50	3d4^{4}s	^{2}P	1/2	1.73[+01]	2.74[+01]
308.79	0.00	3d^5	^{6}S	5/2	32 384.70	3d^5	^{4}D	3/2	6.04[–03]	1.26[–02]
308.80	0.00	3d^5	^{6}S	5/2	32 383.70	3d^5	^{4}D	5/2	1.24[–02]	2.67[–02]
310.31	51 002.70	3d^5	^{2}F	5/2	83 229.00	3d^5	^{2}P	1/2	6.84[+00]	5.72[+00]
311.37	51 059.70	3d^5	^{2}F	7/2	83 176.00	3d^5	^{2}P	3/2	5.78[+00]	5.17[+00]
336.44	39 176.50	3d^5	^{2}I	13/2	68 899.20	3d^5	^{2}G	9/2	4.20[+00]	1.84[–01]
336.50	39 174.40	3d^5	^{2}I	11/2	68 892.00	3d^5	^{2}G	7/2	4.38[+00]	2.10[–01]
341.34	32 307.30	3d^5	^{4}D	7/2	61 603.80	3d^5	^{2}D	5/2	2.67[–01]	3.67[–01]
341.98	0.00	3d^5	^{6}S	5/2	29 241.40	3d^5	^{4}P	1/2	1.22[–06]	1.43[–05]
342.24	32 384.70	3d^5	^{4}D	3/2	61 603.80	3d^5	^{2}D	5/2	1.07[–01]	1.56[–01]
342.33	32 368.90	3d^5	^{4}D	1/2	61 580.20	3d^5	^{2}D	3/2	2.28[–01]	3.26[–01]
342.38	0.00	3d^5	^{6}S	5/2	29 207.30	3d^5	^{4}P	3/2	3.34[–01]	4.95[–01]
342.52	32 384.70	3d^5	^{4}D	3/2	61 580.20	3d^5	^{2}D	3/2	9.25[–02]	1.40[–01]
342.84	0.00	3d^5	^{6}S	5/2	29 167.70	3d^5	^{4}P	5/2	5.15[–01]	7.63[–01]
372.30	0.00	3d^5	^{6}S	5/2	26 859.90	3d^5	^{4}G	7/2	1.05[–08]	
372.33	0.00	3d^5	^{6}S	5/2	26 857.80	3d^5	^{4}G	5/2	9.51[–07]	7.59[–06]
372.42	0.00	3d^5	^{6}S	5/2	26 851.10	3d^5	^{4}G	9/2	1.03[–09]	
377.78	29 207.30	3d^5	^{4}P	3/2	55 677.70	3d^5	^{2}S	1/2	2.63[–01]	3.90[–01]
378.27	29 241.40	3d^5	^{4}P	1/2	55 677.70	3d^5	^{2}S	1/2	5.32[–02]	7.85[–02]
491.02	41 238.10	3d^5	^{2}D	5/2	61 603.80	3d^5	^{2}D	5/2	1.05[–01]	7.43[–02]
499.74	41 569.80	3d^5	^{2}D	3/2	61 580.20	3d^5	^{2}D	3/2	1.16[–01]	8.74[–02]
503.87	26 824.40	3d^5	^{4}G	11/2	46 670.70	3d^5	^{2}H	11/2	1.82[–01]	2.66[–01]
504.55	26 851.10	3d^5	^{4}G	9/2	46 670.70	3d^5	^{2}H	11/2	7.46[–02]	1.09[–01]
508.52	26 851.10	3d^5	^{4}G	9/2	46 515.90	3d^5	^{2}H	9/2	6.91[–02]	1.01[–01]
508.75	26 859.90	3d^5	^{4}G	7/2	46 515.90	3d^5	^{2}H	9/2	6.52[–02]	9.75[–02]
594.61	26 851.10	3d^5	^{4}G	9/2	43 668.84	3d^5	^{4}F	5/2	6.03[–02]	5.41[–02]
594.64	26 857.80	3d^5	^{4}G	5/2	43 674.70	3d^5	^{4}F	3/2	2.29[–01]	2.67[–01]
594.71	26 859.90	3d^5	^{4}G	7/2	43 674.70	3d^5	^{4}F	3/2	7.07[–02]	7.78[–02]
594.85	26 857.80	3d^5	^{4}G	5/2	43 668.84	3d^5	^{4}F	5/2	1.33[–01]	2.09[–01]
594.92	26 859.90	3d^5	^{4}G	7/2	43 668.84	3d^5	^{4}F	5/2	1.12[–01]	1.18[–01]
596.02	26 824.40	3d^5	^{4}G	11/2	43 602.50	3d^5	^{4}F	7/2	3.83[–02]	4.38[–02]
596.97	26 851.10	3d^5	^{4}G	9/2	43 602.50	3d^5	^{4}F	7/2	1.49[–01]	1.78[–01]
597.06	26 824.40	3d^5	^{4}G	11/2	43 573.16	3d^5	^{4}F	9/2	2.48[–01]	3.01[–01]
597.28	26 859.90	3d^5	^{4}G	7/2	43 602.50	3d^5	^{4}F	7/2	1.11[–01]	1.45[–01]
598.01	26 851.10	3d^5	^{4}G	9/2	43 573.16	3d^5	^{4}F	9/2	6.70[–02]	8.63[–02]
615.48	26 857.80	3d^5	^{4}G	5/2	43 105.40	3d^5	^{2}F	5/2	8.69[–02]	7.25[–02]
615.56	26 859.90	3d^5	^{4}G	7/2	43 105.40	3d^5	^{2}F	5/2	1.74[–01]	2.43[–01]
634.70	26 851.10	3d^5	^{4}G	9/2	42 606.50	3d^5	^{2}F	7/2	1.88[–01]	2.73[–01]
635.06	26 859.90	3d^5	^{4}G	7/2	42 606.50	3d^5	^{2}F	7/2	3.05[–02]	4.00[–02]
695.40	26 857.80	3d^5	^{4}G	5/2	41 238.10	3d^5	^{2}D	5/2	4.52[–02]	8.21[–02]
695.50	26 859.90	3d^5	^{4}G	7/2	41 238.10	3d^5	^{2}D	5/2	4.52[–02]	8.10[–02]
717.48	29 167.70	3d^5	^{4}P	5/2	43 105.40	3d^5	^{2}F	5/2	3.86[–02]	4.40[–02]
727.90	47 842.00	3d^5	^{2}G	7/2	61 580.20	3d^5	^{2}D	3/2	7.64[–02]	2.87[–03]
806.32	29 167.70	3d^5	^{4}P	5/2	41 569.80	3d^5	^{2}D	3/2	2.59[–02]	3.36[–02]
808.90	29 207.30	3d^5	^{4}P	3/2	41 569.80	3d^5	^{2}D	3/2	9.51[–02]	1.34[–01]

Table A.14. continued.

λ (nm)	Lower level				Upper level				A(M1+E2) (s^{-1})	
	E (cm^{-1})	Config.	Term	J	E (cm^{-1})	Config.	Term	J	HFR	AUTOS
809.58	26 824.40	3d^5	^{4}G	11/2	39 176.50	3d^5	^{2}I	13/2	4.00[–05]	1.28[–04]
809.72	26 824.40	3d^5	^{4}G	11/2	39 174.40	3d^5	^{2}I	11/2	1.17[–03]	3.28[–03]
811.14	29 241.40	3d^5	^{4}P	1/2	41 569.80	3d^5	^{2}D	3/2	2.44[–02]	3.56[–02]
811.47	26 851.10	3d^5	^{4}G	9/2	39 174.40	3d^5	^{2}I	11/2	3.71[–04]	1.01[–03]
828.47	29 167.70	3d^5	^{4}P	5/2	41 238.10	3d^5	^{2}D	5/2	2.03[–01]	2.85[–01]
831.20	29 207.30	3d^5	^{4}P	3/2	41 238.10	3d^5	^{2}D	5/2	3.89[–02]	5.67[–02]
885.33	32 307.30	3d^5	^{4}D	7/2	43 602.50	3d^5	^{4}F	7/2	4.28[–02]	6.56[–02]
885.74	32 384.70	3d^5	^{4}D	3/2	43 674.70	3d^5	^{4}F	3/2	6.84[–02]	9.32[–02]
886.12	32 383.70	3d^5	^{4}D	5/2	43 668.84	3d^5	^{4}F	5/2	7.06[–02]	1.05[–01]
887.64	32 307.30	3d^5	^{4}D	7/2	43 573.16	3d^5	^{4}F	9/2	6.71[–02]	9.39[–02]
970.95	32 307.30	3d^5	^{4}D	7/2	42 606.50	3d^5	^{2}F	7/2	3.46[–02]	4.65[–02]
1191.01	42 606.50	3d^5	^{2}F	7/2	51 002.70	3d^5	^{2}F	5/2	1.72[–02]	1.13[–02]
1257.18	43 105.40	3d^5	^{2}F	5/2	51 059.70	3d^5	^{2}F	7/2	1.58[–02]	1.79[–02]
1333.99	39 174.40	3d^5	^{2}I	11/2	46 670.70	3d^5	^{2}H	11/2	6.37[–02]	9.50[–02]
1335.73	43 573.16	3d^5	^{4}F	9/2	51 059.70	3d^5	^{2}F	7/2	4.42[–02]	6.61[–02]
1351.31	43 602.50	3d^5	^{4}F	7/2	51 002.70	3d^5	^{2}F	5/2	1.10[–02]	1.35[–02]
1353.02	43 668.84	3d^5	^{4}F	5/2	51 059.70	3d^5	^{2}F	7/2	1.28[–02]	1.32[–02]
1362.12	39 174.40	3d^5	^{2}I	11/2	46 515.90	3d^5	^{2}H	9/2	3.06[–02]	4.87[–02]
1364.63	43 674.70	3d^5	^{4}F	3/2	51 002.70	3d^5	^{2}F	5/2	3.89[–02]	5.00[–02]
1910.04	42 606.50	3d^5	^{2}F	7/2	47 842.00	3d^5	^{2}G	7/2	1.09[–02]	3.32[–03]
2111.22	43 105.40	3d^5	^{2}F	5/2	47 842.00	3d^5	^{2}G	7/2	4.87[–03]	2.51[–03]
2256.30	43 573.16	3d^5	^{4}F	9/2	48 005.20	3d^5	^{2}G	9/2	2.36[–02]	1.31[–03]
2271.33	43 602.50	3d^5	^{4}F	7/2	48 005.20	3d^5	^{2}G	9/2	9.57[–03]	2.85[–04]
2358.77	43 602.50	3d^5	^{4}F	7/2	47 842.00	3d^5	^{2}G	7/2	8.40[–03]	1.43[–03]
2396.27	43 668.84	3d^5	^{4}F	5/2	47 842.00	3d^5	^{2}G	7/2	5.87[–03]	7.44[–04]
3108.49	29 167.70	3d^5	^{4}P	5/2	32 384.70	3d^5	^{4}D	3/2	7.66[–03]	1.21[–02]
3109.45	29 167.70	3d^5	^{4}P	5/2	32 383.70	3d^5	^{4}D	5/2	9.16[–03]	1.42[–02]
3147.23	29 207.30	3d^5	^{4}P	3/2	32 384.70	3d^5	^{4}D	3/2	1.61[–02]	2.46[–02]
3162.96	29 207.30	3d^5	^{4}P	3/2	32 368.90	3d^5	^{4}D	1/2	1.52[–02]	2.37[–02]
3185.12	29 167.70	3d^5	^{4}P	5/2	32 307.30	3d^5	^{4}D	7/2	1.64[–02]	2.55[–02]
3197.44	29 241.40	3d^5	^{4}P	1/2	32 368.90	3d^5	^{4}D	1/2	2.49[–02]	3.75[–02]
29 3255.13	29 207.30	3d^5	^{4}P	3/2	29 241.40	3d^5	^{4}P	1/2	1.80[–06]	1.79[–06]
37 4531.84	26 824.40	3d^5	^{4}G	11/2	26 851.10	3d^5	^{4}G	9/2	2.48[–09]	6.71[–07]

Table A.15. Comparison of total (M1+E2) transition probabilities from our calculations (HFR and AUTOS) and previous works in Fe III. A[B] denotes $A \times 10^B$.

λ (nm)	Lower level				Upper level				A(M1+E2) (s^{-1})	
	E (cm^{-1})	Config.	Term	J	E (cm^{-1})	Config.	Term	J	HFR	AUTOS
143.19	0.00	3d^{5}4s	^{5}D	4	69 836.89	3d^{5}4s	^{5}D	3	4.66[+01]	3.62[+01]
143.48	0.00	3d^{5}4s	^{5}D	4	69 695.89	3d^{5}4s	^{5}D	4	9.43[+01]	7.35[+01]
144.09	435.80	3d^{5}4s	^{5}D	3	69 837.89	3d^{5}4s	^{5}D	2	7.09[+01]	5.54[+01]
144.09	435.80	3d^{5}4s	^{5}D	3	69 836.89	3d^{5}4s	^{5}D	3	1.94[+01]	1.47[+01]
144.19	435.80	3d^6	^{5}D	3	69 788.23	3d^{5}4s	^{5}D	1	4.36[+01]	3.44[+01]
144.38	435.80	3d^{5}4s	^{5}D	3	69 695.89	3d^{5}4s	^{5}D	4	5.14[+01]	4.22[+01]
144.72	738.55	3d^{5}4s	^{5}D	2	69 836.89	3d^{5}4s	^{5}D	3	6.17[+01]	5.00[+01]
144.82	738.55	3d^6	^{5}D	2	69 788.23	3d^{5}4s	^{5}D	1	5.21[+01]	4.10[+01]
144.91	738.55	3d^{5}4s	^{5}D	2	69 747.69	3d^{5}4s	^{5}D	0	1.50[+02]	1.20[+02]
145.13	932.06	3d^{5}4s	^{5}D	1	69 837.89	3d^{5}4s	^{5}D	2	3.46[+01]	2.78[+01]
145.13	932.06	3d^{5}4s	^{5}D	1	69 836.89	3d^{5}4s	^{5}D	3	2.62[+01]	2.21[+01]
145.23	932.06	3d^6	^{5}D	1	69 788.23	3d^{5}4s	^{5}D	1	5.52[+01]	4.52[+01]
145.33	1027.00	3d^{5}4s	^{5}D	0	69 837.89	3d^{5}4s	^{5}D	2	3.53[+01]	2.92[+01]
150.32	0.00	3d^{5}4s	^{5}D	4	66 523.02	3d^{5}4s	^{5}P	2	7.09[+01]	5.78[+01]
150.46	0.00	3d^{5}4s	^{5}D	4	66 464.80	3d^{5}4s	^{5}P	3	7.96[+01]	6.51[+01]
151.16	435.80	3d^6	^{5}D	3	66 591.78	3d^{5}4s	^{5}P	1	8.70[+01]	7.14[+01]
151.45	435.80	3d^{5}4s	^{5}D	3	66 464.80	3d^{5}4s	^{5}P	3	3.75[+01]	3.12[+01]
151.85	738.55	3d^6	^{5}D	2	66 591.78	3d^{5}4s	^{5}P	1	3.43[+01]	2.84[+01]
152.01	738.55	3d^{5}4s	^{5}D	2	66 523.02	3d^{5}4s	^{5}P	2	2.33[+01]	1.94[+01]
152.46	932.06	3d^{5}4s	^{5}D	1	66 523.02	3d^{5}4s	^{5}P	2	2.27[+01]	1.89[+01]
157.56	0.00	3d^{5}4s	^{5}D	4	63 466.67	3d^{5}4s	^{5}G	5	2.73[+01]	2.27[+01]
157.67	0.00	3d^{5}4s	^{5}D	4	63 425.49	3d^{5}4s	^{5}G	6	1.02[+02]	8.66[+01]
158.58	435.80	3d^{5}4s	^{5}D	3	63 494.38	3d^{5}4s	^{5}G	3	1.15[+01]	9.50[+00]

Table A.15. continued.

λ (nm)	Lower level				Upper level				A(M1+E2) (s^{-1})	
	E (cm^{-1})	Config.	Term	J	E (cm^{-1})	Config.	Term	J	HFR	AUTOS
158.60	435.80	$3d^54s$	^5D	3	63 487.08	$3d^54s$	^5G	4	4.00[+01]	3.36[+01]
158.65	435.80	$3d^54s$	^5D	3	63 466.67	$3d^54s$	^5G	5	7.25[+01]	6.20[+01]
159.35	738.55	$3d^54s$	^5D	2	63 494.58	$3d^54s$	^5G	2	1.48[+01]	1.24[+01]
159.35	738.55	$3d^54s$	^5D	2	63 494.38	$3d^54s$	^5G	3	4.48[+01]	3.79[+01]
159.37	738.55	$3d^54s$	^5D	2	63 487.08	$3d^54s$	^5G	4	5.26[+01]	4.52[+01]
159.84	932.06	$3d^54s$	^5D	1	63 494.58	$3d^54s$	^5G	2	4.57[+01]	3.88[+01]
159.84	932.06	$3d^54s$	^5D	1	63 494.38	$3d^54s$	^5G	3	3.96[+01]	3.40[+01]
160.08	1027.00	$3d^54s$	^5D	0	63 494.58	$3d^54s$	^5G	2	3.34[+01]	2.85[+01]
167.25	20 051.10	$3d^54s$	^3H	6	79 840.19	$3d^54s$	^3I	7	1.05[+02]	9.06[+01]
167.94	20 300.32	$3d^54s$	^3H	5	79 844.83	$3d^54s$	^3I	6	8.51[+01]	7.47[+01]
168.41	20 481.58	$3d^54s$	^3H	4	79 860.50	$3d^54s$	^3I	5	8.54[+01]	7.45[+01]
173.75	19 404.19	$3d^54s$	^3P	2	76 956.76	$3d^54s$	^3D	3	3.35[+01]	3.14[+01]
174.56	20 687.78	$3d^6$	^3P	1	77 975.30	$3d^54s$	^3D	1	4.87[+01]	4.32[+01]
178.91	21 207.76	$3d^54s$	^3P	0	77 102.41	$3d^54s$	^3D	2	1.98[+01]	1.95[+01]
180.20	21 461.67	$3d^54s$	^3F	4	76 956.76	$3d^54s$	^3D	3	3.25[+01]	3.04[+01]
180.89	24 558.25	$3d^54s$	^3G	5	79 840.19	$3d^54s$	^3I	7	2.96[+01]	2.63[+01]
182.14	24 940.95	$3d^54s$	^3G	4	79 844.83	$3d^54s$	^3I	6	2.62[+01]	2.33[+01]
182.75	25 142.00	$3d^54s$	^3G	3	79 860.50	$3d^54s$	^3I	5	2.81[+01]	2.50[+01]
183.38	19 404.19	$3d^54s$	^3P	2	73 936.03	$3d^54s$	^3P	0	6.92[+01]	6.29[+01]
183.67	19 404.19	$3d^6$	^3P	2	73 849.13	$3d^54s$	^3P	1	6.16[+01]	5.55[+01]
184.08	19 404.19	$3d^54s$	^3P	2	73 727.79	$3d^54s$	^3P	2	4.03[+01]	3.60[+01]
188.54	20 687.78	$3d^54s$	^3P	1	73 727.79	$3d^54s$	^3P	2	2.33[+01]	2.24[+01]
189.27	25 142.00	$3d^6$	^3G	3	77 975.30	$3d^54s$	^3D	1	8.75[+01]	7.40[+01]
190.85	24 558.25	$3d^54s$	^3G	5	76 956.76	$3d^54s$	^3D	3	6.56[+01]	6.00[+01]
191.33	21 461.67	$3d^54s$	^3F	4	73 727.79	$3d^54s$	^3P	2	7.08[+01]	6.28[+01]
191.71	24 940.95	$3d^54s$	^3G	4	77 102.41	$3d^54s$	^3D	2	6.71[+01]	6.17[+01]
191.76	21 699.44	$3d^6$	^3F	3	73 849.13	$3d^54s$	^3P	1	6.31[+01]	5.61[+01]
192.01	21 856.76	$3d^54s$	^3F	2	73 936.03	$3d^54s$	^3P	0	9.92[+01]	9.00[+01]
192.20	21 699.44	$3d^54s$	^3F	3	73 727.79	$3d^54s$	^3P	2	2.30[+01]	2.25[+01]
192.34	21 856.76	$3d^6$	^3F	2	73 849.13	$3d^54s$	^3P	1	3.68[+01]	3.51[+01]
197.46	20 051.10	$3d^54s$	^3H	6	70 694.17	$3d^54s$	^3G	5	8.58[+01]	7.88[+01]
198.30	20 300.32	$3d^54s$	^3H	5	70 728.93	$3d^54s$	^3G	4	7.94[+01]	7.32[+01]
199.03	20 481.58	$3d^54s$	^3H	4	70 725.22	$3d^54s$	^3G	3	8.69[+01]	8.00[+01]
203.12	21 461.67	$3d^54s$	^3F	4	70 694.17	$3d^54s$	^3G	5	2.10[+01]	2.02[+01]
203.96	21 699.44	$3d^54s$	^3F	3	70 728.93	$3d^54s$	^3G	4	1.61[+01]	1.59[+01]
204.63	21 856.76	$3d^54s$	^3F	2	70 725.22	$3d^54s$	^3G	3	2.13[+01]	2.09[+01]
211.60	30 715.68	$3d^6$	^3D	2	77 975.30	$3d^54s$	^3D	1	2.13[+01]	1.82[+01]
216.64	30 886.01	$3d^54s$	^1G	4	77 044.53	$3d^54s$	^1D	2	1.57[+01]	1.71[+01]
216.75	24 558.25	$3d^54s$	^3G	5	70 694.17	$3d^54s$	^3G	5	2.53[+01]	2.41[+01]
216.92	30 857.32	$3d^54s$	^3D	3	76 956.76	$3d^54s$	^3D	3	2.24[+01]	2.10[+01]
218.40	24 940.95	$3d^54s$	^3G	4	70 728.93	$3d^54s$	^3G	4	1.62[+01]	1.55[+01]
219.38	25 142.00	$3d^54s$	^3G	3	70 725.22	$3d^54s$	^3G	3	1.61[+01]	1.54[+01]
242.47	35 802.99	$3d^54s$	^1D	2	77 044.53	$3d^54s$	^1D	2	6.07[+00]	4.96[+00]
243.90	0.00	$3d^54s$	^5D	4	41 000.09	$3d^54s$	^5S	2	3.20[+01]	3.16[+01]
246.52	435.80	$3d^54s$	^5D	3	41 000.09	$3d^54s$	^5S	2	2.33[+01]	2.31[+01]
248.38	738.55	$3d^54s$	^5D	2	41 000.09	$3d^54s$	^5S	2	1.59[+01]	1.58[+01]
249.58	932.06	$3d^54s$	^5D	1	41 000.09	$3d^54s$	^5S	2	9.29[+00]	9.22[+00]
322.50	19 404.19	$3d^54s$	^3P	2	50 411.69	$3d^54s$	^3P	2	4.85[–01]	4.79[–01]
324.07	0.00	$3d^54s$	^5D	4	30 857.32	$3d^54s$	^3D	3	1.86[–01]	2.59[–01]
328.71	435.80	$3d^54s$	^5D	3	30 857.32	$3d^54s$	^3D	3	6.73[–02]	7.35[–02]
330.85	20 051.10	$3d^54s$	^3H	6	50 275.84	$3d^54s$	^3F	4	1.95[+00]	1.90[+00]
331.43	19 404.19	$3d^6$	^3P	2	49 576.82	$3d^54s$	^3P	1	1.13[+00]	1.11[+00]
332.02	738.55	$3d^54s$	^5D	2	30 857.32	$3d^54s$	^3D	3	6.70[–02]	5.25[–02]
332.34	0.00	$3d^54s$	^5D	4	30 089.42	$3d^54s$	^7S	3	8.83[–04]	7.58[–04]
333.39	20 300.32	$3d^54s$	^3H	5	50 294.89	$3d^54s$	^3F	3	1.92[+00]	1.87[+00]
333.59	738.55	$3d^54s$	^5D	2	30 715.68	$3d^54s$	^3D	2	1.14[–01]	1.24[–01]
335.65	932.06	$3d^6$	^5D	1	30 725.34	$3d^54s$	^3D	1	1.49[–01]	1.61[–01]
335.76	932.06	$3d^54s$	^5D	1	30 715.68	$3d^54s$	^3D	2	1.61[–01]	1.05[–01]
336.19	19 404.19	$3d^54s$	^3P	2	49 149.27	$3d^54s$	^3P	0	1.52[+00]	1.54[+00]
336.43	20 687.78	$3d^54s$	^3P	1	50 411.69	$3d^54s$	^3P	2	5.90[–01]	5.72[–01]
336.67	20 481.58	$3d^54s$	^3H	4	50 184.65	$3d^54s$	^3F	2	1.99[+00]	1.91[+00]
336.72	1027.00	$3d^6$	^5D	0	30 725.34	$3d^54s$	^3D	1	3.93[–01]	1.41[–01]
337.23	435.80	$3d^54s$	^5D	3	30 089.42	$3d^54s$	^7S	3	6.58[–04]	5.60[–04]

Table A.15. continued.

λ (nm)	Lower level				Upper level				A(M1+E2) (s^{-1})	
	E (cm^{-1})	Config.	Term	J	E (cm^{-1})	Config.	Term	J	HFR	AUTOS
340.71	738.55	3d^{5}4s	^{5}D	2	30 089.42	3d^{5}4s	^{7}S	3	2.88[–04]	2.43[–04]
346.15	20 687.78	3d^6	^{3}P	1	49 576.82	3d^{5}4s	^{3}P	1	3.39[–01]	3.38[–01]
347.05	21 461.67	3d^{5}4s	^{3}F	4	50 275.84	3d^{5}4s	^{3}F	4	8.81[–01]	8.83[–01]
349.71	21 699.44	3d^{5}4s	^{3}F	3	50 294.89	3d^{5}4s	^{3}F	3	6.03[–01]	6.08[–01]
353.01	21 856.76	3d^{5}4s	^{3}F	2	50 184.65	3d^{5}4s	^{3}F	2	6.17[–01]	6.22[–01]
372.22	30 355.52	3d^{5}4s	^{1}I	6	57 221.01	3d^{5}4s	^{1}G	4	2.05[+00]	1.99[+00]
388.84	24 558.25	3d^{5}4s	^{3}G	5	50 275.84	3d^{5}4s	^{3}F	4	8.68[–01]	8.91[–01]
394.42	24 940.95	3d^{5}4s	^{3}G	4	50 294.89	3d^{5}4s	^{3}F	3	6.93[–01]	6.88[–01]
399.32	25 142.00	3d^{5}4s	^{3}G	3	50 184.65	3d^{5}4s	^{3}F	2	7.83[–01]	8.06[–01]
400.95	0.00	3d^{5}4s	^{5}D	4	24 940.95	3d^{5}4s	^{3}G	4	1.14[–02]	1.12[–02]
465.95	0.00	3d^{5}4s	^{5}D	4	21 461.67	3d^{5}4s	^{3}F	4	4.98[–01]	5.19[–01]
470.29	435.80	3d^{5}4s	^{5}D	3	21 699.44	3d^{5}4s	^{3}F	3	2.74[–01]	2.80[–01]
473.52	738.55	3d^{5}4s	^{5}D	2	21 856.76	3d^{5}4s	^{3}F	2	1.09[–01]	1.10[–01]
475.60	435.80	3d^{5}4s	^{5}D	3	21 461.67	3d^{5}4s	^{3}F	4	1.19[–01]	9.82[–02]
477.08	738.55	3d^{5}4s	^{5}D	2	21 699.44	3d^{5}4s	^{3}F	3	1.33[–01]	9.74[–02]
477.90	932.06	3d^{5}4s	^{5}D	1	21 856.76	3d^{5}4s	^{3}F	2	8.81[–02]	5.34[–02]
488.24	0.00	3d^{5}4s	^{5}D	4	20 481.58	3d^{5}4s	^{3}H	4	8.47[–03]	1.16[–02]
493.20	932.06	3d^{5}4s	^{5}D	1	21 207.76	3d^{5}4s	^{3}P	0	2.63[–01]	8.23[–01]
498.73	0.00	3d^{5}4s	^{5}D	4	20 051.10	3d^{5}4s	^{3}H	6	9.93[–06]	1.12[–05]
498.86	435.80	3d^{5}4s	^{5}D	3	20 481.58	3d^{5}4s	^{3}H	4	1.92[–03]	2.06[–03]
501.27	738.55	3d^6	^{5}D	2	20 687.78	3d^{5}4s	^{3}P	1	3.68[–01]	6.39[–01]
508.63	1027.00	3d^6	^{5}D	0	20 687.78	3d^{5}4s	^{3}P	1	3.17[–01]	1.13[–01]
511.39	30 857.32	3d^{5}4s	^{3}D	3	50 411.69	3d^{5}4s	^{3}P	2	3.16[–01]	3.40[–01]
527.19	435.80	3d^{5}4s	^{5}D	3	19 404.19	3d^{5}4s	^{3}P	2	3.40[–01]	5.05[–01]
541.36	932.06	3d^{5}4s	^{5}D	1	19 404.19	3d^{5}4s	^{3}P	2	7.54[–02]	4.97[–02]
542.49	30 715.68	3d^{5}4s	^{3}D	2	49 149.27	3d^{5}4s	^{3}P	0	3.52[–01]	3.51[–01]
556.92	24 940.95	3d^{5}4s	^{3}G	4	42 896.90	3d^{5}4s	^{1}F	3	8.44[–02]	1.20[–01]
563.22	25 142.00	3d^{5}4s	^{3}G	3	42 896.90	3d^{5}4s	^{1}F	3	5.46[–02]	6.07[–02]
609.80	19 404.19	3d^{5}4s	^{3}P	2	35 802.99	3d^{5}4s	^{1}D	2	1.01[–01]	9.61[–02]
661.59	20 687.78	3d^{5}4s	^{3}P	1	35 802.99	3d^{5}4s	^{1}D	2	6.10[–02]	3.46[–02]
677.27	34 811.74	3d^6	^{1}S	0	49 576.82	3d^{5}4s	^{3}P	1	3.06[–01]	9.58[–02]
708.02	20 687.78	3d^{5}4s	^{3}P	1	34 811.74	3d^{5}4s	^{1}S	0	4.12[–01]	1.39[+00]
709.04	21 699.44	3d^{5}4s	^{3}F	3	35 802.99	3d^{5}4s	^{1}D	2	1.86[–01]	2.70[–01]
717.04	21 856.76	3d^{5}4s	^{3}F	2	35 802.99	3d^{5}4s	^{1}D	2	1.40[–01]	1.46[–01]
820.94	30 715.68	3d^{5}4s	^{3}D	2	42 896.90	3d^{5}4s	^{1}F	3	5.49[–02]	4.27[–02]
830.59	30 857.32	3d^{5}4s	^{3}D	3	42 896.90	3d^{5}4s	^{1}F	3	6.76[–02]	7.36[–02]
873.12	19 404.19	3d^{5}4s	^{3}P	2	30 857.32	3d^{5}4s	^{3}D	3	7.13[–02]	5.81[–02]
884.06	19 404.19	3d^{5}4s	^{3}P	2	30 715.68	3d^{5}4s	^{3}D	2	5.80[–02]	6.47[–02]
944.67	20 300.32	3d^{5}4s	^{3}H	5	30 886.01	3d^{5}4s	^{1}G	4	1.61[–01]	2.09[–01]
961.13	20 481.58	3d^{5}4s	^{3}H	4	30 886.01	3d^{5}4s	^{1}G	4	7.54[–02]	7.51[–02]
970.46	20 051.10	3d^{5}4s	^{3}H	6	30 355.52	3d^{5}4s	^{1}I	6	9.42[–02]	9.96[–02]
994.51	20 300.32	3d^{5}4s	^{3}H	5	30 355.52	3d^{5}4s	^{1}I	6	7.30[–02]	6.52[–02]
1061.08	21 461.67	3d^{5}4s	^{3}F	4	30 886.01	3d^{5}4s	^{1}G	4	2.21[–01]	2.38[–01]
1088.55	21 699.44	3d^{5}4s	^{3}F	3	30 886.01	3d^{5}4s	^{1}G	4	1.42[–01]	1.17[–01]
1969.41	30 725.34	3d^{5}4s	^{3}D	1	35 802.99	3d^{5}4s	^{1}D	2	7.37[–02]	4.12[–02]
2145.73	20 481.58	3d^{5}4s	^{3}H	4	25 142.00	3d^{5}4s	^{3}G	3	3.15[–02]	4.40[–02]
2218.70	20 051.10	3d^{5}4s	^{3}H	6	24 558.25	3d^{5}4s	^{3}G	5	3.19[–02]	4.11[–02]
2242.47	20 481.58	3d^{5}4s	^{3}H	4	24 940.95	3d^{5}4s	^{3}G	4	2.24[–02]	2.28[–02]
2348.56	20 300.32	3d^{5}4s	^{3}H	5	24 558.25	3d^{5}4s	^{3}G	5	2.65[–02]	2.88[–02]
2874.16	21 461.67	3d^{5}4s	^{3}F	4	24 940.95	3d^{5}4s	^{3}G	4	2.98[–02]	3.27[–02]
2904.82	21 699.44	3d^{5}4s	^{3}F	3	25 142.00	3d^{5}4s	^{3}G	3	3.09[–02]	3.30[–02]
3043.92	21 856.76	3d^{5}4s	^{3}F	2	25 142.00	3d^{5}4s	^{3}G	3	2.74[–02]	2.10[–02]
3229.37	21 461.67	3d^{5}4s	^{3}F	4	24 558.25	3d^{5}4s	^{3}G	5	2.22[–02]	1.97[–02]
22 946.31	0.00	3d^{5}4s	^{5}D	4	435.80	3d^{5}4s	^{5}D	3	2.25[–03]	2.88[–03]
33 030.55	435.80	3d^{5}4s	^{5}D	3	738.55	3d^{5}4s	^{5}D	2	1.29[–03]	1.79[–03]
40 125.19	20 051.10	3d^{5}4s	^{3}H	6	20 300.32	3d^{5}4s	^{3}H	5	3.45[–04]	4.06[–04]
51 676.92	738.55	3d^6	^{5}D	2	932.06	3d^{5}4s	^{5}D	1	4.11[–04]	6.83[–04]
10 5329.68	932.06	3d^{5}4s	^{5}D	1	1027.00	3d^{5}4s	^{5}D	0	4.62[–05]	1.38[–04]

Table A.16. Comparison of total (M1+E2) transition probabilities from our calculations (HFR and AUTOS) and previous works in Co III. A[B] denotes $A \times 10^B$.

λ (nm)	Lower level				Upper level				A(M1+E2) (s^{-1})		
	E (cm^{-1})	Config.	Term	J	E (cm^{-1})	Config.	Term	J	HFR	AUTOS	Previous[a]
119.13	0.00	$3d^7$	^4F	9/2	83 938.90	$3d^64s$	^4D	7/2	6.57[+01]	5.34[+01]	
119.33	0.00	$3d^7$	^4F	9/2	83 799.60	$3d^64s$	^4D	5/2	1.86[+01]	1.53[+01]	
120.34	841.20	$3d^7$	^4F	7/2	83 938.90	$3d^64s$	^4D	7/2	2.28[+01]	1.88[+01]	
120.54	841.20	$3d^7$	^4F	7/2	83 799.60	$3d^64s$	^4D	5/2	3.62[+01]	2.91[+01]	
120.58	841.20	$3d^7$	^4F	7/2	83 773.40	$3d^64s$	^4D	3/2	3.51[+01]	2.87[+01]	
121.44	1451.30	$3d^7$	^4F	5/2	83 799.60	$3d^64s$	^4D	5/2	3.33[+01]	2.74[+01]	
121.45	1451.30	$3d^7$	^4F	5/2	83 789.30	$3d^64s$	^4D	1/2	5.34[+01]	4.36[+01]	
121.47	1451.30	$3d^7$	^4F	5/2	83 773.40	$3d^64s$	^4D	3/2	2.11[+01]	1.69[+01]	
122.07	1866.80	$3d^7$	^4F	3/2	83 789.30	$3d^64s$	^4D	1/2	4.22[+01]	3.44[+01]	
122.09	1866.80	$3d^7$	^4F	3/2	83 773.40	$3d^64s$	^4D	3/2	3.94[+01]	3.26[+01]	
129.18	0.00	$3d^7$	^4F	9/2	77 411.60	$3d^64s$	^2H	11/2	2.95[+01]	2.42[+01]	
129.67	0.00	$3d^7$	^4F	9/2	77 121.10	$3d^64s$	^4G	9/2	2.21[+01]	1.96[+01]	
130.65	841.20	$3d^7$	^4F	7/2	77 383.10	$3d^64s$	^4G	7/2	4.51[+01]	3.90[+01]	
130.69	0.00	$3d^7$	^4F	9/2	76 518.90	$3d^64s$	^4G	11/2	1.40[+02]	1.17[+02]	
131.10	841.20	$3d^7$	^4F	7/2	77 121.10	$3d^64s$	^4G	9/2	1.11[+02]	9.10[+01]	
131.54	1451.30	$3d^7$	^4F	5/2	77 472.30	$3d^64s$	^4G	5/2	5.64[+01]	4.80[+01]	
131.70	1451.30	$3d^7$	^4F	5/2	77 383.10	$3d^64s$	^4G	7/2	9.77[+01]	8.04[+01]	
132.14	841.20	$3d^7$	^4F	7/2	76 518.90	$3d^64s$	^4G	11/2	3.46[+01]	2.82[+01]	
132.15	1451.30	$3d^7$	^4F	5/2	77 121.10	$3d^64s$	^4G	9/2	5.62[+01]	4.52[+01]	
132.27	1866.80	$3d^7$	^4F	3/2	77 472.30	$3d^64s$	^4G	5/2	1.37[+02]	1.13[+02]	
132.42	1866.80	$3d^7$	^4F	3/2	77 383.10	$3d^64s$	^4G	7/2	5.56[+01]	4.55[+01]	
135.98	0.00	$3d^7$	^4F	9/2	73 540.20	$3d^64s$	^4F	7/2	3.10[+01]	2.50[+01]	
136.45	0.00	$3d^7$	^4F	9/2	73 286.00	$3d^64s$	^4F	9/2	1.04[+02]	8.39[+01]	
137.20	841.20	$3d^7$	^4F	7/2	73 726.60	$3d^64s$	^4F	5/2	4.59[+01]	3.71[+01]	
137.55	841.20	$3d^7$	^4F	7/2	73 540.20	$3d^64s$	^4F	7/2	6.22[+01]	4.96[+01]	
138.04	841.20	$3d^7$	^4F	7/2	73 286.00	$3d^64s$	^4F	9/2	1.56[+01]	1.34[+01]	
138.10	1451.30	$3d^7$	^4F	5/2	73 861.80	$3d^64s$	^4F	3/2	4.75[+01]	3.88[+01]	
138.36	1451.30	$3d^7$	^4F	5/2	73 726.60	$3d^64s$	^4F	5/2	4.25[+01]	3.38[+01]	
138.72	1451.30	$3d^7$	^4F	5/2	73 540.20	$3d^64s$	^4F	7/2	2.24[+01]	1.90[+01]	
138.90	1866.80	$3d^7$	^4F	3/2	73 861.80	$3d^64s$	^4F	3/2	5.32[+01]	4.32[+01]	
139.13	0.00	$3d^7$	^4F	9/2	71 873.70	$3d^64s$	^4H	11/2	3.66[+01]	3.04[+01]	
139.16	1866.80	$3d^7$	^4F	3/2	73 726.60	$3d^64s$	^4F	5/2	1.93[+01]	1.65[+01]	
139.35	1451.30	$3d^7$	^4F	5/2	73 214.50	$3d^64s$	^4P	1/2	6.46[+01]	5.42[+01]	
139.62	0.00	$3d^7$	^4F	9/2	71 623.10	$3d^64s$	^4H	13/5	1.61[+02]	1.37[+02]	
139.86	841.20	$3d^7$	^4F	7/2	72 341.90	$3d^64s$	^4P	3/2	7.99[+01]	6.72[+01]	
140.16	1866.80	$3d^7$	^4F	3/2	73 214.50	$3d^64s$	^4P	1/2	9.38[+01]	7.90[+01]	
140.37	841.20	$3d^7$	^4F	7/2	72 083.30	$3d^64s$	^4H	9/2	4.12[+01]	3.45[+01]	
140.78	841.20	$3d^7$	^4F	7/2	71 873.70	$3d^64s$	^4H	11/2	1.20[+02]	1.03[+02]	
140.98	0.00	$3d^7$	^4F	9/2	70 934.10	$3d^64s$	^4P	5/2	1.05[+02]	8.88[+01]	
141.06	1451.30	$3d^7$	^4F	5/2	72 341.90	$3d^64s$	^4P	3/2	5.56[+01]	4.69[+01]	
141.20	1451.30	$3d^7$	^4F	5/2	72 270.50	$3d^64s$	^4H	7/2	3.50[+01]	2.96[+01]	
141.58	1451.30	$3d^7$	^4F	5/2	72 083.30	$3d^64s$	^4H	9/2	1.02[+02]	8.78[+01]	
141.89	1866.80	$3d^7$	^4F	3/2	72 341.90	$3d^64s$	^4P	3/2	1.75[+01]	1.49[+01]	
142.04	1866.80	$3d^7$	^4F	3/2	72 270.50	$3d^64s$	^4H	7/2	1.05[+02]	9.01[+01]	
142.67	841.20	$3d^7$	^4F	7/2	70 934.10	$3d^64s$	^4P	5/2	3.52[+01]	2.96[+01]	
144.29	16 977.60	$3d^7$	^2G	9/2	86 283.80	$3d^64s$	^2G	9/2	1.40[+02]	1.20[+02]	
145.48	15 201.90	$3d^7$	^4P	5/2	83 938.90	$3d^64s$	^4D	7/2	5.75[+01]	4.63[+01]	
145.78	15 201.90	$3d^7$	^4P	5/2	83 799.60	$3d^64s$	^4D	5/2	5.46[+01]	4.39[+01]	
145.83	15 201.90	$3d^7$	^4P	5/2	83 773.40	$3d^64s$	^4D	3/2	3.11[+01]	2.48[+01]	
145.86	17 766.20	$3d^7$	^2G	7/2	86 327.10	$3d^64s$	^2G	7/2	1.68[+02]	1.45[+02]	
145.96	15 428.20	$3d^7$	^4P	3/2	83 938.90	$3d^64s$	^4D	7/2	3.09[+01]	2.56[+01]	
145.99	16 977.60	$3d^7$	^2G	9/2	85 474.10	$3d^64s$	^2I	13/5	8.48[+01]	7.38[+01]	
146.28	15 428.20	$3d^7$	^4P	3/2	83 789.30	$3d^64s$	^4D	1/2	6.73[+01]	5.47[+01]	
146.32	15 428.20	$3d^7$	^4P	3/2	83 773.40	$3d^64s$	^4D	3/2	3.23[+01]	2.62[+01]	
147.08	15 811.40	$3d^7$	^4P	1/2	83 799.60	$3d^64s$	^4D	5/2	2.95[+01]	2.46[+01]	
147.60	17 766.20	$3d^7$	^2G	7/2	85 517.30	$3d^64s$	^2I	11/2	7.03[+01]	6.11[+01]	
152.94	16 977.60	$3d^7$	^2G	9/2	82 363.30	$3d^64s$	^2G	9/2	1.01[+02]	8.81[+01]	
153.48	17 766.20	$3d^7$	^2G	7/2	82 920.70	$3d^64s$	^2G	7/2	9.16[+01]	7.99[+01]	
158.17	23 058.80	$3d^7$	^2D	5/2	86 283.80	$3d^64s$	^2G	9/2	4.50[+01]	3.85[+01]	
159.35	22 720.30	$3d^7$	^2H	11/2	85 474.10	$3d^64s$	^2I	13/5	1.19[+02]	1.04[+02]	

References. [a] Hansen et al. (1984).

Table A.16. continued.

λ (nm)	Lower level				Upper level				A(M1+E2) (s^{-1})		
	E (cm^{-1})	Config.	Term	J	E (cm^{-1})	Config.	Term	J	HFR	AUTOS	Previous[a]
161.06	24 236.80	3d^7	^{2}D	3/2	86 327.10	3d^{6}4s	^{2}G	7/2	3.73[+01]	3.15[+01]	
161.07	23 434.30	3d^7	^{2}H	9/2	85 517.30	3d^{6}4s	^{2}I	11/2	1.19[+02]	1.04[+02]	
161.42	16 977.60	3d^7	^{2}G	9/2	78 927.80	3d^{6}4s	^{2}F	7/2	1.52[+02]	1.35[+02]	
162.18	17 766.20	3d^7	^{2}G	7/2	79 425.30	3d^{6}4s	^{2}F	5/2	1.55[+02]	1.38[+02]	
164.89	16 977.60	3d^7	^{2}G	9/2	77 622.90	3d^{6}4s	^{2}H	9/2	3.40[+01]	3.00[+01]	
165.47	16 977.60	3d^7	^{2}G	9/2	77 411.60	3d^{6}4s	^{2}H	11/2	4.87[+01]	4.34[+01]	
167.07	17 766.20	3d^7	^{2}G	7/2	77 622.90	3d^{6}4s	^{2}H	9/2	4.78[+01]	4.26[+01]	
167.66	22 720.30	3d^7	^{2}H	11/2	82 363.30	3d^{6}4s	^{2}G	9/2	8.25[+01]	7.25[+01]	
168.11	23 434.30	3d^7	^{2}H	9/2	82 920.70	3d^{6}4s	^{2}G	7/2	8.24[+01]	7.37[+01]	
168.62	23 058.80	3d^7	^{2}D	5/2	82 363.30	3d^{6}4s	^{2}G	9/2	3.78[+01]	3.43[+01]	
170.26	20 194.90	3d^7	^{2}P	3/2	78 927.80	3d^{6}4s	^{2}F	7/2	4.55[+01]	3.98[+01]	
170.40	24 236.80	3d^7	^{2}D	3/2	82 920.70	3d^{6}4s	^{2}G	7/2	3.79[+01]	3.41[+01]	
170.92	20 918.50	3d^7	^{2}P	1/2	79 425.30	3d^{6}4s	^{2}F	5/2	3.74[+01]	3.42[+01]	
171.71	20 194.90	3d^7	^{2}P	3/2	78 434.30	3d^{6}4s	^{2}P	1/2	5.95[+01]	4.96[+01]	
172.16	15 201.90	3d^7	^{4}P	5/2	73 286.00	3d^{6}4s	^{4}F	9/2	1.88[+01]	1.75[+01]	
172.26	15 811.40	3d^7	^{4}P	1/2	73 861.80	3d^{6}4s	^{4}F	3/2	1.55[+01]	1.40[+01]	
176.69	20 194.90	3d^7	^{2}P	3/2	76 791.10	3d^{6}4s	^{2}P	3/2	7.20[+01]	6.57[+01]	
177.39	0.00	3d^7	^{4}F	9/2	56 373.80	3d^{6}4s	^{4}D	5/2	5.47[+01]	4.98[+01]	
178.72	841.20	3d^7	^{4}F	7/2	56 794.80	3d^{6}4s	^{4}D	3/2	8.60[+01]	7.86[+01]	
178.98	20 918.50	3d^7	^{2}P	1/2	76 791.10	3d^{6}4s	^{2}P	3/2	4.07[+01]	3.78[+01]	
178.99	23 058.80	3d^7	^{2}D	5/2	78 927.80	3d^{6}4s	^{2}F	7/2	2.72[+01]	2.41[+01]	
179.44	0.00	3d^7	^{4}F	9/2	55 729.20	3d^{6}4s	^{4}D	7/2	1.37[+02]	1.26[+02]	
179.90	1451.30	3d^7	^{4}F	5/2	57 036.80	3d^{6}4s	^{4}D	1/2	1.15[+02]	1.05[+02]	
180.07	841.20	3d^7	^{4}F	7/2	56 373.80	3d^{6}4s	^{4}D	5/2	6.18[+01]	5.66[+01]	
180.59	23 058.80	3d^7	^{2}D	5/2	78 434.30	3d^{6}4s	^{2}P	1/2	4.80[+01]	4.09[+01]	
180.69	1451.30	3d^7	^{4}F	5/2	56 794.80	3d^{6}4s	^{4}D	3/2	3.17[+01]	2.91[+01]	
181.26	1866.80	3d^7	^{4}F	3/2	57 036.80	3d^{6}4s	^{4}D	1/2	7.23[+01]	6.63[+01]	
182.06	1866.80	3d^7	^{4}F	3/2	56 794.80	3d^{6}4s	^{4}D	3/2	7.00[+01]	6.43[+01]	
182.07	1451.30	3d^7	^{4}F	5/2	56 373.80	3d^{6}4s	^{4}D	5/2	6.02[+01]	5.53[+01]	
182.19	841.20	3d^7	^{4}F	7/2	55 729.20	3d^{6}4s	^{4}D	7/2	4.48[+01]	4.12[+01]	
182.84	22 720.30	3d^7	^{2}H	11/2	77 411.60	3d^{6}4s	^{2}H	11/2	9.56[+01]	8.61[+01]	
184.51	24 236.80	3d^7	^{2}D	3/2	78 434.30	3d^{6}4s	^{2}P	1/2	8.21[+01]	7.86[+01]	
184.54	23 434.30	3d^7	^{2}H	9/2	77 622.90	3d^{6}4s	^{2}H	9/2	9.30[+01]	8.24[+01]	
185.88	22 720.30	3d^7	^{2}H	11/2	76 518.90	3d^{6}4s	^{4}G	11/2	2.49[+01]	2.26[+01]	
186.11	23 058.80	3d^7	^{2}D	5/2	76 791.10	3d^{6}4s	^{2}P	3/2	5.95[+01]	5.34[+01]	
212.75	0.00	3d^7	^{4}F	9/2	47 003.10	3d^{6}4s	^{6}D	7/2	3.40[−02]	2.77[−02]	
213.41	841.20	3d^7	^{4}F	7/2	47 698.60	3d^{6}4s	^{6}D	3/2	5.42[−03]	3.27[−03]	
214.71	841.20	3d^7	^{4}F	7/2	47 415.40	3d^{6}4s	^{6}D	5/2	3.08[−02]	2.44[−02]	
215.34	0.00	3d^7	^{4}F	9/2	46 438.30	3d^{6}4s	^{6}D	9/2	2.02[−02]	1.42[−02]	
215.45	1451.30	3d^7	^{4}F	5/2	47 864.80	3d^{6}4s	^{6}D	1/2	1.09[−02]	7.31[−03]	
216.23	1451.30	3d^7	^{4}F	5/2	47 698.60	3d^{6}4s	^{6}D	3/2	2.81[−02]	2.15[−02]	
217.40	1866.80	3d^7	^{4}F	3/2	47 864.80	3d^{6}4s	^{6}D	1/2	3.88[−02]	2.93[−02]	
217.56	1451.30	3d^7	^{4}F	5/2	47 415.40	3d^{6}4s	^{6}D	5/2	5.67[−03]	5.10[−03]	
218.19	1866.80	3d^7	^{4}F	3/2	47 698.60	3d^{6}4s	^{6}D	3/2	1.10[−02]	9.04[−03]	
219.31	841.20	3d^7	^{4}F	7/2	46 438.30	3d^{6}4s	^{6}D	9/2	4.66[−03]	3.29[−03]	
267.98	0.00	3d^7	^{4}F	9/2	37 316.50	3d^7	^{2}F	7/2	1.27[−01]	1.38[−01]	1.24[−01]
284.46	1866.80	3d^7	^{4}F	3/2	37 021.00	3d^7	^{2}F	5/2	1.26[−01]	1.38[−01]	1.23[−01]
314.45	15 201.90	3d^7	^{4}P	5/2	47 003.10	3d^{6}4s	^{6}D	7/2	4.86[−03]	4.10[−03]	
438.88	1451.30	3d^7	^{4}F	5/2	24 236.80	3d^7	^{2}D	3/2	7.34[−01]	8.02[−01]	7.30[−01]
447.03	1866.80	3d^7	^{4}F	3/2	24 236.80	3d^7	^{2}D	3/2	3.86[−01]	4.19[−01]	3.90[−01]
450.09	841.20	3d^7	^{4}F	7/2	23 058.80	3d^7	^{2}D	5/2	7.44[−01]	8.27[−01]	7.50[−01]
491.67	16 977.60	3d^7	^{2}G	9/2	37 316.50	3d^7	^{2}F	7/2	1.84[−01]	1.89[−01]	1.65[−01]
511.50	17 766.20	3d^7	^{2}G	7/2	37 316.50	3d^7	^{2}F	7/2	1.52[−01]	1.65[−01]	1.56[−01]
519.35	17 766.20	3d^7	^{2}G	7/2	37 021.00	3d^7	^{2}F	5/2	1.57[−01]	1.63[−01]	1.39[−01]
533.52	1451.30	3d^7	^{4}F	5/2	20 194.90	3d^7	^{2}P	3/2	6.20[−02]	8.08[−02]	6.43[−02]
545.61	1866.80	3d^7	^{4}F	3/2	20 194.90	3d^7	^{2}P	3/2	4.27[−02]	5.52[−02]	4.46[−02]
589.01	0.00	3d^7	^{4}F	9/2	16 977.60	3d^7	^{2}G	9/2	3.91[−01]	4.34[−01]	4.00[−01]
590.84	841.20	3d^7	^{4}F	7/2	17 766.20	3d^7	^{2}G	7/2	1.50[−01]	1.67[−01]	1.50[−01]
612.94	1451.30	3d^7	^{4}F	5/2	17 766.20	3d^7	^{2}G	7/2	1.12[−01]	1.24[−01]	1.10[−01]
619.72	841.20	3d^7	^{4}F	7/2	16 977.60	3d^7	^{2}G	9/2	1.22[−01]	1.36[−01]	1.20[−01]
657.81	0.00	3d^7	^{4}F	9/2	15 201.90	3d^7	^{4}P	5/2	6.59[−02]	6.65[−02]	4.80[−02]
685.54	841.20	3d^7	^{4}F	7/2	15 428.20	3d^7	^{4}P	3/2	3.69[−02]	3.73[−02]	2.70[−02]
696.34	841.20	3d^7	^{4}F	7/2	15 201.90	3d^7	^{4}P	5/2	1.74[−02]	1.78[−02]	1.35[−02]

Table A.16. continued.

λ (nm)	Lower level				Upper level				A(M1+E2) (s^{-1})		
	E (cm^{-1})	Config.	Term	J	E (cm^{-1})	Config.	Term	J	HFR	AUTOS	Previous[a]
696.37	1451.30	$3d^7$	^4F	5/2	15 811.40	$3d^7$	^4P	1/2	2.71[–02]	2.73[–02]	2.00[–02]
715.47	1451.30	$3d^7$	^4F	5/2	15 428.20	$3d^7$	^4P	3/2	2.18[–02]	2.21[–02]	1.63[–02]
717.12	1866.80	$3d^7$	^4F	3/2	15 811.40	$3d^7$	^4P	1/2	3.57[–02]	3.60[–02]	2.60[–02]
1548.78	16 977.60	$3d^7$	^2G	9/2	23 434.30	$3d^7$	^2H	9/2	1.33[–01]	1.46[–01]	1.30[–01]
1741.34	16 977.60	$3d^7$	^2G	9/2	22 720.30	$3d^7$	^2H	11/2	4.29[–02]	4.69[–02]	4.21[–02]
1764.26	17 766.20	$3d^7$	^2G	7/2	23 434.30	$3d^7$	^2H	9/2	4.03[–02]	4.41[–02]	3.90[–02]
1958.06	15 811.40	$3d^7$	^4P	1/2	20 918.50	$3d^7$	^2P	1/2	1.98[–01]	2.01[–01]	2.00[–01]
2002.80	15 201.90	$3d^7$	^4P	5/2	20 194.90	$3d^7$	^2P	3/2	1.55[–01]	1.58[–01]	1.50[–01]
2097.89	15 428.20	$3d^7$	^4P	3/2	20 194.90	$3d^7$	^2P	3/2	8.04[–02]	8.08[–02]	8.00[–02]
2474.08	20 194.90	$3d^7$	^2P	3/2	24 236.80	$3d^7$	^2D	3/2	1.41[–01]	1.67[–01]	1.50[–01]
11 887.78	0.00	$3d^7$	^4F	9/2	841.20	$3d^7$	^4F	7/2	2.01[–02]	2.00[–02]	2.00[–02]
16 390.76	841.20	$3d^7$	^4F	7/2	1451.30	$3d^7$	^4F	5/2	1.32[–02]	1.31[–02]	1.30[–02]
17 705.38	46 438.30	$3d^64s$	^6D	9/2	47 003.10	$3d^64s$	^6D	7/2	6.77[–03]	6.74[–03]	
24 067.39	1451.30	$3d^7$	^4F	5/2	1866.80	$3d^7$	^4F	3/2	4.65[–03]	4.63[–03]	4.70[–03]
24 254.18	47 003.10	$3d^64s$	^6D	7/2	47 415.40	$3d^64s$	^6D	5/2	4.88[–03]	4.85[–03]	

Table A.17. Comparison of total (M1+E2) transition probabilities from our calculations (HFR and AUTOS) and previous works in Ni III. A[B] denotes $A \times 10^B$.

λ (nm)	Lower level				Upper level				A(M1+E2) (s^{-1})	
	E (cm^{-1})	Config.	Term	J	E (cm^{-1})	Config.	Term	J	HFR	AUTOS
101.79	0.00	$3d^8$	^3F	4	98 237.93	$3d^74s$	^3F	4	9.14[+01]	7.34[+01]
103.48	1360.70	$3d^8$	^3F	3	97 995.81	$3d^74s$	^3F	3	6.00[+01]	4.90[+01]
103.65	1360.70	$3d^8$	^3F	3	97 841.60	$3d^74s$	^3F	2	3.67[+01]	2.88[+01]
104.63	2269.60	$3d^8$	^3F	2	97 841.60	$3d^74s$	^3F	2	7.74[+01]	6.27[+01]
113.74	14 031.60	$3d^8$	^1D	2	10 1954.90	$3d^74s$	^1F	3	2.83[+02]	2.40[+02]
120.13	1360.70	$3d^8$	^3F	3	84 604.10	$3d^74s$	^1P	1	6.31[+01]	3.97[–04]
121.46	2269.60	$3d^8$	^3F	2	84 604.10	$3d^74s$	^1P	1	4.89[+01]	6.62[+01]
121.70	0.00	$3d^8$	^3F	4	82 172.60	$3d^74s$	^3D	3	1.49[+02]	1.20[+02]
122.42	0.00	$3d^8$	^3F	4	81 686.80	$3d^74s$	^3H	6	2.62[+02]	2.21[+02]
122.44	1360.70	$3d^8$	^3F	3	83 033.45	$3d^74s$	^3D	2	1.23[+02]	1.00[+02]
122.58	16 661.60	$3d^8$	^3P	2	98 237.93	$3d^74s$	^3F	4	1.78[+02]	1.39[+02]
122.95	16 661.60	$3d^8$	^3P	2	97 995.81	$3d^74s$	^3F	3	5.84[+01]	4.47[+01]
123.43	16 977.80	$3d^8$	^3P	1	97 995.81	$3d^74s$	^3F	3	1.21[+02]	1.00[+02]
123.66	16 977.80	$3d^8$	^3P	1	97 841.60	$3d^74s$	^3F	2	9.15[+01]	7.34[+01]
123.71	1360.70	$3d^8$	^3F	3	82 193.80	$3d^74s$	^3H	5	2.33[+02]	1.96[+02]
123.74	1360.70	$3d^8$	^3F	3	82 172.60	$3d^74s$	^3D	3	4.99[+01]	4.08[+01]
123.82	2269.60	$3d^8$	^3F	2	83 033.45	$3d^74s$	^3D	2	6.72[+01]	5.57[+01]
124.05	17 230.70	$3d^8$	^3P	0	97 841.60	$3d^74s$	^3F	2	8.18[+01]	6.75[+01]
124.14	2269.60	$3d^8$	^3F	2	82 826.40	$3d^74s$	^3H	4	2.01[+02]	1.71[+02]
124.99	2269.60	$3d^8$	^3F	2	82 277.26	$3d^74s$	^3D	1	9.69[+01]	5.42[+01]
126.35	0.00	$3d^8$	^3F	4	79 143.01	$3d^74s$	^3P	2	7.10[+01]	2.27[+00]
126.83	23 108.70	$3d^8$	^1G	4	10 1954.90	$3d^74s$	^1F	3	4.86[+02]	4.17[+02]
127.57	1360.70	$3d^8$	^3F	3	79 749.22	$3d^74s$	^3P	1	3.46[+02]	3.16[+02]
127.63	2269.60	$3d^8$	^3F	2	80 621.10	$3d^74s$	^3P	0	5.09[+02]	4.54[+02]
127.71	0.00	$3d^8$	^3F	4	78 303.54	$3d^74s$	^3P	2	3.76[+02]	2.55[+02]
129.07	2269.60	$3d^8$	^3F	2	79 749.22	$3d^74s$	^3P	1	1.14[+02]	1.30[+02]
129.90	2269.60	$3d^8$	^3F	2	79 250.11	$3d^74s$	^1G	4	2.61[+01]	5.89[+00]
129.97	1360.70	$3d^8$	^3F	3	78 303.54	$3d^74s$	^3P	2	4.92[+01]	3.13[+01]
130.91	2269.60	$3d^8$	^3F	2	78 657.55	$3d^74s$	^3P	0	2.25[+01]	8.02[+00]
131.21	2269.60	$3d^8$	^3F	2	78 482.43	$3d^74s$	^3P	1	3.89[+01]	9.09[+00]
132.19	0.00	$3d^8$	^3F	4	75 646.61	$3d^74s$	^3G	4	2.25[+01]	1.89[+01]
133.11	0.00	$3d^8$	^3F	4	75 123.65	$3d^74s$	^3G	5	1.67[+02]	1.40[+02]
133.55	1360.70	$3d^8$	^3F	3	76 237.25	$3d^74s$	^3G	3	3.18[+01]	2.67[+01]
134.62	1360.70	$3d^8$	^3F	3	75 646.61	$3d^74s$	^3G	4	1.33[+02]	1.12[+02]
135.19	2269.60	$3d^8$	^3F	2	76 237.25	$3d^74s$	^3G	3	1.30[+02]	1.09[+02]
137.71	14 031.60	$3d^8$	^1D	2	86 645.88	$3d^74s$	^1D	2	2.99[+02]	2.53[+02]

Table A.17. continued.

λ (nm)	Lower level				Upper level				A(M1+E2) (s^{-1})	
	E (cm^{-1})	Config.	Term	J	E (cm^{-1})	Config.	Term	J	HFR	AUTOS
140.09	0.00	$3d^8$	^3F	4	71 384.10	$3d^74s$	^5P	2	1.32[+00]	9.70[–01]
140.71	0.00	$3d^8$	^3F	4	71 067.35	$3d^74s$	^5P	3	2.48[–01]	1.63[–01]
141.70	14 031.60	$3d^8$	^1D	2	84 604.10	$3d^74s$	^1P	1	1.30[+02]	1.28[+02]
141.88	1360.70	$3d^8$	^3F	3	71 842.42	$3d^74s$	^5P	1	3.63[–01]	2.92[–01]
142.81	1360.70	$3d^8$	^3F	3	71 384.10	$3d^74s$	^5P	2	4.50[–01]	3.21[–01]
142.89	16 661.60	$3d^8$	^3P	2	86 645.88	$3d^74s$	^1D	2	5.20[+01]	5.46[+01]
143.46	1360.70	$3d^8$	^3F	3	71 067.35	$3d^74s$	^5P	3	1.12[–01]	7.92[–02]
146.53	14 031.60	$3d^8$	^1D	2	82 277.26	$3d^74s$	^3D	1	9.14[+01]	6.44[+01]
147.18	16 661.60	$3d^8$	^3P	2	84 604.10	$3d^74s$	^1P	1	6.76[+01]	8.68[+01]
152.40	16 661.60	$3d^8$	^3P	2	82 277.26	$3d^74s$	^3D	1	5.84[+01]	3.49[+01]
153.33	14 031.60	$3d^8$	^1D	2	79 250.11	$3d^74s$	^1G	4	9.88[+01]	2.86[+01]
154.74	14 031.60	$3d^8$	^1D	2	78 657.55	$3d^74s$	^3P	0	3.24[+01]	2.95[+01]
155.16	14 031.60	$3d^8$	^1D	2	78 482.43	$3d^74s$	^3P	1	8.22[+01]	5.27[+01]
159.42	23 108.70	$3d^8$	^1G	4	85 834.20	$3d^74s$	^1H	5	2.31[+02]	2.11[+02]
159.73	0.00	$3d^8$	^3F	4	62 605.58	$3d^74s$	^3F	3	6.17[+01]	5.73[+01]
160.05	16 661.60	$3d^8$	^3P	2	79 143.01	$3d^74s$	^3P	2	5.04[+01]	1.78[+01]
160.86	16 977.80	$3d^8$	^3P	1	79 143.01	$3d^74s$	^3P	2	7.96[+01]	
161.00	1360.70	$3d^8$	^3F	3	63 471.93	$3d^74s$	^3F	2	7.66[+01]	7.15[+01]
161.30	16 661.60	$3d^8$	^3P	2	78 657.55	$3d^74s$	^3P	0	1.32[+02]	1.01[+02]
161.52	17 230.70	$3d^8$	^3P	0	79 143.01	$3d^74s$	^3P	2	3.13[+01]	
161.76	16 661.60	$3d^8$	^3P	2	78 482.43	$3d^74s$	^3P	1	6.90[+01]	4.55[+01]
162.59	16 977.80	$3d^8$	^3P	1	78 482.43	$3d^74s$	^3P	1	2.88[+01]	1.79[+01]
163.03	0.00	$3d^8$	^3F	4	61 338.58	$3d^74s$	^3F	4	1.95[+02]	1.82[+02]
163.28	1360.70	$3d^8$	^3F	3	62 605.58	$3d^74s$	^3F	3	1.31[+02]	1.22[+02]
163.39	2269.60	$3d^8$	^3F	2	63 471.93	$3d^74s$	^3F	2	1.56[+02]	1.47[+02]
165.74	2269.60	$3d^8$	^3F	2	62 605.58	$3d^74s$	^3F	3	4.22[+01]	3.99[+01]
166.73	1360.70	$3d^8$	^3F	3	61 338.58	$3d^74s$	^3F	4	3.35[+01]	3.17[+01]
172.98	14 031.60	$3d^8$	^1D	2	71 842.42	$3d^74s$	^5P	1	2.24[–01]	1.85[–01]
178.12	23 108.70	$3d^8$	^1G	4	79 250.11	$3d^74s$	^1G	4	6.74[+01]	1.33[–01]
181.22	16 661.60	$3d^8$	^3P	2	71 842.42	$3d^74s$	^5P	1	4.81[–01]	3.48[–01]
181.99	1360.70	$3d^8$	^3F	3	56 308.24	$3d^74s$	^5F	1	3.82[–02]	2.97[–02]
182.27	16 977.80	$3d^8$	^3P	1	71 842.42	$3d^74s$	^5P	1	1.77[–01]	1.36[–01]
182.96	0.00	$3d^8$	^3F	4	54 657.83	$3d^74s$	^5F	4	5.47[–01]	5.29[–01]
183.80	16 977.80	$3d^8$	^3P	1	71 384.10	$3d^74s$	^5P	2	3.78[–01]	2.99[–01]
185.03	1360.70	$3d^8$	^3F	3	55 406.29	$3d^74s$	^5F	3	3.29[–01]	3.08[–01]
185.05	2269.60	$3d^8$	^3F	2	56 308.24	$3d^74s$	^5F	1	6.01[–02]	4.61[–02]
186.21	0.00	$3d^8$	^3F	4	53 703.93	$3d^74s$	^5F	5	9.15[–02]	7.12[–02]
186.28	2269.60	$3d^8$	^3F	2	55 952.21	$3d^74s$	^5F	2	2.03[–01]	1.87[–01]
259.74	14 031.60	$3d^8$	^1D	2	52 532.00	$3d^8$	^1S	0	1.44[+01]	1.34[+01]
281.26	16 977.80	$3d^8$	^3P	1	52 532.00	$3d^8$	^1S	0	5.25[+00]	5.87[+00]
432.74	0.00	$3d^8$	^3F	4	23 108.70	$3d^8$	^1G	4	3.49[–01]	3.81[–01]
459.81	1360.70	$3d^8$	^3F	3	23 108.70	$3d^8$	^1G	4	1.74[–01]	1.91[–01]
575.92	53 703.93	$3d^74s$	^5F	5	71 067.35	$3d^74s$	^5P	3	4.49[–02]	2.29[–02]
600.18	0.00	$3d^8$	^3F	4	16 661.60	$3d^8$	^3P	2	7.87[–02]	7.91[–02]
640.32	1360.70	$3d^8$	^3F	3	16 977.80	$3d^8$	^3P	1	5.91[–02]	6.17[–02]
653.56	1360.70	$3d^8$	^3F	3	16 661.60	$3d^8$	^3P	2	1.16[–01]	1.50[–01]
668.40	2269.60	$3d^8$	^3F	2	17 230.70	$3d^8$	^3P	0	7.25[–02]	7.56[–02]
679.89	2269.60	$3d^8$	^3F	2	16 977.80	$3d^8$	^3P	1	2.39[–02]	2.54[–02]
789.21	1360.70	$3d^8$	^3F	3	14 031.60	$3d^8$	^1D	2	4.84[–01]	5.19[–01]
850.20	2269.60	$3d^8$	^3F	2	14 031.60	$3d^8$	^1D	2	2.09[–01]	2.27[–01]
3394.20	14 031.60	$3d^8$	^1D	2	16 977.80	$3d^8$	^3P	1	8.83[–02]	1.05[–01]
3802.28	14 031.60	$3d^8$	^1D	2	16 661.60	$3d^8$	^3P	2	9.65[–02]	1.11[–01]
7349.16	0.00	$3d^8$	^3F	4	1360.70	$3d^8$	^3F	3	6.58[–02]	6.55[–02]
11 002.31	1360.70	$3d^8$	^3F	3	2269.60	$3d^8$	^3F	2	2.69[–02]	2.68[–02]